Future Climate
Engineering Solutions

Future Climate Engineering Solutions

13 engineering participating
engeneering associations

Binding targets to drive
development towards
GHG reductions

Call for a framework for
joint technology development

Achieve GHG reductions by
using energy more wisely

Action needed in the transport sector

Joint report

Future Climate
Engineering Solutions

Cover: Rune.Anders.Lars

Printed: IDA's Print Centre

ISBN: EAN 978-87-87254-25-0

Issued by The Danish Society of Engineers, IDA

September 2009

Kalvebod Brygge 31-33
1780 København V

Denmark

Telephone +45 33 18 48 48
Fax +45 33 18 48 99

Email: ida@ida.dk

Editorial:

Jacob Fink Ferdinand
Pernille Hagedorn-Rasmussen
Bjarke Fonnesbech

Table of Contents

Participating organisations

The Swedish Association
of Graduate Engineers

The Norwegian Society
of Engineers, NITO

Union of Professional Engineers,
UIL (Finland)

Institution of Mechanical
Engineers (UK)

The Institution
of Engineers (India)

Federation of Scientific
Engineering Unions
in Bulgaria

The Japan Society of
Mechanical Engineers,
JSME

The Finnish Association
of Graduate Engineers,
TEK (Finland)

APESMA
(Australia)

The Association of German
Engineers, VDI

Engineers Ireland

The American Society of
Mechanical Engineers, ASME (USA)

The Danish Society
of Engineers, IDA

Foreword

Overcoming climate change is a major challenge for the global society, and the foremost engineering challenge of the 21st century. There is crucial need to reduce emissions of greenhouse gases (GHG) in order to keep the rise in temperature below two degrees Celsius.

13 Engineering Associations from around the world are part of the project 'Future Climate - Engineering Solutions'. Within the project the participating associations have been developing national climate plans and technology prospects. The plans and prospects show how GHG emissions can be reduced substantially, and how a sustainable path of development can be reached.

The following Associations have been part of the project:

The Norwegian Society of Engineers, NITO (Norway)

Institution of Mechanical Engineers, IMechE (United Kingdom)

The Institution of Engineers (India)

The Association of German Engineers, VDI (Germany)

The Japan Society of Mechanical Engineers, JSME (Japan)

The American Society of Mechanical Engineers, ASME (USA)[1]

The Finnish Association of Graduate Engineers, TEK (Finland)

Union of Professional Engineers, UIL (Finland)

Engineers Ireland (Ireland)

The Swedish Association of Graduate Engineers (Sweden)

The Association of Professional Engineers, Scientists and Managers, Australia, APESMA (Australia)

Federation of the Scientific - Engineering Unions in Bulgaria, FNTS (Bulgaria)

The Danish Society of Engineers, IDA (Denmark)

This joint report includes summaries of the work provided by the Engineering Associations.

Based on the climate plans and technology prospects, the Advisory Board and the participating Associations of the Future Climate project have extracted five key, common findings that could move the global society onto a low-carbon track. To ensure the necessary GHG emissions reductions for a two-degree scenario, the Associations behind the project have put forward five recommendations for a Global Climate Treaty.

On behalf of the Engineering Associations involved in the project, I urge the leaders of the world to take up the climate challenge and apply solutions for a sustainable future.

Lars Bytoft

President of the Danish Society of Engineers

1. The American Society of Mechanical Engineers fully endorses the objective of the project, but was not yet in a position to endorse the final text of the joint report.

Executive summary

Future Climate Engineering Solutions – Joint Report is the common output and a documentation of more than 1 year's effort by 13 engineering associations – in 12 countries – to demonstrate how technologies can combat climate change.

The report consists of three parts: Summaries of 10 national climate plans and technology prospects, 5 Key Common Findings, and a Climate Call from Engineers to create a new global climate treaty.

The basic assumption of the project is recognition that GHG emissions, and their concentration in the atmosphere, must be reduced to a sustainable level. The project definition of a sustainable level is equivalent to the best-case stabilisation scenario which was presented in the 4th Assessment Report (AR4) by the UN Intergovernmental Panel on Climate Change (IPCC), whereby the global mean temperature is most likely to stabilise at 2.0-2.4°C.

The Future Climate website *www.futureclimate.info* holds more information about the project, including possibility to download project material, including the full national climate plans.

Summaries of national climate plans

The participating organisations have either developed national climate plans or plans for promising low carbon technologies. The engineering organisations of Norway, UK, India, Germany, Finland, Ireland, Sweden and Denmark have developed climate plans, which describe the most important technologies and technological solutions proposed to meet the target of a 50-85% green house gas (GHG) reduction by 2050 (excluding India as a developing country).

	Development in GHG emissions reductions by 2050 compared to 2007	**Development in reduction of total energy consumption by 2050 compared to 2007**
Norway	-76 %	-30 %
UK	-89 %	-42 %
India (10% economic growth pa scenario)	+103%	-
Germany (scenario 1/2/3)	- 50 % / - 50 % / -63 %	- 33 % / -29 %/ -19 %
Japan	- 50 %	-
US	-	-
Finland	-74 %	+12 %
Ireland	-60 %	-
Sweden	No net emissions	-30 %
Denmark	-94 %	-50 %

Table 1: Future Climate GHG emissions and energy reductions by 2050 for the 10 national climate plans

	Biomass	Wind	Solar Heat	Hydro	Wave	Geo-thermal	Photo-voltaics	Waste	Nuclear	Gas	Oil	Coal	Other
Norway	11.5 (incl. waste)	7.5		49.5		7,5	1	See Biomass		19	4		
UK	7	21	1	0,5	6		3	2	32	5	5	13	5
Germany scenario 1	14.5	5.5	0.5	1			<0.5	2.5		16.5	39	20.5	
Germany scenario 2	11.5	3.5	0.5	1			<0.5	2.5	16.5	12	34.5	18.5	
Germany scenario 3	12	2	0.5	0.5			<0.5	2	36	16	27	4	
Finland	25	1,5		3.5				1.5	51.5	6.5	4.5	2	3.5
Sweden	46	7		18.5	3.5		1		20.5		3	0.5	
Denmark	64 (incl. waste)	27	4		2.5		1	See Biomass					2

Table 2: Futureclimate primary energy supply in 2050, main energy sources. Percentage of total energy supply in 2050 by energy source (%)

The Japan Society of Mechanical Engineers has developed roadmaps for promising technologies for a sustainable society, and presents two new findings from these roadmaps: Materials and energy efficiency of automobiles, and high efficiency heat pump systems. Finally, USA has contributed by a General Position Paper[2].

The climate plans include national scenarios for development in, 2015, 2030 and 2050, in GHG emissions (total and by sector), energy consumption, energy supply and energy import and export. The main conclusions drawn from the climate plans and the key indicators are presented in Tables 1 and 2.

Participants in the Future Climate project indicate that developed countries are able to reduce their GHG emissions by 50-94%, with an average being 71% (see Table 1). India, being a developing country, expects to increase GHG emissions, due to a high economic growth and a growing population. The project likewise shows substantial energy savings of 30-50% for the six countries who have projected data.

In three countries, Norway, Sweden and Denmark, renewables is the main energy sources, with biomass being the generally primary source (see Table 2). Wind, and hydro power do play major roles in the total energy supply, but only for a few countries. In Germany, Finland, UK and Sweden nuclear power as a low carbon energy source plays a major role, although the Swedish plan projects a gradual phase out. Renewable energy sources such as wave, solar heat, geothermal and photovoltaics are expected to play minor roles when compared with total energy supplies.

In general high carbon energy sources are radically being substituted by low carbon, in particular coal, which in 2050 is only expected to play a major role in Germany and a smaller role in UK in combination with carbon, capture and storage (CCS).

2. The engineering associations of Australia and Bulgaria have not submitted climate plans.

Key Common Findings

From the vast and rich variety of knowledge documented in the national climate plans, a number of denominators, conclusions and recommendations have been retrieved. Five Key Common Findings have been selected as the most feasible and adequate in order to bring down GHG emissions.:

1. Only reliable GHG reduction targets will bring us on track.
2. The near-term GHG reduction needs can be achieved with proven technologies, and promising technologies exist to meet the mid and long term needs .
3. Conditions must be stimulated for engineering solutions to enhance technological innovations globally.
4. Energy efficiency is the easiest, smartest and most inexpensive path towards substantial GHG reductions.
5. Clean transport calls for global action at multinational corporate and government levels.

Climate Call from Engineers for a new global climate treaty

On the basis of the Key Common Findings five main recommendations for a new global climate treaty is put forward by the engineers:

- Commitment to 'binding but differentiated' targets for all countries, ensuring that GHG emissions can peak as soon as possible, and certainly before 2020.
- Commitment to developing national greenhouse gas reduction plans towards 2050 before 2012.
- Setting-up an appropriate framework of joint technology development, with a multi-faceted technological approach.
- Strengthening financial support to allow transfer of technology, which must be receptive to a variety of relevant technologies.
- Commitment to a common effort in the area of transport.

Key Common Findings

Through the numerous meetings and discussions held during the Future Climate project, and from the vast and rich variety of knowledge documented in the national climate plans, a number of denominators, conclusions and recommendations have been retrieved. Among this, 5 key common findings have been selected as the most feasible and adequate in order to bring forward a common call for action from engineers worldwide.

The 5 key common findings of the Future Climate project are:

1. Only reliable GHG reduction targets will bring us on track.
2. The near-term GHG reduction needs can be achieved with proven technologies, and promising technologies exist to meet the mid and long term needs.
3. Conditions must be stimulated for engineering solutions to enhance technological innovations globally.
4. Energy efficiency is the easiest, smartest and most inexpensive path towards substantial GHG reductions.
5. Clean transport calls for global action at multinational corporate and government levels.

1. Only reliable GHG reduction targets will bring us on track

Target-setting is a basic driver for all change. At all levels, it is a driver for innovation and economic growth in society.

Reliable targets

The Future Climate project has demonstrated that, with available and known technologies, it is possible to make substantial GHG reductions in the near and the long term to meet the project target of an average global temperature rise below 2˚C – the"<2˚C target".

Any target must be achievable, measurable, verifiable, ambitious and binding in order to be reliable. The entity or entities that are accountable for meeting the target must be well defined.

An achievable, measurable and verifiable target encompasses a plan that demonstrates a realistic path to meet that target. A target is ambitious when it seeks to achieve a goal well beyond the business-as-usual line of, for example, energy efficiency improvement; and to a high degree can contribute substantially to the <2˚C target. A target can be binding in the sense of being the core part of a "contract" between two or more parties – on the condition that not achieving the target will involve a degree of sanctions. The binding character can therefore range between voluntary agreements, which involve a risk of poor reputation and a loss of legitimacy, and national legislation, which obviously is legally binding. Reliable GHG reduction targets and agreements further need to be immediately and closely linked to allocation of financial resources.

Targets at all hierarchal levels and at multi-terms

It is imperative, and has proven most relevant, that reliable GHG reduction targets are being set at all hierarchal levels, from international agreements to single entity targets.

Target-setting in the near, medium and long term (in this project defined as 2015, 2030 and 2050) perspective can be a driver for new thinking, and for sustained action towards long-term goals. The Future Climate project itself has demonstrated the strength of this multi-term target setting.

At the national level (in addition to international agreements like Kyoto and in the European Community) examples of types of targets are national commitments to reduce energy consumption by 1-2 % annually; increasing the energy intensity; or even a Climate Act. China's target is to cut energy intensity by 20 percent between 2005 and 2010: carbon-intensive industries like the manufacture of cement, iron and steel have been charged with meeting this target. The national conditions vary and, when a global target setting is being proposed, attention must be paid to the economical and developmental state of each nation.

Government targets and strategic sector policies

By its Climate Change Act of 2008, the UK is the only country that has a long-term legally-binding framework to help meet the <2˚C target. The Act requires that emissions are reduced by at least 80% by 2050, compared to 1990 levels. It also introduces legally-binding 5-year GHG budgets, i.e. near-term targets set by the Committee on Climate Change. This has been established to make the carbon strategies, to monitor them, and to report to Parliament on the annual progress of meeting the targets.

Governments need to make reliable sector targets and strategies with all major energy sectors, including power-generation, transportation, industry, and commercial and residential buildings, focusing on near-, mid-, and long-term timeframes.

Several policy instruments and market mechanisms have been and can be applied towards sectors, and subsectors. The national settings vary and the choice of mechanism is dependent on the national setting. Policies that realise lower carbon life cycle emissions require strategies that address life cycle attributes of energy resources; the conversion to energy carriers; the development of low-carbon propulsion systems; and manufactured products.

Voluntary target agreements, such as between the Government and certain energy-intensive sectors, often nationally-specific, can be very successful. An example is the Norwegian energy efficiency targets/agreement with the aluminium, oil and gas industries. Another is the Integrated Energy and Climate Programme (IEKP) of the Federal Government of Germany.

Emissions' performance standards set to meet certain reduction levels can be very powerful and can create an unequivocal market pull, which can force technological innovation on a fast low-carbon track. Cap-and-Trade, or Carbon Markets like the EU Emission Trading Scheme for the EU power sector, and certain energy-intensive industrial sub-sectors like steel and cement production, have built in pollution limits.

The main point is that there is no single solution to the type of market pull, enforced by target setting, to drive GHG emission reductions.

Corporate agreements

The Future Climate project shows successful examples of more-or-less voluntary target agreements at the entity level:

In the UK local authorities have National Indicators to meet such as NI 185 Percentage CO_2 reduction for Local Authority Operations. Some 300 Local Authorities have signed up to The Nottingham Declaration on Climate Change championed by the Energy Trust.

The Danish "curve-breaker agreement" is an agreement signed, voluntarily, between a state-owned organisation and an entity that commits itself to reducing its GHG emission within a short time.

The Norwegian company Norske Skog Skogn which produces newsprint and magazine paper, and the Norwegian Ministry of Environment and Enova, a public enterprise owned by the Royal Norwegian Ministry of Petroleum and Energy, have been collaborating since 2001. This has resulted in significant energy savings.

Market-driven target agreements between NGOs and private companies, especially in the energy intensive sectors, can be quite forceful. For example, the WWF Climate-Savers programme, which has 20 reduction agreements, schemes and verification procedures with some of the worlds largest CO_2 emitters. The targets are often very ambitious, they are absolute, i.e. independent of the economic growth of the company, and their timeframes are rather short, 4-7 years.

Corporations, associations and government institutions should be encouraged to draw upon experiences from these voluntary carbon-reduction agreements.

