In support of the G8 Plan of Action

ETP 2008: Demand Side Energy Technology Deployment

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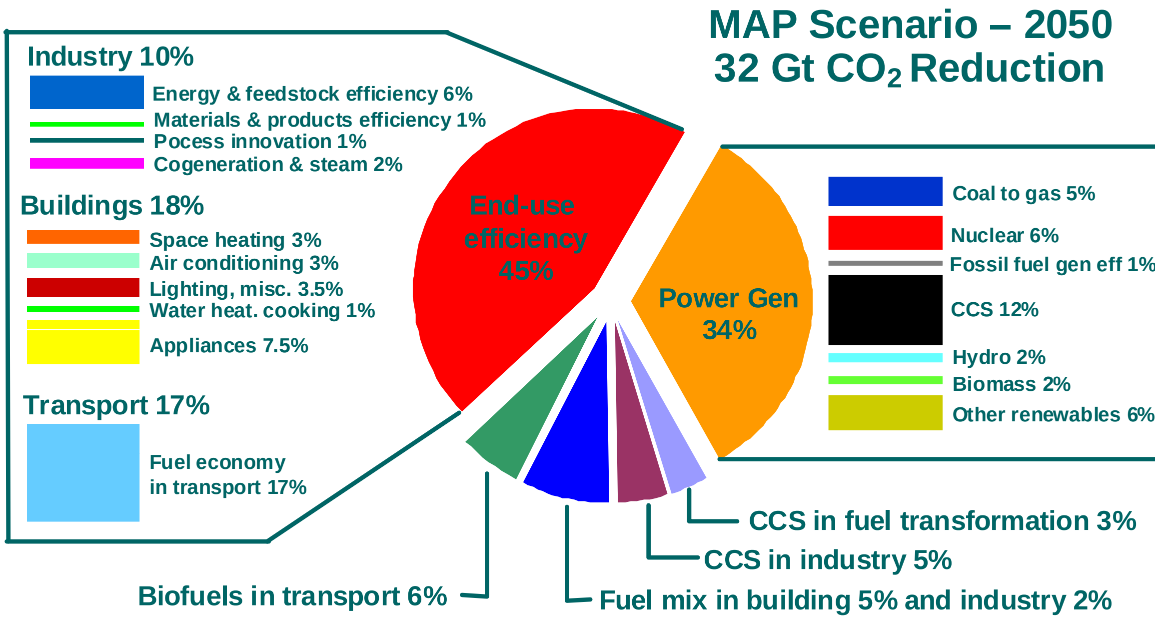
Introduction

The IEA study *Energy Technology Perspectives 2006* (ETP 2006) demonstrates how energy technologies can contribute to a stabilization of CO_2 emissions at today's level by 2050. The results of the scenario analysis showed that no fundamental technology breakthroughs are needed. Technologies that are available today or that are under development today will suffice to meet the target. In this present analysis we focus on technology learning and deployment aimed at overcoming the "valley of death" faced by new technologies which have passed the RD&D phase, but still need to "buy down" high costs before they can enter the commercialisation phase.

The results of the ETP 2006 analysis shows that end-use energy efficiency and emission reduction in electricity production dominate total emissions reduction. Figure 1 shows the contribution of various technology categories to the emission reduction in the ACT Map scenario, in 2050, compared to the Baseline scenario. Forty five percent of the emission reduction is accounted for by end-use energy efficiency. Thirty four percent is accounted for by measures in power generation. CCS plays also an important role in the fuel transformation sector and in industry. Finally biofuels in transport account for 6% of the emissions reduction.

Figure 1: Emission reduction in the ACT Map scenario, 2050



Source: IEA estimates

Reducing CO_2 emissions from demand side energy uses, either through energy efficiency or the use of cleaner technologies and fuels will be critical. Lower emissions from Buildings, Industry and Transport represent 57% of the 32 Gt of CO2 emissions reductions under the ACT Map scenario. The majority of the demand side technologies under ACT Map are available today and many are already cost effective based on a life cycle cost (LCC) analysis. There is less of a technology deployment barrier to overcome than for supply side technologies and more stringent standards and codes can help to speed up market uptake and reduce the cost of deploying certain technologies. More detail on the key technologies in the Buildings, Industry and Transport sector for the ACT Map scenario can be found in Annex I.

The leaders of the G8 countries have stated in their communiqué in Heiligendamm that they will “seriously consider” a 50% CO_2 emissions reduction target by 2050. The 50% target implies a radically different policy than under a stabilization scenario. A new scenario, known as the “Blue” scenario has been developed that shows the technology implications of a 50% reduction in CO_2 emissions or an additional 13 Gt of CO_2 savings beyond the ACT Map scenario.

Technology learning

Most new energy technologies initially have higher costs than the incumbent technologies. Costs can be reduced by further R&D and usually fall, sometimes significantly, as a result of the “technology learning” effect. The process of technology learning – in which production costs decrease and technical performance increases as cumulative installed capacity rises – can make new technologies available at lower costs (Boston Consulting Group 1968, OECD/IEA, 2000). In fact the cost of new technologies may drop below the cost of existing technologies. If this is the case, the switch to the new technologies will reduce the energy cost in the long term. However market forces do not value such long term uncertain benefits highly. This is a major reason why government intervention could be warranted.

The prospect that a given technology will be produced and sold on the market can stimulate private industry R&D (“learning-by-searching”) and improvements in the manufacturing process (“learning-by-doing”). Feedback from the market may suggest avenues for improving a technology, reducing its costs or tailoring some of its features to consumers’ needs (“learning-by-using”). These benefits are only reaped when technology is actually put in the market. The rate of technology improvement is therefore usually a function of the rate of technology adoption.

The reliability of using learning rates to project future cost reductions is unclear. A better understanding of the factors that drive future cost reductions is needed in order to reduce the uncertainty of using learning rates to estimate future deployment costs. Bottom up engineering models alone often lead to over estimates in deployment costs as “learning aspects” are not captured and hence may lead to “technology lockout”. A mixed approach of learning curve analysis backed by engineering models is needed to provide a better analysis for deployment needs.

Technology learning for energy supply technologies

On June 11-12, 2007 the IEA Secretariat held a technology learning and deployment workshop focusing on supply side technologies. The meeting brought together key experts with hands-on experience in technology deployment policy setting from industry, governments and academia. Special attention was given to the application of technology learning for energy research and development (R&D) and energy investment decisions in emerging new technologies. Many of the issues discussed on technology learning are also applicable to demand side technologies.

