

*Rainer Zab, Claudia Binder, Stefan Bringezu,
Jürgen Reinhard, Alfons Schmid, Helmut Schütz*



Future Perspectives of 2nd Generation Biofuels



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SUMMARY

Biofuels made from renewable resources have come under heavy criticism. Energy crops stand in direct competition with food production or biodiversity conservation, and the environmental impacts of biofuels production are often greater than those of fossil fuels. New hope is being placed on the 2nd generation of biofuel technology, where not only oils, sugar and starch but also ligno-cellulosic compounds are transformed into fuels. This leads to a higher conversion efficiency and facilitates the use of alternative feedstocks like wood, grass or biowaste, which serve as more sustainable feedstocks.

Currently, 2nd generation biofuels are on the edge of penetrating the commodity market and it is an open question as to whether they will be able to compete with established 1st generation biofuels or whether they will be overtaken in the mid-term by electric mobility. In the case of a successful market entry for them, however, the effects on global land use, the environment, and the economy are still unclear. The main goal of this study therefore was to discuss the future potential of 2nd generation biofuels for Switzerland.

The discussion is based on different perspectives pertaining to the sustainability of 2nd generation biofuels. First, the different feedstocks, conversion technologies and use forms of bioenergy are compared based on a sustainability performance analysis. Second, full biofuels' value chains are assessed using methods including an actor analysis. Finally, three widely differing biofuel scenarios for Switzerland in the years 2015 and 2030 have been developed and analysed.

The study shows on the value chain level that the sustainability of 2nd generation biofuels depends mainly on the choice of feedstock. The use of waste feedstocks like manure, biowaste or residual wood usually results in a high sustainability potential and large GHG savings. However, if a 2nd generation feedstock has to be cultivated by agriculture or forestry, as it is the case for grassland or short-rotation wood, land consumption will be substantial for relevant volumes of fuel. This increases land use pressure on natural areas, while biodiversity is generally threatened.

Although sustainable production of biofuels is generally possible, the large-scale production of 2nd generation biofuels is restricted either by limited land availability, limited waste feedstocks or – in the case of fuels from algae – high costs and energy consumption. In the scenario with the highest green house gas savings (“Challenges”) these constraints are reflected in a biofuel use of 10 PJ in 2030, with 52% first and 48% second generation biofuels. Based on current fuel consumption, the maximum substitution potential of rather sustainable biofuels for fossil mobility would be 7.3%, from which 4.8% would be produced domestically, while 2.5% would be imported. This 7.3% of biomass-fuelled mobility would bring greenhouse gas savings of 5%, but only 1% more overall sustainability. The scenario with higher shares of biofuels (“Unlimited Growth”) resulted in less GHG savings. On the other hand, electric mobility might substitute roughly 26% of fossil fuels in 2030. Electric mobility has a higher potential than 2nd generation biofuels because renewable electricity from wind or solar power appears to be limited mainly by financial constraints or a scarcity

of the rare metals needed for photovoltaics. Nevertheless, if the electric car fleet were fuelled by imported electricity, such as the European mix or even coal power, greenhouse gas savings and sustainability benefits would be widely eliminated or even over-compensated.

As all biofuel and electric mobility pathways considered are not yet economically competitive, policy regulations will have a major influence on the success of 2nd generation biofuels. Of primary importance is the increase of the tank-to-wheel efficiency of internal-combustion engines. A reduction in average fleet consumption from currently 7.9 l/100km to 4l/100km in the year 2030 would double the potential of sustainable bio-based mobility in Switzerland to 15%, while sustainability would also be increased.

In summary, 2nd generation biofuels allow a more sustainable mobility than both fossil and 1st generation biofuels based on agriculture. Due to the limited availability of both waste feedstocks and cultivation area, however, sustainable bioenergy-based mobility is restricted to clearly less than 8% of individual mobility in Switzerland, if constant mobility and fleet efficiency is assumed. Nevertheless, 2nd generation biofuels may play a relevant complementary part in supplying our future mobility, in particular for long distance transport and aviation where electric mobility is less suitable.

ZUSAMMENFASSUNG

Biotreibstoffe stehen in der Kritik. Energiepflanzenanbau konkurrenziert Nahrungsmittelproduktion, gefährdet Biodiversität und die Umweltauswirkungen von Biotreibstoffen sind oftmals grösser als bei Erdöl. Gegenwärtig ruht deshalb die Hoffnung auf den sogenannten Biotreibstoffen der 2. Generation, bei deren Produktion nicht nur Öl, Zucker und Stärke sondern auch Ligno-Zellulose umgewandelt wird. Dies bewirkt einen höheren Wirkungsgrad und ermöglicht die Nutzung neuer Biomasse-Quellen wie Holz, Grassland oder Bioabfall, welche umweltschonender bereitgestellt werden können.

Biotreibstoffe der 2. Generationen stehen gegenwärtig an der Schwelle zur breiten Markteinführung. Es stellt sich die Frage, ob sie sich gegen konventionelle Biotreibstoffe durchsetzen, oder ob sie mittelfristig von der Elektromobilität verdrängt werden. Falls sie sich erfolgreich auf dem Markt behaupten, gilt es die Auswirkungen auf die globale Landnutzung, auf Umwelt und Wirtschaft zu verstehen. Ziel dieser Studie ist deshalb die Analyse des zukünftigen Potentials von Biotreibstoffen der 2. Generation in der Schweiz.

Die Studie betrachtet die Nachhaltigkeit von Biotreibstoffen der 2. Generation aus drei verschiedenen Perspektiven. Zunächst wird die Bereitstellung, Umwandlung und Nutzung der Biotreibstoffe mittels "Sustainability Performance Analysis" analysiert und mit fossilen Referenzprozess verglichen. Der zweite Schritt untersucht die Nachhaltigkeit ganzer Wertschöpfungsketten und überprüft deren Durchführbarkeit mittels Akteursanalyse. Schlussendlich werden drei Bioenergie-Szenarien für die Schweiz in den Jahren 2015 und 2030 entwickelt und analysiert.

Die Studie zeigt, dass die Nachhaltigkeit der Biotreibstoff-Wertschöpfungsketten hauptsächlich von der Wahl der Biomasse abhängt. Die Verwendung von Abfallmaterialien wie Gülle, Bioabfall oder Restholz wirkt sich günstig auf die Nachhaltigkeit und Treibhausgasbilanz der ganzen Kette aus. Grosse Landflächen werden dagegen beim landwirtschaftlichen Anbau von Energiepflanzen benötigt, beispielsweise bei schnellwachsenden Holzplantagen oder bei Chinaschilf. Dadurch können sowohl die Funktionen der Ökosysteme als auch die Biodiversität gefährdet werden.

Die nachhaltige Produktion von Biotreibstoffen der 2. Generation ist grundsätzlich möglich. Im grossen Masstab ist die Produktionsmenge aber begrenzt durch die Verfügbarkeit von Anbauflächen, die Verfügbarkeit von Abfällen oder – im Fall von Treibstoffen aus Algen – durch hohe Kosten und geringe energetische Effizienz der Wertschöpfungskette. Im Szenario "Herausforderungen", welches die grössten Treibhausgaseinsparungen ermöglicht, werden im Jahr 2030 jeweils 5 PJ Biotreibstoff der ersten und zweiten Generation genutzt. Verglichen mit dem heutigen Treibstoffverbrauch liesse sich damit 7.3% der heutigen Schweizer Individualmobilität betreiben – 4.8% mit Schweizer Biotreibstoffen und 2.5% mit importierten Biotreibstoffen. Diese 7.3% biomasse-basierte Mobilität führt zu 5% Treibhausgaseinsparungen, aber nur zu 1% mehr Nachhaltigkeit. Das Szenario mit einem höheren Biotreibstoff-Anteil ("unbegrenzt Wachstum") bewirkt dagegen noch niedrigere Treibhausgaseinsparungen. Demgegenüber liesse sich mit Elektromobilität im Jahr 2030 circa 26% der Individualmobilität ersetzen. Das Potential von Elektromobilität liegt im Vergleich zu Biotreibstoffen so hoch, weil erneuerbare Elektrizität aus Wind oder Photovoltaik

einzig durch ökonomische Randbedingungen und die Knappheit seltener Metalle limitiert ist. Wenn die Elektromobil-Flotte mit dem Europäischen Strom-Mix oder gar mit Kohle-Strom betrieben würde, wäre der Umweltnutzen aber weitestgehend eliminiert oder sogar überkompensiert.

Da alle untersuchten Biotreibstoff- und Elektromobilitäts-Optionen wirtschaftlich noch nicht konkurrenzfähig sind, sind Fördermassnahmen ein wichtiger Faktor für den Erfolg der 2. Generation von Biotreibstoffen. Die wichtigste Zielgrösse ist dabei die Energieeffizienz der Fahrzeuge. Die technisch mögliche Reduktion des Schweizerischen Flotten-Verbrauchs von gegenwärtig 7.9l/100km auf 4l/100km im Jahr 2030 würde das Potential der Biotreibstoffe auf 15% verdoppeln, was auch auf die Nachhaltigkeit einen sehr positiven Einfluss hätte.

Zusammengefasst erlauben Biotreibstoffe der 2. Generation eine nachhaltigere Mobilität als Biotreibstoffe der ersten Generation und als fossile Treibstoffe. Aufgrund der begrenzten Verfügbarkeit sowohl von Anbaufläche als auch von Abfallmaterialien ist das Potential aber auf weniger als 8% der Schweizer Individualmobilität beschränkt, wenn wir von konstanter Gesamtmobilität und Flotteneffizienz ausgehen. Trotzdem werden Biotreibstoffe der 2. Generation in Zukunft eine wichtige Rolle für unsere Mobilität spielen indem sie urbane elektrische Mobilität im Langstreckentransport oder auch im Luftverkehr ergänzen.

RESUME

Les biocarburants font l'objet de critiques. Les cultures énergétiques concurrencent les cultures alimentaires, mettent en danger la biodiversité et les effets sur l'environnement des biocarburants sont supérieurs à ceux du pétrole. Actuellement l'espoir repose sur ce que l'on appelle les biocarburants de 2^e génération dont la production ne repose pas seulement sur la transformation d'huiles, de sucres ou d'amidon mais aussi de ligno-cellulose. Ce qui s'accompagne d'un meilleur rendement et permet l'utilisation de sources de biomasse telles que le bois, l'herbe ou les déchets biologiques.

Les biocarburants de 2^e génération se trouvent aujourd'hui à la veille de leur commercialisation. On peut se demander s'ils pourront s'imposer face aux biocarburants traditionnels ou encore si, à moyen terme, ils ne vont pas être évincés par l'électromobilité. Leur succès éventuel sur le marché implique de connaître aussi leurs effets sur l'utilisation globale des terres ainsi que sur l'environnement et l'économie. Cette étude a ainsi pour but d'analyser le potentiel des biocarburants de 2^e génération en Suisse

Cette étude considère la durabilité des biocarburants sous trois aspects. Dans un premier temps, elle analyse leurs performances de durabilité pour ce qui est de la disponibilité des matières premières, de la transformation de celles-ci enfin de l'utilisation du biocarburant pour les comparer avec celles d'un processus de référence d'un carburant fossile. Dans une deuxième étape, elle étudie la durabilité de l'ensemble des chaînes de valorisation et vérifie leur faisabilité à l'aide d'une analyse des acteurs. Finalement elle développe et analyse trois scénarios de l'exploitation des bioénergies en Suisse pour les années 2015 et 2030.

Il ressort de cette étude que la durabilité des chaînes de valorisation des biocarburants dépend essentiellement du choix de la biomasse. L'utilisation de déchets, tels que le lisier, les biodéchets ou les déchets de bois exerce un effet favorable sur la durabilité et le bilan des gaz à effets de serre de toute la chaîne de valorisation. La culture des plantes énergétiques, telles que les plantations d'essences de bois à croissance rapide ou de roseau de Chine, nécessite des surfaces de terres importantes et peut ainsi nuire au fonctionnement des écosystèmes et mettre en danger la biodiversité.

Une production durable des biocarburants de 2^e génération est en principe possible. A grande échelle, cette production se heurte toutefois à la disponibilité limitée des surfaces cultivables ou – dans le cas des carburants tirés des algues – aux coûts élevés et à la faible efficacité énergétique de la chaîne de valorisation. Dans le scénario "Herausforderungen" (défi), qui permet la plus grande économie d'émissions de gaz à effet de serre, en 2030 l'utilisation de biocarburant de première et de deuxième génération atteint 5PJ pour chacun d'eux. Avec la consommation de carburants actuelle, ceci permettrait de couvrir 7.3% des besoins de la mobilité suisse – soit 4.8% avec des biocarburant suisses et 2.5% avec des biocarburants importés. Cette mobilité basée sur la biomasse conduit à une économie des émissions de gaz à effet de serre de 5%, mais seulement à 1% d'amélioration de la durabilité. Le scénario comportant une proportion plus élevée de biocarburants ("unbegrenztes Wachstum", croissance illimitée) s'accompagne d'une économie de gaz à effet de serre moindre. Par contre en 2030 l'électromobilité permettrait de couvrir environ 26%

des besoins de mobilité individuelle. Le potentiel à ce point élevé de l'électromobilité par rapport aux biocarburants provient de ce que la production d'électricité renouvelable, éolienne ou photovoltaïque, n'est limitée que par les conditions économiques marginales et une éventuelle pénurie des métaux rares. Si le parc des véhicules électriques était exploité avec de l'électricité du mix européen ou même avec de l'électricité produite à partir de charbon, le bénéfice écologique s'en trouverait annulé, voire même surcompensé.

Comme tous les biocarburants et les options de mobilité étudiés ne sont pas encore économiquement concurrentiels, les mesures de promotion sont un facteur important pour le succès des biocarburants de 2^e génération. L'objectif cible le plus important est ici l'accroissement de l'efficacité énergétique des véhicules. La réduction, techniquement possible, de la consommation du parc de véhicules suisse d'actuellement 7.9 l/100 km à 4.0 l/100 km en 2030 doublerait à 15% le potentiel des biocarburants, ce qui aurait aussi une influence positive sur la durabilité.

En résumé, les biocarburants de 2^e génération permettent une mobilité plus durable que ceux de la 1^{ère} génération et que les carburants fossiles. Du fait de la disponibilité limitée tant des surfaces cultivables que des déchets utilisables, leur potentiel, pour une mobilité globale et une efficacité du parc automobile demeurant constantes, est limité à moins de 8% de la mobilité individuelle suisse. Malgré cela, les biocarburants de 2^e génération joueront dans l'avenir un rôle important pour notre mobilité en tant que complément de la mobilité électrique urbaine, dans les transports à longue distance ou encore aussi dans les transports aériens.

EXECUTIVE SUMMARY

Context

Although until recently fuels made from renewable resources were praised as a panacea for climate-neutral mobility, biofuels are coming under more and more criticism. Positive climatic effects from biomass are turning out to be lower than expected, while biodiversity loss and land use impacts might be even worse than for fossil fuels. New hope is being placed in 2nd generation biofuels. In contrast to 1st generation biofuels, where only easy-to-process components such as sugar, starch or oils are transformed into energy, 2nd generation biofuels allow one to transform almost all organic materials into energy, including lignin and cellulose. That expands the spectrum of usable biomass because rapidly growing plants such as Chinese reeds or wood contain a lot of cellulose.

2nd generation production technologies can be subdivided into biochemical processes, i.e. separating the cellulose using enzymes or microorganisms, and physical-chemical processes such as gasification by pyrolysis (Figure 1). Second-generation production technologies can yield a variety of fuels ranging from bioethanol and synthetic fuels similar to petrol or diesel (BTL, Biomass-to-Liquid), to synthetic methane (SNG, Synthetic Natural Gas) and hydrogen. These new motor fuels offer substantial improvements in energy efficiency from tank to wheel, although they require design modifications to the vehicle fleet like BTL optimization of internal-combustion engines, monovalent gas vehicles and fuel cell technology.

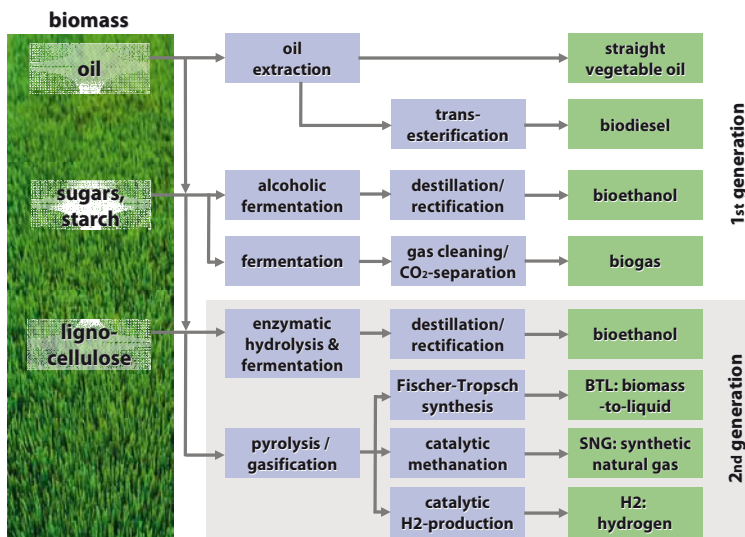


Figure 1: Schematic pathways of biofuels production.

Despite the expanded biomass spectrum and the improved energetic yield many questions remain open which will prove decisive factors for the future success of 2nd generation biofuels. First of all there is the fact that **arable land** will still be needed for cultivating biomass, through which the risk of land-use conflicts could rise, even after a successful introduction of second-generation biofuels.

Furthermore, the successful **market penetration** of 2nd generation biofuels is yet unclear. Most 2nd generation technologies are not yet ready for the market – however massive investments are being made today in first-generation production capacities. Will there be any investment capital left for second-generation plant, or will first generation plant have to be depreciated first?

The production of biofuels has considerable **development potential** for the rural regions of transitional countries, because energy security and local value can be added. However the question remains open as to whether this development potential will be realised in a sustainable way.

In the long run there is the question as to whether biofuels will be able to play any role at all in **our future mobility** when one bears in mind the rapid technology development in alternative drive trains like battery-based electric mobility or hydrogen-based fuel cells.

Goal and Scope

A relatively simple research question such as “What is the future potential of biofuel x?” is complex and requires a high degree of interdisciplinarity to address. If this question is tackled on a general level, the answer is very different depending on the respective boundary conditions (local competitors, feedstock supply, availability of infrastructure, etc.). General conclusions for individual technologies are, on the other hand, difficult to draw when working with concrete production and use scenarios.

The main goal of this project was (1) to assess the sustainability potential of 2nd generation biofuels, (2) to compare this potential with those of 1st generation biofuels and alternative mobility forms and (3) to discuss the future role of 2nd generation biofuels in Swiss mobility. In order to tackle the above-mentioned dilemma on general vs. specific, we analysed in this project three different perspectives – elements, value chains, and scenarios (Figure 2). Each value chain consists of three elements and each scenario includes at least two value chains.

In general, our system boundaries include all potential biofuels which can be used in Switzerland. On this basis production paths of foreign fuels can be compared with domestic biofuels. Such results are important for actors in Switzerland but also for other OECD countries as well as export orientated countries in the global South.

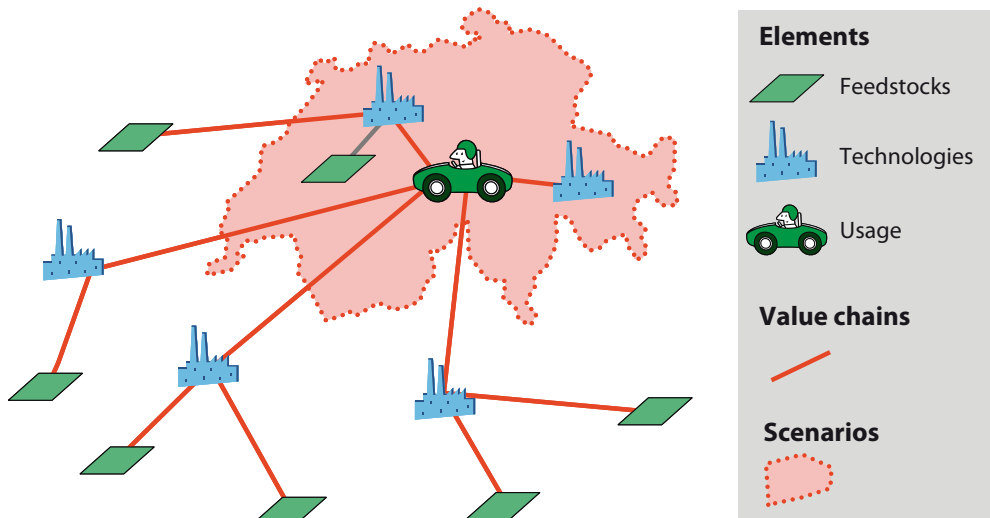


Figure 2: The three perspectives analysed in the project.

Elements

Elements are determined as one essential part of a value chain. Three different types of elements are distinguished: **feedstocks**, **conversion technologies** and **use**.

In the element assessment, the system boundaries are strictly limited to one single element. For example, within the assessment of jatropha as a feedstock the system boundaries include all inputs required and outputs produced which are related to the production of one MJ of jatropha at a farm in a given region in India. In addition to the required inputs and produced outputs, the system boundaries for the assessment of conversion technologies includes also the transport of the feedstock to the plant as well as the potential transport of the product to the place where it can be used, e.g. fuel station. The system boundaries to assess the potential use of the product are limited to the required inputs and produced outputs of the element.

Value chains

As shown in Figure 18, value chains are combinations of elements. On the value chain level the system boundary includes a single full value chain from cradle to grave, i.e. from the raw material acquired from the environment to the disposal of the product back into the environment. For example, the value chain "driving of one person-km with ethanol produced from miscanthus" includes the cultivation of miscanthus, the conversion to ethanol and the use in an average Swiss car.

Scenarios

In a scenario, a possible future state is determined and quantified in terms of the magnitude provided by different value chains. On this basis, the impacts of possible future states can be assessed and the available yields for each of the value chains come into play. Three scenarios were defined for this study (Table 1). For each scenario the study focussed on two points in time:

- **2015:** Some 2nd generation biofuels such as SNG are expected to be ready for the market, thus starting competition with the fossil reference.
- **2030:** Advanced biofuels like BTL or fuels from algae will show up on the market. Furthermore competition between electric mobility and biofuels of the 2nd generation is expected.

Table 1: Definition of scenarios.

Impact factor	Resource scarcity	Challenges	Unlimited growth
Oil price	High	High	Low
Eating habits	Crops (veg.)	Meat	Meat
Food price index	Food crisis	Food crisis	Normal food supply
World econ. growth	Recession	Boom	Boom
Swiss policy	Subsidies for food	Sustainable biofuels	Sustainable biofuels
Global energy & climate policy	Emission red. treaty	Emission red. treaty	No treaty

Sustainability Potential Analysis (SPA)

To assess the sustainability of 2nd generation biofuels, a comprehensive assessment methodology is required that encompasses all relevant components of sustainability in a holistic way. The main idea of the Sustainability Potential Analysis (SPA) is to analyze and assess systems by using coherent general principles, which indicate the 'well-being' of a system. SPA provides a holistic framework for the analysis of sustainable development (SD) from a systemic point of view. The basis for the methodology is the Function-Structure-Context Framework. The three dimensions can be described as follows:

1. **Function:** refers to the goals and demands imposed on a system (e.g., by their stakeholders). Functions of the element “biomass” include, for example, the energy content, the price or the quality of the biomass.
2. **Structure:** is defined as the relevant connectedness, partitioning and modularization of the system under study. The structure of the element “biomass” includes, for example, the homogeneity of the feedstock.
3. **Context:** means external entities such as the regional climate or the geomorphology of the cultivation site that significantly influence the system under study. The context of the element “biomass” includes, for example, the region where the biomass was produced and its proximity to the processing chain.

Six generic criteria should be addressed by comprehensive assessment from a systemic point of view in order to describe the Function-Structure-Context Framework (Figure 3). **Performance, well-structuredness** and **interdependence** mainly correspond to the three main dimensions, whereas **resilience, ability to accommodate** and **inter- and intra-generational equity** contain various aspects of the three main dimensions.

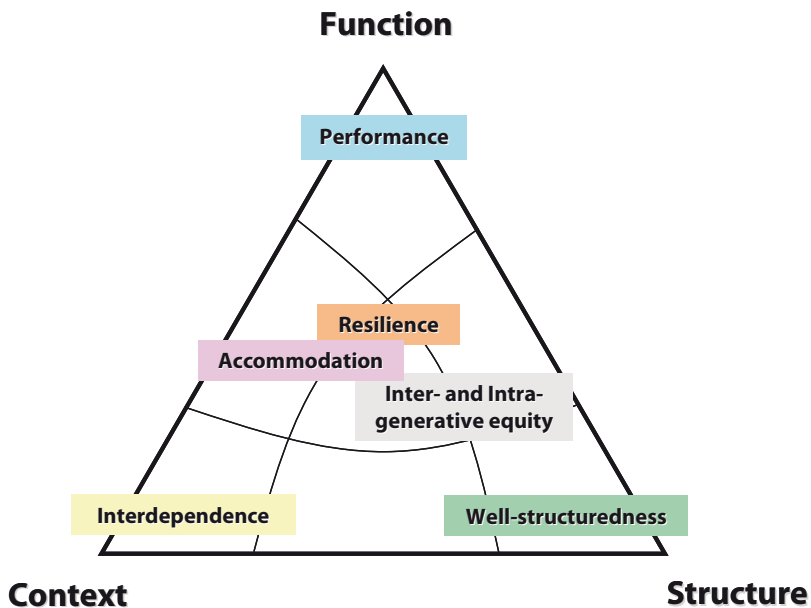


Figure 3: Function-Structure-Context triangle showing the six generic criteria of the Sustainability Potential Analysis (SPA).

For the concrete assessment, each generic criterion was specified according to the specific characteristics of the system by so-called Functional Key Variables (FKVs), which are themselves operationalised using concrete utility or hazard functions (Figure 4).

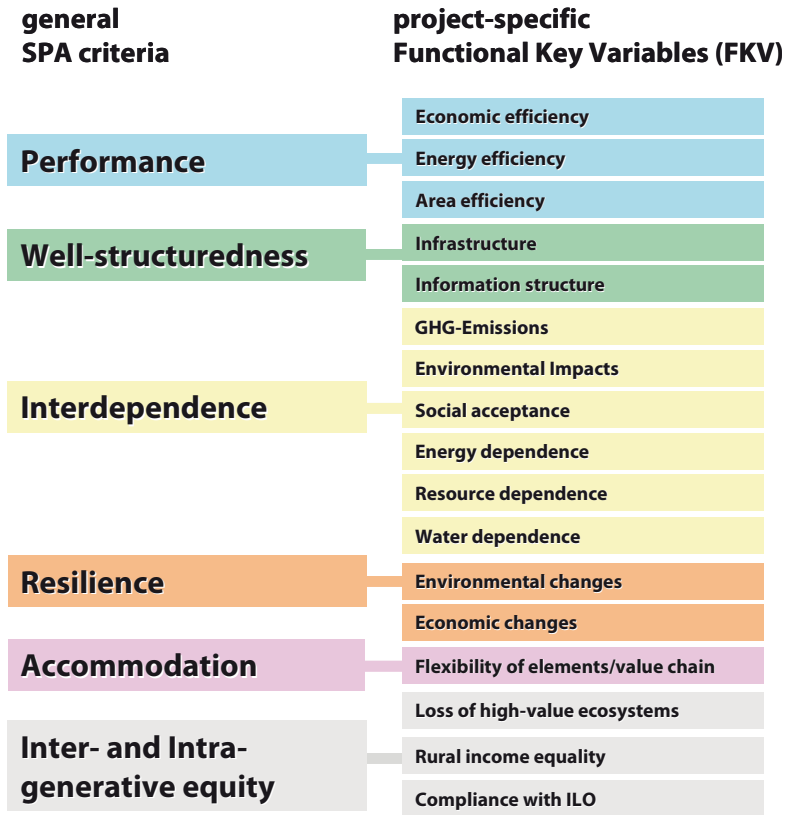


Figure 4: General SPA criteria and their project-specific operationalization as Functional Key Variables (FKV).

Finally, the individual FKV's were aggregated yielding a sustainability score using weighting factors determined by the expert group in an online survey (Figure 5).

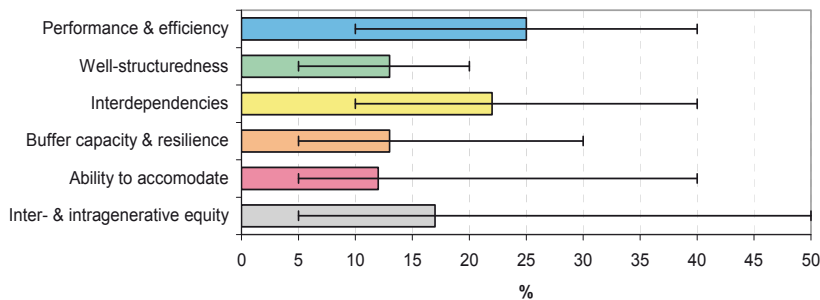


Figure 5: Weighting of criteria.

Feedstocks for 2nd generation biofuels

On the level of **elements**, waste feedstocks like manure, biowaste, indirect and recovered wood fuel exhibit the highest sustainability potential (Figure 6). The main reason is, of course, the low interventions induced by their provision. Only straw and direct wood fuels obtain values on the same low range. All these feedstocks are supplied locally in Switzerland and could therefore foster energy independence and local value creation. The sustainability scores of 1st generation feedstocks like palm oil, sugar cane, jatropha or cultivated 2nd generation feedstocks like miscanthus, short-rotation wood or halophytes are all substantially lower and lie on the same range as those of fossil resources. The main critical factors of both 1st and 2nd generation feedstocks are land consumption and biodiversity impacts:

- Even in 2006 Switzerland required 27% more cropland per capita than was available for the rest of the world population. This highlights the Swiss contribution to the expansion of global cropland. This trend will significantly increase with the advent of agro-based biofuels.
- Biodiversity is generally threatened by large-scale production of biofuels. 1st generation biofuels mainly increase the pressure on fertile and arable lands and therefore on biodiversity-rich natural ecosystems. For 2nd generation biofuels large amounts of ligno-cellulosic feedstock are needed. This increases the land use pressure on dry natural areas, on the intensification of forestry and on soil fertility if crop residues are used excessively for biofuels instead of soil renewal.

Nevertheless, biodiversity could be sustained or even increased by biofuels production if cultivation took place on degraded areas or if integrated agricultural systems were implemented. These options however appear to be niche applications that cannot satisfy the global demand for biofuels on the commodity market.

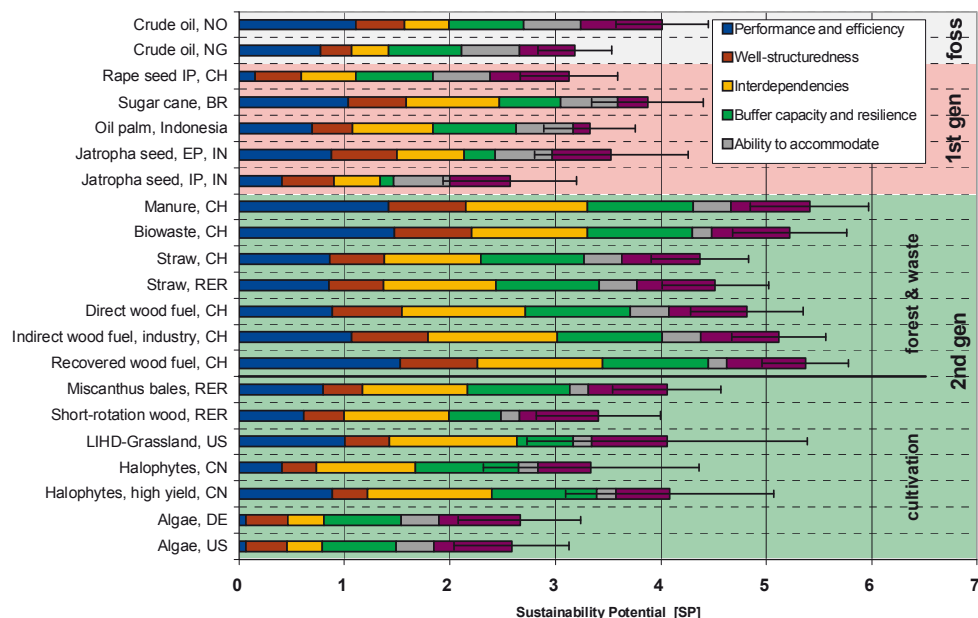


Figure 6: Overall assessment of weighted sustainability potential on the level of feedstocks.

For **conversion technologies**, the overall sustainability is more constant than for the feedstocks (Figure 7). Lower environmental impacts are often compensated by higher costs or less energy efficiency, which leads to relatively consistent results. In general, crude oil refinery reaches the highest scores, as the technologies are well known and have a high economic efficiency. Co-processing of biogenic feedstock in fossil refineries would be a straight-forward option for combining established technologies with advanced feedstocks.

The 1st generation technology of oil extraction and trans-esterification scored surprisingly high. This might be explained by the fact that the process itself is efficient, simple and well-known. This process however depends on the supply of oil-containing feedstock, which is critical on the cultivation level. Mid-scale production technologies like SNG-production or lignocellulosic fermentation are best suited for Switzerland with its complex topography and lack of sea harbours. The SPA shows above average results for both processing technologies.

The sustainability of biomass conversion could be significantly improved by bio-refineries, where the revenue is enhanced by producing a range of high-value products while producing biofuels only from the low-value fractions. The biorefinery approach would be especially feasible for algae biofuels, where production costs are still magnitudes too high and where high-value products for the pharma and nutrition industry could be derived.

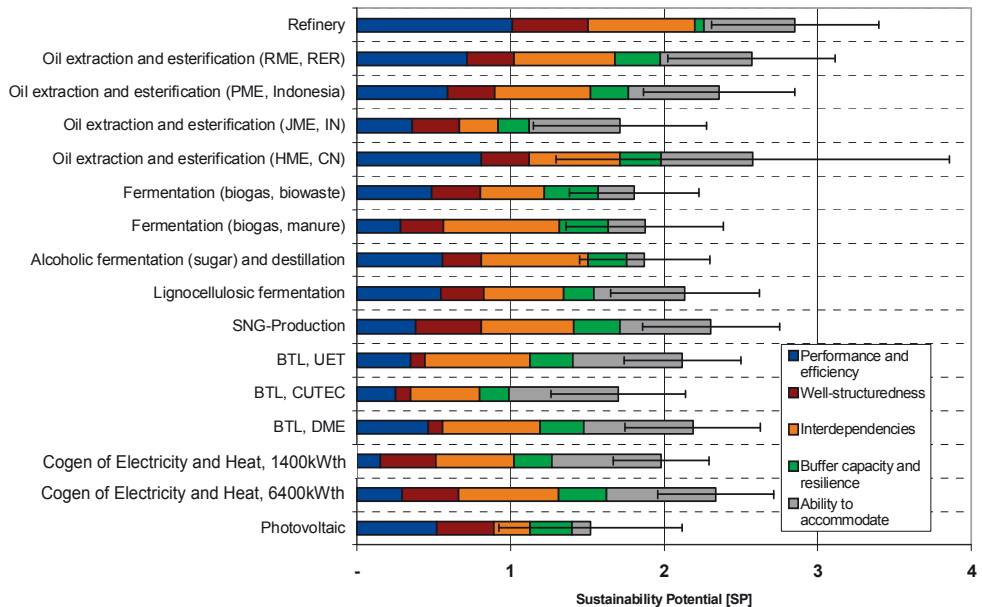


Figure 7: Overall assessment of conversion technologies.

For the **use phase** electric mobility (due to its high efficiency) and the use of BTL (due to low emissions and infrastructure demand) exhibit a distinctively higher sustainability score than the use of fossil and 1st generation fuels (Figure 8). However, the future efficiency of combustion engine-based mobility significantly depends on the development of the car fleet towards more efficient fuel use. This strongly depends on consumer behaviour and policy regulations rather than on the technical potential, as best-in-class cars already reach < 4l/100km while the fleet average is at 7.9l/100km.

The lower value for the interdependent use of electric and hybrid use options is basically determined by higher energy requirements which result from different or additional car components, e.g.a lithium-ion battery.

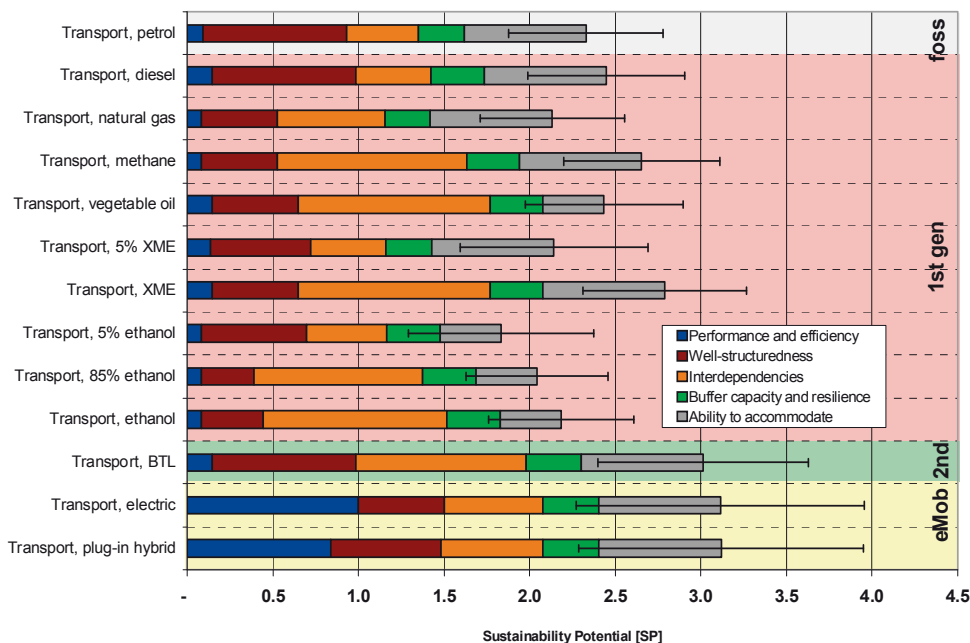


Figure 8: Overall assessment of use options.

2nd generation value chains

Elements on the level feedstock production, fuel production and fuel use were combined to form value chains. The definition of value chains for the two assessment years 2015 and 2030 is based on the availability of the elements in the respective years (Figure 9). Only elements with a favourable sustainability potential score or with a high availability were selected for the value chains.

The sustainability potential of 1st generation value chains is usually lower than the fossil reference (Figure 10). The main reasons are a low structuredness and a negative interdependence with other systems (e.g. large consumption of surface area, high environmental impacts). The exception is 1st generation methane from waste, which scores highest due to its being a well-known and efficient technology and having no dependence on agricultural areas. Most 2nd generation biofuels exhibit significantly higher SPA-values than both 1st generation biofuels and fossil fuels. Nevertheless, algae fuels score on the range of 1st generation biofuels due to their high costs and the lack of a research break-through. Value chains based on electric mobility score a little better than 2nd generation biofuels. The main reason is the high efficiency of both power generation and use of electricity in cars.

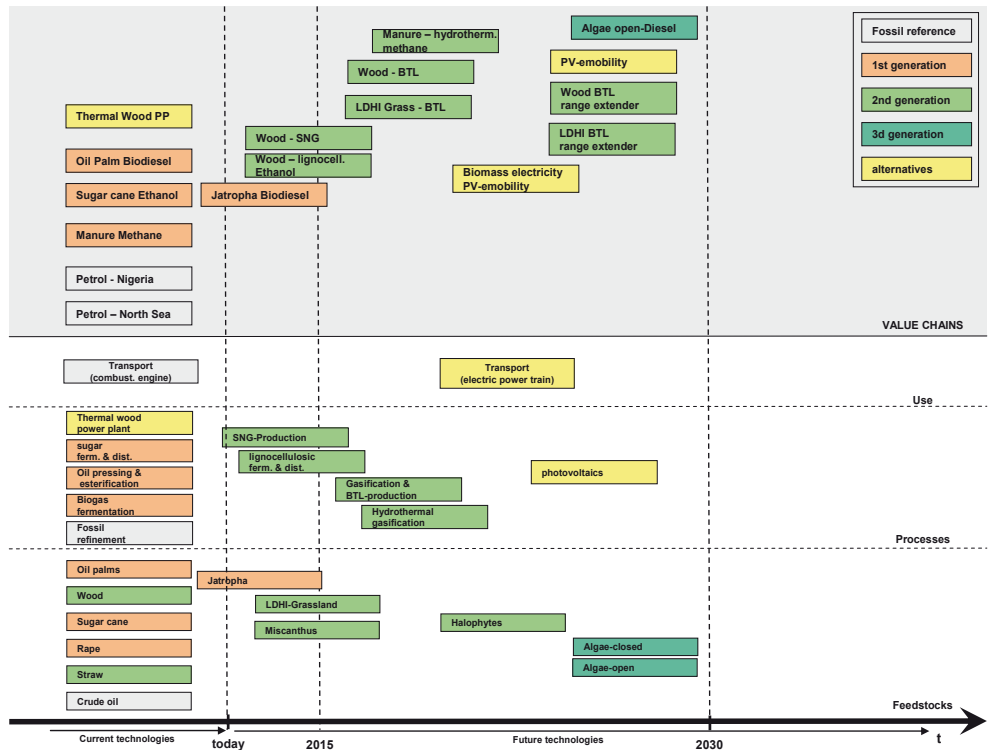


Figure 9: Temporal availability of the various elements on the levels feedstocks, processes and use and the resulting value chains (grey area).

Generally, no clear pattern is visible when comparing the different fuel generations. The variations within each fuel generation are higher than those between the generations. 1st generation biofuels based on agricultural feedstock cultivation such as rape seed and jatropha generally show a low SP, whereas 1st generation biofuels based on residues and wastes score even higher than 2nd generation biofuels. Most 2nd generation biofuels exhibit a significantly higher sustainability performance than both 1st generation biofuels and fossil fuels. The main positive factors of 2nd generation biofuels are the interdependencies with other systems (low GHG emissions, low environmental impacts) and the relatively high buffer capacity with respect to economic and environmental changes.

Although the sustainability potential of 1st generation biofuels is lower, 1st gen. fuels are already available on the market and they are nearly competitive with fossil fuels. Assuming a high oil price and weak sustainability regulations, they could easily outperform 2nd generation fuels on the market.

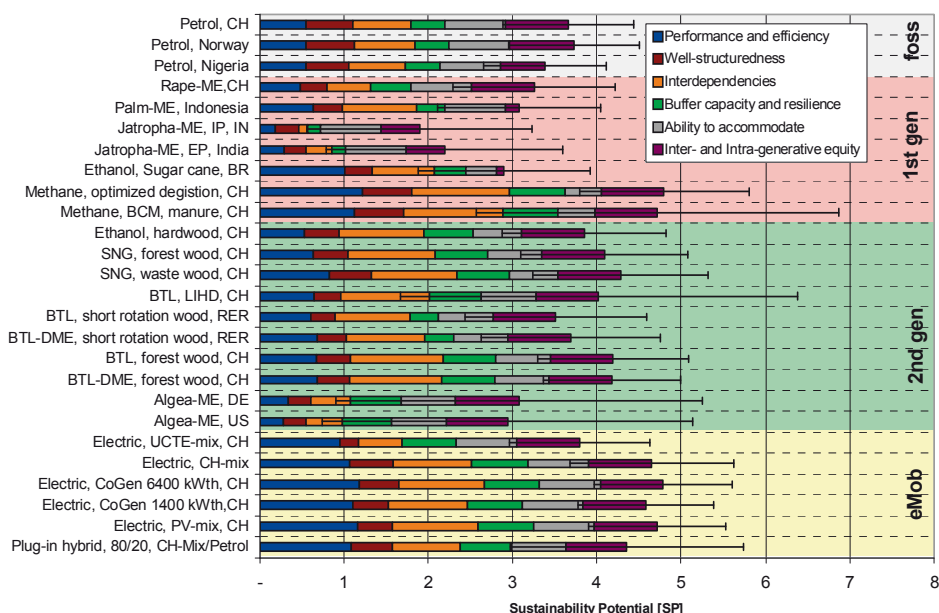


Figure 10: General histogram of SPA-results on the value-chainlevel.

Value chains based on electric mobility scored a little better than 2nd generation biofuels when they are fueled with renewable energy. The reason is the high efficiency of both power generation and use of electricity in cars. The main advantage of electric mobility is the scalability of its energy production. While the production of 2nd generation biofuels is limited by the availability of waste feedstock and arable land, the production of renewable electricity from wind or solar power appears to be limited mainly by financial constraints or a scarcity of the rare metals needed for PV. Nevertheless, if the electric car fleet is fuelled by fossil-intense electricity such as the European mix or even coal power, benefits in greenhouse gas savings and in overall sustainability are widely eliminated or even overcompensated.

Figure 11 goes into more detail showing the specific results for biodiesel production from algae in open ponds. The algae value chain scores low for costs and energy efficiency and high for GHG emissions and environmental impacts. Nevertheless, area efficiency and water and resource dependence are favourable for the algae path. The figure also shows the great uncertainties still associated with the assessment of biofuels from algae. Figure 12 shows the results on top scoring SNG production from waste wood. Synthetic Natural Gas (SNG) from wood is a relatively established 2nd generation value chain with a high economic efficiency, low GHG emissions and environmental impacts and average area efficiency, as the feedstock is based on waste wood and not on agricultural land. Nevertheless, in contrast to the algae value chain, the availability of SNG from waste wood is limited as it depends on a residual product.

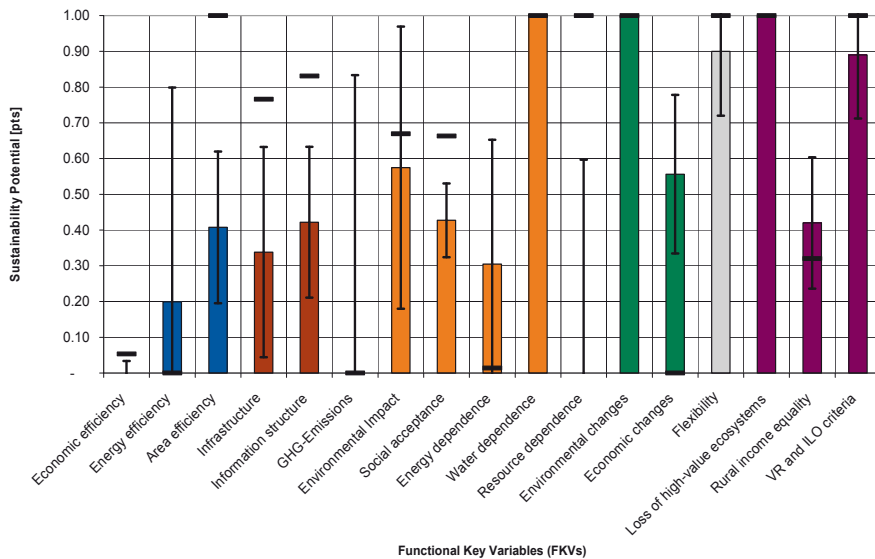


Figure 11: Normalized SPA results for biodiesel production from algae in open ponds (US) and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: our own depiction).

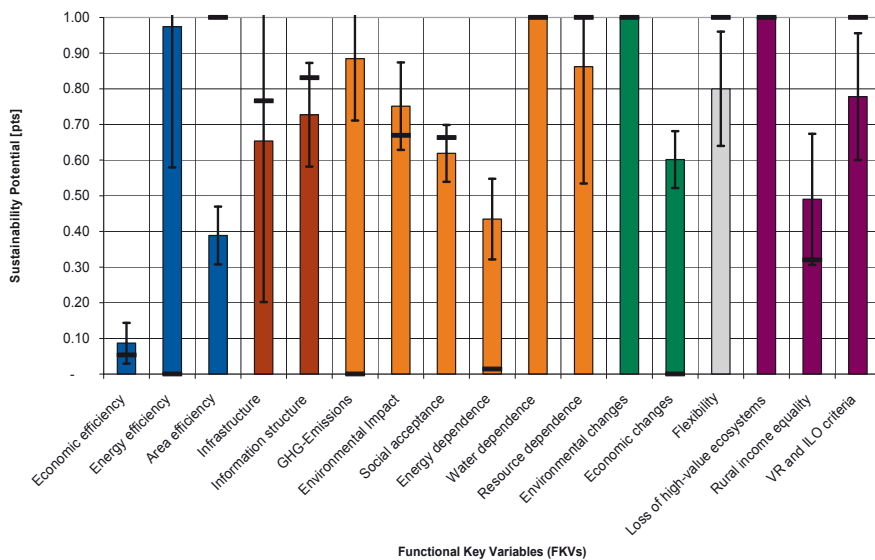


Figure 12: Normalized SPA results for SNG production from waste wood and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: our own depiction).

The potential of 2nd generation biofuels for Switzerland

Figure 13 shows the quantitative potential of 1st and 2nd generation biofuels for the three scenarios (2015 and 2030) compared to the baseline (2010) and the maximum domestic potential (2030) on the basis of current individual mobility per year in Switzerland and assuming a fuel efficiency of 7.9l/100km for the Baseline, 6.0l/100km for 2015 and 4.0l/100 km for 2030.

The **domestic potential** of 2nd generation biofuels is constrained by the availability of ligno-cellulose-based biomass either by (i) high land requirements related to intended cultivation or (ii) limitations of waste and residues.

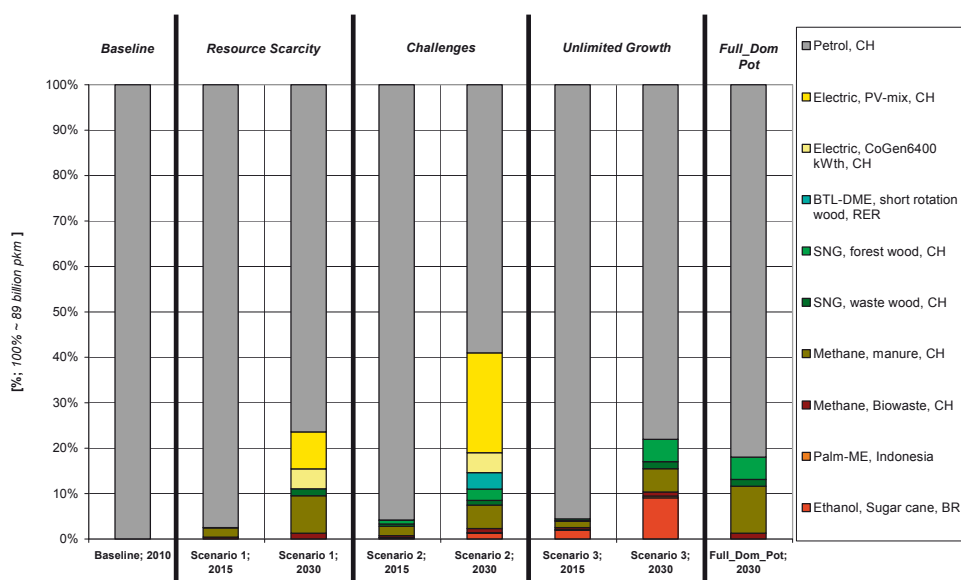


Figure 13: Contribution of pathways to the total amount of pkm per year.

With regard to land availability, the production of ligno-cellulose from intended cultivation of short-rotation wood, miscanthus or grasslands is limited given that the available land in Switzerland is constrained. For example, to replace 1% of the crude oil based mobility with BTL from short-rotation wood would require between 15,000 and 20,000 ha of land. This reflects approx. 3–5% of the land area currently used for agricultural production in Switzerland. In other words, if the domestic production of 2nd generation biofuels on the basis of cultivated feedstocks is to be substituted for great amounts of our current crude oil based mobility, it would induce a radical shift in our current agricultural land use patterns.

With regard to the availability of residues, the production of energy, residue and waste wood is limited by different factors. It is the current forest ownership structure in Switzerland

land, the competition with other use options and the dependent coproduct character¹ of energy, residue and waste wood which places constraints on the availability of additional lignocelluloses potentials. Considering these constraints, we conclude that the available potential for lignocelluloses biomass is 11.69 PJ for forest energy wood, wood from landscape maintenance and industrial wood residues and 3.58 PJ for waste wood. If these additional potentials were used exclusively for SNG or BTL production, they could replace approx. 3–6% (depending on the fleet efficiency) of our current crude oil based mobility. However, considering a potentially halved fleet fuel consumption of 4l/100km in the year 2030 and taking account of the additional manure and biowaste potential (21 PJ and 2.37 PJ, respectively), the maximum domestic biofuel production could fuel up to 18% of the Swiss individual mobility (Figure 13 right).

Table 54 shows the scenario results for material flows of forest biomass. In each scenario studied, the Swiss global consumption is higher than the estimated sustainable NAI (net annual increment) per capita of the global population. Only for the status quo 2006 (data from BAFU) was Swiss consumption of forestry biomass within the global average availability per person. This indicates future risks of over-proportional requirements of Switzerland for global forestry resources.

Table 2: *Swiss global forestry biomass requirements in m³ per person and in comparison with the world population's availability of forest biomass.*

MFA-forestry SWISS in m3 per person and year									
	Status Quo	Reference		Scenario 1 Resource scarcity		Scenario 2 Challenges		Scenario 3 Unlimited growth	
	2006	2015	2030	2015	2030	2015	2030	2015	2030
Biomaterials	0.54	0.66	0.77	0.61	0.78	1.20	2.33	1.06	1.75
Bioenergy	0.30	0.29	0.28	0.51	0.50	0.41	0.40	0.36	0.35
TOTAL	0.84	0.95	1.05	1.12	1.28	1.62	2.73	1.43	2.10
Self-supply ratio MFA	91%	85%	90%	93%	98%	57%	40%	64%	52%
Sustainable NAI World	0.80	0.72	0.63	0.72	0.63	0.72	0.63	0.72	0.63
Swiss minus World	0.04	0.23	0.41	0.40	0.64	0.89	2.10	0.70	1.47

The **import potential** of ethanol and biodiesel is currently very low. Without strong regulations like blending targets infrastructure and investment costs are far too high under current conditions and with respect to expected margins and market shares.

Also the import of 2nd generation biofuels is constrained by a growing global demand for food and water, and competes with other land use functions like conserving biodiversity and carbon stocks. Last but not least, there will be a strong demand competition for sustainably produced biofuels, induced by binding sustainability criteria for renewable energies in the EU.

¹ The production of a dependant co-product is constrained by the demand for the main product. For example, the production of industrial residue wood is constrained by the demand for sawn wood. In other words, an increased demand for industrial residue wood will not result in an increased production of sawn wood given that most of the revenues are related to the sawn wood and not the co-produced residue wood.

However, assuming an increased fleet efficiency of 4l/100km in the year 2030, those limited imports of 1st and 2nd generation biofuels into Switzerland could fuel 5–9% (depending on the scenario) of Swiss individual mobility.

Figure 14 visualises the strong influence of the anticipated fleet consumption on the benefit that could be provided by biofuels. Only if substantial increases in overall fleet efficiency can be achieved, could a biofuel share higher than 10% be reached. Although CONCAWE anticipates an average fleet consumption of 4.1l/100km for 2025, this trend has not been observed in the past, where efficiency gains have instead been widely compensated for by increased car power, car weight or additional fuel consumption by air conditioning and car electronics.

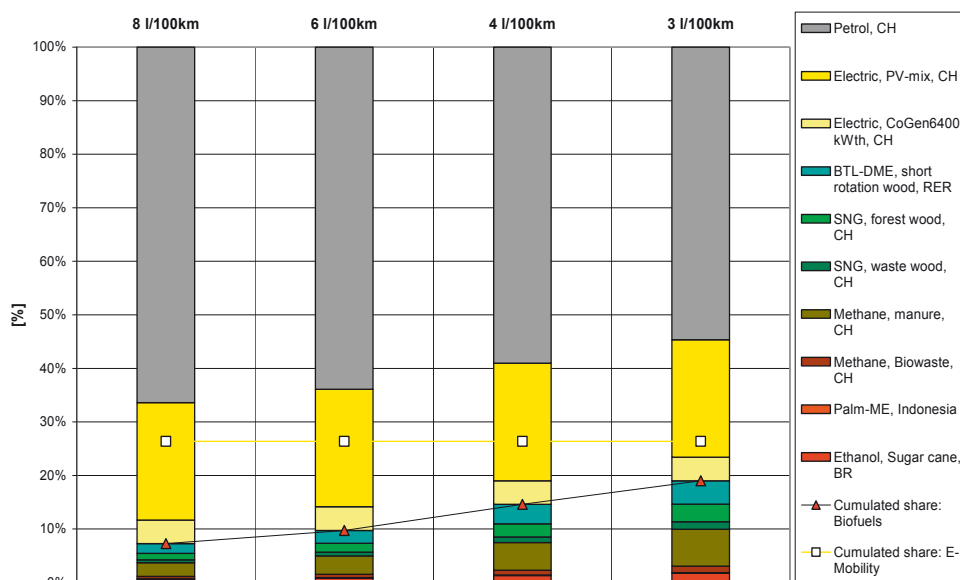


Figure 14: Influence of efficiency gain (in the fuel requirement per pkm) on the total amount of pkm substituted.

Challenges and Risks of 2nd generation biofuels

The main driver in Switzerland for the use of biofuels is their greenhouse gas savings. It is, however, not considered desirable for these GHG savings to have adverse effects on overall sustainability. Figure 15 shows on the right the effect on GHG savings. In this optimistic scenario biofuels contribute approx. 10% to the GHG savings of Swiss individual mobility (4% by 2nd gen., 6% by 1st gen). However, the GHG benefits associated with 1st and 2nd generation biofuels are not sufficient to overcompensate the cumulated negative impacts which will result from (i) the predicted increase in mobility and (ii) the expected increase in fossil fuel impact. This, in turn, emphasizes the importance of vehicle efficiency gains, which not only increase the substitution potential of biofuels but also significantly reduce the GHG intensity of fossil mobility.

When analysing the impact on the overall sustainability potential (Figure 15 left), we found the benefits of both biofuels (2.5%) and electric mobility (5.5%) to be rather small. The sustainability benefits associated with 1st and 2nd generation biofuels are not sufficient to over-compensate the negative impact of either (i) the predicted increase in mobility or (ii) the expected peioration of fossil fuels. Even though the benefits from electric mobility are taken into account, the cumulated impact of both dominates.

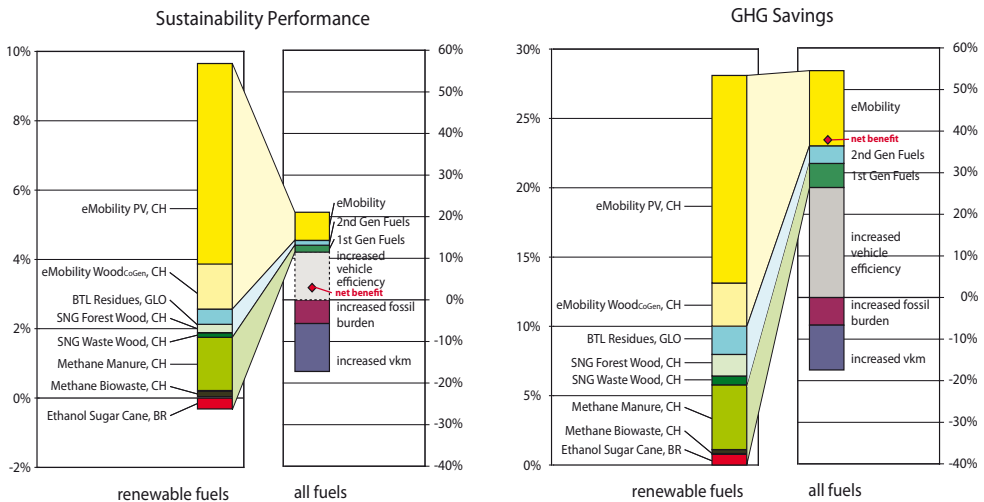


Figure 15: Sustainability potential (left) and GHG Savings (right) that could be reached in the scenario “Challenges” for the year 2030. The left bar shows the relative effect of biofuels and electric mobility compared to the current status quo. The right bar includes the other relevant effects of increased vehicle efficiency, increased fossil burden and increased mobility in Switzerland. The red dot indicates the net effect.

The results show that the future potential of biofuels is not marginal; however, in order to realize a significant effect, the use of biofuels has to be coupled with a strong increase in car efficiency, while mobility in general should not be allowed to grow further. These results fit well to the opinion of Swiss party members that rate the future potential of biofuels as average (Figure 16).

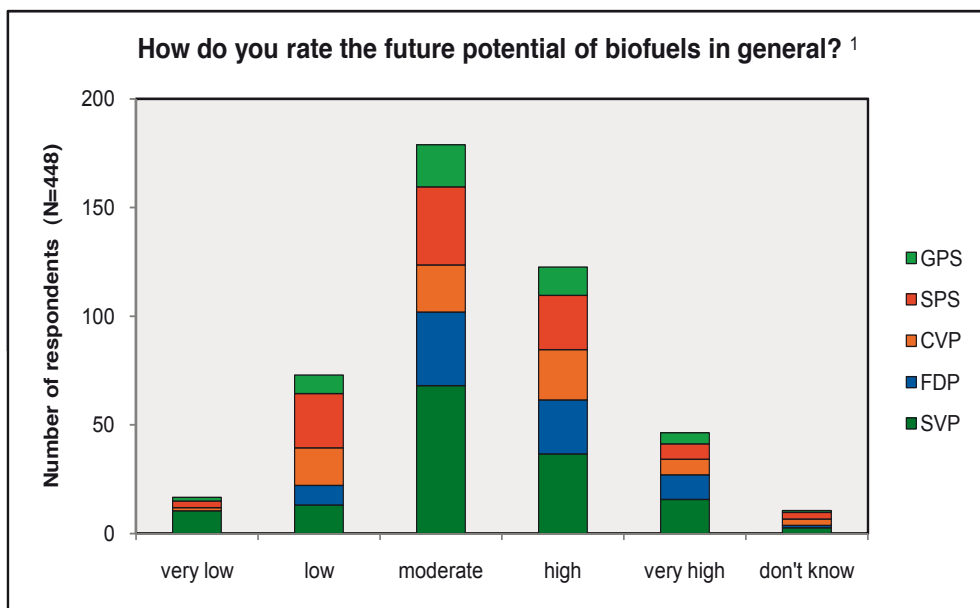


Figure 16: Opinions of Swiss party members on the future potential of biofuels.

Recommendations

- | | |
|----------|--|
| 1 | Promote in parallel vehicle efficiency and the sustainable use of 1st generation biofuels, 2nd generation biofuels and eMobility! |
|----------|--|

This study emphasized that different factors altogether determine the overall potential of 1st and 2nd generation biofuels as well as of electric mobility: (i) the sustainability performance per value chain relative to the fossil reference, (ii) the available energetic potential per value chain and (iii) the conversion efficiency with which the feedstock is transformed into useful energy.

This potential is however challenged by the continuing growth of our mobility demands but also by the increasing fossil burden caused by the transition from conventional to unconventional oil supply. Figure 126 shows as an example that the GHG balance for each of those factors is in the same range or greater than the maximum biofuels potential.

Figure 126 clearly demonstrates that a net benefit can hardly be achieved without increased efficiency, and a maximum benefit would require that all measures are applied in combination. 1st and 2nd generation biofuels and eMobility are complementary in their production and use, while pushing vehicle efficiency and biofuels leads to strong synergies. Consequently, the question for policy makers is not “bio-based, electric or more efficient

mobility?” the key issue is about how to promote efficiency and develop the sustainable potential of the different technologies in parallel!

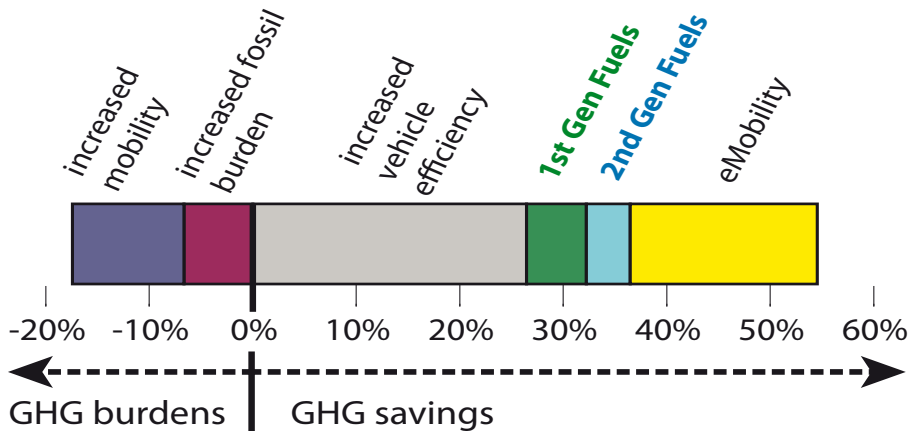


Figure 17: Relevance of various factors for the overall GHG savings potential of 2030.

2

Develop a long-term biofuel strategy that gives the stakeholders regulative and legislative stability and therefore triggers new investments in the sector!

Currently, stakeholders are hesitant to invest in the various technology options for producing 2nd generation biofuels. This is mainly due to an unpredictable and – to a large extent – not existing policy framework for 2nd generation biofuels. This leads to investments in established but out-dated technologies and hinders the penetration of more sustainable and efficient 2nd generation technologies. A long-term biofuel strategy is needed that provides the different stakeholders with a policy framework within which they can make their investment decisions. In particular we recommend to

- Increase security of biomass availability by creating incentives for forest owners to get organized and increase the harvest rate to the maximum sustainable one.
- Develop measures, guarantees and incentives to reduce investment risks such as a clear and binding, technology-based, long-term federal bio-fuel strategy to provide regulative certainty and orientation.
- Develop location-specific, energy master plans linking housing sector, public services and private companies at the municipal and cantonal levels from biomass use to energy production and consumption.
- Build on international certification schemes for sustainable bioenergy production.

3	Develop integrated initiatives for sustainable resource management on the national and international levels!
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The energetic use of biomass is strongly competing with alternative services such as food and fibre production or biodiversity conservation. Purely bioenergy-centric policies will result in unwanted effects on other industrial sectors and ecosystems. Any biofuel strategy needs to be embedded in a wider perspective of sustainable biomass and other resource use.

We therefore propose to develop an overarching programme for sustainable resource management which

- integrates climate and resource protection,
- considers biomass and minerals for various uses (food and non-food materials, power/heat, transport fuels),
- builds the bridge between environment and economy by leading the way towards decoupling of resource use and economic growth,
- is based on sustainability indicators and targets,
- accounts not only for direct and indirect GHG emissions, but also for total material resource consumption, and global land use associated with domestic production and consumption activities,
- reflects on an adequate share of global resources consumed by Swiss activities within the global context, a sound proportion of self-sufficiency, and
- minimizes shifts of environmental and social burden to other regions which is associated with foreign trade.

4	Focus on sustainable feedstock supply and concentrate on waste, wood and marginal agricultural production!
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This study has shown that the main advantage of 2nd generation biofuel technology lies in its potential to make use of more sustainable feedstock. Consequently, the focus of interest should be put on costs, availability, and the social and environmental implications of feedstock supply.

Waste feedstocks allow producing biofuels without competing with agricultural land and without affecting biodiversity and water sources. Furthermore, the production of biofuels from waste is usually a waste treatment process, which reduces uncontrolled environmental emissions, such as N₂O-emissions from untreated manure. However, potential displacement effects when switching to waste feedstock should be carefully evaluated.

The potential for **wood** as a feedstock for 2nd generation biofuels in Switzerland is larger than the potential for waste feedstock. In addition, wood's energy content is significantly higher than waste feedstock's, a fact that could facilitate transport and storage. Generally, wood shows a high sustainability potential, which makes it a perfect feedstock for producing 2nd generation biofuels. Nevertheless, for the successful set-up of wood biofuel chains, forest ecosystem services should not be negatively affected.

The use of **marginal agricultural areas** is another option to produce 2nd generation biofuels in a sustainable way. As this pathway is in competition with both food production and nature conservation, great care should be taken before such projects are implemented. Critical issues are the conservation value, water use impacts, and regional trends in livelihood, migration and food consumption.

5	Develop accepted approaches for dealing with indirect effects!
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Indirect effects of biofuels production are hardly quantifiable but highly relevant. Multi-sectorial statistics on land use, biomass production and market prices are needed on the global scale in order to model the chain of effects induced by an increased production and consumption of biofuels. This is mainly relevant for agricultural and forestry feedstocks, but the competition for biomass residuals such as straw or biowaste is also increasing.

6	Shift from carbon foot-printing to integrated socio-environmental assessment!
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When it comes to the quantification of the environmental impacts most studies concentrate on the carbon footprint or the energy efficiency of biofuels, as these indicators are easy to determine. However, the impacts and benefits of biofuels are manifold and hardly quantifiable factors can be very important, such as soil degradation or land expulsion of farmers. Consequently, integrated assessment methods that go beyond quantification of material flows are strongly needed for assessing the sustainability of 2nd generation biofuels.

7	Understand and overcome the uncertainty of prospective biofuels assessment!
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Some of the findings of this study are uncertain, basically because technological breakthrough is difficult to forecast. This is especially true for

- the penetration rate of eMobility which depends on the costs of electric cars and the acceptance by the user,
- the success of algae-fuels which depends on cost savings and efficiency gains in algae cultivation,
- and the competition between proven conventional technologies (e.g., thermic wood power plants) and advanced but yet unproven 2nd generation technology (e.g., SNG plants).

1 INTRODUCTION

We will soon reach peak oil, i.e. the time after which worldwide oil production declines in the medium term. Sustainable mobility technologies based on renewable fuels are therefore currently in great demand. Biofuels are taking on a key role among them, because they are available today and can be used with existing vehicle technology. They possess the potential both to replace limited fossil energy resources and to limit greenhouse gas emissions. Furthermore the cultivation of feedstock plants is supposed to help improve the income of farmers and thus help develop rural areas.

Although until recently biofuels made from renewable resources were praised as a panacea for climate-neutral mobility, they are now coming under heavy criticism: Firstly, the expected positive climatic effects of many fuels made from biomass are turning out to be lower than hoped for (Zah, Böni et al. 2007). A life-cycle assessment (LCA) often reveals even worse results than with fossil fuels as regards acidification or eutrophication, and the energy yield is often unsatisfactory. Secondly, biofuel feedstocks stand in direct competition with food production for humans and animals. There is also competition with other uses competing indirectly for the cropland (Reinhard 2008). This competition among alternative uses is contributing negatively to an already critical situation as regards the increasing amount of land needed to feed a growing world population (Bringezu et al. 2009a, Howarth and Bringezu 2009).

New hope is being placed in second-generation biogenic fuels. These are not really fuels themselves, but rather new, more efficient production technologies. Then not only easy-to-process components such as sugar, starch or oils are transformed into energy (as is the case with first generation fuels), but rather cellulose is too, then involving (almost) the whole plant. That expands the spectrum of usable biomass because rapidly growing plants such as Chinese reeds or poplar contain a lot of cellulose. With the aid of further improvements it should become possible to boost the efficiency of extracting energy from biomass. Here are a few promising approaches:

- Energy plants that grow on very poor soils such as *Jatropha* or *Rizinus* and therefore hardly compete at all against food production
- Bio- or gene-technically optimized energy plants that give a maximum energy yield even when not much pesticides, fertilizer or water is used
- New kinds of bio-refineries that supply a whole spectrum of chemical products, building materials and energy from biomass
- Fuel from algae or similar non-food plants

Second-generation production technologies can be subdivided into biochemical processes, i.e. separating the cellulose using enzymes or microorganisms, and physical-chemical processes such as gasification by pyrolysis. Second-generation production technologies can yield the most diverse fuels. The spectrum ranges from bioethanol and synthetic fuels similar to petrol or diesel (BTL, Biomass-to-Liquid), to synthetic methane (SNG, Synthetic Natural Gas) and hydrogen. These new motor fuels offer another substantial improvement in energy efficiency as measured from tank to wheel, although they require design modifica-

tions to the vehicle fleet: BTL optimization of internal-combustion engines, monovalent gas vehicles and fuel cell technology.

Despite the expanded biomass spectrum and the improved energetic yield many questions remain open which are decisive factors for the future success of second-generation biofuels (EIA 2010). First of all there is the fact that land area will still be needed for cultivating biomass, through which the risk of land-use conflicts could rise, even after a successful introduction of second-generation biofuels.

Other open questions which have to be considered for a comprehensive assessment include:

- Part of the increased energy yield is destroyed by the lower efficiency of the more demanding (bio-)chemical process steps. How large is the net increase in energy efficiency?
- Current processes are optimized for a constant composition of the biomass, e.g. maize plants; if one wants to process raw materials such as bio-waste, the efficiency drops off sharply. How sensitive will the new process technologies be to variable biomass composition?
- Most second-generation technologies will not be ready for the market for a few years yet – however massive investments are being made today in first-generation production capacities. Will there be any investment capital left for second-generation plant, or will first generation plant have to be depreciated first?
- The production of biofuels has considerable sustainability potential for the rural regions of developing countries, because energy sovereignty and local value can be added (Greiler 2007; IRGC 2008). However there is still the question as to whether this development potential will be destroyed by technologies protected by large concerns' patents?
- In the long run there is the question as to whether biofuels will be able to play any role at all for our mobility in case electric drive systems prevail in individual traffic as they have elsewhere?

Incentives are being set in various regions of the world to increase the percentage of energy consumption supplied by biofuels despite the great uncertainties involved. Sustainability assessment is being given a lot of attention, and many studies are being published on the sustainability of second-generation biofuels (Rautanen 2005; Edwards, Larivé et al. 2006; Leible, Kälber et al. 2006; Jungbluth, Büsser et al. 2008). Most of the studies use specific evaluation methods such as Life Cycle Analyses (LCA), material flow analyses or system-dynamic modelling, and thus look at individual aspects of sustainability, without supplying a comprehensive picture.

Such an approach, however, is especially critical in the case of biofuels, because the cultivation, processing and use of biofuels are closely coupled with the use forms of various other resources – examples including the land-use competition triggered by cultivating energy feedstocks, expanding the area for biofuels at the expense of unused, natural ecosystems, lock-in effects in building biofuel production plants and the competition with other energetic use forms such as electricity and heat.

The approach of technology assessment (TA) provides a framework for combining multiple investigation methods, thus making it possible to deal with the above-mentioned transdisciplinary questions and to sketch a comprehensive picture of the future role that second-generation biofuels could play in our society.

The core research question addressed by the project is: How can fuels made from second-generation biomass be used in Switzerland? How high is the potential when sustainability criteria and the developments in the EU and developing countries are taken into account?

The main question is based on the following sub-questions:

1. What are the relevant biomass sources, production technologies and energetic use forms? What actors are involved in the respective paths of production and use?
2. What are the ecological, economic and societal effects of the production and use paths of second-generation biofuels? How do second-generation biofuels compare to the most efficient biofuels and to other renewable energy forms (such as e.g. electromobility)?
3. What is the sustainability (ecological, economic and social criteria) of various scenarios for the use of second-generation biofuels in Switzerland under consideration of the direct and indirect effects?
4. How big is the potential for energy in a national/international dimension? In what dimension can these technologies be used in an efficient way (size of the production plant or the size of the area needed for raw material)? How much mobility can be derived from that?
5. What strategies should be followed in the production, trade and use of second-generation biofuels in order to ensure the sustainability of such systems? What government incentive mechanisms should reinforce these strategies?

2 GOAL AND SCOPE

2.1 Goal

The goal of the project is the integrated assessment of chosen 2nd generation biofuels. As a reference also 1st generation biofuels are assessed.

2.1.1 Geographical System Boundaries

In general, the system boundaries include all potential biofuels which can be used in Switzerland. On this basis production path of foreign can be compared with domestic biofuels. Such results are important for actors in Switzerland but also for other OECD countries as well as export orientated countries in the southern hemisphere. Figure 2 shows the general system boundaries and their possible content.

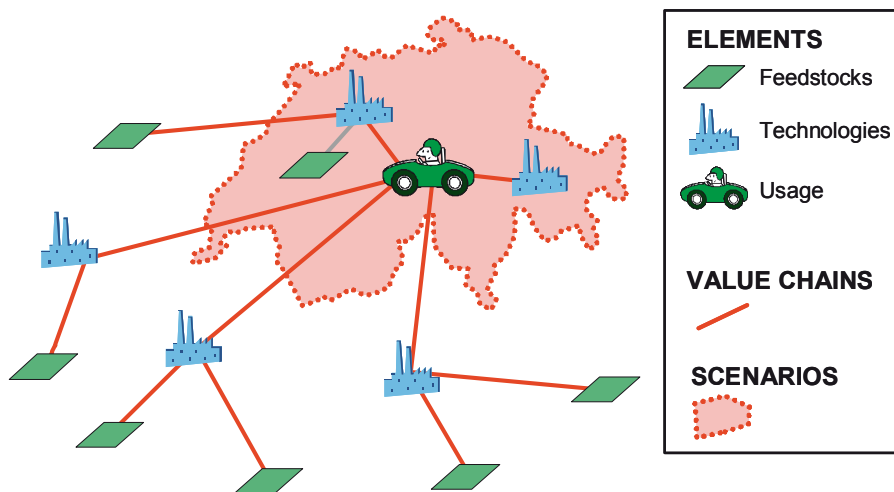


Figure 18: Geographical system boundaries.

In detail, the system boundaries include different contents: elements, value chains and scenarios. In this context, each value chain consists of three elements and each scenario includes at least two value chains. Within the framework of the project, the system boundaries are successive enlarged. In the first step single elements are focused. Subsequently, entire value chains are assessed. In the following, different value chains are summarized within one scenario. All in all, three scenarios are analysed.

Elements

Elements are determined as one essential part of a value chain. Three different types of elements are distinguished: feedstocks, conversion technologies and use. Figure 19 shows the respective system boundaries for those elements.

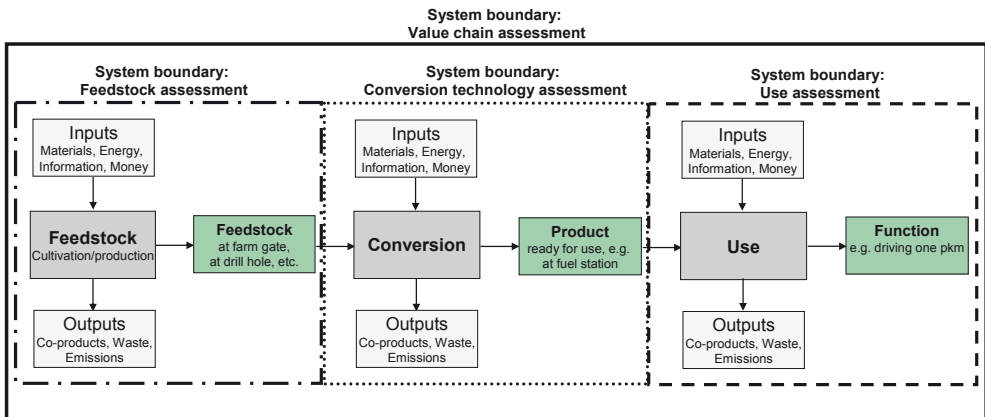


Figure 19: System boundaries related to the assessment of feedstocks, conversion technologies and use.

In the element assessment, the system boundaries are strictly limited to one single element. For example, within the assessment of the feedstock *jatropha* the system boundaries include all inputs required and outputs produced which are related to the production of one MJ *jatropha* at farm in a given region in India. In addition to the required inputs and produced outputs, the system boundaries for the assessment of conversion technologies includes also the transport of the feedstock to the plant as well as the potential transport of the product to the place where it can be used, e.g. fuel station. The system boundaries to assess the potential use of the product are limited to the required inputs and produced outputs of the element.

As shown by Figure 19, value chains are combinations of elements. On the value chain level the system boundary includes a single full value chain from cradle to grave, i.e. from raw material acquisition out of the environment to the disposal of the product back into the environment. For example, the value chain “driving of one pkm with ethanol produced from *miscanthus*” includes the cultivation of *miscanthus*, the conversion to ethanol and the use in an average Swiss car.

In the context of a given scenario, a possible future state is determined and quantified in terms of the magnitude provided by different value chains. On this basis, the impacts of possible future states can be assessed.

2.1.2 Temporal

A challenge for comparative technology assessment studies is how to handle the different levels of technological development. Some first generation biofuels are already available today on the market in large quantities, while future fuels like e.g. algae fuels, are expected to be produced by much more advanced technologies.

On the levels of elements and value chains a probable year of market entry has been assumed for each fuel and the assessment refers to this year (reg. Figure 84: temporal availability of the various elements). Further technological development after market entrance has been neglected. In addition, the value chains and elements have been sorted according to their market entrance in the result figures in order to facilitate the interpretation of technological maturity.

On the level of scenario assessment the study is focussed on two points in time.

- **2015:** Some 2nd generation biofuels such as SNG are expected to be ready for the market starting competition with the fossil reference.
- **2030:** Advanced biofuels like BTL or fuels from algae will show up on the market. Furthermore a competition between electric mobility and bio-fuels of the 2nd generation is expected.

2.2 Examined elements

The value chains of biofuels are composed of so-called **elements**. Along the life cycle of a biofuel, firstly, **feedstock** is needed. The feedstock is then converted into biofuels using a combination of specific **conversion technologies**. Finally, biofuels might serve for different **usages** like mobility or electricity production.

The elements have been defined from two perspectives. On the one hand we tried to cover all elements which might have a future potential. Therefore, also some unusual elements, like e.g. halophytes (salt-resistant plants that grow in brackish water) have been included. On the other hand, all elements which are part of probable value chains have been included, like e.g. wood or sugar cane.

In this project 2nd generation biofuels are defined as value chains where not only oils, sugar and starch but also hemi-cellulosic compounds are transformed into fuel energy. Consequently, feedstock with a high hemi-cellulosic content that is mainly produced for 2nd generation conversion is defined as 2nd generation feedstock. This comprises also feedstocks like manure or algae that might be also converted using 1st generation technology. The allocations to 1st or 2nd generation fuels are shown in Table 3 and Table 4 respectively.

2.2.1 Feedstocks

Table 3: Feedstock elements to be considered in the TA-SWISS project.

Category	Feedstock	Gen.	Why this feedstock?	Geo-graphical source(s)	Scenarios analysed	Source
FOSSIL REFERENCE	Crude oil	-	Used as the baseline	Nigeria vs. North sea (worst and best case)	worst and best case	(Jungbluth 2003)
ENERGY-CROPS	Sugar cane	1st	Reference system, high yield,	Brazil	average	(Lipman, Edwards et al. 2004; Jungbluth, Faist et al. 2007; Zah, Hirschier et al. 2007)
	Rape seed	1st	Reference system, very common, broadly used	Switzerland, eastern Europe	grown on under utilized land	(Jungbluth, Faist et al. 2007; Zah, Hirschier et al. 2007)
	Oil palm	1st	Reference system, high yield, known very well	Indonesia	grown on under utilized land	(Jungbluth, Faist et al. 2007; Zah, Hirschier et al. 2007)
	Jathropa	1st	growth on marginal land, very up to date	India	extensive and intensive production	(Jungbluth, Faist et al. 2007)
	Miscanthus	2nd	hype in the USA	Europe	extensive production	(Styles, Thorne et al. 2008)
	Halophytes	2nd	high future potential is expected	China	low and high yield	(Hendricks and Bushnell 2008; Ruan, Li et al. 2008)
	Algae	2nd	high future potential is expected	-	Open ponds	(Chisti 2007; Rosenberg, Oyler et al. 2008; Ross, Jones et al. 2008)
	Low-Input High Diversity (LIHD) Grassland	2nd	high future potential is expected	USA	average	(Tilman, Hill et al. 2006)
WOOD	Direct wood fuel	2nd	basis for SNG production in CH	Switzerland, European market	average	(Werner, Althaus et al. 2003; Oettli, Blum et al. 2005; Felder and Dones 2007)
	Indirect wood fuel	2nd	basis for SNG production in CH	Switzerland, European market	average	(Werner, Althaus et al. 2003; Oettli, Blum et al. 2005; Felder and Dones 2007)
	Waste wood	2nd	basis for SNG production in CH	Switzerland	average	(Werner, Althaus et al. 2003; Oettli, Blum et al. 2005; Zah, Böni et al. 2007)
WASTE & RESIDUES	Straw	2nd	Ethanol production	Switzerland	average	(Oettli, Blum et al. 2005; Zah, Böni et al. 2007)
	Manure	2nd	Reference system,	Switzerland	average	(Oettli, Blum et al. 2005; Zah, Hirschier et al. 2007)
	Biowaste	2nd	Reference system,	Switzerland	average	(Oettli, Blum et al. 2005; Zah, Hirschier et al. 2007)

2.2.2 Conversion technology

Table 4: Conversion technologies focused within the TA-SWISS project.

Conversion technology	Feedstocks	Gen.	Scenarios analyzed	Source
Refinement	crude oil, vegetable oil	-	average	(Jungbluth 2003)
Oil extraction & Esterification	oil seeds	1 st	cold and solvent extraction	(Bockey 2006; Chisti 2007; Jungbluth, Faist et al. 2007)
Fermentation (biogas)	manure, biowaste	1 st	average	(Edelmann, Schleiss et al. 2001; Jungbluth, Faist et al. 2007)
Alcoholic fermentation & distillation (sugar)	sugar cane	1 st	average	(Hammerschlag 2007; Jungbluth, Faist et al. 2007)
Gasification & methanation (SNG-production)	woody biomass	2 nd	average	(Leible, Kälber et al. 2006; Felder and Dones 2007; Jungbluth, Faist et al. 2007)
Gasification & BTL-production (using Fischer-Tropsch-Synthesis)	woody biomass	2 nd	average	(Jungbluth, Faist et al. 2007)
Fermentation (lignocellulose) & distillation	woody biomass	2 nd	average	(Jungbluth, Faist et al. 2007)
Photovoltaic	sunlight	-	average	(Jungbluth 2003; Frischknecht and Jungbluth 2005)
Cogeneration	biomass	-	average	(Jungbluth, Faist et al. 2007; Zah, Hischer et al. 2007)
Electricity production	biomass, fossil	-	average	(Jungbluth, Faist et al. 2007)

2.2.3 Usage

Table 5: Usage scenarios analyzed within the TA-SWISS project.