Both market pull and technology push

Technology push targets, in order to drive a specific technology or set a framework from technology action programmes and road maps, are equally relevant as market pull methods.

Conservative over-planning is a norm for engineers and should be built into meeting targets in order to be robust enough to withstand a high degree of uncertainty. For instance, the UK is putting some emphasis on additional nuclear capacity which, if not delivered on-time with the number of stations required, would need to be compensated for by additional capacity elsewhere – for example from coal with carbon, capture and storage (CCS) technology. CCS is still in the demonstration phase and may encounter implementation problems that means it will not be able to meet the target as planned.

It is evident that the <2˚C target is a reliable target and not just a political dream or vision. With a collaborative effort by governments it must be implemented through near-term and mid-term target setting and sub-targets at all levels.

2. The near-term GHG reduction needs can be achieved with proven technologies, and promising technologies exist to meet the mid and long term needs

The climate plans of the Future Climate project clearly demonstrate that the <2˚C target is achievable with our current technological knowledge and prospects at hand.

In all four main sectors – power, industry, buildings and transport – technologies and processes exist that are commercialised and readily available, and which make it possible to achieve energy savings and GHG reductions, so that global GHG emissions will peak before 2015. Further optimisation, up scaling and diffusion of several of these technologies are required for long term adequate GHG reductions. In addition a palette of promising technologies needs a coordinated effort to pull through the innovation chain of research, development, deployment and commercialisation. This includes changes in technological systems and infrastructures, e.g. urban planning and intelligent electricity grids.

The power sector

In the power sector, besides lower power production needed due to electricity savings in industry and buildings, near term GHG reductions can be achieved mainly through substitution of high carbon power technologies with more onshore and offshore wind, biomass and geothermal energy. In the promising line of technologies in the mid and long term low carbon power generation are photovoltaic, wave and tidal power, fusion energy and carbon, capture and storage (CCS). This must be supported by new intelligent electricity grids and energy systems that maximise the capacity to utilise fluctuating power generation from wind and photovoltaics.

The industry sector

The Future Climate project shows that there is a large near term potential of up to 25% energy savings in the industry sector with low pay back times. In general, lean management of business processes has high energy savings potential. Most of the electricity savings can be achieved through process optimisation, energy efficient cooling, pumping, ventilation and compressed air, already available on the market. The largest heat consumption savings comes from a shift to heat pumps, and subsequently the diffusion of a large number of available technologies, e.g. introduction of enzymes, heat recovery, and insulation, and more efficient evaporation, drying and separation. Fossil fuels can in the near term be substituted with biomass and bio fuels.

Buildings

A number of construction, heating and power technologies are commercially available to make new buildings net-zero GHG emitters and significantly reduce the carbon emissions from existing building stock, in both cases with economic benefits. This includes inter alia heat pumps, solar power, district heating, efficient electrical appliances, pumps and lighting, and an improved building envelope. In the mid to long term buildings can become power generators and an integrated part of the electricity grid through the introduction of improved photovoltaics.

Transportation

Even current diesel and gasoline combustion engine technology would be able to meet strict CO_2 emission standards for land transportation. Hybrid vehicles, and the introduction of low-carbon bio fuels, further enable immediate savings in emission of CO_2. Infrastructural instruments such as better urban planning, environmental zoning and better public transportation are based on technologies already available.

Further development and commercialisation of electrical vehicles over the medium term, including a low carbon intelligent electricity grid, would radically reduce CO_2 emissions from land transportation. Over the medium term, high speed rail will be able to compete with short-haul air transport. Both maritime and aviation transport have immediate options for substantial reductions of CO_2 emissions. Technologies are available to improve fuel efficiency by use of the following: engine technology; lower friction; change in route patterns; and shift to low carbon fuels for both new and existing vessels and aircraft.

3. Conditions must be stimulated for engineering solutions to enhance technological innovation globally

Governments must place themselves in the forefront of stimulating the development of low-carbon technology. A framework for international cooperation to drive long-term technological change, assist in deploying existing technologies, and providing Research, Development and Deployment (RD&D) opportunities for future technologies, must be established. This will drive the development of national and regional policies.

Technological innovation must be stimulated both through technology push and market pull mechanisms. Focus has primarily been on market push policies such as cap-and-trade, taxes, and emissions-performance standards. This is, however, not sufficient to pull the development through the innovation chain.

Top-down technology strategies needed

Governments should therefore adopt top-down technology strategies for collaborative RD&D to ensure that critical technologies arrive on time and with coordinated funding. Technology roadmaps and innovation, for as wide a mix as possible of sustainable energy supply solutions, should be designed and implemented. All available technologies helping to reduce GHG emissions should be taken into consideration, but with an energy-system based on renewable solutions to as far an extent as feasible. In coordination with this, a global technological funding mechanism needs to be put in place in order to secure reliable implementation and diffusion of the technologies.

Governments should, in general, be more focused on how major technological changes take place in society, in order to be able to stimulate this properly. Real technological change occurs in technological innovation systems, in joint ventures with institutes of knowledge, private companies, government institutions etc. that are embedded in a broad societal structure.

Governments need to put in place stable, long-term policy frameworks that ensure stable, long-term investment environments in which commercial organisations can confidently commit to investment in the technologies and infrastructures required to meet the targets. These frameworks, which include the financial, legislative, regulatory and market tools that government uses to incentivise investments, need to be committed to by all political parties to ensure they do not change as elected governments change.

Stimulate clean technology entrepreneurship and innovation

Innovative clean technology business environments must be stimulated in order to create new local business networks and economies. Entrepreneurship should be promoted and cultivated by implementing policies that remove or minimize the bureaucratic, governance, educational, financial and corporate cultural barriers. Seed funds and other incentives for local low-carbon technologies to develop and mature should be implemented: for example, technologies for energy efficiency, small hydro power plants, biogas, biomass production, photovoltaic, and geothermal power.

Governments should encourage and support ‘green venture’ capital investments. Special attention should be taken during economic turn-downs when private investments tend to become less risk-oriented, and investments in RD&D of new low-carbon technologies can be set back. It is important that Governments are prepared for these negative effects, and will have mechanisms to both stimulate private investments and channel public funds during these periods.

Web 2.0 low-carbon knowledge development and diffusion

New processes and policies to accelerate the innovation chain flows must be developed. Increasingly, solutions are coming from diverse scientific and engineering disciplines. To be most effective, these new processes must be open to all, facilitated by the Internet, as a Web 2.0 low-carbon model. It can be contributed to from all areas of expertise, and can be enhanced by interest groups and engineers. Transmission of technology from government laboratories to private industry must be also simplified, and a more open flow of information across the corporate barriers must be promoted. In conjunction, intellectual property rights (IPR) must be addressed, because they can hinder the free-flow of knowledge

The website "Energibruket" is an initiative to gather engineers in Sweden for discussions and innovation on this issue. The site offers a forum for technology-oriented discussions under headlines like transport and construction. It is also possible to have an idea tested – with support from the expertise that has been associated with Energibruket – on issues such as energy, environment, intellectual property rights and commercialisation. Many ideas conceived by engineers are never realised, since they are brought forward in an environment where they are secondary to the core business. An initiative like this offers an opportunity for such ideas to extend further down the line of innovation.

A coordinated effort to diffuse technology to and in developing countries must be ensured. Developing countries must be an equal stakeholder in international collaboration on RD&D, and must have equal access to new technologies and technological innovation environments. Knowledge-sharing and technology-transfer are imperative in order for the developing countries to be able to adapt the new clean technologies, without the need for them to undergo (to a greater or a lesser degree) the same technological evolution route taken by most industrialised countries.

Emphasis and investment in educating and training the workforce in all advanced energy technologies, and their deployment, should increase. Sustainable development and low carbon know-how must be included in educational and training programmes as permeating themes, and connected to the core know-how in each field of engineering specialisation. In addition to basic education and training, further education and training must also be developed so that the level of competence can be retained and updated to meet arising needs.

Local condition and bottom up-approaches

The climate technology solutions and policies must be adapted to local conditions, because 'one size' does not fit all. An essential assumption when developing international regulations and policies should be that all countries and regions have different conditions in terms of resources, level of technology, industrial structure, social and cultural context, financial capability, governance and regulatory history. GHG Cost Abatement Curves and implementation schemes must be developed to be as nationally-based as possible.

In conclusion, comprehensive top-down strategies with bottom-up mind-sets and approaches are needed for technological innovation. A global financial, institutional and technological framework on low-carbon technological development and diffusion must be established. It is imperative, though, that policy makers and institutional developers understand that innovation only occurs from people to people, and not through financial flows or institutional procedures; the latter are, however, necessary to stimulate innovation and to develop and sustain a strategic focus.

4. Energy efficiency is the easiest, smartest and most inexpensive path towards substantial GHG reductions

The Future Climate project, and many other studies, show that the world is wasting energy and that a substantial part of the needed GHG reductions can be achieved by using the energy more wisely, through smarter usage and changing over to higher energy-efficient devices. In all four main sectors, power, industry, building and transport, there are high energy efficiency poteIn several national reports it is assessed that up to 50% GHG reduction can be met by energy efficiency alone.

A Swedish report from 2009 concludes that Sweden's total energy consumption can be reduced by almost 50% by means of control and new technology. Industrial processes need to be optimised and automation increased, but within many fields a great potential lies in minor changes of already-available technology. In the housing sector it is largely a matter of improving the existing building stock, but to a large extent the technology is already at hand. In Denmark the most profitable energy savings are in industry. With payback times less than 7,5 years, energy consumption can be reduced by more than 25% before 2015.

Industry approach

Especially in the industry sector there is a need to increase the awareness of energy savings through the whole production chain, and the incentives to reduce the payback times for energy investments. The industry sector companies can be targeted at several levels:

- Benchmarking and best practice knowledge-sharing;
- Certification of energy standards for certain energy-intensive industry sectors, including compulsory external energy audits;
- Implementation of industry GHG emission standards;
- Joint ventures between the leading business companies of the sector and, for example, scientific organisations, government institutions, and business associations;
- Tax exemption incentives for the most energy-intensive companies against implementation of energy saving steps (this has been done with success in Sweden), and/or
- Energy-saving funds, including public funds to support energy investments with longer payback time.

All companies with an annual fuel and electricity consumption above a certain level ought to perform an energy inspection and process integration study at least once every three years, using external, quality-assured consultants.

For certain energy-intensive industries there should be a commitment to global industry GHG emission standards, especially in the most GHG-intensive industries like power production from coal plants, cement industry, metal industry, and electronics/ household products (including end-use energy consumption).

The industry, particularly SMEs, lack both the skills to identify opportunities for energy efficiency, and the qualified personnel needed to implement and follow-up the efficiency measures. Energy efficiency must be part of all technology development, so energy efficiency know-how and knowledge-sharing must be part of the expertise possessed by all engineers and designers in the years to come.

Disposing of used products results in the loss of all functional value and embodied energy created through materials processing and manufacturing. Significant energy benefits can therefore be achieved through reuse, re-manufacture, and recycling. Increase useful product-life, and encourage life extension and modularity of product components, by enabling replacement of failed components by products with significant levels of energy-intensive materials and manufacturing. Nevertheless, often new product concepts and design, including replacement materials, are necessary for large energy and resource savings.

Consumer approach

The consumer energy labelling system in EU for household products has proven very effective, and can be expanded to more product groups and geographic areas than at present. Energy efficiency, as selection criterion during public procurements, can also be strong drivers for product manufacturers to focus on energy-efficiency for the end-user. Another way of increasing the demand-driven change in product energy efficiency is by making customers and end-consumers behave in a more climate-friendly way in general through, for example, information and awareness campaigns.

Energy-saving funds needed

Coordinated international and national energy-saving funds should be established, with the objective of promoting electricity and heat savings in households, public areas and trade-and-industry by means of information, advice and grants. The aim is a coordinated and cost-effective energy savings input in all sectors. Subsidies could be granted when binding agreements on energy management are entered into with individual companies. The agreements could relate to specific types of energy and processes and, if applicable, the training of staff responsible for planning, purchasing and operation of plants and systems.

Buildings can become net-zero GHG emitters

It is well known and documented by existing technologies, and with a net positive economy, that new buildings can already become “passive houses” or net-zero GHG emitters. Studies in Germany suggest that energy use can be reduced by 50% for only a minimal increase in construction cost. The U.S. Department of Energy has estimated that by 2050, with advances in building envelopes, equipment, and systems integration, it may be possible to achieve up to a 70% reduction in a building’s energy use, compared with the average energy use in an equivalent building today.

Energy efficiency in buildings can be augmented by energy efficient architecture, highly-insulated building envelopes, and on-site energy technologies like solar thermal systems for hot water and air conditioning, photovoltaics or distributed sources of renewable fuel combined heat and power. Stricter building codes and regulations need to be developed to facilitate the entry of innovative solutions in these areas.

Since the annual new construction in developed countries is normally 1-3%, there is a need to look at energy efficiency in the existing building stock. Here, promotion is needed by stepping-up consumer information, providing training, tightening building regulations and creating incentive schemes aimed at consumers. Public authorities must show the way by imposing special requirements on public buildings.

It is estimated that more than 50% of all new buildings globally are being constructed in China and India alone. This highlights the necessity of increased policy and technological diffusion, as mentioned.

5. Clean transportation calls for global action at multinational corporate and government levels

The Future Climate project shows that the transport sector and its GHG emissions have a more common structure of issues and solutions than any other sector. While the global transportation volume will still increase, utmost and expensive efforts are required to increase efficiency, shift fuels, and make a radical shift to electrical propulsion, especially for smaller vehicles.

Reinvention of transportation

A significant reduction in transportation CO_2 emissions means that all known tools and technologies must be brought into play. Transportation must be reinvented by increasing the diversity of energy resources that supply transportation; displacing petroleum consumption through increased system efficiency and use of lower carbon fuel alternatives; and reducing life-cycle emissions associated with the electrification of the transportation industry. This calls for a coordinated strategic action in large geographic regions, and in the transportation and energy markets between governments and relevant corporations.

In order to fully implement this change there is a need for a multifaceted strategic focus in the near-, mid-and long-term perspectives. Advanced battery and/or other energy storage-power systems for the adoption of plug-in and electric vehicle technologies must be developed and deployed. Bio fuels should be adopted in a cost-effective and environmentally responsible manner. Multiple potential energy carriers, such as liquid and gaseous fuels, and electricity, must be made available. Lower carbon fuels and propulsion alternatives across multiple modes of transport must be utilised, and conventional propulsion systems must be optimised while developing advanced propulsion technologies.

