Overview of the modelling work carried out by E3M-LAB in the context of ETRES Project

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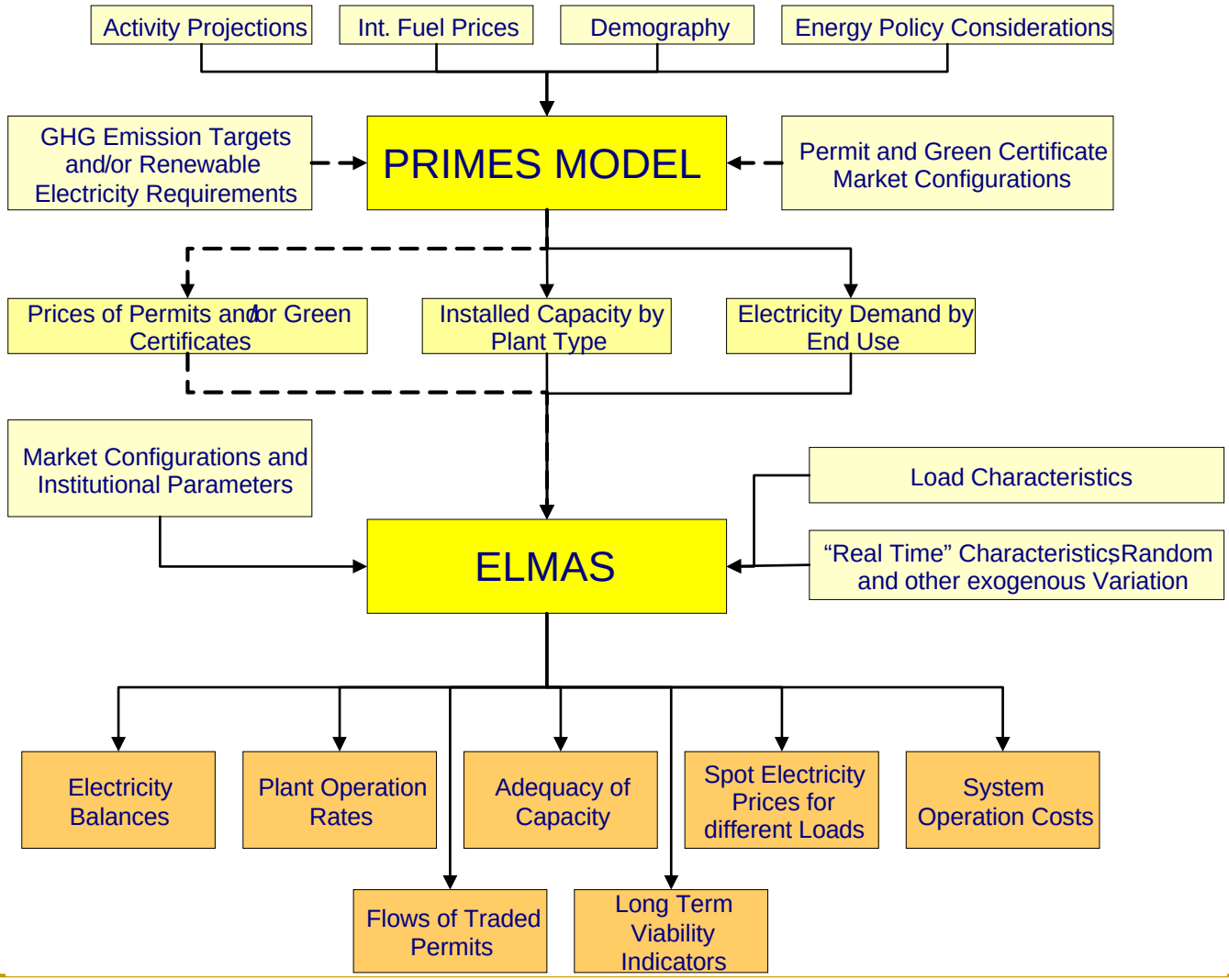
Final Meeting of ETRES Project, Athens 31.3.06

E3M - Lab

Aims of the work undertaken

- Provide detailed computer-based models capable of performing quantitative impact assessment on:
  - Renewable electricity prospects
  - Alternative emission permit market configurations
- Develop a reference scenario and alternative policy scenarios using these models

ETRES Model Configurations



The PRIMES energy system model

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

The ELMAS Model

- Module necessary in view of imminent liberalisation of Greek electricity market
  - Market structure will be radically different than present
  - Could be important for patterns of RES penetration with modifications in the policies promoting it.
- A Nash type oligopolistic competition formulation adopted
  - Identifies individual players of different sizes and distinct capacity and cost structures
- 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

