# Linking MM with MERGE to study national policies under consistent global developments

**IEW & ETSAP Meeting**
**3 July 2008**
**International Energy Agency, Paris, France**

**S. Kypreos**

PAUL SCHERRER INSTITUT PSI

# Outline

- Goal
- Overarching questions
- Extending MERGE by using learning and clusters (done)
- Introducing Hubbert's formula in MERGE (to be done)
- Introducing passenger transport (to be done)
- Extending MERGE by one more region (to be done)
- Defining MM based on existing LP models and a calibration algorithm
- Liking MM and MERGE in one model for direct solution
- Conclusions/Proposal

PAUL SCHERRER INSTITUT PSI

**Goals: - National policies with consistent global developments**
**- Estimation of the macro-economic cost of policies**
**- Simulation of technology dynamics with LbD and LbS**

It is proposed to link the MM model of a country (e.g., USA) with the MERGE model of 9 world regions in order to get **technology dynamics**, **price feed-backs** due to resource depletion (based on Hubbert's logistic NLP-formulations), the **trade** of CO2 permits and other energy products and the **macro-economic feed-backs** due to global policies related to climate change and resource depletion issues.

Overarching questions:

- What exactly are we proposing?
- Why is that development needed?
- How we will do it?
- Are the ETSAP tools enhanced?
- What are the investments for ETSAP?
- What are the questions to be studied?

PAUL SCHERRER INSTITUT PSI

# What exactly is proposed?

**A) Define endogenous boundary conditions for national studies**

- Prices of global resources
- Trade levels/bounds for energy sources,
- CO2 emission permits level or CO2 reduction levels abroad
- Bounds on renewable use like bio-fuels

**B) Path & Policy dependent technology specifications**

- Technological change as result of global LbD and LbS
- Specific cost and efficiencies

**C) Macro-Economic developments**

- Baseline consistent with global growth assumptions
- Macro-economic cost of policies and of normative constraints
- Possibility to perform CBA of global or national environmental policies

PAUL SCHERRER INSTITUT PSI

# Why is this development needed?

**Three basic input/output on the national level will be enhanced:**

A) Endogenous specification of boundary conditions
B) Path & Policy dependent technology specifications
C) Macro-Economic developments and CBA
D) And Eventually, Simulation of oil peak and higher market prices

**Points under A) and B) will establish consistent assumptions for national studies, while Points C) and D) is new information not available yet with the present set of models used**

**And all these points will enhance the available ETSAP tools for national analyses under the condition that all the above can be solved within reasonable computational time**

**Main emphasis of national studies will be on path dependent technology contribution to meet environmental policies and to assess the macroeconomic impacts of policies.**

PAUL SCHERRER INSTITUT PSI

# How we will do it?

Different levels of activities are proposed that become increasingly complex:

A1) Improve MERGE with clusters (done), introduce the Hubbert's formula on resources (to be done), and the passenger sector (done in Cascade Mints but needs integration to the cluster formulation of MERGE)
A2) Extend MERGE by one more region (to be done) splitting the data of the world region where the country belongs, and finally solve the NLP problem.

B1) Define the MM of this region (NLP problem) based on existing TIMES or MARKAL models, an easy algorithm to calibrate growth and demands (PSI contribution to Annex X), and use technology dynamics based on MERGE

C) Put MM and MERGE equations in one model for direct solution as NLP model (done already in 1998 with 5 region MERGE and the MM of USA)

A2 is already a first solution, B1 gives an ETSAP type solution while C is an extension

PAUL SCHERRER INSTITUT PSI

## MERGE with the 2FLC for key components: Introduction of endogenous R&D

- Conventional setting
  - **Technology specific Investment Cost** (INV) as a function of Cumulative Production (CP) and the Knowledge Stock (KS)

$$INVC_{k,t} = a \cdot CP_{k,t}^{-b} \cdot \mathrm{KS}_{\mathrm{k,t}}^{-\mathrm{c}}$$

with

$$KS_{k,t} = (1 - s) \cdot KS_{k,t-1} + AR \,\&\, D_{k,t}$$

- Cluster approach
  - Relationship between **cumulative production** of a given **key component** *kc* at time *t* and **cumulative production** of **technologies** *k* that share the component in the time period *t* is as follows:

