Supplying Europe with Solar Energy

Harry Lehmann

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(hl@isusi.de)

Introduction

The 21st century confronts us with the challenge of creating a sustainable energy sector with viable future development. But what do "sustainable" and "viable future development" mean?

The public first heard mention of "sustainable development" in 1980, an idea that would shape the environmental debates of the 1990s. Giving equal justice to meeting basic needs and life requirements within a generation, within the continents and for the next generations. This constitutes the concept of "development that is viable for the future". Conserving an environment in which mankind can live naturally is a basis for the fair and equitable search for happiness. Sustainability means that our planet should be used only in a way that preserves its fundamental characteristics over time. Individual freedom, and social stability and balance, are essential prerequisites underlying the equitable search for happiness. But a sustainable society needs an economy that carefully manages the world's yields while achieving maximum prosperity, whatever the definition, at the lowest possible cost. Complex connections between ecology, human social welfare and economy demand that sustainable development must integrate all three sides, paying them equal attention and according them equal value.

Science can say little; indeed in most cases it can say nothing at all, about the effect of man's activity on the biosphere. It can say little about how intensely the ecosphere will react to this activity, nor about when or where reactions will take place. At present, and perhaps for all time, mankind will act without knowing how the earth’s “survival system” works and how it reacts to human influence. To be on the safe side and avoid disruptions, our activities should affect this system as little as possible. This precautionary principle must be the guiding rule for all human action if we want to achieve development that is viable for the future.

What is the significance of this precept for the energy technologies we use if: 1), we consider our ignorance; 2), we take into account the precautionary principle, which requires that we create as little energy and material flows as possible; and 3), if we want to act according to a principle of fair and sustainable development for mankind?

Using a source of energy in a sustainable way should not involve direct or indirect risks for coming generations. Material flows should be as limited as possible, even if they use natural resources and are considered harmless. Waste generated by an energy technology, as far as it is produced at all, should consist of natural materials that exist in the biosphere. If the technology produces waste in the form of materials that do not exist in nature, these should be permanently storable and kept separate from the ecosphere. To keep these substances as separated from the biosphere as possible, unavoidable dissipative losses from wear and tear, leakages or evaporating should be as low as possible. Only the very smallest amounts of these materials should be allowed to disperse in the biosphere.

These energy technologies must not rely on finite resources, since at some point these resources are exhausted and no longer available for following generations. Living from yields alone in the energy sector means, strictly speaking, that the energy used during a certain period of time should be the energy "produced" on earth only within that period.

A last important point is that sustainable energy technologies should not be politically destabilising, in other words, not a safety or security risk and available for exploitation in many regions of the world. With regard to safety and security factors, this point is particularly true whenever toxic substances are involved or materials can be abused for military purposes. These unsustainable options appropriate high surveillance costs and harbour the potential for societal and political abuse. A sustainable energy technology must not be destabilising at an international level, in other words, the resources used should be available to all regions in sufficient quantity, preventing monopolies and regional dependencies.

The energy supply technologies in use today only partly fulfil these requirements. Some don't fulfil any at all. They may probably never completely fulfil them, but these requirements should remain in the background as a yardstick for decisions about those technologies or combinations of technologies to use in the future energy sector. If this yardstick is used to measure present-day technologies, fossil and nuclear energy sources would prove nonviable, unsustainable for the future. Only renewable energy technologies, if used correctly, fulfil the requirements listed above.

Today's world economy is not using the earth's resources in a sustainable way. The fossil fuel-based industrial revolution has fostered consumerism and its concomitant use of resources (about 80 tonnes of resources are consumed per person per year in Germany, not including water [Bringezu, Schütz; 1996]). This consumption, heightened by a growing population, point out the limits to this kind of economy. Added to this, wealth, education, life expectancy and opportunity are distributed very unevenly between the industrial nations and all other countries, as they are within many countries as well. Many parts of the world can only dream of political and social stability. Last but not least, the environment faces increasing threats, ranging from the well-known problem of climate change caused by human activity, erosion of fertile soil and water pollution, to the various effects of man-made toxins.

