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ANNEX VIII EXPLORING ENERGY TECHNOLOGY PERSPECTIVES

Toward a Nash Equilibrium MARKAL?

Richard Loulou and Amit Kanudia have been exploring new approaches to MARKAL and TIMES for some time. They now are developing a game-theory approach to a regionalized global bottom-up model with Maryse Labriet.

An example of game theory is the classic Prisoner's Dilemma. Suppose you and a friend are arrested for robbery. You are put in separate cells. The police lack sufficient evidence to convict either of you, so they try to get one of you to testify against each other. The police tell you that if you testify against your friend, you will be released, provided your friend does not testify against you. He, on the other hand, will get 15 years in prison. If neither of you testifies, you will each get only four months in jail. Your friend has been given the same options. What would you do? Puzzles such as these are the work of theorists such as Nobel Prize winner John Nash, who is now well known from the cinema A Beautiful Mind based partly on his life.

Loulou, Kanudia and Labriet explore various equilibrium computations, including cooperative and non-cooperative (Nash) equilibriums to assess different approaches of greenhouse gas abatement in a regionalized, global bottom-up model. The objective function is to minimize the sum of abatement cost and damage cost. There are arguments as to the use of damage costs instead of emissions targets. In the case of a cooperative equilibrium, one could rely on using a concentration target, and then convert it to global emission constraints to be used in the MARKAL model.

Indeed, it is not yet clear whether the real international framework related to climate change will be closer to a cooperative or to a non-cooperative situation. Coupling damage and abatement costs into an integrated MARKAL model would then allow endogenous GHG concentration calculation and the computation of both cooperative and non-cooperative cases.In the case of a non-cooperative equilibrium, the concentration resulting from the players' actions are unknown, since each player (i.e., region) has only its own total cost as an objective. If global agreement on greenhouse gas reductions could not be agreed upon through negotiations, each country (or region) would then examine its own costs and benefits of abatement. But each country would also be likely to take into account the likely actions of other countries when making their decisions, since the latter depend on the emissions of all players. This leads to the Nash equilibrium.

In this case, each region, r, chooses emissions e_r, so as to minimize its total cost:

$$\text{Abatement cost}_r + \text{Damage cost}_r$$

where it is understood that damage cost depends on global emissions.

The causal chain begins with emissions, which are developed in MARKAL. The next step involves a climate model providing concentrations of greenhouse gases in the atmosphere and global temperature over time. Finally, economic damages are produced.

The climate model is based on Nordhaus' 1999 DICE/RICE-99 models. The approach uses a simplified "minimodel" to represent the basic dynamics of climate change (radiative forcing and two-reservoir model for temperature change).

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Visit ETSAP on the www: http://www.etsap.org

Information on ETSAP, its activities and members is also provided on the Internet. The home page contains the latest news, general information on ETSAP, and links to: ETSAP member; ETSAP 'outreach' activities; description of the MARKAL model and its users; archives of new item; selected publications and the ETSAP Newsletter.

Regional MARKAL groups organize

Regional groups have joined with ETSAP partners to take advantage of the MARKAL suite of models. These include the Association of South East Asian Nations (ASEAN),the Asia-Pacific Economic Cooperation (APEC) and outreach programs in Central America.

AAMRUG

The Association of South East Asian Nations (ASEAN) joined with Australia to form the ASEAN-Australia MARKAL Regional Users' Group (AAMRUG). ASEAN members are Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.

At a meeting in Jakarta, October, 2002, delegations came from Indonesia, Malaysia, Philippines, Thailand, and Vietnam, as well as Australian representatives. Mr. Hugh Bannister of Australia, Managing Director of Intelligent Energy Systems was elected as Chairman for this first meeting of AAMRUG.

The principal objectives of AAMRUG are to (1) identify potential areas for regional level cooperation on modeling and research;

(2) identify likely data transfer opportunities between the individual National Project Teams;

(3) discuss potential areas where the ASEAN and Australian host organization could assist the national research and training efforts;

(4) exchange technical information on the methods used and problems encountered in the analysis of particular energy issues; (5) discuss possible changes to project activities to be considered by the Contractor and the Project Coordinating Committee; and (6) identify any additional specific training and technical assistance needs.

