

# Long-term Grid Infrastructure Integration Strategies of Renewable Electricity Generation Technologies in Europe up to 2050

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## 1. Cornerstones of the Project SUSPLAN

Objectives, Innovation, Selection of Regions, ...

## 2. Methodology: RES-E Grid Integration Scenarios

Storyline Approach, Empirical Setting of Key Parameters, ...

## 3. Modelling Long-Term RES Potentials, Barriers and Grid Infrastructure Routes in the Different Regions

GreenNet, eTransport, ...

## 4. Selected Scenario Results in Different Regions: Electricity Grid Investments = f (RES-E Deployment)

Norway, Spain, Austria, ...

## 5. Synthesis of Results & Conclusions

## 1.1 Objectives

- Development, modelling and evaluation of **long-term RES grid integration scenarios** at regional and trans-national level
- Evaluation, comparison and synthesis of results from the scenarios to identify **best development paths** for grid integration of RES at regional and trans-national level
- **Establishment of an advanced toolbox** to support RES grid integration scenarios by combining the best available tools and knowledge
- **Establishment of implementation strategies** for decision makers at regional and trans-national level by generalizing results and experiences from the scenario studies
- **Dissemination of results**

## 1.2 Selection of Regional Scenario Studies

### ■ Islands

- Large RES-E Potentials
- Isolated, Weak Grids
- No Loads

### ■ Northern Europe

- Almost 100% Hydro Generation
- High Potentials of Hydro & Wind
- Not Needed to Meet National Loads

### ■ West/Central Europe

- Low RES-E Potentials inside Region
- Multiple Energy Grid Infrastructure
- High Loads (Dense Area)

### ■ North-East

- Coal Dominated Energy/Electricity System (Less Flexible)
- High Shares of Wind
- Massive Investments into Energy Sector Needed

### ■ South-East

- Energy System with Poor Efficiency
- Partly Obsolete Grid Infrastructure
- High RES-E Potentials (Wind, Hydro)

### ■ South-West

- Already High Wind Generation
- Further High Wind Potentials/Ambitions
- Weak Transmission Grids/Interconnections

### ■ South

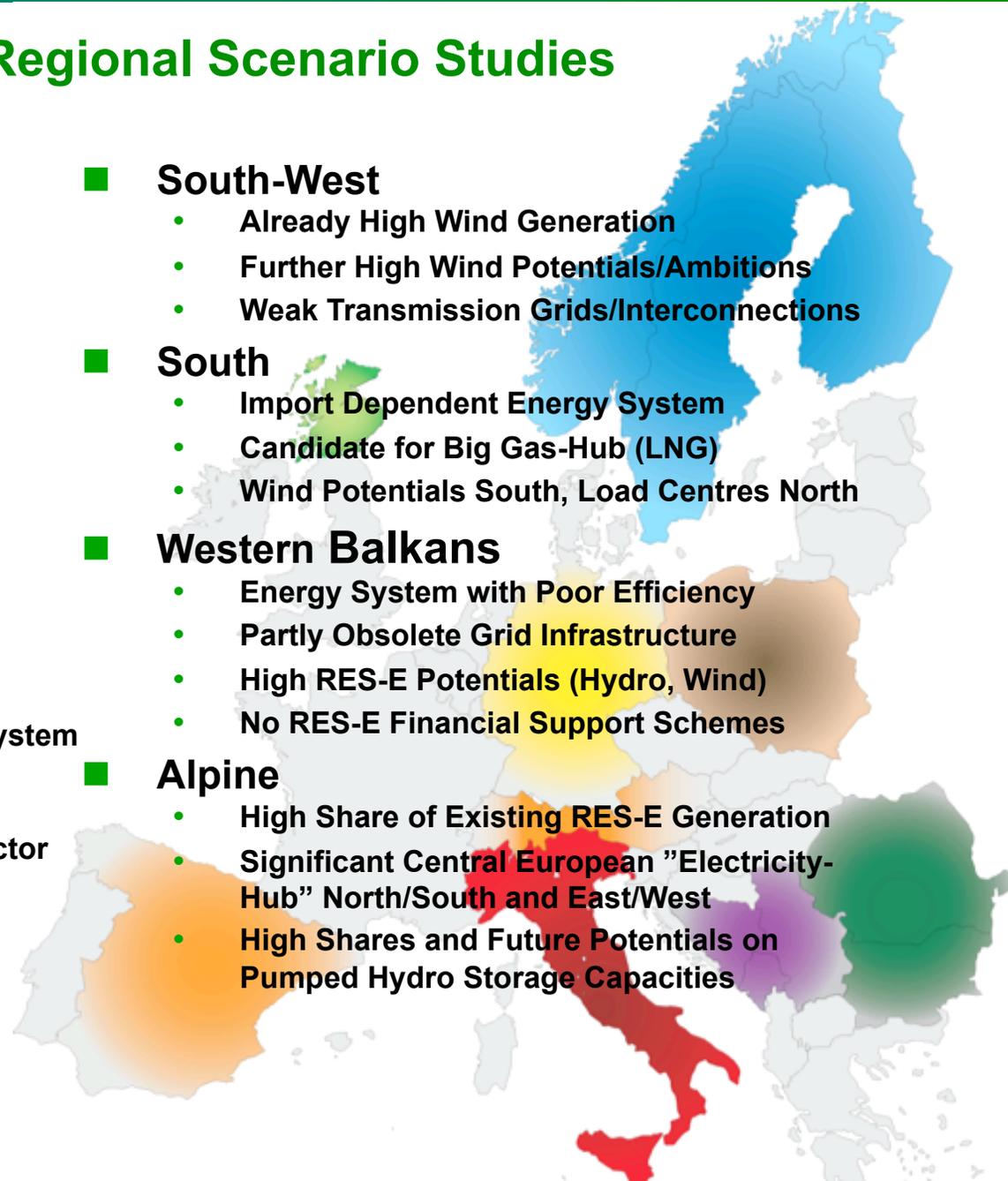
- Import Dependent Energy System
- Candidate for Big Gas-Hub (LNG)
- Wind Potentials South, Load Centres North

### ■ Western Balkans

- Energy System with Poor Efficiency
- Partly Obsolete Grid Infrastructure
- High RES-E Potentials (Hydro, Wind)
- No RES-E Financial Support Schemes

### ■ Alpine

- High Share of Existing RES-E Generation
- Significant Central European "Electricity-Hub" North/South and East/West
- High Shares and Future Potentials on Pumped Hydro Storage Capacities



