Article for Rio02, updated for World Summit for Sustainable Development, August 2002

Sustainable Energy Vision 2050, - A proposal to achieve a sustainable energy system, following environmental and social imperatives.

By Gunnar Boye Olesen, Michael Kvetny, and Emilio Lebre la Rovere,
INFORSE - International Network for Sustainable Energy[1].

Abstract

In the coming 50 years, it will be crucial that the world's energy systems be made environmentally benign and sufficient to meet everybody's energy needs. We have better technologies than ever before to use energy efficiently, and to use the world's renewable energy resources without harming the environment. The purpose of this work is to show how we can use these technologies to change the unsustainable energy system worldwide into a sustainable system, following "imperatives" of securing environmental/ climate stability and equal access of energy services to all, including ensuring basic energy needs for all.

If we can keep global warming below 1°C within the coming century, and if we can return the rate of warming to below 0.1°C per decade within the next two - three decades, we should be able to reduce the speed of climate change to a level that nature can accommodate. To do this, we have to limit greenhouse gas reductions drastically. If we limit global CO_2 to 250 Gton of Carbon or less within the 21st century, it should be possible to keep the atmospheric CO_2 content close to or below 350 ppmv, and to keep climate change within a range that nature can adapt to in general We should also minimise other dangers of energy supply, including the hazards of nuclear power plants and their waste. Thus, nuclear power should be phased out.

From independent researchers some proposals exist with fast CO_2 reductions, fulfilling above imperatives. Based on these studies and proposals from our network, is proposed a path to supply the world with 100% renewable energy by 2050, and accordingly a 100% reduction of energy-related CO_2 emissions. This will be in line with the limitation of global CO_2 emissions to 225 Gton of Carbon in the 21st century.

Regarding the economy of changes to renewable energy and to energy conservation, a massive introduction of new technologies will lead to huge reductions of costs for those new technologies. Many technologies can be competitive with fossil fuels before 2025 if developed vigorously, some are already cost-effective today. The investments necessary for these developments will be paid back with the availability of a cheaper renewable-energy supply and of energy-efficiency technologies in the future.

Initially, there is an urgent need for large-scale changes in energy investments for production of renewable-energy and energy-efficiency equipment, including local production of simple renewable energy equipment in developing countries.

In conclusion, a total shift towards a sustainable energy system is possible within a period of about 50 years. The changes will have a number of beneficial effects, they will give a more stable energy supply than the current, they are compatible with global equity, and the additional costs to the society will be small or even negative, if the changes are well planned and phased in as part of the natural change of plants and equipment. The changes will, however, require initial investments and long-term strategies, nationally and internationally. It will also require a major shift in the energy supply system and in energy consuming equipment and structures.

[1] **Gunnar Boye Olesen**, INFORSE-Europe coordinator, Gl. Kirkevej 56, DK-8530 Hjortshoej, Denmark, email ove@inforse.org. **Michael Kvetny**, INFORSE Secretary, Blegdamsvej 4B[1,] DK-2200 Copenhagen N, Denmark, email mk@inforse.org (to be used for correspondance). **Emilio Lebre la Rovere**, INFORSE-Latin America Coordinator, LIMA, C.P. 68565, Centro de Tecnologia Bloco I/MM 06, Ilha do Fundao, Rio de Janeiro - CEP 21945-970, Brazil, email: emilio@ppe.ufrj.br

1. A GLOBAL RENEWABLE ENERGY SUPPLY FOR 2050

One of the best descriptions of a worldwide energy system without fossil fuel and nuclear energy is given in "A Global Renewable Energy Scenario" (GRES) (Soerensen & Meibom, 1998)[2]. In that study is described, a detailed study on how to supply the world's energy needs with renewable energy in 2050. This scenario is based on the key assumptions:

- That the world population will be 9.4 billion people in 2050
- That all basic energy and food needs are met
- That 60% of the "full goal satisfaction" is fulfilled for all energy demands including leisure time activities etc. This is an increase from 33% today. This gives an increase of a representation of energy services[3] of 4.8 times compared to today's level.
- That the best available energy efficiency technology today is the average technology in 2050.

There are two scenarios for meeting this demand: a decentralised scenario, relying only on renewable energy produced near its use except for hydropower, and a more centralised scenario, with 20% of the energy coming from windparks and solar centrals. Estimations of consumption and renewable energy potentials are based on a worldwide geographical information system (GIS).
In the following part of this article, the centralised scenario is used as basis, and referred to as "GRES".

2. ENERGY CONSUMPTION

In GRES, the energy consumption for 2050 is not described by the future development of GDP, but by a universal "full goal satisfaction", assuming that energy demands can be related to limited physical demands, not to an ever growing economic GDP-figure. As an example, the "full goal satisfaction" includes that that the average person has 40 m^2 of heated (or air-conditioned) home in areas with heating/cooling needs and an additional 20 m^2 of heated/temperated floor space in the service and commercial sectors. It also includes transport energy for leisure time activities equal to 3000-4000 car-km/year pr. person with 2050-technology, equal to e.g. driving 6000-8000 km/year with two persons in the car.

