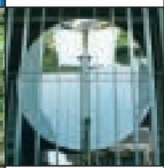
PAUL SCHERRER INSTITUT

PSI

NO. 16 / APRIL 2006

ENERGIE-SPIEGEL

FACTS FOR THE ENERGY DECISIONS OF TOMORROW



Wood – A versatile, renewable energy resource

At least 2 million additional cubic meters of wood could be sustainably harvested each year from Swiss forests. Wood is a CO_2 neutral energy carrier, and the most important biomass resource in Switzerland for the foreseeable future. Since the amount of energy wood is limited, the focus should be on the most valuable energetic uses, without additional burdens on the environment. This task can most elegantly be solved when the wood is transformed into synthetic natural gas (SNG). PSI has developed such a gasification process for the first time.

Energy wood from our forests can, for example, replace heating oil – and so provide a contribution to climate protection. But direct combustion in current, small heating systems without costly filters can create additional air pollution emissions – principally particulates and nitrous oxides.

Biomass wastes from household, agriculture and sewage treatment plants are already fermented into biogas in many locations in Switzerland. But for wood the process is not so simple, because it leaves such fermentation plants practically “undigested.” Therefore PSI has developed a globally unique, new multi-stage process that gasifies wood and then catalytically transforms it into synthetic natural gas. Translating this process to industrial use can provide an ecologically and economically sensible alternative to the decentralized and direct burning of wood. SNG could be distributed through the natural gas pipe network, and used with high efficiency for a wide spectrum of applications, e.g. gas heating, fuel for gas vehicles or in gas-fired power plants for electricity and heat. What path is most economic depends upon political conditions.

The PSI technology for wood methanization is now being demonstrated in Austria at an existing wood gasification plant on an industrial scale. The basis for a first large plant in Switzerland has been established.

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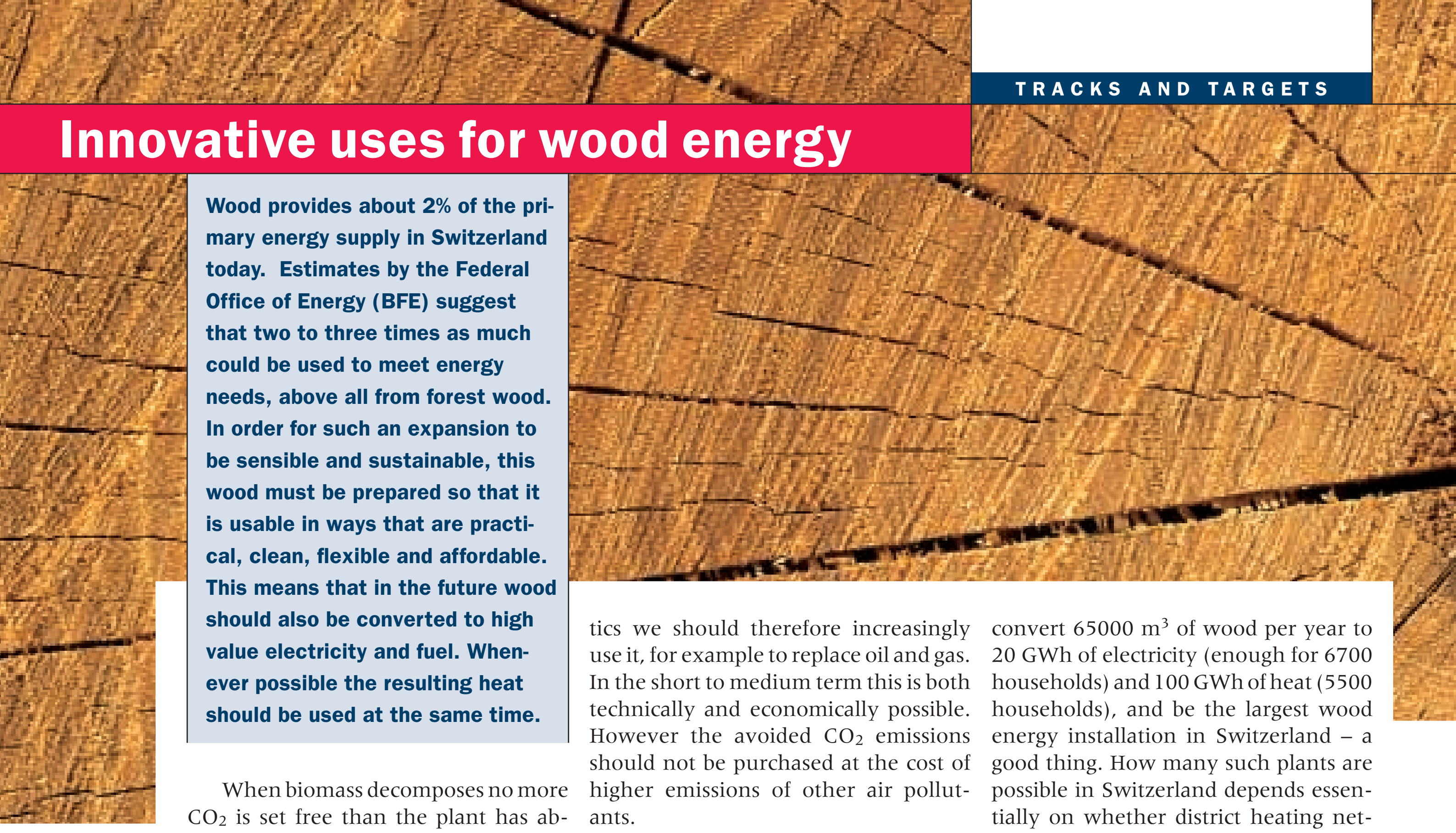
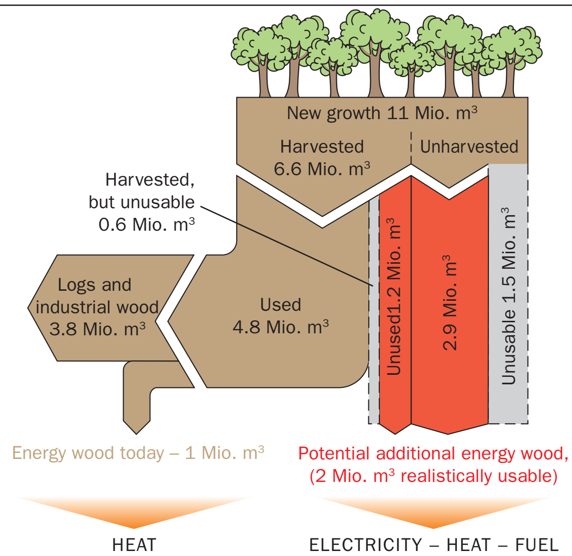