Mainly electrification of vehicles

Environmentally, electric engines are superior to combustion propulsion. It has the advantage of zero emissions (of any gaseous substance) from zero-carbon electricity supply and high energy efficiency of more than 90% compared with 20-30% for gasoline engines and 30-40% for fuel cell, hybrid vehicles and diesel engines.

The full low-carbon advantage of electricity as an energy carrier requires low carbon or zero carbon energy supply. This in turn requires significant improvements to the present electricity grids worldwide, including intelligent electricity consumption. In Europe this could mean an integration of the grids in Europe and North Africa to a smart 'Super Grid'. Plug-in electric cars and their advanced battery technologies will enable two-way power flow of grid-to-vehicle and vehicle-to-grid. The electric vehicles become extra electricity storage, and thereby act as a grid reinforcement function, adding additional economic value to vehicle battery systems. Other energy storage will be of increasing importance to smooth sustainable power generation, and pumped storage projects offer a good solution.

A breakthrough for the commercialisation of electric cars and plug-in hybrids depends upon the development in battery technology, which needs development in higher capacities, faster reload and lower costs. It will be necessary to exempt electric vehicles from taxes for some years still. In the intermediate period before full commercialisation, hybrid vehicles are an option.

Further development in the areas of other alternative fuels, such as cellulosic ethanol and biodiesel, is required to support energy diversity and where electric propulsion is not (yet) an option. Any use of bio fuels must undergo careful life cycle assessment in order to justify its level of sustainability, including GHG reduction potential. Experience with implementation of alternative fuels production policies do show that tradeoffs will be inevitable. Comprehensive multi-dimensional analyses guide governmental and industry policies and practices.

Private and/or public transportation

Managing GHG emissions across the transportation industry will require the management of issues concerning the balance between personal and freight transportation, and public and/or mass transportation. Urban structure has a significant impact on traffic, as well as on the need for energy and energy consumption. Urban planning, to a high degree, defines the volume of and need for traffic. Energy and traffic considerations should be embodied in planning and assessment procedures. Urban planning can be used in directing urban structure to be more close-knit, and also the possibilities for implementing public transport improvement. For example, new residential areas should be centred around railway stations and the location of large residential areas, commerce and shopping facilities in the same local neighbourhood will be supported. Furthermore, heating systems can be optimised, so that the different heating forms will be used in ways that are most appropriate in terms of overall economics and ecology.

Public transport can be promoted by investing in the development of automated rail traffic in densely-populated areas. Car-pooling can be promoted as an alternative. Traffic volumes and the energy consumption of vehicles can be reduced by means of vehicle taxes based on the distances driven. The need for work-related commuting can be reduced by promoting ICT opportunities. Data communications solutions and available ICT services, including teleconference technology, can be applied to significantly reduce work travel miles.

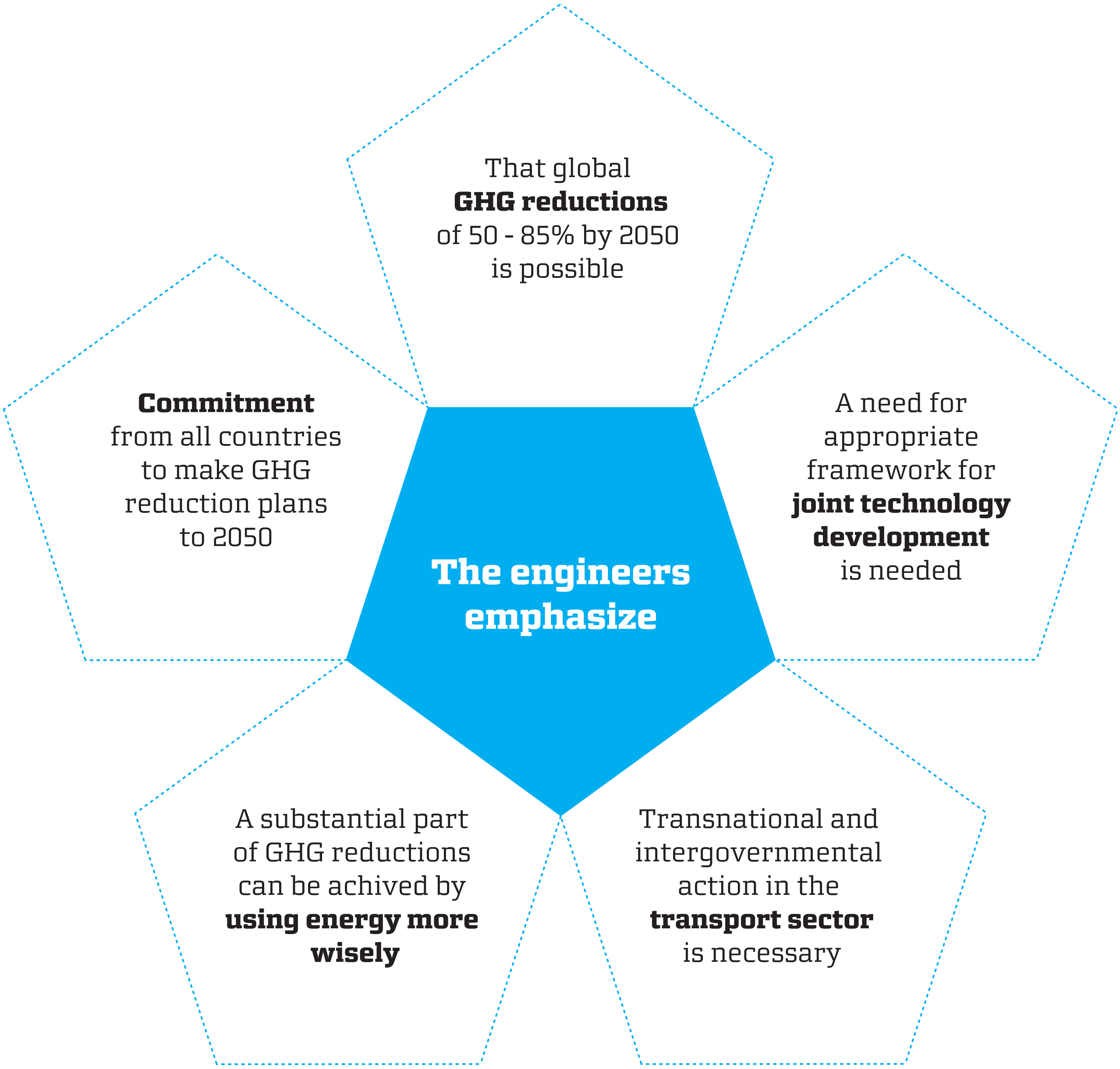
Rail has the great advantage that it can be low-carbon electrically-powered without any new technology. Moreover, rail is competitive with heavy-vehicle freight transport and public-short-haul air transport. The rail network ought also to be developed and improved so that it becomes a real alternative to the car.

Maritime and aviation transportation

Marine transport has a huge energy efficiency potential and options for a shift towards more sustainable fuel. However it faces little or no restrictions on emissions; thus global strategies and policies are needed to create incentives to harvest these potentials.

The aviation industry can improve energy-efficiency through the use of improved engine and fuselage technology, for example, as well as redesigned flight patterns to reduce long haul distances (and hence the fuel used to carry cargo). Ultimately bio fuels represent the only technique available to significantly reduce aircraft emissions. A modal shift from short-haul air to high-speed rail is also desirable.

Engineering Solutions – A Climate call from engineers



From 7 to 18 December 2009, people from all over the world will convene at the United Nations Climate Change Conference (COP-15) in Copenhagen, Denmark, to create a new Global Climate Treaty, by which to reduce greenhouse gas emissions.

A general de-carbonation of society calls for major changes in technologies. A Treaty in Copenhagen must support this. For this reason, the Associations of Engineers in the Future Climate project are calling for a framework that will support energy savings, use of existing low carbon technologies, innovation, and transfer of technology.

A new Climate Treaty must include

- Commitment to ‘binding but differentiated’ targets for all countries, ensuring that GHG emissions can peak as soon as possible, and certainly before 2020.
- Commitment to developing national greenhouse gas reduction plans towards 2050 before 2012.
- Setting-up an appropriate framework of joint technology development, with a multi-faceted technological approach.
- Strengthening financial support to allow transfer of technology must be receptive to a variety of relevant technologies.
- Commitment to a common effort in the area of transport.

The engineers emphasize

- That with available and known technologies it is possible to make substantial GHG reductions over the short- and the long-term, to meet the project target of 50-85% average global reduction by 2050.
- That binding targets on national and local levels are essential to drive development towards reduction of GHG. To achieve the necessary emission reductions, all countries must participate with national-based solutions.
- Energy efficiency is the easiest, smartest and most inexpensive path towards substantial GHG reductions. The world is wasting energy; a substantial part of the needed GHG reductions can be achieved by wiser use of energy.
- Binding targets must be supported by a national commitment from countries around the world, to make GHG reduction plans up until 2050. The plans should address the most polluting sectors in the country (energy production and distribution, energy efficiency, deforestation, transport). The plans should be finished before 2012.
- An appropriate framework for international cooperation should be established to encourage long-term technological change, assist in deploying existing technologies; and provide RD&D opportunities for future technologies. This is needed in order to speed up the pace of innovation, increase the scale of implementation, and make sure that all countries have access to affordable climate technologies.
- The transport sector has a more common structure of issues and solutions than any other sector. This calls for transnational and intergovernmental action. A Climate Treaty should promote common standards, energy efficiency, and also ensure that bio fuels are being adopted in an environmentally-responsible manner. Emissions from international aviation and shipping are substantial sources of emissions and should be addressed within the framework of a Copenhagen Treaty.

Summaries of National Reports

Introduction

The core purpose of the Future Climate project has been to demonstrate a technologically based outline for a sustainable future climate through national climate plans and descriptions of specific promising climate technologies.

The basic assumption of the project and of the national reports is recognition that green house gas emissions and their concentration in the atmosphere must be reduced to a sustainable level. The project definition of a sustainable level is equivalent to the best case stabilisation scenario which were presented in the 4th Assessment Report (AR4) by the UN Intergovernmental Panel on Climate Change (IPCC), whereby the global mean temperature is most likely to stabilise at 2.0-2.4 °C.

In practical terms the assessment report states that in order for this to happen the global GHG emissions have to peak before 2015 and the emissions in 2050 must be reduced by 50-85% compared to the emissions of 2000.

The climate plans of the developed countries have attempted to contribute to this sustainable target range merely by making domestic reduction scenarios.

The climate plans include national scenarios for development in, 2015, 2030 and 2050, in GHG emissions (total and by sector), energy consumption, energy supply and energy import and export.

Summaries of the 10 national reports[3] are presented in the following. The developments of GHG emissions and energy consumption of these reports are summarized in Table 3.

The full national reports can be downloaded from The Future Climate website *www.futureclimate.info*.

	Development in GHG emissions reductions by 2050 compared to 2007	Development in reduction of total energy consumption by 2050 compared to 2007
Norway	-76 %	-30 %
UK	-89 %	-42 %
India (10% economic growth pa scenario)	+103%	-
Germany (scenario 1/2/3)	- 50 % / - 50 % / -63 %	- 33 % / -29 %/ -19 %
Japan	- 50 %	-
US	-	-
Finland	-74 %	+12 %
Ireland	-60 %	-
Sweden	No net emissions	-30 %
Denmark	-94 %	-50 %

Table 3: Future Climate GHG emissions and energy reductions by 2050 for the 10 national climate plans

3. The participating associations of Australia and Bulgaria have not submitted national reports.

NITO

Summary of The Climate Plan for Norway

Norway is a nation rich in both renewable and fossil energy. We have large hydropower resources, and electricity accounts for almost 50 per cent of our energy consumption. Most of our fossil energy is exported, and the utilisation of these resources does not count in the national emission accounts. However, fossil energy used to produce oil, gasoline, diesel and natural gas is included in the national accounts. Norwegian greenhouse gas (GHG) emissions defined by the Kyoto regulations are 53 Mt CO_2 equivalents per year.

Targets

The Norwegian political ambition for GHG emissions is a reduction of 30 percent prior to 2020 relative to the 1990 levels, and to be "climate neutral" by 2030. These targets include the use of flexible mechanisms under the Kyoto protocol, i.e. use of emission-quota trading, joint implementation, and the Clean Development Mechanism.

The NITO plan is based on a bottom-up perspective. The purpose is to reduce the emissions of GHG to a sustainable level, defined as the 'best case scenario' of IPCC, where the increase in global temperature does not exceed 2°C.

Measures

The NITO scenario for reductions in GHG emissions from four nearly equally-large sectors is based on:

- Fossil energy production: In 2050 NITO predicts close to zero GHG emissions from almost-empty oil wells, and very limited emissions from production of natural gas. With renewable on-shore electric power production it is possible to substantially reduce GHG emissions from production of fossil energy in 2050.
- Industry: NITO estimates higher efficiency for Norwegian industry. For large industrial activities – as a result of new research – Carbon Capture and Storage is expected to reduce process-related GHG emissions by 50 %.
- Transport: The national transport sector may be almost independent of fossil fuels by 2050, with gradual increase in the use of electric energy, new batteries and second generations of bio-fuels. Ships may increasingly use methane as fuel, and reduce emissions by new sail technology. Optimising speed in relation to goods with different urgency will reduce the speed-related energy consumption of ships. The emissions from transport of goods may also be reduced by transition to electric railway.
- Heating, waste and agriculture: Heating, waste-management and farming will gradually reduce GHG emissions by 75 percent. The means by which to do so are heat pumps, bio-energy, and highly isolated buildings to reduce energy consumption / increased energy efficiency. Collection and efficient use of methane from landfills and deposits will also reduce GHG emissions.

Main Findings

There is great potential over the short term, as well as towards 2050, to reduce Norwegian GHG emissions. Efficient technology is within reach, and can be used for business development as well as for the actual reductions in GHG emissions. In addition, Norway has the potential for large electricity surpluses that may be exported.

The measures mentioned above result in a scenario allowing for a 74 percent reduction in domestic GHG emissions[4]. Possible future export of Norwegian renewable energy arising from new electric energy production, and increased energy efficiency, is not included in the Kyoto regime. However, export of renewable energy has the potential to contribute towards reduced emissions in the importing countries. If GHG emissions reductions from possible future export of renewable electric energy were taken into account in the Norwegian scenario, this may imply a possible reduction in Norwegian GHG emissions of about 95 percent in 2050.