The following main conclusions from this workshop are also relevant for this analysis:

- Learning curves, when backed by bottom-up engineering models can provide insightful information on future cost reduction potentials in energy technologies;

- For most technologies, where new knowledge spills over national boundaries, global learning rates are recommended over national learning rates;

- Care should be taken to insure that the correct system boundaries are used for a given technology as the resulting learning rate can be significantly different;

- Support is needed on both the technology pull (deployment) side to bring the technology to market and on the technology push (R&D) side to find additional solutions;

- A flexible framework is required to accelerate deployment of clean technologies. Policies should be continuous and predictable, but adjustments should be possible. Too much government support is a problem and industry should be encouraged to establish itself. Government should avoid picking winners in the R&D and deployment stage of technologies;

- Businesses want more clarity and certainty regarding long term market rules so that investment decisions can be made based on calculated risks;

- A value for CO_2 is needed for companies to take effective action on combating climate change;

- More effective international cooperation in energy technology deployment is needed; and

- Exploration and exploitation of niche markets are necessary to open up markets and to reduce the cost of deployment for government.

Deployment of Demand Side Technologies

This discussion paper aims to address a number of important issues which will be discussed at the 8-9 October 2007, *Deploying Demand Side Energy Technologies Workshop*. This paper will draw from the findings of our first workshop and will show how a learning curve approach can also be used to estimate deployment cost needs for end use technologies in buildings, industry and transport. The large majority of these end use technologies are energy efficiency technologies which are already cost effective today and hence this paper will also cover aspects of technology diffusion and policies aimed at overcoming barriers to market uptake. The paper and workshop aim to address the following questions:

- How is technology deployment of demand side technologies defined?
- Which demand side technologies require deployment support?
- How can learning curves be used to estimate deployment costs?
- What are the similarities and differences with respect to supply and demand side technologies?
- What are the estimated deployment costs for demand side technologies?
- What are the total investments costs?
- What policies are needed to over come barriers to deployment of energy efficient technologies?
- How fast can technology deployment expand?
- How can international collaboration promote technology deployment and diffusion?

1 How is technology deployment of demand side technologies defined?

Deployment is the term used for the technology stage between research, development and demonstration (RD&D) and market uptake. The technology is not yet economic, compared to the established technologies, except for certain niche markets. Production takes place on a small industrial scale. Technology learning based on mass production (economies of scale) and series of small product improvements result in cost reductions. Production is rapidly expanding during this production stage.

Figure 2: Stages in Technology Development

R&D:	Technologies in need of R&D to overcome technical barriers and to reduce costs. The outcome is still uncertain, especially in the early stages of development.
Demonstration	Demonstration of the technology. Often government funding is needed to finance part or all of the costs of the demonstration.
Deployment	Successful technical operation, but in need of support to overcome cost barriers. With increasing deployment learning-by-doing effects will result in gradually decreasing costs.
Competitive	Technology is cost competitive in some or all markets, but some technologies may require sustained incentives to value CO_2 emission reduction or other benefits.

Source: IEA

In the case of demand side technologies a life cycle cost (LCC) analysis is applied to determine whether a clean or more efficient technology is competitive vis-à-vis the incumbent technology. For example, compact florescent light bulbs (CFLs), which are more expensive than incandescent light bulbs are seen as cost effective since the total cost of the CFL plus the cost of the energy required during the life of that bulb is estimated to be US$ 25 which is more than three times less than an estimated US$ 80 for an incandescent bulb (IEA 2006). Where technologies are already cost effective, the issue of market uptake is one of technology diffusion and not deployment as defined above in Figure 2.

Contrary to supply technologies, a significant portion of the demand side technologies applied in the ETP analysis are available today and are already cost effective. Of the 45% reduction in CO_2 emissions from energy efficiency, only a third requires additional government support for deployment to bring these technologies to commercialisation. The remaining two-thirds are already cost effective. Government support for deployment is not warranted in these cases, but government interventions through regulation is needed to over-come market barriers and promote technology diffusion.

2 Which demand side technologies require deployment support?

For our analysis of deployment costs we will focus only on technologies which are not cost effective today based on a life cycle cost analysis. These technologies still require government support for deployment as higher capital costs are not justified by lower operating costs. Although fuel cell vehicles are not included in the results for ACT Map we have included it in our deployment costs analysis as it is significant to the results of the Tech Plus and Blue scenarios. A number of technologies listed below represent a group of technologies, but for the purpose of our deployment analysis will be treated together.

Buildings
Solar heating and cooling
Ground source heat pumps

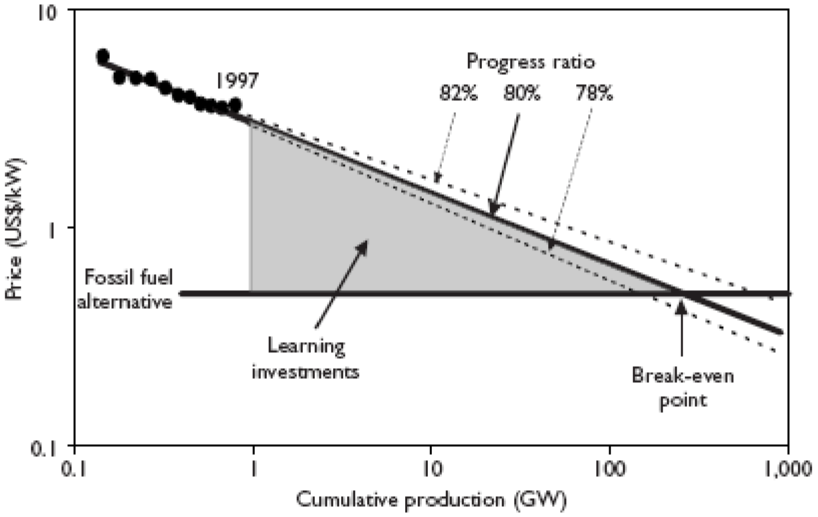
Industry
CO_2 capture and storage for blast furnaces
CO_2 capture and storage for cement kilns
CO_2 capture and storage for black liquor gasifiers
Feedstock substitution

Transport
Hybrid vehicles
Plug in hybrids
Fuel cell vehicles
2nd generation biofuels

3 How can learning curves be used to estimate deployment costs?

Technology learning curves can be used to derive deployment costs for new technologies. Learning curves show a constant reduction of the investment cost for each doubling of production. Figure 3 demonstrates how this relationship can be used to estimate the learning investments necessary for a technology to arrive at the cost of the incumbent technology or “break-even” point. Learning curves are useful tools to help estimate learning costs for new technologies, but the accuracy of the results is uncertain as learning rates are uncertain.

Figure 3: Learning curve for making Photovoltaics break-even



Break-even point and learning investments for photovoltaic modules with a progress ratio of 80%. The shaded area indicates the remaining learning investments to reach the break-even point. The figure also shows changes in the break-even point for progress ratios of 78% and 82%.

Source: IEA 2000
Note: 1 minus the progress ratio is equal to the learning rate.

A review of the current literature on learning curves for energy technology has raised a number of issues on how learning rates should be applied. The common use of price versus cost data due to the confidentiality and therefore lack of available cost based data has resulted in uncertain learning rates. Additional analysis and further data collection is required to examine the right system boundaries to be used when applying learning curves.