Wood provides about 2% of the primary energy supply in Switzerland today. Estimates by the Federal Office of Energy (BFE) suggest that two to three times as much could be used to meet energy needs, above all from forest wood. In order for such an expansion to be sensible and sustainable, this wood must be prepared so that it is usable in ways that are practical, clean, flexible and affordable. This means that in the future wood should also be converted to high value electricity and fuel. Whenever possible the resulting heat should be used at the same time.

When biomass decomposes no more CO_2 is set free than the plant has absorbed from the atmosphere during its growth. So the use of biomass is climate neutral, as long as no more is harvested than is regrown. In view of climate politics we should therefore increasingly use it, for example to replace oil and gas. In the short to medium term this is both technically and economically possible. However the avoided CO_2 emissions should not be purchased at the cost of higher emissions of other air pollutants.



Energy wood from Swiss forests. (Source: BFE)

No more pollutants please

Until now, energy wood and waste from wood processing have almost exclusively been burned to provide heat. The forestry program passed by the Federal Office of the Environment (BAFU) in 2005 has now formulated a list of targets and measures for a sustainable forest economy and a contribution to the net reduction of CO_2 emissions. Among other goals, one target is to double energy wood use from forests over current levels by 2015. To avoid a parallel doubling of particulate and other air pollution emissions, technologies are needed that work with first class filter systems. This makes burning wood more expensive and provides a drive towards large plants, e.g. large cogenerators that produce electricity and can deliver the resulting heat to a district heating network. A cogeneration plant of this type is being built in Basel. It will convert 65000 m^3 of wood per year to 20 GWh of electricity (enough for 6700 households) and 100 GWh of heat (5500 households), and be the largest wood energy installation in Switzerland – a good thing. How many such plants are possible in Switzerland depends essentially on whether district heating networks can be found that need (as far as possible) a constant, year-round delivery of heat.

> Large plants use wood energy more cleanly than small, direct combustion

From wood to gas

To further avoid air pollution wood can also be transformed into gas, similar to the gas from known biogas plants. The process developed by PSI produces synthetic natural gas (SNG) that burns cleanly, e.g. in a gas combined cycle plant, a gas motor or in high temperature fuel cells. Wood gasification plants, as conceptualized for Switzerland, would be of a similar size as the wood cogeneration plant in Basel.

Table: Wood energy can be used with different technologies, efficiencies and particulates emissions.

The maximum usable heat potential shows how much total heat can be produced when all the electricity generated from SNG is used to operate an electric heat pump that transforms one unit of electric energy to four units of heat (coefficient of performance 4).

