European Energy Roadmap to 2050
Role of Electricity Storage

PROF. PANTELIS CAPROS
E3MLAB, SCHOOL OF ELECTRICAL AND COMPUTER ENG., NTUA

WORKSHOP IN THE CONTEXT OF PROJECT STORE
NTUA, ATHENS NOVEMBER 29, 2013

Context of research

The PRIMES energy system model (E3MLab) has been used to simulate alternative energy scenarios to 2050 which aim at decreasing GHG emissions in the EU by 80% in 2050 from 1990 levels

The scenarios have been used in the European Commission Energy Roadmap 2050 published 2011-2012

Among the scenarios, a very high renewables case projects almost 100% power generation from renewables

In this context, PRIMES carried out additional sensitivity analysis and further research on the role of storage systems to deliver a reliable power system with maximum RES, notable variable RES

Model coverage

We use the power generation sub-model of PRIMES which runs with the demand sub-models to simulate power market equilibrium

The power model is multi-annual simulating dispatching, capacity expansion (inter-temporal) and electricity pricing

The model represents the entire European continent (35 countries) system with load/generation nodes by countries and almost 300 interconnectors

The model solves for all EU MS countries simultaneously connected by a DC linearized power flow under reliability constraints and dynamically up to 2050

Load variability represented by typical winter and summer days

Variable RES handled as deterministic power outputs varying by load segment

Model coverage

Wind

- Onshore categorized according to wind speed
- Distinction of very small wind onshore
- Offshore wind (also categorized) linked with DC lines to the shore
- Remote offshore wind in North Sea and Atlantic Ocean also included in potentials, depending on sea depth

Solar

- Solar PV categorized according to radiation intensity
- Distinction of small scale Solar PV (roof)
- CSP solar included depending on radiation

In some scenarios the model includes connections to North Africa and large scale development of solar CSP and wind for exporting to the EU

Also, geothermal, tidal, wave, and

Hydro, biomass in detail (many types of feedstock and technologies)

The model includes thermal generation technologies in detail and solves simultaneously for power sector and cogeneration

Model coverage

Storage possibilities modeled endogenously)

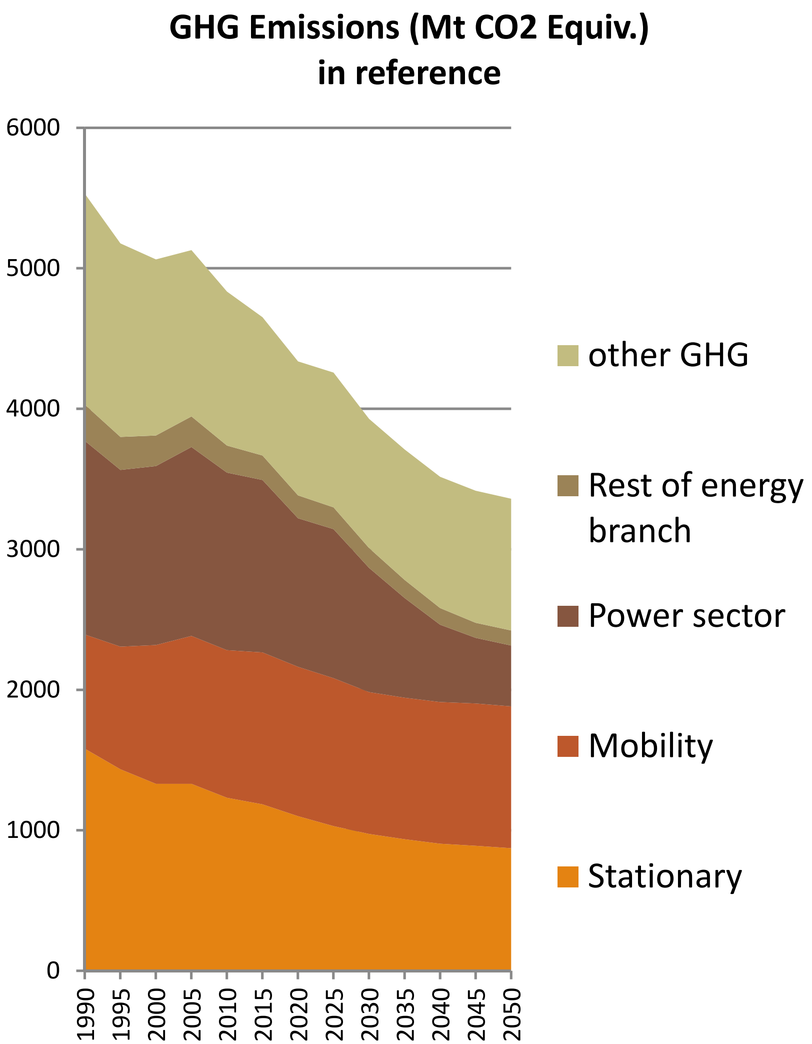
- Hydro Pumping (according to potentials)
- Hydrogen from electrolysis when RES exceed demand and hydrogen use in gas turbines to generate when RES is lower than demand
- Hydrogen from electrolysis mixed (up to 30%) in gas pipelines
- Air-compressed storage (very limited developments due to low availability of underground areas for storage)