The characteristics of a sustainable society have been identified and discussed by several authors, but have been scarcely realised. They include:

- the availability of services with the best possible use of resources (Factor 10)<1> ,
- the transition to renewable energy sources and their efficient use,
- the conservation of soil<2>,
- the analysis of our concept of prosperity and a re-evaluation of how much is enough.

1. siehe auch: F. Schmidt-Bleek, F. "Wieviel Umwelt braucht der Mensch – MIPS das Maß für ökologisches Wirtschaften", Birkhäuser Verlag, Basel (1994)
2. siehe auch: H. Lehmann, T. Reetz "Sustainable land use in the European Union – Actual status and a possible scenario for 2010", Wuppertal Paper, November 1994

Sustainable energy supply system

"The sign of a truly educated man is to be deeply moved by statistics."

George Bernhard Shaw

The shift to using renewable resources in the energy sector must happen soon – present-day changes in our climate call for quick action. But this is not the only reason for converting to solar energy use. Solar energy, geothermal energy, wind power, biomass, hydropower and tides are the earth's only real energy sources. The exploitation of materials deposited in the earth, such as coal, oil and natural gas, formed from these primary sources over very long periods of time, is nothing more than enormous redistribution at the cost of future generations. This situation is intensified by that fact that many people do not share this energy consumption. Every third person in the world, and this figure is increasing, does not have access to electricity. In face of this decentralisation and decreasing fossil fuel reserves, supplying people with power and concomitantly, with information, light, refrigeration and other basic services, can occur only if renewable energy technologies are used. There are many indications that there will be shortages of oil and gas within the next two decades[3], making it clear that renewable energy sources are much more than environmentally sound alternatives – they are the energy basis for a sustainable model of future civilisation.

A sustainable energy supply for Europe will need three bases. First, it must rest on renewable energies; second, it must use available resources efficiently; and third, it must rely on deliberate decision-making regarding the limits of consumption, or sufficiency. Solar power/ efficiency/sufficiency are the cornerstones of a sustainable energy sector.

Considering that most technologies needed for this development already exist and have indeed been tested, the following questions now arise:

- How can renewable energies be integrated on a sufficiently large scale into the present European energy system and do their technologies function all year round?
- How do we attain this goal? How high are the costs and uses of such a strategy?
- What other economic, ecological and social goals can be realised?
- What fundamental obstacles and disincentives prevent such a development?

3. Schindler J., Zittel H. :“Wie lange reicht das billige Öl“, Scheidewege,Jahresschrift für skeptisches Denken,28,1998/99, Baiersbronn 1998

Scenarios and energy supply structures were investigated in past years in several projects, especially one that looked at the "Long-Term Integration of Renewable Energies into the European Energy System and its Potential Economical and Environmental Impacts" (LTI). The LTI project worked on "extreme" scenarios with very different but ambitious economic, social and ecological goals over the next decades. If a European energy supply system based on renewable energy sources remains feasible when it faces high demands, the realisation of a solar-powered Europe is more likely if less ambitious goals are set. [4]

Based on two simplified archetypes of behaviour – exhibited by those who are motivated to protect the environment and those who are interested in consuming – two scenarios were developed that lead to an 80 percent reduction of CO_2 in Europe by 2050. In the "sustainable" scenario, the state makes sure the best ecological mixture of technologies is used and people support this effort by making corresponding changes in their consumption. In the "fair market" scenario, diverse energy technologies compete with each other on the market, taking their external costs into account.

Both scenarios use only those technologies that were available in 1995. More recent developments (such as megawatt-class wind farms, small fuel cells or virtual power plants) are not included. Both scenarios attempt to manage by using only domestic European renewable energy sources. Both scenarios assume that all European Union countries will have the same standard of living by 2050 and the availability of appliances and equipment will be similar to the present-day situation in Denmark, Germany and the Netherlands; in other words, prosperity will considerably increase in many regions of the European Union.

The sustainable scenario makes ambitious assumptions about reaching ecological and social goals (such as the comprehensive introduction of organic agriculture, the designation of 10 percent of European land area as nature conservation reserves, and an even balance of imports and exports regarding non-European land use, meaning food is basically provided by Europe's own farmlands). These factors have made the design of a functioning energy system more difficult, since biomass and wind power potential, among others, were limited.

