Demonstration of PRIMES-ELMAS Models in ETRES

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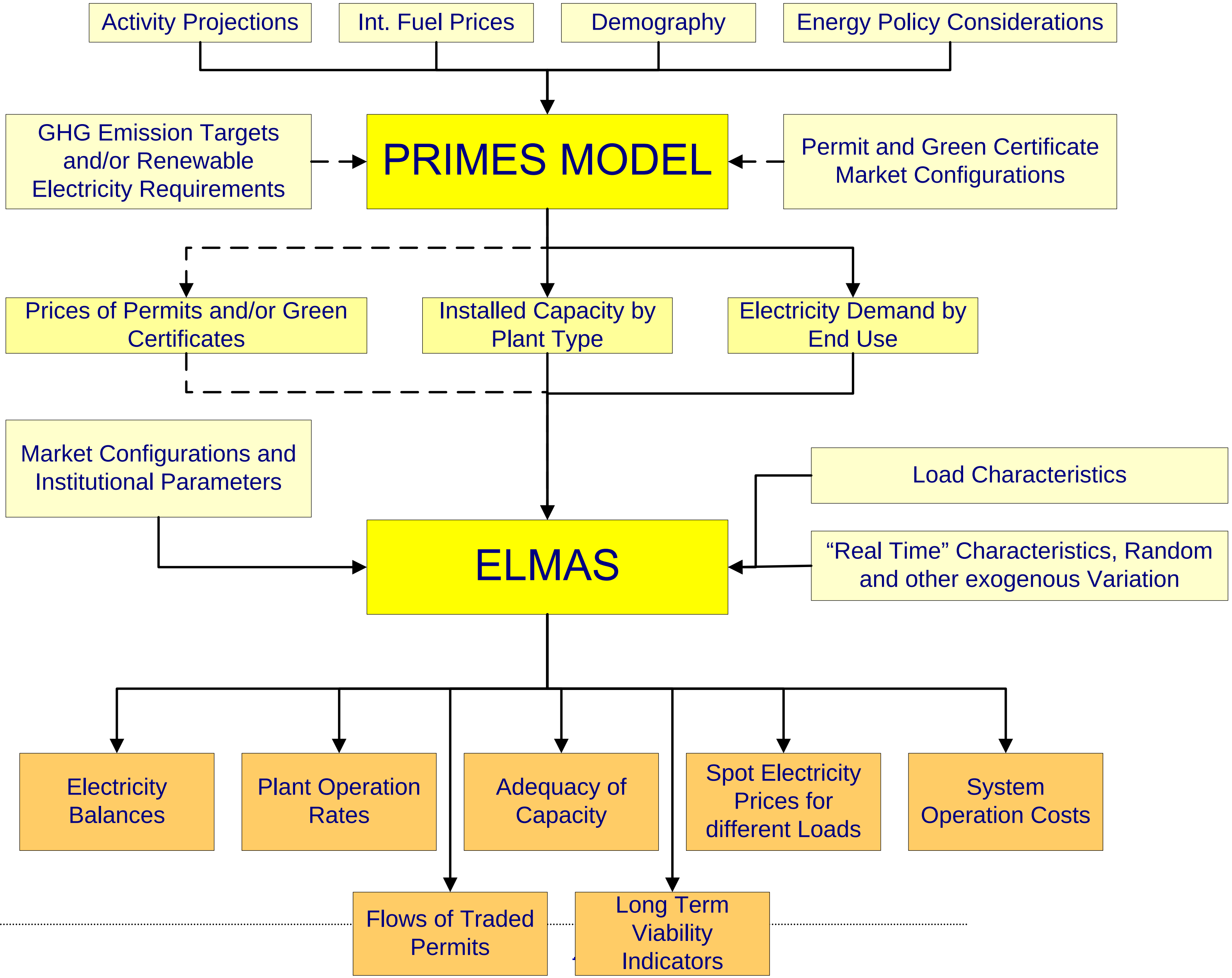
ETRES Model Configurations



The PRIMES energy system model

1. Energy system model: mixed bottom-up (engineering) and top-down (microeconomic behaviors)
2. Modular, with separate modules for demand and supply by sector
3. Market-oriented: market equilibrium prices drive energy balancing of demand and supply per fuel and market
4. Detailed (for 34 countries) and comprehensive (whole of energy system, EU-wide networks)
5. Environment-oriented (climate change, links with RAINS for air pollution, links with special models for transport)
6. Policy-oriented for a large variety of instruments (subsidies, taxes, certificates, permit markets, R&D, …)
7. Very detailed electricity sector sub-model

Recent work with PRIMES model

1. Since DG TREN publications ('Trends' and 'Key Drivers') a complete update of PRIMES database carried out
   - Eurostat statistics up to 2003 and available information for 2004, 2005
   - Revision of the power plant database, including information on new constructions and projects
   - Updated information on prices, taxes and tariffs
   - New database on electricity and gas interconnections and future projects
   - Updated information about renewables: potential, non linear cost curves, learning by doing, etc.
2. New improved electricity and steam sub-model: DC linear optimal power flow and investment expansion over a set of regional electricity markets
3. With DG TREN new projections for
   - Economic growth of the EU and sectoral structure
   - International fuel prices

The ELMAS Model

- In the context of the ETRES project NTUA has developed a high resolution (in terms of time) and detailed Electricity Market Simulator (ELMAS):
  - Necessary in view of imminent liberalisation of Greek electricity market:
    - Market structure will be radically different than present
    - This could be important for patterns of RES penetration with modifications in the policies promoting it.
  - Allows hourly load representation and individual plant and operator identification using detailed data obtained from actual operation

ELMAS model characteristics

- Very high temporal resolution (hourly) with load patterns and plant availability parameters obtained from actual data.
- Capability for identifying individual plants (for major units) or meaningful classifications of smaller ones (e.g. wind power plants).
- Detailed representation of costs and technical performance of different types of plant.
- Mechanism for simulating spot electricity markets assuming variants of the Nash-Cournot oligopolistic behaviour model

Key characteristics of ELMAS specification

- Size and cost structures of market agents are important in determining their behaviour.
- Clear emergence of market leaders and effective price takers.
- Only “short-term” marginal conditions are considered.
- ELMAS solves over a vast hourly sample (containing 61320 time periods) designed to represent the interaction of all relevant market parameters.
  - Sample created by using and analysing “real time” historical data and by design is both realistic and contains a host of typical as well as “extreme” configurations.
  - Capability of using ELMAS for risk analysis

Baseline assumptions concerning the electricity market in Greece

- By 2010:
  - Electricity market liberalised but PPC still dominates and regulated on a maximum rate of return basis
  - Accelerated licensing of wind generators bringing total capacity to over 1.9 GW
  - No explicit effort to reduce CO_2 Emissions

