International Energy Agency: Implementing Agreement for a

Programme of Energy Technology Systems Analysis;

Annex IX: ***Energy Models Users' Group***

Introduction of IEA/ETSAP

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Content

1. The Energy Technology Systems Analysis Program
2. Why it started in 1976?
3. Objective and Strategy
4. Method
5. Achievements:
    - Availability of a group of energy systems analysts
    - Implementation of several economic equilibrium technology explicit models of global, regional, national, local energy systems; and
    - development of systems analysis tools: the MARKAL TIMES model generator (MT)

1 – An international agreement

among:			
Belgium:	VITO/Uni-Leuven	Sweden:	Uni-Chalmers
Canada:	NRCan	Switzerland:	PSI
EC:	DG RTD	UK:	DTI, AEAT
Finland:	TEKES and VTT	US:	BNL/EIA/DOE
Germany:	IER/JFZ		
Greece:	CRES		
Italy:	ENEA/ENI		
Japan:	JAERI		
Korea:	KEMCO/KIER		
Netherlands:	ECN		

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in previous years:

Australia, Austria, Ireland

Denmark, New Zealand,

Norway, Spain, Turkey

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>150 ETSAP tool users

… open to the participation of new parties

2.1 – The energy problems of the '70s …

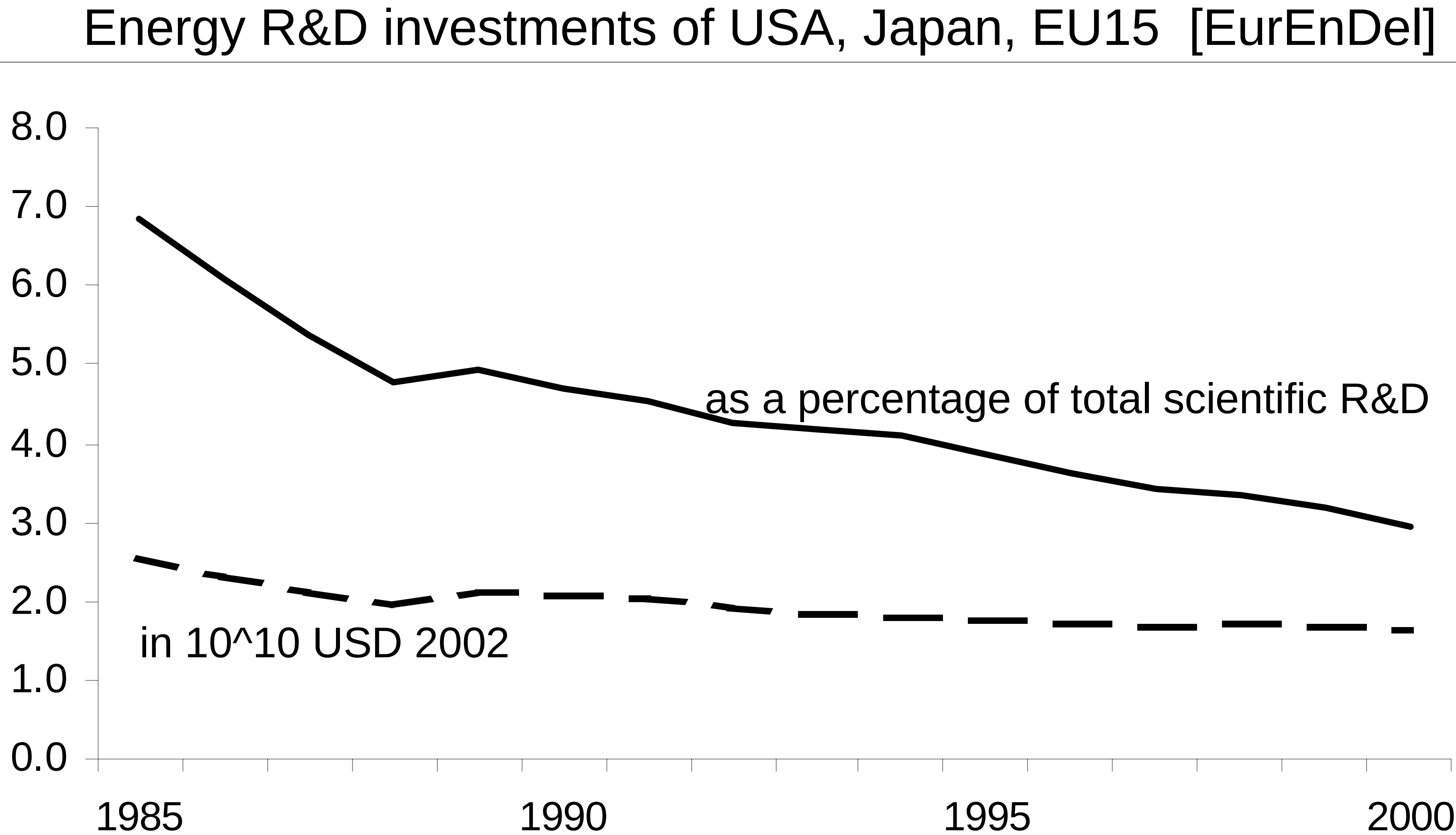
Are there technically and economically feasible alternatives to crude oil?

