Review and Potential of Demand Response Measures

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SESSA Conference
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European experience

	Price methods	Non-price methods
To contain demand	• Free prices revealing costs • Surcharges, introduced for any reason, contribute to contain demand • Progressive tariffs, incompatible with liberalisation	• Obligation on distributors to implement programmes or to buy certificates
To contain peaks	• Real-time pricing or at least time-of-day pricing	• Forced outages
	• Interruptibility clauses (price element in choosing the contract, non-price element in deciding the interruption)	

Reduction of peak demand and sustainability (1)

- ***Lower peak-time demand implies:***
  - **Less generation capacity / less interconnection capacity is necessary (reduced impact on land)**
  - **Effect on emissions uncertain**

Reduction of peak demand and sustainability (2)

- **Reduction of peak demand increases the resistance and resilience of the system in front of capacity shortages**

- **The same instruments, once in place, allow greater resistance and resilience in front of energy shortages**

This paper: effect of real-time or time-of-day pricing on peak demand

- ***Preliminary warnings:***
  - **Little experience, uncertainty on elasticities**
  - **Necessity of metering devices**
  - **Effort in information, persuasion is necessary for all consumers except energy-intensive industrial**

Price elasticities

- ***Own price elasticity (calculated on total demand, average price) is low (IEA 2003)***
  - **Short run between - 0.1 and – 0.2**
  - **Long run between - 0.3 and - 0.7**

- ***Swiss domestic consumers (Filippini 1995)***
  - **Own elasticity at peak time – 0.6 (short run) and – 0.9 (long run)**
  - **Cross (peak, off-peak) elasticities positive**

Substitution elasticities

US studies suggest positive substitution elasticities

- **+ 0.14 in day-ahead market-based RTP program for large customers in Niagara**
- **+ 0.20 / 0.33 in study on residential customers exposed to TOU price**

Issues and Objective

The Issues

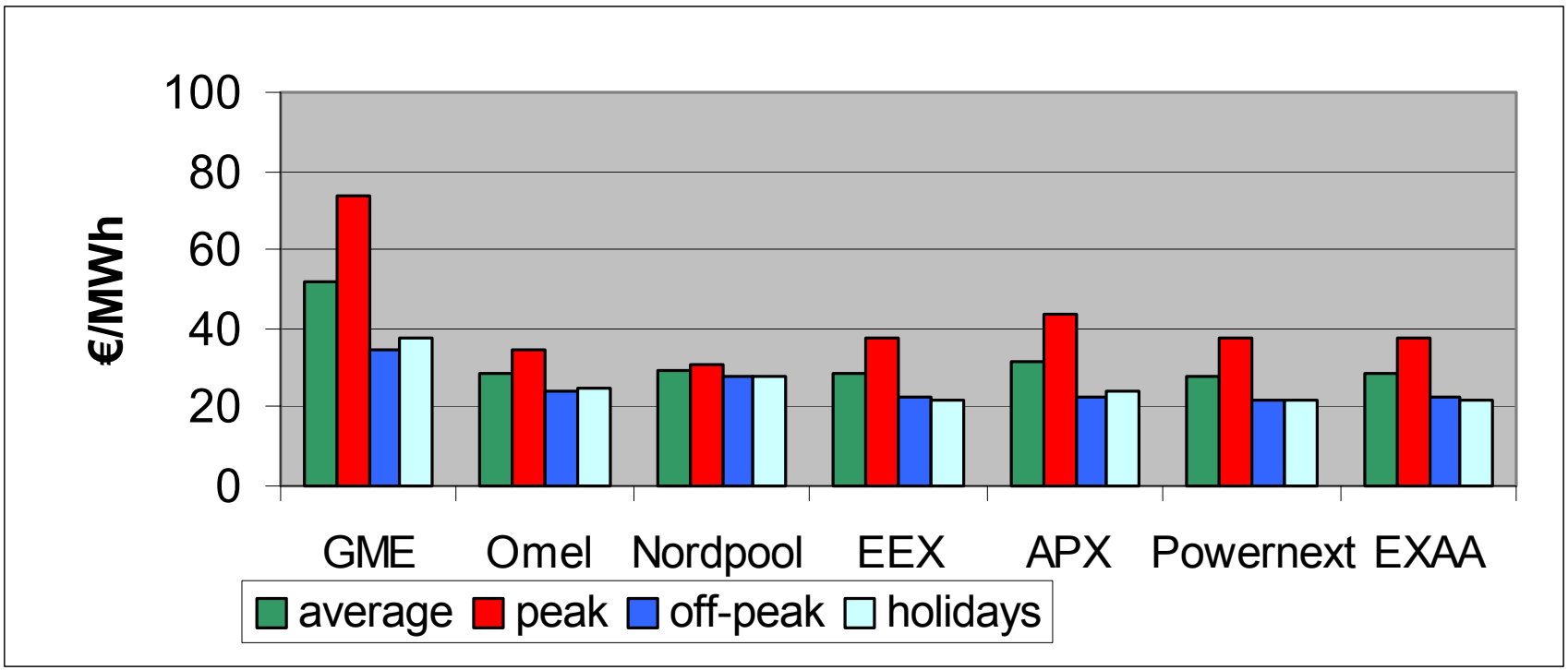
- Demand Response Measures (DRM) change the shape/level of the load profile
- Potential effects
  - in the short run, on the utilisation of existing plants
  - in the longer run, on the optimal generation capacity mix
- Both effects impact on
  - generation costs
  - emissions of pollutants

The Objective

- Assess the potential impact of DRM based on replacing Uniform Pricing with Peak/Off Peak Pricing
- on generation costs and CO2 emissions
- starting from Italian Load Profile Forecast for 2005 and
- keeping Total Demand Constant

