Energy Technology Perspectives 2008[1]

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Secure, reliable and affordable energy resources are fundamental to economic stability and growth. The erosion of energy security, rising energy costs, the threat of disruptive climate change and the growing energy needs of the developing world - all pose major challenges to energy decision makers. What visions of the future that could address these issues are technically feasible and available? Where do we need to focus? And who needs to act and when?

The IEA publication *Energy Technology Perspectives (ETP) 2008* (launched June 6, 2008) tackles these challenges and questions. Innovation in energy technologies and a better use of existing technologies will be fundamental to achieving important policy goals. The book provides an analysis of the status and future prospects of key energy technologies, and shows how they can contribute to a more sustainable, secure and least-cost energy system. It outlines the barriers to the implementation of change and the measures that would be needed to overcome these barriers. It explores how technology can change our energy future.

New Energy Technology Perspectives Insights

The *Energy Technology Perspectives 2008* study builds on the *ETP2006* and on the *World Energy Outlook 2007* and expands the analysis considerably. For the first time the IEA has published scenarios that aim for a halving of energy related CO_2 emissions by 2050.

The goal of the analysis is to provide a technology perspective on the feasibility and costs of deep emission reductions; the book includes various scenarios, amongst them an extremely ambitious one, showing how CO_2 emissions could be reduced to 50% below current levels by 2050. The analysis does not deal with the political feasibility of such targets. However, the results make clear that all countries need to act in the next few years if the goal of halving emissions is to remain affordable. In fact the analysis suggests that such action could also greatly enhance the supply security.

This is the first time that supply and demand side financing needs for technology deployment and commercial investments are elaborated in detail. This study contains roadmaps for all technologies that play a key role in the emissions halving scenario. Also energy related methane emissions and their reduction are discussed. The data for key technology areas have been updated, and the scope of the technology discussion has been broadened.

The Baseline energy demand and emission projections has been revised upward, compared to *ETP2006*. The average growth rate is 3.3% per year.[3] From 2005 to 2050, GDP quadruples

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[3] Purchasing Power Parity based

from around USD 50 trillion per year to around USD 200 trillion per year. This growth is essential to lifting millions in developing countries out of poverty, and the same economic growth rate has been applied in all scenarios.

The book contains three major sections:

Part I: *Technology and the Global Energy Economy to 2050*
This section presents a set of scenarios to 2050. These scenarios analyse the role energy technologies and best practices aimed at reducing energy demand and emissions and diversifying energy sources can play. While the Baseline scenario is descriptive (policies in place to date, consistent with the IEA *World Energy Outlook* 2007 Reference Scenario), the ACT and BLUE scenarios assume new, ambitious policy targets (emission stabilization and halving, respectively).

To meet the most ambitious IPCC scenario aimed at keeping global average temperature increase below 2.4°C, global CO_2 emissions would need to be halved by 2050 compared to their current levels. G8 leaders at the Heiligendamm summit in 2007 agreed to seriously consider a 50% reduction target. The ETP BLUE scenarios explore this target and its energy technology consequences. The goal is challenging, requiring dramatic changes in the way we produce and use energy, with action required globally in the next few years. Oil demand in the BLUE scenarios is below today`s level. This is the first time that the IEA releases energy scenarios where oil demand declines.

Part II: *The Transition from the Present to 2050*
These chapters examine strategies that use energy technologies to help the world move towards a more sustainable energy future and offers technology roadmaps that can achieve this objective. This section also explores the roles of RD&D (research, development and demonstration), deployment and investment (the three steps in the technology lifecycle) in supporting policy outcomes.

Part III: *Energy Technology: Status and Outlook*
The final section provides a detailed review of the status and prospects of key energy technologies in power and heat generation, road transport, industry, and buildings. It highlights the potential of technologies in these sectors and their costs, and discusses the barriers that each technology must overcome before its full potential can be harvested.