Literature sources show that learning curves have been validated for a wide range of energy technologies over many orders of magnitude, see e.g. (IEA 2000, McDonald and Schrattenholzer 2001, Neij 2003, Junginger 2005…). The bulk of this literature has focused on energy supply technologies. Learning curve analysis for demand side technologies has been limited, but significant enough to indicate that “learning-by-doing” effects are also present in demand side technologies and hence also represent a useful tool to analyse future cost reduction potentials in demand side technologies (Newell 2000 and Laitner 2004).

Table 1: Observed learning rates for various demand side technologies

Technology	Country / Region	Period	Learning Rate (%)
Ford Model T	USA	1909 -1923	13
Refrigerators	USA	1980 -1998	12
Freezers	USA	1980-1998	22
Clothes Washers	USA	1980-1998	13
Electric Clothes Dryer	USA	1980-1998	12
Dish Washer	USA	1980-1998	16
Room Air conditiner	USA	1980-1998	15
Selective Window Coatings	USA	1992-2000	17
Heat Pumps	Germany	1980-2002	30
Heat Pumps	Switzerland	1980-2004	24
Facades with insulation	Switzerland	1975-2001	17-21
Double glazed coated windows	Switzerland	1985-2001	12-17
CFL	Global	1990-2004	10
Air conditioners	Japan		10-17

Source: McDonald and Schrattenholzer 2001 & 2003, Laitner 2004, ECN 2005, Jakob 2003, and Ellis 2007.

In the case of energy efficient appliances (which account for 7.5% of the 45% reduction in emissions from energy efficiency), it has been shown that bottom up engineering models have over estimated the cost of bringing these technologies to market (Ellis 2007). These models did not take into account the impacts of “learning-by-doing” which have offset many of the higher costs related to more efficient components. As these “learning effects” are not captured in engineering models, a combination of top down learning curve analysis with bottom up engineering models is required to better estimate the costs of bringing technologies to market.

4 What are the similarities and differences with respect to deployment of supply and demand technologies?

End use or demand side technologies, especially in the building sector are made up of a diverse range of relatively small technologies which vary from light bulbs to a side array of home electronics and appliances; to hybrid electric vehicles; to much larger industry technologies such as electric arc furnaces used in steel production. In contrast supply side technologies, which is dominated by power generation technologies is comprised of a couple dozen very large technologies. These technologies are tremendously capital intensive and in general globally uniform, while most demand side technologies are labour intensive and may vary widely from country to country.

Many of the larger industrial technologies share similarities with many supply technologies in the power sector as they are also capital intensive and have a long capital stock turnover rate which limits the rate of new technology deployment. In a number of cases, the capital stock in industry and that of the power sector are closely aligned as many power plants were built to satisfy the electricity needs of industry.

The differences between supply and demand technologies and even amongst various demand technologies have not led to material differences in the fundamental way technology learning and deployment can be applied to these technologies. Perhaps the main underlying difference is the rate at which deployment can occur, with many of the small end use technologies in the building sector having the potential for quicker deployment given their significantly lower life span.

Both demand and supply side technologies have shown impacts of learning by doing in new technologies. For model consistency both supply and demand side technologies need to include learning by doing effects. To apply learning to just one side without the other would lead to biased results. The impact of learning by doing on the end use technologies effectively reduces the need for investments in supply technologies.

5 What are the estimated deployment costs for demand side technologies?

Deployment cost estimates are very sensitive to assumed learning rates. An overly conservative learning rate may lead to a technology being dropped, while an unjustified high learning rate could lead to unrealistic expectations on potential cost reductions and a misallocation of limited deployment investments. The total investments or deployment costs needed to bring down the cost of each technology was estimated based on a learning curve approach. Table 2 outlines the boundary used for this analysis and the learning rates applied.

Table 2: Applied learning rates for building, industry and transport technologies

			Current Cost ($)	**Learning rate (%)**	**Cost target to reach commericalisation***
	Unit	**Boundary**			
Fuel Cell Vehicles (millions of cars)	$ / kW	FCV drive system cost	1875	22%	50
Hybrid Vehicles (millions of cars)	car	ICE+ electric+ battery	2500	20%	1000
Lignocellulosic ethanol (Mtoe)	$ / litre	fuel cost	1 (2020)	2%	0.5
FT-biodiesel (Mtoe)	$ / litre	fuel csot	1 (2010)	5%	0.5
Plug-in Vehicles (millions of cars)	car	Batteries for plug-ins	10000	20%	3000
Ground Source Heat Pumps (m)	$ / system	heat pump + installation	15000	15%	7000
Solar Heating and Cooling (m m2)	$ / m2	panel	630	10%	450
Feedstock substitution, Mt	t ethylene		1300	10%	650
CCS blast furnace (Mt CO2)	$ / t CO2	CCS cost	150 (2030)	5%	100
CCS cement kilns (Mt CO2)	$ / t CO2	CCS cost	200 (2030)	5%	150
CCS black liquor IGCC (GW)	$ / kW	Production cost	1600 (2030)	5%	1200

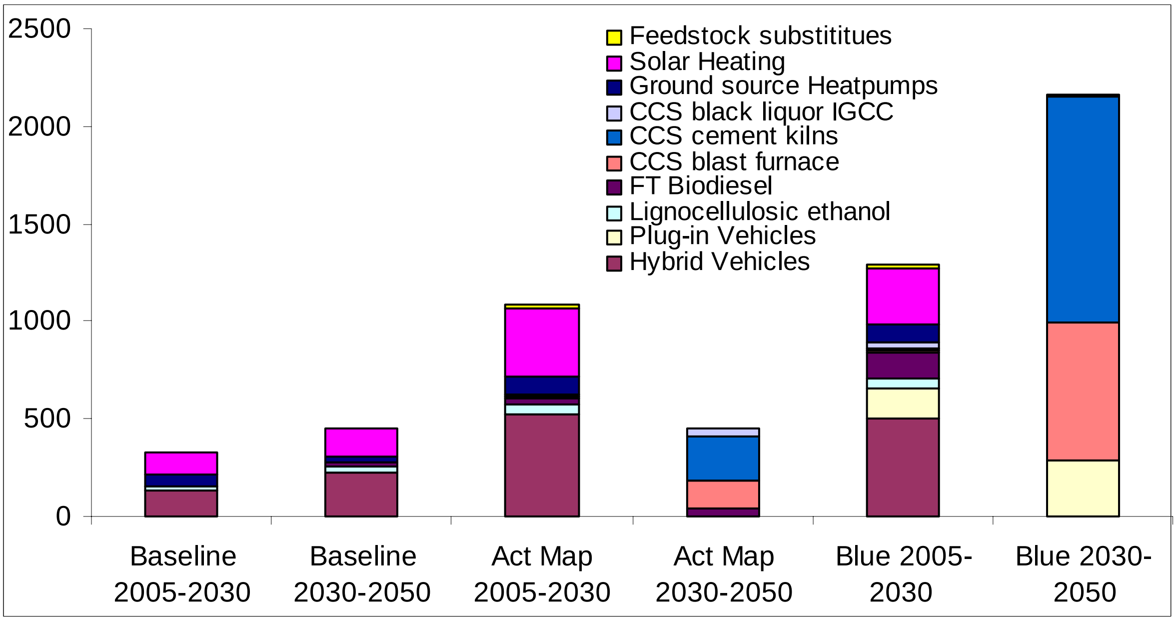
Source: IEA estimates
*A discount rate of 10% was applied to calculate the annualized cost of the incumbent technology and an import fuel cost of $6.5-7 / GJ (7 was assumed for the energy saved.

