Biofuels – Opportunities and Limits

Alternative energy carriers are currently being heavily promoted. Biofuels are one example. Yet can biofuels really make a significant contribution to future energy supply? Are they economically interesting, ecologically responsible and socially compatible?

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Biofuel production

3nd generation
Algae farming
Single-cell algae → Oil → Diesel oil

2nd generation
Agriculture and forestry residues

Wood	→ Sugar	→	Ethanol
Crop residue, waste		→	Gas
Energy crops[1)]	→ Sugar	→	Ethanol
Paper	→ Sugar	→	Ethanol

[1)] cultivated on land not suited for food production.

1st generation
Crops

Corn	→ Sugar	→	Ethanol
Sugarcane	→ Sugar	→	Ethanol
Sugar beets	→ Sugar	→	Ethanol
Rapeseed	→ Rapeseed oil	→	Diesel oil
Palm trees	→ Palm oil	→	Diesel oil

From field to tank

Renewable energies are currently the object of strong encouragement. Biofuels are one example. They are expected to partly replace fossil energy carriers, as they are just as easy to store and transport. Worldwide, first-generation biofuels are currently mainly produced from rapeseed, corn and sugarcane.

Renewable energy sources are currently experiencing a strong boom. In order to cap global warming, worldwide CO_2 emissions must be reduced substantially. At the same time, a bottleneck is looming in petroleum supply, which in coming years will lead to price increases. In its 2007 report «Roadmap - Renewable Energies Switzerland», the SATW examined the potential of indigenous renewable energy sources by 2050. Even though the issue of biofuels was not addressed in detail, the study nevertheless confirmed that biofuels produced in Switzerland (and Western Europe) could substitute current motor fuel consumption only to a small extent.

It is thus clear beyond doubt that fuel consumption will need to decrease greatly over the coming years, e.g. through the use of more energy-saving vehicles, the development of public transport and the reduction of journey numbers. However, as shown by the SATW study «Erdölknappheit und Mobilität in der Schweiz (Oil Scarcity and Mobility in Switzerland)» (2008), this is all but impossible without drastic curtailments of our way of life. Although biofuels will play a comparatively limited role in terms of quantity, it is important to examine the opportunities and limits presented by their production and their use. The present analysis aims to lay the foundations of a balanced assessment of biofuels' future role in Switzerland and in other European industrialised countries.

Substantial encouragement

Various Western industrialised countries have set themselves the goal of reducing their dependency on petroleum imports. In 2004, the US thus decided to invest substantially in the development of biofuels, thereby also indirectly supporting its national farming industry. While US interest in biofuels was chiefly motivated by fears of national supply bottlenecks, in Europe biofuels are mainly encouraged with a view to climate policy. Substantial investments are already being made in Germany in order to produce biofuels in large-scale facilities.

In 2007, biofuels also became a political and public issue in Switzerland, as various measures of encouragement – in particular tax reliefs – were discussed. There is widespread agreement that biofuels can replace fossil energy carriers to a limited extent only. Current consumption and distribution systems would not even require significant modifications. Although biologically produced liquid fuels are considered nearly climate neutral, their production elicits controversy.

Much development work still ahead

Biofuels are produced from plants or plant-derived materials, i.e. renewable resources. Technical processes convert the raw plant material into liquid or gaseous substances such as methane, ethanol and biodiesel, which can then be used as fuels. First-generation biofuels, also called agrofuels, are based on agriculturally produced feedstock – predominantly rapeseed, corn and sugarcane. As with any extensive cultivation of agricultural crop, this can be accompanied by severe downsides: losses in biodiversity, greater water consumption and a substantial use of energy, fertilisers and pesticides in the fields. As a result, first-generation biofuels can display a strongly negative ecobalance.

The development of procedures to produce biofuel from wood, agricultural residue, energy crops and paper (second generation) or even from algae (third generation) is only just beginning. In order to avoid negative repercussions at a later stage, it is important to press ahead not only with technological development, but also with the analysis of social, ethical, legal and environmental issues.