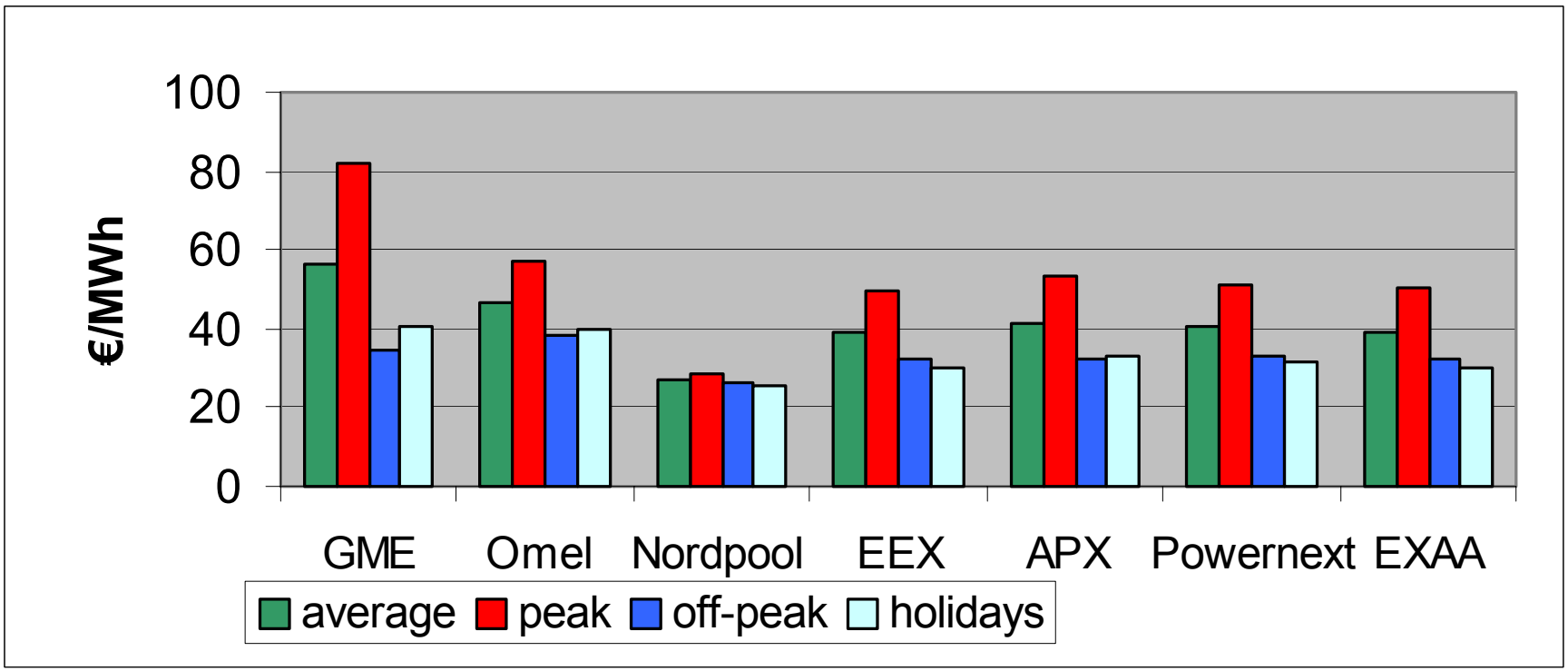
Electricity Prices in Europe

Arithmetic Averages – April to December 2004



Electricity Prices in Europe

Arithmetic Averages – January to April 2005



Electricity Prices in Europe

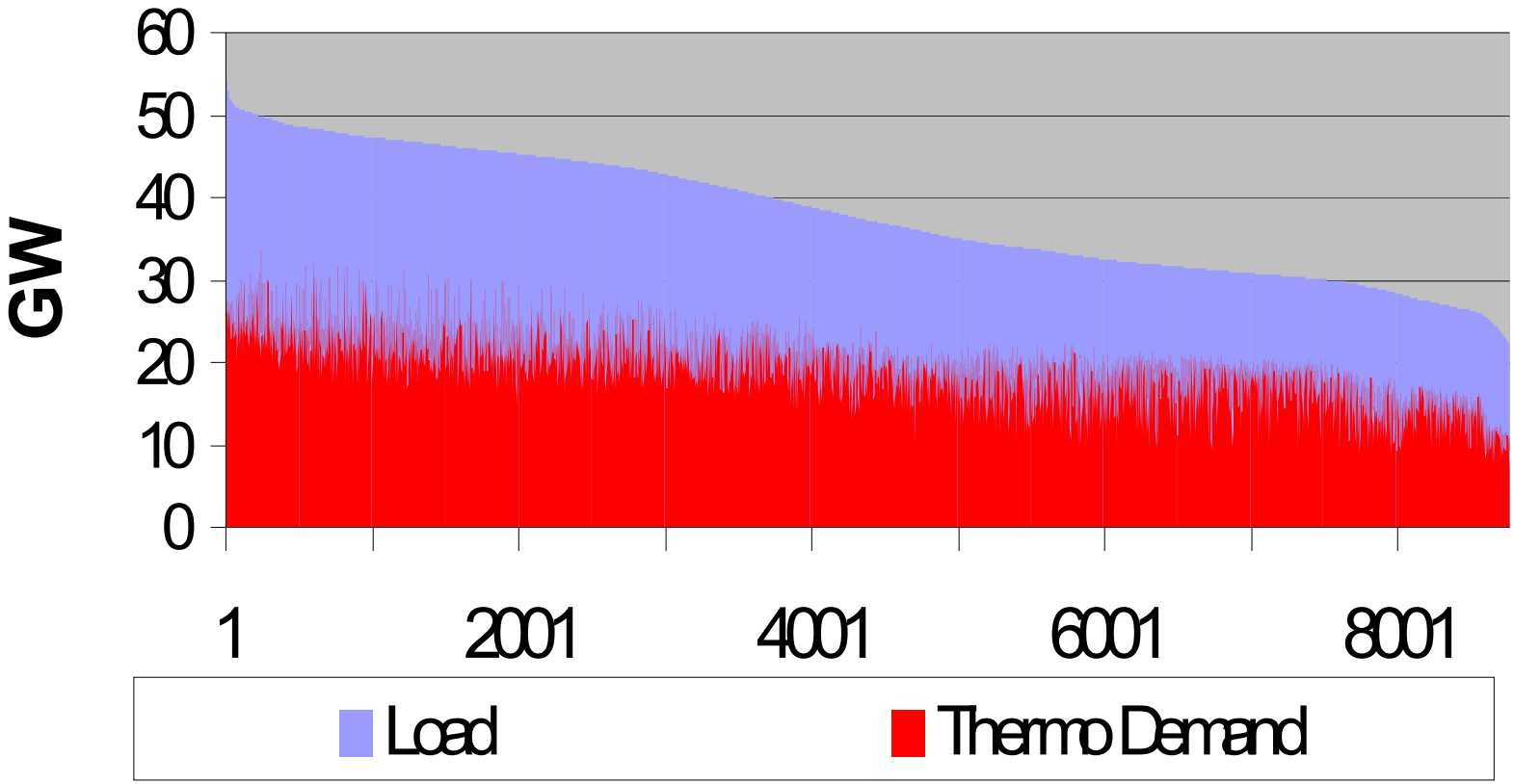
Differences from period averages

	April - December 2004			January - April 2005		
	Peak	Off-Peak	Holidays	Peak	Off-Peak	Holidays
GME	43%	-33%	-27%	46%	-38%	-27%
Omel	20%	-15%	-13%	22%	-18%	-15%
Nordpool	5%	-3%	-4%	6%	-3%	-6%
EEX	31%	-20%	-23%	27%	-17%	-22%
APX	38%	-29%	-24%	29%	-23%	-20%
Powernext	33%	-23%	-23%	27%	-18%	-22%
EXAA	32%	-21%	-24%	28%	-17%	-24%
Average	29%	-20%	-20%	27%	-19%	-19%

Base Case Scenario (1)

- 2005 Load Forecast
- Total Demand = 332.4 TWh
- Average Load = 37,949 MW
- 4212 Peak Hours (Load > Average Load)
- 4546 Off-Peak Hours (Load < Average Load)

Base Case Scenario (2)
Load Duration Curve



Base Case Scenario (3)

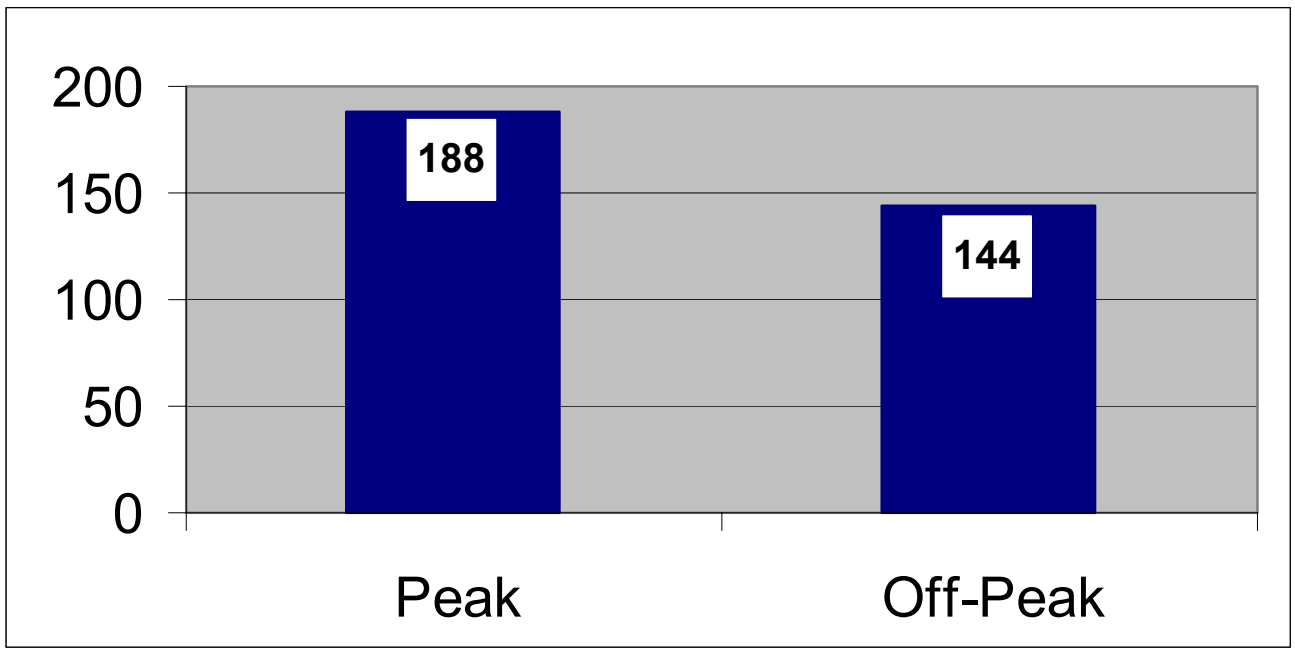
	Average Load (MW)	Minimum Load (MW)	Maximum Load (MW)	Electricity (TWh)
Base Case Scenario				
Peak	***44,730***	***37,956***	***56,514***	***188,5***
Off-Peak	***31,663***	***21,820***	***37,947***	***143,9***
Peak/Off-Peak	***1,413***	***1,740***	***1,489***	***1,310***

The Effect of Peak/Off Peak Pricing (1)

