In support of the G8 Plan of Action

ETP 2008: Technology Learning and Deployment

- A Workshop in the Framework of the G8 Dialogue on Climate Change, Clean Energy and Sustainable Development-

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This document contains the proceedings of the workshop on Technology Learning and Deployment, which took place on 11-12 June 2007, at the International Energy Agency in Paris. This workshop is part of a series of collaborative meetings which will feed in to our Energy Technology Perspectives 2008 publication in the framework of the G8 Plan of Action on Climate Change, Clean Energy and Sustainable Development .

The objective of the workshop was to bring together an advisory group of experts to discuss potential deployment programmes aimed at the key supply technologies discussed in ETP 2006. This document reflects the presentations and discussions of the participants at the workshop. The views expressed in this paper do not necessarily represent those of the IEA, or its member governments. A CD-ROM with the workshop presentations is available from the IEA Secretariat in Paris.

Background

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). Technology learning covers different phenomena in the R&D and deployment stage.

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 established technologies, except for certain niche markets. Production takes place on a small industrial scale. Technology learning based on mass production (economies of scale), industry R&D, learning-by-doing, learning-by-using and series of small product improvements (including improvements in organisation of supply to the market and service and use of the products) result in cost reductions. Production is rapidly expanding during this production stage.

A new energy technology will typically go through several stages to overcome technical and cost barriers before it becomes cost-competitive. Even if a technology is technically proven after the R&D stage, costs may still be too high for the market to take up the technology. This is often referred to as the “valley of death” that new technologies face on the way to full commercialisation. Programmes aimed at taking the technology through the deployment phase can require considerably more resources than the R&D phase. In some cases prolonging the R&D phase to reduce the market entry cost for the technology may lead to reduced overall development costs.

The prospect of future cost reductions is a key issue for energy R&D and energy investment decisions in emerging new technologies. Experience curves help clarify the potential benefits of deployment programmes and provide policy analysts with a tool to explore technology and policy options which can support the transformation of energy systems. Deployment costs can be derived based on these learning curves, which show a constant reduction of the investment cost for each doubling of the installed capacity of a certain technology. A constant decrease for each doubling has been observed for dozens of energy technologies.

However, past experience shows that exceptions to this rule exist as technology characteristics change or as technologies mature. In the case of nuclear energy, increased security needs for new power plants have resulted in cost escalation, and the projected cost reduction has not occurred. Other issues affecting the cost of nuclear power are regulation and licensing of new designs.

A number of issues exist on how learning rates should be applied. The common use of technology price versus equipment production cost data due to the confidentiality of the latter complicates the analysis as prices are subject to fluctuations in the market conditions. This is the case for certain renewable technologies in Europe where ambitious government deployment programmes have resulted in a situation where supply growth cannot follow demand resulting in shortages and increasing prices.

Also material costs can also have an impact on learning rates as currently seen in PV and wind, where learning rates are expected to show a temporary increase as the shortage of silicon, steel and gear boxes have pushed up PV and wind turbine costs.

Different learning rates exist depending on the system boundaries used and certain experts advocate using learning rates based on electricity production costs and not capital costs. Additional analysis and further data collection is required to examine the right system boundaries to be used when applying learning curves.

Total deployment investments from 2005-2050 for the key technologies in the ACT Map scenario of the *Energy Technology Perspectives* publication are estimated at $ 10.5 trillion[1]. Deployment investments for the 2005-2030 period are estimated to be less than $ 3 trillion and the largest portions of these investments are expected to be for nuclear, IGCC, wind and PV technologies. During the 2030-2050 period, total deployment investments are estimated at $ 7.8 trillion, 80% of which are accounted for by hydrogen fuel cell vehicles. This high share of

[1] The estimated deployment figures are based on learning rates for capital costs. Deployment investments are defined as the total cumulative investments in a new technology up to the point where it is cost competitive with the incumbent technology.

a single demand side technology shows the importance of the whole demand side for energy technology deployment cost analysis.

According to a report prepared by New Energy Finance and to be released soon by UNEP, the total deployment in clean energy technologies (includes renewable energy, biofuels, low-carbon technology, and the carbon markets) for 2006 was $ 71 billion, 40% less than the $ 110 billion estimated annual deployment investments needed between 2005-2030. If we exclude investments in nuclear power which make up a large portion of deployment costs from 2005-2030, annual required investments in deployment fall to $ 73 billion per year, in line with reported investments in 2006.

If we consider the cost gap, the total *additional* investment cost for technologies under ACT Map from 2005-2030 compared to baseline is $ 1.3 trillion or $ 54 billion per year. The cost gap is defined as the total investment cost necessary to make these technologies competitive minus the investment cost of the alterative fossil technology necessary to meet the same output. Total additional costs for 2005-2050 are $ 4.6 trillion. If external costs were taken into consideration these learning costs could be reduced even further.

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 based on historical cost data to estimate future deployment costs.