Stored solar energy

In the final analysis, biofuels represent stored solar energy. However, per square metre of shone-upon surface area, plants yield much less final energy than photovoltaic installations. A real photovoltaic collector harvests 15 to 20 per cent of solar energy; the maximum achievable value is around 30 per cent. On the other hand, the collector's manufacturing requires considerable amounts of energy and materials, which need to be considered in an ecobalance (life cycle assessment). Plants, by contrast, convert at best 10 per cent of solar energy into chemical energy. Half of that is required to sustain their metabolism. Agricultural field work and subsequent transformation processes in turn consume about 90 per cent of the energy stored in plants, meaning on average only 0.5 per cent of original solar energy make it into final energy. When it comes to surface requirements, photovoltaics thus scores much better: according to a study by EMPA Materials Science & Technology, driving a given distance by car would require 34 times less land if the car were powered by photovoltaic electricity than if it used biodiesel stemming from palm oil. But an important advantage of liquid biofuels is that the energy can be stored and transported without difficulty. By contrast, the question of how large volumes of electric energy can be stored efficiently remains unresolved. Worldwide, great efforts are currently underway to optimise the efficiency of plants with a view to energy generation (so-called energy crops) and improve production processes for biofuels. Energy crops are preferably perennial, fast-growing grasses (miscanthus) or trees (poplar, willow), requiring little care, water and fertiliser and growing on land unsuitable for conventional agriculture.

Recommendation 1

The SATW recommends the development of second-generation biofuels taking into account internationally agreed criteria of sustainability. While the energetic use of plants currently yields less energy per surface unit than photovoltaics, we may expect efficiency to increase in the long term.

Biological waste – a valuable resource

Biological matter provides valuable substances that can be used for various purposes. This is precisely what hampers the production of biofuels. An interesting potential is seen in using biological waste for fuel production.

There is widespread agreement amongst experts that much biological matter is too valuable to be used as a mere energy provider. With regard to the utilisation of biological products, energetic considerations should thus go hand in hand with other aspects. Unlike technical systems, plants have the ability to build highly complex molecules with a minimum of energy. The fact that plants offer much more complex chemical structures than would be necessary for a simple energetic use (combustion) explains why biofuel production requires so much energy and entails losses.

A very limited potential

It is therefore fundamentally inefficient to make an energetically costly detour via plants for the mere generation of energy. It is far more effective to use plants as food or feed, or as feedstock for chemical products and pharmaceutical ingredients. The same argument, by the way, has long been advanced against the use of petroleum as a combustible and a fuel: the so-called «black gold» contains many substances that can be used for chemical syntheses. In future, if petroleum is no longer available at low cost, plant carbon will increasingly be used in its stead as a chemical feedstock in biorefineries.

If 100 per cent of corn grown in the US – one of the world's major producers – were transformed into biofuel, current yields would only make it possible to cover 7 per cent of US fuel requirements.

It is obvious that biogenic energy carriers of the first generation will satisfy global fuel requirements neither today nor in future. The surface area available for agriculture is too low by a multiple. If 100 per cent of corn grown in the US – one of the world's major producers – were transformed into biofuel, current yields would only make it possible to cover around 7 per cent of US fuel requirements. Under optimal conditions, this percentage could be multiplied by four, if all lignocellulosic waste (woody cell components) were converted into ethanol. Today, bioethanol and biodiesel each cover around 2 per cent of US petrol consumption resp. German diesel consumption.

Compared to fossil fuels, first-generation biofuels will thus remain a niche product, except for special cases such as Brazil, where ethanol produced from sugarcane is able to cover a large percentage of national fuel consumption. With a yearly 20 billion litres, the country is the biggest ethanol producer worldwide. At a global level and in the foreseeable future, however, biofuels will only be able to contribute marginally to bridging bottlenecks in the supply of petroleum products. For Switzerland, in such a scenario indigenously produced biofuels could at best sustain emergency services.

Environmentally sensible uses

Second-generation biofuels would make it possible to substantially increase energy production. While no estimation of the potential is available as yet, it seems obvious that energy yields could be greatly boosted by the increased exploitation of biogenic waste and wood. Biofuel production from waste has been practiced in Switzerland for decades, though far from countrywide. A 2007 study by EMPA Materials Science & Technology showed that using waste as a source of energy makes sense both economically and ecologically.