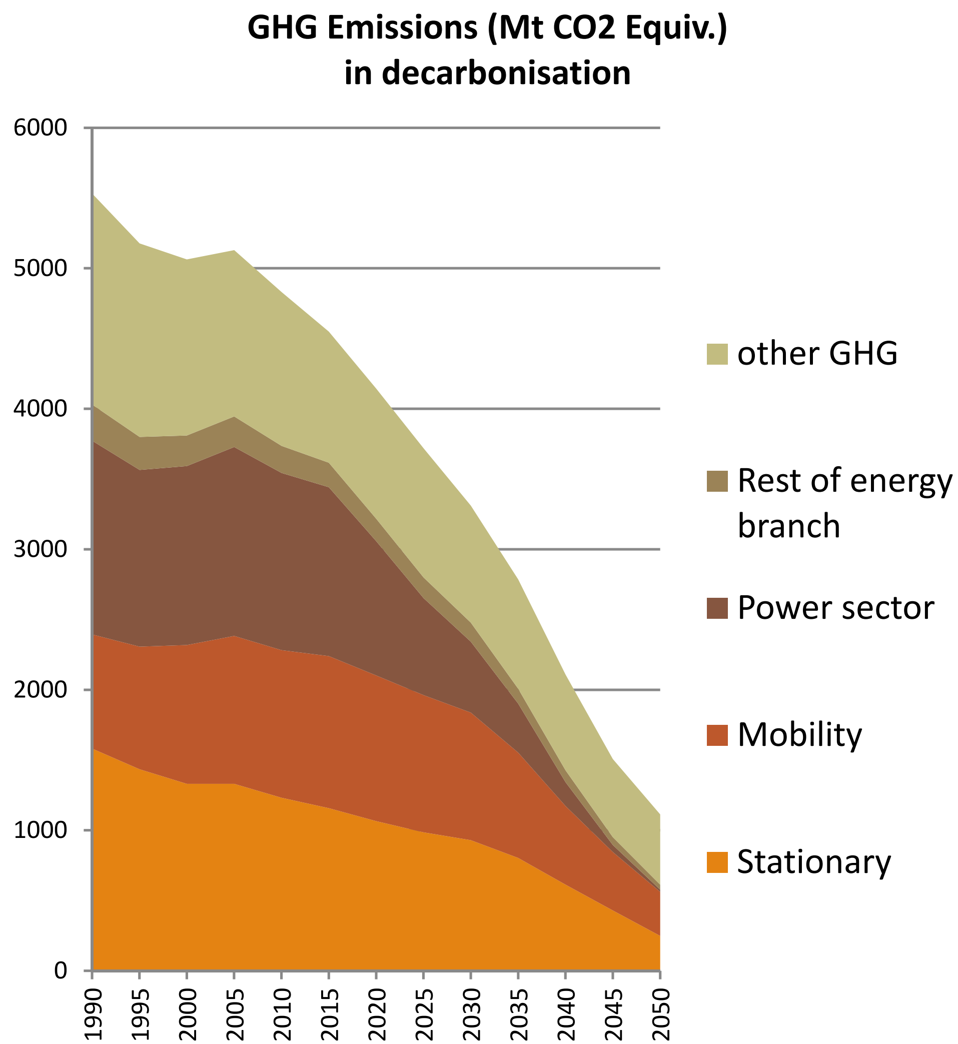
Endogenous transmission grid expansion (only for DC lines) to maximize RES power flows from North Sea (and North Africa in one scenario) and also maximize use of these RES in low RES EU countries

Demand-side response mechanisms including smart metering and intelligent recharging of electric vehicles