4. "Long-Term Integration of Renewables Energy Sources into the European Energy System", The LTI Research Team, Physica Verlag (1998)

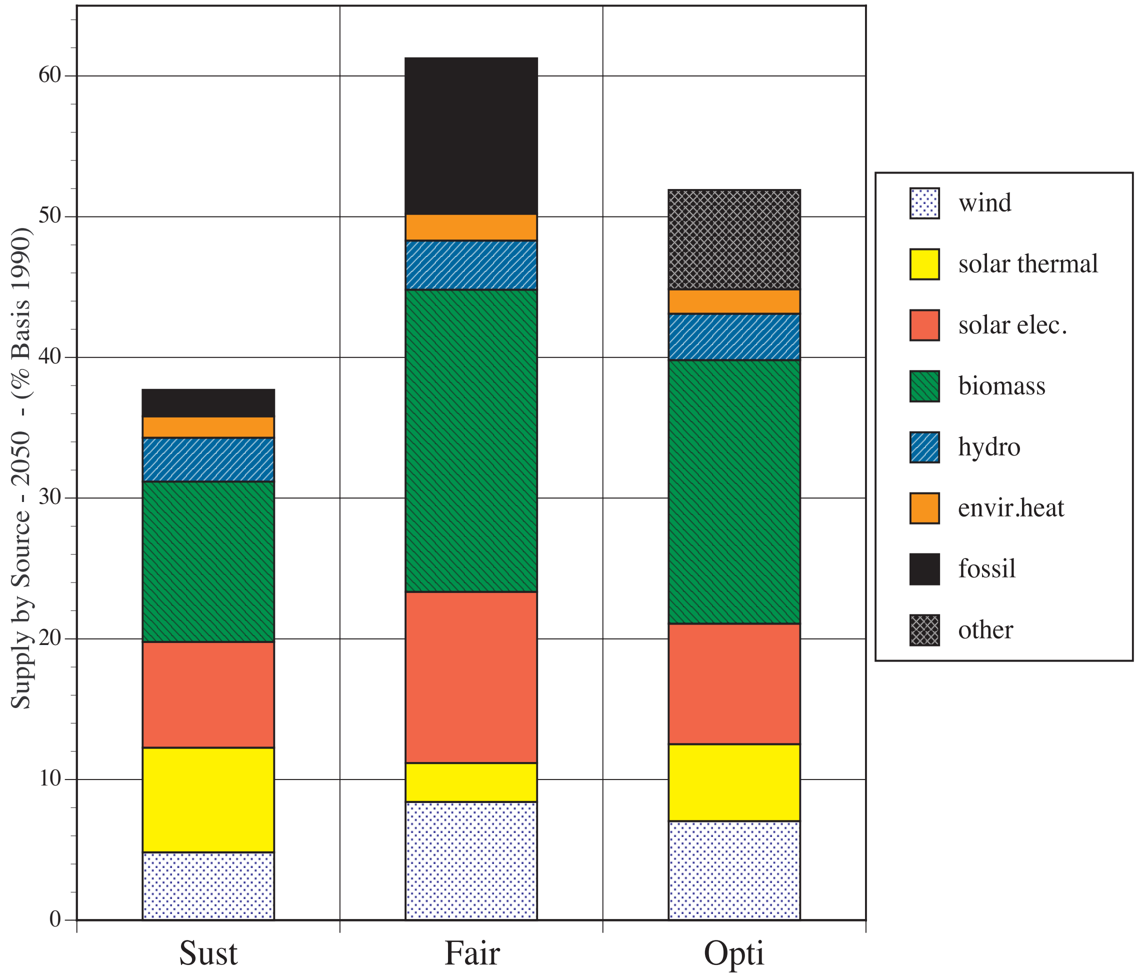

Fig.: 1.) Figure 1: Share of energy sources providing electricity in 2050 in three different scenarios. The effect of passive solar architecture appears in these scenarios only as reduced energy demand for buildings. Energy efficiency and savings have lowered demand by 38 to 62 percent. Geothermal energy, imported solar-generated hydrogen and others are not included in the sustainable and fair market scenarios and are together in the "opti" scenario under "other". Source: LTI research team and own calculations

Other scenarios (such as the "opti" scenario), can include other and more recently developed technologies (in particular, decentralised fuel cells and geothermics) thanks to improved simulation techniques (increased spatial and temporal resolution).