Priority	USAGE	(INPUT)Product(s)	Scenarios	Source:
1	MOBILITY/TRANSPORT	XME, ethanol, SNG, BTL, electricity (Battery), diesel, petrol,	in combustion engine, in hybrid power train, in range extender,	(McAuley 2003; Spielmann, Kägi et al. 2003; EEA 2004; Lipman, Edwards et al. 2004; Hammerschlag 2007; Jungbluth, Frischknecht et al. 2007; Robert 2007; Widmer, Gauch et al. 2007)
2	ELECTRICITY AND HEAT (cogeneration) PRODUCTION	fossil references, relevant biomass	in electric power train	(Felder and Dones 2007; Jungbluth, Faist et al. 2007)

With respect to the usage of fossil fuels and biofuels the highest priority is given to mobility/transport.² However, hybrid forms between combustion and electric drives are analyzed as well.

² According to the advisory group TA-SWISS, this form of usage should be primarily analyzed.

3 METHODS

3.1 Conceptual framework

In this project both a top down and a bottom up approach have been applied (Figure 20). The assessment of elements, value chains and system scenarios with the Sustainability Potential Analysis (SPA) follows a bottom up approach. The derivation of system scenarios follows a top down approach. Finally, both approaches are linked in assessment framework of the SPA (SPA). In the context of SPA, numerous tools and “sub”-methods are applied such as Life Cycle Assessment or the assessment of global land use by forestry and agriculture (GLUF and GLUA) in order to determine all indicators required for the assessment.

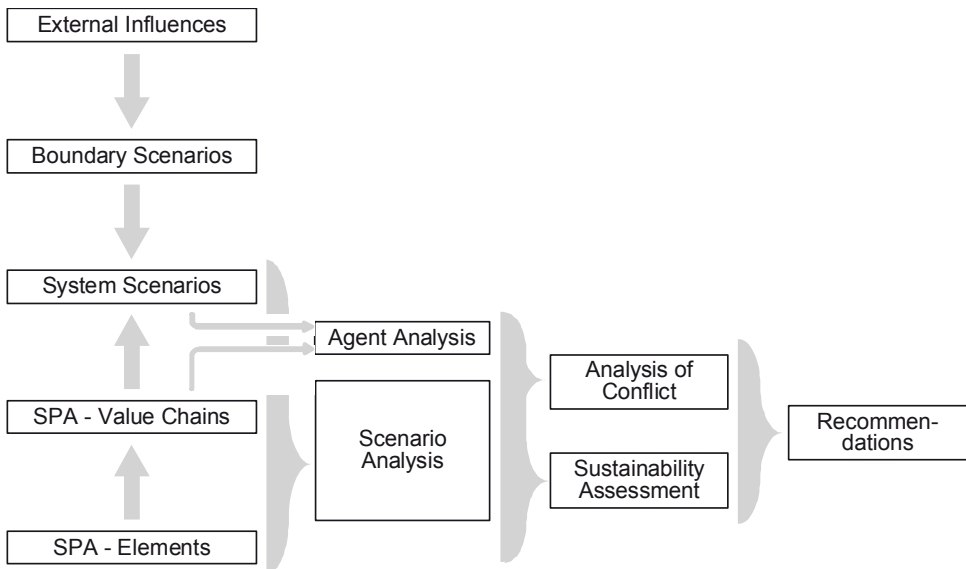


Figure 20: Process framework of the TA-SWISS project.

In addition an agent analysis has been applied. In this agent analysis key actors are identified and characterized according to their aims, their planning horizon and the structural factors influencing them. On this basis restrictions with regards to implementing of 2nd generation biofuels have been identified. In combination with the assessment results of the SPA the sustainability of the focused technologies has been assessed from a holistic point of view.

Bearing both in mind, i.e. the results of the sustainability assessment and the analysis of conflict of aims, proposals for solutions and recommendations for policy are formulated. The three core methods (SPA, Scenario analysis and agent analysis) are explained in detail in the following. The methods applied in the context of the SPA are elaborated within the SPA chapter.

3.2 Sustainability Potential Analysis (SPA)

3.2.1 Theoretical background of SPA

To assess the risks and opportunities of 2nd generation biofuels, a comprehensive assessment methodology is required. In general the assessment should depend on the criteria perceived as important. In this context, a guiding framework is required to assure that the performance of the systems (elements, value chains and scenarios) under study is assessed in a holistic way.

The Sustainability Potential Analysis (SPA) is an extension of the Bio-Ecological Potential Analysis (BEPA) of Scholz and Tietje (Scholz and Tietje 2002). The main idea of SPA is to analyze and assess systems by using coherent general principles, which indicate the 'well-being' of a system. On the basis of evolutionary, developmental and cybernetic system theories, SPA provides a holistic framework for the analysis of sustainable development (SD) from a systemic point of view.

Goal is to apply SPA as a "meta" framework to analyze and assess the sustainability of 2nd generation biofuels.

3.2.1.1 Concept

According to Lang et al. (Lang, Binder et al. 2007), SPA is designed to adequately consider and interrelate the functional, structural, and contextual dimensions needed for assessing sustainable development (SD). The general goal of SPA is to analyze the potential of systems to hinder or support SD. Basis for the methodology is the Function-Structure-Context Framework. The three dimensions can be described as follows:

1. **Function:** the goals and demands that are imposed on a system (e.g., by their stakeholders). Functions of the element "biomass" include, for example, the energy content, the price or the quality of the biomass.
2. **Structure:** Is defined as the relevant spatial and temporal relationship, connectedness, partitioning and modularization of the system units within a defined system boundary. The structure of the element "biomass" includes, for example, the homogeneity of the biomass content.
3. **Context:** Means external entities, such as regional climate, geomorphology or bed-rock, hydrology outside the system boundary including all environmental constraints that are permanently relevant system or impact factors. The context of the element "biomass" includes, for example, the region where the biomass is produced and the proximity to the processing chain.

Figure 21 shows the overall concept of SPA. It starts with a detailed explication of a system and/or problem. After that in a decomposition process, central system attributes (so called preceptors) are defined. Thereafter these are analyzed and evaluated. Finally the insights of these analyses are integrated within a synthesis procedure.

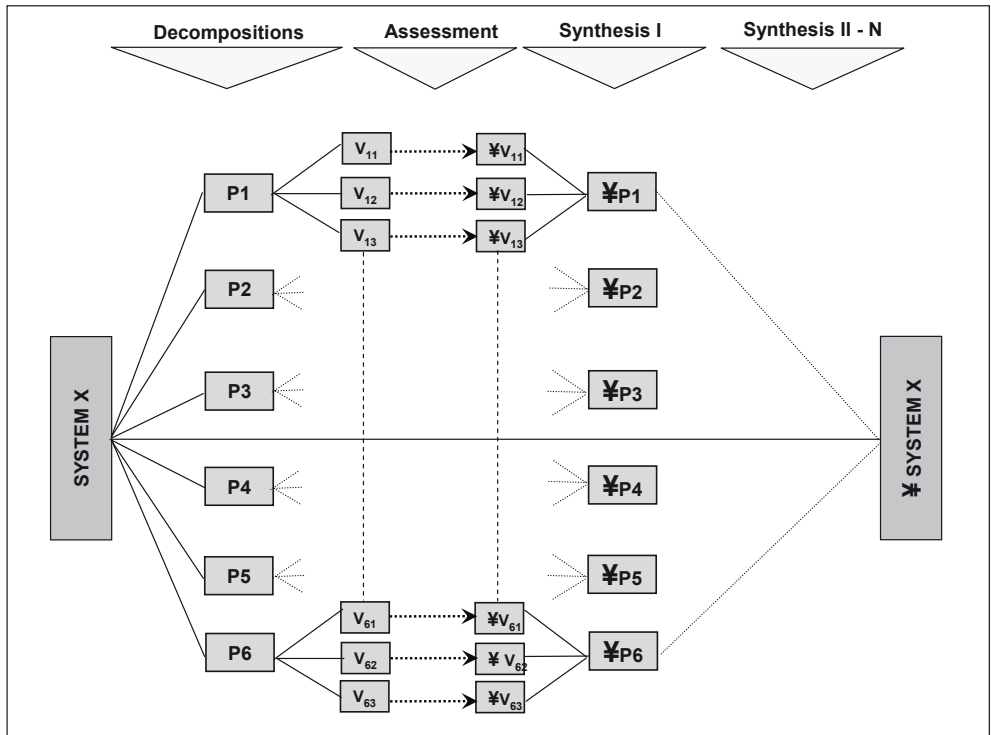








Figure 21: Conceptual outline of SPA. (P_i are Perceptors; V_{ij} are functional key variables and $¥i(j)$ are sustainability-potentials. Source: (Pfister, Selkirk et al. 2002).

3.2.1.2 Decomposition

Lang et al. (Lang, Binder et al. 2007) determined six generic criteria which should be addressed by comprehensive assessment from a systemic point of view. Table 6 shows the six generic criteria of SPA.

Table 6: The six generic criteria of SPA.

Generic criterion	Description with respect to SD
Performance & efficiency	 A system should fulfil its functions as effectively and efficiently as possible. If not, the utilization of resource is suboptimal and does not comply with the concept of SD.
Well-structuredness	 Structural properties essentially determine the quality of a system and its ability to meet given function and to satisfactorily adjust to changing functions.
Interdependencies with other systems	 Each system influences and is influenced by other systems. The characteristics of these influences crucially determine the potential of a system to hinder or support SD.
Buffer capacity & resilience (Assimilation)	 External effects as well as internal changes can unsettle systems. Each system has an existing ability to assimilate and attain a “stable state” again. This ongoing assimilation enables a system to support SD.
Ability to accommodate	 If the capacity to assimilate is exceeded, a system has to adopt inherent structures or interdependencies with other systems in order to attain a new “stable state”.
Inter- & intra-generative equity	 Costs and benefits of any system should be fairly allocated within the present generation and between the present and the future generations. If not, the long term stability and viability of the system is endangered.

The descriptions of the criteria clarify that C1–C3 mainly focus on the systemic dimensions of function (C1), structure (C2) and context (C3), whereas C4–C6 rather concentrate on the interdependencies of these dimensions. Hereby, buffer capacity and resilience (C4) and ability to accommodate (C5) are the results of a specific interplay between function, structure, and context while the idea of inter- and intra-generative equity (C6) concerns all of these systemic dimensions. The realization of the latter normative (functional) goal depends on structural characteristics of the system and the future development of its anthropogenic and natural environment (context), as we are, for instance, incapable of predicting the needs of further generations.

Figure 22 shows the generic criteria's in the context of a Function-Structure-Context Triangle.

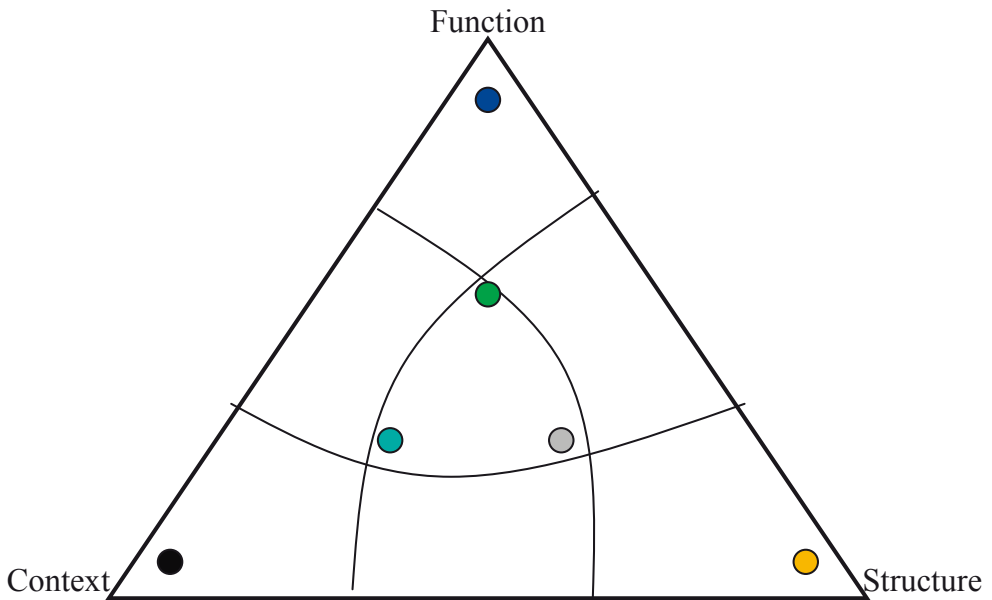


Figure 22: *Function-Structure-Context Triangle to represent how the evaluated landfill assessment methods incorporate the systemic dimensions, Function, Structure and Context, and their interdependencies (source: [Lang, Binder et al. 2007]).*

For a concrete assessment, each generic criterion is specified according to the particular characteristics of the system under consideration using so-called Functional Key Variables (FKVs), which are themselves operationalized using concrete utility or hazard functions.

For example, consider the assessment of biomass/feedstock on the element level. One possible FKV related to the performance and efficiency criterion could be “Economic efficiency”. This FKV could be expressed with the key indicator “production costs” which could be operationalized by the ratio of (i) production costs of the feedstock, and (ii) the arithmetic mean of the production costs of all feedstock’s under study (Table 1).

Table 7: *Example for the operationalization of a FKV.*

Generic criterion	FKV	Specification (key indicators)	Operationalization
Performance & efficiency	FKV ₁₁ : Economic adequacy	Production costs [CHF/MJ]	Ratio of (i) production costs of the feedstock, and (ii) the arithmetic mean of all feedstock’s under study.

3.2.1.3 Assessment

SPA aims to identify the potential of a system to develop sustainably. Therefore a sustainability-potential \mathbb{Y} is defined. In a first approach this measure could range from one to five where one stands for impossibility and five for best conditions to develop sustainably.

The preceptors are of a different nature. Therefore, approaches to value them also have to be diverse. For example productivity and effectiveness could be measured using sciences and economics, whereas inter- and intergenerational equity requires more of a so called "soft-valuation".

3.2.1.4 Synthesis

Synthesis can take place on different integration levels. The most rudimentary is the integration to \mathbb{Y}_{Pi} of the specific preceptor. The most extensive is the integration to \mathbb{Y}_{Total} of the whole system under investigation. Different methods are possible to synthesize the valuations of the specific decomposition levels. In a first setting we choose the weighted sum (Eq. 1).

$$X = \sum_{i=1}^n k_i Y_i$$

Y_i represents the valuations to be integrated and X is the valuation on the superior integration level (either \mathbb{Y}_{Pi} or \mathbb{Y}_{Total}). k_i is a weighting factor max (0,1). The factors of a specific integration level have to sum up to one. The magnitude of these factors could be determined by scientific knowledge or within a stakeholder consensus process.

3.2.1.5 Comparing SPA with other sustainability criteria

A range of sustainability criteria has been developed over the last years for assessing of biofuels. Table 8 compares some of these assessment systems with the SPA-indicators used in this study. Most of the internationally used sustainability criteria are covered by the SPA-indicators (green fields). However, indicators dealing with legality and policy aspects are missing in the SPA-framework (yellow fields). On the other hand, five different aspects of the SPA-framework are not covered by other sustainability concepts (blue fields).

Table 8: Comparison of the SPA-indicators used in this study with three other sustainability criteria systems. Green fields refer to SPA-indicators that are also reflected in other sustainability criteria systems; yellow fields refer to criteria that are not considered in the SPA; blue fields refer to SPA-indicators that are not reflected in other sustainability criteria systems.

Sustainability Potential Analysis This Study	GPSP sustainability indicators Rome, 2010	ISP principles on sustainability Lausanne, 2009	Cranset Criteria The Netherlands, 2007
GHG-Emissions	GHG emissions	GHG emissions (Principle 3)	GHG emissions
Environmental Impacts	Air quality	Air (Principle 10)	Environment
Water dependence	Water availability, use efficiency and quality	Water (Principle 9)	
global land use of agriculture	Land-use change, including indirect effects		
global land use of forestry			
Area efficiency	Productive capacity of the land and ecosystems		
loss of high-value ecosystems	Biological diversity	Conservation (Principle 7)	Biodiversity
Resilience to environmental			
global net area of Swiss	Food security	Local food security (Principle 6)	Competition with food
	Legal, policy and institutional framework and governance regarding the environmental impacts of bioenergy	Legality (Principle 1)	
	Access to land, water and other natural resources	Land Rights (Principle 12)	
	Legal, policy and institutional framework and governance regarding the economic and energy security impacts of bioenergy	Planning, Monitoring and Continuous Improvement (Principle 2)	
Energy efficiency	Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use	Use of Technology, Inputs, and Management of Waste (Principle 11)	
Resilience to economic changes	Economic development		Economic aspects
Economic efficiency	Economic viability and competitiveness of bioenergy		
Infrastructure	Access to technology and technological capabilities		
Information structure			
Flexibility of the value chain			
Energy dependence	Energy security / Diversification of sources, supply, infrastructure		
Resource dependence			
	Human health and safety		
violation risk of human rights and ILO	Labour conditions	Human and Labor Rights (Principle 4)	Well-being
rural income equality	Rural and social development	Rural and social development (Principle 5)	
	Access to energy		
	Legal, policy and institutional framework and governance regarding the social impacts of bioenergy		
Social acceptance			

3.2.2 Methods in the context of the SPA

3.2.2.1 Life Cycle Assessment (LCA)

LCA is a method for analyzing and assessing environmental impacts of a material, product or service along its entire life cycle (ISO 2005). Two main approaches are distinguished: the attributional and the consequential approach. The approaches differ with respect to system delimitation and the use of average versus marginal data.

Attributional LCA (ALCA) is defined by its focus on describing the environmentally relevant physical flows to and from a life cycle and its subsystems (Ekvall and Weidema 2004). Within an ALCA, the system investigated is limited to a single full life cycle from cradle to grave. Hence, co-production has to be treated by applying allocation factors. Furthermore, the attributional approach uses average data in order to attribute the average environmental burdens for producing a unit of the product in the system (Ekvall and Weidema 2004).

Consequential LCA (CLCA) is defined by its aim to describe how environmentally relevant flows will change in response to possible decisions (Ekvall and Weidema 2004). In contrast to ALCA, the system within a CLCA is not limited to one life cycle. The consequential approach uses system enlargement to include additional life cycles and products affected by a change of the physical flows in the focused life cycle.

In the framework of the TA-SWISS project we applied the method of attributional LCA. In this context, the life cycle is strictly limited to one single life cycle and co-production is treated by (economical) allocation. For a further discussion of methodological issues see (ISO 2005).

3.2.2.2 Global land use of agriculture – GLUA

The accounting for global land use of agriculture – GLUA goes back to earlier studies at Wuppertal Institute for EU-15 and Germany (Schütz 2003; Bringezu and Steger 2005; Steger 2005; Bringezu, Schütz et al. 2009a).

For the accounting of the agricultural land required for the consumption of agricultural goods we refer to the accounting of “net consumption land”. This means that land is allocated to several products derived from the crop harvest. For example, the land needed to grow rapeseed for biodiesel is allocated on the basis of the weight of the resulting different products – to biodiesel and to rape-oilcake for animal feed. This procedure avoids double-counting for the total global agricultural land use for all agricultural products.

In addition to domestic land use for agricultural biomass, we calculate global land use for all other imported and exported agricultural commodities, all on the basis of net production land. To this end, imports and exports of agricultural commodities are acquired in detail from national or international foreign trade statistics in metric tonnes, for Switzerland in times series 2000 to 2006 by ca. 400 commodities from FAOSTAT. Yields for agricultural raw materials are taken from the database of FAO as well, and in the case of Switzerland applied to imports and exports on the basis of a rough distinction by origin from EU or World. Yields for agricultural animal or plant products are taken from the database of the

Wuppertal Institute and refer to the German production system or average global production. Land use for imported and exported commodities is obtained from quantities divided by yields.

Commodities imported or exported are further differentiated by use in terms of plant based nutrition, animal based nutrition, material use, and energetic use. Domestic harvest was allocated roughly to animal production (permanent meadows and pastures) and plant production (arable land and permanent crops). Data for material use refer to imports and exports only. Data for energetic use from domestic land and from imports were assembled from other sources (Steenblik and Simón 2007; Baum and Baier 2008), and related yields were adopted from FNR (2006) by adjusting to Swiss yields for oil crops and cereals (FAO 2009).

Adding the domestically available agricultural land to the net land requirement of foreign trade (imports minus exports) derives the global land use for domestic consumption of agricultural goods in Switzerland. Future increased use of non-food biomass will add to the global land requirement, and can be compared with the global per capita availability of agricultural land today and in the future.

Based on preliminary data for 2000 to 2006, Switzerland has required globally around 3,000 m² per Person and year agricultural land, with a declining tendency. Most of this (58%) was for animal based nutrition, followed by plant based nutrition (41%), while material use (0,8%) and energetic use (0,1%) were negligible (data for 2006). Global land requirements for domestic consumption in Switzerland were by ca. 22% to 30% higher than domestically available agricultural area. They were also significantly higher than global land use of Germany with ca. 2,500 m² per Person and year which was close to the global average for intensively cultivated agricultural area (Bringezu et al. 2009).

3.2.2.3 Global land use of forestry – GLUF

Land use accounting for the consumption of timber products is a new dimension of land use accounting (O'Brien 2009). As such, the principles of economy-wide MFA and land use accounting must be applied and adjusted for timber products and forestry. This is done in 3 stages, all of which has required development of methodic approaches within this project.

1. Determine consumed quantities of timber products: Economy-wide MFA is used to calculate the consumption of timber products, which can be derived from removals from the natural environment plus material imports from other economies less exports. To determine the input flows from the natural environment, removals of wood from domestic forests are used. This data is given by national forestry statistics (BAFU 2008). Imports and Exports of the major forestry commodities are reported in standardised Raw Wood Equivalents (RWE) as well by BAFU (2008).
2. Determine forestland needed to provide for the quantity of timber products domestically consumed: In this case, the focus extends to the forest, domestic and abroad, which supply the economic system (Switzerland) with timber products. Our approach is based on the net annual increment (NAI), which is the annual increase in growing stock in a country or region. It is given in units of cubic meters / hectare. In this case the question is: How much land is necessary to grow 'consumed volume X' in 2007? To answer this,

the RWE volume consumed (see 1.) is converted into a felling volume for the respective country of origin (UNECE and FAO 2005), for instance, reports conversion values for European countries) and divided by the NAI in its respective country. This methodic approach results in an amount of hectares domestically and internationally required to grow the consumed volume in one year. This can be compared to the actual productive forestland within the country of consumption in order to indicate whether its requirement exceeds national available resources or not (analogous to agricultural land – see above). Productivity of domestic Swiss harvest can be derived from BAFU (2008) at 6.48 m³ NAI per hectare FAWS (Forest Area available for Wood Supply). Imports data by commodities and countries of origin were used to derive – based on NAI per ha by country from IIASA data – a weighted productivity for all imports at 5.38 m³ NAI per hectare FAWS. Taking the relative shares of domestic harvest and imports to Direct Material Input (total direct supply of materials) into account, a weighted productivity for all exports at 5.86 m³ NAI per hectare FAWS can be derived. Forestry land use (in ha) is derived from m³ RWE divided by NAI per hectare FAWS.

3. Assessing sustainability: In this stage the per capita consumption of timber products from Switzerland will be calculated and compared to a reference value – which is the amount of timber globally available for consumption on a per capita basis under sustainable conditions. Therefore, the governing question of this stage is: How much timber can be consumed per person and year considering a globally sustainable use of forestland? Sustainability in forestry is often measured by comparing net annual growth to annual removals, with the argument that no more wood should be removed than grown annually. This concept can be expanded to the global level and calculated on a per capita basis to obtain the reference value. To obtain the global reference value, a transparent approach for estimating global net annual increment is undertaken. This will be calculated to be as accurate as possible: weighting productivity in different regions of the world by the size of the forest resource (or percent in comparison to the whole).

3.2.3 Functional Key Variable (FKV): Performance & Efficiency

According to Scholz (Scholz and Tietje 2002), performance is the assessment of productivity under a functional perspective. Three indicators are used for the assessment of performance: economics, energy and area efficiency.

3.2.3.1 Economic efficiency

Definition

The economic efficiency is defined as the functional return per unit money. In other words, the indicator measures the functional return in MJ or person kilometer (pkm) per US-Dollar (USD) invested.

Table 9: Specification of economic efficiency.

Generic criterion	Specification	Unit
C ₁ : Performance & efficiency	Functional return per unit USD invested.	[MJ/USD] [pkm/USD]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = 1 MJ/USD 1 (highest) = 165 MJ/USD	
Value Chain Level	0 (lowest) = 2.5 [pkm/USD] 1 (highest) = 3 [pkm/USD]	
Author	Date	
Jürgen Reinhard, Empa	04.09.2009	

Operationalization

The economic efficiency is operationalized using the reciprocal of the cost per MJ return, i.e. how much MJ is received per USD invested?

$$Economic\ efficiency = \frac{1}{\frac{US\$}{Eo_{FU}}}$$

with $US\$$ = Producer price.

Eo_{FU} = Energy output of the system per functional unit (FU).

For example, the average functional return of crude oil in MJ per USD invested is approx. 80 MJ/USD given average crude oil prices at approx. 0.012 USD/MJ in the last year.

Identification

The costs are expressed as the producer price. The producer price is determined as the price received by domestic producers for their output. The main sources for the identification of the cost data are FAO-statistics (FAOSTAT 2009), Oetli et al. and Smeets et al.

Normalization

Feedstock level: Normalization is done with reference to the functional return (in MJ) of crude oil. The determined range (Table 9) is located between double the economic efficiency of crude oil (165 MJ/USD) and one (1 MJ/USD) in order to cover the whole range of possible values. In other words, when the cost of a given feedstock is equal or higher than 165 MJ/USD, the normalized value will be 1 (highest). Otherwise, if the value is equal or smaller than 1 MJ/USD, it gets a 0 (lowest). This range covers 76% of the determined values. The used price of crude oil represents the one year average price from June 2008 to July 2009.

Value chain level: The greatest share of the overall costs for driving one pkm is related to car and maintainace costs, whereas the fuel costs account for between 25% and 5% of the overall costs. However, car and mainainace cost do not differ significantly and thus the influence of different fuel-cost prices on the overall price per km is minor. In order to emphasize the difference between the costs of driving one pkm the determined range (Table 9) is located between 3 pkm/USD (highest) and 2.5 pkm/USD (lowest). This range covers 83% of the calculated values.

3.2.3.2 Energy efficiency

Definition

The energy efficiency is defined as the functional return (MJ or pkm) per non-renewable MJ energy invested. In other words, the indicator measures the return on investment of the non-renewable energy.

Table 10: Specification of energy efficiency.

Generic criterion	Specification	Unit
C ₁ : Performance & efficiency	Functional return per MJ non-renewable energy invested.	[MJ/MJ] [pkm/MJ]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = 3 [MJ/MJ] 1 (highest) = 40 [MJ/MJ]	
Conversion level	0 (lowest) = 3 [MJ/MJ] 1 (highest) = 20 [MJ/MJ]	
Use Level	0 (lowest) = 3 [pkm/MJ] 1 (highest) = 20 [pkm/MJ]	
Value Chain Level	0 (lowest) = 3 [pkm/MJ] 1 (highest) = 20 [pkm/MJ]	
Author		Date
Jürgen Reinhard, Empa		04.09.2009

Operationalization

The energy efficiency is operationalized by the reciprocal of the non-renewable energy proportion at the functional return (MJ, pkm).

$$\text{Energy efficiency} = \frac{1}{\frac{F_{RFU}}{Ei_{fossil_FU} + Ei_{nuclear_FU}}}$$

with Ei_{fossil_FU} = fossil energy input per functional Unit (FU) in MJ

$Ei_{nuclear_FU}$ = nuclear energy input per FU in MJ

F_{RFU} = Functional return per FU

Identification

The energy efficiency is derived from the “Cumulated Energy Demand” (CED). It expresses the required energy per FU broken down in the different energy types (fossil, nuclear, wind, water, and biomass). The CED is calculated using attributional LCA. Where possible the LCIs from ecoinvent have been used. However, in particular LCIs from innovative Feedstocks such like halophytes and algae have been derived from existing publications. This is considered by means of a higher uncertainty.

Normalization

Feedstock level: According to Hall (Gagnon, Hall et al. 2009), a energy supplying system on the feedstock level (like crude oil production) requires an energy output which is three times higher than its energy input given that supplementary conversion steps and transport expenditures further reduce the energy benefit. On this basis our determined range is between 3 and 40, i.e. if the functional return per non-renewable energy invested is equal or lower than 3 the normalized value is 0 (lowest). Otherwise, if the functional return is higher than 40 the normalized value is 1 (highest). This normalization range is also applied on the conversion, use and value chain level.

3.2.3.3 Area efficiency

Definition

The area efficiency is defined as the functional return (MJ/pkm) per square meter and year (m^2a) invested.

Table 11: Specification of net energy yield per area.

Generic criterion	Specification	Unit
C ₁ : Performance & efficiency	Functional return per square meter area invested per year.	[MJ/ m ² a] [pkm/m ² a]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = 3 [MJ/m ² a] 1 (highest) = 480 [MJ/m ² a]	
Value Chain Level	0 (lowest) = 2 [pkm/m ² a] 1 (highest) = 120 [pkm/m ² a]	
Author		Date
Jürgen Reinhard, Empa		03.09.2009

Operationalization

Feedstock: On the feedstock level, this indicator is operationalized by the reciprocal of the net energy output divided by the m^2a per functional unit:

$$\text{Area efficiency} = \frac{1}{\frac{Eo_{FU} - (Ei_{fossil_FU} + Ei_{nuclear_FU})}{m^2a_{FU}}}$$

with Eo_{FU} = energy output per FU in MJ

Ei_{fossil_FU} = fossil energy input per FU in MJ

$Ei_{nuclear_FU}$ = nuclear energy input per FU in MJ

m^2a_{FU} = required land per FU in m^2a

On the value chain level the indicator is operationalized by the reciprocal of the m^2a used per pkm. Here, the indicator measures the amount of pkm which can be driven when investing one m^2a .

$$\text{Area efficiency} = \frac{1}{\frac{F_{RFU}}{m^2a_{FU}}}$$

with m^2a_{FU} = required land per FU in m^2a

F_{RFU} = Functional return per FU

Identification

The indicator is derived from “Cumulated Energy Demand” (CED) and “Land occupation”. CED expresses the required energy per FU broken down in the different energy types (fossil, nuclear, wind, water, and biomass). Land occupation sums the required land of both the background (e.g. the required infrastructure) and the foreground system (e.g. feedstock cultivation). Both CED and land occupation is calculated using attributional LCA. Where possible the LCIs from ecoinvent have been used. However, in particular LCIs from innovative Feedstocks such like halophytes and algae have been derived from existing data. This is considered by means of a higher uncertainty.

Normalization

Feedstock: We used the average net energy yield per m^2a of photovoltaic (PV) system as an orientation in order to determine the range for normalization. The average solar radiation for Switzerland is approx. 3'500 MJ per m^2a . However, the average net yields of the current available PVs in Switzerland are approx. 480 MJ/ m^2a . Thus, if the net energy yield per m^2a is equal or higher than 480 MJ/ m^2a the normalized value is 1 (highest). In order to cover the full range of values, the lower bound (0) is determined as 3 MJ/ m^2a .

Value Chain: Again we used the performance of the average PV system as a reference. In average, the pkm which can be driven per m^2a invested into PV is approx. 120 pkm/ m^2a . In this regard, if the pkm per m^2a is equal or higher than 120 pkm/ m^2a the normalized value is 1 (highest). In order to cover the full range of values, the lower bound (0) is determined as 2 pkm/ m^2a .

3.2.4 Functional Key Variable (FKV): Well-structuredness

3.2.4.1 Infrastructure

Definition

The indicator "infrastructure requirements" expresses the requirements for infrastructure of a system.

Table 12: Specification of infrastructure requirements

Generic criterion	Specification	Unit
C ₂ : Well-structuredness	Infrastructure requierments	[1-10 pts]
Application on	Normalization Range	
Feedstock Level	0 (lowest) = 1; Very high requisites and standard demands towards infrastructure during the production of biomass 1 = 10; Very low requisites and standard demands towards infrastructure during the production of biomass	
Conversion Level	0 (lowest) = 1; Very high requisites and standard demands towards infrastructure during the production of fuel 1 = 10; Very low requisites and standard demands towards infrastructure during the production of fuel	
Use Level	0 (lowest) = 1; Very high infrastructure requirements through fuel use 1 = 10; Very low infrastructure demands through fuel use	
Author		Date
Severin Hegelbach, ETHZ		October 8, 2009

Operationalization

Feedstock level:

Infrastructure requirements on the feedstock level assesses how high, moderate or low the specific requirements of the feedstock are during the planting, maintenance and harvesting operations. In this regard, the indicator measures infrastructure as the means and inputs (e.g. machinery, technology, process systems etc.) needed to accomplish the main operations in feedstock production.

It compares these infrastructure requirements among all the reviewed items and thus gives implicitly a reference on how probable it is for each of them to encounter a sufficient infrastructure in the market.

The assessment is done using central questions associated with the above described infrastructure requirements of feedstock during the cultivation and harvesting period (up to the point where the production output is sent off to a conversion facility).

These questions are defined based on the meaning of infrastructure and on the processes involved in this period of the value-chain. Possible standard answers are defined and justified. These basic answers serve as a benchmark for the evaluation of each feedstock's requirements. The indicator is a variable with four main categories which express different needs towards infrastructure. The answers to these questions are combined and result in a classification and consequent allocation to the categories. The possible standard responses are "none", "low", "moderate" or "high requirements" and 3, 2, 1 and 0 points are distributed respectively. The estimated results are summed up and normalization between 1 and 10 is carried out. For feedstocks which rely in their production on greatly developed and sophisticated infrastructure 1 point is assigned whereas 10 points are distributed for remarkably low infrastructure demands. Below, the determination diagram of infrastructure requirements for feedstocks is depicted.

Evaluation diagram of infrastructure requirements for feedstocks

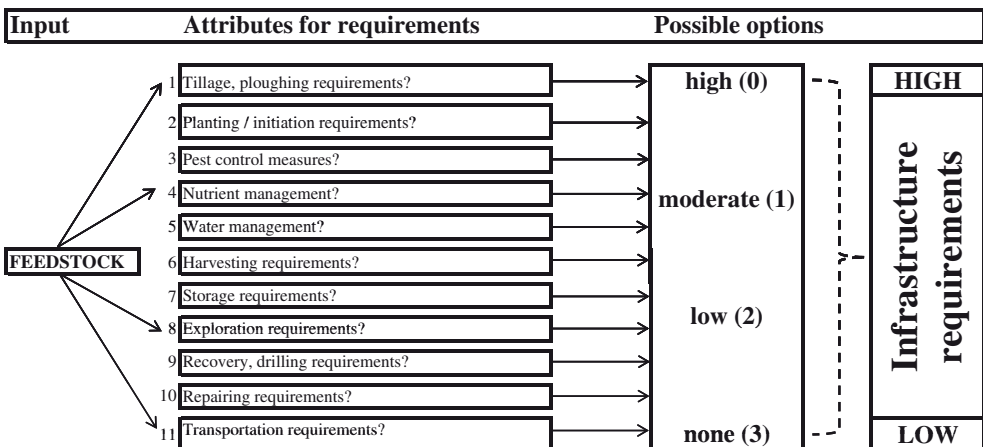


Figure 23: Evaluation diagram of infrastructure requirements for feedstocks.

Conversion level:

The indicator “infrastructure requirements for conversion” is a measure for needs of a certain conversion technology towards infrastructure during the period of processing the biomass to the final product. It assesses how high, moderate or low the specific requirements of the technology are from its construction through to the numerous steps of the conversion process (e.g. extraction, refining, esterification, fermentation, distillation, methanation, gasification etc.) until the delivery at the refueling stations. The conversion process requires generally large industrial complexes (e.g. refineries, biofuel distilleries and more) which in turn need heavy equipment installed for the different process units (Kline, Oladosu et al, 2008). Typically, such plants require also proximity to transportation and energy supply infrastructure (Kline, Oladosu et al, 2008) although it is difficult to allow production sites near population centers (Jagunich 2009). Each process is somehow dependent on infrastructure and has direct (e.g. construction of facility) and indirect (e.g. process of facility) infrastructure impacts and needs (Zah, Hischier et al. 2007). Accordingly, the indicator compares these infrastructure requirements among all the reviewed items and thus gives implicitly a reference on how probable and difficult it is for each of them to encounter a sufficient infrastructure in the market.

The indicator is operationalized using central questions associated with the described infrastructure requirements of conversion technologies and facilities during the numerous process steps up to the point where the fuel is sent off to a conversion facility. These questions are defined based on the meaning of infrastructure and on the processes involved in this period of the value-chain. Possible standard answers are defined and justified. These basic answers serve as a benchmark for the evaluation of each technology's particular requirements. The indicator is a variable with four main categories which express different needs towards infrastructure. The answers to these questions are combined and result in a classification and consequent allocation to the categories. The possible standard responses are “none”, “low”, “moderate” or “high requirements” and 3, 2, 1 and 0 points are distributed respectively. The estimated results are summed up and normalization between 1 and 10 is carried out. For highly complex conversions with numerous process steps combined together with large-scale facility and heavy machinery operations 1 point is assigned because of the high infrastructure requirements. Likewise, for less complicated conversions which do not rely on heavy machinery or technology installations 10 points are distributed because of relatively low infrastructure demands. Below, the determination diagram for infrastructure requirements for conversion technologies is depicted.

Evaluation diagram of infrastructure requirements for conversion

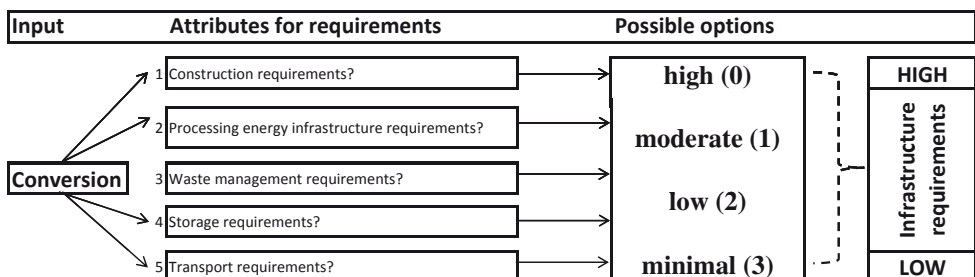


Figure 24: Evaluation diagram of infrastructure requirements for conversion.

Use level:

The indicator “infrastructure requirements for use” is a measure for infrastructure needs that arise from the use of a certain fuel of the examined value-chain. Yacobucci and Schnepf (2007) find that an expansion of ethanol use which goes beyond certain levels will require investment in entirely new infrastructure. Additionally, as pointed out by Plotkin (2000), modification of existing infrastructure (e.g. refueling stations) is an option to use blends. An in depth report of Downstream Alternatives Inc (DAI) about the U.S. ethanol industry (Inc 2002) observes that there are needs for additional tankage (storage tanks) at retail points and fuel terminals, installation of blending systems at fuel terminals and also installation of rail spurs for transport of the fuels. Biofuels do not only require specially adapted tank, pipelines and fittings (Jagunich 2009) but also modifications in vehicles by car manufacturers to allow the use of higher blends or pure fuels (Kondili and J.K.).

Biofuels are relatively similar to conventional fuels and in this manner able to use the same infrastructure up to a certain degree. However they do bring along additional requirements. The indicator assesses how high, moderate or low the specific requirements of the use of a fuel are. Implicitly, the indicator measures how much change to the existent and described infrastructure is needed for the fuel to be compatible and to be used similarly to the reference, gasoline. The variable compares this “overall compatibility” with the existing infrastructure among all the reviewed items for the relevant infrastructure and thus gives implicitly a reference on how difficult it is for each of them to get established and integrated in the market.

The indicator is operationalized using central questions associated with the above described new infrastructure requirements of fuel use for transportation. These questions are defined based on the meaning of infrastructure and on the processes involved in this period of the value-chain. Possible standard answers are defined and justified. These basic answers serve as a benchmark for the evaluation of each fuel's additional requirements. The indicator is a variable with four main categories which express different needs towards infrastructure. The answers to these questions are combined and result in a classification and consequent allocation to the categories. The possible standard responses are “none”, “low”, “moderate” or “high requirements” and 3, 2, 1 and 0 points are distributed respectively. The estimated results are summed up and normalization between 1 and 10 is carried out. For fuels which need a complete new infrastructure to enable their use 1 point is assigned whereas 10 points are distributed if no exceptional demands are posed to the existing infrastructure. The baseline for the comparison is the status-quo – gasoline is attributed 10 points. Below, the determination diagram for new infrastructure requirements for fuel use is depicted.

Evaluation diagram of infrastructure requirements for fuel use

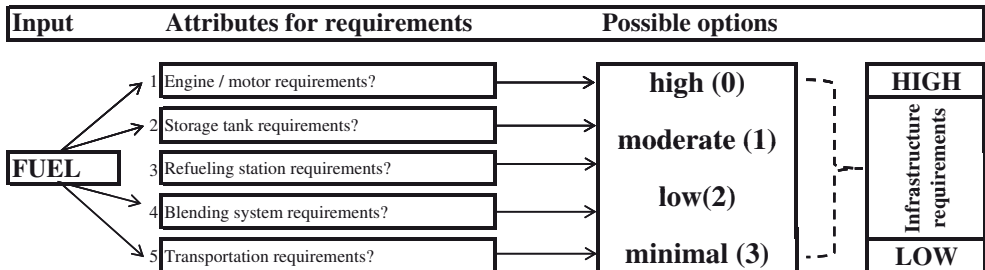


Figure 25: Evaluation diagram of infrastructure requirements for fuel use.

Identification

Feedstock level: The needed data to allocate the feedstocks to the categories of the indicator is obtained for each of them from different scientific sources (specific books, reports, articles and papers), from government institutions and ultimately also from information found on qualified websites. Additionally, information about processes and their requirements were extracted from former LCI-data on biofuels (Jungbluth, Chudacoff et al. 2007) and integrated in the evaluation by means of the central questions. The most essential information needed to determine the variable is for each feedstock the characteristic infrastructure demand of its production having in mind the central questions. All analyzed feedstock elements were considered while the assessment was confined within the borders of the particular state (e.g. for sugar cane: Brazil).

Conversion level: The needed data to allocate the conversion technologies to the categories of the indicator is obtained for each of them from different scientific sources (specific books, reports, articles and papers), from government institutions and ultimately also from information found on qualified websites. Additionally, information about processes and their requirements were extracted from former LCI-data on biofuels (Jungbluth, Chudacoff et al. 2007) and integrated in the evaluation by means of the central questions. The most essential information needed to determine the variable is for each conversion the characteristic infrastructure demand of its processes having in mind the central questions. All analyzed conversion elements were considered on a universal basis, i.e. no specific countries were looked at in detail.

Use level: The needed data to allocate the fuels to the categories of the indicator is obtained for each of them from different scientific sources (specific books, reports, articles and papers), from government institutions and ultimately also from information found on qualified websites. Additionally, information about processes and their requirements were extracted from former LCI-data on biofuels (Jungbluth, Chudacoff et al. 2007) and integrated in the evaluation by means of the central questions. The most essential information needed to determine the variable is for each fuel the characteristic infrastructure demand of its use having in mind the central questions. All analyzed use elements were considered while the assessment was restricted to the use of fuels in the system Switzerland.

Normalization

Feedstock level:

Points	Normali- zation	Criteria	Examples
10 (minimal needs)	1.0	Neither additional nor special infrastructure requirements for feedstock growth and harvest.	Small number of process steps, no irrigation needed, no storage needed, harvested by manual labor, no pest control, and no fertilizer required.
7 (low needs)	0.67	Only low requirements, few processing steps and tools needed for growth and harvest.	Relatively small number of process steps, no irrigation needed, no storage needed, some fertilizer application and pest control.
4 (moderate needs)	0.33	Moderate infrastructure needs, several process steps and tools involved all the main processes.	Higher number of process steps, some water management, outdoor storage, various fertilizer and pesticide applications, considerable transportation needs.
1 (high needs)	0.0	Feedstock comes with high requirements for infrastructure, numerous variety of processing steps, much work and many machines involved in harvesting.	Very high number of process steps, high initiation requirements, water management required, indoor storage and drying, multiple fertilizer and pesticide applications, heavy machinery for harvesting.

Conversion level:

Points	Normali- zation	Criteria	Examples
10 (minimal needs)	1.0	Neither additional nor special infrastructure requirements for conversion processes.	Small number of process steps, no heavy equipment needed, no storage needed, low energy requirements, minimal waste management needs and minimal transportation requisites.
7 (low needs)	0.67	Only low requirements, few processing steps and transportation needed for growth and harvest.	Relatively small number of process steps, some heavy equipment needed, little storage needed, low energy requirements, low waste management needs and low transportation requisites.
4 (moderate needs)	0.33	Moderate infrastructure requirements, several process steps and some heavy machinery involved in all the main processes.	Moderate number of process steps, considerable heavy equipment needed, moderate storage needs, moderate energy requirements, moderate waste management needs and moderate transportation requisites.
1 (high needs)	0.0	Conversion technology comes with high requisites for infrastructure, numerous varieties of processing steps, much work and heavy machines involved in conversion.	High number of process steps, much heavy equipment needed, high storage requirements, high energy requirements, high waste management needs and high transportation requisites.

Use level:

Points	Normali- zation	Criteria	Examples
10 (minimal needs)	1.0	Neither additional nor special infrastructure requirements for use in transportation. Perfectly substitutable.	Minimal overall infrastructure demands. Neither modifications nor renewal of existing infrastructure needed. 100% compatibility.
7 (low needs)	0.67	Only low requirements towards transportation infrastructure.	Low overall infrastructure demands. Slight modifications but no explicit modernization of existing infrastructure needed. High-degree compatibility.
4 (moderate needs)	0.33	Moderate infrastructure requirements for use in transportation.	Moderate overall infrastructure demands. Modifications needed and modernization possible. Only partial compatibility.
1 (high needs)	0.0	High requirements towards transportation infrastructure.	High overall infrastructure demands. Additional infrastructure needed. Renewal and modernization indispensable. Low compatibility.

3.2.4.2 Information structure

Definition

The indicator “information structure” expresses the availability of know-how.

Generic criterion	Specification	Unit
C ₂ : Well-structuredness	Logarithmic value of the total years of experience since the first use of the feedstock until 2009	(log ₁₀ [years of experience with feedstock])
Application on	Normalization Range	
Feedstock Level	0 (lowest) = log ₁₀ (50 years) = 1,69897 1 (highest) = log ₁₀ (500 years) = 2,69897	
Conversion level	0 (lowest) = 10 years 1 (highest) = 30 years	

Conversion level	0 (lowest) = 20 patents 1 (highest) = 1000 patents	
Use Level	0 (lowest) = 7 1 (highest) = 1	
Author		Date
Severin Hegelbach, ETHZ		September 26, 2009

Operationalization

Feedstock level:

The indicator “experience with feedstock” is a measure for the about feedstock and degree of experience in its production. It is defined as the logarithmic value of the total years of experience since the first use of the feedstock until 2009.

In general, the bigger the experience regarding a certain crop or feedstock, the more knowledge is available. The indicator is measured by years of crop plantation or feedstock use since the first introduction in the country until 2009. In order to provide a fair base for comparison, a logarithmic scale is used for the distribution of the final values. This way, it is taken into account that a difference of experience between 10 and 100 years is more important than a difference between 500 and 1000 years, as shown in the example in the next table.

Table 13: *Example operationalization*

Experience in years	Log-scale
10	1
100	2
500	2,69897
1000	3

Conversion level: Experience with technology

The indicator “experience with technology” is a measure for the availability of know-how about technology and experience in its employment. It is defined as the value of the total years of experience, e.g. employment and R&D since the first appearance of the technology in the WIPO PATENTSCOPE® database {WIPO, 2009 #46} until 2009.

The indicator measures the years of total experience of employment and R&D of a specific conversion technology since its first time of appearance in the WIPO PATENTSCOPE® database {WIPO, 2009 #46} until 2009. For each technology there are registered patents at WIPO and the first date of registration is taken as the pivotal value for the indicator. The difference between 2009 and this first specific entry recorded in the database leads to the

values for the variable. No distinction between countries is made on the Conversion level of the value chain for the conversion may take place at another location than the country of origin for the feedstock and has similar characteristics everywhere in the globalized world.

Conversion level: Patent protection

The Indicator “patent protection” is a measure for the amount of knowledge about and development of a technology in the world. It assesses the information structure on the Conversion level. It is defined as the total number of registered patents for a specific conversion technology in the web database of the World Intellectual Property Organization (WIPO) on September 26th, 2009. Patents indicate that there is development, know-how and experience about the use and processes of a conversion technology on the information structure level. Thus a high number of patents for a technology describe a higher experience and also a more in depth know-how on the one hand, and a wide employment and diffusion on the other hand.

Accordingly, the indicator measures the total number of registered patents related to the investigated conversion technologies in the web database of the World Intellectual Property Organization (WIPO's search service PATENTSCOPE® <http://www.wipo.int/patentscope/en/>) and therewith denotes a direct gauging for the sustainability of the conversion on the information structure level.

Use level:

The indicator “consumer information” is a measure for the accessibility and availability of information concerning the use of biofuels for transport in Switzerland. It takes into account the information status of the public towards the investigated biofuels for transport use. Thus it evaluates the information structure on the element level use.

For sustainable development (SD) of biofuels it is essential to provide appropriate standards and certification protocols. These can serve as means to advance SD. As an example, certain product standards can provide helpful information for buyers and sellers in order for them to understand what they are bargaining about. This kind of information can simplify the emergence of the biofuel market (Lynd, Laser et al. 2008).

For the society, to gain knowledge as here about the biofuel market through information, publicity and persuasion is crucial for encouraging behavioral changes {Jacobs, 1999 #50}. Only in this manner the tracks are set in the right direction for a substantial demand and use of biofuels. For the purpose of promotion of the use of biofuels it is essential that people know about the possibilities offered and not least also about the properties of these possibilities compared to their reference which in this case would be gasoline.

The indicator shall give a measure about the status-quo of consumer information of the investigated transport fuel options relative to each other. In a survey of national political parties of Switzerland (see FKV-32: Social acceptance), the following questions are raised concerning these 8 different transportation fuels:

Identification

Feedstock level:

The needed data for this indicator is obtained from different scientific sources (specific books and papers) and country institutions. The most essential information needed is for

each feedstock the year of historical first introduction or of the year of first use or discovery. All investigated feedstock elements and the countries Switzerland, USA, Brazil, India, Indonesia, China, Norway and Nigeria were considered.

Conversion level: Experience with technology

Precise information about the development of markets and technologies can be derived from patent filings. The data can be obtained from the World Intellectual Property Organization (WIPO 2009). The WIPO operates an extensive database that unites registered patents from all over the world. The values for the indicator are derived from this database. A transparent search method yields various results for each technology. Statistics on these results show the year a patent was filed and granted and include the history of the technology's patent development. According to information on the webpage the WIPO database has been keeping account of the entries of records based on international filing dates since 1978 (WIPO 2009).

Conversion level: Patent protection

The data needed for measuring this indicator is available in the international patent statistics of the World Intellectual Property Organization (WIPO 2009).

WIPO's search service PATENTSCOPE® (WIPO 2009) offers the possibility to search international patent applications in all technical fields. By using the structured search option (found on <http://www.wipo.int/pctdb/en/index.jsp>) it is possible to insert and combine the most relevant keywords in the search fields for the technology of interest, e.g. biofuel, conversion, etc. or indeed putting "biofuel conversion" in between inverted commas in order to find an expression. By changing the drop-down window option to "Any Field", the filled in keywords are searched in the whole patent document and not just on the front page.

Correspondingly, a clear search pattern in the PATENTSCOPE® data bank was defined and performed in so doing generating the values for the assessment.

Use level:

The data necessary for the assessment of this indicator is obtained from participating with the mentioned questions in a survey of national political parties of Switzerland about the social acceptance of biofuels (see FKV-32: Social acceptance).

Table 14: *Fuels for transport use.*

Fuels for transport use
Petrol (gasoline, fossil reference)
Biogas (methane, SNG)
Biodiesel (rapeseed, oil palm, jatropha, algae)
Ethanol (sugarcane, biomass)
Ethanol E85
Ethanol E5 (bEnzin5, eSSence5)
Synthetic hydrocarbons (BTL, Fischer-Tropsch)
Electricity for electromobility (e.g. Plug-in hybrids, battery)

1. Have you heard of/about (Biodiesel, E85, Biogas etc.)... before? (Yes or no)
2. Could you order by rank the knowledge you have about the investigated fuels?

Subsequent, the results are analyzed and points from 1–8 are apportioned to the 8 possibilities, according to the relative ranking. 1 point would be equal to a very high accessibility and much available knowledge and information about the specific element whereas 8 points would suggest the opposite, namely a very low accessibility and very few information about the specific element. To sum up, a performance of 1 would be sustainable whilst a performance of 8 would constitute an obstacle to potential SD.

Normalization

Feedstock level:

The normalization is defined to range between 50 years of experience and 500 years of experience with the feedstock. Again, the logarithmic values are used. The values equal to or smaller than 1.69897 ($\log_{10}[50]$) are attributed a 0 (lowest) while the values equal to or above 2.69897 ($\log_{10}[500]$) get a 1 (highest). The other values are normalized internally.

Conversion level: Experience with technology

The normalization is defined to range between 10 years of experience and 30 years of experience with the conversion technology. The values equal to or smaller than 10 are attributed a 0 (lowest) while the values equal to or above 30 get a 1 (highest). The other values in the range are normalized internally.

Conversion level: Patent protection

The normalization is defined to range between 20 and 1000 registered patents in the WIPO database. The values equal to or smaller than 20 are assessed with 0 (lowest) while the values equal to or above 1000 get a 1 (highest). The other values in the range are normalized internally.

Use level:

The normalized value 0 (less sustainable) is given to the transport fuel option ranking at the lowest position 8. On the other side, the transport fuel option on top of the ranking gets the normalized value 1 (more sustainable). The other 6 options are internally normalized in between 0 and 1.

3.2.5 Functional Key Variable (FKV): Interdependence

3.2.5.1 Change in global use of cropland

Definition

The indicator expresses the potential extent of indirect land use change resp. displacement effects which would result from increased global cropland requirements under given scenario conditions.

Table 15: *Specification of change in global use of cropland (source: own depiction).*

Generic criterion	Specification	Unit
C ₃ : Interdependance	Change in global use of cropland	ha
Application on	Range for normalization	
Scenario Level	0 (lowest) = no indirect effect 1 (highest) = highest indirect effect	
Author		Date
Helmut Schütz, WI		25.9.2009

Operationalization

The scenario results will point out additional demand for global net cropland area for Swiss consumption (in ha; see indicator description “global net area of Swiss consumption”) as compared with the current situation. Additional demand may cause indirect expansion of global cropland for e.g. subsistence farming. This can be exemplified at feedstock level. For instance, in case 1st generation biofuels from tropical countries are concerned, indirect effects may concern expansion of cropland into tropical rainforest, peatland forest, savannah, or grassland. The effects will be estimated quantitatively (in ha) based on assumptions as e.g. applied in Bringezu et al. 2009. The result shows how much natural ecosystems land (in ha) would be converted to cropland (e.g. tropical rainforest land cleared in South-East Asia, or Cerrado land cleared in Brazil).

Identification

The conversion of natural ecosystems land to cropland is exemplified. For instance, the current development of land use for palm oil in Indonesia and for soy in Brazil, as highly relevant examples, is analysed to model the conversion of natural land from the expansion of agricultural land.

Exemplary case 1: Palm oil cultivation in Indonesia

In Indonesia, an extension of the cultivation area for palm oil trees by a further 20 million hectares, compared with the current stock of at least 6 million hectares, is planned by the Indonesian government (Colchester, N et al. 2006). According to Biofuelwatch (2007), this plan is intended to cover the next 20 years. The expansion of palm oil cultivation in Indonesia currently depends by two-thirds on the destruction of rain forest, the remaining acreage intended for expansion is based on previously cultivated or to-date fallow land (Grieg-Gran 2007). In the rainforest areas, one quarter of the land is on peat soil with a high carbon content - resulting in particularly high greenhouse gas emissions when cultivated for palm oil. The remaining rainforest land is on mineral soils. By 2030, a share of 50% from peat soils is expected (Hooijer, Silvius et al. 2006).

If current trends continue, almost 26 million ha of palm oil would exist in 2030 in Indonesia, 24% on former peat soils, 43% on mineral rainforest soils and 33% on other soils. This would mean that the total rainforest area of Indonesia would be reduced by 29% as compared to 2005, and would only cover about 49% of the original area from 1990.

Assuming a linear increase in the cultivation area for palm oil, 0.83 million hectares would be newly added in 2030, as compared to the previous year. The share of newly added land in 2030 would be 3.2% of the total palm oil land.

Consequently, cropland demand for palm oil in 2030 would be based by 2.1% on newly converted natural ecosystems land.

Exemplary case 2: Soybean cultivation in Brazil

The current trend in soybean cultivation in Brazil is towards about 100 million hectares (Flaskerud 2003; Kaltner, Azevedo et al. 2005) from almost 23 million ha in 2005 (according to FAO data). According to Flaskerud (2003), the overall expansion of agriculture will occur by 42% in the Cerrado area, 7% in the Amazon rainforest and 51% on former pastureland.

Assuming a linear increase of the cultivation area for soybeans, 100 million hectares in 2030 would be distributed with 8% on former rainforest land, 28% on former Cerrado soils and 64% on other soils. This would mean a reduction of the total rainforest area of Brazil by 2% and the Cerrado area by 14% as compared to 2005.

Assuming a linear increase of the cultivation area for soybeans, 3.1 million hectares would have been newly added in 2030 as compared with the previous year: 0.2 million ha on former rainforest land, 1.3 million ha on former Cerrado land and 1.6 million ha on other soils. The share of newly added land in 2030 would be 3.1% of the total soybean land.

This development would mean that by 2024, 5.5 million ha of tropical rainforest and 20.5 million ha of tropical savannah would have been destroyed. Environmental protection organisations in Brazil reported similar results, of about 16 million ha of savannah and 6 million ha of rainforest being destroyed for soybean plantations up to 2024 (Bickel 2004).

Consequently, cropland demand for soybean in 2030 would be based by 1.5% on newly converted natural ecosystems land.

Normalization

At scenario level only.

In case of equal or lower global net area for Swiss consumption than at current level it is assumed that no indirect effect on global cropland use will occur and the value is 0 (lowest).

In case of higher global net area for Swiss consumption than at current level it is assumed that global expansion of cropland will occur and the value is 1 (highest) for the highest scenario value (in ha) for natural ecosystems land converted to cropland; for other scenario values it is proportional.

3.2.5.2 Greenhouse gas emissions

Definition

The indicator expresses the “Global Warming Potential” in 100 years (GWP100). The GWP100 includes all greenhouse gas relevant emissions transformed to CO₂ equivalents per functional unit (FU).

Table 16: Specification of greenhouse gas emissions (source: own depiction).

Generic criterion	Specification	Unit
C ₃ : Interdependance	Greenhouse gas emission per FU	[g CO ₂ -eq./MJ] [g CO ₂ -eq./pkm]
Application on	Range for normalization	
Feedstock Level	0 = 1 [g CO ₂ -eq./MJ] 1 = -100 [g CO ₂ -eq./MJ]	
Conversion level	0 = 30 [g CO ₂ -eq./MJ] 1 = 0 [g CO ₂ -eq./MJ]	
Use Level	0 = 150 [g CO ₂ -eq./pkm] 1 = 0 [g CO ₂ -eq./pkm]	
Value Chain Level	0 = 130 [g CO ₂ -eq./pkm] 1 = 0 [g CO ₂ -eq./pkm]	
Author		Date
Jürgen Reinhard, Empa		10.07.09

Operationalization

The amount of green house gas (GHG) emissions released to the atmosphere in kg CO₂ equiv. per FU. This value is calculated using the midpoint method IPCC GWP100a.

Identification

GWP100 expresses the global warming potential off all relevant greenhouse gases in kg CO₂ equivalent. GWP100 is calculated using attributional LCA, i.e. it includes the emissions from both the background (e.g. the required infrastructure) and the foreground system (e.g. feedstock cultivation). Where possible the LCIs from ecoinvent have been used. However, in particular LCIs from innovative feedstock's such like halophytes and algae have been derived from existing data. This is considered by means of a higher uncertainty.

Normalization

Feedstock: The values are normalized using crude oil as a point of reference. When GWP100 is equal or higher than the value for crude oil the normalized value is 0 (lowest). The highest sustainability potential (1) is determined at -0.10 kg CO₂ equiv./MJ. The reason for choosing a negative value is the uptake of biogenic CO₂ related to the cultivation of energy crops.

Conversion: If the GWP100 is equal or higher than 30 g CO₂ equiv./MJ the normalized value is 0 (lowest). In order to cover the full range of values, the lower bound for normalization is determined as 0 g CO₂ equiv./MJ (highest).

Use: If the GWP100 is equal or higher than 150 g CO₂ equiv./pkm the normalized value is 0 (lowest). In order to cover the full range of values, the lower bound for normalization is determined as 0 g CO₂ equiv./MJ (highest).

Value chain: According to the Swiss law on tax exemption for biofuels, agro-biofuels are only exempted from tax when they provide a GHG reduction of at least 30% in comparison to the fossil reference system over the full life cycle. Using this as a reference, if the

GWP100 is equal or higher than 130 g CO₂ equiv./pkm, i.e. higher than 70% of the petrol system, the normalized value is 0 (lowest). In order to cover the full range of values, the lower bound for normalization is determined as 0 g CO₂ equiv./pkm(highest).

3.2.5.3 Aggregated environmental impact

Definition

The indicator expresses the aggregated environmental impact to the environment per FU (MJ or pkm).

Table 17: Specification of aggregated environmental impact (source: own depiction).

Generic criterion	Specification	Unit
C ₃ : Interdependence	Aggregated environmental impact per FU	[UBP/MJ] [UBP/pkm]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = 30 [UBP/MJ] 1 (highest) = -40 [UBP/MJ]	
Conversion Level	0 (lowest) = 30 [UBP/MJ] 1 (highest) = 0 [UBP/MJ]	
Use Level	0 (lowest) = 130 [UBP/MJ] 1 (highest) = 0 [UBP/MJ]	
Value Chain Level	0 (lowest) = 218 [UBP/MJ] 1 (highest) = 0 [UBP/MJ]	
Author		Date
Jürgen Reinhard, Empa		10.07.09

Operationalization

The aggregated environmental impact is determined by means of the Swiss method of ecological scarcity 2006 (UBP06). UBPO6 expresses the total environmental impact off all environmental interventions recognized by the Swiss legal framework. For details, see Frischknecht (Frischknecht, Steiner et al. 2008).

Identification

The indicator is calculated using attributional LCA, i.e. it includes the environmental impact from both the background (e.g. the required infrastructure) and the foreground system (e.g. feedstock cultivation). Where possible the LCIs from ecoinvent have been used. However, in particular LCIs from innovative feedstock's such like halophytes and algae have been derived from existing data. This is considered by means of a higher uncertainty.

Normalization

Feedstock: The values are normalized using the fossil system as point of reference. When UBPO6 is equal or higher than double the fossil reference, i.e. approx. 30 UBPO6/MJ the

normalized value is 0 (lowest). The lower bound for normalization is determined as -40 UBP/MJ. The reason for choosing a negative value is the uptake of biogenic CO₂ related to the cultivation of energy crops.

Conversion: If UBP06 is equal or higher than 30 UBP/MJ the normalized value is 0 (lowest). In order to cover the full range of values, the lower bound for normalization is determined as 0 UBP/MJ (highest).

Use: If the UBP06 is equal or higher than 130 UBP/pkm the normalized value is 0 (lowest). In order to cover the full range of values, the lower bound for normalization is determined as 0 UBP/pkm (highest).

Value chain: According to the Swiss law on tax exemption for biofuels, agro-biofuels are only exempted from tax when they provide not more than 125% of the UBP impact in comparison to the fossil reference system over the full life cycle. Using this as a reference, if the UBP is equal or higher than 218 UBP/pkm, i.e. higher than 125% of the petrol system, the normalized value is 0 (lowest). In order to cover the full range of values, the lower bound for normalization is determined as 0 UBP/pkm (highest).

3.2.5.4 Social acceptance

Definition

“Social acceptance” describes the affirmative attitude of people towards something at a certain point in time, expressed through their opinions or their behaviour (Fischedick 2008). Research concerning acceptance often deals with time issues, in terms of determining the probability of a positive reaction on a certain stimulus in the future. The aim is to conclude from present opinions on future behaviour (Endruweit 1986). In this study, the social acceptance of Swiss people towards value chains or scenarios of biofuel use in the future is defined as an index from 0 to 1. The higher the value, the larger is the social acceptance. It is based on a public rating of several FKVs.

Table 18: Specification of social acceptance.

Generic criterion	Specification	Unit
C ₃ : Interdependence	Positive attitude of people towards something at a certain point in time	Score [0-1]
Application on	Range	
Value Chain Level	0 (lowest) = 0 1 (highest) = 1	
Scenario Level	0 (lowest) = 0 1 (highest) = 1	
Author		Date
Lukas Diethelm, Uni ZH		15.10.2009

Operationalization

Social acceptance can drive or hinder social change (Lucke 1995). It is crucial to analyze questions of acceptance when planning to introduce new technologies. Even in the plura-

lized and individualized societies of today, there is still a collective consensus relying behind every action, thus, making social acceptance still very important (Lucke 1995). The measurement of a complex and elusive phenomenon such as the social acceptance implies several challenges, e.g. discrepancy between interrogated vague opinions and actual behavior, uncertainties of future behavior and the fact, that there is no uniform concept how to deal with it. Research tools include quantitative and qualitative surveys or interviews, and field experiments.

In this study, the social acceptance is measured with an online survey. As there is still very few discourse in the public about biofuels 2nd generation, people cannot be asked directly for their opinion. Furthermore, biofuels – in particular biofuels 1st generation – have been criticized a lot in the past few years because of their competition to food and their unfavorable ecobalance, thus putting a negative light on biofuels 2nd generation. Finally, as the future is never predictable and statements to it are hypothetical, people cannot be asked how they would behave in a given future scenario. That is why the social acceptance of biofuels 2nd generation is derived indirectly, by using factors people base themselves upon when deciding whether to buy or not to buy biofuels. These factors are obtained through discourse and text analysis of two major swiss newspapers, namely the “Neue Zürcher Zeitung” (incl. “NZZ am Sonntag”) and the “Tages-Anzeiger” (incl. “Sonntags-Zeitung”) by counting and listing often used arguments. Out of these arguments, 9 factors are built, considering a broad coverage of different subjects (see below).

Identification

The data necessary for the assessment of the social acceptance are obtained through an online survey with the five major national political parties of Switzerland, from the left to the right (GPS, SPS, CVP, FDP and SVP). Thereby, the aim is not only to interrogate the political leaders, but rather to intentionally reach the basis of each party, people who would later on probably buy biofuels 2nd generation themselves. Beside the political basis, the online survey is also sent to the members of the parliament of all Swiss cantons, with the exception of the canton Ticino, as the survey isn't translated into Italian. The goal is not to achieve a representative survey, neither for the Swiss population nor even for the political parties. A representative survey needs a considerably bigger sample and a totally different approach. By choosing the political parties as a sample, we get more an overview, an assemblage of different opinions. In this sense, when analyzing the results later on, we can speak of tendencies, but not of existing facts.

The members of the political parties are asked to rate the relative importance of the 9 factors. This evaluation is part of the Analytic Hierarchy Process (AHP), a methodology in the field of decision making. In AHP the rating is obtained by a pairwise comparison of all the factors. As a result of this pairwise comparison we get a quantitative ranking of the 9 factors, where all the factors sum up to 1. For further information about the AHP see Saaty (1990).

The assessment of the value chain and the scenarios is obtained by multiplying each factor with the final value of the corresponding FKV. All the 9 factors as well as the corresponding FKV have values between 0 and 1. For doing this aggregation the following procedure is defined:

1. Relate each factor to an FKV or several FKVs. (for example the factor “Low GHG-Emissions” is identical to the FKV “GHG-Emissions”)

- 2.If several FKV's relate to the same factor, the FKV's are summarized by taking the mean. The value of the summarized FKV's is again between 0 and 1.
- 3.Multiply each factor with its corresponding FKV's and add the resulting values to get the social acceptance. The final spread lies between 0 and 1.

Table 19: Overview of the survey-factors and their corresponding FKV's.

Proximity to fuel stations	Factor 1
Fictive FKV (estimation)	No FKV
Low price	Factor 2
Economic efficiency	FKV 11
Independence of petrol	Factor 3
Economic changes	FKV 43
Low GHG-Emissions	Factor 4
GHG-Emissions	FKV 31
Low resource demand	Factor 5
Resource dependence	FKV 41
Low environmental damage	Factor 6
Environmental Impact	FKV 32
Loss of high-value ecosystems	FKV 61
Low food competition	Factor 7
Area efficiency	FKV 13
Protection of human rights	Factor 8
VR and ILO criteria	FKV 64
High efficiency	Factor 9
Energy efficiency	FKV 12
Area efficiency	FKV 13
Social acceptance	FKV 33

For the factor "Proximity to fuel stations" there is unfortunately no FKV which corresponds. To integrate these values nevertheless, a fictive FKV is created with assumed values. The assumptions are very conservative. For the three fossil feedstocks the value is 1. The petrol station network serves as a reference for all other feedstocks, as there probably won't be a any denser fuel station network in the near future, especially for biofuels. For all other feedstocks a value of 0.5 is assumed. To consider these vague assumptions, an error of 50% is assigned to all feedstocks in this fictive FKV, except for fossil (0% error).

Normalization

As the values of the social acceptance after the aggregation lie already between 0 and 1, a normalization isn't necessary. Not even an internal normalization is made due to the fact, that the actual values should be conserved.

3.2.5.5 Non-renewable energy dependence

Definition

The non-renewable energy dependence is defined as the share of non-renewable energy required to produce one unit of the FU. It expresses the dependence on non-renewable energy.

Table 20: Specification of fossile energy dependence (source: own depiction).

Generic criterion	Specification	Unit
C ₃ : Interdependence	Non-renewable energy dependence per FU	[MJ _{fossil} /MJ] [MJ _{fossil} /pkm]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = 0.3 [MJ _{fossil} /MJ] 1 (highest) = 0 [MJ _{fossil} /MJ]	
Conversion level	0 (lowest) = 0.3 [MJ _{fossil} /MJ] 1 (highest) = 0 [MJ _{fossil} /MJ]	
Use Level	0 (lowest) = 1 [MJ _{fossil} /pkm] 1 (highest) = 0.4 [MJ _{fossil} /pkm]	
Value Chain Level	0 (lowest) = 3 [MJ _{fossil} /pkm] 1 (highest) = 0.4 [MJ _{fossil} /pkm]	
Author		Date
Jürgen Reinhard, Empa		10.07.09

Operationalization

The non-renewable energy dependence is operationalized by the amount of fossil energy required to produce one unit of the functional unit.

$$\text{Non - renewable energy dependence} = \frac{(Ei_{\text{fossil_FU}} + Ei_{\text{nuclear_FU}})}{Eo_{\text{FU}}}$$

with O_{FU} = Output per FU.

$Ei_{\text{fossil_FU}}$ = fossil energy input per functional Unit (FU).

$Ei_{\text{nuclear_FU}}$ = nuclear energy input per FU.

Identification

The fossil energy dependence is derived from the “Cumulated Energy Demand” (CED). The CED expresses the required energy per FU broken down in the different energy types (fossil, nuclear, wind, water, and biomass). The CED is calculated using attributional LCA. Where possible the LCIs from ecoinvent have been used. However, in particular LCIs from innovative Feedstocks such like halophytes and algae have been derived from existing data. This is considered by means of a higher uncertainty.

Normalization

Feedstock and conversion level: According to Gagnon (Gagnon, Hall et al. 2009), a energy supplying system on the feedstock level (like crude oil production) requires an energy output which is three times higher than its energy input given that supplementary conversion steps and transport expenditures further reduce the energy benefit. In general it is imperative that as higher the non-renewable energy dependence as lower the sustainability. On

this basis our determined range of the non-renewable energy dependence is between 0.3 and 0, i.e. if the fossil energy dependence is equal or higher than 0.3MJ/MJ the normalized value is 0 (lowest). Otherwise, if the non-renewable energy dependence is equal 0 MJ/MJ the normalized value is 1 (highest).

Use level: If the non-renewable energy dependence is equal or higher than 1 MJ/pkm the normalized value is 0 (lowest). The lower bound for normalization is determined as 0 MJ/pkm (highest) in order to consider the full range of values.

Value chain level: The determined range of the non-renewable energy dependence is between 3 MJ/pkm and 0 MJ/pkm, i.e. if the fossil energy dependence is equal or higher than 3 MJ/pkm the normalized value is 0 (lowest). Otherwise, if the non-renewable energy dependence is equal 0 MJ/pkm the normalized value is 1 (highest).

3.2.5.6 Resource dependence

Definition

This indicator shows the intensity respectively extent of use of abiotic (non-renewable) material resources in terms of global Total Material (resource) Requirement (TMR_{abiotic}) per given unit of output and as total from scenario results.

Table 21: Specification of resource dependence (source: own depiction).

Generic criterion	Specification	Unit
C ₃ : Interdependence	Intensity and extent of use of abiotic (non-renewable) material resources.	[metric tonnes]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = lowest intensity of range 1 (highest) = highest intensity of range	
Conversion level	0 (lowest) = lowest intensity of range 1 (highest) = highest intensity of range	
Value Chain Level	0 (lowest) = lowest intensity of range 1 (highest) = highest intensity of range	
Scenario Level	0 (lowest) = lowest total of range 1 (highest) = highest total of range	
Author		Date
Helmut Schütz, WI		25.9.2009

Operationalization

TMR_{abiotic} indicates the non-renewable part of the global total material resource requirement of products, services or whole economies, it thus represents their respective physical basis (Bringezu, Hinterberger et al. 1994; Adriaanse, Bringezu et al. 1997). It comprises both used and unused extraction with the latter being nevertheless as well the cause of environmental impacts. TMR_{abiotic} accounts for minerals (metallic ores and non-metallic minerals) and fossil fuels in terms of mass (metric tonnes).

TMRabiotic is a pressure indicator based on mass turnover of primary materials, and integrates all flows exerting specific impacts (robust against substitution, and captures problem shifting). It is an input/up-stream oriented generic pressure indicator.

TMRabiotic for a whole economy can be related to a global sustainability target of achieving 50% less material requirements at equal distribution per capita worldwide (Schmidt-Bleek 1992). For the world in 2050 this would translate into a target value of 5.6 to 6.1 tonnes per capita (Bringezu, Schütz et al. 2009b).

TMRabiotic is calculated for products and services by multiplying absolute amounts with MIT-values for abiotic materials (see below).

The level of TMRabiotic is used to indicate dependence on total non-renewable material resources. It is expressed either as specific requirement per unit output (from high to low; at material level) in comparison with the range of MIT-values (see below).

On scenario level it is expressed in absolute amounts (metric tonnes per capita) and can be set into relation to the total TMRabiotic of Switzerland, which equals e.g. ca. 40 tonnes per person in 2006 (Mayerat-Demarne and Kohler 2007; BFS 2008).

Identification

MIT-values³ are based on life-cycle-wide material resource requirements and available for a number of products in the data base of the Wuppertal Institute (Ritthoff, Rohn et al. 2002), (own data base of research group "Material Flows and Resource Management").

Normalization

Feedstock level: total of abiotic material resources required to produce 1 unit of output, e.g. X metric tonnes TMRabiotic (comprising e.g. mineral fertilizer, diesel, electricity, and their unused or indirect material requirements like overburden from coal mining respectively energy carriers and associated unused extraction for transport of imported oil) per tonne rapeseed harvested. The lowest value in the range of all known MIT-values for products is taken as the normalized value 0, the highest one as the normalized value 1. TMRabiotic values for feedstocks are calculated proportionally.

Conversion level: total of abiotic material resources required to produce 1 unit of process output, e.g. X metric tonnes TMRabiotic per MJ biodiesel from rapeseed. The lowest value in the range of all known MIT-values for processes is taken as the normalized value 0, the highest one as the normalized value 1. TMRabiotic values in between are calculated proportionally.

Value chain level: total of abiotic material resources from feedstock respectively Conversion level and use required to produce 1 unit of service, e.g. X metric tonnes TMRabiotic per tkm driving with 10% blend of biodiesel from rapeseed. The lowest value in the range of all known value chains reported as material intensity in g per tkm is taken as the normalized value 0, the highest one as the normalized value 1. TMRabiotic values in between are calculated proportionally.

Scenario level: total of abiotic material resources is expressed as TMRabiotic per capita (in metric tonnes). A TMR abiotic per capita of zero is taken as the normalized value 0, the

³ http://www.wupperinst.org/info/entwd/index.html?beitrag_id=437&bid=169

TMR_{abiotic} per capita of Switzerland is taken as the normalized value 1. TMR_{abiotic} values from scenarios are normalised proportionally.

3.2.5.7 Potential water dependence

Definition

The water use impact is measured by the amount of water needed to produce feedstocks and the local water availability at the place of production.

Table 22: Specification of water use impact (source: own depiction).

Generic criterion	Specification	Unit
C ₃ : Interdependence	Dependence on blue water per FU	[liter/MJ] [liter/pkm]
Application on	Sustainability Range	
Feedstock Level	0 (lowest) = [1 liter/MJ] 1 (highest) = [0 liter/MJ]	
Value Chain Level	0 (lowest) = [10 liter/pkm] 1 (highest) = [0 liter/pkm]	
Author	Date	
Rimousky Menkveld, Empa		

Operationalization

The indicator selected to assess the water dependence of biofuels was the blue water footprint. Blue water is defined as freshwater withdrawals which are evaporated or incorporated into a feedstock. This means we quantified the total amount of irrigation water used during the complete growing season of a feed stock. It is important to note that blue water requirement do not indicate an impact but rather a dependence. More detailed information on the water footprint and the water use impact of biofuel production is found in chapter 5.3.

Identification

The water requirement for each feedstock was calculated using the model CROPWAT to estimate reference evapotranspiration based on the FAO Penman-Monteith method (Allen, Pereira et al. 1998). The crop coefficient of different feed stocks was found from various sources in literature while the climatic data used as an input for CROPWAT was derived from the model CLIMWAT 2.0. The water use per resource was calculated based on the methodology of Leenes et al. (2009).

Normalization

Feedstock: Given that each liter of blue water required can result in a potential impact, we determined 10 liter/MJ as the upper bound of the normalization range. The lower bound for normalization is determined as 0 liter/MJ. The same range for normalization is applied on the value chain level.

3.2.6 Functional Key Variable (FKV): Buffer capacity & resilience

3.2.6.1 Resilience to environmental changes

Definition

The resilience to environmental changes is assessed by how well feedstocks can respond to different environmental conditions.

Table 23: Specification of resilience to environmental changes (source: own depiction).

Generic criterion	Specification	Unit
C ₄ : Resilience	Resilience to environmental changes	[1-14 pts]
Application on	Sustainability Range	
Feedstock Level	0 (lowest) = 10 1 (highest) = 0	
Author		Date
Rimousky Menkveld, Empa		08.10.09

Operationalization

We determined optimal production conditions based on specific requirements of feedstocks, e.g. the range of water or temperature in which the feedstock can produce acceptable performance. All together we defined seven categories. We then calculated a risk factor for each feedstock meaning that we evaluated whether feedstocks could still be produced under different environmental conditions. This was assessed by comparing current optimal environmental conditions to future projected environmental conditions. If the feedstock is slight outside the optimal boundaries in one category it gets one point, whereas it gets two points when it is strong outside the boundaries. The resilience to environmental changes is expressed by summing up the point. Given seven categories the maximal points are 14.

Identification

The optimal production conditions of different feedstocks, both the upper and lower boundaries, were identified from various sources of literature. A high degree of uncertainty resides in these values because socio-economic factors such as management practices also have an effect on resilience. Defining, limiting and reducing factors considered were crop physiology and phenology, temperature, water, nutrients and tolerance to pest, drought and frost. Future trends in environmental changes were based on the IPCC reports (2007). Worst case scenario values were ascribed to two key variables: temperature (4 degree increase) and precipitation (20 percent increase or decrease). We considered interdependencies between variables, e.g. higher temperatures can lead to drought, increase evapotranspiration, and provide more favourable conditions for pests by enabling them to over winter whereas decreased precipitation can reduce freshwater supplies and also lead to drought. However, we did not quantify these ecological linkages using a model thus uncertainties still remain regarding ecological thresholds. Nonetheless, by using extreme values for future

environmental conditions we can determine the resilience of a feedstock to environmental changes.

Normalization

The upper (0) and lower bound (1) for normalization are determined as 10 and 0 pts, respectively.

3.2.6.2 Resilience to economic changes

Definition

There is a close link between crude oil prices and agricultural prices, mediated by biofuels demand. Biofuel policies have important implications for farm output and incomes, commodity prices and food availability, returns to land and other resources, rural employment and energy markets (FAO 2008).

The resilience to economic changes is assessed using the amount of crude oil required per FU. The indicator expresses how resilient the system is against changes in oil prices. The general assumption behind is that as higher the crude oil dependence per FU as less resilient is the system against changes in crude oil prices.

Table 24: Specification of resilience to economic changes (source: own depiction).

Generic criterion	Specification	Unit
C ₄ : Resilience	Crude oil requirements per FU.	[MJ crude oil/MJ] [MJ crude oil/pkm]
Application on	Range for normalization	
Feedstock level	0 (lowest) = 0.1 [MJ/MJ] 1 (highest) = 0 [MJ/MJ]	
Conversion level	0 (lowest) = 0.1 [MJ/MJ] 1 (highest) = 0 [MJ/MJ]	
Use level	0 (lowest) = 0.3 [MJ/pkm] 1 (highest) = 0.2 [MJ/pkm]	
Value Chain Level	0 (lowest) = 1 [MJ/pkm] 1 (highest) = 1 [MJ/pkm]	
Author		Date
Jürgen Reinhard, Empa		10.10.2009

Operationalization

The crude oil dependence is operationalized by the amount of crude oil in MJ required to produce one unit of the functional unit.

$$\text{Crude oil requirements} = \frac{Ei_{\text{crude oil}_{-FU}}}{O_{FU}}$$

with O_{FU} = Output per FU.

$Ei_{\text{crude oil}_{-FU}}$ = crude oil energy input per FU.

Identification

The fossil energy dependence is derived from the “Cumulated Energy Demand” (CED). The CED expresses the required energy per FU broken down in the different energy types (fossil, nuclear, wind, water, and biomass). The CED is calculated using attributional LCA. Where possible the LCIs fromecoinvent have been used. However, in particular LCIs from innovative Feedstocks such like halophytes and algae have been derived from existing data. This is considered by means of a higher uncertainty.

Normalization

Feedstock and conversion level: The upper and lower bound for normalization are determined as 0.1 MJ/MJ and 0 MJ/MJ, respectively.

Use level: The upper and lower bound for normalization are determined as 0.3 MJ/pkm and 0.2 MJ/pkm, respectively. The reason for this is that the difference between the use options is less significant.

Value chain level: The upper and lower bound for normalization are determined as 1 MJ/pkm and 0 MJ/pkm, respectively.

3.2.7 Functional Key Variable (FKV): Ability to accommodate

3.2.7.1 Flexibility of the individual elements/value chain

Definition

Flexibility is considered to be a positive attribute of the value chain and is defined as the systems ability to respond or adapt to potential internal or external changes.

Table 25: Specification of ability to accommodate (source: own depiction).

Generic criterion	Specification	Unit
C ₅ : Accomodation	Flexibility of the individual elements /value chain.	[options]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = 0 [options] 1 (highest) = 4 [options]	
Conversion level	0 (lowest) = 0 [options] 1 (highest) = 6 [options]	

Use Level	0 (lowest) = 0 [options] 1 (highest) = 2 [options]
Value chain level	0 (lowest) = 4 [options] 1 (highest) = 10 [options]
Author	Date
Rimousky Maria Menkveld, Empa	

Operationalization

Flexibility of the value chain is determined by the sum of the individual elements flexibility, namely at the feedstock level, conversion level and use level. Flexibility at the feedstock level is determined by the feedstock's ability to produce different types of products. We identified different product end-use categories: food, fuel, industry and agriculture. The feedstock which can be used for all product end-use categories is the most flexible. Flexibility at the conversion level is assessed by the total number of feedstock's a conversion technology can process. E.g. a 2nd generation BTL refinery that can be fed by various feedstocks (wood, straw, miscanthus) has a higher ability to accommodate than a refinery specifically designed for straw. Flexibility at the use level is determined by the possible use options of the feedstock, either blended or pure, for mobility and transport of a commercially existing vehicle in Switzerland in 2009. Fuel from a feedstock which can be used without requiring additional vehicle modification is considered to be flexible.