This representation is highly simplified and is intended only to depict the broad features of climate change (Nordhaus). Still, given the uncertainties, it is not clear whether complicating the model with a more elaborate specification would produce more reliable results.

Damage functions based on RICE-99 are available on a regional and sector basis (agriculture, see-level, health, non-market, catastrophic impacts, etc.). Damage expressed as a GDP loss due to temperature increase is considered as quadratic.

Some caveats include the high degree of uncertainty on shape and parameters of the damage functions, the speed of temperature increase is not taken into account in damage calculation, and adaptation to climate change is not clearly separated from damage calculation. There is also a lack of feedback to MARKAL demands.

Two approaches were considered: a full representation and a simplified one. A full representation augments MARKAL with the complete set of climatic equations and damage functions. The drawbacks of that include creation of many additional non-MARKAL constraints, some of which are non-linear, non-convex. The simplification asks the basic questions: "What error is made in assuming that damages depend only on total cumulative emissions, irrespective of the shape of emission trajectory?" And "are damages a function of global cumulative emissions?"

To test this hypothesis, they chose 30 emission trajectories (21 from literature, 9 artificial). Some examples are:

- Emissions scenarios from IPCC ("SRES-Emissions scenarios"): A1-AIM, B1-IMAGE, A2-ASF, B2 MESSAGE;
- Stabilization Scenarios from IPCC ('Post-SRES"): IMAGE 350/450/650/750ppm, MARIA 550ppm, MERGE Stbz;
- Other scenarios: RICE 2001, EMI constant at 90 level;
- Fictitious emission trajectories: e.g., Constant emissions through time, increasing emissions.

The emissions trajectories range widely, from increasing to decreasing to increasing and then decreasing, illustrating the full range of possibilities. Yet the combined results of all the scenarios resulted in a linear plot of damage (trillion$ in 2100) vs. cumulative emissions (GtC in 2100). Although the value was different, the same linear form was produced on the 2050 horizon. The conclusion appear to be that: a) damages can be considered as independent of emissions trajectory on the time horizon considered; b) linear damages related to cumulative emissions are a good approximation in view of the uncertainties. The reason the authors give is that late emissions have less time to be absorbed by ocean layers, but have also less time to provoke damages. The analysis was done for global damages as well as for damages in each of the 15 regions of the model. The linearity property was verified for the regional damage functions as well.

PART II: Computing abatement strategies with integrated model

Based on these results, cooperative and non-cooperative games can be much more easily solved via an augmented technico-economic optimization model as they are equivalent to local optimization problems where only the cumulative emissions of the local country is involved:

- In the non-cooperative case with GHG interdependency[1], each country minimizes its own abatement costs and residual damages by taking into account the world cumulative emissions (Nash equilibrium where cumulative emissions by other countries are representative of decision taken by the other countries); in other words, each country solves a local optimization problem. But given the linearity of damages, this is equivalent to a case where each country decides its non-cooperative strategy by considering only the part of its damages due to its own emissions.

- In the cooperative case with GHG interdependency, countries together minimize the world abatement costs and residual damages of climate change. Given linear damages, this is equivalent to a case where each country takes into account only its own contribution to the damage incurred by all countries.

Consequently, the integrated MARKAL model includes damage function for each of the 15 regions of the world model. Climate modeling and damage calculation are in fact "hidden" in these damage parameters, and any change in the climate and damage assumptions (eg.: climate sensitivity, discount rate, GDP projections and time horizon for damage calculation, etc.) will be reflected in new damage parameters (sensitivity analysis).

First results show that Nash equilibrium is better for all regions (total system cost, including damage, of each region is reduced compared to business-as-usual), but that USA, China, Australia-NZ, Eastern Europe and Former Soviet Union loose from cooperation. Reallocation of the gain from global cooperation (side-payments) will have to compensate these regions.

Resulting temperature increase in 2050 is 1.54 C (BAU), 1.38 C (cooperation), 1.53 C (Nash). Atmospheric concentration in 2050 is: 490 ppm (BAU), 439 ppm (cooperation), 485 ppm (Nash). Technology choices behind the results rely on coal decline (electricity production), increase of renewable energy and reduction of demands (elastic demands).