Because of their extremely varying assumptions, the examined scenarios represent the "crash barriers" of possible development. These scenarios are not prognoses of possible development. Indeed, reality will be a mixture of different trends.<5> The scenarios have been designed so that we learn as much as possible about supplying solar energy to European states.

5. Here we note changes in land use and agriculture that seemed utopian at the time the study was completed, but that today fit into the study's projected trend because BSE and foot-and-mouth disease have had impact on developments.

A solar energy system that provides a reliable energy supply throughout the year includes the consistent use of local renewable energy sources, whether they are wind power along the coast or in windy regions, biomass in rural areas, photovoltaics in developed localities, the passive and active use of solar heat, solar thermal power plants in sunny regions and hydropower, wherever possible. A second feature of such an energy supply structure is the intelligent exchange of energy between these regions. This exchange can take place through the power grid or a gas network or by transporting biomass. A national or international network can serve to exchange energy or to store surpluses. The stored material can be biogas or even solar-generated hydrogen.

Different technologies using renewable energy sources and the potential of different regions with varying strengths and weaknesses will mutually replenish a functioning energy supply system throughout the year. This approach balances the fluctuations in energy provision that can occur with some renewable energy technologies (such as wind farms). If the wind stops blowing in one region, power is then initially supplied by other regional sources such as local biomass power plants or photovoltaic units. If this is not enough, plants in other regions deliver power.

Such an energy supply structure must be much more intelligent than today's. It would start with regulating the system, including the planning of energy production with the help of weather forecasts, and end with consumers who would adapt their energy needs to the availability of electrical power. Small fuel cells, sure to appear on the market in the next few years, produce heating and power by burning hydrogen or biogas and will enable a new form of intelligent consumption. Consumers need only a gas supply (based more or less on solar-generated hydrogen) and can then provide themselves with heating and electricity. But they can do more. This "personal power plant" can also deliver power to the grid when, for example, a central control authority needs to shore up a peak load or create a virtual power plant by connecting several personal power plants (such plants are not incorporated in the scenarios described here).

Foresighted management can guarantee consumers a stable energy supply by combining in a national exchange structure those technologies whose energy production is varying and seasonal with those whose energy sources are available at any time. Modern computers and the communications technology that gave rise to the Internet have made this possible only today.

Renewable energy sources in the scenarios include biomass, hydropower, solar heating, photovoltaics and wind power. Other sources such as geothermal energy, wave action and tidal energy have not been included. But this does not mean that these technologies are not interesting; indeed, they should be used at suitable locations. In addition, the scenarios take into account as reduced demand the increase in energy efficiency described in several current studies of various sectors.

The scenarios look only at the following technologies regarding power production: wind turbines, solar-thermal power plants, photovoltaics, existing large-scale hydroelectric plants and additionally, small hydroelectric plants.

In the scenarios, heat is generated by solar collectors, solid and liquid biological fuels, hydrogen, heat pumps, and electricity, and is stored in hot water tanks. For systematic reasons, solar architecture is taken into account as a gain in efficiency. Environmental heat is exploited by heat pumps.

In the scenarios, combined power and heat is produced by cogeneration systems and fuel cells. Biomass is converted to different gas fuels such as biogas or hydrogen for reversible fuel cells. Biomass is also used in the form of liquid fuel in the transportation sector. In some cases where efficiency measures and renewable energy cannot sufficiently cover energy demand, fossil fuels are used, primarily in the transportation sector and in some remaining backup systems. Solar power plants are used for electrolysis to produce hydrogen, which is then either distributed through pipelines, directly burned or used in fuel cells for power production.

