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NOTE

from:	General Secretariat of the Council
to:	Delegations
Subject :	Energy Technology - Vision Paper for EU Strategic Energy Technology Plan

With a view to contributing to the ongoing reflections and debates on Energy Technology, the Presidency has prepared the abovementioned paper, set out in the Annex.

A new energy ERA

Efficiency, Renewables and clean thermal generation and

Advanced state-of-the-art grid and storage infrastructure

Vision Paper for EU Strategic Energy Technology Plan

When all is said and done, the one and best cause for hope is the increase of knowledge and continued material achievement. Only enhanced means can improve the lot of all, however difficult and hazardous the task. We shall not thrive by ineptitude. We have to keep trying. We must choose life. And that means continued industrial revolution.

David Landes, The Unbound Prometheus

Mission Abstract

The European Strategic Energy Technology Plan is a blueprint to

- Guide the main choices until 2020 and beyond towards the establishment of a low carbon energy model based on the adoption of new technologies; and
- Create the appropriate governance and implementation model to coordinate the response at the demand and supply level.

Action taken now will only produce effects in several years. Therefore, Europe cannot wait until new cars are designed, new buildings are built, CCS technology is stabilised and nuclear fusion becomes a reality. Given that from an energy and environment perspective the cost of inaction is very high, Europe must act now.

Europe has a unique opportunity to lead a process that will involve an investment of trillions of Euros (the IEA estimates that €22 trillion will be invested worldwide in energy-supply infrastructure to meet projected global demand) and create around 1,5 million direct and indirect jobs in large companies, SME and research.

To achieve this result, Europe needs to adopt a strategy, to set up an appropriate governance model and implementation structure, and to increase resources allocated to R&D in the energy sector. Given the need to attract private investment to the energy sector on an unprecedented scale, the response must provide a clear picture of medium term objectives, set a stable regulatory framework and create the right incentives. An efficient response requires the effort of looking at EU policies in a horizontal manner and, given that this is a global challenge that needs a global response, the solution requires strong international commitment and coordinated cooperation.

Excessive dependence on fossil fuels and the outstanding economic performance of countries like China and India has created an unsustainable situation both in terms of competitiveness and security of supply. Oil and gas prices, which have seen a fourfold increase since 2001, are currently at a historic high and medium term scenarios suggest that the market will remain tight. Furthermore, there is growing evidence that greenhouse gas emissions (GHG emissions) may damage the planet sooner and in a more irreversible manner than was previously expected. The need to create a low carbon economy without checking economic growth is one of the main challenges of this century.

Public awareness of the interdependent nature of energy and environment polices has created very supportive conditions for change. Other developments go in the same direction. The increase in oil and gas prices is driving down the relative price of renewable energy sources and making them more competitive than ever before. Setting a transparent global carbon price will, when achieved, be a major step towards eliminating the distortion between individual and social costs, which is one of the main reasons why technological change is so sluggish and R&D so low in the energy sector.

The solution involves demand policies targeting energy efficiency and supply policies aimed at accelerating technological change. To accelerate technological change in Europe the best option consists of a two-pronged approach. This approach involves the scaling up of alternative wedge strategies based on already commercialised technologies and, at the same time, the development of new technologies through major R&D breakthroughs.

Although there is no "silver bullet", there are different wedge strategies which are capable of delivering the results in terms of CO2 emissions and energy consumption. Each country should have enough flexibility to choose its preferred wedge, that is, which portfolio of technologies to push in the following decades, taking into consideration its resource endowments, institutional capabilities and political preferences.

From a technological perspective the common denominator of all the different wedge strategies will be: renewable and distributed generation complemented by advanced thermal generation on the production side, state-of-the-art network and storage infrastructure on the distribution side and efficient appliances and vehicles on the consumption side.

However, the major innovation will be the interaction between these two formerly opposed poles. On an organizational level, the transformation will make the system bi-or multi-directional, instead of top-down, with homes, industries and vehicles contributing to the general supply in the same way as they contribute to demand. On a technological level, the major breakthroughs that will constitute the new basic infrastructure of the XXIst century are open and intelligent energy grids, CCS technologies and diversified and decentralized storage solutions able to cope with the stochastic power generation of renewable sources.

The energy and climate challenge is very demanding. A scenario with energy consumption in Europe stabilised at the 1990 level by 2050 and with CO2 emissions reduced by 60-80% would imply the following:

- Double the present energy efficiency targets, i.e. achieve a 40% improvement;
- Expand the renewable contribution to more than 1/3 of total primary energy;
- Tend towards a zero-emission electrical sector; and

- Reduce emissions in the transportation sector by 40% while tending to zero-emissions houses within the residential sector.

The task is extremely complex. However, Europe is well positioned to respond to this challenge and has the resources to be a leader. By taking the initiative, Europe has the opportunity to transform a challenge into an opportunity to improve energy efficiency, drive down the cost of existing technologies and introduce the new generation of technologies required to create a sustainable situation in the medium term, both in terms of energy and the environment.

1. Oil and gas: the medium term scenario is not optimistic

- ✓ Oil prices which have increased fourfold since 2001 and are hovering near $100/bbl
- ✓ Medium-term scenario oil and gas price forecasts are not optimistic and raise issues regarding competitiveness and security of supply

The combined effect of population growth and rapid economic development has been a strong increase in demand for fossil fuels, the share of which in total European primary energy requirements is 61%. Europe imports 50% of its fossil fuel consumption (over €300 billion in 2006), and this share is predicted to keep rising in the future. If they persist, rising energy prices and high external dependency may have a dramatic impact on security, the balance of payments and competitiveness.

Forecasts formerly considered pessimistic, predicting oil prices of $100/bbl, have become a reality. Forecasts do not point to a much more optimistic scenario in the medium term and raise serious concerns regarding competitiveness and security of supply.

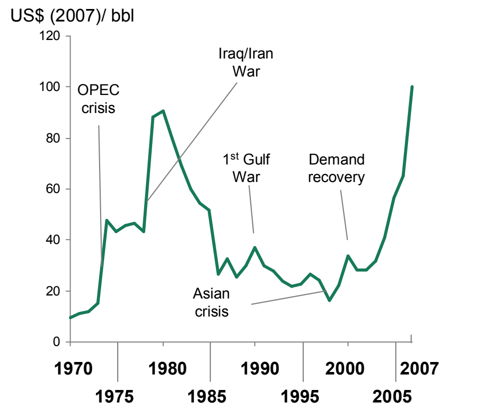
The IEA reference scenario projects that fossil fuel will be the dominant source of primary energy, accounting for 84% of the increase in world demand between 2005 and 2030. Demand for oil is projected to grow by 37% and demand for coal by 73%. This growth will be mainly driven by China and India. The share of OPEC in the supply of oil is projected to grow from 42% today to 52% in 2030.

Rising global energy demand triggered by countries like China and India creates uncertainty in terms of energy security. The combined imports of China and India in 2030 are expected to be higher than present imports by Japan and the US, according to IEA reference scenario.

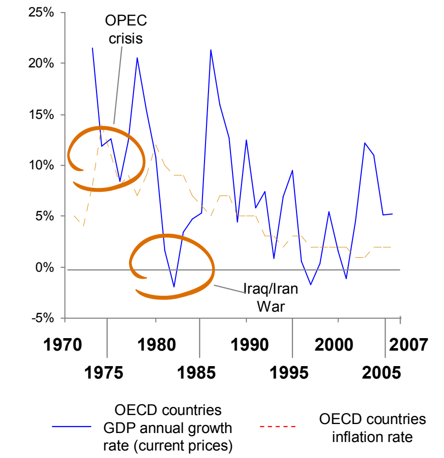
Demand pressure combined with diminishing of production capacity and increasing worldwide consumption will increase the scarcity of fossil fuels. This raises serious concerns about long-term prices and access to oil and gas. The EIA does not rule out a supply-side crunch involving an abrupt escalation in oil prices by 2015.

Oil and gas prices have risen to a historic high on par with the 1979 crisis levels. So far, this has failed to produce the same negative effect on economic growth and inflation as it did then. However, it has created downside risks that cannot be ignored.