The GRES scenario is assuming a high efficiency compared with assumptions of the "business as usual" development of e.g. IPCC (IPCC, 2001)[4], being demanding on energy efficiency developments, and less demanding on energy supply. A number of regional analyses give consumption in 2050 comparable to GRES, as shown in Fig.1. In addition to GRES, the comparison includes:

- Wuppertal/ZEW: Scenario for a Sustainable Future Energy System, Harry Lehmann et.al. Wuppertal Institut für Klima, Umwelt, Energie in co-operation with Zentrum für Europäisches Wirtschaftsforschung (ZEW) and others, 1998
- "Fair Market": A Fair-Market Scenario for the European Energy System, Stefan K. Nielsen & Bent Sørensen, Roskilde University and others, 1998
- FFES: Towards a Fossil Free Energy Future, Michael Lazarus et.al. Stockholm Environmental Institute - Boston Center 1993 (situation for 2030).

[2] Prof. Bent Sørensen and Peter Meibom, A Global Renewable Energy Scenario, Roskilde University Center, Institute 2, Energy & Environment Group, Denmark 1998. (IMFUFA tekst no. 354, see also: mmf.ruc.dk/energy/abstracts/ipcc.zip)
[3] "energy services" is referring to the benefit in non-energy terms (heated area, light, prepared food, etc.) that end-user have of his/her energy consumotion. In the report of Bent Sørensen et.al., the concept is quantified as end-use energy use with the efficiency in 2050.
[4] See e.g. IPCC Third Assessment Report , WG3 (mitigation) Summary for Policy Makers' "alternative development paths", IPCC, 2001 (www.ipcc.ch)

The chart in fig. 1 is made with conversion of data by author. The very low estimate for medium and high temperature heat for GRES compared with other scenarios is partly caused by differences in division of heat categories.

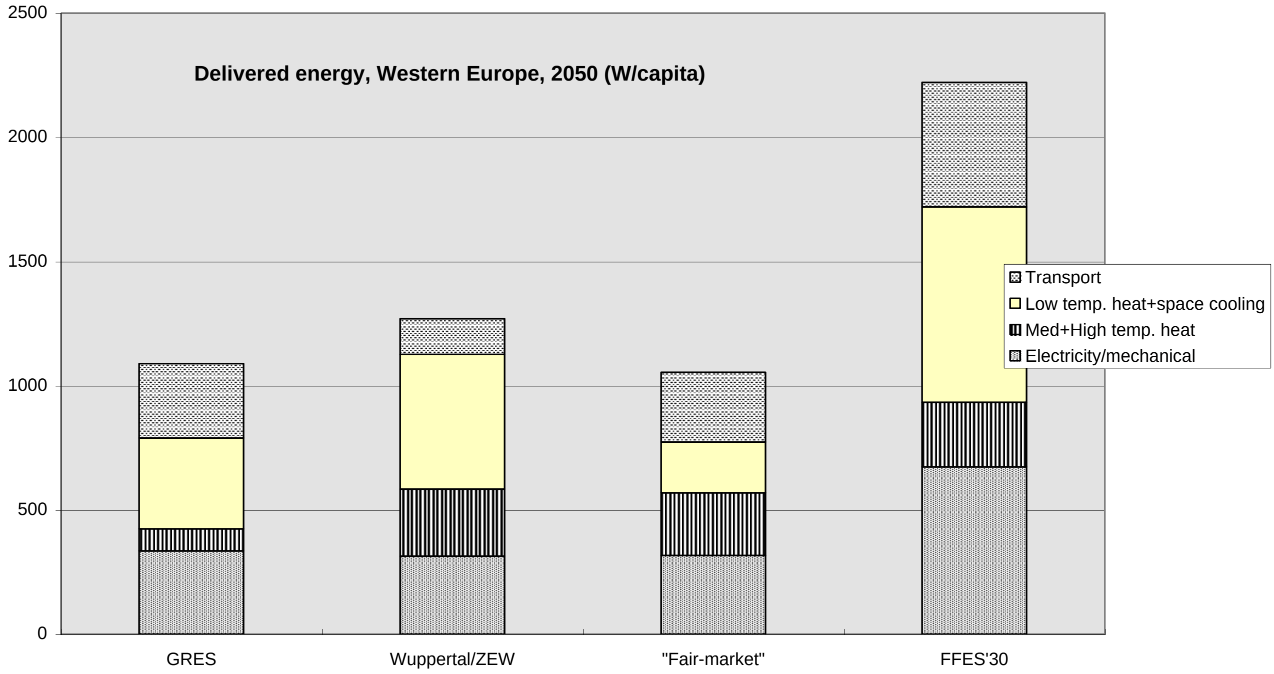

Figure 1 Comparison of delivered energy per capita in Western Europe for different analysis of future energy demand with strong climate policies. The scale is watt of average consumption pr. person.

2.1 The Path to an Energy Efficient Economy in 2050

One of the crucial points in realising the GRES and other sustainable energy scenarios is the possible rate of introducing energy efficient technologies. The GRES scenario does not include a description of the development from today to the situation in 2050, while others have made such descriptions for low-energy scenarios, such as above-mentioned scenarios from Wuppertal Institute and others.

To come from the current situation to the GRES scenarios situation for 2050, the stationary energy consumption (i.e. excluding transport) is assumed to have an average efficiency-increase of 8 times. Part of this efficiency increase is assumed to be achieved by the use of heat pumps for space heating and low-temperature process heat. In addition to this is a general increase of end-use efficiency of about 6 times, equal to 3.7% annual increase in efficiency[5]. The realisation of this is ambitious, given that the "natural" development of energy efficiency can be expected to be about 1% per year[6]. However, the development is based on introduction of technologies that are already commercially available or are near commercial and well known.

[5] Own calculation based on comparison of todays stationary fuel and electricity consumption (assumption for 2000, based on International Energy Agency - IEA's statistics for 1998 for final consumption of gas, coal, oil, biomass), with the stationary fuel and electricity consumption according to GRES in 2050, and the assumption of about 4 times increase in energy services 1994-2050, following GRES.