Baseline scenario assumptions for Greece

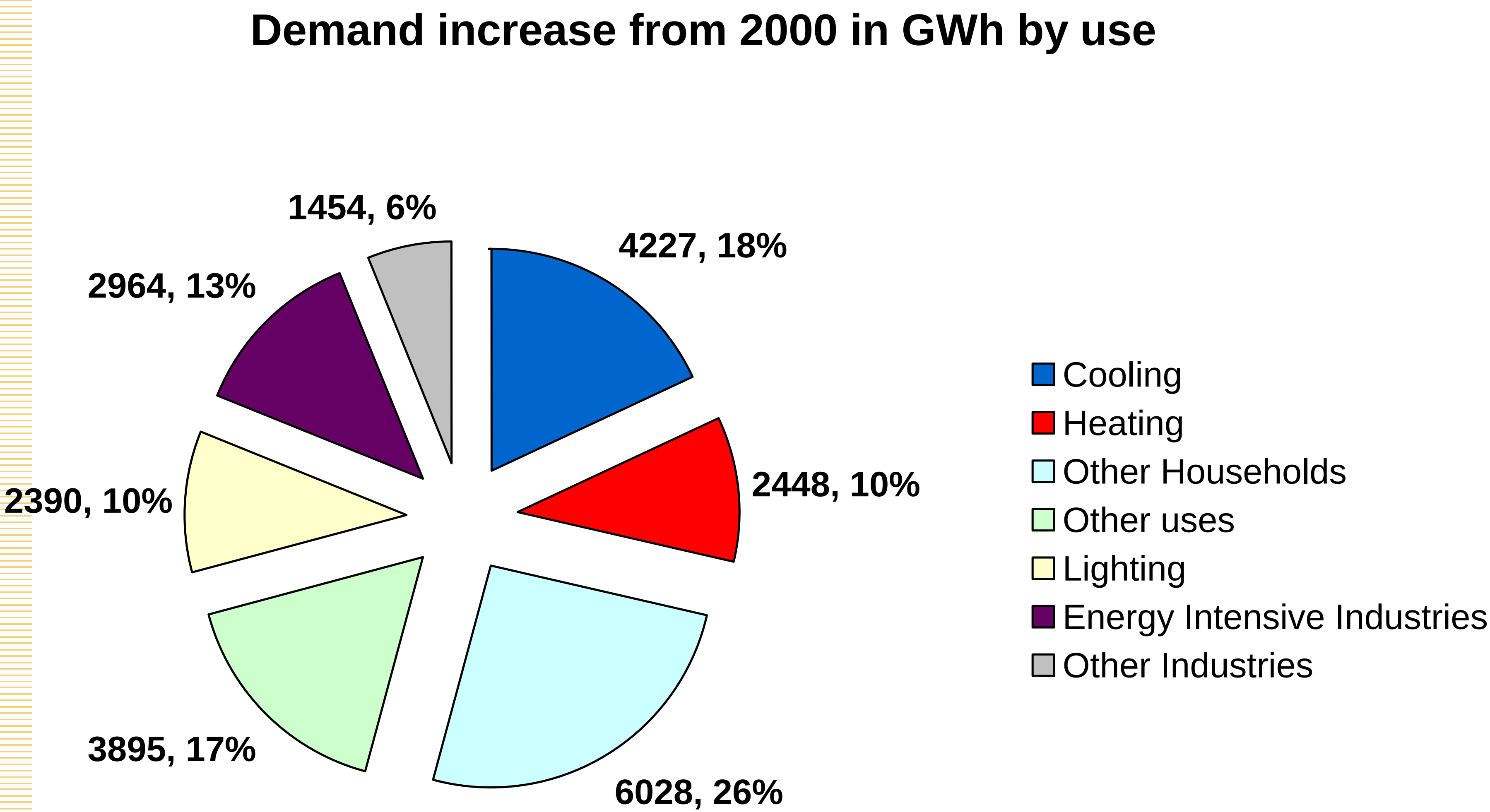
- Demographic and macroeconomic

	2000	2010	Annual % Change '00 - '10
Population (Millions)	10.6	11.1	0.5
Household size (inhabitants/household)	2.8	2.7	-0.4
Household income (in Euro00/capita)	6820	10742	2.6
GDP (BEuro'00)	123	181	4.0
Energy Intensive Manufacturing (Beuro'00)	4	7	4.6
Non - Energy Intensive Manufacturing (BEuro '00)	9	13	4.0
Services (BEuro '00)	79	121	4.4
Agriculture (BEuro '00)	10	13	3.0

- Fuel prices including taxes in €00/toe

	2000	2005	2010
Lignite	78	78	78
Natural Gas	216	230	226
Fuel oil	227	244	205
Diesel	459	602	554

Demand projection for 2010 in Greece (Baseline)



¾ of the total demand increase is attributed to end uses that accentuate the peaking characteristics of the load