Recommendations

In general, NITO strongly emphasizes the importance of supporting energy efficiency in all sectors of society. NITO also strongly advocates improving conditions under which growth of renewable electricity production may take place.

Fossil Energy Production

- New production should, when technology permits, take place from subsea facilities.
- New production should use electricity from renewable sources.

4. Excluding use of the flexible mechanisms under the Kyoto protocol.

Industrial Sector

- Hydropower and other renewable sources of energy should be considered as an asset of great value for future industry in Norway.
- The authorities should hire and educate “Energy Hunters”, making them available free-of-charge for companies wanting to identify possible energy efficiency projects.
- Active energy management with certification requirement should be mandatory for companies using more than 50 GWh annually.
- Utilize the potential of surplus heat from the industry.

Transport

- Norwegian industry must have the competence and production methods to meet the needs of the new generation of cars.
- The “Plug-in Hybrid” concept must be supported and given priority by the government.
- Production of fuel from Norwegian renewable biomass must be supported by the government.
- The ship owners must be given incentives to extend their use of Methane.
- New sail technology should be used to optimize speed and fuel consumption, relative to the weather, and the urgency of the goods being transported.
- Infrastructure must be built to accommodate effective transfer of heavy-duty transport from road, to electric railway and ship.

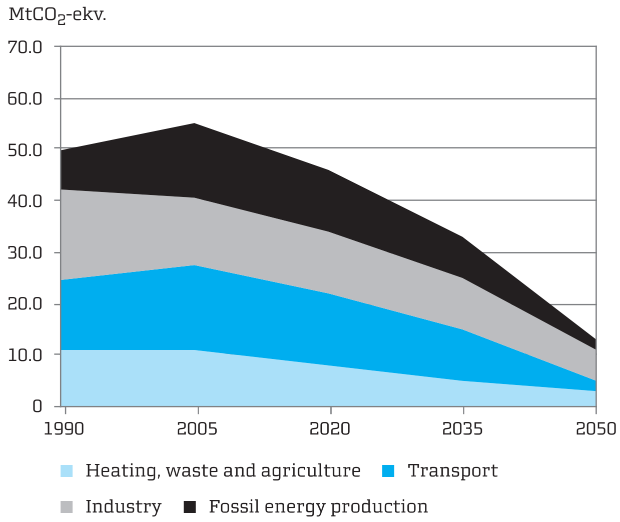


Figure NITO-1: NITO scenario with 74 per cent domestic reductions in GHG emission by 2050

Heating, Waste and Agriculture

- Norway must adapt and adhere to the EU target of 20 percent increase in energy efficiency in buildings.
- Renovation of old buildings, in accordance with current standards, must be increased by 4-to-5 times.
- All new houses should be built with technology for "Passive Houses" by 2020.
- Heating systems in public buildings must be changed to flexible systems that run on energy from different renewable sources by 2020.

Acknowledgements

With assistance from the Institute of Transport Economics (TØI) and the Centre for International Climate and Environmental Research – Oslo (CICERO), NITO has made plans for engineering solutions in Norway. The methodology is based on status, technological ideas, calculation charts and graphics, used to present sustainable climate scenarios up to 2050. The Norwegian statistics for energy consumption, and figures for GHG emissions, are collected from "Low Emission Commission", 2006 where CICERO performed the function of secretariat.

NITO would like to thank Rolf Hagman (TØI) and Knut H. Alfsen (CICERO) for the assistance in making the plans for engineering solutions in Norway.

NITO would also like to thank the Norwegian engineers who contributed valuable knowledge and opinions to the project, through surveys, different gatherings and working groups.

The tools and calculation charts are being used by NITO internally, and in the national public debate on energy and climate.

Norway facts	
Population (2008)	4.8 million
Area	324,000 km²
Total GHG emissions (2007)	45 Mt CO_2eq.
Future Climate GHG emissions proposal	**2015**: 40 Mt CO_2eq. **2030**: 25 Mt CO_2eq. **2050**: 10 Mt CO_2eq.
National Targets	**2020**: 30 % reduction **2050**: "carbon neutral"

Institution of MECHANICAL ENGINEERS

Summary of National Report from the Institution of Mechanical Engineers, UK

Targets

The UK national commitment in support of the Global Objective of limiting the average global temperature rise to within the guideline of 2°C, is to reduce the UK GHG emissions to 80% of the 1990 level of 779 Mt CO_2eq. by the year 2050.

The IMechE Future Climate report proposes that the total UK primary energy supply is targeted to reduce by at least 48% by 2050 (compared to 2006). The remaining supply must move to zero-or-low-carbon sources to achieve a proposed overall 89% reduction in UK GHG emissions, relative to 2006. This equates to a 90% reduction in UK GHG emissions relative to 1990 levels. It is so set to reflect the degree of over-planning and over-design necessary in risk management to ensure that implementation is robust enough to meet the project target of an 80% reduction. This is an important aspect of our plan. A plan conceived to exactly meet the target inherently carries the risk that if one technology does not deliver on time, or at the performance that was anticipated, then the target will be missed.

Measures

The 48% reduction in primary energy supply will be made by

- Improvements in vehicle efficiency and a modal shift from road and short-haul air, to rail and sea, resulting in a 50% reduction in transport energy use.
- Significantly reducing (space) heating demand, by using much improved thermal insulation and much improved heating systems. Also, widespread use of more efficient electrical devices, resulting in a 50% reduction in building energy use.
- Improving power generation efficiency, especially to capture both heat and power from new-built facilities.
- Reducing industrial demand in a continued shift away from heavy manufacturing, and making efficiency improvements to reduce energy consumption in the remaining sectors.
- Changes in agriculture leading to less processing and transport, with more emphasis on local supply.

Reductions in emissions will also be achieved by

- Converting transport largely to electric vehicles, reducing overall transport emissions by 90%.
- Switching primary energy supply from 91% fossil fuel to 69% low-carbon or renewable sources (oil and gas use is cut 90% by 2050, and coal use is more than halved).
- Developing and using carbon capture and storage (CCS) for all large-scale fossil-fuel power generation, and fossil-fuel intensive process plant, e.g. steel and cement.

- Major investment will be required to improve the electricity distribution grid, set up local heating networks, and encourage new clean energy sources. Increased water-pumped and other electricity storage capacity will be needed to cope with the inherently greater intermittency of renewable sources. HVDC grid connections to other EU countries will be significant in allowing better management of the grid.

Main Findings and Recommendations

The plan will require government placing and maintaining stable long-term policies that create investment environments in which commercial organisations can confidently commit to invest in the technologies and infrastructure necessary for meeting the target.

Training skilled people to fill newly-created jobs for the new 'green' economy will be a major issue requiring national leadership.

Public engagement will be needed to help drive the change in our eating, food sourcing, heating and transport expectations.

Key programmes of work are already underway in the UK to enable some of the new technologies of Carbon Capture and Storage (CCS), Electric and Improved Efficiency Vehicles, and Smart Metering of buildings – but more initiatives are needed.

CCS, or some alternative technology to allow clean coal power generation, may be the most crucial technology in achieving global GHG reduction. This is due to the widespread availability and low cost of coal, and it's key position in generating energy in many countries, including China, the USA and Germany.

EU passenger transport emission targets need to be tightened overall, leading to a target 30 gm/km in 2050, and emission targets also applying to Freight vehicles. Greater use of local sea freight should be encouraged to help to reduce emissions from road freight transport.

International agreement on reducing power plant sector emissions would be a major step in advancing the international reduction of GHG emissions.

The reward is not only a climate under control, but major business opportunities flowing from the new technologies needed. In essence we need nothing short of a second industrial revolution. The UK is extremely well-placed to take advantage of this opportunity.

Acknowledgements

A large number of people from both the IMechE and other institutions have formed a working group and contributed to this Report. After initial Working Group discussions, the report was assembled by the lead author, Brian Cox, and then subjected to peer review by other members of the team and by IMechE staff. We would particularly like to thank Alison Cooke for her enthusiasm in driving this project forward. Positive UK Government thinking on Climate Change mitigation has resulted in many useful documents, which have been referred to and acknowledged in the main report.

United Kingdom facts	
Population (2008)	61.9 million
Area	244,820 km^2
Total GHG emissions (2007)	630 Mt CO_2eq.
Future Climate GHG emissions proposal	**2015**: 570 Mt CO_2eq. **2030**: 257 Mt CO_2eq. **2050**: 75 Mt CO_2eq.
National Targets	**2020**: 514 Mt CO_2eq. **2050**: 156 Mt CO_2eq. maximum

Future Sources of UK Electricity Generation

GW output capacity	2006	2015	2030	2050
Net Imports	1	1	3	10
Hydropower	1	1	1	1
Geothermal	0	0	0	0
Biomass	2	2	9	12
Wind	1	7	27	40
Solar Heat	0	0	1	3
Waste	3	4	6	3
Wave and Tidal	0	0	6	11
Photovoltaic	0	0	2	6
Nuclear	10	8	20	25
Coal	26	20	17	11
Gas (e)	50	50	13	5
Total				**127**

Coal and Gas CCS from 2030
Imports include solar power from abroad.

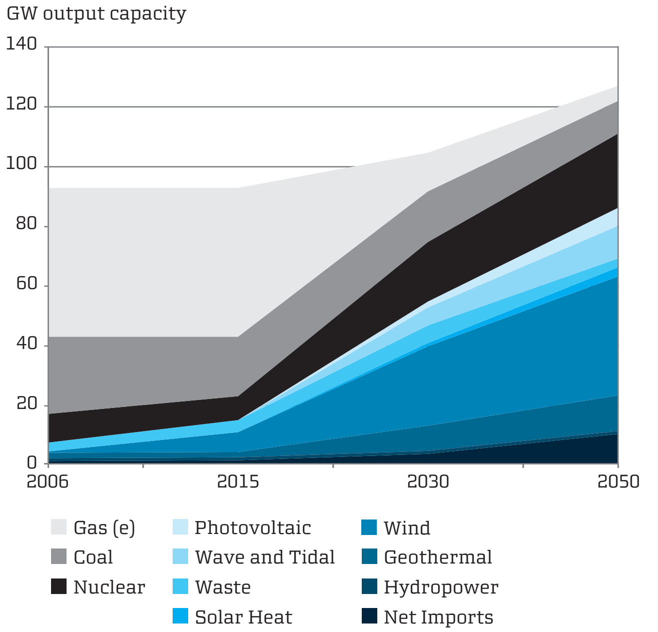


Figure UK-2: Future Sources of UK Electricity Generation

Summary of the Climate Plan for India

The purpose of the project "Technological Solutions and Climate Plan for India" is to develop the technology-based climate plan for India, to present the sustainable, clean/green technologies & measures, and the requirements for developing these technologies & measures. This project also details the implementation of environmentally-friendly technologies in India. The project includes the National Action Plan for Climate Change (NAPCC), and national goals for climate change mitigation or adaptation.

"Technological Solutions and Climate Plan for India" is a project supported by The Institution of Engineers India (IEI), in partnership with The Danish Society of Engineers (IDA) Copenhagen, Denmark. Ten other Engineering Associations worked on 'Technological Solutions and Climate Plan' for their countries.

Targets

India, being a developing country, has no binding targets under Kyoto Protocol.

Main findings

A vision up to the year 2031 is provided by The Government of India: therefore the authentic data up to 2031 is provided. Data for year 2050 is only an extrapolation based on 2031 in BAU scenario. A comparative analysis and key results, across all the scenarios, are presented in summary. It also provides deeper insight into the variations of the final energy and end-use consumption mix, under alternative sets of assumptions.

This project focuses on clean technologies so, therefore, technologies for 4 selected sectors are listed:

Carbon dioxide or equivalent emissions from selected sectors for the year 2001, in millions of tonnes, are approximately:

1. Power	:	789.00
2. Construction	:	29.40
3. Transportation	:	19.80
4. Agriculture	:	328,081.00

India is the second-largest populated country in the world, and it is counted under top four emitters in the world in absolute terms. However, per capita emissions' rank is 137th in world. Currently, globally, per capita emission (PCE) is 4.48 tonnes CO_2 equivalent per year. India's PCE is around 1.2 tonnes per year, while the average of the Annex-1 countries is 10 tonnes.

Energy efficiency in all sectors is identified as the best approach and cost-efficient method for climate change mitigation. Clean technologies in all selected sectors that can be implemented at present or that are in the R&D stage and will be available within the next few years, are listed in the project.

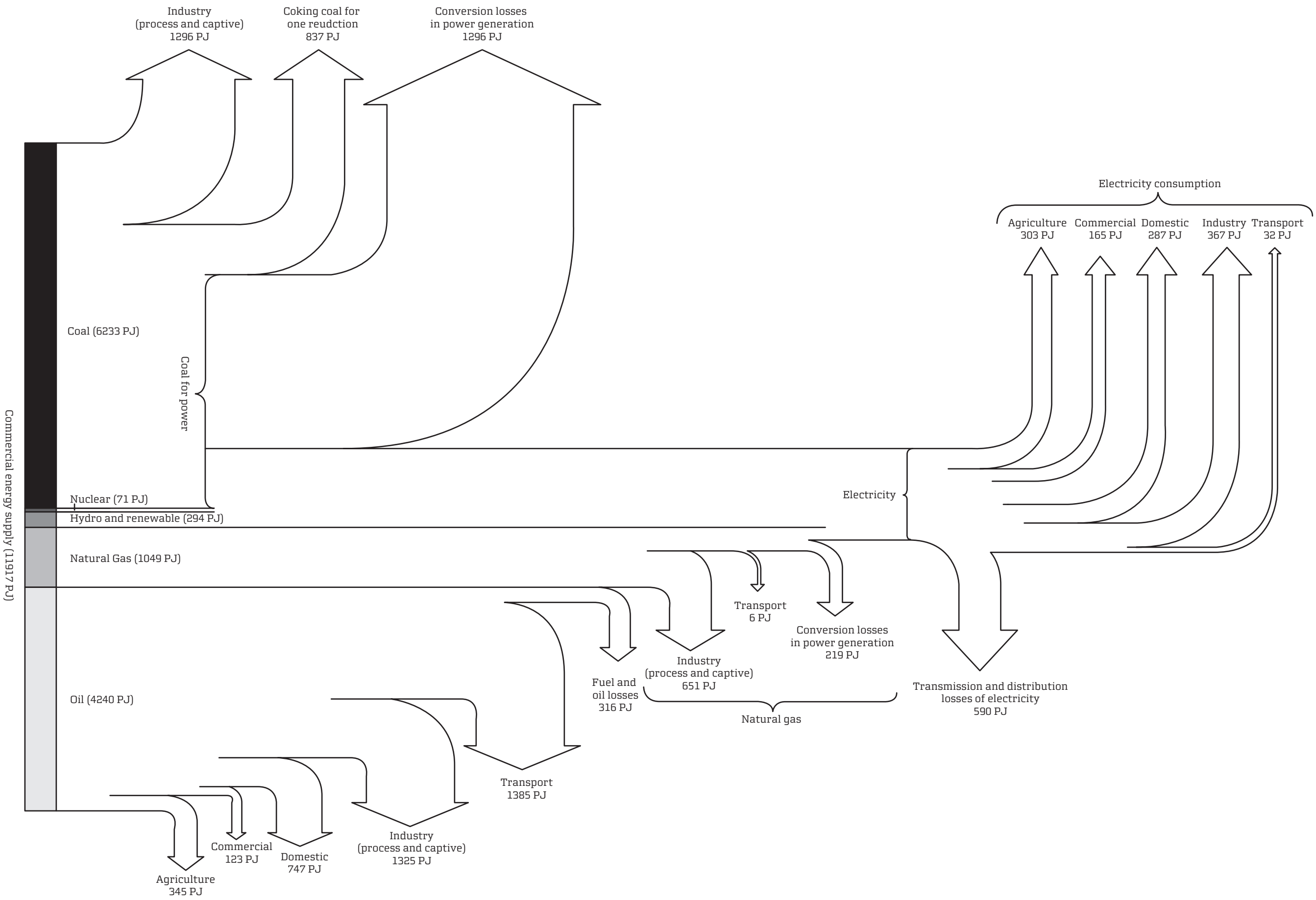


Figure India-1: Sankey diagram for the business-as-usual scenario (2001)

The country hopes to continue its efforts to provide electricity to rural areas, and to eliminate poverty.

