The TIMES Integrated Assessment Model (ETSAP-TIAM): Contribution to the discussion

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1a. Uncertainty about outcomes vs. likelihood

In WG3, uncertainty relates to <u>outcomes</u>. Example:

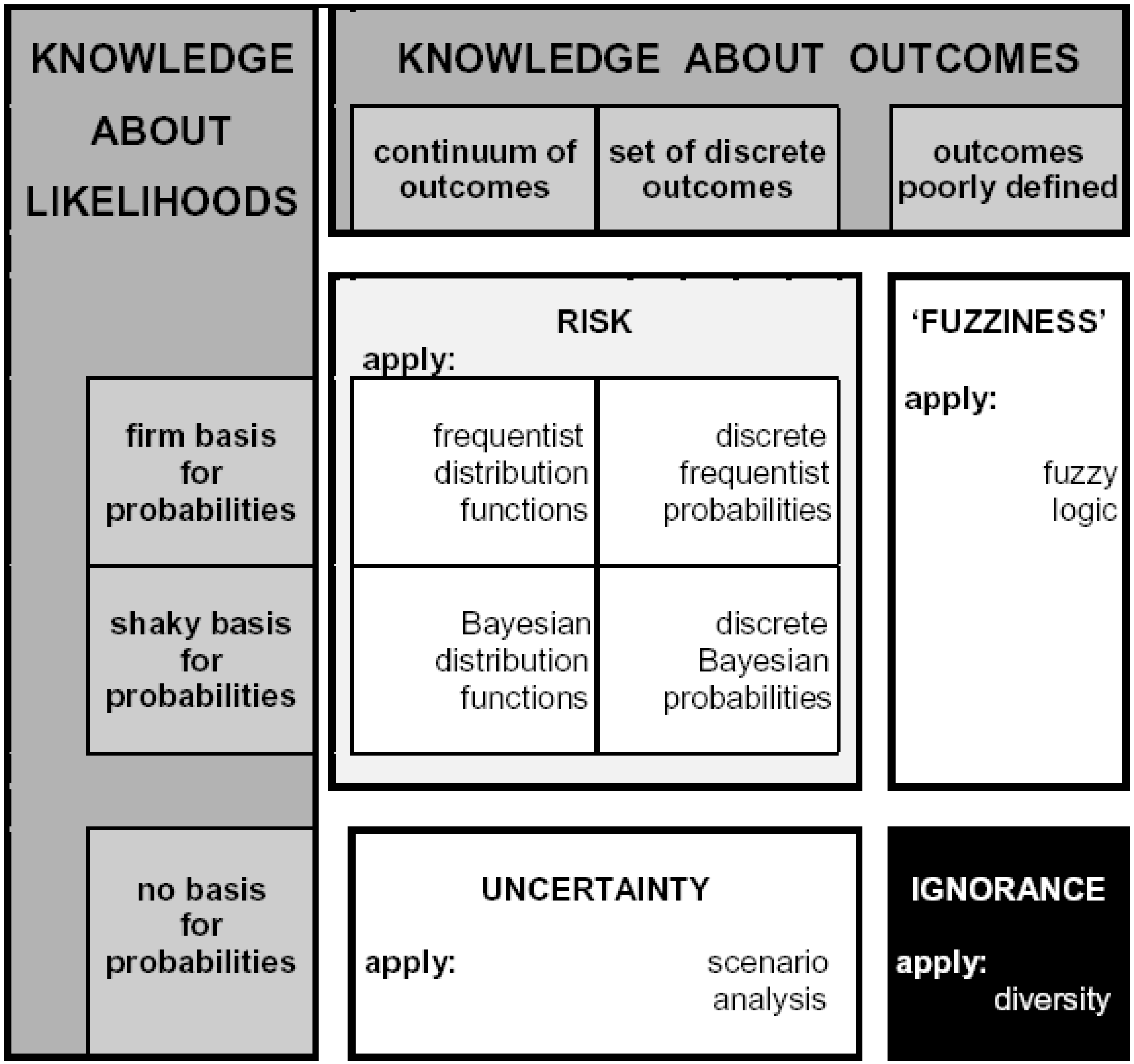
Population or GDP in 2100, as quantities, do not exist now, and cannot be determined now because they are the outcome of billions of (partly) independent and free decisions.

As far as I understand, in WG1 and 2, uncertainty relates to <u>likelihood</u>. Example:

Climate sensitivity as a quantity – a time independent physical parameter – exists. So far scientist were able to associate a likelihood level to different possible value of the unique Cs value. In principle in the future a value with likelihood close to 100% can be determined.