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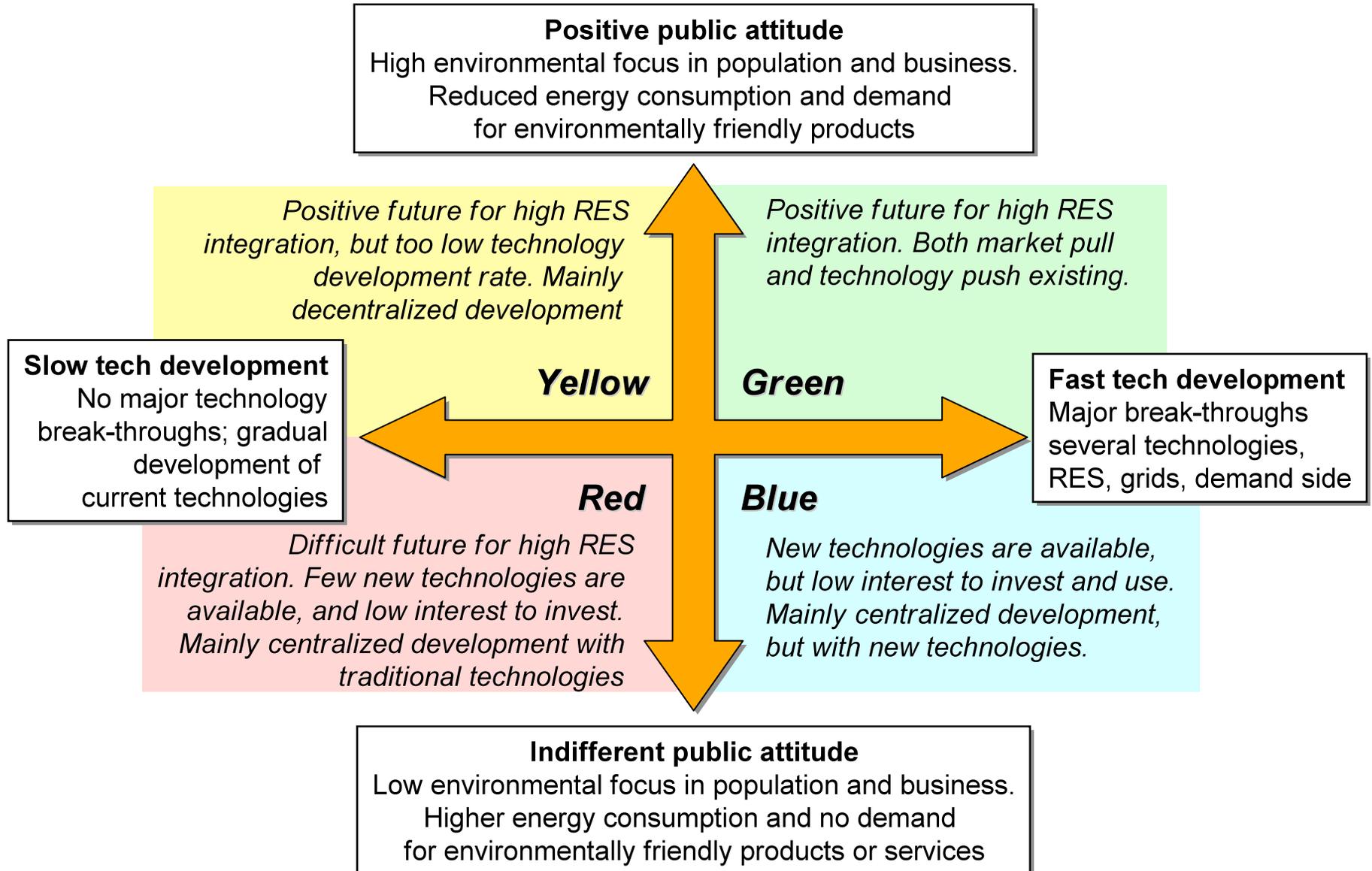
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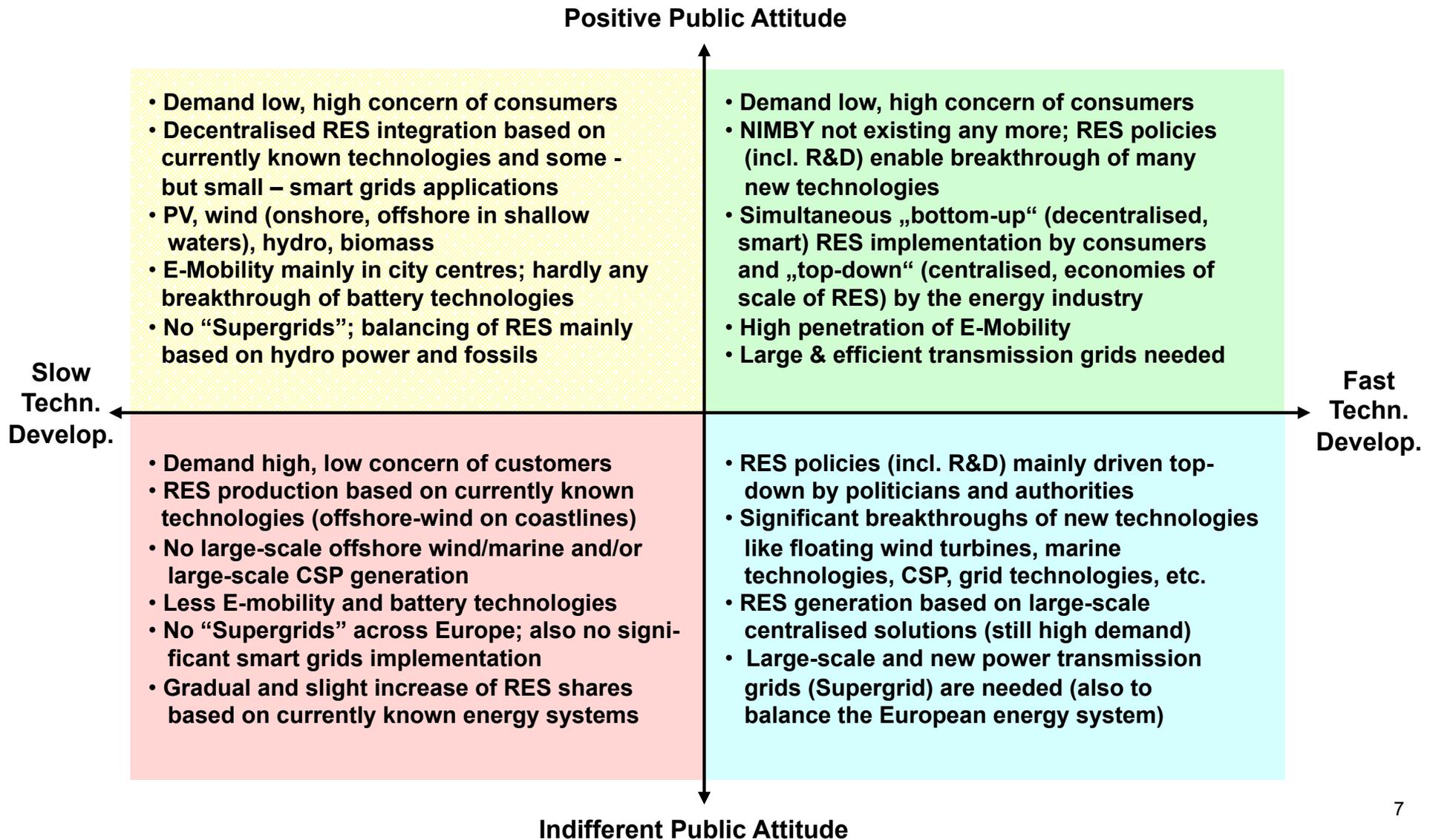
Norway, Spain, Austria, ...

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## 2.1 Dimensions Describing 4 Different Storylines

