"Bottom-Up", "Top-Down" and Non-Convex: Recent Modeling Activities at IIASA-ECS

Leonardo Barreto and Leo Schrattenholzer (Project Leader)

Environmentally Compatible Energy Strategies Project (ECS)
International Institute for Applied Systems Analysis (IIASA)

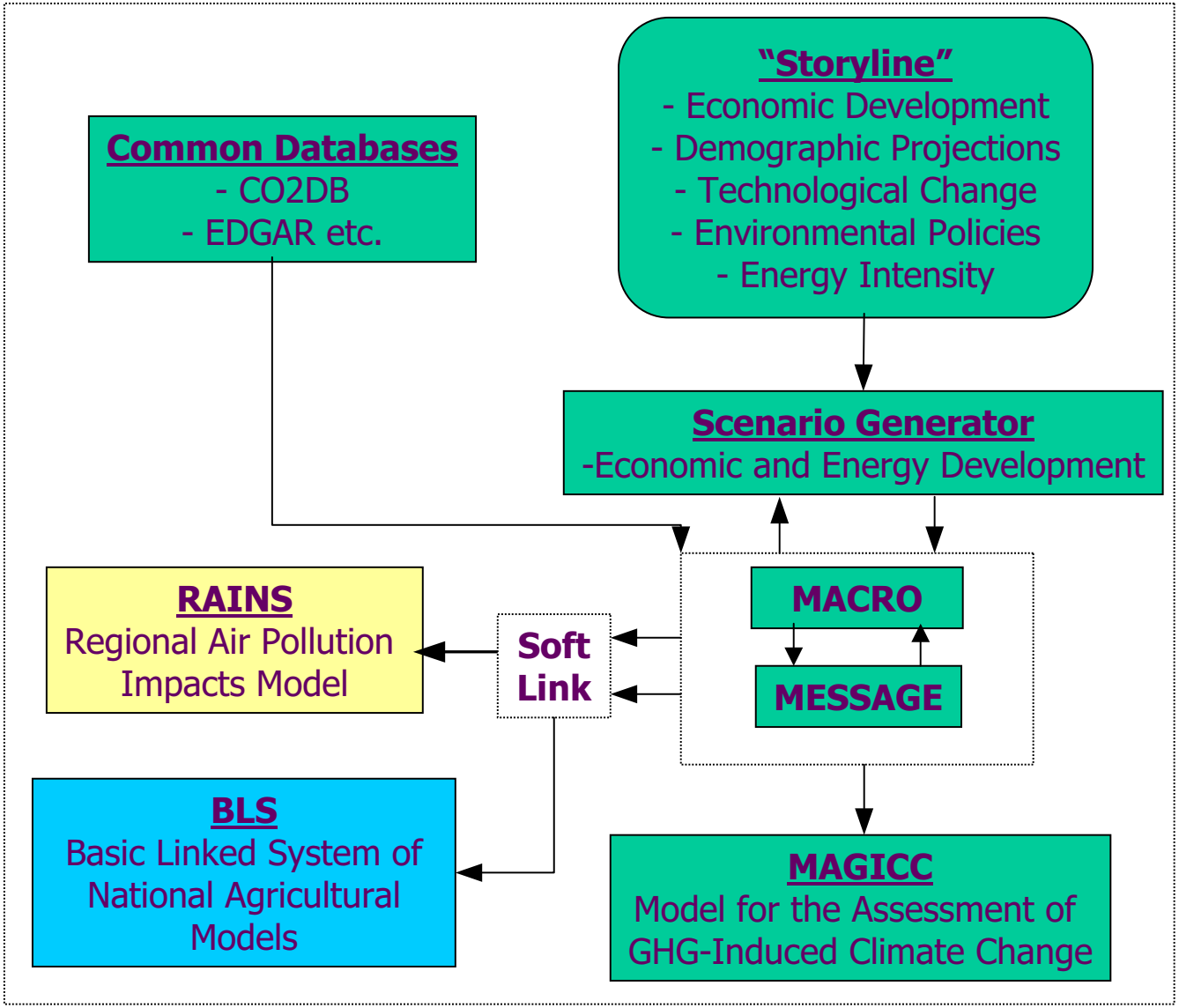
AEO/NEMS Conference

Washington D.C., March 12, 2002

Outline

- IIASA Modeling Framework
- Combining “Top-down” and “Bottom-up”
- Endogenizing non-convex technical change
- Conclusions

The IIASA Modeling Framework



Other Models Used at IIASA-ECS

ERIS
Small-scale model
Endogenous Technical Change
-Learning-by-Doing
-Learning-by-Searching
Technology Policy, R&D

