Policy Analyses Tools for Global Sustainability

IEA Energy Technology Systems Analysis Programme

Annex XII 2011-2013

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NEET Workshop on Integrate Approaches to Energy Technologies
Beijing, 27 November 2012

Overview of Presentation

A. Introduction to IEA-ETSAP

B. Policy Analyses Tools for Global Sustainability

C. Selected Outputs (focus on China)

D. Conclusions

A – Introduction to ETSAP

1. Program
2. Objectives
3. Strategy
4. Tasks - Annexes
5. Participants

A1 – The Energy Technology Systems Analysis Programme…

… is a multilateral **international** agreement, promoted and sponsored by the International Energy Agency (Paris).

This **cooperation** started after the first oil crisis, in order to understand through **systems analysis**, whether:

- alternatives to oil were technically feasible, economically and environmentally sustainable;
- solutions were global or dependent on national circumstances;
- global energy RD&D paths were possible or advantageous.

After two years of analyses (1976-77), since the tools available at the time were not sufficient to provide answers, the group developed a new tool, the **MARKAL** model generator.

A2 – Objectives

ETSAP experts assist decision-makers in assessing policies intended to meet the challenges of

- energy needs,
- **technological** progress,
- environmental concerns, and
- economic development,

… by carrying out

- **co-operative** energy technology systems analysis, and
- modelling possible future **energy pathway** developments.

A3 – Strategy

The objectives are achieved through a twofold strategy:

1. ETSAP has established, and now maintains / enhances the flexibility of consistent multi-country energy / engineering / 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. In fact they implement several economic-equilibrium technology-explicit models of **global, regional, national, and local systems.**

A4 – Tasks (Annexes)

XII	**2011-13**	**Policy Analyses Tools for Global Sustainability**
XI	2008-11	JOint STudies for New & Mitigated Energy Systems
X	2005-07	Global Energy Systems and Common Analyses
IX	2003-05	Energy Models User's Group
VIII	2002-05	Exploring Energy Technology Perspectives
VII	1999-01	Contributing to the KYOTO Protocol
VI	1996-98	Dealing with uncertainty together
V	1993-95	Energy options for sustainable development
IV	1990-92	Greenhouse gases and national energy options
III	1987-89	International forum on energy environment studies
II	1984-86	Information exchange project
I	1981-83	Energy technology systems analysis programme
	1978-80	MARKAL Model generator development (BNL, KFA)
	1976-77	Analysis of existing tools for evaluating R&D strategies

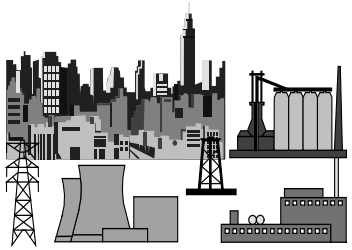
A5 – Participants - Annex XII

Country	CP/Institution	Country	CP/Institution
Belgium	FPP/ VITO-KUL	**Japan**	
Canada	NRCan/GERAD	**Korea**	KEMCO
Denmark	DEA/Risoe	**Netherlands**	ECN
EC	DGRTD/JRC (IET,IPTS)	**Norway**	IFE
Finland	TEKES/VTT	**Russia**	ERI-RAS
France	DGEMPEDAD/ADEME-EDMP	**Spain**	CIEMAT
Germany	IER	**Sweden**	STEM/Chalmers
Greece	CRES	**Switzerland**	PSI
Ireland	SEAI/UCC	**UK**	DECC/AEAT
Italy	CNR-IMAA / ENEA	**US**	DOE/BNL

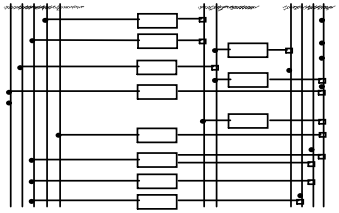
B – Policy Analyses Tools For Global Sustainability

1. MARKAL / TIMES Tools
2. Energy Technology Data Source (ETechDS)
3. ETSAP-TIAM Model
4. Workshops and training

B1 Reality and energy systems modelling



Reality



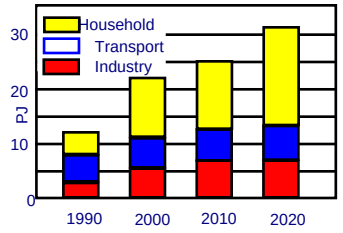
Model structure

$$P_{BHKW\_S} = \eta_{BHKW} \cdot P_{Coal\_BHKW}$$
$$O_{BHKW\_CO_2} = \varepsilon \cdot P_{Coal\_BHKW}$$
$$Q_{BHKW\_H} = \eta_{2\_BHKW} \cdot P_{Coal\_BHKW}$$

Mathematical description

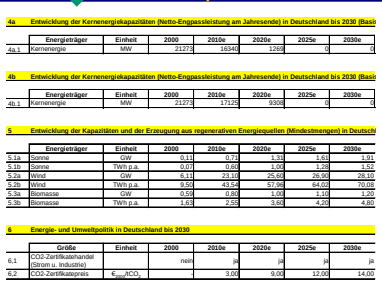
Cross-checking results with reality.