1b. The two dimensions of uncertainty

Box 2: A formal scheme for the definition of 'risk', 'uncertainty' and 'ignorance'



Taken from:

Andrew Stirling,

On the Economics and Analysis of Diversity, SPRU, Electronic Working Papers Series, Paper N. 28, 1998?

2. Consistency in a scenario and among scenarios

How to enhance the quality of the scenarios produced trough models by the IAMC community?

In engineering, models are usable only after being “validated” by comparing model results with results of actual experimental.

Since we can carry out only mental experiments based upon future development of not yet existing variables, our models cannot be validated. The most we can check is the consistency.

In establishing a standard data reporting format, is it possible to include variables and develop simple benchmarking procedures that check at least high level consistency of technological and macro-economic aspects?

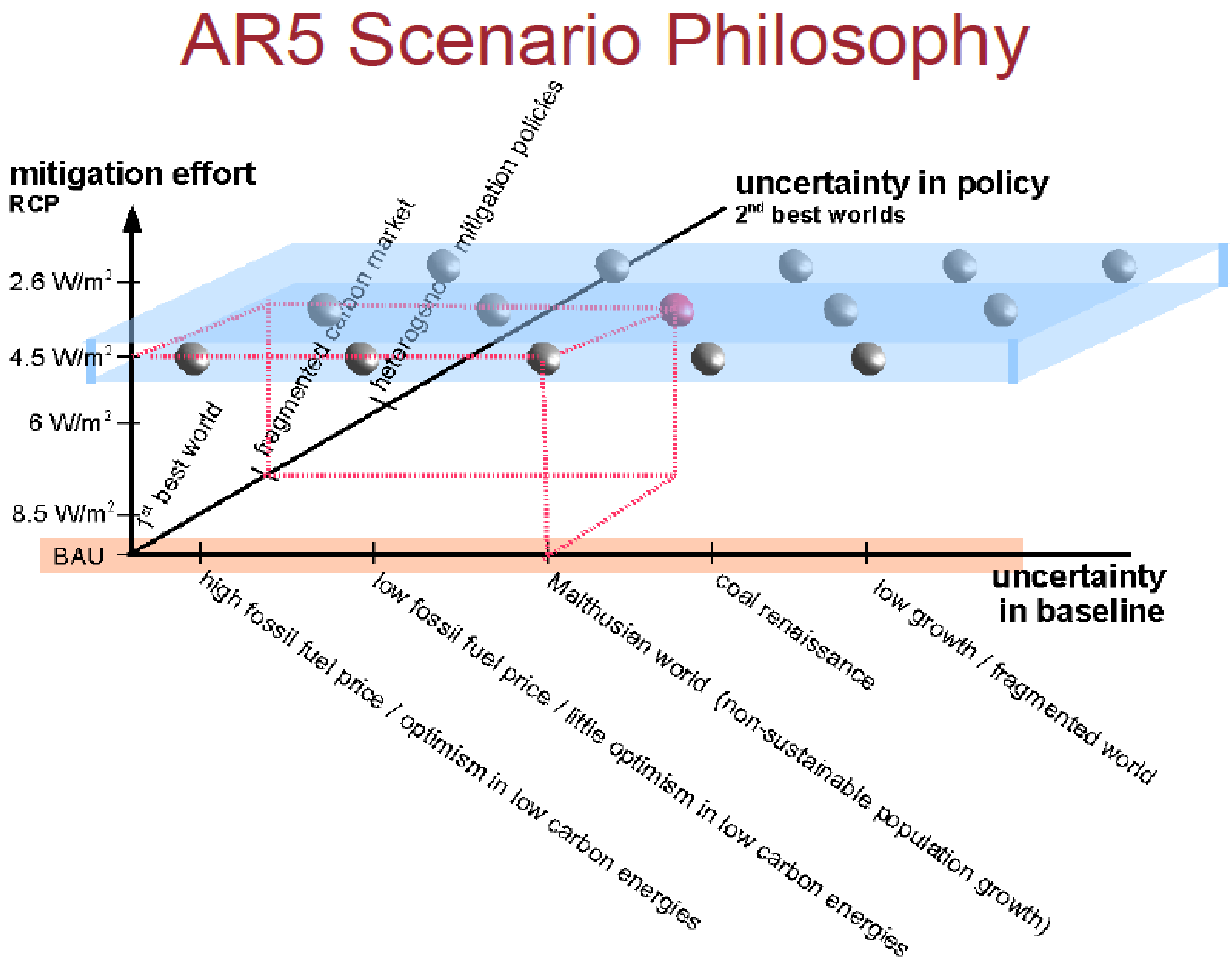
3. The research question

- The 4 Representative Concentration Pathway (RCP) scenarios explore the radiative forcing dimension.
- Each RCP scenario is an internally consistent starting point, covering all the most relevant aspects related to emissions scenarios.