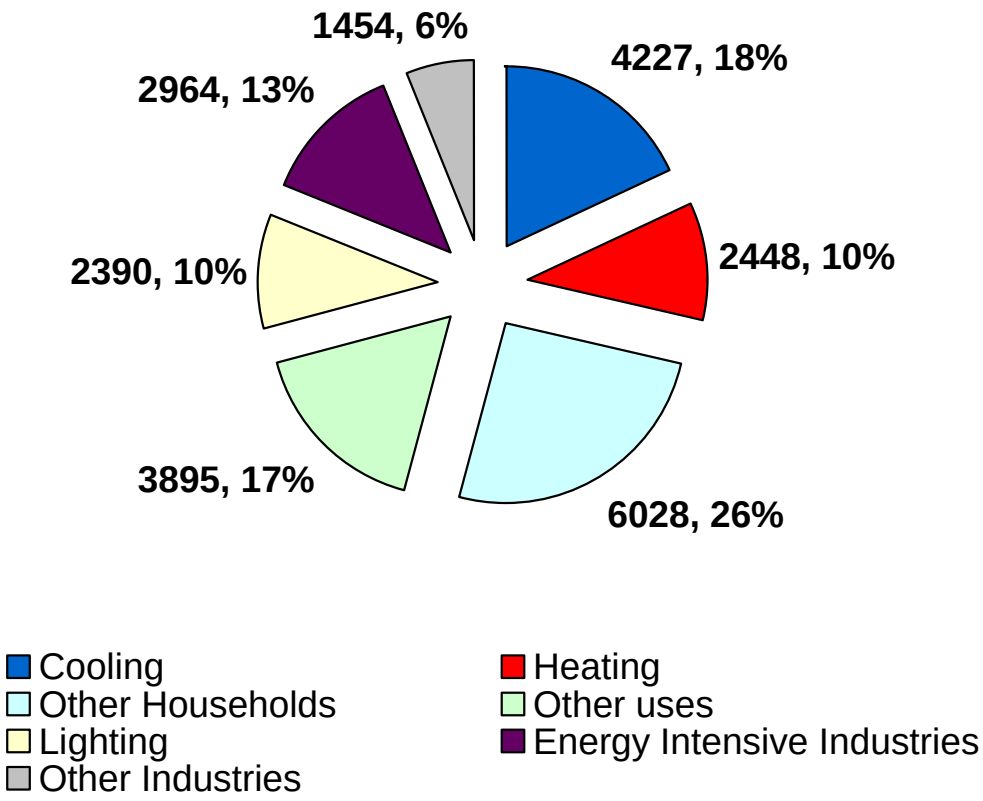
			Annual % Change
	2000	2010	'00 - '10
Population (Millions)	10.6	11.1	0.5
Household size (inhabitants/household)	2.8	2.7	-0.4
Household income (in Euro00/capita)	6820	10742	2.6
GDP (BEuro'00)	123	181	4.0
Energy Intensive Manufacturing (Beuro'00)	4	7	4.6
Non - Energy Intensive Manufacturing (BEuro '00)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

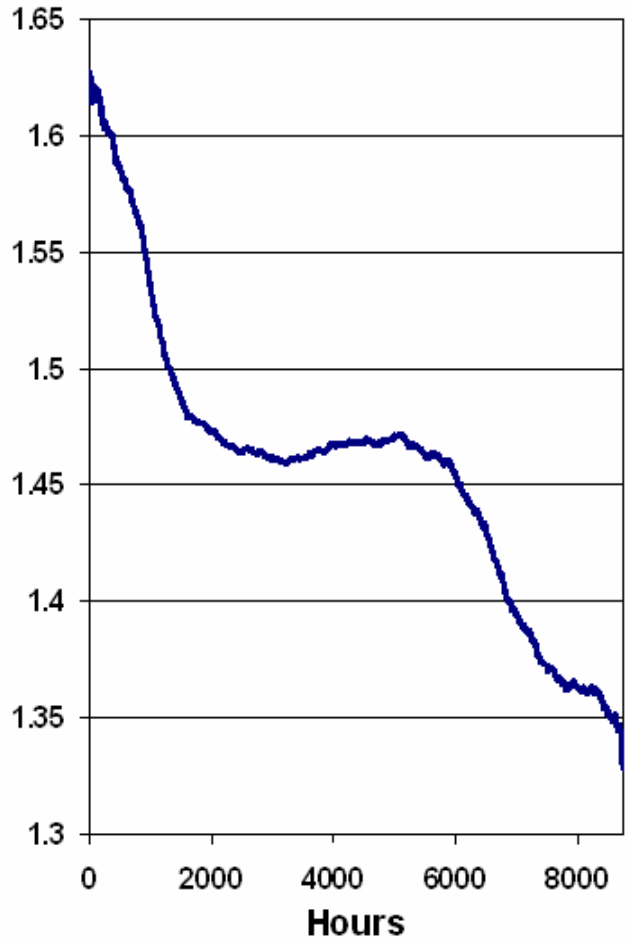
	2000	2005	2010
Lignite	78	78	78
Natural Gas	216	230	226
Fuel oil	227	244	205
Diesel	459	602	554