[6] Several studies and plans assumes in increase of energy efficiency of 1% per year compared with economic growth in a "business as usual" situation with no measures. This is also included in the report for EU's "Action Plan to Improve Energy Efficiency in the European Community", COM(2000)-247, see www.europa.eu.int. While there is not a simple relation between economic growth and growth in energy services, the 1% annual growth can be seen as a rough indication of technical development without special policies and measures for energy efficiency.

Within the time-span of 50 years, most energy consuming equipment will be replaced twice or more times, giving sufficient time to introduce new generations of highly efficient technology without extra costs of early retirements of equipment.

2.2 Proven Energy Efficiency Successes

A number of energy efficient technologies have "taken off" in the last decade, i.e. have been successfully disseminated in large numbers with decreased costs and increased quality at the same time. A good example of this is fluorescent light bulbs. Following their commercial introduction in the mid-80's, they were for sale in 1989, via special channels and stores for prices about 25 US$ + sales tax/VAT. Today they are sold in many countries in normal retail shops for prices in the range of 3-8 USD + sales tax/VAT (current prices, the lower prices are for less-known brands with a standardised quality, while the higher prices are for well-known brands and usually for bulbs with longer service-life[7]. With the assumption of 25% inflation, this gives an effective price reduction of 5-10 times, changing the economical balance in favour of fluorescent lamps in the large majority of applications in Western Europe and USA, and also making them economical favourable in many applications in countries with low electricity prices such as former Soviet Union.
Other examples of recent successful energy-efficient technologies are:

- Efficient refrigerators and freezers. Take-off in the EU countries following labelling schemes
- Electronically controlled pumps, continuously adjusting power consumption to the need. Take-off worldwide for larger applications.
- Efficient motors and electronically controlled variable-speed motors, adjusting power demand to the need.
- Consumer electronics that use considerable less energy for the same service (such as music played, television shown, calculations made). Unfortunately, the total consumption for consumer electronics have increased considerably because of increased service level, and in particular because of increased use of stand-by functions.

In the future can be expected breakthrough of a number of new, efficient technologies, such as energy efficient stand-by functions, using 1/10 - 1/100 of the energy consumption of today's market average.

Common for these energy efficient technologies are that they are introduced with the natural replacement of equipment, and that they are cost-effective for the users.

2.3 The Challenge of Improving Buildings

For buildings, the situation is different because buildings often have lifetimes of 100 years or more. Most of the houses to be heated in industrialised countries in 2050 are probably already built. For GRES is assumed that the annual specific heat demand will be 0.6 W/m^2'C for houses in 2050. For the EU countries, this is equal to about 30 kWh/m^2 as average. This will require almost a 5 times increase of efficiency, compared with current EU-average (in 1990 this was 150 kWh/m2). If energy-efficiency measures are included in renovations, the change is possible. As an example, it could be reached in the following way:

- Until 2010 the efficiency is increased 30%, corresponding to the increase proposed in the EU's energy efficiency strategy (EU Commission, 2000)[8], adopted in 2001. It is assumed that this includes that 15% of the houses in 2010 will be low-energy houses with consumption of 40 kWh/m2.
- After 2010, 2% annual renovation/re-building to an average standard of 20 kWh/m^2 is assumed. 2% p.a. is the renovation-rate proposed in the Wuppertal/ZEW scenario (Lehman,

[7] Compact flourescent lamps, examples from 1989 from the mail order company "Rising Sun Enterprises Inc."., Old Snowmass, Colorado, USA, and examples from 2001 from Danish co-op shop "Brugsen" for respectively own import from China, sold as "STLITE", 5000 hours service life and General Electric, 12000 hours

[8] EU's "Action Plan to Improve Energy Efficiency in the European Community", COM(2000)-247, see www.europa.eu.int

Harry et.al., 1998)[9]. It seems to be a good estimation of the rate of major renovations/re-building of the building-stock in EU. With this effort, 80% of the buildings are renovated to an average annual specific consumption of 20 kWh/m2, 15% are renovated to 40 kWh/$m^2$and 5% remains at current average level of 150 kWh/m2.

The average standard of 20 kWh/m^2could be achieved as a combination of 1/4 of the buildings with consumption of 40 kWh/m^2 (Northern Europe), 1/4 of the buildings with 30 kWh/m^2 (middle EU: Austria, Belgium, Southern Germany, France), 1/4 of the buildings with 10 kWh/m^2 (Southern Europe), and 1/4 of the buildings built as passive houses with no need for external heating or cooling. This could be realised by raising building-codes to current low-energy housing levels by 2010 (with a first step in 2005), requiring that all major renovations include a major energy-renovation, and embark on a major program for passive-houses to achieve that 50% or more of all new buildings are made as passive houses, where internal energy sources and passive solar energy supply close to 100% of the demand for space heating.
Similarly space cooling must be done efficiently. Wide application of common, inefficient air-conditioners could give considerable new energy consumption, but as the European space cooling demand is only about 1% of the space heating demand, efficient methods for space cooling could cover this demand with minimal energy use compared with heating.
This example illustrates that even in the slow changing sector of buildings, it is possible to reach the target for 2050, starting from current short-term proposals (in the EU at least).