Are them global or dependent on national circumstances?

How to compare and rank different possibilities?

The group came out with different technological proposals, each of them based upon an enhanced Research & Development effort.

2.2a – Energy R&D investments: trend …

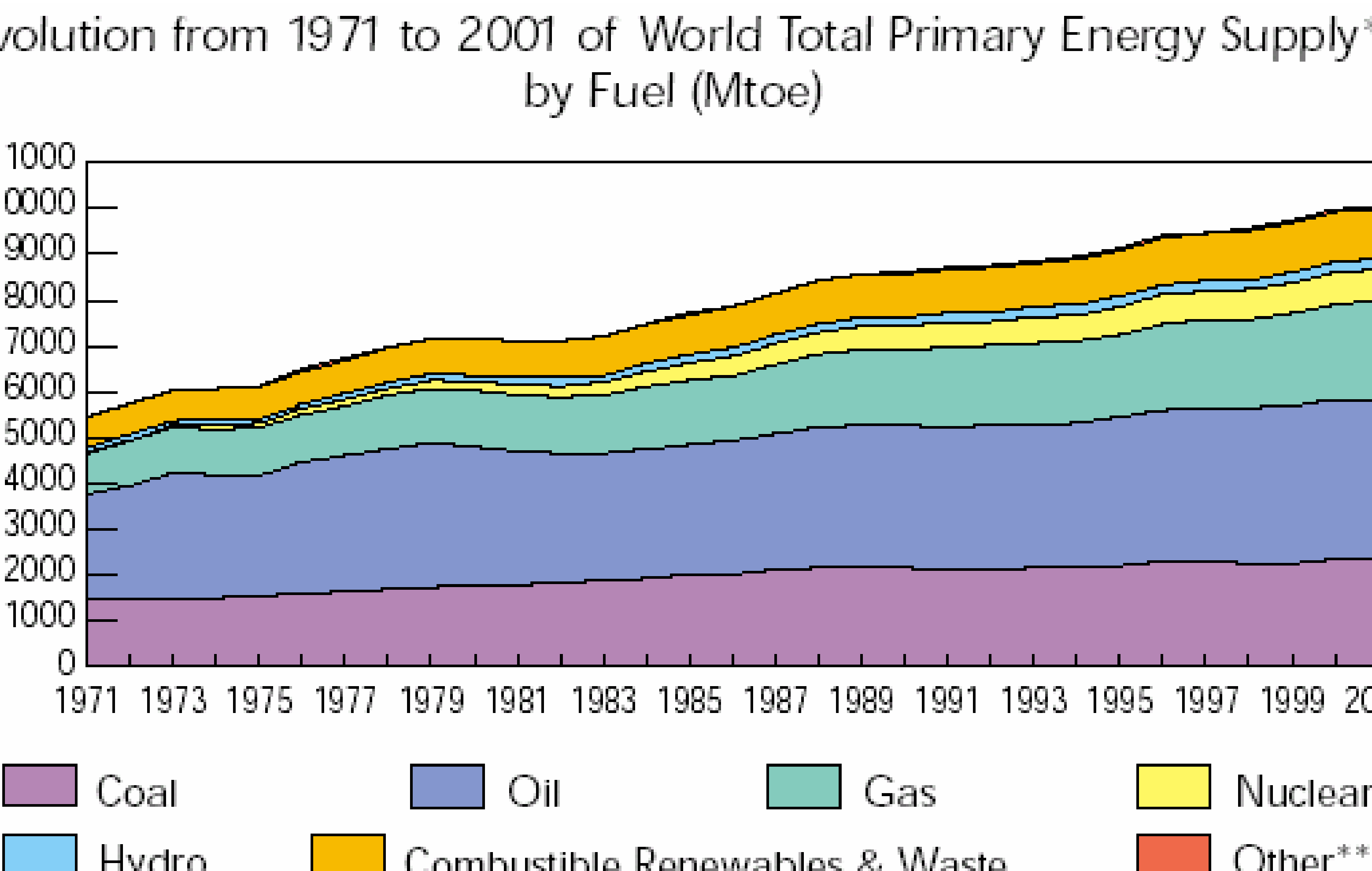


2.2b – … and present gap

Global values (year 2000, in BUS$)		% GDP
Economic resources	about 70000	
GDP	35000	
Primary energy (TPES)	1400-1800	4-5%
Final energy (TFC)	3000-3500	10%
Useful energy (UE)	about 10000	30%
Total R&D funding	about 600	1.7%
	(EU Lisbon objective 2010	*3%)*
Energy R&D	about 10	

(1.7% of total R&D, and 0.3% of energy sales)

2.3a – The present situation in figure …



2.3b – … and in words

- Limit to the amount of fossil fuels extractable from reserves?
- Limit to the ultimate amount of CO_2 accepted by the atmosphere?
- Energy services security, distribution and affordability?

2.4 – How to find a sustainable development path?

Waiting for the scientist to:

- Develop as many alternative energy chains as there are food & drink chains (security),
- innovate energy technologies as it happened in telecommunication a century after the discovery, and
- Find a way to remove CO2 fast enough to leave the climate unchanged,

decision makers ask to the energy systems scientists what is the less damaging combination of alternatives capable of satisfying the best combination of objectives.

3.1 – ETSAP objective …

… is to assist decision-makers in assessing new energy technologies and policies in meeting the challenges of

- energy needs,
- environmental concerns, and
- economic development,

… by carrying out a programme of co-operative energy technology systems analysis and modelling studies of possible developments.

3.2 – … and strategy

… in achieving the objectives is twofold.

1. ETSAP has established, and now maintains / enhances the flexibility of consistent multi-country energy / economy / environment analytical tools and capability (the MARKAL TIMES family of models), through a common research programme.

2. ETSAP members also assist and support government officials and decision-makers by applying these tools for energy technology assessment and analyses of other energy and environment related policy issues.

4 – ETSAP tools: energy systems analysis and model

1. From the energy balance of the system to be modelled,
2. By correlating energy to several other data,
3. Each energy market is represented by means of (linearised) demand supply curves;
4. Assuming framework projections,
5. MARKAL TIMES generates economic equilibrium models,
6. Which are formulated as mathematical programming problems, making use of structured modelling techniques
7. And calculates the economic and environment impact of different energy policies and technologies.