How to explore the effect of other dimensions on the time development of radiative forcing?

What follows outlines ways to produce interesting exploratory and policy scenarios with the ETSAP-TIAM model out of the almost infinite possible variants.

3a. What dimensions have to be explored?



3.1 – Uncontrollable variables, exogenous events

Unknown variables, such as future development of

1. Population, and urbanization
2. GDP and sectoral added values
3. Economic convergence – divergence
4. Globalization or trade conflicts,
5. Etc.

will be explored with the ETSAP-TIAM model with the traditional approach.

Is it worth issuing guidelines? How to have the wider possible exploration with the minimum possible effort?

3.2 - Controllable variables: policies

The ETSAP-TIAM technical economic model can simulate many detailed and complex policies and measures:

1. based on technology selection, such as portfolio standards, emission intensity targets, sectoral climate agreements, micro-measures, etc.
2. other variants related more specifically to climate policy: incomplete coalitions, late entries, separate trading bubbles, contrasted allocations of permits, etc.
3. or security of supply and technological risk levels.

3.3 – Climate sensitivity: hedging strategies

1. Assuming that in 2030 or some other time in the future the science of climate assesses with precision the now uncertain value of climate sensitivity C_s
2. The ETSAP-TIAM model can be run stochastically till the time the uncertainty is resolved in 2030 and deterministically thereafter to the then determined value of C_s.
3. In principle the same can be repeated to treat other scientific parameters, which are now uncertain but have a precise value that will possibly be known some time in the future: technological sensitivities, resource base availabilty, etc.

3.4 – ETSAP TIAM improvement path:

Extend the time horizon to 2300

Endogenize the retroactions between climate change and:

1. Demand for energy services,
2. Availability of renewable energy resources,
3. Etc.

4.1 - Overview of TIAM (1/2)

- **Global multi-regional energy model**: 15 regions (+ OPEC/Non-OPEC) linked by trade of energy + emissions
- **Technology rich** (bottom-up)
- **Driven by 42 demands for energy services** (based on socio-economic patterns) in industry, residential, commercial, transport, agriculture. Eg. tons alu or iron&steel to produce, lighting, hot water, veh-km by car, by bus, etc.
- Service demands **elastic to their own price** ⇒ feedback effects between energy and the rest of the economy
- Computes a partial equilibrium on the entire energy system that **maximizes the total surplus** - via LP (GAMS)
- **CO_2, N_2O and CH_4** from all anthropic sources (energy-related, land, agriculture, and waste) + **exogenous radiative forcing** for the other gases and forcing factors
- **Climate module** included
- Time horizon **2005-2100**, 9 periods of different lengths, time-slices (eg. seasons, day/night) ⇒ load curves, peak

4.1 - Overview of TIAM (2/2)

- **Objective function**: NPV of all costs (capital, fixed and variable O&M, taxes, subsidies, welfare loss from reduced end-use demands, salvage value, etc.) → *output of the model*
- **Other typical outputs (by region, period, sector)**:
  - investments/capacity/operation of all technologies
  - flows of energy, materials, and emissions
  - marginal values (shadow price) of energy, of CO_2
  - imports/exports, extraction
  - demand reductions
  - other mitigation options (CH_4, N_2O)
- **Competitive markets with perfect foresight**
- But TIAM can also run in near-sighted mode (**time-stepped**) and with imperfect foresight (**stochastic mode**)