For the developing countries, the situation is different in several ways. Most of the houses in use in 2050 are not built today, making it easier in principle to use high-efficient technologies. On the other hand, many houses are constructed today without heating or cooling equipment and low standards of thermal insulation. A large part of these houses will be equipped with heating or cooling installations within the next 50 years, if the GDP grows as expected in the GRES[10]. This will raise the inefficient energy use. To avoid problems like this it is important that housing designs are fit to the climate and to the possible installation of heating/cooling systems. If heating or cooling is installed, they should be accompanied by cost-effective energy efficiency measures, to reduce costs as well as energy consumption. With increasing energy prices and large-scale use of efficient energy technologies in industrialised countries, as proposed above, an increasing number of energy efficiency measures will be cost-effective when heating/cooling is installed.

2.4 Efficient Transport

For transport is assumed that the conversion-efficiency from transport fuel is increased 2.5 times (from current average of 20% in combustion engine systems to 50% in fuel cell systems with break-energy recoverage), and that vehicles are equipped with recoverage of break-energy, so the “end-use” of energy in transport is limited to the unavoidable friction losses in transport (except for aviation). The total efficiency increase is assumed to be in the order of 6 times compared with today's average transport efficiency. This efficiency gain, combined with growth of transport activity of 3 times will result in a halving of transport energy demand[11].

2.5 How to Implement Energy Efficiency Measures

Past experience have shown several successes with energy efficiency, such as those mentioned above, but this has only in a few cases lead to decrease in energy consumption on the macro level. This is partly because the rate of introduction was too slow compared with the growth of the energy services, and partly because of emerging new energy services. The realisation of energy efficiency measures to the extent proposed require probably that a number of countries will take the lead in development and

[9] Wuppertal/ZEW: Scenario for a Sustainable Future Energy System, Harry Lehmann et.al. Wuppertal Institut für Klima, Umwelt, Energie in co-operation with Zentrum für Europäisches Wirtschaftsforschung (ZEW) and others, 1998
[10] The GRES scenario (source above) does not specify GDP in 2050, but assumes energy-consuming activities in developing countries close to todays level in industrialised countries.
[11] Comparing IEA Energy Statistics for 1998 with GRES Table 6.

use of increasingly energy-efficient technologies. The national measures to support introduction of energy efficient technologies are well-known, and include measures such as inclusion of external costs of energy and introduction and regular improvements of mandatory energy efficiency standards including building codes. While these measures have proven successful, they should be used in a co-ordinated and yet flexible way. Flexibility and readiness to act on new developments are important factors for success. As an example, the increasing stand-by consumption of electric appliances have been known as a problem for more than 5 years, yet any regulation about this, or even a labelling scheme is not introduced in the EU countries. Such lack of action gives substantial unnecessary energy consumption.

3. ELECTRICITY STORAGE

A main new element of the supply system is the electricity storages that are needed because of the large supply from intermittent resources: solar and wind. While it can be assumed that 20% intermittent sources can be introduced in current electricity supply without large investments in electricity storages, storages will have to be introduced on a large scale to reach substantially higher coverage from intermittent supply, such as 84% of electricity supply in the centralised GRES scenario. With the assumption of a gradual change, the need for large storages will start in industrialised countries after 2015 and in developing countries after 2025. These new storages are in addition to existing hydro storage capacity. It is assumed that they are made with reversible fuel cells that have a cycle efficiency of 60%. Because 40% of the electricity has to be stored, this structure introduces a loss of 16% in the electricity supply. The electricity storage loss does not have to be completely wasted, it is likely that energy storage plants can replace current cogeneration plants for heat and electricity to some extent and the waste heat can be used to supply existing district heating networks.

4. MASSIVE USE OF RENEWABLE ENERGY

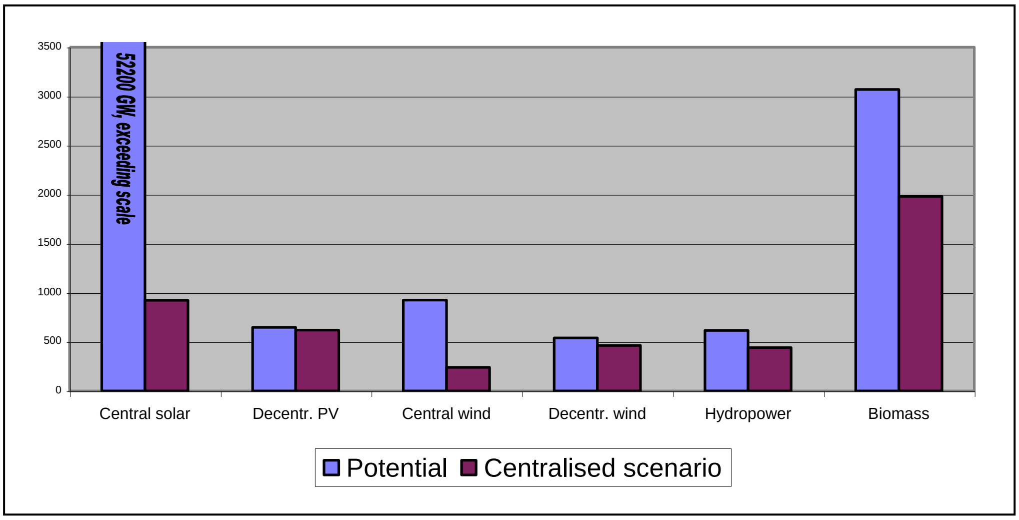

Figure2 Comparing renewable energy potentials and use in centralised GRES scenario in GW of continues average energy supply (GWyear/year).

