2011
Geneva
4-9 September

World Engineers' Convention

WEC 2011 – Call from Geneva

Engineers Power the World – Facing the Global Energy Challenge

Preface

Dear engineers from around the world,

People want to know how the energy supply can continue to be guaranteed for future generations. The peak of cheap oil, global warming, scarcity of resources, risk factors in energy production, higher prices and the war on energy are all creating fear and raising questions. It is our duty as engineers to help to answer these questions – in a simple and comprehensive way that enables an objective discussion not overshadowed by fear. This is even more important, after the tragic incidents in the nuclear power station in Fukushima, Japan. Time is changing and new answers need to be given, alternatives considered and new solutions presented. We must leave our ivory towers, universities, research laboratories and libraries, contribute to public debate and answer the questions people are asking about the future of our energy supply. Thus the call from Geneva is aimed not only at researchers but at society as a whole.

On the occasion of the World Engineers' Convention in Geneva (WEC 2011) we, engineers from around the world, have dealt with the question of how our future energy supply can be guaranteed in a sustainable and safe way. Our conclusion is that there is enough green energy to meet the increasing global demand for energy. We already have the technologies we need to achieve an environmentally friendly low-carbon energy supply and rational use of energy. The challenge is to convert, store and transport available energy in a way that is both affordable and causes no damage. The time has come, therefore, for societies and politicians at national level to take the necessary steps to avoid a further increase in global warming and finally meet the 2-degree target. It is our duty to inform people all around the world about what we know.

Ruedi Noser
President of the Association World Engineers' Convention 2011
and member of the Swiss parliament

1. Energy consumption

Will our energy consumption continue to rise?

An improvement in the general standard of living always entails a higher demand for energy services; until now, this has meant an increase in energy consumption. Since the beginning of the industrial revolution, the rate of energy consumption has been increasing steadily and global energy consumption is likely to keep increasing over the next 50 years unless major breakthroughs in energy efficiency are achieved and/or the cost of energy increases substantially. To enjoy a decent quality of life and a reasonable level of prosperity, people must be able to satisfy their basic energy needs (Figure 1). It is a fact that per-capita energy consumption is spread very unevenly around the world, with a small percentage of people consuming substantially more than the majority and a large number of people around the globe suffering because they have insufficient energy services to provide a decent quality of life.

Demand for energy is increasingly sharply and is forecast to rise by around 40%, or approximately 17,000 Mtoe (197,000 TWh), by 2030 (Figure 2). In the period from 2030 to 2060, a further significant increase is expected. The main reason for this is the improvement in living standards in developing countries and emerging economies, particularly China and India. By the year 2060, the standard of living in these countries is expected to be on a par with that of today's industrialised nations.

Thesis 1

If everyone is to be guaranteed a decent quality of life and we wish to provide additional energy services to individuals without making significant energy efficiency efforts, global energy consumption is expected to increase by some 40% by 2030.

2. Quality of life

Is there sufficient energy to guarantee everyone a similar quality of life?

The amount of solar energy alone that reaches our planet every day is between 10,000 and 15,000 times greater than the total amount of energy consumed in the world. Consequently, there is more than enough energy for all of us. If we can convert, store, transport and utilise this energy efficiently, it will be possible in the long run to meet a demand for energy services at least twice as high as current demand. Per-capita consumption, or rather its intended reduction, then becomes of secondary importance. However, building a new energy infrastructure requires a significant amount of time and money, particularly when dealing with technologies that are not yet technically or economically mature.

For these reasons, there is no simple or uniform solution for satisfying global energy demand. The optimum energy mix for any particular country will depend upon its available natural resources, population distribution, growth in energy demand and the status of its technical and economic capacity.

Energy efficiency is one of the main technological drivers of sustainable development as dematerialisation and recycling will further reduce the energy intensity. The overall impact is that a lower energy input will be required to provide the same service to users. Efficiency slows down the growth in primary energy demand, but it often requires a longer-term vision of investment than is generally adopted at present. Quantity, quality and price of energy use, along with the availability of primary energy resources, are important elements for implementing energy efficiency programmes.

Thesis 2

There is abundant renewable energy available particularly from solar radiation. The question is whether we have the technologies, the capital, the time and the will to convert these energy sources efficiently and economically without damaging our environment and destabilising our economies.

3. Low-carbon supply

Can the increasing energy demand be met without further deteriorating the global environment or should we drastically reduce our energy consumption?

Energy is linked to global warming through the emissions of greenhouse gas (GHG). The development and implementation of advanced energy technologies, including cleaner fossil fuels, energy efficiency and renewable energies, and technologies that contribute to the reduction of greenhouse gas emissions, are currently top priorities for energy engineering.
Current trends in energy consumption and supply show a persistent dominance of fossil fuels – oil, gas and coal – in the energy mix. This pattern of energy consumption continues to have serious climate change implications since carbon dioxide emissions and the world's temperature are steadily increasing, which could have a potentially catastrophic outcome. To set the world on a different path, a change in energy policy is needed to reduce the growth in GHG concentrations. One aggressive scenario considered by the International Energy Agency (IEA) involves reducing the concentration of GHG to 450 ppm; the IEA estimates that this would limit the atmospheric temperature increase to less than 2°C (450 Policy Scenario, see Figure 4).