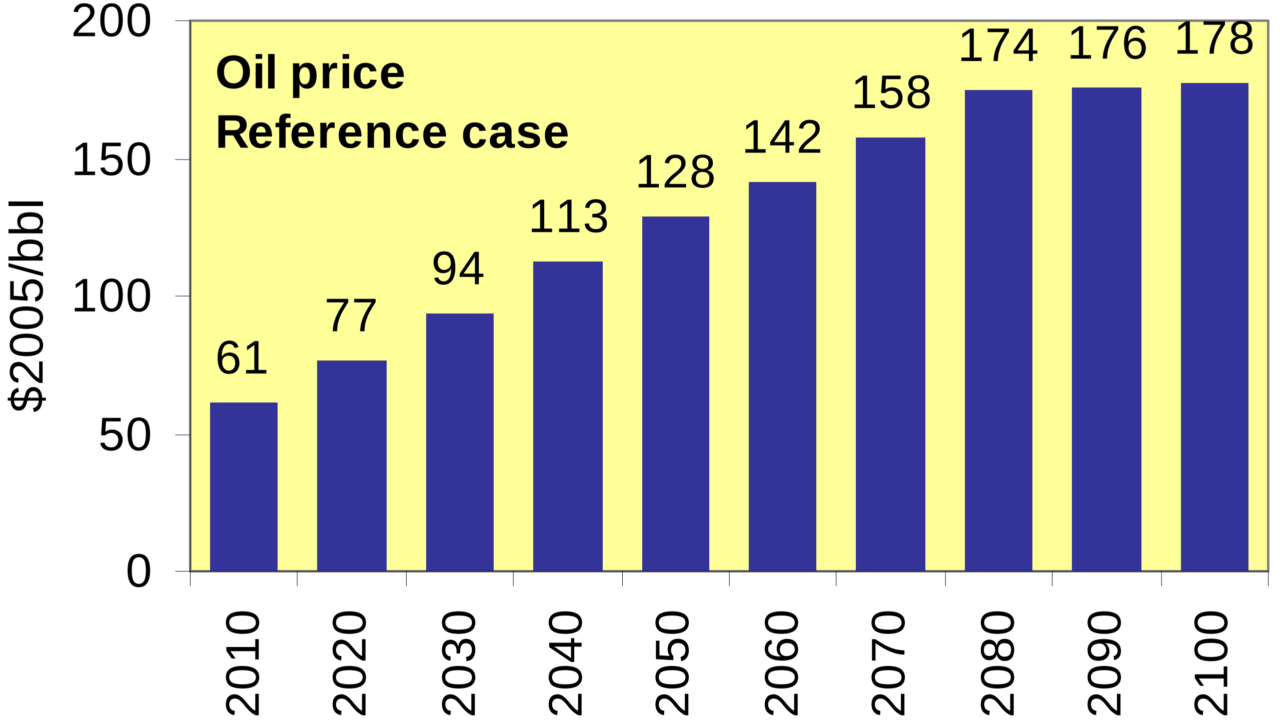
4.1 – Fossil fuels

- **Primary resources disaggregated by type**
  - proven/enhanced recovery/undiscovered reserves, conventional oil/gas, oil sands, oil shales, coalbed methane, associated gas, brown/hard coal etc.
  - technical annual extraction limits, fixed and variable costs
- **OPEC's quotas (market power)**: 80% of the production of the competitive equilibrium where OPEC is not a cartel
- **Endogenous price** of fossil resources and fuels
  Oil: 94$$_{2005}$/bbl in 2030, 128$$_{2005}$/bbl in 2050 in Reference
  Role of synthetic fuels?