The diagrammatic representation of the detailed energy balance for BAU scenario in 2001 and 2031 is provided through the Sankey diagrams.

Conclusions & Recommendations

- India, being a developing country, does not have any binding targets under Kyoto Protocol.
- 40% of the population does not have electricity connection, and about 300 million people live in abject poverty: therefore, the provision of food is a priority, whereas implementation of clean technologies takes a lesser position.
- All the growth and development is based on energy. India cannot cap the emissions, otherwise its growth process will be crippled.

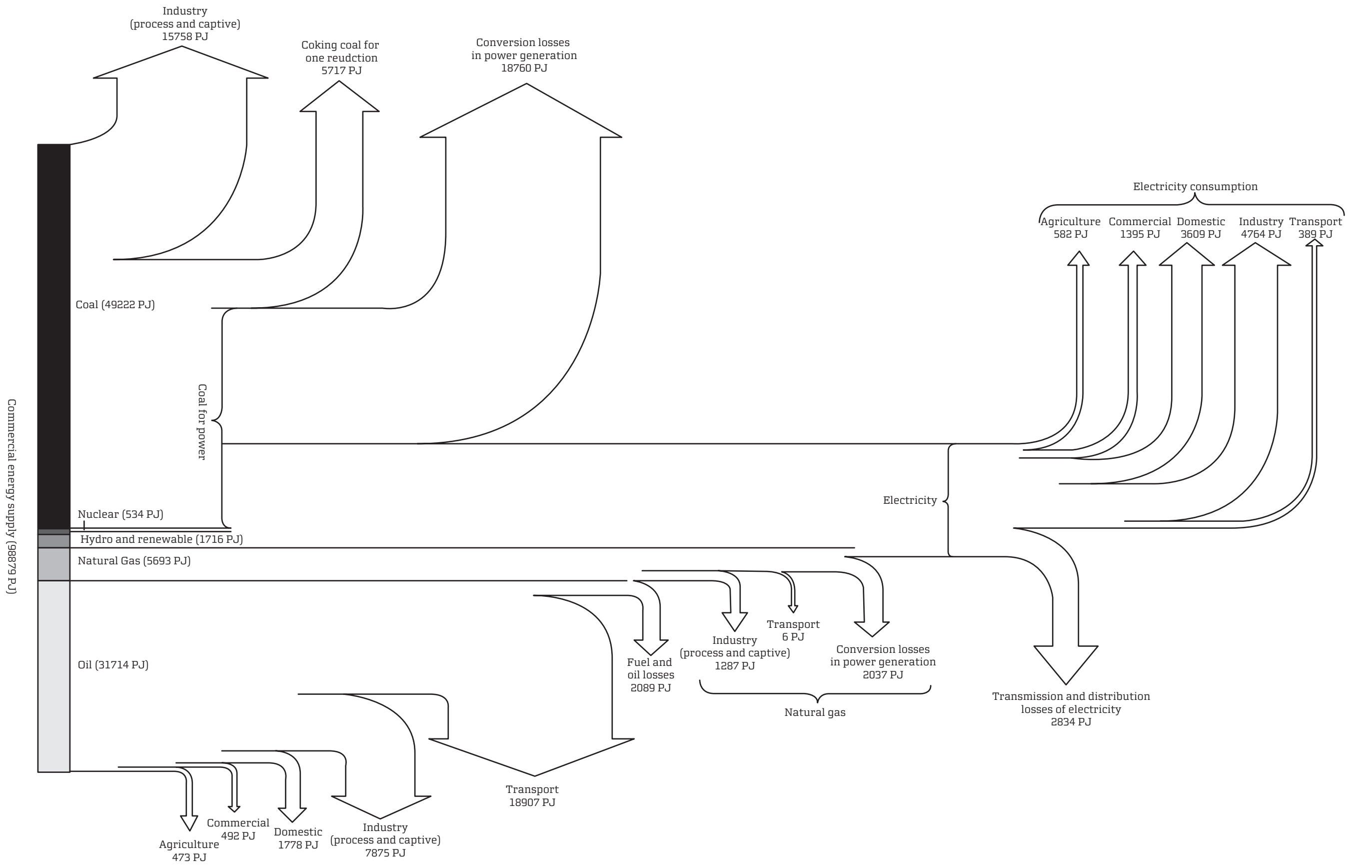


Figure India-2: Sankey diagram for the business-as-usual scenario (2031)

- India will continue its development as per the current BAU status. Sustainable development practices can be adopted for sectors, i.e. Power, Construction, Transportation and Agriculture.
- Major steps that can be implemented for climate change mitigation in developing and developed countries are:
    - » Use of energy-efficient technologies and equipments
    - » Use of clean & green technologies
    - » Technology transfer
    - » Holistic approach for overall development – globally
- Energy efficiency is a measure that can be implemented for all lifestyles, as well as in the industrial sector.
- Additional financial requirements may be met by technology transfer or fund transfer by the developed countries. Technology transfer – modulus operandi is still to be finalized.

- Global warming and climate change are global concerns, and all countries need to work together on these issues. Therefore a "Holistic approach for worldwide development" should be taken into consideration. Now the developed countries may stabilize their development (i.e. emissions), while supporting the developing and less-developed countries to attain average living status.

- India is committed to deviation from the BAU trajectories they have provided; this is supported and enabled by financing, technology and capacity-building by developed countries.

- >85% reduction (from 2000 levels) will provide a high probability of preventing a 2 degree increase. A global effort is required for this, and India is in agreement and is committed to work towards climate change abatement. IPCC 4th Assessment report also suggests 85% CO_2 and equivalent gases emission reduction.

Acknowledgements

Experts from Power, Construction, Transport and Agriculture sector provided their expertise and recommended the measures for sustainable development, and formulating the Climate Plan For India.

High level technical inputs and guidance provided by Rear Admiral K.O. Thakre, President, IEI; Cdr A. K. Poothia, Secretary and Director General, IEI; Dr. V. Bakthavatsalam, Honorary Chairman cum Visiting Professor, Centre for Climate Change (CCC), ESCI; Dr. S. Nagabhushana Rao, Director, ESCI; Shri Pradeep Chaturvedi, Chairman, Indian Association for the Advancement of Science (IAAS) and Shri J.K. Mehata, GM, NTPC; Shri H.R.P. Yadav, Dy. Director, IEI, during the development of this project.

Centre for Climate Change, ESCI, is thankful to all the experts for their cooperation and immense support provided during the project.

India facts	
Population (2008)	1,028.7 million
Area	3,287,240 km^2
Total GHG emissions (2007)	1,164 Mt CO_2eq.
Future Climate GHG emissions proposal	
High Economic Growth (10%)	**2015**: 1691 Mt CO_2eq. **2030**: 2561 Mt CO_2eq. **2050**: 3427 Mt CO_2eq.
Low Economic Growth (6%)	**2015**: 1546 Mt CO_2eq. **2030**: 2043 Mt CO_2eq. **2050**: 2755 Mt CO_2eq.
Based on Prices	**2015**: 1612 Mt CO_2eq. **2030**: 2263 Mt CO_2eq. **2050**: 3187 Mt CO_2eq.
National Targets	India being a developing country and do not have any binding targets under Kyoto Protocol.

VDI

Summary of the VDI Report for Germany

Targets

In this VDI study various scenarios were investigated, regarding which technical possibilities could be used, and which measures should be taken to reduce energy-related CO_2 emissions by 50% (or even 75%) from 2005 up to 2050. The boundary conditions were chosen by a VDI Committee from reliable forecasts, including modest economic growth and a slightly decreasing population in Germany.

The following technical opportunities by which to reduce CO_2-emissions in Germany today have been identified:

- Efficiency measures reducing conversion losses and final energy consumption (FEC);
- Use of locally available biomass in all sectors;
- The use of wind and nuclear energy in the generation of electricity.

Measures and Main Findings

- Industry must, in all scenarios, lower its FEC by 30%, despite a production increase that will be 180% higher than at present.
- Residential and commercial sectors have to reduce their fossil energy consumption by more than 50%. This will be achieved through better insulation. The annual energy demand of existing housing should be lowered to 60kWh/sqm, which is about 1/3 of current demand.
- While personal transportation will remain constant, cargo will nearly double by 2050. Nevertheless, transportation's FEC has to be reduced by 15%. The CO_2 emission of car fleets must be reduced below the 120g/km threshold.
- Cost-attractive solutions have to be developed in order to increase the share of bio fuel and electrical energy for cars, such as 2nd generation bio fuel and battery systems
- No significant reduction in power consumption is to be expected, despite high saving potentials in industrial drives and household appliances. However, nearly all energy efficiency efforts lead to higher power consumption.
- The fluctuating input of growing, renewable power such as wind and photovoltaic has to be balanced within the EU grid by reliable power sources such as biomass, fossil and nuclear power stations. This must also be supported by storage systems and demand management.

Recommendations

- The huge challenge of GHG reduction, without energy shortage, can only be achieved during the coming decades by better technologies and improved engineering solutions. It requires that all available technologies supporting this objective in energy supply and use have to be developed further.
- With the technologies available today, the cost of CO_2 reduction rise very strongly beyond 50%. The VDI therefore recommends to strongly subsidize energy research, in order to widen the field of available technologies, thereby battling the expected cost increase.
- Subsidizing development and market introduction of new technologies is advocated, but this should not turn into a continuous subsidy of supply, burdening the economy
- Measures to minimize the demand for transportation should be investigated, and how to substitute road transport and local air transport with rail transport.
- The efforts of GHG reduction must be considered, together with the objectives of security, the economics of energy supply, environmental and social compatibility, as well as securing a competitive economy and job situation. Migration of production is not a viable global solution.
- A reduction of GHG emissions beyond 50% can not be achieved without nuclear energy. Therefore the present nuclear capacity has to be maintained. Between 2015 and 2020 decision can be made about whether building new reactors is needed or whether nuclear power can be substituted by regenerative sources.
- Results of the climatologic research have to be validated continuously to provide a solid base for ongoing political decisions.
- GHG Reduction has to be optimized across borders; financial means have to be directed to those countries where maximum effects can be achieved.

Acknowledgements

This project was elaborated by a VDI committee with support of the Institute of Energy Research at Jülich Research Centre.

Thanks are given also to the management of the VDI e.V. for financially supporting this project.

Germany facts	
Population (2008)	82.1 million
Area	357,104 km²
Total GHG emissions (2007)	826 Mt CO_2eq.
Future Climate GHG emissions proposal	**2015**:670[1]-750 Mt CO_2eq. **2030**:434[1]-600 Mt CO_2eq. **2050**:271[1]-400 Mt CO_2eq.
Achievable percentages[2]	**2015**: 9% - 19%[1] **2030**: 27% - 47%[1] **2050**: 52% - 67%[1]

1) Values for nuclear power extension
2) Basis 826 Mt/a (2005)

The Strategy of Japan Society of Mechanical Engineers (JSME)

Targets

The most essential principle in engineering solutions and recommendations for UN COP 15 would be to do our best to reduce the emission of carbon dioxide, not only in Japan but also all over the world. We should concentrate all our efforts on research to realize challenging energy technologies; the development and the wide application of high efficiency energy systems; and the estimation and evaluation of future improvement of energy efficiencies and emerging technologies. Consequently, producing various kinds of promising energy technologies; innovative improvement in the energy efficiency of the various energy systems; and reliable estimation of the financial 'payback period' of energy systems would be our foremost targets by which to accelerate the prevention effect for global warming.

Measures

In our role as the Academic and Engineering Society of JSME, we should stress the following important activities:

- To evaluate the technological innovation correctly in the near future, we should continue to produce engineering technological roadmaps (JSME Technology Roadmaps for Sustainable Society) and disseminate them all over the world, to promote the necessary researches of challenging energy technology, to promote quantitative discussions of energy usage and CO_2 emissions, and to accelerate the prevention effect for global warming.
- We should produce the quantitative engineering data of energy usage and CO_2 emission and promote the discussion about the importance of various activities of our daily life and various kinds of engineering industries.
- We should produce various kinds of quantitative estimations, such as economical payback period of energy technologies; quantitative CO_2 emission reduction; and the amount of energy saving and necessary total budget of energy policy.

Hence, we should contribute to reducing the amount of energy usage and the CO_2 emission as much as possible. We can do this by disseminating the JSME Technology Roadmap for Sustainable Society and related engineering data and economical estimations, which would be extremely useful measures to provide the engineering solutions and recommendations.

New findings

The systematic organization of JSME Technology Roadmaps for Sustainable Society has been produced over several years by various engineering divisions of JSME.

Two good results have been obtained in the discussions by combining several technological roadmaps as the new findings.