Using biogenic waste as a source of energy makes sense not only economically, but also ecologically.

For over 100 years, the company Borregaard AG in Riedholz close to Solothurn (former Cellulose Attisholz) produced up to 30 per cent of ethanol used in Switzerland from wood. As a by-product, the chemical pulping of wood to produce pulp fibre generated a liquid with a high sugar content, which was fermented and then distilled to produce ethanol.

Positive results for biogas

The Swiss company Kompogas AG successfully operates over ten facilities in Switzerland and abroad, producing biogas from garden, kitchen and restaurant waste. Decentrally, manure is also being converted into biogas (mainly methane) on numerous farms. This biogas is oftentimes used for power generation. However, in this process over 50 per cent of energy is lost as heat. Biogas is not suited to being fed into the natural gas grid without prior purification, as it contains too many secondary gases and its pressure is too low. So far, purification and pressure increase have not been achieved under commercially viable conditions.

Using crop residue on farmed land to produce biofuel makes sense in principle. However, some of the crop residue, such as roots and a short stubble, must remain on the fields, since a minimum of biological matter is required to maintain the soil's humus layer.

Recommendation 2

The plant parts used as a feedstock for biofuels contain valuable substances, from which – just as from petroleum – a variety of materials can be produced. Next to a focus on biofuels, the SATW thus recommends also encouraging the production of higher-value products from biomass.

Fuel or food?

The production of first-generation biofuels keeps generating controversy. Many fear that the production of biofuels may lead to bottlenecks in food supply. What often goes unmentioned is that conflicts may also be expected as regards the use of water.

Time and again, biofuel production generates controversy. If plants are grown for energy rather than food production, conflicts of use may arise. In 2007, such conflicts contributed to the shortage in corn and were partly responsible for the steep hike in tortilla prices in Mexico and for hunger riots in various Southern cities. Next to the production of bioethanol, however, other factors were also at play at the time, such as droughts in Australia and the Ukraine, floods in parts of Africa, as well as soaring oil prices and the heightened demand for animal feed in emerging nations. A further important factor for the increase in food prices at that time was the speculatively induced rise of grain quotations at futures exchanges. Prices have already sharply come down for wheat and rice: yet they are not expected to completely fall back to their 2006 levels. Overall, however, hunger and malnourishment are still caused mainly by poverty and social factors, and are not primarily the consequence of production bottlenecks.

> In future, the production of biofuels could lead to increasing conflicts of water use.

Type of use is a political decision

Yet higher prices for agricultural products could also have positive repercussions for the world's poorest: indeed, the vast majority of malnourished people lives in the country and could thus benefit from higher agricultural prices, as long as political and economic framework conditions support small and medium-size producers. Unfortunately, reality is often less rosy, particularly in large tropical plantations: in many places, working conditions are not consistent with the most basic human rights.

In Switzerland, the production and use of food to generate fuel is considered by most to be socially and ethically unjustifiable. In the densely populated Northern regions, such a strategy does indeed lack both economical and ecological sense. In other regions, this issue is assessed differently and can be less crucial, such as in Brazil. A direct and significant competition between biofuels and food will undoubtedly complicate the alleviation of global hunger. Yet the question of which use to favour over the other is always also a political one. As seen in the case of cotton, the cultivation of textile fibres instead of food is broadly accepted worldwide.

The SATW is opposed to starting biofuel production with easily exploitable plants and only later widening production to lignocellulose, waste and energy crops. In its opinion, facilities for the transformation of food into biofuels should on no account be encouraged in Switzerland.

The issue of water

Unlike the tension between food and energy, the tension between water and energy remains barely broached as an issue today, despite the fact that in various regions water is obviously becoming a scarce resource. Large volumes of biofuels can mainly be produced where water is available in large quantities. If corn were cultivated only using artificial irrigation, each litre of bioethanol would require 3000 litres of water. Since over half of global grain production stems from irrigated fields, the factor water worsens the ecobalance of first-generation biofuels. Biofuel production could in future lead to increasing conflicts of water use.