A 15-region MARKAL model of the world energy supply and demand is the analytical backbone. For the ETP2008, this has been complemented with spreadsheet models for the three end-use sectors: transportation, industry and buildings. These end-use sector models are detailed at the level of G8+5 countries and world regions.

The BLUE Scenarios and the Role of Energy Technologies

The ACT and BLUE scenarios represent sets of optimal pathways to reduce energy-related greenhouse gas emissions, to the scenario goal, while at the same time, also enhancing the security of supply. The demand for energy services is the same in all scenarios – that is to say, no change in lifestyles is assumed - but the technology mix is radically different.

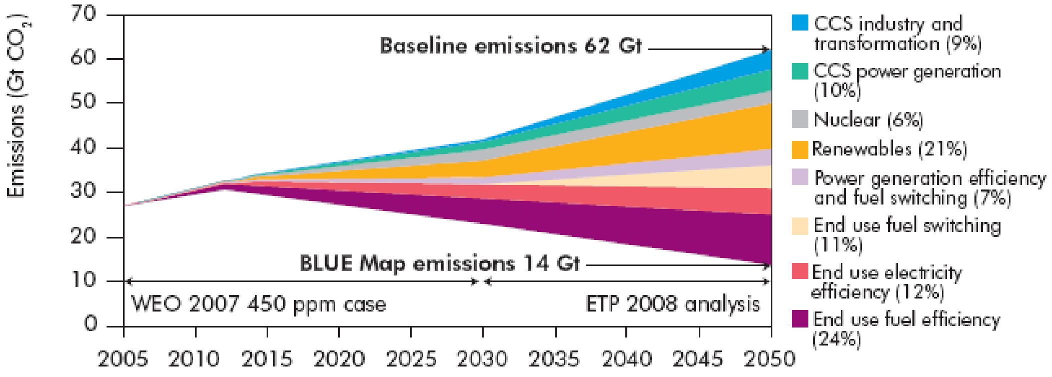
The family of ACT scenarios describe least-cost pathways to return energy CO_2 emissions back to 2005 levels by 2050. There are five ACT scenarios. In addition to the ACT MAP scenario, there are variants with different assumptions for key technology options for power supply (nuclear, CO_2 capture and storage, renewables) and end-use efficiency. The ACT Map scenario is the central variant with relatively optimistic assumptions for all technologies.

The BLUE scenarios describe least-cost pathways to reach a 50% reduction of CO_2 emissions by 2050 compared to the level of 2005. For the power sector the same five areas of uncertainty as for ACT have been covered through the same five sets of assumptions, but it also contains four sets of assumptions for the transport sector. This gives a total of twenty BLUE scenario variants. The BLUE Map scenario is the central variant.

The study concludes that end-use efficiency and a virtually CO_2-free power sector can yield emissions stabilisation in 2050 at today's level (the accelerated technology scenario ACT). However, halving emissions would also require significant fuel switching, CO_2 capture and storage in end-use sectors and steps to ensure that rapidly growing emissions from transport are not just slowed, but reduced. The BLUE scenarios are therefore more challenging, require earlier and stronger action, and they will be much more costly.

The scenarios require a broad portfolio of technologies to be used. End-use efficiency accounts for 36% of all savings in the BLUE Map scenario, renewables for 21%, and CO_2 capture and storage 19%. The remaining 24% is accounted for by nuclear, fossil fuel switching and efficiency in power generation (Figure 1).

Figure 1: Contribution of emissions reductions options in the BLUE Map Scenario of ETP 2008, between 2005 and 2050