Oil price doubled in only three years (2004-2007)



Historic oil price peaks followed by significant decreases in GDP growth and increases in inflation rate



Source: IMF; BP Statistical Review Full Report; Global Upstream Performance Review 2007 – John S. Herold Inc.;The Economist Intellegence Unit; www.x-rates.com; Datastream

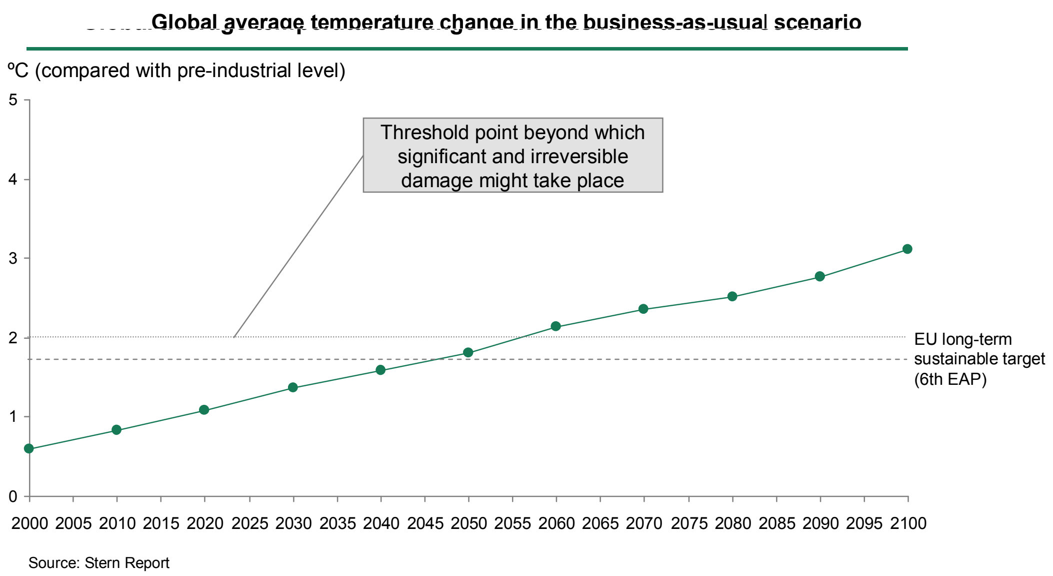
2. Environment: the cost of inaction is higher than the cost of action

- ✓ In a business-as-usual scenario, global GHG emissions may treble by 2050
- ✓ This would lead to an increase in average temperature greater than 2ºC and would cause irreversible damage to the planet
- ✓ The cost of inaction is higher than the cost of action

One side effect of high dependency and increasing fossil fuel demand is an unsustainable level of GHG emissions which may produce irreversible damage to our planet. It is generally recognised that a reasonable boundary for CO2 emissions is equivalent to doubling the atmospheric concentration of pre-Industrial Revolution times. However, there are indications that in a business-as- usual scenario the level of global GHG emissions may treble rather than double. Rising awareness of the negative impact of allowing GHG emissions to grow at present rates has been the tipping point for a drastic change in public perception of the problems caused by the excessive dependence on fossil fuels.

The cost of inaction regarding GHG emissions is higher than the cost of action. The Stern report strengthens this argument by demonstrating that an increase in the average temperature greater than 2ºC is expected if we carry on with business as usual, and 2ºC is generally accepted as the point beyond which significant and irreversible damage might occur. However, despite strong political commitments and the increasing pressure of public opinion, Europe has so far been unable to reduce CO2 emissions in line with its obligations.

Some of the effects of the increase in temperature are already visible. Two examples of this are the de-icing of the legendary Northwest Passage in the Arctic Ocean making it likely to be declared "fully navigable" and the significant increase of warm-water plankton species which have now become more than twice as abundant as cold-water species.



The risk of irreversible damage, such as the rise of sea levels, the flooding of coastal cities and entire islands, the increase in desertification in dry areas or the extinction of 20-50% of animal species calls for action. Ignoring climate change will hurt economic growth. The Stern Report's[1] greatest merit was to show not only that inaction is costlier than action, but also that delayed action becomes more costly as time goes on. According to the Stern Report, a 10-year delay almost doubles the requisite annual rate of decline.

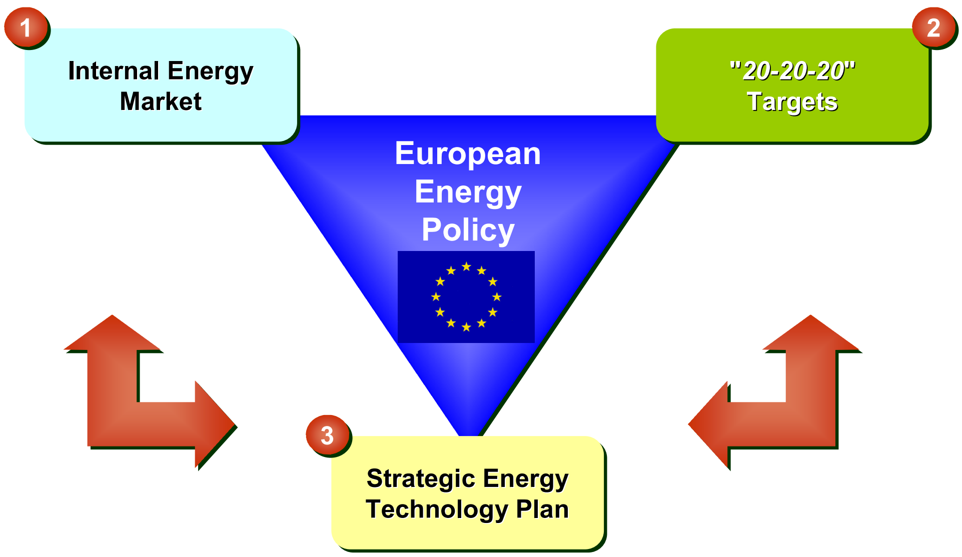
3. European energy policy and the need for international cooperation

- ✓ Europe has undertaken 3 major energy policy initiatives: Single Market, "*20-20-20 targets*", SET Plan
- ✓ Given that Europe accounts only for 14% of global GHG emissions and 16% of world fossil fuel demand it follows that international cooperation is needed

Europe has undertaken several important initiatives in Energy Policy. They consist in the preparation and adoption of a number of measures required to:

- Create an integrated Internal Energy Market for electricity and gas;
- Establish the so-called "*20-20-20*" binding targets for renewable sources, energy efficiency and CO2 emissions reduction as well as create an emissions trading scheme (ETS); and
- Adopt a vision to increase efficiency, drive down the cost of existing technologies, develop new low carbon technological solutions and accelerate their deployment.

[1] The Economics of Climate Change, The Stern Review

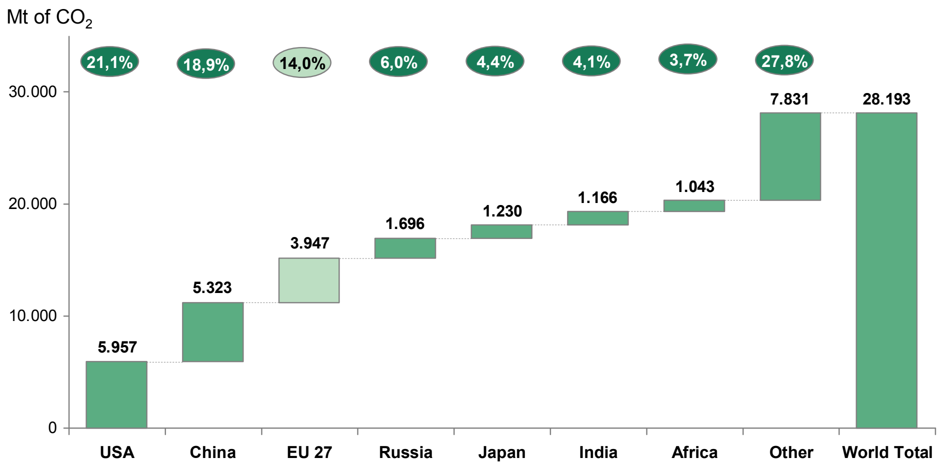


These initiatives should not be seen as a group of isolated measures. They reflect a comprehensive approach to deal with fossil fuel dependence and GHG emissions. From now on the priority is to enforce them. Time is of the essence.

Although security of supply and competitiveness are problems that Europe needs to address on its own, environmental sustainability is a global issue and hence requires international cooperation. Currently Europe accounts for only 14% of global GHG emissions whereas together the US and China are responsible for 40%. Unilateral action by Europe is by no means sufficient to solve the problem. The immediate task is to convince other countries of the need to implement an emissions trading mechanism on a global basis.

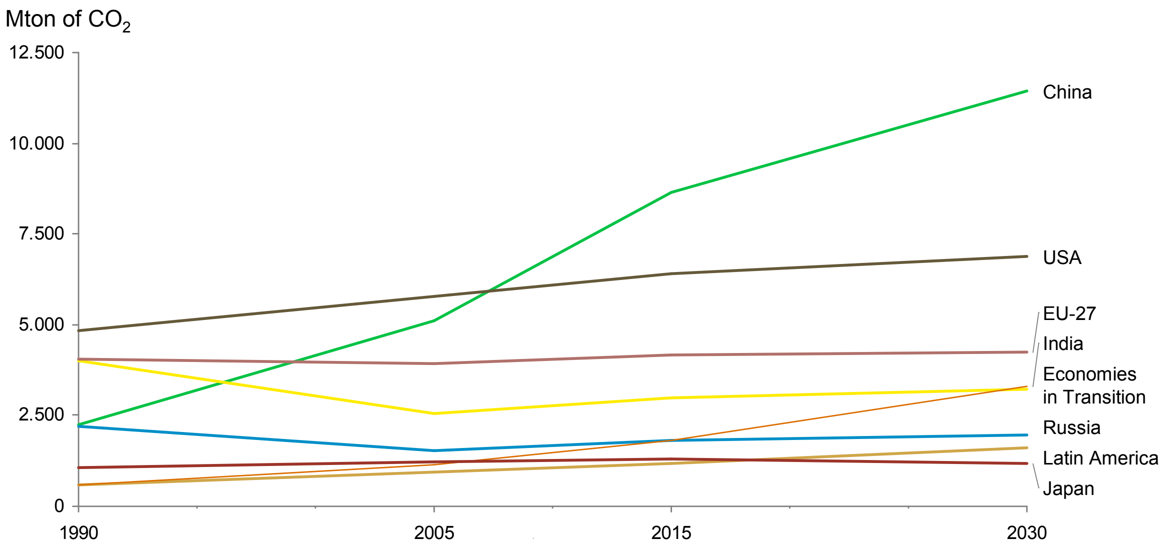
Still, Europe can set an example that may inspire other regions of the world to adopt the right solutions. First movers will be able to create the critical mass needed to deploy new technologies on a large scale. By taking this initiative Europe can transform a challenge into an opportunity.