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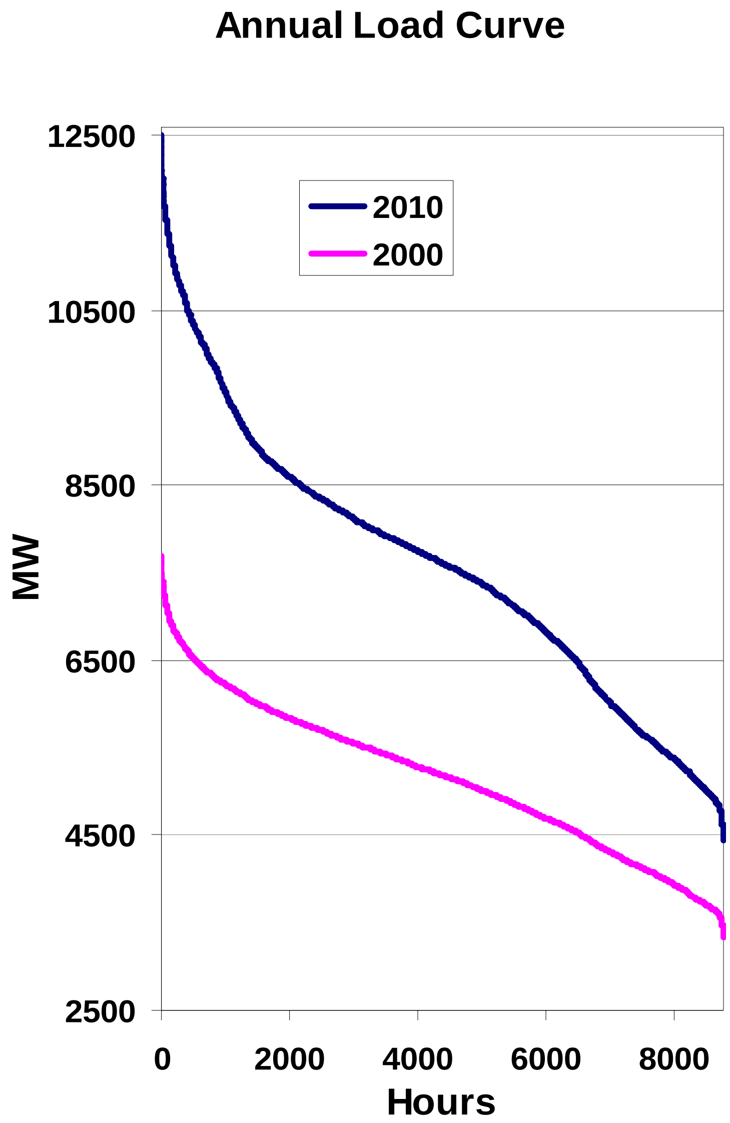
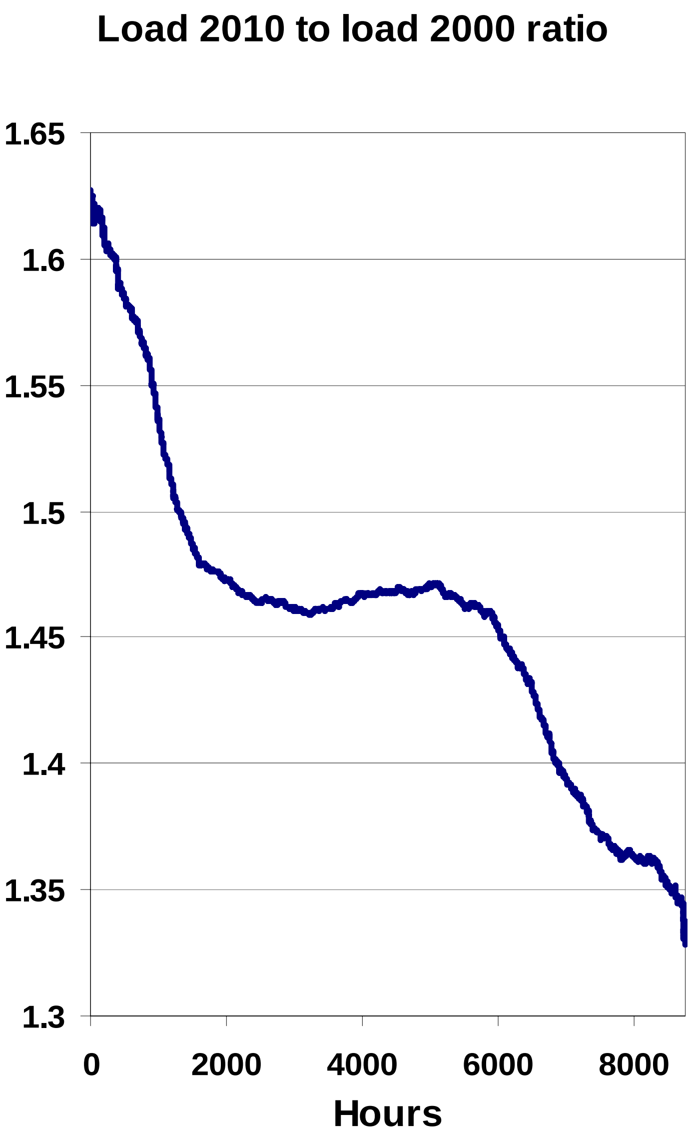
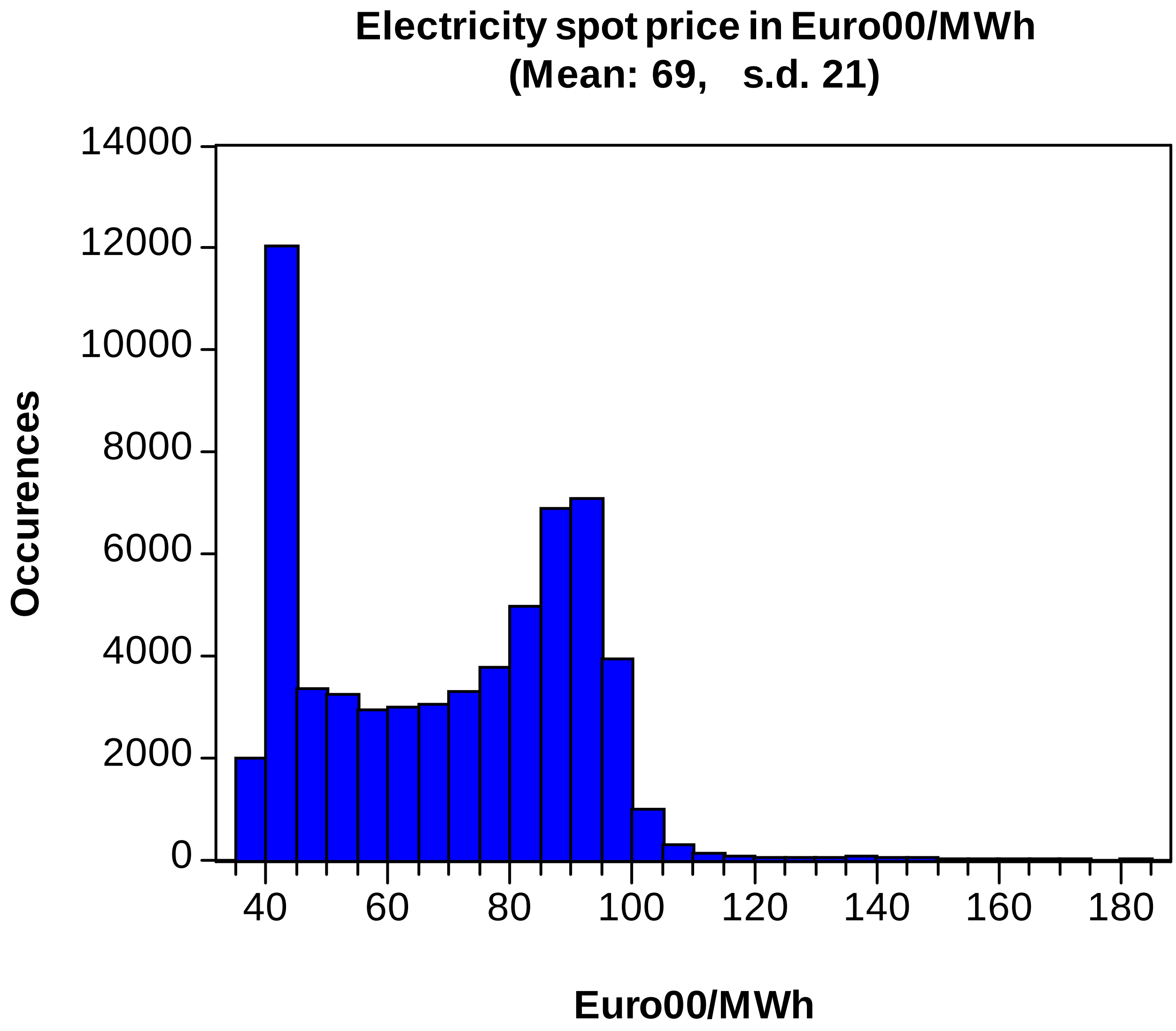
Changes in annual load in Greece (Baseline)