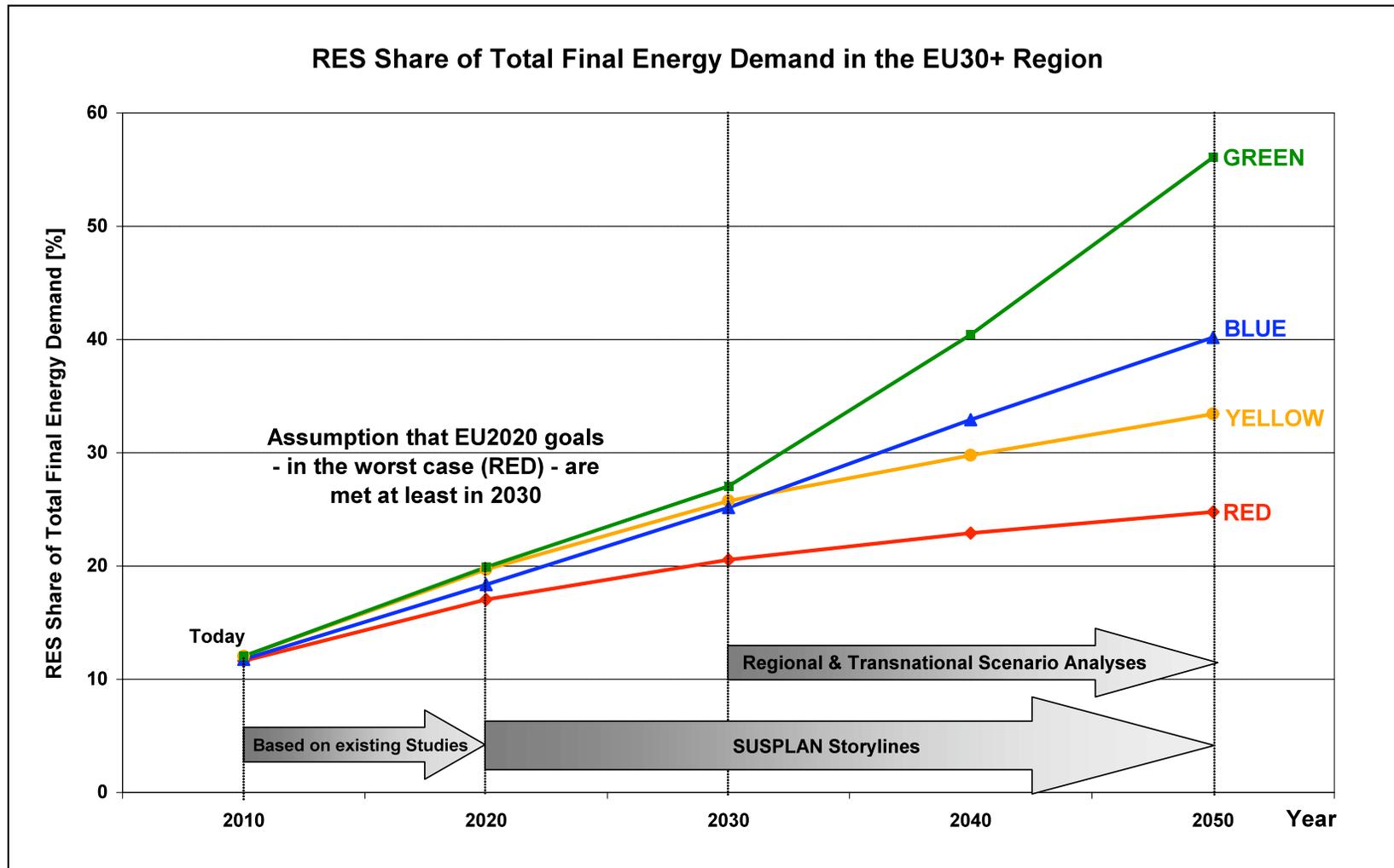


## 2.2 RES Grid Integration Philosophy in the 4 Different Storylines



## 2.3 Consistent Empirical Data Set for Scenario Analyses

### RES-Shares in the Time Horizon (2050) of Scenario Analyses



Until 2030: Green-X

## Prices (Fossil Fuels, CO<sub>2</sub>) in the Time Horizon (2050) of Scenario Analyses

Positive Public Attitude

WEO2009 "450 ppm Scenario" (\$2008 Prices)	2008	2015	2020	2025	2030	2035	2040	2045	2050
IEA crude oil imports (\$/bbl)	97,2	86,7	90,0	90,0	90,0	90,0	90,0	90,0	90,0
Natural gas imports (\$/Mbtu PCS)	10,3	10,5	11,0	11,0	11,0	11,4	11,4	11,4	11,4
Natural gas imports (\$/Mbtu PCI)	11,5	11,6	12,3	12,3	12,3	12,3	12,3	12,3	12,3
Natural gas imports (\$/MWh PCI)	39,2	39,7	41,9	41,9	41,9	41,9	41,9	41,9	41,9
OECD steam coal imports (\$/t)	120,6	85,6	80,1	72,5	64,8	57,2	49,6	41,9	34,3
OECD steam coal imports (\$/MWh)	16,5	11,7	10,9	9,9	8,8	7,8	6,8	5,7	4,7

Lower demand of Fossils in Yellow/Green than Red/Blue -> Lower Price Level

WEO2009 "Reference Scenario" (\$2008 Prices)	2020	2030	2040	2050
CO <sub>2</sub> Price [\$/tCO <sub>2</sub> ]	43	54	65	76

Public adapts production and consumption of energy themselves in a sustainable way; CO<sub>2</sub> market less important instrument and, therefore, prices are lower

Slow  
Techn.  
Develop.

Fast  
Techn.  
Develop.

WEO2009 "Reference Scenario" (\$2008 Prices)	2008	2015	2020	2025	2030	2035	2040	2045	2050
IEA crude oil imports (\$/bbl)	97,2	86,7	100,0	107,5	115,0	122,5	130,0	137,5	145,0
Natural gas imports (\$/Mbtu PCS)	10,3	10,5	12,1	13,1	14,0	15,0	15,9	16,9	17,8
Natural gas imports (\$/Mbtu PCI)	11,5	11,6	13,5	14,6	15,6	16,7	17,7	18,8	19,8
Natural gas imports (\$/MWh PCI)	39,2	39,7	45,9	49,7	53,2	56,8	60,4	64,0	67,6
OECD steam coal imports (\$/t)	120,6	91,1	104,2	107,1	109,4	112,0	114,5	117,0	119,5
OECD steam coal imports (\$/MWh)	16,5	12,4	14,2	14,6	14,9	15,3	15,6	16,0	16,3

Higher demand of Fossils in Red/Blue than Yellow/Green -> Higher Price Level

WEO2009 "450 ppm Scenario" (\$2008 Prices)	2020	2030	2040	2050
CO <sub>2</sub> Price [\$/tCO <sub>2</sub> ]	50	100	125	150

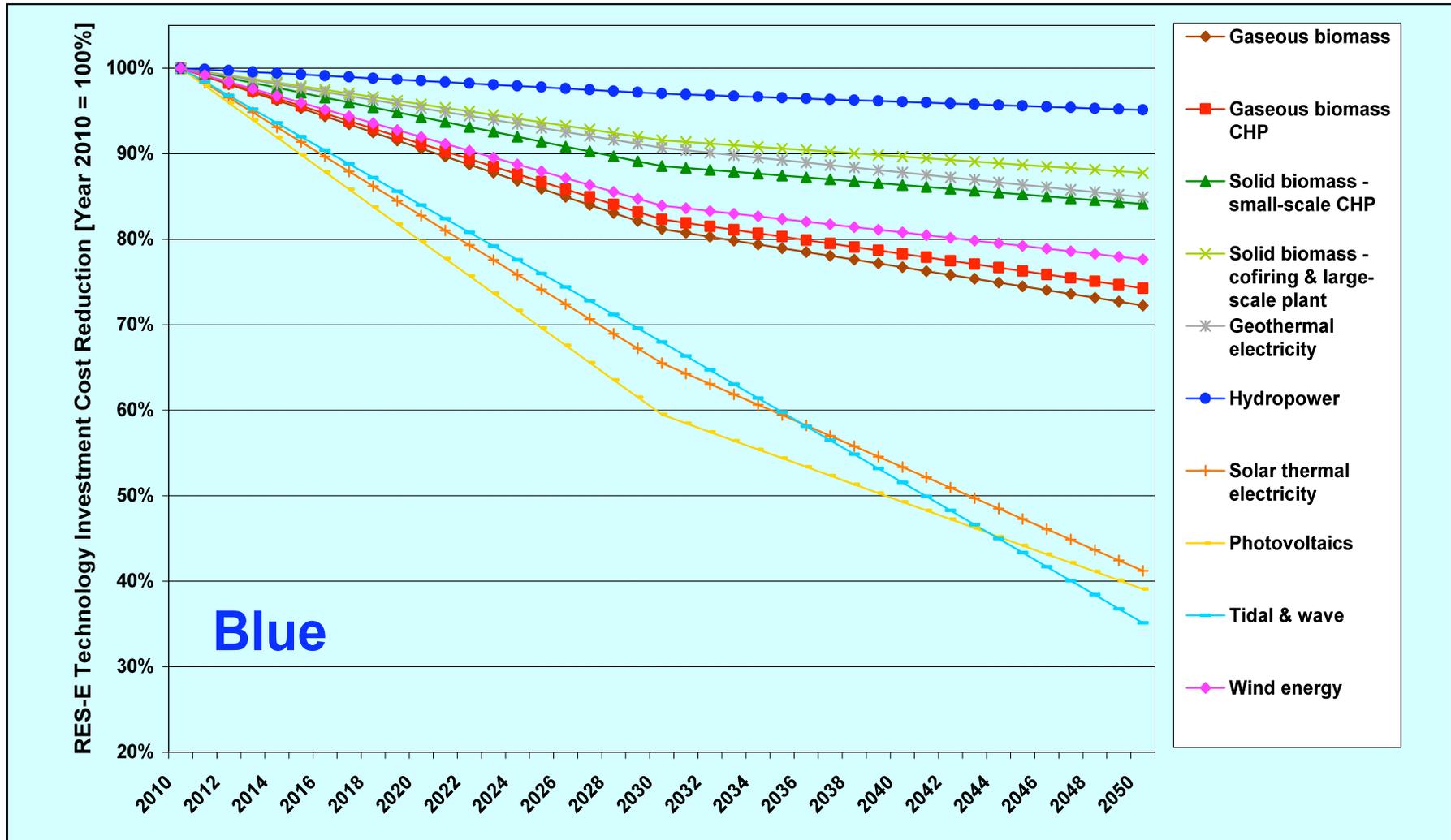
High CO<sub>2</sub> market price is important instrument (for authorities) to influence production and consumption of energy (due to indifferent „public“)