$$INVC_{kc,t} = a \cdot CPROD_{kc,t}^{-b} \cdot KS_{kc,t}^{-c}$$

with

$$CPROD_{kc,t} = \sum_{ktokc} \sum clust_{ktokc} CP_{k,t}$$

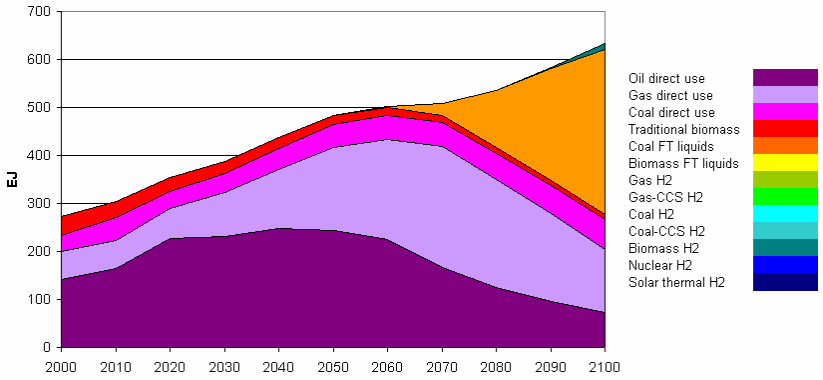
PAUL SCHERRER INSTITUT PSI

## Technology clusters - Learning rates assumptions

| | Mature | Speculative |
|---|---|---|
| Key components | Gasifier | CCS Pre-combustion |
| | Gas turbine | CCS Post-combustion |
| | Advanced nuclear | CCS - H2 prod |
| | Wind | Stationary fuel cell |
| | Coal BoP | Solar PV |
| | Biomass BoP | Solar Thermal - H2 prod |
| | Advanced Coal | Advanced nuclear - H2 prod |
| Learning rates | | |
| LbD | 5% | 10% |
| LbS | 5% | 10% |

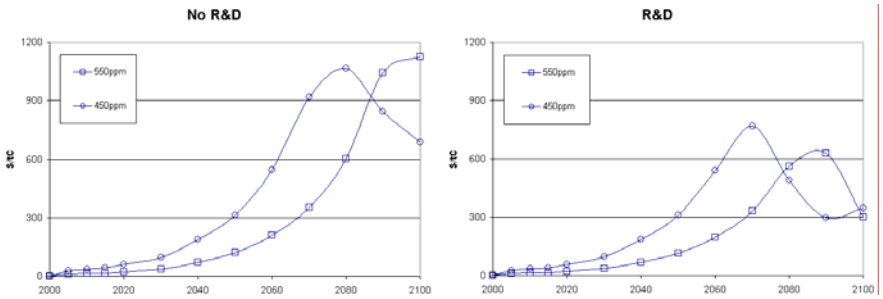
PAUL SCHERRER INSTITUT PSI

## Baseline non-electric energy supply with R&D



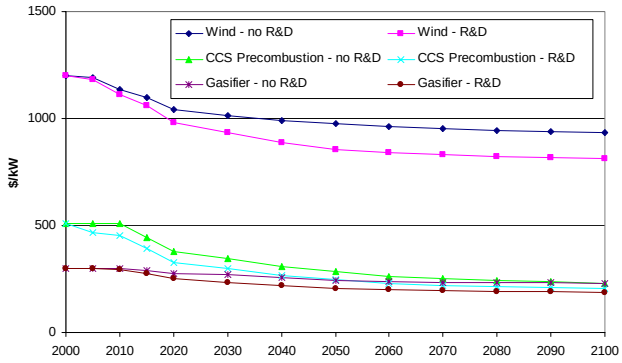

PAUL SCHERRER INSTITUT PSI

## Carbon price




PAUL SCHERRER INSTITUT PSI

## Time development of investment costs for selected key components under a 550 ppm target




PAUL SCHERRER INSTITUT

## MERGE and Oil Resources: Key assumptions of IPCC models



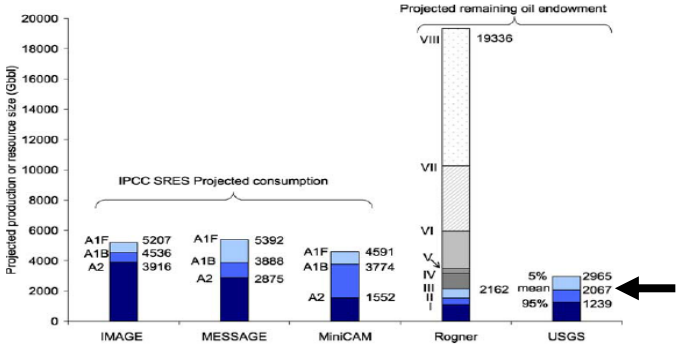



Fig. 2 Comparison of projected petroleum production in three studied SRES models in three scenarios (*A2*, *A1B*, *A1F*) to two estimates of remaining petroleum resources. Notes: Projected production for IMAGE from IMAGE (2001), and for MESSAGE and MiniCAM from Intergovernmental Panel on Climate Change (2000). Values for Rogner and USGS are from Fig. 1 and Table 1. Rogner's categories explained in Fig. 1, USGS categories are 95% likely to be achieved (low estimate), mean probability, and 5% likely to be achieved (high estimate). Note that projected production in the SRES models is significantly higher in the high-consumption scenarios than even the low-probability USGS estimates for remaining conventional oil, and are much higher than Rogner's estimates of remaining conventional oil (categories *I–III*). This implies production of significant amounts of unconventional oil (Rogner's categories *IV–VIII*, or unconventional resources not estimated by USGS)