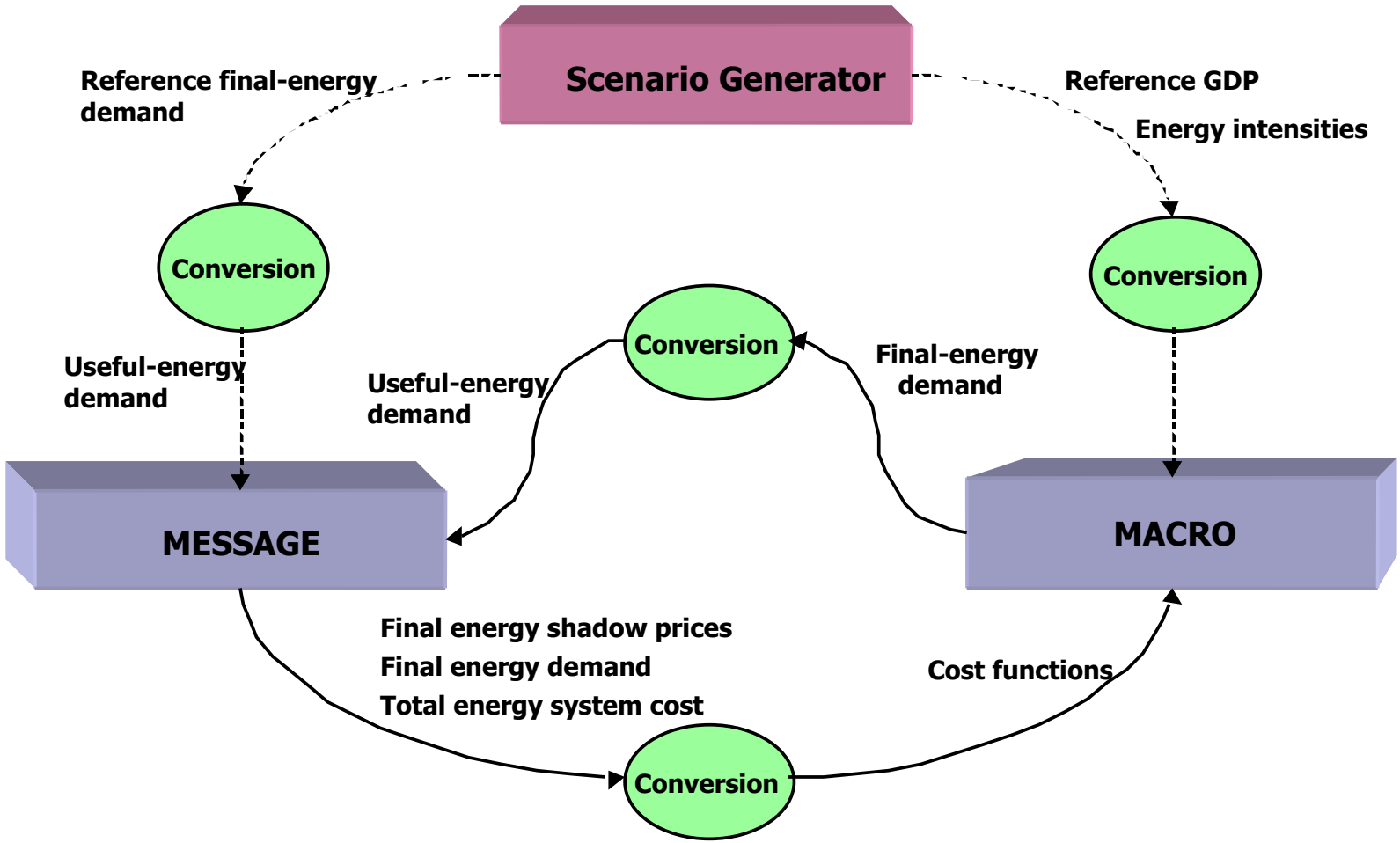
ISPA
Stochastic Meta-model for Multi-Objective Policy Analysis

MERGE
Model for Evaluating Regional and Global effects of GHG Policies

The MESSAGE-MACRO Link-1

- Iterative link between the "bottom-up" MESSAGE and "top-down" MACRO models
- The link keeps consistency between demand and supply cost curves and thus between scenarios
- The models are solved independently
  - Nonlinearities are collected in one place
  - High flexibility