As shown in Figure 6, life-time GHG emissions vary for the different energy supply technologies: nuclear, solar, wind, hydro and biomass produce less than 100 g_{CO_2}/kWh, whereas the emissions from fossil fuels like natural gas, oil and coal range between 450 and 1,250 g_{CO_2}/kWh.

Thesis 3

The goal is a low-carbon supply of energy services at reasonable cost. It is important that the GHG emissions generated by the conversion and use of energy, in particular CO_2 emissions, be drastically reduced in order to meet the 2-degree target.

4. Technologies

Do we have the technologies to realise a low-carbon energy supply?

The first available generation of renewable technologies includes hydropower, biomass combustion, and geothermal power and heat. Since the 1980s, as a result of research, development and demonstration (RD&D), second-generation technologies, including solar heating and cooling, wind power, modern forms of bio-energy, and solar photovoltaic have entered the energy supply markets. Third-generation technologies are still under development and include advanced biomass gasification, bio-refinery technologies, systems for concentrating solar thermal power, hot dry rock geothermal energy, and ocean energy. Energy storage systems are also a key to the integration of intermittent energy sources into the energy distribution mix. Advances in nanotechnology may also play a major role. These technologies heavily depend on long-term scientific and engineering research and development commitments.

We already have the knowledge and technologies to use solar and wind energy. Although carbon capture and sequestration technologies are being developed and still need to be demonstrated on a large scale, we can make further oil and gas fields accessible and increase the efficiency of extraction and refining. We are capable of building networks to transport and distribute the produced energy vectors. For storage we have different possibilities for attaining the appropriate balance between supply and demand, including pumped storage power stations, compressed-air plants and innovative batteries. In the transport sector, measures designed to promote cleaner fuels and greener vehicles must be complemented by policies to reduce overall demand for personal vehicle use by promoting public transport that meets people's everyday needs. In some countries, modifying unsustainable transportation energy consumption patterns will certainly require difficult cultural adjustments.

Thesis 4

We already have the knowledge and engineering capabilities we need for several energy-supply technologies and are developing third-generation technologies to guarantee a low-carbon energy supply worldwide. In the transport sector, modifying unsustainable energy consumption patterns will entail difficult adjustments.

5. Costs

How much does a low-carbon energy supply cost?

The World Energy Outlook of the International Energy Agency (IEA) estimates that the shift in the energy mix needed to lower emissions requires a substantial increase of investment in energy-related infrastructure and equipment. Worldwide investment in complementary energy in 2010-2030 will total US$9.3 trillion (=9.3 x 10^{12}) higher in the 450 Policy Scenario, compared to the current scenario.

According to the European Commission, approximately € 1 trillion need to be invested in energy infrastructure by 2020 to secure the supply of oil, gas and electricity in Europe*, the main focus being on the 20-20-20 principle which states that by 2020, 20% of energy demand should be covered by renewable energy; CO_2 emissions are to be reduced by 20% and energy demand should be cut by 20% through efficient usage.
Further investments are necessary to meet the goal of capping per capita CO_2 emissions at two tons by the year 2050.

Thesis 5

Between 2010 and 2030, additional worldwide investment in energy-related infrastructure and equipment totalling around US$ 9.3 trillion will be required in the 450 Policy Scenario compared to the current scenario. By 2020, approximately € 1 trillion need to be invested to secure the supply of oil, gas and electricity within Europe alone.

*Statement of the EU energy commissioner Günther Oettinger in occasion of the media conference on November 17, 2010 in Brussel at the presentation of a plan on European energy networks. The amount does not only comprise networks but also new power stations, storage plants as well as terminals.

6. Investments

Can industrial regions like Europe make these huge investments in their energy supply without losing their competitiveness on the global market?

If we assume that investments between € 2 to 3 trillion are written off in 50 years (2 generations), this would result in amortised costs totalling € 50-100 billion (€ 40-80 billion for write-downs and € 10-20 billion in interest). Maintaining this energy infrastructure would cost approximately € 100-200 billion. So the annual costs incurred for Europe's energy infrastructure would total € 150-300 billion. That level of expenditure would make it possible to reach the goal of a maximum of 2 tons of CO_2 emissions per person.

Today, the annual energy costs of private households and the economy amount to € 1.4 trillion, whereby € 237 billion of this total is spent for obtaining energy resources from countries outside Europe. On the other hand, governments receive € 200 billion in the form of taxes*.

Reducing CO_2 emissions to 2 tons per person will lower non-European acquisition costs by approximately 75% because demand for oil and gas (imports) will decrease strongly. Assuming stable energy costs, € 178 billion would become available to help finance energy infrastructure. Any financing shortfall could be covered by taking a share of existing energy taxes, which could be slightly increased, to avoid unnecessary tax deficits. The total energy costs for private households and the economy would then not increase by more than 10% (see figure 8).

Thesis 6

In industrial regions like Europe, investments in a low-carbon energy supply could be carried out at stable or not significantly higher energy costs. This would probably not entail any major disadvantage with respect to Europe's international competitiveness. The ensuing tremendous gains in innovation through the development of new technologies have not been taken into consideration in the calculation.