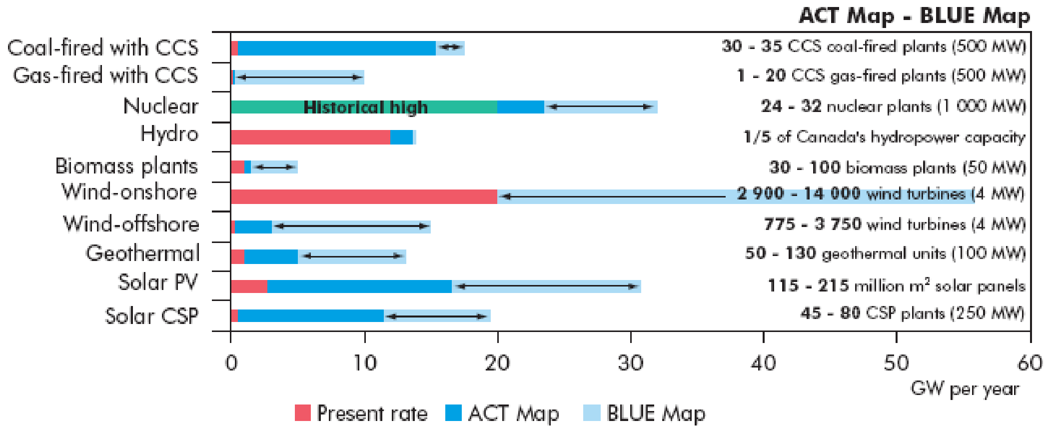
The average annual investments between 2010 and 2050 needed to achieve a virtual decarbonisation of the power sector, include, among others: 55 fossil-fuelled power plants with CCS, 32 nuclear plants, 17 750 large wind turbines, and 215 million square metres of solar panels (Figure 2). Although such rates of new technology adoption may seem daunting the historical rate of nuclear addition and that of current onshore wind additions suggest that they are achievable. Investments in CO_2-free power generation need to increase six- to sevenfold, from around 50 GW per year today to 330 GW per year in the period 2035-2050.

The BLUE sceanrio also requires widespread adoption of very energy-efficient buildings, with near zero emissions; and, on one set of assumptions, deployment of nearly a billion electric or hydrogen fuel cell vehicles. Sales of conventional vehicles with internal combustion engines would be all but phased out in 2050.

Compared to previous IEA scenarios, the outlook is considerably more optimistic for renewables and for nuclear energy. The electricity mix in BLUE Map consists of nearly half renewables, a quarter nuclear and a quarter fossil fuels with CO_2 capture and storage. In the scenario which halves CO_2 emissions, renewables account for up to 46% of total power generation. Hydro, wind and solar each provide around 5000 TWh in 2050.

In the transport sector, plug-in hybrid electric vehicles and battery electric vehicles have emerged as a promising strategy and are now a key part of some of the more ambitious scenarios.

Figure 2: Annual investment in the electricity sector in the ACT Map and Blue Map scenarios, 2010-2050



While energy efficient equipment is available today, more ambitious standards and regulations are needed to ensure its rapid uptake. Significant cost reductions will also be needed in some cases in order to lower the cost of abatement in difficult market segments. The average energy efficiency in 2050 needs to be twice the level of today, a significant acceleration compared to the developments in the last 25 years.

The Baseline scenario would require a massive expansion of fossil fuel production, to an extent that calls into question supply availablity. For example oil production would have to rise from today's level or around 85 million barrel per day to around 135 million barrels a day in 2050. Even if such an expansion was feasible, it would require a massive production of oil from unconventional resources. In contrast, oil demand in BLUE Map in 2050 is 27% below the level of 2005. Such a development would certainly ease the supply challenge. However even this level of production will require massive investments in new supply in the coming years and decades as oil fields are depleted. Total fossil fuel demand in the extreme BLUE Map scenario in 2050 is still at the same level as today. So in any case fossil fuels will continue to be a key pillar of our energy supply in the coming decades.

To meet the BLUE scenarios, we need to urgently develop and implement new far-reaching policies to a degree unknown in the energy sector and to substantially decarbonise power generation. A significant discrepancy exists between current trends and the BLUE scenario targets. We will need to launch in the coming decade a global revolution in the way we produce and use energy, with a dramatic shift in government policies and unprecedented co-operation amongst all major economies.