PAUL SCHERRER INSTITUT

## Oil Resource to Oil Reserves : Going down from 3 Tbbl (USGS- 5% probability of finding) to 2 Tbbl (50%)

**Reserve additions** are defined such that they cannot exceed a fixed fraction (e.g., 3%- 5%) of **undiscovered resources (URSC):**

$$RA_{x,r,t} \leq rdf \cdot URSC_{x,r,t}$$

**Undiscovered resources (URSC) , are balanced by a distributed lag function of reserve addition (RA):**

$$URSC_{x,r,t+1} = URSC_{x,r,t} - 0.5 \cdot nypp \cdot (RA_{x,r,t+1} + RA_{x,r,t})$$

**The change of proven reserves (PRSV) equals the reserve additions minus the energy production PN:**

$$PRSV_{x,r,t+1} - PRSV_{x,r,t} = +0.5 \cdot nypp \cdot (RA_{x,r,t+1} + RA_{x,r,t}) - 0.5 \cdot yppr \cdot (PN_{x,r,t+1} + PN_{x,r,t})$$

**Again, energy production, cannot exceed a fraction of proven reserves:**

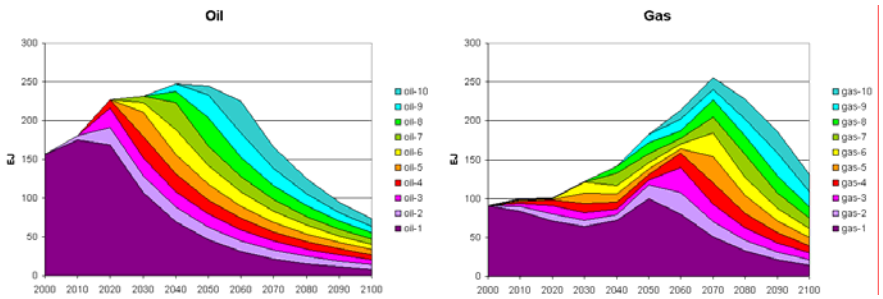
$$PN_{x,r,t} \leq prv \cdot PRSV_{x,r,t}$$ **(where *prv* has a value of 5 percent):**

**Finally, the summation of oil production by region and time for all categories of oil reserves, balance the activity of energy technologies using oil plus the net exports (NEXP) of the region:**

$$\sum_{x} PN_{x,r,t} \geq \sum_{j \subset oil} PE_{j,r,t} \cdot HTRT_{j,r,t} + \sum_{k \subset oil} NE_{k,r,t} + NEXP_{oil,r,t}$$

PAUL SCHERRER INSTITUT PSI

## Baseline oil and gas peaking consumption by resource grade




PAUL SCHERRER INSTITUT PSI

## Introducing Hubbert's formula in MERGE

**Instead of using these linear relations of e.g., " energy production, cannot exceed a fraction of proven reserves" :**

**We define now a logistic curve:**

$$PN_{x,r,t} / QPR_{x,r,t} \le k_x \cdot (1 - QPR_{x,r,t} / URSC0_{x,r})$$

**With k being the logistic growth rate (5%-6%) and the intercept of the well known linearized Hubbert formula for the resource category x that could be defined by interpolation of time series on past oil use; QPR being the cumulative production in time t; PN the production in t; and USRC0 the ultimate resource availability (e.g, a total of 2-3 Tbbl according to USGS-2000). The extra constraints needed are those defining the QPR per period and its maximum bound:**

$$\sum_{\tau=1,t} PN_{x,r,\tau} + QPR_{x,r,0} = QPR_{x,r,t} \le \mathrm{URSC0}_{x,r}$$

**Finally, the summation of oil production by region and time for all categories of oil reserves, balance the activity of energy technologies using oil plus the net exports (NEXP) of the region:**

$$\sum_{x} PN_{x,r,t} \ge \sum_{j \subset oil} PE_{j,r,t} \cdot HTRT_{j,r,t} + \sum_{k \subset oil} NE_{k,r,t} + NEXP_{oil,r,t}$$