*excluding VAT

7. Global decisions

Do we need global decisions or can we already take decisions at the regional level today?

As energy is available almost everywhere and in unlimited quantities, the question should rather be this: can a country or a region reorganise its energy supply autonomously without creating disadvantages in competition for the economy through higher energy costs?

Thesis 7

A region with a high per capita percentage of CO_2 emissions can reorganise its energy supply system without necessarily substantially increasing energy costs or creating competitive disadvantages. Thus, there is no a priori reason why global decisions should be necessary. But there must be a willingness to adapt the political framework accordingly.

Conclusions

1. **To guarantee a decent quality of life for everyone, all available energy sources must be considered. Greater energy efficiency will slow down growth in energy demand, but will entail not necessarily negligible costs.**

2. **The use of any given technology requires a thorough analysis of the technological, economical, and environmental feasibility of implementing scientifically sound and efficiently engineered solutions.**

3. **The technologies we need to supply energy for substantially improving global quality of life are available or at an advanced stage of development or are currently being piloted. Pioneer regions will house the dominant industries for the power supply of the future and will on long run gain from high innovation dividends.**

4. **The goal is to secure a low-carbon energy supply. If the 2-degree target is to be met, it is important that GHG emissions – and CO_2 emissions in particular – be drastically reduced during the production and consumption of different forms of energy.**

5. **Switching to a low-carbon economy will take substantial investment and time. In the transport sector, modifying unsustainable energy consumption patterns will necessitate difficult adjustments.**

6. **Single regions or countries could autonomously reorganise their energy supply without necessarily suffering any major competitive disadvantage.**

Basic Concepts

Europe EU27 including CH

Renewable energy Resources which are automatically renewed in the short run or do not contribute to the exhaustion of resources. Examples include hydropower, wind power, solar energy, biomass and geothermal energy.

Energy consumption Energy consumption is expressed in terawatt hours ($TWh=10^{12}Wh$). In calculations, the energy content of a primary energy source is typically expressed in oil equivalents. This unit of measurement makes it possible to compare various forms of energy by converting energy consumption into the energy content of mineral oil. Primary energy is energy found in nature that has not been converted in any way. Examples of primary energy resources include coal, gas and biomass.

Low-carbon energy supply Per capita greenhouse gas (GHG) emissions by 2050 should total approximately 2 tons. By 2100, that figure should have come down to 1 ton of CO_2 equivalent (1 ton of CO_2 per person) if we assume a world population of 10 billion. These values tally with the scenarios envisaged by the Intergovernmental Panel on Climate Change (IPCC).

Two-degree goal According to IPCC estimates, the proportion of CO_2 in the atmosphere must be stabilised at around 500 ppm if the average temperature increase around the globe – compared to the pre-industrial level – is to be limited to 2°C. (IPCC, Climate Change Mitigation: findings and relevant steps of the WGIII Report by Dr Youba Sokona, Copenhagen, 8 December 2009).

Many scientists agree that global warming of approximately 2°C is a critical level, for if the average global temperature increases by more than this the broad consensus in the scientific community is that the consequences of the climatic change could become uncontrollable for humankind and the environment.

Goal 20-20-20 In 2010 the European Commission (EU) defined its climate protection goals. By 2020 the following goals are to be met within the EU-27:

1) 20% of energy demand is to be covered by renewable energy;
2) CO_2 emissions need to be cut by 20% compared to 1990 emissions;
3) energy demand is to be lowered by approximately 20% by using efficient technologies.