In this analysis we have applied learning rates to a number of technologies which are still at the RD&D phase which is very uncertain as the evolution of costs in unproven technologies can be difficult to predict. Unexpected measures, externalities or market changes could result in a significant increase in costs that lie outside of a given learning curve boundary system. On the other hand, the analysis does not include other external benefits such as reduced local air pollution or increased supply security.

The deployment costs in Figure 4 are undiscounted. Discounted costs would show significantly lower costs. However the slower the technology develops, the lower the value of future benefits once the technology becomes cost effective. In an extreme case, the cost may exceed the long-term discounted benefits.

It should also be noted that the analysis assumes 100% success in technology development. In practice, technology development is a very uncertain process. For example in the field of car technologies, many options have been tried in the past three decades, while only very few have survived. If the failure of certain technologies were assumed the costs would be higher.

Figure 4: Breakdown of deployment costs for demand side technologies



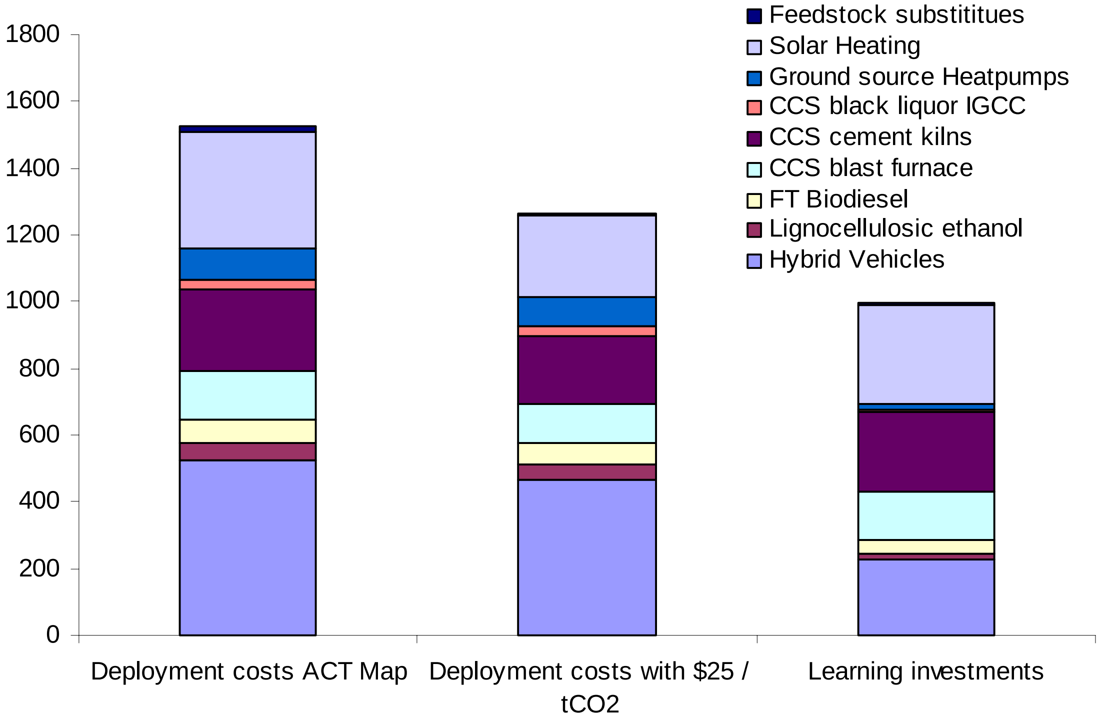
Source: IEA estimates
Note: figures are not discounted
* The figure above excludes investments for Fuel Cell Vehicles under the Blue scenario which total $ 15 bn from 2005-2030 and $ 1.16 trillion 2030-2050

Total deployment costs under Act Map from 2005-2050 for energy technologies in Buildings, Industry and Transport are estimated at $ 1.53 trillion. Deployment costs for the 2005-2030 period are estimated to be $ 1.08 trillion and the largest portion of these investments are expected to be for hybrid vehicles and solar heating. During the 2030-2050 period, total deployment costs are significantly lower at $ 0.45 trillion. In comparison, deployment costs for power generation technologies are estimated at $ 3.95 trillion from 2005-2050, of which $ 2.61 trillion are needed from 2005-2030 and a much smaller $ 1.35 trillion are required from 2030-2050. Total deployment costs for the technologies under the ACT Map scenario are estimated to be $ 5.48 trillion from 2005-2050. The deployment costs represent the total costs of cumulative production needed for a new technology to become competitive with the current incumbent technology. The difference between the deployment costs and the cost of the incumbent technology are the learning investments.

The deployment costs estimates vary significantly between the baseline, ACT Map and Blue scenarios. Fuel cell vehicles and plug-in hybrids are only applicable under the Blue scenario. These two technologies are too expensive under the ACT Map scenario which assumes $25 / tCO_2. In the baseline scenario, there is no CCS in industry or feedstock substitution and as in the ACT Map scenario no fuel cell vehicles and plug-in hybrids. Figure 4 above shows the estimated deployment costs for each technology under the baseline, ACT Map and Blue scenario. Deployment costs for 2005-2030 under the baseline scenario are estimated to be $ 0.79 trillion, just slightly more than half the $1.53 trillion under ACT Map. Deployment costs for buildings, industry and transport under the Blue scenario are more than 4.5 times greater at $ 7.1 trillion. Half of the deployment costs under Blue can be attributed to fuel cell vehicles which require estimated investments of $ 3.6 trillion.

The deployment costs above are based on current costs of incumbent technologies and do not include a value for the reduction in CO2 emissions. If a credit of $25/ tCO2 saved were applied to the technologies, the total deployment costs in buildings, transport ad industry under ACT Map would fall by 17% from $ 1.5 trillion to $ 1.3 trillion.

Figure 5: Deployment costs and learning investments under ACT Map 2005-2050



Source: IEA estimates

7 What policies are needed to over come barriers to deployment of energy efficient technologies?

Energy efficiency represents the single largest solution to reducing future CO_2 emission and the majority of the technologies needed are available today at low or negative costs. Numerous market barriers exists which need to be overcome if energy efficient technologies are going to deliver on expected savings. The main barriers are listed in Table 3 below.