4.1 – From the Energy Balance of the system

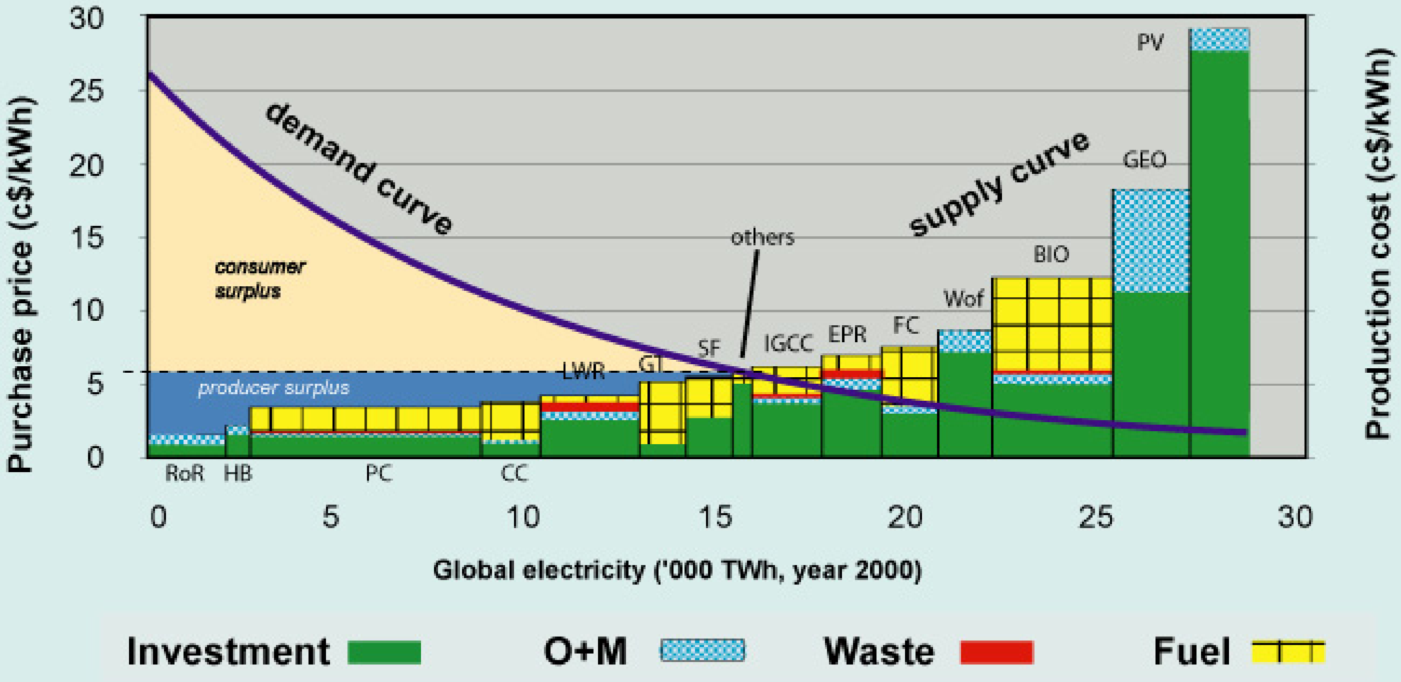
	Thousand tonnes of oil equivalent										
SUPPLY AND CONSUMPTION	**Coal**	**Crude Oil**	**Petroleum Products**	**Gas**	**Nuclear**	**Hydro**	**Geotherm. Solar, *etc.***	**Combust. Renew.**	**Electricity**	**Heat**	**Total**
Production	698779	164131	-	31365	4553	23859	-	215930	-	-	1138617
Imports	1369	60260	28315	-	-	-	-	-	155	-	90098
Exports	-67316	-7550	-11495	-	-	-	-	-	-876	-	-87238
Intl. Marine Bunkers	-	-	-3969	-	-	-	-	-	-	-	-3969
Stock Changes	4526	-1297	-1369	-	-	-	-	-	-	-	1860
TPES	**637358**	**215544**	**11481**	**31365**	**4553**	**23859**	**-**	**215930**	**-722**	**-**	**1139369**
Transfers	-	-	-	-	-	-	-	-	-	-	-
Statistical Differences	13753	-3824	-1989	-3988	-	-	-	-	-	-	3952
Electricity Plants	-290951	-816	-11103	-1344	-4553	-23859	-	-838	126563	-	-206903
Heat Plants	-35986	-123	-4096	-1697	-	-	-	-490	-	36585	-5807
Gas Works	-4670	-	-228	3827	-	-	-	-	-	-	-1072
Petroleum Refineries	-	-204068	201793	-	-	-	-	-	-	-	-2275
Coal Transformation	-45850	-	-	-	-	-	-	-	-	-	-45850
Own Use	-30016	-4422	-15046	-7822	-	-	-	-	-19240	-9335	-85882
Distribution Losses	-126	-	-17	-643	-	-	-	-	-8881	-430	-10097
TFC	**243511**	**2291**	**180795**	**19697**	**-**	**-**	**-**	**214602**	**97720**	**26820**	**785435**
Industry	165870	2092	51984	12449	-	-	-	-	61562	20110	314067
Transport	5280	-	69161	228	-	-	-	-	1307	-	75977
Agriculture	3688	-	16119	-	-	-	-	-	6676	57	32841
Comm. and Publ. Services	5400	-	16014	588	-	-	-	-	6439	450	28892
Residential	43981	-	13652	6431	-	-	-	214602	15817	5581	300064
Non-specified	4174	136	-	-	-	-	-	-	5917	622	10912
Non-energy use	8818	-	13865	-	-	-	-	-	-	-	22683
Electr. Generated - GWh	*1121973*	*-*	*47343*	*5474*	*17472*	*277432*	*-*	*1963*	*-*	*-*	*1471657*
Heat Generated - TJ	*1307224*	*-*	*147659*	*63965*	*-*	*-*	*-*	*13187*	*-*	*-*	*1532035*