Indifferent Public Attitude

Until 2030: WEO2009 (cross-check with others like EC/EET based on PRIMES; DOE/AOE 2009)

## 2. Methodology

### Example: RES-E Technology Cost in the Time Horizon (2050) for the Blue Storyline



Until 2030: Green-X (RES-E Technology Cost)

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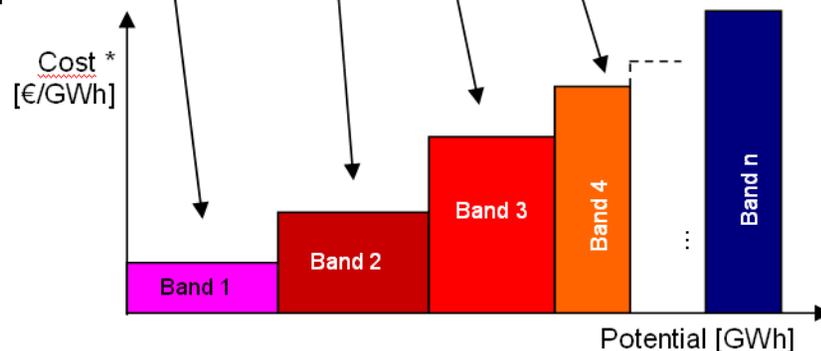
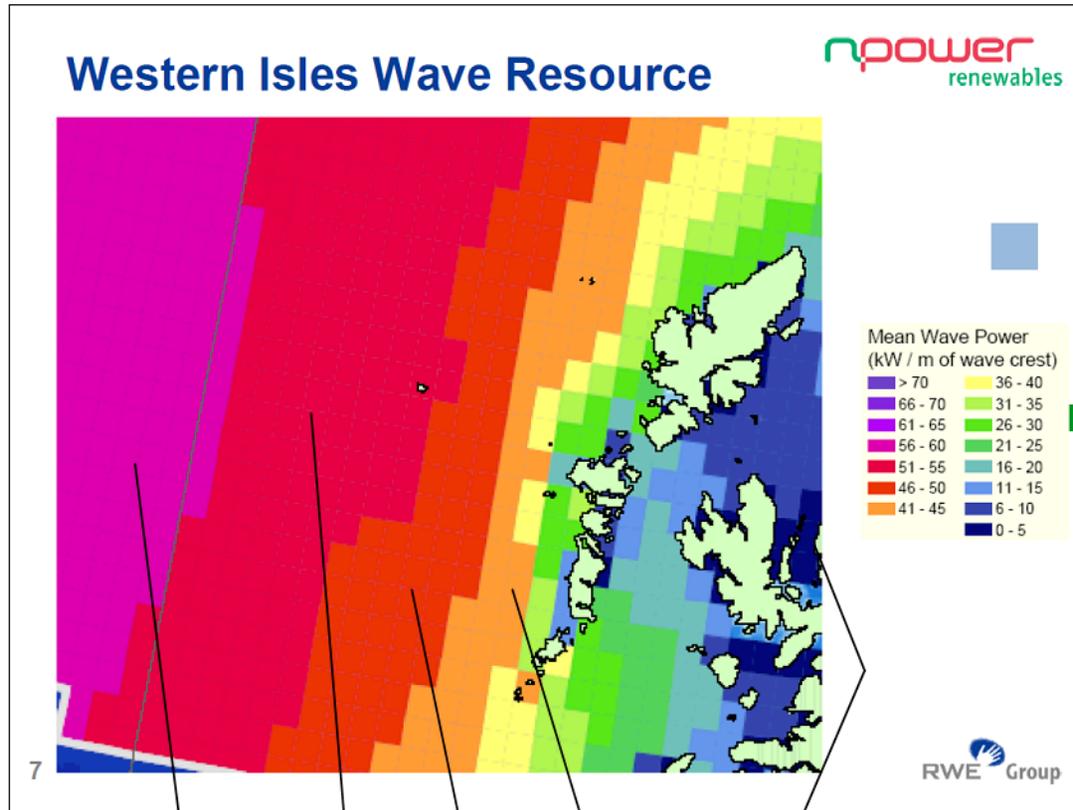
GreenNet, eTransport, ...

## 4. Selected Scenario Results in Different Regions: Electricity Grid Investments = f (RES-E Deployment)

Norway, Spain, Austria, ...

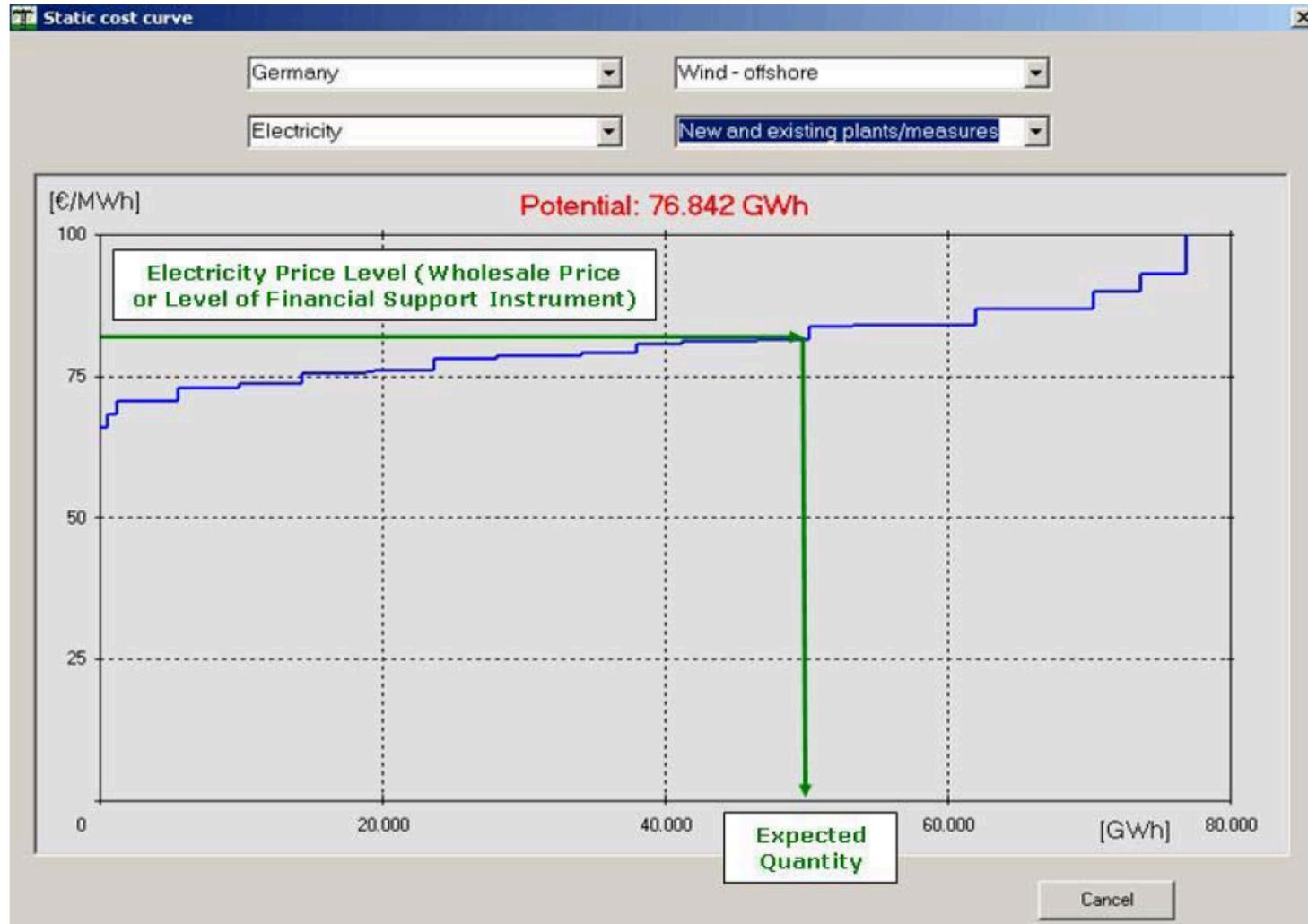
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## 3.1 Merit Order of RES-E Potentials/Cost (GreenNet-Model; Step 1)