World Carbon Dioxide Emissions from the Consumption of Energy (2005)



Source: Energy Information Administration, International Energy Annual 2005

Actual and projected CO2 emissions (1990-2030) in the IEA "Reference" and EU 27 "Baseline" Scenario

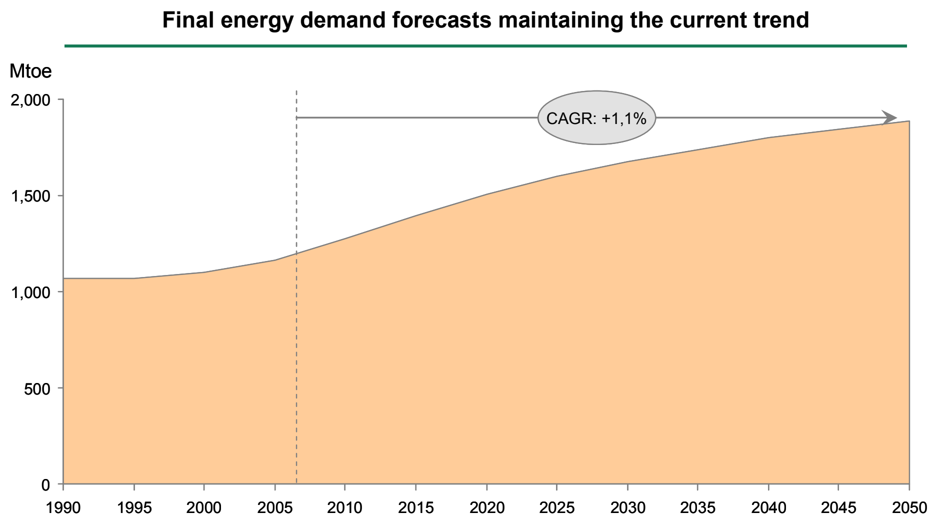


Source: E3MLab, PRIMES Model; International Energy Agency, World Energy Outlook 2007

4. Targets and governance model for the SET Plan

✓ Stabilising energy consumption at the 1990 level by 2050 and reducing CO2 emissions by 60-80% implies the following targets for 2050:
- Doubling the present energy efficiency targets, i.e., achieve a 40% improvement;
- Expanding the contribution from renewables to more than 1/3 of total primary energy;
- Moving towards a zero-emission electrical sector;
- Reducing emissions in the transportation sector by 40% while moving towards zero-emission houses within the residential sector.

On the current trend, final energy demand in Europe will grow at a rate of more than 1%/year[2]. At this growth rate, the situation would be unsustainable for Europe long before 2050.



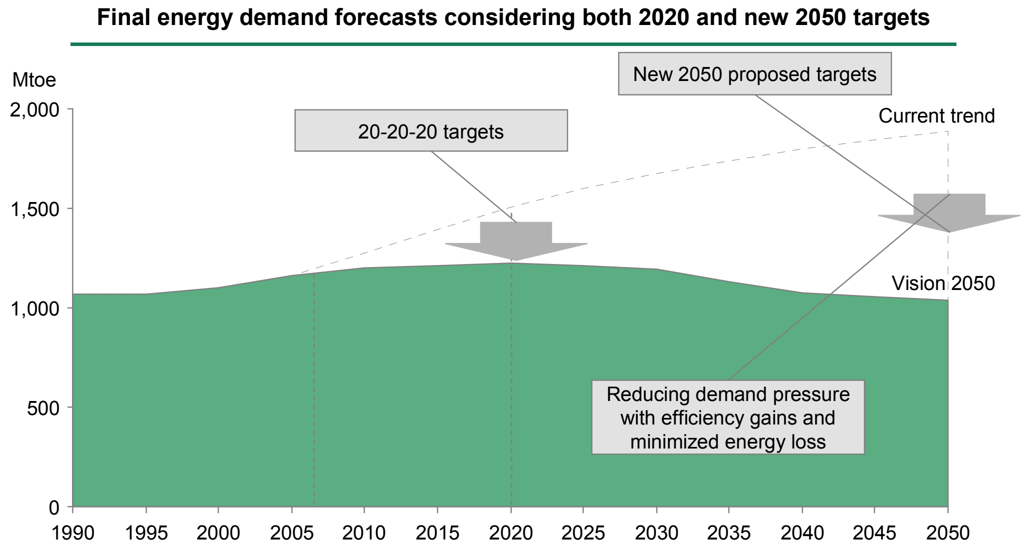
Source: European Commission; E3M lab; Primes model

Stabilising energy consumption at the 1990 level by 2050 and reducing CO2 emissions by 60-80% implies the following targets for 2050:

- Doubling the present energy efficiency targets, i.e., achieve a 40% improvement;
- Expanding the contribution from renewables to more than 1/3 of total primary energy;

2 1.1% in 2007-50, or 1.45% in 2007-30.

- Moving towards a zero-emission electrical sector; and
- Reducing emissions in the transportation sector by 40% while moving towards zero-emission houses within the residential sector.



Source: E3MLab – Primes Model

Europe has already taken the initiative of setting mandatory targets for 2020:
20% renewable penetration, 20% reduction of CO2 emissions and 20% gain in energy efficiency.

The European "*20-20-20 targets*" are a breakthrough for energy and environment policies. The next stage will be to distribute the adjustment burden between individual countries and develop an efficient market for carbon.

Targets

Reducing global emissions by 60%-80% by 2050 vs. 1990 levels

Doubling the present energy efficiency 2020

targets by 2050
- Increase to 40% improvements by 2050 vs. *business as usual* scenarios

Expanding the renewable sector to more than 1/3 of total primary energy by 2050

Move towards a zero-emission electric sector

Reducing emissions in the transportation sector by 40%

Reducing fossil fuel needs by 30-40% by 2050

In March 2007, the European Council recognized that the "*20-20-20 targets*" are only an intermediate objective and emphasised the importance of more ambitious goals for the reduction of GHG emissions in the long run. The European Council suggested achieving a 60-80% reduction by 2050 relative to 1990.

This strengthens the credibility of Europe's commitment to create a new energy model and gives private investors an indication of the long term adjustment path[3]. Bearing in mind that private investment must be the main force behind the creation of a new energy model, this becomes crucial.

Rapid change and determined action is necessary to achieve this result. Given the large number of actors, the need to create a time-scale, the lead time of new technologies and the size of investments it follows that Europe needs to develop an appropriate governance model and implementation structure for the SET Plan.

For this purpose, the Commission has already defined a set of governance proposals for the R&D agenda:

- New joint Strategic Planning based on a Steering Group for Energy Research and Innovation, a European Technology Summit to be held on an annual basis and a Technical Information System;
- Six new European Industrial Initiatives in the form of public-private partnerships or joint programmes to be launched in 2008 on wind, solar, bio-energy, CO2 capture, transport and storage, electricity grid and sustainable fission; and
- A European Energy Research Alliance, focused on implementing programmesrather than collaborating on projects, possibly using the European Institute of Technology as a vehicle.

These proposals should be complemented with additional and broader measures and policies. Given the importance and the complexity of the task at hand, these structures must be empowered with the adequate level of decision-making capacity, authority and financial resources. There are three issues deserving priority:

- First, the need to create the right incentives to attract private investment to the process on an unprecedented scale, namely market mechanisms, stable regulation and mandatory ceilings, among others;
- Second, proper coordination of policies at a horizontal level; for example, biofuels-agricultural policy, hydro-environment policy, biomass-forest policy;

[3] The 2020 target may be seen as the first derivative, while the 2050 target is the second derivative.

- Third, the creation of a Europe-wide intergrid with a strong interconnection capacity and ITC features.