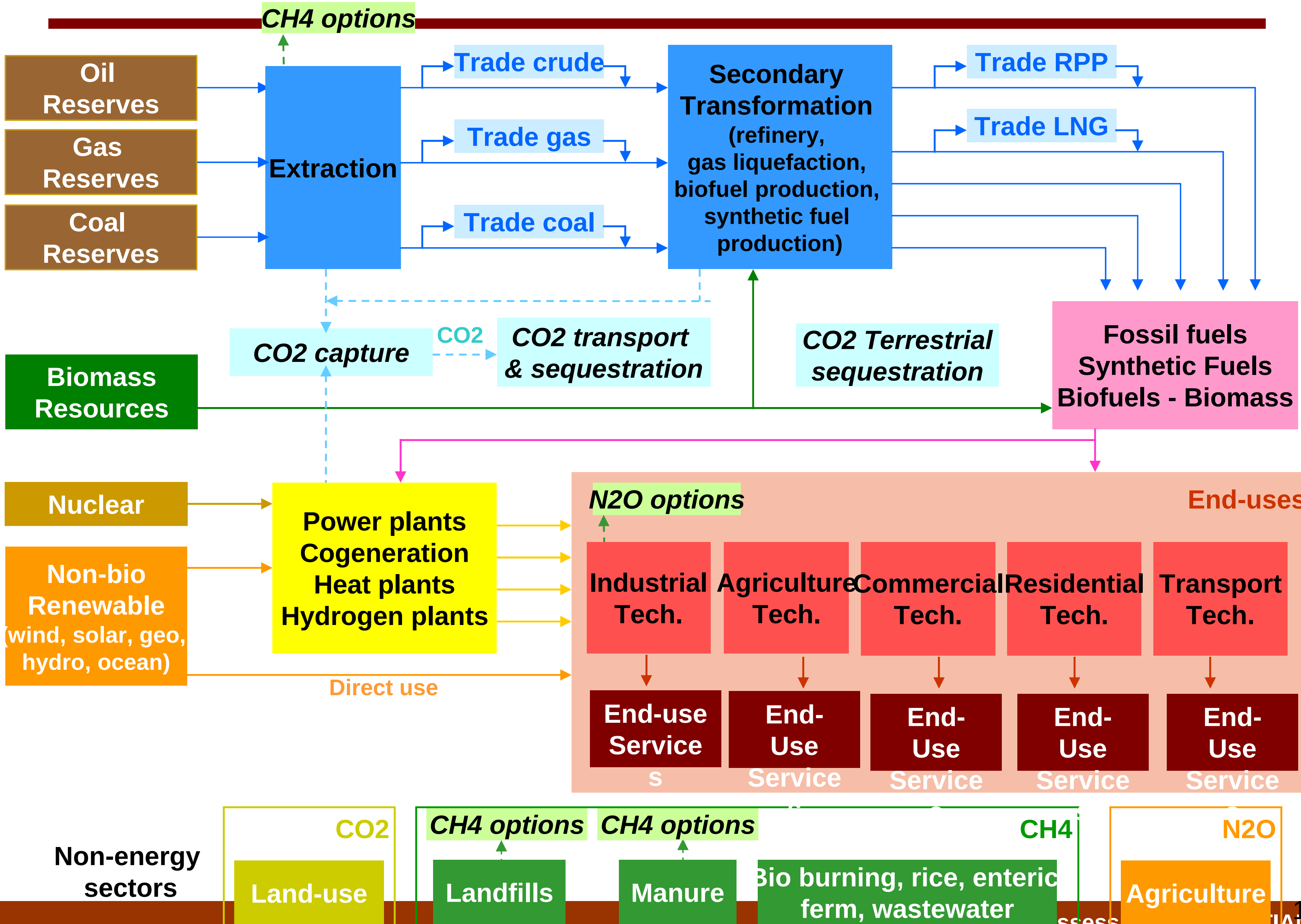
WORLD FOSSIL RESOURCES	TIAM	IPCC	USGS MEAN	USGS F95	USGS F50	USGS F5
TOTAL COAL (EJ)	119020	142351				
TOTAL OIL (EJ)	28262	35576				
Conventional	15783	13562	15281	9647	14008	21224
Unconventional	12480	22014				
TOTAL GAS (EJ)	38821	36020				
Conventional	17708	17179	14395	9001	13111	20258
Unconventional / Undiscovered	21123	18841				

TIAM: Reviewed by Remme *et al* (2007)