Identification

Information regarding commercial products derived from feed stocks was mainly found in 'biofuels for transport' (Worldwatch Institute, 2006). Information about the flexibility of different conversion technologies to accommodate different feedstocks was found from a combination of sources ([Berndes, Hoogwijk et al. 2003; Jungbluth 2003; IEA 2004; Nemecek, Heil et al. 2004; Oettli, Blum et al. 2005; Jungbluth, Faist et al. 2007]), the same method was applied to assess flexibility at the use level.

Normalization

Feedstock level: The upper (1) and lower (0) bound for normalization are determined as 4 and 0 options, respectively.

Conversion level: The upper (1) and lower (0) bound for normalization are determined as 6 and 0 options, respectively.

Use level: The upper (1) and lower (0) bound for normalization are determined as 2 and 0 options, respectively.

Value chain level: The upper (1) and lower (0) bound for normalization are determined as 10 and 4 options, respectively.

3.2.8 Functional Key Variable (FKV): Intra- and inter-generative equity

3.2.8.1 Loss of high-value ecosystems

Definition

The indicator expresses the contribution of the cultivation of a feedstock to loss of high-value ecosystems by expansion of cropland into such areas. This is projected to the value chain and scenario levels.

Table 26: Specification of loss of high-value ecosystems (source: own depiction).

Generic criterion	Specification	Unit
C ₆ : inter- and intra-generative equity	Potential loss of high-value ecosystems	[1–10 pts]
Application on	Range for normalization	
Feedstock Level	0 (lowest) = no effect 1 (highest) = strong effect	
Value Chain Level	0 (lowest) = no effect 1 (highest) = strong effect	
Scenario Level	0 (lowest) = no effect 1 (highest) = strong effect	
Author		Date
Helmut Schütz, WI		25.9.2009

Operationalization

The EC (2008) in its renewable energy directive, Article 17.3, states that biofuels and bio-liquids should not be made from land such as

- primary forest and other wooded land, namely of native species;
- areas designated for nature protection purposes; or for the protection of rare, threatened or endangered ecosystems or species recognised by international agreements or included in lists drawn up by intergovernmental organisations or the International Union for the Conservation of Nature;
- highly biodiverse grassland;
- land with high carbon stock like wetlands and continuously forested areas;
- peatland.

The indicator “change in global use of cropland” will show if indirect land use change resp. displacement effects with associated loss of high-value ecosystems would result from increased global cropland requirements under given scenario conditions. In addition, increased cultivation of a feedstock for biofuels production may lead to direct land use change and loss of high-value ecosystems.

The indicator will evaluate in a qualitative manner, in which countries and for which feedstocks the risk exists for direct (e.g. by expansion of feedstock land like oil palm for biodiesel production into rainforest in Indonesia) and indirect loss (e.g. by causing expansion of cropland for subsistence farming into rainforest in Brazil) of high-value ecosystems. The results on feedstock level are projected to the value chain and scenario level.

Identification

Derivation of the respective data has been described for the indicator “change in global use of cropland” which provides results for probable indirect effects on expansion of global cropland into natural ecosystems due to increased domestic demand for agricultural biomass.

Normalization

At all levels concerned the value is 0 (lowest) if no effect is to be expected, the value is 1 (highest) in case of the strongest effect to be expected among all.

3.2.8.2 Global net area of Swiss consumption

Definition

The indicator expresses the quantitative resource use (in m^2) in terms of productive land for agriculture and forestry that is required to meet the domestic demand for biomass based goods, and sets this – on per capita basis – into relation to land available per person of the world’s population.

Table 27: Specification global net area of Swiss consumption (source: own depiction).

Generic criterion	Specification	Unit
C ₆ : inter- and intra-generative equity	Global productive land requirements for domestic consumption of agricultural and forestry goods – in relation to land available per person of the world population.	[m ² /inhabitant]
Application on	Range for normalization	
Scenario Level	0 (lowest) = least area requirement 1 (highest) = highest area requirement	
Author		Date
Helmut Schütz, WI		25.9.2009

Operationalization

The harvest of biomass comes mainly from agriculture and forestry, and thus is bound to the availability of productive land. Therefore, we have to consider land as another basic natural resource, and its interrelations with the socio-industrial metabolism.

The method for accounting for global land use agriculture – GLUA is described in section 3.2.2.2 of this report.

The second account is for forest area required to produce the consumed quantities under sustainability conditions, i.e. if wood is removed only to the extent of sustainable net annual growth. This methodology has been developed in the course of the TA SWISS study and is described in section 3.2.2.3 of this report.

In this study, global net area for Swiss consumption of biomass from agriculture (GLUA) has been accounted for 2000–2006, and global land use for forestry products (GLUF) for 2000–2007 (Schütz and O'Brien 2009). Based on these methodological approaches for the Status Quo, and based on scenario specific values for key parameters in the model calculation, GLUA and GLUF are calculated for the different scenarios.

Identification

Results from value chain analysis and scenarios for the domestic consumption of biomass from agriculture are used to account for global net consumption land of biomass from agriculture (GLUA) which is further differentiated by use for nutrition (animal based and plant based), biomaterials and biofuels, while area productivity increases over the scenario time scale are taken into account. The accounting procedure is described in section 3.2.2.2.

Land demand for forestry products (GLUF) is determined in terms of forest area required to produce the consumed quantities of forestry products under sustainability conditions, i.e. if wood is removed only to the extent of net annual growth (NAI = net annual increment). The accounting procedure is described in section 3.2.2.3.

Normalization

Global net consumption area (GLUA) per person of the Swiss population is compared with global available cropland per capita of the World population indicating whether Swiss consumption would be above or below global limits.

For forestry products, land required for the timber consumed (GLUF) per person and year in Switzerland is evaluated versus a reference value for globally sustainable use of forestland.

In case scenario results are equal to or below land available per person of the World population, the value is 0 (lowest). In case scenario results indicate higher resource requirements per capita of the Swiss population than on global average, the highest per capita GLUA resp. GLUF value is taken as 1 (highest). Normalised results for GLUA and GLUF are added up.

3.2.8.3 Rural income equality

Generic criterion	Specification	Unit
C ₆ : inter- and intra-generative equity	Ratio of average monthly salary in the agricultural sector and average monthly salary of all sectors per country	[local currency/local currency]
Application on	Range	
Feedstock Level	0 (lowest) \leq 0.3 1 (highest) = 1	
Value Chain Level	0 (lowest) \leq 0.3 1 (highest) = 1	
Scenario Level	0 (lowest) \leq 0.3 1 (highest) = 1	
Author		Date
Alfons Schmid, Uni ZH		12.08.2009

Operationalization

Income justice of a specific economy is one of several possible aspects of intra-generative equity. This indicator was chosen due to its relatively simple measurement and the high data availability in different countries.

Determination

The average monthly salary of each country is divided by the total average income of the country. Average monthly salaries per country and sector are published by the labour statistic database LABORSTA of the International Labour Organization (ILO 2009). We considered the countries Switzerland, Brazil, Indonesia, Norway and China. In the case of Norway (Oil) the average salary in the mining and quarrying sector was used. Data for Nigeria was not available.

Normalization

The normalized value is 0 (less sustainable), if the ratio of the average monthly salary in the agricultural sector and the average monthly salary of all sectors is equal or less than 0.3. The normalized value is 1 (more sustainable), if the ratio equals 1. Ratios of 0.3 and 1 are reached by Bahrain in 2007 and Cuba in 2006 (ILO 2009). Inverted normalization was used for ratios above 1.

3.2.8.4 Violation risk of human rights and ILO conventions

Generic criterion	Specification	Unit
C ₆ : inter- and intra-generative equity	Violations of human rights and ILO conventions	[1–10 pts]
Application on	Range	
Feedstock Level	0 (lowest) = Very high risk of violations of Human Rights and ILO conventions 1 (highest) = Very low risk of violations of Human Rights and ILO conventions	
Value Chain Level	0 (lowest) = Very high risk of violations of Human Rights and ILO conventions 1 (highest) = Very low risk of violations of Human Rights and ILO conventions	
Scenario Level	0 (lowest) = Very high risk of violations of Human Rights and ILO conventions 1 (highest) = Very low risk of violations of Human Rights and ILO conventions	
Author		Date
Alfons Schmid, Uni ZH		21.07.2009

Operationalization

The United Nations Human Rights Council (UNHRC) and the International Labour Organisation (ILO) have defined universal basic human rights and conventions (UN 1948; ILO 2009). There is no continuous measure or index of compliance to these specific rights available. The functional key variable violation risk of human rights and ILO conventions is a variable with four categories. For reported common violations of Human- and ILO-Rights 1 risk point is assigned to a specific value chain and 10 for general compliance disregarding whether the violation occurred on the feedstock, processing or usage level. On the scenario level the arithmetic mean of all involved chains is used.

Determination

Violations of Human Rights and ILO conventions are mostly reported by NGOs like Amnesty International (AI) and the International Trade Union Confederation (ITUC) or public and international authorities like governments or UN departments (UN 1997). The Human Rights Council does a periodic country-specific review (UNHCR 2009); Human Rights Watch (HRW) does an annual world report (HRW 2009); the ITUC carries out an annual survey of violations of trade union rights (ITUC 2009) and AI publishes an annual report about the state of the world's Human Rights (AI 2009). Publications of these four organisations are used to determine the variable violation risk of human rights and ILO conventions. Additionally, government reports are used e.g. from the US Department of Labour (USDOL 2002). All relevant violations since 2004 considered for the variable violation risk of human rights and ILO conventions have to occur within the specific economic activity (e.g. sugar cane production) and state (e.g. for sugar cane: Brazil).

3.3 Weighting

FKVs and their sub-indicators were weighted by means of an online survey of the members of the partner group and the project group. A total of 13 persons took part in the survey.

3.3.1 Weighting of criteria and FKVs

The FKV headed Performance and efficiency was given the highest weighting with an average of 25.5%. After that, Interdependencies and Intra- and Intergenerative equity followed with 21.9% and 15.8% respectively. The rest three FKVs were estimated about the same with averages between 12% and 12.8%.

Persons who weighted the FKV headed Performance and efficiency heavily displayed a trend to weight Interdependencies and Inter- and Intra-generative equity weakly and the other way around. Those surveyed displayed the greatest agreement with their weighting of Well-structuredness. A low degree of agreement was displayed in descending order with Inter- and Intra-generative equity, Ability to accommodate, Performance and efficiency und Interdependencies – the high maximal value for Inter- and Intragenerative equity constituted an outlier of 50%; given weightings between 5% and 25% for all other persons surveyed. Something similar applies to Ability to accommodate, with an outlier of 40% given weightings between 5% and 15% by the other persons surveyed.

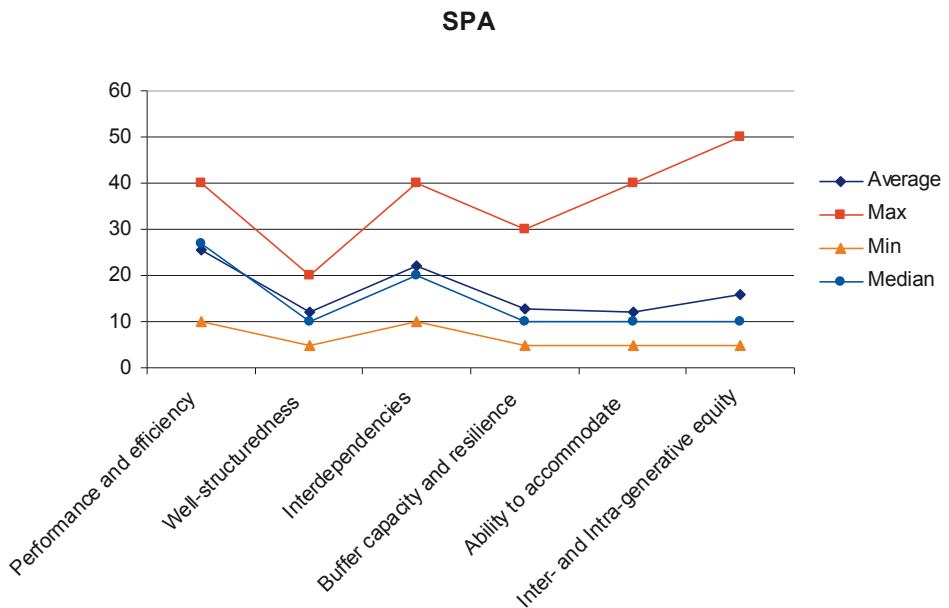


Figure 26: Weighting of criteria (source: author).

Table 28: *Result for criteria*

FKV's SPA	Average	Median
Performance and efficiency	25.5	27
Well-structuredness	12.1	10
Interdependencies	21.9	20
Buffer capacity and resilience	12.7	10
Ability to accommodate	12.0	10
Inter- and Intra-generative equity	15.8	10

Table 29: *Result for performance and efficiency*

Performance and efficiency	Average	Median
Economic efficiency	26.2	30
Energy efficiency	39.4	40
Area efficiency	34.5	33

Table 30: *Result for well-structuredness*

Well-structuredness	Average	Median
Infrastructure	58.5	50
Information structure	41.5	50

Table 31: *Result for interdependencies*

Interdependencies	Average	Median
Change in global use of cropland	19.3	20
Greenhouse gas emissions	18.2	20
Aggregated environmental impact	15.7	15
Social acceptance	13.6	12.5
Non-renewable energy dependence	8.9	10
Resource dependence	11.1	10
Potential water dependence	13.2	10

Table 32: *Result for buffer capacity and resilience*

Buffer capacity and resilience	Average	Median
Resilience to environmental changes	53.2	55
Resilience to economic changes	46.8	45

Table 33: *Result for inter- and intra-generative equity*

Inter- and Intra-generational equity	Average	Median
Loss of high-value ecosystems	29.6	27.5
Global net area of Swiss consumption	28.2	22.5
Rural income equality	20.4	20.0
Violation risk of human rights and ILO conventions	21.8	20.0

Table 34: *Total weight of single indicators*

FKV	Weight (%)
Flexibility of individual elements/value chain	12.00
Energy efficiency	10.06
Area efficiency	8.80
Infrastructure	7.06
Resilience to environmental changes	6.75
Economic efficiency	6.68
Resilience to economic changes	5.94
Information structure	5.02
Loss of high-value ecosystems	4.67
Global net area of Swiss consumption	4.45
Change in global use of cropland	4.23
Greenhouse gas emissions	3.99
Aggregated environmental impact	3.45
Violation risk of human rights and ILO conventions	3.44
Rural income equality	3.21
Social acceptance	2.98
Potential water dependence	2.90
Resource dependence	2.43
Non-renewable energy dependence	1.96

3.3.2 Effects of the applied weighting

- a) Hierarchy effect: The high value of the indicator Flexibility of the individual elements/value chain comes from the fact that only this one indicator represented the FKV Ability to accommodate. That gave it a high value in relation to the other indicators. For the same reason the indicators of the FKV Interdependence had very low weightings. The weighting of the FKV Interdependence was distributed over seven indicators.

- b) Distribution effect: Distributing the 100 points over the FKV's or their indicator the first FKV's or their indicators may keep them from being weighted relatively, and instead simply distributed over the remaining points. That may cause an over- or underestimation of the indicators listed at the end. However, since this effect does not set in until a larger number of distribution possibilities exists, this danger applies only to the interdependencies and during the weighting of all FKV's. Giving the persons surveyed ways to correct the numbers on their online questionnaires whenever necessary, however, weakened this effect.

3.4 Uncertainty assessment

Within the methodology set applied in the SPA framework a huge amount of single FKV's are assessed, normalized, aggregated and weighted. A strategy is necessary which verify how to deal with uncertainties and how to determine plausibility. In general, three kinds of uncertainties can be distinguished within the applied methodologies.

- Impreciseness: Emerge primarily on stage of the included inventory data. Basically there is a right value but deviations occur for example due to measurement errors or averaged data.
- Fuzziness: Perhaps there is a true value but it is only to determine with high exposure or not at all. These kinds of uncertainties appear for example with regard to the applied calculation to assess the effects to the climate. By sensitivity, plausibility and pertinence analyses the uncertainties could be reduced or at least explained. This is necessary for the interpretation and discussion of the results.
- Precariousness: Appears on the stage of decisions which don't cover the right value. Possible examples are the goal definition of a LCA but also the definition of aims for protection. This kind of uncertainty is also handled by sensitivity, plausibility and pertinence analyses.

In a strict scientific sense a correct assessment does not exist, since all elaborated kinds of uncertainties appear. For this reason one quality feature of a study is its audit ability and transparency ((Zah, Hischier et al. 2007)). In this study, the following methods are applied in order to handle the uncertainties:

Error propagation:

The goal of the error propagation equations is to assess how the quantified uncertainties in model inputs propagate in model calculations to produce an uncertainty range in a given model outcome of interest (Sluijs, Janssen et al. 2004). For the most common operations, the error propagation rules are summarized in Figure 27.

In our study, error propagation is used to determine the uncertainty range of the normalized and weighted sustainability potential. The standard deviation related to a given FKV value is derived by the expert responsible for the data. If the definite standard deviation is not to determine the expert has to estimate a standard deviation of 20%, 30% and 50%, respectively.

On the basis of the standard deviations the accumulated uncertainty range of the normalized, aggregated and weighted sustainability potential is calculated.

Addition and Subtraction: $z=x+y+..$ or $z=x-y-..$

$$\sigma_z = \sqrt{(\sigma_x)^2 + (\sigma_y)^2 + ..}$$

Multiplication by an exact number: cx

$$\sigma_z = c\sigma_x$$

Multiplication and Division: $z=xy$ or $z=x/y$

$$\frac{\sigma_z}{z} = \sqrt{\frac{(\sigma_x)^2}{x^2} + \frac{(\sigma_y)^2}{y^2} + ..}$$

Products of powers: $z=x^m y^n$

$$\frac{\sigma_z}{z} = \sqrt{\frac{(m\sigma_x)^2}{x^2} + \frac{(n\sigma_y)^2}{y^2} + ..}$$

Figure 27: Error propagation rules using standard deviation (σ) (Sluijs, Janssen et al. 2004).

Sensitivity analyses

We use sensitivity analysis (SA) to give insight in the potential influences of all sorts of changes in inputs. According to Saltelli et al. (2000), SA is the study of how the variation in the output of a model can be apportioned to different sources of variation, and of how the given model depends upon the information fed into it. In this study we apply local SA for the assessment of scenarios. Local SA focus on the effect of the variation in one input factor when the others are kept at some constant level (Saltelli, Chan et al. 2000).

Plausibility checks

The results, i.e. the differences between the results, are analysed with regard to their logical sense. Could the results be explained in a logical way on the basis of the background data? The reasons are evaluate and documented.

Pertinence analyses

The reasons for the relevant indicator value are analyzed and discussed systematically. Which is the reason primarily responsible for the result of indicator X?

The conducted analyses aim not only the discovery of uncertainties and errors but rather to demonstrate room of improvement which could provide deeper insights and inputs as regards possible future developments.

3.5 Scenario analysis

3.5.1 Definitions

3.5.1.1 Scenarios

Scenarios are concerned with possible future conditions and the development of complex systems (Wiek, Binder et al. 2006). Unlike forecasts, scenarios do not represent the future condition likely to be encountered but rather the funnel of possible futures, thus revealing degrees of freedom in the present (Figure 28). Scenarios are used in the following to provide possibilities estimates of the future development of second-generation biofuels in Switzerland.

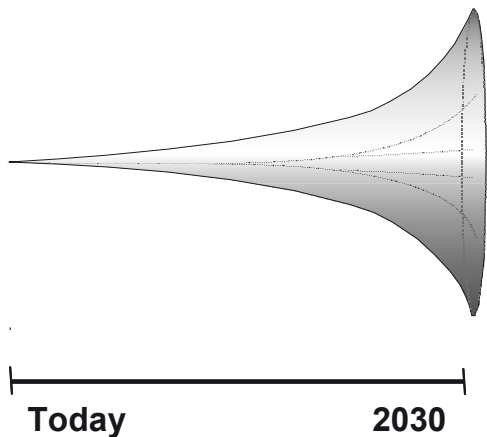


Figure 28: Scenario funnel (Scholz and Tietje 2002; Binder 2003).

In this report, scenarios consist of two parts: a boundary scenario and two system scenarios for the years 2015 and 2030 respectively. They correspond to different method and content levels.

3.5.1.2 External Impact Factors

When estimating the future state of the biofuels system in Switzerland (see 2.1.1), it would not be acceptable to leave external influences on the system out of consideration. Factors such as the price of oil or government regulations play a decisive role in the creation of biofuel value chains. These factors are called external impact factors as they are not determined by Swiss biofuel value chains. They rather characterize the context in which the future value chains are embedded (Figure 29).

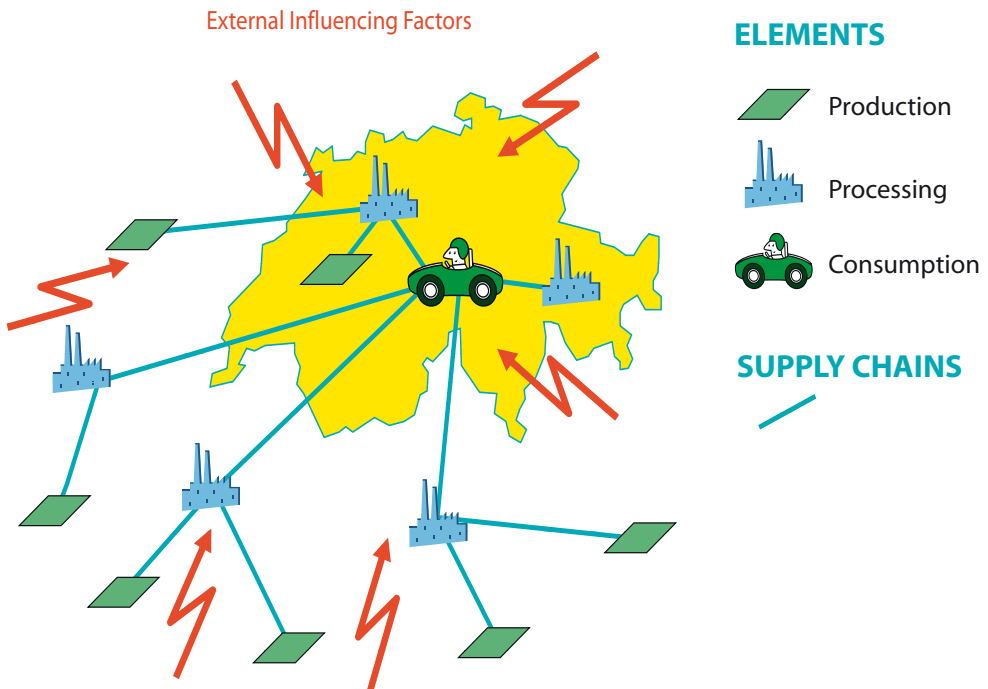


Figure 29: Biofuel system Switzerland with value chains and external impact factors.

Various developments are possible for an external impact factor. Therefore, two or three possible developments are given for each impact factor: a minimal value, a maximal value and sometimes a mean value. These values apply to the years 2015 and 2030. In this way, a certain spectrum of future developments can be covered and the scenario funnel (Figure 28) opens up.

3.5.1.3 Boundary scenarios

Boundary scenarios describe a possible future context in which the Swiss biofuel value chains are embedded. The combination of the external impact factors opens up the funnel by means of their possible minimal and maximal developments as shown in Figure 28. Whenever multiple impact factors are considered simultaneously, this results in a combination of different developments. Two impact factors with two possible developments each, yield four possible combinations. These combinations are called boundary scenarios. Boundary scenarios consist of a set of external impact factors, each of them characterized by a certain development.

3.5.1.4 System Scenarios

A system scenario describes a group of biofuel value chains that corresponds to a boundary scenario and to either the year 2015 or 2030 respectively because of its characteristics. The system of second-generation biofuels in Switzerland consists of multiple possible value chains. The value chains in turn consist of various elements, feedstocks, technologies

and uses. Certain characteristics of elements and value chains (specific FKV values from the SPA) cause these elements and chains to be either favored or disfavored in the context of a boundary scenario. The type of favoring or disfavoring changes in addition with time. Two system scenarios were derived from each boundary scenario, one for the year 2015 and one for 2030.

3.5.2 Development of Boundary Scenarios

The procedure used to develop boundary scenarios for second-generation biofuels in Switzerland follows mainly the Formative Scenario Analysis (FSA) developed by Scholz and Tietje (2002) (Figure 30).

3.5.2.1 Determination of External Impact Factors

The external impact factors were determined iteratively using a transdisciplinary approach. In a first step, a provisional set of impact factors with their possible developments was assembled on the basis of a literature search. This set was presented to the project group in the context of an online survey. The expert survey made it possible to evaluate and estimate the relevance of the proposed impact factors, in order to evaluate the possible developments and to gather comments. Developments specified to the set and to the factors were then revised and adapted (see Annex: Scenarios 11.2).

3.5.2.2 Consistency Analysis

The second step is the consistency analysis. The consistency analysis provides the necessary information for the selection of **consistent** scenarios. Consistency analysis begins with filling out a consistency matrix. Consistency values are calculated for all possible scenarios using various techniques.

Consistency Matrix

The consistency matrix summarizes all possible combinations of strengths of various impact factors for the probability of their simultaneous occurrence. One distinguishes among:

Inconsistence:	Both strengths do not occur simultaneously.
Coexistence:	Both strengths occur independently of one another.
Reinforcement:	The occurrence of one strength is supported by the occurrence of the other strength.
Conditional:	The occurrence of one strength depends necessarily on the occurrence of the other strength.

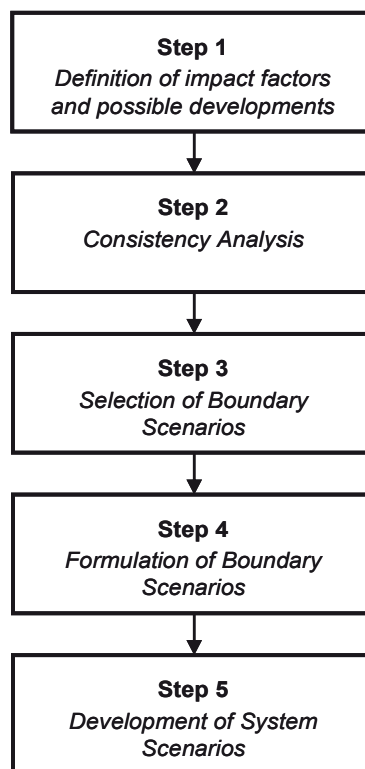


Figure 30: Steps in Formative Scenario Analysis (Scholz & Tietje 2002; Binder 2003).

The consistency matrix was filled during an expert workshop. Each part of the matrix was filled by two different groups. This allowed for crosschecking and validating the values obtained. The matrix was filled using a voting procedure. If all workshop participants agreed on the relationship, the main argument was recorded. If there was no consensus, each participant gave his/her argument and the group voted again. All the arguments were recorded in minutes. After the workshop, the project group checked the matrix for inconsistencies using the voting results, the recorded arguments and literature data. The result was the consensus version (Figure 31), which served as a basis for deriving the boundary scenarios.

			Possible Developments		Influencing Factor		1		2		3		4		5			6														
							Oil Price		Eating Habits		Food Price Index		World Economic Growth		Swiss Government Policy			Global Energy and Climate Policy														
							150 US\$/bbl		3200 US\$/bbl		1 more vegetarian		2 more meat		1 normal food supply		2 food crisis		1 boom		2 recession		1 subsidies for food production		2 subsidies for biofuels		3 sustainable biofuels		1 no treaty		2 emission reduction treaty	
	Influencing Factor	Possible Developments																														
1	Oil Price	1 50 US\$/bbl																														
		3 200 US\$/bbl																														
2	Eating Habits	1 more vegetarian	0	1																												
		2 more meat	1	-1																												
3	Food Price Index	1 normal food supply	0	-1	0	1																										
		2 food crisis	0	1	1	-1																										
4	World Economic Growth	1 boom	1	1	0	1	0	0																								
		2 recession	0	1	1	-1	0	0																								
5	Swiss Government Policy	1 subsidies for food production	-1	1	0	1	0	2	0	0																						
		2 subsidies for biofuels	0	-1	0	0	0	-1	0	0																						
		3 sustainable biofuels	0	0	0	0	0	0	0	1	0																					
6	Global Energy and Climate Policy	1 no treaty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		2 emission reduction treaty	0	1	1	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure 31: Consistency matrix (consensus version). Code: -1 = Inconsistency, 0 = Coexistence, 1 = Reinforcement, 2 = Condition.

Calculation of Consistency Values

On the basis of the consistency matrix scenario-based consistency values were calculated as a measure of the evaluation of the various scenarios (a scenario is the combination of six factors). To obtain the consistency assessment for the 96 scenarios, a multiplicative and

an additive method were applied. With the additive techniques the consistency values of each scenario are added up according to Formula 3-1 (Scholz and Tietje 2002; Wiek 2002). With the multiplicative technique the consistency values are first transformed according to Table 35. Hereafter, the multiplication of the consistency values is done according to Formula 3-2 (Scholz and Tietje 2002; Wiek 2002). During the transformation, each inconsistency is assigned the value of 0. That results in giving all scenarios with inconsistencies a consistency value of 0 in the multiplicative consistency evaluation. In this way, the inconsistent scenarios can be easily identified and rejected.

Table 35: Transformation values (Wiek 2002).

Consistency value	Transformed consistency value
-1	0
0	1
1	2
2	3

$$c_{add}(S_k) = \sum_{n_i, n_j \leftrightarrow S_k, i \neq j} c(d_i^{n_i}, d_j^{n_j}) = \sum_{i=1}^{N-1} \sum_{j=i+1}^N c(d_i^{n_i}, d_j^{n_j}) \quad \text{Formula 3-1}$$

$$c_{mult}(S_k) = \prod_{n_i, n_j \leftrightarrow S_k, i \neq j} c(d_i^{n_i}, d_j^{n_j})' = \prod_{i=1}^{N-1} \prod_{j=i+1}^N c(d_i^{n_i}, d_j^{n_j})' \quad \text{Formula 3-2}$$

$$c(d_i^{n_i}, d_j^{n_j})' = c(d_i^{n_i}, d_j^{n_j}) + 1 \quad \text{Transformation formula}$$

d_i Impact factor

$d_i^{n_i}$ Possible development of the impact factor d_i

$c(d_i^{n_i}, d_j^{n_j})$ Consistency value of the possible development $d_i^{n_i}$ of impact factor d_i and the possible development $d_j^{n_j}$ of impact factor d_j

$c_{add}(S_k)$ Additive consistency value of boundary scenario S_k

$c_{mult}(S_k)$ Multiplicative consistency value of boundary scenario S_k

Selection of Scenarios

The techniques for selecting scenarios can be grouped into three classes. The dichotomy “Mathematical Level – Systemic Level” comprised the criterion for classification. The mathematical level includes such techniques as cluster analysis, distance formation or agglomeration. They characterize exclusively the consistency evaluations of the scenarios. The systemic or meaning level includes techniques that characterize systemic aspects derived from the strengths of the impact factors for selecting scenarios. Finally there is a third class, “hybrid techniques”, that characterizes on both levels and proceeds from the mathematical level or the systemic level (Wiek 2002). In the present case, a hybrid technique was used based on a preselection on the mathematical level.

The following criteria were considered:

- Consistency criterion: The scenarios should display consistency values as high as possible.
- Inconsistency criterion: The scenarios should display no consistency values or as few as possible.
- Diversity criterion: The scenarios should differ sufficiently from one another.
- Probability criterion: The probability of occurrence should be considered during selection.

22 consistent scenarios were found out of a total of 96 scenarios. Three out of them were selected using the program KD-Consistency from the Systain Company. Further information can be found in 11.2.3.

Drafting the Boundary scenarios

As a complement to the simple isolated listing of external impact factors for each scenario, the various development of external impact factors were woven together into a coherent whole taking into consideration the recorded arguments.

3.5.3 Development of System Scenarios

Basics

The boundary scenarios together with the defined value chains (4.2.1) comprised the basis for deriving the system scenarios for Switzerland. In addition, other important factors for Switzerland, such as the use of biofuels, were brought in. In this connection, the speed of technological development, import, land use, and the degree of Switzerland’s self-sufficiency in food supply all played a role. These variables were intended to be included in the estimation of the type, composition, and production volume of the possible value chains. Further information on the different relevance of external impact factors was determined by an expert survey (11.2.2). Taking into consideration all these variables, we derived two system scenarios for biofuels in Switzerland in 2015 and 2030 per boundary scenario. That is a total of six system scenarios, which were created out of three boundary scenarios.

Selection of Value Chains

As value chains and their grouping into system scenarios were determined, the following three factors (Figure 33) played a role:

a) SPA-results at element level

Based on the SPA results value chains were generated, whereas the elements which were rated negative were excluded from the procedure.

b) Time frame

The remaining value chains were ordered according to their availability in time. Then, two groups of value chains that were potentially available were formed for the years 2015 and 2030.

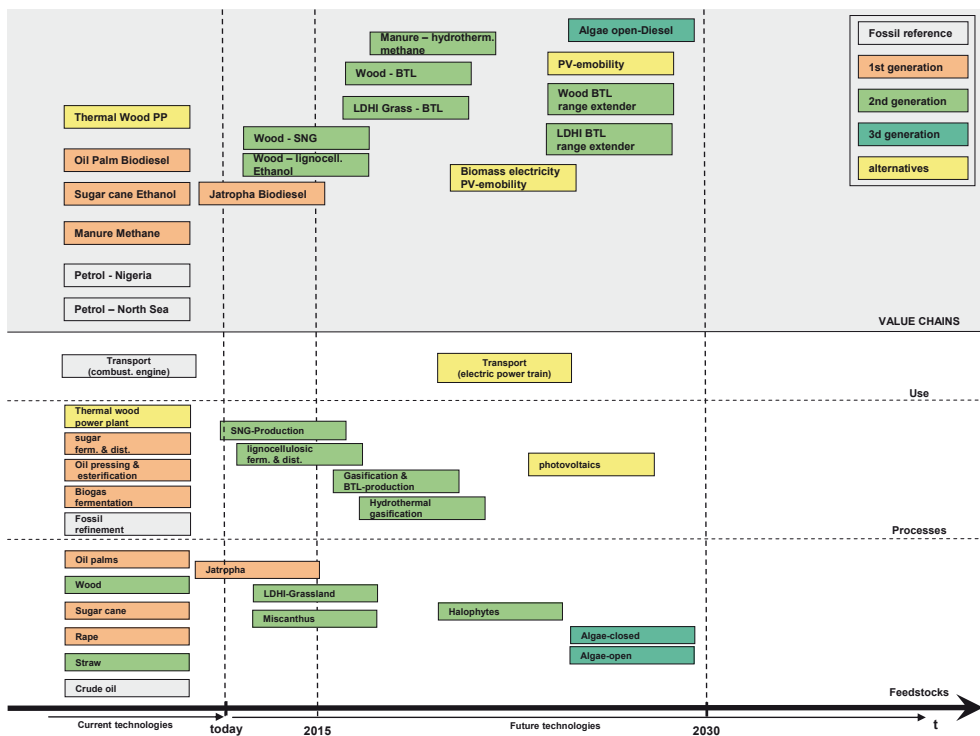


Figure 32: Expected availability of elements and value chains.

c) The boundary scenarios impact on the system scenarios

First, they have direct influence on the type and composition of value chains, e.g. , not all chains are competitive at a low oil price.

Second, they have specific indirect effects on the various value chains. Three types of indirect effects on Switzerland were included:

The speed use strategy and degree of self-sufficiency in food.

These three factors are influenced, and in turn, themselves influence, the type and composition of value chains.

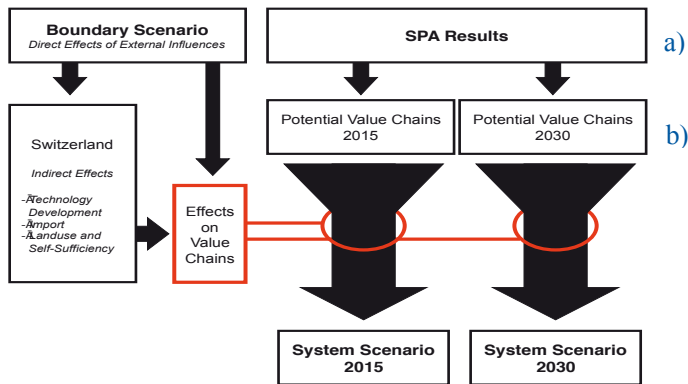


Figure 33: Development of system scenarios.

3.5.4 External Factors

3.5.4.1 Price of Crude Oil

The price of oil determines the economic competitiveness of alternative fuels. That makes oil into an important external factor influencing potential value chains for second-generation biofuels.

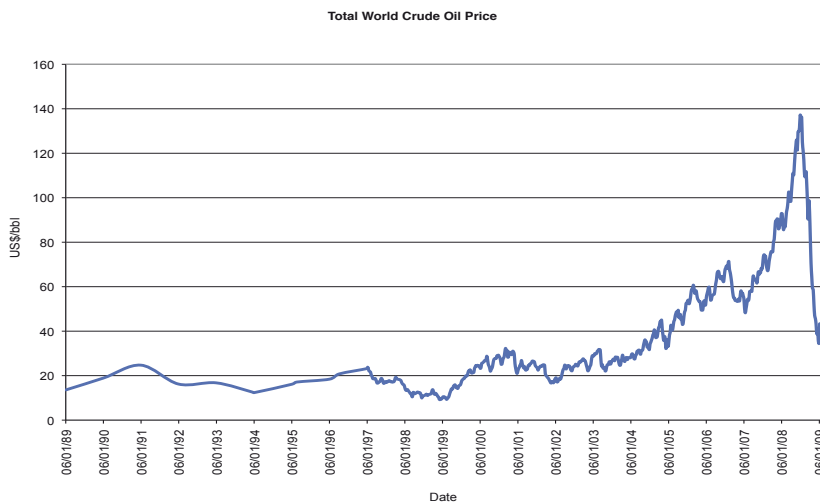


Figure 34: Development of nominal oil prices (EIA 2009).

Outlook

The U.S. Energy Information Administration (EIA 2008) assumes a rising nominal oil price on the world market of up to US\$ 186/bbl (per barrel) in its High World Oil Price scenario for the year 2030. In its Low World Oil Price scenario a price of US\$ 46/bbl is expected for the year 2016 and a price of US\$ 69/bbl for year 2030. The Reference scenario expects an oil price rising up to US\$ 113/bbl in the year 2030.

In the year 2030 it is expected that second-generation biofuels will be competitive starting with an average oil price of US\$ 75 /bbl (EIA 2008).

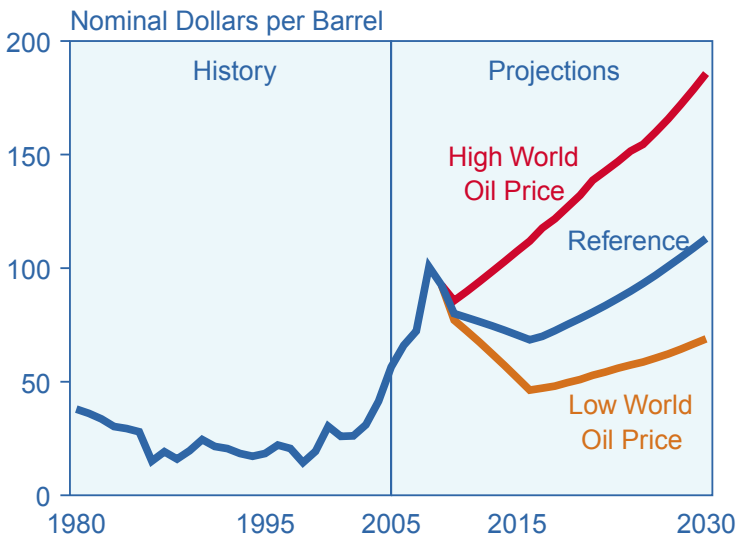


Figure 35: Scenarios of the EIA (EIA 2008).

Possible developments

Two possible developments on the world market are assumed to simulate the influence of the oil price:

- Min. value: US\$ 50/bbl
- Max. value: US\$ 200/bbl

3.5.4.2 Eating Habits

Since the early 1990s the global consumption patterns have been shifting from crop based towards animal based products. The increase in consumption per person in percentages of meat, milk and milk products, and vegetal oils on the basis of 2001 is used because the production of these foods requires considerably more land area and resources.

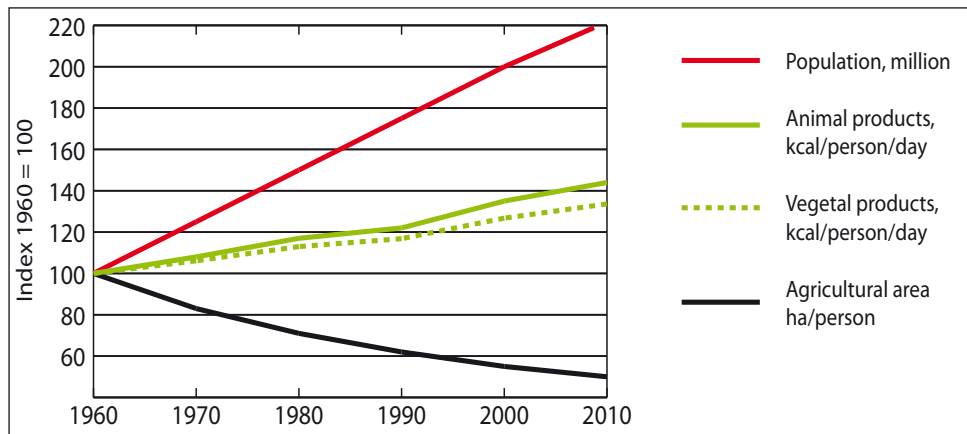


Figure 36: Development of global population, available agricultural area per person and total food consumption per person (1960–2005) (UN, Online; FAOSTAT, Online, graph: Wuppertal Institute).

Outlook

In the future, the world population may grow concomitantly with expected average hectare yields. The consumption patterns in developing countries, however, will change in favour of consuming more meat and dairy products, thus causing more demand for land and grazing. In order to feed the world population, the global land area has to expand. The land area needed for energetic and other non-food-purposes will increase this demand.

Table 36: Expected development of food consumption; (FAO 2006), graph: Wuppertal Institute).

	Consumption (kg/person)		Change in %
	1999-2001	2030	
Cereals	307	324	5
Root crops	69	75	8
Sugar	24	26	10
Pulses	6	6	2
Vegetable oils	17	25	45
Meat	38	46	22
Milk and dairy products	94	105	11
Edibles total in kcal/person/day	2789	3040	9

Possible developments

- Min. value: Meat +0%, milk and milk products +0%, vegetable oils +0%
(Basis 1999–2001, see table above)
- Max. value: Meat +30%, milk and milk products +15%, vegetable oils
+75% (basis 1999–2001, see table above)

3.5.4.3 Food Prices

Food prices might increase with increasing use of grains as raw material for biofuels and the associated competition for land. If the food price rises too heavily, it can cause global food crises. This correlation could affect the acceptance of biofuels and their production.

The Food Price Index of the Food and Agriculture Organization of the United Nations (FAO) shows the real price development on the world market for food (FAO, 2009).

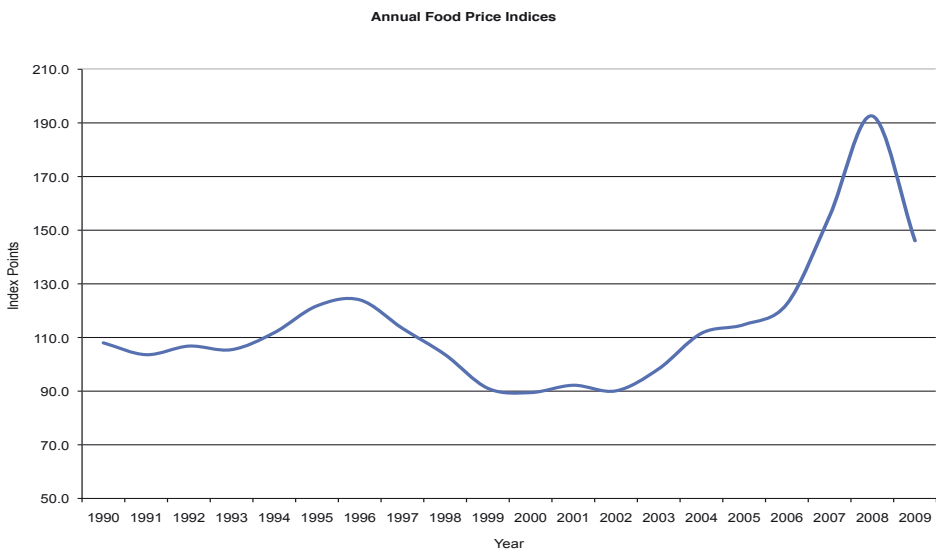


Figure 37: Development of the FAO Food Price Index (FAO 2009).

Outlook

In the years 1970 until about 2000, food prices fell worldwide. Then, in the 1990s, they levelled off, and it is assumed that a slight trend shift could take place raising prices again.

Grain and vegetable oil supplies are currently at a relatively low level compared with demand. That reduces their buffer effect on food prices. In the next ten years, the FAO expects that supplies will stay at a low level. Since the supply expansion in agricultural products takes place relatively slowly for structural reasons, the low level will cause a high volatility in food prices (OECD-FAO 2008, 28–40).

Possible developments

- Min. value: 100 points (100 = average over the years 2002–2004) (normal supply)
- Max. value: 240 points (food crisis)

3.5.4.4 World Economic Growth

The growth of the world economy increases the demand for fuels and their prices. However, a good economic climate makes investments in high-risk new technologies more probable. The economic climate influences the practicability and profitability of various kinds of biofuel production.

The International Monetary Fund (IMF 2007) defines a global recession as an average real economic growth of under 3%. For purposes of comparison, the GDP of Switzerland and the World Real GDP are shown below.

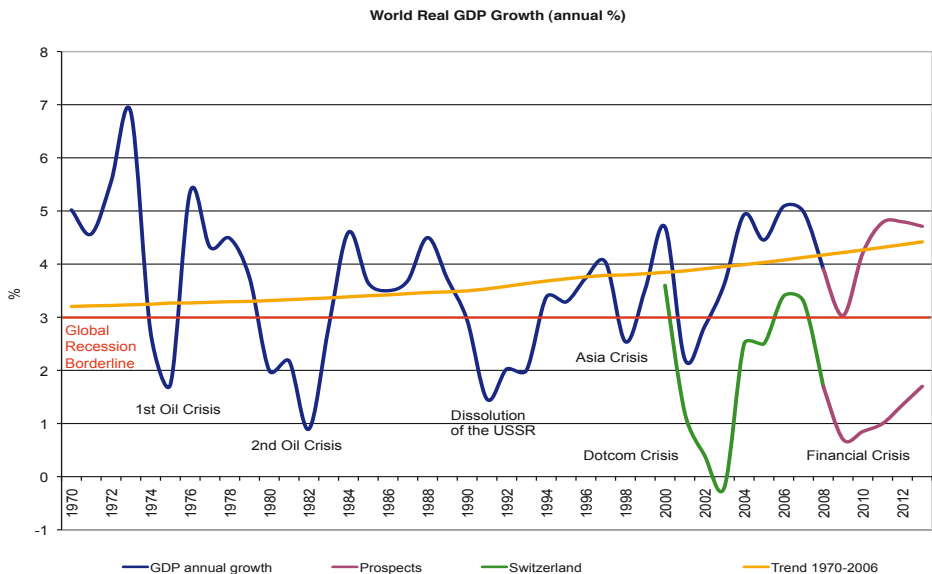


Figure 38: Global and Swiss real average annual growth (IMF, 2009).

Outlook

The world economy is very likely at the beginning of a massive downturn. The major industrial nations are already in a recession or just before entering one. The forecasts for the world economy are very unsure. A gradual recovery of the markets is not expected before the end of 2009, and world economic growth will hardly reach its long-term trend again before 2010 (IMF 2008: 1, 23–24). The World Bank is expecting a shrinking of the world economy for the first time since the Second World War. The greatest risks are to be found

in currency crises and balance-of-payments crises in individual states, a phenomenon that has already become a reality for some developing countries (Worldbank 2008).

Possible developments (average annual real GDP until 2030)

- Min. value: 2%
- Max. value: 5%

3.5.4.5 Swiss Government Policy

Biofuels are currently not competitive with fossil fuels except in special cases. Even an introduction of second-generation biofuels would require favourable political framework conditions.

Outlook

A blending requirement of mixing biofuels with fossil fuels has been discussed and was rejected by the Swiss Parliament. The Parliament refused to take such an intrusive measure onto the market. Incentive systems to increase efficiency in energy production and energy consumption are preferred.

Possible developments

- Min. value: No regulation of biofuels but additional subsidies for food production, in order to prevent biofuel production from competing with it.
- Mean value: State support to make biofuels competitive with fossil fuels (e.g. tax waiver, subsidies) without a sustainability standard.
- Max. value: State support to make biofuels competitive with fossil fuels (e.g. tax waiver, subsidies) plus import control by means of a sustainability standard.

3.5.4.6 Global Climate and Energy Policy

Today's global energy system is internationally networked in many ways: one of them is financial, through the energy and capital markets; another one is political, producing future international treaties under the United Nations Framework Convention on Climate Change (IEA-UNEP 2007; UNFCCC 2009). Since 1995 goals and measures have been negotiated on the international level, which if signed and ratified, would be intended to combat climate change. During the third annual climate change conference of the United Nations (under the UNFCCC) in Kyoto binding goals were agreed on for the first time to reduce GHG emissions in 37 industrialized countries by 2012. This "Kyoto Protocol" came into effect in 2005. However major signatories of the UNFCCC have failed to ratify the protocol or are not in agreement with its reduction goals.

Since the Kyoto Protocol became effective, the focus has shifted to the time after 2012. The Bali Action Plan was signed in 2007 in the Indonesian city of that name, acknowledging the

IPCC Report and its conclusions. It was a general text that called for quicker action to face climate change. The Bali Action Plan laid the basis for new negotiations for the 2009 climate conference in Copenhagen, where a new treaty is supposed to be negotiated (MCE 2009). Such a treaty could influence the strategies for energy production and use.

Outlook

The ongoing negotiation process within the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) is trying to come up with compromise proposals, to reflect adequately on ideas of the various negotiating parties, and to deal with discord for the 2009 climate conference. In the list of suggestions for a common vision on long-range cooperation, one hears of broad multi-party support to establish science-based goals for reducing GHG emissions to come into effect by the middle of the 21st century. Initial proposals call for emission reductions of 25–40% by 2020 on the basis of 1990 for Annex I countries (Kyoto Protocol signers) and a reduction of 15–30% for the group of developing countries, although no developing country has announced any reduction goals of its own (UNFCCC 2009). U.S. President Obama intends to reduce U.S. GHG emissions to the level of 1990 by 2020. If the U.S. participates, the hope is that India and China may feel obliged to participate as well (MCE 2009).

Possible Developments

- Min. value: No binding treaty results.
- Max. value: A binding treaty result with sanctions for non-compliance with the following limits:
- 40% emission reduction as compared with the year 1990 by 2020 for industrialized countries.
- 15% emission reduction as compared with the year 1990 by 2020 for developing countries.

3.5.5 Boundary Scenario “Resource Scarcity”

The oil price has increased up to US\$ 200/bbl since 2010, which was caused by decreasing pumping, political instabilities in several drilling countries, and the global treaty on CO₂ emission reduction. That has slowed global economic growth sharply. At the same time, the high oil price and other factors have caused a sharp increase in food prices and thus worsen the hunger problem in many developing countries. Because of the high meat prices and the economic crisis, people in industrialized countries are eating more crop products instead of meat. In Switzerland the cultivation of food is government subsidized, so Switzerland can ensure a high degree of self-sufficiency. Food production is otherwise hardly competitive with feedstocks to produce biofuels due to the high oil price and international emission controls.

Table 37: Developement of external impact factors in boundary scenario "Resource Scarcity".

External Impact Factor	Development
Oil price	Level 2: High oil price
Eating habits	Level 1: Increasingly crop products
Food price index	Level 2: Food crisis
World economic growth	Level 2: Slow economic growth (Recession)
Swiss policy	Level 1: Additional subsidies for food production
Global energy & climate policy	Level 2: Emission reduction treaty

3.5.5.1 Impact on the Use of Biofuels in Switzerland

The policy of subsidizing food production, eating habits oriented toward crop products, and a conversion of grazing to food production land have given Switzerland a degree of self-sufficiency of 65% (2015) and 80% (2030). Bio energy is produced mainly from residual materials and forest utilization has been increased to the maximum sustainable yield. Converting grazing pasture has reduced animal production and less liquid manure is produced. Switzerland holds internationally a medium rank in regard of technology use and development. Second-generation technologies are used to produce biofuels. Since most countries use their biomass themselves due to the high energy prices and the emission reduction treaty, practically no import of biofuels or biomass takes place.

Direct impacts

Impact factor	Direct impacts
High oil prices	<ul style="list-style-type: none"> → Biofuels are competitive → Expensive production methods → may result in expensive end product → Electro mobility → Heating oil expensive → wood heating popular
Increased consumption of crop products	→ Increase in Swiss self-sufficiency
Food crisis	<ul style="list-style-type: none"> → No cultivation of feedstocks → Increasing food prices → reduction of subsidies → constant production
Slow economic growth (global recession)	<ul style="list-style-type: none"> → Technologies preferred with low start-up investments → Newer/ more expensive technologies possible with low final price of fuels/high efficiency
Swiss policy of subsidizing food production	<ul style="list-style-type: none"> → No cultivation of energy plants → Forest use, residue use, residual materials
Global treaty to reduce emissions	<ul style="list-style-type: none"> → Electro mobility is doing well, subsidized → Emission minimization

Indirect impacts

Type of impact	Causality chain	Indirect impacts
Technological development	A high oil price accelerates the development of alternative energies. However biofuels have a bad reputation because of the food crisis. Fuels from residual material, waste and forest wood are preferred.	→average
Imports into Switzerland	Import of biofuels is unpopular and hardly possible since most countries use their bio energy resources themselves.	→hardly any imports
Land use and degree of self-sufficiency with food	Switzerland does not want to cultivate any energy plants. Land use is optimized for food production, even if it reduces meat production. Pasture is transferred more and more for production. Together with a transition to more crop products the degree of self-sufficiency increases. Forest use is optimised.	→No energy plants →Expansion of cultivation of plants instead of pasture →High degree of self-sufficiency (65% or 80% respectively) →Larger use of forests

3.5.6 Boundary Scenario “Challenges”

The strong global economic growth, the increased global energy demand, the decreased oil production rates, increasing political instabilities in several countries, and the global treaty on CO₂ emission reduction have caused the oil price to rise since 2010 to US\$ 200/bbl. The high oil price and other factors have caused food prices to rise sharply and thus to exacerbate the hunger problem in many developing countries. Despite the high meat prices, more and more people worldwide are eating meat. In Switzerland biofuels are government-subsidized due to the energy demand of an expanding economy and the international treaty on emission reduction, but they are coupled to strict sustainability standards.

Table 38: Development of external impact factors in boundary scenario “Challenges”.

External Impact Factor	Development
Oil price	Level 2: High oil price
Eating habits	Level 2: Increased meat consumption
Food price index	Level 2: Food crisis
World economic growth	Level 1: Fast economic growth (boom)
Swiss policy	Level 3: Sustainable biofuels
Global energy & climate policy	Level 2: Treaty with emission reduction

3.5.6.1 Effects on the Use of Biofuels in Switzerland

Switzerland is a frontrunner in technology development. First-generation biofuels are produced and imported in the country. Imports of sustainable biofuels are coming in to cope with the economic potential of the facilities. Switzerland's degree of self-sufficient supply in food stays constant because the expansion of food production in reaction to increased food prices is compensated for by increased meat consumption. The efficiency of land use is increasing in Switzerland as it is elsewhere. The challenge is to have both more food and more biomass, but in a sustainable way.

Direct Impacts

Impact factor	Direct impacts
High oil price	<ul style="list-style-type: none"> → Biofuels are competitive → Expensive production methods / may result in expensive end product → Electro mobility → Heating oil expensive → wood heating popular but only a small amount of heat is needed because advanced isolation and construction technologies are applied
Increased meat consumption	<ul style="list-style-type: none"> → Change of meat types/animals (more white meat) → but constant amount of production
Food crisis	→ Increasing food prices → reduction of subsidies → constant production
Fast growing global economy (boom)	<ul style="list-style-type: none"> → Increased energy demand → A lot of capital for investment → Even new and expensive technologies get applied quickly
Swiss policy to promote sustainable biofuels	<ul style="list-style-type: none"> → Subsidizing sustainable biofuels → Sustainable cultivation of feedstocks outside Switzerland, forest utilization, waste utilization
Global treaty on reducing emissions	<ul style="list-style-type: none"> → Favours electro mobility → Emissions minimization

Indirect Impacts

Type of impact	Causality chain	Indirect impacts
Technological development	A high oil price and a favourable investment climate foster the development of alternative energies. However only sustainable biofuels from monitored production, residual material, waste and wood are used.	→ Faster than expected

Imports into Switzerland	The import of biofuels is coupled to sustainability criteria and is promoted.	→A lot of imports →Feedstocks from sustainable production outside Switzerland
Land use and degree of self-sufficiency with food	Land use is optimized for food cultivation and farm animals as it is lucrative. Switzerland's degree of self-sufficiency with food stays constant. Switzerland hardly cultivates any feedstocks anymore. Forest utilization is optimised.	→Expansion of food production →Hardly any feedstocks →Constant degree of self-sufficiency (60%) →Larger use of forests

3.5.7 Boundary Scenario “Unlimited Growth”

The oil price has stayed on a level of US\$ 50/bbl despite strong global economic growth. Petroleum production from oil sands has become very cheap due to technological progress, and new oil and gas deposits in the Northern Polar Sea have been discovered. The negotiations for a global treaty on an emissions reduction have failed due to resistance from the large countries consuming fossil fuels despite the increased level of CO₂ emissions. Productivity increases in agriculture keep food prices constant, thus making it possible to feed the growing world population despite western eating habits. In Switzerland the use of bio energy has been coupled to severe sustainability criteria, despite a lack of international pressure.

Table 39: Development of external impact factors in boundary scenario “Unlimited Growth”.

External impact factor	Development
Oil price	Level 1: Low oil price
Eating habits	Level 2: Increased meat consumption
Food price index	Level 1: Normal food supply
World economic growth	Level 1: Fast economic growth (boom)
Swiss policy	Level 3: Sustainable biofuels
Global energy & climate policy	Level 1: No treaty

3.5.7.1 Impacts on the Use of Biofuels in Switzerland

Switzerland's degree of self-sufficiency is at 60%; more and more meat is being consumed. The oil price is low, providing little incentive to invest in the bio energy sector. For this reason international technology development in the bioenergy sector is advancing slowly. Still, Switzerland is holding a top pioneer position in bioenergy technologies directed at sustainability in comparison to the low international technology level. Wood, waste and liquid manure are being transformed into energy using SNG Technologies. However first-generation fuels still dominate. Since many countries are hardly using any biomass or bio energy,

given the low oil price, a great potential for imports exists. This great import potential for biofuels and biomass however is used only partially as there is a lack of economic incentives.

Direct Impacts

Impact Factor	Direct Impacts
Low oil price	<ul style="list-style-type: none"> → Competitiveness of biofuels weak → More expensive production methods and more expensive end products are at a serious disadvantage → Electro mobility weak (too expensive) → Heating oil cheap
Increased meat consumption	<ul style="list-style-type: none"> → Change of meat types/animals (more white meat) → But constant amount of production
Normal food supply	→ No competition with feedstock
Fast growing global economy (boom)	<ul style="list-style-type: none"> → Increased energy demand → Biofuels are not lucrative compared with other possibilities for investment
Swiss policy to promote sustainable biofuels	<ul style="list-style-type: none"> → Subsidization of sustainable biofuels → Sustainable import, forest utilization, waste utilization
No global treaty on emission reduction	<ul style="list-style-type: none"> → No prevention or taxing of emissions → Delay for electro mobility

Indirect Impacts

Type of impact	Causality chain	Indirect impacts
Technology development	A low oil price slows down the development of alternative energy. Only sustainable biofuels from monitored production, residual material, waste, liquid manure and forest wood are used.	→ Slower than expected
Imports into Switzerland	Imports are competitive only because of subsidies (e.g., tax break)	→ Hardly sustainable though
Land use and degree of self-sufficiency with food	Land use is optimized for keeping farm animals because that is lucrative. More liquid manure collects. The degree of self-sufficiency remains constant. Switzerland cultivates hardly any feed stocks itself.	<ul style="list-style-type: none"> → Degree of self-sufficiency 60% → Production of liquid manure increased

3.6 Structural Agent Analysis

The implementation of a strategy and the backward planning for achieving a desired scenario or implementing a value chain requires a thorough understanding of the agents involved, their system understanding, their goals and their planning horizons. This is even more so if a new technology is aimed to be implemented and several stakeholders along the value chain play a specific role in achieving this goal.

In the early stages of implementation of innovative technologies the agent analysis thus, supports the identification of lock-ins and supports the consensus building process.

In the presented study, the goal of the agent analysis to identify which agents and factors might support or hinder the implementation of these favourable chains within certain boundary conditions.

3.6.1 General description

For analyzing the potential agents involved in the biofuels value chains, the structural agent analysis (SAA) was chosen. The SAA provides a basis for understanding the underlying social structures restricting or enabling decisions within the system of biofuels second generation. In particular the SAA considers the interaction and dynamics of social structure (resources, traditions, regulations, etc.) and human actions, which allows for defining long-term policies aiming at providing an optimal structure for e.g. the innovative technology to develop. Furthermore the SAA supports the study of interferences among agent groups, providing an early recognition of potential stumble stones. Finally, it takes into account different time scales of change of social structures allowing for a more dynamic perspective (Binder 2007).

3.6.1.1 Background

The SAA is based on + providing a framework for studying the systems of social interaction.⁴ Within this framework social structures (e.g., legislation, culture, economic system) affect human action but also human action itself changes or perpetuates (intended or unintended) the present social structures. That is, there is an interaction and a feedback between social structures and human action.

In particular, agents make decisions and act within existing social structural conditions (external factors) as well as their personal motivations and individual environmental awareness (internal factors). The action of agents has two effects. First, it affects the environment. Here we distinguish according to Scholz and Binder (2003), a short and long-term effect. The change in the environment, in turn, can affect agents and structures as follows: It might affect the environmental awareness of agents directly (e.g. health problems related to air pollution). Or it might affect the environmental awareness of the society (e.g., effects of climate change), leading to changes in social structures (e.g. laws, feebates for reducing CO₂ emissions).

Second, as mentioned above, agents' action affects the social structure by either reproducing or changing it.⁵ Whereas the impact of social structure on human action is immediate,

⁴ The structuration theory can be related to the theory of cybernetics as found in technical and natural sciences.

⁵ One typical example is language. We reproduce the grammar and the language each day, but slowly change part of the vocabulary over time.

the potential effect of action on structure can be understood as a long-term feedback loop. Thus, the way social structure affects current human action, i.e. by restricting or enabling certain patterns of human agency, is synchronic; that is, the effect of structure on decision-making occurs in the moment of decision-making. The feedback of actions on structure, however, is diachronic; that is, structure is not changed simultaneously as action occurs.

3.6.1.2 Definitions and operationalization

Within the SAA the following components of Giddens structuration theory are utilized and operationalized as follows Table 40.

Table 40: Definition of the components of the SAA and examples from biofuels (adapted from Binder [2007]).

Term	Definition	Examples biofuels
System of social interaction	Interdependence of actions, conceived as: <ul style="list-style-type: none"> • homeostatic causal loops • self-regulation through feedback • reflexive self regulation 	System of agents interaction related to a value chain or a scenario; i.e. feedstock producers, feedstock processors and fuel consumers
Structuration	Generation of a system of interactions through action and structure	Support of the most sustainable scenario through regulation, labeling, etc.
Structural elements	Generative rules and resources <ul style="list-style-type: none"> • Signification (semantic rules) • Legitimation (implicit or explicit moral rules) • Domination (unequally distributed resources) <ul style="list-style-type: none"> ○ Authoritative resources ○ Allocative resources 	<ul style="list-style-type: none"> • Culture, social acceptance • Regulations regarding biofuels • Power <ul style="list-style-type: none"> ○ Power structure along the chain ○ Capital (financial, physical)
Structural factors	Operationalization of the structural elements for the specific case studied	

3.6.2 Application of the methodology

The methodology is structured into a prerequisite phase, the SAA and a follow up phase. The SAA itself includes three main parts: (i) identification of the main agents and the structural factors affecting their decisions; (ii) agents options, facilitators and interferences; and (iii) feedback of action on structure. In this study step 7 (effects of agents' actions on structure) is not carried out, as this would go beyond the scope of the project. For details on the methodology please see Binder (2007). Here only the key points relevant to the study are shortly presented.

Step	Description	Method (references, exemplified)
	Prerequisite	
	Define goals to be achieved	Scenario analysis and as-
	Define elements or value chains to be optimized	essment of elements and value chains

Structural Agent Analysis

Main agents and the structural factors affecting their decisions (steps 1–4)

Step 1	Identify the relevant agents	
Step 2	Analyze for each agent the relevant structures affecting his/her actions.	Agent network analysis (Salganik, MJ & Heckadorn DD [2004]; Hermanns, LM. [2005]; Conway, S., [2000])
Step 3	Weigh the current impact of the relevant structures on agents' actions.	Structured interviews, standardized survey, expert interviews (Mieg HA. [2000])
Step 4	Draw an agent-structure diagram.	Multicriteria analysis (Keeney, RL. & Raiffa, H. [1976]; Jia, J. et al. [1998])
Step 5	Agents' options, constraints, facilitators and their interferences (steps 5–6)	

Agents' options, constraints, facilitators and their interferences (steps 5–6)

Step 6	Identify interferences among agents.	Expert interviews (Mieg HA. [2000])
Step 7	Feedback of action on structure (step 7)	Criteria for identification (Scholz, RW. [2001])

Feedback of action on structure (step 7)

Follow up

First examples from organizational theory (Yuthas et al. [2004])

Define strategies for reaching the above-defined goals considering:

Short-term measures applicable under the given structural conditions

Long-term measures aiming at changing structure

Consensus building
(Cormick G. [1996];
Susskind L. et al. [1999])

3.6.2.1 Prerequisite

The SAA will be based on the results of the scenario analyses and the assessment of the value chains. It will be carried out for the most favourable value chains from sustainability perspective considering the scenarios as background information.

3.6.2.2 Main agents and the structural factors affecting their decisions

Step 1: Identification of the relevant agents

In this step the direct and indirectly involved agents with respect to the value chains selected are identified. The direct agents are directly involved in the value chains, e.g. feed-stock producers, consumers. The other agents are identified using the “snowball principle” or nomination technique, through their functional relationship along the production consumption chain, and by analysing information flows. A first draft of the main agents is shown in Figure 39.

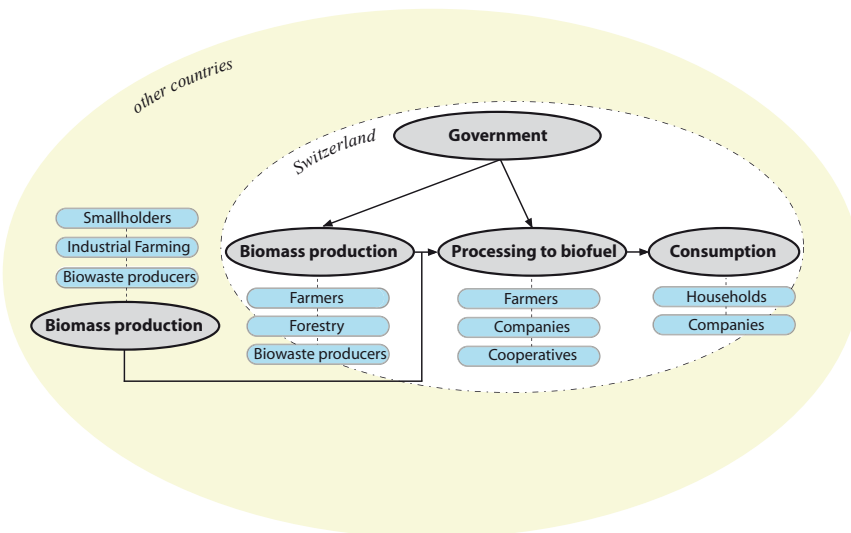


Figure 39: Agents involved directly in the system biofuels second generation (first draft).

Step 2: Structural factors affecting agents' actions

This step aims at understanding the structural factors affecting agents' decisions within or impacting a selected value chain. That is, the factors affecting the decision of a farmer to produce a certain feedstock are determined and structured as presented in table 1. For example, factors such as subsidies, security of the demand sector (contracts on amounts) will be considered for the main agents within the chain. Furthermore the influence the agents among each other (authoritative resources) is included in the analysis.

Step 3: Weight of the impact of structural factors on agents' actions

In this Step the relative relevance of the different impact factors on the action of the agent are weighted. Thus, it can be derived how an intervention (e.g. a regulation) might be most effective.

Step 4: Agent-structure diagram

The results obtained in Steps 1–3 are visualized in an agent-structure diagram validated discussed with selected experts. A first draft of an agents' structure diagram for the system of biofuels second generation is presented in Figure 40.

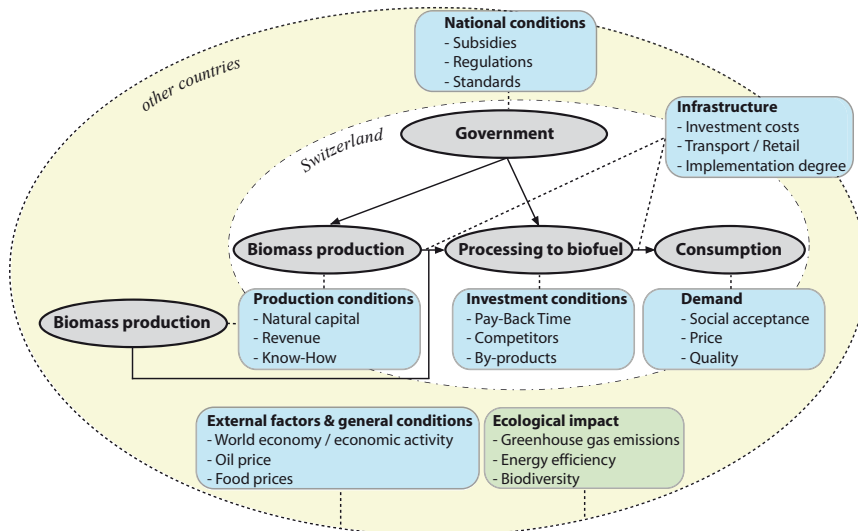


Figure 40: Agent structure diagram for the system biofuels second generation (first draft).

3.6.2.3 Agents' Options, Constraints and Facilitators

Step 5: Identify options, constraints and facilitators

The goal of this step is to move from the understanding of the agents system to a potential management of the biofuels. Thereby the time frame of a potential implementation plays a crucial role.

We define "Options" as sustainable ways of acting (Hirsch-Hadorn 2002). They affect the value chains as determined in the prerequisites, Steps 1 and 2. That is, for each agent, several options for action affecting – either directly or indirectly (through another agent) – a value chain are determined. For example farmers can choose to produce feedstock or food or to leave the land in rest. "Constraints" are defined as structural factors that might prevent agents from choosing a certain option. Constraints, for example, can be laws prohibiting a specific management type (e.g., Swiss forest law). On contrary, "Facilitators" are structures that support sustainable action. Facilitators, for example, can be subsidies for Swiss regional wood production (Binder 2007).

Step 6: Interferences among agents

The goal of this step is to identify the interferences among agents regarding e.g. the implementation of certain value chains. The reason for this step is that the information on constraints and facilitators directly relates to agent-specific options. However, agents' options and constraints might interfere with each other and, thus, hinder their implementation of specific options. An interference can occur among structural factors affecting one agent (e.g., price incentives vs. legal constraints). It can also occur between agents (e.g., differing planning horizons and structural factors).

In identifying interferences among agents, the following aspects are considered: (i) planning horizon; (ii) options; and (iii) constraining or facilitating structural factors. The planning horizon of agents is necessary for understanding the time within which a behavioural change can be expected. The options as well as constraining or facilitating factors (determined in Step 5) have to be regarded in relation to their planning horizon, differentiating between short- and long-term options. Interference occurs when the planning horizon, the options, and the structural factors among agents differ with respect to a specific flow or material goal (Binder 2007).

The interferences are determined in expert interviews. The results provide the basis for planning a consensus building process and design appropriate policies for implementing the desired value chains or supporting the desired scenarios.

3.6.2.4 Follow up

Finally based on the results of the SAA and the results of the assessment, specific recommendations at short- and long-term are defined which should support the most sustainable path. This step feeds directly into chapter 5.8.1.

4 RESULTS

4.1 Assessment of Elements

It is important to note that the following assessment is strictly limited to single elements in order to focus and emphasize important individual aspects of those. In other words, the interpretations of the results are only valid for the element assessed. The combination of the single elements is the content of chapter 4.2.

4.1.1 Feedstocks

4.1.1.1 Crude oil

Crude oil refers to a complex mixture of hydrocarbons of various molecular weights, plus other organic compounds and is the primary energy resource on earth followed by coal, gas, hydroelectric and nuclear energy (BP 2009).

According to British Petrol (BP 2009) the world production/consumption in 2008 amounts to approx. 3928 million tonnes. The amount of crude oil consumed by Europe and Eurasia in 2008 equals approx. 24.3% of the world's crude oil consumption (Figure 41).

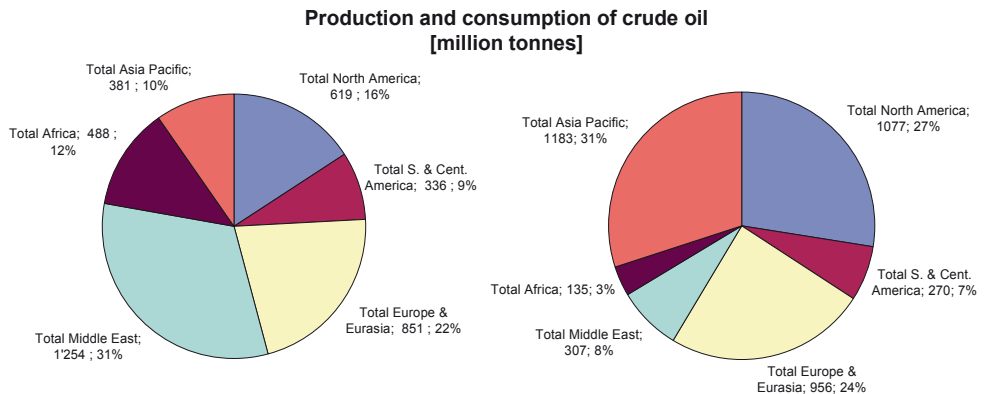


Figure 41: Production (left) and consumption (right) of crude oil (source: [BP 2009])

Switzerland used approx. 12.1 million tonnes of crude oil in 2008 which equals approx. 0.3% of the world consumption. The main oil products consumed in Switzerland are heating oil (4.4 mio t), petrol (3.4 mio t), diesel (2.2 mio t) and kerosene (1.4 mio t). The greatest share of the consumed oil products are imported as finished products from Europe (60.1%). Crude oil imports account for approx. 36.6% with Africa as the prime importer (31.8%). In this regard and in order to show the difference between the best and the worst crude oil

source, we assess the production of crude oil in two countries, namely Norway (NO) and Nigeria (NG). Figure 42 shows the normalized SPA results for both.

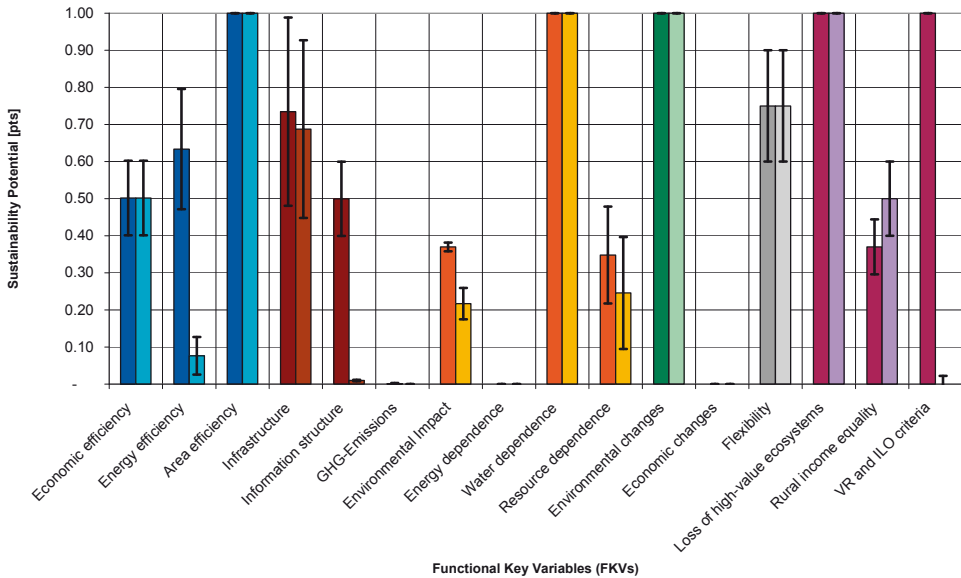


Figure 42: Normalized SPA results for crude oil at drill hole in Norway (first bar) and Nigeria (second bar) for all indicators assessed on the feedstock level (source: own depiction). In this case rural income equality was replaced by income equality of mining and quarrying industry.⁶

Crude oil NO scores equal or a higher than crude oil NG. The main reason for this is the burning of the co-produced methane gas at the drill hole in Nigeria that reduces energy efficiency and increases environmental impacts. The difference between income equality⁷ and violation risk and ILO criteria is caused by the producing country, e.g. Norway has much lower risk of violating ILO and Human Rights than Nigeria. The very low result for GHG emissions can be explained by the biogenic CO₂ uptake of all other feedstocks considered, i.e. in comparison to biogenic feedstocks GHG emissions of both crude oils are significantly higher. The resilience to economic changes is rated zero given the crude oil inherent sensitivity to changes in oil prices. The flexibility of crude oil is rated high due to its numerous fields of applications.

Concerning infrastructure, the requirements of both crude oil NO and crude oil NG are comparatively low because crude oil has low infrastructure requirements in the initiation phase and during operation (only low additional input requested). There is merely a slight difference between the best and the worst case. This negligible difference arises from higher transportation infrastructure requirements in Nigeria.

⁶ According to the International Standard Industrial Classification of all Economic Activities (ISIC-Rev. 3) (ILO, 2009)

⁷ No data available for Nigeria.

With regard to information structure, the sustainability potential of Crude oil NO is medium whereas crude oil NG receives a low value. This difference is due to the time lag of about 100 years from the discovery of the former to the discovery of the latter. Thus Norway has over 100 years more experience with crude oil than Nigeria, which is displayed by the obtained results. It achieves still only medium level because other feedstocks count on significantly more experience.

4.1.1.2 Sugar cane, BR

Sugarcane is a giant perennial grass belonging to the genus *Saccharum*. It is believed to have originated in the South Pacific and is primarily grown in tropical and subtropical climates. All commercial canes grown today are inter-specific hybrids of different species (Wrigley, 1982). Sugarcane has many industrial uses including the production of table sugar, molasses, alcoholic beverages and ethanol. In fact, 40 percent of all fuel ethanol is supplied by sugarcane (Worldwatch Institute, 2006). Bagasse, a by-product of production, is often the main source of fuel in sugar factories but can also be used in paper and cardboard manufacturing.

Sugarcane cultivation is based on a ratoon-system, which means that after the first cut the same plant is cut several times on a yearly basis. Sugarcane stands have a productive lifespan of approximately 3–6 years (Purseglove 1979). After 12–18 months the cane is ready for the first cut. Yields decline approximately 15 percent after the first harvest and 6–8 percent in the following years (Smeets, Junginger et al. 2006). Sugarcane requires a minimum precipitation of 600 mm for survival but optimal growth conditions are in the range of 1500–2500 mm y^{-1} (Smeets, Junginger et al. 2006). However, these requirements could be lower depending on the evapo-transpiration rate at the location of cultivation. The crop does not tolerate frost well and ideal temperatures should be between 25–35 °C. Sugarcane is labour intensive and requires a large input of nutrients to maintain productivity in subsequent harvests. Nonetheless, being a C4 plant, it has very high productivity and today ethanol produced in Brazil is the only biofuel which can effectively compete with fossil based fuels without government subsidies and incentives.

Brazil is the largest producer of sugarcane with 514 million tonnes in 2008, followed by India and China with respectively 355 and 106 million tonnes (FAO 2008). Nearly half of Brazil's annual sugarcane harvest is used to produce ethanol, this represents approximately 0.5 per cent of the country's total agricultural area (Worldwatch 2006). Sugarcane is mainly produced in two regions: the Centre-South with 85 percent of total production (São Paulo State) and North-Northeast with 15 percent (Smeets, Junginger et al. 2006). This study will look at average production in Brazil with yields of 68,700 kg/ha and an energy content of 4.95 MJ/kg of feedstock in the state of São Paulo in the South and Alagoras in the North East.

Figure 43 shows the SPA results for sugarcane. Economic efficiency is high due to the low costs of labour in Brazil and the large scale production of sugarcane. In general, lots of interventions related to the cultivation of sugar cane are done by manual labour. Thus both the energy dependence and resilience to economic changes show a high SP. However, rural income equality is low and repeated cases of forced labour and displacement of indigenous people due to agricultural land consumption occurred. With regard to GHG emissions, SP is elevated because the high yield diminishes the interventions per MJ sugarcane harvested. Nevertheless, the SP of area efficiency is low. It must be taken into account that the upper bound for the normalization of area efficiency is determined by a net energy out-

put of 480 MJ/m²a, i.e. the area efficiency of PV systems in Switzerland. Sugarcane is among the most flexible at the feed stock level with products in three end-use categories: food, fuel and industry.

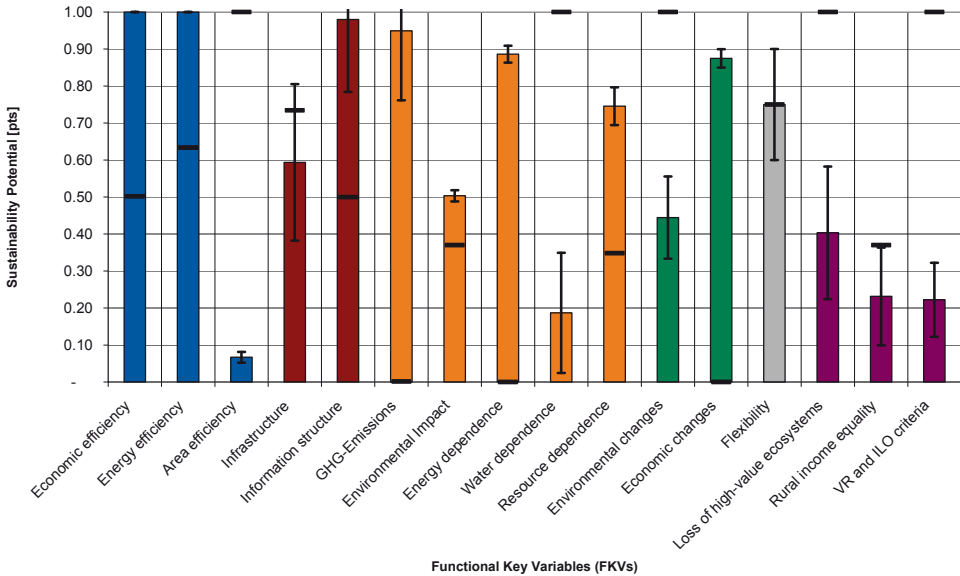


Figure 43: Normalized SPA results for Sugar cane, BR. The black line shows the normalized results for crude oil production NO (source: own depiction).

Sugarcane shows a low SP for potential water dependence since it requires approx. 8 l blue water per MJ produced. Infrastructure requirements for sugarcane from Brazil are moderate to low as depicted by a value of around 0.6. During all the process steps of feedstock production, sugarcane shows low or moderate infrastructure requirements. Furthermore, sugarcane attains a high SP regarding information structure. The feedstock has been introduced to Brazil 477 years ago (Worldpress 2009). Hence the result can be explained with the high experience and availability of know-how on sugarcane in Brazil.

4.1.1.3 Rape seed, IP, CH

Rapeseed (*Brassica napus*), also known as rape and canola, is believed to have originated in the Mediterranean area and is a bright yellow flowering member of the Brassicaceae family. Rapeseed is grown for the production of animal feed, vegetable oil for and biodiesel. It is the primary feedstock for biodiesel production in Europe because it produces more oil per hectare than soybeans and sunflower seed (Worldwatch 2006).

Rapeseed is cultivated in temperate regions. There are two types of rape: summer and winter rape. Summer rape is grown in Canada whereas winter rape is mainly grown in Central Europe. Sowing takes place in autumn and it is harvested early the following summer.

Rapeseed provides a good winter cover for soil and limits nitrogen run-off. Water use is low, in the range of 200–500 mm y⁻¹, and optimum temperature are between 10–30 °C, although it can withstand lower temperatures as well. Leading producers in the world include the European Union, Canada, the United States, Australia, China and India.

Worldwide production of rapeseed (including canola) rose to 46.4 million metric tons in 2005, the highest recorded total (FAO, 2005). In Europe, 1.4 million hectares of rapeseed was planted specifically for biodiesel use in 2005 (Worldwatch 2006). Rapeseed has an energy content of 27.80 MJ/kg dry mass. This study will look at intensive production in Switzerland (3,155 kg/ha). As regards water use impact and resilience to environmental changes we also focused on rape seed production in Poland with yields of 2,673 kg/ha and Ukraine, 3,415 kg/ha. Figure 44 shows the SPA results for intensive rape seed production in Switzerland.