References

- Labriet M. and R. Loulou, 2003. *Coupling climate damages and GHG abatement costs in a linear programming framework*. Environmental Modeling and Assessment, Special Issue on "Modeling the economic response to global climate change". To appear.
- Nordhaus, W. D. and J. Boyer, 1999. *Roll the DICE Again: Economic Models of Global Warming* Yale University, manuscript edition.

Notes

[1] The approach assumes that climate impact (due to global GHG emissions) is the only interdependency between countries; in other words, it assumes that international trade is not significantly affected by emission reductions.

Two Approaches to Long Term, Low Carbon Options

Two studies looking at long term, low carbon futures take different routes. Both extrapolate to 2050. The UK analysis used MARKAL, while the German study used TIMES. In addition, the UK study a range of possible futures, assuming the global development of new technologies, practices and fuels. The analysis therefore provides a view of what the UK might be able to achieve in a world in which other countries are also making substantial reductions in CO_2 emissions. The German analysis focused on renewables to achieve a low carbon future.

The UK Analysis

The UK study, using MARKAL, was described by Peter Taylor of AEA Technology. The study explored a range of possible scenarios, which all assumed the global development of low carbon technologies, practices and fuels. It further assumed that new technologies and fuels (such as CO_2 sequestration and hydrogen) would become available and that technologies with low deployment prospects in the UK would gain the benefits of volume of production if they had significant global potential. These results are not forecasts. They are an analysis of what technology can in principle deliver and what might be the costs and effects on emissions.

Three scenarios were studied: a baseline, in which current values of society remain unchanged and policy on environment continue as at present; a world market scenario with individual consumerist values, a high degree of globalization and scant regard for globalization or environment (WM); and a global sustainability scenario based on the predominance of social and ecological values, strong collective environmental action and globalization of governance

Regional MARKAL groups organize

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Regional energy policy topics include the Trans-ASEAN gas pipeline, rural "energization"/renewable energy markets, energy market liberalization, cost-effective energy efficiency and conservation, energy security in case of Asian crisis, greenhouse gas abatement, and environmental standards.

The immediate goal for all countries was to have the national databases at a satisfactory standard to be workable by the end of November 2002. Following that, regional policy studies should be initiated in February 2003.

MARKAL Outreach Programs in Central America

Organized by John Lee, this program aims to build the region's analytical capability in energy planning and greenhouse gas emission mitigation, explore the market potential of efficient and renewable energy technologies in the region, and to identify and evaluate cost-effective projects in carbon emission reduction under flexible mechanisms. The sponsors are the US Agency for International Development (AID), the US Department of Energy (DOE), US Environmental Protection Agency and the Taiwan Environmental Protection Agency. Participating countries are Belize, Bolivia, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, and Puerto Rico. Environment ministries, universities, the Office of CDM projects, and other institutions are involved. In 2000, a conference for inter-governmental cooperation in model development was held in San Salvador, El Salvador. In 2001, a MARKAL training workshop was conducted at Brookhaven National Laboratory in New York. System-setup and database development workshops were held in El Salvador, Honduras, Panama, and Puerto Rico. A progress report and project review workshop was held in Panama City. In 2002 a second MARKAL model training workshop was held at Brookhaven and a conference for inter-governmental cooperation in model development and CDM projects was held in

Regional MARKAL groups organize

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San Juan, Puerto Rico. Planning was in progress for a database development workshop in Bolivia and system-setup and data base development workshops were being organized in Belize, Costa Rica, Guatemala, and Nicaragua. A project review and 2003 planning workshop in Panama City and Taipei, Taiwan.

Asia-Pacific Economic Cooperation (APEC)

Among the various models available to the Asia-Pacific Economic Cooperation (APEC) economies, the MARKAL model is used or is under development in no less than 15 of the 21 member economies. This puts MARKAL in a unique position of being able to serve as a common analytic platform for examining issues of interest to the APEC Economies.

The objective of this work was to enhance the energy-modeling capabilities in APEC Member Economies with respect to new and renewable energy technologies and to work with the participating member teams to perform case studies on the effects of different penetration rates of renewable technologies. The MARKAL modeling teams from Australia, China, Japan, and the United States agreed to participate in the study. The participants included Gary Goldstein, (coordinator), Decisionware (USA); Pat Delaquil, Clean Energy Commercialization (USA); Barry Naughten (Australian Bureau for Agriculture and resource Economics), Wenying Chen, Tsinghua University (China); Osamu Sato, Japan Atomic Energy Research Institute (Japan), and John Lee (Brookhaven National Laboratory (USA).