Feedback



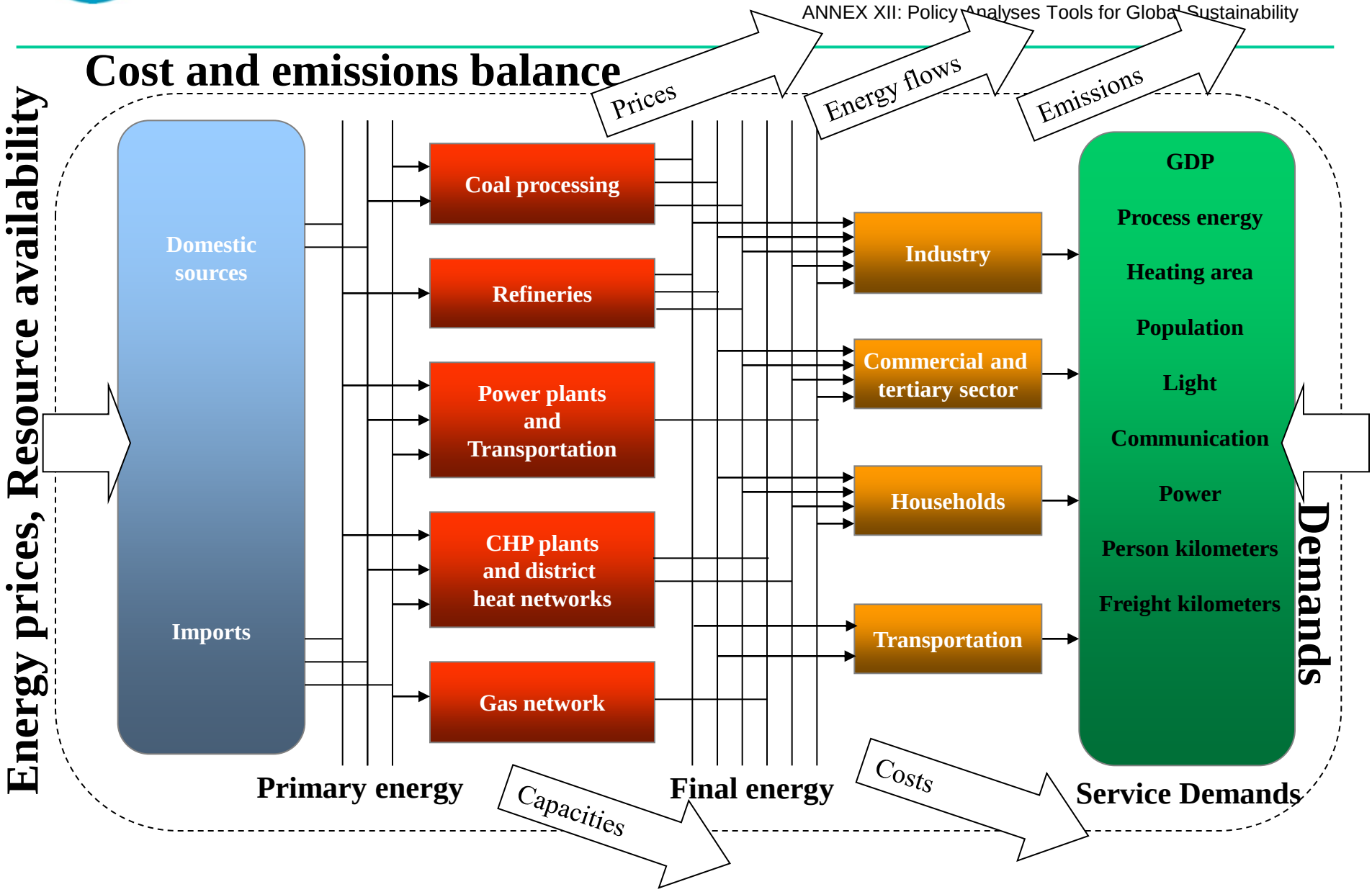
Model results

Optimiser (CPLEX/MINOS/CONOPT/XPRESS/etc.)