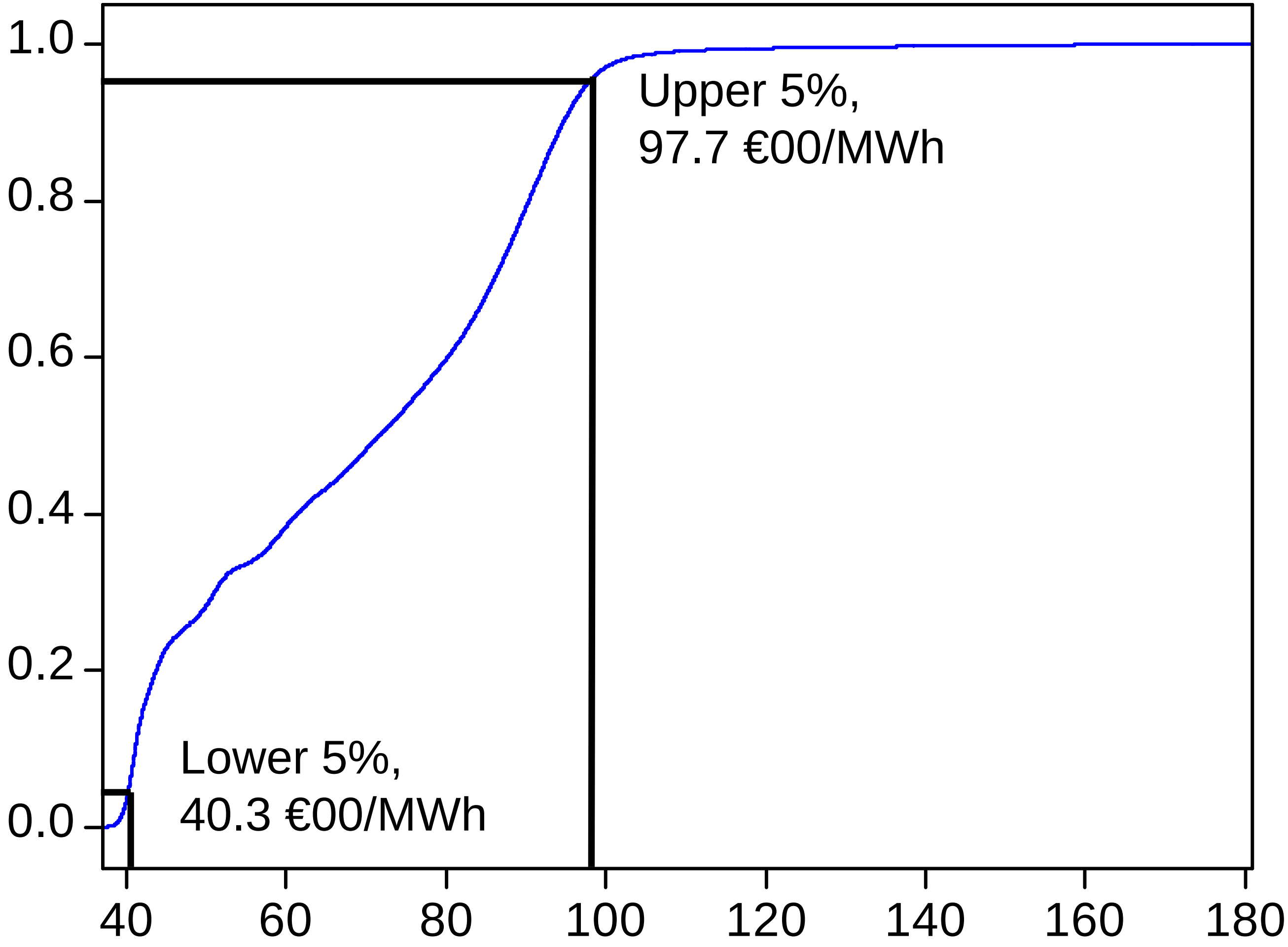




Electricity spot price distribution in 2010 in Greece (Baseline)



Electricity spot price cumulative distribution in 2010 in Greece (Baseline)



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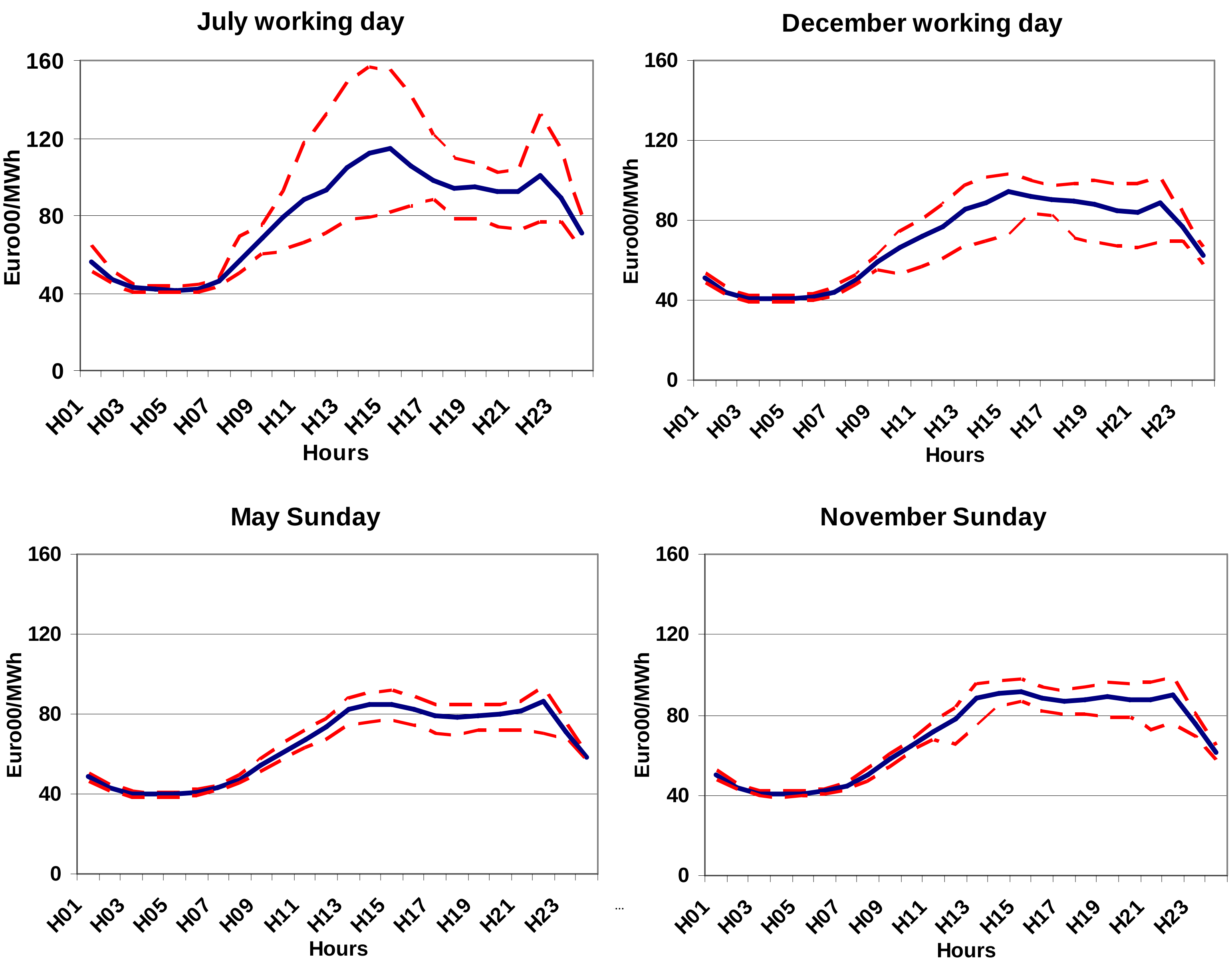
Electricity spot price per hour in 2010 in Greece (Baseline)