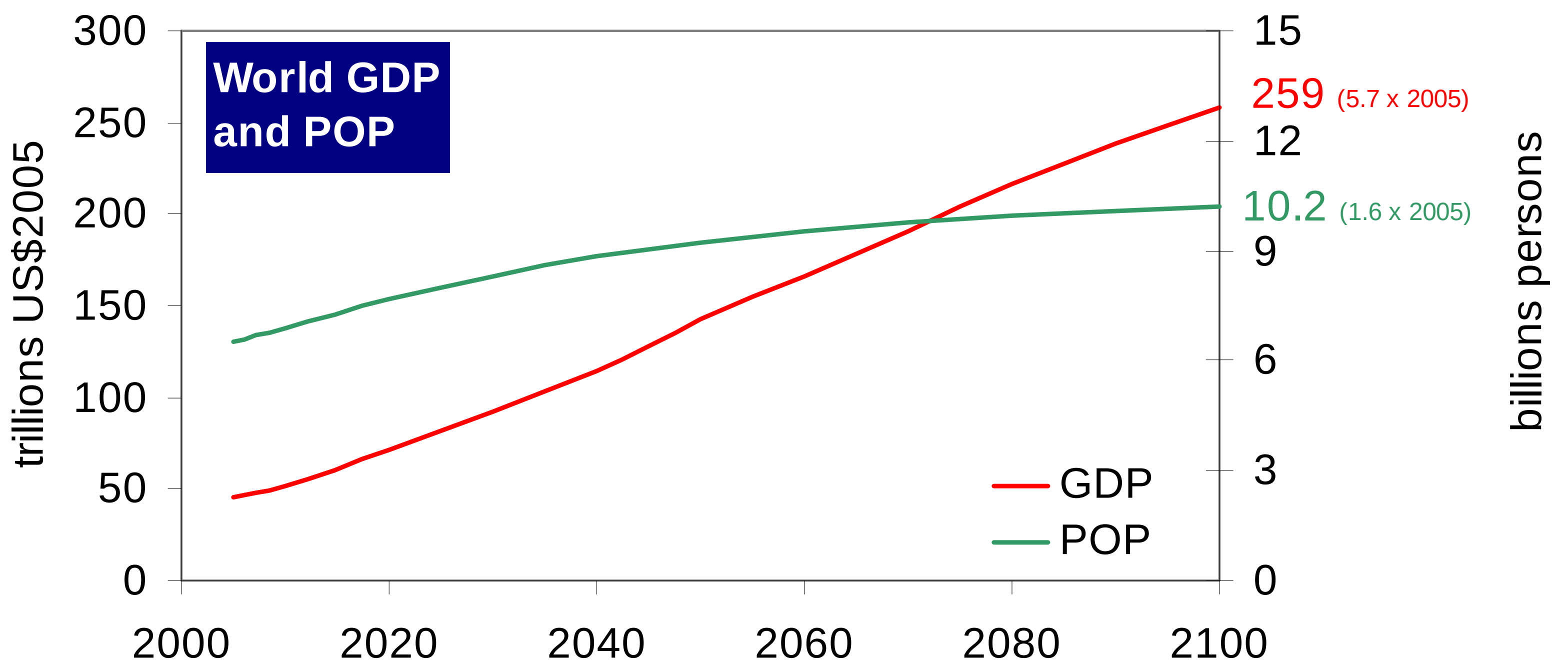
4.1 – International oil price



4.1 - TIAM: Reference Energy System



4.1 – Population and GDP projections



4.1 - Demands for energy services (1/2)

	Code	Unit
Transportation segments (15)		
Autos	TRT	Billion vehicle-km/year
Buses	TRB	Billion vehicle-km/year
Light trucks	TRL	Billion vehicle-km/year
Commercial trucks	TRC	Billion vehicle-km/year
Medium trucks	TRM	Billion vehicle-km/year
Heavy trucks	TRH	Billion vehicle-km/year
Two wheelers	TRW	Billion vehicle-km/year
Three wheelers	TRE	Billion vehicle-km/year
International aviation	TAI	PJ/year
Domestic aviation	TAD	PJ/year
Freight rail transportation	TTF	PJ/year
Passengers rail transportation	TTP	PJ/year
Internal navigation	TWD	PJ/year
International navigation (bunkers)	TWI	PJ/year
Non-energy uses in transport	NEU	PJ/year
Residential segments (11)*		
Space heating	RH1, RH2, RH3, RH4	PJ/year
Space cooling	RC1, RC2, RC3, RC4	PJ/year
Hot water heating	RWH	PJ/year
Lighting	RL1, RL2, RL3, RL4	PJ/year
Cooking	RK1, RK2, RK3, RK4	PJ/year
Refrigerators and freezers	RRF	PJ/year
Cloth washers	RCW	PJ/year
Cloth dryers	RCD	PJ/year
Dish washers	RDW	PJ/year
Miscellaneous electric energy	REA	PJ/year
Other energy uses	ROT	PJ/year

4.1 - Demands for energy services (2/2)