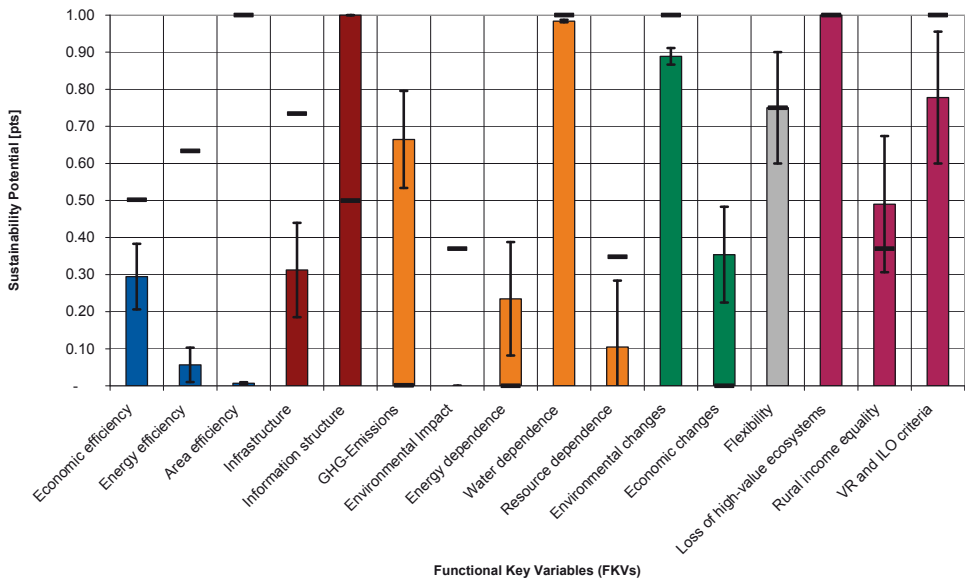


Figure 44: Normalized SPA results for rape seed, CH. The black line shows the normalized results for crude oil production NO (source: own depiction).

Rape seed production in Switzerland shows a low SP for most indicators assessed. In general, the prime reason for this is the relatively low yield resulting from an intensive production. This is reflected in the SP of economic, energy and area efficiency but also energy

and resource dependence, resilience to economic changes and last but not least environmental impacts. The major environmental impacts of rape seed from Switzerland come from fossil energy (coal, crude oil), minerals (iron) and nitrogen from air (for nitrogen containing fertilisers). Rapeseed is among the most flexible at the feed stock level with products in three end-use categories: food, fuel and agriculture. For Switzerland the potential blue water required is neglectable. However, when rape seed is cultivated in other regions such like Ukraine the SP of potential water dependence would decrease significantly (see 5.2). The SP for resilience to environmental changes is high since rape seed could only be affected by pests when climate changes significantly. Rape seed shows high infrastructure requirements and thus achieves low SP. The main influential factors behind this result are the high pest control needs and the high nutrient management and harvesting demands. For information structure, however, rape seed exhibits high sustainability potential since it is used in Europe for about 500 years and thus covering a big time of experience in the field.

4.1.1.4 Oil palm, Indonesia

Oil palm is a tropical palm tree belonging to the Arecaceae family of the *Elaeis* genus with two species: *Elaeis guineensis* known as the African oil palm native to West Africa, and *Elaeis oleifera* the American oil palm, originating from Central and South America. Oil palm has a variety of uses including edible vegetable oil, soap, and biodiesel.

Oil palm grows in tropical regions because it requires nutrient rich land and is not frost or drought resistant. Optimal temperatures are between 25–35 °C and water requirements are in the range of 1500–2500 mm y⁻¹. Oil palm produces fruits in compact bunches whose weight varies between 10–40 kg. The palm fruit takes five to six months to mature from pollination. Oil is extracted from both the pulp and kernel of the fruit. Being a perennial tree, oil palm has a lifespan of about 50 years, but after 20–30 years it becomes difficult to harvest because of its height, and usually at this stage plantations are cleared and replanted (Fedepalma).

The demand for palm biodiesel is expected to increase rapidly, particularly in Europe (Worldwatch 2006). The two largest producers of oil palm are Malaysia and Indonesia with 80 percent of the world's total production with each country producing approximately 15.000 million tonnes (USDA, 2005). However, since 2007, Indonesia has emerged as the largest producer of palm oil producing roughly 50 percent of the world's volume. This study will look at average production in Indonesia (Sumatra and West Kalimantan) with yields of 17,390 kg/ha and an energy content of 16 MJ/kg of feedstock.

The production of oil palm in Indonesia scores the highest SP with regard to economic efficiency and its resilience to environmental and economic changes. It is also among the most flexible feedstocks with possible products in three end-use categories (food, fuel and industry) and less dependent on non-renewable energy. Oil palm scores a high SP for resilience to environmental changes given that it shows a decreased pest tolerance when significant climatic changes occur.

The SP for area efficiency is low due to chosen normalization range (480 MJ net energy/m²a equates an SD potential of one). Oil palm show no SP for potential water dependence since it requires more than 1 liter of blue water per MJ produced. Due to its cultivation in Indonesia/Malaysia both SP for rural income equality and violation risk and ILO criteria are low.

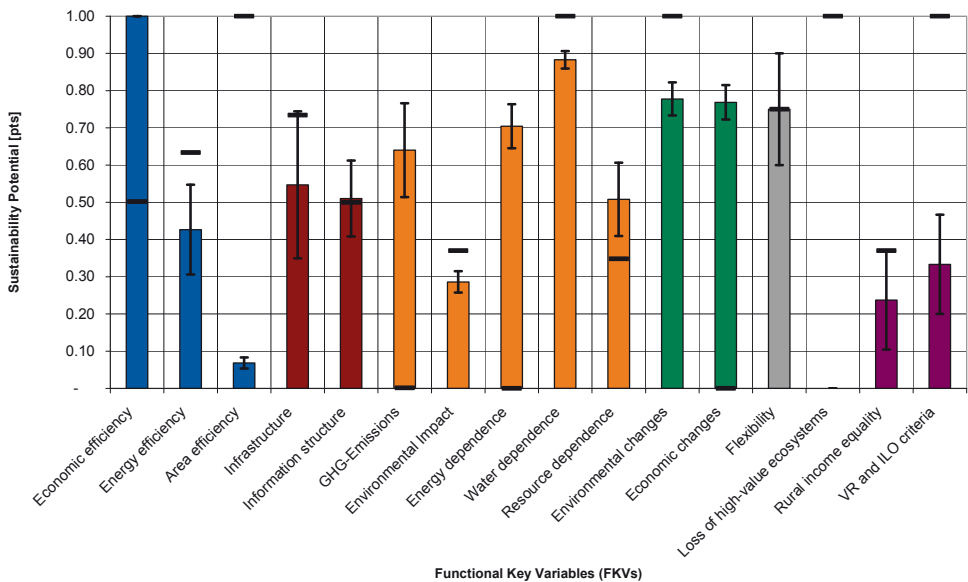


Figure 45: Normalized SPA results for Palm fruits, at farm. The black line shows the normalized results for crude oil production NO (source: own depiction).

Similarly to sugarcane from Brazil, oil palm from Indonesia comes along with moderate infrastructure requirements. This is reflected by an average sustainability potential. Here the result is mainly influenced by high requirements for pest control measures and water management. Relating to information structure, oil palm's sustainability potential is average because it has only been introduced to Indonesia 161 years ago (Santosa 2008). As a result, in the overall comparison of experience with feedstock, oil palm receives a medium value.

4.1.1.5 Direct wood fuel, CH

Direct wood fuel includes all wood in the rough (from trunks, and branches of trees) directly or indirectly extracted from the forest, used for purposes such as cooking, heating and power production. In general, the direct wood removals in all sectors has increased within

the last ten years with regard to both globally (by 9%) and in Switzerland (by 15%) (FAOSTAT 2009). The total share of direct wood fuel at the total roundwood usage in Switzerland has increased from 21% (or 1 mio. m³) in 2000 to 40% (or 2.2 mio m³) in 2007. This amount accounts for approx. 56% of the total energy wood used in Switzerland in 2007.

Currently, direct wood fuel is primarily used for heat production in the industry and the production of heat and electricity in cogeneration plants. Given the overall sustainable potential of direct wood fuel of 3.1 mio m³ estimated for Switzerland an additional potential of almost 1 mio m³ can be expected within the coming years (Pauli 2009). Unaffiliated, this amount could be used for the production of second generation biofuels such like SNG, BTL and ethanol.

This study looks at direct wood fuel by means of all requirements related to the production of 1 MJ 'wood chips mixed, at forest road' with a moisture content of 55%.

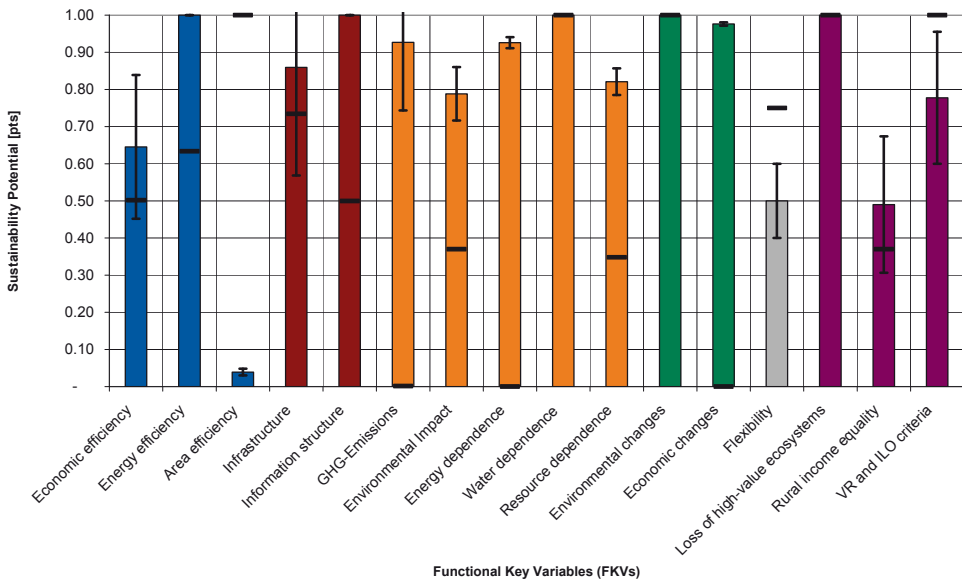


Figure 46: Normalized SPA results for direct wood fuel. The black line shows the normalized results for crude oil production NO (source: own depiction).

Compared with the interventions related to agro-biofuel production, the expenditure for the production of wood chips is lower. This is reflected in the high SP of energy efficiency, GHG emissions, environmental impact, energy dependence, water requirement, resource dependence, resilience to environmental changes and economic changes. Direct wood fuel is

moderately flexible at the feedstock level with products in two end-use categories: fuel, industry. As explained prior, the low SP for area efficiency is related to the range of normalization. However, a further reason is grounded in the fact that the area requirement per kg wood is not related to the possible wood yield per hectare but calculated on the basis of the totally harvested forest wood in relation to the total forest area in Switzerland. This means the area requirement per kg wood is overestimated meaning the SP potential of wood as regards area efficiency is underestimated.

Direct wood fuel from unused forest growth has relatively low infrastructure requirements. This is reflected by a high SP which is mainly due to low infrastructure requirements during the tillage, nutrient and water management and storage process steps. On the information structure level the highest sustainability potential is reached. Wood has been used in one way or another for thousands of years and thus great experience is available.

4.1.1.6 Indirect wood fuel, CH

Indirect wood fuel refers to solid biofuels produced as coproducts from wood processing activities such like sawmills. Examples are pellets and wood chips.

Indirect wood fuel is a subcategory of industrial residual wood. According to (Pauli 2009), the total production of industrial residual wood in Switzerland in 2003 was approx. 1 mio m³ in 2008. The most dominating producer of industrial residual wood is the sawmilling sector with a total share of approx. 95% (Werner, Althaus et al. 2003). Currently, most of the industrial residual wood is used as indirect wood fuel (approx. 92%) in central and local combustion plants⁸, whereas 8% is used as a raw material in the particle board industry.

The additional potential of industrial residual wood is estimated at 0.2 mio m³ (Pauli 2009). Unaffiliated, this amount could be used for the production of second generation biofuels such like SNG, BTL and ethanol.

This study will look at indirect wood fuel by means of all requirements related to the production of 1 MJ 'wood chips mixed, from industry' with a moisture content of 29%. The detailed properties of indirect fuel wood are listed in the annex.

⁸ Most sawmills burn the occurring industrial residual wood locally in order to dry the incoming wood before processing (Wirth, 2009).

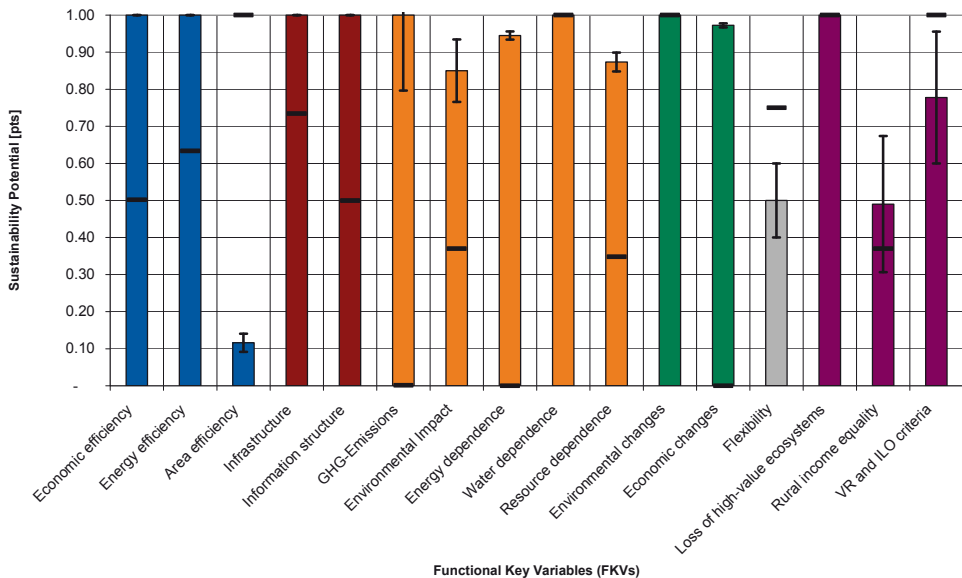


Figure 47: Normalized SPA results for indirect wood fuel. The black line shows the normalized results for crude oil production NO

In general, indirect wood fuel shows the same patterns than direct wood fuel, i.e. most of the indicators show a high SP. The main reason for this is the co-product attribute related to indirect wood fuel meaning that most of the interventions related to the provision and processing of wood are allocated to other products such like sawn wood. Industrial residual wood is moderately flexible at the feed stock level with products in two end-use categories: fuel, industry. On the information structure level the highest sustainability potential is reached. Wood has been used in one way or another for thousands of years and thus great experience is available.

4.1.1.7 Recovered wood fuel, CH

Recovered wood fuel addresses wood used directly or indirectly as fuel, derived from socio-economic activities outside the forest sector, e.g. waste wood from buildings. According to (Pauli 2009), approx. 0.65 mio tons of recovered wood fuel is currently used in Switzerland. Approx. 0.1 mio tons are used in industrial furnances and approx. 0.20 are used in KVAs. In the past, a great amount of waste wood has been exported to Italy (approx. 0.25 mio tons) or illegally burned (approx. 0.13 mio tons). However, this amount is decreasing given the revision of the VeVa⁹ and new channels of domestic distribution.

All in all, an overall use of approx. 1.3 mio m³ recovered wood fuel is estimated for Switzerland. In this regard it can be expected, that the domestic use of recovered wood fuel can be doubled in the future.

⁹ Verordnung über den Verkehr mit Abfällen

This study will look at indirect wood fuel by means of all requirements related to the production of 1 MJ 'waste wood chips mixed, from industry' with a moisture content of 29%.

The provision of waste wood only includes the transport of waste urban and demolition wood to the chopping facility and the chopping of the wood into chips. Thus the overall patterns of waste wood show a high SP as regards most of the indicators assessed. However, waste wood is one of the least flexible at the feed stock level with products in only one end-use category: fuel. Recovered wood fuel from waste wood has very low infrastructure requirements. This is reflected by the highest possible SP which is mainly due to minimal infrastructure requirements.

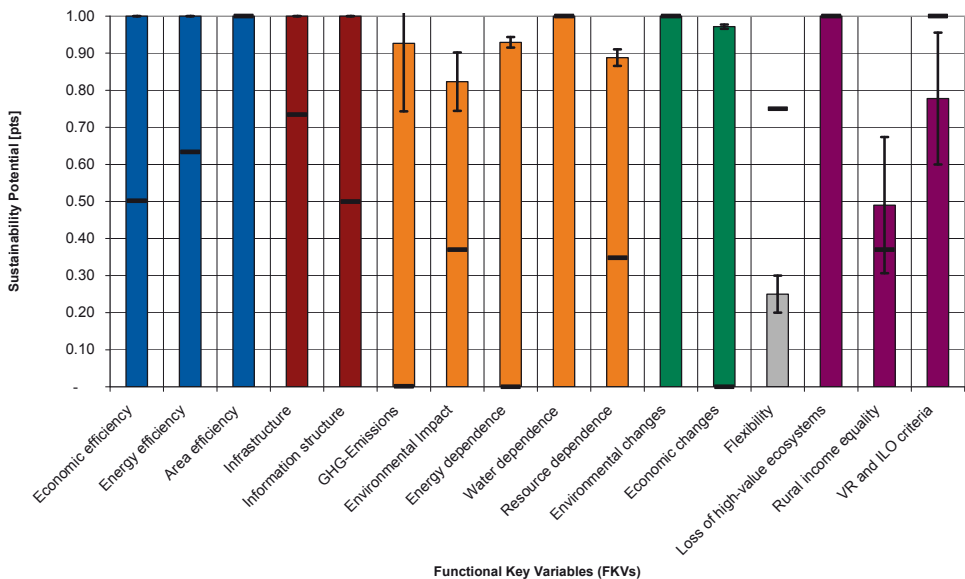


Figure 48: Normalized SPA results for recovered wood fuel. The black line shows the normalized results for crude oil production NO (source: own depiction).

4.1.1.8 Biowaste, CH

In this study, biowaste includes all types of waste, typically originating from plant sources, which may be broken down by other living organisms. In this regards, biowaste can be found in municipal solid waste as green waste, food waste and paper waste.

Currently, approx. 73% of the available biowaste in Switzerland is used energetically, whereas the rest is composted. The primary energetic use of biowaste is in KVAs (89%) and only 11% is used as a feedstock for fermentation. This study will look at biowaste as a waste material, i.e. only the interventions related to the transport of biowaste are accounted for. The life cycle inventory (LCI) of ecoinvent 'biowaste, at collection point' was used (Jungbluth, Faist et al. 2007) (Figure 49).

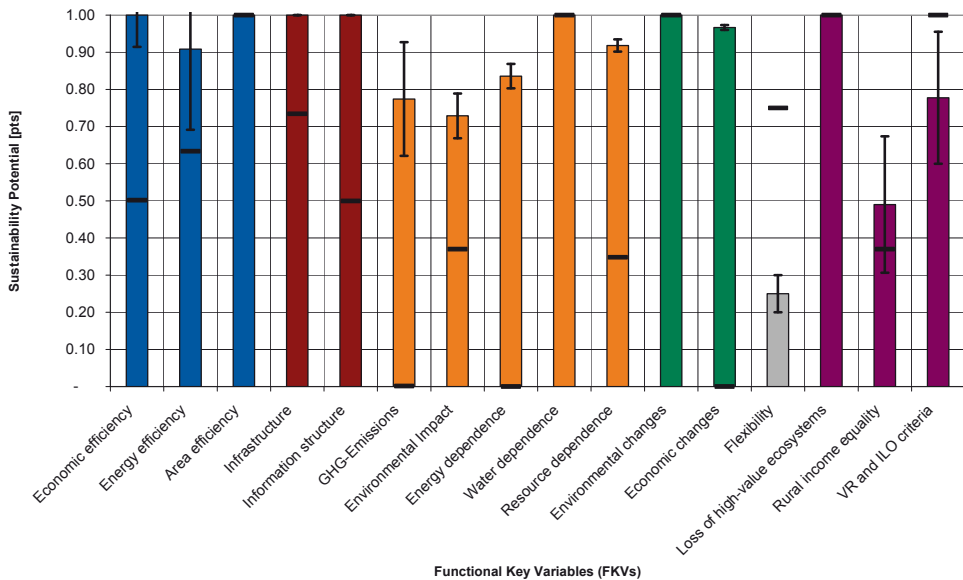


Figure 49: Normalized SPA results for Biowaste, CH. The black line shows the normalized results for crude oil production NO (source: own depiction).

Due to the waste attribute, biowaste shows a high SP for most of the indicators analysed. SP for GHG emission and environmental impacts is reduced given the higher uptake of biogenic carbon of other crops. Biowaste is one of the least flexible at the feed stock level with products in only one end-use category: fuel.

4.1.1.9 Manure, CH

In this study, manure includes liquid and solid manure. According to Oetli (Oetli, Blum et al. 2005), manure has the highest future potential for energetic use in Switzerland given the current energetic use is estimated only to approx. 0.1 PJ, whereas the potential use under ecological restrictions is estimated to approx. 21 PJ.

The cultivation type being explored in this study looks at manure as a co-product of cattle farming. Thus, the interventions related to manure production are limited to its provision. Figure 49 shows the normalized SPA results for manure.

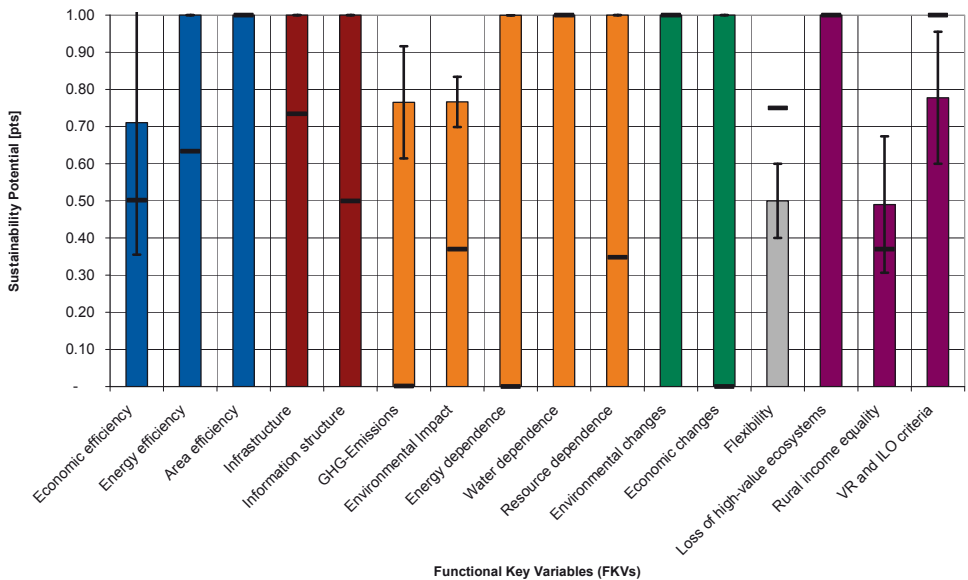


Figure 50: SPA results for manure. The black line shows the normalized results for crude oil production NO (source: own depiction).

Manure has minimal infrastructure requirements when compared to the other feedstocks. This is reflected by the highest possible SP which is mainly due to generally low to minimal infrastructure requirements during all relevant process steps. As regards the initiation and transportation infrastructure requirements, manure performs even better than biowaste.

Manure is moderately flexible at the feed stock level with products in two end-use categories: fuel, industry. However, due to the waste attribute, manure shows a high SP for most of the indicators analysed. SP for GHG emission and environmental impacts is reduced given the relatively low uptake of biogenic carbon, i.e. the uptake of CO₂ is not as high as for other feedstocks.

4.1.1.10 Straw, CH

Approx. 580,000 t (approx. 8.5 PJ) was harvest in Switzerland in 2006. Currently, straw is exclusively used as litter in the animal husbandry. It is only used indirectly as a feedstock for biofuel production when it comes to the digestion of manure. However, in this study we focus on straw as a direct feedstock for BTL production. Thus, the provision of straw is assessed separately. Given that merely 50% of the straw is harvested, the direct use of straw as a feedstock for biofuel production might offer additional potentials in the near future.

In this study we look at the interventions related to the average straw production in Switzerland with an average yield of 2,580 kg/ha per year.

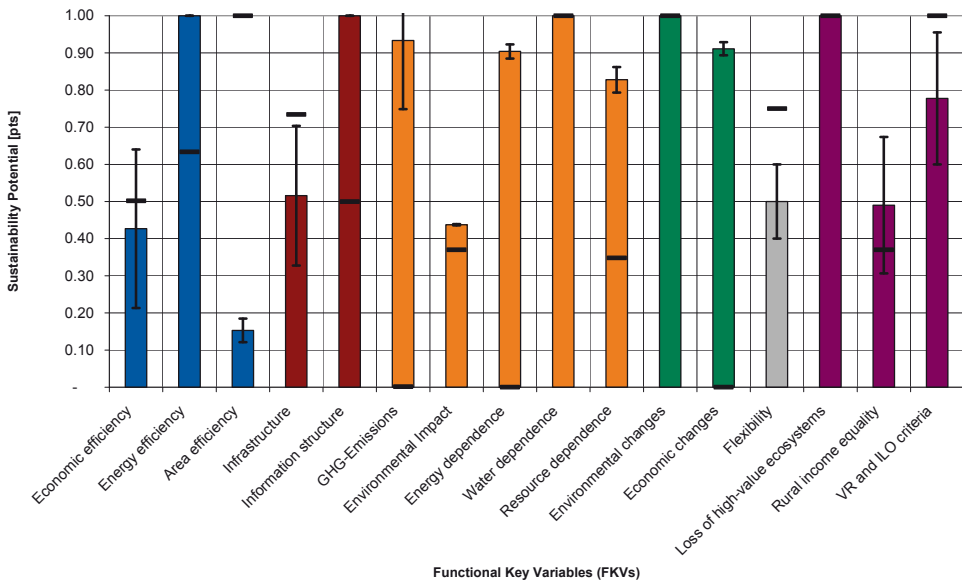


Figure 51: SPA results for straw. The black line shows the normalized results for crude oil production NO (source: own depiction).

Most of the indicators show a high SP for straw. In general, on the basis of market prices approx. 90% of the interventions related to cereal production are allocated to the resulting seed, whereas straw is merely attributed with 10% of the interventions. Due to the market price of approx. CHF 250/ton, the SP for economic efficiency is low in comparison to other feedstocks. Energy efficiency is high since only minor non-renewable energy interventions are allocated to straw. Straw on the other hand has moderate infrastructure requirements given the harvest infrastructure required. The SP for area efficiency is low due to benchmark of PV-systems in Switzerland. However, straw scores higher area efficiencies than most other agricultural feedstocks. The low SP for environmental impacts is caused by emissions of heavy metals which are partly allocated to straw. Straw is moderately flexible at the feed stock level with products in two end-use categories: fuel, agriculture.

4.1.1.11 Miscanthus, US

Miscanthus giganteus also known as giant miscanthus is one of the 15 species of perennial grasses of the genus *Miscanthus*, native to subtropical and tropical regions of Africa and southern Asia. It is a sterile hybrid between *M. sinensis* and *M. sacchariflorus* and has been trialed in Europe as a biofuel since the early 1980s because of its high cellulose content (Lewandowski et al. 2000).

Miscanthus is highly persistent; once planted it requires 2–3 years to reach full production potential and has an estimated stand life of about 20–25 years (Lewandowski et al. 2003). It is a perennial warm-season (C4) grass, with a growing season in temperate climates that begins approximately in late April and goes dormant following the first frost, usually in October. The normal production cycle of miscanthus is a single harvest late in the fall or early spring before new shoots emerge. Miscanthus being a C4 plant has high photosynthetic levels even at relatively cool temperatures. Other advantages include high yields, rapid growth, a low demand for nutrient inputs, and the ability to grow on poor soils. Average annual temperatures and precipitation for the European trials range from 7.5 to 17.5 °C and 500 to 1000 mm y⁻¹ (Lewandowski et al. 2000). Although water use efficiency is high, the crop may nevertheless require substantial amounts of water for maximal growth, because of its high productivity (Walsh and McCarthy 1998).

The BP's Energy Biosciences Institute at the University of California, Berkeley has started a US\$ 500 million centre in Illinois to study different varieties of miscanthus (Kintisch, 2008). Although the feedstock is not produced commercially yet it is expected to enter the market in 2015. This study will look at extensive cultivation in Switzerland with an energy content of 15 MJ/Kg of feedstock and average yields of 15,000 kg/ha per year. Figure 52 shows the normalized SPA results for miscanthus.

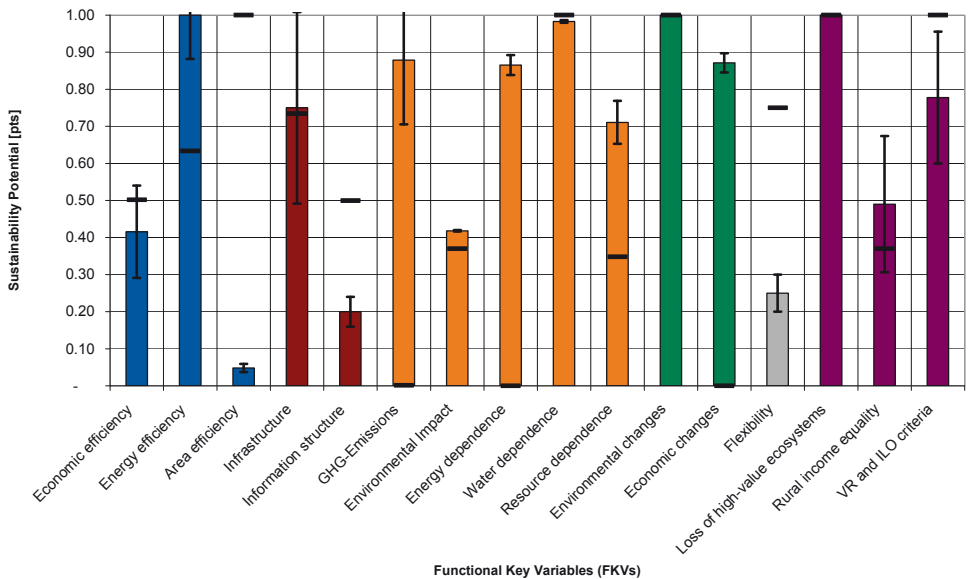


Figure 52: Normalized SPA results for miscanthus. The black line shows the normalized results for crude oil production NO (source: own depiction).

Miscanthus shows a broad range of the results for SP. As regards energy efficiency, GHG emissions, energy dependence, water dependence, resource dependence and resilience to environmental and economic changes miscanthus scores a high SP. In general, the interventions related to its cultivation are diminished due to the high yield. On the other side, miscanthus is one of the least flexible at the feed stock level with products in only one end-use category: fuel. It shows also a low SP for area efficiency and information structure with the latter indicating a low experience with the feedstock since there it was first cultivated in Europe in the 1930s (Lewandowski, Clifton-Brown et al. 2000). Miscanthus grown in Switzerland does not require irrigation water and has no impact whereas miscanthus grown in the US would have some water dependence. Miscanthus has a moderate infrastructure requirement during tillage, planting and pest control processes.

4.1.1.12 Jatropha, IN

Jatropha Curcas L. also known as physic nut, is a drought resistant deciduous tree belonging to the genus Euphorbiaceae. This species is native to Central America but is now abundantly found in India, Africa and Asia. The non-edible oil from jatropha can be used to make candles, soap and biodiesel. Once the seeds have been pressed, the remaining cake can also be used as fertilizer, feed in digesters or to produce biogas for cooking.

In its natural distribution jatropha grows in semi-arid and arid conditions and in tropical humid areas. *Jatropha* has a productive lifespan of as much as 30 years and stands reach maturity and full production 3–4 years after planting (Worldwatch Institute, 2006). *Jatropha* is an attractive energy crop because it can grow on marginal soils, has low water and nutrient requirements, and is drought and pest resistant. Moreover, under semi arid conditions jatropha can potentially reclaim marginal soils, because of its root system, although oil production is not at a commercially viable level (Jongschaap et al. 2007). *Jatropha* seeds have an average oil content of 34.4 percent (Jongschaap et al. 2007). At least 3 to 4 months are required to secure crop growth, flowering and ripening of seeds. Temperatures in the range of 20–28 °C favour plant growth and development. Optimal precipitation for production of fruits and seeds is between 500–600 mm y⁻¹ although the tree can survive with as little as 200–300 mm y⁻¹ (Daey Ouwens et al. 2007).

Jatropha has been identified in India as one of the most promising feedstock for large-scale biodiesel production where nearly 64 million hectares of land is classified as wasteland or uncultivated land (Worldwatch Institute, 2006). The cultivation type being explored in this study is intensive and extensive production in the regions of Andhra Pradesh, Rajasthan and Bihar. Average yields are 4,935 kg/ha for intensive and 857 kg/ha for extensive production, with an energy content of 24 MJ/kg of feedstock. Figure 53 shows the normalized SPA results for jatropha extensive (first bar) and intensive (second bar) production.

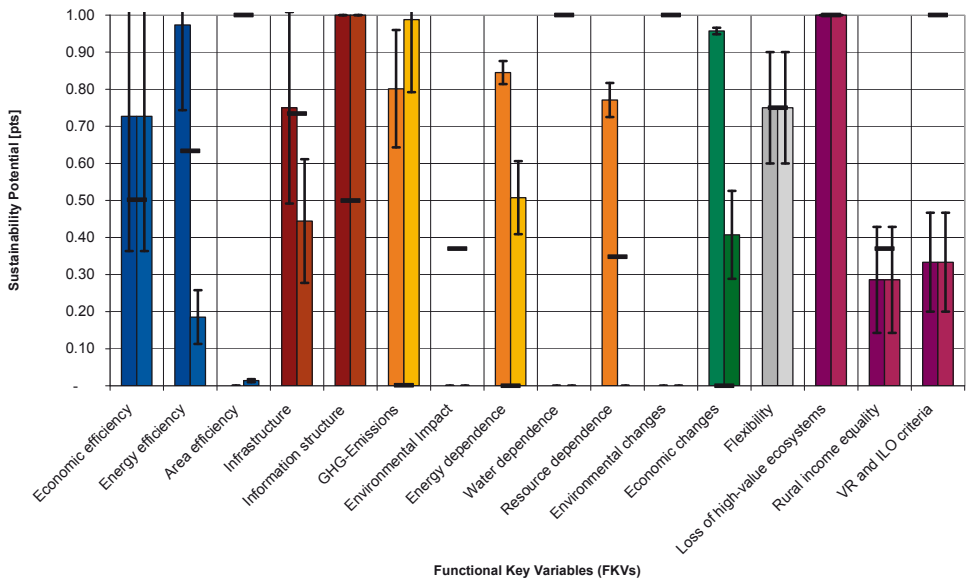


Figure 53: Normalized SPA results for jatropha extensive (left bar) and intensive (right bar). The black line shows the normalized results for crude oil production NO (source: own depiction).

Both Jatropha systems show a high SP as regards information structure and a moderate SP for infrastructure requirement. Concerning infrastructure this result from minimal tillage, pest control and nutrient management requirements. The high SP for information structure is explained with 500 years of cultivation experience in Asia, this number representing the upper benchmark of the normalization range.

Otherwise, the SP is zero for environmental impacts, water dependence and resilience to environmental changes. The results for environmental impacts are primarily founded in the emissions of nitrate and heavy metals which are caused by the application of fertilizers and pesticides. Jatropha requires substantial amounts of irrigation water which could have an impact if there is competition with other users. The SP for resilience to environmental changes reveals the sensitivity of jatropha against changes in temperature and precipitation. A rise in temperature will increase irrigation requirements if precipitation patterns remain the same and might hinder optimal crop development. Jatropha is among the most flexible at the feed stock level with products in three end-use categories: fuel, industry and agriculture.

The difference between extensive and intensive production become apparent with regard to energy and area efficiency, GHG emission, energy dependence, resource dependence and resilience to economic changes. The results show the conflict of aim between inherent to different production methods. For example, the SP for energy efficiency is higher for extensive whereas area efficiency is higher for intensive production.

4.1.1.13 Low-Input High Diversity (LIHD) Grassland, US

LIHD Grassland stands for low input high diversity perennial herbaceous grassland species. The proposed advantages of using LIHD grassland for biofuels are the low-energy input required for production, the use of all aboveground biomass for energy rather than just the seed, and the fact that LIHD grassland can grow on marginal land and does not compete with food production (Tilman, Hill et al. 2006).

According to Tilman (2006), LIHD grassland provides more usable energy, larger greenhouse gas reductions and less pollution from fertilizer use than corn grain ethanol or soybean biodiesel from degraded infertile land. These results are based on experimental plots planted in 1994 and sampled annually until 2005 for above ground biomass. However, according to Russelle (2007), the results of the study are not substantiated by experimental protocols. To date, experiments with cellulosic crop based fuels have only been conducted on small scale plots and further studies are required on a larger scale to verify the results. Moreover, results from a study on Switchgrass show that yields from farms using fertilizer and other inputs were much higher (as much as six times) compared to yields from farms using no inputs, leading the authors to conclude that low input systems are not as economically viable (Schmer, Vogel et al. 2008).

Since the results of to Tilman (2006) are subject to a lot of controversy and have not yet been verified this study will substitute yields and energy content of LIHD grassland with organic grass cultivation in Switzerland. Organic grass has an energy content of 17.9 MJ/kg and average production gives yields of 3,600 kg/ha. Using these values may lead us to underestimate the full potential of LIHD grassland. However we believe that organic grass is the closest substitute since its cultivation requires minimal inputs as well. Figure 54 shows the normalized SPA results for LIHD grassland.

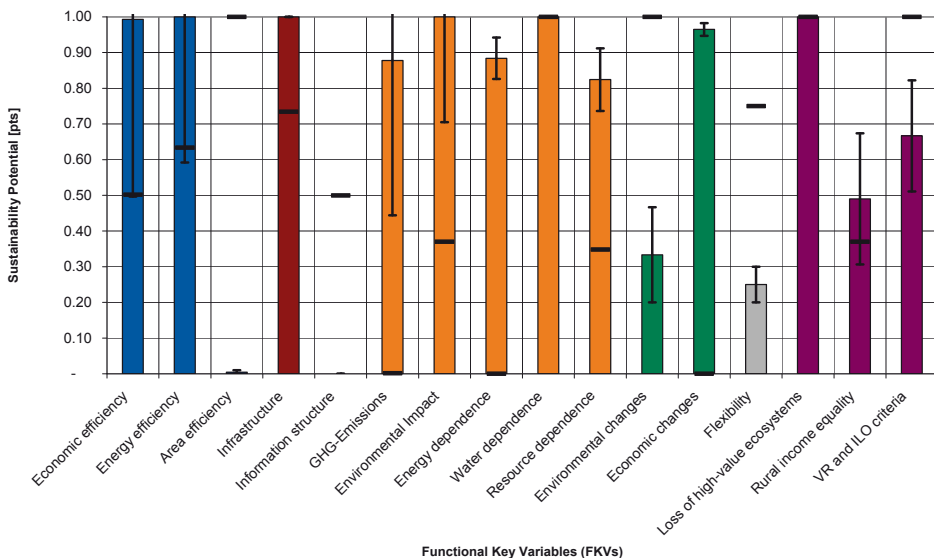


Figure 54: Normalized SPA results for LIHD-grassland, US. The black line shows the normalized results for crude oil production NO (source: own depiction).

In general, most of the results for LIHD grass show a high SP. This is founded in the minimal interventions required to cultivate such grass. In this regard, LIHD grass only poses low to minimal requisites upon tillage, planting, pest control, and nutrient and water management and thus scores high SP for infrastructure requirements. Economic efficiency was determined using the price of straw. However, due to the low yield per hectare and the fact that not much information is available about this crop area efficiency and information structure is rated zero. However, if the numbers of Tillman et al. (2006) prove to be correct, the yield of LIHD grasslands is underestimated in this study meaning that the SP for area efficiency could be higher than outlined. If temperatures rise it is likely that LIHD grassland will require irrigation water to meet crop water requirements. Furthermore, LIHD are one of the least flexible at the feed stock level with products in only one end-use category: fuel.

4.1.1.14 Halophytes (*Kosteletzkya virginica*), CN

A halophyte is a salt tolerant plant, tree or shrub that can grow in seawater or brackish waters in saline semi-deserts, mangrove swamps, marshes and sloughs, and seashores. Relatively few plant species are halophytes – perhaps only 2% of all plant species (Glenn, Brown et al. 1999).

If we consider that roughly 43 percent of the Earth's landmass is arid or semi-arid, and that 97 percent of the earth's water is seawater, the potential for halophyte production becomes very large (Hendricks and Bushnell 2008). Halophytes do not compete with food crops for limited freshwater supplies and can be cultivated in areas where conventional crops cannot grow, for instance on the coast. Moreover, unsuitable land for agriculture is on the rise particularly in arid and semiarid climatic zones as a result of soil salinization and desertification (Rozema and Flowers 2008). A further advantage of saline agriculture is that halophyte cultivations can be combined with aquaculture since it appears that the effluent from shrimp ponds increases the growth rate of halophytes (Brown, Glenn et al. 1999). It has also been suggested that halophytes can grow at comparable rates to conventional forage crops with comparatively greater biomass (Glenn, Brown et al. 1999; Niazi, Rozema et al. 2000).

For example, *Salicornia bigelovii*, a potential oil-seed crop which contains high levels of unsaturated oil, approximately 30 percent (Glenn, Brown et al. 1999), produces about 18 tons/ha of biomass and 2 tons/ha of seeds over a 200-day growing cycle (Rozema and Flowers 2008). This study will look at extensive production of *K. virginica* in China. *K. virginica* produces a seed yield of 1 ton/ha with an oil content of 20 percent. It is a non invasive perennial crop which once planted could be harvested for over 10 years (Ruan, Li et al. 2008). Figure 55 shows the normalized SPA results for halophytes.

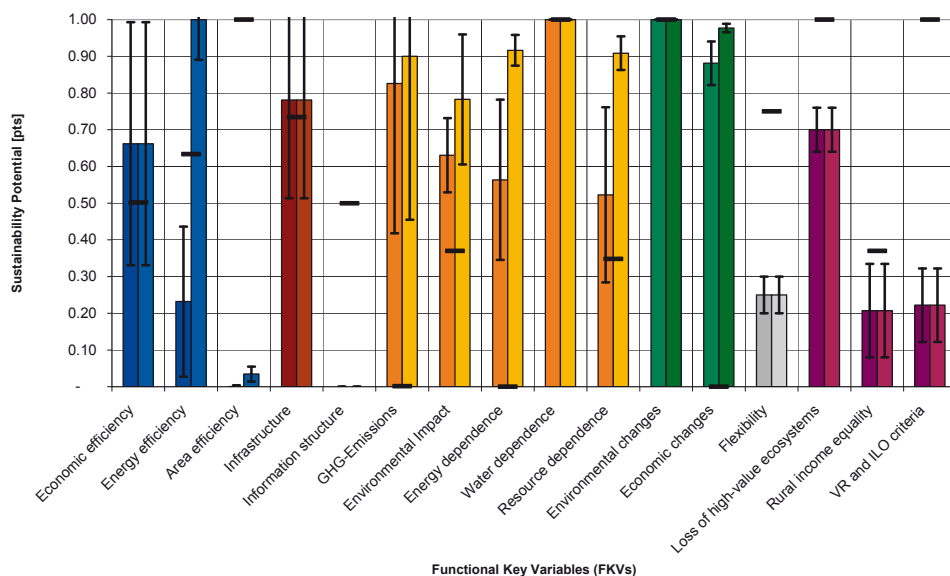


Figure 55: Normalized SPA results for halophytes. The respective bar on the right hand side shows the results if the yield quadruples. The black line shows the normalized results for crude oil production NO (source: own depiction).

Due to the low input attribute, the cultivation of halophytes shows a high SP for most FKVs assessed. Halophytes are attributed low infrastructure requirements. As a result they show a high SP. The main reason why they do not perform better in the evaluation is that moderate initiation and harvest infrastructure demands are aligned with halophytes feedstock production. Analogously to LIHD grass, there is not much information available yet about halophytes and that is why they are rated zero as regards SP in information structure.

The comparison to the high yield system shows the importance of the yield for the energy efficiency, the energy dependence and the resource dependence. For example, dependence of non-renewable resources of Halophytes amounts to 19 g abiotic Total Material Requirement (TMR_{abiotic}) per MJ. Dependence of non-renewable resources of high yielding Halophytes amounts to 4 g abiotic Total Material Requirement (TMR_{abiotic}) per MJ. The major contributions to TMR_{abiotic} of Halophytes come from minerals (iron) and fossil energy (oil, coal).

The cultivation of Halophytes might endanger high-value coastal ecotones like mangrove forests or shallow waters that serve as habitats for juvenile fish. Consequently, halophyte cultivation scores low on “loss of high-value ecosystems”.

4.1.1.15 Algae, RER

“Algae” is a generic term that describes macro-algae, or seaweeds as well as micro-algae. Micro-algae are microscopic photosynthetic organisms and can be used in the production of microalgal oil and biofuels (Amin 2009). Due to their simple cellular structure, micro-algae convert the solar energy into biomass in a more efficient way than crop plants (Carlsson, van Beilen et al. 2007).

Algae are commonly used since several decades in different areas like nutrition, pharmaceutical products or aquaculture. Recently algae have drawn much attention because of their potential as biofuels. The key advantage of biofuels based on micro-algae over existing biofuels from crop plants is that they do not compete with food and other agricultural products (Chisti 2008).

The requirements for algae growth are light, water, land, CO₂ and nutrients. Microalgae grow in marine and freshwater environments (Sheehan, Dunahay et al. 1998). The light can be either sunlight or artificial light. However for a large algal biomass cultivation in order to produce biofuels, sunlight is believed to be a more viable solution because otherwise the energy use and the costs will become too important (Chisti 2008; Ugwu, Aoyagi et al. 2008).

The geographical location of production for the algae feedstock is less important, because the cultivation site for algae can be settled anywhere and does not have to be implemented on arable land. The amount of solar radiation is nevertheless decisive for an optimal photosynthesis process. Consequently, algal cultivation facilities have to be constructed in a region with sufficient solar radiation. However the evaporation process can in some culture systems be significant. The design of a cultivation facility is decisive regarding the production of the algal biomass and its induced costs. Nowadays there exist two main types of culture systems, namely open and closed culture systems.

Open culture systems are shallow ponds which allow the culture of algae. There exist several types of open culture systems that can be categorized into shallow big ponds, tanks, circular ponds and raceway ponds (Borowitzka 1999). To ensure the large-scale production needed for biofuels, the only practicable method is the use of raceway ponds (Chisti 2007). Raceway ponds consist of shallow closed loops of recirculation channels in which mixing and circulation of the broth are produced by a paddlewheel (Chisti 2007). During growth, the system must be fed continuously by nutrients and CO₂.

In the most recent studies (Carlsson, van Beilen et al. 2007; Chisti 2007; Ugwu, Aoyagi et al. 2008; Mata, Martins et al. 2009), the open culture systems are reported to be economically favorable because of their low cost of construction and operation as well as their low energy use. The water loss through evaporation can however be significant for open culture systems (FAO 2009). Other recognized issues are diffusion of CO₂ to the atmosphere, contamination and predation (Ugwu, Aoyagi et al. 2008).

Typical yield for open culture systems is between 20–50 t ha⁻¹ y⁻¹ (Carlsson, van Beilen et al. 2007). In this study we assumed an average yield of 30 t/ha and year.

The most common type of closed algae culture systems are photobioreactors (PBR). There exist several types of photobioreactors namely flat-plate PBR, tubular PBR and vertical column PBR (Ugwu, Aoyagi et al. 2008). High photoconversion efficiency is currently reported for the flat-plate PBR (Hu, Guterman et al. 1996; Richmond 2000) and they are therefore suitable for mass culture of algae (Ugwu, Aoyagi et al. 2008).

The main advantage of photobioreactors over open culture systems lies in their inherent closed and protected environment. Mixing conditions and properties of growth as pH, temperature, CO₂ provision and oxygen removal, can be controlled in a better way than in open ponds. However the main disadvantage of closed systems is their high cost because of important capital investments (at present reported as 10 times higher than for open ponds (Carlsson, van Beilen et al. 2007) and high energy use.

Concerning typical yield, higher productivity can be obtained with PBR (50 t ha⁻¹ y⁻¹ (Carlsson, van Beilen et al. 2007).

Values for open ponds were defined using a Simapro modeling procedure with the help of adapted inputs from the unique available life cycle assessment of biodiesel production from microalgae (Lardon, Hlias et al. 2009). Production of algae in raceway ponds in Switzerland and in United States of America was considered. The uncertainties in this modeling step are therefore quite large. No results have been generated for PBV systems given that the data currently available is very limited. Figure 56 shows the normalized SPA results for Algae.

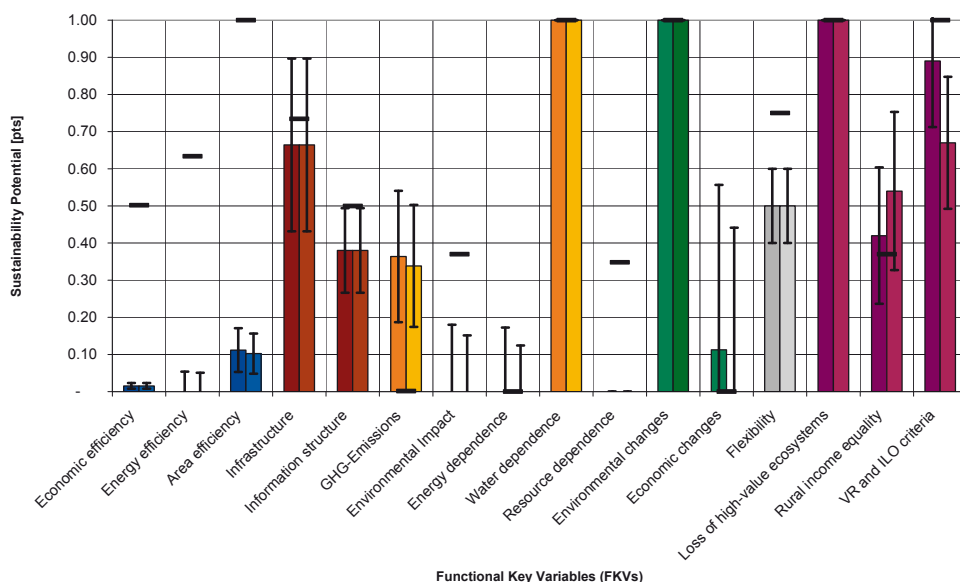


Figure 56: Normalized SPA results for Algae (the respective bar on the right hand side shows the results when Algae is cultivated in the US. The black line shows the normalized results for crude oil production NO (source: own depiction).

Concerning the economic efficiency, the functional return per unit money invested for algae is for the moment relatively low compared to other feedstocks. The value of 0.57 MJ/\$ for the closed culture systems (photobioreactors) comes from an averaged range which was defined with the help of the few sources from literature. Indeed a very optimistic value, assuming an annual biomass production of 10000 t and because of economy of scale (with a price of US\$ 0.47 per kg algae (Chisti 2007), and a pessimistic value (with a price of US\$ 70 per kg algae (Carlsson, van Beilen et al. 2007) were defined as possible range. Here it is observed that the price difference can be significant and even with an optimistic value, the economic efficiency stays quite low. Costs for the algae feedstock production are at present too high, particularly because of large capital investments and significant harvesting costs (up to 20–30% of total costs (Carlsson, van Beilen et al. 2007). More details on cost efficiency of algae biofuels can be found in the spotlight on algae biofuels (Chapter 5.5). Another relevant aspect is the area efficiency criterion. Even if the results for open ponds are considered as sustainable, better results would have been expected because of the often announced high areal yields for algae culture. Nevertheless to ensure a large-scale production of biomass which is needed for microalgal biofuels, the space required for the facility production for open ponds can be quite significant. Concerning photobioreactors, the area needed to install a facility will be smaller than for open ponds but energy for building and during processing is important in comparison with the energy output which is produced.

The results concerning the energy returned on energy invested (EROEI) are not efficient enough in a sustainable point of view (1.73 and 1.83 MJ/MJ for open ponds produced in Switzerland and United States of America respectively). The small difference between the two values comes from a different electricity mix composition for each country. For photobioreactors the EROEI will be at present lower or even lower than 1 because of their high energy consumption for building the facility and mixing the broth. Even if the open ponds use less energy than photobioreactors, the energy invested for the two culture systems is for the moment too important regarding the energy that the feedstock is given. Future perspectives to reduce the energy consumption will be discussed in the spotlight.

Dependence of non-renewable resources of Algae, Germany, amounts to 318 g abiotic Total Material Requirement (TMR_{abiotic}) per MJ, which is the highest TMR_{abiotic} per MJ of all examined feedstocks. The major contributions to TMR_{abiotic} of Algae come from minerals (gravel, calcium) and fossil energy (coal). The high TMR_{abiotic} per MJ is due to low energy yields from algae cultures.

In terms of the considered infrastructure processes algae have moderate to low infrastructure requirements. They do not perform better here because of high water, storage and transportation requirements. This leads to the medium to high SP rating.

As regards information structure, algae have been used for over 100 years for several purposes. Thus, in comparison with other feedstocks, it gets attributed a relatively low SP.

4.1.2 Technologies

4.1.2.1 Refinery

An oil refinery is an industrial process plant where crude oil is processed and refined into more useful petroleum products, such as gasoline, diesel fuel, asphalt base, heating oil, kerosene and liquefied petroleum gas.

Crude oil is separated into fractions by fractional distillation. The fractions at the top of the fractionating column have lower boiling points than the fractions at the bottom (reg. Figure 57). The heavy bottom fractions are often cracked into lighter, more useful products. All of the fractions are processed further in other refining units.

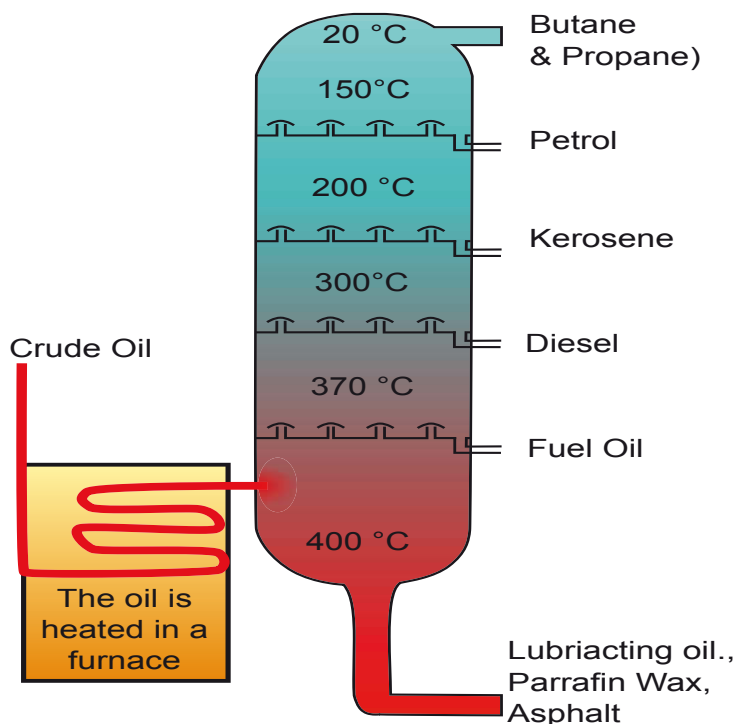


Figure 57: Schematic diagram of a oil refinery (Taken from Wikimedia Commons).

Due to the very large plant size and the multi-output processing, the economic efficiency of petrol refining is high. In contrast, the fossil energy efficiency is low because all processes are driven by fossil energy. As regards infrastructure requirements the petrol refinery has a medium sustainability potential. This outcome refers mainly to the moderate to low general requirements during all the relevant process steps and also to the specifically low storage requirements compared with the other conversion technologies. For the information structure petrol refinery is rated one (i.e. high SP), meaning that among all the conversion technologies regarding experience and patent protection, for petrol refinery most know-how is indicated. GHG-emissions and environmental impacts are medium basically, because due to the large plant scale and the relatively simple process, emissions per liter of petrol are relatively low. The high dependence on fossil energy leads to a low score for energy dependence, while the dependence on other abiotic resources is very low. Of course, the sensitivity towards oil-based economic changes is critical, leading to a low score for this

indicator. The flexibility of an oil refinery with respect to feedstocks is quite high – in theory, co-refining of biogenic feedstocks would be possible.

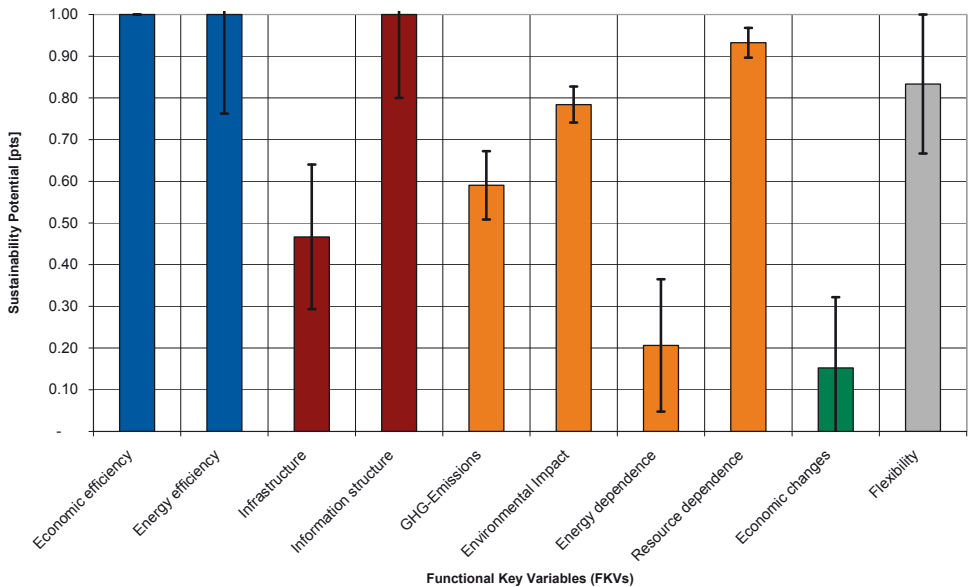


Figure 58: SPA-results on petrol refinery.

4.1.2.2 Alcoholic fermentation (sugar) and distillation

Ethanol production by fermentation is one of the oldest processes known to humankind, and has been employed basically for the elaboration of alcoholic beverages since more than 5,000 years. While pretreatment and juice extraction is differing for the various feedstocks (corn, sugar cane, sugar beets, etc.), the fermentation and distillation steps are widely the same (reg. Figure 59).

In the pretreatment, the feedstock is usually washed to remove impurities like sand and earth. Subsequent juice extraction is crucial for the efficiency of the whole value chain. Various mechanical extraction methods (dry-milling) or chemical extraction methods (wet-milling) adopted to the different feedstocks are in use. The low-sugar fibres can be used for generation of heat for the downstream processes. Fermentation, distillation and rectification are all standard industrial processes that are widely used on the market.

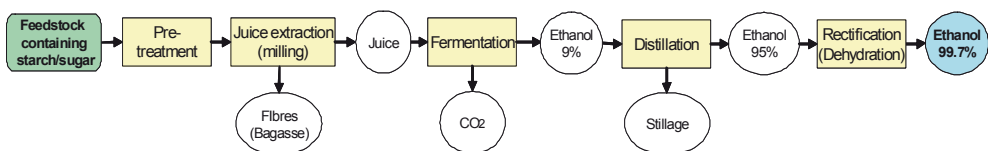


Figure 59: Production of Ethanol.

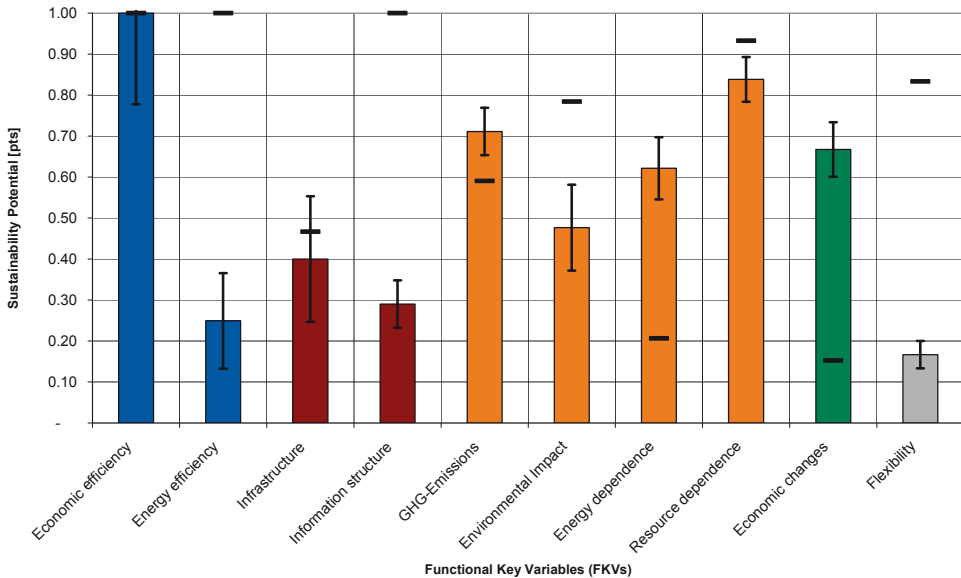


Figure 60: SPA-results: Ethanol fermentation of sugar cane. The black lines show the respective reference value of the petrol refinery for each FKV.

The Brazilian process of Ethanol fermentation of sugar cane has the highest economic efficiency of all biobased processing technologies. Reason for this is the 30 years of know-how and process optimisation, as ethanol refineries have been introduced and heavily subsidized in Brasil already in the 1970s. Because all process heat is generated by the sugar cane bagasse and surplus electricity is fed into the grid, the technology also scores high in terms of fossil energy efficiency. As regards infrastructure requirements, ethanol fermentation has a medium to low sustainability potential. This outcome is primarily caused by the comparatively high requirements for transportation infrastructure. While the experience with the technology is medium when compared among all the conversion technologies, there are not many patents registered concerning this technology. The overall know-how available is thus rated low. GHG-emissions are relatively low, because of the high efficiency and independence of fossil fuels of the plant. Environmental impacts are medium. The high dependency on fossil energy leads to a low score for energy dependence, while the dependency on other abiotic resources is very low. Because a sugar cane ethanol factory can be run widely independent of fossil energy, the resilience to oil-based economic changes is quite high. However, the flexibility of a sugar cane ethanol plant is very low, because the plant is completely optimised for sugar cane feedstock.

4.1.2.3 Oil extraction and esterification

Similar to fermentation, oil extraction is employed since some thousand years mainly to produce oil as a food or drug. While already the crude vegetable oil can be used as a fuel for modified trucks or for stationary applications, the crude oil is usually trans-esterified into

a Methyl-Ester, which is more similar to conventional Diesel and can be mixed up to 15% with Diesel.

Most critical is the efficiency of the oil extraction (reg. Figure 61). Different mechanical extraction methods, chemical extraction methods (solvent extraction, e.g. with hexane) or combined methods are used. Solvent extraction leads to higher yields. However the method is more costly than mechanical extraction.

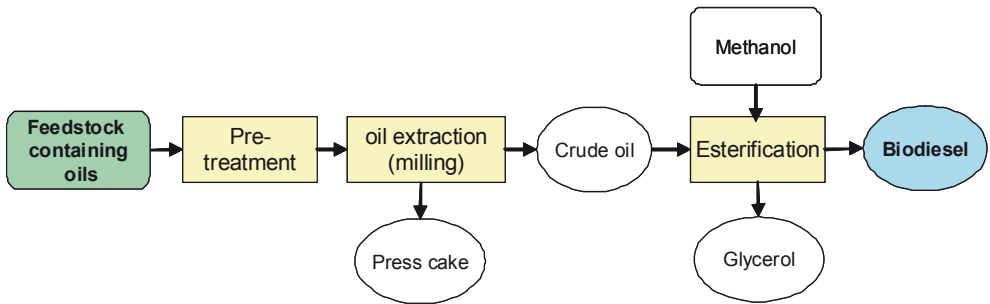


Figure 61: Production of Biodiesel.

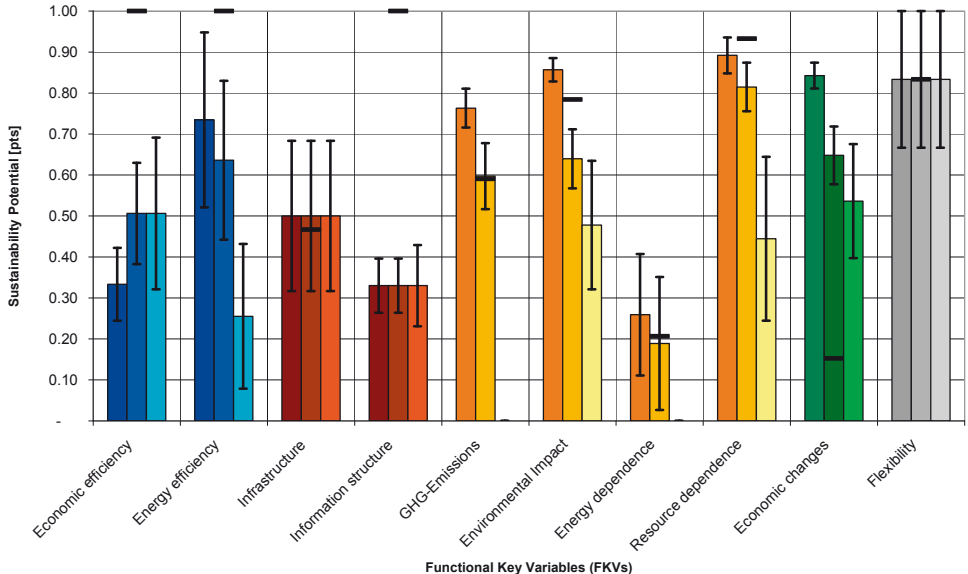


Figure 62: SPA-results from oil extraction and esterification (left: Rape-Biodiesel, Europe; middle: PalmOil-Biodiesel, Malaysia; right: Jatropa-Biodiesel, India). The black lines show the respective reference value of the petrol refinery for each FKV.

The economic efficiency of Biodiesel-production is average, while the fossil energy efficiency is low, in parts because of the need for 5% Methanol for the esterification step. As regards infrastructure requirements, oil extraction and esterification shows an average sustainability potential due to the relatively moderate requirements during all the relevant process steps. Concerning information structure oil extraction and esterification is attributed a low SP. GHG-emissions and environmental impacts are medium but very different for the three production countries, due to different energy mixes. Worst case is India where the electricity mix is highly based on coal. Resilience to economic changes is medium and again dependant on the respective electricity mixes. The flexibility of the whole process is high, as different oil-based feedstocks could be used – only pre-treatment has to be adapted.

4.1.2.4 Fermentation (biogas)

The digestion of biomass to biogas is a standard process that is in use since many years. The cleaning of the raw biogas and the removal of the CO₂ is a more complex process, where different technologies exist. The main challenge for the whole value chain is the reduction of methane losses.

In this project, we considered for the gas upgrade the process of amin washing (so-called BCM-process). The BCM-process leads to very low Methane loss, while consuming only little electricity.

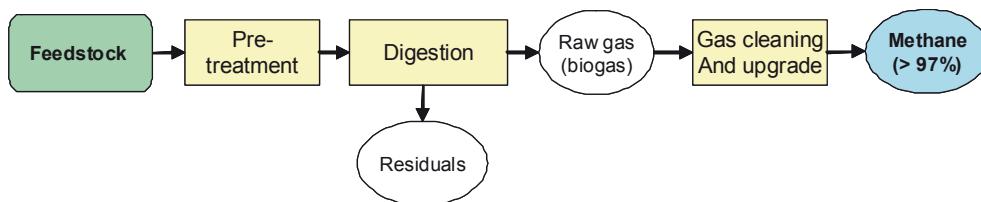


Figure 63: Production of Methane.

Both economic efficiency and energy efficiency of Methane-production is below average. As regards infrastructure requirements, fermentation (biogas) has a relatively high sustainability potential. This outcome is due to the low general requirements during all the relevant process steps, where they are particularly low for processing energy infrastructure requirements. The value for information structure is put together as a mean from the high experience available with the technology and the medium patent protection found. The overall know-how available is thus moderate. GHG-emissions are relatively high for the Biowaste-process due to some methane loss and relative low for the manure-process as an efficient methane capture technology has been used for the methane upgrade. The energy intensity is high, as substantial amounts of energy are needed basically for the upgrading and cleaning of the raw gas. Because the process can be driven using parts of the produced gas for process energy, the resilience to oil-based economic changes is high. The flexibility is average as the process is limited to fermentable feedstocks in adequate concentrations.

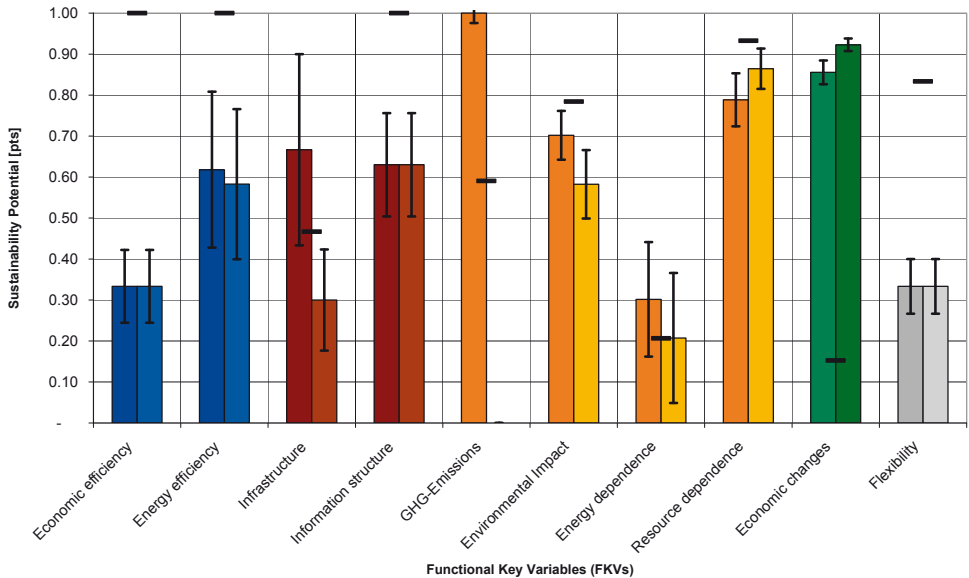


Figure 64: SPA-results for production of methane (left: Biowaste-Methane, Switzerland; right: manure-Methane, Switzerland). The black lines show the respective reference value of the petrol refinery for each FKV.

4.1.2.5 SNG-Production

The production of synthetic natural gas (SNG) consists of two main processes, namely gasification and methanation of the syngas, followed by cleaning and conditioning procedures. The PSI-research on methanation using a 10kW pilot reactor in Güssing (Austria) is considered as state-of-the-art (Felder and Dones 2007).

Gasification is performed using the Fast Internally Circulating Fluidized Bed (FICFB) principle. In the first section of the reactor, biomass is gasified with steam. Unconverted biomass (char) is transported to the second section together with bed material (olivine), where it is combusted completely with air. The heat released thereby is transported with the circulating bed material back to the first section where it keeps up the steam gasification.

Gasification: At a gasification temperature of 850°C and a wood humidity of 15%, the cold gas efficiency is maximum 73%. From the gasification as well as the exothermic methanation part, secondary heat can be used for drying the wood to the desired 15% humidity. Undesired traces of tar, ammonium, and dust are removed from the gas by scrubbers and fed back into the gasifier.

Gas cleaning: Sulphur is absorbed by a ZnO bed to form ZnS. ZnO can be regenerated by a reaction of ZnS with oxygen contained in air. Thereby, SO₂ is formed which can be converted with calcium carbonate into calcium sulphate, which is finally deposited in a sanitary landfill.

Methanation: In the catalytic methanation stage, the C-containing substances are transformed into methane and CO₂. The CH₄ yield rises with increasing pressure and falling temperature.

Membrane separation: Finally, CO₂ is separated from the gas mixture using a membrane separation unit. The final product is 97% Methane.

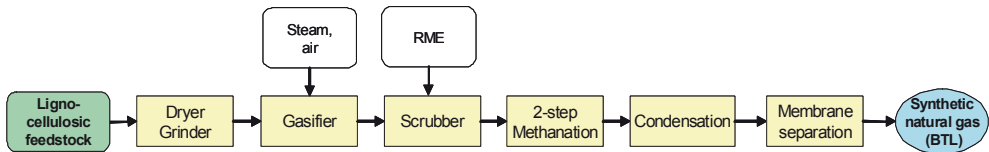


Figure 65: Production of Synthetic Natural Gas (SNG).

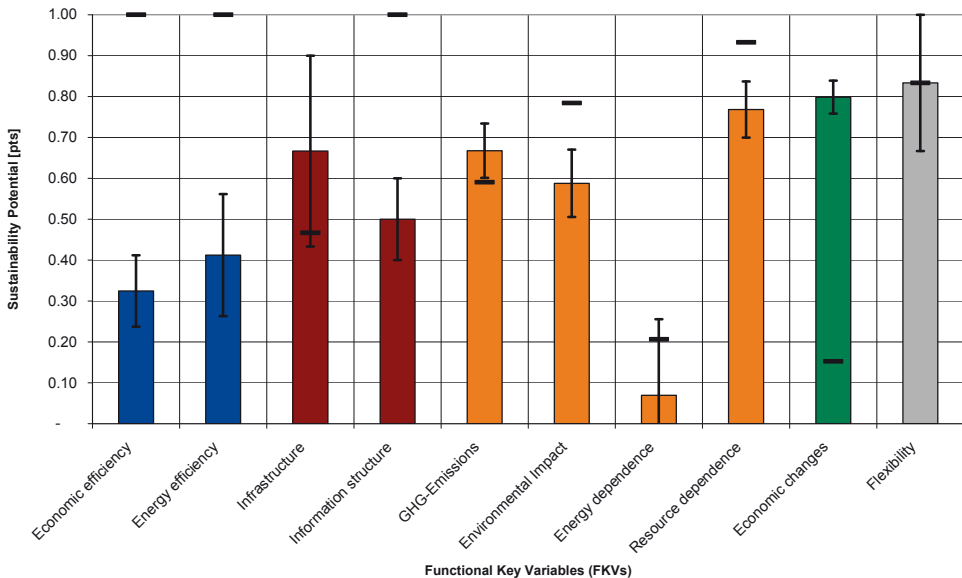


Figure 66: SPA-results for SNG production. The black lines show the respective reference value of the petrol refinery for each FKV.

Both economic efficiency and energy efficiency of SNG-production is below average. As regards infrastructure requirements SNG-production has a relatively high sustainability potential. This outcome is due to the low infrastructure requirements in particular in the construction and the transportation process step. A medium SP is assigned to SNG-production for information structure. While the experience with the technology is rated very high, the patent protection is rated considerably low. This leads to a medium availability of overall know-how. While both, GHG-emissions and environmental impacts are relatively low, the energy intensity is high, due to the relative complex gasification and methanation process. Because the process can be driven using parts of the produced gas for process

energy, the resilience to oil-based economic changes is high. The flexibility will also be high, as the process can be adapted to various cellulosic feedstocks.

4.1.2.6 BTL production

The production of Biomass-to-Liquid fuels (BTL) is largely based on technologies that have already been in use since long time for the processing of fossil fuels (coal-to-liquid, gas-to-liquid) and chemicals. BTL production basically consists of two steps. First a synthetic gas (syngas) is produced out of the biomass followed by gas cleaning and the Fischer-Tropsch process (FT) to create synthetic biofuels ranging from synthetic diesel to synthetic petroleum. The advantage is that FT is an off-the-shelf process, since decades used by SASSOL in South Africa for the production of coal-to-liquid or since 1993 by Shell in Malaysia to produce synthetic fuel from natural gas.

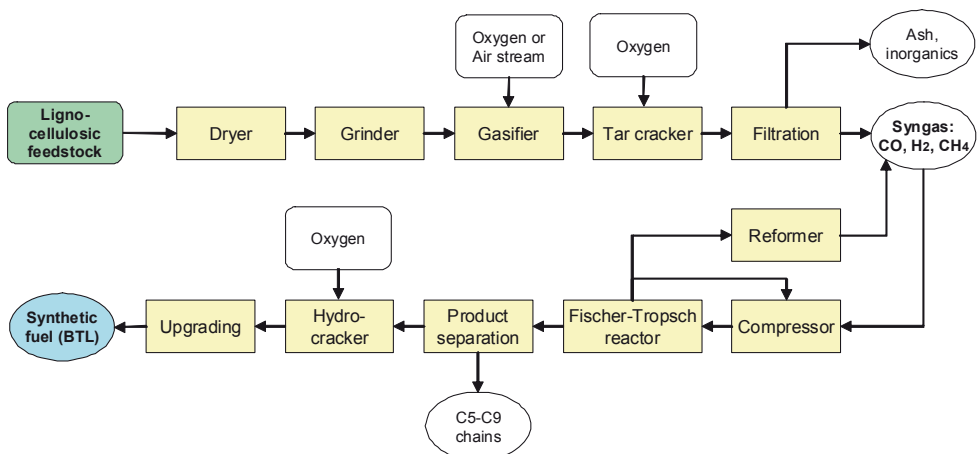


Figure 67: BTL production from ligno-cellulosic feedstock via the thermo-chemical route.

The stages of syngas and BTL production are described in Figure 67.

Biomass drying and grinding: For efficient gasification, the feedstock should contain < 20% moisture with an even particle size. Usually drying has to be applied for ligno-cellulosic feedstock. The challenge is to combine secondary heat with the high drying capacity needed for the large plant scale.

Gasification process: Gasification is achieved by partial combustion at 700°–1500°C in limited oxygen conditions. This generates the syngas that can be used in the FT-process. Contamination of the syngas and building-up of chars is critical, as this could poison the catalysts of the FT-process. Despite of many years of research cost efficiency and reliability are still critical factors. Given the large scale of commercial BTL production, pressurized oxygen-blow direct entrained flow gasifiers appear to be the most probable concept for BTL as they can easily reach several 100 MW of capacity. Various such reactors are under

development by different research institutes. Technically, the most advanced FT-gasifier is probably that of Choren that has a 45 MW_{input} pilot reactor running.

Gas clean-up: Several types of clean-up technologies are under assessment, but tar-cracking remains a major problem in most demonstration plants. Inorganics also have to be removed from the gas stream using cyclone or filter technology.

FT-conversion: The gaseous products are synthesized to various types of fuels by passing over specific catalysts. For large-scale commercial FT synthesis reactors, heat removal and temperature control are the most important design features for optimising product selection and catalyst lifetimes.

Although a number of fairly mature technologies are already available, gasification and FT-process still need development for market penetration. A main challenge for the production of BTL is actually the heterogeneous composition of most biomass feedstocks. The number of inhibitory substances in the syngas and the overall composition of the gas-mix is varying and causing problems with the catalysts in the FT-synthesis. More R&D is needed to ensure long-term reliability on the market scale.

The cost of syngas production can make more than 50% of the total process cost. To be economically viable, large-scale commercial plants in the size of 500-1000MW have to be built. Large-scale plants on the other hand are critical with respect to feedstock supply. The investments in the range of US\$ 500 M have not been done until now.

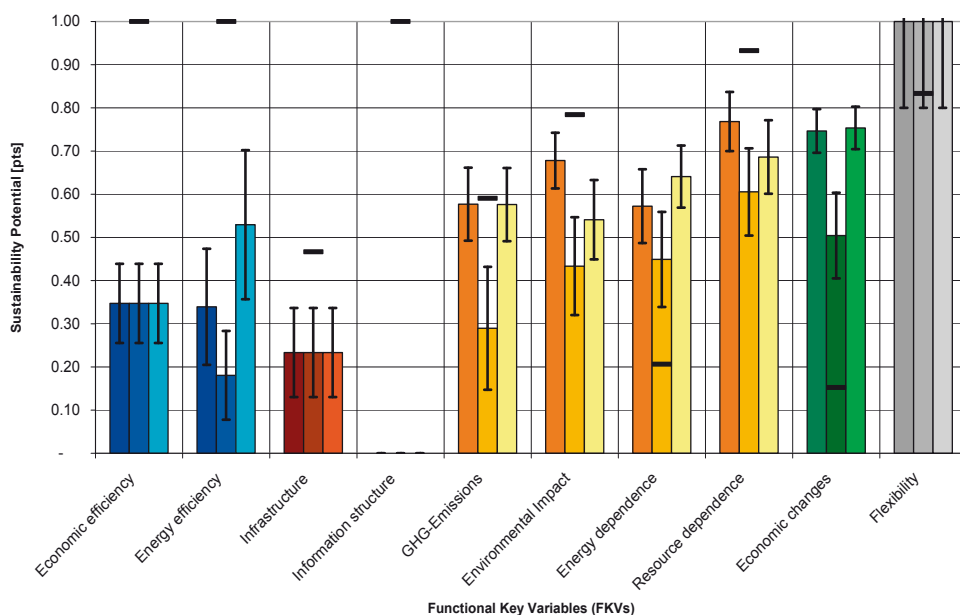


Figure 68: SPA-results for BTL production (left: BTL-UET process; middle: BTL-CUTEC process; right: BTL-DME process). The black lines show the respective reference value of the petrol refinery for each FKV.

While the economic efficiency is below average, the energy efficiency can be relatively high, especially for large-scale plants. As regards infrastructure requirements, BTL production has a low sustainability potential. This outcome is due to the high general requirements during all the relevant infrastructure process steps, particularly in the construction, the waste management and the transportation step. A low SP (practically 0) is assigned to BTL production for information structure. Both the experience with technology and patent protection is rated minimal.

For GHG-emissions, environmental impacts, energy dependence and resource dependence, values are relatively good. The best values can be achieved with the UET¹⁰ and Dimethylether (DME) technologies, while the CUTEC-process¹¹ scores generally lower. Because the process can be driven using parts of the produced gas for process energy, the resilience to oil-based economic changes is high. The flexibility will also be high, as the process can be adapted to various cellulosic feedstocks.

4.1.2.7 Lignocellulosic fermentation

The process is in principle the same as conventional fermentation of starch to ethanol. However, each of the process steps requires additional measures when ligno-cellulosic feedstock is used:

- The strong bonds in lingo-cellulosic feedstock require a pre-treatment to make the polysaccharides accessible for conversion.
- Cellulose, unlike starch is not hydrolysed by conventional enzymes. It requires the application either of sophisticated and still expensive enzymes or of more conventional acid.
- Finally, novel micro-organisms or novel forms of yeast are required to ferment the xylose sugars extracted from the hemi-celluloses. Common yeasts will not work.

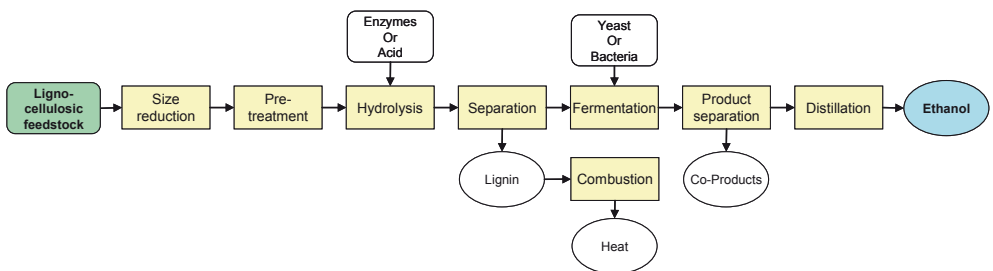


Figure 69: Ethanol production from ligno-cellulosic feedstock via the bio-chemical route.

¹⁰ Umwelt- und Energietechnik Freiberg

¹¹ Clausthaler Umwelttechnik-Institut

It has been estimated, that the bio-conversion of ligno-cellulosic feedstock has a net-efficiency in the range of 12 to 35%, which is an uncertainty factor of 3. The low end of this range leads to 2.3 GJ Ethanol/t dry matter. The upper end leads to 6.3 GJ Ethanol/t dry matter, which is close to the theoretical max conversion rate. The low values correspond with the current commercial technology; the high values have only been reached under laboratory conditions. Consequently, future gains in efficiency strongly depend on advances in process development for pre-treatment, hydrolysis and fermentation.

Pre-treatment: biological, physical, chemical and combined methods are under development, each having its disadvantages. Usually, expensive waste treatment installations have to be implemented for dealing with large amounts of process emissions like acid neutralisation or ammonia capturing. The choice of pre-treatment technology strongly depends on the feedstock characteristics and the processing infrastructure already available on-site. Future trends are not clear.

Hydrolysis: Today, most producers use acid-based hydrolysis. However, the majority of proposed commercial-scale processes will build on enzymatic hydrolysis. Over the last years research has been focussed on reducing the cost of enzymatic hydrolysis, which must be tailored to the complexity of the lingo-cellulosic matrix.

Fermentation: a key goal for the market success of lingo-cellulose ethanol is that all types of sugar released in the pre-treatment and hydrolysis are fermented into ethanol. However, no natural organisms are able to convert both pentose and glucose sugars at high yields.