Climate Policy Scenarios

- **Baseline Scenario**:
  - Takes into account current policies and trends without including explicit effort to reduce CO_2 Emissions
- **Present Allocation Plan Scenario**:
  - Second trading period (2008-2012) NAPs remain unchanged relative to those specified for the first trading period (2005-2007)
  - NAPs only for the Emission Trading Sectors (ETS) – No constraints imposed to the Non Trading Sectors (NTS)
- **Optimal Allocation Scenario:**
  - PRIMES generates an Optimal Allocation of NAPs and optimal NTS targets
  - To do so, the scenario calculates equal marginal abatement costs for both ETS and NTS and across all member-states of the EU-25, so that the emission reduction target (in terms of CO_2 emissions) imposed by the Kyoto protocol to the EU-25 as a whole is achieved at least cost

Scope of the scenarios

- The two scenarios present alternative National Allocation Plans that could be applied for the Second Period (2008-2012) of the Emission Trading Scheme in the European Union
- Forecasts to 2010 based on the recently updated (November 2005) PRIMES Baseline Scenario
- Model results on scenarios are presented for 2010 (middle year of the next trading period)
- Imposition of emission constraints is equivalent to the inclusion of a shadow variable (marginal abatement cost) and represents the economic cost of avoiding the last (marginal) unit of carbon that is required by the constraint
- The constraint is applied only to CO2 emissions
- The analysis covers the EU-25 region (with the exception of Cyprus and Malta)

Permit price and emissions in 2010 in EU-25

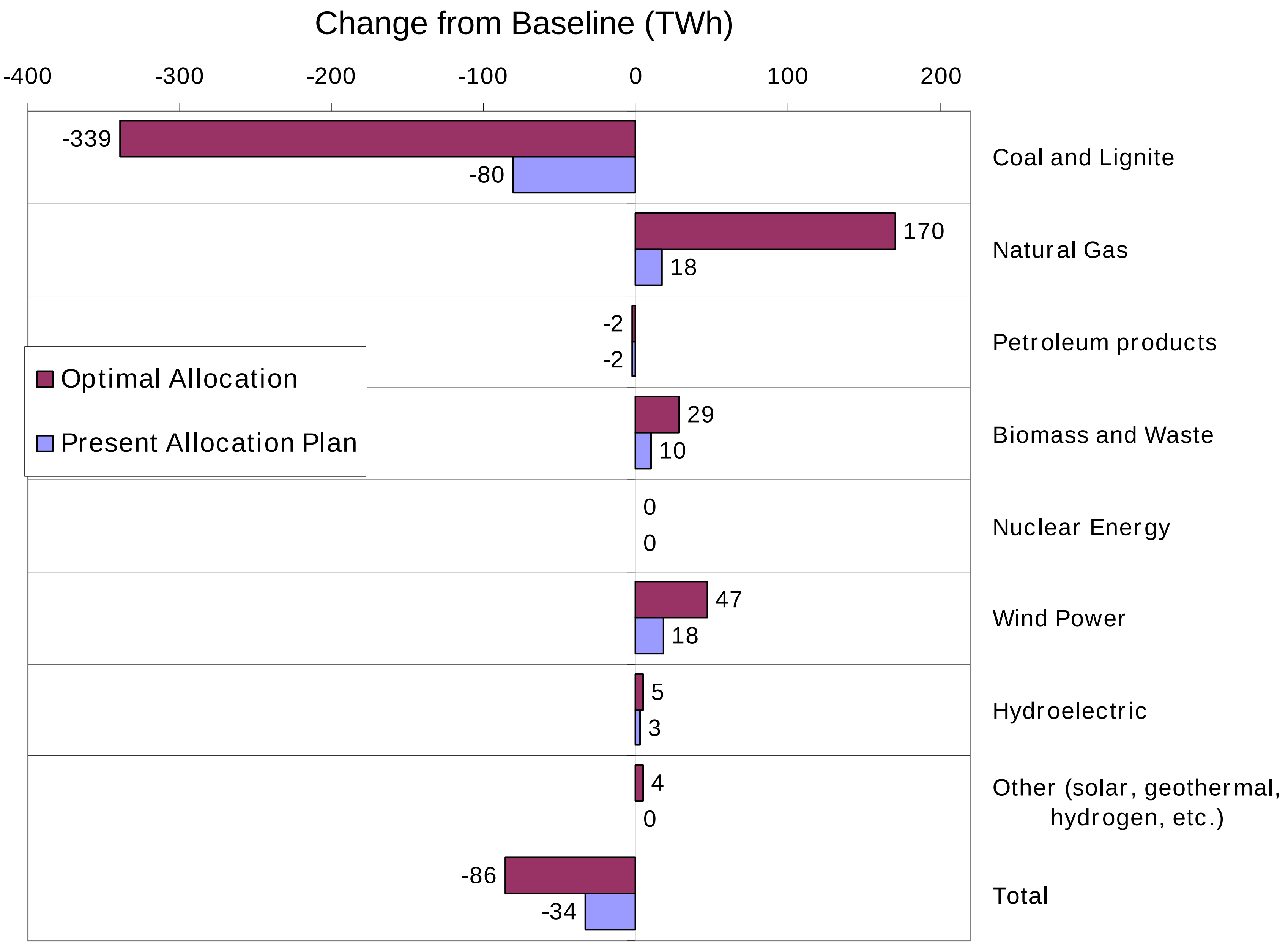
Market clearing price in €00/tn of CO2

Scenarios	Market Clearing Price
Present Allocation Plan	16
Optimal Allocation	41

CO_2 Emissions from Electricity Sector relative to Baseline (in $MtonCO_2$)

	Baseline	Present Allocation Plan	Optimal Allocation
CO2 Emissions	**1480**	**1374**	**1147**
Change from Baseline		**-106**	**-333**
% Change from Baseline		**-7.20%**	**-22.50%**