5. Wedge strategies for a new energy model

> ✓ There is no "silver bullet" capable of solving this problem in one shot
> ✓ However, there are alternative strategies capable of achieving the objectives in terms of CO_2 emissions, consisting of a combination of "wedges" based on existing or new technologies

The creation of a new energy model requires a two-pronged approach:

- Promote the adoption of already available clean technologies (wind, first generation biofuels, biomass, etc.) or those in the final stages of development (second generation biofuels, off-shore wind, PV and concentrated solar power, smart grids);
- At the same time develop a new generation of technologies that will impact beyond 2020 (hydrogen and fuel cells, CCS, Gen-IV fission reactors) through major breakthroughs**.**

No "silver bullet"

No single technology today holds the solution but a wide portfolio of possible technologies already exists

A flexible roadmap giving priority to technologies with the greatest potential is required

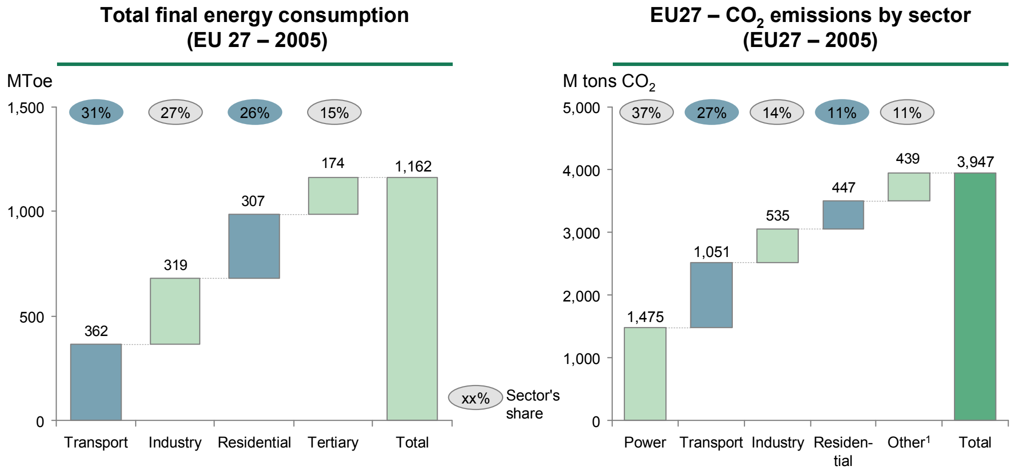
- To foster commercial deployment of existing technologies in the short term
- To focus R&D efforts on the most promising technologies in the long term

By acknowledging long lead times for the information of energy-related technologies Europe recognizes the need to take prompt action

There is no "silver bullet" capable of achieving all the objectives at the same time.

No single technology today holds on its own the promise of an environment-friendly, secure and competitive energy future.

The end-result has to address the specific situation of different sectors in the economy, i.e. Transport, Residential, Industry and Power.



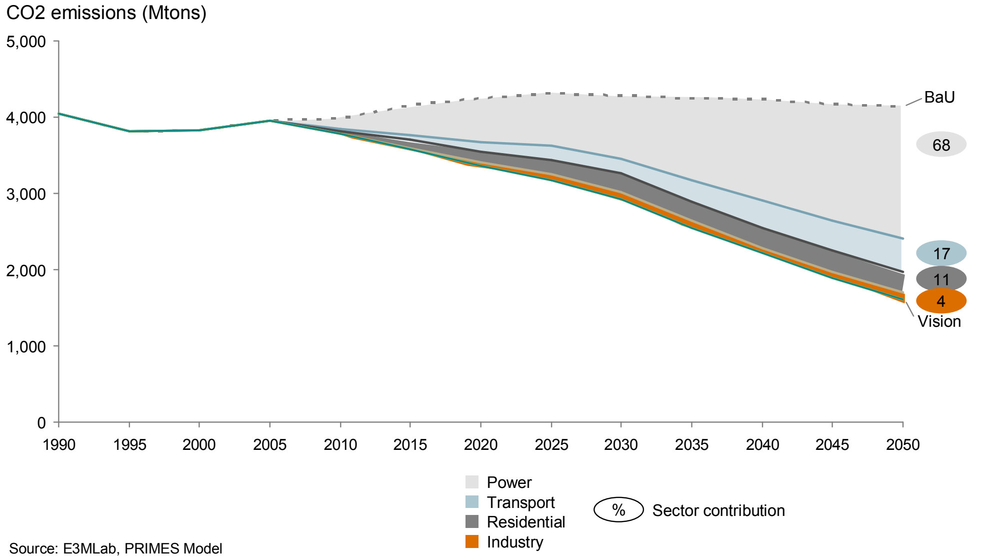
1. Includes: Tertiary, District Heating and Energy Branch".
Source: E3M Lab; Primes Model

It has been shown[4] that there are alternative solutions capable of achieving the objectives in terms of CO2 emissions, each one consisting of a combination of "wedges" based on existing and new technologies.

For example, the targets set out for 2050 in the previous section represent a scenario with different wedges compounding the contribution of specific measures taken in the electricity sector (responsible for a 68% share of the total reduction), in transport (17% share of the reduction), in the housing sector (11% share of the reduction) and, lastly, in the industry sector (4% share of the reduction). The contribution of the electricity sector, for its part, can be achieved through different portfolios of technologies, i.e. renewable, CCS or nuclear. Still, in all cases, the weight of renewable sources should be higher than today, while other "wedges" must also contribute to reaching the objective.

4 Pacala, S. and R. Socolow, 2004, Stabilization wedges: Solving the climate problem for the next 50 years with current technologies, Science 305,968-72

CO2 emissions forecast according to business-as-usual scenario and new targets for both 2020 and 2050



Source: E3MLab, PRIMES Model

In view of this, there can be no waiting for new solutions that might appear only in 20 years' time. The question is how to design the right institutional setting, create the appropriate incentives to bring in private investment, drive down the cost of new technologies and accelerate their market deployment.

In this setting electricity generation and industry, which are sectors covered by the current ETS scheme, have an important role in the transition to a low carbon economy, given that they account for around 50% of CO2 emissions. Where renewables are concerned, energy sources such as hydro power, wind, biomass, biofuels, solar energy and wave power should be promoted aggressively through the appropriate instruments.

However, promoting RES alone would not be enough. Energy efficiency must also play a major role. Major changes must take place in the transport and residential sectors. Together, they account for almost 40% of total CO2 emissions, approximately three times the share of the industrial sector, and more than 55% of total energy demand in Europe.

Energy efficiency is therefore a top priority. Transportation and households must be among the main targets for reducing energy consumption, and thus be among the triggers for new technology shifts and breakthroughs.

6. The need to accelerate technological change

- ✓ There is a mandatory need to accelerate the intrinsic nature of slow technological development in the energy sector
- ✓ Different policies and incentives should be tailored to the different steps of technological development

It is well documented that technological change has been relatively slow in the energy sector. This must change. It is important to understand why this has happened and to what extent the obstacles to innovation can be removed by means of the appropriate policies.

Need for change and urgent action

- **Europe is in dire need of change. Transition from an excessively fossil fuel dependent economy towards a more sustainable development paradigm**
  - EU has been consistently increasing its dependency on oil and gas in a context of high prices and an urgent need to reduce GHG emission
- **Europe needs to take urgent action since the negative impact and cost of inaction are already visible in the environment, economy and society as a whole**

There are two important exogenous factors that help explain why technological change has been so slow in the past:

- The low price of fossil fuels until the beginning of the decade;
- The market failure created by the difference between private costs faced by investors and social costs, given the absence of a carbon price.

These two obstacles have been removed or are in the process of being eliminated and this should facilitate technological change in the future. However, several endogenous factors persist:

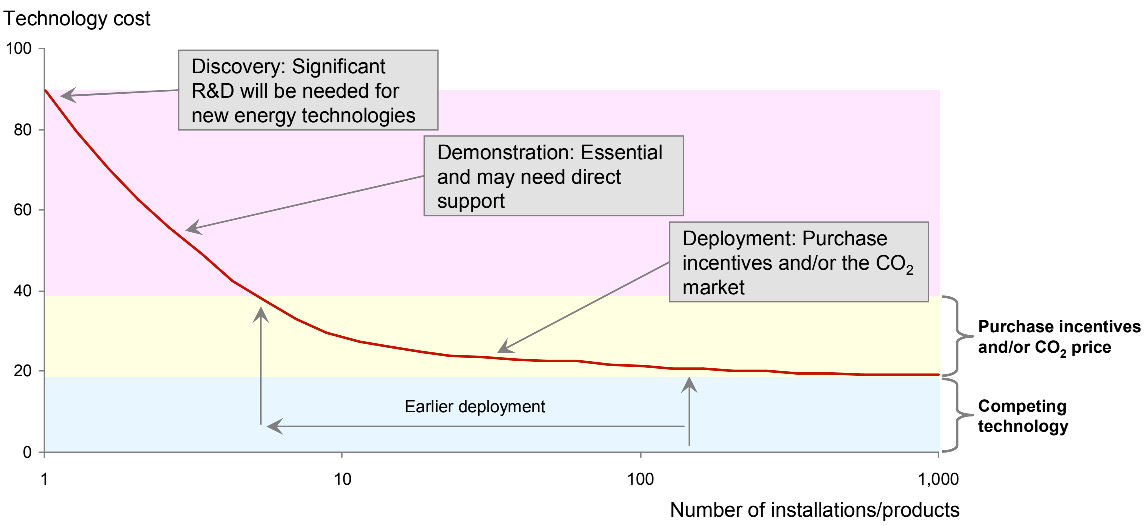
- Nature of the learning process. It may take several decades before new technologies are deployed on a large scale because the costs of new technologies are initially higher than that of the technologies they replace and because there are only a few niche markets which allow innovators to sell at a profit during the early stage. In any case, cumulative investment, R&D, feed-in tariffs and operating experience tend to accelerate maturity and improve the economies of scale and costs of new technologies to the point where they become competitive and ready to replace existing solutions;

- Nature of infrastructure. National grids tend to be tailored to specific technologies and to the needs of incumbents. With the available equipment and expertise it is already possible to upgrade national grids and increase their interconnection capacity. This should be a priority for Europe[5];

- Market distortions resulting from direct and indirect subsidies and the nature of competition in markets usually dominated by a small number of players;

- Low level of expenditure on R&D.