Figures 1, 2

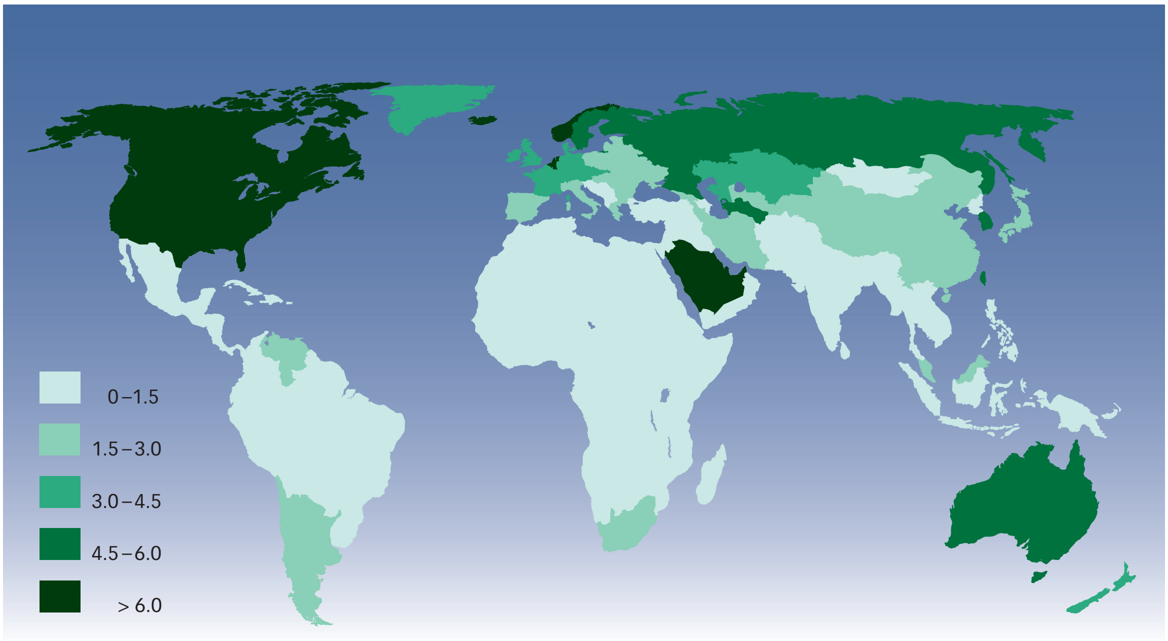


Figure 1: Per capita consumption of primary energy in 2009 in tonnes of oil equivalent, Reference: BP Statistical Review of World Energy, June 2010

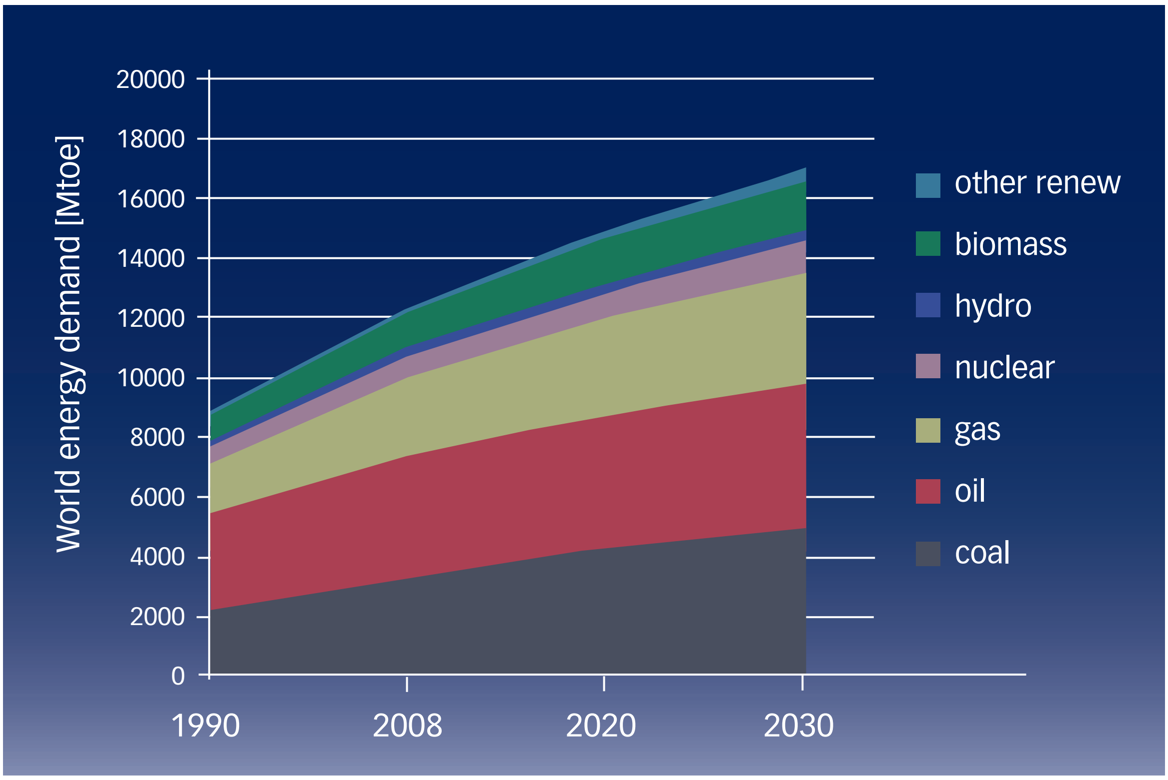


Figure 2: Expected change in global energy demand (IEA current policy scenario)