A generic database of renewable technology characterizations, derived from the most recent information available from the US Department of Energy, the National Renewable Energy Lab and the Princeton Energy Research Institute was developed that may be used in APEC as well as non-member countries.

system (GS). Each scenario was run at no carbon constraint and then constrained at reduction targets of 45%, 60% and 70%. Thus, a wide range of futures are considered.

Prices for oil, natural gas, and coal were "at the beach." These were developed in consultation with the Department of Trade and Industry and the Department for Environment, Food and Rural Affairs, taking into account the long run supply position.

Carbon emissions under all three scenarios cover years 2000 - 2050. The baseline scenario sees a 22% reduction, the WM scenario 11% and the GS scenario 33%. This equates to a fall in emissions intensity (carbon emissions per unit GDP) between 2.5% and 3.1% per year, compared to the average over 30 years of 2.9%/year. Use of natural gas has been increasing over 30 years at the expense of coal.

All sectors are involved in emissions reduction. Under the baseline scenario with a 60% reduction in total emissions, CO_2 from the domestic sector was reduced by 55% relative to 2000. Reductions from industry were 65%, from services 61%, and from transport 65%. These reductions come from a combination of switching to less carbon intensive fuels, reduced emissions from electricity generation and improvements in end-use energy efficiency. Without carbon emission constraints, conventional technologies and fossil fuels continue to dominate. Gas turbine combined cycle technology continues to grow under all scenarios. Existing coal and nuclear plants come to the end of their lifetime and are not replaced. The internal combustion engines remain, but with substantial. efficiency improvements. Industry achieves greater efficiency largely through automation. Building technology sees improvements in heating, lighting and better controls.

In order to achieve substantial reductions in carbon emissions from electricity generation, there is a significant increase in technologies with low or zero carbon emissions between 2030 and 2050 under all scenarios. By 2050 gas turbine combined cycle with CO_2 capture, biomass, and on-shore wind are important.

Carbon emissions fall under all the baseline scenarios because primary energy supply and final energy demand are either broadly flat or decline slightly over the period to 2050.

Primary energy intensity falls between 2.6 and 3.0 % per year, considerably faster than the historical average of 1.8 % per year over the last 30 years, due to the uptake of more efficient technologies in both the demand and supply sectors. The conversion efficiency (ratio of Final Energy to Primary Energy demand) also improves, by a little over 10%, in all three scenarios. This ratio has stayed fairly constant for the UK over the last 30 years, with conversion efficiency improvements being off-set by the growth in demand for electricity. The comparison is not complete however because the modeling results miss some conversion processes, most notably oil refining.

The most significant feature of the primary fuel mix over the period 2000 to 2050 is the increasing share taken by natural gas. By 2050 it accounts for almost two-thirds of total final energy demand under all scenarios. Gas use increases in all sectors, with the exception of transport, although it is in the electricity sector where growth is the greatest.

Other changes in the electricity generating mix include an expansion of renewables, which contribute between 170 and 290 PJ by 2050 depending on scenario (11% to 20% of total electricity generation) and the phasing out of coal and nuclear.

Oil consumption stays broadly constant. Most of the demand comes from the transport sector. Coal use declines substantially so that by 2050 it accounts for less than 3% of total primary energy use.

In the transport sector, major changes only occur under the 60 % and 70% constraint on CO_2 and hydrogen takes on a significant share. By 2050, use of hydrogen is more widespread, capturing a 30% share.

With the 60% reduction of carbon emissions, the nuclear capacity was replaced with gas turbine combined cycle plant with carbon dioxide capture and storage, small increases in hydro, wind and biomass generation, and further energy saving in the industry sector. A similar pattern was followed with 70% abatement except that more GTCC capacity was needed, and wave energy deployment was increased in addition to the other renewable technologies listed previously.