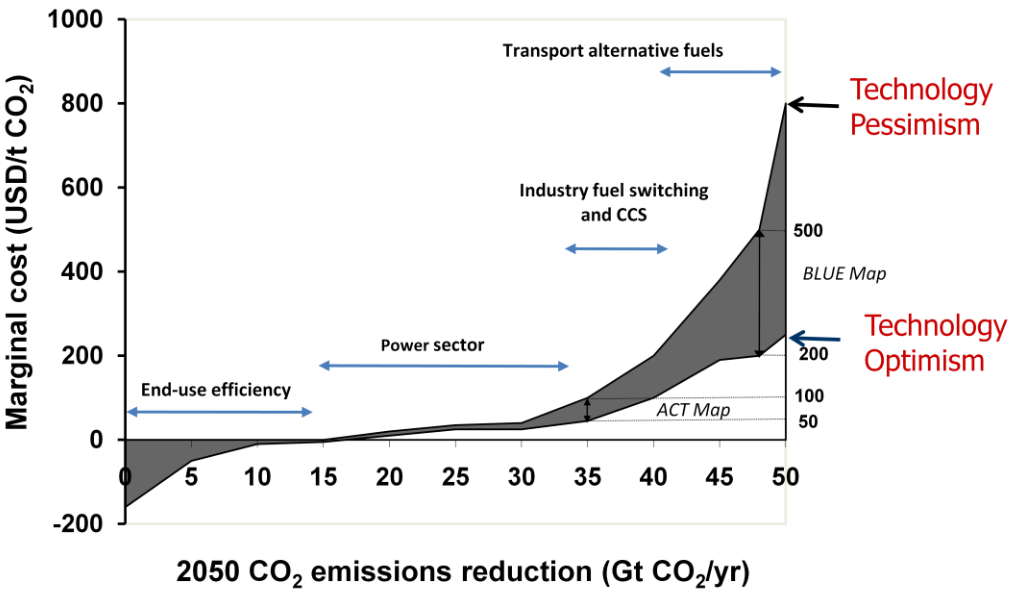
The Financing Needs

The marginal cost and financing required to achieve these scenarios represent an important outcome of the study. The ACT Map scenario requires options with a marginal cost up to USD 50/t CO_2. This figure is double that reported in ETP2006. There are a number of reasons: higher economic growth projections, rising materials and engineering costs , new technology insights and the declining value of the United States dollar (all costs have been evaluated in US dollars).

The BLUE Map scenario requires options with a marginal cost up to USD 200/t CO_2.[4] These marginal cost estimates are based on reasonably optimistic assumptions about significant technology cost reductions. Assuming less optimistic cost reductions, notably in the transport sector, would result in the marginal cost for BLUE rising to up to USD 500/t CO_2. A key insight is that the cost uncertainty increases for more ambitious targets, as technologies are needed that are not yet mature and whose future cost are therefore highly uncertain. The average emissions reduction costs in BLUE Map are about a fifth of the marginal cost, and range from USD 38/t CO_2 to USD 117/t CO_2.

The options can be grouped into distinct categories, indicated in Figure 3. This suggests that a generic pricing approach may not be the best way to achieve substantial emissions reductions.

Figure 3: Marginal abatement cost curve, 2050



Increased energy technology R&D will be essential. Current technology RD&D investments by IEA governments amount to around USD 10 billion per year, and industry spends around USD 40 billion per year.[5] Efficiency, re-allocation and increased spending can all help to achieve the rate of RD&D change that is needed. Consequently, the actual level of additional funding that is needed is unclear. Literature suggests a range of USD 10 to 100 billion a year. Given the current total level of spending the higher end of this range seems more likely.

Apart from RD&D, significant deployment investments are needed in order to achieve the necessary learning effects that reduce the cost of achieving the ACT and BLUE scenarios. Total learning investments – on top of Baseline investments – amount to USD 1.75 trillion between 2010 and 2030, and USD 5.25 trillion between 2030 and 2050 in the BLUE scenario.

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[4] USD 200/t CO_2 translates into additional cost of USD 80/bbl of oil.
[5] This is a preliminary estimate. The share of energy spending in total private sector RD&D needs to be analysed in greater detail.