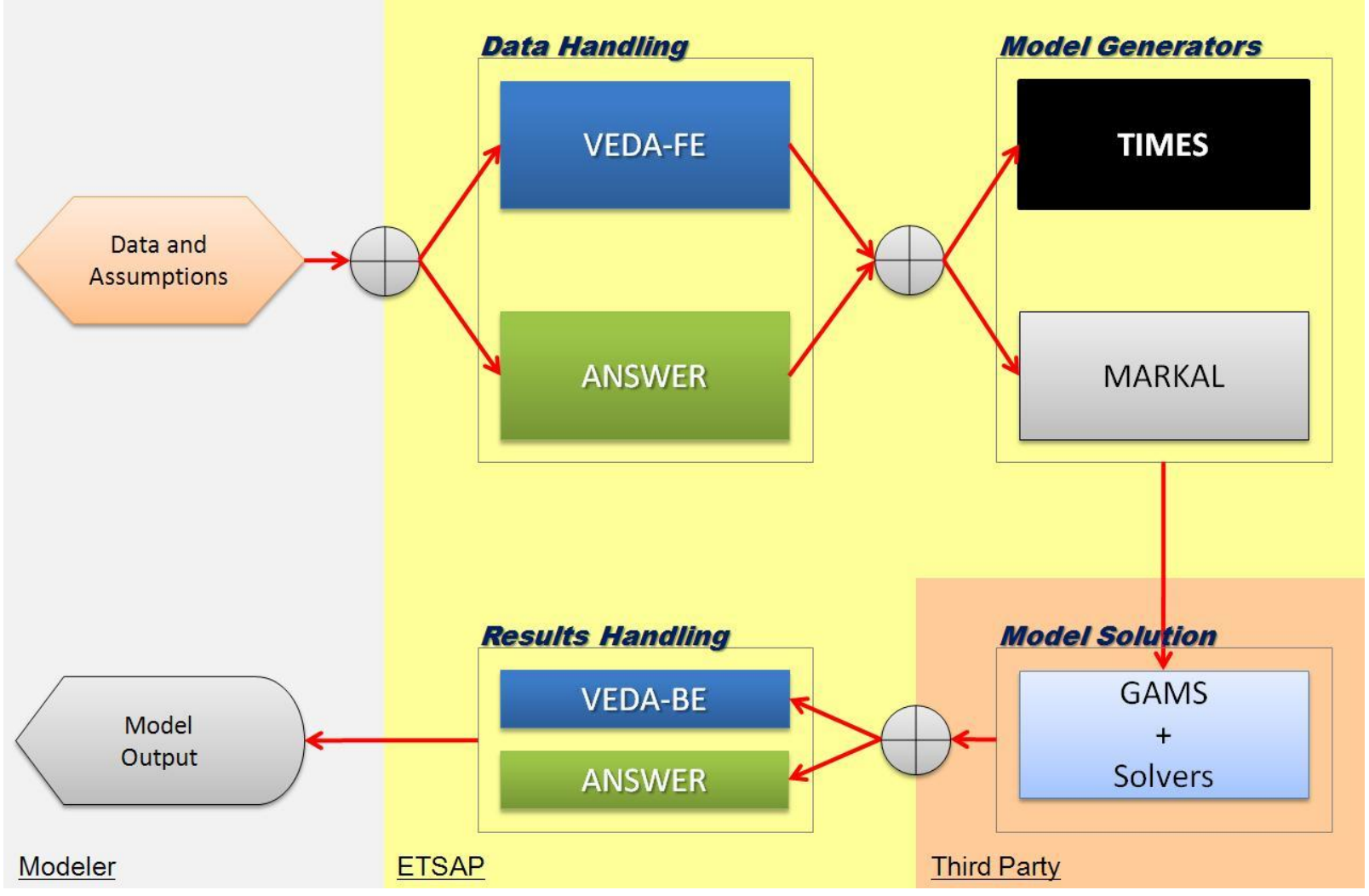


Data

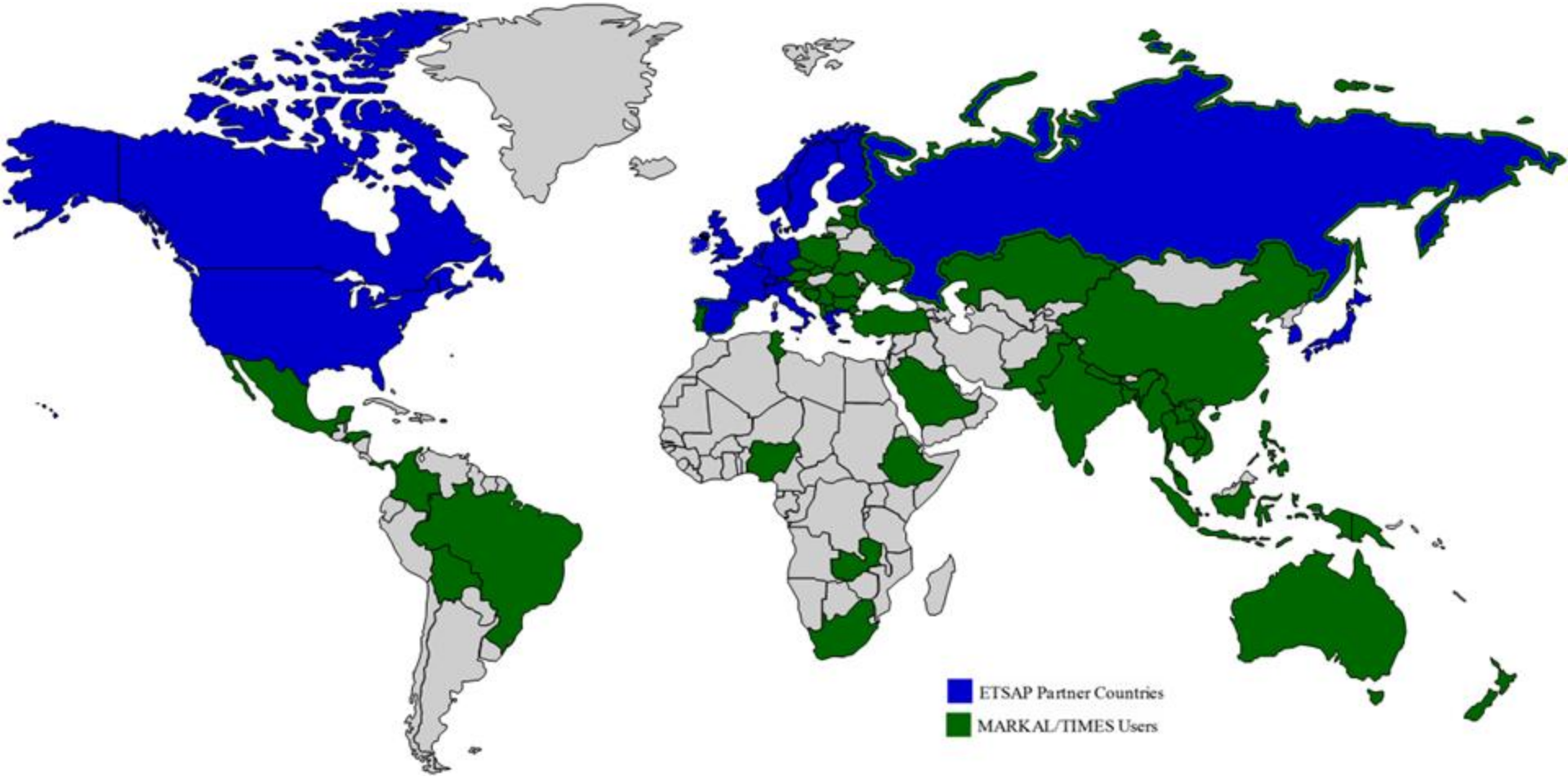
Cost and emissions balance



B1 – Building a MARKAL or TIMES Model



B1 – MARKAL–TIMES licensed tools users (>200)



Only those countries with at least one MARKAL/TIMES modelling team active during the period are "painted."

B2. Energy Technology Data Source

- **Exhaustive** in scope, internally consistent, well documented data source, with a planned maintenance and updating programme.
- ETech-DS is a commented **energy technology database** building on the basic idea of the IEA Energy Technology Essentials
  - ✓ Concise **profiles** on today's energy technologies for producing, transporting and using energy;
  - ✓ **Updated** information and key data on status, performance, emissions, costs, markets, potential and barriers;
  - ✓ **Insights** for decision-taking

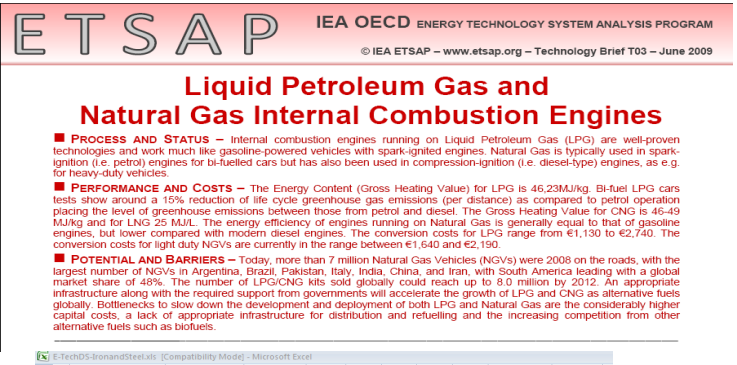
Since September 2011, ETASP E-TechDS is working in cooperation with the **International Renewable Energy Agency (IRENA)** to develop and update Briefs on renewable energy technologies.

Available on line at: **http://www.iea-etsap.org/web/E-TechDS/Technology.asp**

B2. Energy Technology Data Source

Three sections in each brief

1. Summary for Policymakers



ETSAP IEA OECD ENERGY TECHNOLOGY SYSTEM ANALYSIS PROGRAM

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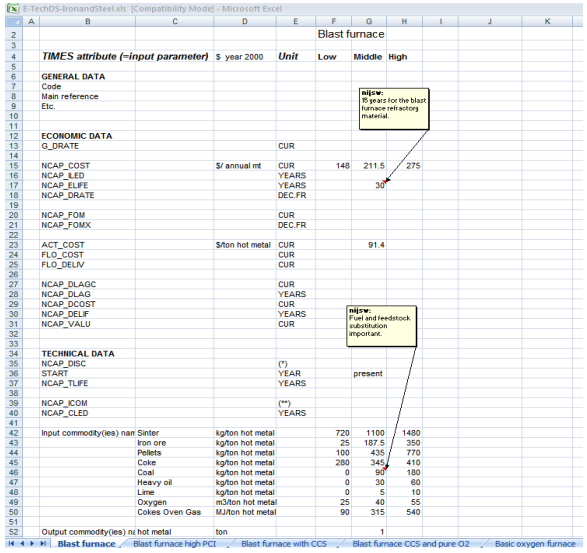
Liquid Petroleum Gas and Natural Gas Internal Combustion Engines

■ **Process and Status –** Internal combustion engines running on Liquid Petroleum Gas (LPG) are well-proven technologies and work much like gasoline-powered vehicles with spark-ignited engines. Natural Gas is typically used in spark-ignition (i.e. petrol) engines for bi-fuelled cars but has also been used in compression-ignition (i.e. diesel-type) engines, as e.g. for heavy-duty vehicles.

■ **Performance and Costs –** The Energy Content (Gross Heating Value) for LPG is 46,23MJ/kg. Bi-fuel LPG cars tests show around a 15% reduction of life cycle greenhouse gas emissions (per distance) as compared to petrol operation placing the level of greenhouse emissions between those from petrol and diesel. The Gross Heating Value for CNG is 46-49 MJ/kg and for LNG 25 MJ/L. The energy efficiency of engines running on Natural Gas is generally equal to that of gasoline engines, but lower compared with modern diesel engines. The conversion costs for LPG range from €1,130 to €2,740. The conversion costs for light duty NGVs are currently in the range between €1,640 and €2,190.

■ **Potential and Barriers –** Today, more than 7 million Natural Gas Vehicles (NGVs) were 2008 on the roads, with the largest number of NGVs in Argentina, Brazil, Pakistan, Italy, India, China, and Iran, with South America leading with a global market share of 48%. The number of LPG/CNG kits sold globally could reach up to 8.0 million by 2012. An appropriate infrastructure along with the required support from governments will accelerate the growth of LPG and CNG as alternative fuels globally. Bottlenecks to slow down the development and deployment of both LPG and Natural Gas are the considerably higher capital costs, a lack of appropriate infrastructure for distribution and refuelling and the increasing competition from other alternative fuels such as biofuels.