The renewable energy sources included in the scenario are solar, wind, hydro, and biomass. In GRES is estimated potentials for the renewable energy sources, see fig.2. Data for fig.2 from GRES report table 8 and Fig.74. Central solar potential is 52200 GW (exceeding scale in chart).
The potentials are far from the physical limits, but are chosen as potentials that are assumed to be in line with a sustainable development with sufficient land and resources for other needs.

Hydro is expected to increase 80% with almost all increase taking place in developing countries.

Biomass is expected to increase 33%[12], but with a massive change from heating purposes to transportation fuels (hydrogen for fuel cells), and with most increase taking place in industrialised countries. This is not a dramatic increase of biomass use, compared e.g. with EU's indicative targets for 2010 (EU Commission, 1997)[13], but of course it can be problematic to reach in some countries that already use their biomass resources beyond the limits of sustainable use, and interregional trade in biofuel is probably necessary.

Wind is expected to increase rapidly from today's level of 15,000 MW worldwide-installed capacity. If it follows the scenario in Windforce'10 (EWEA, FED, Green peace, 1999)[14], to reach 3,000,000 MW in 2040, it will have to decrease 20% afterwards to reach the level proposed in GRES for 2050. The centralised windpower in fig. 3 is windparks on marginal land and offshore.

Solar is expected to be a major source of electricity, providing almost 60% of the electricity supply in 2050. 60% of the solar electricity is expected to come from central solar electricity stations. Solar heating is not included specifically, but passive solar heating is a necessary element in achieving the low space-heating demand. Central solar is solar power plants such as PV-fields on marginal land. The potential for central solar is taken as coverage of 5% of the world's marginal land. This is the only source where the use in the GRES is order of magnitudes below the estimated potential (only 1.7% of the potential used in the scenario).

The main challenge in the supply system seems to be development of the solar electric supply, and the change of the biomass to supply hydrogen for transportation. The current solar electricity installation rate is 200 MWp in 1999 with a growth rate of 33% p.a. If this growth rate continues until 2003, where the world market will be large enough to have one PV manufacturing facility producing 500 MWp/year, it can lead to rapid decreases of prices as documented in the KPMG/Greenpace study on increased development of PV technology (KPMG & Maijburg, 1999)[15]. If this is followed by an annual increase in installation of 25% p.a. from 2003 and the next 30 years, the solar capacity necessary for the scenario in 2050 will be available.

4.1 How to realise the Renewable Energy Supply?

The last decade's development of windpower, hydropower, and PV are in line with the necessary trends to realise a scenario such as GRES. Plans for biomass such as those of the EU White Paper for Renewable Energy (EU Commission, 1997) sets a trend that is in line with the biomass use in 2050 following GRES. To realise the renewable energy supply, it is important to maintain the positive developments, and make a take-off for biomass use, following plans such as the EU White Paper. While many of the current renewable energy successes have been achieved in situations with public support, the future larger scale developments must increasingly be supported by ensuring equal access to energy markets and capital, and by inclusion of external costs for all energy supply sources. The below mentioned decreases of renewable energy supply costs is an important factor for the continued successful development.

It is not enough to achieve a quantitative development of renewable energy use. The energy products should be able to cover all demands, which give a special requirement for delivering fuels for efficient transportation systems, probably in the form of hydrogen or electricity. This requires commercialisation of hydrogen technology for mobile use and/or improved battery technology.

[12] Own calculation based on current biomass supply (assumption for 2000, based on IEA Statistics for 1998 with GRES fig. 74.

[13] EU White Paper for Renewable Energy, COM(97)599, table 3 and 4

[14]Wind Force 10: A Blueprint to Achieve 10% of the World's Electricity from Wind Power by 2020, EWEA, FED, Greenpeace, October 1999. Based on work by Birger Madsen, BTM Consult, Ringkøbing, Denmark.

[15] Solar Energy: from perennial promise to competitive alternative - final report -Project number: 2562. Written on the commission of: Greenpeace Nederland by KPMG Bureau voor Economische Argumentatie & Steins Bisschop Meijburg & Co Advocaten, Hoofddorp, Netherlands, August 1999.

5. ECONOMICAL CONSIDERATIONS

Regarding the economy of changes to renewable-energy and energy-efficient energy use, a massive introduction of new technologies will lead to massive reductions of costs for the new technologies. For specific renewable-energy and energy-efficiency technologies it has been estimated that they would be able to compete with fossil fuels within 25 years under average conditions, if developed vigorously (e.g. large-scale windpower could be cost-effective within 10 years, photovoltaic in 15-25 years, biomass for cogeneration of heat and electricity in 10-20 years, all compared with fossil fuels without environmental costs, but with equal financing) (INFORSE-Europe, 2000)[16] (IEA, 2000) [17]. For certain applications, the technologies are already cost-effective today. The investments necessary for these developments will be paid back with the availability of cheaper renewable-energy supply and energy-efficiency technologies in the future. In general, they will be cost-effective for the society.

5.1 Windpower Example

An example of a possible development that probably will pay back well comes from "Windpower for Western Europe"(INFORSE-Europe, 1998), where it is estimated that compared with large, efficient, combined-cycle gas turbines, the development of 220,000 MW of wind power in Western Europe in the period 2000 - 20120 has a positive net present value, i.e. it is cost-effective, even without environmental costs included in energy prices. The calculation shows a positive value of $EUR 89 billion, equal to $EUR 400 per kW of the 220,000 MW. The calculation is quite sensitive to the gas price development, which is taken from the IEA 1998-forecast (IEA, 1998)[18]. Fig. 3 shows the development of prices and annual costs of this example with an expectation of a learning curve with a cost reduction of 12% for each doubling of worldwide installed windpower capacity. The annual cost / benefit for each year is the economic result of turbines installed up to that year, including capital costs. In fig. 3, costs and benefits as well as the windpower price are for the society as a whole with a social discount rate of 6%p.a., inflation 3% p.a. and no profits for owners of turbines or land.
This example shows the long-term benefits from new technology. The example shows increasing costs with increasing installation rate in the first years, until a turning-point after which the windturbines will have a net income. The turning-point is largely dependant on the gas-price development.