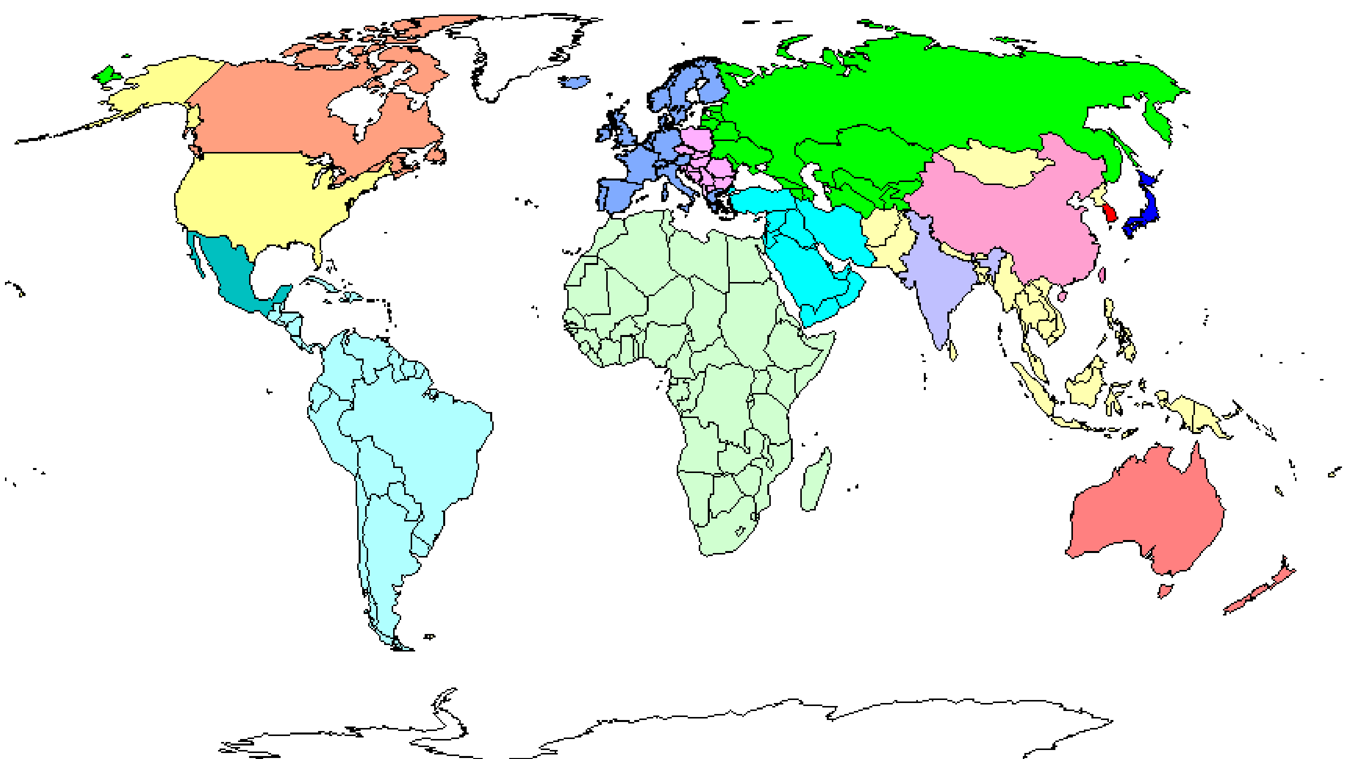
Commercial segments (8)*		
Space heating	CH1, CH2. CH3, CH4	PJ/year
Space cooling	CC1, CC2. CC3. CC4	PJ/year
Hot water heating	CHW	PJ/year
Lighting	CLA	PJ/year
Cooking	CCK	PJ/year
Refrigerators and freezers	CRF	PJ/year
Electric equipments	COE	PJ/year
Other energy uses	COT	PJ/year
Agriculture segment (1)		
Agriculture	AGR	
*Industrial segments** (6)*		
Iron and steel	IIS	Millions tonnes
Non ferrous metals	INF	Millions tonnes
Chemicals	ICH	PJ
Pulp and paper	ILP	Millions tonnes
Non metal minerals	INM	PJ
Other industries	IOI	PJ
Other segment (1)		
Other non specified energy consumption	ONO	PJ/year

* RLi, RCi, RLi, RKi, CHi, CCi represent the demands for sub-regions available in some regions (e.g., USA, CAN)
** Industrial energy services are made up of a “recipe” of more detailed services: steam, process heat, machine drive, electrolytic service, other, and feedstock

4.1 - Regions of TIAM (15 regions)

Africa*
Australia-New Zealand
Canada
Central and South America*
China
Eastern Europe
Former Soviet Union
India
Japan
Mexico
Middle-East*
Other Developing Asia*
South Korea
United States
Western Europe

* *OPEC and Non-OPEC countries are separated in primary and secondary sectors*
⇒ appropriate modelling of oil production strategies and oil price control by OPEC countries



4.1 - Regions of TIAM (16 regions)

Africa*
Australia-New Zealand
Canada
Central Asia and Caucase
Central and South America*
China
Europe (EU30)
India
Japan
Mexico
Middle-East*
Other Developing Asia*
Other Eastern Europe
Russian Federation
South Korea
United States

* *OPEC and Non-OPEC countries are separated in primary and secondary sectors*
⇒ appropriate modelling of oil production strategies and oil price control by OPEC countries