REFERENCE

DECARBONISATION

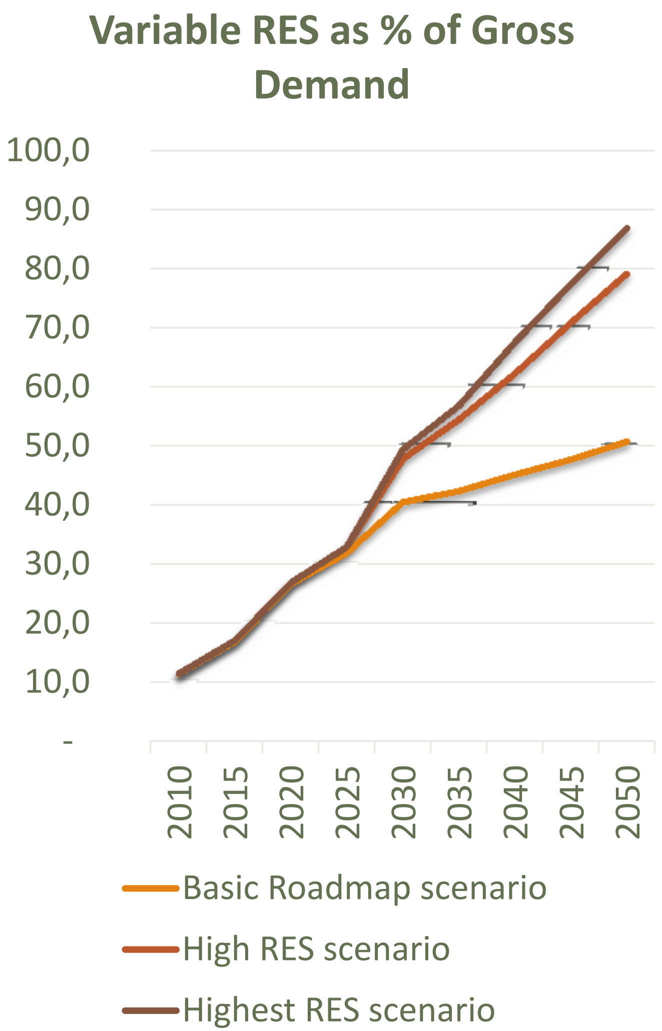


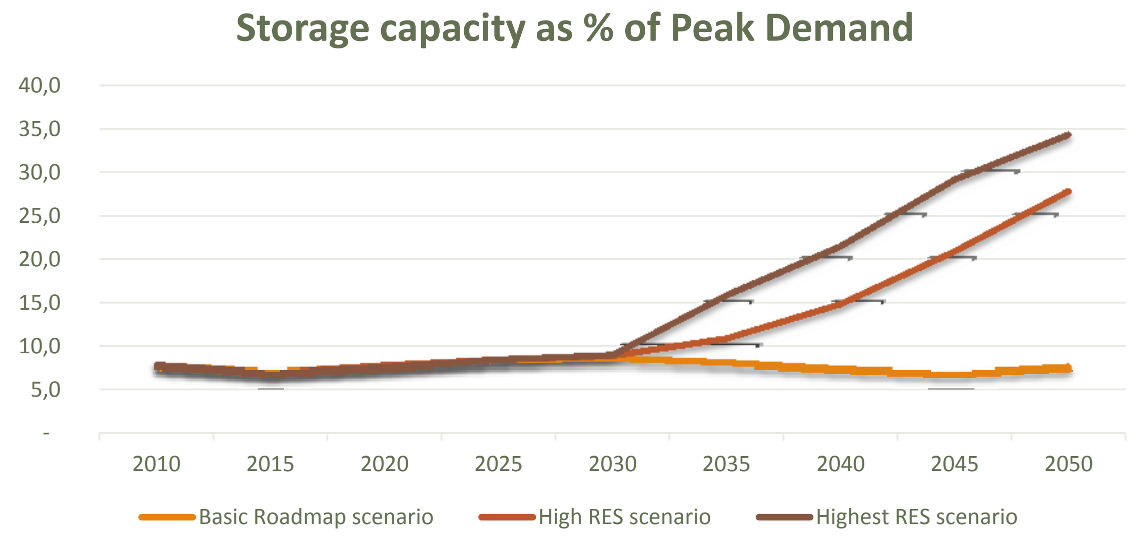


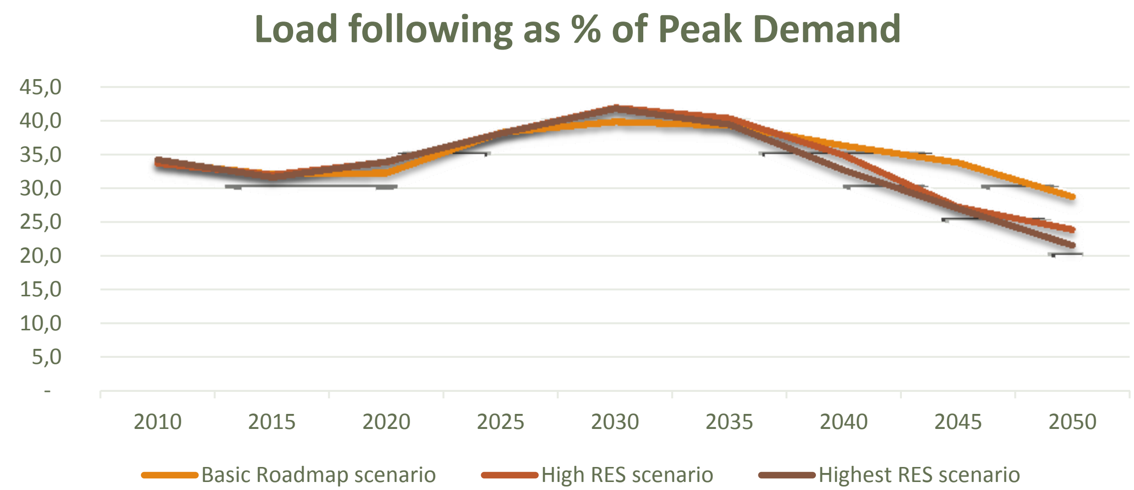
Common Policies for Decarbonisation

- Power generation becomes almost emission free by 2050; emission reduction is strong already in 2030
- Renewables in all sectors develop strongly and are further supported and facilitated
- Energy efficiency improvement policies strongly develop for buildings, appliances and other equipment
- Electric mobility in road transport and electrification in heat uses
- Crops and waste management for bio-energy
- Internal market network infrastructure, smart grids
- Strong R&D support ensuring learning

High RES implies strong development of storage







Sensitivity Analysis-High RES

Ambitious GHG emission reduction target (-80% by 2050)

Sensitivity analysis for a range of RES penetration targets in power generation with various options: H for hydrogen, DC for a DC super grid development

		Quantified scenarios with PRIMES			
		None	Only H	Only DC	Both
RES penetration	60%	60	60-H	60-DC	60-full
	70%	70	70-H	70-DC	70-full
	80%	80	80-H	80-DC	80-full
	90%	90	90-H	90-DC	90-full

Impacts on RES production

RES curtailment as percentage of potential RES					
		Quantified scenarios with PRIMES			
		None	Only H	Only DC	Both
RES penetration	60%	1.8%	1.7%	1.7%	1.6%
	70%	5.1%	1.9%	3.4%	1.7%
	80%	7.4%	2.9%	5.0%	2.4%
	90%	33.8%	4.1%	12.0%	2.9%

RES curtailment is rather small except if RES penetration is at 90% and none of the moderators develop

The hydrogen system alone is sufficient to avoid RES curtailment

Developing only the DC super grid avoids RES curtailment at high extent but cannot fully handle the 90% RES case

Combining the moderators keeps RES curtailment very low

Model Results

Thermal back-up and reserve capacity as percentage of peak demand in 2050					
		Scenarios quantified with PRIMES			
		None	Only H	Only DC	Both