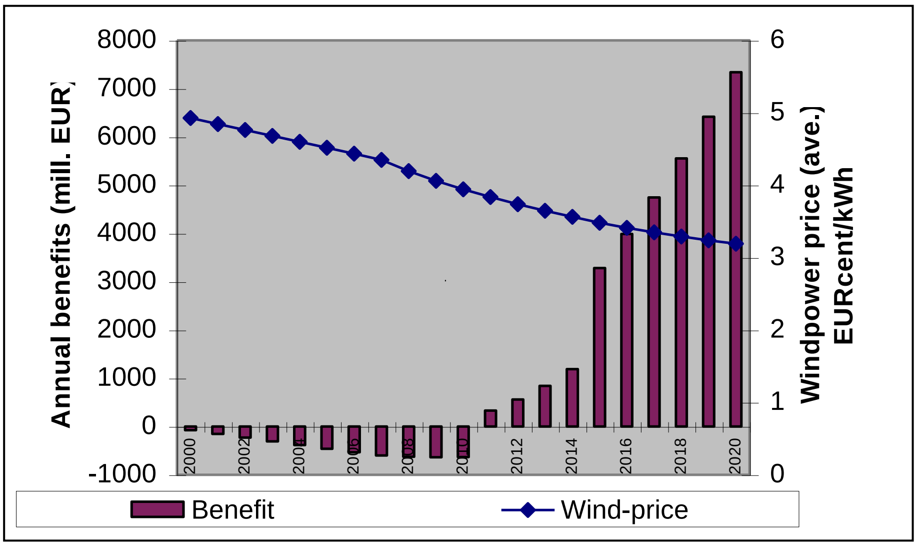

Figure 3. Example of possible development of windpower costs and benefits for Western Europe from realising the Windforce'10.

[16] Wind Power for Western Europe, - an INFORSE Proposal for 2000-2020, INFORSE-Europe, Denmark, 2000. (See: www.orgve.dk/inforse-europe)
[17] Experience Curves for Energy Technology Policy, IEA, Paris, France, April 2000.
[18] IEA World Energy Outlook, IEA, Paris, France, 1998.

5.2 Benefits for the World Economy

The above example shows a possible economy for one technology. This can be repeated for most of the proposed technical solutions, but the economy of an entire scenario is more than the sum of single technologies. A sustainable energy development has a number of benefits for the world's economy, in addition to its contribution to reduce climate change problems and other environmental problems. It will first and foremost contribute to stability on many levels, while continued or increased use of the limited fossil fuel resources is likely to increase tensions and give price fluctuations that adversely affect the world economy. Nuclear power has its own problems, as well as high and often unexpected costs.

6. LIMITS TO GROWTH IN A SUSTAINABLE ENERGY SCENARIO

In GRES is assumed increased global equity regarding use of energy services, with large growth in energy services in developing countries and small growth in industrialised countries. The expected growth in energy services in industrialised countries is smaller than the current trends for some of the fastest growing, energy consuming sectors, such as transport. Thus, to realize the scenario, it is necessary to reduce the expected growth of e.g. transport, and use other means to cover future transport needs, e.g. better logistics, spatial planning that requires less urban transport, etc. It is, however, not necessary to reduce consumption.

The energy consumption level in GRES is not the only possible level for a fossil and nuclear free future. If the demand for energy services are higher than expected, or the introduction of energy efficient technology is slower, it is possible to increase renewable energy supply, mainly from central solar and windpower. While this is possible to some extent, increased reliance on a single source such as central solar power will require substantial additional investments in energy storage and transport infrastructure, in particular if it is to supply the Northern industrialised countries.

7. ADRESSING THE POOR

While the development described in this paper will lead to a more equal division of energy services between industrialised and developing countries, there is a special need to address the poor that lack access to basic energy services today, about 2 billion people, or 1/3 of the world's population. To cover these basic needs is only required a tiny fraction of the world energy supply, and it is not a problem that need 50 years to solve. It has been proposed by Greenpeace and others to supply these basic needs with renewable energy within a period of just 12 years (Greenpeace & The Body Shop, 2001)[19]. Such a development would be in line with the development proposed in this paper, and we support it. It will require special efforts, in addition to the technology and market measures proposed in this paper because many of those that lack basic energy needs are not well integrated in the market economy and could not pay for the solutions, even if they were beneficial for them and they were offered to them. There are no insurmountable technical, financial or institutional barriers to achieving the goal, but it will require commitment from the international community and radical changes in the way in which energy development is funded and subsidized.

8. AN OVERVIEW OF A POSSIBLE DEVELOPMENT

With the above assumptions, it is possible to give an overview of a possible development to reach the situation described in GRES in 2050.

Comparing today's situation with GRES, the increase in energy services would be an important achievement for developing countries. The difference between energy services in developing countries and industrialised countries is partly because of different climates, partly because an assumption of a remaining, smaller difference between the two parts of the world. See fig. 4, bars for 2000 are based

[19] power to tackle poverty - getting renewable energy to the world’s poor, Greenpeace/The Body Shop June 2001 (© IT Power May 2001, UK, ISBN 90 73361 74 5)

on GRES table 2, "end-use energy" with division between industrialised and developing countries and extension from 1994 to 2000 made by authors.