E-TechDS-IronandSteel.xls [Compatibility Mode] - Microsoft Excel

Blast furnace

TIMES attribute (=input parameter)	$ year 2000	Unit	Low	Middle	High
GENERAL DATA					
Code					
Main reference					
Etc.					
ECONOMIC DATA					
G_DRATE		CUR			
NCAP_COST	$/ annual mt	CUR	148	211.5	275
NCAP_ILED		YEARS			
NCAP_ELIFE		YEARS		30	
NCAP_DRATE		DEC.FR			
NCAP_FOM		CUR			
NCAP_FOMX		DEC.FR			
ACT_COST	$/ton hot metal	CUR		91.4	
FLO_COST		CUR			
FLO_DELIV		CUR			
NCAP_DLAGC		CUR			
NCAP_DLAG		YEARS			
NCAP_DCOST		CUR			
NCAP_DELIF		YEARS			
NCAP_VALU		CUR			
TECHNICAL DATA					
NCAP_DISC		(*)			
START		YEAR		present	
NCAP_TLIFE		YEARS			
NCAP_ICOM		(**)			
NCAP_CLED		YEARS			
Input commodity(ies) nam	Sinter	kg/ton hot metal	720	1100	1480
	Iron ore	kg/ton hot metal	25	187.5	350
	Pellets	kg/ton hot metal	100	435	770
	Coke	kg/ton hot metal	280	345	410
	Coal	kg/ton hot metal	0	90	180
	Heavy oil	kg/ton hot metal	0	30	60
	Lime	kg/ton hot metal	0	5	10
	Oxygen	m3/ton hot metal	25	40	55
	Cokes Oven Gas	MJ/ton hot metal	90	315	540
Output commodity(ies) na	hot metal	ton		1	

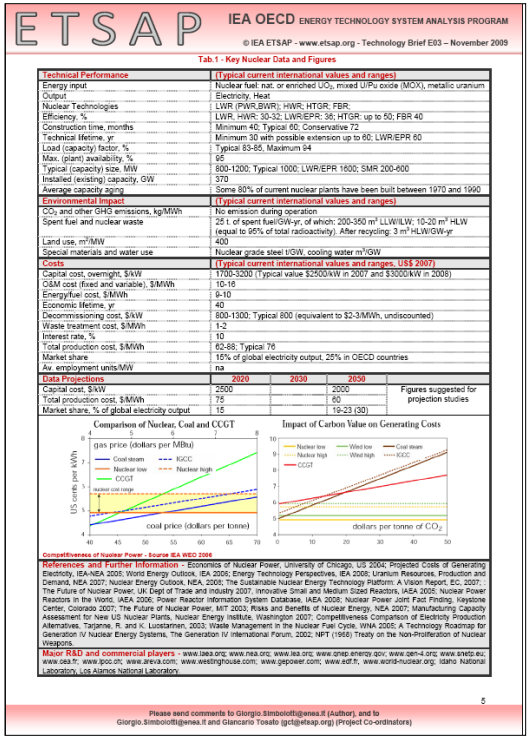
nijsw: 15 years for the blast furnace refractory material.

nijsw: Fuel and feedstock substitution important.

Blast furnace | Blast furnace high PCI | Blast furnace with CCS | Blast furnace CCS and pure O2 | Basic oxygen furnace

2. Technical Section

- Process and technology status,
- Technical & environmental performance, costs and projections,
- Potential (incl. market status & prospects) and Barriers, plus …
- Summary Table & References



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Tab.1 - Key Nuclear Data and Figures

Technical Performance	(Typical current international values and ranges)
Energy input	Nuclear fuel: nat. or enriched UO_2, mixed U/Pu oxide (MOX), metallic uranium
Output	Electricity, Heat
Nuclear Technologies	LWR (PWR,BWR); HWR; HTGR; FBR;
Efficiency, %	LWR, HWR: 30-32; LWR/EPR: 36; HTGR: up to 50; FBR 40
Construction time, months	Minimum 40; Typical 60; Conservative 72.
Technical lifetime, yr	Minimum 30 with possible extension up to 60; LWR/EPR 60
Load (capacity) factor, %	Typical 83-85, Maximum 94
Max. (plant) availability, %	95
Typical (capacity) size, MW	800-1200; Typical 1000; LWR/EPR 1600; SMR 200-600
Installed (existing) capacity, GW	370
Average capacity aging	Some 80% of current nuclear plants have been built between 1970 and 1990
Environmental Impact	**(Typical current international values and ranges)**
CO_2 and other GHG emissions, kg/MWh	No emission during operation
Spent fuel and nuclear waste	25 t of spent fuel/GW-yr, of which: 200-350 m^3 LLW/ILW; 10-20 m^3 HLW (equal to 95% of total radioactivity). After recycling: 3 m^3 HLW/GW-yr
Land use, m^2/MW	400
Special materials and water use	Nuclear grade steel t/GW, cooling water m^3/GW
Costs	**(Typical current international values and ranges, US$ 2007)**
Capital cost, overnight, $/kW	1700-3200 (Typical value $2500/kW in 2007 and $3000/kW in 2008)
O&M cost (fixed and variable), $/MWh	10-16
Energy/fuel cost, $/MWh	9-10
Economic lifetime, yr	40
Decommissioning cost, $/kW	800-1300; Typical 800 (equivalent to $2-3/MWh, undiscounted)
Waste treatment cost, $/MWh	1-2
Interest rate, %	10
Total production cost, $/MWh	62-88; Typical 76
Market share	16% of global electricity output, 25% in OECD countries
Av. employment units/MW	na

Data Projections	2020	2030	2050	
Capital cost, $/kW	2500		2000	Figures suggested for projection studies
Total production cost, $/MWh	75		60	
Market share, % of global electricity output	15		19-23 (30)	

Comparison of Nuclear, Coal and CCGT

Impact of Carbon Value on Generating Costs

Competitiveness of Nuclear Power - Source IEA WEO 2006

References and Further Information - Economics of Nuclear Power, University of Chicago, US 2004; Projected Costs of Generating Electricity, IEA-NEA 2005; World Energy Outlook, IEA 2006; Energy Technology Perspectives, IEA 2008; Uranium Resources, Production and Demand, NEA 2007; Nuclear Energy Outlook, NEA, 2008; The Sustainable Nuclear Energy Technology Platform: A Vision Report, EC, 2007; The Future of Nuclear Power, UK Dept of Trade and industry 2007; Innovative Small and Medium Sized Reactors, IAEA 2005; Nuclear Power Reactors in the World, IAEA 2006; Power Reactor Information System Database, IAEA 2006; Nuclear Power Joint Fact Finding, Keystone Center, Colorado 2007; The Future of Nuclear Power, MIT 2003; Risks and Benefits of Nuclear Energy, NEA 2007; Manufacturing Capacity Assessment for New US Nuclear Plants, Nuclear Energy Institute, Washington 2007; Competitiveness Comparison of Electricity Production Alternatives, Tarjanne, R. and K. Luostarinen, 2003; Waste Management in the Nuclear Fuel Cycle, WNA 2005; A Technology Roadmap for Generation IV Nuclear Energy Systems, The Generation IV International Forum, 2002; NPT (1968) Treaty on the Non-Proliferation of Nuclear Weapons.

Major R&D and commercial players - www.iaea.org; www.nea.org; www.iea.org; www.gnep.energy.gov; www.gen-4.org; www.snetp.eu; www.oea.fr; www.ipoc.ch; www.areva.com; www.westinghouse.com; www.gepower.com; www.ecf.fr; www.world-nuclear.org; Idaho National Laboratory, Los Alamos National Laboratory.

