Pre-print of conference paper

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In 1998, the Paul Scherrer Institute (PSI)[3] and ECN carried out the first MARKAL experiments with endogenous technology learning (ETL) in the framework of an EU[4] sponsored research project 'TEEM' (Energy Technology Dynamics and Advanced Energy System Modelling). This paper summarises recent experience gained at ECN with its comprehensive energy system model MARKAL for Western Europe, including endogenous technology learning based on the learning-by-doing mechanism and expanding on the concept of technology clusters.

These experiments have confirmed the benefits expected from adoption of the mechanism. An important issue, often overlooked in simple models is the notion of interdependency between (families of) technologies, rather than considering individually learning technologies. An approach to address such clusters has been developed and tested. The results indicate that the new 'cluster feature' improves the internal consistency and allows for assessment of spill-over and cross-over effects, and other mechanisms identified in technology dynamics. Insights are gained in economic benefits associated with context-driven technological progress, as well as in the potential of R&D and market deployment policies.

Notes:

1. Paper to be presented at the European IAEE/AEE Conference 'Technological Progress and the Energy Challenge', 30 Sep - 1 Oct 1999, Paris, France.
2. Address: ECN Policy Studies, P.O. Box 1, NL-1755 ZG Petten, The Netherlands, E-mail: seebregts@ecn.nl
3. The co-operation with Leonardo Barreto and Socrates Kypreos from PSI is highly acknowledged.
4. The European Commission is acknowledged for sponsoring the ECN contribution to the TEEM project (Non Nuclear Energy Programme JOULE III, contract JOS3-CT97 0013).

More details and other references on ETSAP site about Technology Learning:

1. Modelling technological progress in a MARKAL model for Western Europe including clusters of technologies
   ECN report ECN-RX-99-028, August 1999
   Paper presented at the European IAEE/AEE Conference 'Technological Progress and the Energy Challenge', 30 Sep - 1 Oct 1999, Paris, France.
   A.J. Seebregts, T. Kram, G.J. Schaeffer, A.J.M. Bos
   Full ECN paper as pre-print available in PDF format (194 kbytes)
2. A Simple Global Electricity MARKAL Model with Endogenous Learning
   S. Kypreos and L. Barreto
   First PSI paper from ETSAP workshop October 1998 now available also as PDF file
3. Endogenous technological learning: Experiments with MARKAL - Contribution to Task 2.3 of the EU-TEEM project
   ECN report ECN-C--98-064, December 1998
   Seebregts, A.J.; Kram, T.; Schaeffer, G.J.; Stoffer, A.
   Abstract available

4. Endogenous technological change in energy system models - Synthesis of experience with ERIS, MARKAL, and MESSAGE
   ECN report ECN-C--99-025, April 1999
   Seebregts, A.J.; Kram, T.; Schaeffer, G.J.; Stoffer, A. (ECN Policy Studies, Petten (Netherlands)); Kypreos, S.; Barreto, L. (Paul Scherrer Institut PSI, Villigen (Switzerland)); Messner, S.; Schrattenholzer, L. (International Institute for Applied Systems Analysis IIASA, Laxenburg (Austria))
   Abstract available or as full report in PDF format, 168 kbytes)
5. Technological Learning in Energy Models: Experience and Scenario Analysis with MARKAL and the ERIS Model Prototype
   PSI report Nr. 99-08, September 1999
   L. Barreto and S. Kypreos
   Executive summary available
6. Technology Learning and the Role of Renewable Energy in Reducing Carbon Emissions UPDATE 07.12.99
   USDOE/BNL/PSI report, December 1999 (pre-publication of a chapter in a book to be published in 2000)
   P. Tseng, J. Lee, L. Barreto and S. Kypreos
   Executive summary available

Summary USDOE/BNL/PSI report: Technology Learning and the Role of Renewable Energy in Reducing Carbon Emissions

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PSI and ECN have worked on endogenous technology learning since 1998.
An overview of ETSAP information and publications related to technology learning is available on this site.

Introduction and Summary

The Kyoto Protocol requires the United States and other major developed countries to reduce greenhouse gas emissions from the Kyoto baseline, which is the 1990 emission level for CO_2, CH_4, N_2O, and the 1995 level for SF_6, HFCs, and PFCs. For the United States, the required emission reductions between 2008 and 2012 will be 7 percent below the 1990 level. The United States insisted that the Protocol include where and when emission must be reduced. International permit trading and the Clean Development Mechanism are the resulting products of such negotiation; they form a framework in which all the countries can reduce greenhouse gas emissions at the least cost. This framework also provides time and incentives for countries to adopt energy efficient technologies and carbon free technologies. Many of these technologies, renewable energy-based ones in particular, are still in their infancy and need to be improved further in costs and performances before they can compete in the market place. In the long run, the potential contributions of these technologies to reducing of carbon emissions could be very significant if correct policies are implemented to accelerate their penetration into the market.

Empirical evidence shows that the decline in the unit cost of a technology is closely related to its cumulative production and use. Knowledge and experience accumulated from manufacturing, installing, and using a technology help to improve its performance and reduce cost (1). Technology learning, therefore, is a crucial process for to bringing about the large-scale commercialization of a new technology. Without of technology learning, currently more expensive, renewable energy technologies will have no opportunity to move down the learning curve and compete with the matured fossil fuel technologies. Recognizing the potential benefits that renewable technologies could bring to the environment, and the need to reduce their cost in the long point to the fact that governments must play an active role in encouraging technology learning.

This raises several important questions. What technologies to support? How, and at what level to support them? What benefits will they bring with their increased market share? These questions can best be answered within an integrated modeling framework in which endogenous learning processes are explicitly simulated.

In this study, we used two different modeling approaches to analyze the effects of technology learning. First, the U.S. MARKAL-MACRO model calibrated to the 1998-Annual Energy Outlook (AEO98)(2) was used to study the impact of technology learning on four renewable technologies for generating electricity (wind, photovoltaics, solar thermal, and biomass). The second approach presents the results of MARKAL for a simplified global electricity system using the Mixed Integer Programming (MIP) formulation of endogenous learning. In both models, technology learning is limited to the relationship between reduction in investment cost and the cumulative installed capacity. The key parameter characterizing this relationship is the progress ratio. In the U.S. case, the learning curve for each technology is generated based on the estimated cumulative capacity for the planning horizon and an increasing progress ratio over time. The learning curves were made time-dependent and simulated in the dynamic structure of MARKAL-MACRO. These curves allow the study on the effect of accelerated or delayed learning and the buildup of manufacturing capacity to meet the market demand implied in the installed capacity. Under this structure, the effects of endogenously learning were evaluated as the change in electricity generation mix, the cost of the total energy system, environmental emissions, and in the marginal cost of reduction in carbon emission. The level of governmental support (e.g., subsidies) required for earlier adoption of these technologies was derived.