The benefits of technology learning are typically shared on a global level. This emphasises the need for international collaboration on technology development and deployment[2]. In many cases, deployment costs can be lowered through international collaboration. In the case of wind, the most cost effective sites in each country would be developed first and the aggregated impact would reduce the overall cost of reaching the required deployment level to buy down a given technology. If deployment was left to just one country or a few countries less economical sites would be required, driving up the total deployment costs. 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.

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

Workshop Summary

- Learning curves, when backed by bottom-up engineering models can provide insightful information on future cost reduction potentials in energy technologies;
- The sole use of learning curves to estimate future technology costs can lead to over optimistic results on cost reductions and deployment needs;
- 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;
- Many technologies such as wind, PV and nuclear are or expected to experience material supply pressures that have or will drive up prices in the short term;
- Prices are expected to fall again in the medium to long term as new capacity helps to alleviate supply constraints;
- It is not possible at this stage to specify the optimal for R&D and deployment expenses for technology categories such as solar and wind. R&D from other industries could help in deploying clean energy technologies. For example, information technology can help to deal with variability in power generation;
- 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;
- Wind is expected to be the most important source of new renewable energy (excluding hydro and traditional biomass) by 2020 with wind (onshore and offshore) capacity tripling;
- In a carbon constrained environment both CCS for fossil energy and additional nuclear power generation will be required;
- 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.

Key Messages

Learning Curves and Technology Learning

- In general, learning curves can be used to estimate future cost reductions of a given technology…

- … but exploring future cost reductions based on experience curve analysis should be cross-checked with bottom-up engineering approaches and market analysis to check if prices are expected to follow production costs.

- Propagating uncertainties in learning rates through models can provide additional information for policymakers, for example, about the reliability of buy down cost estimates and about the likelihood of short-term cost deviations.

- Analysis has shown that learning rates do not vary widely over time. However technology characteristics sometimes change due to new regulations and more intricate designs may raise cost.

- Ultimately what matters in power generation is the cost of electricity, rather than simply installation costs, and hence it was suggested that learning rates be based on electricity production costs.

- For most technologies, global learning rates were recommended as local support measures can lead to distortions in national learning rates. Although for cases in which learning occurs locally (e.g. PV installations), a global curve may misrepresent learning.

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

- The choice of the initial cumulative point for starting data collection can have an important impact on the resulting learning rate.

- Although the results of learning curve analysis are well known the mechanism for learning are not. Additional analysis is required to better understand the learning process.

- A cost needs to be assigned to externalities and a price for CO_2 should be included in the analysis of cost for future energy technologies.

- Learning rates for wind vary widely depending on the system boundary used. Current bottlenecks will result in higher prices over the next couple of years.

- Learning rates for PV have ranged from 17% to 24%. Further deployment is required to make PV cost competitive with grid power. Due to knowledge spillovers, it is unlikely that private companies would fund these deployment investments without government subsidies.

- National learning curves were justified for ethanol due to the dominate position of Brazil and the US in cane and corn ethanol production. Overall ethanol production costs can be split into feedstock production and industrial processing, with higher learning rates for feedstock production. The learning rates for the overall production costs for cane and corn ethanol are reported to be 20% and 18% (although for corn this is based on limited data).

- Learning rates for power plants with carbon capture are estimated to be between 2-5% depending on the power generation technology (this analysis does not include the cost of transport and storage). IGCC with carbon capture appear to offer the highest learning rate. As CCS has yet to enter the demonstration stage, using learning curves for unproven technologies can lead to uncertain results.

- For almost every energy technology in the deployment stage, supplier profit margins are non-zero and thus prices do not equal costs. Technology dynamics drive costs while market dynamics drive profit margins. Models should characterize prices because technology adoption decisions are ultimately based on prices.

Deployment of Renewable Technologies

- The wind industry is currently experiencing a price bubble with prices up about 20% due to supply constraints on steel and gear boxes. A few participants indicated that higher prices were expected to last for another 5 years before returning to previous levels. Others indicated that it was difficult to define such a period of higher prices.

- Historically up scaling has helped investment costs to fall. There is limited scaling up left in wind. Future cost reductions are expected to come from material improvements, efficiency gains in the production and operation of large engines and discounts given for large quantity orders.

- PV costs have fallen sharply, but with the exception of certain niche markets are far from being competitive. Although not universally accepted, some experts have indicated that a technology shift or radical new innovation (eg. thin film) is needed to make PV competitive with other technologies.

- Competition for biomass resources will be an important issue in the future as the food & fodder, pulp & paper, buildings, industry, power and transport sectors compete for biomass resources. This may raise the cost of feedstocks, and thus of biofuels for transportation and electricity /heat from.

- Learning by doing and experience curves are not as applicable for bioenergy technologies as for other technologies. In bioenergy increased size often leads to increased costs as biomass must be brought in over a longer distance, but logistics can be optimized to allow for longer transportation distances and conversion efficiency of plants can increase with scale.