To remove the barriers to technology development and innovation, a different set of policies and incentives to attract industry and private capital should be tailored to each step of the R&D value chain: Discovery, Demonstration and Deployment.



Source: Shell Business Scenarios

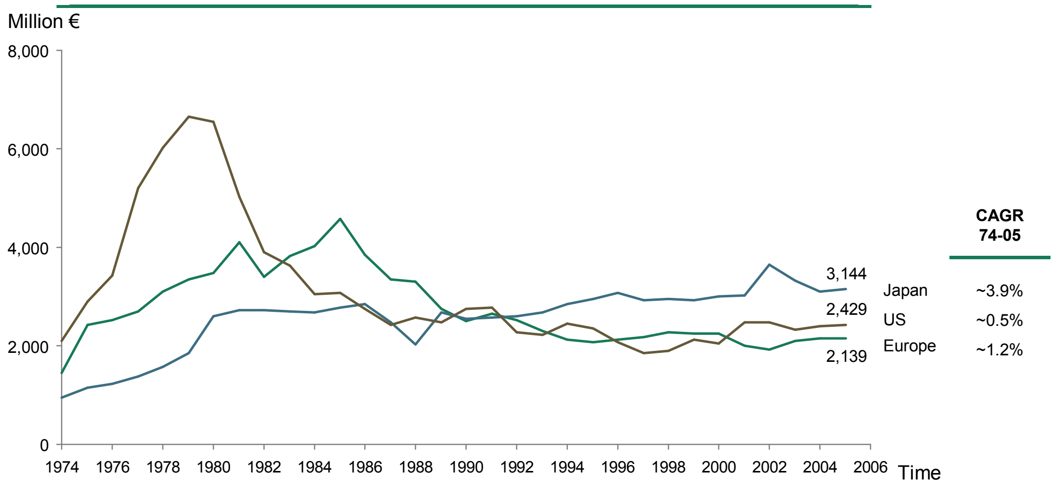
5 Investment in improving the interconnection capacity facilitates the appearance of newcomers and fosters technology innovation. The deployment of renewables in Europe is an example of the benefits Europe can achieve by leveraging the network infrastructure. Investments in infrastructure have accommodated the fragmented nature of this type of generation while mitigating the constraints associated with its higher volatility. Europe should follow this example in other areas like the Carbon Capture and Storage (CCS) technologies, for which transportation and storage are key elements.

7. A boost in research and development

- ✓ R&D public expenditure has been declining in Europe, increasing the risk of the EU lagging behind the US and Japan in energy technology innovation
- ✓ Europe needs to *invest more* and to *invest better*
  - Doubling the current R&D budget in 3 years should be a priority

To be a leader, Europe needs to invest more and to invest better in R&D in the energy sector.

Public R&D investments (1974-2005)

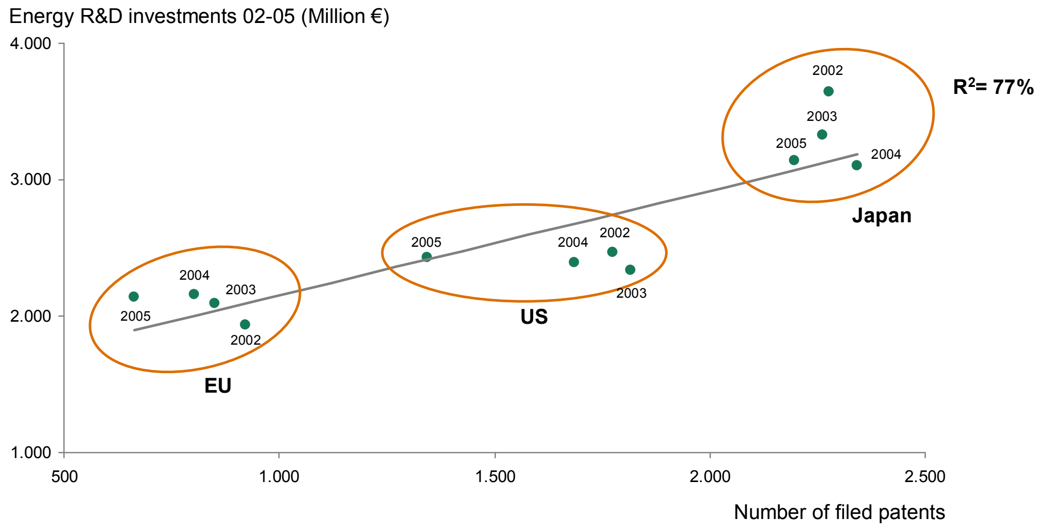


Note: Data for Europe relative to UE-15
Source: IEA – Energy Technology R&D Statistics Service (http://www.iea.org/RDD/);Eurostat Databases GBAORD

Since 1985, R&D public expenditure in the energy sector has declined in Europe. If Europe were to invest the same percentage of GDP in energy R&D as Japan, it would have to increase the amount spent in 2005 by almost 5 times. This would mean spending over €10.000 Million instead of €2.140 Million.

The footprint in new technology patents seems to demonstrate the evidence that Europe is lagging behind the US and Japan. Empirical evidence shows a strong correlation between investment in R&D and the deployment of new solutions, and since 2002 Europe has filed fewer patents than the US and Japan.

To be a leader in the new technologies of the future, Europe must alter these trends.



Note: Data for Europe relative to UE-15
Source: IEA – Energy Technology R&D Statistics Service (http://www.iea.org/RDD/); Micropatent

The first priority is to *invest more*. As a short term measure, Member States should agree to increase national public expenditure on energy R&D using the US and Japan as a reference. This implies doubling the R&D budget in 3 years.

The second priority is to *invest better*. The Commission proposed creating a virtual Energy Research Alliance to coordinate the efforts of National Research Institutes and to change the current model of collaboration on projects to a new model of implementing programmes aligned with the SET Plan priorities.

Finally, ensuring first-class R&D and industrial skills is also a priority. Promoting education and training opportunities, fostering mobility and creating attractive working environments is mandatory to increase the quality and the number of engineers and researchers. They are a critical factor for innovation and Europe must find ways to overcome the scarcity of young people in these areas. Without a solid human capital base, the European goal of leading this new industrial revolution may be at risk.

8. A new energy ERA

- ✓ A new energy ERA is proposed for Europe in 2050
  - **E**nergy efficiency, **R**enewables and clean thermal generation and **A**dvanced state-of-the-art grid and storage infrastructure
- ✓ This new energy model must be supported by 4 main principles
  - Efficiency, Low carbon content, Decentralisation and a Holistic approach

In 2050 Europe will be in the middle of a new **ERA,** the features of which will be

- **E**nergy Efficiency;
- **R**enewable up-scaling and Clean Thermal Generation;
- **A**dvanced state-of-the-art open and intelligent grid and storage infrastructure.

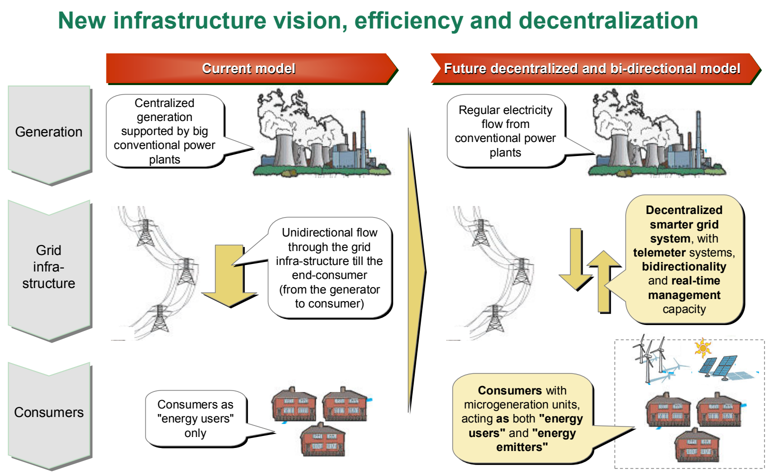
In the new ERA Europe will be less dependent on fossil fuels and will strongly reduce greenhouse gas emissions. Simultaneously, Europe will create thousands of high-tech jobs and will establish solid leading-edge industries around the energy sector capable of exporting products, services and know-how to the rest of the world. Europe will find that its first-mover endorsement of this new model will be the source of sustainable long-term competitiveness.

The new model can be summarised as follows:

- ***E***fficiency: reducing energy waste at all stages of the chain
- ***L***ow carbon content: aiming towards zero emissions in each segment of the system
- ***D***ecentralisation: empowering all actors in the system
- ***H***olistic approach: although each sector will benefit from specific action plans, a global vision should eliminate the traditional division between demand and supply simultaneously encompassing all the major energy needs: electricity, heat and mobility.

These principles dictate what technologies will need to be promoted in the coming decades: renewable and distributed generation, complemented by new clean thermal generation on the production side, efficient appliances and vehicles and new building codes on the consumption side. However, the major innovations will be in the interaction between these two formerly opposed poles.