For example: 122 = 13 x 4 +70

	Efficiency % electricity / heat	Maximum heat use potential %	Particulates[e] (PM10) mg/MJ heat[g]
Direct use of small firewood	75	75	50
Direct firing of wood chips	80	80	90
Direct firing of wood pellets	85	85	30
Automatic wood-firing with filter	80	80	5[f]
Wood-fired steam power plant with filter	13 / 70	122	5[f]
Wood-gasification cogeneration with filter	25 / 55	155	0.7
Wood-fired power plant without heat use, with filter[a]	30 until 45	120 until 180	5[f]
Synthetic natural gas for combined cycle plant	36[b] / 10[c]	154	0.7
Synthetic natural gas as vehicle fuel (forest to tank)	60[d] / 10[c]	–	0.7

a Large power plant, optimized for high generation efficiency
b With generation by combined cycle power plant of 60 % efficiency.
c Local use of 10% of waste heat from SNG production
d Efficiency of SNG-Production
e Representative of total air pollution emissions
f Represents about 50% of legal air pollution limit for 2007
g MJ heat = MegaJoule of energy in wood input

Wood in the tank and on tap

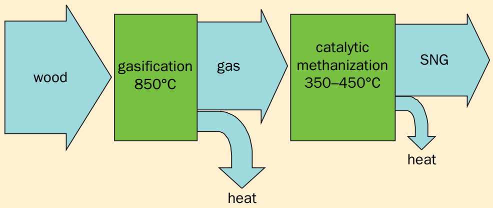
The production of methane from wood is an environmentally friendly and economic alternative to the decentralized burning of firewood. Energy wood is transformed into a conventional energy carrier, and so opened up to a broad spectrum of convenient applications – independent of a heating network. Whether synthetic natural gas replaces fuel or produces electricity and heat depends upon the political and financial conditions.

Wood gasification has been used since the Second World War to provide transportation fuel. But due to its composition, this wood gas cannot be fed directly into the natural gas distribution network. It must be chemically changed so that it is composed predominantly of methane, the principal component of natural gas. PSI has researched the necessary basis for such a process, called catalytic methanization. This new technology is being adapted to further upgrade a wood gasification process developed in Austria. Through a cooperative effort with the Technical University of Vienna, the biomass power plant in Güssing and one plant construction company in both Switzerland and Austria, a complete technology for the production of SNG has been developed. It will now be tested on an industrial scale in the framework of an EU project with support from swisselectric research, thus preparing the way for a first commercial installation in Switzerland.

Ecologically desirable: replace as much gasoline and diesel as possible by wood gas

The high value SNG can be readily mixed with natural gas, and transported over the existing natural gas distribution network. Together with treated biogas from the fermentation of green biomass and agricultural waste, SNG can replace natural gas everywhere it is used today and in the future, preferably in transportation as a low emission fuel for gas vehicles. That also makes more ecological sense than use for heating, where there are already climate-friendly alternatives to heating oil. In the longer term, SNG can also be used for electricity generation in gas-fired power plants and cogeneration plants. An SNG plant that is conceivable in Switzerland in five years time would produce 18 million m^3 of SNG annually from 50 000 tonnes of wood (with 10% moisture content), enough to drive a fleet of 13 000 gas cars each for 15 000 km. Twenty such plants are theoretically possible.

The most important step of the transformation from wood to SNG



60% of the heating value contained in wood is transferred to the synthetic natural gas; the rest is released as heat that can be used at least partially as process heat or for electricity generation.

Biomass power plant Güssing (Burgenland, Austria).

Costs

If wood is available for 70 CHF per cubic meter, then a plant of about 20 MW capacity can produce SNG for 8 to 10 Rp./kWh. That is three to four times more expensive than the price of imported natural gas from Siberia. The price of wood is critical in two regards. If it is too low, wood will not be harvested from the forests. If it doubles to 140 CHF/m^3, the gas production costs will climb to 12 to 14 Rp/kWh. For such a biofuel to be successfully introduced into the market under these conditions it must be freed of the petroleum tax, a political position that has already been proposed. If the SNG is used in gas power plants or cogeneration plants, then higher efficiencies of 60% and low investment costs lead to interesting average generation costs. With a range of 15 to 20 Rp/kWh, these costs are comparable to those of a wood-fired power plant of similar size.

International Dimensions

The European Union has set ambitious goals for the use of biomass in the energy supply. Biofuels should supply 5.75% of the fuel demand by 2010, and even 8% by 2020. In the short term, this requirement can only be met by ethanol or plant oils from specifically grown crops. But synthetic fuels via gasification better exploit the biomass energy and bring a higher return. They therefore are in the center of technological and industrial interest. In the EU the concentration is on processes that follow gasification with a Fischer-Tropsch synthesis (so-called biomass to liquids, or BTL) to produce synthetic diesel fuel. This technology is very demanding, and only economical in large plants (500 to over 1000 MW). There are no appropriate sites in Switzerland for such plants. In contrast, for SNG production the plants that are envisioned are approximately 20 times smaller and appropriate to Swiss geographic and economic conditions. But the production of SNG is also more attractive and economic when the logistics can be managed more rationally, i.e. when there is an abundance of wood and the transportation distances are short, as in the forested regions of northern Europe. There has already been interest expressed from Scandinavia in plants of the 100 MW class.