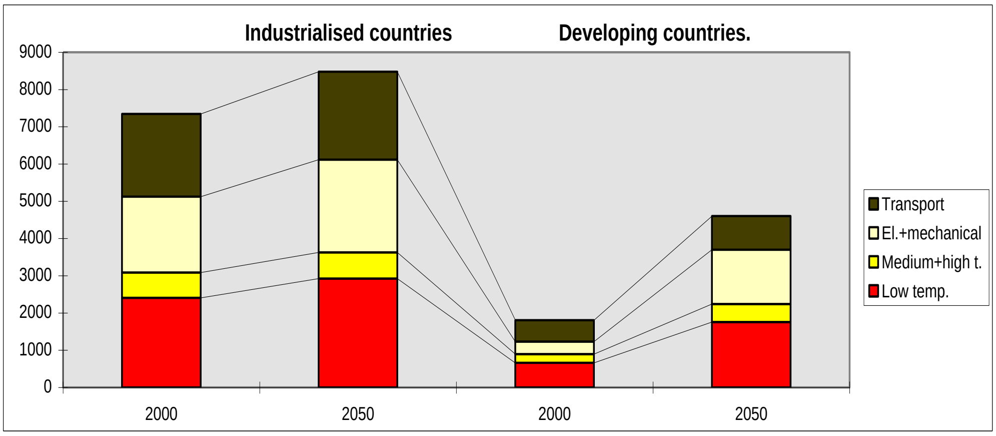

Figure 4 Comparison of current situation of energy services and the proposed situation in 2050, following GRES. The scale is TWh of energy used with the efficiency-level of 2050.

Because of the high efficiency in the energy system and in the end-use of energy, the primary energy consumption is assumed to be lower in 2050 than today, in spite of the growth in energy service levels, see fig. 5.

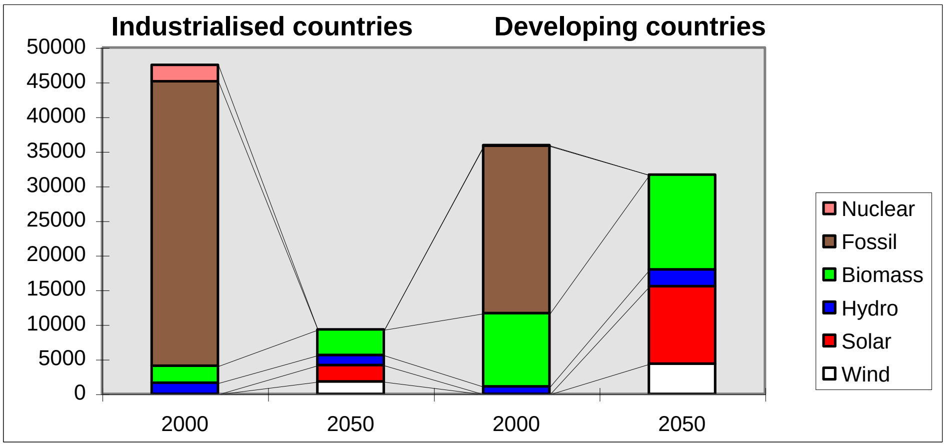

Figure 5 Comparing current primary energy consumption (from IEA statistics for 1998, extended to 2000 following trends 1995-1998) and the proposed situation in 2050, following GRES.

A major result would be the decreasing energy-related CO_2 emissions, exemplified in fig. 6. The slow increase in the first decade of the century includes emission-reduction in industrialised countries and growth in developing countries. The graph in fig.6 and the underlying figures after 2000 are by authors, figures before 2000 from IEA statistics.

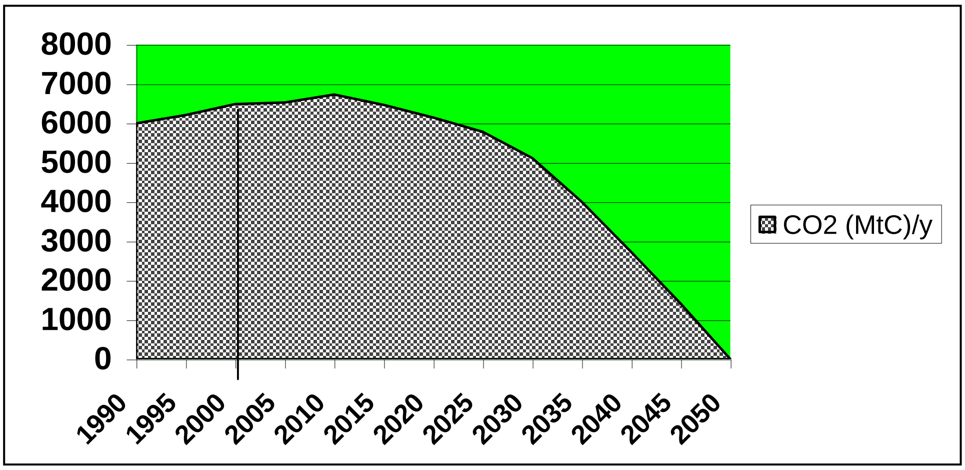

Figure 6 Example of a worldwide CO_2 emission scenario in line with GRES and keeping 21st century energy-related CO_2 emissions to 250 Gton of Carbon.