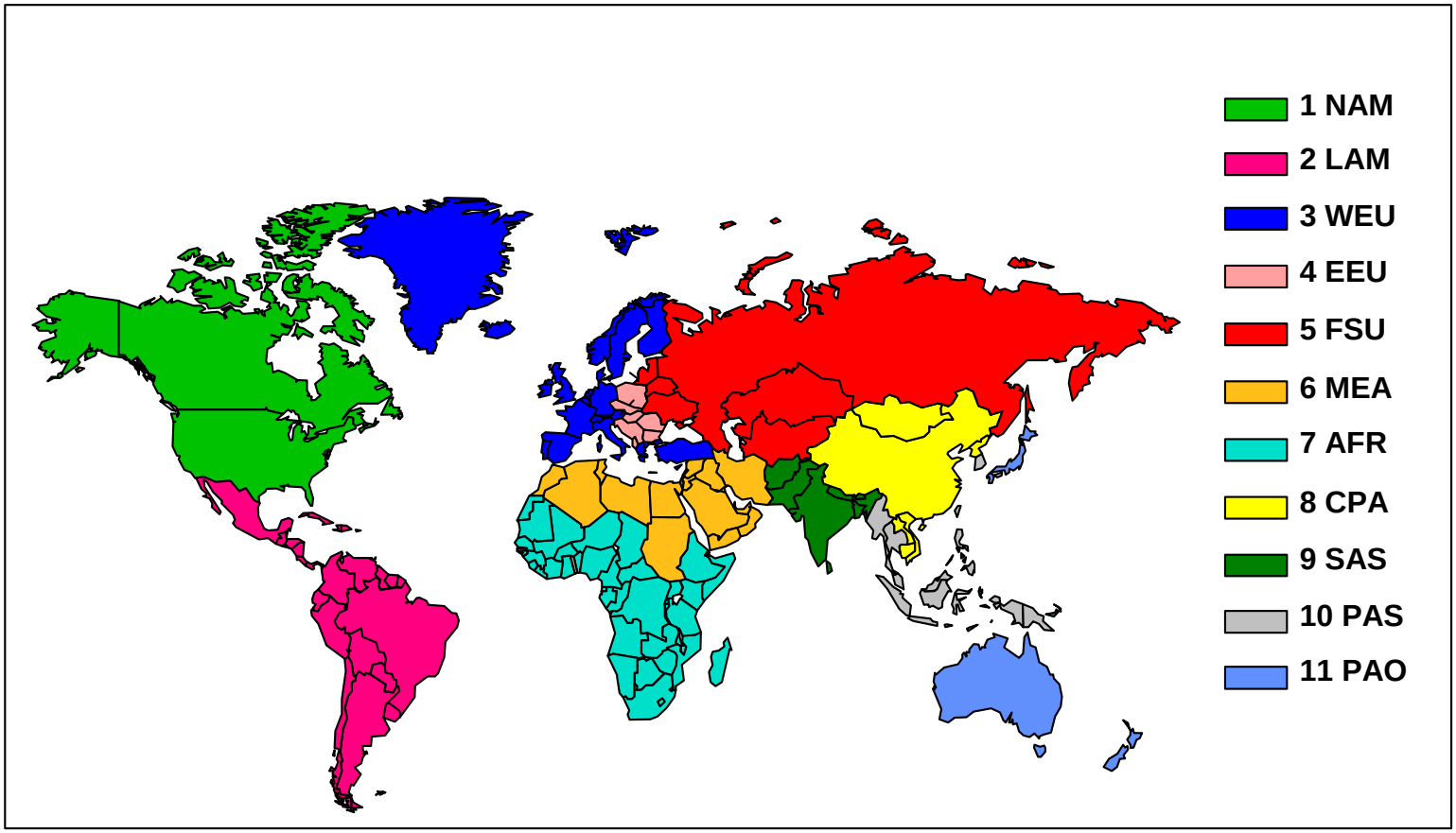
The MESSAGE-MACRO Link-2



The MESSAGE Model

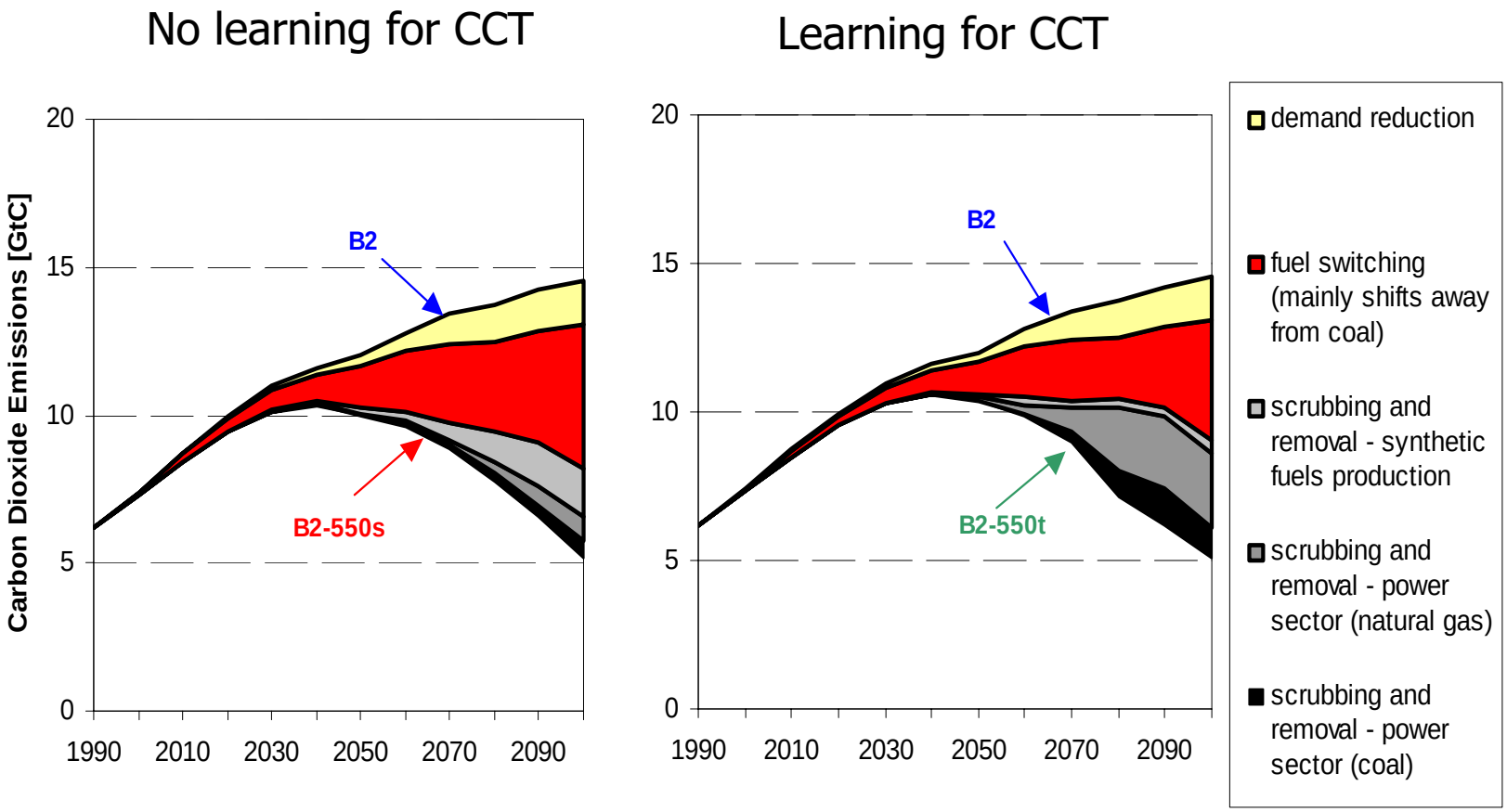
- Includes 400 individual energy conversion and end-use technologies
- 11 World Regions
- Calculates least-cost optimal energy supply technology structure, which satisfies a given useful-energy demand
- Technological progress in different path dependent directions according to the scenario specification