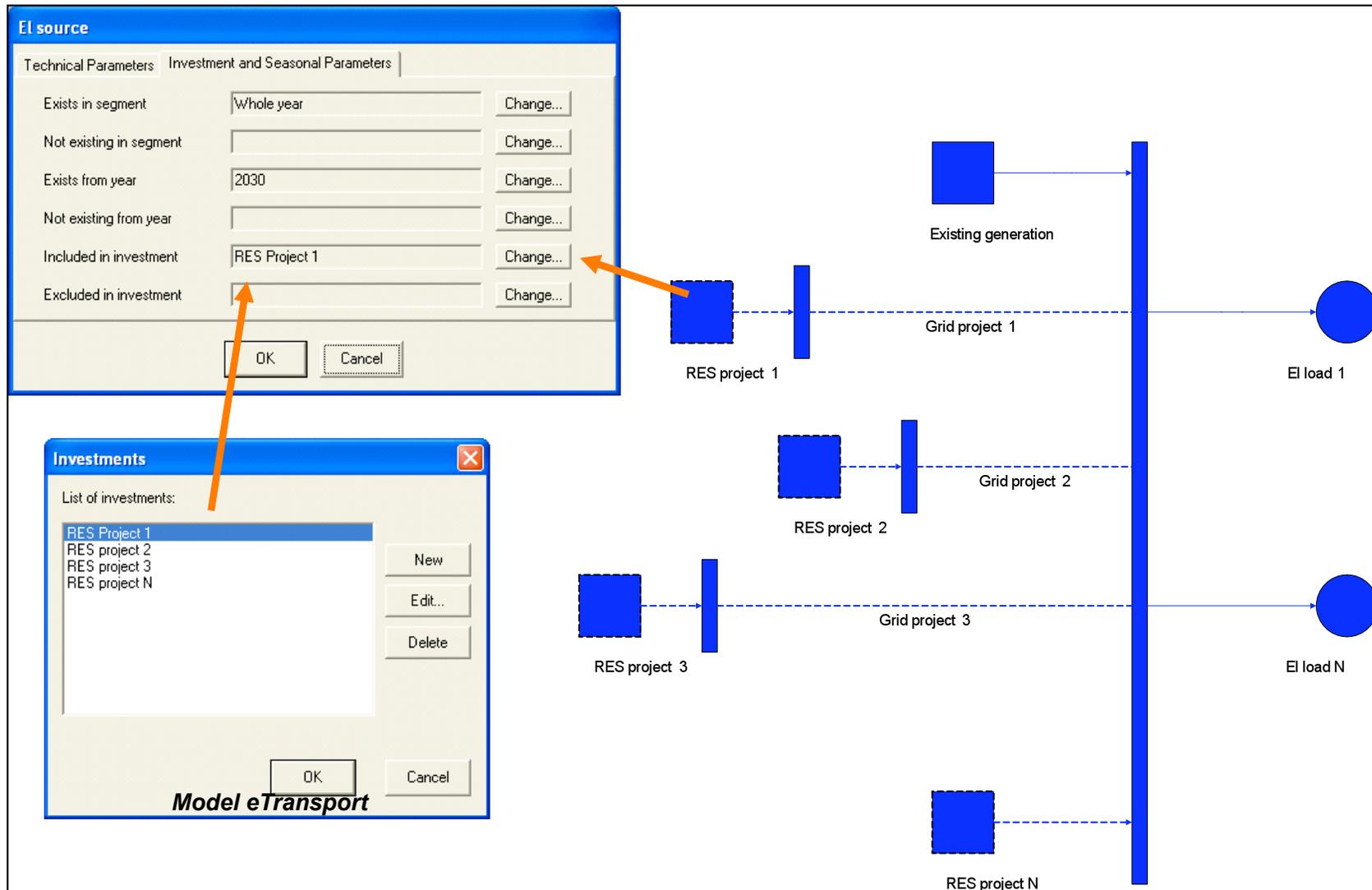


All RES generation potentials of a region with the same / similar background parameter describing the RES potential & the on-site generation costs (the mean wave power in this case) are added up to form one band of the cost-resource curve. Only one couple of location coordinates (i.e. latitude & longitude) per band is necessary.

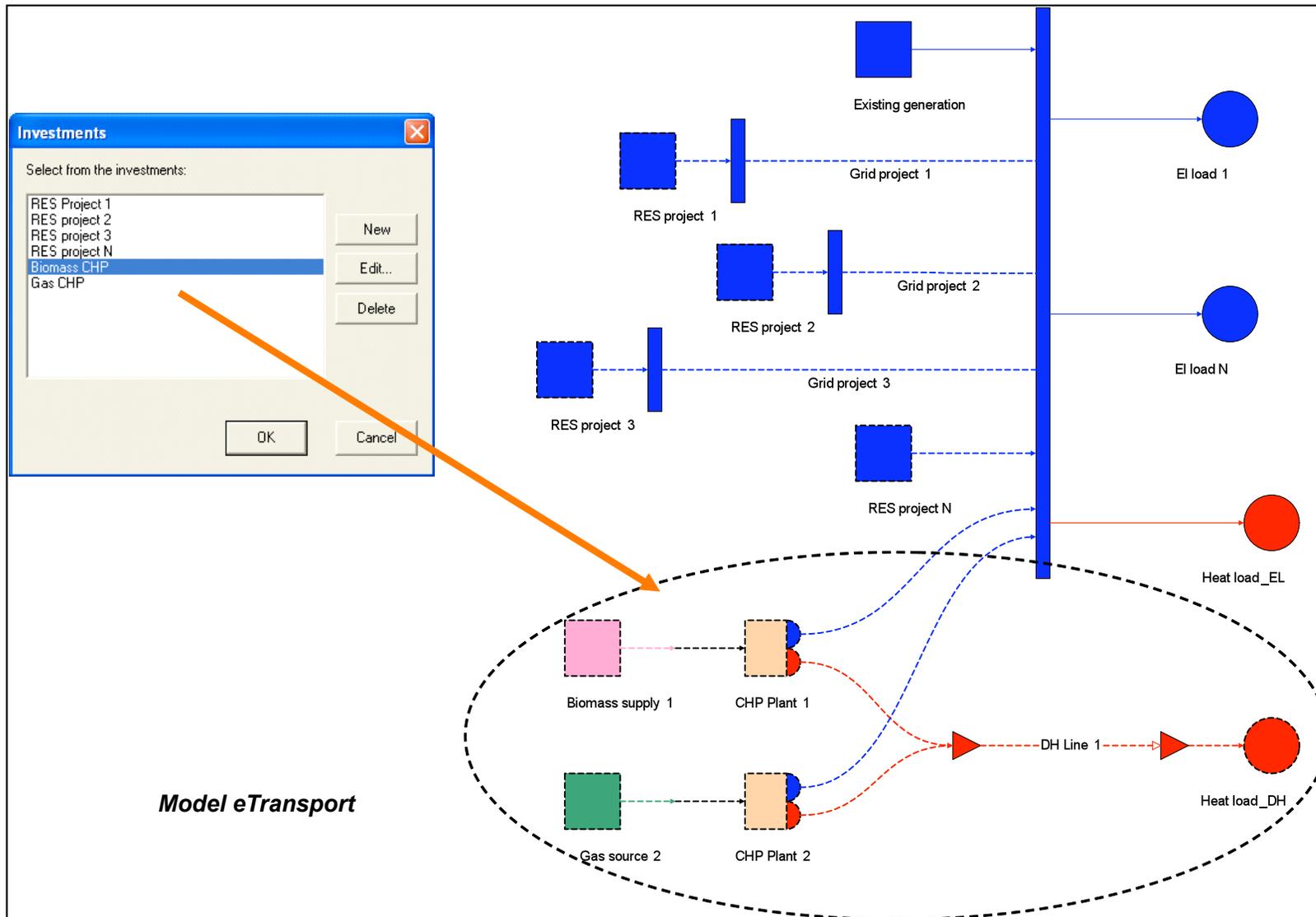
## 3.2 „Trade-off“ Calculation of RES Potentials/Costs and the Wholesale Electricity Market Price (GreenNet-Model; Step 2)



## 3.3 Consideration of Spatial Distribution of RES-E Sites, Electricity Load Centres and Geography of Electricity Grid Infrastructure Routes (eTransport-Model; Step 1)