Demand projection in 2010 in Greece

Demand increase from 2000 in GWh by use

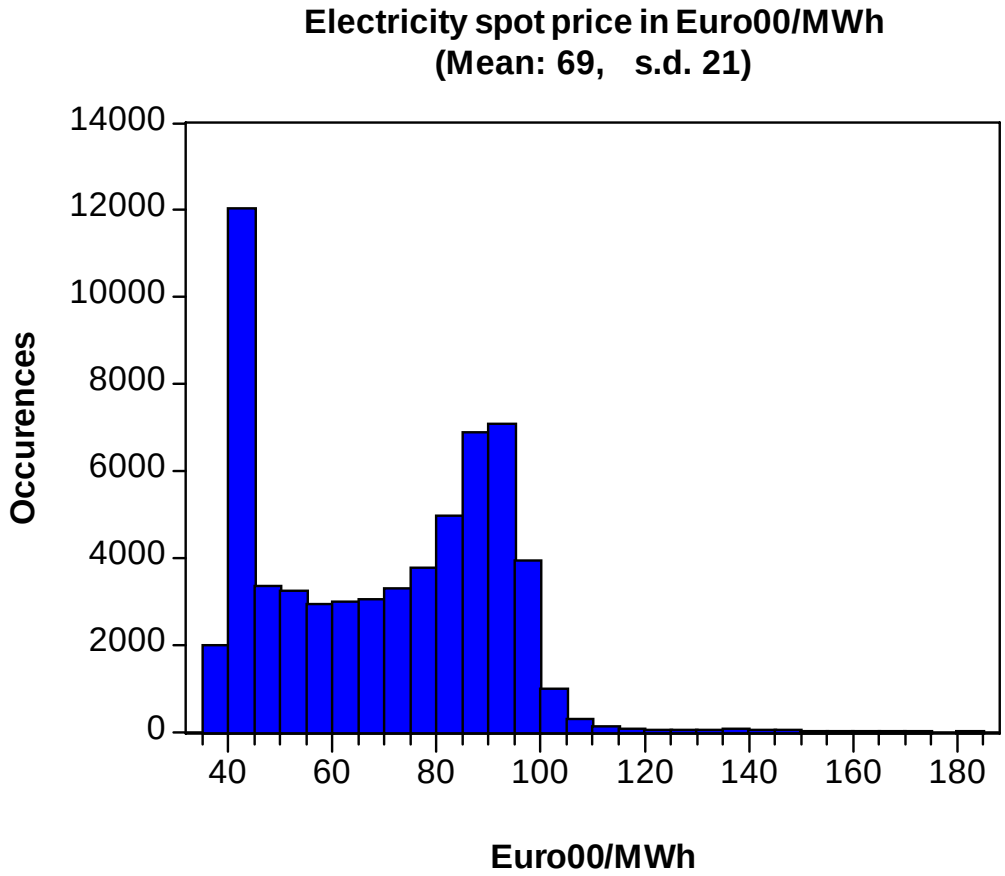


Load 2010 to load 2000 ratio



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

Electricity Spot Price Distribution in 2010 in Greece



Climate Policy Scenarios

- Baseline Scenario:
  - Takes into account current policies and trends without including explicit effort to reduce CO2 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 CO2 emissions) imposed by the Kyoto protocol to the EU-25 as a whole is achieved at least cost

Permit price and emissions in 2010 in EU-25

- Market Clearing Price in €00/tn of CO_2

Scenarios	Market Clearing Price
Present Allocation Plan	**16**
Optimal Allocation	**41**

- CO_2 emissions from Electricity Sector relative to Baseline(in Mton of CO_2)