Code	Name	Countries
AFR	Africa	Algeria, Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia, Zimbabwe, and Other Africa*.
AUS	Australia, New-Zealand, Oceanía	Australia, New-Zealand, Oceanía
CAC	CentralAsia&Caucase	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Armenia, Azerbaidjian, Georgia
CAN	Canada	Canada
CHI	China	China
CSA	Central & South America	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and Other Latin America.
IND	India	India
JPN	Japan	Japan

Code	Name	Countries
MEA	Middle East	Bahrain, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen, and Turkey, Cyprus.
MEX	Mexico	Mexico
ODA	Other Developing Asia	Bangladesh, Brunei Darussalam, Cambodia, Chinese Taipei, Indonesia, DPR of Korea, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam and Other Asia**
OEE	Other EastEurope	Belarus, Moldova, Ukraine Albania, Bosnia-Herzegovina, Croatia, Macedonia, Montenegro, Serbia (Kosovo)
RUS	Russia	Russia
SKO	South Korea	South Korea
USA	USA	USA
EUR	Europe 27+	Austria, Belgium, Bulgaria, Cyprus, Switzerland, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia, United Kingdom

4.2 – Projects where the model is used

1. EMF-22; http://www.stanford.edu/group/EMF/
2. REACCESS, EC, FP7, 2008-2010; http://reaccess.epu.ntua.gr/
3. PLANETS, EC, FP7, 2008-2010; http://www.feem-project.net/planets/
4. TOCSIN, EC, FP6, 2007-2009; http://tocsin.epfl.ch/
5. GICC I (2007-2008) and II (2009-2010), French Ministry of Ecology and Sustainable Development
6. European Fusion Development Agreement. 2003-2004

4.3 – References, TIAM

TIAM

- www.etsap.doc/documentation
- www.kanors.com/TIAM
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- Loulou R. 2008. ETSAP-TIAM: the TIMES integrated assessment model Part II: Mathematical formulation, *Computational Management Science*, Vol. 5 (1–2), 41-66.
- Loulou R. and M. Labriet.2008. ETSAP-TIAM: the TIMES integrated assessment model Part I: Model structure, *Computational Management Science*, Vol. 5 (1–2), 7-40.

4.3 – References, Data sources (1/3)

Data

- **Transversal sources**: Experts, IEA reports, IPCC reports, World Energy Council
- **POP**: UN Population Projections, Mediant variant, http://esa.un.org/unpp.
- **GDP and industrial growths**: macro-economic model GEMINI-E3 (http://gemini-e3.epfl.ch) coupled with TIAM + EU PLANETS project
- **Base year**: 2005 Energy Statistics of the IEA
- **Non-energy CO2, CH4 and N2O emissions**:
  - CH4 from landfills, manure, rice paddies, enteric fermentation, wastewater, based on the EMF-22 data;
  - N2O from agriculture, based on the EMF-22 data;
  - CO2 from land-use, based on the Reference scenario of the United States Climate Change Science Program (Prinn *et al.*, 2008)
- **CH4 and N2O abatement options**: Energy Modelling Forum, EMF-21 group (http://emf.stanford.edu/research/emf21/)
- **Forestation and avoided deforestation**: Sathaye *et al*. (2005) and adopted by the Energy Modelling Forum, EMF-21 and 22 groups
- **Climate equations**: Nordhaus and Boyer (1999) + CH4 and N2O atmospheric cycles (Monni et al., 2003; Manne and Richels, 2004)

4.3 – References, Data sources (2/3)

Specific references

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- Monni, S., Korhonen, R. & Savolainen, I. 2003. Radiative Forcing Due to Anthropogenic Greenhouse Gas Emissions from Finland: Methods for Estimating Forcing of a Country or an Activity. Environmental Management, vol 31, No. 3, p. 401–411.
- Nordhaus W. D. and J. Boyer (1999). *Roll the DICE Again: Economic Models of Global Warming*. Yale University, manuscript edition.

4.3 – References, Data sources (3/3)

Specific references (cont'd)

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- Remme U., M. Blesl, U. Fahl, (2007). *Global resources and energy trade: An overview for coal, natural gas, oil and uranium.* IER, Stuttgart, 101 p.. http://elib.unistuttgart.de/opus/volltexte/2007/3252/
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- Smeets E., Faaij A. and Lewandowski I. (2004). A Quickscan of global bio-energy potentials to 2050. An analysis of the regional availability of biomass resources for export in relation to the underlying factors. Report NWS-E-2004-109.