11 World Regions in MESSAGE



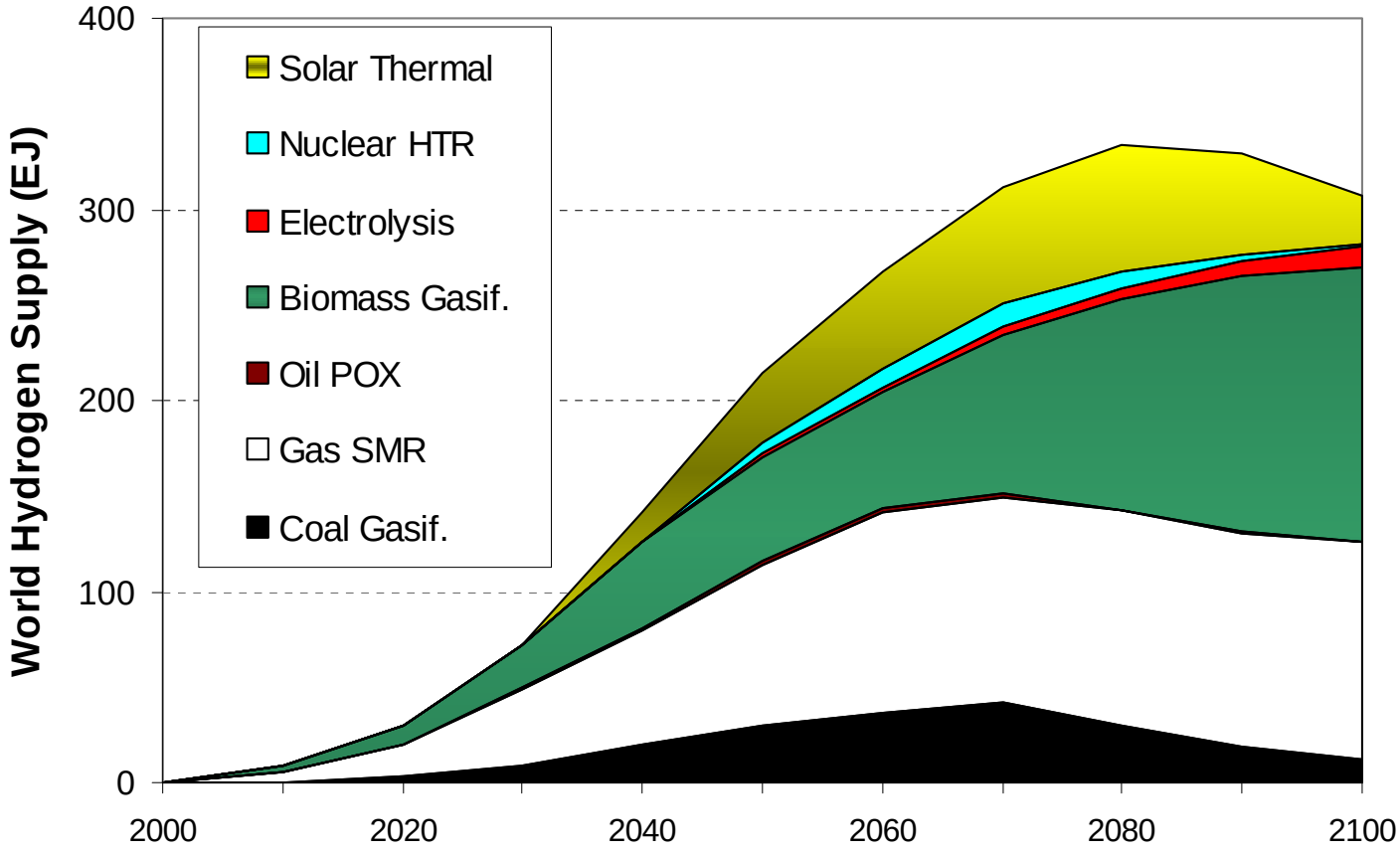
1 NAM North America
2 LAM Latin America & The Caribbean
3 WEU Western Europe
4 EEU Central & Eastern Europe
5 FSU Former Soviet Union
6 MEA Middle East & North Africa
7 AFR Sub-Saharan Africa
8 CPA Centrally Planned Asia & China
9 SAS South Asia
10 PAS Other Pacific Asia
11 PAO Pacific OECD