The total investment needs in ACT Map for the period 2010-2050 are USD 17 trillion higher than in Baseline, and this rises to USD 45 trillion in BLUE Map. These are the optimistic cost estimates with substantial technology learning and least-cost investments. Investment needs would be higher in the event of less technology learning progress. The investment figures include the investment to achieve massive gains in end-use efficiency, which in turn reduce investment needs in power generation and fuel processing. Clearly the activation of this efficiency potential through standards and regulation will be an important challenge.

The pattern that emerges is one where additional investments amount to USD 100-200 billion per year in the coming years; this needs to increase to USD 1-2 trillion by 2030 and USD 2-5 trillion per year in 2050. The range reflects the uncertainty of future technology cost. Although these figures seem large, they should not be viewed in isolation. The additional investments represent a huge sum, but to put it into perspective 2 trillion equals 1% of world GDP in 2050.

The additional investment needs are balanced by lower fossil fuel expenses (an undiscounted amount of USD 51 trillion, if valued at market prices). The net outcome depends on the discount rate for future fuel savings and the value used for fuel prices (market prices or production cost). However, in the BLUE Map scenario the additional investment needs exceed fuel savings by USD 0.8 trillion (assuming 3% discount rate and market fuel prices).

An important issue is the uneven distribution of burden across countries. Energy exporting countries would face a GDP reduction of 10%, while major developing countries such as China and India would face a reduction of around 5%. The cost would be relatively modest for OECD countries (OECD, 2008). Therefore burden sharing across regions and sectors will be an important theme in the negotiations about a post-Kyoto framework.

The technology mix is another key outcome of the study. The rate of change that is needed is unprecedented. The analogy is not that we need an Apollo project or other grand undertaking, but more like we need an energy technology revolution. While the necessary technologies are ready or being tested on a pilot scale, their mass application is in many areas still far away, while for many, costs must also come down. The rate of technological change in many areas is in the order of decades. Important issues are the rapid build-up of mass production capacity required, as well as the barrier to rapid change that the life-span of existing capital stock, planning procedures and public acceptance represent.

An important insight is that the future energy system will be determined by decisions taken in the next few coming years and that not acting now with policies to achieve the ambitious long–term goal implied by the BLUE scenario will impose higher costs in the future. Clear long-term targets are needed to convince decision makers in industry to make the capital investments needed to dramatically change our energy system. Technology learning investments are needed to achieve the necessary cost reductions for more sustainable technologies. Energy RD&D levels must be raised and restructured in order to accelerate the development of new energy technologies with superior characteristics.

Next Steps

The report contains roadmaps for 17 groups of technologies that cover over four fifths of the total emissions reduction (Table 1). These roadmaps describe the role of technologies in the ACT Map and BLUE Map scenarios, and give RD&D and implementation targets and policy needs for the period between now and 2050 that must be met in order to be consistent with the desired 2050 outcome – so-called transition paths. These roadmaps need further development in the coming months and years, and building an international implementation framework supported by the public and private sector will be essential. Closer international cooperation will be needed. Indicators must be elaborated and used to track progress on the roadmaps. These roadmaps should not be straightjackets but signposts that guide the developments and accelerate the change towards a more sustainable energy future. The IEA and its Implementing Agreements are ready to support the major economies in the roadmap progress.

Table 1: ETP Roadmaps

Supply Side	Demand Side
• CCS fossil-fuel power generation • Nuclear power plants • Onshore and offshore wind • Biomass IGCC & co-combustion • Photovoltaic systems • Concentrating solar power • Coal: integrated-gasification combined cycle • Coal: ultra-supercritical • 2nd generation biofuels	• Energy efficiency in buildings and appliances • Heat pumps • Solar space and water heating • Energy efficiency in transport • Electric and plug-in vehicles • H_2 fuel cell vehicles • CCS industry, H_2 and fuel transformation • Industrial motor systems

Energy Technology Perspectives – Scenarios and Strategies to 2050. IEA/OECD, Paris, 2008.