Table 3: Barriers to technology diffusion

Barrier	Key Characteristic
Information	Availability and nature of a product must be understood at the time of investment
Transaction costs	Costs of administering a decision to purchase and use equipment
Buyer's risk	Perception of risk may differ from actual risk
Finance	Initial cost may be high threshold Imperfections in market access to funds
Capital stock turnover rates	Sunk costs, tax rules that require long depreciation and inertia
Excessive / inefficient regulation	Regulation based on industry tradition laid down in standards and codes not in pace with development
Uncompetitive market price	Scale economies and learning benefits have not yet been realised

Source: IEA 2003

Energy efficient technologies which are cost effective today require government intervention through policies aimed at removing barriers to greater market uptake. Codes and standards are the most effective way of bringing these energy efficient technologies to commercialisation. A wide range of other policy instruments are available such as public information campaigns, non-binding guidelines, labels and targets and fiscal and other financial incentives.

The policy framework has to be flexible enough to allow for innovation because this is an area that is constantly evolving. There is a need for minimum energy performance standards, but such standards should be broadened to more products and they should reflect the globalisation of manufacturing. Steps should be taken to avoid the dumping of less efficient products in developing countries. Performance standards should be accompanies by labelling programmes, which are carefully designed to give consumers information in a way they can make use of at the time of purchase. Both performance standards and labels need to be reviewed regularly to keep up with and anticipate technological change. They need to be sufficiently ambitious to reward industry that is prepared to be innovative and produce highly efficient products.

Incentives like labelling schemes, tax reductions (for more efficient equipment) and improved information would encourage the public to purchase more efficient energy consuming goods which would send signals to industry to develop more energy efficient and cleaner products.

8 What determines the speed of technology diffusion?

Technology diffusion can be defined as the rate at which new technologies expand in the market. The speed to which a technology can be deployed will be limited to the rate of technology diffusion which is constrained by the capital stock turnover or the rate in which old equipment is replaced by new equipment. New technologies are purchased either to replace old equipment or as first time purchases. The rate of economic growth and increase in new homes are the main factors impacting first purchases of most durable goods. The rate of equipment replacement will usually be determined by the useful lifetime of a particular good.

The rate of technology diffusion depends on a number of factors, such as:

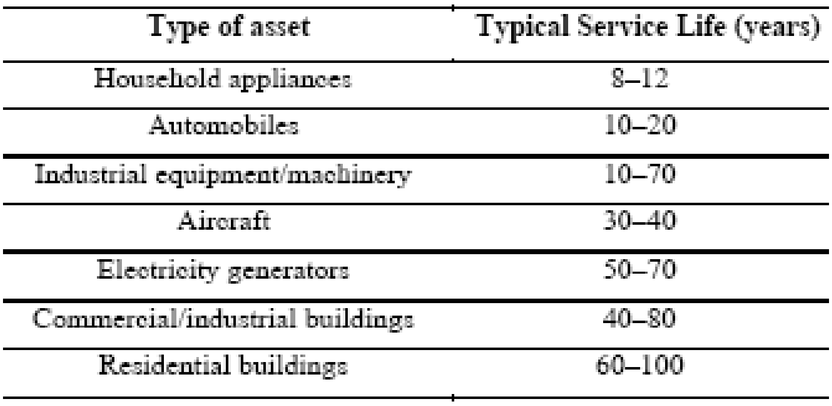
- The market growth rate, and the rate at which old capital stock is phased out
- The rate at which new production capacity can come onstream (factories)
- The extent of market fracturing
- The availability of a supporting energy infrastructure (eg hydrogen supply)
- The viability and competitiveness of alternative options
- The existence and phase out of constraining standards and regulations
- The rate at which skilled personnel can be educated for the production and the installation and possibly maintenance of such equipment
- Market power of existing suppliers and their involvement in marketing new solutions
- Consumer information and interest
- Existence of policies that support the introduction of a new technology

The relevance of these factors depends on the specific product. The first five factors can be estimated for individual products based on market characteristics. The last six are often hard to quantify. However policies can be put in place to mitigate the delays caused by these factors.

For this study, market growth and capital stock are considered the key constraining factors. As a consequence the uptake can take place at a faster rate in rapidly growing markets (developing countries) and the rate is higher for short life products than for long life products.

The table below outlines the typical life time of a range of energy consuming goods and shows that for most technologies the timeframe for diffusion of many new energy technologies will be in the order of decades. Technology diffusion will often start slowly until consumers are confident that the new technology is reliable. In the ETP scenarios, new technologies are assumed to replace old technologies only at the end of their useful life.

Table 4: Typical life time for energy consuming capital goods



Type of asset	Typical Service Life (years)
Household appliances	8–12
Automobiles	10–20
Industrial equipment/machinery	10–70
Aircraft	30–40
Electricity generators	50–70
Commercial/industrial buildings	40–80
Residential buildings	60–100

Source: Jaffe 1999

In the case of more energy efficient vehicle technologies, diffusion in many OECD countries will be limited by the trend towards heavier vehicles that has resulted in a large fleet of SUVs, pick-up trucks and vans, which are relatively inefficient and will likely remain in circulation for the next 10-20 years. In the US these types of vehicles represent 41% of register passenger vehicles in 2005 (Gallager 2007).

Market growth rates are often overestimated. For example it took 10 years to get to one million cumulative hybrid vehicle sales. In comparison, 70 million cars are sold per year. The purchase of consumer durables, especially cars and home electronics and appliances are not often based on energy efficiency or environmental issues and hence market growth rates will be difficult to predict unless policies are implemented (such as minimum efficiency standards, building codes and tax incentives) to promote the uptake of these technologies. Sales of energy efficient products such as condensing gas boilers, compact fluorescent lamps are growing, but getting a significant market share takes decades.

The long life of many goods indicates that deployment of clean technologies will require international collaboration and significant benefits exists to speed up technology deployment by focusing efforts in newly industrialised countries where a large market of first time buyers exists. An important barrier will be costs, as clean technologies are often more expensive and first time buyers in these countries are generally constrained by limited budgets and high financing costs.

For many products market growth rates are high following introduction, but they tend to slow as a larger share of the market is taken. For new products it is difficult to forecast accurately this saturation effect.

9 How can international collaboration promote technology deployment?

The benefits of technology learning are typically shared on a global level. This emphasises the need for international collaboration on technology development and deployment[1]. In many cases, deployment costs can be lowered through international collaboration. From an industry policy perspective, these higher deployment costs may be justified by countries wanting to build a national industry for a certain energy technology. This industry policy dimension has been an important driving factor in the past.

Technology transfers from OECD to non-OECD countries would help to not only promote the up-take of cleaner technologies in non-OECD countries, but could also speed up the deployment phase as manufacturing costs are generally lower in non-OECD countries. However such a strategy runs contrary to the industry policy argument.

Developing countries can benefit from international technology transfer by leapfrogging to the most advanced energy technologies, rather than repeating the path taken by developed countries. In reality, the high cost of advance energy technologies and the lack of know how and expertise often limits the amount of actual energy technology leapfrogging which occurs. Greater international collaboration is needed to promote the deployment of clean technologies in developing countries to avoid technology lock-in. Rapid demand growth for a wide range of consumer goods in developing countries represents a unique opportunity to deploy cleaner technologies and provide a market for technology transfer.