Examining Carbon Scrubbing



Exploring Hydrogen Futures

The B1H2 Scenario



The ERIS Model

- ERIS (Energy Research and Investment Strategy)
- Small-scale model with endogenized learning curves (learning-by-doing and learning-by-searching)
- Flexible tool to assess approaches to endogenize technological change
- Global, multi-region, electricity generation model with CO_2 trading

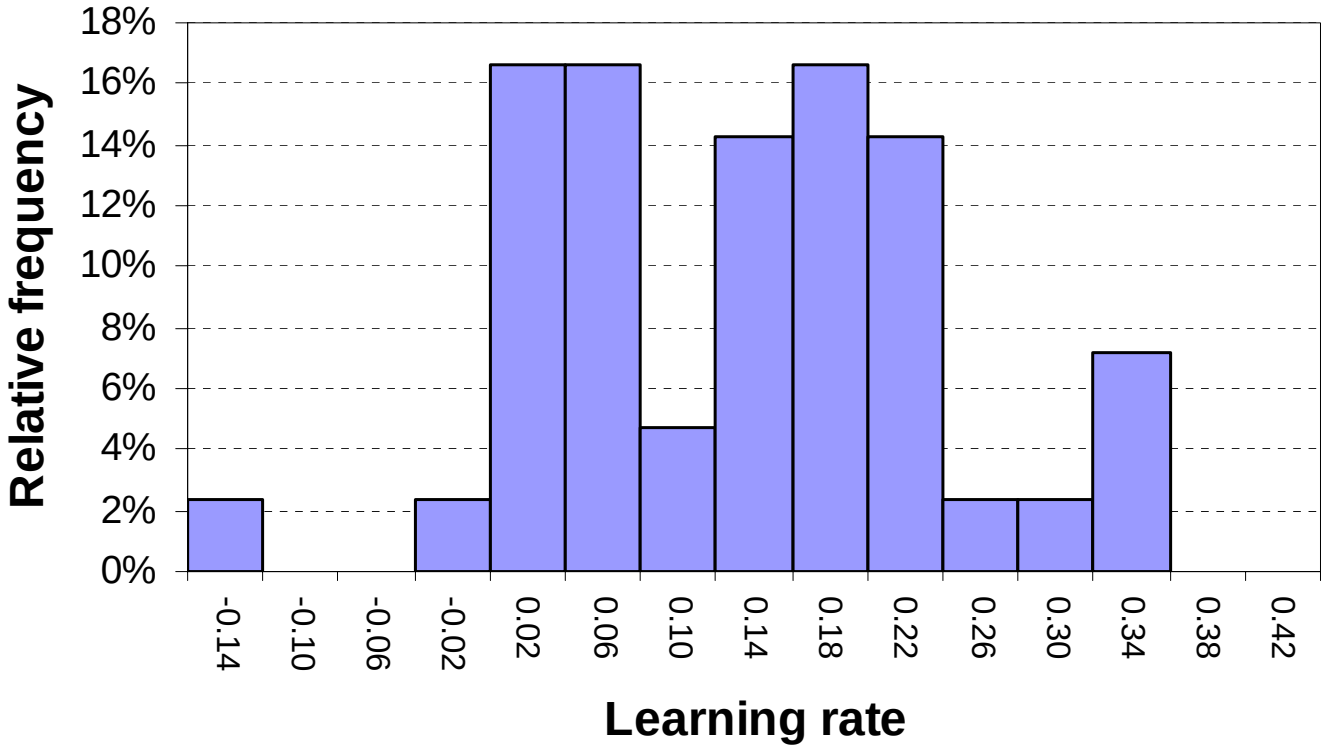
Two-Factor Learning Curves

- R&D should be examined as a technological learning mechanism
- Specific cost as function of Cumulative Capacity and Knowledge Stock