While significant progress has been made on pentose fermentation on ideal substrates, the application on heterogeneous real-world feedstocks is still missing. The micro-organisms are highly sensitive to inhibitors and the production of unwanted by-products remains a serious problem for the commercial viability. For example for woody biomass, lignin separation and utilisation is a critical issue.

Potential

Currently, ethanol production from ligno-cellulosic feedstocks remains at the late pilot stage with a share <0.1% on world ethanol production (Sims, Taylor et al. 2009). Due to the sustainability criteria coupled with mineral oil tax reduction, all bioethanol on the Swiss market (approx. 0.1% of total gasoline consumption) is ligno-cellulosic ethanol. Borregaard in Attisholz produced it as a by-product of cellulose production until the factory was closed end of 2008. Until end of 2009 it will be imported from SEKAB Sweden, where it is produced with acid-based hydrolysis from residual wood (SEKAB 2008).

According to Novozymes, the leading producer of enzymes, the cost of enzyme production for hydrolysis has been decreased by a factor of 10 since 1999 and future cost reductions might lead to a commercially viable use from 2015 (Jensen 2009).

In general, bio-chemical conversion of cellulosic feedstock has the potential to be applied on various scales of biofuels production and it also has a future optimisation potential with respect to costs, efficiency. Critical are the interactions between pre-treatment, hydrolysis and fermentation and the sensitivity of the overall process to variable feedstock composition.

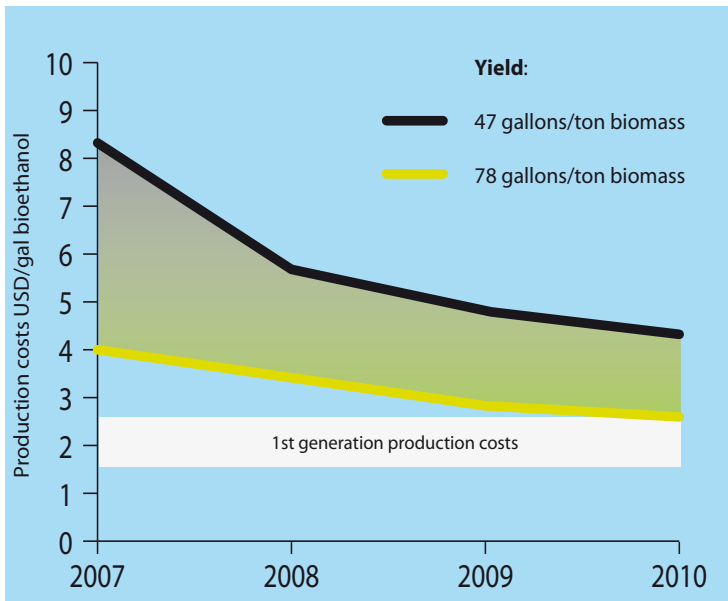


Figure 70: Cost assessment by Novozyme for enzyme-based cellulosic bioethanol (Jensen 2009).

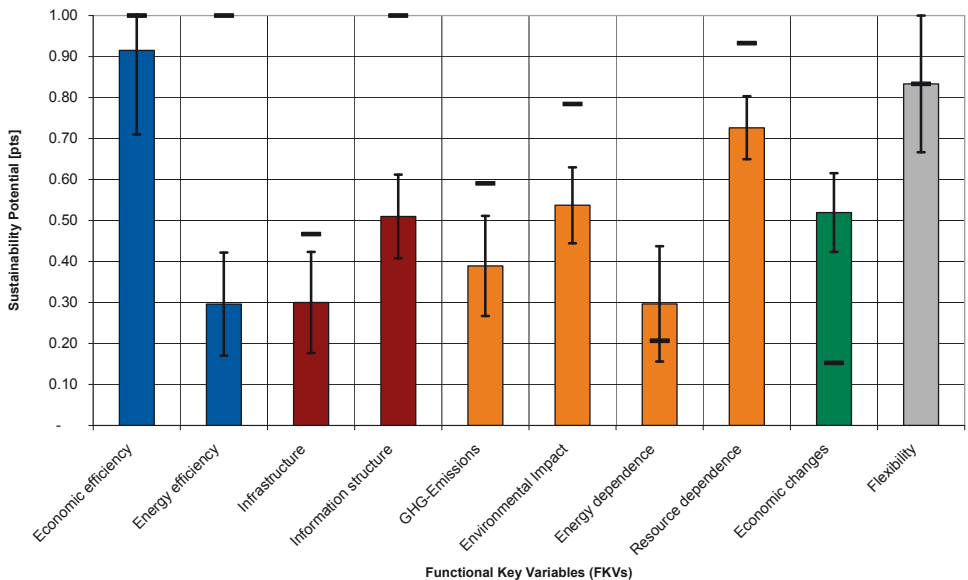


Figure 71: SPA-results for cellulosic ethanol production. The black lines show the respective reference value of the petrol refinery for each FKV.

In contrast to the BTL-technology, economic efficiency of cellulosic ethanol is expected to be relatively high, because the process is relatively simple and main cost factors are enzyme prices, which are expected to decrease further. As regards infrastructure requirements, lignocellulosic fermentation has a relatively low sustainability potential. This outcome is mainly due to the high requirements during the storage and the transportation phase. A medium SP is assigned to lignocellulosic fermentation for information structure. While the experience with the technology is rated high, the patent protection is rated moderate. This leads to a medium availability of overall know-how. For GHG-emissions, environmental impacts, energy dependence and resource dependance, values are all medium. The flexibility will be high, as the process can be adapted to various cellulosic feedstocks.

4.1.2.8 Co-generation of electricity

Co-generation of electricity and heat is a simple and straight-forward process that is on the market available in various scales. Feedstock is burned for generating steam for producing electricity and waste heat. Main challenge is to make a suitable use of the processed heat.

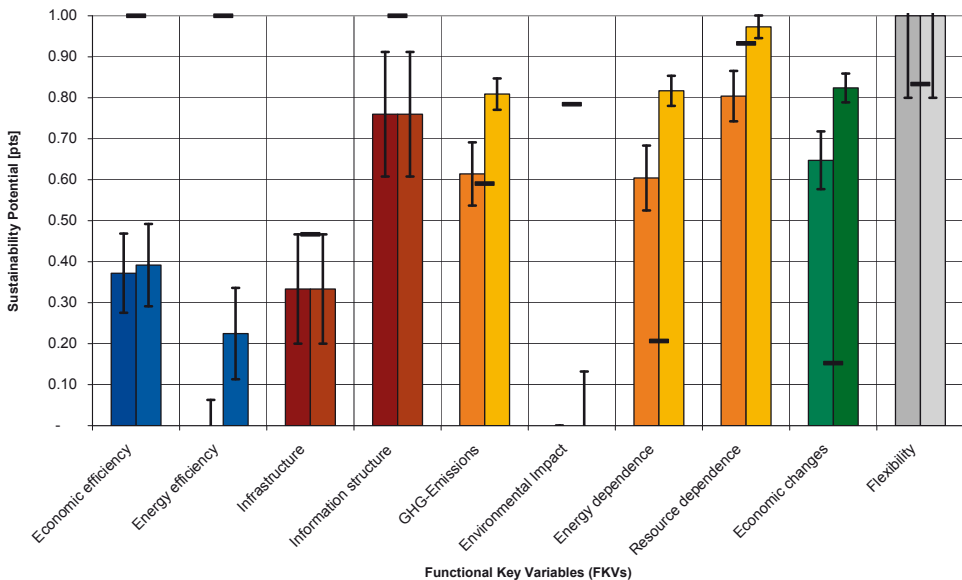


Figure 72: SPA-results for CO-generation of power and heat (left: CoGen 1600kWh; right: CoGen 6400kWh). The black lines show the respective reference value of the petrol refinery for each FKV.

While costs are still below average for the assessed plant scales, energetic efficiency is very high, especially for a 6,400kWh plant. Infrastructure requirements are below average as a local heat consumer is needed. Environmental impacts are substantial as combustion emissions are occurring. Due to the simplicity and high efficiency of the process all other categories are rated very high.

4.1.2.9 Photovoltaics

For assessing the sustainability of photovoltaic (PV) electricity one has to distinguish between the production phase and the use phase of the PV-modules.

Production phase: Basic raw material is silicon, a product of the chemical industry. Solar cell manufacturing requires diffusion, oxidation, and contacting steps for which different chemicals are employed. They are either recycled or disposed of in a very controlled manner. Thin-film modules involve different manufacturing processes, which sometimes employ noxious gases. The production is generally very energy intensive. The site of the production plant is therefore very relevant for the greenhouse gas balance, because of the electricity mix of the respective country (coal vs. hydro) (Goetzberger and Hoffmann 2005).

Use phase: Normally PV systems do not have any effect on the environment from their operation. They do not emit noise, solid waste, or gases that could harm the environment. Energy pay back times differ a lot between PV-technologies as shown in Table 41.

Table 41: Mean energy payback times for PV modules of different technologies (Goetzberger and Hoffmann 2005).

Technology	Mono-Si	Multi-Si	a-Si	CIS	CdTe
Pay back time [years]	7.3	4.6	2.8	1.9	1.5

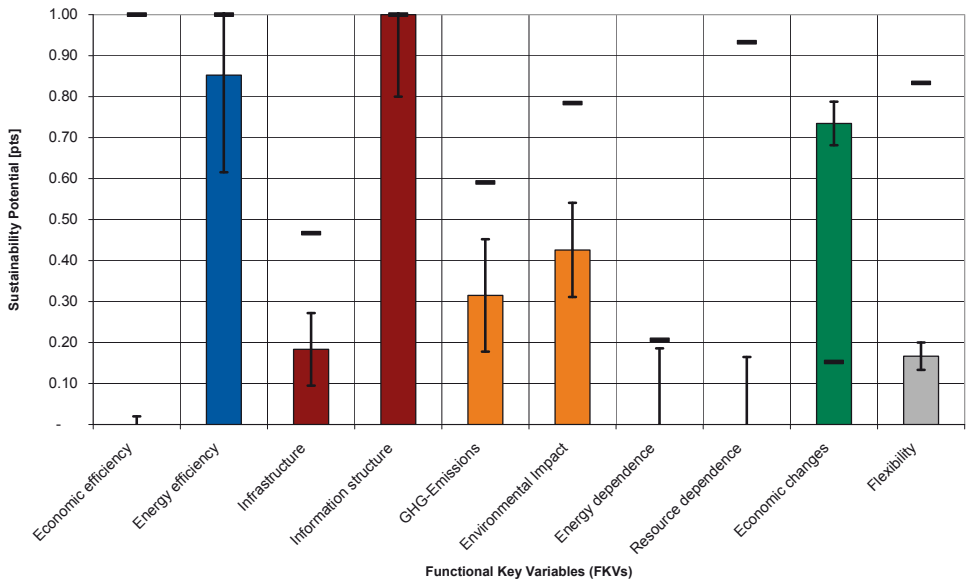


Figure 73: SPA-results for electricity production from photovoltaics modules. The black lines show the respective reference value of the petrol refinery for each FKV.

The SPA-results of photovoltaics cannot be directly compared with the other processing technologies, as PV is the only process, where no “feedstock” is needed. As a pre-requisite for the assessment of the full value chain, the process-indicators of the SPA have been defined nevertheless.

The costs are a factor 10 higher, than for typical processing technologies, consequently economic efficiency of PV is very low. Due to the high energy intensity of the PV modul production, overall energy efficiency is also low, compared to other processing technologies. Regarding infrastructure requirements photovoltaics have a low sustainability potential (0,18). This outcome is mainly due to the high general requirements during all the relevant process steps and also in particular due to the exceptionally high requirements during the processing energy infrastructure and waste management phase.

A high SP of one is assigned to photovoltaics for information structure. Both the experience with the technology and the patent protection are rated very high (1), meaning that PV systems are being researched already for a considerable time window and that an abundance of patents have been registered.

Due to the high production effort, both GHG emissions and environmental impacts are slightly below average and PV production is strongly dependant on non-renewable energy and mineral resources. Flexibility to economic changes is high. Flexibility to various feedstocks is theoretically low, as the technology works only with sunlight.

4.1.3 Usage

On the use level the system boundaries are strictly limited to the inputs and outputs required to drive on pkm with a given car. The input flow of the fuels and the related impacts are not considered. On the other hand, the emissions which are caused by the burning of the fuels are taken into account.

In this regard it must be noted, that the differences between the assessed cars are minor for the precise results. In fact, in order to show the differences between the alternatives we used a tight range for normalization. In other words, the section emphasizes much higher difference between possible car operations than highlighted by the precise results.

4.1.3.1 Transport fossil

Within the fossil alternatives a petrol, a diesel and a natural gas operating car are assessed. Figure 74 shows the SPA results for these types of car operation.

In general, the SP for fossile fuel based cars show high scores for resource and energy dependence, economic changes and flexibility. In comparison to all other operating cars assessed this indicates a high SP. Nevertheless, the non-renewable energy (excluding the fuel) required for driving of one pkm with a fossile fuel based car consumes approx. 0.88 MJ/pkm. Energy efficiency of the diesel operating car shows the highest SP followed by the petrol and natural gas car. However, given that the highest SP of 1 is related to an overall energy efficiency of 0.25 MJ used per MJ invested¹² and the fact that the energy efficiency

¹² The outlined efficiencies include (i) the non-renewable energy input caused by the infrastructure requirements (car production, street production, etc.) and (ii) the fuel consumed. Both is added and related to the kinetic energy used per pkm.

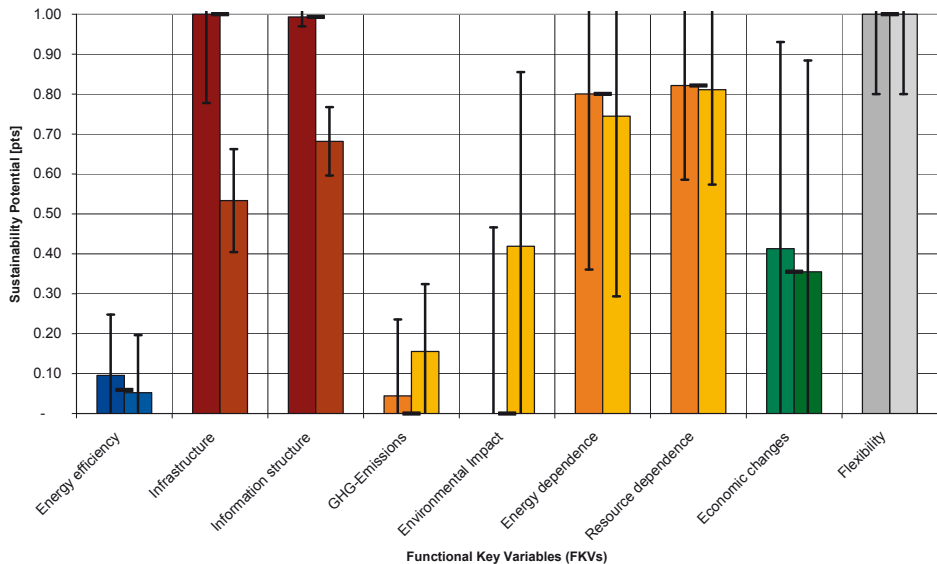


Figure 74: Normalized SPA results for transport using a petrol (black line), a diesel (left bar) and a natural gas (right bar) operating car (source: own depiction).

of the assessed operating cars is merely approx. 0.11 MJ used per MJ invested, SP for energy efficiency is low. SP results for GHG emissions and environmental impact are also low. This is founded in the low impacts of the biofuel benchmarks which merely emit biogenic CO₂. For both indicators the SP of the natural gas operating car shows better results than the petrol and diesel based cars. In contrast, the natural gas operating car shows a lower SP for energy efficiency, infrastructure and energy dependence.

With respect to infrastructure requirements, petrol and diesel show a high sustainability potential (1) due to the fact that today's infrastructure supports vehicles running on those fuels. In this regards, natural gas shows a moderate SP given the adaptations required for storage.

4.1.3.2 Transport, ethanol

Within the ethanol alternatives we assess a petrol (left bar) operating car using E5, i.e. petrol which is blended with 5% ethanol. Furthermore we assess a full adapted operating car once with the emissions for E85 (middle bar, petrol blended with 85% ethanol) and once with the emissions for E100 (left bar, pure ethanol). Figure 75 shows the SPA results for these types of car operation.

The SP for energy efficiency of all ethanol blends is low given that the max. SP of 1 is determined at 0.25 MJ used per MJ invested, i.e. above the performance of electric cars.

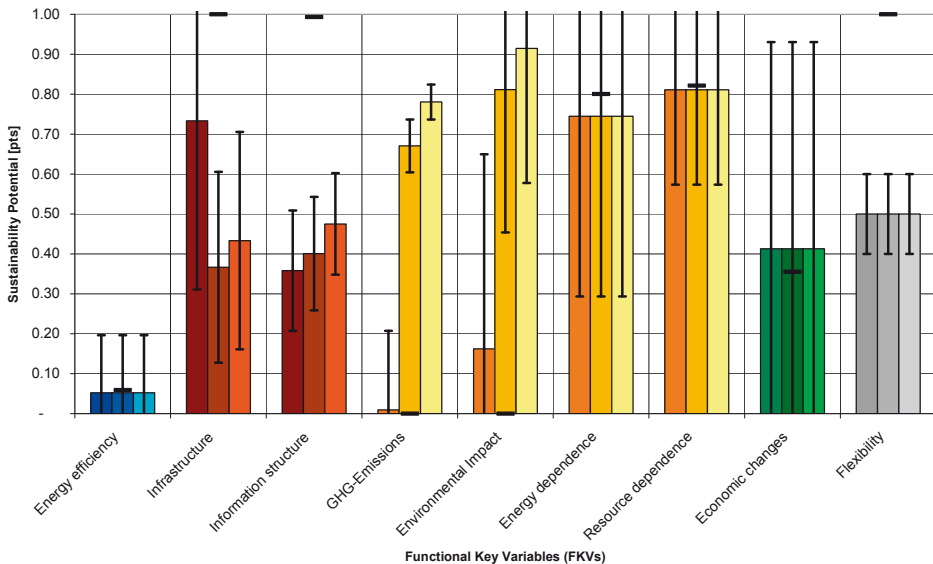


Figure 75: Normalized SPA results for transport assessing E5 in a usual petrol car (left bar) and a full adapted (middle bar (E85) and right bar (E100)) operating car. The black lines show the results for a petrol operating car (source: own depiction).

The differences between the car operations options become apparent as regards infrastructure, GHG emissions and environmental impact. For GHG emissions and environmental impact the driving with E100 shows the highest SP due to the substitution of fossil with biogenic CO₂ emissions. Where the first causes impacts, the latter is not accounted for. In contrast, the SP for infrastructure is highest for E5 followed by E85 and E100. This is founded by the adaptation requirements induced by engine, storage tanks and refuelling stations which, in general, increases with the purity ethanol is used.

In general, the SP for car operation options for ethanol show high scores for GHG emissions, environmental impact, resource and energy dependence, and economic changes. This indicates a high SP only in comparison to the assessed alternatives. Basically, the results for energy and resource dependence and economic changes are primarily determined by the infrastructure required for car operation, e.g. car and street production; whereas the results for GHG emissions and environmental impact are sensitive to the emission profiles of different fuels. The SP for flexibility is moderate given that ethanol can only be used in a normal petrol car when it is blended.

4.1.3.3 Transport, XME & SVO

Within the XME & SVO (biodiesel and straight vegetable oil) alternatives we assess a diesel operating car using SVO. Furthermore we assess a diesel operating car using 5% XME and 95% diesel. Finally, we assess a diesel car using 100% XME. Figure 76 shows the normalized SPA results.

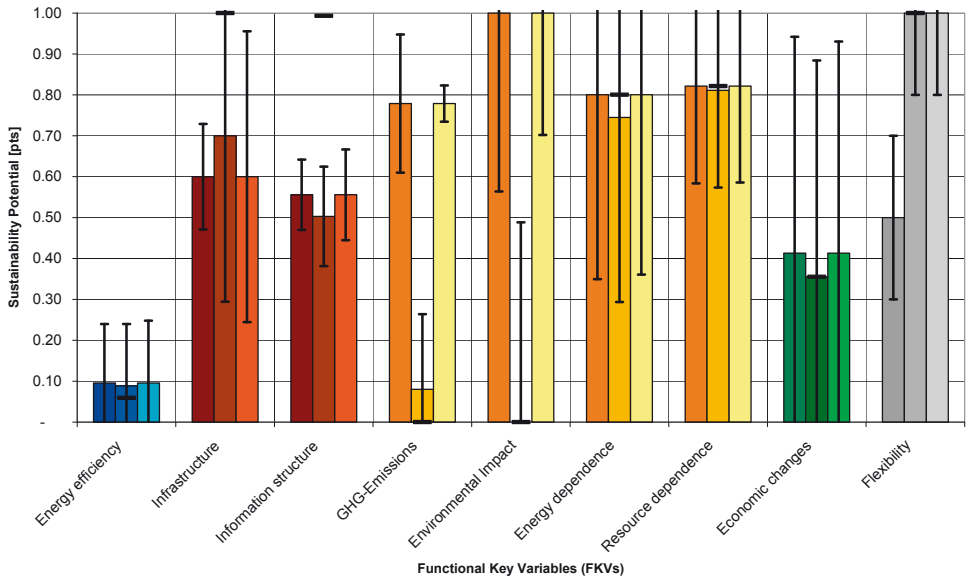


Figure 76: Normalized SPA results a diesel car using SVO (left bar), 5% XME (middle bar) and XME (right bar). The black line shows the results for a petrol operating car (source: own depiction).

Basically, the results for energy and resource dependence and economic changes are primarily determined by the infrastructure required for car operation, e.g. car and street production; whereas the results for GHG emissions and environmental impact are sensitive to the emission profiles of different fuels. As regards energy efficiency, petrol shows a lower SP than all other alternatives.

The results for car operation using SVO and XME are equivalent and show a high SP for most indicators assessed. As shown be the results for GHG emissions and environmental impact, the car operation using 5% XME and 95% diesel is dominated by the negative influence of fossile diesel. As regards infrastructure, the results show reverse results. Bio-diesel has a medium sustainability potential (0,6). The reasons are the additional modifications and new infrastructure needed when driving with pure biodiesel.

All alternatives require approx. 236 g non-renewable resources per pkm. Major contributions to total material requirement, i.e. resource dependence expressed with TMRabiotic, come from fossil fuels (coal) and minerals (gravel, iron).

4.1.3.4 Transport methane

Within the ethanol alternatives we assess an adapted operating car using biomethane. Figure 77 shows the SPA results for this type of operation.

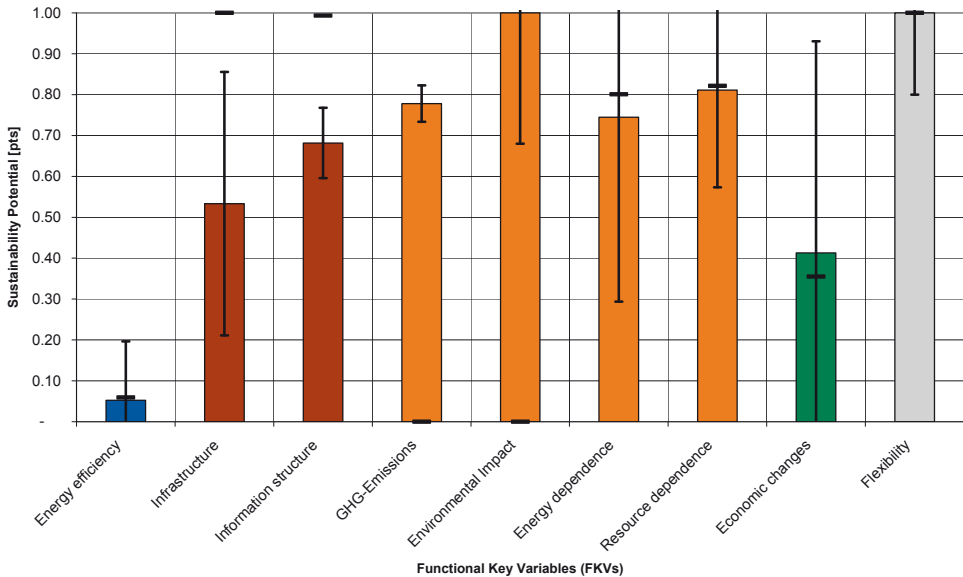


Figure 77: Normalized SPA results for transport using a biomethane operating car. The black line shows the results for a petrol operating car (source: own depiction).

With respect to infrastructure requirements methane has an average sustainability potential (0.53). Modifications and new infrastructure have to be installed for its use on a moderate to low basis. The existing infrastructure can be used up to a certain degree.

The results show the equivalent patterns than other biofuels. The SP for flexibility is high given that biomethan can be used in an adapted combustion engine blended and un-blended.

4.1.3.5 Transport, BTL

BTL can be used in a diesel operating car without adaptations. In fact, due to its properties BTL is reported to reduce the emissions of nitrogen oxides, hydrocarbons and sulphure dioxide. In this study, we assess a diesel operating car using BTL. Figure 78 shows the SPA results.

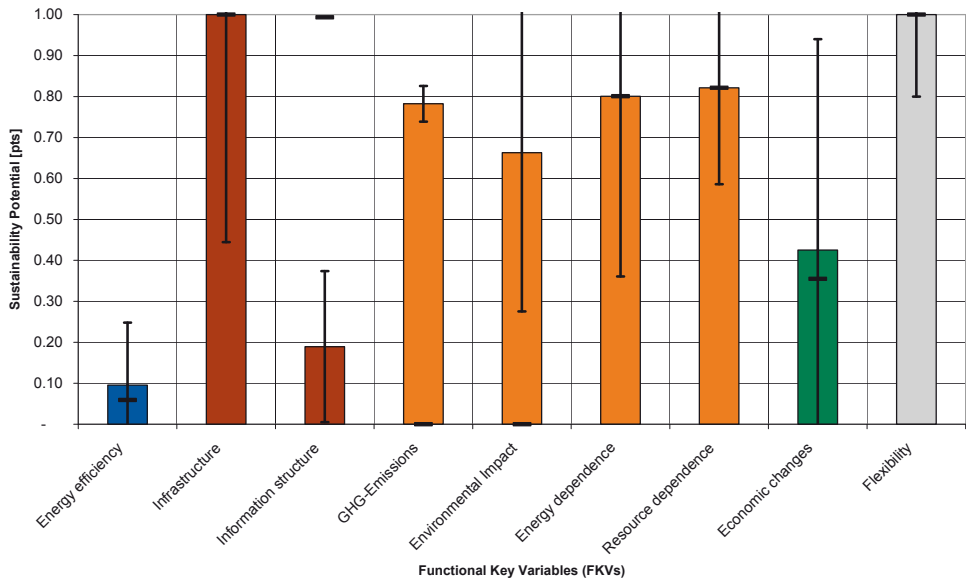


Figure 78: Normalized SPA results for transport using a BTL operating car. The black line shows the results for a petrol operating car (source: own depiction).

In general, the results for energy and resource dependence and economic changes are primarily determined by the infrastructure required for car operation, i.e. in particular car and road production, whereas the results for GHG emissions and environmental impact are sensitive to the emission profiles of different fuels. BTL shows a high SP for flexibility since it can be used without adaptations both blended and unblended in usual diesel engines. With respect to infrastructure requirements synthetic hydrocarbons have a high sustainability potential (1). This value is based on the fact that today's infrastructure can be used without any need for modifications. On this basis, the overall compatibility of synthetic hydrocarbons is 100% and the infrastructure requirements are low because no additional requirements arise from the use of fossil fuels.

4.1.3.6 Transport, electricity

As an alternative to biofuels, we assessed the requirements of driving one pkm with an electric car. Figure 79 shows the SPA results for these types of operation.

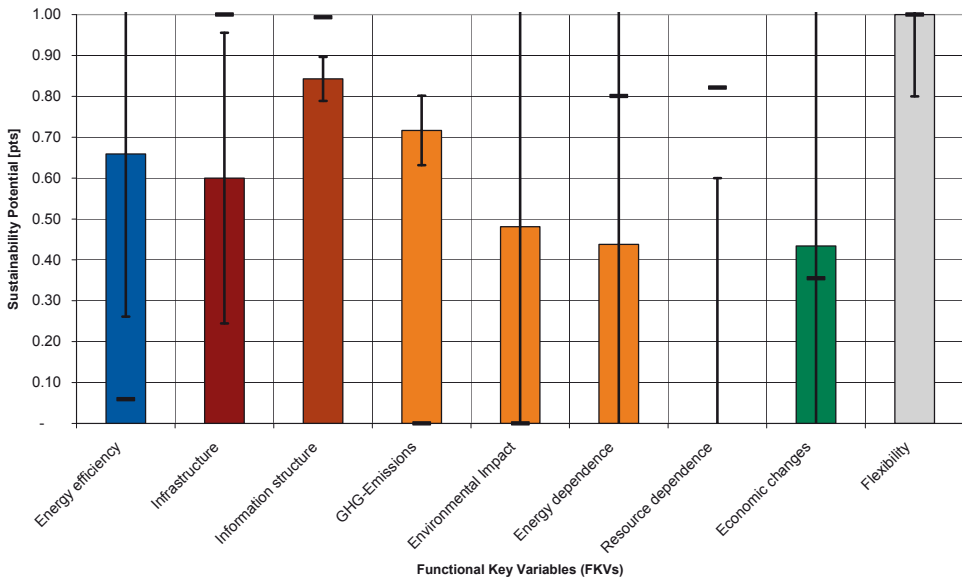


Figure 79: Normalized SPA results for transport using an electric car. The black line shows the results for a petrol operating car (source: own depiction).

Compared to all other alternatives, energy efficiency shows the highest SP for electric cars. Except for GHG emissions and environmental impacts transport with an electric car shows a lower or equal SP than transport with a petrol based car. The prime reason for this is the production of the lithium ion battery which increases GHG emissions, environmental impact, energy dependence and in particular resource dependence. This use requires 400 g non-renewable resources per pkm whereas the petrol based car uses approx. 236 g non-renewable resources. Major contributions to TMRabiotic come from fossil fuels (coal) and minerals (gravel, iron, copper). However, it must be kept in mind, that the differences between the results are accentuated due to the chosen normalization range.

With respect to infrastructure requirements electricity for electromobility has a medium sustainability potential (0.56) comparable to methane. The use of electricity as a fuel to propel vehicles brings along different new infrastructure requirements. Thus the main contributions to the measured value are high requirements for engine and very high demands for fueling system infrastructure. The remaining infrastructure processes have only low requisites to infrastructure.

4.1.3.7 Transport, Hybrid (93% electricity & 7% range extender)

As a further alternative, we assessed a hybrid car which uses electricity and, in addition, a range extender for the production of electricity using fossil or biofuels. Given that most transport distances are below 100 km we assumed that 14,000 of the 15,000 km are driven with electricity from the lithium-ion battery. In other words, only 1,000 km per year are driven with electricity from the range extender, i.e. electricity stemming from the burning of fossil or

biofuels. In this regard, we adapted the emission profile for one fossil (petrol) and one bio-fuel (BTL).

Figure 80 shows the SPA results for driving one pkm with a hybrid car once with BTL from forest wood (left bar) and once with petrol (right bar) as fuel for the range extender. As prior the production of the fuel itself is not considered.

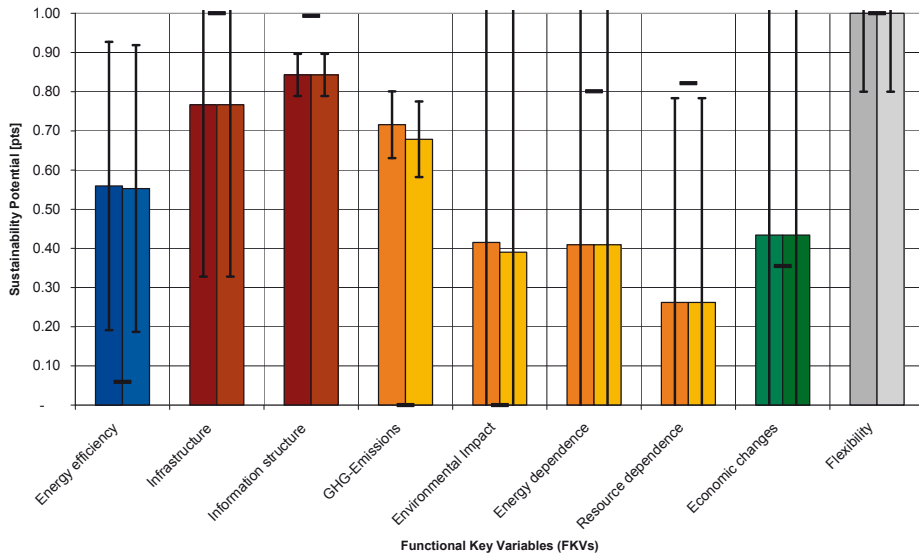


Figure 80: Normalized SPA results for transport using a hybrid car. Left bar: BTL-forest wood; right bar: petrol). The black line shows the results for a petrol operating car (source: own depiction).

In general, the results show the same patterns than the electric car. In most cases the SP is slightly reduced. The reason for this is the additional interventions related to the production of the range extender. Except for GHG emissions and environmental impact both alternatives assessed show equivalent results. Using petrol for the production of electricity increases the emissions and thus decreases SP for GHG emissions and environmental impacts.

With respect to infrastructure requirements electricity for electromobility has a medium sustainability potential (0.56) comparable to methane. The use of electricity as a fuel to propel vehicles brings along different new infrastructure requirements. Thus the main contributions to the measured value are high requirements for engine and very high demands for fueling system infrastructure.

4.1.4 Conclusions

In the following the prior outlined results are discussed integrated. For example, in order to compare all feedstocks the specific SP for each FKV are aggregated to their generic criterion and added up. In this context, each criterion is weighted against each other. Moreover, the FKVs accumulated to one criterion are weighted. For details see Chapter 3.3.

4.1.4.1 Feedstocks

Figure 81 shows the results for the aggregated feedstock assessment.

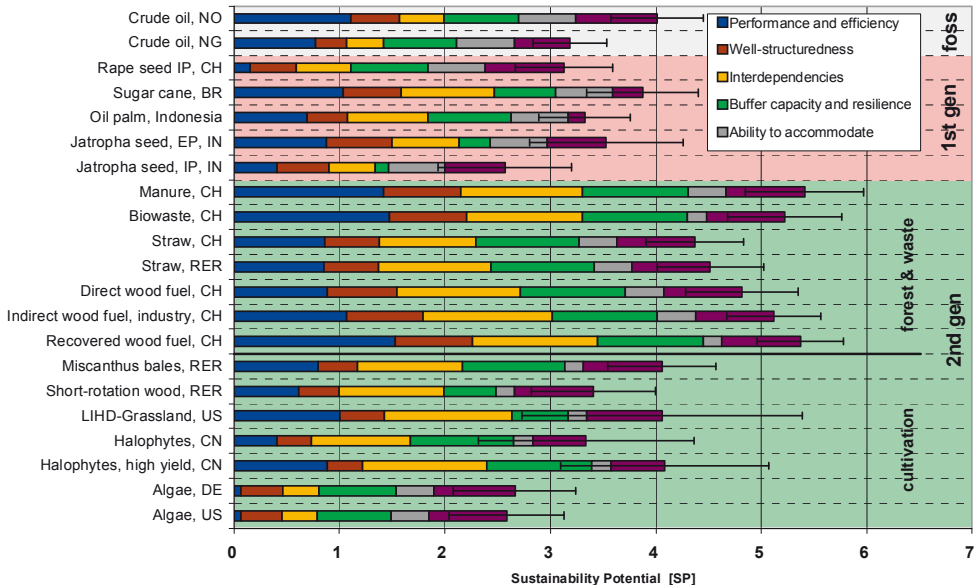


Figure 81: Overall assessment of feedstocks weighted (source: own depiction).

The general pattern exhibits the highest SP for waste feedstocks, i.e. manure, biowaste, indirect and recovered wood fuel. The main reason for this are the low interventions related to their provision. Only straw and direct wood fuels obtain values which are in the same range. For straw the reason is founded in the co-product attribute, whereas direct wood fuel benefits from the low inputs related to its production. Basically, all feedstocks with such a SP show high values for the criteria performance, well-structuredness, interdependencies, buffer capacity and inter- and intra-generative equity. The first four criteria are affected by the low interventions, while the last one is determined by the country of production, i.e. Switzerland. Merely the ability to accommodate is reduced since the application area of those feedstocks is limited to fuel and/or agricultural application.

As shown by the results for performance, interdependencies and buffer capacity, it is primarily the dependence on fossil fuels which limit the SP of the best fossil reference (crude oil, NO). Sugar cane and oil palm show a SP in the same range mainly due to high values for the criteria performance, resilience, and flexibility as well as moderate values for well-structuredness and interdependencies. The results for inter- and intra-generative equity are low since both feedstocks are produced in countries with a high violation risk of human rights and unequal allocation between rural and urban income.

Extensive jatropha production scores a higher SP than intensive jatropha production. In comparison to intensive jatropha production, this results from higher values for performance, interdependencies and resilience.

The results for miscanthus are characterized by a low well-structuredness and a low ability to accommodate. All other criteria show high SP since the high yield of miscanthus diminishes the impacts of the high input system. In contrast, the low input system LIHD grassland shows an equivalent SP primarily due to an elevated SP performance, well-structuredness and interdependencies.

The lowest SP is shown by crude oil (NG), halophytes, and algae. For crude oil, this is primarily founded in the higher energy requirements per MJ non-renewable fuel invested. As shown by the high yielding halophytes, it is the yield but also the ability to accommodate and the inter- and intra-generative equity which limit the SP of halophytes.

The current cultivation of algae is characterized by a high input of fossil energy and a low energy return on fossil energy invested. This has a significant impact on the SP of the criteria performance and interdependencies.

4.1.4.2 Conversion technologies

Figure 82 shows the results for the aggregated conversion assessment.

Compared with the feedstocks, the differences among the conversion technologies are smaller typically ranging from a sustainability potential of 1.7 to 2.7. Surprisingly, Photovoltaics scores lowest, which can be explained by the high costs (→ low performance score), the low ability to accommodate to different feedstocks (this indicator actually makes no sense for Photovoltaics) and the fact, that for Photovoltaics, no feedstock is needed. Generally, the scoring system is not adequate for PV and it should be excluded from discussion on this level.

Crude oil refinery and conventional vegetable oil extraction reach the highest scores. Both technologies are well known and have a high economic efficiency.

The overall differences among the biomass-based conversion technologies are rather small and no clear pattern is visible. For both, 1st and 2nd generation more and less sustainable technologies exist which depend a lot on how a specific technology is implemented. The large differences within conventional oil extraction, basically depend on the type of electricity used, are remarkable.

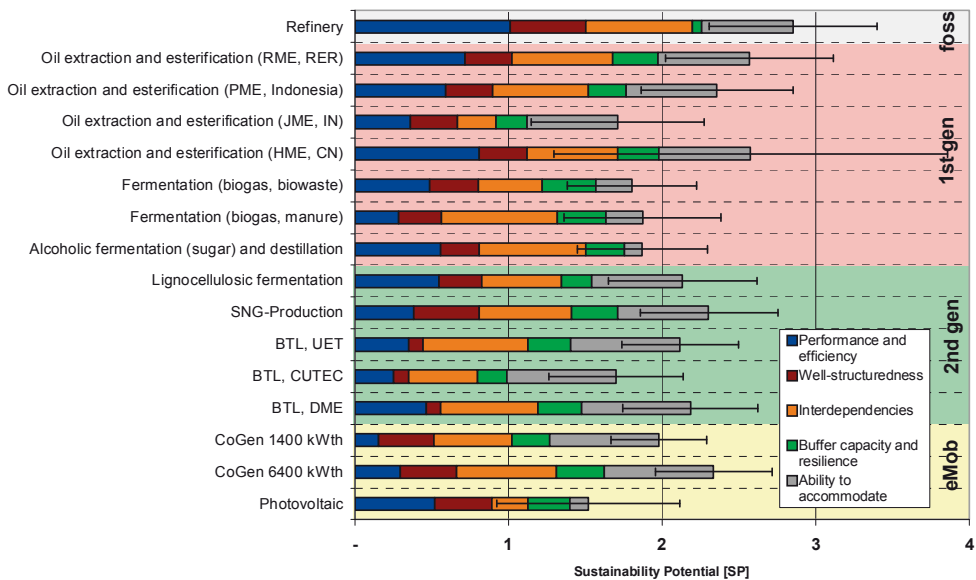


Figure 82: Overall assessment of conversion technologies (source: own depiction).

Two general conclusions from the assessment of the conversion technologies could be drawn. First, overall sustainability of different conversion options is not very different. Less environmental impacts are often compensated by higher costs or less energy efficiency, which leads to relatively consistent results.

Second, an efficient and sustainable option for producing biofuels could be the co-processing of bio-based feedstocks in a crude oil refinery. Main problems are on the marketing level as the products are always a mixture of fossil and biogenic feedstocks.

4.1.4.3 Use

For the use merely 5 generic criteria are assessed. Hence, the highest possible SP is 5. As shown by Figure 83, the transport options with electricity/hybrid and BTL show the highest SP followed by the fossil references (petrol, diesel), XME, methane, 5% XME, natural gas, and the ethanol variants.

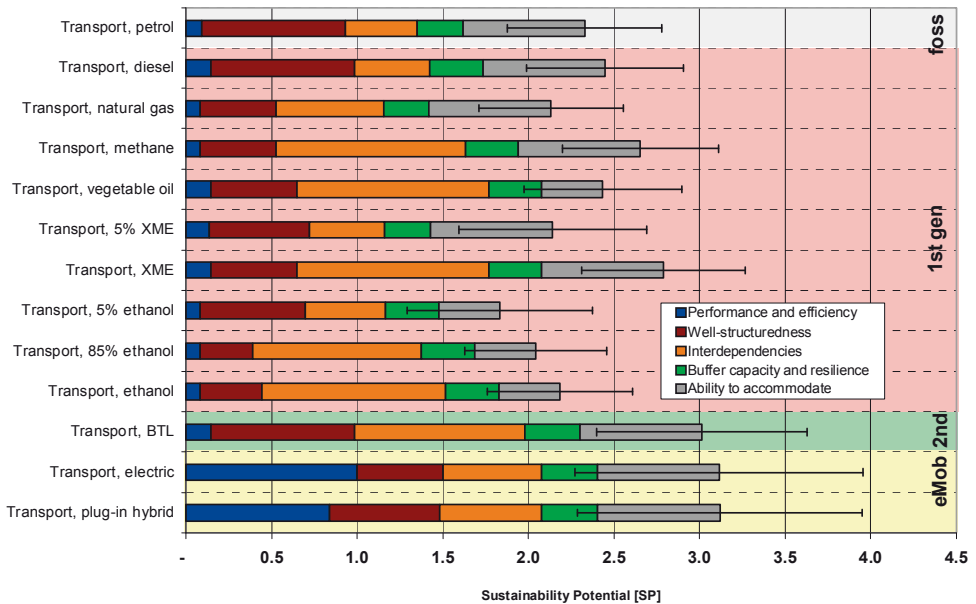


Figure 83: Overall assessment of use options (source: own depiction).

Basically, the benefits of alternative transport options increase in particular the SP of interdependencies, i.e. lower the GHG emissions and environmental impacts. However, except for the BTL use option, these benefits are overcompensated by a lower SP for well-structuredness which is induced by the additional infrastructure requirements related to alternative use options.

The lower value for interdependency of electric and hybrid use options is basically determined by higher energy requirements which results from different or additional car components, e.g. lithium-ion battery.

4.2 Assessment of value chains

4.2.1 Definition of value chains

Elements on the level feedstock production, fuel production and fuel use have been combined to value chains. The definition of value chains for the two assessment years 2015 and 2030 is based on the availability of the elements at the respective years (Figure 84). Only elements with a favourable sustainability potential score or with a high availability have been selected for the value chains.

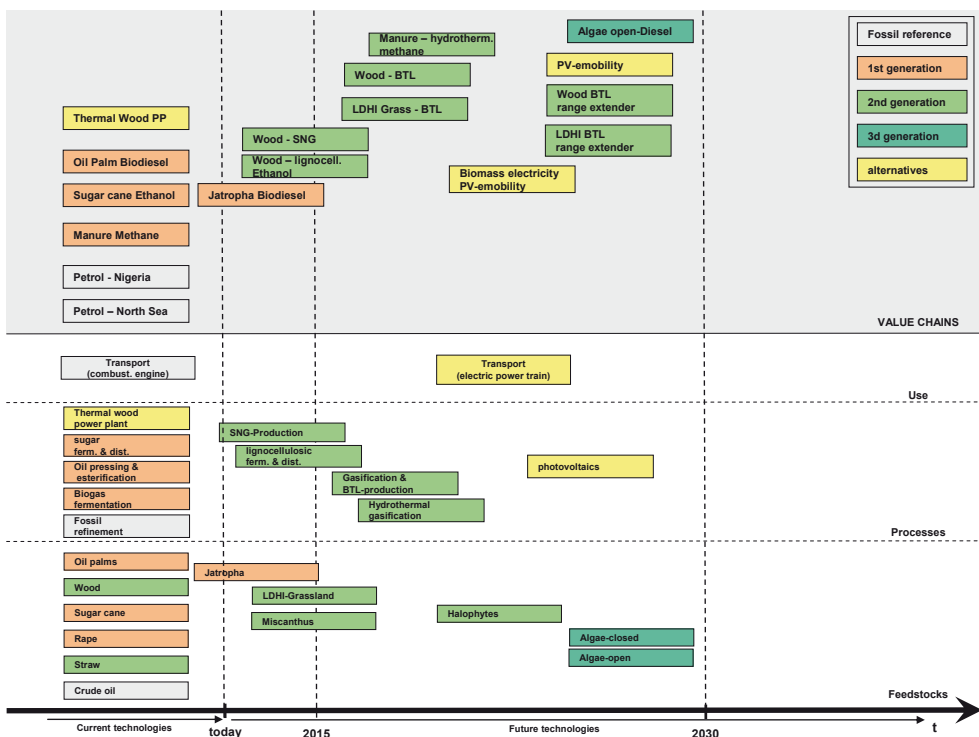


Figure 84: Temporal availability of the various elements on the levels feedstocks, processes and use and the resulting value chains (grey area).

4.2.2 Reference: Petrol

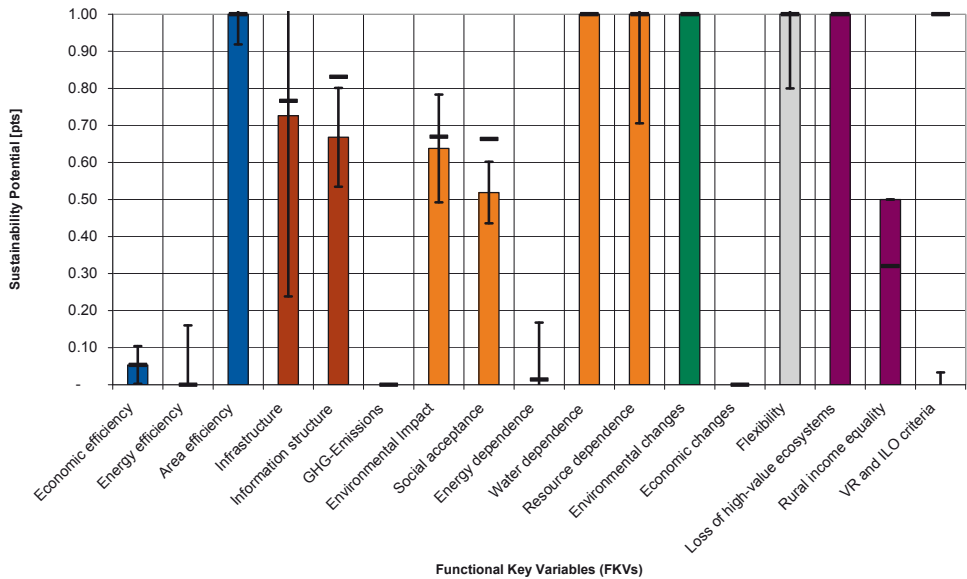


Figure 85: Normalized SPA results for petrol produced from crude oil Nigeria over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

The price of petrol includes the mineral oil tax of 0.74 CHF/l whereas the price of biofuels is without the tax. Main advantage of fossil fuels are the high area efficiency with consequently a low impact on biodiversity, generally low environmental impacts, while flexibility is high and infrastructure is already well established. Main disadvantages are the high GHG emissions and the high resource and fossil energy dependence. As shown in Figure 85, petrol produced from crude oil Norway scores an equal or higher SP than petrol produced from crude oil Nigeria for all assessed indicators.

4.2.3 1st: Sugar Cane – Ethanol, Brazil

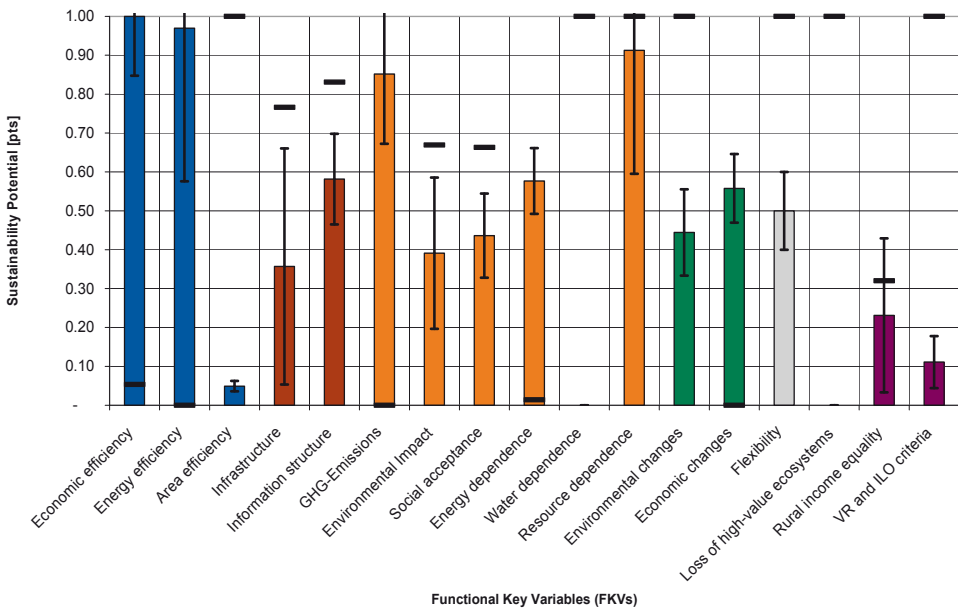


Figure 86: Normalized SPA results for ethanol production (from sugar cane) and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

Brazilian sugar cane ethanol scores high regarding production costs, GHG emissions, energy efficiency and resource dependence. Most critical factors are however the large land consumption, which is also related to the loss of high-value ecosystems, like the Cerrado dry lands (reg. Chapter 5.4 on biofuels and biodiversity) and the impacts of water use.

4.2.4 1st: Oil Palm – Biodiesel, Malaysia

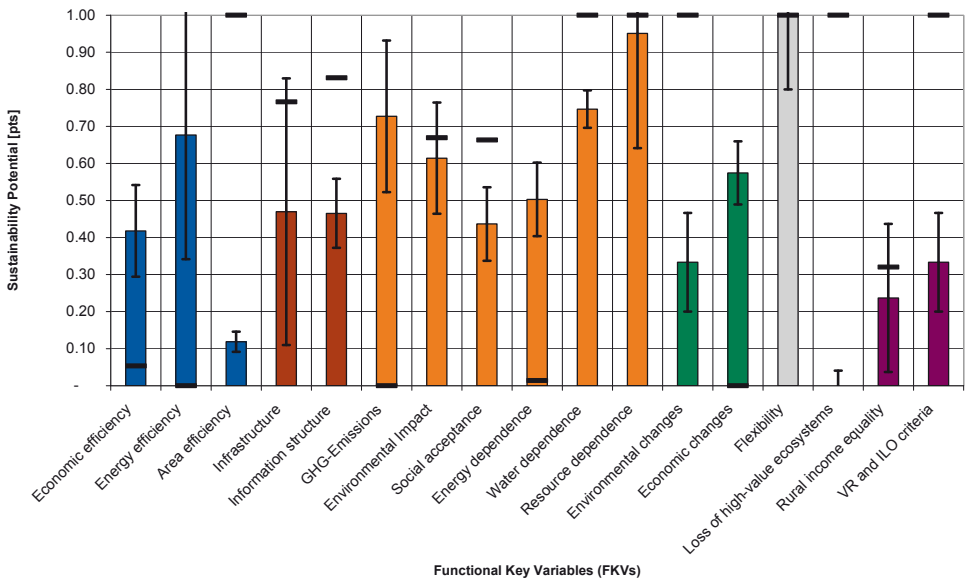


Figure 87: Normalized SPA results for Palm-ME production and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

As oil palms have a high energy yield per hectare, resource dependence and GHG emissions are high for a biogenic value chain. As the cultivation takes place in tropical regions, water use impacts are not an issue, but the potential impact on biodiversity and also GHG emissions due to land use changes are the most critical issues.

4.2.5 1st: Jatropha – Biodiesel, India

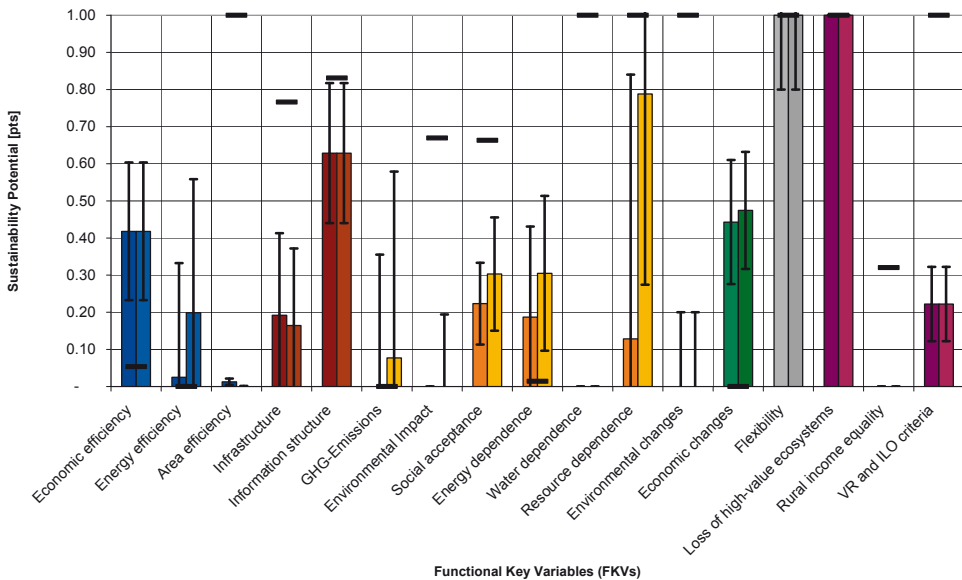


Figure 88: Normalized SPA results for Jatropha-ME production and use over the full life cycle. Left bars: intensive cultivation; right bars: extensive cultivation. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

The value chain of Jatropha-Biodiesel scores rather low. Main reasons are the high land consumption that leads to relatively high environmental impacts and GHG-emissions per litre of fuel. Furthermore, the cultivation of Jatropha is not yet established and adopted to the local agricultural conditions as it takes several years until full harvests could be reached – this leads to relatively low values for the well-structuredness. Nevertheless, the values of Jatropha-Biodiesel are high for ecosystem conservation, as Jatropha cultivation usually takes place on degraded or less fertile lands. No data was available for the assessment of rural income equality, i.e. the value is not zero but not available.

4.2.6 1st: Manure – Methane, CH

Methane production from Manure scores rather high for most indicators. As the methane is produced from waste feedstock, area efficiency is very high, while GHG-emissions, environmental and water impacts are low.

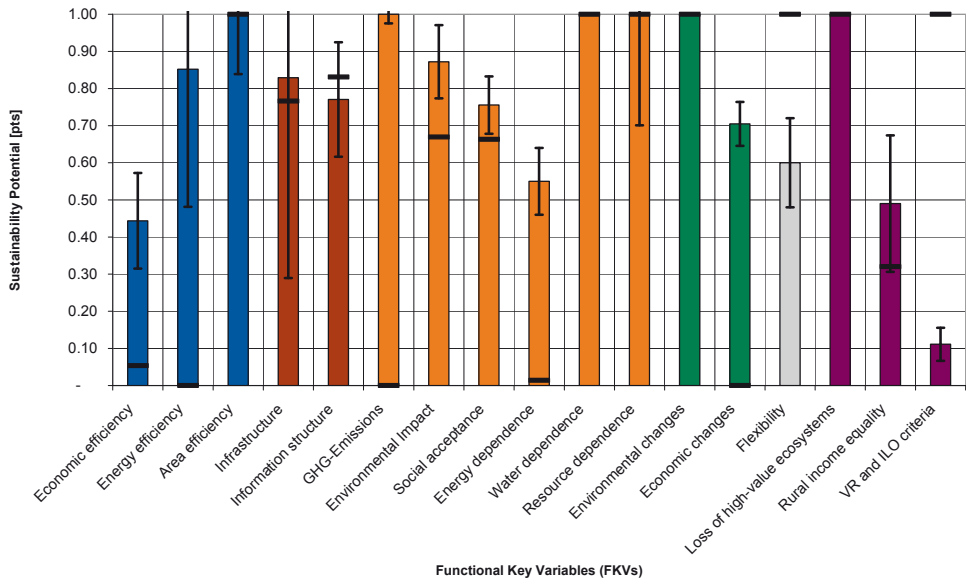


Figure 89: Normalized SPA results for Methane production from manure and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.7 2nd: Wood – SNG, CH

Synthetic Natural Gas (SNG) from wood is a relatively established 2nd generation value chain with high economic efficiency, low GHG emissions and environmental impacts and average area efficiency, as the feedstock is based on waste wood and not on agricultural land.

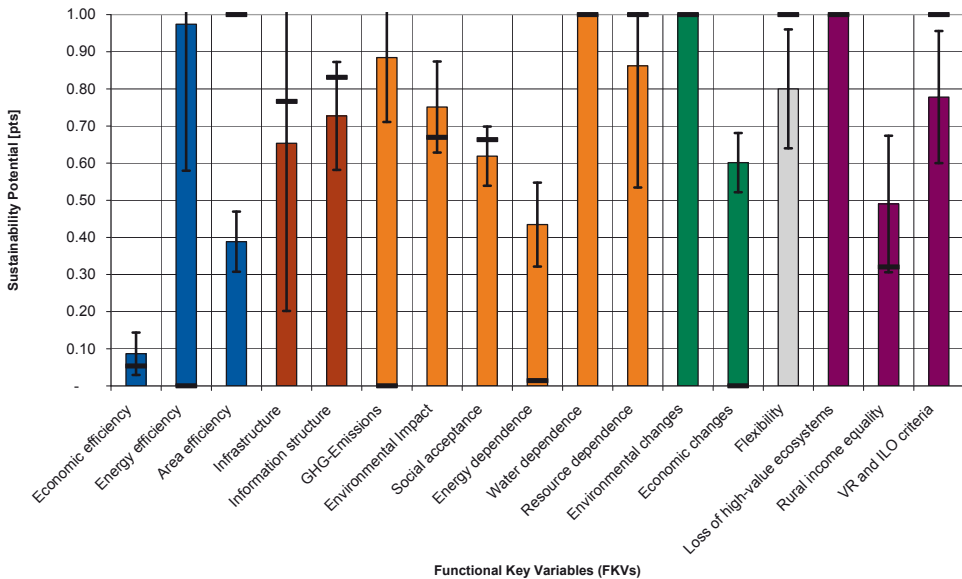


Figure 90: Normalized SPA results for SNG production from waste wood and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.8 2nd: Wood – Lignocellulosic Ethanol CH

The SPA results of lignocellulosic Ethanol from wood are relatively similar to SNG from waste wood. However, the costs of the ethanol pathway are still higher, as some process steps need further development. However, energy efficiency is expected to be higher, as the process is more simple compared to SNG production. The low SP for area efficiency is grounded in the fact that the area requirement per kg wood is not related to the possible wood yield per hectare but calculated on the basis of the totally harvested forest wood in relation to the total forest area in Switzerland. This means the area requirement per kg wood is overestimated meaning the SP potential of forest wood as regards area efficiency is underestimated.

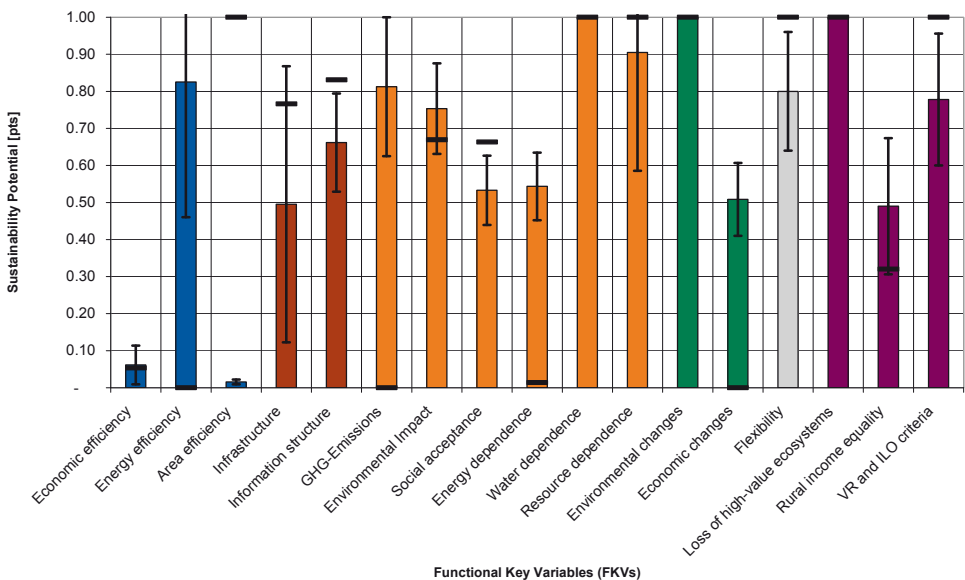


Figure 91: Normalized SPA results for lingo-cellulosic ethanol production Swiss hardwood and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.9 2nd: LIHD Grass – BTL, Germany

The SPA of BTL from LIHD Grass shows high values for energy efficiency and environmental impacts. Nevertheless, economic efficiency and area efficiency are low.

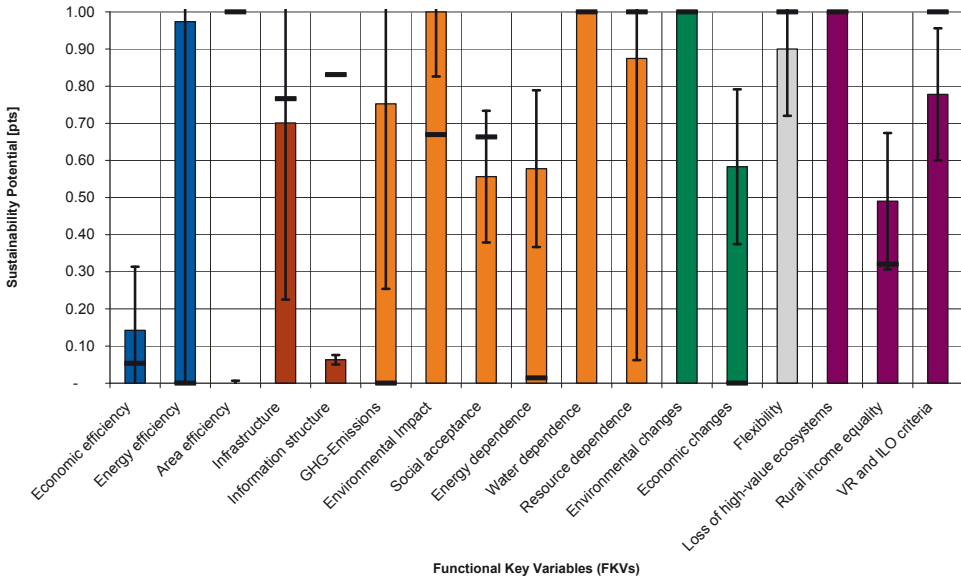


Figure 92: Normalized SPA results for German BTL production from Swiss LIHD-grassland and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.10 2nd: Wood – BTL, Germany

The SPA results are similar to the BTL production from grass. However, GHG-emissions and environmental impacts are higher for the wood path, because of the more complex harvesting. Area efficiency is slightly better, than for the grass path.

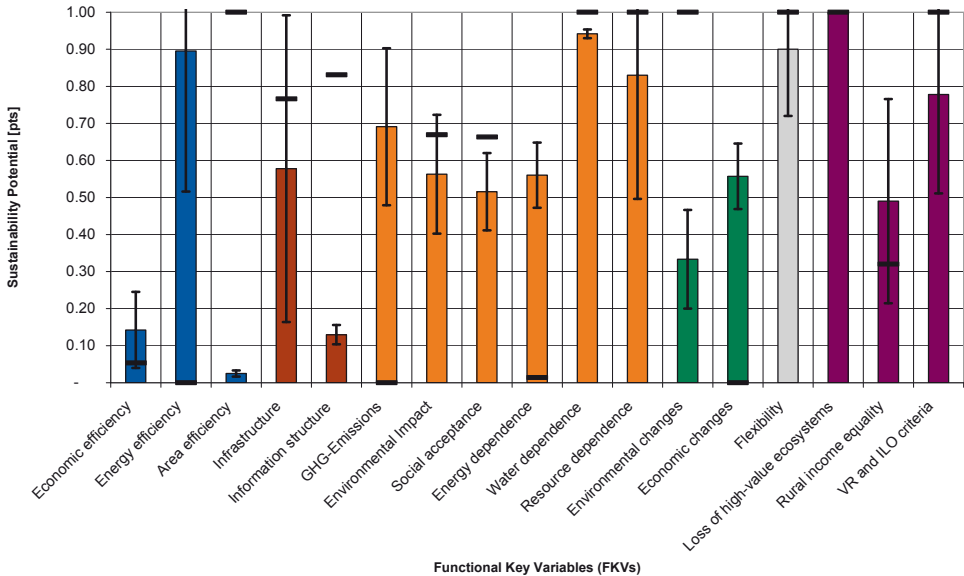


Figure 93: Normalized SPA results for BTL production from wood and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.11 2nd: Wood – BTL, Range Extender

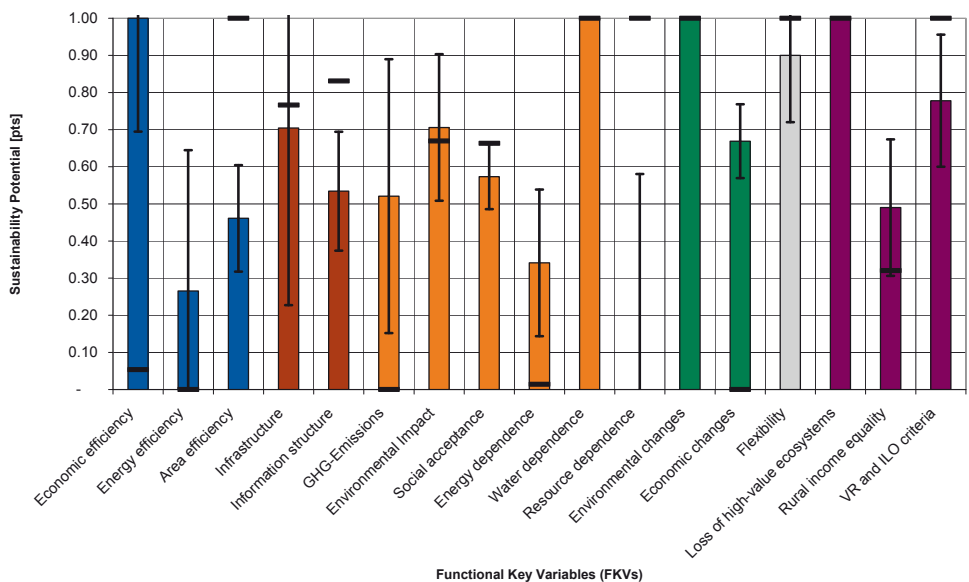


Figure 94: Normalized SPA results for UCTE-based electric mobility plus Wood-BTL range extender over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.12 3rd: Algae – open ponds (US)

The algae value chain scores low for costs and energy efficiency and for high GHG emissions and environmental impacts. Nevertheless, area efficiency and water and resource dependence is favourable for the algae path. The Figure also shows the high uncertainties associated with the assessment of biofuels from algae.

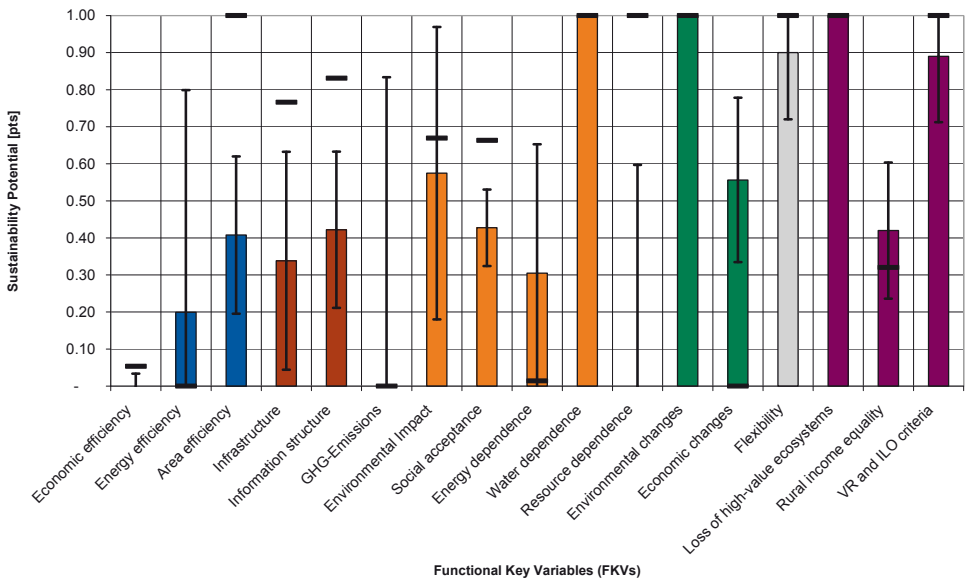


Figure 95: Normalized SPA results for biodiesel production from algae in open ponds (US) and use over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.13 Alternative: Thermal Wood Power Plant – eMobility, CH

The SPA scores high in most categories for wood-based eMobility. However, area efficiency is reduced, due to the land occupation of the forest, the information structure is assessed as very low, as the technology has not yet been established and resource consumption is also lowered, due to the demand for rare metals, especially in the lithium-ion batteries.

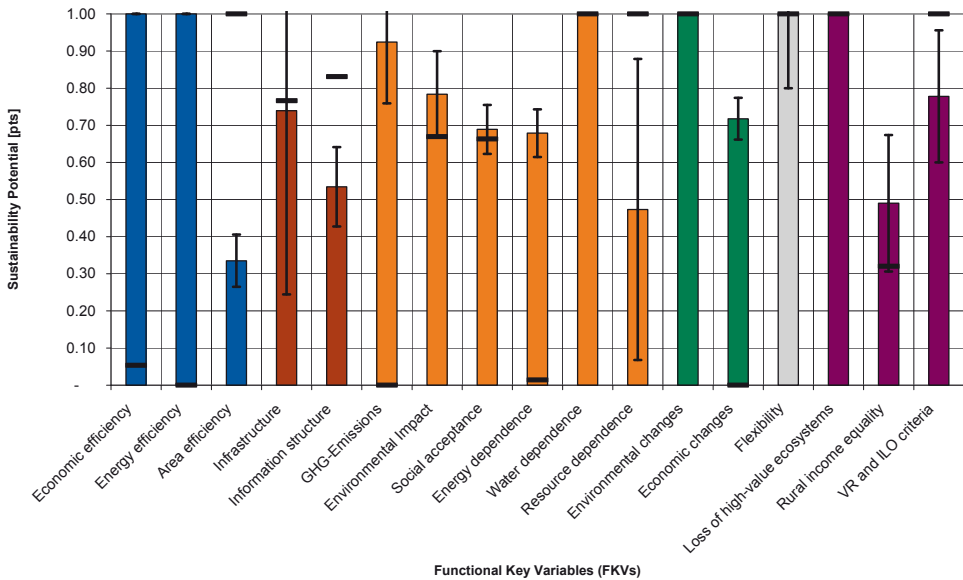


Figure 96: Normalized SPA results for electric mobility from a Swiss thermal wood power plant over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.14 Alternative: PV – eMobility, CH

The SPA is very similar to the eMobility from wood-chain except the low economic efficiency but high area efficiency of electricity from Photovoltaics. The value of rural income equality is not zero but not available.

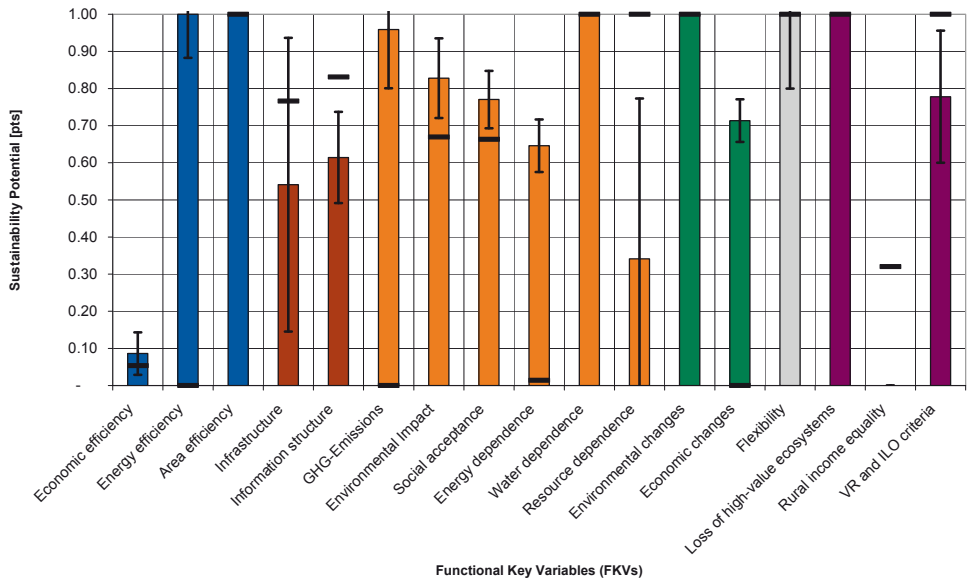


Figure 97: Normalized SPA results for electric mobility from Photovoltaics over the full life cycle. The black line shows the results for petrol produced from crude oil Norway (source: own depiction).

4.2.15 Conclusions

The results of the analysis on the value chain-level are summarized in Figure 98. The use of petrol in Switzerland has currently a SPA-value of 3.7 with a decreasing trend towards 3, due to the exploitation of more and more unconventional oil. The SPA-values of 1st generation biofuels are generally lower than the fossil reference with values <3.3. Main reasons are a low structuredness and a negative interdependence with other systems (e.g. large area consumption, high environmental impacts).

Most 2nd generation biofuels exhibit significantly higher SPA-values than both, 1st generation biofuels and fossil fuels. Main positive factors are the interdependencies with other systems (low GHG emissions, low environmental impacts) and a relatively high buffer capacity with respect to economic and environmental changes. Nevertheless, algae fuels score relatively in the range of 1st generation biofuels, due to their high costs and the still missing research break-through.

Value chains based on electric mobility score a little better than 2nd generation biofuels. Main reason is the high efficiency of both, power generation and use of electricity in cars. The best eMobility value chain is based on the Swiss mix, the worst is based on the UCTE-mix (high ratio of fossil power plants). Electric mobility based on thermic wood power plants score rather well.

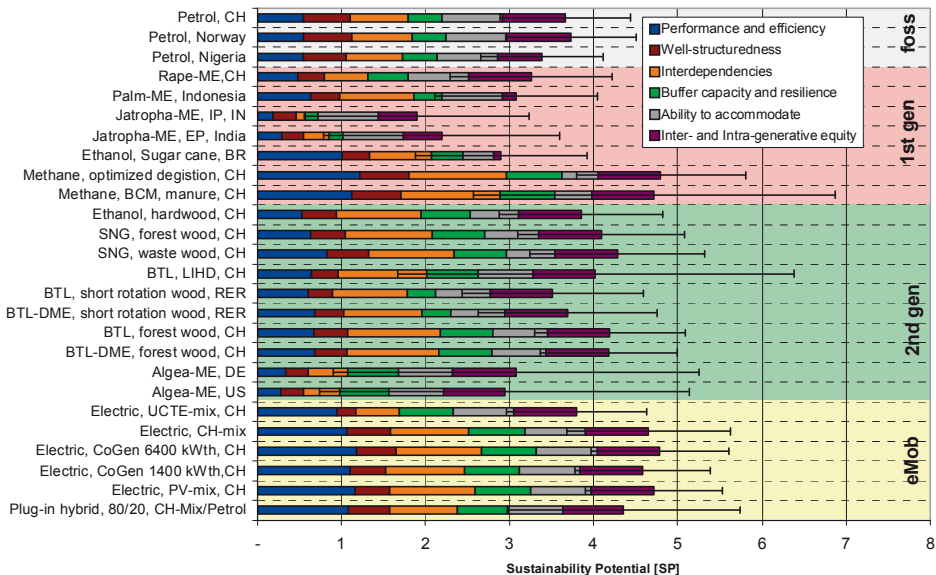


Figure 98: General Histogram of SPA-results on the value-chain-level.

4.3 Assessment of scenarios

4.3.1 Derivation of scenarios

4.3.1.1 Baseline scenario

In this study we focus on the 56.6 billion vehicle kilometres (vkm) that will be driven in 2010 by passenger cars in Switzerland (INFRAS 2004). This reflects approx. 85% of all vkm driven in Switzerland but equals only 145 PJ fossil fuel¹⁴ or 61% out of 237 PJ which are allocated to the mobility sector in 2008, i.e. the consumption of petrol and diesel (BFE 2006).¹⁵ The remaining 15% of the vkm consume approx. 39% of the energy allocated to the mobility sector, primarily caused by fuel intensive vehicles such as lorries and heavy vehicles (Table 42).

Table 42: *Contribution to total vehicle kilometres by transport type and the related fuel consumption in PJ. The respective fuel consumption is calculated using average values from ecoinvent (Jungbluth, Faist et al. 2007). Thus the outlined shares must be seen as proxies. (source: in accordance with (INFRAS [2004]).*

Name	Unit	Passenger car	Lorry	Heavy vehicles	Buses	Motorcycles	Total
Vehicle kilometres [Billion]	vkm/a	56'537	4'635	2'296	302	2'485	66'255
Share vehicle kilometres	%	85.3%	7.0%	3.5%	0.5%	3.8%	100%
Calculated fuel consumption	PJ/a	145.00	48.69	28.28	4.51	10.52	237
Share fuel consumption	%	61.2%	20.5%	11.9%	1.9%	4.4%	100%

According to CONCAWE an average fuel consumption of 4.1 l per 100 km is possible until 2025. On this basis we assumed an average fuel consumption of 6 l per 100 km for the scenarios (2015) and of 4 l per 100 km for the scenarios (2030), i.e. the expected technical advance in vehicle efficiency is taken into account in all analyzed scenarios.

4.3.1.2 System scenario "Resource Scarcity"

Table 43 shows the value chains, their respective potential and their contribution to the total amount of pkm derived for the scenario "resource scarcity" in the year 2015 (for a definition of the scenario refer to Chapter 3.5.5).

¹⁴ Applying the fuel requirement determined by ecoinvent (Jungbluth, 2007 #276), i.e. 2.56 MJ fuel per vkm.

¹⁵ Excluding the fuel consumption induced by trains and planes.

Table 43: *Value chains included in the scenario resource scarcity 2015. The bold numbers represent the basis for the calculation (source: own depiction).*

Value chains	Potential = Feedstock			Potential = Fuel	Mobility	Share
Unit	[PJ available]	[% used]	[PJ used]	[PJ used]	[Billion pkm/a]	[%]
Petrol, CH	-	-	-	105.43	87.63	97.49%
Methane, manure, CH	21.26	30%	6.38	2.23	1.85	2.06%
Methane, biowaste, CH	2.37	50%	1.18	0.47	0.39	0.43%
Electric, CoGen6400 kWh, CH	11.69	0.2%	0.02	0.01	0.02	0.02%
Total	35.31	21%	7.58	108.13	89.89	100.00%

The additional feedstock potentials have been taken from Steubing et al. (2010). However, the additional potentials for manure (21.26 PJ) and biowaste (2.37 PJ) will not be fully utilized as biofuels in 2015. According to the boundary conditions energetic use rates of 30% for manure and of 50% for biowaste have been assumed. Although the scenario emphasizes the use of residues, the production of SNG from waste wood is not considered since the period until 2015 is assumed to be too short for the implementation of SNG. The increased production of SNG from forest wood is constrained, given that heat production is preferred. Nevertheless, due to co-generation the increased usage of wood for heating will most likely result in an additional production of electricity.¹⁶ The amount of additional electricity (0.02 PJ) is derived on the basis of the additional demand for electricity resulting from electric cars which are expected to be sold until 2015. The selling of electric cars is determined by a conservative introduction on the market.¹⁷

Table 44 shows the value chains, their respective potential and their contribution to the total amount of pkm derived for the scenario “resource scarcity” in the year 2030 (for a definition of the scenario refer to Chapter 3.5.5).

Table 44: *Value chains included in the scenario resource scarcity 2030. The bold numbers represent the basis for the calculation (source: own depiction).*

Value chains	Potential = Feedstock			Potential = Fuel	Mobility	Share
Unit	[PJ available]	[% used]	[PJ used]	[PJ used]	[Billion pkm/a]	[%]
Petrol, CH	-	-	-	55.10	68.70	76.42%
Methane, manure, CH	21.26	80%	17.01	5.94	7.41	8.24%
Methane, biowaste, CH	2.37	100%	2.37	0.93	1.16	1.29%
SNG, waste wood, CH	3.58	100%	3.58	1.09	1.36	1.51%
Electric, CoGen6400 kWh, CH	11.69	50%	5.84	1.79	3.96	4.41%
Electric, PV-mix, CH	-	-	-	3.31	7.30	8.13%
Total	27.21	84%	22.95	68.16	89.89	100.0%

¹⁶ According to Holzenergiestatistik 2008 BFE (2008). Schweizerische Holzenergiestatistik. Bern, Bundesamt für Energie (BFE): 78., approx. 8% of the energy wood is used in co-generation units greater than 1,000 kW. If this share levels of until 2015 approx. 0.37 PJ additional electricity can be produced.

¹⁷ The amount of electric cars in Switzerland in 2015 is calculated on the assumption that 1% of the new cars bought in Switzerland will be electric cars. In average, approx. 250 thousand cars are bought in Switzerland per year. Given that the selling of electric cars will not start prior to 2015, 2,500 electric cars require electricity in 2015. For details see Annex.

Induced by resource scarcity, it is expected that 100% of biowaste and waste wood as well as 80% of manure will be used for transportation. Pkm resulting from electric cars (using PV and CoGen as electricity source) is calculated using the expected amount of electric cars in 2030. The selling of electric cars is determined by a conservative assumption on market penetration. Assuming that in 2020 10% and in 2030 50% of the sold cars are electric, a cumulated amount of 720'000 electric cars could be assumed for 2030, which is more conservative than the vision 2020 of ALPIQ (2009). This amount of electric cars would place an additional demand of approx. 5.10 PJ of electricity per year (for details see Annex). Using 50% of the expected forest wood potential (5.84 PJ) in co-generation units, 1.79 PJ electricity can be provided. The remaining 3.31 PJ are assumed to be covered by PV-systems. This appears realistic given that the Swiss potential for electricity from PV in 2035 is estimated up to 9.72 PJ (ETS 2009).

4.3.1.3 System scenario "Challenges"

Table 45 shows the value chains, their respective potential and their contribution to the total amount of pkm derived for the scenario "Challenges" in the year 2015 (for a definition of the scenario refer to Chapter 3.5.6). Similar to the scenario "resource scarcity" 50% of the additional biowaste and waste wood as well as 30% of the manure potentials are assumed to be used for transportation until 2015. Due to increased technology development, an additional 25% of the forest wood potential is assumed to be used for the production of SNG for transportation.

Table 45: *Value chains included in the scenario Challenges 2015. The bold numbers represent the basis for the calculation (source: own depiction).*

Value chains	Potential = Feedstock			Potential = Fuel	Mobility	Share
Unit	[PJ available]	[% used]	[PJ used]	[PJ used]	[Billion pkm/a]	[%]
Petrol, CH	-	-	-	103.63	86.14	95.82%
Methane, manure, CH	21.26	30%	6.38	2.23	1.85	2.06%
Methane, biowaste, CH	2.37	50%	1.18	0.47	0.39	0.43%
SNG, waste wood, CH	3.58	50%	1.79	0.54	0.45	0.50%
SNG, forest wood, CH	11.69	25%	2.92	0.89	0.74	0.82%
Ethanol, Sugar cane, BR	-	-	-	0.30	0.25	0.28%
Palm-ME, Indonesia	-	-	-	0.03	0.03	0.03%
Electric, CoGen6400 kWth, CH	11.69	0.46%	0.05	0.02	0.05	0.05%
Total	50.58	24%	12.33	108.10	89.89	100.0%

The potential of foreign imports of ethanol from sugar cane and palm methyl ester is expected to account for 0.3% of the expected global traded biofuels.¹⁸ The amount of 0.3% reflects the current share of Switzerland in total world crude oil consumption. In other words, the consumption share of Switzerland at the global biofuel market is assumed to be equal to its current share to the global crude oil market.