- Peak/Off-Peak Demand Ratio = 1.31
- **Transition from uniform price to peak/off-peak prices**
- Peak/Off-Peak price ratio = 1.3/0.8 = 1.625
- Peak/Off-Peak Demand ratio 1.000 $\rightarrow$ 1.625 (+62.5%)
- US Studies suggest elasticity of substitution
  - + 0.14 for large customers (Niagara)
  - + 0.20 / 0.33 for residential customers
- Assume elasticity of substitution = 0.16
- Reduction in Peak/Off-Peak Demand Ratio =
  = 0.16 * 62.5% = 10%
- Resulting Peak/Off-Peak Demand Ratio = 1.18

The Effect of Peak/Off Peak Pricing (2)

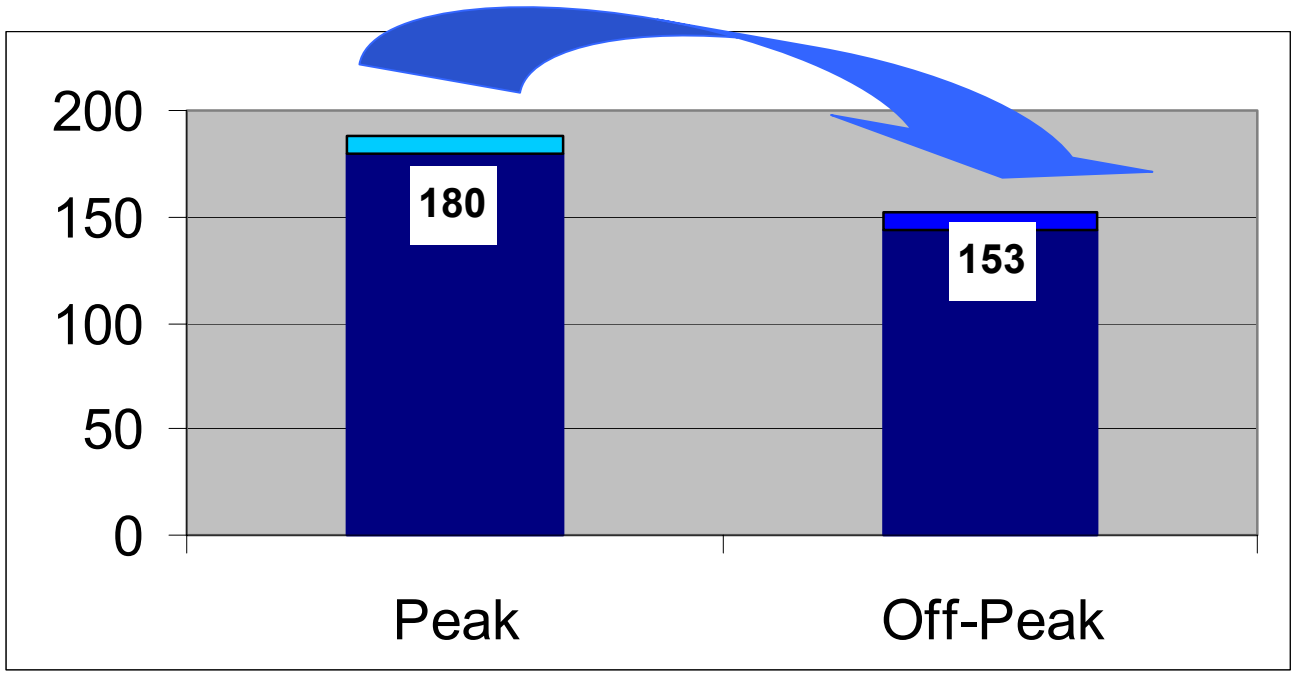
Electricity Demand: Base Case Scenario (TWh)



Peak/Off-Peak Demand Ratio = 1.31

The Effect of Peak/Off Peak Pricing (3)

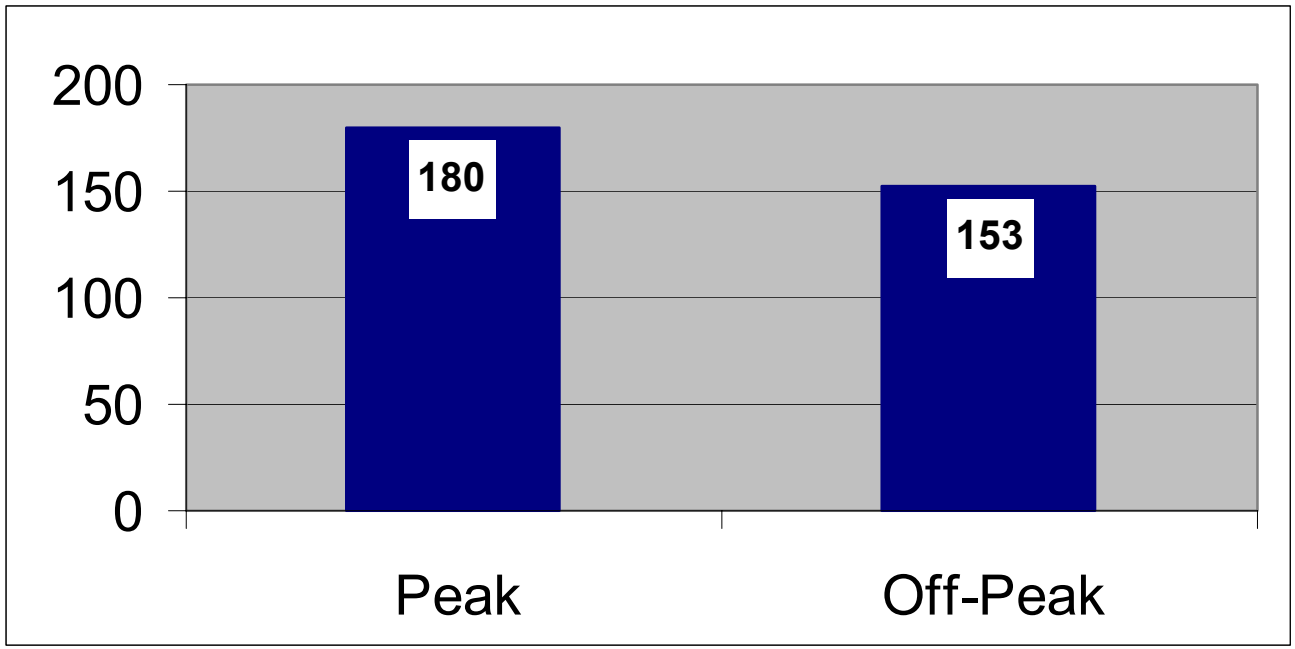
Electricity Demand: Demand Response Scenario (TWh)



Peak/Off-Peak Demand Ratio = 1.18

The Effect of Peak/Off Peak Pricing (4)

Electricity Demand: Demand Response Scenario (TWh)