Figures 3, 4

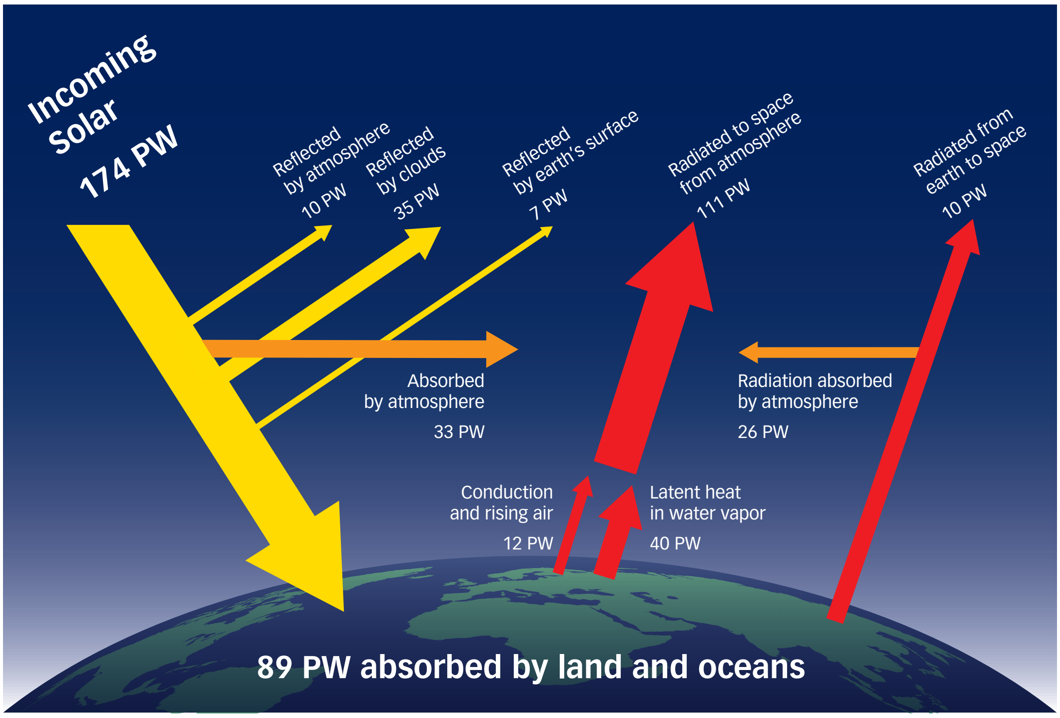


Figure 3: Breakdown of incoming solar energy

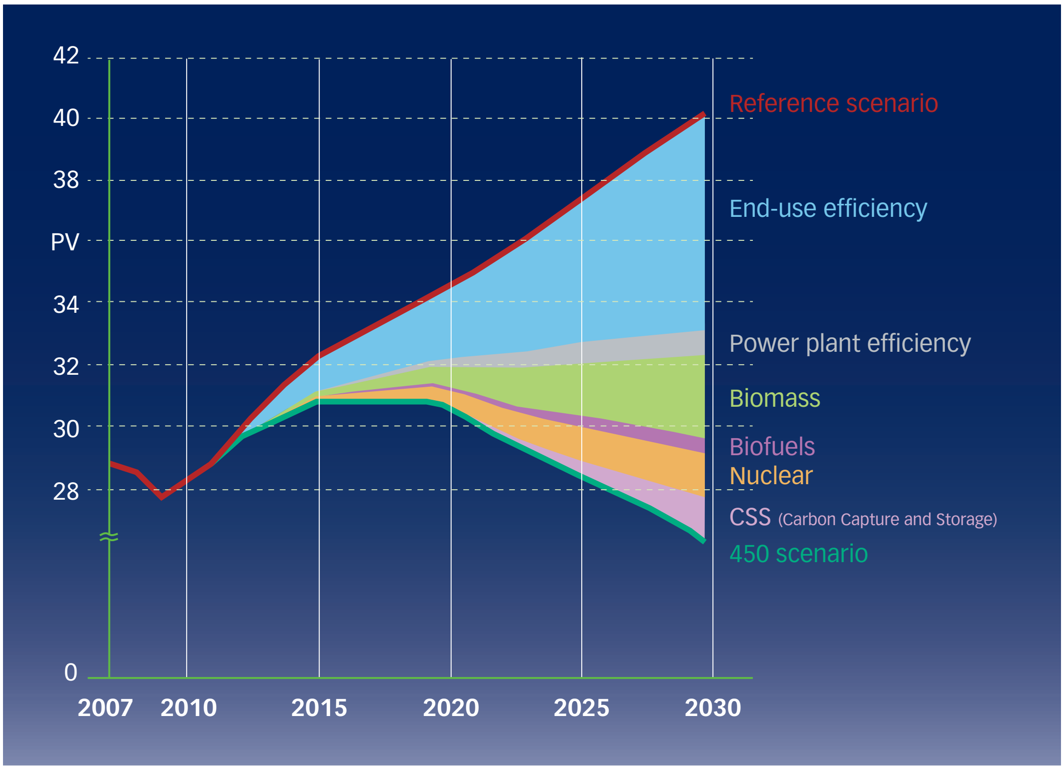


Figure 4: Measures required to achieve the IEA's 450 ppm scenario

Figures 5, 6