Decoupling production and use

What are the most important reasons for upgrading biogas and wood gas to the quality of natural gas?

Basically, it is desirable to extend the use of biomass to decrease our dependence on imported fossil energy carriers and to reduce greenhouse gas emissions. But the biomass potential is limited and not as quick to realize as we would like. For now, the fermentation of moist biomass to biogas, and the gasification of wood to SNG offer the chance to decouple the location of production from the location of use. In this way cogeneration plants can be better utilized by locating them where the heat is needed. But quite new areas of application are also being developed, like gas vehicles for transportation.

> Not the production, but rather the use of biogas must be reliably promoted

In the EU, and above all in Germany, there is a great potential for the production of synthetic diesel from wood. With this background, what are the chances of SNG in the EU?

In Germany activities on liquid fuels from biomass (BTL) are primarily driven by the automobile industry, which would like to develop new perspectives for the established diesel technology. What is emerging apart from this is that SNG is comparable with BTL over the entire transformation chain. Therefore wood as a raw material can also be used for fuel with similar efficiency – and with lower air pollution emissions than synthetic diesel. However it is still an open question whether there will be proponents in politics and industry who will drive the SNG technology forward in the coming years with the necessary pressure. There is a need for action here.

What would be the effect of introducing a massive expansion of renewable gas on the operation of the European natural gas network?

These effects must be seen in the context of the long-term development. In Germany, for example, the step-wise introduction of potential biogas production would take place at the same time as a decrease in domestic natural gas production – the replacement would be about 1 to 1. And in the long term the delivery structure can be adapted to a foreign gas supply. So there are no fundamental limitations expected, especially if the use of gas is expanded to the transportation market, which represents a constantly high demand. Possible bottlenecks on the local level remain untouched however, and demand targeted measures for strengthening the gas network where appropriate.

Can the gas network serve a storage function for biogas?

In principal, the answer is yes for small amounts. The question is rather, how well can biogas production be fitted to swings in natural gas demand (low summer demand and day/night swings) through flexible plant management and intermediate hourly storage.

Under what conditions can a market for renewable gas exist?

It is not the production of biogas, but rather its introduction in applications with high climate protection efficiencies that must be promoted in a reliable and long term way. At the same time, it would be helpful to put the fair burden of their real environmental costs on fossil energy carriers (e.g. through CO_2 certificates).

Fuel or Electricity: What makes more sense for wood as a resource?

This depends upon the context of the current energy system. Replacing electricity from German coal power plants saves more CO_2 than if we replace gasoline or diesel used for transportation. Substitution for clean hydropower makes little sense. In each case, one should never evaluate the biomass energy option in isolation, but on the contrary it should always be part of a comprehensive and coordinated strategy for providing sustainable energy. Unfortunately this is missing in most cases.

Dr. Ing. Stephan Ramesohl is an engineer and author of a comprehensive study on the introduction of biogas into natural gas networks*. This study was published in 2006 as part of his activities at the Wuppertal Institute for Climate, Environment and Energy, where he led the focus project "New Energy Carriers and Fuels" in the research group "Future Energy and Mobility Structures." Stephan Ramesohl holds degrees in engineering economics (Technical University Karlsruhe) and economics (Université Aix-Mar-seille II). He did his PhD in the area of electrical engineering and electrical energy systems at the University of Paderborn.

*www.dvgw.de/aktuelles/presse/pm03_06.html

Impressum

Energie-Spiegel, or Mirror On Energy, is the newsletter of PSI for the comprehensive analysis of energy systems (Project GaBE). It appears every four months. Contributors to this issue include Dr. Samuel Stucki and Alfred Waser.

ISSN-Nr.: 1661-5107

Circulation: 15 000 German, 4000 French, 800 English
previous issues as PDFs (D, F, E) at: http://gabe.web.psi.ch/

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Layout: Irma Herzog

Energy Systems Analysis at PSI: The goal of energy systems analysis at the Paul Scherrer Institute in Villigen is to analyze present and future energy systems in a comprehensive and detailed way, considering in particular health, environmental and economic criteria. On the basis of Life Cycle Assessment (LCA), energy-economic models, risk analysis, pollution transport models and finally multi-criteria decision analysis, it is possible to compare different energy scenarios to create a basis for political decision-making.

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