- On an organizational level, the transformation will make the system bi- or multi-directional, instead of top-down, with homes, industries and vehicles contributing to the general supply in the same way as they contribute to demand.
- On a technological level, this implies two major breakthroughs that will constitute the new basic infrastructure of the twenty-first century: open and intelligent energy grids and diversified and decentralised storage solutions.



The underlying approach consists in accelerating and giving priority to the commercial deployment of existing and emerging technologies up to 2020; and focusing R&D on those fields that will enable quantitative breakthroughs in all parts of the energy systems' value chain – generation, grid infrastructure and consumption.

9. What our energy future could look like

a. Households and Tertiary

The targets for the residential sector are the following:

- Reduce average household energy consumption by ~30% by 2050;
- Move towards zero-emission houses by 2050.

Residential

New and improved construction materials

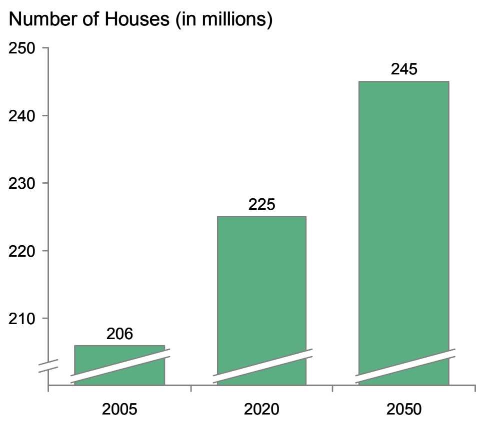
Continuous upgrading of domestic appliances

Changing consumer behaviour will reduce household energy waste and improve energy efficiency
- Technology
- Education
- Information

Household energy consumption[6] will be minimised through behavioural changes and new technology. All appliances will be Class A or A+ and all light bulbs efficient. Currently, standby consumption accounts for almost 10% of total electricity consumption in the residential sector. Technology will enable the stand-by consumption of appliances to be reduced to near zero and policy will provide the necessary information and incentives to remove less efficient appliances from the market.

New environment-friendly buildings taking advantage of active and passive technologies will result in healthier and more efficient homes and offices. New building codes, new materials, improved spatial and urban planning as well as a substantial increase in the use of renewables for heating and cooling will be a must. Energy efficiency improvements ought to encompass aspects such as thermal insulation, air conditioning performance, natural ventilation, solar passive lighting and heating, PV or other renewable electricity generation. A policy supporting the achievement of these objectives also in existing buildings should be implemented.

EUR27 Evolution of the Number of Houses

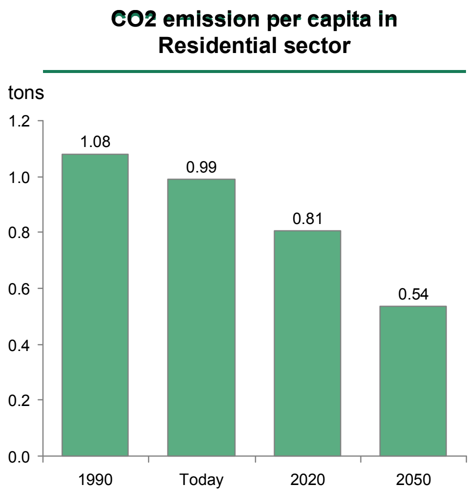


Source: E3MLab, PRIMES Model

6 Household energy consumption accounts for 11% of CO2 emissions

Pushing information and consumer empowerment a step further holds great promise. Intelligent demand-side management, with automatic control over lighting, entertainment and heating and cooling devices, ideally interacting with network operators, will reduce consumption and contribute to flatten demand peaks.

It is also expected that homes will move towards self sustainability and will be able to produce a substantial share (more than 80%) of the energy they consume by 2050. If we add to this the possibility that houses may also store electricity and exchange it with smart power grids we get a picture in Europe that is very different from today's. All in all, 2050 emissions per capita in this sector are expected to be less than half of the 1990 level (i.e. 0,5 TonCO2).



Source: E3M Lab, Primes Model

Despite accounting for only 6% of total emissions and 15% of total final energy consumption, the tertiary sector presents significant potential and will face similar changes to those in the household sector. Current energy intensity (24 Toe/€million) will substantially decrease to 17 Toe/€million in 2020 and 11Toe/€million in 2050, mainly due to better use of technology in heating, cooling and ventilation. Improvements in the energy efficiency of appliances are also expected with more likely impact in lighting and data processing equipment.

b. Industry

Industry

Rise of less energy intensive industries
- Leading edge industries appearing
- Eventual relocation of heavy industry

Gains in energy efficiency
- New technologies
- New processes
- Cogeneration

CCS in the more polluting industries appearing in the long term

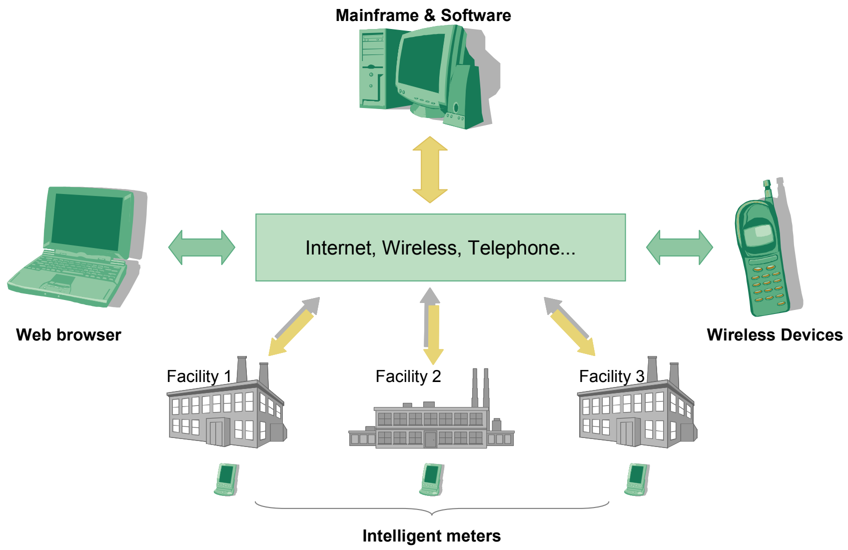
Simultaneously, the **industry**[7] profile in Europe will continue to evolve. First, industries will become less energy intensive[8]. By 2020, the energy intensiveness of the five most "intensive" industries[9] is expected to fall by 20% in real terms. Second, efficiency standards will continuously improve as energy waste in industrial processes is minimised.

7 Industry accounts for 14% of CO2 emissions
8 Energy intensiveness refers to the amount of energy consumed per unit/Euro of output
9 Iron & steel, non-ferrous metals, chemicals, non-metallic minerals and pulp and paper

Third, the ongoing appearance of new leadingedge industries will rebalance the current portfolio in favour of cleaner and less energy-intensive industries.

As a whole, industry will contribute towards the envisaged low-carbon economy. The 2050 target set for the entire industry sector implies a 25% reduction in CO2 emissions compared with 1990 levels.

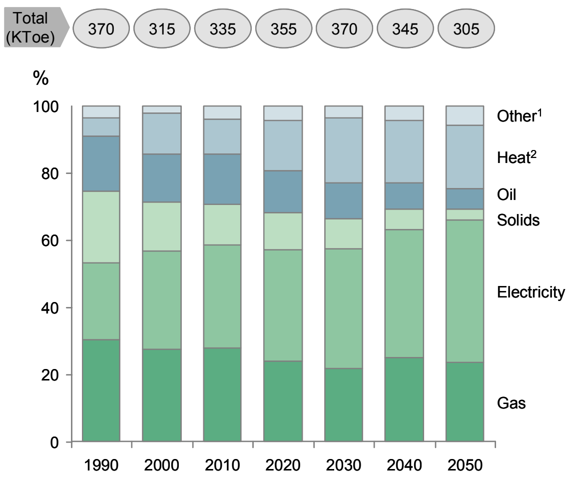
The positive trend will also be due to a more rational use of energy. Technological innovations and the market signals given by widespread use of advanced energy management systems will reduce energy bills. A network of intelligent meters linked to a central server running specialized software will enable agents to monitor consumption in detail.



In 2050 the efficiency levels of non-core processes will be far higher than they are today. In other words, cross-cutting technologies common to most industrial processes will consume energy in a more efficient fashion. Improvements are expected in a wide array of systems including motor, pump and compressed air systems. Regulation and compliance with minimum standards will serve as incentives for industries to upgrade from the old, more polluting predecessors.

Another factor underlying the emissions trend is an increase in the proportion of RES, Renewable Energy Sources, in the sector's fuel mix. SME will embrace small wind installations and thermal process heating applications. For example, it has been estimated that in the long term approximately 400 tonnes of CO2 emissions can be avoided with each GWh of electricity generated from Photovoltaic systems. Biomass will also become an important energy source for industry as a whole. Installing the abovementioned systems requires know-how and manpower. In fact, by 2050 a large highly skilled job-market dedicated to RES within industry will exist.