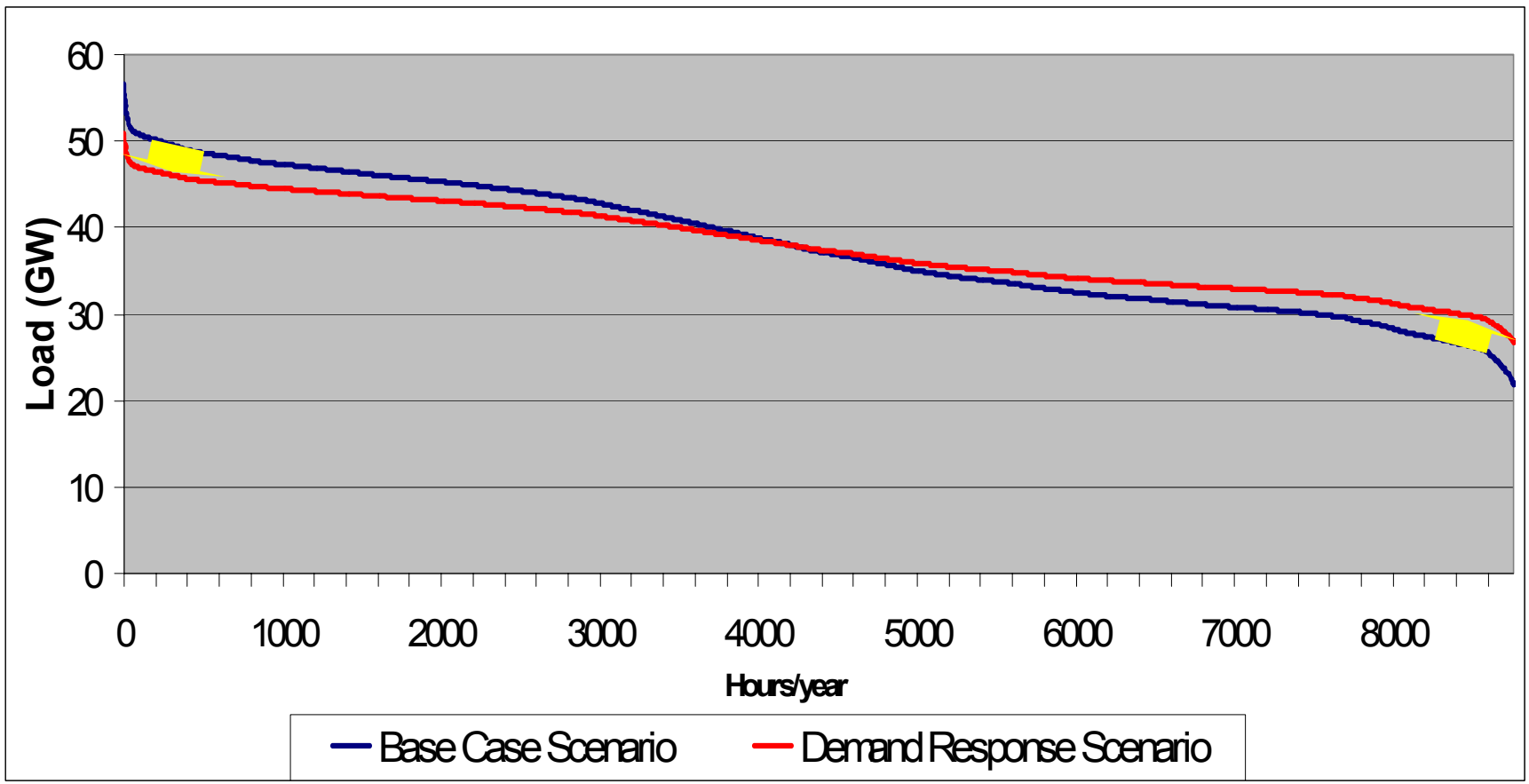


Peak/Off-Peak Demand Ratio = 1.18

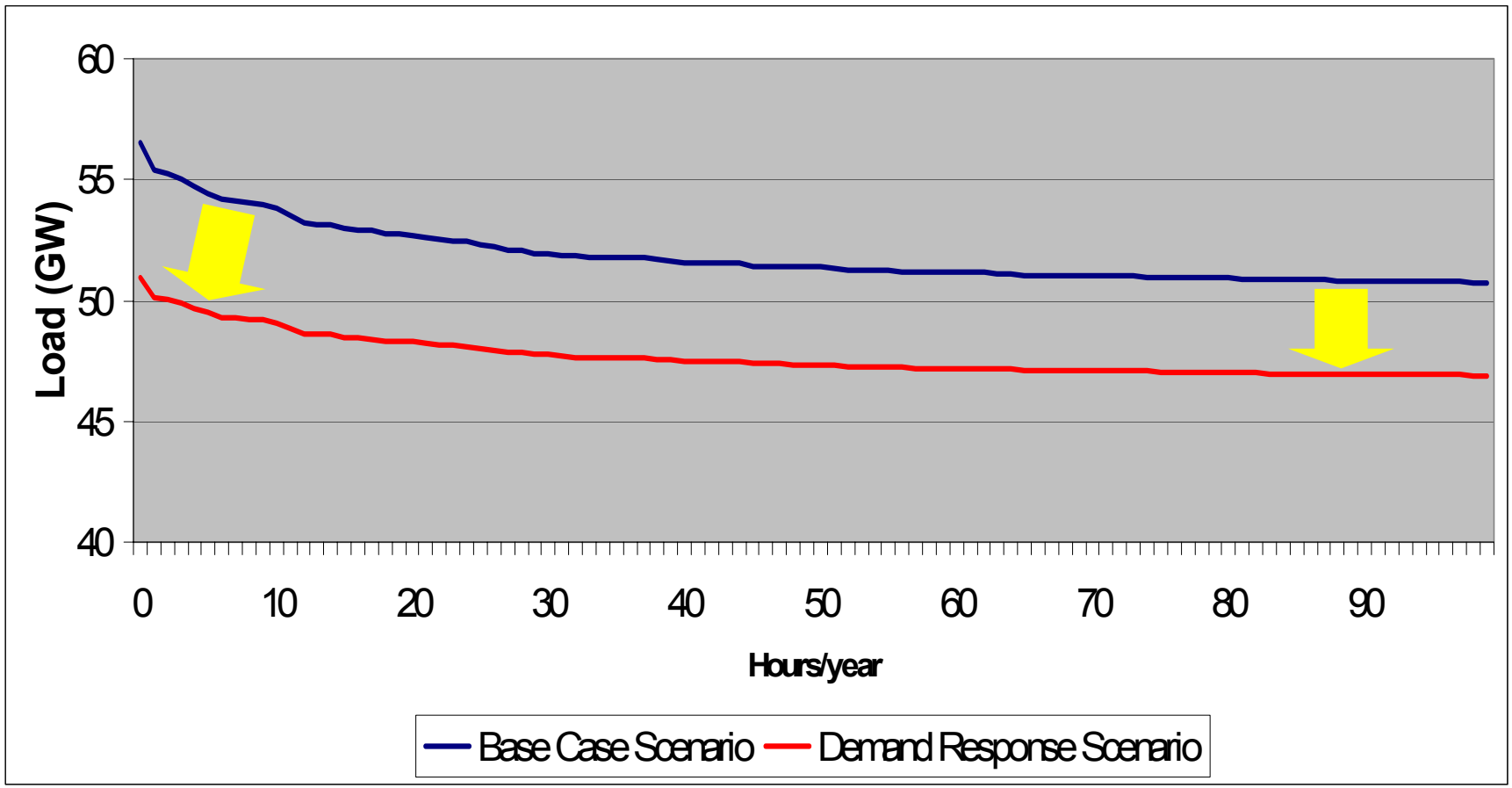
The Effect of Peak/Off Peak Pricing (5)

	Average Load (MW)	Minimum Load (MW)	Maximum Load (MW)	Electricity (TWh)
Base Case Scenario				
Peak	***44,730***	***37,956***	***56,514***	***188,5***
Off-Peak	***31,663***	***21,820***	***37,947***	***143,9***
Peak/Off-Peak	***1,413***	***1,740***	***1,489***	***1,310***
Demand Response Scenario				
Peak	***42,696***	***37,954***	***50,945***	***179,9***
Off-Peak	***33,549***	***26,659***	***37,948***	***152,5***
Peak/Off-Peak	***1,273***	***1,424***	***1,342***	***1,180***

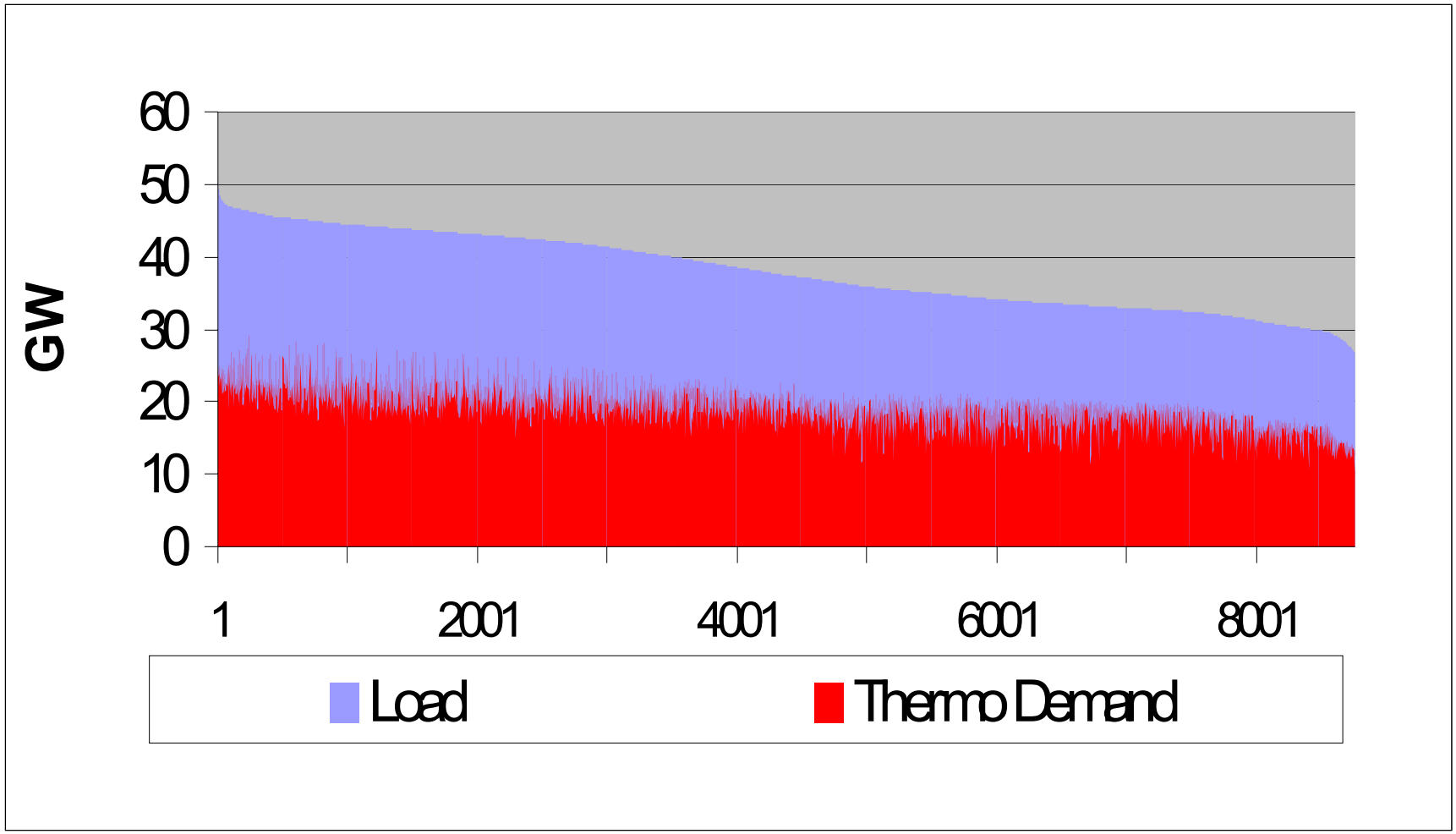
Effect of Peak/Off Peak Pricing on the Load Duration Curve