- Technical challenges still remain before 2^{nd} generation biofuels can be deployed. The first demonstration plants are now under construction and significant production is expected in about 15 years. The availability of feedstock, the cost of feedstock, cost reductions in conversion technology, and the future price of oil will determine the growth of the 2^{nd} generation biofuels market.

- Governments are not good at picking winners. It was suggested that government should therefore decide on the desired policy outcome in general terms and leave industry flexibility to choose technologies to arrive at the chosen outcome. Long term policy certainties in terms of goals and instruments could be sufficient to generate industrial deployment programmes.

- The use of learning curves was seen as better than omitting them, but they should be applied over a long time scale, backed up with both engineering studies and market assessments.

- Support policies should not be too generous as they can be disincentives for innovation, raise prices and lock in technologies, but finding the right balance between too low and too high is quite difficult.

Deployment of CCS, Nuclear and Battery Technologies

- 10 full scale CCS demonstration plants are needed by 2015 and will require government support.

- Clear legal and regulatory frameworks are needed to accelerate the deployment of CCS. Electricity cost estimates for coal plants with CCS are estimated at $43-67 / MWh in 2030.

- A wide variation exists in the estimate for future nuclear generation capacity amongst different studies (13% - 101%). To reach meaningful CO_2 abatement approximately 400GW of nuclear needs to be added by 2030 or about 20 GW / year. This level is similar with past experiences, but manufacturing bottlenecks could place pressure on nuclear generation costs in the short term.

- Gen III+ nuclear plants are expected to benefit from significant learning as more plants are built. Cost reductions from the 1^{st} to 5^{th} plant built might reach 30-35%.

- Construction time plays an important role in total investment costs as the interest payments on non-performing assets make up a large part of the financial costs.

- Japan has been promoting R&D in large-scale lithium batteries since 1992 and in 2007 launched together with industry a next-generation battery R&D project for the commercialization of electric vehicles, plug-in hybrids and fuel cell vehicles.

Accelerating the Deployment of Clean Technologies

- There is no proper ratio for R&D and deployment and R&D from other industries could help in deploying clean energy technologies.

- 7 types of barriers to deployment were identified: cost, market structure, capital stock turnover rate, infrastructure, regulation, public acceptance and financing. Some barriers can be alleviated by more government support, others by institutional/ organizational changes, yet others by providing public information/ education.

- 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.

- Niche markets should be explored and developed to find additional funding for learning investments and to reduce the cost of deployment.

- Niche markets can be developed by governments or companies who are looking for a “first-mover” advantage, consumers with high alterative costs, or a consumer who wants to take a leadership role.

Industry view on Deployment of Clean Technologies

- Businesses want more clarity and certainty regarding long term market rules.

- More and more private companies are showing support for clear action on climate change.

- In the US and Europe voluntary action programmes, which have been very successful in Japan, are not expected to have much impact.

- A value for CO_2 is needed for companies to take effective action on combating climate change. Industry can be competitive and prosper in a carbon constrained world.

- Technology diversity can contribute to energy security.

- The end of support mechanisms can lead to the collapse of the market (Denmark in the 90s was given as an example) and hence sustained policies are required for deployment of renewables.

- Future prices for wind turbines are difficult to predict as higher current material costs and production bottlenecks have driven prices up in the short term.

- Iberdrola is investing 90% of all new investments in Renewables as energy security and environmental concerns make investments in renewables economically attractive.

- Wind will be the most important source of new renewable energy (excluding hydro and traditional biomass) by 2020 with wind capacity tripling. The US represents a huge potential market for wind.

Role of Governments in Funding, Policy and International Co-Operation

- Funding is needed on the technology pull (deployment) side to bring new technology to market and on the technology push (R&D) side to find additional solutions.

- Industry needs to be engaged early in the innovation cycle as they are the most important agent in deployment.

- The potential for enhanced international cooperation in technology deployment must be utilized more effectively.

- Deployment programmes should identify and address public concerns about new technologies as these concerns have the potential of impeding the progress of new technologies.

- Canada's office of Energy R&D has implemented a Technology to Market pilot programme to help bridge the gap between R&D and the market. This programme provides early stage market assessments for promising technologies.

- Japan is working with other Asian countries to support the deployment of new clean coal technologies. International collaboration is needed to bring about dramatic cost reductions. New materials and new production structure offer potential for cost reductions and signal need for additional support in R&D.

- The EU has a 20% energy efficiency target and 20% mandatory renewables objective for 2020. The EU ETS will continue to play an important role in stimulating emissions reduction. CCS is being developed for sustainable power generation from fossil fuels.

- The feed-in tariff in Germany has resulted in rapid deployment of wind energy and today on-shore wind has reached high levels with future wind projects aimed at reducing the cost of off-shore wind. In the medium-long term, the large potential offered by offshore wind could see offshore wind overtaking onshore wind.