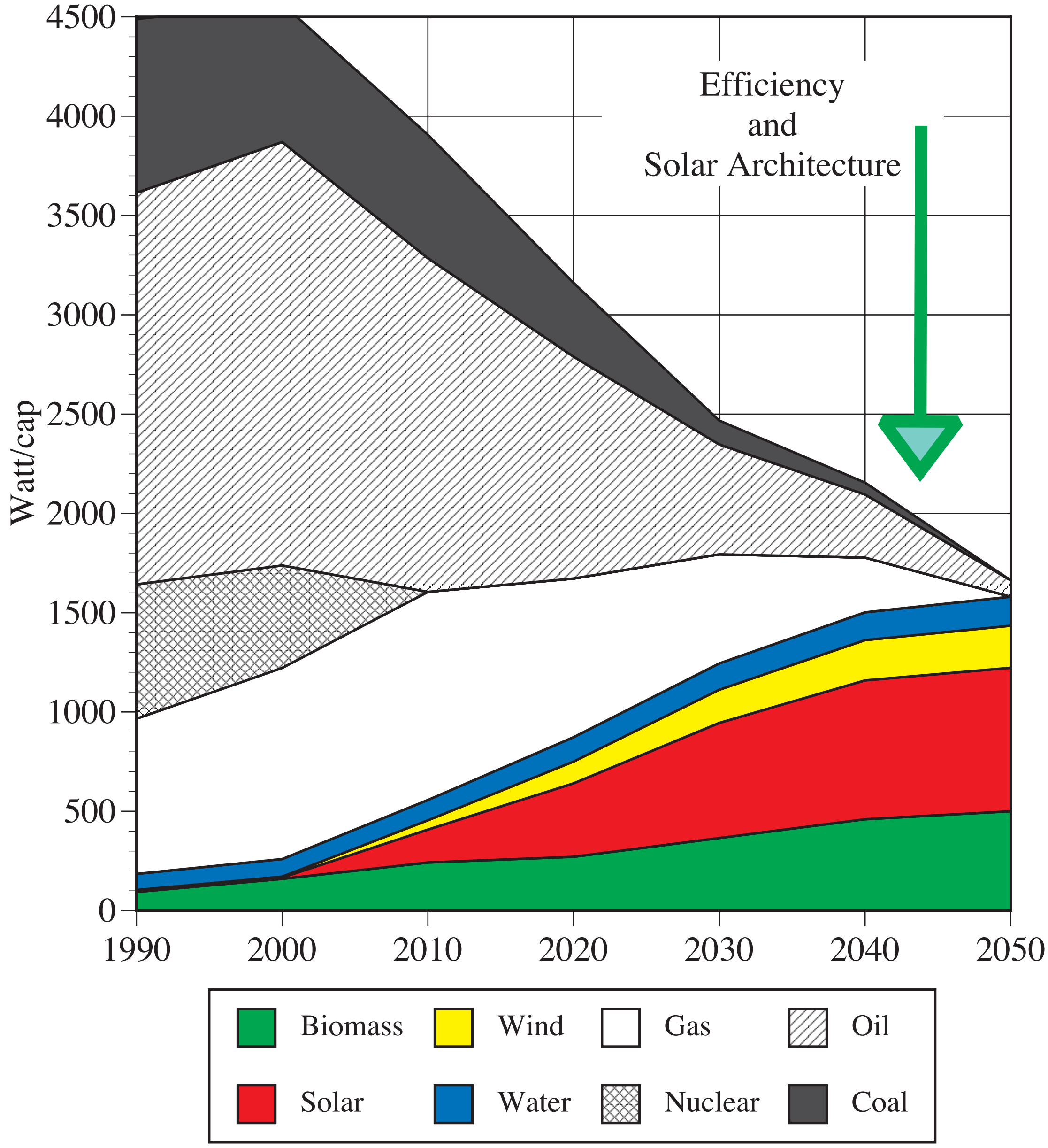

Figure 2: Chronological development of the sustainable scenario, Source: LTI research team, 1998.

Test of consistency

Some critical questions can be asked about the proposed solar energy supply structures and their attendant market entry scenarios.

Does this system work throughout the year?