## 3.4 Addition of Parallel Grid Infrastructures (incl. Corresponding Resources and Grid Components) and Heat Loads to the “Electricity-Related” Part of the *eTransport-Model* (Step 2)



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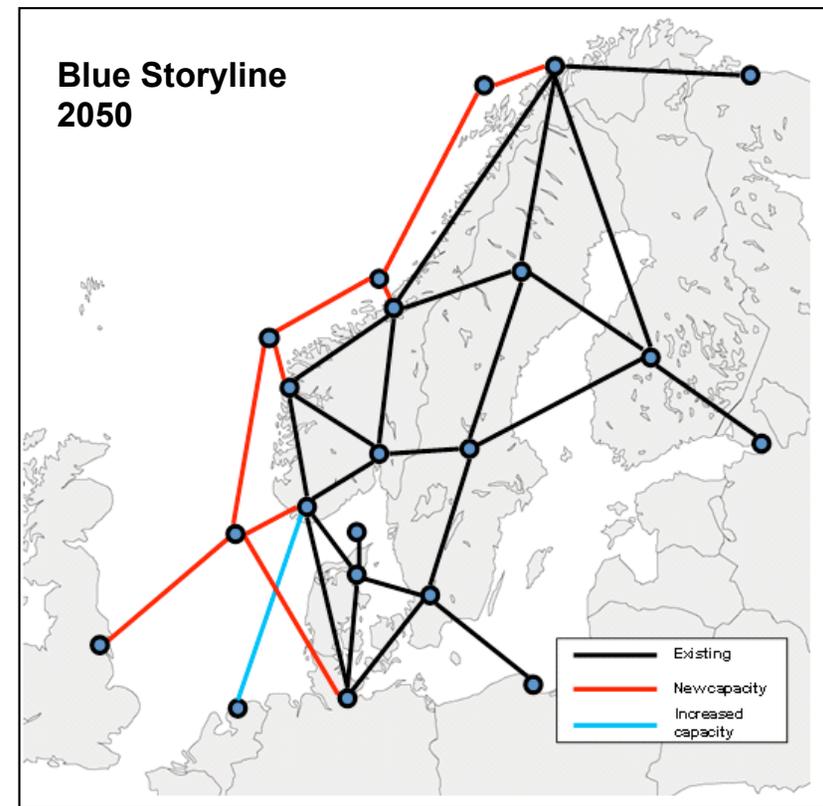
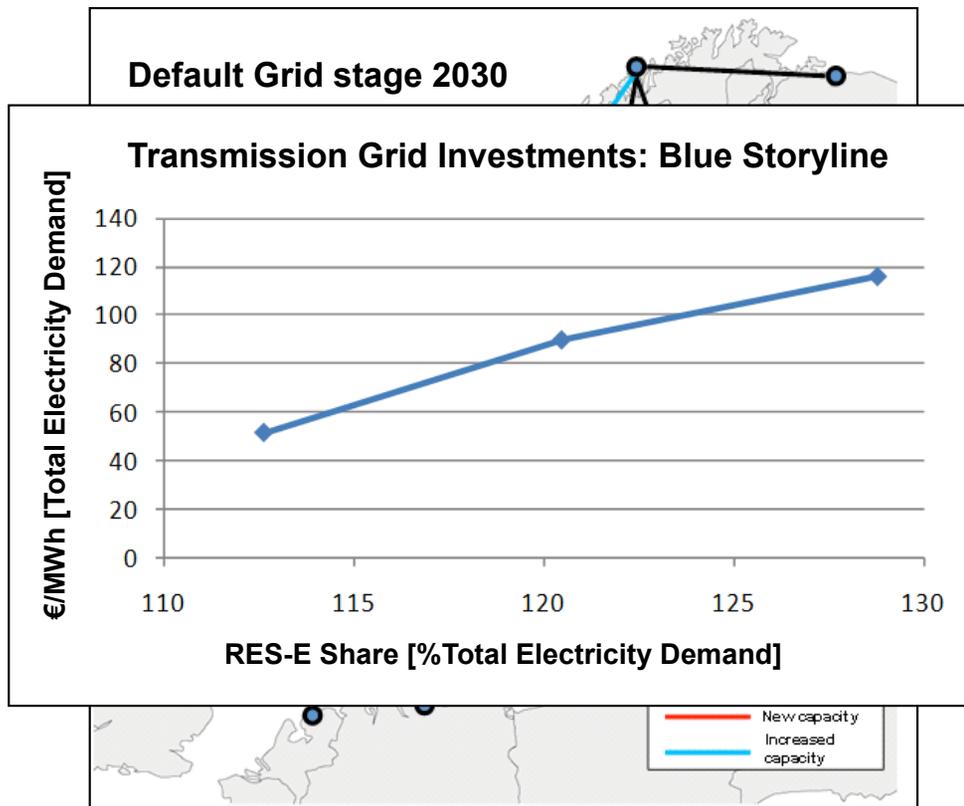
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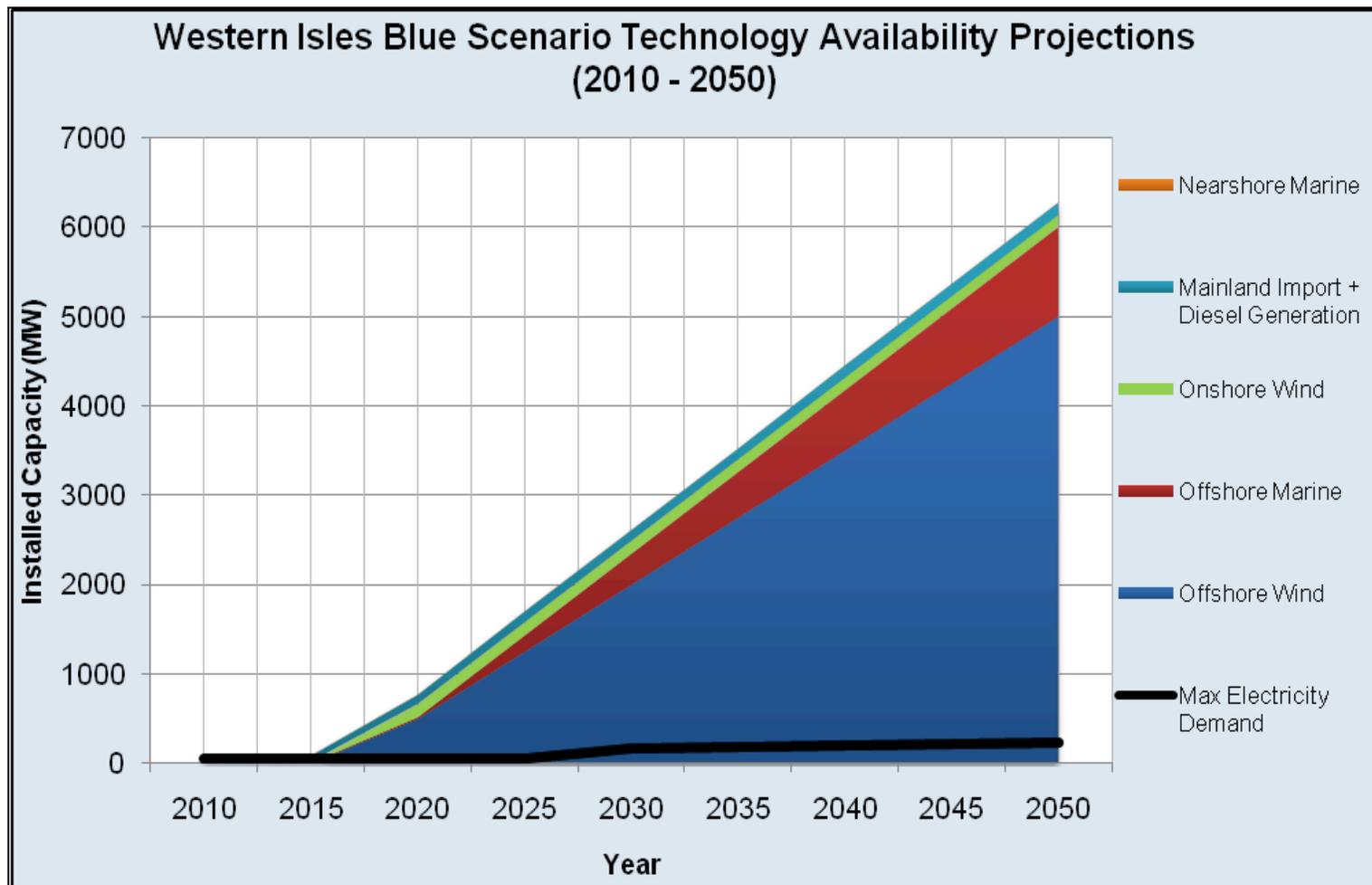
## Norway