Effect of Peak/Off Peak Pricing on the Peak Load Duration Curve



Peak/Off Peak Pricing Scenario
Load Duration Curve



The Approach

- Analyse the effect of a 10% reduction in Peak/Off-Peak load ratio
  - Short term Effects: Optimal dispatch given current Italian plant mix
  - Longer-term Effects: Optimal generation capacity mix (comparative static analysis)
  - Profile of hydro, import and priority generation exogenously determined
  - Total demand and contribution from hydro, import and priority generation are constant
  - Therefore, focus on dispatched thermoelectric generation
  - Comparison/interaction with Emission Trading

El-fo optimal thermo dispatch model (1)

- ***El-fo*** (Electricity forecasting) model simulates optimal dispatch in order to determine the equilibrium in case of perfect competition among firms in the market
- The model considers all the Italian Transmission System Operator (GRTN) areas (North, Centre-North, Centre-South, South, Calabria, Sicily and Sardinia) and their inter-area transit constraints
- El-fo considers a series of generating sources that have dispatching or economic/contractual priority
    - Not programmable renewable sources
    - CHP
    - Sources supported by contracts with GRTN (CIP6 plants, micro generation)
    - Auto-production
    - Import
    - Programmable renewable sources with green certificates

El-fo optimal thermo dispatch model (2)

- The residual demand (total demand minus the generation from priority-dispatched plants) is satisfied by thermoelectric plants. By iterations El-fo minimises annual total cost of thermoelectric production and simulates optimal dispatch of each plant.
- The minimisation takes into account plants' variable costs, plants' technical constraints (start up time, ramps, maintenance period) and inter-area network constraints
- El-fo main outputs:
  - Hourly thermoelectric production and variable costs for each plant
  - Hourly marginal price (SMP) and average costs for each area
  - Hourly CO_2, NO_x, SO_x and PM emissions for each plant
  - Summary statistics from the above results

Generation Cost Assumptions

- Capital and O&M costs assumptions

	Capital cost, euro/MW	*O&M, euro/MW per year*	*Useful life, years*
New CCGT	490 000	24 500	20
Coal steam turbine	1 113 948	1 113 948	35
OCGT	326 000	326 000	20

- Annual fixed and variable costs

	Fixed cost [1], euro/MW per year	*Variable cost, euro/MWh*
New CCGT	74 399	39.6
Coal steam turbine	134 037	23.5
OCGT	42 982	76.3

[1] Annualized capital cost and O&M

- Annual fixed costs are based on IRR = 8%
- Variable costs are based on:
  - price of gas = 0.22 €/m^3
  - price of coal = 60 €/t

(Short Term) Effect of Peak/Off Peak Pricing on Generation Mix

(given current Italian plant mix)

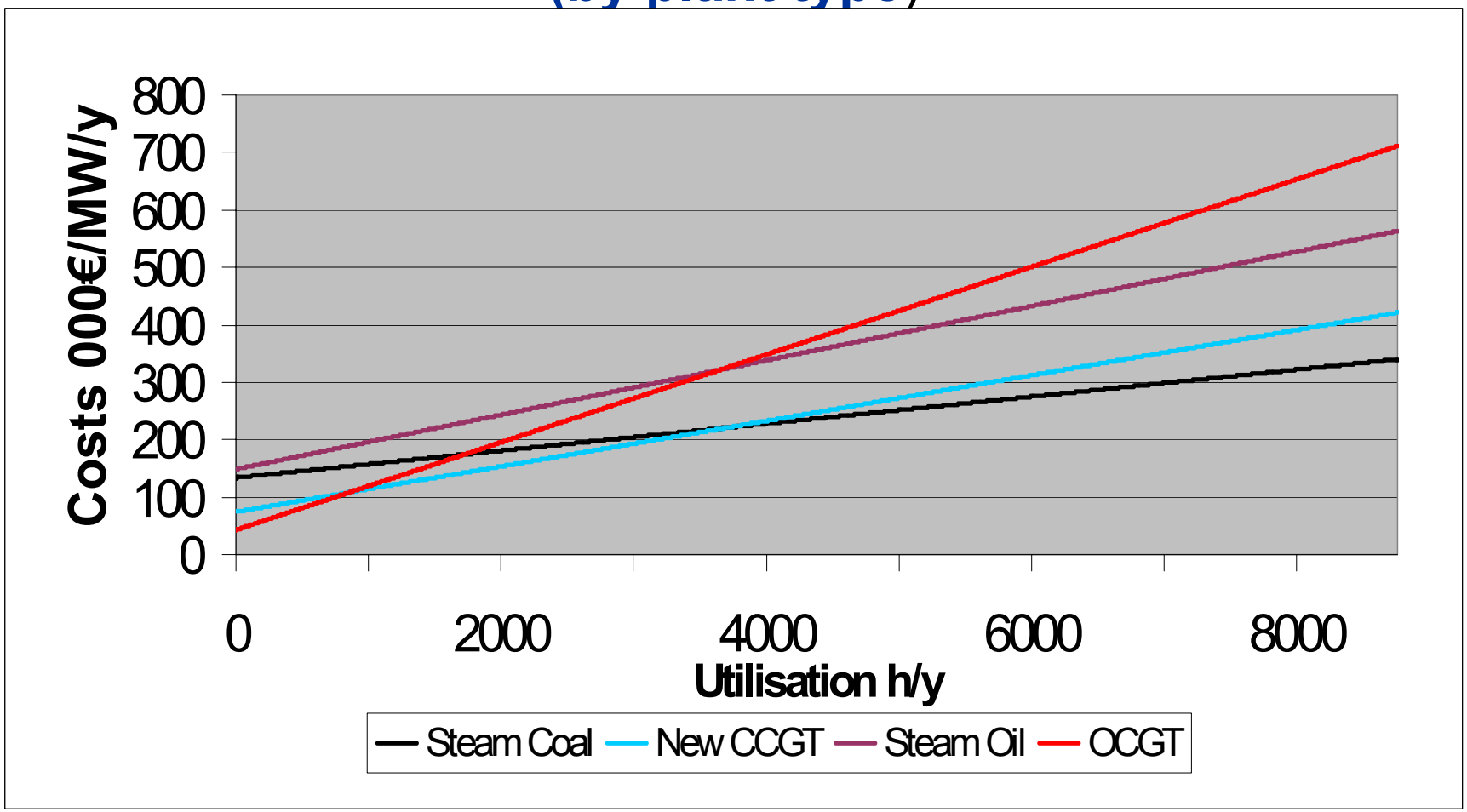
Electricity Generation (TWh)	Steam Coal	Steam Gas	Steam Oil	New CCGT	Old CCGT	OCGT	Others	Total
Without Emissions Trading								
Base Case Scenario	41.64	1.57	13.10	99.01	2.94	0.00	0.01	158.27
Demand Response Scenario	41.71	0.66	11.22	101.95	2.73	0.00	0.00	158.27
Difference	0.07	-0.90	-1.89	2.93	-0.21	0.00	0.00	0.00
With Emissions Trading - Allowances @15€								
Base Case Scenario	41.63	1.91	11.39	99.81	3.52	0.00	0.00	158.27
Demand Response Scenario	41.68	0.68	10.04	102.44	3.44	0.00	0.00	158.27
Difference	0.04	-1.23	-1.36	2.63	-0.08	0.00	0.00	0.00
With Emissions Trading - Allowances @30€								
Base Case Scenario	35.26	4.13	9.35	105.87	3.66	0.00	0.00	158.27
Demand Response Scenario	33.92	4.75	9.58	105.92	4.10	0.00	0.00	158.27
Difference	-1.34	0.62	0.23	0.05	0.44	0.00	0.00	0.00