Example: China, 2001 (Excluding Hong Kong)

4.2 – by correlating energy to other data

1. The energy balance is extended to end users and their demand for energy services
2. Each energy flow is
   - Cross-checked with the stock of existing energy technologies (Reference Energy System)
   - Linked to the emission of various species and
   - Correlated to economic flows and investments
3. Demand and supply curves are built for each market, as illustrated

4.3 – each energy market is represented by linearised demand / supply curves



Power plants

RoR = run of the river
HB = hydro basin
PC = pulverized coal
CC = combined cycle
LWR = existing nuclear
GT = gas turbine
SF = steam fossil
others existing
IGCC = int. coal GCC
EPR = new nuclear
FC = fuel cells
Wof = wind offshore
BIO = biomass steam
GEO = geo hot dry
PV = photovoltaic

Typical representation of an energy commodity in MARKAL - TIMES.
The algorithm maximises the global surplus over thousands such markets.

4.4 – assuming framework projections

1. Availability of energy resources, by type, region, cost, technology, etc.
2. Economic macro variables by region, year, scenario, etc
3. Environmental constraints by species
4. Technological development, by technology
5. Etc.

4.5 – MARKAL TIMES generates partial equilibrium models

Technology explicit and Multi-regional, which assume *Price elastic demands;* and *Competitive markets:* with *Perfect foresight (*resulting in *Marginal value Pricing).*

Underlying principles central to the MARKAL equilibrium are:

- Outputs of a technology are linear functions of its inputs;
- Total economic surplus is max. over the entire horizon,
- Energy markets are competitive, with perfect foresight.

As a result of these assumptions the following properties hold:

- The market price of each commodity is exactly equal to its marginal value in the overall system, and
- Each economic agent maximizes its own profit (or utility).

4.6 – *formulated as a mathematical programming problem,* *composed of*

	a Primal Problem and	a Dual Problem
	Max $c^t x$	Min $b^t y$
s.t.	$Ax \leq b$	$A^t y \geq c$
	$x \geq 0$	$y \geq 0$

where x is a vector of decision variables, $c^t x$ is a linear function representing the objective to maximize, and $Ax \leq b$ is a set of inequality constraints.Each dual variable y_i may be assigned to its corresponding primal constraint.

If the primal problem has a finite, optimal solution x*, then so does the dual problem (y*), and both problems have the same optimal objective value.

The optimal values of the dual variables are also called the shadow prices of the primal constraints. The vector (x*, y*) represents the equilibrium.