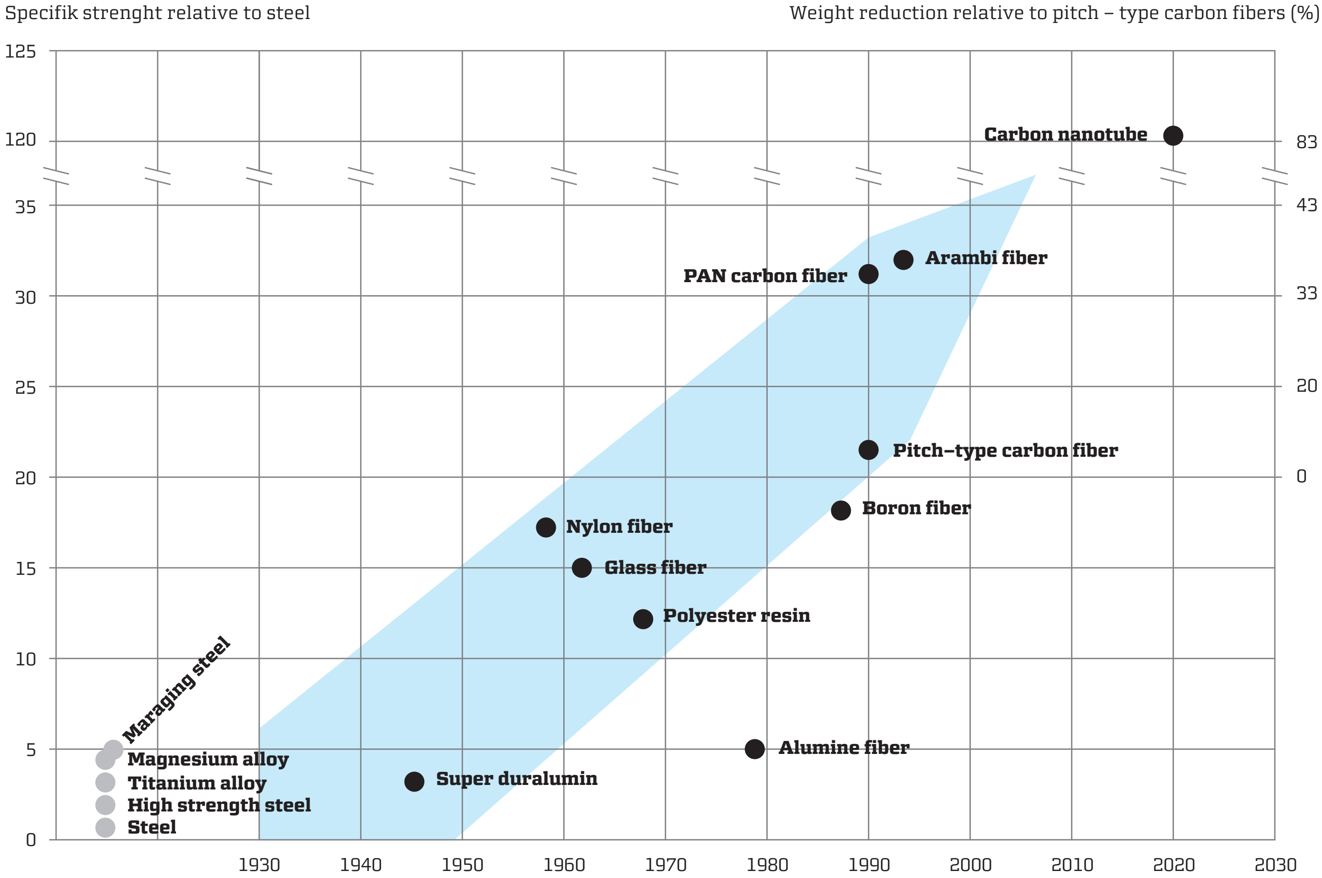


Figure JSME-1: JSME Technological Roadmap for Specific Strength of Materials

- Energy Usage and CO_2 Emission Reduction for Automobiles
  According to the JSME Technology Roadmaps, there would be several improvement factors for the reduction of CO_2. Fig.1 shows the specific strength of materials, and new materials such as Aramic fiber would be useful to reduce the weight of automobiles. As shown in Fig.2, the thermal efficiency of engines has been increased gradually by many kinds of technological breakthroughs. Furthermore, the average travelling speed has been increased by improving traffic-control technology. The total potential amount of CO_2 reduction would be 100Mt/year, and the most effective method would be increasing the speed of travel.

- Energy-Saving for Air-conditioning and Hot Water Supply, by Utilizing High Efficiency Heat Pump Systems. Fig.3 shows the roadmap of heat pump hot water supply systems, which demonstrates that the COP of supplying hot water would have the value of 5 or higher. By considering the efficiency of about 40% of electric power generation, over twice the total heat released by combustion could be used for heating and hot water supply, by utilizing high efficiency heat pumps. Thus, the use of high efficiency compression heat pump systems would be effective for reducing the CO_2 emission. The CO_2 reduction potential to replace the boiler, heater and absorption heat pumps would become the order of 200Mt/year. This value would be over 10% of the total CO_2 emissions in Japan.

Recommendations

Our role would be to do our best to promote energy saving, and reduce CO_2 emissions, and therefore we recommend the following:

- By utilizing our engineering specialty we should produce reliable technology roadmaps for estimating the future technological performance; for selecting the future energy and environmental policy; and for accelerating the prevention effect for global warming.
- By presenting comprehensible engineering data of energy usage and CO_2 emission in public, we should promote the quantitative discussion for accelerating the reduction of the CO_2 emission, which would assure enjoyable daily activities of members of our global community also in the future.

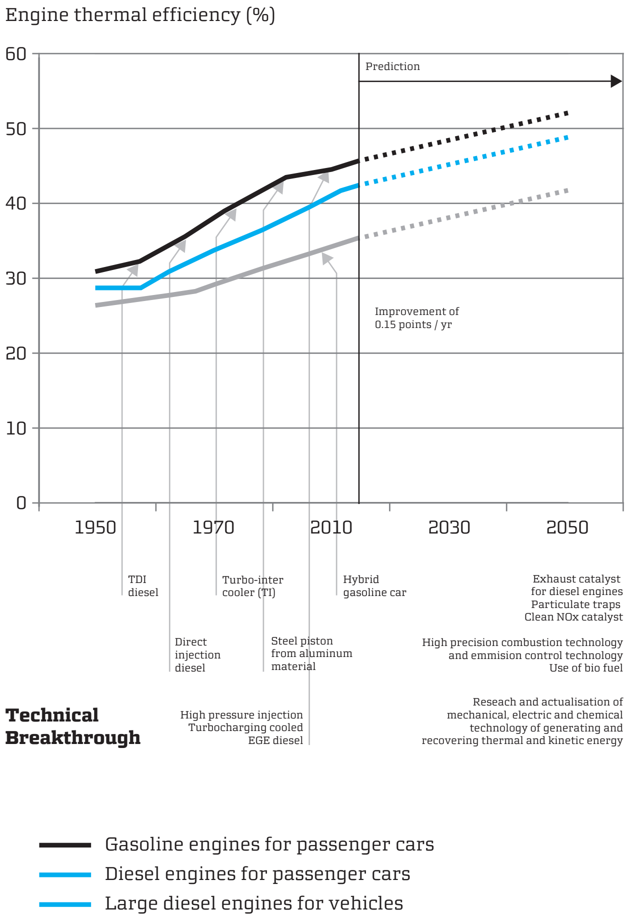
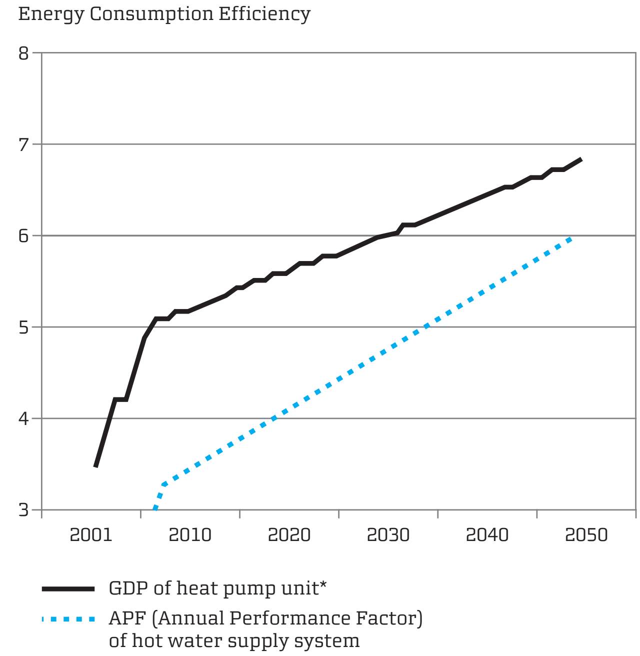


Figure JSME-2: JSME Technological Roadmap for Thermal Efficiency of Engines

Japan facts	
Population (2008)	127.8 million
Area	377,923 km²
Total GHG emissions (2007)	1,371 Mt CO_2eq.
Future Climate GHG emissions proposal	**2050**: 50% compared with 2007



* Rated heating condition
Outdoor temperature: 16°C DB/12 °C WB
Teperature of cold water supply: 17°C
Temperature of outgoing hot water: 65°C

Figure JSME-3: JSME Technological Roadmap for Heat Pump Hot Water Supply System (Trends of COP & Technical Breakthrough)

Technical breakthrough	
2007~2010	
	Development of CO_2 refrigerant Heat Pump Water Heater
4	High-efficiency ejector cycles
5	Optimum design of high-efficiency Small-size DC motors
6	SiC power devices
9	Vacum heat insulators
13	Utilization of underground heat
2010~2020	
1	High-efficiency refrigerant circuit design technology
6	High-efficiency matrix converter
12	Exhaust heat recovery
10	Load forecast control
13	Using solar heat panels together
1	Advanced refrigerant control technology
2	Further size reduction using surface tension
3	Micro-channel type heat exchangers
4	Power recovery compressors with integrated expanders
13	Decompressed-boiling solar panel evaporators
2020~2030	
1	Development of new refrigerant
5	Next-generation sensor-less PM motors
9	High-density thermal storage and latent thermal storage
1	Water refrigerant double-bundle condenser hot water supply systems (heat recovery systems)
12	Heat recovery from wastewater

Summary of The Climate Plan for USA

Founded in 1880 as the American Society of Mechanical Engineers, ASME is a 127,000 global member professional organization focused on technical, educational and research issues of the science, engineering, and technology community. Our organization has long advocated for a balanced energy portfolio for our nation and the world.

Summary

The technology recommendations set forth in the position paper are intended to provide an engineering perspective to the public policy debate on carbon mitigation and climate change adaptation in order to realize the substantive goals of revolutionizing the carbon footprint of electricity, reinventing the transportation sector, transforming the buildings sector, promoting more sustainable industry, and empowering innovation to drive breakthrough technologies.

The paper was developed by a task force of ASME's Knowledge and Community Sector, with Dr. Landis Kannberg as chair.

Some of the technology recommendations contained within the document include:

- Resolving nuclear waste management, closing the nuclear fuel cycle, and streamlining regulatory approval of safe, secure, next-generation nuclear power plants.
- Accelerating the development of electric vehicles as well as an advanced electric grid capable of energy storage in order to better accommodate this technology with renewable electricity.
- Enhancing electric transmission and distribution, and developing and deploying the "smart grid."
- Accelerating development of alternative propulsion technologies, including more efficient engine and power trains concepts and systems, such as those employing renewable fuels.
- Developing environmentally sustainable transportation fuels such as cellulosic ethanol, hydrogen fuel cells, algae-generated and other alternative fuels.
- Mandating development, demonstration, and deployment of codes and standards encouraging building construction and retrofit to enable the use of sustainable materials and highly energy-efficient architectural, equipment, and operating systems.
- Increasing generation efficiency, demonstrating environmentally sound carbon capture and storage (CCS) from coal and natural gas fired generation, and exploring revolutionary improvements in carbon-based fuel cycles.
- Increase research, development, and demonstration of methods to increase energy efficiency in building operations and integration of building equipment (including on-site generation) into the local energy infrastructure (particularly the electric grid).

- To view the ASME General Position Paper entitled “Technology Policy Recommendations and Goals for Reducing Carbon Dioxide Emissions in the Energy Sector” please look at *http://files.asme.org/asmeorg/NewsPublicPolicy/GovRelations/PositionStatements/17971.pdf*

Uusi Insinööriliitto

Summary of The climate plan for Finland

Targets

The methods enabled by technology play significant roles in our endeavour to achieve the reductions. The technology for reducing emissions exists. However, large inputs in research and product development are still needed.

The target of this assessment is to present measures to reduce the greenhouse gas emissions in Finland. Nationally-available solutions, and their effects on reducing emissions, have been studied during the course of the project. Because the problem is global, global methods are needed to solve it; but in this assessment the focus is on national solutions.

Measures

Securing the generation and availability of energy are matters of particular importance when considering Finland's climatic conditions. In this assessment we looked at the different energy-generating options, the proposals pertaining to them, and the effects on the overall situation.

This assessment is based on an estimate that total consumption of primary energy in Finland can rise to as much as 1700 PJ in 2030, and then take a downward trend. The use of fossil fuels will considerably diminish, becoming less than one third of its 2007 level. The most significant increase is in the share of nuclear power. Also the use of bio-energy will increase, reaching its peak in 2030.

In addition, the generation of wind-power and hydropower, the use of waste in generating energy, and the use of heat pumps will all increase. Net imports of electricity will gradually decrease, and by the year 2020 they will cease altogether. Figure 1 shows the estimated total consumption of primary energy during the period 2007 – 2050.