5

Please send comments to Giorgio.Simbolotti@enea.it (Author), and to Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org) (Project Co-ordinators)

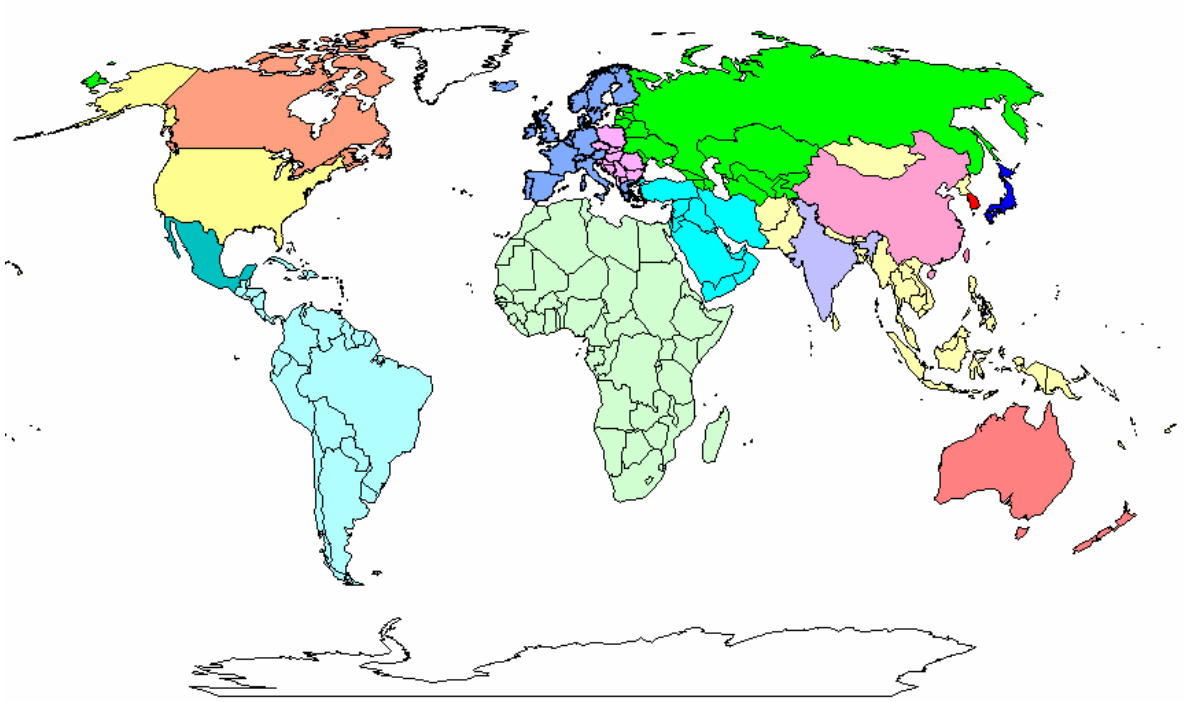
3. Excel Spreadsheets for Modellers

B2. Energy Technology Data Source

Total Brief Number	80
Posted	50
In preparation (commissioned)	17
To be commissioned	13 (Authors identified for 10 briefs)

E-TechDS STATUS - May 21, 2012 - Energy Supply Technologies			
	PRIMARY ENERGY SUPPLY, TRANSPORTATION AND DISTRIBUTION		
P01	Conv. Oil and Gas Production	May 2010	IFE-Norway
P02	Unconv. Oil and Gas Production	May 2010	IFE- Norway
P03	Oil and Gas Logistics	August 2011	IFE- Norway
P04	Oil refineries	Dec. 2012, to be assagned	Gerad Canada, K. Vaillancourt
P05	Syngas from Coal (coal gasific.)	May 2010	IER-Germany
P06	Liquid Fuels from Coal and Gas	May 2010	IER- Germany
P07	Coal Mining and Logistics	Dec. 2012, to be assagned	ETSAP GS?
P08	H2 Production & Distribution	March 2012	CRES –Greece
P09	Biomass Production & Logistics	June 2012, to be assagned	Maryse Labriet
P10	Biofuels Production	January 2012	ETSAP GS
P11	Biogas Production	Sept 2012, to be assagned	Maryse Labriet
P12	Biogas Production for Transportation	Sept 2012	IRENA
	TRANSPORTATION		
T01	Adv. Autom. Gasoline Eng.	April 2010	AEA – UK
T02	Adv. Autom. Diesel Eng.	April 2010	AEA – UK
T03	Autom. LPG and Nat. Gas Eng.	April 2010	AEA – UK
T04	Hybrid Vehicles	June 2010	AEA – UK
T05	Electric & Plug-in Hybrid Vehicles	June 2010	AEA – UK
T06	Ethanol IC engines	June 2010	AEA – UK
T07	Hydrogen and Fuel Cell Vehicles	Under Revision	AEA – UK
T08	Light Trucks	January 2011	AEA – UK
T09	Heavy Trucks	January 2011	AEA – UK
T10	Public Transport	January 2011	AEA – UK
T11	Rail Transport	January 2011	AEA – UK
T12	Aviation Transport	January 2011	AEA – UK
T13	Shipping Transport	January 2011	AEA – UK
T14	Road Transport Infrastructures	August 2011	AEA – UK
T15	Rail Infrastructures	June 2011	AEA – UK
T16	Aviation Infrastructures	August 2011	AEA – UK
T17	Shipping Infrastructures	June 2011	AEA – UK
T18	Weight & Drag Reduction (Autom.)	January 2011	AEA – UK
T19	Two-Three Wheelers	Sept. 2012, to be assagned	AEA – UK
	ELECTRICITY & HEAT PRODUCTION, TRASMISSION AND DISTRIBUTION		
E01	Coal Fired Power Plants	April 2010	ECN – Netherland
E02	Gas Fired Power Plants	April 2010	ECN– Netherland
E03	Nuclear Power	April 2010	ETSAP GS
E04	Combined Heat and Power (CHP)	May 2010	ECN– Netherland
E05	Biomass for Heat & Power	May 2010	ECN– Netherland
E06	Hydro Power	May 2010	ECN– Netherland
E07	Geothermal Power	May 2010	ECN– Netherland
E08	Marine Power	November 2010	ECN– Netherland
E09	Wind Energy	Sept. 2012	IRENA
E10	Concentrated Solar Power	March 2011	ETSAP GS
E11	Photovoltaic	February 2011	ETSAP GS
E12	Nuclear Fuel Mining to Waste Management	Dec 2012, to be assagned	ETSAP GS ?
E13	Fuel Cells	Dec 2012, to be assagned	Adam Hawkes, Imperial Col.
E14	CO_2 Capture & Storage	October 2010	ETSAP GS
E15	Renewable Energy Integration	March 2012	CRES –Greece
E16	District heating systems	March 2012	Chalmers -Sweden
E17	Energy Storage (Thermal)	January 2012	FZ-Bayern - Germany
E18	Energy Storage (Electric)	January 2012	ETSAP
E19	Heat Pumps	March 2012	JHPC – Japan
E20	Electricity Transmission & Distribution	Dec 2012, to be assagned	Gerad, Canada
E21	Biomass Co-firing	In preparation – March 2012	IRENA
E22	Marine Energy Wave Devices	In preparation – Sept 2012	IRENA
E23	Marine Energy Current Devices	In preparation – Sept 2012	IRENA
E24	Energy from Waste	In preparation – Sept 2012	IRENA

B3. ETSAP-TIAM (TIMES Integrated Assessment Model)



- Now global model (ETSAP-TIAM) available in addition to modelling tools (TIMES)
- 15 Region global TIMES model available to ETSAP Contracting Parties
- Developed by GERAD and currently updated by ESAP Collaborative Project
- Includes several thousand technologies and models climate forcing

B3. ETSAP-TIAM (TIMES Integrated Assessment Model)

- distributed to 10 ETSAP Contracting Parties
- on the web at: www.kanors.com/DCM/TIAM
- Several projects have used TIAM:
  - EMF-22, EMF-24 (Stanford, US)
  - Low Carbon Society (NIES, Japan, UK-ERC, …)
  - IPCC-IAMC, special report on Renewable Scenarios
  - IEA-RETD, Achieving Climate and Energy Security (ACES)
  - EC-FP7, REACCESS on Energy Corridors for EU
  - Asian Modelling Exercise
- Continuously improved

B4 – Workshops and training

- Two workshops per annum on energy systems modelling
- Joint organiser of IEW (International Energy Workshop)
- Deliver training courses for the ETSAP tools biannually.