RES penetration	60%	22.4	21.6	21.5	21.1
	70%	24.6	22.3	23.3	21.5
	80%	28.8	23.6	26.9	22.2
	90%	31.1	24.6	30.1	22.0

Increase of RES penetration increases the need for scarcely used thermal capacities (mostly gas turbines develop and old thermal kept in cold reserve)

More smooth load curve thanks to hydrogen energy storage reduces the need for thermal reserve capacity

Developing only the DC super grid is not sufficient to lead to lower thermal capacity reserves

The combination of both moderators keeps thermal reserve capacity unchanged (at 21-22%) despite increase of RES penetration in the power system

Model results – cost implications

Relative total electricity supply cost for period (2030 to 2050) expressed as percentage change over the cost of scenario 60-both

		Quantified scenarios with PRIMES			
		None	Only H	Only DC	Both
RES penetration	60%	101.4	101.2	100.0	**100.0**
	70%	108.2	105.6	103.6	103.5
	80%	122.3	111.6	110.4	108.9
	90%	137.3	120.1	126.2	116.9

- Enhancement of transmission system reduces costs (compare column only DC to column None)
- Hydrogen storage system reduces cost (Only H versus None)
- Presence of both moderators most cost effective

High Penetration of Renewable Energy Sources – Conclusions

- Developing RES at levels above 90% in power generation is very costly without storage systems and/or DC super-grid systems
- Hydro-pumping (large-scale) is the first priority but potential is limited and non sufficient to support RES at very large scale
- Advanced storage systems, such as hydrogen-based studied in this paper, are absolutely required for very high RES penetration (80% and above)
- The combination of DC super-grid and hydrogen is very cost-effective and leads to low thermal capacity reserve requirements
- Energy storage other than hydro pumping and hydrogen deserve further examination

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THANK YOU FOR YOUR ATTENTION