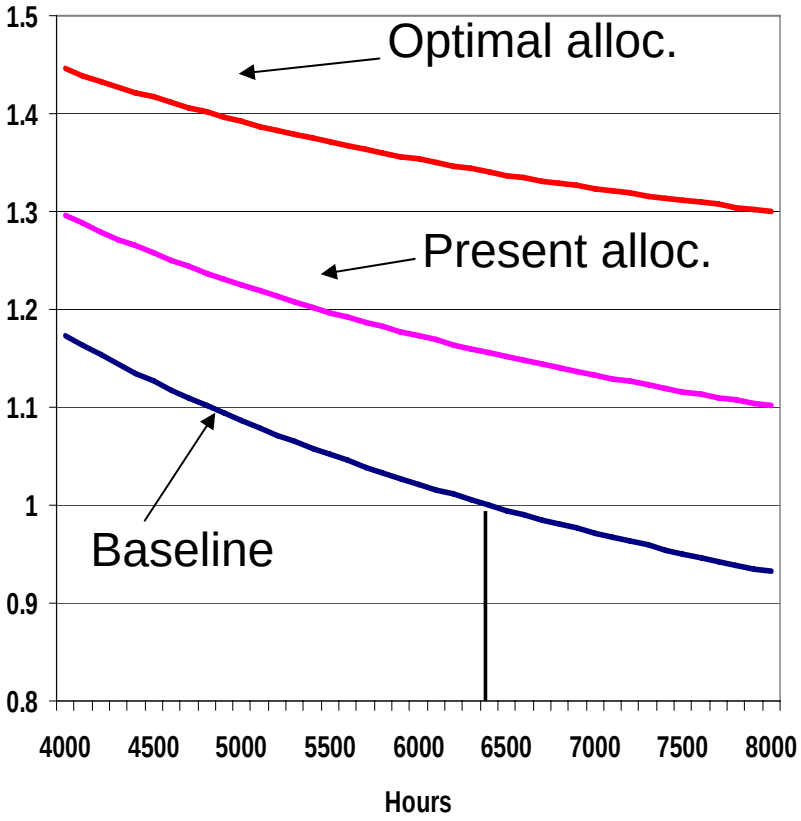
	Baseline	Present Allocation Plan	Optimal Allocation
CO2 Emissions	**1480**	**1374**	**1147**
Change from Baseline		**-106**	**-333**
% Change from Baseline		**-7.20%**	**-22.50%**

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

Impact of scenarios on generation costs in Greece (2010)

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



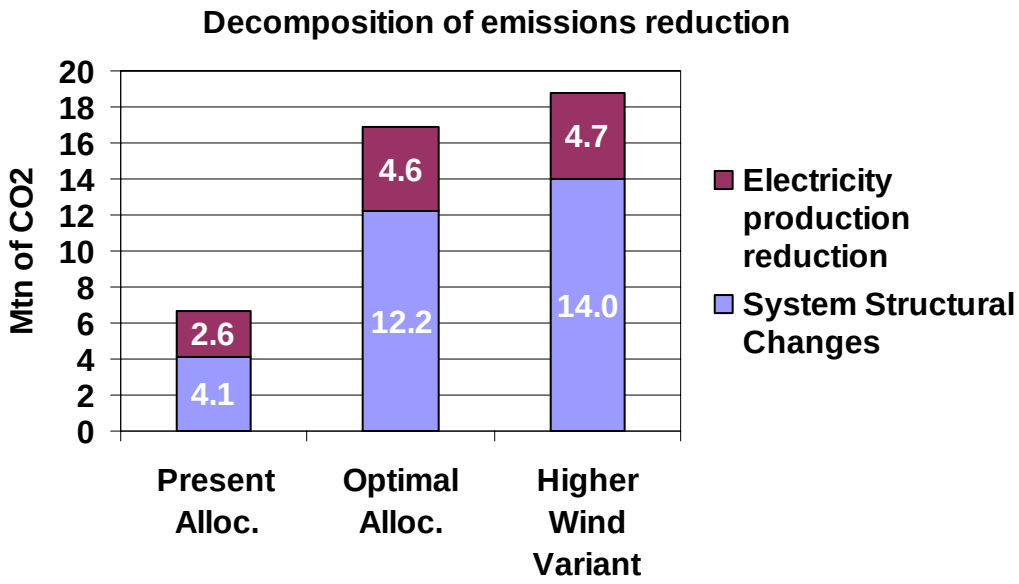
Fuel prices for power generation including taxes in €00/toe					
	Baseline			Present allocation	Optimal allocation
	2000	2005	2010	2010	2010
Lignite	78	78	78	145	248
Natural Gas	216	230	226	264	322
Fuel Oil	227	244	205	257	337
Diesel	459	602	554	603	680