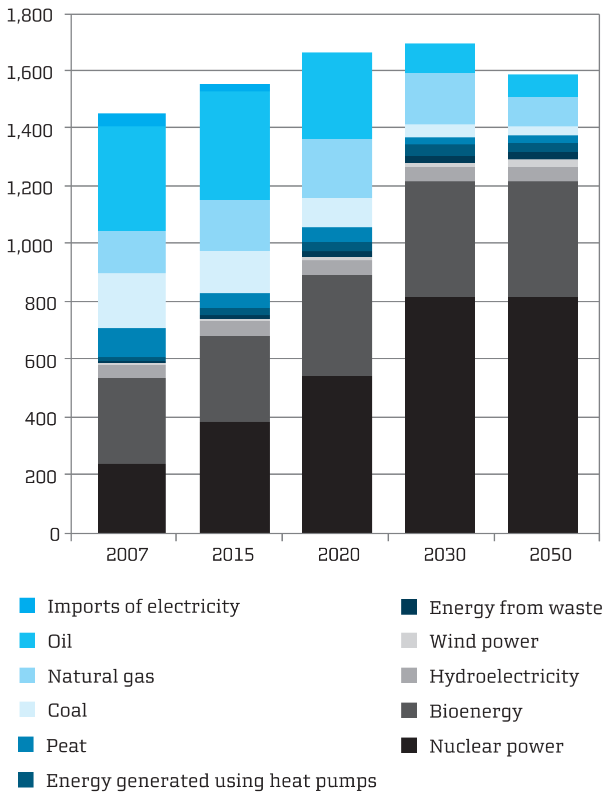


Figure Finland-1

Main Findings

Calculations indicate that the objectives set for climate emissions can be implemented, and that the technological means for doing so are available. The energy sector is the most significant source of emissions, and the solutions implemented in this sector will thus have the biggest impact on future emissions. By applying the recommendations and default values related to changes in energy generation, as presented in this programme, the energy sector's emissions will decrease by 73% from their 2007 level by the year 2050. Figure 2 shows the estimated trends in the total consumption of energy and the energy sector's CO_2 emissions during the period 1990-2050.

Other significant sources of greenhouse gas emission include industrial processes, agriculture and waste. The emissions of these sectors are not examined more closely in this connection.

Recommendations

In addition to the generation of energy, ways of using energy and improvement of energy efficiency are of decisive importance. The basic precondition for this development is, however, to achieve an acceptable and equal international emissions trade and sharing of the burden. Being able to maintain favourable development in Finland requires both the development of positive market-based incentives, as well as sensible use of mandatory regulation-based steering. Other essential requirements are large investments into research and development, and into education.

Regulations are being developed in the building sector. The aim in heating is – by means of tax incentives or regulations – to promote the use of emission-free forms of heating, e.g. heat pumps.

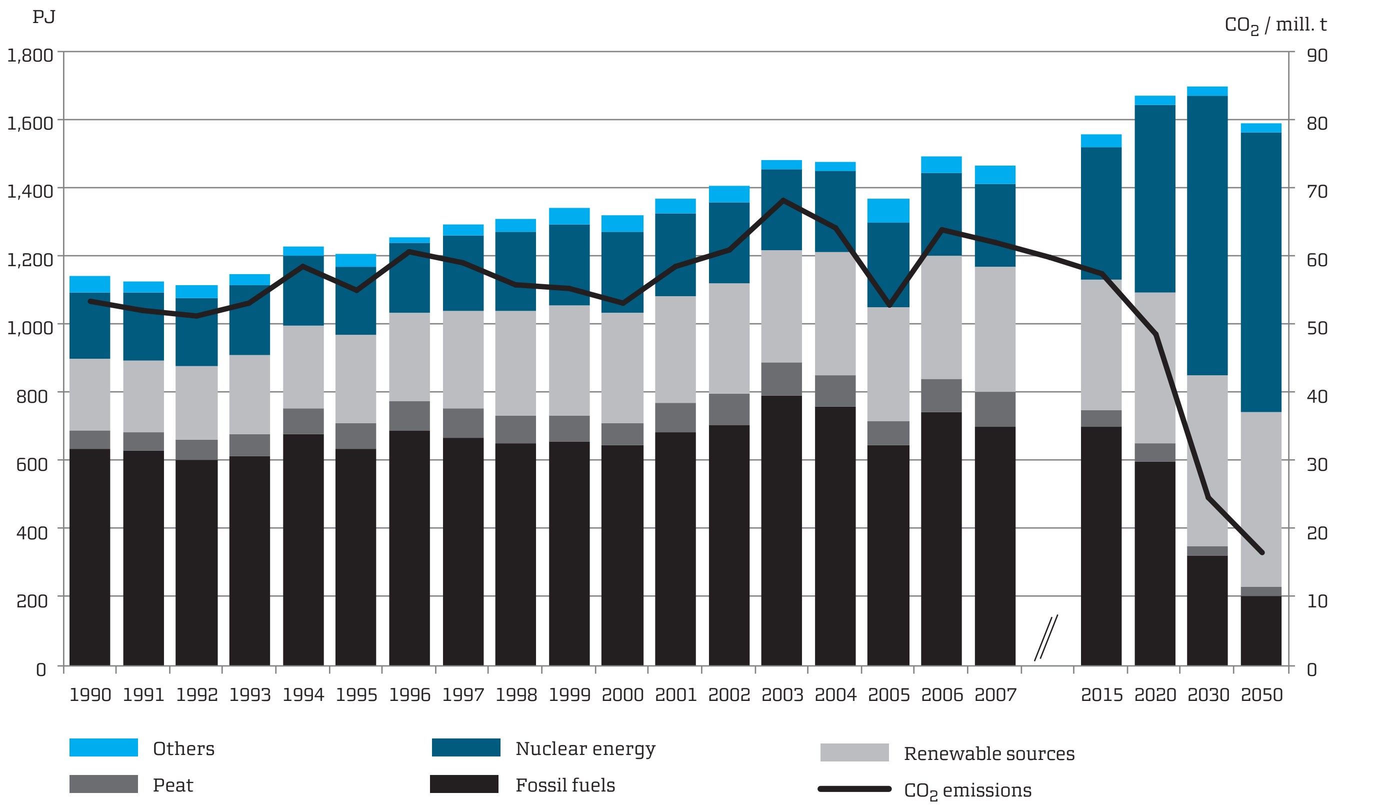


Figure Finland-2

Public transport is being developed to be more attractive to commuters. Taxation-related means are being applied to encourage motorists to shift over to low-emission vehicles.

Education is in a key position to ensure that skilled people will also be available in the future to develop technology. Expertise in sustainable development must be included in all education and training programmes in the field of technology, and this must be linked to core know-how.

The role of technological development is of decisive importance in the production and distribution of energy, as well as in its end use. Technology also creates possibilities for directing and influencing end users and consumers. For the objectives to be achieved, these possibilities must be fully utilised.

Finland facts	
Population (2008)	5.3 million
Area	338,145 km²
Total GHG emissions (2007)	78.5 Mt CO_2eq. of which the energy sector (emission caused by the use of fuels) 61.8 Mt CO_2eq.
Future Climate GHG emissions proposal	**2015**: 57.2 Mt CO_2eq. **2030**: 24.5 Mt CO_2eq. **2050**: 16.6 Mt CO_2eq. for energy sector (use of fuels)

Acknowledgements

Finland's contribution to the "Future Climate" project was drawn up by The Finnish Association of Graduate Engineers TEK, and Union of Professional Engineers in Finland (UIL). The key persons involved were Mrs Heidi Husari (UIL), Mr Pekka Pellinen (TEK) and Mr Martti Kivioja (TEK).

Numerous individuals representing universities, research institutions, ministries and branches of industry have contributed to the preparation of this programme, and they were interviewed in their capacity as experts at various points in time. Also, committees and the boards of both unions have contributed to processing the work.

As background material for the project, views on energy and climate matters were collected from members of TEK and UIL by means of a questionnaire.
In addition, a seminar open to the members was arranged.

Summary of the Climate Plan for Ireland

Engineers Ireland was invited to participate in the Future Climate: Engineering Solutions project in September of 2008. We participated in the initial conference, setting the Project Objectives and Protocols and have since then been preparing our input from an Irish Context.

It is the view of Engineers Ireland that this document and the Future Climate: Engineering Solutions project will not just form a snapshot of the engineering and technological solutions to the Climate Change challenge. The project should form a platform on which further and more detailed work can be completed in support of our national policy objectives and the implementation of EU Directives.

Targets

The objectives of this project and report were to produce a climate plan from a technological viewpoint. This would present the critical technological and infrastructural measures required to help Ireland contribute to the 2 degree climate change stabilization target. Engineers Ireland has adopted an approach whereby a 60% reduction in emissions would be required by 2050 to achieve a meaningful contribution to this target. With a 96% dependency on carbon-producing fossil fuels and an 89% dependency on imported energy in 2007, it is critical that we reduce both our overall demand, and develop alternative and indigenous primary fuel sources. All of this will hinge on our ability to address our position as an isolated country with limited electrical interconnectivity.

Measures

The primary measures that need to be examined in Ireland can be summarised as follows:

- Increased diversification of our generation portfolio towards lower carbon technologies.
- Our isolation with regard to energy interconnectivity needs to be addressed through a combination of interconnection and storage measures.
- Increased consideration of carbon in transport planning and the integration of biofuel and electrification into the Irish Transport Fleet.
- An Continued increase in efficiency in the built environment, considering not only individual measures but critically 'whole-building' approaches.
- Engineers need to continue to facilitate GHG emissions reductions in the Agricultural sector wherever poss

Main Findings

The main findings span a broad range of issues and can be summarized as follows:

- Ireland's dependency on external primary fuel is significant and needs to be addressed to facilitate both a greater security of supply and a greater degree of control over our GHG emissions.
- Ireland's isolation from a larger electrical network inhibits the penetration of renewable and alternative technologies into our generation mix. Our internal electrical transmission and distribution infrastructure and the potential for interconnection need to be addressed.
- The infrastructural additions required to facilitate the electrification of our transport fleet and an increased use of biofuels is likely to be significant.
- Electrical interconnection may not provide a complete solution for Ireland. Where this is the case, alternative forms of energy and electricity storage need to be examined.
- A range of renewable and alternative technologies will be required to provide a solution for Ireland's supply challenges, both with regard to security of supply and GHG emissions.
- Addressing energy efficiency and demand side management is likely to provide the most significant and cost effective GHG emissions reductions in the short to medium term (to 2030)

Recommendations

The primary recommendations of the Engineers Ireland Climate Plan are that:

- Ireland's internal electricity grid and external interconnection needs to be improved to facilitate the diversification of our generation portfolio.
- Energy and gas storage options need to be delivered and ultimately operate in tandem with interconnection to alleviate the problems associated with our isolated energy grid.
- All potential energy generation options should be considered from a technological and implementation viewpoint in the first instance. Following this exercise, a suite of options should then be subjected to policy review.
- The most cost and carbon effective method for transferring the Irish transport fleet over to less carbon intensive fuel sources needs to be defined.
- Engineers need to take a leadership role in the delivery of an overall carbon solution for Ireland.
- Engineers need to engage directly with Policy Makers, Land-use Planners and Environmental Stakeholders

Acknowledgements

Engineers Ireland would like to thank the project Initiators and project Partners for the opportunity to participate and will continue to engage with them up to and following COP15 in Copenhagen. Engineers Ireland would also like to thank the contributors to our report and the organisations whose previous reports and analysis supported our work.

Ireland facts	
Population (2008)	4.4 million
Area	68,889 km^2
Total GHG emissions (2007)	69.2 Mt CO_2eq.
Future Climate GHG emissions proposal	**2015**: 62.3 Mt CO_2eq. **2030**: 41.5 Mt CO_2eq. **2050**: 27.7 Mt CO_2eq.
National Targets	The current national Irish policy target for CO_2 emissions is to cut GHG emissions by 20% compared to 2005 emission levels by the year 2020. This will be supported by an aspiration to increase the share of renewals in our generation portfolio to 20% and also to deliver 20% energy efficiency savings by 2020.

Sveriges Ingenjörer

Summary of The Climate Plan for Sweden

Targets

All in all, there is great potential during the short term, as well as towards 2050, to reduce Sweden's climate impact. Also, several Swedish technologies could contribute, globally, to limiting the temperature increase to 2 degrees centigrade, compared with the pre-industrial level. The government's goal is to gradually reduce GHG emissions, so that by 2050 we will have no net emissions. Due to our substantial uptake of carbon dioxide, this can be interpreted as a rather modest goal. We believe that the target could be even more ambitious: no use of fossil fuel for transportation at all in 2050.

Measures

The Swedish Association of Graduate Engineers has presented information about the Future Climate project on our website. There is also a short description, and some questions related to the current developments in different areas of technology. We have also sent questions directly to knowledgeable people in different fields. This way we have gained valuable information. The estimate of the key issues, and the desirable progress of sectors and technologies, is made by the authors of the national report. This has been supported by analyses from, among others, the Swedish Energy Agency and the Swedish Environmental Protection Agency. We have also established the web forum Energibruket, in the effort to engage engineers for energy efficiency.

Main Findings

First and foremost we want to emphasize the potential for improving energy efficiency, and we foresee great potential in almost every field. Even if major enterprises have been working on the issue, there are still simple steps to be taken that would pay-off over the short term. Small and medium-sized industries have not yet tackled the issue systematically. Reduced energy costs are an incentive per se. Change is accelerated, however, if low-energy consumers will have an instrument of control similar to the one providing the energy-intensive enterprises with tax reduction opportunities. Furthermore, enterprises could often be aided by external individuals looking at their activity in an unbiased way. Through the initiative Energibruket, the Swedish Association of Graduate Engineers wishes to draw attention to technology and ideas for improved energy efficiency.

To a large extent our production, as well as our consumption of electric energy, will be affected by political resolutions on nuclear power during the coming years. If we choose to replace all existing reactors as they grow older, we will have a large surplus of electricity that could be exported. However, if we choose to phase out nuclear power completely, we will have to improve energy efficiency considerably in order to attain self-sufficiency of electric power. In any case, renewable electricity production will continue to grow during the first stage from wind-power and bio-energy. We envisage great potential for Swedish know-how in hydroelectric and nuclear power playing an international role, and also for contributions to wind, sea-wave and solar energy.

In the transportation sector, the future of Volvo and Saab is highly essential for our prospect of being conducive in technological progress. Continued survival for the two manufacturers of passenger cars requires continued adjustment to a market that will, increasingly, demand solutions with low climate impact. Should Volvo and Saab succeed with the conversion, and if their new owners will allow development and manufacturing to remain in Sweden, they will be important evolutionary pacemakers for a multitude of Swedish technologies in the vehicle sector. In the current financial situation, Volvo Trucks and Scania are encountering problems; but strong positions in ecological adaptation will enable them to join and even lead the global development of heavy vehicles.

Since Sweden generally has no production of electricity from coal-fired power plants we have not, like Norway, ventured into capturing and storing carbon dioxide. The Swedish electricity producer Vattenfall is, however, involved in a pilot project in Germany; moreover, research and some experimental activity takes place in Sweden. What might be of immediate interest is a Swedish effort in this field, concentrated on developing solutions for capturing and storing carbon dioxide. This would derive either from industries whose processes inevitably generate carbon dioxide, or from emissions using biomass.