- huge wind-offshore RES-Electricity potentials
- but with nearly 100% hydropower, no interest to invest
- business model needed



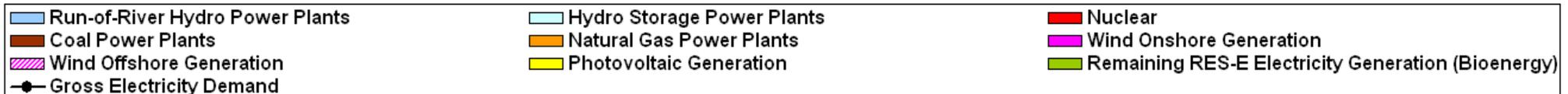
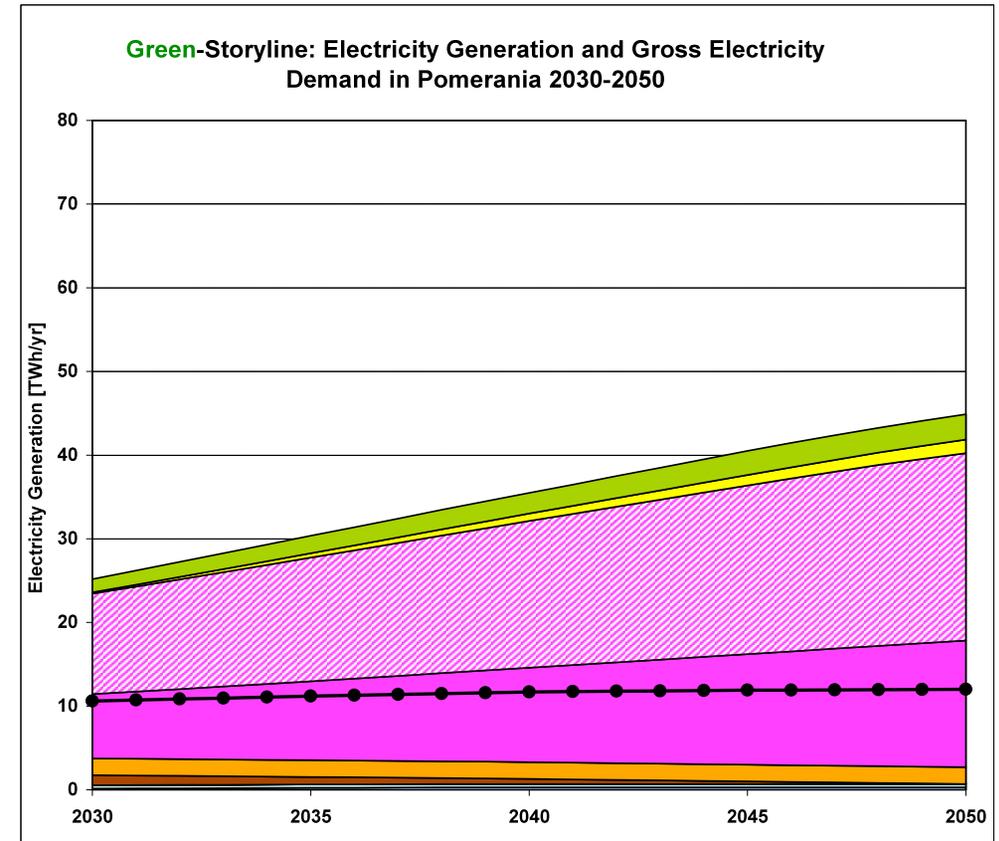
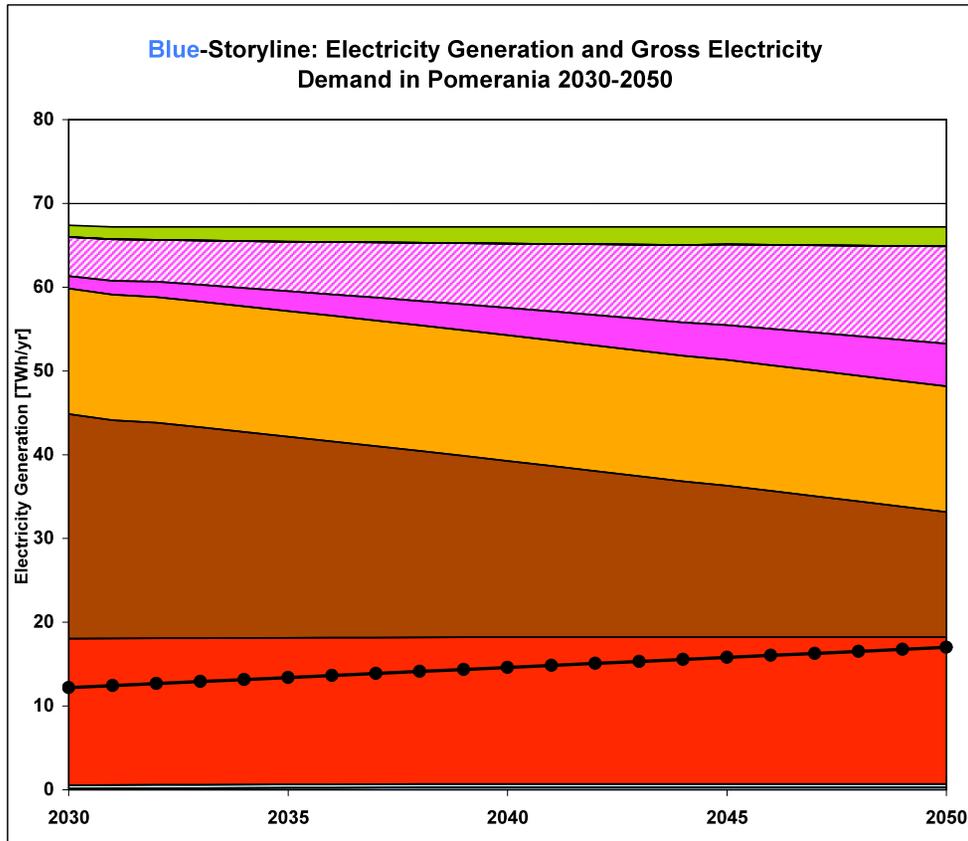
## Western Isles (Northern Scotland)

- massive marine RES-Electricity potentials
- load centres far away (London region, continental Europe)