Variable cost in €00/MWh			
	Baseline	Present allocation	Optimal allocation
	2010	2010	2010
Lignite Thermal	22	39	67
GTCC	36	42	50

*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

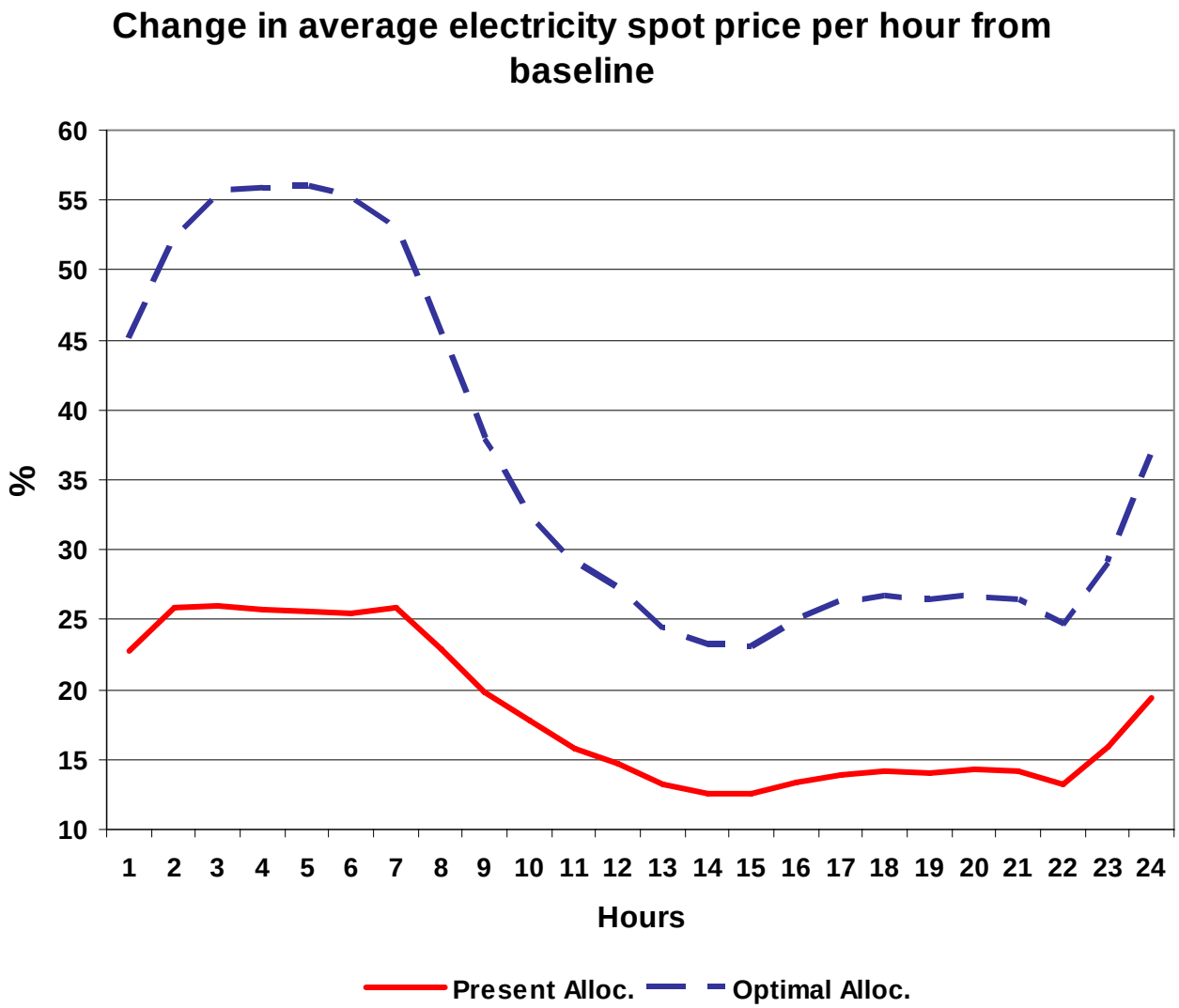
Changes from Baseline in MW		
	Present Alloc.	Optimal Alloc.
GTCC	205	3737
Wind	228	367
Biomass	2	16
Peak devices	0	132
Total	*435*	*4252*

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

Electricity spot price in Greece in 2010



The abatement scenarios affect base load electricity prices more severely

Electricity average production cost in 2010 (Greece)