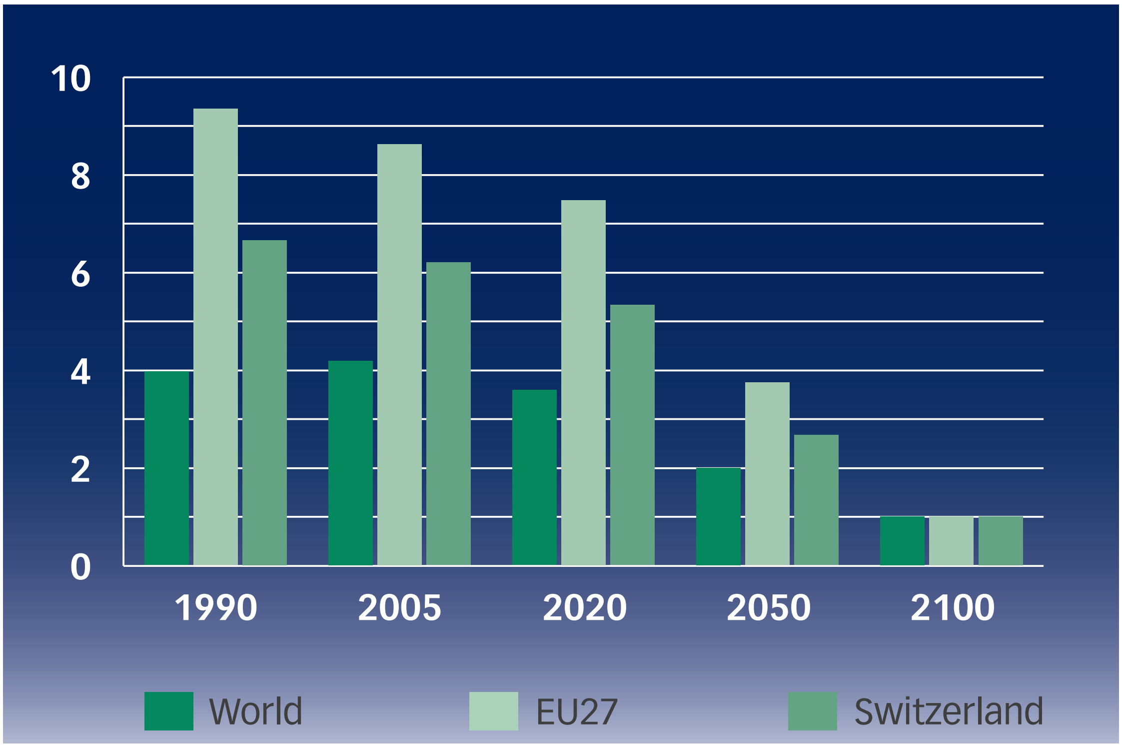


Figure 5: Per capita CO_2 emissions in tons

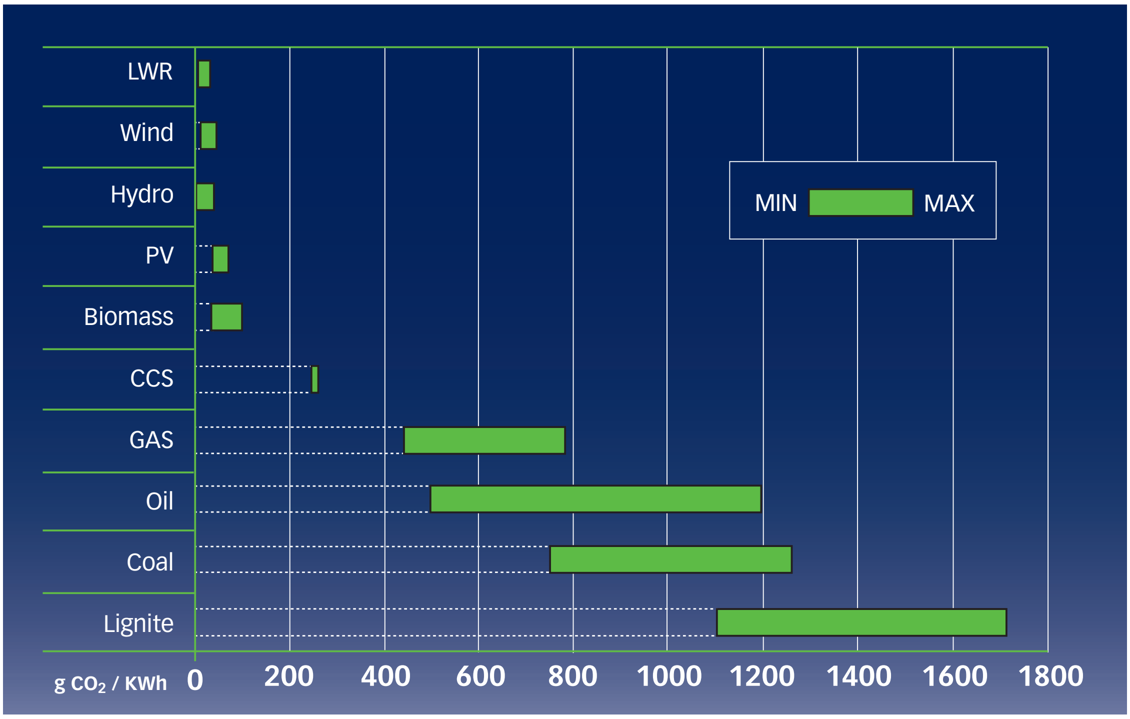


Figure 6: Life cycle emissions of GHG (in equivalent g CO_2) to generate 1 kWh of electricity