Key Results

- There is a diversity of technology options for reducing CO_2 emissions from both energy supply and the main energy consuming sectors of transport, industry, domestic and services.
- The implementation of energy efficiency technologies and measures is central, but not sufficient on its own, for achieving the abatement targets irrespective of which supply side technologies are used.
- Natural gas is attractive economically and has low CO_2 emissions compared to other fossil fuels, and therefore is likely to take a growing share of primary energy supplies.
- Abatement costs are highly uncertain, but the effects on the UK's economic growth prospects are likely to be small, and may even be positive if other benefits such as increased security of supply, other environmental benefits and new business opportunities were to be taken into account.
- Innovation and technical progress are central to the attainment of a low carbon economy while continuing to provide energy related services at costs that are not far removed from current levels.

Table UK-1. UK average and marginal costs of abatement in 2050 (£/tC)

	Baseline			World Markets			Global Sustainability		
	-45%	-60%	-70%	-45%	-60%	-70%	-45%	-60%	-70%
Average	148	205	283	151	207	360	85	204	268
Marginal	203	351	1032	228	448	1734	92	329	529

Table UK-2. UK projections of primary energy consumption in the baseline scenario with different levels of CO_2 emission constraint (PJ/y)

Fuel	Baseline 2000	Baseline 2050	Constraint		
		No CO_2 constraint	45%	60%	70%
Coal	1621	159	140	101	8
Oil products	2289	1979	1498	675	478
Natural gas	3568	4232	3050	3847	3764
Nuclear	296	0	519	528	765
Biomass	21	129	401	401	433
Primary renewables	35	114	356	368	300
Total	7795	6499	5607	5551	5449

The German Analysis

The second study analyzed the German energy system using the model TIMES. The focus of the analysis was different: existing obstacles were characterized as far as possible in the base scenario. Moreover, the analysis focused primarily on an increase in renewables as a means of reducing greenhouse gas emissions.

Three scenarios were described by Markus Blesl of the Institute for Energy Economics and the Rational Use of Energy, University of Stuttgart. These were a base scenario,

Regional MARKAL groups organize

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In the next step, the characterization (technical performance and costs) of renewable electric-generating technologies currently used in the participating-Member MARKAL models was examined. The APEC characterizations fell toward the optimistic end but were generally within the range of what was found in the various Member models. The renewable technology characterizations to be used in the assessment were then assembled for each database, refined for local conditions in each of the Member Economies, and structured for being conveniently incorporated into the existing Member MARKAL models.

A series of scenarios looking to establish increasing percentages of electric generation from renewables were run, with and without modest reductions in future carbon dioxide (CO_2) emissions. Owing to the cost effectiveness of the selected technologies (especially after 2020), some level of adoption of these technologies was seen even without imposing any renewable portfolio goals.

Over the entire model period, the overall impact on the energy system of modest renewable targets was an initial increase in costs, but the cost impact was surprisingly small. In addition, MARKAL results with the technology characterizations in the database showed the following benefits to each of the Economies:

1. Improvement in long-term energy security, as characterized by lower energy imports;
2. Slight change in economic conditions, as characterized by modest increases in total system cost over the modeling horizon;
3. A lower cost of meeting any CO_2 reduction targets; and
4. Reduced environmental pollution—both in CO_2 (figure below) and in local air pollutants.

In figure 1 the APECR+% indicate the inclusion of the APEC renewable technologies with %-electric from renewables, with the CO_2 scenarios adding