The system scenario "challenges 2015" is oriented towards the IEA (2006) reference scenario. Trade of 1st generation biofuels is relatively low as the production is basically used to satisfy domestic demand. According to OECD (2008) global biofuels production would rise

¹⁸ Based on the assessment of 1st generation value chains, only ethanol from sugar cane and palm methyl ester from oil palm meet the sustainability requirements placed by the Swiss ordinance on mineral oil tax exemption.

from 1.4 EJ/a in 2007 to 2.8 EJ/a in 2015 (2.2 EJ/a bioethanol; 0.6 EJ/a biodiesel). Projections of future biofuels production and trade in terms of biodiesel and bioethanol, by countries and feedstocks, and in time series 2007 until 2017 are provided by FAPRI¹⁹. These were used as a basis for own scenario developments for 2015 and 2030.

Only 4.5% of global bioethanol production are assumed to be traded in 2015 stemming almost entirely from Brazilian sugar cane. Trade of biodiesel in 2015 would be 7.2% of global production and come mainly from Argentina (from soybeans), Brazil (from soybeans), Indonesia (from palm oil), and US (from soybeans).

The contribution in pkM resulting from the co-generation of wood is calculated on the expected availability of electric cars in 2015 using optimistic penetration assumptions (ALPIQ 2009).

Table 46 shows the value chains, their respective potential and their contribution to the total amount of pkM derived for the scenario 'Challenges 2030' (for a definition of the scenario refer to Chapter 3.5.6).

Table 46: *Value chains included in the scenario Challenges 2030. The bold numbers represent the basis for the calculation (source: own depiction).*

Value chains Unit	Potential = Feedstock			Potential = Fuel	Mobility	Share
	[PJ available]	[% used]	[PJ used]	[PJ used]	[Billion pkM/a]	[%]
Petrol, CH	-	-	-	42.56	53.06	59.03%
Methane, manure, CH	21.26	50%	10.63	3.71	4.63	5.15%
Methane, biowaste, CH	2.37	70%	1.66	0.65	0.81	0.91%
SNG, waste wood, CH	3.58	70%	2.51	0.76	0.95	1.06%
SNG, forest wood, CH	11.69	50%	5.84	1.78	2.21	2.46%
Ethanol, Sugar cane, BR	-	-	-	0.94	1.17	1.30%
Palm-ME, Indonesia	-	-	-	0.06	0.09	0.10%
BTL, forest wood, RER	-	-	-	2.42	3.27	3.63%
Electric, CoGen6400 kWh, CH	11.69	50%	5.84	1.79	3.96	4.41%
Electric, PV-mix, CH	-	-	-	8.94	19.73	21.95%
Total	50.58	52%	26.48	63.62	89.89	100.0%

The utilization of the additional residue potential is increased to 50% for manure, 70% for biowaste and 70% for waste wood. Half of the additional forest wood potential is used for the production of SNG. The remaining forest wood potential (5.84 PJ) is used in co-generation units for the production of heat and electricity (1.78 PJ). All those numbers are compatible with the Swiss energy perspective where 15 PJ of Biofuels are predicted for 2035 in scenarios III and IV (BFE 2007).

The system scenario "challenges 2030" assumes 3.9 EJ/a global biofuels production in 2030 which is split using the same shares as for the baseline into 3.1 EJ/a for bioethanol and 0.8 EJ/a for biodiesel. Bioethanol trade would be 10% of global production in 2030. Biodiesel trade as Palm-ME from Indonesia would be 21.6 PJ in 2030. In addition, cellulosic ethanol would be traded at 16% of global production in 2030. Like in 2015, Swiss import potentials would be 0.3% of global biofuels trade. Important drivers of considerable global trade of second-generation biofuels are assumed to be in particular the US and EU man-

¹⁹ Food and Agricultural Policy Research Institute, Iowa/U.S.: <http://www.fapri.iastate.edu/outlook/2008/tables/14BiofuelsTables.pdf>

FAPRI is a joint effort of Iowa State University's Center for Agricultural and Rural Development (CARD) and the University of Missouri-Columbia.

dates, since current IEA analysis sees a shortfall in domestic production in both the US and EU that would need to be met with imports (IEA 2009). The IEA (2010) further assumes that regarding second-generation biofuels, this shortfall could be particularly favourable for Brazil and China, where pilot plants are already operating and infrastructure allows for biofuel exports. In other countries, like Cameroon and Tanzania, the IEA sees the lack of R&D activities combined with poor infrastructure and shortage of skilled labour form considerable obstacles to being able to profit from second-generation biofuel demand in the EU and US in the near future. Feedstock trade, however, could be an option for these countries to profit from a growing biomass market for second-generation biofuels outside their own borders, since requirements for financing and skilled labour are smaller (IEA 2010).

Under the boundary conditions of the scenario "Challenges" electric mobility will certainly play a role in the future. Forecasting the penetration rate of eMobility for the year 2030 is however difficult, as cost reductions and public acceptance are difficult to assess. Based on a recent study on the eMobility potential for Switzerland (ALPIQ 2009) we assumed that in 2020 10% and in 2030 50% of the sold cars are electric, which leads to the cumulated amount of 1.66 million electric cars in 2030. This would place an additional demand of 10.73 PJ electricity per year (for details see Annex) of which 1.79 PJ is covered by the mentioned co-generation of forest wood. The remaining 8.94 PJ are assumed to be covered by PV-systems. This appears to be feasible given that the potential for electricity from PV in 2035 is estimated up to 9.72 PJ (ETS 2009). Potential interactions among the different forms of renewable mobility (e.g., higher efficiency of ICE vehicles could damp the demand for electric vehicles) have been neglected in order to keep the assumptions simple and transparent.

4.3.1.4 System scenario "Unlimited Growth"

Based on the prior determined conditions, Table 47 shows the value chains, their respective potential and their contribution to the total amount of pkm derived for the scenario 'Unlimited Growth 2015' (for a definition of the scenario refer to Chapter 3.5.7).

Table 47: *Value chains included in the scenario Unlimited Growth 2015. The bold numbers represent the basis for the calculation (source: own depiction).*

Value chains	Potential = Feedstock			Potential = Fuel	Mobility	Share
	[PJ available]	[% used]	[PJ used]	[PJ used]	[Billion pkm/a]	[%]
Petrol, CH	-	-	-	103.36	85.92	95.57%
Methane, manure, CH	21.26	20%	4.25	1.49	1.24	1.37%
Methane, biowaste, CH	2.37	50%	1.18	0.47	0.39	0.43%
SNG, waste wood, CH	3.58	20%	0.72	0.22	0.18	0.20%
SNG, forest wood, CH	11.69	10%	1.17	0.36	0.30	0.33%
Ethanol, Sugar cane, BR	-	-	-	2.09	1.74	1.93%
Palm-ME, Indonesia	-	-	-	0.16	0.14	0.16%
Total	38.89	19%	7.32	108.13	89.89	100.0%

The utilization of the additional potential of wastes and residues is assumed to be 20% for manure (4.25 PJ), 50% for biowaste (1.18 PJ) and 20% for waste wood (0.72 PJ). Furthermore, 10% of the additional forest wood (1.17 PJ) is used for the production of SNG.

In this scenario merely sustainable biofuels are traded. Thus, the potential of global traded biofuels is shared between countries which have determined sustainability criteria. Currently it is Europe, the USA and Switzerland which have determined sustainability criteria for the imports of biofuels. Bearing this in mind, the current share of Switzerland at the total crude oil consumption of Europe and the USA (0.66%) is used to determine the foreign imports of ethanol from sugar cane (2.09 PJ) and palm methyl ester (0.16 PJ). In other words, the consumption share of Switzerland at the global biofuel market is assumed to be equal to its current share at the total crude oil consumption of Europe and the USA.

The system scenario “unlimited growth 2015” is oriented towards the IEA policy alternative scenario because import and use of 1st generation biofuels is high. For production in 2015 we used the baseline data as described above. Bioethanol trade would be 14% of global production in 2015. Biodiesel trade as Palm-ME from Indonesia would amount to 24.5 PJ in 2015.

Table 48 shows the value chains, their respective potential and their contribution to the total amount of pkm derived for the scenario ‘Unlimited Growth 2030’ (for a definition of the scenario refer to Chapter 3.5.7).

Table 48: *Value chains included in the scenario Unlimited Growth 2030. The bold numbers represent the basis for the calculation (source: own depiction).*

Value chains	Potential = Feedstock			Potential = Fuel	Mobility	Share
	[PJ available]	[% used]	[PJ used]	[PJ used]	[Billion pkm/a]	[%]
Petrol, CH	-	-	-	56.28	70.18	78.07%
Methane, manure, CH	21.26	50%	10.63	3.71	4.63	5.15%
Methane, biowaste, CH	2.37	70%	1.66	0.65	0.81	0.91%
SNG, waste wood, CH	3.58	100%	3.58	1.09	1.36	1.51%
SNG, forest wood, CH	11.69	100%	11.69	3.55	4.43	4.92%
Ethanol, Sugar cane, BR	-	-	-	6.53	8.15	9.06%
Palm-ME, Indonesia	-	-	-	0.25	0.34	0.38%
Total	38.89	71%	27.55	72.08	89.89	100.0%

The utilization of the additional potential of wastes and residues increases to 50% for manure (10.63 PJ), 70% for biowaste (1.66 PJ) and 100% for waste wood (3.58 PJ). Furthermore, 100% of the additional forest wood (11.69PJ) is used for the production of SNG.

The outlined foreign import of ethanol from sugar cane (6.53 PJ) and palm methyl ester (0.25 PJ) reflects a share of 0.66% at the total amount of global traded biofuels. Again, the consumption share of Switzerland at the global biofuel market is assumed to be equal to its current share at the total crude oil consumption of Europe and the USA, i.e. 0.66%.

System scenario “unlimited growth 2030” assumes 6.2 EJ/a biofuels production in 2030 which is split using the same shares as for the baseline into 5 EJ/a for bioethanol and 1.2 EJ/a for biodiesel. Bioethanol trade would be 20% of global production in 2030. Biodiesel trade as Palm-ME from Indonesia would be 38.6 PJ in 2030.

4.3.2 Sustainability assessment of scenarios

4.3.2.1 Substitution of fossil based mobility

Figure 99 compares the latter scenarios and the baseline (2010) on the basis of the amount of pkm driven per year in Switzerland.

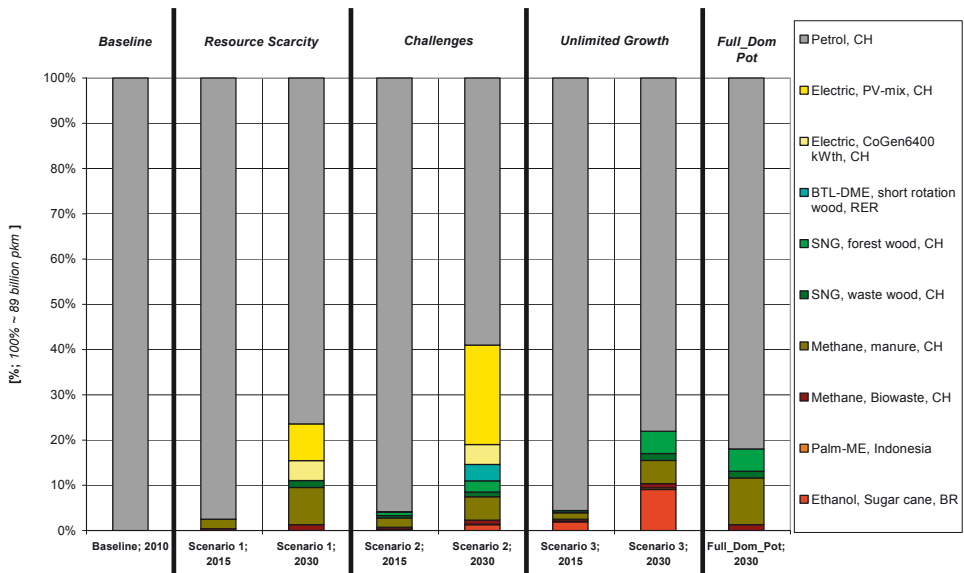


Figure 99: Contribution of pathways to the total amount of pkm per year.

In the baseline scenario the share of biofuels used for transport is not considered given that it is not relevant (approx. 0.02%) (BFE 2009). Consequently, the full amount of pkm is driven by petrol.

In scenario 1 (2015), with a fuel input of 2.70 PJ from alternative sources 2.51% of the fossil based mobility is substituted. In detail, the input of 6.38 PJ of manure and 1.18 PJ biowaste substitutes 2.06% and 0.43% of the total fossil mobility, respectively. The usage of 0.02 PJ forest wood for electricity production and e-mobility, in turn, substitutes 0.02%. In scenario 1 (2030), 13.07 PJ fuel energy from alternative sources substitute 23.58% of the fossil mobility. The main parts of the substitution result primarily from the contributions of electric mobility (12.53%) and mobility based on methane from manure (8.13%). Although the full potential of biowaste and waste wood is used for methane production (2.37 PJ and 3.58 PJ, respectively) its contribution to total mobility is rather small (1.51% and 1.29%, respectively).

In scenario 2 (2015), 4.47 PJ fuel from alternative sources substitutes 4.18% of the fossil based mobility. The lion's share comes from methane from manure (2.06%) and forest wood (0.82%). In this context, the substitution induced by imported 1st generation biofuels is minor, i.e. 0.28% by sugar cane ethanol and 0.03% by PME. This is also the case for electric mobility (0.05%). This changes in scenario 2 (2030) where electric mobility substitutes 26.36% of the fossil based mobility. The main reason for this is the high conversion efficiency inherent to both the conversion and the use phase of the electric mobility pathway. For example, the use of 5.84 PJ forest wood for electric mobility substitutes 4.41% of the fossil mobility, whereas the equivalent input used for SNG production substitutes 2.46%. In addition it is the import of BTL and the domestic utilization of manure which decreases fossil based mobility within this scenario (3.63% and 5.15%, respectively). All in all, a fuel input of 21.06 PJ from alternative sources substitutes 40.97 % of the fossil mobility.

The total substitution of fossil based mobility in scenario 3 (2015) amounts to 4.43% with the main part coming from methane from manure (1.37%) and ethanol from sugar cane – importing 2.09 PJ sugar cane ethanol from Brazil substitutes 1.93% of the mobility in Switzerland. In scenario 3 (2030), 6.53 PJ of imported ethanol substitute 9.1% of the fossil based mobility. In addition to the contributions from ethanol, it is methane from manure, SNG from forest wood and SNG from waste wood which substitute most of the fossil mobility (5.15%, 4.92% and 1.51%, respectively). In sum, using 15.79 PJ fuel energy from alternative sources substitute 21.93% of the fossil mobility.

The last bar shows the possible substitution when the full domestic potential of feedstock is used for biofuel production. The lion's share of the substitution is caused by methane from manure (10.31%) and SNG from forest wood (4.92%). The full domestic potential of SNG from forest wood and methane from biowaste, in turn, substitute merely 1.51% and 1.29%, respectively. In sum, using 38.89 PJ feedstock (transformed to 13 PJ biofuel) substitutes 18.03% of the fossil mobility.

On the basis of the scenario 2 (2030) Figure 100 shows the influence of an increased fuel consumption efficiency of the Swiss passenger car fleet on the substitution of fossil based mobility. The first bar reflects the consumption of 8 l petrol per 100 km driven, i.e. the average consumption which was applied in the original scenario analysis for the whole passenger car fleet.

Based on the decrease in the fuel consumption from 8 l to 3 l per 100km, the substitution of fossil based mobility increases from 33.62% to 45.36%, respectively. The share of electro mobility stays constant with 26.36% in all analysed alternatives, but the share of biofuels at the total substitution increases from 7.26% to 19%.

This highlights one essential role of an increased vehicle efficiency – a bisection of the average fuel requirement in 2030 would imply that the same amount of biofuel can substitute double the amount of fossil mobility.

It must be noted that the fuel consumption of 3 l/100km represents the lowest possible fuel consumption for combustion engines and is not assumed to be realistic for the whole Swiss passenger car fleet. However, according to CONCAWE an average fuel consumption of 4.1 l per 100 km is possible until 2025.

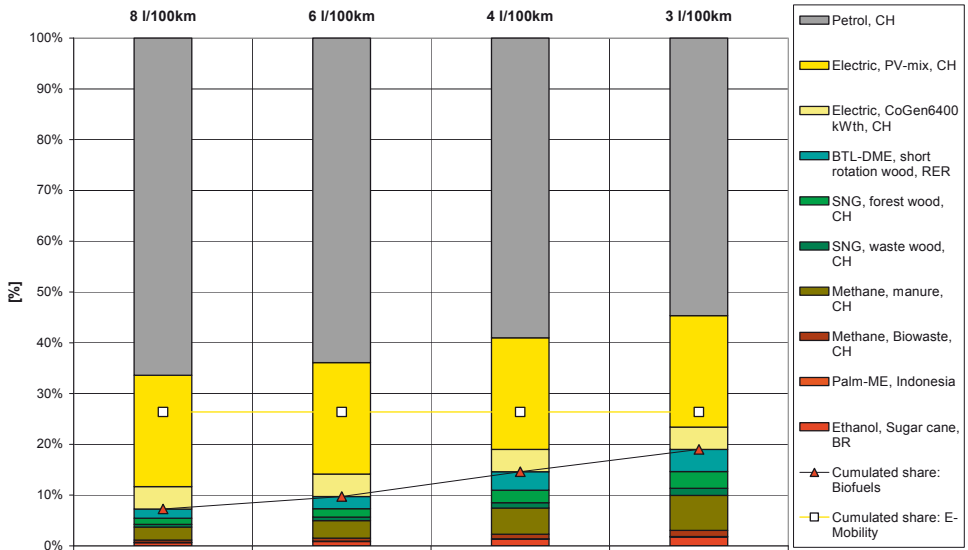


Figure 100: Influence of efficiency gain (in the fuel requirement per pkm) on the total amount of pkm substituted.

As mentioned prior, we assumed an average fuel consumption of 6 l per 100 km for the scenarios (2015) and of 4 l per 100 km for the scenarios (2030).

4.3.2.2 Benefits resulting from alternative mobility

GHG benefits

Figure 101 shows the benefits resulting from the implementation of the respective value chains in comparison to the baseline (2010) with focus to GHG emissions. The GHG benefit is calculated by multiplying the difference between the GHG emissions of a specific value chain and the fossil reference with the amount of pkm driven by a specific value chain. In other words, the outlined benefits are a function of (i) the amount of pkm driven with the fuel potential of a given value chain and (ii) the net benefit of an alternative pathway in comparison to the fossil reference.

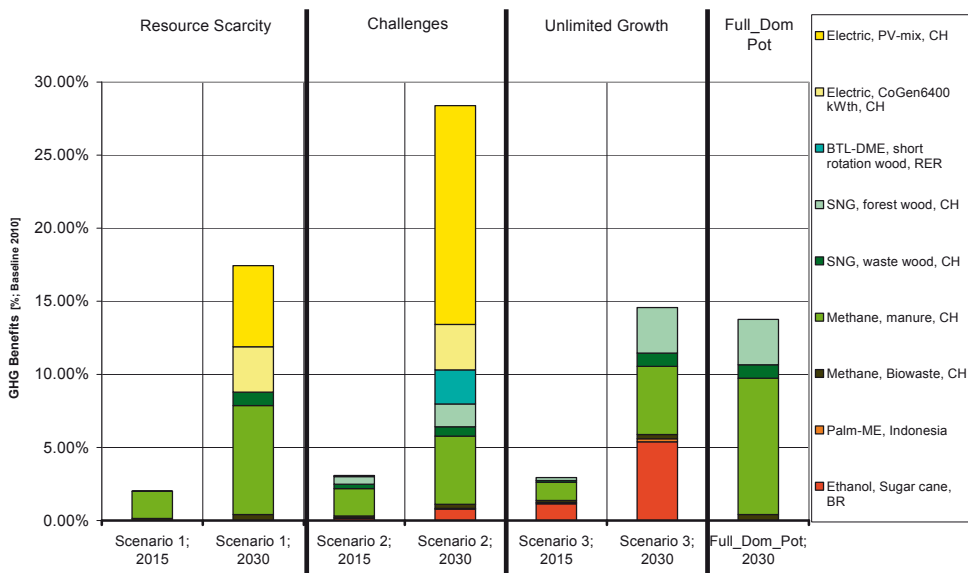


Figure 101: Benefits associated with the value chains per scenario with focus to SP in percent (source: own depiction).

In scenario 1 (2015), most of the GHG benefit is caused by methane from manure (1.87%) and methane from biowaste (0.14%). Within scenario 1 (2030) the main GHG benefits result from methane from manure (7.46%), followed by electric mobility PV (5.54%), electric mobility co-generation (3.11%), SNG waste wood (0.92%) and methane from biowaste (0.41%). All in all, the total benefits amount to 17.44%. In other words, scenario 1 (2030) causes only 83.66% of the GHG emission related to the baseline (2010).

The total GHG benefit in scenario 2 (2015) (3.08%) are caused by 1.87% methane from manure, 0.52% SNG from forest wood, 0.31% SNG from waste wood, 0.17% ethanol from sugar cane, 0.14% methane from biowaste, 0.04% BTL from forest wood Europe, 0.04% electro mobility from co-generation and 0.02% PME. In scenario (2030) the GHG benefit amount to 28.10% with the main part resulting from electric mobility, i.e. 14.97% for electric mobility from PV and 3.11% for electric mobility from co-generation, respectively. The remaining pathways cause a benefit of 10.31%.

In scenario 3 (2015) it is the benefit of methane from manure (1.24 %), ethanol from sugar cane (1.15%), SNG from forest wood (0.21%), methane from biowaste (0.14%), SNG from waste wood (0.12%) and PME (0.09%) which add up to a total GHG benefit of 2.95%. The total GHG benefit in 2030 (14.57%) is mainly caused by ethanol from sugar cane (5.39%), methane from manure (4.66%) and SNG from forest and waste wood (4.03%).

The full domestic potential (2030) shows a total GHG benefit of 13.76%. Major benefits result from methane from manure (9.33%). This is a result of its high feedstock potential and its low GHG emissions. SNG from forest and waste wood causes a benefit of 4.03%, whereas biowaste contribute with 0.41%.

SP benefits

Figure 102 shows the benefits as regards the sustainability potential (SP) resulting from the implementation of the respective value chains in comparison to the baseline (2010). As with GHG emissions, the outlined benefits are a function of (i) the amount of pkm driven with the potential of a value chain and (ii) the benefit of an alternative value chain in comparison to the fossil reference.

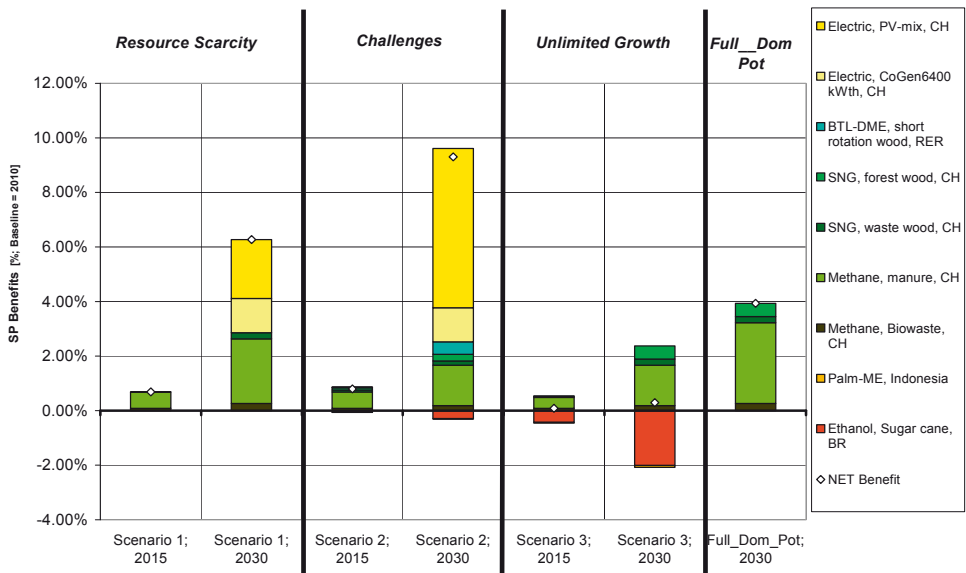


Figure 102: Benefits associated with the value chains per scenario with focus to SP in percent (source: own depiction).

In general, the net SP benefit per scenario is much smaller than the net GHG benefit given that the SP includes the perception of numerous indicators.

For the scenarios (2015) the net benefit as regards the SP is rather small, i.e. 0.69%, 0.80% and 0.09% for scenario 1, 2 and 3, respectively. The reason for this is the short time period for implementation. The SP benefit related to the scenarios (2030) is much higher, i.e. 6.27%, 9.30% and 0.29%.

In scenario 1 (2030) it is primarily the substitution induced by electro mobility from PV (2.16%), electro mobility from co-generation (1.25%) and methane from manure (2.37%) which increases the SP benefit.

Most of the benefits in scenario 2 (2030) result from electro mobility from PV (5.83%), electro mobility from co-generation (1.25%) and methane from manure (1.48%). The remaining value chains contribute merely with 0.73% although their cumulated fuel input amount to 6.62 PJ. The reason for this is the negative SP benefit associated with ethanol from sugar cane and PME. In comparison, the SP benefit associated with electro mobility (7.09%) results from the fuel (electricity) input of 10.73 PJ. The reason for this high difference is

grounded in the fact that in comparison to the fossil references electric mobility has one of the highest SP and the highest transformation efficiency.

The net SP benefits outlined for scenario 3 (2030) is primarily a result of the contributions of methane from manure (1.48%), methane from biowaste (0.18%) and SNG from forest and waste wood (0.48% and 0.23%, respectively). The import of 6.53 PJ ethanol and 0.25 PJ PME contribute negative with -2.01% and -0.07%, respectively given that both pathways have a lower SP than petrol.

With a fuel input from alternative sources of 13.00 PJ, the scenario Full_Dom_Pot (2030) shows a net SP benefit of 3.93%. The lion's share of this benefit comes from methane from manure (2.96%) and SNG from forest and waste wood (0.23% and 0.48%, respectively).

4.3.2.3 Benefits of biofuels in an overall context

In order to emphasize the benefits of biofuels we excluded so far the important influence of the following factors:

- (i) the benefits for fossil mobility resulting from an advanced vehicle efficiency,
- (ii) the impact resulting from the predicted rise in domestic mobility, and
- (iii) the impacts resulting from the expected pejoration of fossil fuels.

Regarding (i), so far we only considered the benefits of advanced vehicle efficiency for biofuels, i.e. that the same amount of biofuel in 2010 can substitute double the amount of fossil mobility in 2030. However, an increase in vehicle efficiency will also significantly affect the impacts associated with the fossil mobility given that until 2030 the amount of kilometre which can be driven per unit fuel input is assumed to double. In other words, to drive the same amount of kilometres only half the amount of petrol/diesel is required. Consequently the cumulated environmental impact associated with the production and import of petrol/diesel is reduced by approx. 50%. In addition, the emissions related to use of petrol/diesel in combustion engines will half. Both effects were considered with respect to GHG emissions, i.e. the GHG intensity of the fossil pathway was calculated considering both effects. An average fuel consumption of 6 l/100 km (scenarios [2015]) results a GHG emission reduction of approx. 21%, whereas an average fuel consumption of 4 l/100 km results a reduction of approx. 42% (scenarios (2030)). For the SP, however, we estimated the benefit using half the reduction calculated for the GHG emission (10.5% for 2015 and 21% for 2030, respectively) given that calculation of the possible reduction would have required the re-evaluation of the relevant petrol pathways for all indicators related to the SPA.

As regards (ii) (INFRAS 2004) predicts an increase of the mobility in Switzerland (total vkm driven by passenger cars) until 2030. In detail, in comparison to our baseline scenario (2010) the increase in mobility predicted by (INFRAS 2004), amounts to 4.04% for the scenarios (2015) and 16.68% for the scenarios (2030). In order to determine the associated impacts, the vehicle kilometers per pathway are multiplied with the respective impacts (GHG emissions and SP) at the respective time the scenario refers to.

With respect to (iii) the energy return per unit energy invested for crude oil will decrease given that we no longer find large, cheap and easy to exploit reserves and that oil production is moving to more remote and challenging areas (Cellier 2009; Gagnon, Hall et al. 2009). In other words, the energy requirements per unit of crude oil extracted is expected to increase. This, in turn, would increase the GHG emissions related to oil based fuels in

2030. In order to show the impact of a possible increase, we used the current impacts (GHG emissions and SP) of petrol produced from crude oil in Nigeria given that this crude oil source causes the highest impacts from all available alternatives. Compared to the average petrol mix CH, the decrease in the environmental impacts of petrol in 2030 amounts to -11% for GHG emissions and -13% for the SP.

GHG emissions

Figure 103 shows the scenario related benefit for GHG emission outlined in Figure 101 in the context of the above determined influencing factors.

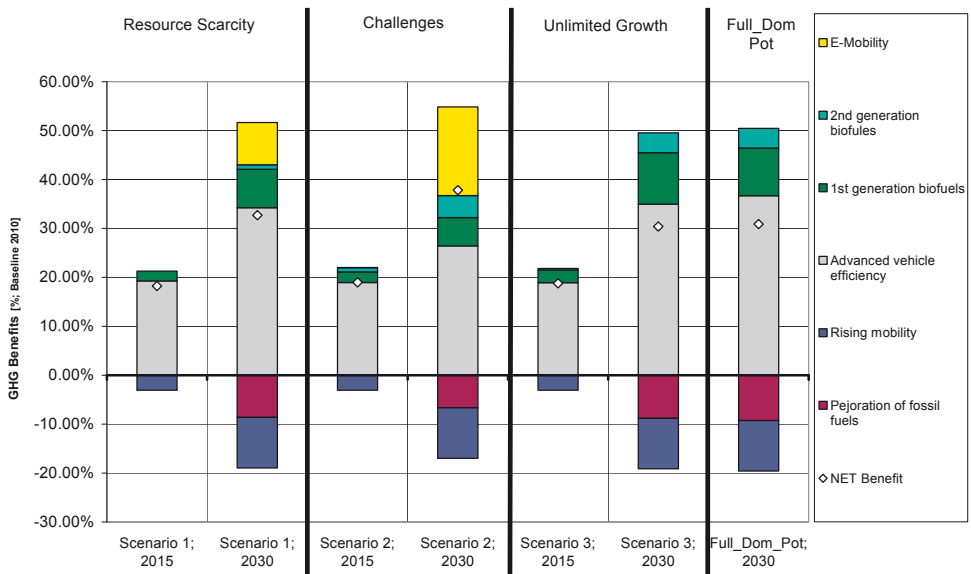


Figure 103: Benefits associated with the value chains per scenario with focus to GHG emissions in percent using 2010 as the baseline (source: own depiction).

Comparing across the scenarios, the net GHG benefit amount to 17.4% and 25.2% in scenario 1, 18.2% and 30.1% in scenario 2, 18.0% and 22.9% in scenario 3 and 23.4% in the Full_Dom_Pot scenario.

The GHG benefit associated with the influence of the advanced vehicle efficiency on fossil mobility is the most dominating factor. This becomes apparent when the benefits related to the advanced vehicle efficiency would be excluded. In this case, except for the scenario 2 (2030), the net benefit of all assessed scenarios would be zero or even negative. The GHG benefit differs based on assessment time (2015 or 2030, respectively) and the amount of fossil mobility substituted, i.e. as lower the amount of fossil mobility substituted as higher is the associated GHG benefit. For the scenarios (2015) the benefit ranges from 18.90% (scenario 3) to 19.28% (scenario 1). For the scenarios (2030) the GHG benefit ranges from 26.44% (scenario 2) to 36.71% (Full_Dom_Pot scenario).

The negative benefit related to the projected increase in mobility always amount to -3.06% for the scenarios (2015) and to -10.33% for the scenarios (2030). However, it must be noted that this factor strongly depend on the assumed vehicle efficiency. If no increase in vehicle efficiency will take place the negative contribution of this factor would increase to -3.8% for the scenarios (2015) and -17% fro the scenarios (2030).

The pejoration of fossil fuels is only considered for the scenarios (2030). It contributes negative with -8.63%, -6.66% and -8.81% for scenario 1, 2 and 3, respectively – as lower the amount of fossil mobility substituted as higher the negative contribution.

In sum, the GHG benefits associated with 1st and 2nd generation biofuels are not sufficient to overcompensate the cumulated negative impacts which will result from (i) the predicted increase in mobility and (ii) the expected pejoration of fossil fuels. This holds true for most scenarios even though the benefits from electric mobility are taken into account. This, in turn, emphasizes the importance of vehicle efficiency gains which do not only increase the substitution potential of biofuels but also significantly reduce the GHG intensity of the fossil mobility.

Sustainability Potential

Figure 104 shows the scenario related benefit for SP outlined in Figure 102 in the context of the above determined influencing factors.

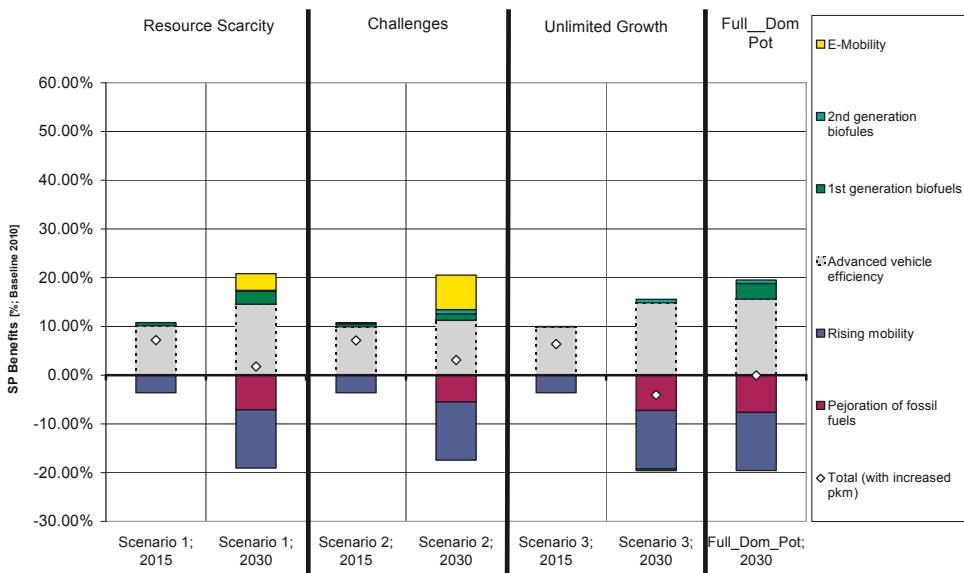


Figure 104: Benefits associated with the value chains per scenario with focus to the SP in percent using 2010 as the baseline (source: own depiction).

Comparing across the scenarios, the net SP benefit amount to 7.2% and 16.3% in scenario 1, 17.1% and 14.3% in scenario 2, 16.3% and 10.8% in scenario 3 and 15.56% in the Full_Dom_Pot scenario.

As with GHG emissions, the SP benefit associated with the influence of the advanced vehicle efficiency on fossil mobility is the most dominating factor. This becomes apparent when the benefits related to the advanced vehicle efficiency would be excluded. In this case the net benefit of all assessed scenarios would be negative. The SP benefit differs based on assessment time (2015 or 2030, respectively) and the amount of fossil mobility substituted, i.e. as lower the amount of fossil mobility substituted as higher is the associated SP benefit. For the scenarios (2015) the benefit ranges from 9.90% (scenario 3) to 10.1% (scenario 1). For the scenarios (2030) the SP benefit ranges from 11.24% (scenario 2) to 15.6% (Full_Dom_Pot scenario).

The negative benefit related to the projected increase in mobility always amount to -3.60% for the scenarios (2015) and to -11.95% for the scenarios (2030). However, it must be noted that this factor strongly depend on the assumed vehicle efficiency. If no increase in vehicle efficiency will take place the negative contribution of this factor would increase to -4% for the scenarios (2015) and -15% for the scenarios (2030).

The peioration of fossil fuels is only considered for the scenarios (2030). It contributes negative with -7.11%, -5.49% and -7.26% for scenario 1, 2 and 3, respectively – as lower the amount of fossil mobility substituted as higher the negative contribution.

In sum, the SP benefits associated with 1st and 2nd generation biofuels are not sufficient to over-compensate the negative impact of either (i) the predicted increase in mobility or (ii) the expected peioration of fossil fuels. Even though the benefits from electric mobility are taken into account the cumulated impact of both dominates. This, in turn, emphasizes the importance of vehicle efficiency gains which do not only increase the substitution potential of biofuels but also increases the SP of the fossil mobility.

4.3.3 Scenario results for global land use

4.3.3.1 Global Land Use of Agriculture

Based on the scenario the assumptions made to account for the indicator results for “Global Land Use Agriculture – GLUA” are summarized in Table 49.

Table 49: *Scenario-related assumptions relevant for agricultural production.*

	Reference	Scenario 1 Resource scarcity (A)	Scenario 2 Challenges (B)	Scenario 3 Unlimited growth (C)
	constant per capita	constant per capita	constant per capita	constant per capita
Nutrition	no change in composition	more crop products	more white meat but constant amount of production	increasingly meat in production and consumption; no competition with feedstock
Population	medium scenario A-00-2005	medium scenario A-00-2005	medium scenario A-00-2005	medium scenario A-00-2005
Domestic agriculture	trends	conversion pastures to cropland (less livestock)	food crops and farm animals; hardly any feedstocks for biofuels anymore	land use optimised for farm animals; hardly any feedstocks
Productivity domestic	trends (=constant)	increasing at 1% p.a. on average	increasing for animal production due to shift to white meat	increasing at 1% p.a. on average
Productivity global	same as domestic	same as domestic	same as domestic	same as domestic
SVG in %	58.5 for status quo; calculated: 60 in 2015, 61 in 2030	65% (2015); 80% (2030)	constant at 60%	constant at 60%
Bioenergy	trends	mainly from residues, residual materials, waste, forest	subsidizing sustainable bioenergy, residuals and waste utilisation, forest	use coupled to strong sustainability criteria
		2nd generation	new technologies	Wood, waste, liquid manure (high) using SNG technologies for energy
		no imports	almost no 1st generation	1st generation dominates
		no domestic energy plants	high imports of more sustainable biofuels and biomass to supply CH capacities	high import potentials but only partly used; more sustainable imports
Biomaterials	trends	trends	trends	trends

Note: SVG = Self-supply ratio for nutrition

The system scenario results for 2015 and 2030 as compared with the status quo in 2006 (described in chapter 3.2.2) and the reference scenario results are given in Table 50 and illustrated in Figure 105. The Swiss consumption of agricultural goods requires globally about 626 m² more agricultural land per capita than it is available per capita of the World population (refer to line “Swiss minus World” in Table 50). Thus Switzerland in 2006 had required 27% more cropland on the global scale than was available per person of the world population (refer to line “GLUA CH in % of GLUA World”). This indicates the contribution to the expansion of global cropland (see also below).

The reference is building on continuing trends, not compensated by increasing productivities²⁰, and leads to more global agricultural land requirements than for the status quo level, and well above the per capita cropland availability of the world population. Currently, the Swiss economy is supplied by less than two thirds from its own agricultural area (Self-supply ratio GLUA = 63%; see Table 50). In the reference case, this is not expected to change. In scenario 1, the self-supply ratio in terms of land use may increase up to 88%. In scenario 2, the increase would be lower, up to 74%, whereas in scenario 3, there would be hardly any difference to the reference development.

- Scenario 1: The shift towards more plant based nutrition, accompanied by productivity increases, leads to less global agricultural land requirements below the status quo level and in 2030 even to less land requirements than in the reference case for food consumption of the world population.

²⁰ The Swiss domestic productivity trends 2000–2006 do not imply any significant increases but rather slight decreases.

- Scenario 2: A shift towards more white meat, but no productivity increases, leads also to less global agricultural land requirements below the status quo level, but still above the per capita availability of the world population.
- Scenario 3: A shift towards more meat consumption, largely compensated by productivity increases, still leads to more global agricultural land requirements than for the status quo level, and well above the per capita availability of the world population. The result is similar to the reference case at continuing trends and no productivity increases.

Table 50: *Swiss global agricultural land requirements in m² per person and in comparison with the world population's availability of cropland.*

GLUA SWISS in m2 per person and year									
	Status Quo	Reference		Scenario 1 Resource scarcity		Scenario 2 Challenges		Scenario 3 Unlimited growth	
	2006	2015	2030	2015	2030	2015	2030	2015	2030
Plant based nutrition	1'225	1'225	1'225	1'152	1'102	1'225	1'225	987	688
Animal based nutrition	1'733	1'733	1'733	1'520	848	1'386	1'253	2'026	2'120
Material use	23	51	87	51	87	51	87	51	87
Energetic use	2	3	5	0	0	3	25	19	48
TOTAL	2'983	3'012	3'051	2'722	2'037	2'666	2'590	3'083	2'944
Self-supply ratio GLUA	63%	63%	62%	68%	88%	72%	74%	62%	66%
GLUA World	2'357	2'244	2'229	2'244	2'229	2'244	2'229	2'244	2'229
Swiss minus World	626	768	822	479	-192	422	361	840	715

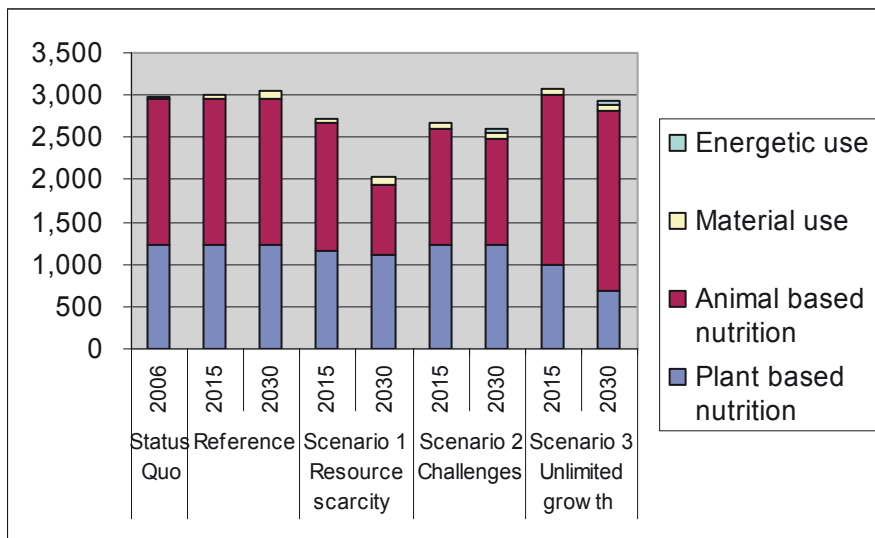


Figure 105: *Swiss global agricultural land requirements in m² per person.*

4.3.3.2 Change in global use of cropland

The system scenario results for 2015 and 2030 as compared with the reference scenario results are given in Table 51 and illustrated in Figure 106. In the reference case as well as in the scenario “unlimited growth” Switzerland would require more cropland than at status quo, and thus contribute to further expansion of global cropland.

Factors contributing to reduced cropland requirements like a shift towards more plant based nutrition, accompanied by productivity increases as in scenario “resource scarcity” lead to less global agricultural land requirements below the status quo level. This is also the result of a shift towards more white meat, even at no productivity increases, in scenario “challenges” which leads also to less global agricultural land requirements below the status quo level. Such alternative development paths have the potential to reduce global cropland requirements and counteract a development towards global expansion of cropland.

Table 51: *Swiss additional global cropland requirements in 1000 ha as compared with the status quo in 2006.*

Change in global use of cropland								
	Reference		Scenario 1 Resource scarcity		Scenario 2 Challenges		Scenario 3 Unlimited growth	
	2015	2030	2015	2030	2015	2030	2015	2030
additional area to status quo in 1000ha	125	242	-103	-583	-147	-133	181	155

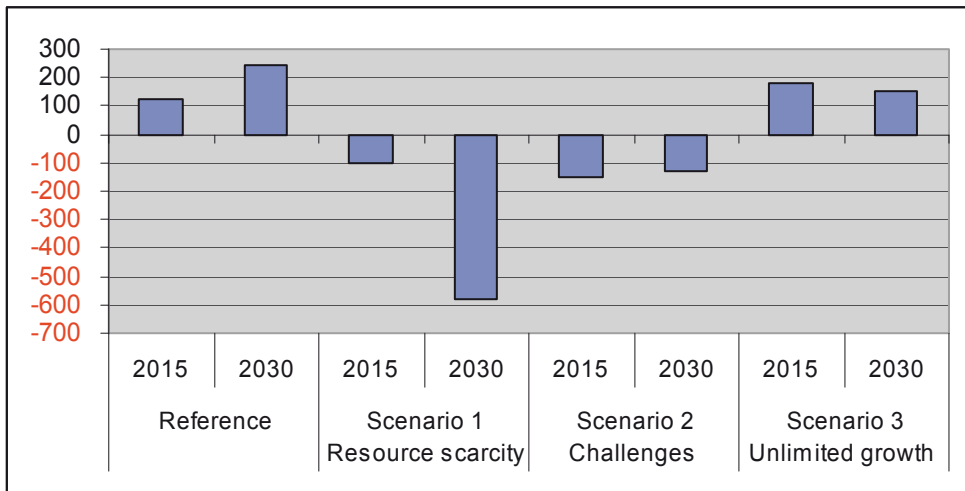


Figure 106: *Swiss additional global cropland requirements in 1000 ha as compared with the status quo in 2006.*

4.3.3.3 Global Land Use of Forestry

Based on the scenario outlines, the assumptions made to account for the indicator results for “Global Land Use of Forestry – GLUF” are summarized in Table 52.

Table 52: *Swiss global forestry land requirements in m² per person and in comparison with the world population’s availability of forest land.*

	Reference	Scenario 1 Resource scarcity	Scenario 2 Challenges
Population	medium scenario A-00-2005	medium scenario A-00-2005	medium scenario A-00-2005
Domestic forest land	trends	trends	half trend
Domestic forest harvest	trends	area * productivity	area * productivity
Domestic forest land for export	median for 2000-2007; productivity like domestic	median for 2000-2007; productivity like domestic	median for 2000-2007 multiplied with ratio of domestic land scenario2 / domestic land baseline; productivity like domestic
Productivity domestic	derived: 62% of sustainable yield in 2015; 75% of sustainable yield in 2030	80% of sustainable yield in 2015; 100% sustainable yield in 2030	70% of sustainable yield in 2015; 87.5% sustainable yield in 2030
Imports	constant 2007, productivity constant over time	constant 2007, productivity constant over time	trends (increasing); productivities increasing like domestic
Exports (excl. from domestic land)	constant 2007, productivity constant over time	constant 2007, productivity constant over time	constant 2007, productivity constant over time
SVG in %	derived	derived	derived
Bioenergy	domestic current use ie. 56% of potential (TA SWISS); productivities like domestic	100% domestic potential (TA SWISS); productivities like domestic	80% of domestic potential (TA SWISS); productivities like domestic
Biomaterials	as difference between total and bioenergy (and exports for biomaterials from domestic)	as difference between total and bioenergy (and exports for biomaterials from domestic)	as difference between total and bioenergy (and exports for biomaterials from domestic)

The system scenario results for 2015 and 2030 as compared with the status quo in 2006 and the reference scenario results are given in Table 53 and illustrated in Figure 107. The Swiss consumption of forestry goods at status quo in 2006 requires globally about 3,500 m² less forestry land per capita than is available per capita of the World population (refer to line “Swiss minus World” in Table 3). Thus Switzerland in 2006 had required only about one third of the per capita forestry land on the global scale that was available per person of the world population (refer to line “GLUF CH in % of GLUF World”).

All scenarios, as well as the status quo, show significantly lower per capita forest land requirements than per capita on the global level. This is because Switzerland imports about 93% of its total forestry products from EU-27 (BAFU 2008) where productivities are similar high as in Switzerland and significantly higher than on the global average. Results are different if material flows (in m³) are accounted (see below).

- In the Reference scenario continuing trends lead to more global forestry land requirements than for the status quo level.
- Scenario 1: Increasing sustainable yields do not affect the total of GLUF as compared with the reference case, but only lead to a shift towards more land use for bio-energy relative to biomaterials.
- Scenario 2: Forest land requirements increase significantly versus the reference case. This is due to higher total forest biomass use and increasing imports.

Scenario 3: Forest land requirements are in between scenario 1 and 2 because the domestic potential for bio-energy is used to a less degree than in scenarios 1 and 2 and imports are lower as compared with scenario 2.

Table 53: *Swiss global forestry land requirements in m² per person and in comparison with the world population's availability of forest land.*

	Status Quo	Reference		Scenario 1 Resource scarcity		Scenario 2 Challenges		Scenario 3 Unlimited growth	
	2006	2015	2030	2015	2030	2015	2030	2015	2030
Biomaterials	1'146	1'322	1'412	1'130	1'266	1'686	2'617	1'521	2'032
Bioenergy	562	505	423	697	568	626	501	557	456
TOTAL	1'709	1'827	1'834	1'827	1'834	2'312	3'118	2'078	2'489
Self-supply ratio GLUF	83%	77%	78%	77%	78%	60%	44%	68%	57%
GLUF World	5'210	4'703	4'133	4'703	4'133	4'703	4'133	4'703	4'133
Swiss minus World	-3'501	-2'876	-2'299	-2'876	-2'299	-2'391	-1'015	-2'625	-1'645

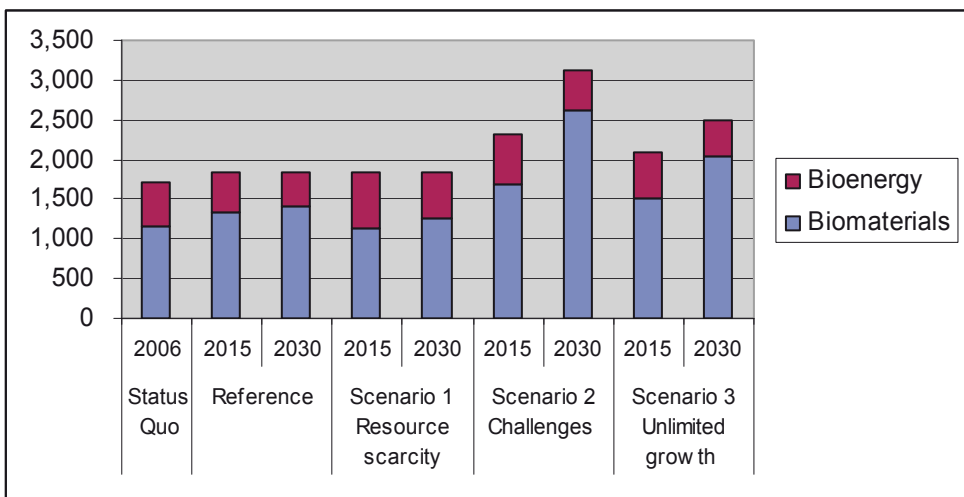


Figure 107: *Swiss global forest land requirements in m² per person.*

Table 54 shows the scenario results for material flows of forest biomass. In each systems scenario studied, the Swiss global consumption is higher than the estimated sustainable NAI (net annual increment) per capita of the global population. Only for the status quo 2006 (data from BAFU) was Swiss consumption of forestry biomass within the global average availability per person. This indicates future risks of over-proportional requirements of Switzerland for global forestry resources.

Global reference values were calculated assuming no net increase of global forest area and productivities, thus mirroring the effects of population growth only. This should be subject to further analysis in future studies.

The self-supply ratio (SSR) of Switzerland for forest biomass was at 91% in 2006 what underpins the importance of the country's forestry sector. SSR would not change much in the reference scenario. Due to maximum sustainable use of domestic forest biomass in scenario 1, SSR would even go up to almost 100%. Contrary, reduced use of domestic sustainable potentials at increasing overall demand in scenarios 2 and 3 would lead to significant reductions of the self-supply ratio to levels between two fifths and two thirds of the domestic consumption.

Table 54: *Swiss global forestry biomass requirements in m³ per person and in comparison with the world population's availability of forest biomass.*

MFA-forestry SWISS in m3 per person and year									
	Status Quo	Reference		Scenario 1 Resource scarcity		Scenario 2 Challenges		Scenario 3 Unlimited growth	
	2006	2015	2030	2015	2030	2015	2030	2015	2030
Biomaterials	0.54	0.66	0.77	0.61	0.78	1.20	2.33	1.06	1.75
Bioenergy	0.30	0.29	0.28	0.51	0.50	0.41	0.40	0.36	0.35
TOTAL	0.84	0.95	1.05	1.12	1.28	1.62	2.73	1.43	2.10
Self-supply ratio MFA	91%	85%	90%	93%	98%	57%	40%	64%	52%
Sustainable NAI World	0.80	0.72	0.63	0.72	0.63	0.72	0.63	0.72	0.63
Swiss minus World	0.04	0.23	0.41	0.40	0.64	0.89	2.10	0.70	1.47

4.3.4 Conclusions

In sum, the boundary scenarios have a significant impact on the future development of the biofuels second generation. In the case of resource scarcity in the year 2030 about 84% of all the biomass potentially available within Switzerland will be used for biofuel production. This amount is slightly reduced in the case of the system scenario unlimited growth to 71% and in the scenario challenges to 52%.

However, even in the most optimistic scenario only 7% of the fossil fuel based mobility could be replaced by biofuels second generation and only 7% by biofuels first generation, whereas electric mobility could provide up to 26%. In other words, bioenergy-based mobility is restricted to less than 15% of individual mobility in Switzerland in 2030 even though a vehicle efficiency of 4.0 l/100 km is taken into account. Without the technical advances in vehicle efficiency (VE), however, bioenergy-based mobility in Switzerland is restricted to clearly less than 10% in 2030.

Table 55 summarizes the prior analyses on the basis of the input of 1 PJ fuel and the related benefits categorized for 1st and 2nd generation biofuels as well as electro mobility.

Table 55: *Fuel input, the coupled mobility substitution and the resulting benefit (SP and GHG) for 1st and 2nd generation biofuels as well as electro mobility (source: own depiction).*

Criteria	Unit	Scenario 1; 2030			Scenario 2; 2030			Scenario 3; 2030		
Technology		1 st	2 nd	E-mobility	1 st	2 nd	E-mobility	1 st	2 nd	E-mobility
Fuel used	[PJ]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-
Share at total mobility	%	1.39%	1.39%	2.46%	1.39%	1.44%	2.46%	1.39%	1.39%	-
Share at total mobility (without VE)	%	0.69%	0.69%	2.46%	0.69%	0.72%	2.46%	0.69%	0.69%	-
Benefit SP	%	0.38%	0.21%	0.67%	0.25%	0.17%	0.66%	-0.04%	0.15%	-
Benefit SP (without VE)	%	0.19%	0.10%	0.67%	0.13%	0.09%	0.66%	-0.02%	0.08%	-
Benefit GHG	%	1.14%	0.84%	1.70%	1.08%	0.91%	1.69%	0.95%	0.87%	-
Benefit GHG (without VE)	%	0.57%	0.42%	1.70%	0.53%	0.45%	1.69%	0.47%	0.43%	-

Comparing between 1st and 2nd generation biofuels, with the input of 1 PJ fuel approximately the same amount of fossil mobility can be substituted. But except for scenario 3 (benefit SP), 1st generation biofuels show a higher benefit (SP and GHG) per PJ fuel invested than 2nd generation biofuels. This results from the fact that most of the contributions of 1st generation biofuels come from wastes and residues which have a high SP and GHG benefit, respectively. Consequently, if the value chains based on waste and residues feedstocks are excluded from the analysis these pattern change, i.e. 2nd generation biofuels

show a better performance in particular for the SP benefit but also for the GHG benefit. In other words, when comparing 1st and 2nd generation biofuels whose feedstocks are produced with intention, 2nd generation biofuels shows a better performance.

However, Switzerland already uses global cropland above global average for its national consumption. This will not change due to biofuel use unless consumption of animal based diet is significantly reduced (as simulated in scenario 1 in 2030); therefore, any additional demand for crop based biofuels has to be seen critical. Similarly, according to preliminary estimates, Switzerland would consume Net Annual Increment of domestic and foreign forests above global average in all scenarios, with scenario 2 and 3 also significantly diminishing the self-supply ratio; therefore, an increasing demand for biofuels derived from increased wood imports would also be critical.

Table 55 depicts that the highest substitution potential per PJ fuel energy invested can be ascribed to electro mobility (2.46%). This is a result of its high energy conversion efficiency. Furthermore, electro mobility shows the highest benefit for SP and GHG per PJ fuel invested (0.67% and 1.7%, respectively). In this regard it must be noted that the exergy content, i.e. the amount of useful work embedded in the energy carrier, is much higher for electricity than for (bio)fuels. Moreover, it must be emphasized that the electricity source is most important for the performance of electro mobility, i.e. when the electricity comes from fossil sources the benefit trends to zero.

Overall, the scenario assessment emphasizes that technical advances in vehicle efficiency are most important not only to (i) increase the substitution potential of biofuels but also to (ii) increases the SP (and decrease GHG emissions) of the fossil mobility.

As regards (i), we assumed a vehicle efficiency of 6 l/100 km for 2015 and of 4 l/100 km for 2030. In other words, compared to 2010 the equivalent amount of biofuels can substitute double the amount of fossil mobility. As shown by Table 55, without this increase in vehicle efficiency the substitution potential and consequently the SP and GHG benefit of biofuels bisect. However, it must be noted that this outcome is only true, when assuming that 1 vehicle km driven with a biofuel substitute 1 vehicle km driven with a fossil fuel. This means that possible rebound effects induced by an increased vehicle efficiency are not included in our calculation, e.g. people drive more because they have less fuel expenditures per vehicle km. On the other hand, we didn't consider the benefit associated with the reduced biofuel requirement per vehicle km, i.e. the related reduction in GHG emissions and increase in the SP, respectively.

With respect to (ii) the main benefits associated with the increase in vehicle efficiency are related to the fossil mobility. Making the lion's share of the passenger car mobility more efficient causes a substantial reduction in GHG emissions and increases in the SP, respectively. The scenario analysis shows that without this benefit the assessed 1st and 2nd generation biofuels are not sufficient to over-compensate the negative impact of the predicted increase in mobility or the expected pejouration of fossil fuels.

The projected increase in mobility always amount to -10.33% for GHG emissions and to -11.95% for the SP. However, it must be noted that this factor strongly depend on the assumed vehicle efficiency. If no increase in vehicle efficiency will take place the negative contribution of this factor would increase to -17% for GHG emissions and -15% for the SP.

A decrease in the SP of petrol by 13% (and an increase in GHG emissions by 11%) would significantly reduce or even over-compensate the benefits associated with the implementation of alternative fuels. Given that it is not only the impact of the fuels consumed by pas-

senger cars (61%) which would increase but the impact of all crude oil based mobility in Switzerland the outlined negative impacts are higher than outlined in our scope.

In the light of both, the upscaling of alternative mobility options in a short period of time is most important, i.e. an alternative mobility should not only have a higher SP (and lower GHG emissions) than the fossil based mobility but should also provide enough energetic potential to displace great amounts of the fossil based mobility as soon as possible. In the meantime, increases in vehicle efficiency are the most important option to further increase the substitution potential of biofuels and to decrease the negative impacts of the fossil mobility.

5 SPOTLIGHTS

5.1 Future availability of cropland for biofuels (H. Schütz & S. Bringezu)

A key criterion for evaluating global resource use is the per capita availability of agricultural land. Of particular interest is the area of cropland, which encompasses arable land and permanent crops. On the one hand, this land provides the basis for plant derived nutrition for the world's population, and on the other its cultivation is associated with various environmental impacts and its extension competes with natural ecosystems. In 2004, global cropland was approximately 2,500 m² per person. Based on forecasts from the UN and FAO (2003, 2006) the world's population in 2030 will have increased by about 30% as compared to 2004, and the yields per hectare for cereals will have increased by about 29%, i.e. roughly keeping the same pace (Figure 108).

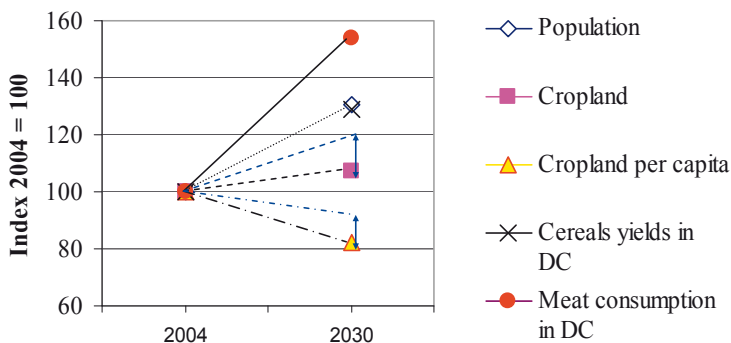


Figure 108: Global trends in agriculture (cropland, cropland per capita, cereals yields), population growth, and meat consumption in developing countries, 2004 to 2030. Arrows indicate expected range of change based on FAO projections (FAO 2003; FAO 2006; UN 2009).

Yield increases will probably not compensate for the growing and changing food demand, cropland will have to be expanded only to feed the world population. Data from the FAO show that in the period between 1961 and 2006 cereal yields rose, but that this increase in the last decade was weakened (Hazell and Wood 2008), so that an extrapolation of linear growth, or even higher increases in average yields, has to be treated with caution. Scenarios from IFPRI (Rosegrant, Cai et al. 2002) show that under unfavourable conditions in the water sector (scenario "water crisis") the global cereals supply per person would decline by 14 kg between 1995 and 2025 (or by 4.6%). On the other hand, a favourable sustainable water supply worldwide would lead to increases of 19 kg more cereals per person between 1995 and 2025 (plus 6.2%), and BAU development would result in a surplus of 17 kg per

person over the same period (plus 5.4%). Future developments in the agricultural sector thus range from declining to increasing per capita supply of the world's population with cereals. Part of the increase will be offset by the increasing demand for meat and dairy products in developing countries (see below).

In this context one should also consider the fact that yields on cropland cannot be increased indefinitely if ecological restrictions are taken into account. For example, even at maximised efficiency, fertiliser application and thus yield, may be limited due to the leaching of minerals into the groundwater and the resulting water quality problems. For instance, in the Mississippi drainage basin, increased corn acreage and fertiliser application rates, due to growing biofuel production, have been shown to increase nitrogen and phosphorus losses to streams, rivers, lakes and coastal waters, particularly in the Northern Gulf of Mexico and Atlantic coastal waters downstream of expanding production areas, leading to serious hypoxia problems (Donner and Kucharik 2008).

In 2030, only about 2,000 m² of cropland will be available per person in the world, even when considering the FAO forecasts of an absolute extension of cultivated area by 120 million ha (FAO 2003). This would mean, that per capita, one fifth less will be available than in 2004. As such, factors like consumption patterns (animal versus plant based diet) and yield increase will strongly effect the provision of the world's population with products from agriculture.

In reality, however, food demand is changing towards a higher share of animal based diets, particularly in developing countries where meat consumption was low. Meat consumption in developing countries will increase from 2004 to 2030 by 55%, while cereal consumption will increase by "only" around 28% (FAO 2006). Since the production of animal feed requires considerably more land than would be needed for a direct vegetarian diet of human beings, this development alone will significantly increase the pressure for the expansion of agricultural land at the expense of natural ecosystems. The extent of the increased land requirement for higher meat consumption as opposed to plant nutrition depends on the types of meats consumed, and on factors such as the yield of different feedstuffs and the efficiency of feed conversion. As a starting point for comparison, figures from Germany may be analysed, which reveal that consumption of animal based food per nutrition value (cal), requires a 4.8 times larger land area than the consumption of plant food (Busch 2008). It is also expected that in countries currently suffering from hunger, food consumption will rise significantly in the future, and thus further increase the demand for additional acreage requirements (for arable land and permanent crops), although this additional requirement can hardly be quantified (OECD 2008).

Consequently, the demand for nutrition alone puts growing pressure on the further expansion of cultivated land. The demand for biofuels as fuel crops will increase this pressure on the scarce agriculturally usable land.

The discussion so far has focused on cropland as intensively managed agricultural land in terms of arable land and permanent crops. Pastureland was not taken into account for data related to the world situation. The reason for this is that much global pastureland resembles semi-natural land instead, and is generally less extensively managed than cropland. More-

over, there is a controversy regarding the physical extension of global pastureland and a study by Ramankutty (2008) based on satellite data has claimed that significantly less area exists than had been previously suggested by FAO data. Nevertheless, future studies should also take into account the area of intensively managed pastureland for global supply with agricultural goods.

It is difficult to predict the overall effect of these factors regarding the global supply of food and non-food biomass. So far no explicit projection of global land use change induced by changing food demand seems to be available. From the Gallagher report, an estimated additional requirement of 144 to 334 Mha of global cropland for food in 2020 can be derived. Any further land requirements, for instance for fuel crops, will be added on top of this demand. In the future, factors such as increased land degradation and the impacts of climate change will affect average yields. Given these parameters, developed countries like Switzerland should aim to reduce their resource requirements in order to avoid conflicts, to mitigate land use competition and to pave the way for a more sustainable global resource management.

The potential development of 1st generation biofuels use with regard to global cropland requirements was studied by Ravindranath et al. (2009) based on six simple and robust scenarios for a 10% supply of global fuel demand in 2030. The authors assumed constant crop yields, considering the uncertainty of further increases and that the improvement of crop varieties and increased inputs might be balanced by the expansion of crops onto "marginal" lands, which will cause yields to decrease. Under each scenario, either jatropha, palm oil or soy bean would completely meet the projected demand for biodiesel, and maize or sugar cane would completely meet the projected demand for ethanol. The authors stressed that soy bean, maize and palm oil are also food crops, particularly in many developing country regions and thus, may have added constraint and a limited potential for meeting the biofuel demands. According to the estimates, the least amount of land would be required when palm oil and sugar cane were considered (118 Mha), whereas soy bean and maize crops would require 508 Mha.

According to Ravindranath et al. (2009), total land area required for producing biofuels to meet the 10% petroleum fuel substitution scenario would be equal to 3-15% of the permanent pastures. Permanent pastures may have previously avoided conversion to cropland because of their unsuitability for cropping due to infertile soils or the lack of precipitation. Consequently, the extent of area required may not reflect the likely land categories that will actually be used for producing biofuels. If, in contrast, cropland is used for biofuel production, the land area required could account for 8 to 36% of the current arable area. Furthermore, the authors regarded it quite likely that oil palm could replace wetlands and forests. Current rates of global deforestation are about 13 Mha per year (FAO 2006). If present trends continue, 286 Mha would be deforested by 2030. The biofuel land demand scenarios considered by Ravindranath et al. represent a land demand equivalent to 40 to 180% of ongoing deforestation. Thus, biofuels, depending on where the biomass is produced, could have globally significant impacts through land use change.

5.2 Land Use Impacts of Jatropha in Brazil – A Case Study (J. Baka and R. Bailis²¹)

According to a 2008 study of the global Jatropha market, Brazil is poised to become one of the world's top three cultivators of Jatropha by 2015 (GEXSI 2008). Based on company surveys and interviews with industry experts, the study's authors predict a near 75-fold increase in Jatropha cultivation between 2008 and 2015 from approximately 17,500 hectares (ha) to 1.3 million ha (GEXSI 2008). The main drivers of this massive scale-up are Brazil's biodiesel program and increased global demand for Jatropha, particularly from the aviation industry.

Hoping to match its success in establishing a domestic ethanol industry, in 2004, the Brazilian government enacted the National Program on Production and Use of Biodiesel (PNPB) to catalyze the biodiesel industry. The program established mandatory biodiesel blending targets of 2%, starting in 2008 and 5%, starting in 2013 (Pousa, Santos et al. 2007). Further, the program established a biodiesel Social Fuel Stamp (Selo Combustível Social) to promote the inclusion of small holders from poorer regions of the country. The program requires biodiesel producers to purchase certain percentages of their feedstocks from family farmers, varying from 10–50% depending on cultivation location. Additionally, the producers must sign commercial contracts with the farmers and provide technical assistance. By receiving the Stamp, producers gain the opportunity to participate in government-sponsored auctions in which Petrobras, the country's semi-public oil company, guarantees the purchase of biodiesel. As well, producers qualify for tax exemptions depending on the location of feedstock purchases, ranging from 4–12% of the commercial price of diesel (Garcez and Vianna 2009; Hall, Matos et al. 2009). Producers earn the largest tax exemptions by purchasing castor or palm feedstocks from family farmers in the North or Northeast, the poorest regions of the country. Although well intended, the Social Fuel Program has experienced a lack of demand and at present, Petrobras has waived its requirement to only allow producers who receive the Stamp participate in its auctions (Hall, Matos et al. 2009).

To date, Jatropha does not qualify for the Social Fuel Stamp because Jatropha is not recognized as a cultivar under the PNPB. However, the government's agricultural research agency, EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), is currently sponsoring research and development trials to evaluate the feasibility of using Jatropha for biodiesel production (Durães 2009). Additionally, the Brazilian Jatropha Grower's Association (ABPPM) has been established to further stimulate the industry and promote the inclusion of Jatropha in the government's biofuel programs.

Continued international demand is another factor promoting the Jatropha market in Brazil. Jatropha trees are capable of growing on marginal lands thus potentially avoiding competition with food production and reducing land use change impacts. As such, Jatropha has received increased attention from various governments, development agencies, biofuel roundtables and industries seeking to promote the use of sustainable biofuels. The aviation industry has been one of the key promoters as numerous airlines, starting with Virgin Atlan-

²¹ Yale School of Forestry and Environmental Studies

tic in February 2008, have conducted biofuel test flights using *Jatropha* (Hileman, Ortiz et al. 2009).

Within Brazil, stakeholders are particularly interested in situating *Jatropha* projects in the Center-west, North-east and South-east regions of the country because of favorable climatic conditions (GEXSI 2008). Based on our interviews with key stakeholders, companies are targeting regions with large amounts of degraded cattle pasturelands, specifically in the states of Tocantins, Minas Gerais and Bahia. At present, the *Jatropha* market is still in its infancy in Brazil and companies are engaged in a mix of plantations and contract farming operations to cultivate *Jatropha*. However, efforts are underway to mechanize *Jatropha* cultivation, particularly harvesting, in order to increase the scale of production and avoid Brazil's relatively high labor costs (US\$ 15 per day) and strict labor laws. If mechanization is successful, it will likely lead to an increase in number and size of *Jatropha* plantations to achieve economies of scale and reduce production costs.

During the summer of 2009, a research team from the Yale School of Forestry and Environmental Studies with funding from the Sustainable Aviation Fuel Users Group (SAFUG) surveyed *Jatropha* farmers in Minas Gerais to evaluate the potential land use change impacts of *Jatropha* cultivation (Figure 109). The team surveyed 58 total farmers (55 males and 3 females) in both Northern and Southern Minas Gerais (38 Northern, 20 Southern). The 58 farmers surveyed cultivated just over 87 ha with *Jatropha* with an average of 1.5 ha per farmer (Table 56). Figure 109: Map of survey sites. Although this is a small area under cultivation, it is important to reemphasize the young age of the *Jatropha* industry in Brazil on the whole.

Of the farmers surveyed, 23 continue to cultivate *Jatropha* while 35 have stopped growing *Jatropha*. We refer to these farmers in our analysis as participating and abandoned farmers, respectively. Farmers started planting trees between 2004 and 2008 with cultivation in Southern Minas starting earlier than in Northern Minas. At present, *Jatropha* trees for participating farmers are just under 3 years old and have thus not reached maturity as *Jatropha* trees typically take 3–4 years to achieve maximum yields. Many of the abandoned farmers expected *Jatropha* to “take care of itself” and abandoned the trees after realizing the maintenance needs required.

To examine the potential land use change impacts of *Jatropha*, the team surveyed farmers about the land use history of the sites where they are (were) growing *Jatropha*. Nearly half of the farmers (28 farmers, 49% of total sample) used to grow crops where they decided to plant *Jatropha*, while 22 farmers (39%) did not use the land for any purpose (ie. responded nothing). The remaining 7 farmers (12%) used the land to graze animals. Amongst farmers in Northern Minas, the majority of participating and abandoned farmers (24 farmers) grew other crops on the land while the remaining 14 farmers previously did not use the land. In Southern Minas, 4 farmers formerly grew crops on the land, 7 grazed animals and 8 did not use the land.

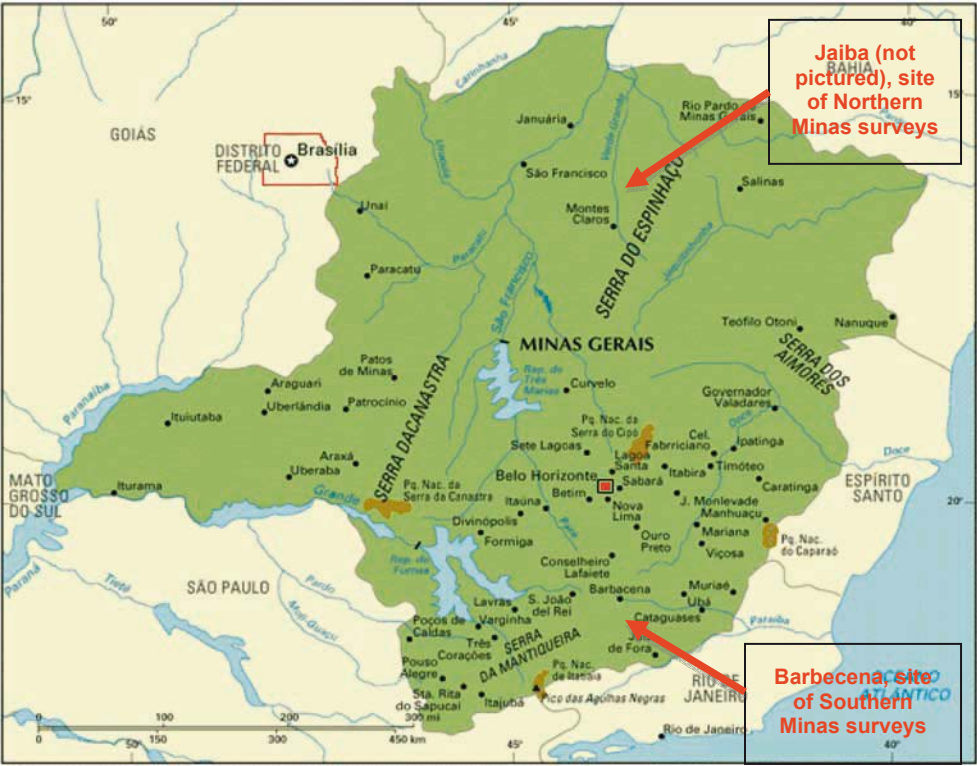


Figure 109: Map of survey sites.

Table 56: Prior Land Use Decisions, Farmer Location and Status.

	Northern Minas		Southern Minas		TOTAL
	Participating	Abandoned	Participating	Abandoned	All
	% (#)	% (#)	% (#)	% (#)	% (#)
Grew other crops	71% (12)	57% (12)	4% (2)	14% (2)	49% (28)
Grazed animals	0% (0)	0% (0)	0% (0)	50% (7)	12% (7)
Nothing	29% (5)	43% (9)	50% (3)	36% (5)	39% (22)
Other	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
TOTAL	100% (17)	100% (21)	100% (5)	100% (14)	100% (57)

Source: Yale SAFUG Brazilian Farmer Survey, Summer 2009.

More specifically, farmers reported 53 instances of replacing other crops with *Jatropha* and 11 instances of discontinuing animal grazing. However, not all of these instances were related to a farmer's decision to cultivate *Jatropha*. In nearly 40% of the reported 64 instances (25 total: 20 crop decisions and 5 animal decisions²²), farmers stated their decision to discontinue a crop or animal farming activity was directly related to their decision to cultivate *Jatropha* (Table 57). In 14 (56%) of the 25 instances, farmers discontinued a crop or animal farming activity to take up *Jatropha* cultivation while in the remaining 11 instances (44%) farmers discontinued these activities because the introduction of *Jatropha* interfered with these farming activities. Regarding crop cultivation, farmers reported *Jatropha* negatively impacted the performance of other crops by shading out crops or reducing a farmer's ability to intercrop. Regarding animal rearing, farmers sold four animals due to concern that the animals would trample *Jatropha* trees.

Table 57: Instances of Crop and Animal Replacement Related to Jatropha Cultivation.

	Northern Minas		Southern Minas		TOTAL
	Participating	Abandoned	Participating	Abandoned	All
Crop replacement (#)	24	25	2	2	53
Related to <i>Jatropha</i> (#)	10	9	1	0	20
% Related to <i>Jatropha</i>	42%	36%	50%	0%	38%
Animal replacement (#)	2	1	0	8	11
Related to <i>Jatropha</i> (#)	2	0	0	3	5
% Related to <i>Jatropha</i>	100%	0%	n/a	38%	45%
Total crop/animal instances (#)	26	26	2	10	64
Total related to <i>Jatropha</i> (#)	12	9	1	3	25
Total % related to <i>Jatropha</i>	46%	35%	50%	30%	39%

Source: Yale SAFUG Brazilian Farmer Survey, Summer 2009.

In summary, there is some evidence of competition between *Jatropha* cultivation and both crop production and animal grazing based on an analysis of farmer cultivation decisions. On the whole, farmers at the two sites in Minas Gerais are planting *Jatropha* on cultivable land. Over 60% of farmers surveyed reported discontinuing crop cultivation or animal grazing on the lands where they cultivated *Jatropha*. These findings indicate *Jatropha* cultivation could increase deforestation rates if new lands are cleared to replace crops and animals displaced by *Jatropha* cultivation. However, at present, the *Jatropha* market in Brazil is too

²² In terms of crops, farmers reported replacing maize (8 instances) and beans (6 instances) with *Jatropha* and in terms of animals, farmers reported replacing 4 cattle and 1 horse on account of *Jatropha*. Maize and beans are two of the country's main subsistence crops grown primarily for domestic consumption (Garcez, 2009 #848).

young to make definitive conclusions on the links between *Jatropha* cultivation and land use change.

Based on interviews with key stakeholders in Brazil, the industry hopes to establish plantations on degraded cattle pasturelands as the industry matures. This could reduce threats to deforestation if establishing such plantations does not displace other farming activities. Yet locating the industry on degraded cattle pasturelands can still increase the environmental impacts of *Jatropha* cultivation depending on the biomass content of such lands. Moreover, while Brazilian biofuel policy targets production on degraded pasture, and key players in the biofuel industry stress the great distance between biofuel production areas and the country's rich tropical forests (UNICA 2008), several researchers have noted the complex interconnections between agriculture in the cerrado region, cattle production, and deforestation (Nepstad, Stickler et al. 2006; Sawyer 2008). The introduction of *Jatropha*, if it takes off, is likely to shift that dynamic. However, it is too early to guess whether that will lead to increasing or decreasing pressure on Brazil's forest areas. Thus, it is imperative to closely monitor the *Jatropha* industry in Brazil as it matures.

5.3 Agrofuels and water – a growing conflict? (R. Menkveld)

5.3.1 Introduction

Globally, there is enough land and water available to grow a substantial amount of biomass for both food and bio-energy but regionally there are shortages both with regards to land and water (Berndes, Hoogwijk et al. 2003). The amount of water withdrawn for the production of biofuels worldwide is modest, approximately 1 percent of all water withdrawn for irrigation is used for the production of bio-ethanol, but in water stressed areas water scarcity problems may worsen due to the irrigation of feedstocks (Hoogeveen et al. 2009). China and India for example, are two countries that will account for 30 to 40 percent of the global energy demand by 2030 but have very little land and water available to expand agriculture (Muller et al. 2008). In order to assess the water use impact of biofuel production it is important to know both the amount of water needed to produce feedstocks as well as the local water availability at the place of production.

5.3.2 Methodology

The water footprint (WF) is a useful concept to describe the various forms of water use and consists of three components: green, blue and grey water (Hoekstra and Chapagain, 2008). Green water refers to the consumptive use of rainwater (water evaporated), blue water is consumptive use of freshwater withdrawn from groundwater or surface water which is evaporated or incorporated into a feedstock, while grey water refers to volume of water required to dilute pollutants emitted to a water body so that water quality standards are maintained (Hoekstra and Chapagain, 2008). Information about blue water is especially important in regions where water scarcity exists as water used for production of biofuels could potentially compete with other uses such as food production. Pfister et al. (2009) have developed a water stress index (WSI) at the watershed level with values ranging from

0–1. Water stress is defined by the ratio of freshwater withdrawals to hydrological availability with a factor correcting for temporal variation in precipitation.

This study integrated data from several sources which adds a degree of uncertainty to the results. Blue water which is returned to the hydrological cycle either as runoff, precipitation or grey water was not included in the assessment and we did not distinguish between the source of blue water (groundwater or surface water). Additionally, the amount of water used to process feedstocks was not quantified since it falls outside the scope of the study and is generally limited when compared to evapo-transpiration and irrigation extractions. The results are based on fresh water requirements and theoretical maximum conversion efficiencies. Water use is considered to be equal to crop water requirements, and we assume 100 percent irrigation efficiency (although this is unlikely to occur in practice) as well as optimal agricultural practices. The distinction between first and second generation biofuels is based on the conversion technology used; all biomass in second generation technology can be converted into fuel, heat and electricity unlike first generation technology. This poses a problem of definition for some feedstocks, such as algae in open air ponds and halophytes, which are not yet commercially available but fall into the category of first generation biofuels.

5.3.3 Calculations

Specific production locations were identified for the calculation of crop water requirements and the complete growing season of feedstocks was taken into account. Crop water requirements were calculated using the model CROPWAT, based on the FAO Penman-Monteith method (Allen, Pereira et al. 1998), and climate data was derived from the model CLIMWAT 2.0. The water use per resource was calculated based on the methodology of Gerbens-Leenes et al. (Gerbens-Leenes, Hoekstra et al. 2009). The water stress index (WSI) of production locations was derived from an application developed for google earth based on the calculations of Pfister et al. (2009).

5.3.4 Results and Discussion

Some feedstocks are more water use efficient in producing a unit of ethanol or biodiesel than others (Figure 1). Generally second generation biofuels are more efficient because they either do not have a WF (manure, biowaste,) or do not require blue water for production (straw, used wood, industrial wood, and waste wood). For wood derivatives we did not allocate a production factor primarily because these feedstocks are wastes or residues in the production of other industrial products. Additionally, forest growth generally occurs under rain fed conditions and does not require freshwater withdrawals. Similarly, halophytes and algae do not use freshwater because they can grow in brackish, saline or grey water environments. In fact, it is these unusual characteristics which make these feedstocks particularly attractive for production in water scarce, arid regions where soil salinization is occurring. However, one should not underestimate the huge volumes of water required for algae open air ponds, which if not located close to a water source could involve high infrastructure costs.

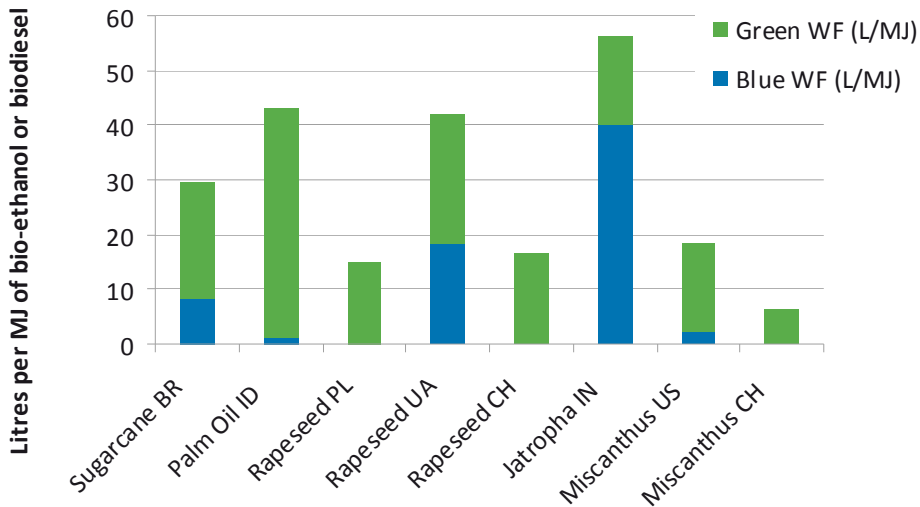


Figure 110: The green and blue water footprint of crops providing ethanol and oil for biodiesel.

Most first generation biofuels have a WF because they are agricultural feedstocks but not all feedstocks have a blue water footprint. Jatropha grown in India is the most water dependent: 71 percent of the total WF consists in blue water. This represents the largest blue WF when compared to rapeseed in Ukraine (43.7 percent), sugarcane in Brazil (27.5 percent), miscanthus in the US (12.7 percent) and palm oil in Indonesia (2.7 percent). The blue WF however only gives an indication of the water use dependence. Potential water use impacts will depend on both the amount of blue water used and on the local water availability. According to Pfister et al. (2009) moderate water stress occurs above a threshold of 0.2 with severe water stress occurring above 0.4 to 0.6. Only production of jatropha in India could have severe water use impacts with a WSI of 1 since all the other feed stocks have a WSI below 0.2.

Some feed stocks like sugarcane and palm oil have large green WFs. Green water is primarily a land use issue and could have impacts on land productivity since soil moisture is directly related to soil fertility. In order to assess the long term implications of increased green water use on land productivity one would have to compare the volume of green water currently used for biofuel production to that of native vegetation. However, in most cases it is hard to identify reference vegetation due to multiple land use changes over the years. Another issue regarding land productivity is the use of all biomass in second generation biofuels. In nature the concept of waste does not exist. Residues from first generation biofuels (woody biomass, bagasse, etc.) are either used as fuel or returned to the field as soil cover and fertilizer. However, with second generation technology these residues could be

used to produce cellulosic ethanol which could lead to reduced soil fertility in the long run, requiring the need of additional inputs (fertilizers) which cost energy to produce.