C – Selected Outputs

1. IEA's Global Model (ETP)
2. Other Global TIAM Models
3. National Models

C – Recent Outputs

Annex XI Report > 350 publications 2008-2010 (86 peer-review articles, 7 Ph.D. theses, 9 books or book chapters and 120 research papers and reports) from:

i) **Global Models:** incl. IEA ETP model, original TIMES Integrated Assessment Model (TIAM), derived TIAM models, ETSAP-TIAM model

ii) **Regional Models**: Pan-European TIMES model, MARKAL-TIMES Models for Europe, Asia and North America.

iii) **National Models** of 32 countries (including China).

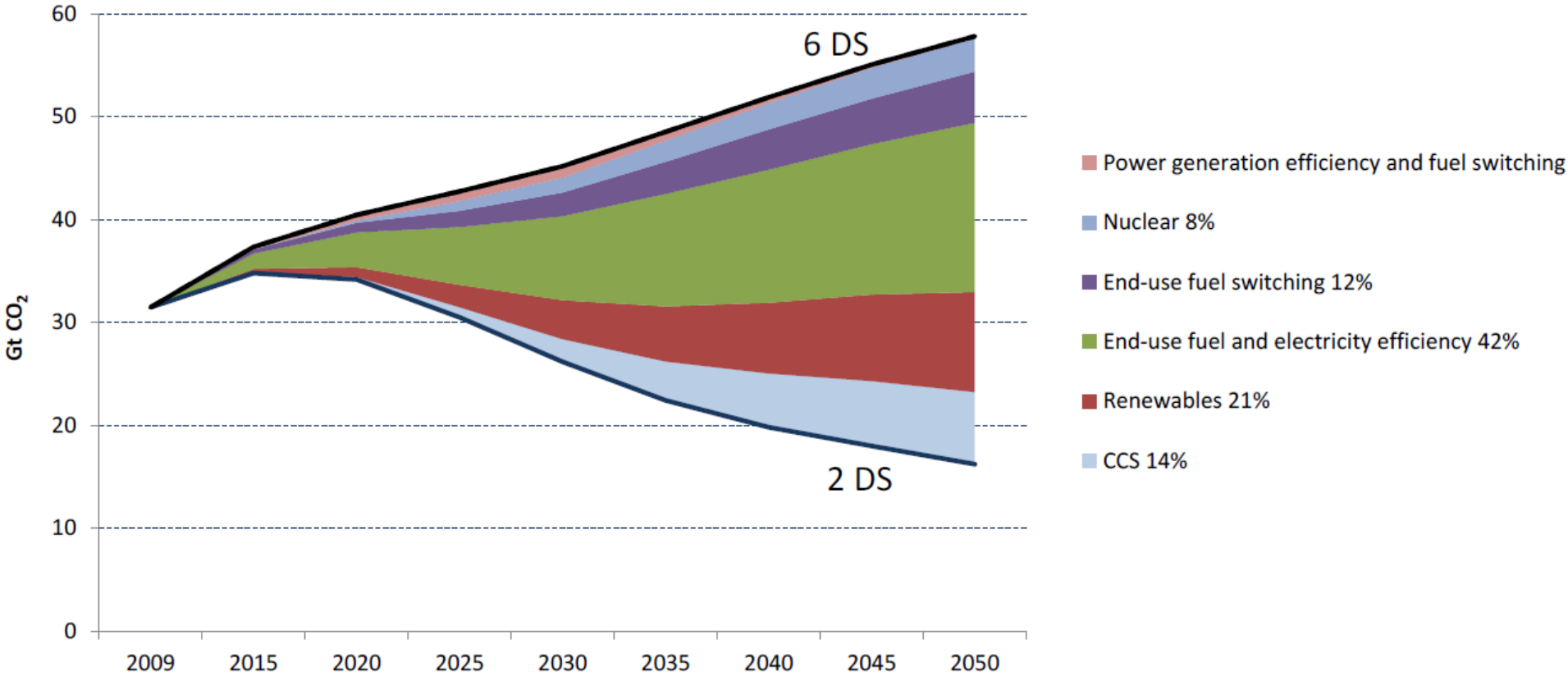
iv) **Sub-National Models:** Western China, Reunion Island (France), Lombardy (Italy), Pavia (Italy), and Kathmandu Valley (Nepal).

v) **Local Models** for rural areas and cities in Austria, Germany and Italy, other bigger cities such as Madrid (Spain), Beijing, Guangdong and Shanghai (China) and New York City (United States).

www.iea-etsap.org/web/FinReport/ETSAP-Annex-XI-final-report-final%20version-June-2012-v03.pdf

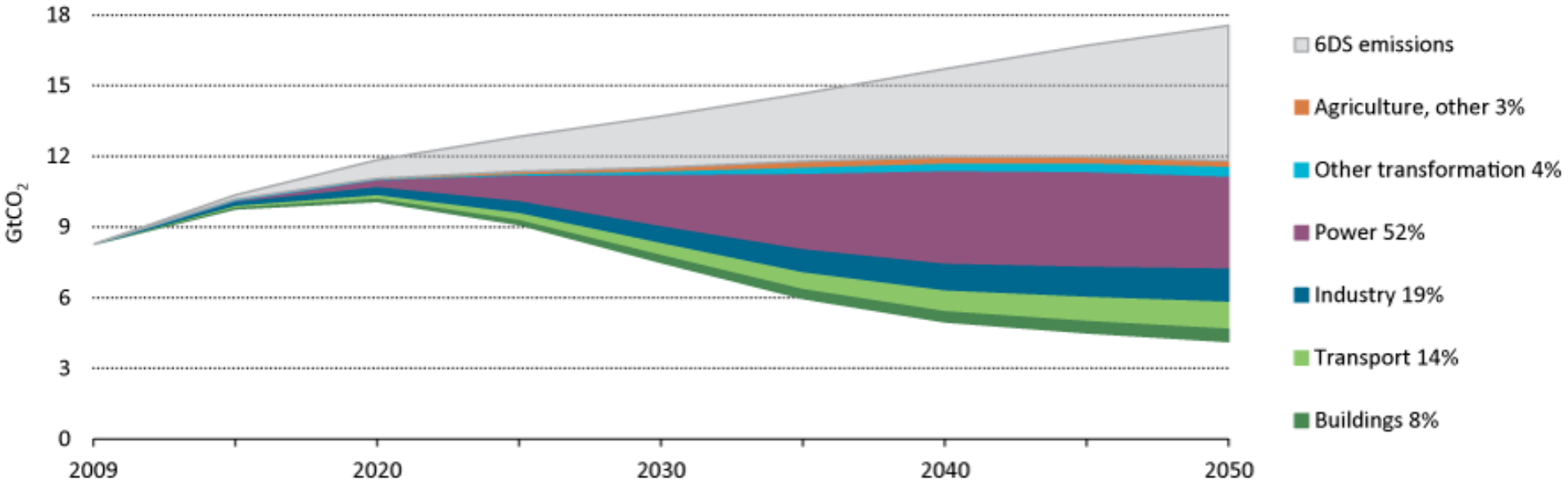
C1 – IEA Energy Technology Perspectives (ETP)

IEA ETP 2012 (www.iea.org/etp) uses the global multi-regional **ETP-TIMES** model.