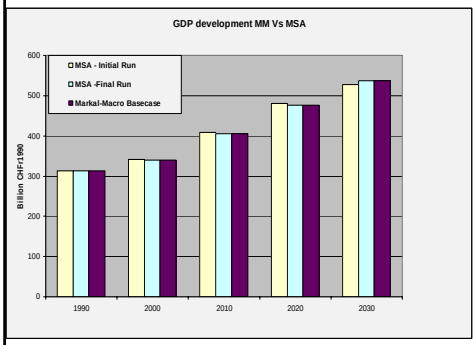
PAUL SCHERRER INSTITUT PSI

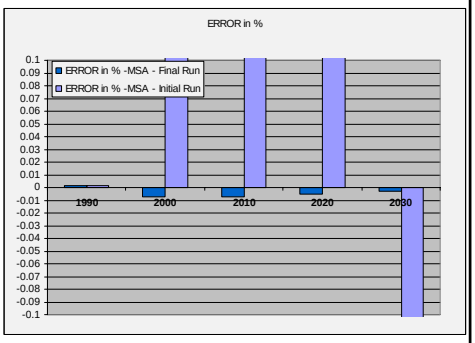
## Defining MM based on existing LP models and a simple calibration algorithm

- The scenario generator (SG) defines GDP, population and the reference demands as input for MARKAL-ED (MED) ( see the NEEDS project)
- Running now MED we establish the equilibrium demands, the energy costs (EC) and the marginal prices of demands.
- As GDP and EC (i.e., via the solution of MED) are defined, we could calibrate the CES production function of MM for the demands and the marginal prices of MED by adjusting the potential growth rates (i.e., the exogenous effective labour force in MM) such that the "GDP target" and MED demands are exactly reproduced in MM.
- The reduced set of equations and the Macro-Stand-Alone (MSA) are described in my contribution to the previous Annex of ETSAP and results are shown next with an error of 1.E-04 on desired GDP

PAUL SCHERRER INSTITUT PSI

## Defining MM based on existing LP models and a simple calibration algorithm (MSA)



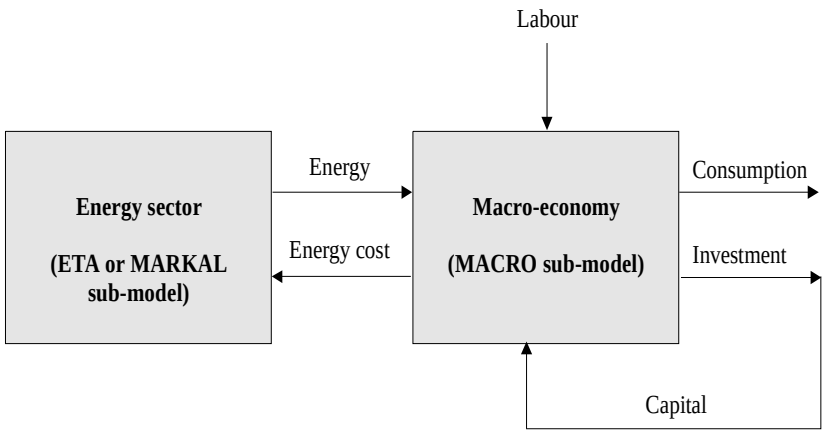

PAUL SCHERRER INSTITUT PSI

## Modelling framework: MERGE&MM

- **MERGE&MM** : 9 region **ETA-MACRO** from **MERGE-ETL**
  & One region **MARKAL-MACRO**
- **MERGE&MM** will be a combination of '**bottom-up'** & **'top-down'** approaches
- **MERGE&MM** will be an **optimisation** equilibrium model
- **Traded commodities**: *oil, gas, synthetic fuels, etc., CO2 permits, numeraire*

PAUL SCHERRER INSTITUT PSI

# Overview of ETA/MARKAL-MACRO




PAUL SCHERRER INSTITUT PSI

# Investments for ETSAP and Proposal

**The work as foreseen now, includes only two man-month per year for the duration of the Annex (depending on progress) and the cost of my participation to report in the ETSAP meetings.**

**I will deliver the needed software and I will study one region of importance, say USA, making a peer-review publication out of this work for ETSAP. Software will become ETSAP property like all other models of ETSAP**

**This could be financed by**

- **a direct ETSAP contribution**
- **establishing a cooperation contract between PSI and ETSAP having Switzerland participating to the current Annex and PSI financing the work, or**
- **voluntary contributions by those participants they want to have their MM case analyzed and integrated in MERGE**

PAUL SCHERRER INSTITUT PSI