These energy systems are illustrated here in detail and simulations use real weather data (see Figure 3 on p. 11). The consistency test using a simulation model on an hourly basis showed that the sustainable scenario might have a problem providing enough heating during cold winter periods. This deficit could be bridged by using fossil fuels and would not stand in the way of reducing CO2 by 80 percent. A simulation run revealed that just an additional 450 W/per person would solve this problem; this power could even be provided using non-fossil measures. Options include producing more hydrogen or more fuels from biomass, or improving the insulation of living space; they also include reducing the capacity of photovoltaics (there is a surplus of power in the summertime) and using the cleared roof space for solar thermal cells, which would also require more seasonal heat storage capacity. As a result, this scenario would be able to provide sufficient energy (power, heating and fuel) throughout the year. Fluctuations in the power supply would be evened out with the appropriate management of coupled power plants (such as fuel cells). Recent simulations with a higher temporal and spacial resolution show that fluctuation problems are much smaller than expected, thus reducing the need for storage.

In both other scenarios, the high share of fossil fuels or imported solar energy (such as hydrogen or electricity imports) makes it easier to offer a stable energy supply throughout the year.

Are the market entry curves realistic for these energy technologies?

If the calculated market entry curves for renewable energy technologies are compared to those for historical technological developments (such as automobiles, air transportation, computers, and especially wind power after 1995), these examples have indeed been more rapidly introduced to the market. The scenarios work on the assumption that the average increase in the installation of renewable energies until 2050 (with 1990 as the basis) will be 5.8 to 7 percent each year. But this doesn't mean that market entry will happen by itself. In fact, in some cases (especially photovoltaics), massive efforts will be necessary. By historical chance but nevertheless worth mentioning, the sustainable scenario's projected value for 2010 is not far from the goal formulated in the White Paper for renewable energies in Europe.

Conservative values were used to calculate improvements in efficiency in the industrial and transportation sectors and in household appliances. The sustainable scenario with the highest efficiency increases assumed that the average increase would be only 1.6 percent per year, which is not much higher than current average efficiency increases.