(Short Term) Effect of Peak/Off Peak Pricing on CO2 Emissions

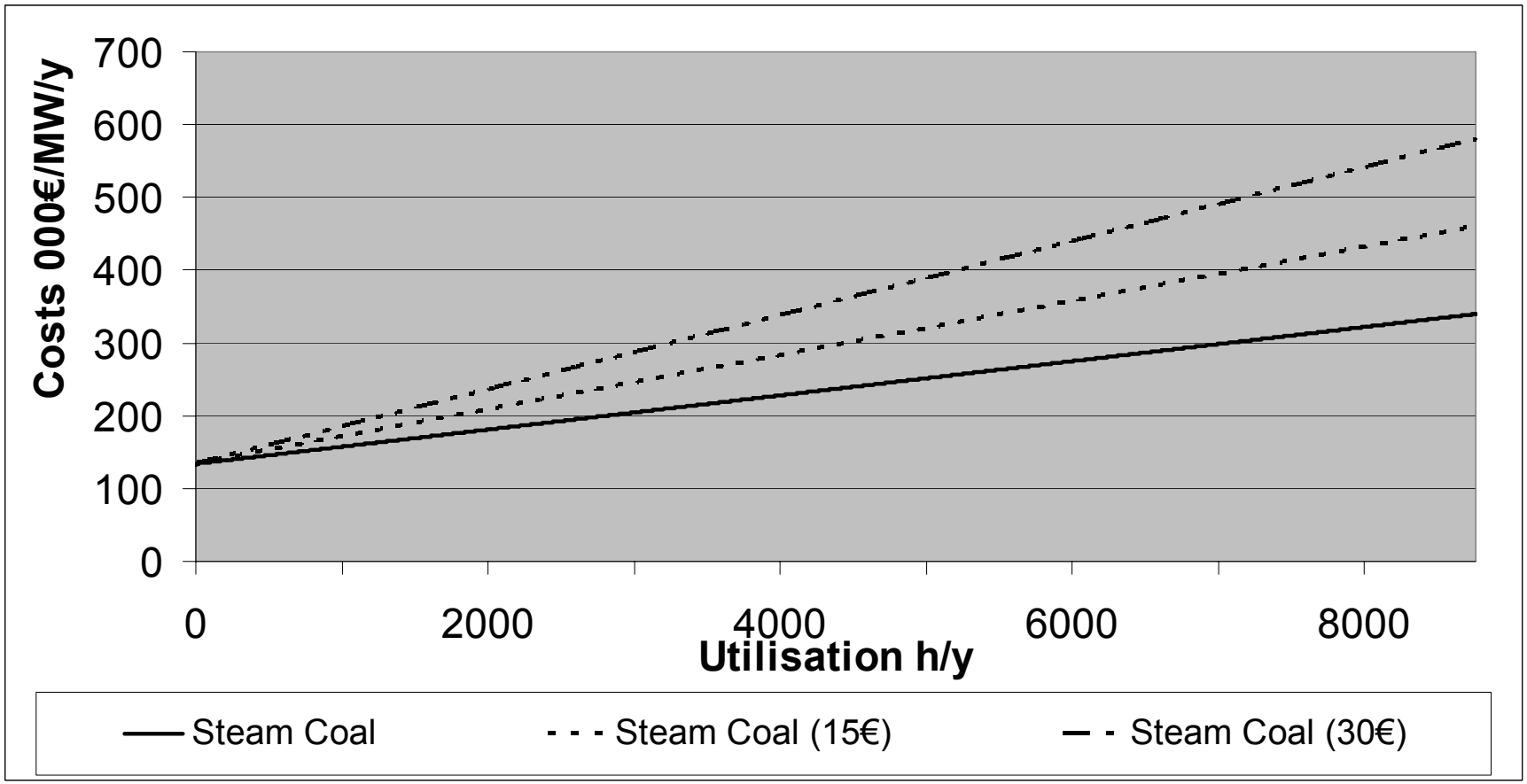
(given current Italian plant mix)

CO2 Emissions (million tonnes)	Steam Coal	Steam Gas	Steam Oil	New CCGT	Old CCGT	OCGT	Others	Total
Without Emissions Trading								
Base Case Scenario	36.92	1.13	10.44	39.19	1.39	0.00	0.00	89.08
Demand Response Scenario	36.98	0.53	8.86	40.29	1.28	0.00	0.00	87.95
Difference	0.06	-0.60	-1.58	1.09	-0.10	0.00	0.00	-1.13
With Emissions Trading - Allowances @15€								
Base Case Scenario	36.92	1.06	9.05	39.03	1.58	0.00	0.00	87.64
Demand Response Scenario	36.95	0.38	7.94	40.06	1.56	0.00	0.00	86.89
Difference	0.03	-0.69	-1.11	1.03	-0.02	0.00	0.00	-0.76
With Emissions Trading - Allowances @30€								
Base Case Scenario	31.31	2.29	7.35	41.08	1.60	0.00	0.00	83.63
Demand Response Scenario	30.11	2.63	7.55	41.12	1.80	0.00	0.00	83.22
Difference	-1.19	0.34	0.21	0.03	0.20	0.00	0.00	-0.41

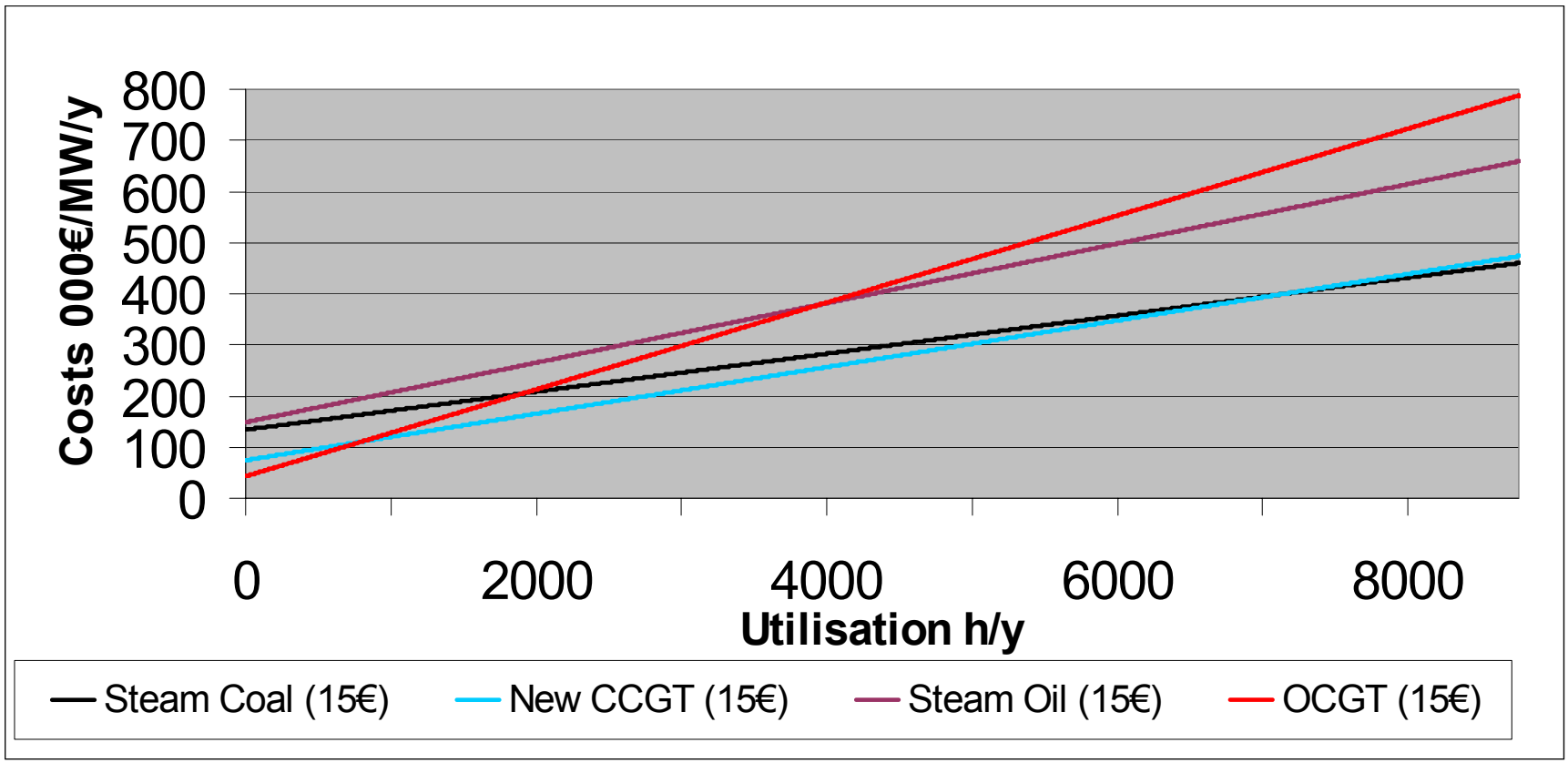
Generation Costs
(by plant type)