Generation of Electricity by Type (EU25) in 2010



New power capacity (GW) built by primary energy in EU-25 in 2010

EU25 : New power capacity built by primary energy (2005-2010)	Baseline	Present Allocation Plan	Optimal Allocation	Change From Baseline	
				Present Allocation Plan	Optimal Allocation
Coal and Lignite	4.9	4.6	7.7	-0.2	2.8
Natural Gas	80.1	84.0	108.6	4.0	28.5
Petroleum products	7.9	8.9	10.2	1.0	2.3
Biomass and Waste	7.1	8.2	11.0	1.0	3.9
Nuclear Energy	2.48	2.5	2.5	0.0	0.0
Wind Power	41.8	49.7	62.2	8.0	20.4
Hydroelectric	4.4	4.9	5.7	0.5	1.3
Other (solar, geothermal, H2	0.9	0.9	3.7	0.0	2.8
Total EU 25	149.7	163.9	211.8	14.2	62.0

Implementation of the scenarios for the electricity market in Greece

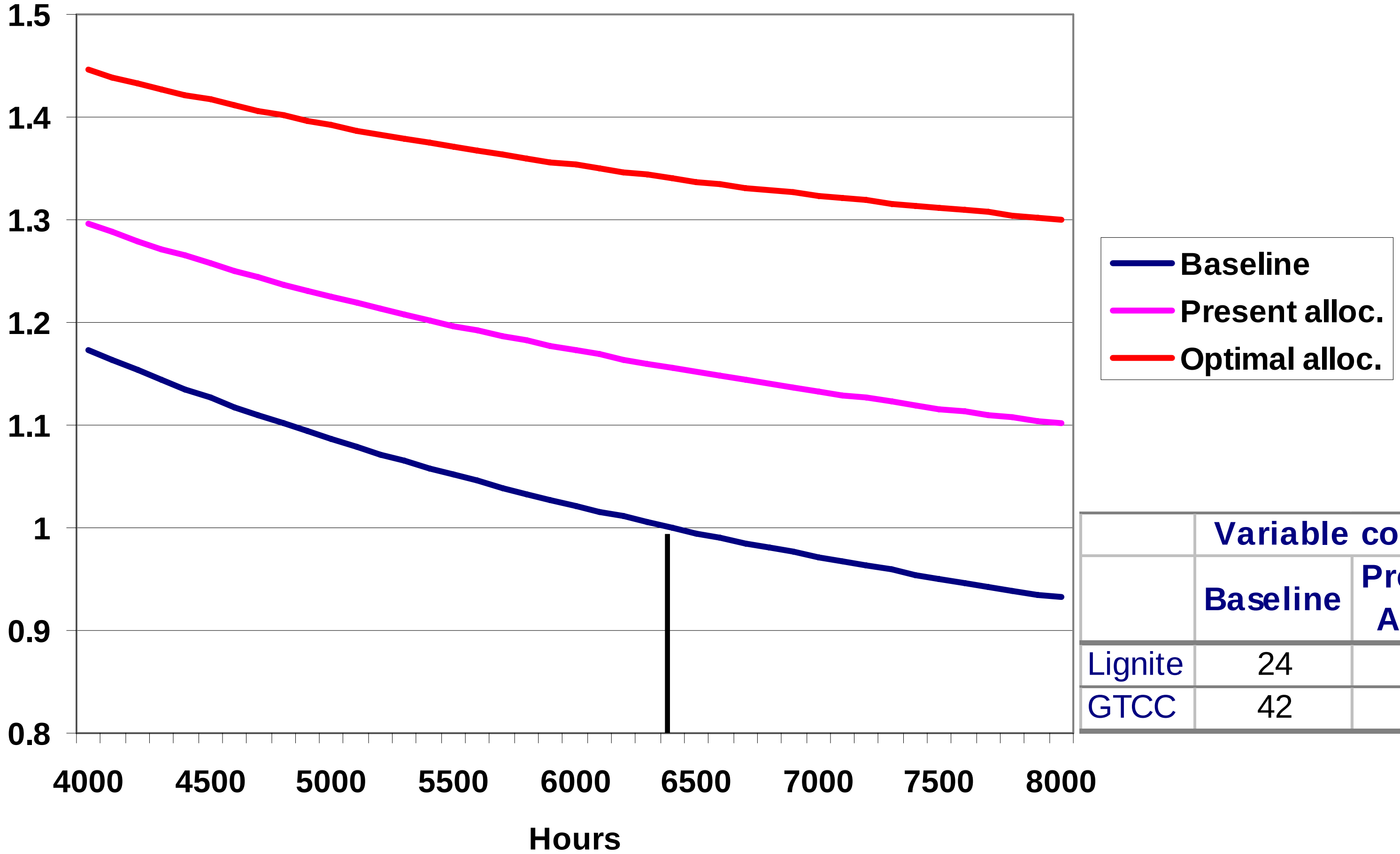
- The PRIMES model has provided input to ELMAS concerning:
  - The carbon values that have resulted from the EU-wide emission permit market equilibrium
  - The changes in power plant investments resulting from the different scenarios
- An additional variant to the “Optimal Allocation” scenario which introduced for Greece involving a more rapid deployment of wind power

Fuel prices (including taxes) in €00/toe in Greece for power generation

	Baseline			Present allocation plan	Optimal allocation
	2000	2005	2010	2010	2010
Lignite	78	78	78	145	248
Natural Gas	216	230	226	264	322
Fuel oil	227	244	205	257	337
Diesel	459	602	554	603	680

Impact of scenarios on generation costs in Greece (2010)

Ratio of full costs of lignite thermal plant to GTCC in 2010

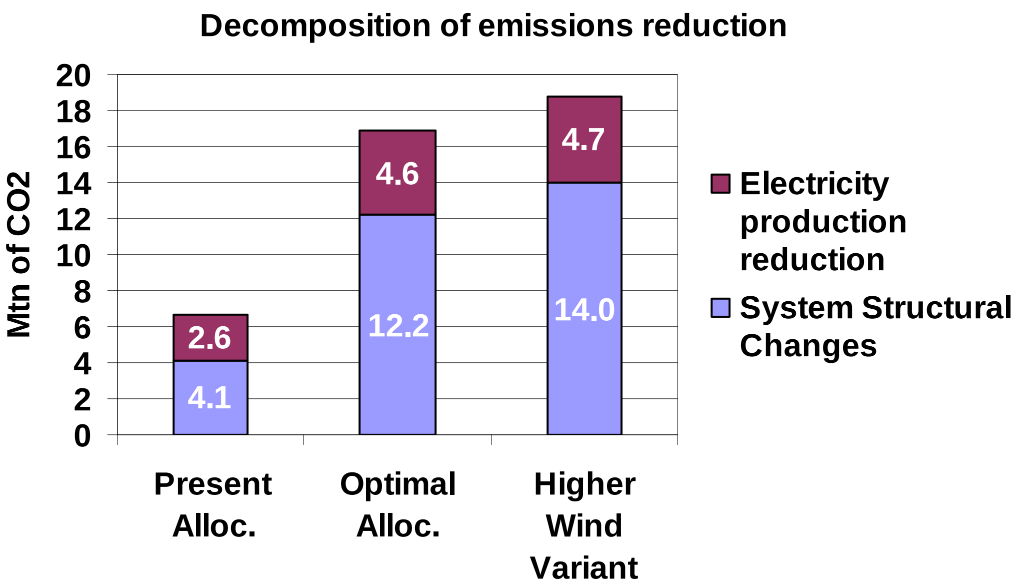


	Variable cost in €00/MWh		
	Baseline	Present Alloc.	Optimal Alloc.
Lignite	24	40	65
GTCC	42	49	59