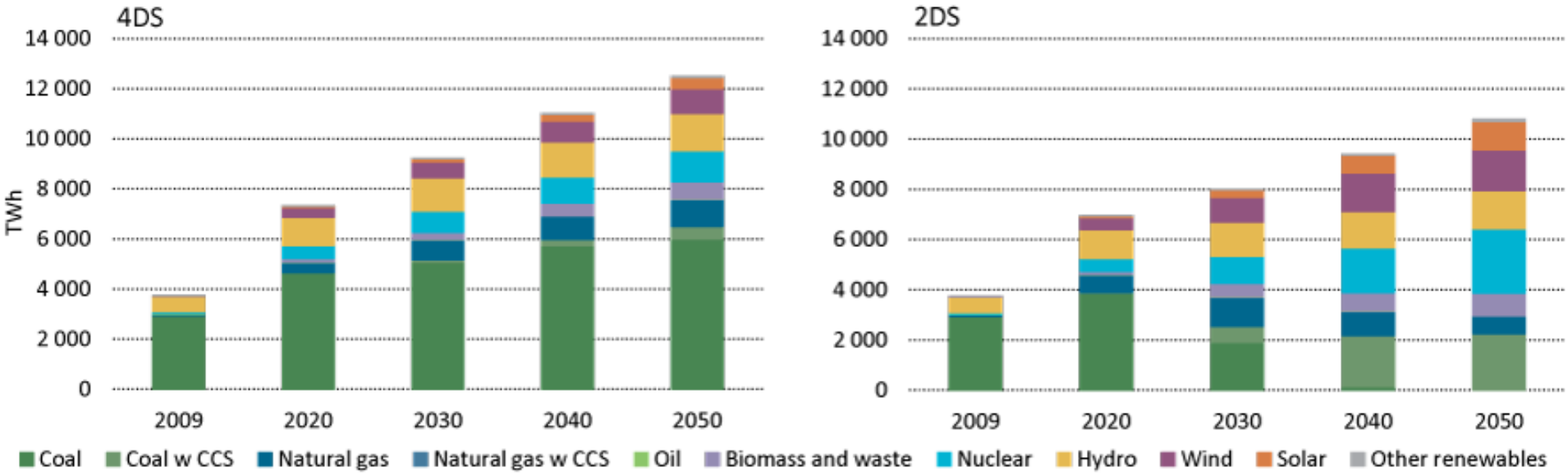
Key technologies for reducing CO_2 emissions under the 2°C scenario

C1 – ETP 2012 Results for China by sector



- Strong, sustained **actions** are needed to deliver ETP 2012 2ºC Scenario (2DS)
- These could **halve** China's projected emissions in 2050 relative to 2009 levels.
- The **power sector** provides half of the cumulative emissions reductions compared with the 4DS.
- If China succeeds in this it will provide a powerful **example** for the world.
- www.iea.org/publications/freepublications/publication/ETP_Executive_Sum_Chinese_WEB-1.pdf

C1 – ETP 2012 Power Results for China



- In 4DS, **coal** share **decreases** from almost 80% in 2009 to around **50%** in 2050 due to growth in natural gas, nuclear and renewables
- In 2DS, **CO_2** emissions in the power sector are reduced by more than **80%** in 2050 compared with 2009
- **RE** share in 2050 increases from ~30% in the 4DS to **~50%** in the 2DS

C2 – TIAM WORLD Model Results for China

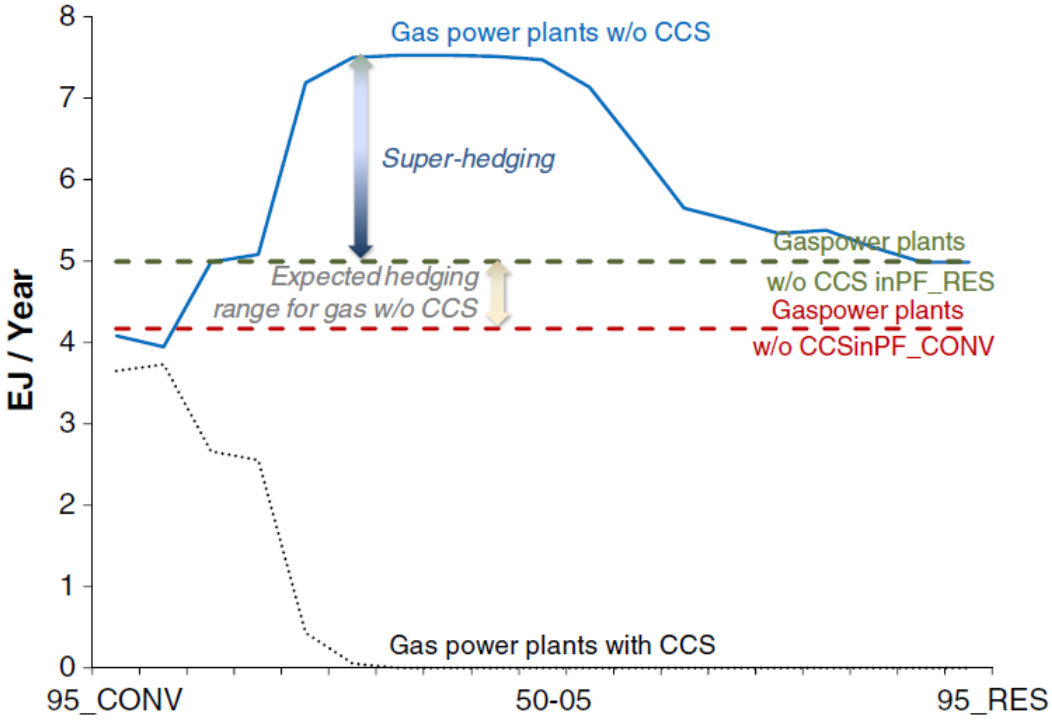


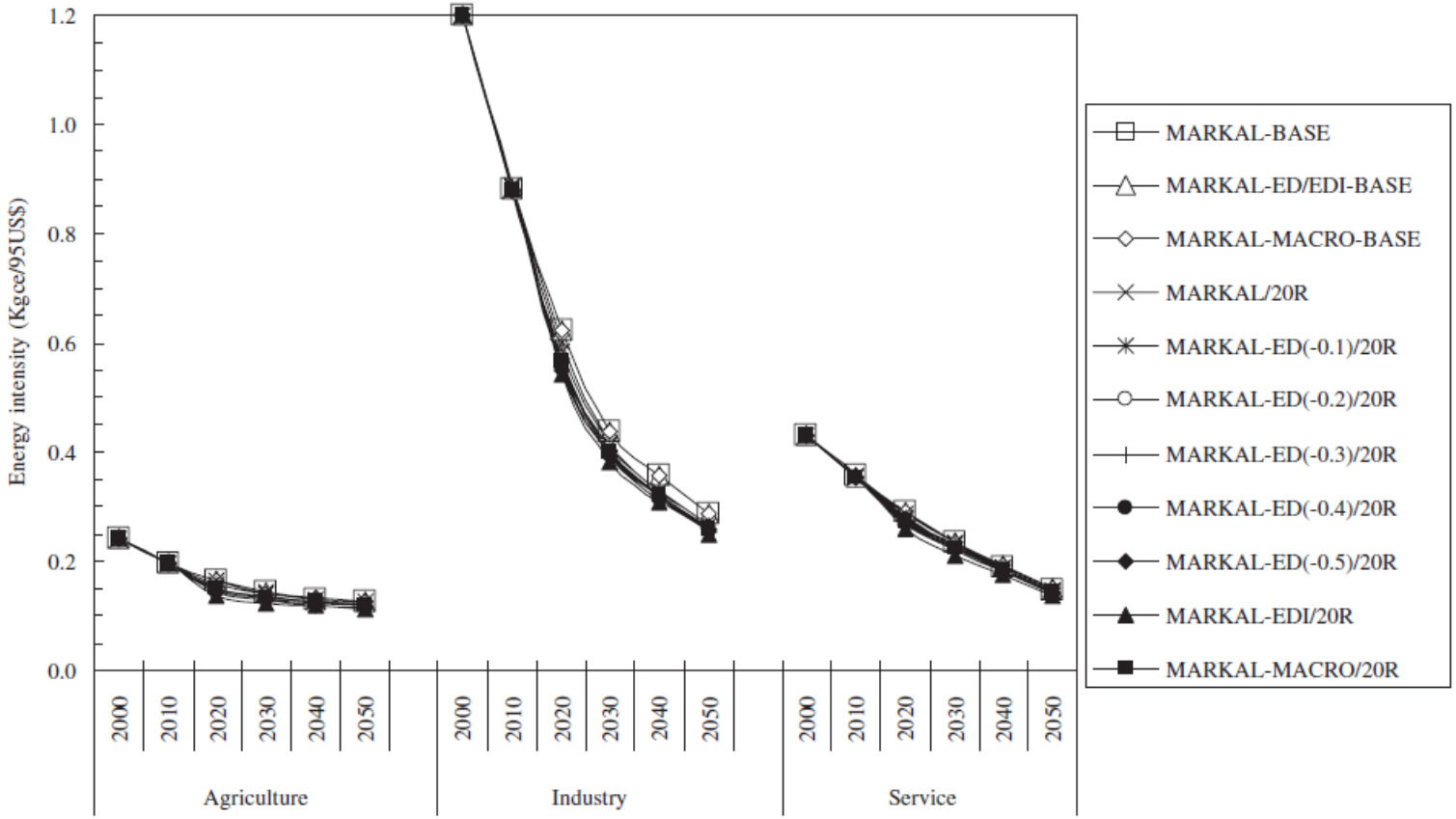
Figure 1 Role of Gas in elec gen in China in 2030 (in 3.7 W/m^2 ~ 550 ppm scenario)