$$SC_{te,t} = a * CC_{te,t}^{-b} * KS_{te,t}^{-c}$$

b: Learning-by-doing elasticity
c: Learning-by-searching elasticity

Learning Rates of Energy Technologies



Source: McDonald and Schrattenholzer (2001), 42 technologies

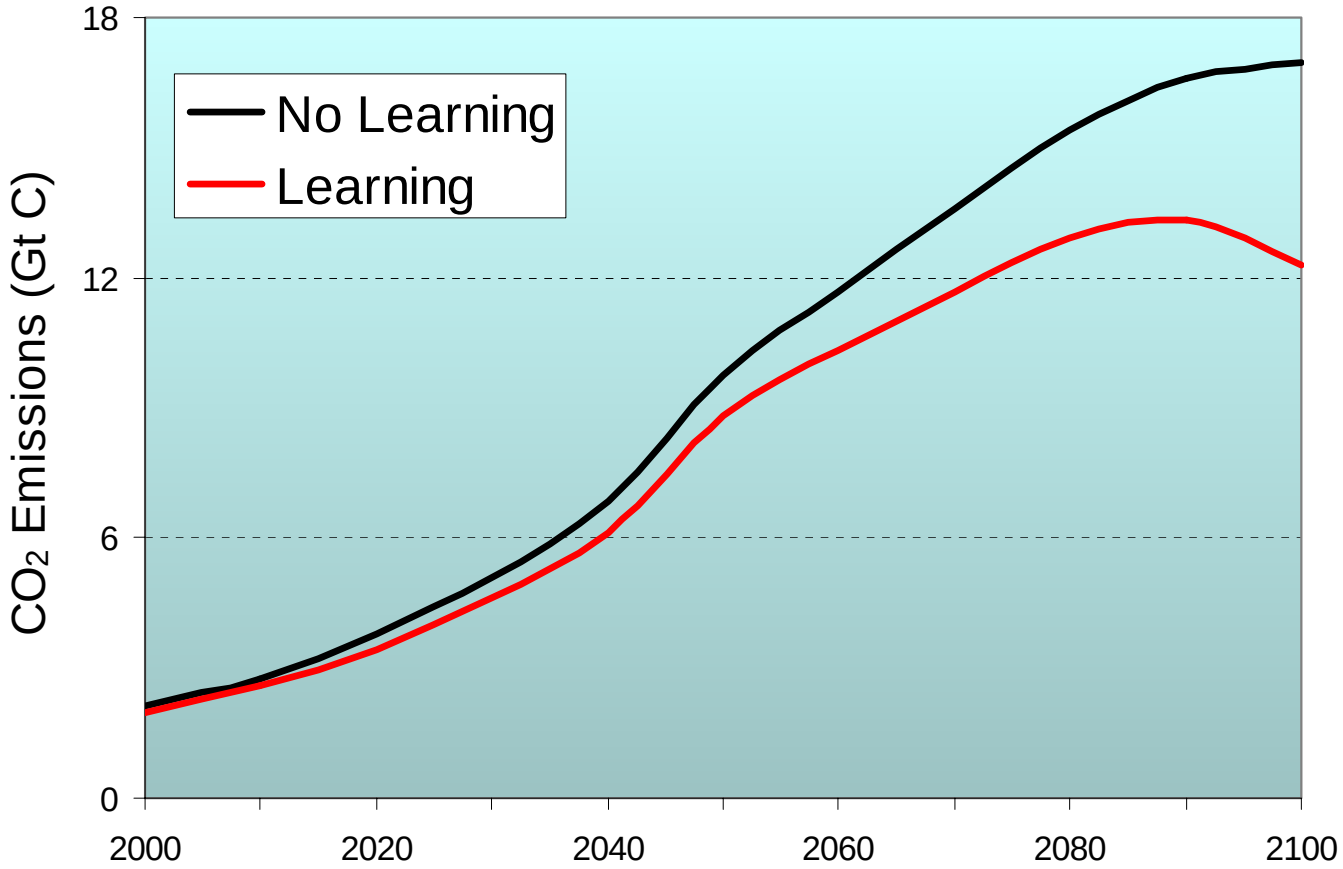
Endogenizing Learning Curves

- Non-linear, non-convex optimization problem
- Multiple locally optimal solutions: Alternative paths the energy system may follow
- Globally optimal solution: Least-cost energy system path
- No guarantee of globally optimal solution with conventional NLP solvers

Solving the Problem

- Mixed Integer Programming (MIP) if other nonlinearities do not exist
- "Guided" optimization with conventional NLP algorithms (different solvers/starting points)
- Global optimization algorithms (e.g. BARON)