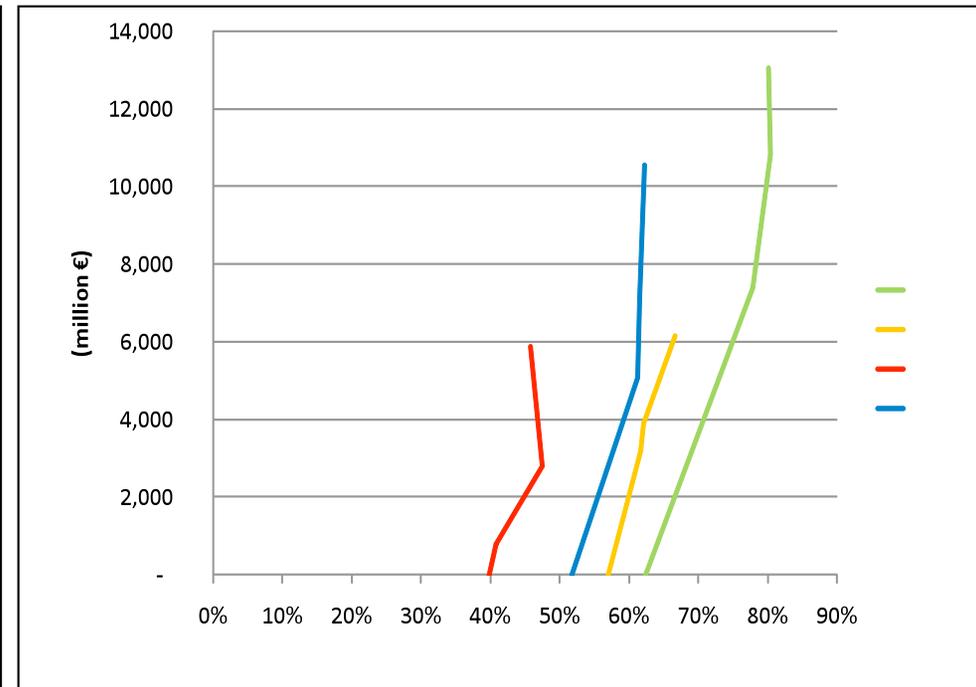
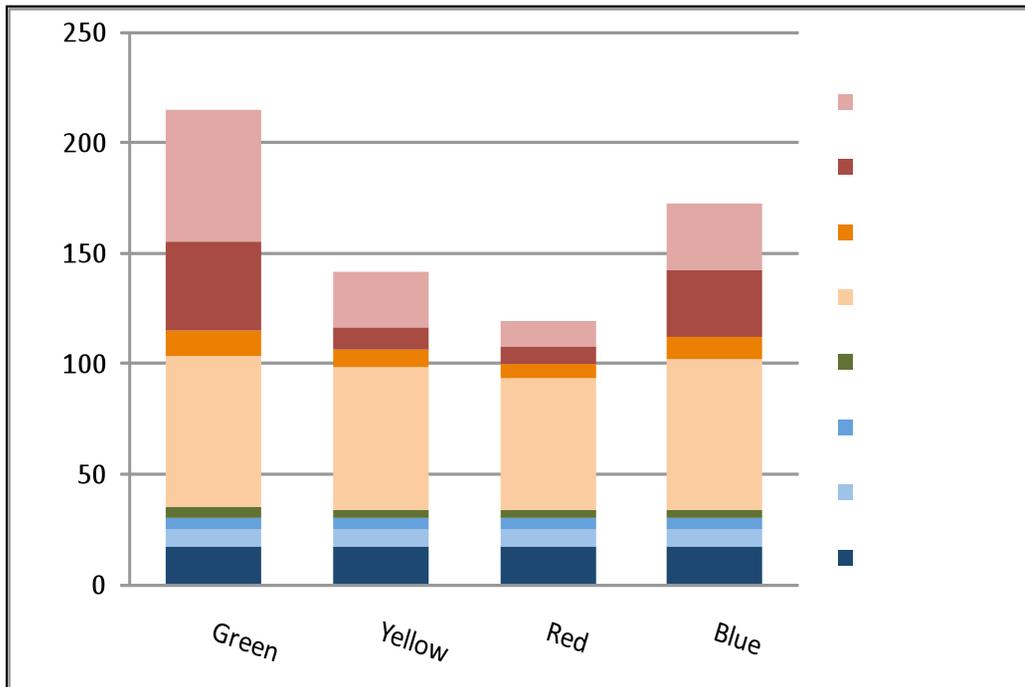
## Pomeranian Region

- significant RES-Electricity potentials (wind-offshore in Baltic Sea)
- will become exorbitant net-exporter of electricity
- Nuclear/conventional- or RES-Electricity generation
- reserve/balancing capacities needed (Alps/Scandinavia)



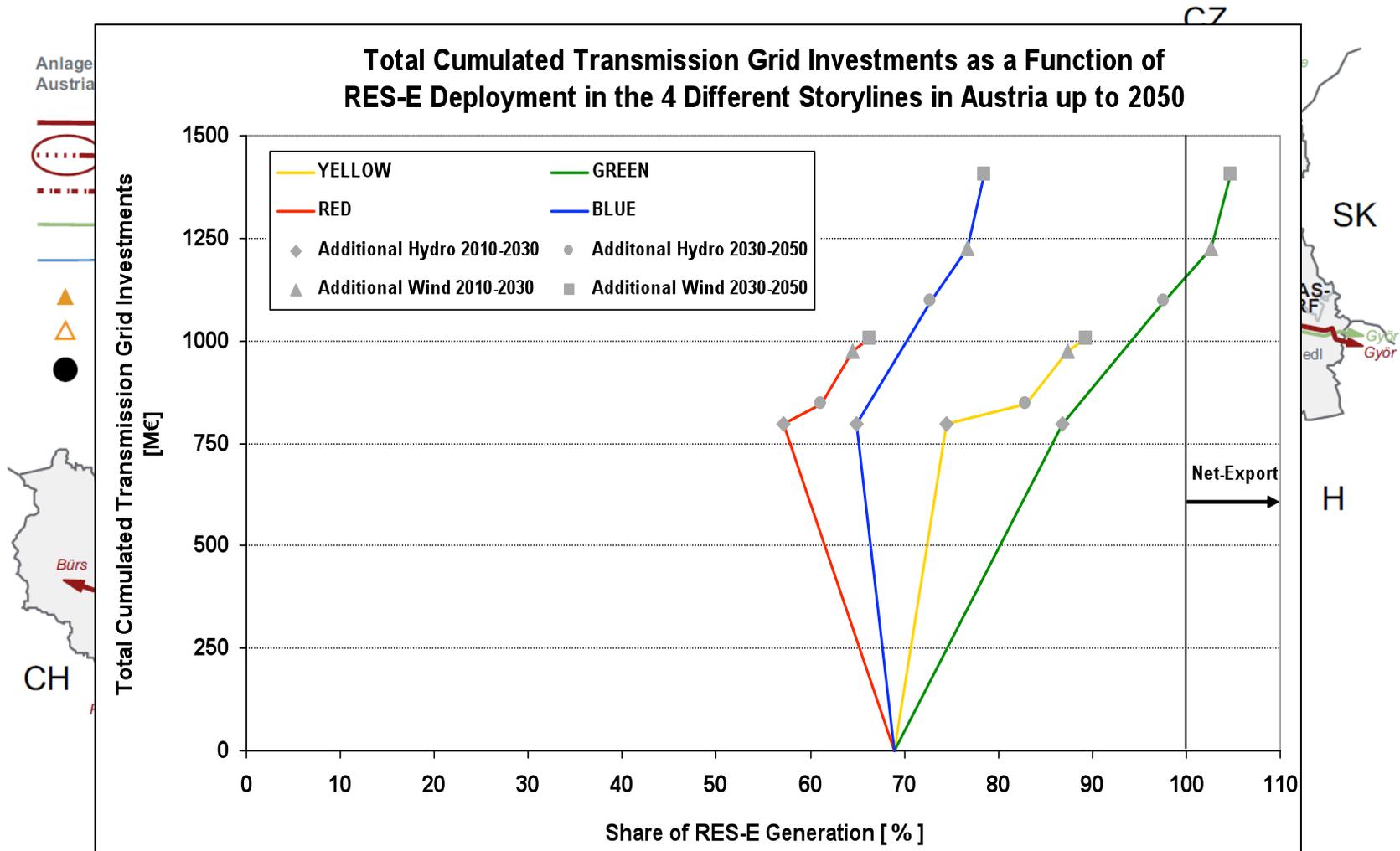
## Spain

- huge RES-Electricity potentials (solar PV & CSP, wind)
- up to 80% of total electricity generation from RES in 2050
- reserve/balancing capacities needed
- backup conventional (gas-fired) electricity generation



## Austria

- significant RES-Electricity potentials (hydro, building-integrated-PV)
- balancing power provision
- transmission grid investments needed



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### Selection of most important lessons learnt:

- Try to overcome „artificial“ borders (political, institutional, etc.) when identifying RES-E potentials and developing RES-E grid integration cases / business models (operation of electricity systems finally is governed by physical laws).
- Try to utilize economies of scale of RES-E generation at attractive RES-E potential sites; try to find fitting load centres.
- The nearest grid connection point is not necessarily the nearest fitting connection point (insufficient network capacity).
- If needed, develop inter-regional (and also European-wide) business and cost remuneration models for transmission investments.
- Enable access to efficient/effective system balancing and reserve capacity provision technologies in an inter-regional context.
- Harmonize legislative and regulatory frameworks in the context of grid integration of RES-E generation technologies in the EU27+.
- Involve local/regional people/communities from the beginning of a planning phase; develop business/participation models for them.

# Thank You for Your Attention!

For more Information about the **SUSPLAN**  
Project please visit:



[www.susplan.eu](http://www.susplan.eu)