*GTCC: Gas turbine combined cycle

Scenarios Comparison in 2010 (Greece)

Changes from Baseline				
		Present Alloc.	**Optimal Alloc.**	**Higher wind variant**
Final Demand	(%)	-4.3	-7.9	-8.1
Imports	(GWh)	528	749	730
Exports	(GWh)	-283	-531	-507
Average spot price	(%)	16.8	32.5	33.2
CO_2 emissions	(Mtn)	-6.7	-16.8	-18.7
Net Sales of permits	(Mtn)	1.2	5.9	7.7



Capacity and production implications in Greece in 2010

Investment in new plants

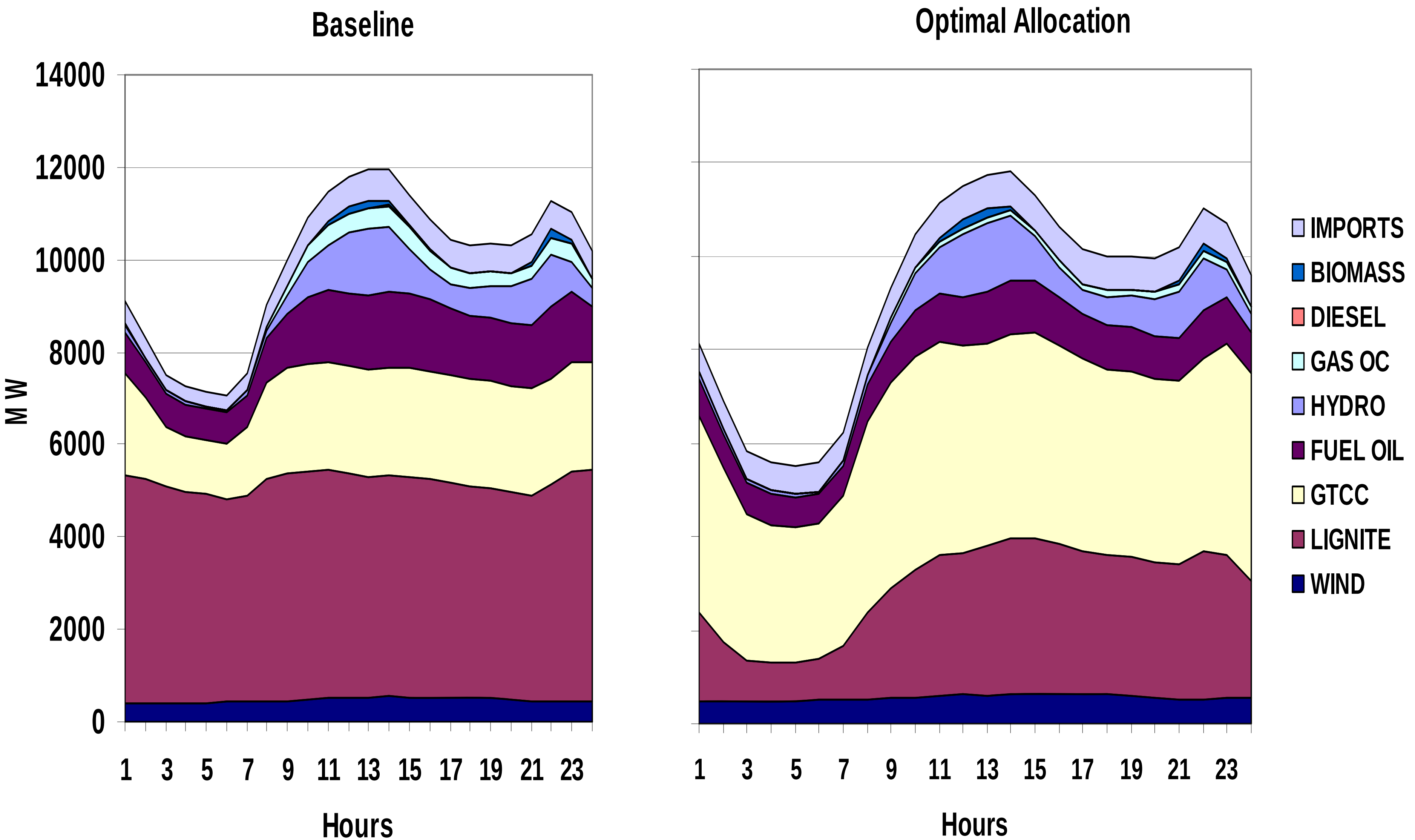
Changes from Baseline in MW		
	Present Alloc.	Optimal Alloc.
GTCC	205	3737
Wind	228	367
Biomass	2	16
Peak devices	0	132
Total	*435*	*4252*

For the “Higher wind” variant to the “Optimal Allocation” scenario an additional 1.3 GW of wind turbines has been introduced