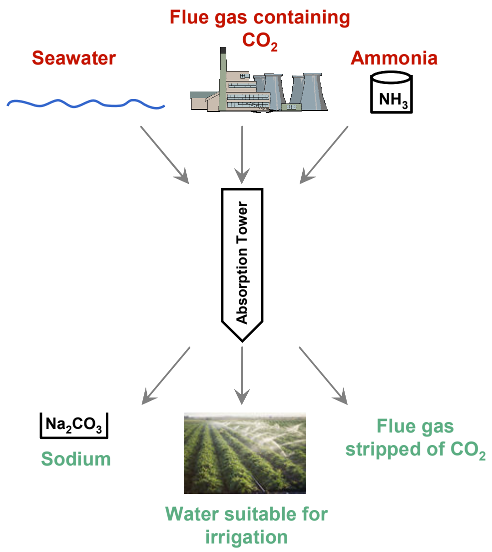
Evolution of Industry Sector Final Energy Demand by Fuel



1. Biomass, waste, hydrogen etc. 2. From CHP
Source: E3MLab, PRIMES Model

Co-generation, also known as combined heat and power (CHP), will also be significantly responsible for the anticipated trends. Until 2030, the amount of energy produced using CHP units is expected to increase and joint-research programmes at a European level will propel this already mature technology forward. The increase on CHP will promote a higher penetration of heat and electricity and reduce industrial consumption of oil, gas and solids (coal).

Example CCS technology



Another feature of the industrial sector will be the widespread use of Carbon Capture and Storage (CCS) technologies. The commercial deployment of these technologies is expected some time between

2020 and 2030. Once these technologies become cost-competitive they will drastically reduce emission levels, particularly in the more pollutant industries.

Government and EU regulations, together with public opinion, will encourage the rapid adoption of CCS technologies throughout the various industries. Carbon Trading will be part of everyday business for future industries complying with the 2050 version of the EU emissions trading scheme.

Finally, energy production in the industrial sector, whether in small wind installations or in micro-CHP units, will contribute to the decentralized energy production system of 2050. Developments in other fields such as fuel cell technology will lead to the creation of advanced storage systems. Consequently, industry in 2050 will have the ability to buy energy from a smart grid in times of shortage and sell it back in times of surplus. More importantly, it will have the ability to anticipate its needs and buy in advance. Hence, peak loads will be dramatically reduced as will the energy wasted in production and transportation.

c. Transportation

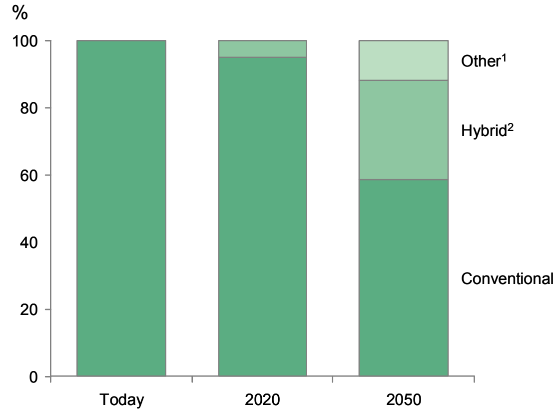
Reshaping the **transport** sector is crucial as it currently accounts for around31% of the energy consumed in Europe and around27% of Europe's CO_2 emissions. Consequently, Europe should have ambitious targets for this sector for 2050. In particular, an approximate 40% reduction in CO_2 emissions compared with 2005 levels and at least a 40% gain in energy efficiency with respect to the levels in 2000.

Transport

	Medium Term	Long Term
Equipment	• Hybrids	• Plug-in Hybrids • Electric cars • Fuel cells • H2 engines • Advanced combustion engines
Fuel shifts	• 1G biofuels	• 2G biofuels • 3G biofuels
Systems	• Car pooling • Public transportation • Improved network infrastructure • Improved urban spatial planning • Improved intermodality	• Improved network infrastructure • Improved urban spatial planning • Improved intermodality

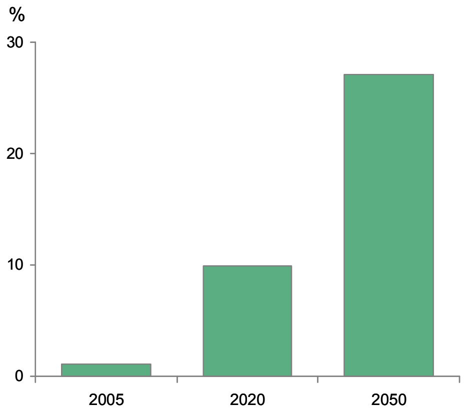
Synchronized action is expected on three main levels, namely equipment, fuel mix, and systems. Regarding equipment, the widespread adoption of more efficient combustion engines with fewer emissions and lower energy consumption per kilometre and a progressively higher penetration of hybrid cars is to be expected. Coupled with the probable successful development of hydrogen, fuel cell and electrical vehicles, this trend will contribute decisively to a more sustainable and environmentally friendly world. By 2050, approximately 40% of Europe's car market should consist of what are today considered non-conventional vehicles.

Evolution of car type in total car stock



1.Electric car, Hydrogen internal combustion engine, Fuel cells. 2. Conventional hybrids and plug-in hybrids
Source: E3MLab, PRIMES Model

Biofuels in Gasoline and Diesel (%)



Source: E3MLab, PRIMES Model

Secondly, a new fuel mix in the transport sector is expected to be a key element of the future landscape. Biofuels, especially second and third generation fuels, which should no longer compete with food crops, will play an important part in reducing dependency on fossil fuels. Nowadays, biofuels (first generation) still represent less than 1% of fuel for road transport. This share is expected to increase to 10% in 2020 and almost 30% in 2050. A 30% biofuels penetration by 2050 would result in a reduction of CO2 emissions of approximately 18%.

Third, without behavioural changes the impact of technological change will not be enough. Improving the quality, reliability and accessibility of current public transportation systems will help stimulate behavioural changes. Measures include spatial and road network infrastructure planning, priority lanes, car-pooling and intermodality between transport alternatives. Taxes and other economic incentives favouring public transportation systems will also help promote change.

Finally, structural changes in society in general may also contribute to positive trends in the transport sector. For example, the evolution of telecommunications and changes in company behaviour may result in a larger population of home-based workers and in an increase in the use of video-conferencing.

d. Power generation

The **power sector**[10] is today one of the major sources of CO_2 emissions. It is a sector where so far policy has had effective impact due to the limited number of actors. However, there is still a large transformation potential in three major directions: increasing the share of **Renewable Energy Sources** (RES), developing **Clean Thermal Generation** and preparing for ever more **Decentralised Production**.

Power

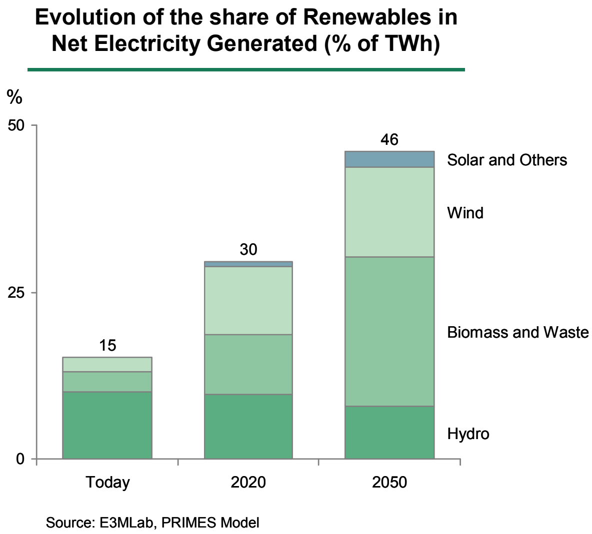
	Medium Term	Long Term
RES	• Hydro • Wind on-shore • 1G Biomass	• Wind off-shore • Photovoltaic • 2G Biomass
Thermal Generation	• Fuel switch (coal to gas)	• CCS • Nuclear fusion

RES account for less than 10% of current total energy demand. Europe has to push forward a much wider use of its endogenous energy resources.

In 2020 the European renewable energy landscape will already be different. It will encompass a wide-ranging portfolio of different technologies, exploring the earth's, the sun's and the wind's natural potential, and making them increasingly competitive vis-a-vis other conventional alternatives. These changes are already becoming visible.

[10] Generation accounts for 37% of CO_2 emissions

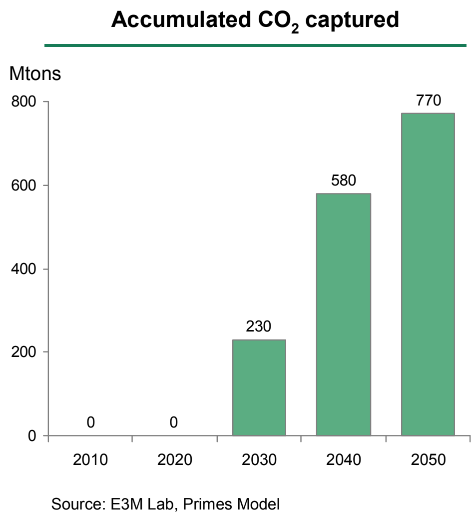
The potential of proven technologies such as hydropower will be further explored. Doubling the power generating capacity of the largest wind turbines should be achieved, with off-shore wind as the leading source. Biomass will also continue to grow rapidly, reaching approximately 9% of total net electricity generation by 2020. Photovoltaic energy and concentrated solar power, due to its versatility and integrability, will also begin to be a major contributor. Finally, incipient technologies such as wave energy or the exploration of new sources of Biomass such as *algae* might also become significant contributors sooner than expected.