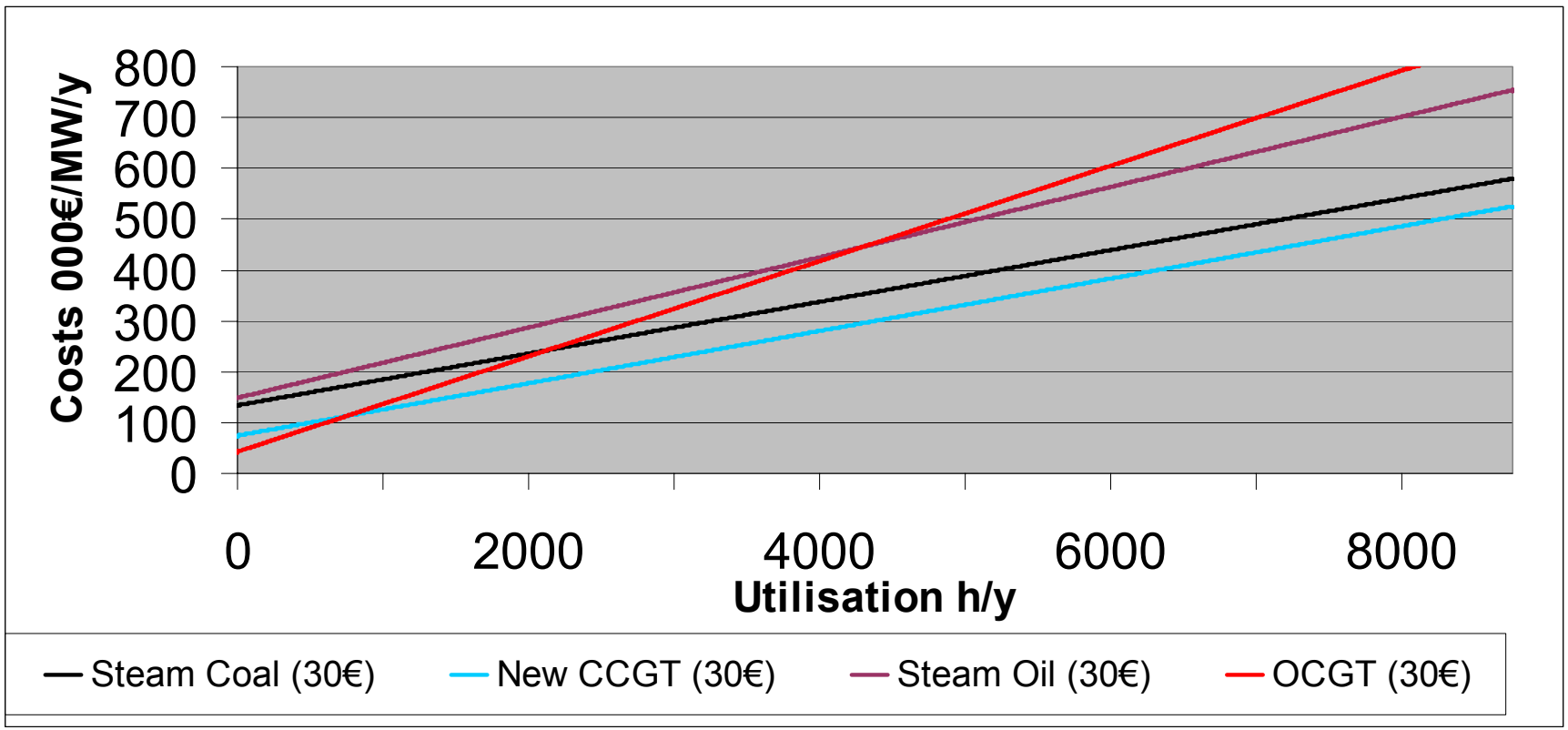
Effect of Emission Trading on Generation Costs



Generation Costs with Emission Trading (15€)
(by plant type)



Generation Costs with Emission Trading (30€)
(by plant type)



(Long-Term) Effect of Peak/Off Peak Pricing on Optimal Generation Capacity

Generating Capacity (GW)	Steam Coal	New CCGT	OCGT	Total
Without Emissions Trading				
Base Case Scenario	18.908	4.067	10.503	33.478
Demand Response Scenario	18.606	2.675	7.790	29.071
Difference	-0.302	-1.392	-2.713	-4.407
With Emissions Trading - Allowances @ 15€				
Base Case Scenario	14.676	8.491	10.311	33.478
Demand Response Scenario	15.898	5.518	7.655	29.071
Difference	1.222	-2.973	-2.656	-4.407
With Emissions Trading - Allowances @ 30€				
Base Case Scenario	0.000	23.331	10.147	33.478
Demand Response Scenario	0.000	21.541	7.530	29.071
Difference	0.000	-1.790	-2.617	-4.407

(Long-Term) Effect of Peak/Off Peak Pricing on Electricity Generation

Electricity Generation (TWh)	Steam Coal	New CCGT	OCGT	Total
Without Emissions Trading				
Base Case Scenario	148.318	8.349	1.606	158.272
Demand Response Scenario	151.734	5.362	1.176	158.272
Difference	3.416	-2.987	-0.429	0.000
With Emissions Trading - Allowances @15€				
Base Case Scenario	124.546	32.279	1.447	158.272
Demand Response Scenario	136.569	20.638	1.065	158.272
Difference	12.023	-11.641	-0.382	0.000
With Emissions Trading - Allowances @30€				
Base Case Scenario	0.000	156.951	1.321	158.272
Demand Response Scenario	0.000	157.304	0.969	158.272
Difference	0.000	0.352	-0.352	0.000

