**Hybrid Modeling of Energy-Environment Policies: Reconciling Bottom-up and Top-down**

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## Hybrid Modeling: New Answers to Old Challenges
## Introduction to the Special Issue of *The Energy Journal*

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### Abstract

After nearly two decades of debate and fundamental disagreement, top-down and bottom-up energy-economy modelers, sometimes referred to as modeling 'tribes', began to engage in productive dialogue in the mid-1990s (IPCC 2001). From this methodological conversation have emerged modeling approaches that offer a hybrid of the two perspectives. Yet, while individual publications over the past decade have described efforts at hybrid modeling, there has not as yet been a systematic assessment of their prospects and challenges. To this end, several research teams that explore hybrid modeling held a workshop in Paris on April 20–21, 2005 to share and compare the strategies and techniques that each has applied to the development of hybrid modeling. This special issue provides the results of the workshop and of follow-up efforts between different researchers to exchange ideas.

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## WITCH: A World Induced Technical Change Hybrid Model

By Valentina Bosetti (Fondazione Eni Enrico Mattei), Carlo Carraro (University of Venice and Fondazione Eni Enrico Mattei), Marzio Galeotti (University of Milan and Fondazione Eni Enrico Mattei), Emanuele Massetti (Fondazione Eni Enrico Mattei), Massimo Tavoni (Fondazione Eni Enrico Mattei)

**Abstract**

The need for a better understanding of future energy scenarios, of their compatibility with the objective of stabilizing greenhouse gas concentrations, and of their links with climate policy, calls for the development of hybrid models. Hybrid because both the technological detail typical of Bottom Up (BU) models and the long run dynamics typical of Top Down (TD) models are crucially necessary. We present WITCH – World Induced Technical Change Hybrid model – a neoclassical optimal growth model (TD) with energy input detail (BU). The model endogenously accounts for technological progress, both through learning curves affecting prices of new vintages of capital and through R&D investments. In addition, the model captures the main economic interrelationships between world regions and is designed to analyze the optimal economic and environment policies in each world region as the outcome of a dynamic game. This paper provides a detailed description of the WITCH model, of its Baseline, and of the model calibration procedure.

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**Macroeconomic Consistency Issues in E3 Modeling:**
**The Continued Fable of the Elephant and the Rabbit**

By Frédéric Ghersi (PREG-X (UMR CNRS-École Polytechnique), Paris, France) and Jean-Charles Hourcade (CIRED (UMR EHESS-CNRS), France)

**Abstract**

Using a variant of the IMF's Global Economy Model (GEM), featuring energy as both an intermediate input into production and a final consumption good, this paper examines the macroeconomic implications of large increases in the price of energy. Within a fully optimizing framework with nominal and real rigidities arising from costly adjustment, large increases in energy prices can generate inflation persistence similar to that seen in the 1970s if the monetary authority misperceives the economy's supply capacity and workers are able to temporarily resist some of the erosion in their real consumption wages resulting from the energy price increase. In the absence of these two responses, the model suggests that energy price shocks cannot generate the type of stagflation witnessed in the 1970s. The analysis goes some way toward reconciling the results found in the empirical literature on the changing nature of the macroeconomic implications of oil price shocks.

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**The ObjECTS Framework for Integrated Assessment:
Hybrid Modeling of Transportation**

By Son H. Kim, Jae Edmonds, Josh Lurz, Steven J. Smith, and Marshall Wise (The Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, USA)

**Abstract**

Technology is a central issue for the global climate change problem, requiring analysis tools that can examine the impact of specific technologies within a long-term, global context. This paper describes the architecture of the ObjECTS-MiniCAM integrated assessment model, which implements a long-term, global model of energy, economy, agriculture, land-use, atmosphere, and climate change in a framework that allows the flexible incorporation of explicit technology detail. We describe the implementation of a "bottom-up" representation of the transportation sector as an illustration of this approach, in which the resulting hybrid model is fully integrated, internally consistent and theoretically compatible with the regional and global modeling framework. The analysis of the transportation sector presented here supports and clarifies the need for a comprehensive strategy promoting advanced vehicle technologies and an economy-wide carbon policy to cost-effectively reduce carbon emissions from the transportation sector in the long-term.