The worldwide electricity consumption is expected to increase, see fig. 7. The overall increase is a combination of an increase in developing countries and a decrease in industrialised countries to about half of current level. Figures for 2050 are from GRES; figures 1990-1995 from IEA statistics and figures for the period in-between are from authors.

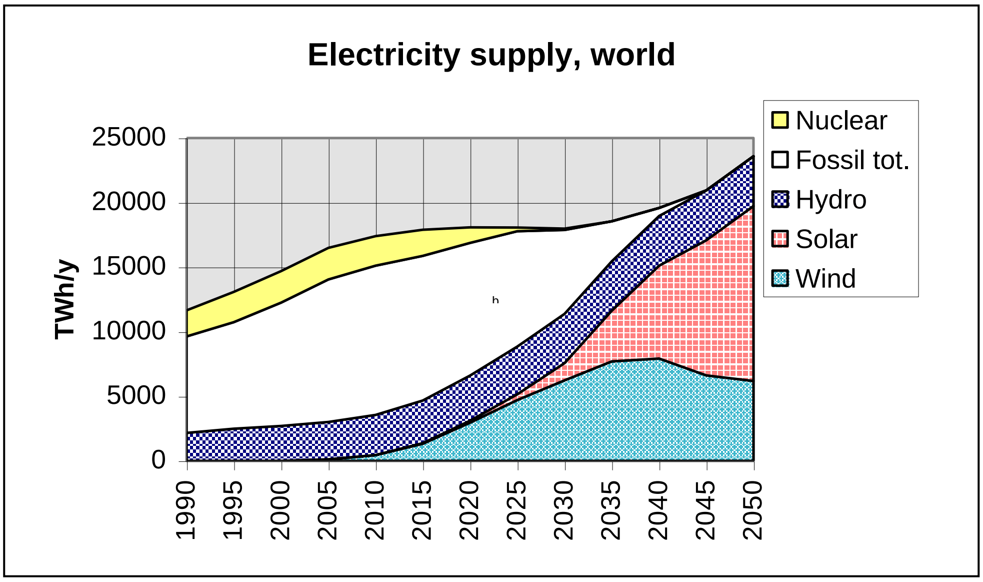

Figure 7 Example of development of the world energy supply, from the current situation to GRES in 2050.

9. POLICIES TO MAKE THE CHANGES HAPPEN

When the development is technical possible, environmentally desirable and economical beneficial, the question that remains is how to make it political possible, how to make it happen?

To start the changes, there is a huge need to change energy investments for production of renewable-energy and energy-efficiency equipment in large scale, including local production of simple renewable energy equipment in developing countries. As part of this, energy research and development (R&D) should be focused on renewable energy and energy efficiency. The current energy R&D funding is primarily used for development of nuclear energy and fossil fuels, and this funding must be changed to finance entirely the development of renewable energy and energy efficiency.

To attract investments for production of the new technologies, there is a need of mass markets and of long-term markets. It is up to political decisions to create these markets. To create markets for renewable energy, targets and portfolios must be defined at local, national, regional, and global level. To create markets for energy efficiency, labelling, progressive energy efficiency standards and other measures should be introduced.

Currently some renewable-energy technologies have difficulties in competing with traditional energy sources, of which some are subsidised. To cope with this, environmental harmful subsidies must be phased out as soon as possible. In addition, the environmental benefits of renewable energy compared with fossil and nuclear energy must be reflected in the pricing.

The targets for renewable energy can be reached by different means. A successful way is fixed price arrangements for renewable-energy production with high enough prices to attract investments. Another way is via targets for individual consumers including companies. Then consumers can then decide to produce their own renewable energy, to purchase renewable energy, or to purchase renewable energy certificates that proofs the production of the requested amount of renewable energy.

The new technologies are by nature decentralised, and their introduction is dependant on local participation in decision-making regarding their installation and in their use. There is much more need for local involvement and local decision-making in the application of the new technologies than in the traditional, centralised energy systems.

9.1 Who Will Organise the Changes?

While the push for changes from the world climate negotiations are currently far too small for a fundamental shift of the world energy system, a dynamic development takes place in a number of countries, replacing fossil fuel with renewable energy in several sectors.

To achieve the necessary changes, the motivated nations, groups of nations, companies, towns, local groups, and individuals must act – not letting the resistance/reluctance of others hindering them of taking their own action. They should set their own targets for renewable-energy portfolios and for energy efficiency. Those doing it first will have the biggest benefits by being involved in the related technology development, and their industries will be in the front.

Also, on the international level, there is a need for organisations that will take the lead in the changes. The international organisations should be in charge of technical co-operation, co-ordination of policies, technology transfer and the programs to supply essential energy services for those lacking it today. Preferably, this should include one or more focussed organisations, such as the proposed "International Sustainable Energy Agency".

10. CONCLUSION

According to our findings, a total shift towards a sustainable energy system is possible within a period of about 50 years, that the changes will have a number of beneficial effects, that they will give a more stable energy supply than the current, that they are compatible with a sustainable development and with global equity, and that the additional costs to the society will be small or even negative, if the changes are well planned and phased in as part of the natural change of plants and equipment. The changes will, however, require initial investments and long-term strategies, nationally and internationally. It will also require a major shift in the energy supply system and in energy consuming equipment and structures.

While the conclusion is well supported by the available sources, there is a need to develop the analysis of the path to a sustainable energy system further, including an analysis of the economical results of the proposed development with large-scale introduction of sustainable energy solutions and corresponding low costs, compared with developments without this shift.