4.7 – MARKAL TIMES is coded making use of Structured Modelling Techniques

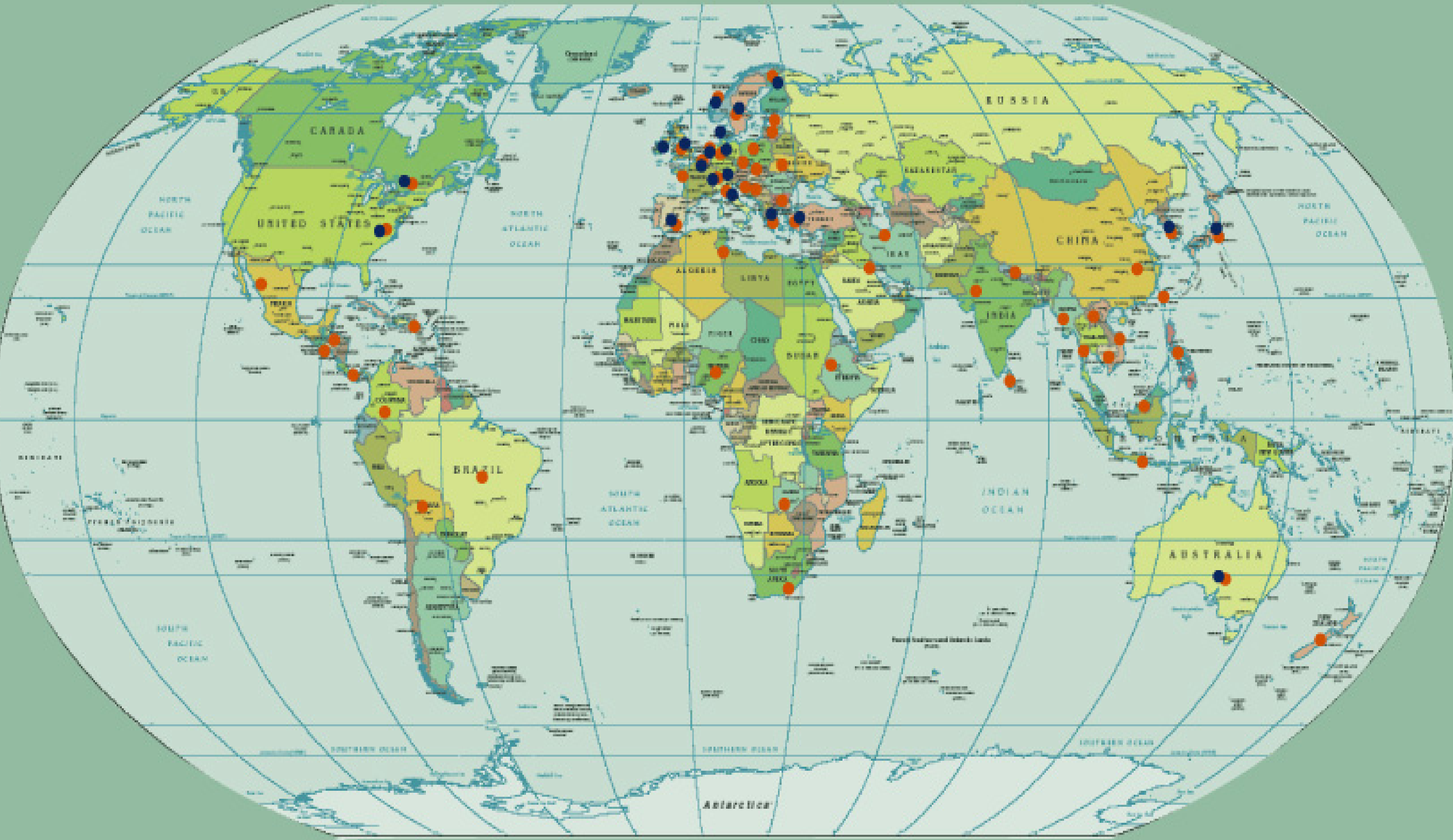
Real size energy system models, with a detailed representation of commodities and technologies, are huge:

- hundreds of thousand of variables and equations, and
- million of coefficients.

How to contain in a feasible size the definition procedures of such huge models?

Instead of being formulated directly by means of decision variables, resource constraints and input parameters, the MARKAL TIMES mathematical programming problem is formulated by means of primitive and compound entities, which are mainly sets (variables, constraints and parameters), indexes and hierarchies.

5 – MARKAL TIMES users across the world



ETSAP Participants

and MARKAL - TIMES users

http://www.etsap.o