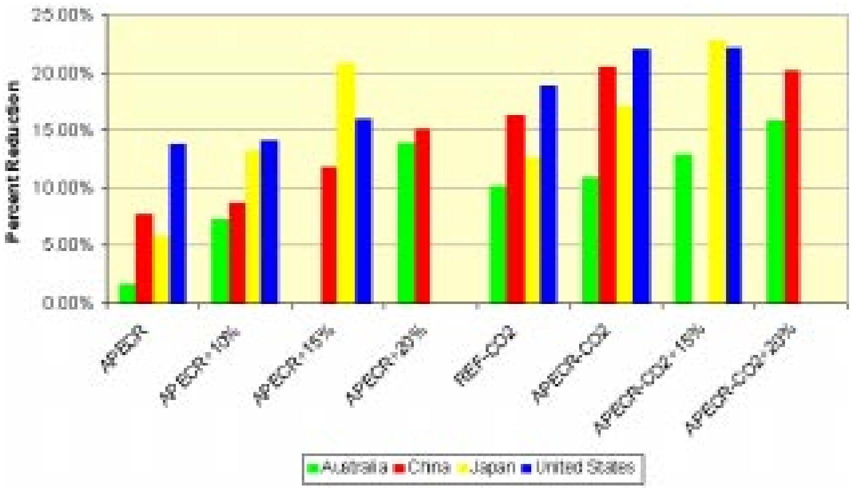


Figure 1. Change in Cumulative Power Sector CO_2 Emissions

Table 1. APEC Member Economies and MARKAL Capabilities

Economy-level MARKAL models	MARKAL models under development	No MARKAL Models
Australia Canada China Hong Kong, China Indonesia Japan Korea Mexico Philippines Chinese Taipei United States	Malaysia New Zeland Thailand Papua Viet Nam	Brunei Darussalam Chile New Guinea Peru The Russian Federation Singapore

a modest (% below Reference levels in 2030) limit of CO_2. [Note, not all scenarios were run for all countries.] As can be easily seen, the APECR scenario alone have a direct and substantial impact on the level of CO_2 (and other) emissions.

This assessment highlights the potential role of renewable resources and energy technologies within selected APEC Economies, and demonstrates the merits of using a common framework to examine APEC energy/economy issues. This endeavor represents only an initial foray in this arena for APEC, with other potential areas for future studies such as alternate fueled vehicles, hydrogen potential, energy security and other pressing issues of interest all the APEC community under consideration.

the REG scenario in which renewables will be met by indigenous production, and the REG+Imp scenario, which allows imports of renewables.

Final energy consumption by sector in the base scenario is shown in table Germany-1. Increased floor space demands coupled with increasing energy efficiency contribute to the marginal growth through 2020. After 2020, demand decreases due to declining population. In the commercial sector, increased efficiency contributes to marginal growth to 2030 followed by further decline. Industrial demand increases to 2010, but slowly falls after that. Substantial increases in vehicle efficiency maintain steady downward demand.

In 1998, primary consumption in Germany by fuel was 24.8% coal, 40.1% oil, 21.2% natural gas, 10.6% nuclear and 3.5% renewables. Renewables are projected to increase 218% by the year 2050. In the base scenario, coal declines to 22.6% share in 2010, then increases to 25.1% in 2020 and to 27.1% in 2050. Petroleum's share declines from 40.1% in 1998 to 32.4% in 2050. The share of natural gas continually increases from 21.2% in 1998 to 27.4% in 2050, surpassing coal.

In the REG scenario, final energy consumption (excluding non-energy uses) increases from 9444 PJ in 1998 to 9683 PJ in 2010. After that, consumption falls continuously to 7976 PJ in 2050. Consumption of coal declines in REG and REG-Imp scenarios. Consumption of petroleum products, mainly in the transportation sector, decreases significantly. Natural gas peaks in 2020 in the REG scenario and in 2030 in REG+Imp. Thereafter, it declines to below 1998 levels in 2050 in both REG and REG+Imp.The contribution of renewables increases from 186 PJ in 1998 to 310 PJ in REG and 345 PJ in REG+Imp in 2050.

The share of coal and lignite was 25.1% in 1998, then it declines to 20.4% in 2010, and reaches 19.1% in 2050. The share of Petroleum falls steadily from 40.1% in 1998 to 32.2% in 2050. Natural gas continuously increases from 21.2% in 1998 to 23.3% in 2050 in the REG scenario and 26.0% in REG+Imp. Nuclear declines from 10.2% in 1998 until it totally fades out in 2030.

The base scenario projections show emissions of 860 million tons CO_2 equivalent between 2010 and 2020. The GHG per year will be approximately 860 million tons CO2 equivalent. After 2010 there is a short increase in emissions due to the nuclear phase-out. By 2030, emissions are 856 million tons in 2030, and 725 million tons in 2050.

Compared with the base scenario, the GHG emissions in the REG and REG+Imp scenarios result in lower emissions. In the REG scenario, GHG emissions are reduced continuously from 821 million tons CO_2 equivalent in 2010 to 603 million tons CO_2 equivalent in 2050. Due to the higher emissions in the conversion section, the absolute emissions are on average about 30 million tons of CO_2 equivalent higher in the REG+Imp scenario.