For the Swiss Plateau, current knowledge predicts milder winters, more rainfall in spring and autumn, as well as more extreme events and less rain in summer. As long as we are spared severe droughts in summer, we may thus expect higher yields. However, in future some regions of the world will have to make do with much reduced water volumes. In these regions, hope rests on the development of drought-tolerant plant species.

Cultivation is greatest burden

In a comprehensive study compiled in 2007, EMPA Materials Science & Technology surveyed the production of biofuels from an environmental viewpoint. The following aspects were systematically recorded and brought towards a general assessment: energy efficiency, greenhouse gas reduction, acidification potential, topsoil erosion and losses in biodiversity caused by extensive cultivation. According to the study, by far the greatest environmental burden stems from agricultural cultivation. Deforestation or farmland conversion can even further worsen the ecobalance and augment greenhouse gas emissions. While these potential effects have already been the object of heated debates, they should be examined further. Numerous studies have confirmed that ethanol production from corn does not display a positive energy balance. On the other hand, perennial energy crops grown on land unsuitable for conventional agriculture display a markedly better energy balance. By contrast, the transformation of waste and residual matter generates no significant burden, on the contrary: they display a significantly more positive ecobalance than the transformation of agricultural crops.

Recommendation 3

An increasing world population, the diminishing availability of water in many regions and the loss of farmland increasingly threaten food security. The production of biofuels exacerbates this conflict. Furthermore, first-generation biofuels can replace only a small part of the petrol and diesel oil currently used in the transport sector, and they often display an unfavourable environmental and energy balance. The SATW thus recommends that Switzerland swiftly pull out of the research, development and encouragement of first-generation biofuels.

An opportunity for poor countries?

Biofuel production exhibits impressive growth rates and could lead to a long-term increase in agricultural prices. However, this could also represent a great opportunity for the rural population of poor countries – as long as economic and social framework conditions are set accordingly.

Bioethanol production from corn (US) and sugarcane (Brazil) is currently growing by almost 10 per cent a year. Around half of the sugarcane grown in Brazil goes into the production of ethanol. From a purely economic viewpoint, such growth rates look highly promising: they could result in a global increase of agricultural prices, which would represent a positive development for farmers. This could provide opportunities for development especially in rural areas of industrialised and developing countries – so long as appropriate social and economic framework conditions are created.

Local markets are decisive

Not all biofuels are commercially equally interesting. A decisive factor is the local market. Bioethanol produced from sugarcane in Brazil is thus currently the cheapest biofuel, while biodiesel produced in the EU is the most expensive. By the same token, not all biofuels contribute equally to improving the greenhouse gas and energy balances. Ethanol from sugarcane (Brazil) also scores highly on this count.

The production of bioethanol from lignocellulose is currently still much more complex and costly than its production from sugarcane. Yet it is assumed that lignocellulose will be the most important feedstock for second-generation bioethanol, as it is available in huge quantities, devoid of any nutritional purpose. There is room for improvement as regards both the plant feedstock and transformation processes. Opinion varies on the increase in yield offered by optimised energy crops. Estimations of yearly growth rates vary between two and four per cent.

The issue of subsidies

The production of biofuels is currently encouraged by generous subsidies, especially in the EU and in the US. These subsidies are granted independently of whether biofuel is produced from edible plants or from waste matter. In the US, several hundred million dollars a year flow into the biofuel industry as venture capital. However, between 2007 and 2008, this inflow shifted almost entirely from first to second-generation biofuels.

> Subsidising biofuels can improve the income situation in agriculture. However, the risk is that these subsidies distort competition in the global market.

In Switzerland, exemption from the petroleum tax requires proof that the biofuels and their production processes display a better greenhouse gas balance (at least 40 per cent less CO_2 emissions) and no considerably worse ecobalance than petrol. In future, it should be possible to provide such proof by certification. Given appropriate economic framework conditions, subsidising biofuels can improve the income situation in agriculture. This is what happened on a large scale in the US in the past two years. However, the risk is that these subsidies may distort competition in the global market.