Agricultural practice determines yields and thus differences among WFs of feed stocks, even where there is a similar climate. Generally, if yields are low WFs are high and vice versa. This is particularly true for intensive and extensive cultivation of jatropha in India (Annex 1). It should be noted that agricultural yields can be increased without additional use of water if good land stewardship is practiced (crop rotation, tillage, fertilizers, drip irrigation), although fertilizer use could have an impact on water quality (eutrophication of surface waters). However, it is important not to underestimate the importance of climate in the cultivation of feedstocks. Results for rapeseed show large differences in crop water requirements among countries, caused by climate. The crop water requirement of rapeseed grown in India for example, is four times the average value of rapeseed grown in Switzerland. Low yields combined with an unfavourable climate results in a very high WF for India (143.8 L/MJ) compared to Switzerland (17.6 L/MJ). The blue water component of rapeseed in India is also very high (45.6 percent) compared to rapeseed grown under rain fed conditions in Switzerland.

5.3.5 Conclusions

The impact of biofuel production on land and water resources varies according to the feedstock used, agricultural production system, and climate. Some feedstocks like biowaste, manure, algae, halophytes and wood residues do not have a WF because they do not require freshwater for their production. The same is true for miscanthus, palm oil and rapeseed in Switzerland and Poland which are mostly grown under rain-fed conditions and do not require freshwater for irrigation. Rapeseed in Ukraine has a relatively high blue WF compared to other feedstocks but there appears to be no water stress. Jatropha on the other hand has both a high blue WF as well as a high WSI which means that water used in the production of biofuels could compete with other uses and aggravate existing water scarcity problems.

Although agricultural production systems determine yields and indirectly WFs of feedstocks climate at the place of production is the most important factor in determining water use efficiency. Unfavourable local conditions will result in high blue WFs. Generally, it would appear that all feedstocks, with the exception of jatropha, are grown in suitable locations. However, it is important to remember that the water use impacts of biofuels are local issues and cannot be assessed on a global scale. Even a small blue WF in a water scarce region can have a huge impact depending on the scale of production. Therefore it is important to assess the blue WF and WSI together and not separately. Governments therefore are cautioned from being seduced by the hype surrounding biofuels. It is imperative to find the right mix between energy independence and food production which can only be assessed on a local or regional scale.

5.4 2nd generation biofuels and biodiversity (R. Zah)

Fertile land is needed for the production of biomass. This is in general true for both, 1st generation and 2nd generation biofuels, except for algae.

5.4.1 Biodiversity impact of 1st generation biofuels

If we assume, that the cultivation of 1st generation energy crops is additional to current food production, biofuels production must either expand into currently natural regions or the current food production must be further intensified to account for the additional demand. According to Searchinger et al. (Searchinger, Heimlich et al. 2008) corn ethanol production in the US has been mainly expanded at the expense of Amazonian rain forest and Koh & Wilcove (Koh and Wilcove 2008) showed that oil palm extension in Malaysia and Indonesia accured to more than 55% on forest areas.

Land use change from forest to cropland has of course a direct impact on plant biodiversity. However, also the reduction in animal biodiversity is significant. Koh and Wilcove (Koh and Wilcove 2008) measured a loss of more than 70% of bird and butterfly species when converting primary and secondary forests into forest plantations of oil palms or rubber trees (Figure 111). Similar results with a reduction of more than 50% have been found for other vertebrate species like lizards and mammals. On the other hand the mean total species richness of invertebrates did not differ significantly between oil palm and forest sites. Nevertheless, only 31% of invertebrate species found in forests were also found in plantations (Danielsen, Beukema et al. 2009).

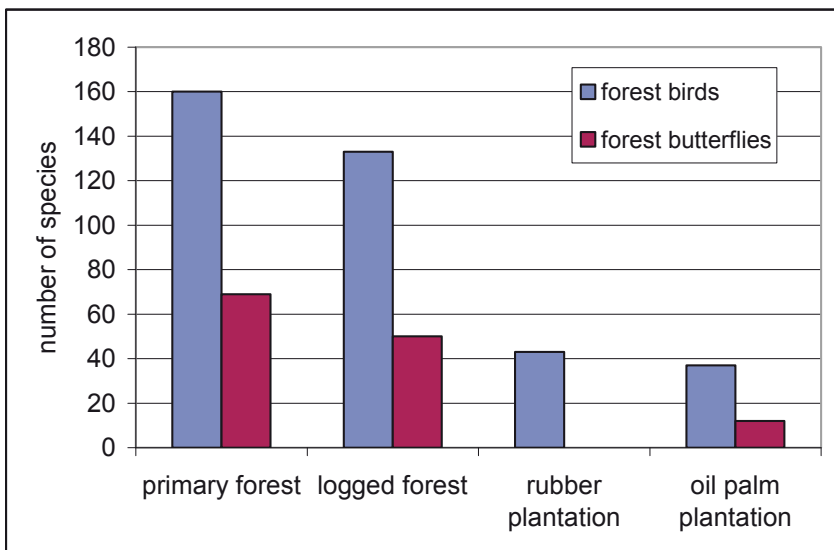


Figure 111: Species numbers of birds and butterflies in Malaysian forests and forest plantations (Koh and Wilcove 2008).

However, biodiversity loss is not only an issue for tropical rain forests. For example, the richly structured Brazilian Cerrado (Figure 112) is a global biodiversity hot spot with the richest flora among the world's savannas (>7000 species) and high levels of endemism (Myers, Mittermeier et al. 2000).

The Cerrado area is under land use pressure by cattle farming and sugar cane cultivation. Conservation efforts, however, have been modest with only 2.2% of its area under legal protection (Klink and Machado 2005). Numerous animal and plant species are threatened with extinction, and an estimated 20% of threatened and endemic species do not occur in protected areas.



Figure 112: Brazilian Cerrado, recovering from wood fire (source: www.istockphoto.com).

5.4.2 Biodiversity impact of 2nd generation biofuels

For the production of 2nd generation biofuels it is planned to use ligno-cellulosic feedstock. To avoid pressure on croplands and natural areas, crop residues from already existing agricultural areas could be used as feedstock. However, according to Lal (Lal 2006) removal of crop residues can adversely affect soil quality. Retention of crop residues on the soil surface as mulch has numerous beneficial impacts on soil fertility and on biodiversity such as low soil erosion hazard, enhancement of soil aggregation, low nutrient leaching or high activity and species diversity of soil fauna. To avoid negative impacts, the removal of crop residues should be kept under a threshold, which depends on soil type, climate and topography. Consequently, the sustainable use of surplus crop residues is widely limited.

Another option for the cultivation of ligno-cellulosic feedstock has been proposed by Tilman et al. (Tilman, Hill et al. 2006). A diversity of native prairie species has been grown on a site with degraded soils, using little or no fertilizer or pesticide inputs and irrigation only in the first year. Fuel yields comparable to those of corn could be achieved. Such systems would serve as habitat for native species, and cropping may increase soil fertility over time and reduce erosion rates compared with traditional crops on tilled prairie. Finally, because native prairie supports a diversity of pollinators, expansion of such systems adjacent to crops requiring pollinator services could provide an additional ecosystem service. However, the results of Tilman are subject to a lot of controversy and have not yet been verified. Furthermore, large areas would be needed for a substantial amount of Biofuels production and

the impact of the logistics of cultivating and harvesting prairie grass biomass on a market scale has to be investigated in more depth.

Land degradation is a severe and widespread environmental problem. Regions with a significant decrease in primary production are shown in orange in Figure 113. The cultivation of drought-resistant energy crops could help in improving soil fertility in such regions. Preferred crops are *Jatropha*, *Rhizinus* or Sweet Sorghum. Cultivation on degraded lands has the potential to be beneficial for both, biodiversity and soil carbon stock. Nevertheless, degraded areas should not be cultivated at the expense of increased use of scarce water resources.

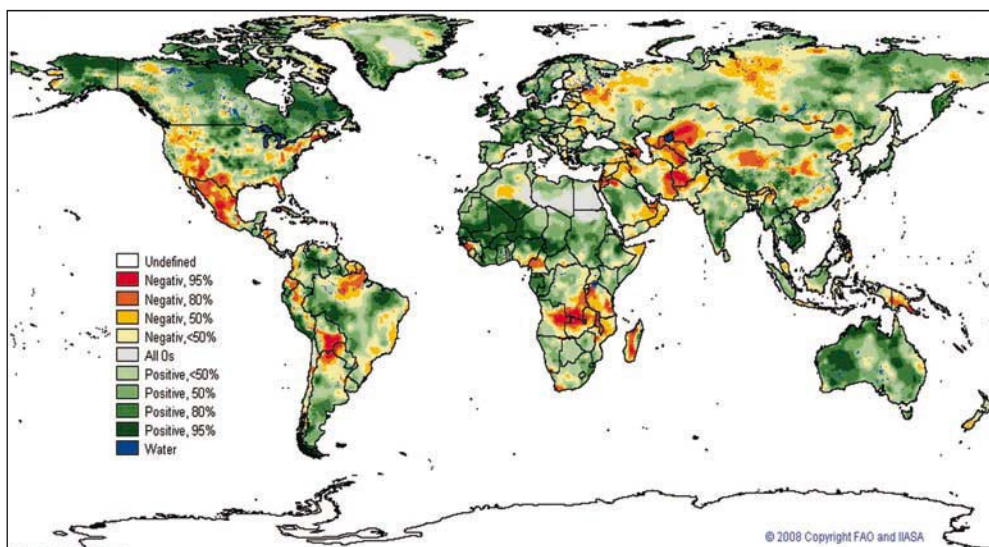


Figure 113: Direction of 1980-2000 trend in Net Primary Production (IIASA 2009).

5.4.3 Conclusions

To sum up, biodiversity is generally threatened by large-scale production of biofuels. 1st generation biofuels mainly increase the pressure on fertile and arable lands and therefore on biodiversity-rich natural ecosystems. For 2nd generation biofuels large amounts of ligno-cellulosic feedstock are needed. This increases the land use pressure on dry natural areas, on the intensification of forestry and on soil fertility if crop residues are excessively used.

Nevertheless, biodiversity could be sustained or even increased by biofuels production if the cultivation takes place on degraded areas or if integrated agricultural systems are implemented (Ranganathan, Daniels et al. 2008). These options however appear to be niche applications that cannot satisfy the global demand for biofuels on the commodity market.

5.5 Fuels from algae (A. Fahrni & R. Zah)

In the mid-term, production of algae-based biofuels stays expensive in terms of both, costs and energy use. Lardon (2009) showed in an extensive Life Cycle Assessment of the best available algae production chains, that the cumulative energy demand needed for the fuel production is in the same range or even greater than the energy content of the algae fuel. A significant improvement of the best available technologies is mandatory to reach a positive energy balance which is linked to a reduction in GHG emissions.

Current studies show (Krassen 2007; Alabi, Tampier et al. 2009), that even under optimistic assumptions, overall production costs of algae-fuels are a magnitude higher than the respective costs for 1st generation biofuels (Figure 114).

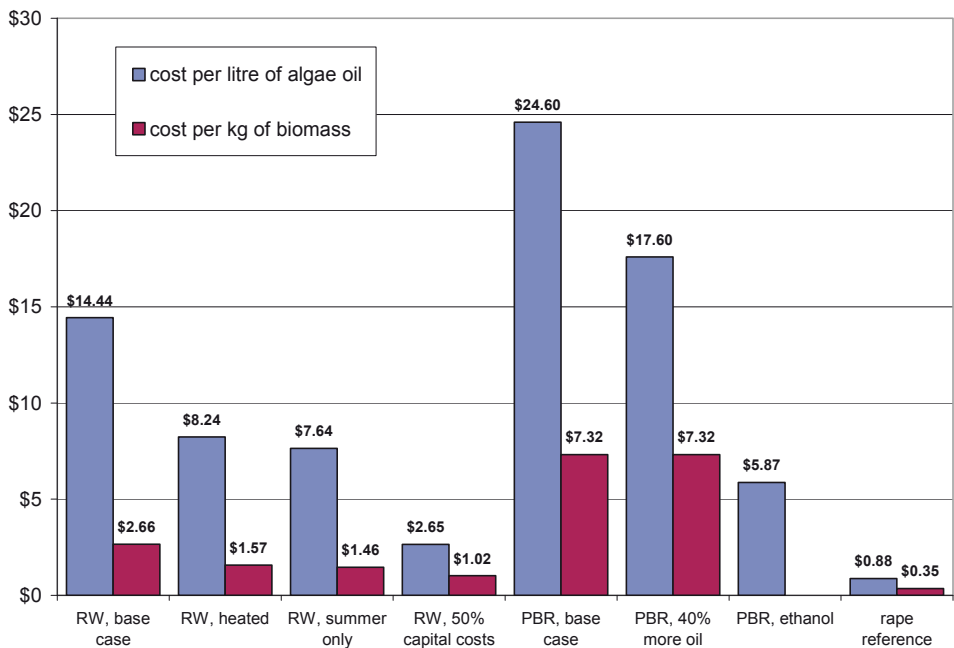


Figure 114: Cost per kg of algal biomass and per litre of oil/ethanol produced under different scenarios in Canada (Alabi, Tampier et al. 2009).

Consequently, business cases for algae cultivation are basically oriented towards bio-refineries where the main revenue lies on premium algae-based products for the pharma and food sector (e.g., US\$ 5/kg for functional proteins; US\$ 200/kg for synthetic Astaxanthine). Biofuels production plays rather a minor role with a biomass allocation of <20% and a revenue share of <10% (Pattarkine and Eckelberry 2009).

However, to reduce costs of algae cultivation and increase production efficiency, cultivation could be optimized on maximum carbon yield rather than oil yield and algae could be converted into synthetic natural gas (SNG).

5.5.1 Microalgae classification

Microalgae, which are eukaryotic organisms, can be categorized in term of abundance into three different classes that are diatoms (Bacillariophyceae), green algae (Chlorophyceae) and golden algae (Chrysophyceae) (Carlsson, van Beilen et al. 2007). Cyanobacteria also known as blue-green algae are prokaryotic organisms and are often subject of controversy for classification. They are here also considered as microalgae.

Microalgae generally grow photoautotrophically either in salt water or in fresh water. Heterotrophic cultivation with organic carbon source is also possible and this sort of cultivation is often used in closed systems (fermenters). Despite the well known fermentation process, heterotrophic cultivation is not possible for all microalgae and their chemical composition often change in such conditions (Borowitzka 1999). According to Chisti (2007), heterotrophic growth is not as efficient as photosynthesis. The current focus on photoautotrophic cultivation in academic research suggests that this system is the most promising for producing biofuels in the coming years.

5.5.2 Algae species

The selection of an algae species depends on culture conditions (salinity, pH and temperature), culture system (open ponds vs. closed systems) and the desired final product. Lipid content, oil content, oil productivity and growth rates can vary substantially from one species to another. More than 50,000 microalgae species exist but only 30,000 species have been studied and analyzed for algae culture (Mata, Martins et al. 2009). Of course, not all of them are suitable for producing biofuels. The problem of contamination in open ponds can be partly resolved by selecting algae that are adapted to open air conditions and therefore remain relatively free of contaminants (Borowitzka 1999). For that reason only a small number of algal species can be grown successfully in open air systems. In photobioreactors (PBRs), the issue of hydrodynamic stress during broth's mixing is a major determinant for choosing microalgal species whose cell is resistant enough. In terms of an optimal CO₂ fixation it is advantageous if the microalgae species is also tolerant to high carbon dioxide levels. A good example with high tolerance to CO₂ is the marine algae *Chlorococcum loittorale* (Mata, Martins et al. 2009).

An advantage of algae over other feedstocks for producing biofuels is the possibility to select species optimized for local growth conditions of the respective facility.

According to the EPOBIO report, microalgae used for energy production should be highly productive, easily harvestable by mechanical techniques and cost-efficient (Carlsson, van Beilen et al. 2007). In the same sense the study of Lardon (2009) advises to consider primarily species and with high productivities rates and high lipid content for which oil recovery is easy.

There is not one absolute best species of algae for producing biofuels because of all previous cited factors, but in literature most studies about microalgal biofuels refer to strains of *Chlorella*; like e.g. *Chlorella vulgaris* (Carlsson, van Beilen et al. 2007; Lardon, Hlias et al. 2009; Mata, Martins et al. 2009).

5.5.3 Site selection and water supply

Selecting adequate algae species is as important as the choice of a good site for the culture facility. Assuming that culture systems for a large-scale production are situated outdoors, climate conditions (temperature, evaporation, precipitation) and solar radiation are primor-

dial to assure an optimal growth. Temperatures should generally stay in the range of 20 to 30°C (Chisti 2007). Daily and seasonal variations in the parameters have also to be considered in site selection. Algae do not need arable land which is a major advantage for algae culture over crop plants.

For the implementation of a microalgae culture facility a relative big area of several hectares is needed. Lardon proposes a facility of 100ha while Zijffers et al. (2008) even propose 1000ha for open ponds. The important size of envisaged facilities can be a problem in certain countries with high densities of construction. Because of lower productivity rate, open ponds require a bigger area than photobioreactors. In order to achieve a cost-effectiveness production of algae, cost of land should be carefully considered.

Freshwater is scarce in many parts of the world. Therefore an often highlighted advantage of algae is that they can grow either in freshwater or in saline water. The question of water supply is foremost related to algae species (marine or freshwater algae). As algae culture do not need fertile soil to grow, it is possible to imagine for example an algae culture in deserts with access to saline ground water as water supply. Deserts will be ideal for solar radiation supply but the evaporation of the water in the ponds can become an issue. Mainly open culture systems will suffer from evaporation. The salt concentration can become important as a result of evaporation, and growth rate will be decreased (FAO 2009). Every species of algae has a different optimum of salinity (Mata, Martins et al. 2009). The solution to reestablish optimal salt concentration is to add freshwater. According to Lardon (2009) open ponds have to be flushed every two months to control development of bacteria and to avoid accumulation of toxic or inhibiting compounds. In order to estimate the amount of water that is needed for open ponds culture, Lardon speaks about a value of around 4 litres of freshwater per kilo of dry algae. Generally, the amount of water required for algae culture is much lower in comparison with agriculture of other crops.

Algae culture facilities can be coupled with oil extraction facilities or even with facilities where oil is transformed into biodiesel for example. This “industrial symbiosis” will minimize the transport of feedstock and oil to the respective facilities.

5.5.4 Open ponds vs. photobioreactors?

The two most important systems of algae culture are open ponds and photobioreactors (PBRs). Both systems have their strengths and limitations.

Currently, open ponds culture systems are reported as economically more favorable in comparison with PBRs, but the results for the economic efficiency (expressed in MJ/\$) in the SPA showed that they still remain too expensive in comparison with others feedstocks. A noteworthy point is that, without too many problems, the open ponds can be enlarged to ensure the large-scale production that is needed for producing biofuels. Water losses through evaporation and contamination problem are both issues that have to be considered in such systems.

On the other hand, PBRs are nowadays being studied and theoretically render larger productivity rates than open ponds. Theoretical production capacities of 130–150 t ha⁻¹ y⁻¹ have been claimed in a plant in Klötze in Germany (Carlsson, van Beilen et al. 2007). However the current academic research suggests that such production capacities seem to be difficult to be achieved on large-scale production. The concentration of algae achieved in PBRs is higher than in open ponds. In open ponds a concentration of about 0.2–0.5 g/L is observed whereas a concentration of 3–10 g/L is observed in PBRs.

It is clear that for the moment PBRs are too expensive in acquisition costs and energy. The high costs come from high capital costs but also operating costs are substantial. According to Phelan (2008){Phelan, 2008 #1102} 40–50% of the costs are consumed by circulating and mixing the broth composed of algae, water, CO₂ and nutrients. The energy used for this process is very important and is responsible for the moment for a negative energy balance. Oxygen accumulation and overheating are other issues that have to be considered in PBRs.

5.5.5 Photoconversion efficiency

In photoautotrophic growth cultures, an important issue is the photoconversion efficiency (PCE). Only a small band of the whole solar radiation is photosynthetically active and through energy losses and because of respiration, the PCE is theoretically limited to 8.8% (Lehr and Posten 2009). There is a consensus that the PCE of terrestrial plants is 1% or less. Promoters of algae technology for biofuel expect the limits of microalgae photosynthetic efficiency to be pushed out to somewhere between 3 and 6% (Bruton, Lyons et al. 2009). However, current conversion rates of open pond pilot plants are in the same range as terrestrial plants.

5.5.6 CO₂ supply and fixation

The fact that algae cultures have to fix CO₂ during growth can be used to lower greenhouse gas emissions by uptaking industrial sources of CO₂. Coupling flue gases CO₂-rich sources from power plants to microalgae cultivation is therefore a suitable future option. According to Chisti (2007), producing 100t of dry algal biomass fixes roughly 183t of carbon dioxide. As often claimed in studies, CO₂ injection is not free of costs because of transport and treatment (Lehr and Posten 2009). Therefore an algae culture that can directly uptake the CO₂ flue gas emissions of a power plant or industrial sources is a great opportunity.

5.5.7 Nutrients and wastewater treatment

Apart from light and CO₂, adequate nutrients are crucial for algae to grow. The most important nutrients are nitrogen and phosphorous. Nutrients can be provided by fertilizers but this solution is generally expensive. The life cycle assessment study of biodiesel production from microalgae of Lardon showed cultures with normal and low nitrogen concentration. The nitrogen limitation showed significant lipid production but such culture conditions affect slightly the growth rates and thus the net productivity (19.25 gm⁻²day⁻¹ against 24.75 gm⁻²day⁻¹ for normal nitrogen conditions). The study of Lardon (2009) also showed that fertilizers have an important impact on cumulated energetic demand. However the diminution of fertilizer use reduces sensibly certain impacts such as the abiotic depletion, the acidification and the toxicity.

Another opportunity in order to diminish the fertilizer use is to couple the algae culture with wastewater treatment. In this solution microalgal growth and biological cleaning can occur simultaneously. Besides the biological cleaning of industrial effluents for example, the use of wastewater as nutrients for microalgal growth can reduce eutrophication in the environment.

5.5.8 Harvesting

Several harvesting methods for algae exist such as centrifugation, flocculation, filtration or sedimentation (Mata, Martins et al. 2009). Harvesting is a crucial phase in algae cultivation as it is known to be very energy intensive. In total, costs induced by harvesting are significant (up to 20–30%) (Carlsson, van Beilen et al. 2007). Other possible drawbacks of harvesting are flocculant toxicity and non-feasibility of scaling-up. The concentration of algae in broth is also an issue to look at. Open ponds cultures where algae concentration is lower in comparison with PBRs require more energy for harvesting. It is therefore crucial to reduce costs and optimize harvesting systems (Mata, Martins et al. 2009; Rodolfi, Zittelli et al. 2009).

Centrifugation seems to be suitable because it rapidly concentrates the microorganisms. However centrifugation is usually considered as too expensive (Lardon, Hlias et al. 2009). Flocculation can be a solution to reduce energy costs of harvesting. According to Zijffers (2008) it is feasible to reduce costs from 2.72 Euro/kg (for centrifugation) to 0.7 Euro/kg for concentrating microalgae from 0.3 g/L to 100 g/L (10% dry matter) when the algae are first flocculated (in combination with sedimentation) before further centrifugation. In addition the energy demand will also decrease from 4.76 kWh/kg to 0.5 kWh/kg. Flocculation algae with pH adjustment and addition of synthetic flocculant and the addition of lime are also assumed in the study of Lardon (2009). He assumed a 90% of algal biomass flocculating at a pH of 11. Flocculation is unfortunately poorly understood because optimal conditions of the algae in this process are difficult to predict. Improving actual research and further research is needed in the domain of flocculation.

5.5.9 Cost reduction

The literature review made about biofuels from algae and the SPA of algae feedstock has clearly shown that both capital costs and operating costs are far too high for biofuels production. Nevertheless, different cost reduction options do exist.

An effective option would be to increase the photo conversion efficiency (PCE). Wijffels and his research group in Wageningen have argued that the increase of PCE to 5% would decrease the production cost by 85% in future PBRs (Phelan 2008). Another option to reduce costs is to diminish the energy used by mixing the broth. Wijffels and his team claim that it is possible to pump less, to use alternative degassing methods and to utilize the waste heat produced by future PBRs. The use of flocculation before centrifugation may also be an advantage in order to reduce the energy consumption during harvesting.

Genetic engineering is illustrated by the study of Beer (2009). He presents improvements in manipulating gene expression on eukaryotic algae for optimizing the production of biofuels.

The solution to connect the algae culture with CO₂ flue gas emissions or wastewater can also reduce costs. However, such waste streams will probably not be available for free in the future.

In order to improve economics Chisti suggest implementing a biorefinery based production strategy. He argues that by using all components of the biomass, the revenue could be maximized (Chisti 2007). The cake (residual biomass) of oil extraction can be used as animal feed, excess power of biodiesel production could be sold and the residual biomass might be used to produce methane by anaerobic digestion.

Costs of algae cultivation could also be reduced by selecting algae that are optimized on maximum carbon yield rather than oil yield. This might lead to significantly higher yields that could be converted into synthetic natural gas (SNG) instead of producing biodiesel.

5.6 Biofuels and developing countries (S. Gmünder & B. Portner)

5.6.1 Introduction

Biofuel production is a highly contested topic with different driving forces and diverging interests. While the global North is pushing biofuel production to get more climate friendly fuels and decrease its dependence on fossil fuels, the global South additionally sees it as a mean to promote rural development. Biofuel production may also provide employment opportunities, access to new markets and help with expanding agricultural production technology. Increasing purchasing power and decreasing vulnerability to food and energy price shocks would lead to significant welfare gains. Biofuels thus have been considered by many as a remedy to solve parts of global society's problems.

However, current research has revealed that biofuels have a significant impact on food security (FAO 2008), land use rights (Cotula, Dyer et al. 2007) and on the environment (Scharlemann and Laurance 2008). Particularly in the rural South, the massive and rapid expansion of biofuel production is having negative effects as well as positive ones. However, the magnitude of the impacts of biofuel production is still widely unknown since research has only started and sound scientific results are still lacking.

The aim of this spotlight is thus to address the opportunities and risks of biofuel production and to present a way how these can be addressed by the scientific community. In order to show the relevance of biofuels in the context of current energy usage, we present an overview of global biofuel production and the most relevant policies in order to appraise the future development of biofuel demand. Further, the most important impacts of biofuel production in the context of the rural poor in developing countries is discussed. The discussion focuses on impacts of first generation biofuels, since second generation biofuels will most likely not be relevant to developing countries in the near future. Finally, we explain the reasons why we believe that biofuel production can be beneficial for small-scale farmers as well as commercial companies, how indicators can help monitor impacts and why these aspects need to be addressed from an inter- and transdisciplinary perspective.

5.6.2 Biofuel production and promotion

5.6.2.1 Global production

Currently the global primary energy demand amounts to approx. 510 exajoules (EJ) per year. About 49 EJ are covered by the energetic use of biomass (IEA 2009). For about 2.5 billion people biomass – such as fuelwood, charcoal and dung – is still the main energy provider for basic human needs such as cooking, lighting and heating (IEA 2002). Modern biofuels used as transport fuels make up approximately 1.5 EJ or 1.54 percent of 97 EJ globally used transport fuels.

About 14 million hectares or approximately 1% of the world's currently available agricultural land were used for energy crops in 2006 (Kampman, Brouwer et al. 2008). Compared to the global use of agricultural land estimated at 1500 million hectares this share is relatively small (FAO 2008). However, land requirements for biofuels will increase in future. According to E4Tech about 56 to 166 million hectares land will be required to cover the biofuel demand in 2020 (E4Tech 2008). The expansion of the cultivated land will cause direct and indirect shifts to current land use patterns and put pressure on ecosystems.

The global biofuel demand is based on bioethanol and biodiesel from a few main producers (see Figure 115a). The main producers of bioethanol are the U.S.A. (from maize) and Brazil (from sugarcane) with India and China also having significant shares of the global ethanol production. The biodiesel market is dominated by rape methyl ester from Europe. Malaysia and Indonesia, using palm oil, contribute 7% to the global biodiesel production. However, most developing countries do not yet have significant biofuel market shares.

Over the last decade biofuel production has increased rapidly. From 2000 to 2007 the world ethanol production for transport fuel tripled from 17 billion to more than 52 billion litres, while biodiesel expanded eleven-fold from less than 1 billion to almost 11 billion litres (Figure 115b) (OECD(2008) and adapted for India).

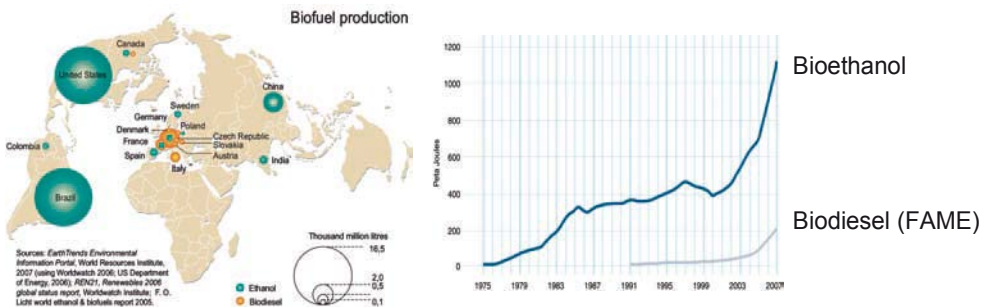


Figure 115: Global biofuel production in 2005. a) by region (Kirby 2008) and b) temporal (Bringezu, Schütz et al. 2009a)

Biofuel production might have a positive effect on energy security and the trade balance of certain developing countries. Most least-developed countries are not only net food importers, but also net crude oil purchasers. These countries typically spend a high amount of their foreign exchange on oil imports and thus are vulnerable to energy price shocks. The potential for liquid biofuels to reduce dependence on oil imports, however, should not be overestimated. Despite the rapid increase in biofuels, so far liquid biofuels have only replaced around one to two percent of global fossil fuel use for transport and a much lower percentage of total fossil fuel use (FAO 2008).

5.6.2.2 Blending targets and policies

At the current crude-oil price biofuels are economically not competitive with fossil fuels; the main exception is Brazilian bioethanol (IEA/OECD 2009). However, numerous countries promote or mandate the use of biofuels in order to stimulate biofuel demand and benefit

from the multiple opportunities linked to its production. Elimination of global support for biofuels would reduce global ethanol production by over 10% and world biodiesel production by 60% (FAO 2009). The most frequently used political instruments are tax exemptions and mandatory blending quotas (summarized in Table 58).

Table 58: *Overview of the global use of biofuels for transport during 2005–2007, blending mandates and total biofuels targets, volumes required per year to reach targets about the most relevant biofuel targets (UNEP 2009).*

	Fuel ethanol plus biodiesel in 2005–2007				Blending mandates		Biofuel targets	Volumes required per year	
	billion litres	%	Mt	PJ	Bioethanol	Biodiesel	Biofuels total	Bioethanol	Biodiesel
Canada	0.781	1.67%	0.62	17	E5 by 2010	B2 by 2012			
USA	21.946	46.86%	17.41	473			20% by 2022	130 billion litres by 2022*	
EU Total	7.563	16.15%	6.64	226			10% by 2020		
Australia	0.262	0.56%	0.22	8	regional only				
Japan	0.000	0.00%	0.00	0			5% by 2030	6 billion litres by 2030	
South Africa	0.000	0.00%	0.00	0	E8-E10 proposed	B2-B5 proposed	4.5% biofuels		
Ethiopia	0.002	0.00%	0.00	0					
Mozambique	0.001	0.00%	0.00	0					
Tanzania	0.004	0.01%	0.00	0					
Brazil	13.657	29.16%	10.80	290	E22 to E25 exist.	B5 by 2013			
Columbia	0.268	0.57%	0.21	6	E10 existing	B5 by 2008			2.5 billion litres by 2013
Peru	0.000	0.00%	0.00	0	E7.8 by 2010	B5 by 2010			
China	1.565	3.34%	1.24	33	E10 in 9 provinces			13 billion litres by 2020	
India	0.544	1.16%	0.45	15	E20 by 2017	B20 by 2017	20 % by 2017		2.3 billion litres by 2020
Indonesia	0.047	0.10%	0.04	2					
Malaysia	0.000	0.00%	0.00	0		B5 by 2008			
Philippines	0.017	0.04%	0.01	0	E10 by 2011	B2 by 2011			
Thailand	0.134	0.29%	0.11	3	E10 by 2007	3% share by 2011			
Turkey	0.043	0.09%	0.03	1					
World Total	46.834	100.00%	37.63	1073					

Currently most nations are trying to achieve biofuel blending targets with first-generation biofuels, since the second-generation technology is not yet ready for the market. Furthermore, it is most likely that the blending targets set by developed countries can only be achieved by importing biofuels from developing countries. Previously, the EU considered its 2020 target of a 10% share of biofuels in transport fuels unrealistic and revised the target to a 10% share of overall renewable energy in the transport sector (EC 2008). It has been estimated that between 22% and 54% would be met by imports in order to meet blending targets (Gallagher 2008). The main reason is that ecosystems in Western Europe, as well as in Asia, are widely over-utilized: Imhoff et al. compared the amount of net primary production (NPP) required by humans (human appropriation of terrestrial NPP, HANPP) and compare it to the total amount generated NPP. South America and Africa exhibit a relatively high terrestrial primary production, while human appropriation is still relatively low (Figure 116) (Imhoff, Bounoua et al. 2004).

Furthermore, most developing countries have a comparative advantage in biofuel production due to lower land and labour costs, warm tropical climates and a longer growing season. This means that they can produce more cost effectively compared to industrialized nations.

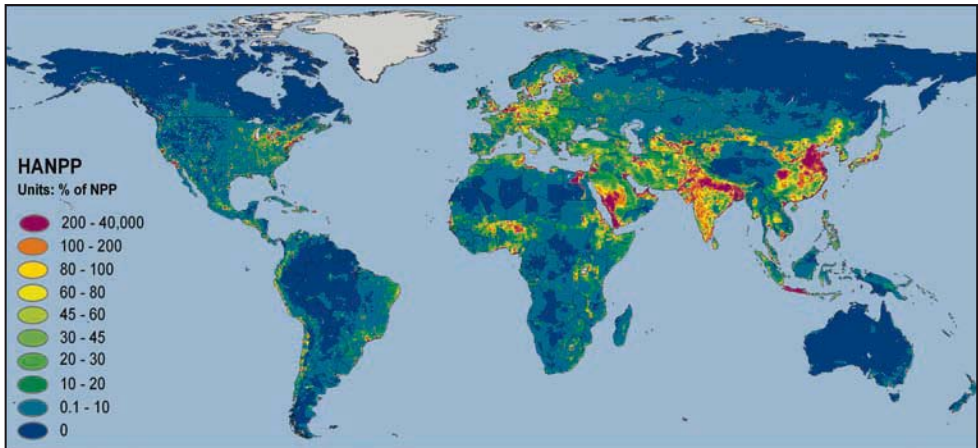


Figure 116: *Spatial distribution of annual NPP resources required by the human population, as measured by HANPP as a percentage of local NPP. Values higher than 100 percent are due to increased NPP via fertilizing and irrigation (Imhoff, Bounoua et al. 2004).*

The majority of biofuel policies in sub-Saharan Africa were set up during the last five years and many countries are still in the process of developing biofuel policies (Jumbe, Msiska et al. 2009). Almost all of these policies are part of the respective national energy policies and do not have a favourable institutional strategy for the implementation and monitoring of biofuel production. Woods (2006) mentions that developing countries may be able to leapfrog first-generation technologies and only start when second-generation technologies are available. This strategy however, can also lead to a lock out from second-generation biofuels, since most research and development is conducted in developed countries and the implementation requires substantial capital investment. Moreover, most of the innovations will be patented. Given the current state of technology, licensing fees will be very high for a long time and most probably not accessible to developing nations wanting to produce biofuels (Barton 2007).

5.6.2.3 International trade

The current international trade volume is quite small, since most of biofuels are produced for domestic use (approx. 7% of the globally produced biofuels are traded) (IEA 2009). However, the imbalance between demand (mainly EU, US and Japan) and the largest potential for producing biofuels (South America and Africa) will cause increased international trade over the coming years (Worldwatch 2006). In the short term it is most likely that the biofuel export market will be dominated by a few large-scale biofuel producers, such as Malaysia and Brazil.

Moreover, developing countries' access to the international biofuel market is uncertain. Trade opportunities may be reduced by measures that focus exclusively on enhancing production in industrialized countries or protectionist measures to limit market access. The global North is currently subsidising agriculture with approximately 300 billion USD per year. Current biofuel support policies risk repeating mistakes made in the field of agricultural policies. European ethanol production, for example, is protected with tariffs equivalent to 39% and 63%. Further, every litre of bioethanol consumed is subsidised with 0.74 Euro and every litre of biodiesel with 0.5 Euros. The protection of domestic agriculture in developed countries results in enormous costs for taxpayers and is disproportionately affecting developing countries. The removal of all trade barriers and substitution would lead to a price increase of 10% for ethanol, which would increase the competitiveness of many developing countries. Thus, some voices claim that the EU biofuel policy is a form of 'green protectionism' that is no longer an environmental policy addressing climate change concerns, but an industrial policy aimed at promoting domestic biofuel production (Erixon 2009).

One opportunity for developing countries to improve their access to markets are unilateral preferential trade agreements and other political instruments with the US and EU. However, for countries that do not benefit from preferential access, preferential trade initiatives can also be unfair. In any case, the development of a successful export-oriented biofuel sector, requires getting access to technologies for efficient biofuel production and complying with relevant technical standards. Besides, developing a suitable transport infrastructure to reach these markets is required and thus harmonizing policies and governmental support is crucial.

5.6.3 Opportunities and constraints for the rural poor

5.6.3.1 Access to energy

Currently, more than one quarter of the world population is living without access to electricity and four out of five people without electricity live in remote areas of the developing world (IEA 2002). In most developing countries, households' energy demand for cooking, lighting and heating are far greater than the demand for transport fuels. Instead of producing transport fuels, the shift from traditional to modern bioenergy services to cover household energy needs may increase local energy availability and access, thus positively affecting productivity, health, education, and communication services. However, this would require making suitable technologies and devices available for local use of energy. Biodiesel and straight vegetable oils for instance offer opportunities for power production at relatively small scales at village or community level (Mukherjee 2008).

In addition, especially women and children will benefit from a shift to modern energy, by i) time savings spent for collecting firewood and charcoal (more time for other income generating activities) and ii) reduced exposure to indoor pollution caused by inefficient cooking stoves (improving health). In order to determine the net impact of modern liquid biofuels on women's time-use, it should be considered that additional work may be generated if women produce the biomass to make the fuel (FAO 2009).

5.6.3.2 Resource competition

Besides land, biofuel feedstocks compete with other productive resources, such as water, fertilizer and pesticides, leading to water and land degradation (Zah, Hirschier et al. 2007). Since certain biofuels feedstocks require significant water withdrawals the production of biofuels might contribute to aggravating existing problems, particularly in countries where water is already scarce (De Fraiture, Giordano et al. 2008).

The expansion of biofuels production is putting pressure on the environment (Scharlemann and Laurance 2008). Particularly in areas with relatively high biodiversity and organic matter contents the pressure will increase both greenhouse gas (GHG) emissions (Fargione, Hill et al. 2008) and loss of biodiversity (Groom, Gray et al. 2008). In Indonesia for instance, two-thirds of palm oil is produced on rainforest land (Grieg-Gran 2007). The planned expansion of palm oil production from 7.9 million ha to 10 million ha by 2020 (Adnan retrieved June 2009) will most likely displace rainforests too. Large-scale land conversion, however, does not necessarily need to be harmful, nor is small-scale land conversion necessarily less harmful, as both large-scale and small-scale plantations can negatively affect ecosystem services. Thus, sustainable land management practices have to be considered independent from the scale of plantations (Hurni, Herweg et al. 2008).

Nevertheless, energy crops such as *Jatropha curcas* have recently raised hopes that marginal and degraded areas could also be used for biofuel production. But the definition of marginal or idle land is a subject of controversy, as land in this category is often used for fuelwood collection by women or as grazing land by pastoralists (SWISSAID 2009). The loss of ecosystem services provided by such land particularly affects those whose depend most on them, i.e. subsistence farmers and the rural poor.

Second generation biofuels generated from agricultural and forest residues and by-products are seen as a promising way out of the current problem of resource competition with agriculture for food production. However, the increasing demand for by-products from agriculture and forests will most likely also affect current land use patterns. This is especially true for short rotation crops and *Miscanthus*, mostly grown on agricultural land.

5.6.3.3 Land rights and food security

Establishing large-scale biofuel plantations might lead to resource conflicts with local users, who have typically no means to claim land rights. As land availability and land values change, some groups are at a greater disadvantage than others. Indigenous communities for example are particularly vulnerable because many governments do not recognize the legitimacy of their land and territorial rights. In Colombia human rights activists warn that the land demanded for palm oil production threatens the territories of smallholders, indigenous groups and other minorities (Rodriguez 2009). This problem is also persistent in Africa, where 90% of the land remains outside the formal legal system (FAO 2008). According to Madoffe "Africa is currently facing a massive land grabbing scramble", since European countries are establishing enormous monoculture fields for biofuel production (Madoffe 2009). Many poor smallholders thus may lose their livelihoods and the possibility for subsistence farming, with severe consequences for food security.

Since biofuel production requires massive amounts of land and productive resources it puts pressure on grain and oilseed markets. The increased demand for biofuels is partly responsible for the 83% food-price increase over the past three years (Worldbank 2008). Various studies have shown that future biofuel demand will lead to an increase in prices for major commodities over the next decade (Ewing and Msangi 2009). Higher agricultural commodity prices will lead to increased income generation and welfare for net producers of food. At the same time, higher food prices pose an immediate threat to the welfare and nutrition of net food purchasers. Particularly at risk are poor urban consumers and poor net food buyers in rural areas, since they often spend more than half of their income on food (FAO 2008; Rossi and Lambrou 2009).

At a national level, higher food prices can create additional income for net food exporting countries. However, most least developed nations would suffer from increased food prices, since for the past 25 years they have typically shown an agricultural trade deficit. Especially for low-income food-deficit countries (LIFDCs), higher import prices can severely strain their food import bills (FAO 2008). In the longer run, the growing demand for biofuels may help reverse the long-term decline in real agricultural commodity prices, creating opportunities for promoting agricultural growth and rural development in developing countries. However, this requires strong government commitment to enhance agricultural productivity, for which public investments are crucial. Support must focus particularly on enabling poor small producers to expand their production and gain access to markets.

5.6.3.4 Employment and working conditions

In general the biofuel industry can create about 100 times more jobs per unit of output than the fossil fuel industry (Worldbank 2008). Brazil's ethanol industry for instance employs about half a million workers (Worldwatch 2006). The vast majority of employment in the biofuel industry is in farming and most jobs will be in rural communities. However, with increasing efficiency and mechanization, employment opportunities – especially for low-skilled agricultural workers – decrease. In Sao Paulo for instance already 40% of the sugarcane is harvested mechanically, causing direct and indirect impacts on employment (Guilhoto 2000). Furthermore, the potential shift towards second generation biofuels would decrease the number of agricultural workers drastically.

Apart from employment opportunities the quality of working conditions is also a matter to be considered, since working conditions are a major concern in several developing countries. Due to the lack of enforced labour standards, biofuel production is associated with poor working conditions such as health and safety risks, forced and child labour and the denial of the right to organize (Oxfam 2008).

5.6.4 The way ahead

5.6.4.1 Linking economies of scale and smallholder farmers

Economies of scale usually favour the establishment of large-scale biofuel processing plants (especially for the processing of bioethanol and second generation biofuels) and these large-scale plants demand for large feedstock pools which are typically provided by large-scale plantations. Even though large-scale schemes tend to be more efficient (Peters and Thielmann 2008), small-scale schemes offer greater opportunities for poverty alleviation and tend to offer higher social returns on public investment (FAO 2009). Highest finan-

cial and social capital opportunities occur if producer groups and co-operatives are developed and rural market systems are in place (PAC 2009). Local market chains with greater numbers of processes, linkages and by-products are increasing the resource efficiency of the whole system, and at the same time spreading livelihood benefits more widely within rural communities. On the other hand large scale investment is needed for establishing necessary infrastructure e.g. processing, collection and distribution networks (Gallagher 2008).

Thus, a key challenge is to link the big investors with small rural producers. Out-grower schemes and contract farming may offer a means of for smallholders to ensure their participation in biofuel crop production, while maintaining some independence. Such biofuels schemes may imply availability of credit, timely supply of inputs, provision of extension services and access to markets to smallholders. Further they may induce technology and knowledge spillovers into food production (Ewing and Msangi 2009) and provide employment opportunities for smallholders and labourers in the cultivation, conversion and processing of biofuels.

5.6.4.2 Sustainability criteria and certification schemes

In order to monitor the environmental and socio-economic impacts, several certification schemes and sustainability criteria are under development. There are various national and international approaches like e.g. the UK the Renewable Transportation Fuel Obligation (RTFO) (Bauen, Watson et al. 2007), the European Renewable Energy directive standards (EC 2008), or the voluntary criteria of the Roundtable for Sustainable Biofuels (RSB 2008).

However, sustainability criteria and certification mechanisms are controversial issues, as they rely mainly on indicators that have to be comparable, operational and measurable. But indicators face various critiques such as the difficulty to achieve meaningful interpretation (Hezri and Dovers 2006) as the definition of margins of sustainable biofuel production is in most cases entirely normative; the lack of causal linkages between indicators and outcomes (Briassoulis 2001) or their failure to reflect a system's ability to maintain or improve over time (Milman and Short 2008). Hence, approaches using indicators to measure the sustainability potential of biofuel production have to be negotiated with all actors concerned, require a sound database, and should take into account the dynamics of social and ecological systems.

5.6.4.3 Implications for future research on biofuels

The biofuel production chain from farming, milling, refining, and distribution to end use is a highly complex issue that cannot be addressed by a single academic discipline. This does not mean that disciplinary research is not needed anymore; on the contrary, it is crucial to get meaningful and valid results, which need to be cross-checked from different perspectives. Thus, the key to address the multiple challenges of biofuel research is the integration of findings from different disciplines.

Moreover, biofuel production is driven by a demand from society for sustainable energy and every single stakeholder involved in biofuel production has different needs and views. While requirements are goals derived from considerations and negotiations, 'needs' are goals expressed by stakeholders (Kiteme and Wiesmann 2008). Thus, the scientific community cannot appropriately address the problems of sustainable biofuel development on its own: it needs to work with stakeholders. Nor can individual research disciplines find answers ca-

pable of taking into account the complexity of the issue. There is thus a need for an alternating use of transdisciplinary, interdisciplinary and disciplinary research in order to achieve results that can be implemented (Hurni, Wiesmann et al. 2004).

The research consortium 'Bioenergy in Africa and Central America: Opportunities and Constraints of *Jatropha* and Related Crops' (BIA)²³ is an example of a framework that tries to integrate these requirements and needs by addressing the issue of biofuel production from a trans- and interdisciplinary perspective. The project's main objective is enhanced information and knowledge on bioenergy, upon which sustainable and pro-poor development strategies and policies can be designed and implemented by development partners and governments in both the North and the South, within a multi-objective decision-support system.

5.6.5 Conclusions

For sustainable biofuels to be competitive on the global energy market, market access for small-scale farmers and economies of scale, especially for efficient processing of biofuel feedstocks are required. This calls for innovative business models such as out-grower schemes or agreements between investors and local producer organisations. The key is an institutional framework that integrates and harmonises development, trade, agriculture, energy and land policies and provides an attractive environment and guidelines for investors. In addition, biofuel production enhances rural development most effectively if it is designed to cover rural energy needs and meet them with affordable and accessible energy – over the long run and in sufficient quantities and quality without degrading ecosystems and undermining food security. In order to steer current biofuel production towards sustainability, a great deal of ideas and knowledge still need to be developed. The integration of different views and perspectives is crucial for enabling the innovations required for biofuel production.

5.7 Agent analysis of biofuels (A. Schmid & C. Binder)

5.7.1 Conceptual Biofuel Value Chain

In order to analyze and structure the biofuel value chains, one can group the various agents involved into agent clusters such as the following: biomass suppliers, biofuel producers, dealers and importers and consumers. These agent clusters relate to one another primarily through the exchange of biomass or biofuels for money. In addition, all agents are characterized by specific resources and rules, which influence their actions (internal factors). Furthermore these actions are subject to important influences from other agents in the value chain and additional agents such as the state (external factors) (see Chapter 3.4. Structural Agent Analysis; [Binder 2007]).

²³ www.bioenergyinafrica.net

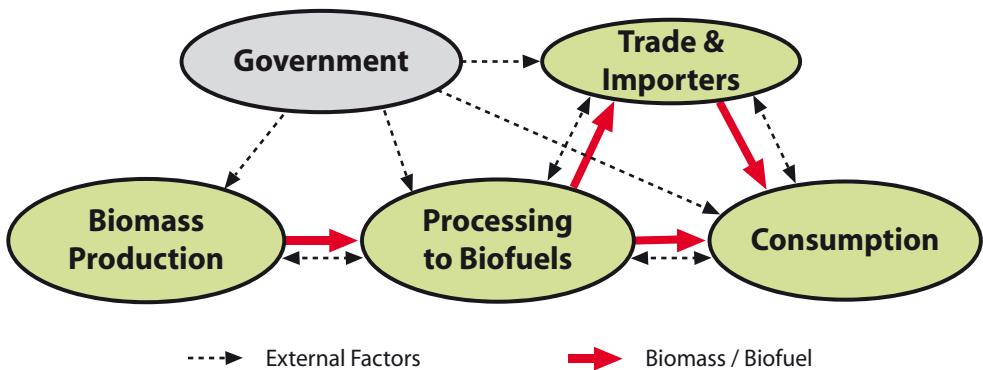


Figure 117: Systematic representation of biofuel value chains.

The breakdown into biomass suppliers, biofuel producers, dealers and importers and consumers allows to combine the various agents of Swiss biofuel chains, although it is not always possible to assign agents to a specific chain in a single way. For instance, agricultural biogas facilities can be assigned to biomass suppliers as well as they can to biofuel producers. Such overlapping however does not hinder one from doing a detailed analysis and contributes to a better understanding of the agents and value chains.

The first-generation biogas- and bioethanol chains were considered because they have the greatest similarity to the second-generation value chains defined in Chapter 4.2. We have not included BTL in this analysis as on the one hand there are no plans for building a facility of this kind in Switzerland, and on the other hand it will not be realistic that a company will engage in building such a facility in Switzerland for a long time. Such facilities are too large and require an enormous amount of biomass, making them practical only at locations such as inland or ocean havens or at locations with existing refineries and chemical parks (Dena, 2006).

5.7.2 First-Generation Biofuels in Switzerland

5.7.2.1 Biogas

In Switzerland there are mainly three types of biogas facilities: agricultural, commercial and sewage gas from sewage facilities. The biogas is usually fed into a combined-heat-and-power plant and used to produce electricity and heat. Heat that is used to run the fermenter is not counted as usable heat. Since 1996 biogas has also been fed into the natural gas network and sold at service stations to drive cars (BFE 2009).

Table 59: *Biogas facilities in Switzerland and energy production in 2008 (BFE, 2009b).*

Type of facility	No. of facilities	Gas production (TJ)	Usable heat (TJ)	Electricity (TJ)	Gas network (TJ)	Auto gas (TJ)
Agricultural	76	352.0	33.0	118.2	-	-
Commercial	20	364.5	34.7	81.3	35.4	16.2
Sewage gas	281	1783.0	911.0	421.0	56.0	-
Landfill gas	7	95.0	19.0	19.0	-	-
Industrial waste water	22	156.5	108.5	8.7	-	-

Agricultural biogas facilities

The number of agricultural facilities dropped in the 1990ies by 35%; however, since 2005 there has been a rapid increase, especially in larger cooperative facilities (BFE, 2009: 32, Köhli, 2009). Usually liquid and solid manure are fermented (approx. 80% of the biomass input). However more and more co-substrates are being used (approx. 20% of the biomass input) such as commercial food waste and green waste, in order to improve the gas production efficiency (BFE, 2009: 32; Köhli, 2009). Given a co-substrate share of over 20%, the amount of money paid under the "cost-covering feed-in tariff" (KEV), namely 15Rp./kWh of fed-in electricity, drops. The Zone Rule forbids farmers from using any more than 50% of co-substrate inside the agricultural zone. The coordination of procurement, transport and distribution of the co-substrate is taken care of by the cooperative Ökostrom Schweiz, in order to be able to guarantee sales and security of supply (Köhli, 2009).

In addition to the sale of energy products (usually as electricity), the agricultural facilities finance themselves mainly from the KEV and the disposal fees paid for co-substrate. After about 15 to 20 years the capital expenditures of an agricultural biogas facility have paid for themselves. The fermented biomass is used as fertilizer (Köhli, 2009).

Usually more than one agricultural plant is involved in a biogas facility. The trend is going in the direction of larger facilities with five to ten plants each. Smaller facilities are possible wherever they can be operated at low costs, in a simple manner, compactly, in modular construction and require a small amount of co-substrate (Köhli, 2009).

Farmers usually build biogas facilities with the goal of diversifying their income. Biogas facilities are additional income, and not one's main income. They contribute to increasing the share of renewable energy in accordance with the objectives set by the Federal Government and use industrial and commercial wastes. Using farm fertilizer in this way is, however, not a primary goal, because it can be used in other ways (Köhli, 2009).

Generally one expects the amount of biomass fermented to increase, and on the long run the amount of farm fertilizer to increase as well. It is expected that heat and electricity production will continue to rise until 2015, and then to slow down starting in 2030 due to an increase in the amount fed into the gas network.

Procurement of co-substrate is influenced by the following factors: disposal fees, coordination points, competition from composting facilities, sewage facilities (ARA), commercial facilities and waste incinerators (KVA), the location, the type of biomass and legal requirements. Especially the importance of coordination points, location and transport distances will increase.

The type of energy produced, electricity/heat or gas for network feed-in depends on the size of the facility, the location, the KEV, the investment costs, standards, product requirements and gas-purchase and supply contracts. It is expected that the feed-in tariff and regulation for the sector will become more important in the future (Köhli, 2009).

Commercial-industrial Biogas Facilities

The number of commercial-industrial biogas facilities has risen sharply since the mid-1990s. Mainly municipal, commercial and industrial waste is being fermented into biogas, such as green clippings, kitchen waste, rotten fruit, slaughterhouse waste, etc. (BFE, 2009b: 36). The commercial industrial biogas facilities are the largest biogas facilities in Switzerland. Axpo Kompogas AG is the largest operator with eight of its own facilities and interests in five more. In 2009 it processed 18% of the total amount of biomass fermented (Axpo Kompogas AG, 2009).

Unlike agricultural facilities, commercial industrial facilities have to fulfil stricter laws and standards and therefore finance themselves primarily through the fees paid for the disposal of biomass (about 80%) and to a lesser extent through the KEV and the sale of energy products (20%). After 15 to 20 years the facility has paid for itself (Schild, Ruoss, 2009).

The main goal of a commercial industrial biogas facility is the energetic use of waste, and that is their largest source of income. The production of electricity is more common than the gas sales, a development that could be reinforced in the future. The utilization of heat in particular is expected to come more important. The greatest growth potential regarding biomass input is seen primarily in the utilization of municipal waste; however, there is also potential in using waste from the food industry and restaurants as well as other biogenous industrial wastes.

Important factors in procuring biomass include transport costs and the trouble of collecting it, the possible competitive uses, its availability, the biomass price and the middlemen such as municipalities and companies that supply the biomass and ensure supply. It is expected that the competition for biomass will increase, a development that will affect disposal costs and the amounts available. The willingness to accept high transport costs will also rise.

The question as to what is produced from biomass is determined on the basis of the relative prices of the energy carriers gas, electricity and heat in addition to operation and investment costs, the availability of an existing gas network, gas sale and supply contracts (running for about 15 years) and the heat utilization potential of the location. In Future, the acquisition of CO₂ emission certificates for conventional gas substitution and methane emission reductions could become additional factors (Schild, Ruoss, 2009).

Sewage gas facilities

Many municipal sewage treatment facilities produce sewage gas along with their sludge. As is the case with agricultural and commercial biogas facilities, the gas is burned downstream in a combined heat-and-power plant and produces electricity. The heat is used to supply buildings and the fermentation tower (BFE, 2009: 37). Sewage facilities are using more and more co-substrate in order to increase their gas output and to profit from the KEV. In this way they comprise competition to the agricultural and commercial biogas facilities. Since these facilities do not depend directly on energy production, i.e. are primarily funded by municipalities, they can buy biomass at very good conditions (Köhli, 2009).

5.7.2.2 Ethanol and Biodiesel

Ethanol

Whereas 19.2 GWh were produced in 2008, i.e. some 3.1 million liters of ethanol in Switzerland, since 2009 no ethanol is being produced anymore due to the closure of the sole production facility, Borregaard in Attisholz. Ethanol was produced as a side-product of cellulose production. Today the entire quantity of ethanol, some 4 million liters, is imported from Scandinavia. Since 1 July 2008 the ethanol market has been liberalized, but private-sector importers have shown little interest. Ethanol used to be imported mainly by Alcosuisse (Schaller, 2009).

Given first-generation technologies, we no longer expect any ethanol to be produced in Switzerland for use as a fuel. Second-generation production of ethanol is conceivable in the future, but at best as a niche product (Schaller, 2009).

The European Union levies a tax on ethanol imports, but not on ethanol from Switzerland. Therefore it is conceivable that Switzerland will import ethanol and re-export it (Schaller, 2009; Henggeler, 2009).

The import of ethanol to be used as a fuel is influenced by factors such as sustainability criteria, exemption from petroleum tax, long-term supply contracts, the high capital expenditures needed for new infrastructure, the costs of logistics, limitation of the vapor pressure of petrol, the price of oil, and the poor image of the fuel. These factors make the business unattractive for fuel dealers; a few agents have already left the field with their losses. The chance that they will resume or expand their business anytime soon is estimated to be very low and even unrealistic, unless there is a blending requirement (Schaller, 2009; Henggeler, 2009; Hofer, 2009).

Biodiesel

In 2008 108.1 GWh of biodiesel were produced, and some 12 million liters were consumed. The quantity imported is negligible (BFE, 2009). The interest of the petroleum sector in Swiss biodiesel is very modest. Quality problems, infrastructure costs competition with food production and the image problem that brings with it for biodiesel play important roles. The rising requirements being placed on the quality of diesel by modern, optimized engines are making sales more difficult (Henggeler, 2009; Hofer, 2009).

5.7.3 Second-Generation Biofuels – Outlook

5.7.3.1 Biomass Suppliers

Forest owners

About 72% of Switzerland's forests are held publicly, of whom 90% are local political municipalities, citizen communities or cooperatives. The rest (28%) is owned privately by some 250,000 forest owners who own 1.39 ha of forest on average. Whereas 2,700 private

and public forest operators having each more than 50 ha own over 339 ha on average. Public authorities pay subsidies to forest owners for the production of public goods (Thees, Lemm, 2009:19, 45, 46; BFS, 2009a).

Table 60: Structure of Swiss forest ownership and operators (BFS, 2009a).

Area class	Number of operators	Number of owners	Total forest area (ha)
>50 ha	not available	244,084	341,481
<50 ha	1,026	1,036	19,677
51–100 ha	412	484	32,952
101–200 ha	406	433	67,582
201–500 ha	435	635	164,487
501–1000 ha	252	913	209,825
1001–5000 ha	190	3,334	400,302
>5000 ha	4	409	28,543
Total	2,725	7,246	923,368

In addition to public-sector forest operators, most of whom are public-sector forest owners too and exercise forest-police duties along with the logging, some private-sector forest enterprises exist. Private-sector forest enterprises are pure service providers and offer mostly timber logging services on behalf of the forest owners. Since wood sales are done primarily with the product in a lying position, wood remains in the hands of the forest owner until sold to the wood industry. A total of 5 million m³ per year is sold. Wood utilization as a function of forest area was 5.6 m³/ha in private-sector forest as compared with 3.6 m³/ha in public-sector forest for 2008 (Thees, Lemm, 2009: 46–49; BFS, 2009b).

The goals of forest owners differ widely depending on the particular region in question. Urban forests, mountain forest and the forest in lower and flatter areas of Switzerland have very different stakeholder groups, functions and user profiles. Generally speaking, the wishes placed on the forest and their effects have increased and will presumably continue to increase in the future. Only in lowlands does the material utilization of the forest take top priority, followed by energetic utilization. In the Alpine and urban regions the forest fulfils protection and recreation functions, which inhibit or prohibit any economic use (Thees, 2009).

From an energetic perspective, around 14,200 GWh of Swiss wood is used as raw material or energetically, and the unused annual new growth comprises 6,700 GWh. It is expected that primarily the use of wood as a raw material will increase, and with it the quantity of forest energy wood. That will be taken primarily from the natural new growth. As the ownership and production relations are varied, decisions on use take place very decentrally. Furthermore, the quantitative development of forest energy wood depends on the development of energy prices, long-term supply contracts with a term of about 10 years, the price structure on the lumber market and locally very different logging costs. In future, though, the importance and duration of long-term supply contracts will decline in the forest sector. That will be due to the expected increase in demand and increase in local utilization possibilities, for example, for heat production (Thees, 2009).

The Wood Business

Switzerland's forests consist of 69% coniferous and 31% deciduous trees. In average, more coniferous lumber (74%) is cut than deciduous (26%). About 63% of the logs harvested are further processed in sawmills and the rest is used primarily as pulpwood or energetically, whereby part of the coniferous pulpwood is used as a raw material (in paper, for instance). In the final analysis 34% of all the wood harvested becomes softwood boards, about 4% hardwood boards, about 30% are used as raw material (and the remaining 33% are used energetically.)

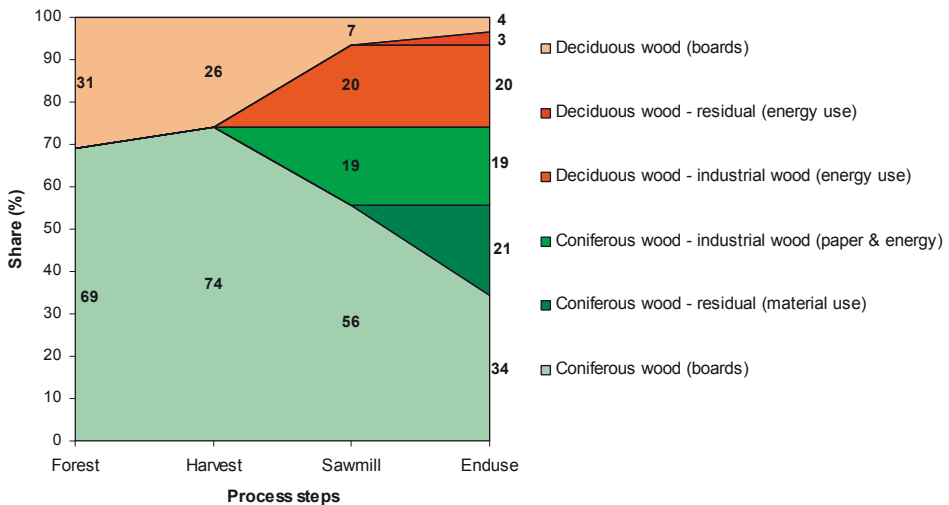


Figure 118: The wood utilization path (Streiff, 2009; authors' rendering).

The main driver of the wood utilization path is the utilization of softwood as a raw material (34%), as it represents the largest value-added component (Streiff, 2009).

The Swiss wood industry has set itself the goal of stronger growth. The forest utilization rate is supposed to be expanded to its sustainable optimum. The focus is on the use of wood as a raw material. However, as the importance of paper and cellulose industry declines, residual wood quantities that have been used as raw material until recently will become free, which can be used for energy production. Pellet production will probably be expanded at the cost of chipboard production (Streiff, 2009).

Seen energetically, over one third of the entire quantity of wood in Switzerland is used as a raw material. Almost half is exported and the rest is converted into energy (Baum, Baier, 2008). It is to be expected that the percentage of exports comprised by timber will decline and that comprised by lumber will increase. The quantity exported will decline, although the value of the wood will increase. The utilization of wood as a raw material will expand, whereas the energetic use will be more apt to stagnate or to rise only slightly (Streiff, 2009).

The sale of residual wood is very important for sawmills, so that their operations are not blocked. This is one of the factors that is most important today for the quantities of pulp-wood and residual wood used for energy production. The sales possibilities, the buyer structure, guarantees to take, the growth of the entire quantity of wood, ways to use wood in one's own operation, transport costs and wood prices are determining factors. Since usually only a small number of large buyers are on hand, sawmills react with diversification and invest, for instance, in wood drying facilities. One trend towards more local utilization of wood for energy production might result from the interaction of buyer structure, utilization in-house, and transport distance to the buyer. The trend toward concentration in the sawmill business could stop with rising oil prices, or even reverse itself. In addition to the forest ownership structure in Switzerland, transport costs comprise a limiting factor, because they jeopardize the security of supply for large installations (Streiff, 2009).

The Construction Business

The construction business can deliver scrap lumber for energy production. The most important goal for the construction business as regards scrap lumber consists of a disposal that is as cheap and quick as possible. About 50% of the scrap lumber is exported to Italy. Firstly, that can be explained through the price differential between Italy and Switzerland. Italian chipboard industry and combustion installations offer better conditions for buying scrap lumber, a trend reinforced by the high energy prices in Italy. Secondly, export for logistical reasons is very cheap. Transport companies tend to have more trips empty when going to Italy, which they can partly compensate for by taking scrap lumber along. The Swiss environment agency FOEN tried to encourage the use of scrap lumber in Switzerland by setting up IG-Altholz. However IG-Altholz had to be discontinued because the transport sector did not want to support it anymore (Vock, 2009).

Results of the export trend become apparent, for instance, in the burning of scrap lumber in Switzerland. As compared with 1990, the combustion capacity of scrap lumber burnt rose by 38.4% to 380 MW. Since 2002 the combustion capacity, however, has remained relatively constant, and in 2008 even dropped by 22.6% again, when three installations were taken out of service (BFE, 2009, S. 24).

5.7.3.2 Synthetic Natural Gas

Biomass procurement

Although wood is anticipated as the raw material for producing SNG, the problems in obtaining biomass appear to be similar to those encountered in agricultural and commercial biogas facilities. Transport costs, the trouble of collecting it, competitive uses, availability, biomass price and middlemen such as municipalities or companies that supply biomass and ensure the security of supply are important. In addition it has to be remembered that in the case of wood, unlike the case of the feedstocks used in conventional biogas facilities, no disposal fees are received, and instead a price has to be paid. Likewise it is expected that the competition for wood waste and energy wood will increase (Köhli, 2009; Schild, Ruoss, 2009; Sennhauser, 2009; Peyer, 2009).

Problems Commonly Encountered with Investment in an SNG Facility

At present the high capital expenditures and investment risk are the most important hurdle to take in building an SCNG facility. At least half of the capital expenditures must be depreciated right from the start. Securing an adequate supply of biomass at favourable conditions, the secured sales of energy products and the existence of heat user comprise together with the capital expenditures a requirement to cooperate that last about 15 years until the facility is paid off.

Only if multiple partners – from biomass suppliers to buyers of the energy products – are available and can agree on a total plan that goes beyond the construction of the facility can such a facility be implemented. The availability of biomass must be ensured in a contract right from the start, and the same applies to the sales of the energy products. It may well be that heat sales are on the whole less important than in the case of conventional biogas facilities; however, heat sales are still relevant due to the size of the facility and the high capital expenditures. The biomass has to be cheap, because the biomass price will be reflected in the electricity price at 60 to 70%. That implies that biomass suppliers, local companies with a large need for heating and/or chilling, local and regional utilities, municipalities and even Cantons have to agree on a long-term project that secures supply and sales.

In conjunction with the cooperation partners there is the location problem. There have to be biomass suppliers of adequate size and heat buyers for the whole year at a single location with enough available land for construction, preferably with a connection to the gas network.

The fact that an SNG facility can supply various kinds of energy raises its chances of sales success. The insecurity as to the development of energy prices, the development of technological alternatives, government regulations and the various supply developments of biomass, heat, electricity, methane and biogas increase the investment risk and make assessment more difficult (Peyer, 2009; Sennhauser, 2009).

Bioenergy Sales

An SNG power plant can produce electricity, heat, biogas and synthetic gas (methane). The market share of the expensive ecological electricity generated not only from biomass has reached 2–3% today. A similar market share is to be expected in the case of biogas because of the high prices. Given a current price for natural gas of about 9 Rp./kWh, it is hard to sell SNG at 18–20 Rp./kWh (Sennhauser, 2009). Swiss gas suppliers have set an objective of covering 10% of the total energy consumed for mobility purposes to be provided by using gas. 20% of this 10% is to be covered using biogas. (Peyer, 2009). It is expected that in the future more biogas will be fed into the gas network and the heat production from biomass will tend to fall in the long term. When fed into the gas network, there is no heat loss as there is in the case of electricity production; however, at present there is not always a network connection available for gas (Peyer, 2009; Sennhauser, 2009).

As is the case with sales of electricity, the price plays a decisive role in the case of biogas. Additional factor such as personal preferences, the willingness to pay more for an ecological product, the image of the particular energy carrier, the location, the customer profile, the gas quality and the type of customers, whether household or companies, all play a role (Peyer, 2009; Sennhauser, 2009).

Agent Landscape

Figure 119 shows all potentially involved agents of an SNG value chain. We have drawn in material and energy flows, probable or necessary holding structures and potential money flows without raising any claim to completeness. The figure visualizes the requirement to cooperate among various agents and the necessity of vertical integration. The federal government does its part by issuing the KEV. The canton and the municipalities take a financial share in the project, and provide the site at favourable conditions and biomass. The forest industry and the wood business have to participate via supply contracts. The local energy suppliers and energy companies participate in project finance and give commitments to buy.

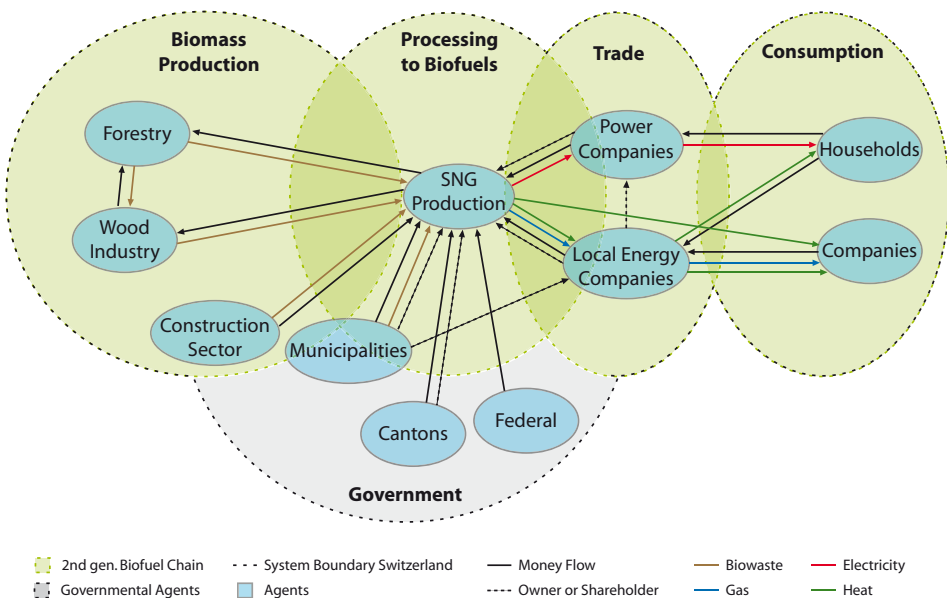


Figure 119: Potential agents in an SNG value chain.

5.7.3.3 Lignocellulose Ethanol

Biomass procurement

Framework conditions analogous to those in the case of SNG apply to the procurement of biomass to make ethanol from lignocellulose (see Chapter 5.7.3.2)

Problems Commonly Encountered with Investment in a Facility Making Ethanol from Lignocellulose

In a facility of this type as well, the high capital expenditures and investment risk comprise important hurdles to take. So do securing an adequate supply of biomass at favourable conditions, securing sales of ethanol along with the capital expenditures and risks and the requirement to cooperate that lasts until the facility is paid off.

Only if multiple partners – from biomass suppliers to buyers of the ethanol – are available can such a facility be implemented. In particular, the availability of large quantities of biomass comprises a big problem. In addition, this technology is not yet so far advanced (Schaller, 2009).

Agent Landscape

Analogous to the case of SNG above, below shows all agents potentially involved in a lignocellulosic ethanol value chain. We have again here drawn in material and energy flows, probable or necessary holding structures and potential money flows without raising any claim to completeness. Analogous to the case of SNG above, the figure below visualizes the requirement to cooperate among the various agents and the necessity of vertical integration. A new, very important element is the imports.

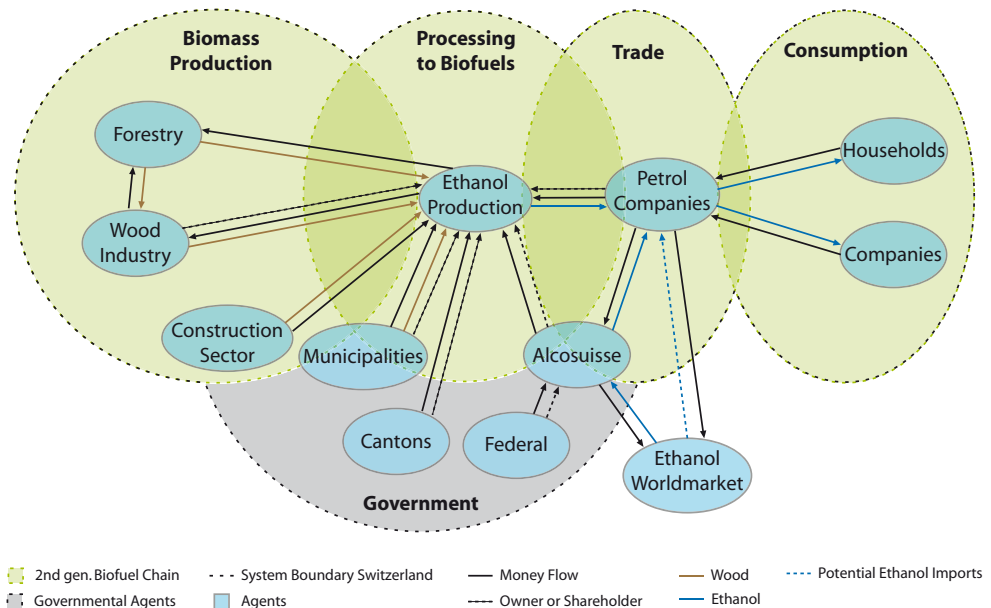


Figure 120: Potential agents in a lignocellulosic ethanol value chain.

5.7.4 Synergies and Conflicts

5.7.4.1 Agent Overview

Agent or agent group	Goal ranking	Time horizon	Chain options	Constraining/facilitating factors	Effect of structural factor
Forest owners (Thees, 2009)	1. Wood production material use ²⁴ 2. Wood production energy use	10–100 years	Providing wood for energetic use	Wood prices Ownership structure Supply contracts	Material use preferred over energy use Small-scale forest owners make concerted action more difficult Supply contract of up to 10 years reduce the flexibility of forest owners and might induce a lock in effect
Wood industry (Streiff, 2009)	1. Increase forest use to sustainable max. 2. Wood processing for material use 3. Using wood residues as material 4. Using wood residues for energy production	5–10 years	Providing wood residues for energetic use	Sales opportunities, customer structure, growth of wood demand Own use Transport costs Wood prices	40% of residual wood output can hinder production by blocking the plant, sales must be warranted, only few big customers Diversification strategy, burning wood for drying processes Local use (short distances) preferred Increasing prices for energy wood

²⁴ Only for Northwestern Switzerland and the Alpine foothills is wood production not an important goal in urban and alpine forests.

Agent or agent group	Goal ranking	Time horizon	Chain options	Constraining/facilitating factors	Effect of structural factor
Construction sector (Vock, 2009)	Cheap and fast wood waste disposal	1–2 years	Providing waste wood	Wood type and separation costs	Deciduous wood is becoming more attractive due to lower processing costs in bigger factories
				Availability of forest wood	Changing forest ownership structure to allow optimised forest use
				Disposal prices	Export to Italy is the cheapest option, strong trend for export
Local energy company (Sennhauser, 2009)	1. Providing heat out of biomass 2. Building and running their own plants for heat, electricity and gas production (SNG and others)	5–20 years	Build an SNG plant	Investment costs	High investment costs and risks might impede
				Supply contracts, biomass price and availability	Biomass supply secured for 15 to 20 years
				Customer contracts for products (energy, heat)	Long-term contracts for energy and heat output support investment decision
				Availability of local partners	Allows for sharing investment costs and lowering risks
				Insecurities of future technologies	High insecurity about future technology developments and governmental regulations might lead to negative investment decisions
				Selling bioenergy	If too expensive not possible

Agent or agent group	Goal ranking	Time horizon	Chain options	Constraining/facilitating factors	Effect of structural factor
				Willingness to buy and pay for a green product	The greater the willingness, the better the demand for bioenergy
				Customer information	Promotion of new energy technologies
				Location	Availability of long-distance heating net or gas net allows output diversification
Gas trading company (Peyer, 2009)	1. Securing biomass, technology development 2. Own plants 3. Biogas trade 4. Biogas for cars	5–20 years	Build an SNG plant	Supply contracts, biomass price and availability Customer contracts for products (energy, heat) Investment costs Location Government regulations	Biomass supply secured for 15 to 20 years Long-term contracts for energy and heat output support investment decision Very high investment costs and risks in relation to energy prices Local biomass availability, transport costs, partnerships Insecurity about future biomass and energy regulations
			Selling biogas	Price KEV regulation Biomass price Gas quality Gas net	If more than 20% higher as conventional gas price no sales possible Will lead to biomass shortage in future Direct and strong effect on energy price High quality needed Availability of gas net connection

Agent or agent group	Goal ranking	Time horizon	Chain options	Constraining/facilitating factors	Effect of structural factor
Oil traders (Henggeler, 2009; Hofer, 2009)	1. Sell oil products		Ethanol trade	Regulations	Tax reduction is outpaced by sustainability criteria. Without blending target no relevant ethanol sales possible
				Availability of sustainable ethanol	Difficult to buy sustainable ethanol (produced only by Scandinavian countries). Certification and compliance costs.
				Technical factors	Vapour pressure regulation, E85 car fleet
				Margin and infrastructure costs	Petrol stations, depots, and logistics are very expensive for small ethanol amounts
				Image	Ethanol image problems
Alco-suisse (Schaller, 2009)	1. Research and ethanol technology development 2. Ethanol supply 3. Its own ethanol production in the future 4. Import of ethanol		Build an ethanol plant	Biomass availability, competition for use	Large amounts needed, difficult to organise
				Contracts	Secured biomass supply and ethanol sales
				Oil price	Price difference
				Political willingness	Blending target needed
				Regulations	Vapour pressure regulation
				Sustainability criteria	Hinder import opportunities
			Ethanol trade and import (for cars)	Contracts	Long-term contracts needed due to high logistical infrastructure investment costs

Agent or agent group	Goal ranking	Time horizon	Chain options	Constraining/facilitating factors	Effect of structural factor
				Regulations and policy	Vapour pressure regulation, tax release has low positive effect compare with hindering sustainability criteria, mandatory depots increase demand, need for short-term CO ₂ reductions can increase demand
				Oil price and alternative technologies	Higher oil price expected, competition to other technologies, electric cars can outpace biofuels
Swiss Government (BAFU, 2008; BFE, 2008)	Cascade use: 1. Using wood as material 2. Using wood for energy production		Promote biofuels	Setting priority	Using biomass to produce fuel for cars has low priority in federal wood and biomass strategies and is coupled to high sustainability standards

5.7.4.2 Organising Biomass for Lignocellulosic Ethanol and SNG Plants

The boundary conditions for producing biomass from wood and biomass from organic waste differ significantly from each other.

Regarding wood, studies have shown that the forests are underutilized and that significant amounts of wood would still be available. This is particularly true, as the wood industry focuses mainly on the use of pinewood, leaving some room open for the higher utilization of deciduous wood. Furthermore, the concentration process taking place in the wood industry could support the flow of wood to the SNG plant with low transaction costs. The decreasing demand for wood in paper production might also support an increasing flow of wood for energy purposes, but not necessarily for SNG or ethanol production.

However, the utilization of these wood sources is limited for five reasons:

First, the Federal Office for Environment (FOEN) states in its wood utilization strategy that wood should first be used as a material in construction and furniture and with a second priority for energetic purposes. This is in line with the main income sources of the wood processing companies who achieve a much higher price for wood earmarked towards construction and furniture use.

Second, the ownership structure, with a total of 250,000 owners and an average parcel size of 1.39 ha make it difficult to maintain a concerted and coordinated action, and thus to ensure a constant wood flow to the relatively large potential SNG and ethanol plants.

Third, forest owners are usually engaged in long-term contracts (running up to 10 years) with the wood industry which has to have guaranteed supplies. This might lead on the one hand to a kind of a lock-in situation in which the forest owners might not be able to quickly change their buyers in an environment of increasing wood prices.

Fourth, the regional differences between the Swiss lowlands and the Alps and urban forests might lead to a regionally specific flow of wood, and thus limit the places in which such a plant might be functional. Furthermore, with rising oil prices, the potential for transporting wood across the country will become less feasible.

Fifth, the availability of waste wood is very low due to the high competition for this resource.

5.7.4.3 Trading and Selling Biofuels

There are two types of conflict fields that affect the trading and selling of biofuels: one is a cost/benefit problem and the other regulative hurdles and uncertainties.

The cost/benefit problem:

As with all green products in the case of biofuels as well there is only a limited sales potential. The customers have to be willing to pay more for an ecological product. In addition, SNG would cost twice as much as natural gas with SNG going for 20 Rp./kWh. That means that only lower market shares can be reached with ecological energy products (max. ca. 2–3%) than has been the case with bio groceries (4.7%) (Peyer, 2009; Sennhauser, 2009; Bio Suisse, 2007).

Unlike the case of conventional biogas facilities, SNG facilities or ethanol production from wood cannot be funded from disposal fees, but instead have to pay for their raw materials. There is strong price sensitivity in SNG production related to the type of biomass used: biomass prices are reflected in the energy price at rates of 60–70%. Although SNG and ethanol are becoming more competitive with rising oil and natural gas prices, bioenergy prices will rise from more expensive biomass and transport costs as well. That can have a negative effect on the price differential between bioenergy and fossil fuels.

With SNG and ethanol, infrastructure costs play an important role. An SNG facility has to have a gas connection, which makes its already difficult siting even more difficult. Ethanol requires tank farms, the logistics become more complex and more expensive and filling stations have to be retrofitted – costs that become prohibitive for small quantities. Without a blending requirement to significantly raise the quantities, these investments are not being taken.

Regulative hurdles and uncertainties:

Ensuring (i) supply with enough biomass at favourable conditions, (ii) sales commitments for the energy products and (iii) the availability of a heat buyer together with capital expenditures comprise great risks and thus force multiple agents to cooperate despite their varied interests for the duration of about 15 years until the facility is paid off.

Benzines with a low ethanol component (E5, E10) do not fulfil the requirements for vapor pressure (SN EN 228, RVP value) in the warmer summer months. Too many volatile organic components are emitted.

The image of ethanol has deteriorated in recent years and ethanol is now suspected by the public of competing against food production. There is a need to raise awareness of the possibility of producing sustainable ethanol.

The sustainability criteria for exemption from the fuel tax can only be achieved for imported ethanol with a great deal of trouble and expense.

Without clear, long-term, reliable, technology-specific government objectives and subsidy strategy almost no one is willing to take the risks in an environment of high capital expenditures, limited biomass potential, uncertain technological developments and energy price trends.

5.7.5 Conclusions

Regarding biofuels first generation, the current situation in Switzerland clearly favours the utilization of waste biomass in agriculture and households for the production of biogas. Based also on the governmental investment support, the biogas facilities have rapidly developed and seem to have a stable position in the market. On contrary, the ethanol production plants, mostly oil plants have encountered several drawbacks and the agents have withdrawn from the market.

Regarding biofuels second generation, the agent analysis performed with the main agents in the current and the potential future value chains of the second-generation biofuels showed that there are several problems ranging from biomass supply through building plants for biofuel trade. For the two chains SNG and Lignocellulosic ethanol this implies.

a) SNG chain:

At short term this value chain has a limited market potential due to high prices and uncertain fossil fuel price developments, even though the multi-energy output is likely to lower lowering investment risks. In order to establish a SNG biofuel chain the following factors were found to be decisive:

1. Constant and secure flow of biomass, which requires contracts with forest owners or even a change in forest ownership.
2. Cooperation among several agents with different interests to lower the high investment costs and risks of building a plant.
3. Security and continuity in regulation regarding the use of wood (i.e. trade-off between wood for material use and wood for energy use)

4. Subsidies in order to support the time during which the final energy prices of SNG are higher than fossil fuels prices.

b) Lignocellulosic ethanol chain:

The problems for implementing a lignocellulosic ethanol chain seem even larger than the ones for implementing an SNG chain. The major issues refer to biomass availability (within Switzerland and biomass imports) and compliance with European standards (???). In order to establish a SNG biofuel chain the following factors were found to be decisive:

1. Constant and secure flow of biomass, which requires contracts with forest owners or even a change in forest ownership.
2. Check the possibility of new import sources of biomass, in particular wood.
3. Reduction of infrastructure and logistic costs to overcome the bad experiences of the key agents, such as oil companies, had with biofuels first generation, which were mostly related with high infrastructure and logistic costs.
4. Security in regulation regarding the use of wood (i.e. trade-off between wood for material use and wood for energy use)

In summary we recommend that to increase the use of biofuels in Switzerland, the following measures should be considered:

- a) Increase security of biomass availability by creating incentive for forest owners to get organized and increase the harvest rate to the maximum sustainable one.
- b) Develop measures, guarantees and incentives to reduce investment risks such as a clear and binding, technology-based, long-term federal biofuel strategy to provide regulative certainty and orientation.
- c) Develop location-specific, overarching energy master plans linking housing sector, public services and private companies at the municipal and cantonal levels from biomass use to energy production and consumption.
- d) Create measures to reduce cooperation costs e.g. biomass coordination offices.

