TASK 5 – ENVIRONMENT & ECONOMICS – DEFINITION OF BASE CASE

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Content

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1. Goal – research question

- **Research question**: how can we quantify the economic and environmental value of smart appliances flexibility
- Approach:
  - Definition of a **base case** without smart appliances
  - For **two** distinct **use cases**
  - Calculation of 3 relevant **KPIs**:
    - Environmental value:
      1. **Efficiency of generation mix** (primary energy savings) → decreased utilization of peaking units, increased utilization of RES
      2. **Reduction of CO_2 emissions**
    - Economic value: **Reduction in total system costs**

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2. Use Cases for Flexibility from Smart Appliances

Two use cases are distinguished (what can the flexibility be used for?):

- **Day-ahead use case**: optimization of the day-ahead scheduling of electricity production and consumption
- **Imbalance/reserve use case**: real-time matching of supply and demand
- *Note: use cases for congestion management or frequency containment reserve not considered here, still immature use cases but could create substantial value in the future*

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2. Use Case 1 - Day-ahead use case

- Based on the estimated consumption, balancing responsible parties/ suppliers adapt their production volume and/or buy on the market the needed volumes to match supply and demand
  - Demand response (DR) can participate directly on the wholesale markets
  - DR can be used directly by the BRP to optimize its production schedule
- The presence of DR will enable to avoid electricity production with expensive and polluting power plants during certain hours
  - Hours with low wind and solar
  - Hours with structural high or low consumption (morning peak/evening peak, night)
  - Hours during seasons with higher consumption (very cold days during winter)

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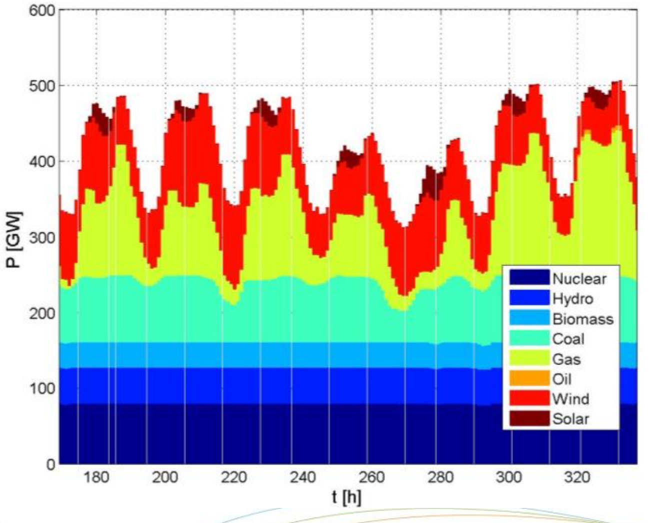
2. Day-ahead use case – peak shaving

» EU 28



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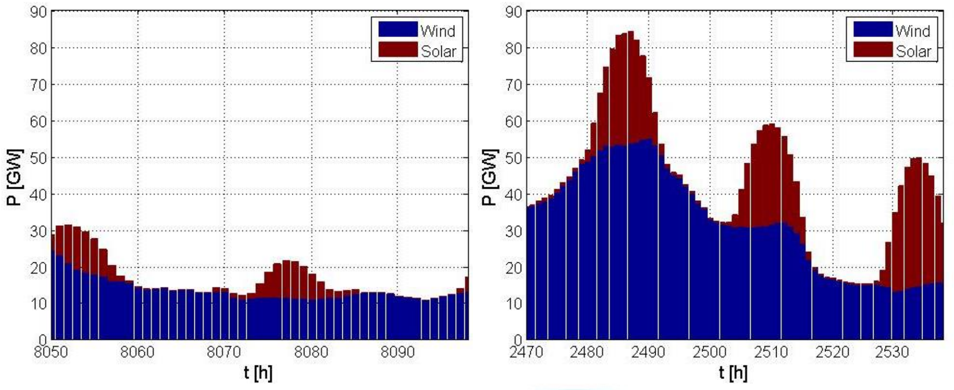
2. Day-ahead use case – integration of renewables

» 3 days (week 47 versus week 15)



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2. Use Case 2 - Imbalance use case

- In real-time, deviations are observed between supply and demand
- Primary origin: changing weather conditions (temperature, wind, …), but also sudden outages of dominant power plants → **forecast errors**
- In theory – deviations cannot be forecasted beforehand
- Deviations can be solved by:
  - (1) TSO who activates ancillary services (reserves) – BRPs/suppliers receive a penalty for their imbalance
    - FCR (Frequency Containment Reserve): fast reserve – 15 sec response time, **continuous** (less suited for some smart appliances)
    - FRRm and FRRa (Frequency Restoration Reserve): slower response time, limited duration
  - (2) BRPs can try to solve directly their imbalances by activating reserves from their own portfolio to avoid imbalance penalties

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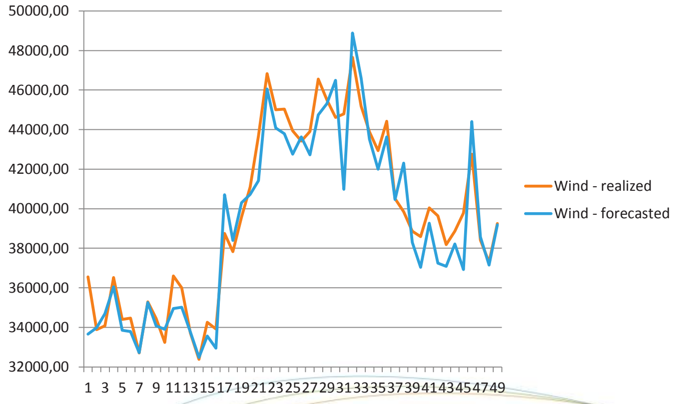
2. Imbalance/reserve use case