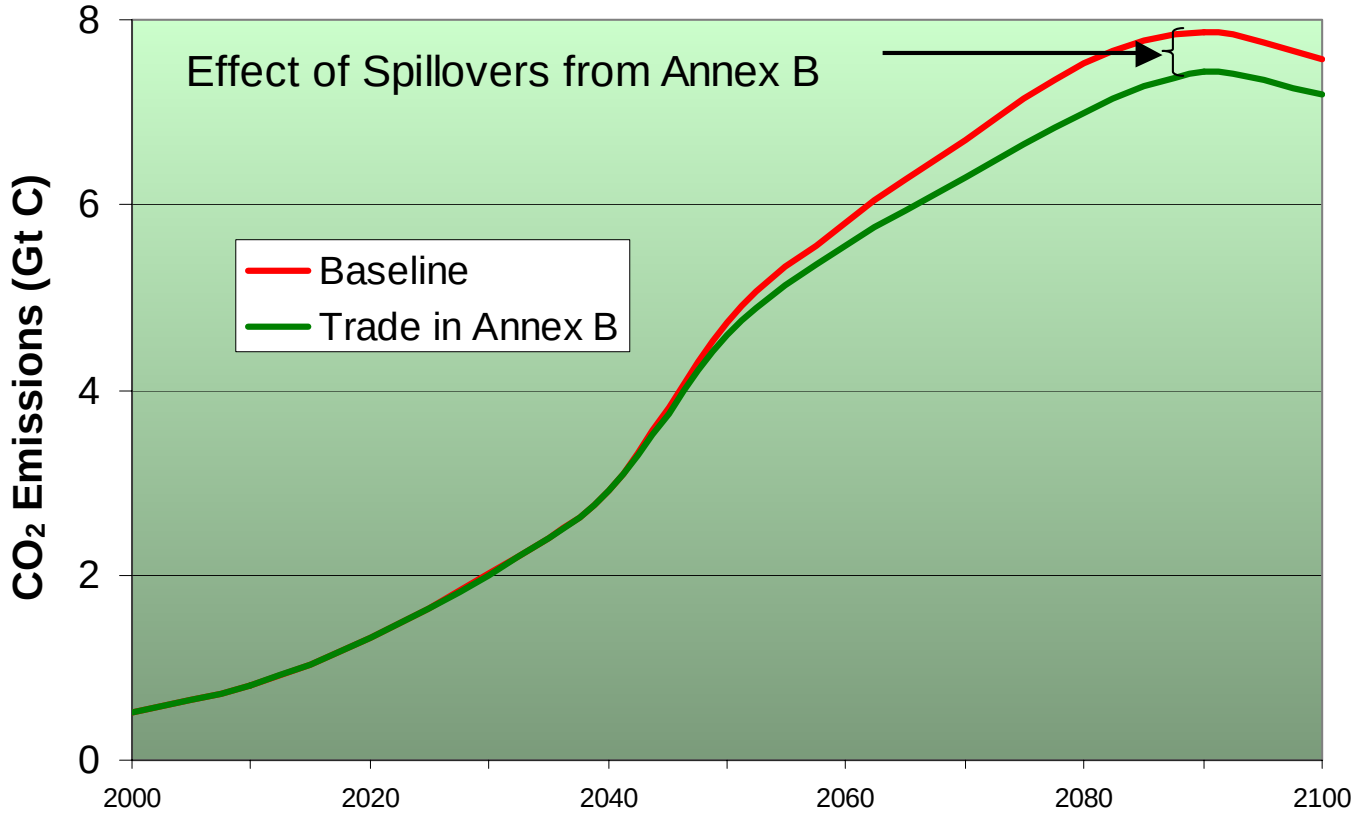
Different Model Outcomes with Learning



ERIS and Spillovers of Learning

- Multi-regional ERIS endogenizing learning-by-doing using MIP approach
- Learning investments in one region may drive to cost reductions also in others
- With spillovers of learning deploying a technology in a region can affect technology choices in other regions
- This phenomenon cannot be captured by models with exogenous technical change

Spillovers of Learning
Carbon Emissions in Non-Annex B



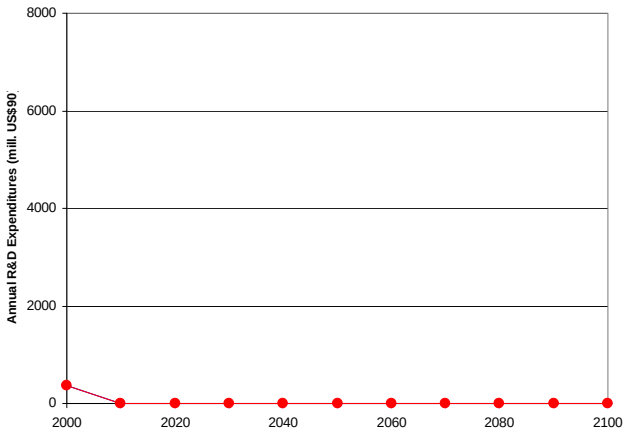
Finding Globally Optimal Solutions

- BARON: Branch and Reduce Optimization Navigator (Sahinidis, 2000)
- General purpose global optimization software
- Combines enhanced branch and bound with range reduction techniques
- GAMS/BARON

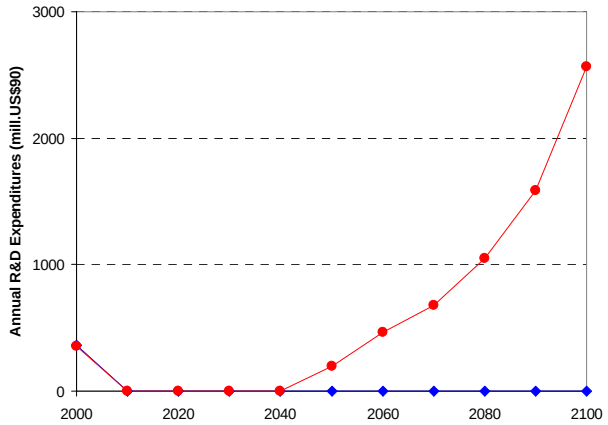
Example: 4 Locally Optimal Solutions

R&D Expenditures (Mill. US$90)