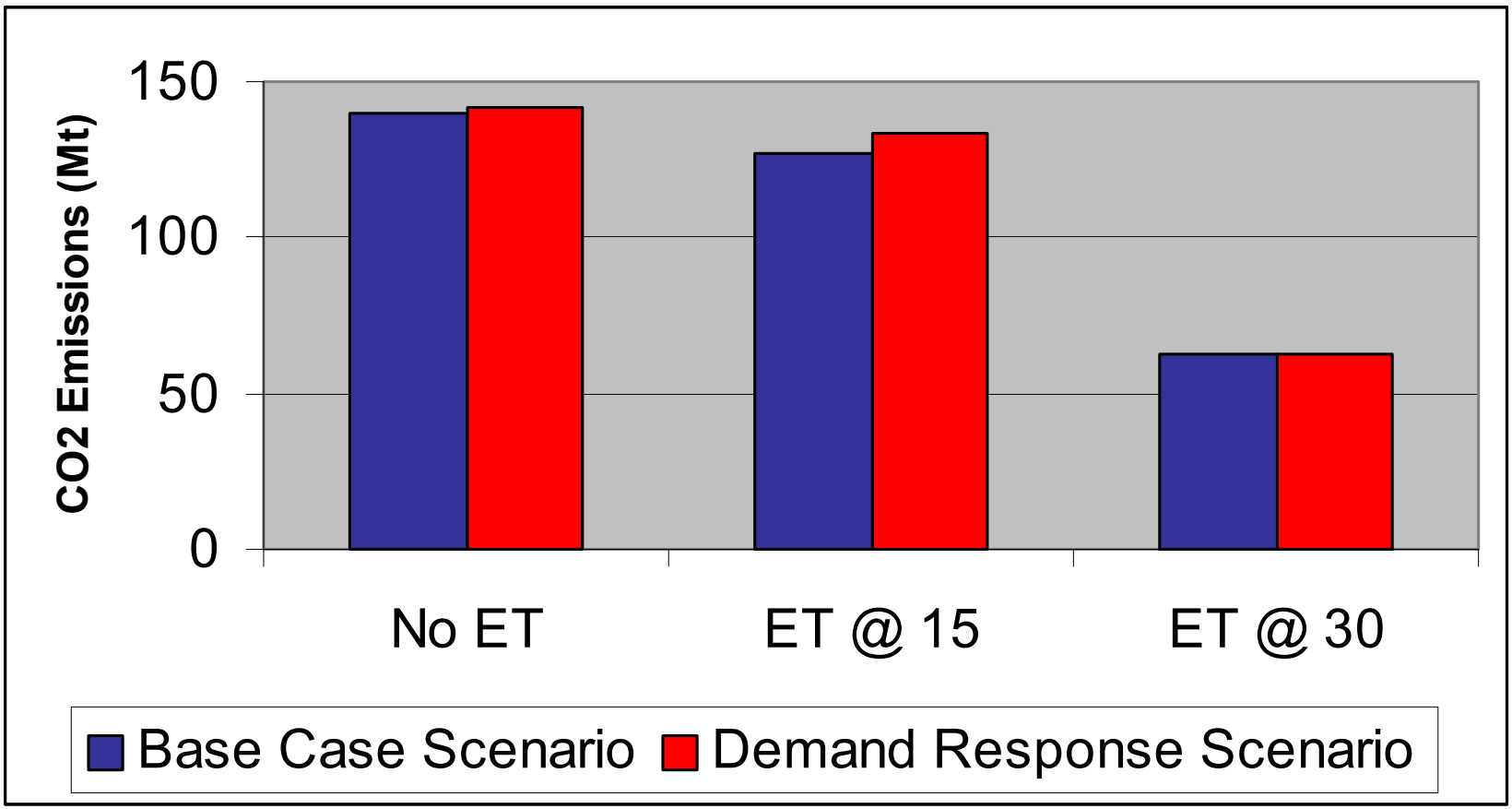
(Long-Term) Effect of Peak/Off Peak Pricing on Generation Costs

Generation Costs	Excluding Allowances Costs		Including Allowances Costs		Difference	
	Total (M€)	Average (€/MWh)	Total (M€)	Average (€/MWh)	Total (M€)	Average (€/MWh)
Without Emissions Trading						
Base Case Scenario	7,227	45.66	7,227	45.66	0	0.00
Demand Response Scenario	6,896	43.57	6,896	43.57	0	0.00
Difference	-331	-2.09	-331	-2.09		
	-4.59%	*-4.59%*	*-4.59%*	*-4.59%*		
With Emissions Trading - Allowances @ 15€						
Base Case Scenario	7,358	46.49	9,268	58.56	1,910	12.07
Demand Response Scenario	6,979	44.09	8,981	56.74	2,002	12.65
Difference	-379	-2.40	-287	-1.81		
	-5.15%	*-5.15%*	*-3.10%*	*-3.10%*		
With Emissions Trading - Allowances @ 30€						
Base Case Scenario	8,490	53.64	10,377	65.56	1,888	11.93
Demand Response Scenario	8,231	52.01	10,117	63.92	1,886	11.91
Difference	-259	-1.63	-261	-1.65		
	-3.05%	*-3.05%*	*-2.51%*	*-2.51%*		

(Long-Term) Effect of Peak/Off Peak Pricing on CO2 Emissions

CO2 Emissions (million tonnes)	Steam Coal	New CCGT	OCGT	Total
Without Emissions Trading				
Base Case Scenario	135.41	3.31	0.93	139.65
Demand Response Scenario	138.53	2.12	0.68	141.34
Difference	3.12	-1.18	-0.25	1.69
With Emissions Trading - Allowances @15€				
Base Case Scenario	113.71	12.78	0.84	127.33
Demand Response Scenario	124.69	8.17	0.62	133.48
Difference	10.98	-4.61	-0.22	6.15
With Emissions Trading - Allowances @30€				
Base Case Scenario	0.00	62.15	0.76	62.92
Demand Response Scenario	0.00	62.29	0.56	62.85
Difference	0.00	0.14	-0.20	-0.06

(Long-Term) Effect of Peak/Off Peak Pricing on CO2 Emissions



DRM offset approx. 50% of the emissions reduction from ET @ 15€

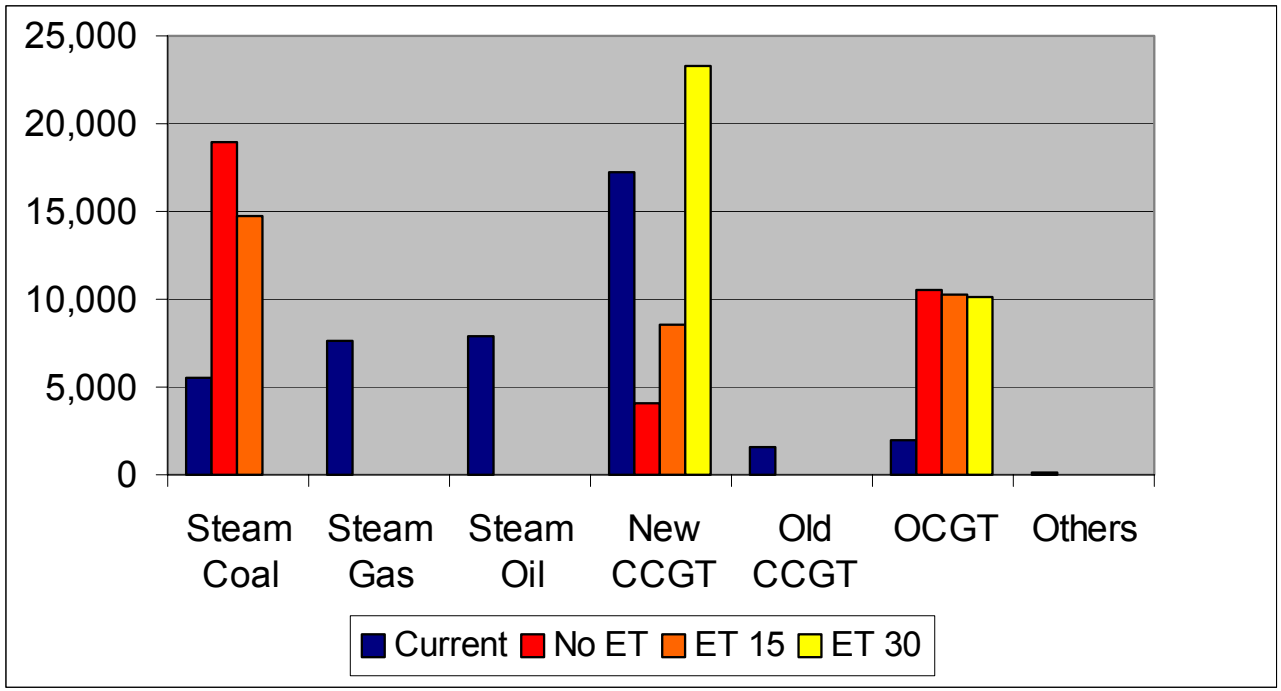
Conclusions

- Do Demand Response Measures (DRM) lead to higher utilisation of base-load, lower-cost but more-polluting generation technologies, and therefore to higher emissions?

- The answer depends on the time horizon and, in the short term, on the generation capacity mix
- Our findings, based on the analysis of the Italian Electricity Sector, suggest that a 10% reduction in Peak/Off-Peak demand ratio:
  - In the Short Term, reduces CO2 emissions by between 0.5% (with ET and P = 30 €/tCO2) and 1.3% (without ET)
  - In the Longer Term, the change in plant/generation mix:
    - increases CO2 emissions by 1%, without ET
    - increases CO2 emissions by 5%, with ET and P = 15 €/tCO2
    - has no appreciable effect on CO2 emissions, with ET and P = 30 €/tCO2

Italian Thermoelectric Generation Capacity

(MW)



Generation Capacity (MW)	Current	Optimal		
		No ET	ET 15	ET 30
Steam Coal	5,528	18,908	14,676	0
Steam Gas	7,583			
Steam Oil	7,830			
New CCGT	17,282	4,067	8,491	23,331
Old CCGT	1,613			
OCGT	1,942	10,503	10,311	10,147
Others	69			
Total	41,847	33,478	33,478	33,478

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Thank you for your attention

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