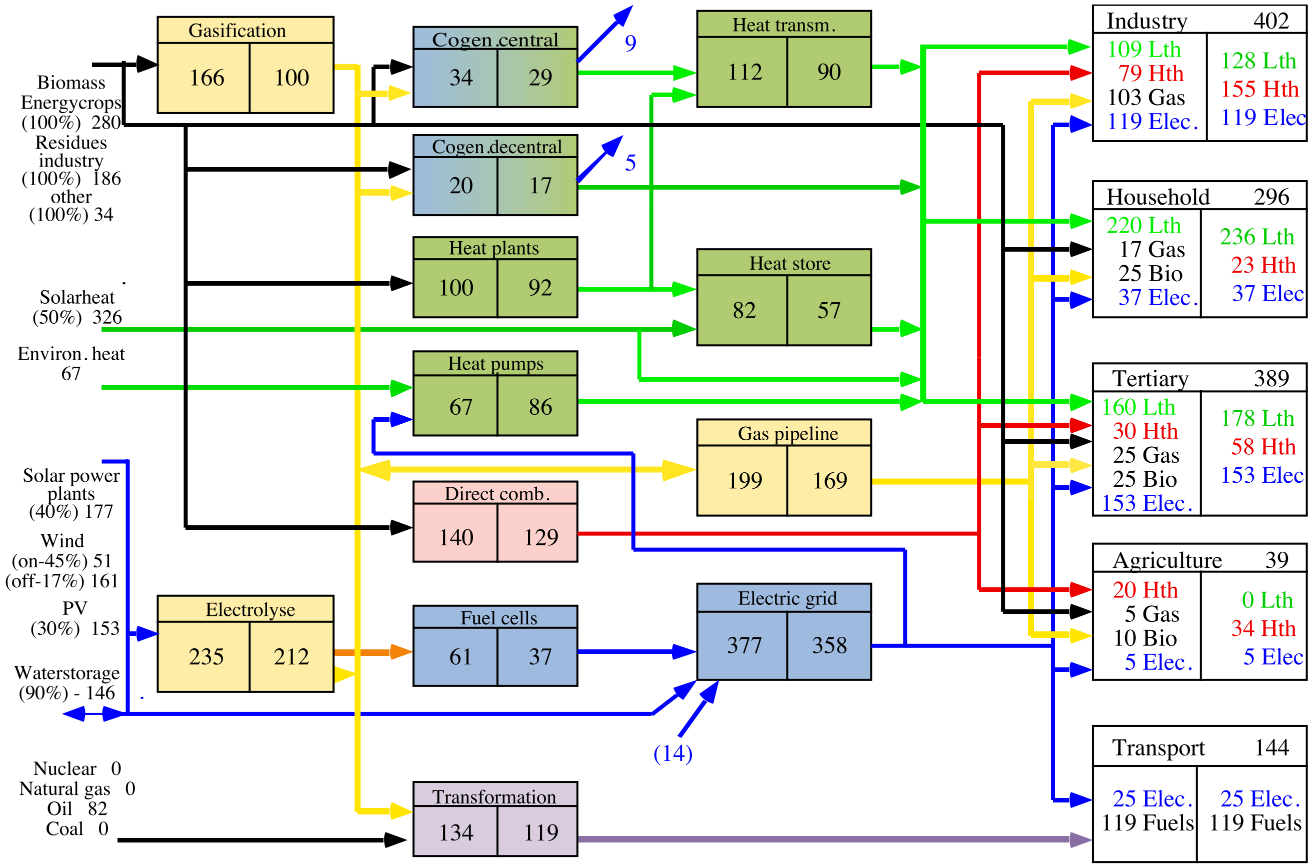

Figure 3: The structure of the sustainable scenario's energy supply system for Europe in 2050. The share of potential exploitation of renewable energies is given in percent. All figures are watts/year per person. Source: LTI project

The picture changes if we look at the building sector. Technically feasible but very large increases in efficiency and solar energy use must be assumed in this sector to meet climate protection goals. These changes must also be integrated into existing buildings. The renovation rate in Europe should be doubled to allow the sustainable scenario's projected development. The sustainable scenario works on the assumption that average energy consumption in 2050 will be 30 KWh for heating and/or refrigeration per square meter and year (passive gains are already included)[6]. The use of small fuel cells for decentralised heating/power production could significantly solve this problem. This problem does not appear in the other scenarios.

6. In comparison, energy consumption in 1990 in Germany was 150 KWh/m^2 for heating.

Will these potential sources be enough?

Even under the sustainable scenario's restricting assumptions regarding the potential of renewable energies, there is sufficient potential in each technology. If the other ecological goals are softened somewhat (especially for land use and organic farming), potentials (particularly for biomass) sharply increase. This creates "reserve space" to absorb such problems as trying to increase efficiency in the building sector. If we give up the sustainable scenario's hardly realistic assumption that Europe will supply itself with energy, other sources can be drawn in that would make supplying Europe with solar energy much easier. Whether these sources are solar-thermal power plants in North Africa, hydropower from Canada or biomass from Russia is an open question and can be left to the future. If we make less conservative assumptions about the efficiency of renewable energy technologies (calculations are based, for example, on 600 KWh wind turbines at most), potentials dramatically expand. This also helps solve the problem regarding existing building stock.

Can renewable energy sources feasibly supply 100 percent of needs?

The sustainable scenario's solar energy supply system cannot fill the gap created by the transportation sector. Since the scenarios refer only to those technologies that are already on the market, some that are important for solar energy provision, such as fuel cells (mobile and decentralised), are not included. These technologies, together with the potentials described above, would enable complete solar energy provision in Europe, even if the goals for buildings are not fully met.

The fair market scenario needs only to replace the remaining share of fossil energy sources with imported solar energy. In the "opti" scenario, complete solar energy provision is attained.

A solar or renewable energy system that covers 100 percent of Europe's needs is feasible. Whether this can happen by 2050 or not until 2100 depends on what measures are taken and upon their consequences.

The costs and job effects of solar energy provision

The LTI project estimated that the annual running costs of existing renewable energy plants in 1990 in the European Union were about €43 billion. In the sustainable scenario, this figure increases to €253 billion by 2050 (assuming that market entry leads to lower prices for renewable energy sources). Although this appears to be very high at first glance, it is less than €700 per inhabitant per year. While costs increase by a factor of six within the 60 years in question, the installed capacity increases by a factor of 16 from 144 GWp to 2,300 GWp. Compared to present-day figures, a KWh is 50 percent more expensive in 2050, but since in all three scenarios energy needs sink, total energy costs for most sectors stay the same.