Industrialised countries need to promote technology transfer to developing countries and developing countries need to apply more stringent standards and codes to encourage the market uptake of cleaner technologies. Many developing countries are reluctant to impose tough standards and codes for fear of hurting local businesses, but this often results in less efficient technologies being commercialised and creates barriers to technology transfer of

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[1] The IEA Implementing Agreements offer a good opportunity to improve international collaboration on technology development and deployment.

clean technologies. Without more aggressive local regulations, local firms will not be able to access cleaner technologies through the technology transfer process.

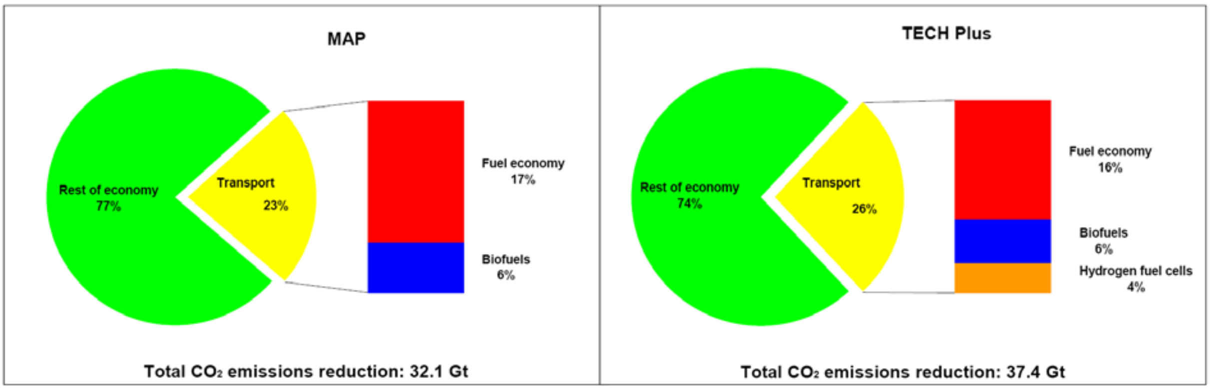
Annex I

The Accelerated Technology scenarios or ACT scenarios show the potential of energy technologies and best practices aimed at reducing energy demand and emissions. The scenarios focus on technologies which exist today or which are likely to become commercially available in the next two decades. The ACT Map scenario leads to a 6% increase in CO_2 emissions in 2050 compared to 2003 and represents a 55% reduction in CO_2 emissions in 2050 compared to a baseline scenario where CO_2 emissions are 137% higher than in 2003. The key transport; buildings and industry technologies considered under the ACT Map scenario are outlined below.

Transport Technologies

Transport vehicle technologies and fuels contribute 23% of total emission reductions in the Map scenario and 26% in the TECH Plus scenario (Figure 6) In Map scenario improved fuel economy from increased use of hybrids and from improvements in engine and non-engine components contribute a little more than two-thirds of the transport savings. The rest is from biofuels including biodiesel, grain and sugar-based bioethanol and cellulosic ethanol. In the TECH Plus scenario, the overall contribution from biofuel increases due to higher penetration of cellulosic ethanol, although its share of CO_2 emissions reduction remains the same. In this scenario hydrogen fuelled fuel-cell vehicles contribute 4% of the total global emission reduction. The total reduction attributable to hydrogen fuel-cell vehicles comes from both using CO_2-free hydrogen as a fuel and through the high efficiencies fuel-cell vehicles offer relative to other vehicle alternatives. Fuel cell vehicles have about 30% of the global market share by 2050 and this limits the total fuel economy improvement for other vehicles. This explains the slightly lower share for fuel economy improvements in TECH Plus relative to Map.

Figure 6: Share of road transport in global CO_2 emission reductions relative to Baseline in the Map and No CCS scenarios, 2050



By 2015 options to improve the fuel economy of internal combustion engines (variable valve control, direct injection and improved combustion technologies) and non-engine fuel saving measures (increased use of energy-efficient tyres, lighter materials and more efficient air conditioners and lighting) dominate. By 2030, increased use of hybrid powertrains and biofuels start to have a significant impact. In the long-run, further improvement of the technologies in these two categories plays a key role in reducing emissions. In the TECH Plus scenario, more than half of the emission reductions by 2050 are due to cellulosic ethanol and fuel-cell vehicles fuelled with CO_2-free hydrogen.

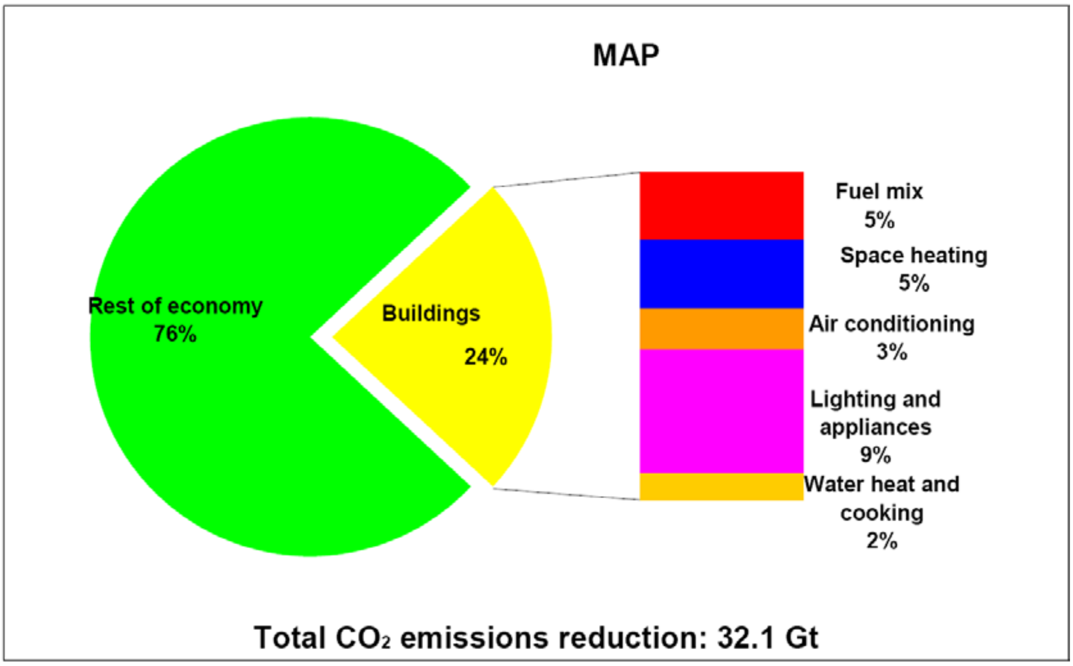
Table 5: CO_2 savings and Technology Status in Industry

Technology	Amount of CO2 savings in 2050 – Gt CO2/ yr	Deployment Status
Fuel efficiency improvements	2.2	Cost effective based on LCC, deployment via policies on standards
Non-engine savings	1.8	Cost effective based on LCC, deployment via policies on standards
Hybrid Vehicles	1.4	Further R&D and deployment needed
Fuel Cell Vehicles	0.8	Further R&D and deployment needed
Conventional biofuels	1.7	Cost effective today
2nd generation biofuels	0.7	Further R&D, Demonstration and Deployment needed
Hydrogen	0.7	Further R&D, Demonstration and Deployment needed

Building Technologies

Buildings account for about 24% of the total CO_2 emission reductions below the Baseline Scenario in 2050 in the Map scenario. Given the generally high CO_2 emissions intensity of electricity generation, end-uses where significant electricity savings are made due to efficiency measures dominate the share of total savings. Lighting, appliances and air conditioning account for half of the total CO_2 emissions reduction in the building sector by 2050 (Figure 7).