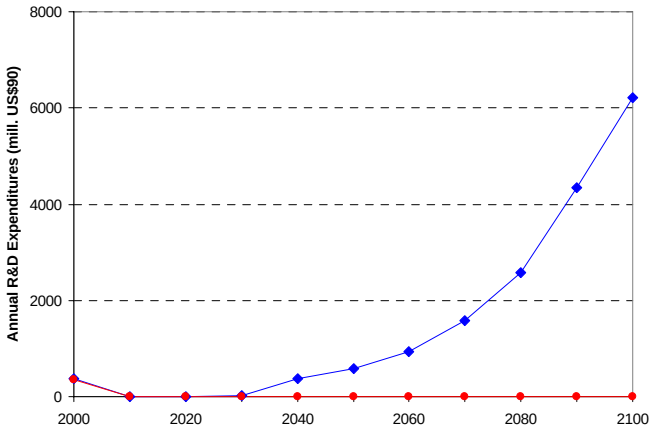
1



2

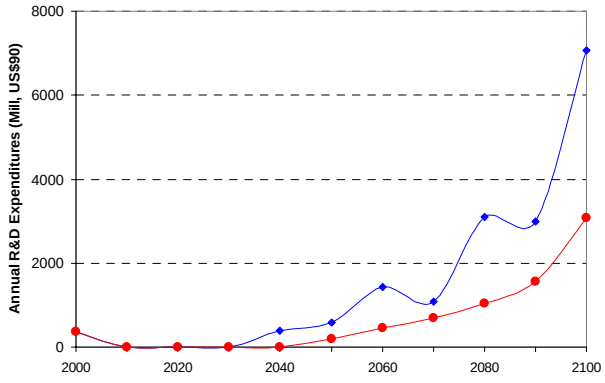


3



4

Global Optimum

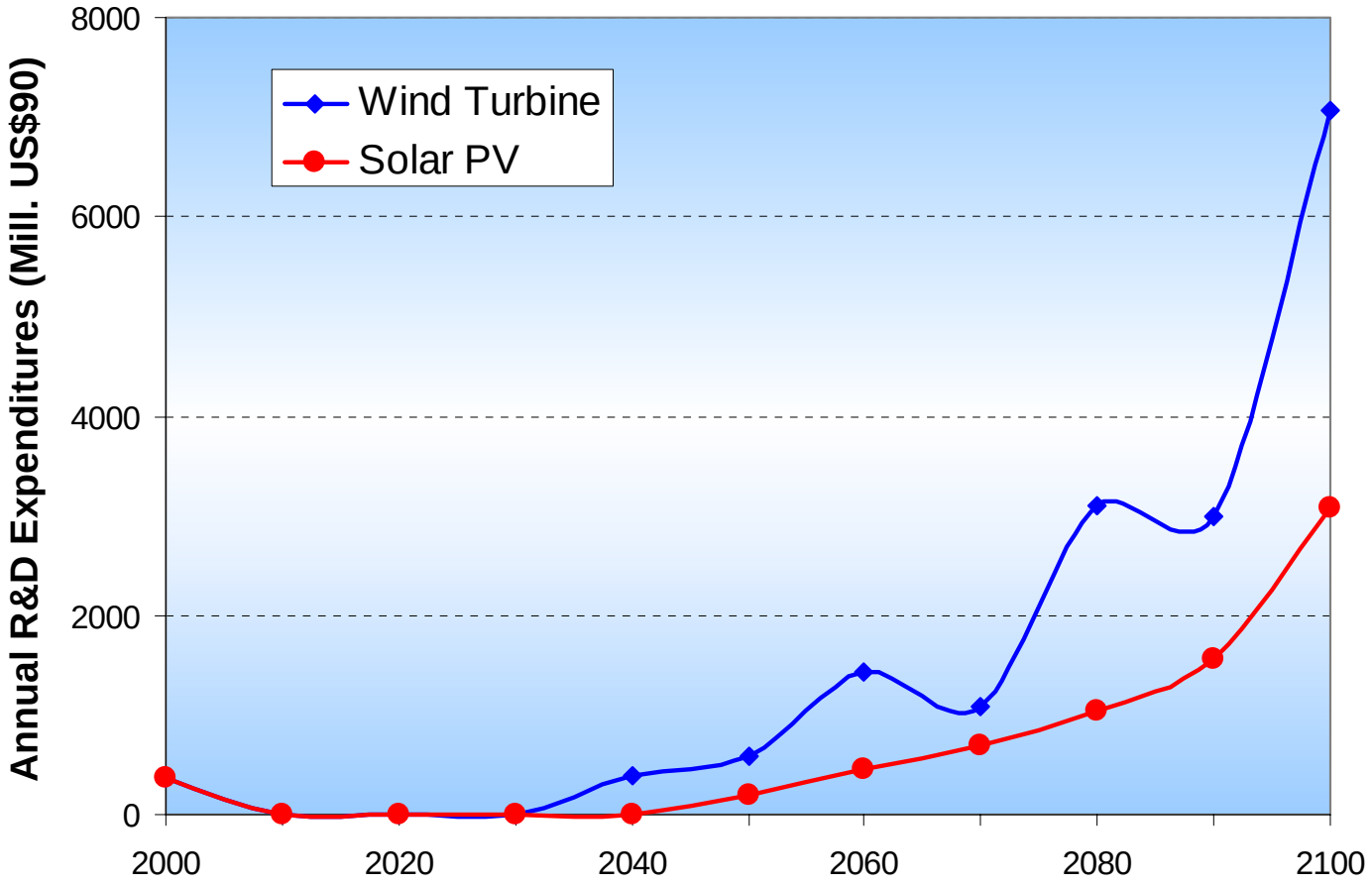


Wind Turbine

Solar PV

Globally Optimal R&D Expenditures

Example with two Technologies



Conclusions

- MESSAGE-MACRO provides a flexible combination of top-down and bottom-up approaches and allows consistent quantification of E3 scenarios
- ERIS endogenizes learning-by-doing and learning-by-searching mechanisms and allows investigating energy technology dynamics