Figures 7, 8

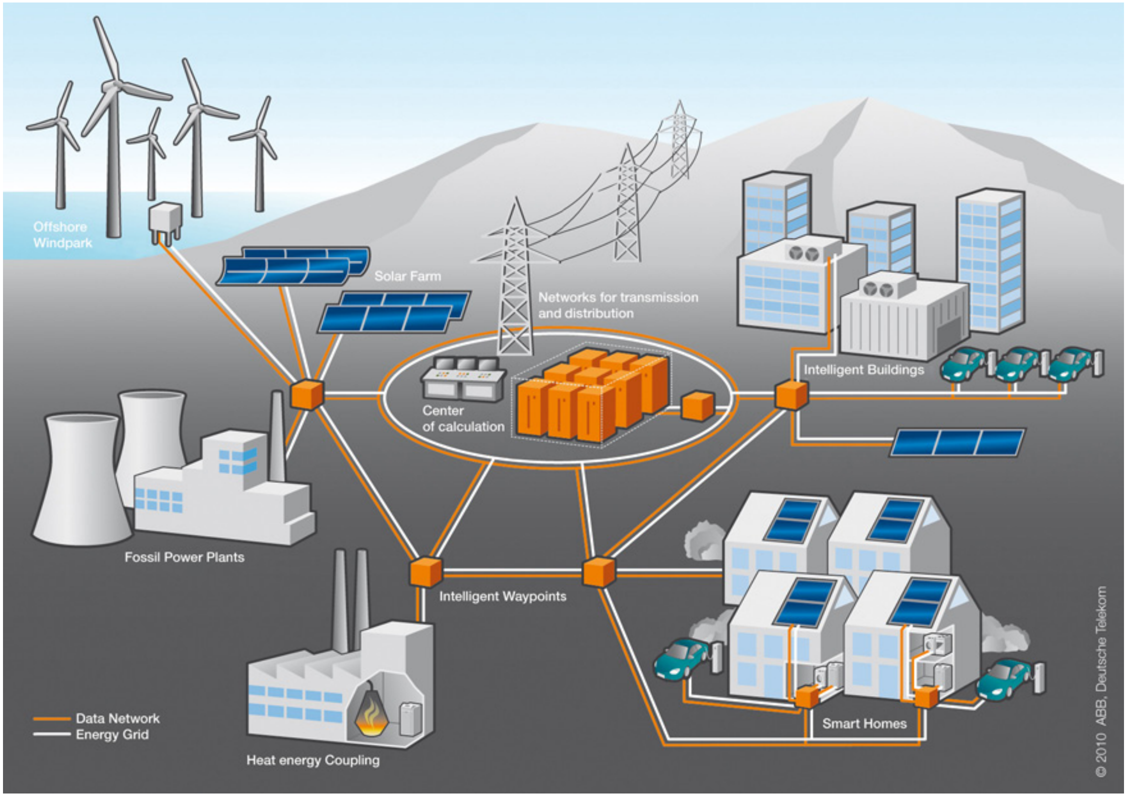


Figure 7: Low-carbon energy supply thanks to smart grid technologies

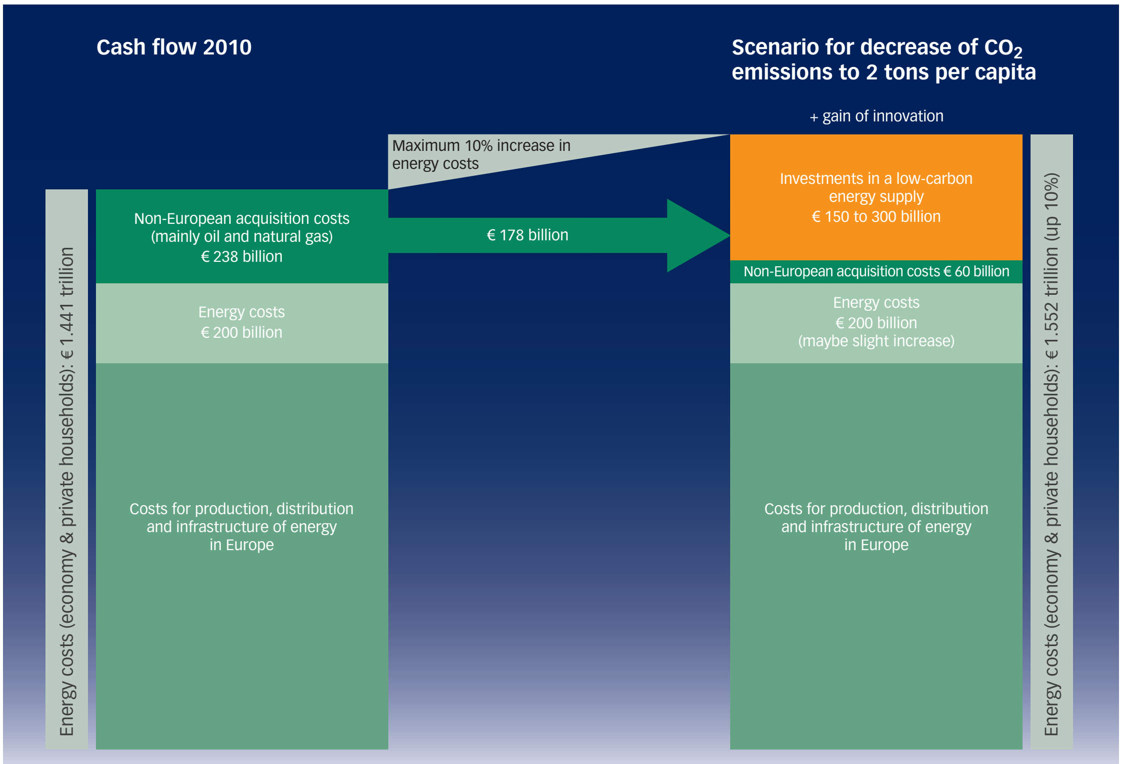


Figure 8: Financing a low-carbon energy supply

Appendix

International statistics and studies on energy and the environment

International Energy Agency (www.iea.org)