Figure 7: Share of buildings and appliances in global CO_2 emission reductions relative to Baseline in the Map and No CCS scenarios, 2050



Many of the technologies that offer significant energy efficiency opportunities are currently cost competitive and can contribute to reducing CO_2 emissions in the short- to medium term. The CO_2 emissions reduction potential in the buildings sector in the short to medium-term is therefore quite high compared to some other sectors. Savings in many of the electricity end-uses, particularly lighting and appliances can be achieved early and at low or even negative cost. Savings grow to 2050, with the largest contributions coming from heating and cooling technologies and building shell measures.

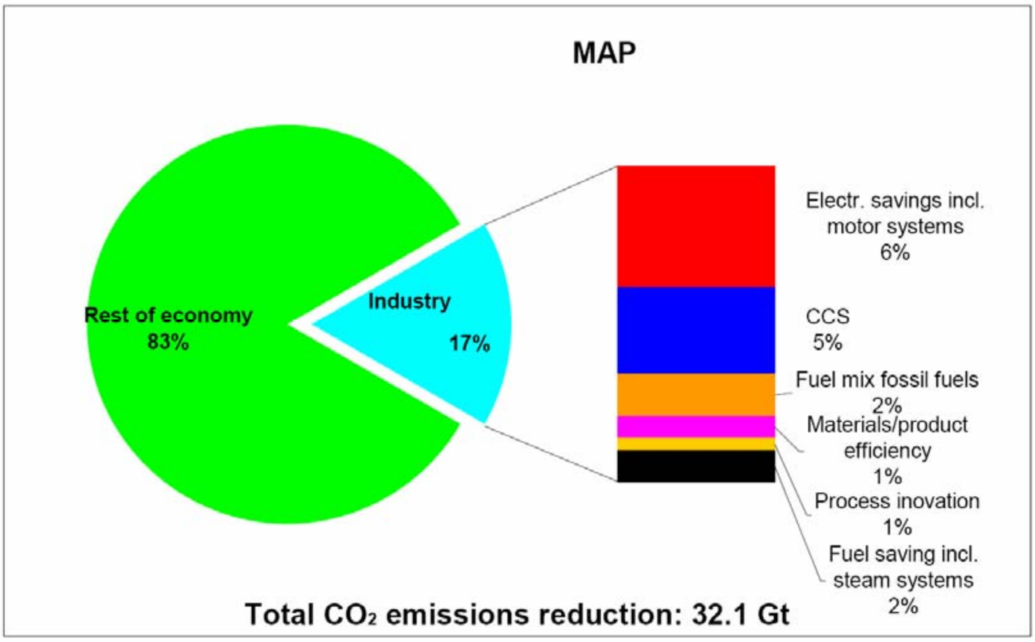
Table 6: CO2 savings and Technology Status in Buildings

Technology	Amount of CO2 savings in 2050 – Gt CO2/ yr	Technology Status
Heating and cooling technologies	1.1	Cost effective based on LCC, deployment via policies on standards
District heating and cooling systems	0.5	Cost effective based on LCC, deployment via policies on standards
Building shell measures	1.6	Cost effective based on LCC, deployment via policies on building codes
Lighting systems	1.0	Cost effective based on LCC, deployment via policies on standards
Appliances	2.1	Cost effective based on LCC, deployment via policies on standards
Stand by losses	0.3	Cost effective based on LCC, deployment via policies on standards
Building energy management systems	0.2	Cost effective based on LCC, deployment via policies on standards
Solar Heating and cooling	0.6	Further R&D and deployment needed

Industry Technologies

Industry consumes about 30% of the world's primary energy demand. The sector's fuel consumption is responsible for about 23% of total CO_2 emissions. Any improvement in the energy efficiency of industry will provide carbon savings. Other options can increase the CO_2 reduction potential further.

Figure 8: Share of industry in total global emission reduction relative to Baseline scenario ACT Map scenario, 2050



Total industrial CO_2 emissions reduction is 5.4 Gt CO_2, of which 2.4 Gt CO_2 are due electricity savings that reduce emissions in the electricity sector. Another 0.3 Gt CO_2 is accounted for in the other transformation sector. CCS accounts for 27% of industrial savings, while fuel and feedstock substitution account for 18%. Energy, product and process efficiency improvements account for 55%.

Several options rely on technologies that are available today. Certain options, such as more motor systems, are in fact cost-effective today, with their uptake limited by non-cost barriers.

If the remaining barriers can be removed in a timely fashion, these options could play an important role by 2015. Such options include better maintenance of steam systems and the retrofit of existing inefficient plants, or the closure of outdated small plants. These measures can be induced through proper energy pricing, better management systems and standards and regulations.

Other options are further from market introduction. While some biomass feedstocks are already in use today (*e.g.* for detergents), others will require further R&D, such as new production routes for biopolymers. Where additional R&D is needed, the main uptake is projected for the 2030-2050 period. This is also a period with oil and gas prices that are considerably higher than in 2015, which further increases the potential uptake of all energy saving options.

Table 7: CO_2 savings and Technology Status in Industry

Technology	Amount of CO2 savings in 2050 – Gt CO2/ yr	Deployment Status
Co-generation	0.3	Cost effective
Motor systems	1.5	Cost effective
Steam systems	0.3	Cost effective
Energy efficiency in processes	0.4	Cost effective
Process innovation	0.2	Further R&D, Demonstration and Deployment needed
Fuel substitution	0.5	Further R&D, Demonstration and Deployment needed
Material / product efficiency	0.3	Further R&D, Demonstration and Deployment needed
Feedstock substitution	0.4	Further R&D, Demonstration and Deployment needed
CCS	1.5	Further R&D, Demonstration and Deployment needed

Blue Scenario

The IPCC has concluded that a 50 to 80% reduction of global CO2 emissions by 2050, compared to 2000 levels, can limit long term global mean temperature rise to less than 2 degrees Celsius (Table 8). Higher emission levels will result in a more significant climate change. The IPCC has not recommended any targets. Cost and benefits of both must be balanced. The Stern report as concluded that the benefits of a 2 degrees scenario would outweigh the cost. Goal of this analysis is to provide an IEA technology perspective on the cost of deep emission reductions. The analysis does not deal with the political feasibility of such targets. However it is obvious from the start that such a target is infeasible if only OECD countries would comply.