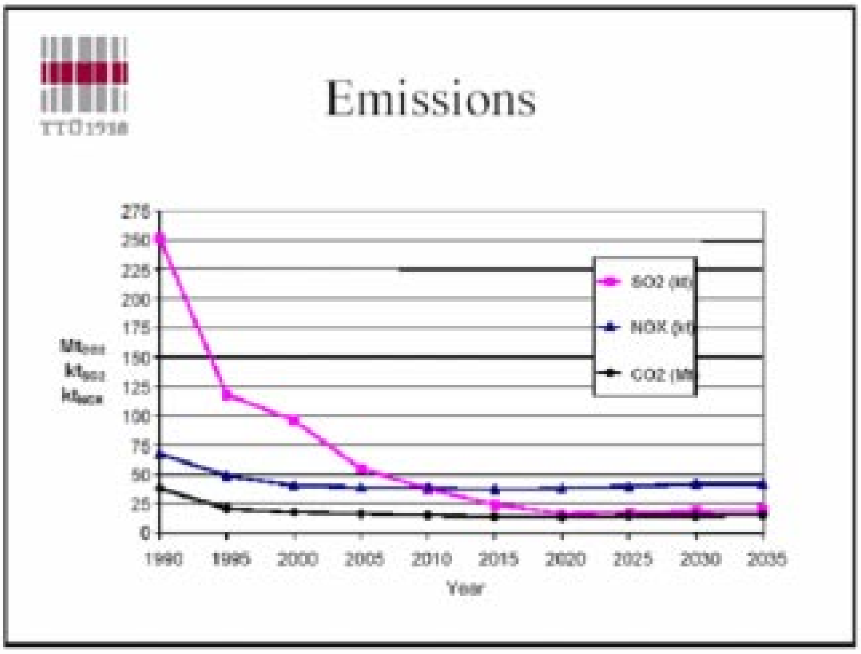
To reach the greenhouse gas reduction target of the Kyoto protocol and the EU burden sharing, GHG emissions need to be reduced by 9 millions of tons of CO_2 equivalent in the year 2010, as compared to 38.4 million tons in the Base Scenario.

Costs are higher in the REG and REG+Imp scenarios because of the higher cost of renewables. Due to the higher renewable quota and the short time, costs are highest in 2010. The average incremental costs per unit of generation from renewable sources are nearly 20.9 €Cent/kWh in 2010 in the REG scenario and 19.7 €Cent/kWh in REG+Imp. In 2050, costs are higher by about 5.2 €Cent/kWh to 13.1 €Cent/kWh.

Table Germany-1. Final energy consumption (PJ)

	Industry	Commercial	Households	Traffic	Total
Base Scenaro					
2000	*2430*	*1472*	*2550*	*2745*	*9197*
2010	*2536*	*1520*	*2841*	*2838*	*9735*
2020	*2496*	*1516*	*2868*	*2757*	*9637*
2030	*2493*	*1530*	*2718*	*2639*	*9380*
2050	*2334*	*1377*	*2229*	*2304*	*8243*
Scenario REG					
2010	*2470*	*1516*	*2850*	*2847*	*9683*
2020	*2456*	*1516*	*2873*	*2762*	*9607*
2030	*2450*	*1538*	*2735*	*2640*	*9362*
2050	*2091*	*1381*	*2187*	*2317*	*7976*
Scenario REG+Imp					
2010	*2470*	*1520*	*2852*	*2847*	*9689*
2020	*2470*	*1516*	*2882*	*2757*	*9625*
2030	*2490*	*1533*	*2725*	*2640*	*9387*
2050	*2334*	*1377*	*2219*	*2305*	*8234*

Figure 2. Projected emissions from Estonia.



The visitors corner

Olev Liik, of course, is not a stranger to ETSAP, having been to ETSAP meetings before. He provides us with the challenges Estonia faces joining the European Union.