Implications difficult to assess

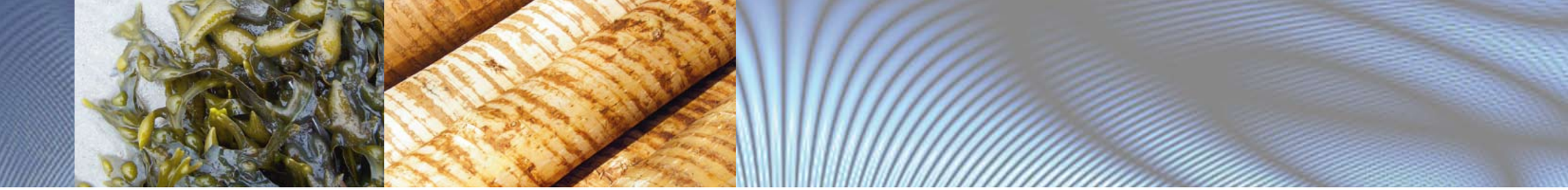
The impact of biofuel production on global trade is currently the focus of intensive research. The EPFL's «Roundtable on Sustainable Biofuels» has confirmed that a rise in the prices of agricultural products would improve the situation for rural populations. However, at the same time it is expected that the situation of the urban poor will deteriorate with rising agricultural prices. The UNEP and other international organisations have established that the demand for energy to satisfy mobility requirements will remain high. Managing the transition from the petroleum age to the post-fossil energy future in a sustainable and distributionally fair manner must thus be given highest priority. TA-SWISS has undertaken a comprehensive study on the topic of second-generation biofuels, which should be completed by early 2010; in Germany, the Federal Ministry of Education and Research has recently published a detailed report.

> Managing the transition to the post-fossil future in a sustainable and distributionally fair manner must be a priority.

It is difficult to assess how biofuel production for Northern countries will impact developing countries. Palm oil and jatropha oil, which like rapeseed oil can be used as diesel fuel, are at the forefront of these considerations. Revenue generated by the sale of these fuels or their raw materials can be an opportunity for poor countries, and the increase in world-market prices could improve these countries' economic situation. In the longer term, however, this development is only beneficial for poor countries if cultivation and trade take place under socially compatible conditions.

Recommendation 4

Increasing environmental problems caused by the use of fossil energy sources, as well as foreseeable petroleum scarcity, bolster investments in alternative energy carriers, amongst them biofuels. Many questions regarding biofuels remain unanswered. The SATW welcomes Swiss efforts to assess the issues at hand. It considers it an imperative to examine not only questions pertaining to the natural and technical sciences, but also economic, ethical and social aspects.



Proceeding with caution

While first-generation biofuels are already being produced on a large scale, the development of second and third-generation biofuels is only just beginning. Numerous questions also remain to be answered at a political level. The aim should be to avoid undesirable social and environmental consequences by establishing appropriate framework conditions.

Much research remains to be done on the production and use of biofuels, in the field of natural, technical and environmental sciences as well as in the socio-political domain. If a new technology is to be introduced successfully, a broad segment of public opinion must be convinced of its benefits. Next to opinion surveys, the general public must also be involved in the decision-making process.

Many open questions remain

There is an important need for research and development from the point of view of the natural and technical sciences. Only few demonstration facilities are in operation for the production of second-generation biofuels, producing ethanol from plant waste. Major investments are already underway in North America, while Europe is lagging behind.

More particularly, research and development are needed in the following technology fields:

- Further development resp. breeding of plants particularly suited to the production of biofuels. These include plants containing readily degradable substances and little lignin, such as poplar, willow, alfalfa or miscanthus. Another attractive option could be given by plants which when processed release their own enzymes, introduced by breeding or gene transfer, and break down polymers.
- Breeding of microorganisms able to efficiently break down plant polymers (cellulose, hemicellulose, lignin) into fermentable sugars.
- Use of enzymes on an industrial scale. The optimal chemical or biological procedures must be found for the various substrates (woodchips, straw, corn shrubs, miscanthus, biological waste) in order to produce chemical compounds that can be converted into biofuels.
- Development of chemical-catalytic procedures to break down plant polymers.
- Production of other end products such as butanol, propanol, precursors of isoprene or plastics.