Table 8: The Relation Between Emissions and Climate Change (IPCC, 2007)

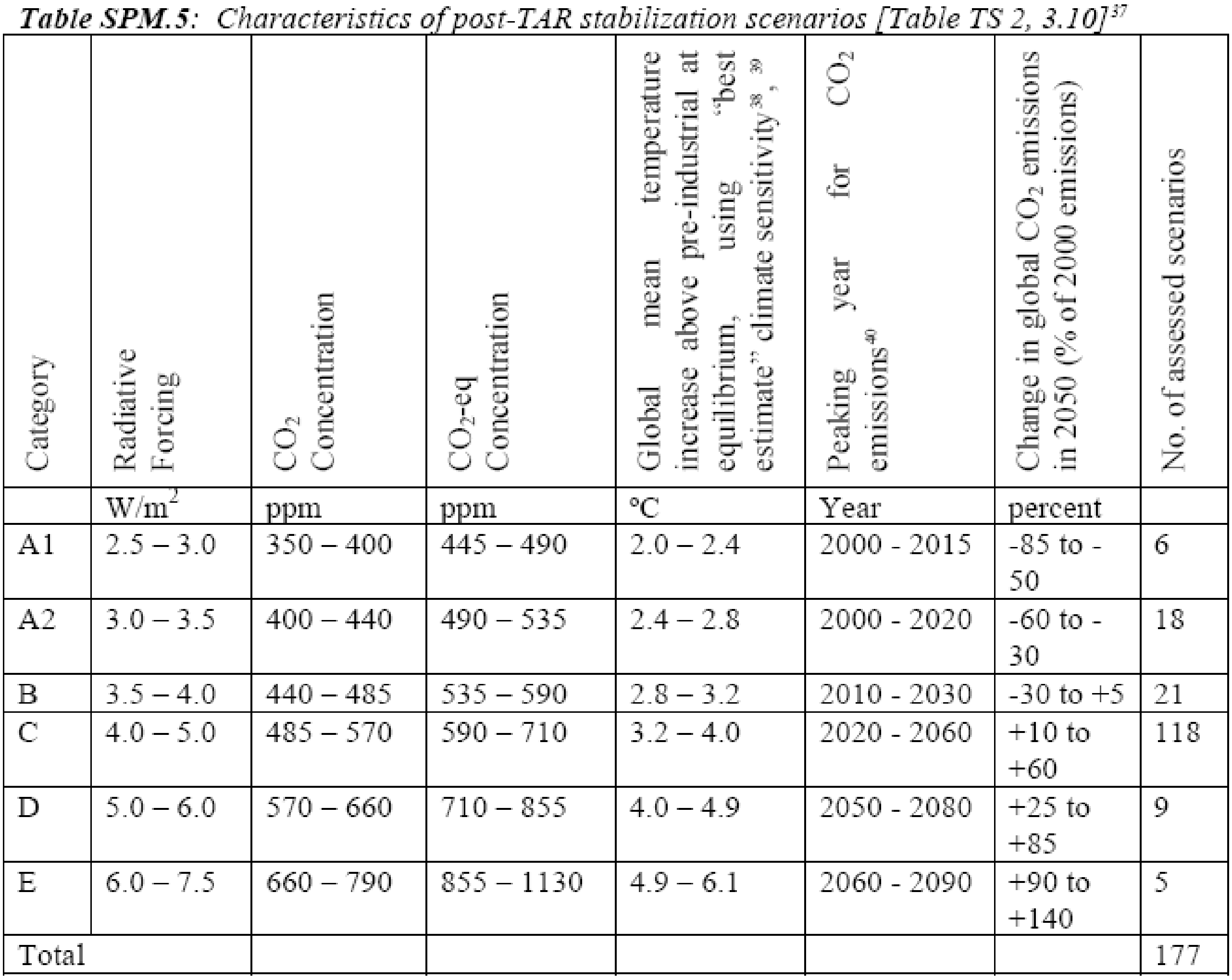


Table SPM.5: Characteristics of post-TAR stabilization scenarios [Table TS 2, 3.10][37]

Category	Radiative Forcing	CO_2 Concentration	CO_2-eq Concentration	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[38], [39]	Peaking year for CO_2 emissions[40]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)	No. of assessed scenarios
	W/m^2	ppm	ppm	°C	Year	percent	
A1	2.5 – 3.0	350 – 400	445 – 490	2.0 – 2.4	2000 - 2015	-85 to -50	6
A2	3.0 – 3.5	400 – 440	490 – 535	2.4 – 2.8	2000 - 2020	-60 to -30	18
B	3.5 – 4.0	440 – 485	535 – 590	2.8 – 3.2	2010 - 2030	-30 to +5	21
C	4.0 – 5.0	485 – 570	590 – 710	3.2 – 4.0	2020 - 2060	+10 to +60	118
D	5.0 – 6.0	570 – 660	710 – 855	4.0 – 4.9	2050 - 2080	+25 to +85	9
E	6.0 – 7.5	660 – 790	855 – 1130	4.9 – 6.1	2060 - 2090	+90 to +140	5
Total							177

The leaders of the G8 countries have stated in their communiqué in Heiligendamm that they will "seriously consider" a 50% CO_2 emissions reduction target by 2050. The 50% target implies a radically different policy than under a stabilization scenario. The reason is that, as the ACT Map scenario shows, even a stabilization of CO_2 emissions implies a huge effort. Cost will rise exponentially as the emission reduction target is increased. Emissions were more than halved in Act Map, compared to the baseline in 2050. If the marginal cost per tonne double in this additional tranche, it implies a doubling of the policy cost. However if the marginal cost increase tenfold, it implies a six-fold increase of the cost.

Four categories of options can be discerned that can help to reduce emissions further:

- Consider new options that have not been included such as:
    - Electrification:
        - Heatpumps for residential heating
        - Electric cooking
        - Heatpumps for LT heat supply for industry
        - Plug-in hybrid electric vehicles
    - Biomass - DME for cooking (instead of LPG)
    - Biomass - pellets for residential heating
    - Solar water heaters
    - Efficiency measures and early replacement of airplanes, ships and trucks
    - Modal shift (air to high-speed train, truck to rail, car to common urban transportation systems)
    - Hydrogen FCVs

- More of the same – speed up Tech Plus Options
    - Even more end-use efficiency
    - More CCS in industry (BF, cement kilns)
    - Larger share of nuclear to replace coal in baseload power generation
    - FT-biofuels for freight, airplanes and shipping
    - More intermittent renewables based on new solutions for variability in power supply, such as long-range DC transmission systems

- Consider more costly options
    - CCS for gas fired power plants
    - Early closure coal fired power plants without CCS
    - Biomass IGCC + CCS

- Change consumption patterns through pricing policies

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