The Swedish housing sector is characterized by the fact that, at an early stage, we reduced our dependence on oil; we chose instead, to a large extent, to use electricity for heating. This technology was chosen at a time when electricity was cheap in Sweden. District heating has also been expanded, but since Sweden has a large area and a small population, a comparatively large proportion of Swedes live in small houses in regions where district heating is not profitable. Occasional low-energy houses were built in Sweden as early as 25 years ago, but the technology has never enjoyed large-scale breakthrough. The reason is not a lack of technology, but rather the absence of collaboration between operators in the construction process, and an inability of holistic views to break through traditional standpoints on buildings and use of dwellings.

Sweden has an extensive basic industry which is a major energy consumer. Access to electricity at competitive prices is an essential condition for the survival of these enterprises. To the extent that these enterprises move or close down, corresponding operations will be run somewhere else in the world, where environmental requirements are probably lower. Thus, the global environment would not gain if activities in Sweden were driven out of business. Basic industries, in many ways, endeavour to make their operations more efficient; by international comparison they have come far on the road to sustainable products and processes. Besides the basic industries, Sweden possesses an extensive manufacturing industry, to a large extent developing products which, when used, are conducive to reduced environmental impact.

Recommendations

- One of the most important things is to support energy efficiency in all sectors of society, including instruments of control for small and medium-sized companies.
- We strongly support the growth of renewable electricity production, mainly from wind and biomass, but to an increasing extent also from wave and solar energy. Swedish technology can endorse global development in some fields, but it requires cooperation between established and new companies, university research and supportive public funding.
- We must find ways for Swedish know-how in the transportation sector to be maintained and developed further. This will prove beneficial for the environment.
- Sweden should develop technologies for capturing carbon dioxide from industrial processes and from using biomass.
- We must also strengthen the collaboration between the operators in the construction process in the housing sector.

Acknowledgements

We would like to thank the Swedish engineers, who found interest in the information about the Future Climate project on our website, and who contributed with valuable knowledge and opinions.

Sweden facts	
Population (2008)	9.3 million
Area	449,964 km^2
Total GHG emissions (2007)	51 Mt CO_2eq.
Future Climate GHG emissions proposal	Faster pace and more ambitious target possible.
National Targets	Gradually towards no net emissions in 2050.

STRENGTH THROUGH KNOWLEDGE

Summary of the IDA Climate Plan for Denmark

Over the past 20 years, Denmark has experienced relatively stable greenhouse gas emissions. The IDA Climate Plan 2050 wants to speed up the Danish reductions.

Targets

The Danish government's vision is for Denmark to become independent of fossil fuels in the long term. As a step towards achieving this vision, Denmark is striving to reduce its greenhouse gas emissions. Under the Kyoto Protocol, Denmark has committed to reducing its emissions of greenhouse gases by 21% in the period 2008-2012 relative to the 1990 level.

The IDA Climate Plan 2050 describes the way in which Denmark can reduce its greenhouse gas emissions by 90 % by 2050. The plan is a simultaneous description of the way in which investments in technology and infrastructure can help Denmark develop into a modern society, based on sustainable energy sources and efficient utilisation of all available resources.

Main findings

Wind turbines and biomass constitute the backbone of the IDA Climate Plan 2050 that is based solely upon sustainable energy. In 2050, Danish greenhouse gas emissions will originate largely from agricultural production and emissions that are linked with food consumption.

The IDA Climate Plan 2050 emphasises cost-effective solutions, which means that energy streamlining and more efficient utilisation of nature's resources constitute a cornerstone of the plan. All in all, the plan looks at Danish energy consumption being reduced to 707 PJ by 2015, to around 556 PJ by 2030, and to around 442 PJ by 2050.

There are good opportunities to reduce the impact on the climate from Danish production and consumption of foods. Climate Plan 2050 looks at reducing greenhouse gas emissions from agriculture and food production by around 50% by 2050.

Measures

In The IDA Climate Plan 2050, 60-65% of the electricity production is based on wind power. The majority of the combined heat and power production is based on biomass and waste, and thus constitutes the stabilising element of an otherwise fluctuating energy production. The remaining electricity and combined heat and power production are based on solar cells, wave power, geothermics and solar heat.

The energy consumption in buildings and homes are markedly reduced through a combination of energy savings, the integration of sustainable energy, and the development of district heating. Denmark currently has the world's most stringent energy requirements for buildings, but it will still be necessary to sharpen those requirements.

A significant reduction in transportation climate emissions is necessary, and means that all known tools and technologies must be brought into play. This includes reducing climate emissions from individual forms of transport, changing transportation work and planning, and urban densification that can reduce transportation work as such.

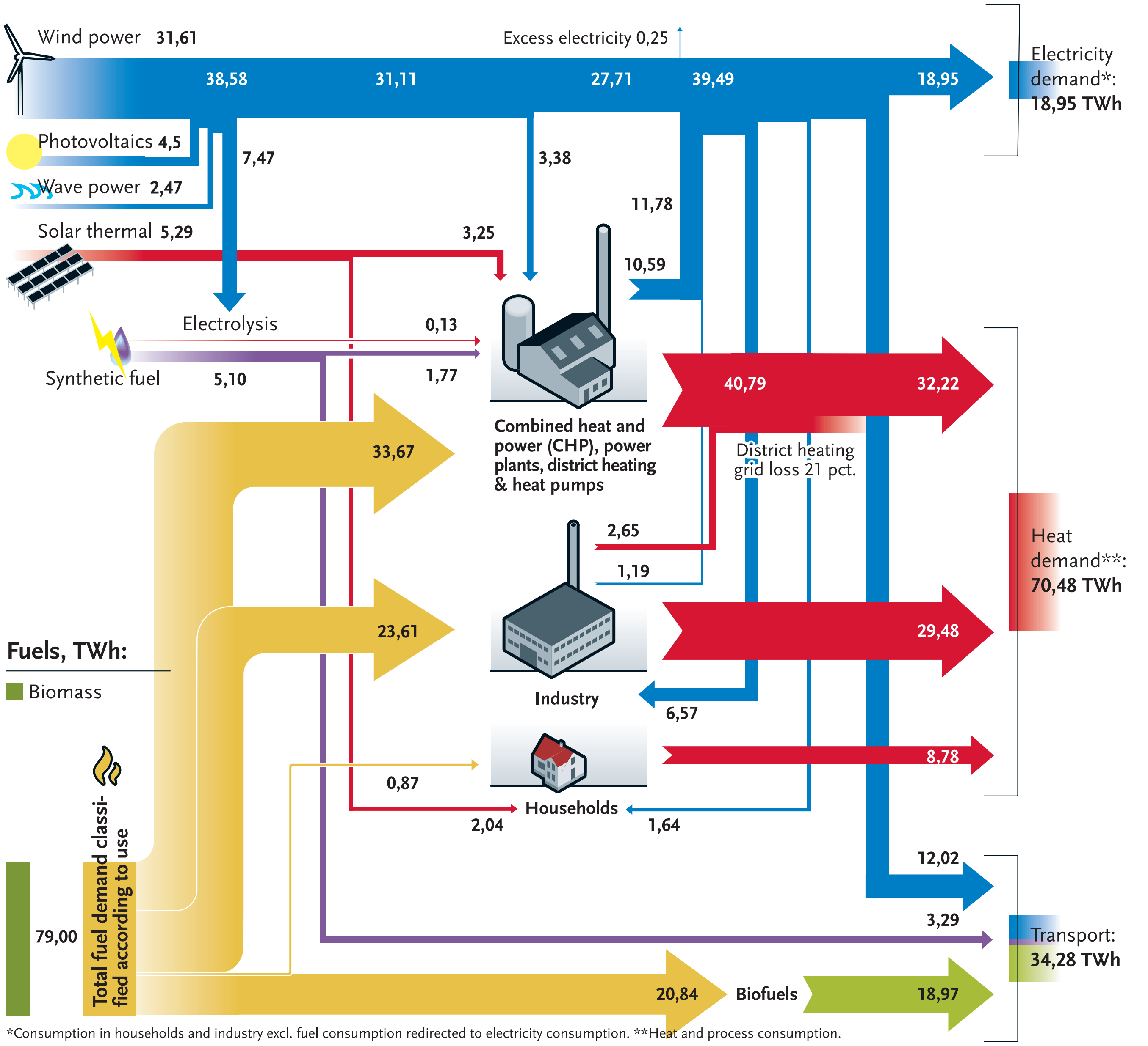


Figure DK-1: The IDA Climate Plan 2050. 100% renewable energy. Primary energy supply, total: 122,86 terawatt hour (TWh).

Climate Plan 2050 looks at reducing greenhouse gas emissions from agriculture and food production through climate optimisation of agricultural production, a change in dietary habits, and halving the food waste in households.

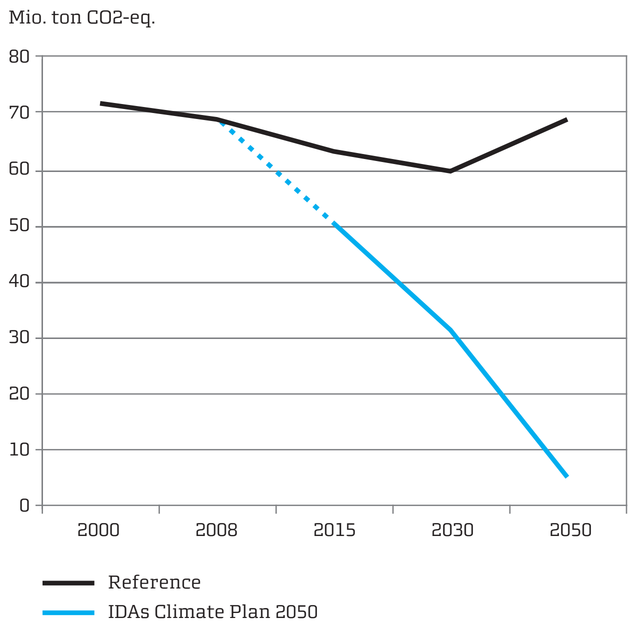


Figure DK-2: All Danish climate gas emissions in CO_2-eq (million ton).

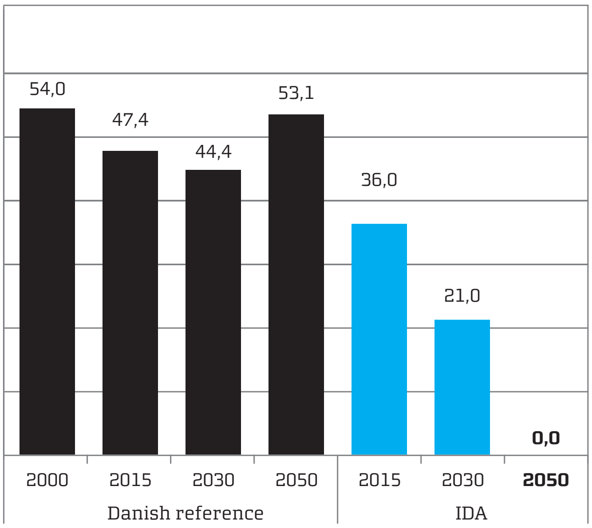


Figure DK-3: CO_2 emissions from the energy system (million ton).

9 key recommendations

The following nine recommendations are key to being able to realise The IDA Climate Plan 2050.

1. National energy-saving agreement

It is recommended to enter into a national energy-saving agreement, stating that Danish energy consumption should be reduced by 2% each year up until 2030.

2. Establishment of a coordinated energy-saving fund

It is recommended that an energy-saving fund should be established, with the objective of promoting electricity and heat savings in households, public areas, trade and industry.

3. Innovation markets and feed-in tariffs to promote sustainable energy

Denmark occupies a leading position within sustainable energy technologies, and if this position is to be maintained, an advanced domestic market that demands new and more efficient technologies is required.

4. Innovation based on research, development and demonstration

The funds for research, development and demonstration of efficient and sustainable energy technologies should be increased to DKK 4 billion a year in 2020.

5. Infrastructural reorientation

There should be a requirement for all major infrastructure plans to include considerations regarding the CO_2 emissions from transportation. Also the Danish vehicle fleet should change to electric cars.

6. Expansion of rail transport

The reorganisation from road to rail requires a huge expansion of rail transport. Investments in rail transport have a significant mobility effect, in addition to the energy benefits.

7. Climate-optimised production and consumption of foods and biomass

A change in dietary habits, less food waste and a change to agricultural production will mean that greenhouse gas emissions from food production can be reduced significantly.

8. Danish climate adaptation strategy

Denmark needs a climate adaptation strategy ensuring that Denmark is robust in the face of future climate changes.

9. Denmark should work towards an ambitious international climate agreement

Denmark itself should proceed by announcing a target that greenhouse gas emissions must be reduced by 90% by 2050.

Acknowledgement

The IDA Climate Plan 2050 is based on the work of six subject groups that originate from IDA's professional societies. During the process, a number of seminars, conferences and workshops have been held, at which individual sectors, technologies, etc. have been presented and discussed. A project coordination group has collated the many threads and has drawn up The IDA Climate Plan 2050.

Denmark facts	
Population (2008)	5.5 million
Area	43,094 km^2
Total GHG emissions (2007)	66.6 Mt CO_2eq.
Future Climate GHG emissions proposal	**2015**: 50.5 Mt CO_2eq. **2030**: 31.1 Mt CO_2eq. **2050**: 5.2 Mt CO_2eq.
National Targets	21 % reductions in 2012 compared to 1999. Long term to become independent of fossil fuels.

Advisory Board

To facilitate international co-operation, a scientific advisory board have been set up. This board consist of climate and energy experts from Denmark, Norway, Sweden, Germany, India and Japan.

The advisory board

Jürgen-Friedrich Hake
Head of Systems Analysis and Technology Evaluation, Research Centre Jülich

Professor Henrik Lund
Aalborg University

Senior Research Specialist Kirsten Halsnæs
Risø DTU National Sustainable Energy Laboratory

M.Sc.Eng., Senior Research Engineer Rolf Hagman
Institute for Transport Economics, Norwegian Centre for Transport Research

Professor Erik Dahlquist
Mälardalen University

Senior Advisor Jørgen Henningsen
European Policy Centre

Professor Tomohiko Sakao
Linköping University

Professor Narendra Kumar Bansal
Shri Mata Vaishno Devi University

Sponsors

Gold sponsor

Silver sponsor

Bronze sponsor