5.7.6 Outlook

The actors analysis has shown that establishing a new technology in the area of biofuels is a challenging undertaking in a complex system, with a high diversity of agents with different interests and time horizons.

Not surprisingly, further research issues emerged: First, a consensus building process (Binder, 2007; Susskind, 1999) among the agents who would potentially participate in a specific value chain should be envisioned. Within this consensus process, the time horizons of the different agents, their options and constraints should be brought forward. A participatory model building process could further support the setting of common goals and the design of strategies to support the innovation and transformation process within the value

chain. In this process policymakers should also be involved, in order to guarantee the development of optimal boundary conditions to implement the desired value chain.

Second, a comparison of agent structures and the effect of boundary conditions on the potential value chains should be compared across countries. This would permit researchers to further scrutinize the necessary conditions for a successful implementation of the most sustainable chain.

Third, a link to global change scenarios would help researchers to more specifically analyze potential future supply as well as potential future demand.

5.8 Acceptance of 2nd generation biofuels (L. Diethelm, C. Binder, A. Schmid)

5.8.1 Introduction

When talking about social acceptance, soon the question arises, what is social acceptance exactly? Most people do often talk in their everyday life about topics that are in some way or other related to this subject, in many cases not noticing that they are speaking of social acceptance actually. A good example is the current discourse on manager bonuses. It is discussed in all media, between friends and up to on a global scale. The question here is, till what amount manager wages are justifiable, or in other words, whether high manager wages are socially accepted or not? But you hardly hear the term “social acceptance” in the public. If asking people to define social acceptance you seldom get a clear and uniform answer. It is not the term itself which is difficult to explain, it is rather that what lies beneath it. As a common denominator you could say that it deals with personal opinions, positive attitudes of people towards something. By determining social acceptance, you want to analyze the probability of a positive reaction on a certain stimulus, often linked to the future. If so, the aim is to conclude from present opinions on future behavior (Endruweit, 1986: 81). Nowadays it is crucial to know the attitudes of the public, especially true for the fields of marketing research for example when planning to introduce new products or technologies. That is why it is so important to put a special focus on the social acceptance of biofuels 2nd generation. Biofuels have been discussed frequently and questioned critically in the past years. This spotlight lights up the darkness that encloses social acceptance of biofuels and provides a state-of-the-art insight into this topic. As social acceptance is difficult to conceptualize, an indirect approach is chosen. The participants are not directly asked for their acceptance, you would not get reliable responses. Social acceptance is here deduced from various factors that are related to biofuels as well as from other questions describing all parts of this topic. The spotlight shall provide you with answers to the following questions:

In a first section: How was the social acceptance investigated and what was the sample of this study? In a second section: What are the driving and most important factors people think at when being confronted with biofuels? What is the present image of biofuels? And how does this differ between the political parties of Switzerland? In a third section, addressing the knowledge: Do people know the difference between 1st and 2nd generation biofuels and what generations have they got in mind when thinking about biofuels? Through what

information sources do people inform themselves about biofuels? In a fourth section, dealing with issues that are of highest political significance: How do people judge the future potential of biofuels? Should biofuels be subsidized or not? Where should biofuels be produced? These are all relevant questions describing the social acceptance and therefore mentioned briefly in this spotlight.

5.8.2 Sample of the study

The results presented here are based on a non-representative online survey with members of the five major national political parties of Switzerland (Table 61). The link to the online survey was sent through a newsletter or through a separate E-mail (depending on the party) to addresses in the database of the national political parties. The survey was also transmitted to all members of the cantonal council, except for the canton Ticino. With a total number of 584 started questionnaires it is not sufficient to make representative conclusions for the Swiss population or the individual political parties. Besides another sample approach would be needed for that. However, the quantity of respondents is enough to speak of a reliable portraiture of a broad range of various opinions and to assess tendencies between different groups. It has never been the goal to achieve a representative study of the social acceptance.

Table 61: Overview of the sample.¹

Political Party	GPS	SPS	CVP	FDP	BDP	SVP	others/ none		
	209	121	62	88	7	71	26		
	35.8%	20.7%	10.6%	15.1%	1.2%	12.2%	4.5%		
Language	German	French							
	467	117							
	80.0%	20.0%							
Sex	M	W							
	413	171							
	70.72%	29.28%							
Age	< 18	18-29	30-44	45-64	65 +				
	2	73	155	314	40				
	0.3%	12.5%	26.5%	53.8%	6.8%				
Edu- cation	Primary School	Second. School	Appren- ticeship	Profess. College	Univ. of Appl. Sc.	Univer- sity			
	2	35	97	95	115	240			
	0.3%	6.0%	16.6%	16.3%	19.7%	41.1%			
Income ²	< 3,000	3,000 - 5'999	6,000 - 8,999	9,000 - 11,999	12,000 - 14'999	≥ 15,000	not specified	missing	
	46	223	161	80	15	17	30	12	
	7.9%	38.2%	27.6%	13.7%	2.6%	2.9%	5.1%	2.1%	

¹ Total number of respondents = 584

² Gross equivalent income

5.8.3 Factors related to biofuels and the overall image of biofuels

5.8.3.1 Driving factors

The methodology used in this chapter is called Analytic Hierarchy Process (AHP). AHP belongs to the field of decision making. In a first part of the AHP people are asked to rate the relative importance of nine different factors in pairwise comparisons resulting afterwards in a quantitative ranking of these factors (Table 62). For further information see chapter 3.2.5.4 or consult Saaty (1990). The question was: If buying biofuels, which factor in each pairwise comparison would you consider more important (on a scale from 0 to 4)? The following table shows the final ranking as a result of these comparisons. The ranking is provided for each political party to analyze possible trends between the parties as well as a total value. Because the number of respondents in each party varies significantly, the total is calculated out of the different party values and weighted by their political power in the National Council, giving you an idea of the composition of different opinions in the parliament (source: elections for the National Council 2007). The total number of respondents differs from the number of started questionnaires mentioned above because inconsistent answers have been removed and some people (about 20% of all) have aborted the questionnaire at some point.

Table 62: *Ranking of the nine factors according to their importance (for each party and as a total).*

Factors ¹	Breakdown by political parties					Total ²
	GPS	SPS	CVP	FDP	SVP	
Number of respondents	138	67	41	45	31	322
Low food competition	20.38	21.87	18.78	17.11	18.06	19.10
Protection of human rights	21.95	22.97	16.43	9.25	7.38	14.23
Low environmental damage	18.62	15.26	14.97	13.83	10.22	13.67
Low GHG-Emissions	11.51	11.87	12.10	12.29	7.80	10.61
Low resource demand	11.50	10.45	10.32	9.71	8.13	9.65
Independence of petrol	5.02	5.02	9.15	12.73	12.29	9.46
High efficiency	6.45	6.41	7.59	9.75	12.33	9.14
Low price	1.99	2.53	4.76	7.42	13.07	7.16
Proximity to fuel stations	2.59	3.61	5.89	7.91	10.73	6.97
Total of points	100	100	100	100	100	100

¹ sorted by the rank in the total ² weighted by the political power of the parties

The pairwise comparisons are translated in a scale which is normalized to 100. You can interpret the individual values as a fraction of a total of 100 points in each column. In the aggregated column "Total", 19.10 of the 100 points are given to the factor "Low food competition" which ranks therewith by far on top of the list, followed by "Protection of human rights" with 14.23 points. People considered "Proximity to fuel stations" as the least important factor of all with only 6.97 points. It is interesting to see that the ranking is headed by the two social factors. Ecologic factors are located in the middle of the scale and the economic factors are assigned the lowest importance. One would believe that economic factors, especially the price of biofuels, would be the most important factors when deciding whether to buy biofuels or not. This ranking shows something different. Even though the factor "Low price" gets in the GPS only 1.99 points, the points for that factor are continuously ascending from the left to the right, ending in 13.07 points given from members of the SVP. A possible explanation for that anomaly would be that in surveys people act on the assumption of idealistic ideas. Even in the best surveys there will unfortunately always be a gap between attitudes and true actions. The SVP is the only party, who does not rank "Low price" last, but second last. Because of the political power of the SVP in the National Council, "Low price" is also ranked second last in the total column. The rating of members of the GPS is very similar to that of the SPS, giving no statistical significance between all the factors, except for the "Low environmental damage". Throughout the five parties the discrepancies between the parties for all the factors differ significantly. The least difference is observed in the factor "Low food competition" which ranks first. Here, all the parties are surprisingly in common. Although there is low discrepancy in "Low food competition" it does not mean that this applies also to the other social factor "Protection of human rights": the given points vary here from 7.38 in the SVP till 22.97 in the SPS. The biggest variance of individual answers is found within the SVP, constantly decreasing throughout the parties on the way to the left, till the GPS.

The relevance of these factors is the following: You can conclude that biofuels need to fulfill social and ecological standards to be accepted by the public. This fact is shown by the Table 62 evidently. The more the protection of employees and the less the impact to other humans and to nature, the higher the social acceptance will turn out. Biofuels thus should be produced sustainably.

5.8.3.2 Overall image of biofuels

Getting now to one of the most interesting questions: What is the present image of biofuels? How do the interrogated people perceive biofuels compared to other fuel options like petrol and electric drives? To answer that, again, people are asked to evaluate these three fuel options in pairwise comparisons, regarding each of the nine factors described above. For example a question could be: In your opinion, which of the following fuels in each comparison compete less against food (on a scale from 0 to 4)? These comparisons of options complete the AHP and result again in a ranking, but this time for the fuel options. The ranking of the fuel options can be interpreted as the image people advise to the fuels.

Table 63: *Ranking of the three fuel options according to their image (for each party and as a total).*

Fuel options ¹	Breakdown by political parties					Total ²
	GPS	SPS	CVP	FDP	SVP	
Number of respondents	122	49	28	35	31	265
Electricity	54.11	49.05	50.38	50.10	45.46	48.83
Petrol	22.36	26.89	26.20	28.09	33.53	28.67
Biofuels	23.53	24.06	23.42	21.81	21.01	22.50
Total of points	100	100	100	100	100	100

¹ sorted by the rank in the total

² weighted by the political power of the parties

With almost 50 of 100 points electricity ranks by far on top and has therewith the best image of these three fuel options, given the nine factors to compare it with. Astonishingly, biofuels come off badly, with only 22.50 points. Even petrol results in a better image in this study. This is mainly because biofuels are rated poor in the factor “Low food competition” which is given a high importance as we have seen before. According to its high importance it also gets a higher weight in the final calculation of the fuel option ranking. Besides, in the ecological factors that are also rated as quite important, biofuels never make it to the top. Even though the image of biofuels in the ecological domain is always better than that of petrol, electricity gets considerably more points. It is also interesting to observe that the bad image of biofuels crosses all political parties. The values stay more or less the same leading to no significant difference throughout the parties. Only in the GPS, biofuels perform better than petrol. In contrast to biofuels, electricity and especially petrol differ significantly between the parties. The image of petrol is almost continuously increasing going from the left to right, meanwhile the image of electricity is more or less continuously decreasing. The variance of the individual answers within the political parties is quite even throughout the parties. 95% of all given answers range around ten points for each fuel option. An exception is the GPS, whose members again seem to have the same opinion. Here, 95% of the respondents range around just five points or even less.

According to this sample, only electricity seems to be a reasonable alternative to fossil fuels, being highly socially accepted under the given conditions and assumptions. Interestingly this finding corresponds with the results in the TA-Swiss project. In general, electric mobility performs the best in the Sustainability Potential Analysis, mainly due to its high efficiency in power generation and use of electricity in cars.

5.8.4 State of knowledge of biofuels

Speaking of assumptions, it is important to know what people have in mind when doing these pairwise comparisons. After all, the term biofuels is not a homogenous term. It is rather a generic term describing lots of different feedstocks and conversion technologies. You can assume that people thinking of biofuels 1st generation, while filling out the questionnaire, rate biofuels different than people thinking of biofuels 2nd generation. To get to know these assumptions lying beneath every decision, three open questions have been included in the questionnaire, where the participants of the study were asked to list three aspects of biofuels that were important to them. The evaluation of the comments shows that the participants attach the greatest importance to the topic of food competition. This corresponds to the results made in the ranking of the factors. Subjects concerning the protection of the environment and a carbon neutral production are mentioned a lot as well. These topics are related mainly to biofuels 1st generation.

The initial hype that biofuels are a good and sustainable alternative to fossil fuels, has in the meantime turned into disillusion. Especially after many studies attested most of the biofuels 1st generation a bad environmental balance and after blindfold subsidies made by various governments. The complicity of biofuels to the increasing food prices widely discussed in the media, has ultimately induced a bad image on biofuels. This is now clearly revealed in the comments made by the participants of the online survey. It is also seen in the low ranking of biofuels compared to the other two fuel options. One question in the online survey was whether they know the difference between biofuels 1st generation and 2nd generation or not. Only 122 of 476 (round 25%) stated yes. So the majority of the respondents did not know the difference or have not even heard of biofuels 2nd generation so far. Out of all these insights, it can be assumed that most of the people thought about biofuels 1st generation when answering the pairwise comparisons.

The 122 respondents knowing the difference between biofuels 1st and 2nd generation were asked to assess the more reasonable generation. More than half of them rated the 2nd generation extremely or much more reasonable (Figure 121). Six participants rated the 1st generation extremely more reasonable. In text boxes they could then note the advantages and disadvantages of biofuels 2nd generation. The most commonly mentioned advantages include: compete less with food; are more sustainable; are more efficient; use the whole plant as also biowaste. To the mentioned disadvantages belong: are not yet available; are complex, energy and cost intensive in their production and conversion; risk of genetic engineering and monocultures; still compete with food and harm the environment.

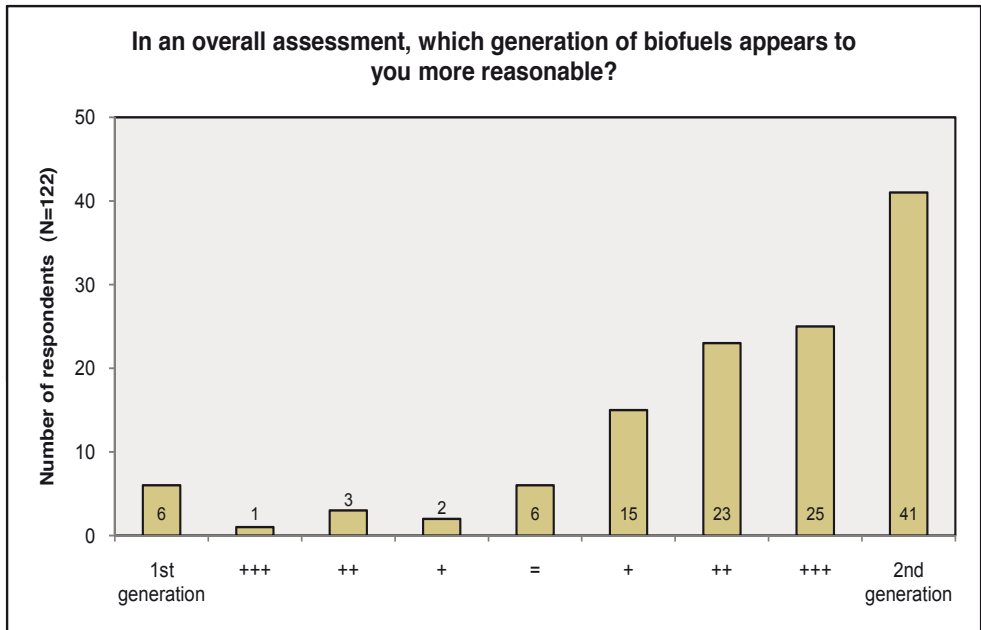


Figure 121: Acceptance of 1st vs. 2nd generation biofuels.

Asking the participants to estimate their own state of knowledge of biofuels, only three of a total of 475 named it very high which seems surprisingly low. Especially when considering the fact that many of the participants are politically active in their party or in the cantonal council or at least members of a party. The big majority with 317 people, representing two thirds of all, estimates their state of knowledge conservatively and calls it moderate, whereas 78 rated it high and 77 of the 475 rated it low. The present state of knowledge is one point. Another interesting point is to collect, if people would like to increase their knowledge, or in other words if the participants of the study would like to inform themselves more often about biofuels. The question in the survey was: Shall the media and the public discuss and report more often about biofuels? Almost a third, 128 of 475, said yes, lot more. The majority with 234 people (nearly 50%) believes that there should be little bit more discourse in the public, whereas 89 people answered that going on like up to now is the best. Only 18 respondents think that there should be less attention in the media and in the public about the topic biofuels.

Out of these results you can make conclusions about the social acceptance. It seems that people are quite open minded about more news coverage and are willing not only to consume it passively, but also to inform themselves actively. This might be astonishing, especially after the controversial discussion in the media in the past few years concerning the sustainability of biofuels. Furthermore the results show that there is still a big lack of information. This counts for the 1st generation. To a greater extent this is also true for biofuels

2nd generation. Most of the people still do not know what the term “2nd generation” means. Therefore, the question arises, how these people can be informed? What kind of information sources do they consult to get updated about biofuel news? And what information sources are specifically useful for such news? Figure 122 shall give an insight to these two questions.

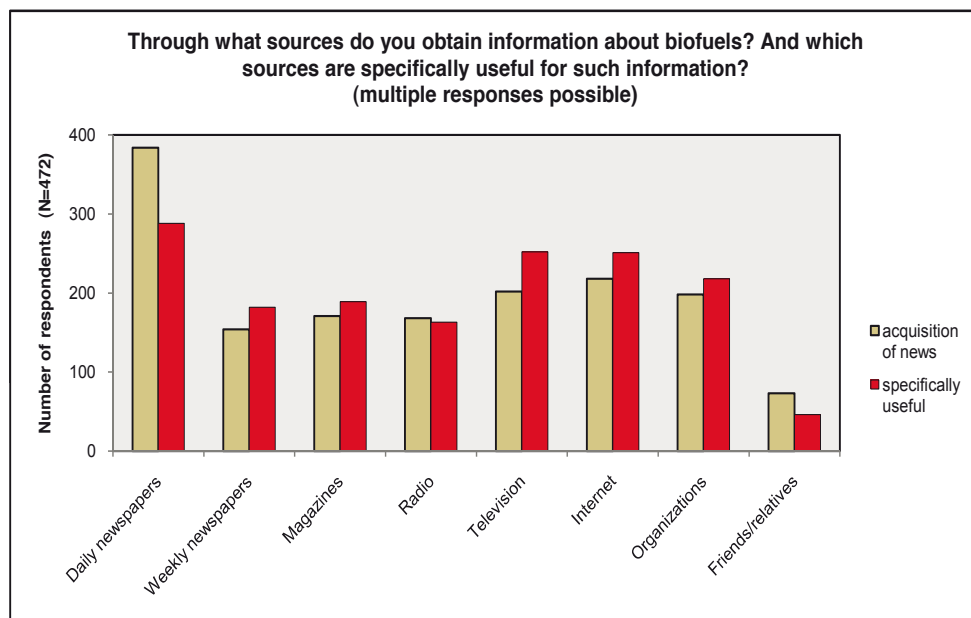


Figure 122: Sources to get informed on Biofuels.

The figure shows that there are various sources used, often even from the same person. Today we have access to a broad bunch of different media sources that we regularly call up. A clear trend cannot be observed unfortunately, neither for a specifically useful source. Along with the mapped information sources, scientific journals have also been mentioned several times as a possible source, which is rated as very useful for getting information.

5.8.5 Policy relevant questions

Having discussed mostly questions concerning the status quo of social acceptance of biofuels, an outlook shall now be given. The topics presented in this section are relevant for actions, thus making this section especially interesting for policy. From these questions the government can possibly deduce some concrete measures. Acting according to the results in the following graphs could raise the social acceptance of biofuels. Because of the non representative number of respondents within each political party, the results in this section are weighted by their corresponding political power in the National Council and presented apart. A further advantage of this weighting is that the results show the possible distribution

of opinions in the National Council. Would the results be representative, you could assume that an acclamation would more or less come out as shown in the graph, but as the results are not quite representative, you can only identify tendencies.

The participants of the study were asked, whether the policy should promote biofuels or not. Almost 25% (108 of 448) agreed (Figure 123), whereas 135 said yes, if certain conditions would be fulfilled. The conditions mentioned here overlap quite well with the aspects listed at the beginning of the last section (no food competition, no environmental damage etc.). In addition to that, some new aspects have been stated, mainly related to policy, such as: only through incentives or policies, not subsidies; only if the subsidies are selected accurately; only if there are no cross-subsidies; only in an international corporation, only if produced in Switzerland; only biofuels 2nd generation. Most of the people (173 or 39%) said no to biofuel subsidies. Most SVP members are against subsidies. The GPS and SP vote mainly for conditioned subsidies. The parties in the middle are more or less equally distributed among the different answer options.

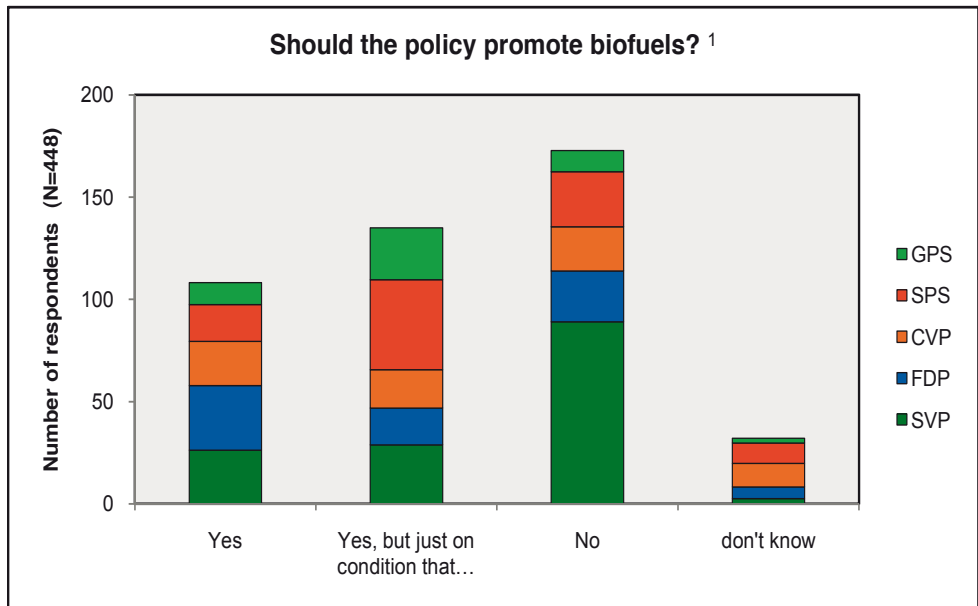


Figure 123: *Opinions on Biofuels promotion:*
¹ weighted by the political power of the parties.

In another question people were queried whether standards that ensure certain ecological and social specifications should be encouraged more often or not (Figure 124). Here, the conclusion is clear: 324 of 448 (72%) answered with yes, a surprising uniform statement, also throughout the political parties. Just 97 respondents said no, mainly consisting of members of the SVP and some of the FDP and CVP. Almost all members of the GPS and SPS voted for more standards in the market. One reason why so many people agreed with

more standards might be that it is easy to vote for such standards, especially when not being confronted in everyday life with the impact of that decision. That is why the respondents saying “yes” or “don’t know” were afterwards asked if they could imagine to also pay more. It is obvious that sustainably produced biofuels cost more. Almost 40% (138 of 351) said “yes, sure”. Exactly the same number answered this question with “yes, perhaps”. Therefore, 80% of all the respondents agreeing to standards, are willing or at least not averse to pay more. 73 people disagreed to pay more, saying “No, rather not” or “No, certainly not”. Again, most of the people disagreeing belong to the SVP. To recall: this is mainly due to the high percentage of the SVP in the National Council. Within the SVP, 69 members said yes versus 46 saying no, thus making the share agreeing to pay more, larger.

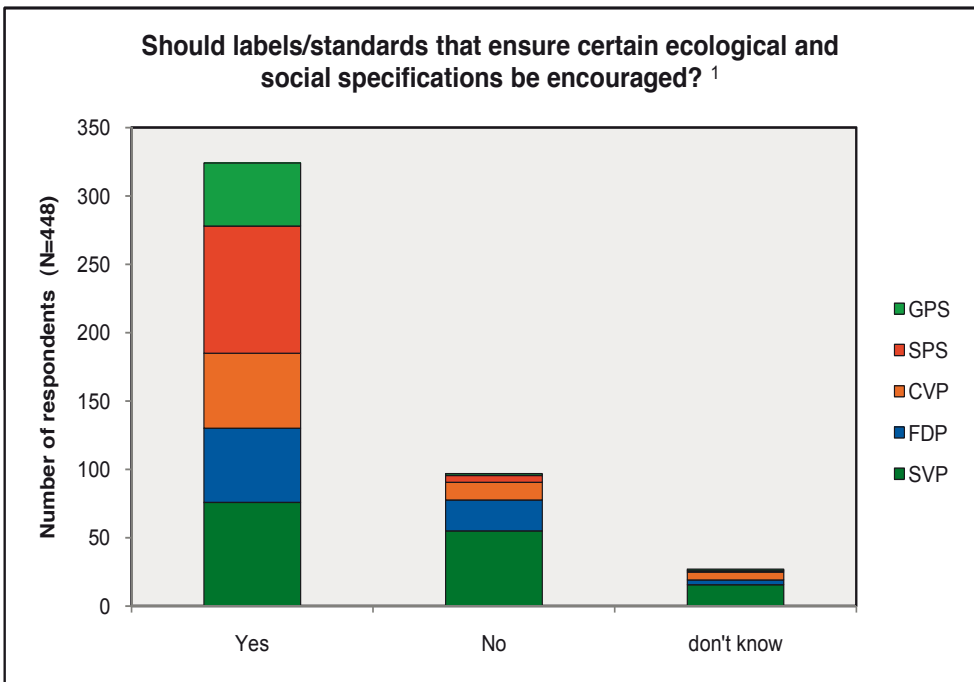


Figure 124: *Opinions on Biofuels labelling:*
¹ weighted by the political power of the parties.

As having noted in the conditions of whether the policy should promote biofuels actively or not, there is also great importance attached to the question of where to produce and converse biofuels. Biofuels made in Switzerland account for added value on home soil, reducing hereby the dependence from foreign countries and reducing even the GHG-emissions due to shorter route of transport.

An own question was devoted to the subject of where to produce biofuels for Swiss consumption. A bright majority of 200 of 448 (45%) answered that biofuels should mainly be produced in Switzerland. Approximately 15% said they should be fabricated only in Switzerland and again 15% said it should be evenly allotted between Switzerland and foreign countries. The options “mainly produced abroad” got 28 votes (6%) and “only produced abroad” just four votes (1%). 39 people (9%) answered to the question of where to manufacture biofuels that biofuels should not be produced at all, therewith ascribing biofuels a very low social acceptance. Political distinctions cannot be spotted in this question: The majorities of all parties believe biofuels should mainly be produced in Switzerland. The rest is distributed similarly relative to the other parties.

Finally, to sum up the foregoing questions, Figure 125 highlights how the participants estimate the future potential of biofuels in general, according to their own opinion. It shows that most of the people (179 or 40%) and throughout the parties ascribe biofuels a moderate future potential. 38% of the respondents think biofuels have a high to very high potential, and 20% think they have a low to very low potential.

Apart from the neutral answer “moderate”, the share of people ascribing biofuels a high to very high potential is slightly bigger. Comparisons between the political parties seem to reveal no difference in judging the overall future potential of biofuels which is quite interesting to notice.

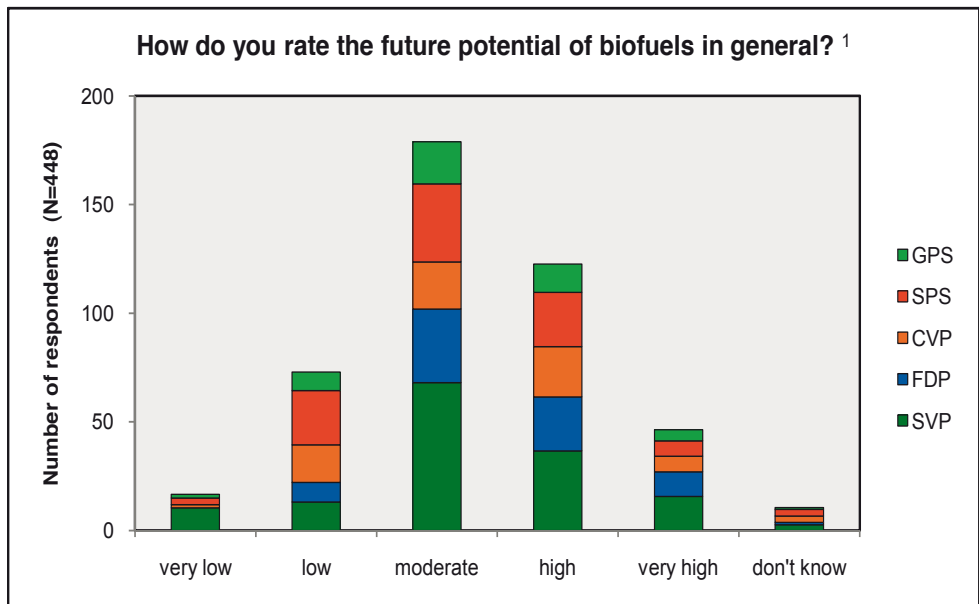


Figure 125: *Opinion on future potential of Biofuels:*
¹ weighted by the political power of the parties.

5.8.6 Conclusions

The **overall social acceptance of biofuels is quite low**. The results obtained through the AHP in pairwise comparisons of factors and fuel options show that the image of biofuels is even lower than the one of petrol. Furthermore, biofuels are mostly associated with aspects like competition to food and environmental damage, e.g. GHG-emissions, deforestation, biodiversity reduction. All these aspects were important for the participants of the survey, independently of the political party they corresponded to. Nevertheless, 85% of the respondents who knew the difference between first and second generation biofuels **assigned 2nd generation biofuels a better image** than 1st generation. It is notable that there is a significant lack of information, especially concerning biofuels 2nd generation, which the interviewed are willing to overcome provided sound information on biofuels. One last issue emerged clearly throughout the whole questionnaire and independently of the political party: There is a **high demand for standards that ensure ecological and social specifications of biofuels**. Only by doing so, confidence can be regained and the flawed reputation of biofuels overcome, and therewith the social acceptance be enhanced.

6 DISCUSSION

6.1 What are the most relevant feedstocks, technologies and use types?

On the level of **elements**, waste feedstocks like manure, biowaste, indirect and recovered wood fuel exhibit the highest sustainability potential. Main reason is the low interventions induced by their provision. Only straw and direct wood fuels obtain values which are in the same range. All of these feedstocks are supplied in Switzerland and could therefore foster energy independence and local value creation. The sustainability of 1st generation feedstocks like palm oil, sugar cane or jatropha but also of cultivated 2nd generation feedstocks like miscanthus, short-rotation wood or halophytes scores substantially lower and are in the same range as the supply of fossil resources. Main critical factors of both 1st and 2nd generation feedstocks are land consumption and biodiversity impacts:

- Switzerland required in 2006 already 27% more cropland on the global scale than was available per person at the world level (reg. Table 50). This highlights the Swiss contribution to the expansion of global cropland. This trend will significantly increase with the advent of agro-based biofuels.
- Biodiversity is generally threatened by large-scale production of biofuels. 1st generation biofuels mainly increase the pressure on fertile and arable lands and therefore on biodiversity-rich natural ecosystems. For 2nd generation biofuels large amounts of ligno-cellulosic feedstock are needed. This increases the land use pressure on dry natural areas, on the intensification of forestry and on soil fertility if crop residues are excessively used.

Nevertheless, biodiversity could be sustained or even increased by biofuels production if the cultivation takes place on degraded areas or if integrated agricultural systems are implemented (Ranganathan, Daniels et al. 2008). These options however appear to be niche applications that cannot satisfy the global demand for biofuels on the commodity market.

For **conversion technologies**, overall sustainability is relatively constant. Less environmental impacts are often compensated by higher costs or less energy efficiency, which leads to relatively similar results. In general, crude oil refinery reaches the highest scores, as the technologies is well known and has a high economic efficiency. Co-processing of biogenic feedstock in fossil refineries would be a straight-forward option for combining established technologies with advanced feedstocks.

The 1st generation technology of oil extraction and trans-esterification scores surprisingly high. This might explained by the fact, that the process itself is efficient, simple and well-known. This process however depends on the supply of oil-containing feedstock, which is critical on the cultivation level. Mid-scale production technologies like SNG-production or lignocellulosic fermentation are best suited for Switzerland with its complex topography and its missing sea harbours. The SPA shows above average results for both processing technologies.

The sustainability of biomass conversion could be significantly improved by bio-refineries, where the revenue is enhanced by producing a range of high-value products while producing biofuels only from low-value fractions. The biorefinery approach would be especially feasible for algae biofuels, where production costs are still magnitudes too high and where high-value products for the pharma and nutrition industry could be derived.

For the **use phase** electric mobility (due to its high efficiency) and the use of BTL (due to low emissions and infrastructure demand) exhibit a distinctively higher sustainability score than the use of fossil and 1st generation fuels. However, the future efficiency of combustion engine-based mobility significantly depends on the development of the car fleet towards more efficient fuel use. This strongly depends on consumer behaviour and policy regulations, rather than on the technical potential, as best-in-class cars already reach <4l/100km while the fleet average is at 7.9l/100km.

6.2 Which will be the relevant value chains?

The sustainability potential of 1st generation value chains is usually lower than the fossil reference (reg. Figure 98). Main reasons are a low structuredness and a negative interdependence with other systems (e.g. large area consumption, high environmental impacts). The exception is 1st generation methane from waste, that scores highest due to well-known and efficient technology and no dependence on agricultural areas. Most 2nd generation biofuels exhibit significantly higher SPA-values than both, 1st generation biofuels and fossil fuels. Nevertheless, algae fuels score relatively in the range of 1st generation biofuels, due to their high costs and the still missing research break-through. Value chains based on electric mobility score a little better than 2nd generation biofuels. Main reason is the high efficiency of both, power generation and use of electricity in cars.

The **agent analysis** pointed out many challenges in implementing biofuel value chains. Import potentials of ethanol and biodiesel highly depend on factors like infrastructure costs for the oil trading companies, sustainability regulations, quality standards, blending targets, a negative image and the fact that some of the oil trading companies already made expensive negative experiences with biofuels. Their willingness for further investments is very low under current conditions. Setting up a 2nd generation biofuel plant demands a high degree of cooperation between all the agents involved in the value chain because of high investment costs, difficult biomass supply, warranted sales and uncertainties about future technology developments and energy prices. These hindering factors depend not only on the agents directly involved in the chain rather on agents indirectly involved. Therefore a larger biofuel plant needs a multi-level energy concept or strategy to reduce investment risks. Such an energy strategy should involve potential local customers, municipalities and cantonal governments beside biomass suppliers and energy companies.

6.3 How do 2nd generation biofuels compare to 1st generation and to electric mobility?

Generally, no clear pattern is visible when comparing the different fuel generations. The variation within each fuel generation is higher than between the generations. 1st generation biofuels based on agricultural feedstock cultivation such as rape seed and jatropha generally show a low SP, whereas 1st generation biofuels based on residues and wastes score even higher than 2nd generation biofuels. Most 2nd generation biofuels exhibit a significantly higher sustainability performance than both, 1st generation biofuels and fossil fuels. Main positive factors of 2nd generation biofuels are the interdependencies with other systems (low GHG emissions, low environmental impacts) and a relatively high buffer capacity with respect to economic and environmental changes.

Although the sustainability potential of 1st generation biofuels is lower, 1st gen fuels are already available on the market and they are nearly competitive with fossil fuels. Assuming a high oil price and weak sustainability regulations, they could easily outperform 2nd generation fuels on the market (Figure 99, scenario 3).

Value chains based on electric mobility score a little better than 2nd generation biofuels when they are fueled with renewable energy. Reason is the high efficiency of both, power generation and use of electricity in cars. The main advantage of electric mobility is the scalability of its energy production. While the production of 2nd generation biofuels is limited by the availability of waste feedstock and arable land, production of renewable electricity from wind or solar power appears to be limited mainly by financial constraints or the scarcity of rare metals for PV. Nevertheless, if the electric car fleet is fuelled by fossil-intense electricity, such as the European mix or even coal power, benefits on greenhouse gas savings and on overall sustainability are widely eliminated or even over-compensated.

6.4 How big is the potential for 2nd generation biofuels in Switzerland?

The **domestic potential** of 2nd generation biofuels is constrained by the availability of ligno-cellulose-based biomass, i.e. in detail either by (i) high land requirements related to intended cultivation of ligno-cellulose-based biomass or (ii) limitations of waste and residues.

With regard to land availability, the production of ligno-cellulose from intended cultivation of short-rotation wood, miscanthus or grasslands is limited given that the available land in Switzerland is constrained. For example, to substitute 1% of the crude oil based mobility by BTL from short-rotation wood between 15,000 and 20,000 ha land is required. This reflects approx. 3–5% of the land area currently used for agricultural production in Switzerland (FAO 2008). In other words, if great amounts of the crude oil based mobility should be substituted, the domestic cultivation and production of 2nd generation biofuels would induce a radical shift in the current agricultural land use patterns.

With regards to the availability of residues, the production of energy, residue and waste wood is limited by different factors. It is the current forest ownership structure in Switzerland, the competition with other use options and the dependant co-product character²⁵ of energy, residue and waste wood which places constraints on the availability of additional lignocelluloses potentials (Vock, 2009; Streiff, 2009; Thess, 2009). Considering these constraints, Steubing et al. (Steubing, Zah et al. 2010) determine the available potential for lignocelluloses biomass as 11.69 PJ for forest energy wood and for industrial wood residues and 3.58 PJ for waste wood. When these additional potentials would be used exclusively for SNG or BTL production approx. 3–6% of the crude oil based mobility could be substituted (depending on the technical advances in vehicle efficiencies).

The **import potential** of ethanol and biodiesel is currently very low according to Schaller (2009), Hofer (2009) and Henggeler (2009). Without strong regulations like blending targets infrastructure and investment costs are far too high under current conditions and regarding expected margins and market shares.

Also the import of 2nd generation biofuels is constrained by a growing global demand for food and water and competes with other land use functions like conserving biodiversity and carbon stocks. Last but not least, there will be a strong demand competition for sustainably produced biofuels, induced by binding sustainability criteria for renewable energies in the EU (EU-Commission 2008) and in the US (CARB 2009).

However, considering an increased fleet efficiency of 4l/100km in the year 2030, those limited imports of 1st and 2nd generation biofuels into Switzerland could fuel 5–9% (depending on the scenario) of the Swiss individual mobility in 2030 (Figure 99).

6.5 The role of 2nd generation biofuels in future energy scenarios

2nd generation biofuels can be produced from ligno-cellulosic waste feedstocks. Therefore, 2nd generation technology is able to tackle both, waste treatment and bioenergy production in a combined manner while minimizing indirect effects. Consequently, 2nd generation biofuels will be mainly produced in highly developed countries, where waste materials are abundant, underutilised land is scarce and investment capital is available. This is reflected in all three scenarios, where domestic production is expected to be mainly 2nd generation; while imports will be dominated by 1st generation ethanol from Brazil.

Although sustainable production of biofuels is generally possible as shown in the value chain analysis (reg Chapter 4.2.15), the dilemma of 2nd generation biofuels lies in its dependence on either limited land or on limited waste feedstocks. This dilemma is illustrated by the case of fuels from algae. Biofuels from algae are neither limited by land nor by feedstock availability, but their production is highly energy and cost intensive.

This above mentioned dilemma leads to a maximum substitution of fossil based mobility by 1st and 2nd generation biofuels of 14%, whereas the substitution caused by electric mobility

²⁵ The production of a dependant co-product is constrained by the demand for the main product. For example, the production of industrial residue wood is constrained by the demand for sawn wood. In other words, an increased demand for industrial residue wood will not result in an increased production of sawn wood given that most of the revenues are related to the sawn wood and not the co-produced residue wood.

adds up to 26% but could be even higher basically depending on technology development and cost reductions. The assumed increase of non-conventional oils in the fossil fuel mix would significantly increase the impacts associated with the use of fossil fuels and eliminates or even overcompensates the benefits associated with the implementation of biofuels compared to the baseline scenario (2010). This emphasizes the importance of finding alternative forms of mobility that are scalable without adverse effects.

The analysis of the three scenarios further highlights the relevance of the boundary conditions Swiss biofuel production might be confronted with. The full potential of 2nd generation biofuels from manure and waste wood are expected to be realized under conditions of high oil prices, resource scarcity, recession and food crisis. In this case the prices for biofuels might be relatively low to the ones of fossil fuels and they will become competitive.

As all considered biofuel and electric mobility pathways are economically not yet competitive, policy regulations will have a major influence on the success of 2nd generation biofuels. Of primary importance however is the increase in tank-to-wheel efficiency of combustion engines. A reduction of the average fleet consumption from today's 7.9l/100km to 4.0l/100km as predicted by CONCAWE for the year 2025 is mandatory to reach the assumed biofuel ratios. Without this technical advance in vehicle efficiency (VE) bioenergy-based mobility in Switzerland is restricted to clearly less than 10% in 2030.

7 RECOMMENDATIONS

1

Promote in parallel vehicle efficiency *and* the sustainable use of 1st generation biofuels, 2nd generation biofuels *and* eMobility!

This study emphasized that different factors altogether determine the overall potential of 1st and 2nd generation biofuels as well as of electric mobility: (i) the sustainability performance per value chain relative to the fossil reference, (ii) the available energetic potential per value chain and (iii) the conversion efficiency with which the feedstock is transformed into useful energy.

The study also revealed that the implementation of electric mobility is an important option for partially replacing fossil based mobility: an additional 5% of the current Swiss electricity consumption could be substituted for approx. 26% of Switzerland's fossil based mobility. However, as the sustainability of e-mobility is strongly dependent on the type of electricity (coal, hydro, etc.) used, it is important to insist on a renewable and sustainable form of electricity production. The potential of increased fuel efficiencies in combustion-driven transport is a further central outcome of the study. Increased fuel efficiency not only directly decreases the dependence on fossil fuels per pkm and decreases GHG intensity but also significantly increases the outcome of the available biofuel potential, which indirectly further diminishes our dependence on fossil fuels.

This potential is however challenged by the continuing growth of our mobility demands but also by the increasing fossil burden caused by the transition from conventional to unconventional oil supply. Figure 126 shows as an example that the GHG balance for each of those factors is in the same range or greater than the maximum biofuels potential.

Figure 126 clearly demonstrates that a net benefit can hardly be achieved without increased efficiency, and a maximum benefit would require that all measures are applied in combination. 1st and 2nd generation biofuels and eMobility are complementary in their production and use, while pushing vehicle efficiency and biofuels leads to strong synergies. Consequently, the question for policy makers is not "bio-based, electric or more efficient mobility?" the key issue is about how to promote efficiency and develop the sustainable potential of the different technologies in parallel!

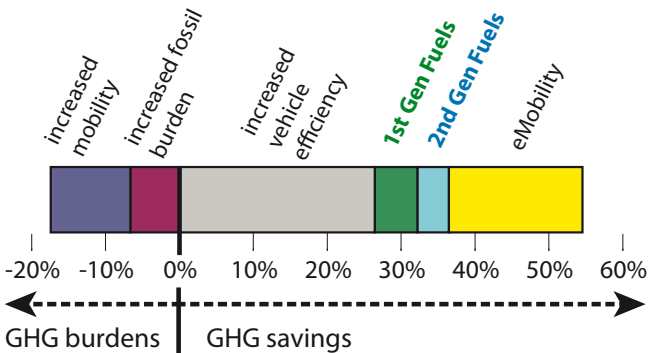


Figure 126: Relevance of various factors for the overall GHG savings potential of 2030.

2

Develop a long-term biofuel strategy that gives the stakeholders regulative and legislative stability and therefore triggers new investments in the sector!

Currently, stakeholders are hesitant to invest in the various technology options for producing 2nd generation biofuels. This is mainly due to an unpredictable and – to a large extent – not existing policy framework for 2nd generation biofuels. This leads to investments in established but out-dated technologies and hinders the penetration of more sustainable and efficient 2nd generation technologies. A long-term biofuel strategy is needed that provides the different stakeholders with a policy framework within which they can make their investment decisions. In particular we recommend to

- Increase security of biomass availability by creating incentives for forest owners to get organized and increase the harvest rate to the maximum sustainable one.
- Develop measures, guarantees and incentives to reduce investment risks such as a clear and binding, technology-based, long-term federal biofuel strategy to provide regulative certainty and orientation.
- Develop location-specific, energy master plans linking housing sector, public services and private companies at the municipal and cantonal levels from biomass use to energy production and consumption.
- Build on international certification schemes for sustainable bioenergy production.

Also from the side of consumers there is a high demand for standards that ensure ecological and social specifications of biofuels. Only by doing so, confidence can be regained and the flawed reputation of biofuels overcome, and therewith the social acceptance, enhanced.

3	Develop integrated initiatives for sustainable resource management on the national and international levels!
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The energetic use of biomass is strongly competing with alternative services such as food and fibre production or biodiversity conservation. Purely bioenergy-centric policies will result in unwanted effects on other industrial sectors and ecosystems. Any biofuel strategy needs to be embedded in a wider perspective of sustainable biomass and other resource use.

We therefore propose to develop an overarching programme for sustainable resource management which

- integrates climate and resource protection,
- considers biomass and minerals for various uses (food and non-food materials, power/heat, transport fuels),
- builds the bridge between environment and economy by leading the way towards decoupling of resource use and economic growth,
- is based on sustainability indicators and targets,
- accounts not only for direct and indirect GHG emissions, but also for total material resource consumption, and global land use associated with domestic production and consumption activities,
- reflects on an adequate share of global resources consumed by Swiss activities within the global context, a sound proportion of self-sufficiency, and
- minimizes shifts of environmental and social burden to other regions which is associated with foreign trade.

A programme for sustainable resource management is requested for EU member states by the Thematic Strategy for Sustainable Use of Natural Resources. The Swiss Federal Agency for Statistics has already provided indicators such as GHG emissions and Total Material Consumption for the Swiss Economy. The accounting of global land use is currently under development, e.g. in the European Environment Agency.

4	Focus on sustainable feedstock supply and concentrate on waste, wood and marginal agricultural production!
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This study has shown that the main advantage of 2nd generation biofuel technology lies in its potential to make use of more sustainable feedstock. Consequently, the focus of interest should be put on costs, availability, and the social and environmental implications of feedstock supply.

Waste feedstocks allow producing biofuels without competing with agricultural land and without affecting biodiversity and water sources. Furthermore, the production of biofuels from waste is usually a waste treatment process, which reduces uncontrolled environmental emissions, such as N₂O-emissions from untreated manure. However, different aspects have to be considered, if it is desired that biofuels from waste become a success story:

- The energy content of biogenic waste fractions is often low due to their high water content, and waste is typically generated decentrally on fields, in individual households or industries. Collection and transport efforts are therefore high. Consequently, waste should be processed locally to avoid costly transport with its high environmental impacts. For large-scale 2nd generation technologies like the BTL-process, a local pre-treatment step should be planned for (e.g. pyrolysis) in order to increase the energy content and to bundle the feedstock for more efficient transport to the BTL plant.
- Crop residues are available in higher quantities and are of major interest for 2nd generation biofuels production. However, retention of crop residues on the soil surface as mulch has numerous beneficial impacts on soil fertility and on biodiversity, and a low soil erosion hazard, increased soil carbon storage, enhancement of soil aggregation, low nutrient leaching or the high activity and species diversity of soil fauna. To avoid negative impacts, the removal of crop residues should be kept under a threshold depending on soil type, climate and topography.
- Biogenic waste fractions like used vegetable oil or industrial waste wood are also primary sources of waste feedstock for 2nd generation biofuels. Nevertheless, such fractions are in many cases already being used for other purposes. E.g., industrial wood is burned in a waste incineration plant to generate heat and power and used vegetable oils may be used in the cement industry as a replacement for heavy oil. Therefore, potential displacement effects when switching to waste feedstock should be carefully evaluated.

The potential for **wood** as a feedstock for 2nd generation biofuels in Switzerland is larger than the potential for waste feedstock. In addition, wood's energy content is significantly higher than waste feedstock's, a fact that could facilitate transport and storage. Generally, wood shows a high sustainability potential, which makes it a perfect feedstock for producing 2nd generation biofuels. Nevertheless, for the successful set-up of wood biofuel chains, some recommendations have to be followed.

- Producing biofuels from wood as a measure to reduce climate change is in competition with the climate mitigation function of the forest. Thus there must be some safeguard that taking out woody biomass will not impinge upon the overall carbon stock of the forest (i.e. consider maximum harvest rates). Even slight decreases in the net carbon stock of the forest can completely abolish the climate benefit of the wood-based biofuel. Consequently, sustainable forest management practices should be applied.
- Forest biodiversity should not be negatively affected. The worst case example is the conversion of primary forests into forest plantations like oil palms or eucalyptus trees. Even if the carbon stock remains on a high level, flora and fauna biodiversity are massively reduced. As mentioned above, sustainability criteria should be applied to ensure a sustainable forest management without affecting natural ecosystems.
- Energy wood is definitely not a waste product but it is rather in use competition between biofuels production, electricity and heat production and also material use (wood fibre plates, insulation material, pulp and paper). Therefore

displacement effects should be carefully evaluated before implementing a new pathway for biofuels from wood.

- The current self-supply ratio of Switzerland with forest products is relative high. A growing demand for forestry products – for bioenergy or other purposes – tends to increase the dependence on imported biomass. In all scenarios studied, Switzerland is expected to consume more forest growth than will be available globally on a per capita basis.

The use of **marginal agricultural areas** is another option to produce 2nd generation biofuels in a sustainable way. As this pathway is in competition with both food production and nature conservation, great care should be taken before such projects are implemented:

- Large-scale use of marginal land should not take place until the conservation value of the land has been assessed. International sustainability standards like the one developed by the Roundtable on Sustainable Biofuels should be considered.
- Even if the land is currently underutilised, regional trends in livelihood, migration and food consumption should be taken into account for assessing the future availability of marginal lands for biofuels production.
- One of the main reasons for the underutilization of agricultural land is a scarcity of water. Especially in semi-arid regions, the irrigation of bioenergy crops might have a major and long-lasting impact on regional water availability, soil fertility and biodiversity. The water footprint should be carefully evaluated.
- When developing marginal land, a focus should be laid on degraded land which had been cultivated before, but was abandoned. Usually increased investments are required to restore soil fertility and recover productivity of those areas, and conservation status will also have to be considered.

5

Develop accepted approaches for dealing with indirect effects!

Indirect effects of biofuels production are hardly quantifiable but highly relevant. Multi-sectorial statistics on land use, biomass production and market prices are needed on the global scale in order to model the chain of effects induced by an increased production and consumption of biofuels. This is mainly relevant for agricultural and forestry feedstocks, but the competition for biomass residuals such as straw or biowaste is also increasing. We recommend the following tasks for improving the modelling of indirect effects:

- Modelling increased use of 2nd generation biofuels, advanced traditional energetic use of biomass (e.g. pellets), and growing consumption of wood products on a global scale with regard to the consequences for deforestation and forest degradation, subsequent GHG emissions and biodiversity loss in the main world regions.
- Elaboration of an improved data basis for the assessment of net annual increment of world forests in the main regions, in order to provide solid reference values for assessing national consumption.

- Further development of national statistics to account for global land use, in particular crop and other agricultural land, which is associated with national consumption both inside the country and in other regions, considering real land use for imports and exports, and possibly related environmental pressures linked to land use change.
- Further development of national statistics to account for total consumption of forest resources of a country, by considering both domestic production and foreign trade in round wood equivalents, and adequate indicators or reference values to assess changes in consumption patterns with regard to regional and global sustainability.

6	Shift from carbon foot-printing to integrated socio-environmental assessment!
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When it comes to the quantification of the environmental impacts most studies concentrate on the carbon footprint or the energy efficiency of biofuels, as these indicators are easy to determine. However, the impacts and benefits of biofuels are manifold and hardly quantifiable factors can be very important, such as soil degradation or land expulsion of farmers. Consequently, integrated assessment methods that go beyond quantification of material flows are strongly needed for assessing the sustainability of 2nd generation biofuels.

This project presents the first integrative, quantitative and systemic assessment of both 1st and 2nd generation biofuels. In doing so we tackled the process perspective, the value chain perspective and the scenario perspective. The results show that the three views complement each other and put the results into perspective. With focus to the methods applied in this study, the following research issues have emerged:

- Develop more robust approaches that quantify the social impacts of biofuel production and biomass use.
- Weighting of different interest groups: The first issue of interest is to understand whether the assessment results would significantly change with the weighting of the different interest groups. Our preliminary analyses show that this might be the case. In doing an in-depth research on this issue a sustainability range could be developed.
- Improve the understanding of factors enabling or hindering cooperation regarding an implementation of multi level energy agendas supporting a large scale biomass plant.
- Develop a sustainability solution space to assess the trade-offs of different strategies regarding the different sustainability dimensions.

7	Understand and overcome the uncertainty of prospective biofuels assessment!
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Some of the findings of this study are uncertain, basically because technological breakthrough is difficult to forecast. This is especially true for

- the penetration rate of eMobility which depends on the costs of electric cars and the acceptance by the user,
- the success of algae-fuels which depends on cost savings and efficiency gains in algae cultivation,
- and the competition between proven conventional technologies (e.g., thermic wood power plants) and advanced but yet unproven 2nd generation technology (e.g., SNG plants).

In order to deal with this uncertainty, more research is needed in the following directions:

- More detailed assessment of electric mobility and the corresponding development of a Swiss eMobility strategy.
- Uncertainty and fuzzy analysis: To account for the uncertainty in the data and the weighting uncertainty or fuzzy analysis could be performed to test the robustness of the results.
- Interaction between the indicators: In a next step the interaction between the indicators should be studied. This includes analyzing whether there is a relationship among the indicators, whether it is significant and which functional form it may have. This would allow to analyze the trade-offs between different alternatives.

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11 ANNEX

11.1 Additional information FKV's

11.1.1 FKV-21: Infrastructure

11.1.1.1 Indicator Infrastructure requirements for feedstocks

Nr.	Feedstock	Points	Norm. (categ.)	Norm. (1-0)	Uncertaint.	References
1	Crude oil, best (NL, onshore)	20.75	7.609375	0.734375	0.25	(Jungbluth, Chudacoff et al. 2007) & other sources)
2	Crude oil, worst (NG)	20	7.1875	0.6875	0.25	(Jungbluth, Chudacoff et al. 2007) & other sources)
3	Sugar cane, BR	18.5	„34375	0.59375	0.2	(Jungbluth, Chudacoff et al. 2007; Goldemberg 2008) & other sources)
4	Rape seed, IP, CH	14	3.8125	0.3125	0.2	(Jungbluth, Chudacoff et al. 2007) & other sources)
5	Oil palm, IN	17.75	5.921875	0.546875	0.2	(Jungbluth, Chudacoff et al. 2007) (Santosa 2008) (Bangun 2006)
6	Unused forest growth, CH	22.75	8.734375	0.859375	0.2	(Jungbluth, Chudacoff et al. 2007)
7	Industrial residual wood, CH	21.25	7.890625	0.765625	0.2	(Jungbluth, Chudacoff et al. 2007)
8	Waste wood, CH	25.5	10	1	0.5	Other sources
9	Straw, CH	17.25	5.640625	0,515625	0.2	(Jungbluth, Chudacoff et al. 2007) & other sources
10	Manure, CH	28	10	1	0.5	Other sources
11	Biowaste, CH	27.75	10	1	0.2	(Jungbluth, Chudacoff et al. 2007) & other sources

12	Miscanthus, RER	21	7.75	0.75	0.2	(Jungbluth, Chudacoff et al. 2007; Styles and Thorne 2007) (Lewandowski and Clifton-Brown 2000) (Lewandowski and Scurlock 2003)
13	Jathropa, INDIA	21	7.75	0.75	0.3	(Francis and Edinger 2005, Rajagopal 2008; Gonsalves 2006; Achten 2007; Jungbluth, Chudacoff et al. 2007; Rajagopal 2008)
14	LIHD Grassland, US	25	10	1	0.25	(Tilman, Hill et al. 2006; Zhou and Xiao 2007)
15	Halophytes, CN	21.5	8.03125	0.78125	0.2	(Jungbluth, Chudacoff et al. 2007; Ruan, Li et al. 2008)
16	Algae	19.625	6.9765625	0.6640625	.0.25	(Borowitzka 1999; Chisti 2007; Mata, Martins et al. 2009); (Spolaore, Joannis-Cassan et al. 2006; Möller and Martins 2007)

11.1.1.2 Indicator Infrastructure requirements for conversion

Nr.	Conversion	Points	Norm. (categ.)	Norm. (1-0)	Uncertainties	References
1	Refinery	7	5.2	0.46666667	0.2	(Jungbluth, Chudacoff et al. 2007)
2	Alcoholic fermentation (sugar) and distillation	6	4.6	0.4	0.4	(Jungbluth, Chudacoff et al. 2007; Goldemberg 2008)
3	Oil extraction and esterification	7.5	5.5	0.5	0.2	(Jungbluth, Chudacoff et al. 2007) (Goldemberg 2008)
4	Fermentation (biogas)	10	7	0.66666667	0.2	(Jungbluth, Chudacoff et al. 2007)
5	Gasification and methanation (SNG-Production)	10	7	0.66666667	0.2	(Jungbluth, Chudacoff et al. 2007)

6	Gasification and BTL production	3.5	3.1	0.23333333	0.2	(Jungbluth, Chudacoff et al. 2007)
7	Fermentation (lignocellulose) and distillation	4.5	3.7	0.3	0.4	(Gnansounou 2009)
8	Photovoltaics	2.75	2.65	0.18333333	0.2	(Jungbluth, Chudacoff et al. 2007)
9	Cogeneration	5	4	0.33333333	0.2	(Jungbluth, Chudacoff et al. 2007)
10	Electricity production	6.5	4.9	0.43333333	0.2	(Jungbluth, Chudacoff et al. 2007)

11.1.1.3 Indicator Infrastructure requirements for use

Nr.	Conversion	Points	Norm. (categ.)	Norm. (1-0)	Uncertainties	References
1	Petrol (gasoline, fossil reference)	15	10	1	0	By Definition
2	Biogas (methane, SNG)	8	5.8	0.53333333	0.3	(BiomassEnergie 2009)
3	Biodiesel (B100), (rapeseed, oil palm, jatropha, algae)	9	6.4	0.6	0.4	(Yacobucci and Schnepf 2007; DOE 2009)
4	Biodiesel (B5)	10.5	7.3	0.7	0.35	(BiomassEnergie 2009; DOE 2009)
5	Ethanol (sugarcane, biomass)	6.5	4.9	0.43333333	0.4	(Goldemberg 2008; Regalbuto 2009) (BiomassEnergie 2009; Gnansounou 2009)
6	Ethanol E85	5,5	4,3	0.36666667	0.3	(DOE 2005; Yacobucci and Schnepf 2007; DOE 2009; DOE 2009)
7	Ethanol E5 (bEnzin5, eSSence5)	11	7,6	0.73333333	0.25	(DOE 2005); (Yacobucci and Schnepf 2007)
8	Synthetic (liquid) hydrocarbons (BTL, Fischer-Tropsch)	15	10	1	0.2	(Regalbuto 2009; Wikipedia 2009)
9	Electricity for electromobility (e.g. Plug-in hybrids, battery)	8	5.8	0.53333333	0.3	(DOE 2009; DOE 2009)

11.1.2 FKV-22: Information structure

11.1.2.1 Indicator Experience with Feedstock

Type	Feedstock	Years of experience	Normalization	Uncertainties	References
FOS SIL	Crude oil, best (NL, onshore)	158	0.49968708	0.006	(Wikipedia 2009) – first use of North Sea oil
1 st	Crude oil, worst (NG)	51	0.00860017	0.02	(Wikipedia 2009) – first discovery in Nigeria in late 1950s
1 st	Sugar cane, BR	477	0.97954837	0.002	(Worldpress 2009) – first year of introduction: 1532
1 st	Rape seed, IP, CH	505	1	0.01	(SBV 2009) – Since beginning 16th century.
2 nd	Oil palm, IN	161	0.50785587	0.006	(Santosa 2008) – Introduced in 1848
2 nd	Unused forest growth, CH	10000	1	0.2	Exists and is used for a long time
2 nd	Industrial residual wood, CH	10000	1	0.2	Exists and is used for a long time
2 nd	Waste wood, CH	10000	1	0.2	Exists and is used for a long time
2 nd	Straw, CH	5000	1	0.2	Exists and is used for a long time
2 nd	Manure, CH	5000	1	0.2	Exists and is used for a long time
2 nd	Biowaste, CH	5000	1	0.2	Exists and is used for a long time
2 nd	Miscanthus, RER	75	0.19865709	0.06	(Lewandowski and Clifton-Brown 2000) – First cultivated in Europe in 1930s
2 nd	Jathropha, INDIA	500	1	0.01	(CJP 2009) – Cultivated since 16th century
2 nd	LIHD Grassland, US	16	0	0.03	(Tilman, Hill et al. 2006)
2 nd	Halophytes, CN	17	0	0.03	(Ruan, Li et al. 2008)
2 nd	Algae	119	0.37657696	0.004	(Borowitzka 1999)

11.1.2.2 Indicator Experience with Technology

Type	Conversion technology	Years of experience	Normalization	Uncertainty	References
FOS SIL	Refinery	30	1.000	0.03	(WIPO 2009); PATENTSCOPE®
1 st	Alcoholic fermentation (sugar) and distillation	21	0.550	0.03	(WIPO 2009); PATENTSCOPE®
1 st	Oil extraction and esterification	22	0.600	0.03	(WIPO 2009); PATENTSCOPE®
1 st	Fermentation (biogas)	27	0.850	0.03	(WIPO 2009); PATENTSCOPE®
2 nd	Gasification and methanation (SNG-Production)	30	1.000	0.03	(WIPO 2009); PATENTSCOPE®
2 nd	Gasification and BTL production	2	0,000	0,03	(WIPO 2009); PATENTSCOPE®
2 nd	Fermentation (lignocellulose) and distillation	27	0.850	0.03	(WIPO 2009); PATENTSCOPE®
0	photovoltaic	30	1.000	0.03	(WIPO 2009); PATENTSCOPE®
0	cogeneration	27	0.850	0.03	(WIPO 2009); PATENTSCOPE®
0	electricity production	29	0.950	0.03	(WIPO 2009); PATENTSCOPE®
0	biorefinery	14	0.200	0.03	(WIPO 2009); PATENTSCOPE®

11.1.2.3 Indicator Patent Protection

Type	Conversion technology	Patent Protection	Normalization	Uncertainty	References
FOSSIL	Refinery	9085	1.000	0.125	(WIPO 2009); PATENTSCOPE®
1 st	Alcoholic fermentation (sugar) and distillation	48	0,029	0,05	(WIPO 2009); PATENTSCOPE®
1 st	Oil extraction and esterification	78	0.059	0.1	(WIPO 2009); PATENTSCOPE®
1 st	Fermentation (biogas)	428	0.416	0.05	(WIPO 2009); PATENTSCOPE®

2 nd	Gasification and methanation (SNG-Production)	17	0.000	0.075	(WIPO 2009); PATENTSCOPE®
2 nd	Gasification and BTL production	22	0.002	0.05	(WIPO 2009); PATENTSCOPE®
2 nd	Fermentation (lignocellulose) and distillation	187	0.170	0.05	(WIPO 2009); PATENTSCOPE®
0	photovoltaic	7100	1.000	0.075	(WIPO 2009); PATENTSCOPE®
0	cogeneration	669	0.662	0.1	(WIPO 2009); PATENTSCOPE®
0	electricity production	3073	1.000	0.15	(WIPO 2009); PATENTSCOPE®

11.1.3 FKV-63: Rural Income equality

11.1.3.1 Normalization and results

The normalized value is 0 (less sustainable), if the ratio of the average monthly salary in the agricultural sector and the average monthly salary of all sectors is equal or less then 0.3. The normalized value is 1 (more sustainable), if the ratio equals 1. Ratios of 0.3 and 1 are reached by Bahrain in 2007 and Cuba in 2006 (ILO, 2009). Inverted normalization was used for ratios above 1.

State	Year	Average monthly salary agriculture/ average salary	Normalization
Norway*	2008	1.473	0.32
Cuba	2006	1	1
US	2006	0.745	0.64
US (algae)*	2008	1.323	0.54
Germany*	2008	1.404	0.42
Switzerland	2006	0.643	0.49
Indonesia	2007	0.466	0.24
Brazil	2002	0.462	0.23
China	2007	0.445	0.21
Bahrain	2007	0.3	0
India	No data		
Nigeria*	No data		

* instead of agriculture the category mining and quarrying was used for Norway and Nigeria and an average of the categories manufacture of coke, refined petroleum products and nuclear fuel and manufacture of chemicals and chemical products for Germany and US (algae).

11.1.4 FKV-64: Violation risk of human rights and ILO conventions

11.1.4.1 Normalization

Points	Normali- zation	Criteria	Specification	Examples
10 (very low risk)	1.0	Additional rights granted	No violations known for the specific economic activity and additional rights granted	Accident insurance, minimal wages, unemployment insurance either private or public guaranteed
7 (mod- erate risk)	0.67	Human Rights and ILO conventions widely complied	No severe violations known for the specific economic activity, minimal standards accepted and implemented	Freedom of association and collective bargaining recognized, collective labour agreements established
4 (risky)	0.33	Known violations of Human Rights and ILO conventions	Violations known for the specific economic activity, minimal standards accepted and implemented	Cases of child labour, forced labour or displacement of indigenous people reported
1 (very high risk)	0.0	Serious violations of Human Rights and ILO conventions common	Serious repeated violations known for the specific economic activity, minimal standards not accepted or not enforced, violent conflicts	Repeatedly reported cases of child labour, forced labour or displacement of indigenous people, violent conflicts

11.1.4.2 Results

State	Points	Normali- zation	Relevant economic activity	Reported violations	Un- cer- tainty	Reference
Switzer- land	8	0.78	Agriculture, Processing Industry	Discrimination of trade union members	+/-1 Point	ITUC (2009), ITUC (2008), ITUC (2007), ITUC (2006)
Brazil	3	0.22	Agriculture, Processing Industry	Several cases of forced labour in rural areas including sugar cane plantations, land con- flicts with indigenous people, attacks on trade union offices, killings of trade union members, using military police against strikers	+/-2 Points	HRW (2005), HRW (2006), HRW (2007), HRW (2008), HRW (2009), AI (2006), AI (2007a), AI (2008), AI (2009), ITUC (2009a), ITUC (2008), ITUC (2007), ITUC (2006)
Indone- sia	4	0.33	Agriculture, Processing Industry	Military involvement in private business activi- ties including palm oil sector, highly insufficient labour rights, using paramilitary, military and police forces against trade unions and strikers	+/-2 Points	HRW (2009), HRW (2008), HRW (2007), ITUC (2009), ITUC (2007), ITUC (2006)
China	3	0.22	Agriculture, Processing Industry	No right to form inde- pendent trade unions, imprisonment of strikers and violent actions against protesters, social unrests because of bad working condi- tions, unpaid wages and pensions, forced over- time, no working con- tracts, no access to health care and other social services for rural migrant workers and illegal land seizures, child labour	+/-2 Points	HRW (2005), HRW (2006), HRW (2007), HRW (2008), HRW (2009), AI (2006), AI (2007), ITUC (2006), ITUC (2007), ITUC (2008), ITUC (2009)

Norway	10	1	Oil Industry	None	+/- 1 Point	HRW (2005), HRW (2006), HRW (2007), HRW (2008), HRW (2009), AI (2006), AI (2007), ITUC (2006), ITUC (2007), ITUC (2008), ITUC (2009)
Nigeria	1	0	Oil Industry	violence and armed conflicts between ethnic groups, gangs, militia and security forces in order to control the theft of crude oil in the Niger delta, attacks on oil facilities, some practices of oil companies contribute to the ongoing conflict, kidnapping and killings of expatriate and Nigerian oil workers common, extrajudicial executions, torture and destruction of homes by security forces, armed police is used to attack protesting workers, unpaid salaries, discrimination of trade union members	+/- 1 Point	HRW (2005), HRW (2006), HRW (2007), HRW (2008), HRW (2009), AI (2006), AI (2007), AI (2008), AI (2009), ITUC (2006), ITUC (2007), ITUC (2008), ITUC (2009)
India	3	0.22	Agriculture, Processing Industry	Displacement of indigenous people, worst forms of child work, social, political, economic and cultural discrimination, oppression and violence against Dalits, Tribes, Adivasi communities, marginal/landless farmers because of development projects, severe discriminations of trade union members, police violence against strikers, rising power of leftwing maoist extremists called Naxalites in several	+/-2 Points	HRW (2006), HRW (2007), HRW (2008), HRW (2009), AI (2006), AI (2007), AI (2008), AI (2009), ITUC (2006), ITUC (2007), ITUC (2008), ITUC (2009)

				Indian states (13 of 28 states (HRW, 2007)) supported by rural poor, violent conflicts between security forces, paramilitary and Naxalites		
US	7	0.67	Agriculture, Processing Industry	Widely accepted discrimination of trade union members, existence of anti trade union consulting industry	+/- 1 Point	ITUC (2006), ITUC (2007), ITUC (2008), ITUC (2009)
Germany	9	0.89	Agriculture, Processing Industry	Discrimination of trade union members	+/- 1 Point	ITUC (2006), ITUC (2007), ITUC (2008), ITUC (2009),

11.2 Scenarios

11.2.1 Results of the Survey

Participants in the survey included a total of 14 persons from the expert groups: TA-SWISS and ProClim. They were asked about possible future developments of the impact factors. Furthermore, they were supposed to judge the suggested set of impact factors and comment on them. On the basis of these answers the set would be revised.

11.2.1.1 Possible Developments of the Impact factors

The survey showed that the impact factors had been explained mostly to the satisfaction of all, and that the proposed developments were accepted. Nonetheless, whenever a lack of clarity became apparent, it was dealt with as well as possible. The minimal and maximal values were adapted, whenever more than one person made an alternative suggestion pointing in the same direction. The greatest controversy about the future involved average annual world economic growth, reflecting the uncertainty caused by the current economic crisis. Several people wanted to have the development range expanded and the minimum value reduced from 3% to 2%.

Table 64: Do you agree with the selection of the possible developments?

Impact factor	Yes	No	Note
Oil price	71.4%	28.6%	Integration of comments
World population	100.0%	0.0%	
Eating habits	71.4%	28.6%	Integration of comments
Food Price Index	78.6%	21.4%	Integration of comments
World economic growth	50.0%	50.0%	Integration of comments
Swiss government policy	64.3%	35.7%	Integration of comments
Swiss electricity price	85.7%	14.3%	

11.2.1.2 Evaluation of the Set of Impact factors

The factors oil price and Swiss policy were regarded as the impact factors most relevant to the Swiss biofuel value chain. The lowest average rating (Rating Average) and one estimate as “very relevant” were given to world population and Swiss electricity price. None of the factors was estimated to be “not relevant”.

Table 65: How relevant are the impact factors in the context of Swiss biofuels?

Impact factor	very relevant	relevant	moderately relevant	hardly relevant	not relevant	Rating Average	Response Counts
Oil price	85.7% (12)	14.3% (2)	0% (0)	0% (0)	0% (0)	3.86	14
World population	42.9% (6)	57.1% (8)	0% (0)	0% (0)	0% (0)	3.43	14
Eating habits	21.4% (3)	50% (7)	28.6% (4)	0% (0)	0% (0)	2.93	14
Food Price Index	28.6% (4)	28.6% (4)	21.4% (3)	21.4% (3)	0% (0)	2.64	14
World economic growth	21.4% (3)	21.4% (3)	28.6% (4)	28.6% (4)	0% (0)	2.36	14
Swiss government policy	7.1% (1)	35.7% (5)	35.7% (5)	21.4% (3)	0% (0)	2.29	14
Swiss electricity price	7.1% (1)	35.7% (5)	35.7% (5)	21.4% (3)	0% (0)	2.29	14

The set of impact factors was not thought to be complete. The following were listed as missing factors:

- Climate
- World energy and climate policy
- Technology, technological innovation
- Cost degression
- Public perception, acceptance

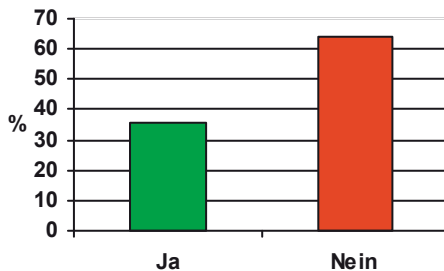


Figure 127: Are the most important external impact factors for the Swiss biofuel production chains covered by this Set?

11.2.2 Integration of the Survey Results

11.2.2.1 Adaptations to future developments and definitions

Most of the suggestions to make the impact factors more easily understandable were integrated into the definitions. Since most of them were only relatively small adaptations, we shall not list them here. The definition of food price index was supplemented by further data in the Appendix.

Future developments were adapted as follows based on the comments received for the factors oil price, eating habits, world economic growth and Swiss policy or reasons are given why they were not adapted:

- Oil price:
 - Raised the minimal oil price from US\$ 40/bbl to US\$ 50/bbl.
 - Mean value was deleted.
- Eating habits:
 - Reduction of the maximum value from meat +40%, Milk and milk products +20%, vegetable oils +90% to Meat +30%, Milk and milk products +15%, vegetable oils +75%.
 - The minimum value was kept, as it corresponded to a condition with rising consumption in emerging and developing countries, and at the same time dropping consumption (crop scenario) in industrialized countries.

- World economic growth:
 - Reduction of the minimum value from 3% to 2%.
- Swiss policy:
 - The minimum value no regulation was expanded into no regulation of biofuels, but additional support for food production, in order to keep them from competing against biofuel production. Purpose is to be able to represent the possibility of a high-energy price scenario more consistently.
 - The extreme option of a blending requirement was not covered because the Swiss Upper House had expressed its rejection of this measure clearly and increasing criticism had been heard elsewhere against this measure.

11.2.2.2 Adaptation of the Set of Impact factors

The external impact factors world population und Swiss electricity price were excluded from the set because they were regarded as not having much relevance (Tab. 2).

Around 64% of those surveyed found the set of impact factors to be incomplete and listed additional factors. These suggestions were integrated into the rest of the investigation as follows:

- Climate change:
 - Will not have any substantial impact until 2030.
- World energy and climate policy:
 - Was added as a new impact factor.
- Technology development and technological innovation:
 - Was integrated separately into the development of system scenarios.
- Cost degression:
 - Will be covered in SPA as FKV 11 Economic Efficiency.
- Public perception and acceptance:

Was covered in SPA as FKV Social Acceptance.

11.2.3 Selection of the scenarios

During scenario selection one has to take care that, on the one hand, as few inner conflicts (inconsistencies) as possible occur and consistency values as high as possible are reached, so that the scenarios simulate a possible future that is likely to occur. On the other hand, scenarios that are very different from each other should be selected so that the scenario funnel appears (Figure 28).

In order to fulfill the consistency criterion, the consistency values calculated using the additive or multiplicative method, as the case may be, should be as high as possible. The inconsistency criterion is fulfilled whenever scenarios yield a multiplicative consistency value larger than zero. The diversity criterion is applied by calculating a distance value. The distance value (Table 35) equals the number of impact factors having a strength different from the selected scenario (Tietje, 2006).

In an initial selection step two extreme scenarios were determined. The scenario with the ID 62 and the highest consistency value was selected as the initial scenario (Table 35). The subsequent distance calculation A reveals that two scenarios differ from Scenario A (Szenario Resource Scarcity) in all 6 impact factors. These are Scenarios ID 35 and ID 19. Scenario ID 35 is selected as having the highest consistency value and was used to determine the second extreme scenario C (Unlimited Growth).

Repeating Distance Calculation AC reveals that the remaining scenarios differ from the selected extreme scenarios A and C by impact factors between 0.857 und 1.714. Unlike the selection of Scenarios A and C, now not only a single third scenario B is possible. Depending on the prioritization of one of the two consistency values or the distance value AC, different scenarios can be selected. It no longer makes sense to continue on the purely mathematical level, and the number of possible scenarios is thus observed more closely and limited to the systemic level.

11.2.4 E-Car Penetration

In order to determine the possible market penetration of electric cars, we calculated two scenarios; one conservative and one optimistic. The conservative scenario assumes that in the year 2030 50% of the new cars bought in Switzerland will be electric. The optimistic scenario assumes that in the year 2025 50% of the new cars bought in Switzerland will be electric. Starting from 2010 we used a logistic function to determine the yearly increase in the share of e-car selling at the total car selling.

11.2.4.1 Scenario 1: Conservative market penetration

As shown Table 66 the accumulated amount of e-mobility in 2030 amounts to 750'000 e-cars or a share of 18.8% at the total vehicle fleet in Switzerland. For 2020 82,823 e-cars are calculated. This amount is significant lower than the e-car penetration estimated by ALPIQ (2009), which estimates approx. 720,000 electric pluggable cars in 2020. In this context, our scenario is rather conservative.

Table 66: Conservative market penetration of e-mobility (source: own depiction).

Year	Share at total car selling [%]	E-car selling per year [Stk/a]	E-fleet accumulated [Stk]	Share at total fleet [%]	Electricity consumption per year [GWh/a]	Share at total electricity consumption [GWh/a]	Share at total electricity consumption [%]
2010	0.67	1'673	1'673	0.0	64'000	3	0.0
2011	0.86	2'144	3'818	0.1	63'800	7	0.0
2012	1.10	2'747	6'564	0.2	63'600	12	0.0
2013	1.41	3'516	10'080	0.3	63'400	19	0.0
2014	1.80	4'497	14'577	0.4	63'200	28	0.0
2015	2.30	5'744	20'321	0.5	63'000	38	0.1
2016	2.93	7'328	27'649	0.7	62'800	52	0.1
2017	3.73	9'332	36'981	0.9	62'600	70	0.1
2018	4.74	11'856	48'837	1.2	62'400	92	0.1
2019	6.01	15'022	63'859	1.6	62'200	121	0.2
2020	7.59	18'965	82'824	2.1	62'000	156	0.3
2021	9.53	23'837	106'661	2.7	61'400	201	0.3
2022	11.92	29'801	136'462	3.4	60'800	258	0.4
2023	14.80	37'012	173'473	4.3	60'200	327	0.5
2024	18.24	45'606	219'080	5.5	59'600	413	0.7
2025	22.27	55'675	274'755	6.9	59'000	518	0.9
2026	26.89	67'235	341'990	8.5	58'800	645	1.1
2027	32.08	80'205	422'196	10.6	58'600	797	1.4
2028	37.75	94'385	516'581	12.9	58'400	975	1.7
2029	43.78	109'456	626'037	15.7	58'200	1'181	2.0
2030	50.00	125'000	751'037	18.8	58'000	1'417	2.4

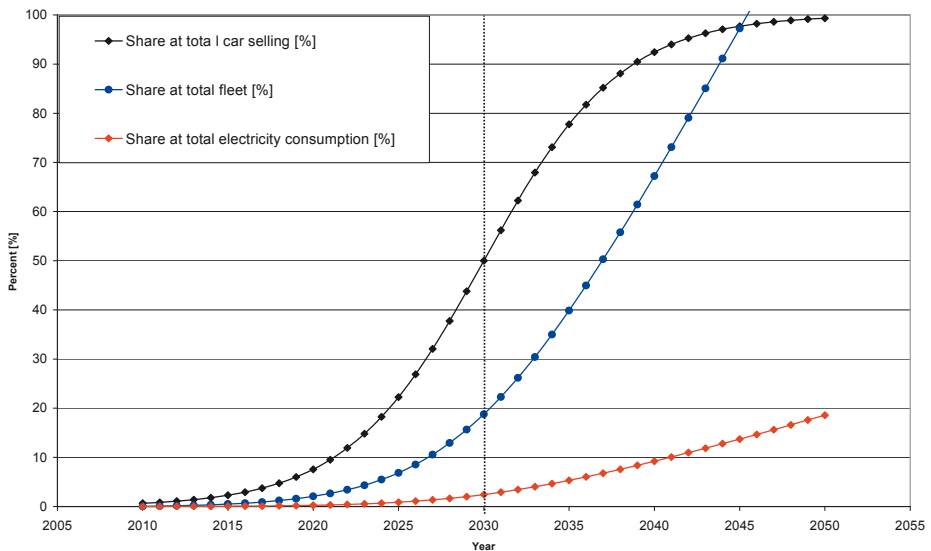


Figure 128: E-car market penetration according to the conservative scenario (source: own depiction).

11.2.4.2 Scenario 2: Optimistic market penetration

As shown Table 67 the accumulated amount of e-mobility in 2030 amounts to 1.5 million e-cars or a share of 39.9% at the total vehicle fleet in Switzerland. For 2020 260,178 e-cars are estimated. This amount is still significant lower than the e-car penetration estimated by ALPIQ (2009), which estimates approx. 720,000 electric pluggable cars in 2020.

Table 67: Optimistic market penetration of e-mobility (source: own depiction).

Year	Share at total car selling	E-car selling per year	E-fleet accumulated	Share at total fleet	Electricity consumption per year	Share at total electricity consumption
	[%]	[Stk/a]	[Stk]	[%]	[GWh/a]	[%]
2010	2.30	5'744	5'744	0.1	11	0.0
2011	2.93	7'328	13'072	0.3	25	0.0
2012	3.73	9'332	22'404	0.6	42	0.1
2013	4.74	11'856	34'261	0.9	65	0.1
2014	6.01	15'022	49'282	1.2	93	0.2
2015	7.59	18'965	68'247	1.7	129	0.2
2016	9.53	23'837	92'084	2.3	174	0.3
2017	11.92	29'801	121'885	3.0	230	0.4
2018	14.80	37'012	158'897	4.0	300	0.5
2019	18.24	45'606	204'503	5.1	386	0.6
2020	22.27	55'675	260'178	6.5	491	0.8
2021	26.89	67'235	327'413	8.2	618	1.0
2022	32.08	80'205	407'619	10.2	769	1.3
2023	37.75	94'385	502'004	12.6	947	1.6
2024	43.78	109'456	611'460	15.3	1'154	1.9
2025	50.00	125'000	736'460	18.4	1'390	2.3
2026	56.22	140'544	877'004	21.9	1'655	2.8
2027	62.25	155'615	1'032'619	25.8	1'949	3.2
2028	67.92	169'795	1'202'413	30.1	2'269	3.8
2029	73.11	182'765	1'385'178	34.6	2'614	4.4
2030	77.73	194'325	1'579'503	39.5	2'981	5.0

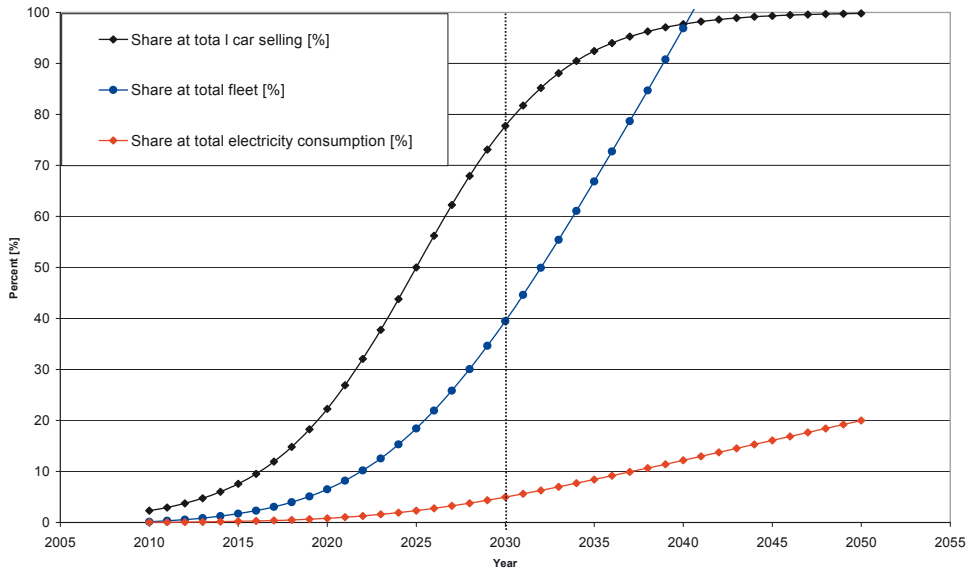
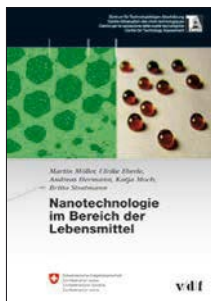


Figure 129: E-car market penetration according to the optimistic scenario (source: own depiction).

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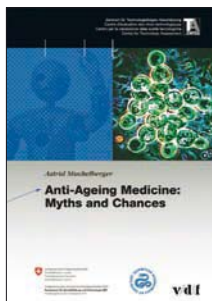
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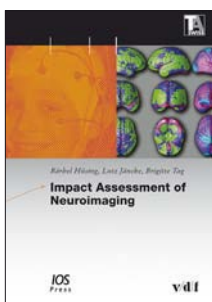
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