Estonia faces many challenges. Joining the European Union provides advantages to Estonia, but causes some difficulty in regard to the energy system. Estonia must accelerate the process of replacing 93% of its electricity generating capacity by 2015 to meet EU environmental restrictions.
A long-term development plan using MARKAL for the fuel and electrical power sector was developed. Other projects using MARKAL include Estonia-21, a national program of sustainable development and an analysis of possibilities for greater efficiency and the use of wind generators. Three energy scenarios were considered:

· Integration to the West plus good relations with the Commonwealth of Independent States (CIS)
· Slow integration to the West plus present relations with CIS
· Integration to West with weak relations with CIS

While in the world scale, the importance of Estonian energy consumption and emissions are insignificant, on a per capita basis, they are not so small. SO_2 emissions are 75 kg/capita (highest in Europe). CO_2 emissions have been cut in half, from 24 t/capita in 1990 to 12 t/capita in 2000.

Conclusions

· Estonia has to renew almost all its electricity production capacity during 15 years. optimization of this task is extremely important.
· Analysis shows that presently dominating local fuel oil shale will be in big difficulties in competition with imported fuels (mainly natural gas).
· Substitution of oil shale is not easy. It means increase of import. Being an indigenous fuel, the oil shale creates a sophisticated complex of economical, political, national security, social and environmental problems.
· Sharp increase of the share of natural gas suggested by modeling results causes serious problems to the security of energy supply and to national trade balance.
· Investment needs into conversion and abatement technologies, energy networks, conservation measures, etc. are impressive comparing with the financial resources of the country and its citizens.
· It is hard to fulfill EU target on renewable electricity production due to expensive solutions. Main resource is wind, but it requires extensive grid building + construction of fast regulating capacity (gas turbines, cable to NORDEL).

Below is a graph of projected emissions from Estonia.

ANNEX IX, Energy Models Users' Group

ETSAP has years of experience building bridges among specialists of energy sectors, energy technologies, environment and economy to carry out joint system modeling analyses.

The prime aim of this Agreement is to diffuse the MARKAL methodologies to new national groups operating in the countries of the Contracting Parties, organizations active in other IEA Member countries, organizations active in non-Member countries, governmental and non-governmental international groups and organizations, and universities and educational bodies.

How it works

The participants share the coordinated work necessary to carry out this task. Examples are:

(a) Facilitating the widespread dissemination and adoption of ETSAP methodologies and analysis in different regions, countries, and local areas;

(b) Carrying out coordinated analyses of energy technologies systems, such as energy efficiencies, deregulation, RD&D ranking;

(c) Collecting, analyzing and disseminating information and data related to energy systems, energy technologies, energy and environment models and scenarios;

(d) Improving the modeling tools, by means of integration with other existing tools, developing new research ideas, testing new solutions, fine tuning experimental models and software, e.g., to foresee links to spatial variables and local GIS;

(e) Organizing annual meeting of experts, as appropriate to exchange information and experience in the areas of work covered in the agreement;

(f) Exchanging specialists, experts, and students active in the sector.

Specific Obligations and Responsibilities of the Participants

(a) Participants provide the Operating Agent with reports on the results of the work carried out;

(b) Participants exchange reports and reviews on the work for quality improvement;

(c) Participants participate in the editing and review of draft reports; and

(d) Participants support the Operating Agent in efforts to disseminate the methodologies and their use in assessing local or regional systems.

Funding

(a) Annual meetings shell be hosted in turn by the Participants. The cost of organizing and hosting the meetings shall be borne by the host Participant.

(b) The Program of work is carried out in a task sharing basis. A wide use of the web will increase the opportunities of exchange at low cost;

(c) The cost of publishing reports and summary assessments shall be met by the Operating Agent;

(d) Each Participant shall bear all the costs it incurs in carrying out its activities, including the purchase of the proprietary software necessary to run the models;

(e) The level of work to perform the program specified in this Annex is estimated at 3 person-months per year for the Operating Agent, 2 additional person-months for each Participant in the first year, and an additional person-month per year for each participant during the remainder of the Annex.

Operating Agent

The IEA/ETSAP Newsletter is published under Annex VIII "Exploring Energy Technology Perspectives" of the Implementing Agreement for a Programme of Energy Technology Systems Analysis". Operating Agent for ETSAP/Annex VIII is the Energy Department of the Politecnico of Torino (http://www.polito.it/ricerca/dipartimenti/dener).

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