By 2050, RES should be a major contributor to electricity supply accounting for more than one third of total EU27 final energy demand. Europe will continue to evolve in this new ERA of carbon free endogenous sources by introducing new sources and technologies in fields like Nanotechnology, Distributed IT and Biotechnology.

However, to make this vision possible, it will be necessary to increase storage capacity substantially. In addition, it will also be necessary to improve the transmission network in order to enable decentralised generation.

On the other hand, **thermal generation** will continue to play an important role in the system over the coming decades, especially as a back-up shock absorber. Still, it will be necessary to ensure zero emissions by 2050.



In order to allow thermal generation to maintain an important role in a low carbon economy, Carbon Capture and Storage (CCS) is crucial. CCS technology is a solution with worldwide potential as coal-fire plants will continue to be common around the world. Estimates indicate a CCS potential of approximately 700-800 MTons of CO_2 sequestered by 2050. However, this technology still requires significant investments before becoming commercially viable in a large scale. It is necessary to fund real-scale demonstration projects and to support the development of transportation and storage infrastructure. CCS will gain additional importance if the expected demand-side management gains fall short or take longer to produce their effects.

At the same time, some countries might opt to extend the life of nuclear plants or even increase existing capacity. A new generation of nuclear technology will be in place by 2020 (G4) and further improvements can be expected in the long term. Developments in nuclear technology are crucial to improve safety and minimise residues. This will be particularly important in order to enable the implementation of this technology in emerging economies, where substantial increases in the numbers of nuclear power plants are anticipated.

Finally, R&D development on both fission and fusion facilities should continue to progress. Although nuclear fusion is generally seen as a long term solution, it is necessary to continue to invest in R&D to fulfil this promise. Despite the massive investment that will be needed, experts predict that the first demonstration project will not be ready before the 2030/2040 period.

e. Infrastructure

One of the key drivers of a more efficient and decentralised energy model is the **infrastructure**.

In the short term, a major increase in interconnection capacity and national grid infrastructure is essential. This is crucial to reduce barriers to the entry of newcomers.

Infrastructure

	Medium Term	Long Term
Storage	• Hydro reservoirs • Gas caves	• Fuel cells • Hi-power batteries • Carbon storage
Transmission	• Better intercon-nection	• Smartgrids

In addition to better interconnection between countries or markets, Europe should consider creating a more sophisticated grid system including the implementation of telemeter systems, bi-directionality and real-time management capacity. To that end, it is important to define standards and to harmonize regulation in this area in order to speed up development of the infrastructure.

Meanwhile, Europe must also work on immediate opportunities relating to its storage capacity such as hydro power reservoirs and gas caves as well as on technologies with long-term potential such as hydrogen and other fuel cells. Such solutions will influence RES development, overcoming its intrinsic volatility and making this source of generation more sustainable and secure. For example, windmills will be able to produce electricity overnight for daytime consumption and plug-in cars will be able to sell stored energy to the grid during peak periods.

The result of these changes will enable European energy production to switch to a more decentralized model in which micro generation will be abundant and more widespread. Power in Europe will flow through a more interconnected, decentralised and intelligent system. The information technology revolution applied to energy networks will enable a similar change of paradigm to that introduced by the Internet into the world of communications, i.e. the creation of an open and multi-directional network in which generation and transport are piloted in real time.

10. Effects on security of supply, environmental sustainability and economic competitiveness

Overall effects in the energy sector

Europe will experience several important socio-economic and environmental impacts

Socio-economic effects

- around € 190 billion yearly savings
- Cost of energy per GDP unit will fall
- 1,5 million new direct and indirect jobs
- ˜around € 2000 billion (2005) to be invested in the power sector by 2050

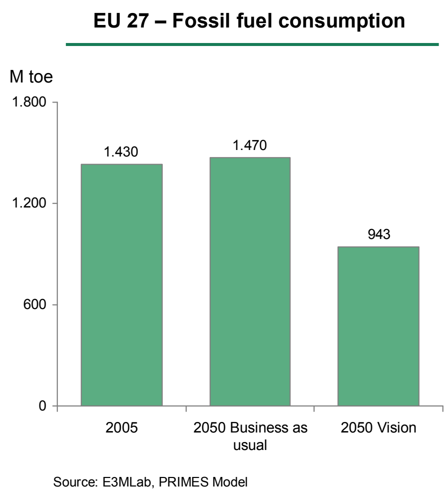
Environmental effects

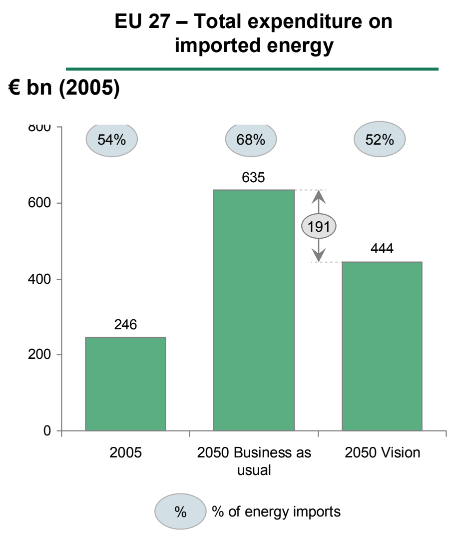
- More than 60% GHG emissions reduction by 2050
- More than one third RES proportion of total final energy demand

Europe aims at improving the security of supply, environmental sustainability and competitiveness.

Fossil fuel consumption will be significantly lower when compared to a b.a.u. scenario (more than 30% decrease expected by 2050). This implies that Europe will be able to reduce its external dependency on fossil fuels. An increase in the share of RES, in conjunction with greater energy efficiency in consumption, may offset lower internal fossil fuel production. The net effect is a fall in the proportion of fossil fuel imports in total fossil fuel consumption to 52% as against 68% in the b.a.u. scenario. This represents approximately €190 billion (at 2005 values) of savings per year and improvements will not be more noteworthy because internal production of oil and gas is expected to decrease strongly.

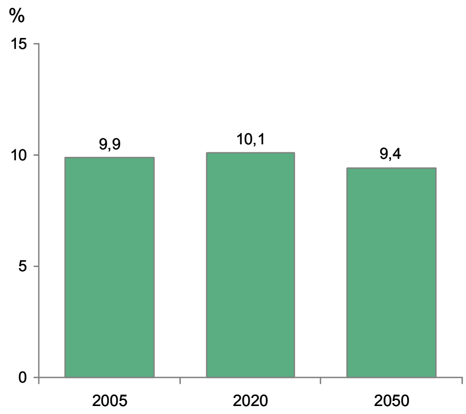
While this change naturally represents an increase in energy costs, the proportion of energy expenditure in GDP will be lower in 2050. By 2050, the proportion of energy expenditure in GDP will be 9.4% instead of the current 2005 figure of 9.9%.





The envisaged scenario represents a moderate increase in unit energy costs. A number of factors may be able to dampen the cost impact, namely, economies of scale and experience and efficiency improvements. This price effect may be expected to be somewhat compensated by energy efficiency gains. For example, the 2050 average household fuel bill is expected to be around €100 lower.

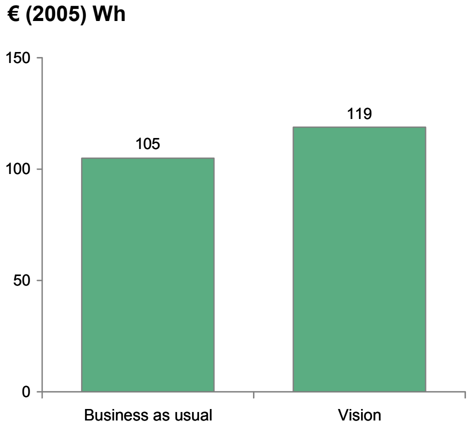
EU 27 – Total direct and indirect cost of energy per unit of GDP



Source: E3MLab, PRIMES Model

If Europe's initiative is followed by other regions of the world, then the avoided inaction costs more than compensate for higher energy costs. On the other hand, if Europe is not followed by the rest of the world, European competitiveness in energy intensive sectors could suffer a serious setback and the achievement of climate change goals could be severely compromised.

EU 27 – Average price of energy purchases by consumers in 2050



Source: E3MLab, PRIMES Model

The power sector is expected to invest approximately €2 000 billion (2005 values) until 2050 in new generating capacity, meaning an increase of around500 billion as compared to b.a.u. projections. This investment increases significantly if account is taken of the additional investment to be made in other energy-supply infrastructures applied to all economical sectors. The extra investment in smaller, more dispersed and more RES based generation will create, by itself, over 1.5 million new jobs in and around the energy sector. Furthermore, European companies will be able to export products, services and know-how to the rest of the world. Moreover, spillover effects from leading-edge research in the energy sector will take place. This is expected to more than offset the extra investments and costs.