Algae cultivation as an alternative?

It should further be assessed whether water-dwelling single-cell algae are better suited to bind carbon dioxide than agricultural crops. Experiments with the green alga botryococcus braunii show that 85 per cent of these rapidly growing unicellular organisms' dry mass consist of isoprene-type lipids, which can be transformed into petrol-type hydrocarbons via cracking processes. The use of algae bred in closed systems requires much development work, and the commercial viability of such processes is far from assured.

It remains largely unclear which impact the widespread introduction of biofuels would have at an environmental, economic and social level. Various regions of the world should be assessed for how to cultivate energy crops in a socially compatible manner. A number of issues must be considered: does the production of biofuels improve, complement or crowd out traditional agriculture and forestry? Does additional revenue create added value? How is the added value distributed amongst small and medium-size producers on one hand and large corporations and institutions on the other? How can the pace of change be controlled? Which factors are of particular importance for an optimal introduction of biofuels in Southern countries: markets, schools, water, hospitals, credit systems, roads, agricultural advisory systems, the Internet?

A current political challenge is the definition of environmental and social criteria to be met in order to benefit from tax reliefs. The SATW demands that Switzerland take an active role in pushing for a binding international agreement governing the production and handling of biofuels, both from a technical and from a social viewpoint. The SATW rejects the idea of a general moratorium on biofuel imports originating in Southern countries.

Clear international rules

The SATW recently highlighted the potential consequences of so-called peak oil. Considering the fact that in the foreseeable future petroleum production will have reached its peak, it is important to seek alternative energy sources and assess their suitability. Swiss day-to-day politics is concerned amongst other issues with deciding to which extent biofuels should benefit from public support. The SATW advocates biofuels having to display a positive energy and greenhouse gas balance, as well as meeting environmental and social minimal requirements, in order to benefit from tax reliefs.

In this context, the central requirement is that the cultivation of energy crops do not lead to food shortages in any country. This goal can be achieved by assessing and certifying social conditions in producer countries on a case-by-case basis. In a next step, the Swiss Federal Council is called upon to seek an international agreement akin to the Biodiversity Convention, setting binding framework conditions for the production and trade of biofuels. As an immediate measure, some NGOs are demanding a temporary moratorium to prevent the preferential fiscal treatment of biofuels from developing countries. The NGOs fear that large corporations from industrialised nations will crowd out small farmers in the South. The SATW urges a critical assessment of the suggested moratorium, as it would also prevent those countries and regions of the South that operate in a socially compatible and sustainable manner from increasing their agricultural revenue. While political decisions must presently be made regarding the first generation of biofuels, the development of second-generation biofuels is only just beginning. We must therefore proactively assess social and political consequences and take appropriate measures in good time.

Recommendation 5

The development of second and third-generation biofuels requires major investments, especially in research. The SATW recommends that public and private investors promptly undertake these investments after weighing up technical, environmental, economic, developmental and social criteria. The SATW recommends also assessing the environmental and social consequences of the large-scale cultivation of energy crops in Southern countries.

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Summary

For various reasons, alternative energy carriers are currently the focus of intensive research. Biofuels are one example. There is some dispute as to whether and to what extent they should be encouraged: indeed, many open questions remain as to their energy efficiency, commercial viability, as well as environmental and social compatibility.

In principle, the SATW supports the encouragement of biofuels, as long as their production and trade result in a positive net energy balance; biofuels must further significantly improve the greenhouse gas balance and meet economic, social and environmental sustainability criteria. However, biofuels produced in Switzerland will at most be able to take on a niche role in future energy supply.

The SATW recommends limiting production in Switzerland to biofuels made from biological waste as well as plants unsuitable for human or animal consumption. Before Switzerland begins researching, developing, producing, importing and using biofuels more intensely, rules must be defined to minimise conflicts between food production, environmental protection and energy generation. The Swiss Federal Council is called upon to work towards an international agreement and join it, ensuring that the same principles apply in all countries.

Further reading

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