- Stochastic programming with TIAM-WORLD used to explore long term technical and climate **uncertainty**.
- Explores two contrasting **technology outlooks** *RES* and *CONV*
- Use of **gas** in China 50% higher in **hedging** rather than perfect foresight scenarios

Maryse Labriet , Amit Kanudia , Richard Loulou 2012 *Climate mitigation under an uncertain technology future: A TIAM-World analysis* **Energy Economics** (In Press)

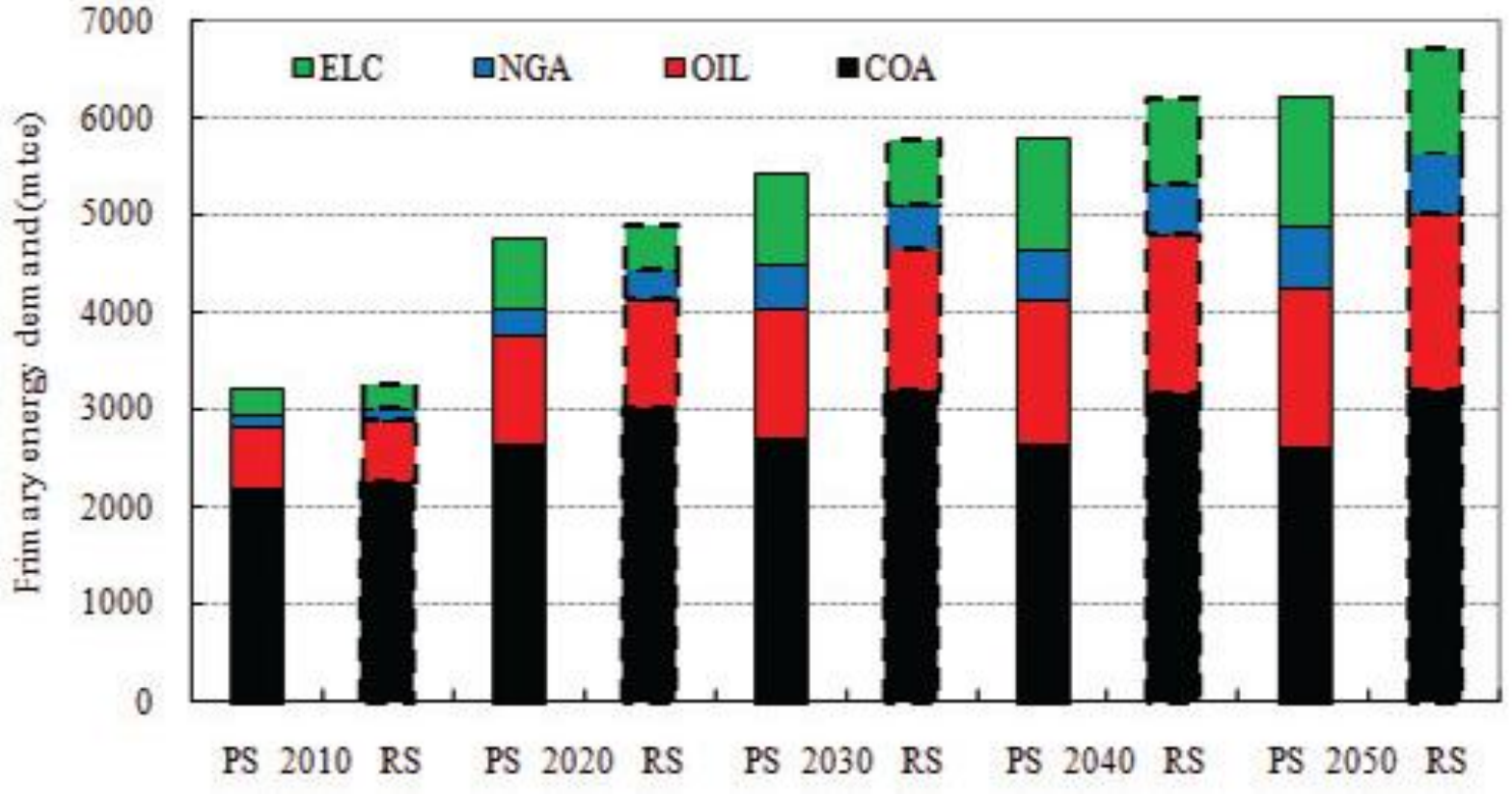
C3 – China MARKAL Model Results

Energy intensity improvements 2000 – 2050 for agriculture, industry, and service sectors from different **China MARKAL** model variants for emission reduction rate of 20% from 2020 Onwards.



Chen W. et al. 2007 *Carbon emission control strategies for China: A comparative study with partial and general equilibrium versions of the China MARKAL model* **Energy**, Vol 32, Pages 59-72

C3 – China TIMES Model Results



Primary Energy Requirement for China 2010 – 2050 for Reference (RS) and Policy (PS) Scenarios

Liu J., Chen W., Liu D, 2011 *Scenario analysis of China's future energy demand based on TIMES model system*, **Energy Procedia**, Vol 5 Pages 1803-1808

D – Conclusions

- ETSAP represents 36 years of collaborative effort
- Policy Analyses tools (TIMES, MARKAL, VEDA, ANSWER) used by over 200 users
- Tools inform national policy and international negotiation
- ETSAP-TIAM Model available to contracting parties
- Analyses inform key international policy decisions
- Considerable analysis undertaken on (and in China)
- Invitation remains open to China's to become Contracting Party
- Annex XIII work programme discussed at ETSAP 10 – 11 Dec Lisbon meeting
- For more information - www.etsap.org

Policy Analyses Tools for Global Sustainability

IEA Energy Technology Systems Analysis Programme

Annex XII 2011-2013

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