- Key World Energy Statistics 2010
- CO_2 emissions from fuel combustion. Highlights
- http://www.iea.org/w/bookshop/add.aspx?id=422

U.S. Energy Information Administration (www.eia.doe.gov)

- International Energy Outlook 2010 (Highlights)

British Petroleum (www.bp.com)

- BP Statistical Review of World Energy June 2010
- BP Energy Outlook 2030

European Environment Agency (www.eea.europa.eu)

- The European environment – state and outlook 2010 (synthesis climate change)

Eurostat (epp.eurostat.ec.europa.eu)

- Energy data
- Environmental data

European Commission, Energy (www.ec.europa.eu/energy)

- EU Energy and Transport in figures 2010

Organisation for Economic Co-operation and Development OECD (www.oecd.org)

- Environment portal

United Nations Framework Convention on Climate Change (www.unfccc.int)

- Greenhouse Gas Inventory Data

United Nations Statistics Division (unstats.un.org)

- Energy statistics

Activities of the European Union (EU)

European Strategy: Energy 2020

- Overview
- Brochure
- Communication “Energy 2020 – A strategy for competitive, sustainable and secure energy”

Energy infrastructure: New priorities for 2020 and beyond

- Overview
- Brochure
- Communication “Energy infrastructure priorities for 2020 and beyond – A Blueprint for an integrated European energy network”

Definition*

Although there is no standard global definition, the European Technology Platform SmartGrids defines smart grids as electricity networks that can intelligently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimising the operation of the system;
- Provide consumers with greater information and options for choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;
- Maintain or even improve the existing high levels of system reliability, quality and security of supply;
- Maintain and improve the existing services efficiently;
- Foster market integration towards a European integrated market.

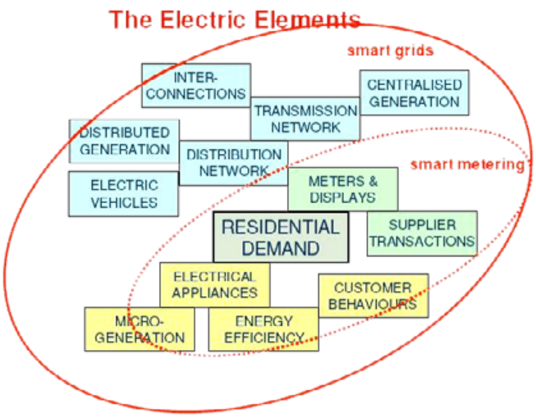
What does "smartness" imply?

SmartGrids do not only supply power but also information and intelligence. The "smartness" is manifested in making better use of technologies and solutions to better plan and run existing electricity grids, to intelligently control generation and to enable new energy services and energy efficiency improvements.

*Published on SmartGrids: European Technology Platform (http://www.smartgrids.eu)

What does it NOT mean?

- The smart grid relates to the electricity network only (not gas) – it concerns both distribution and transmission levels.
- Smart grids are not new "super grids". They will not look significantly different to today's "conventional" electricity grids transporting and distributing power over "copper and iron". However, smart grids will lead to improved cost-efficiency and effectiveness.
- The smart grid is no revolution but rather an evolution or a process within which electricity grids are being continuously improved to meet the needs of current and future customers.
- There will not (and cannot) be any "roll-out" of smart grids, since such a "roll-out" is continuously occurring.
- Although the concepts are sometimes confused, the smart grid is not smart metering – the smart grid is a much broader set of technologies and solutions (see diagram below).



- While many utilities have put their focus on smart metering, smart metering does not provide a smart grid. Indeed, it is possible to have smarter electricity grids (i.e. distribution and transmission networks) without smart metering. But, there are several benefits to smart metering which can reinforce other policy actions on climate change. For example, when used with other parameters (such as differential tariffs and information) smart meters can encourage consumers to reduce their demand (load) when prices are high or when system reliability or power quality is at risk.

Technologies

Storage systems*

- CAES (compressed air energy storage)
- Electrochemical capacitors
- Flywheels
- Lead-acid batteries
- Lithium-ion batteries
- Metal-air batteries
- Sodium sulphur batteries
- Pumped hydro
- Vanadium redox batteries
- Zinc-bromine batteries (redox)

Energy technologies**

- Concentrated solar power (CSP)
- Geothermal power
- Hydropower
- Nuclear fission power
- Wave power
- Solar heating and cooling
- Solar photovoltaic
- Wind power

*Source and further information: Electricity Storage Association (ESA)
**Source: European Commission, SETIS Strategic energy technologies information system