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**Towards General Equilibrium in a Technology-Rich Model with
Empirically Estimated Behavioral Parameters**

By Chris Bataille (Energy and Materials Research Group, School of Resource and Environmental Management, Simon Fraser University, Vancouver, Canada), Mark Jaccard, John Nyboer and Nic Rivers

**Abstract**

Most energy-economy policy models offered to policy makers are deficient in terms of at least one of technological explicitness, microeconomic realism, or macroeconomic completeness. We herein describe CIMS, a model which starts with the technological

explicitness of the “bottom-up” approach and adds the microeconomic realism and macroeconomic completeness of the “top-down” CGE approach. This paper demonstrates CIMS’ direct utility for policy analysis, and also how it can be used to better estimate the long run capital-for-energy substitution elasticity (ESUB) and autonomous energy efficiency index (AEEI) technology parameters used in top-down models. By running CIMS under several possible energy price futures and observing their effects on capital and energy input shares and energy consumption, we estimate an economy-wide ESUB of 0.26 and an AEEI of 0.57%, with significant sectoral differences for both parameters.

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**Combining Energy Technology Dynamics and Macroeconometrics: The E3MG Model**

By Jonathan Köhler (Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge, Cambridge, United Kingdom), Terry Barker (Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge, Cambridge, United Kingdom), Dennis Anderson (Imperial Centre for Energy Policy and Technology (ICEPT) Dept of Environmental Science and Technology, London) and Haoran Pan (CEMARE, University of Portsmouth, Portsmouth, UK)

**Abstract**

This paper introduces a novel approach to the hybrid modelling of technological change climate stabilisation cost literature. We describe how a post-Keynesian macroeconomic model of sectoral demand, E3MG, has been combined with investments in 26 energy technologies from a submodel, ETM. E3MG is a 20-region global energy-environment-economy (E3) econometric, dynamic simulation model. It is a component of the UK Tyndall Center’s Community Integrated Assessment System. Technological change is endogenous, through its effects on general energy use and sectoral demand, and on energy technologies through the cost-reducing effects o f learning by doing and economies of scale. This approach directly challenges the notion that historically estimated models cannot be use for long-term analysis. The paper concludes with an account of how technological progress is induced in this hybrid system by high relative prices of carbon designed to achieve climate stabilization at 450ppmv.

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**Promoting Renewable Energy in Europe:**

## A Hybrid Computable General Equilibrium Approach

Christoph Böhringer (Centre for European Economic Research (ZEW), Mannheim, Germany. University of Heidelberg, Center for Environmental Economics, Germany) and Andreas Löschel (Institute for Prospective Technological Studies (IPTS), DG Joint Research Centre, European Commission, Seville, Spain. University Pablo de Olavide, Department of Economics, Seville, Spain)

### Abstract

We illustrate the use of a large-scale computable general equilibrium model to investigate the economic and environmental effects of renewable energy promotion within the European Union. Our hybrid model incorporates the technological explicitness of bottom-up energy system models for the electricity sector while production possibilities in other sectors are described at an aggregate level through top-down constant-elasticities-of-substitution (transformation) functions. The discrete activity analysis of technology options within conventional top-down computable general equilibrium models is possible when adopting the so-called mixed complementarity problem approach – a flexible mathematical representation of market equilibrium conditions which accommodates weak inequalities and complementary slackness.

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## Modeling Detailed Energy-Efficiency Technologies and Technology Policies within a CGE Framework

By John A. “Skip” Laitner (American Council for an Energy-Efficient Economy, Washington, DC, USA) and Donald A. Hanson (Argonne National Laboratory, Argonne, IL, USA)

### Abstract

Policy makers and analysts are raising questions about the adequacy of policy and technology representation in conventional energy and economic models. Most conventional models rely on a highly stylized and limited characterization of technology. In these models, any desired changes in energy demand are driven largely by pure price mechanisms such as energy taxes or carbon charges. In this paper, however, we explore the mapping of discrete technology characterizations and examine how cost-effective technologies and programs might prompt desirable increases in energy efficiency. Using the commercial health care sector as an example, we show how changes in energy efficiency and technology investments might be more properly represented in policy models.

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**Experiments with a Hybrid CGE-MARKAL Model**

By Andreas Schäfer (Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology) and Henry D. Jacoby

## Abstract

This paper summarizes the main features of a linked CGE-MARKAL model system capable of simulating the macro-level economy and micro-level technology detail of the transport sector. Emphasis is given to issues of calibration of such a hybrid system, with references provided to already published papers based on this research for coverage of other details.