An important finding from the sustainable scenario is that improvement in efficiency must run parallel to the market entry of renewable energies. Only then can the reduction of energy consumption compensate the simultaneous increase in costs caused by market entry so that negative effects on the economy can be avoided. Parallel market entry also avoids the creation of investment barriers.

The static EMI 2.0 input-output model was used to calculate the job effects created by restructuring the energy system in the sustainable scenario. Unfortunately, only the input-output tables for West Germany in 1988 were available, so that only these were used for an approximation for all of Europe. This region provides a suitable reference point due to its high degree of rationalisation and its great work productivity in view of the assumed future convergence of standards of living and economic structures in Europe. For each of the eight renewable energy technologies looked at, two input vectors were put together from other sectors' needs. The first vector describes construction costs for the year in which the investment was made. The second vector contains the operation and maintenance costs and also the costs of biomass fuel for the whole lifespan of the facilities. The construction and operation of renewable energy facilities employs four million people per year in 2050 (four million person/years). These jobs are primarily in the area of biomass. Of the 1.6 million person/years needed each year to operate biomass plants, two-thirds concern jobs in agriculture and forestry.

Job effects regarding a fossil fuel reference case were calculated as a comparison. In this case, the construction and operation of the energy system (again without the fossil fuel based transportation sector) will employ 1.7 million people per year in 2050. To compare both cases, it was assumed that a cost difference of 71 billion ECU/year will flow completely into private consumption. As a result, employment figures increase by 1.5 million person/years due to higher private consumption if we base calculations on the average German savings rate of 14 percent and the economic structure of Germany in 1988. If all additional costs for consumption are spent, which is likely in the face of the long period of time in question, the number of those employed increases. If we look only at a national economic system, we must subtract the sum of imported goods. But, since we are assuming that the major portion of European Union members' trade activities also take place within the EU, this effect was ignored. Taken altogether, employment in the reference case results in 3.2 to 3.4 million person/years.

Compared to the reference case, employment in the sustainable scenario based on renewable energies increases by an additional 340,000 to 580,000 person/years. One reason for the relatively small difference is that work intensity in 1988 was much higher in consumer goods than in the energy sector. Besides, the assumptions for the fossil reference case are very optimistic and they don't include the jobs required for renovating buildings. The sustainable scenario is the one with the lowest installation figures (which means it has the highest improvement in efficiency).

Thus the net values calculated here can be seen as very conservative estimates. In spite of the many rough assumptions in these calculations, this allows us to be sure that an economic system based on renewable energies will employ more people than a system based on conventional energy. This result is reinforced for Europe by the fact that more jobs are created within the EU to produce investment goods at the cost of jobs outside Europe in the fossil energy sector. If the jobs needed for the solar renovation of buildings are included in the calculation, we can expect conversion to a solar energy supply system to have a slightly positive effect on employment in the order of a million.

Conclusions

It was shown that the European energy system can be changed within the next 60 years to use energy in a sustainable way. Implementing energy efficiency measures and converting to a comprehensive use of renewable energy sources can end nuclear power use and at the same time starkly reduce fossil fuel use, with the goal of ultimately ending it as well. In the medium and long terms, a restructured energy system will not be more expensive than the present one and will even create more jobs than a conventional system does. Initially, higher investments will be needed to push this development. There are no principle technical or financial hurdles in the way of a completely solar/renewable energy supply system.

However, economic, legal and institutional conditions for the energy system must fundamentally change and indeed, this must happen soon. In practice, we will need to rely on a mixture of instruments. The building sector is a key area that must be tackled quickly. Every house now being built or renovated without incorporating enough energy efficiency measures or solar energy uses will prove to be an additional obstacle in the coming decades. The goals envisioned today (such as doubling the use of renewable energies by 2010 – EU White Paper) are the correct first steps toward a comprehensive solar energy supply. But that is not enough. These figures must double again between 2010 and 2020.

Research and development have created renewable and efficient energy technologies for a permanent energy supply. Together the political community and industry must take measures to implement a "solar strategy". The measures described above are feasible and make sense. The most important step is to start now, since every day that goes by without enforcing a solar strategy only increases and complicates the problem – because energy consumption is increasing, money is still being invested in fossil fuel systems and finding ways to solve the problem of climate change is merely being postponed.