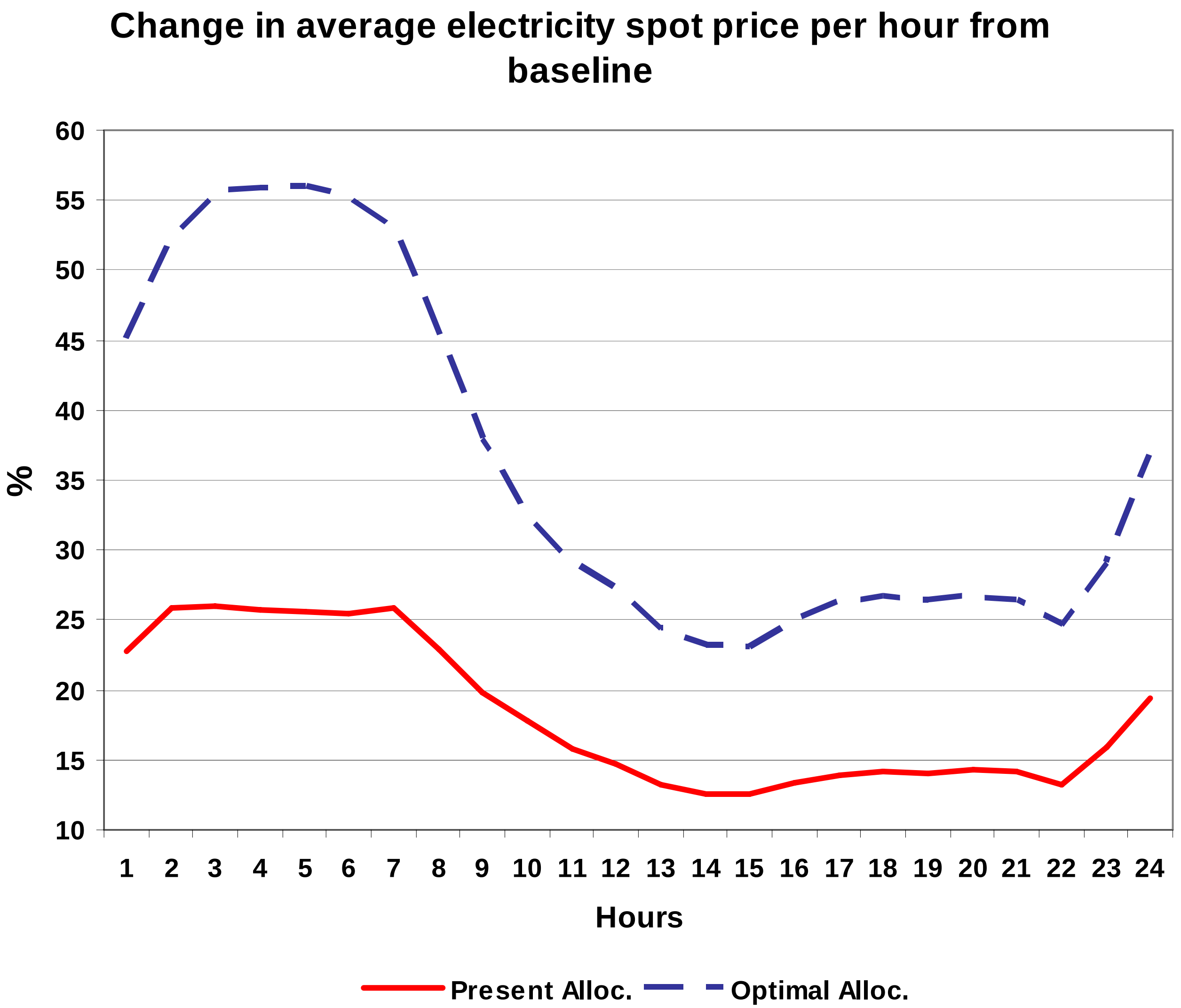
Production by plant type

Changes from Baseline in TWh			
	Present Alloc.	Optimal Alloc.	Higher wind variant
Hydro	0.0	0.0	0.0
Lignite	-6.2	-16.8	-17.3
Gas	2.1	10.5	9.6
Oil	-0.2	-1.1	-2.6
Biomass	0.0	0.1	0.1
Wind	0.5	0.8	3.6
Net Imports	0.8	1.3	1.2

Production per hour in 2010 – July working day in Greece

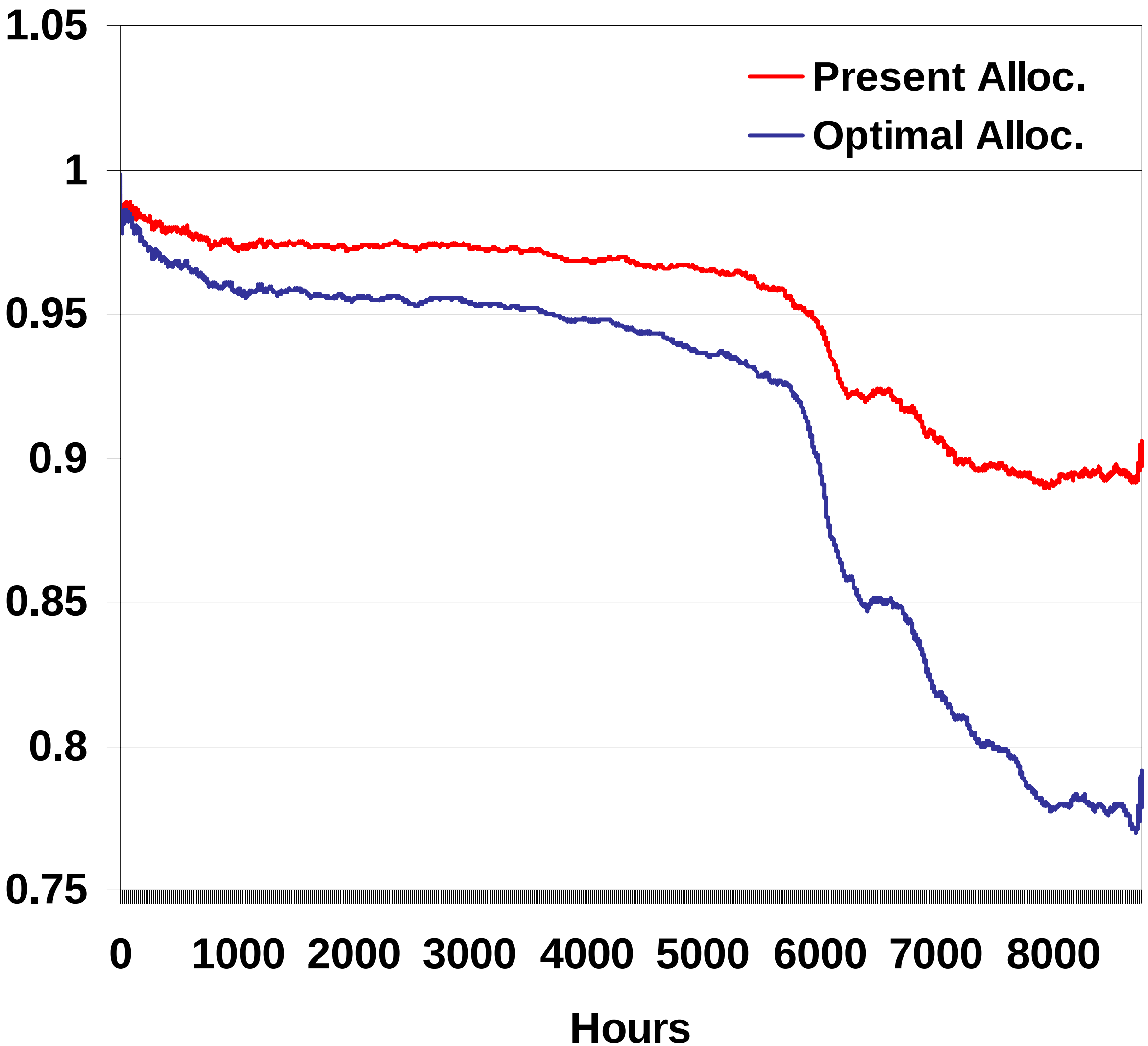


Electricity spot price in Greece in 2010



The abatement scenarios affect base load electricity prices more severely

Ratio of load in 2010 compared to Baseline for Greece



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Electricity average production cost in 2010 (Greece)