Wind power production and forecast for aggregated EU28 for 2 days in 2014



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3. European context

» EU-28 member states considered jointly

» Installed capacity European Target Model for Market Integration
  - Different markets (day-ahead, intraday, imbalance,…) will be coupled within the EU → considered as a whole
  - Investment in cross border interconnections → still some limitations

» EU 2020 & 2030 objectives
  - Significant increase of renewable energy between 2015 and 2030

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3. Assumptions - generation mix and transmission system

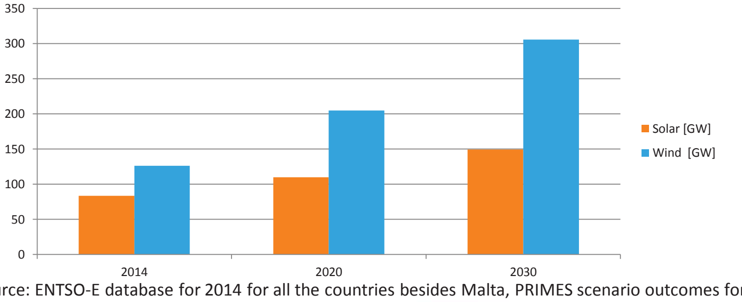
» Installed capacity per country
- Based on ENTSO-E published data of 2014 for EU 28
- Installed capacity in 2020 and 2030 – based on Primes reference scenario's

» Transmission system – cross-border transmission
- Based on ENTSO-E published data of 2014 for EU 28
- Based on ENTSO-E 10 year development plan for 2020 and 2030

3. Assumptions - installed generation

Predicted installed renewable energy capacity – EU 2020 & 2030 objectives
- Significant increase of renewable energy between 2015 and 2030

Figure: Installed RES capacity in [GW] for the whole EU-28 area

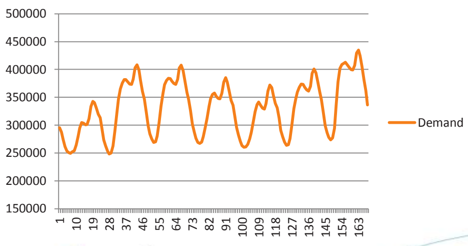


- Source: ENTSO-E database for 2014 for all the countries besides Malta, PRIMES scenario outcomes for 2020 and 2030, and for Malta for 2014, and for peak load in Malta Enemalta

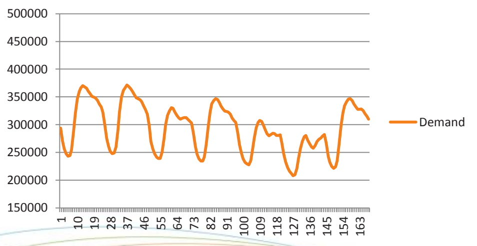
3. Assumptions - demand hourly profiles

» **Demand or Load**
- Based on ENTSO-E published data of 2014 for EU 28
- Corrected for import and export with unmodeled neighbouring countries
- Load in 2020 and 2030 – yearly increase of 0.5% per year up to 2020; and 1% per year thereafter is assumed

Winter



Summer



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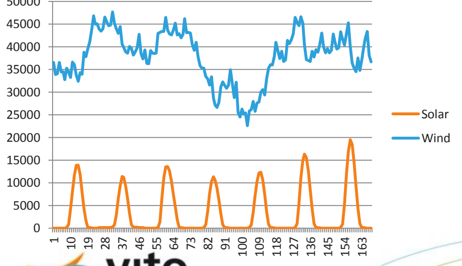
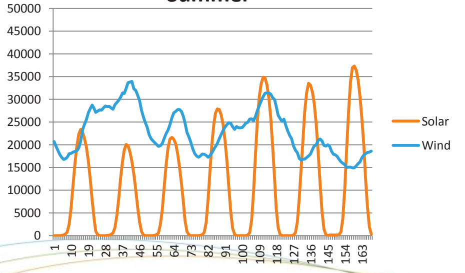
3. Assumptions - RES hourly profiles

» **Wind and Solar Power**
- Based on ENTSO-E country historical data (country TSO webpage)
- For countries that do not publish such profiles, an estimation based on neighbouring countries is used
- 2020 and 2030 - increase proportional to the increase of the installed capacity is assumed (same load factor)

Winter



Summer



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3. Assumptions - Fuel prices

- Prices remain relatively stable between 2014 and 2020
- In 2030 expectations are that mainly the price of CO_2 will have risen significantly → impact on profitability of thermal plants and system costs

Fuel	2014	2020	2030
Nuclear [EUR/MWh_prim]	6,98	6,98	6,98
Coal [EUR/MWh_prim]	9,20	11,93	11,97
Natural gas [EUR/MWh_prim]	18,75	31,66	32,71
Biomass/wood pellets [EUR/MWh_prim]	5,06	4,84	4,84
Oil [EUR/MWh_prim]	48,48	53,54	57,42
CO2 [EUR/tCO2]	5,96	9,07	48,00

Sources: realised market prices as published by ICE Endex & knoema for 2014; IEA scenario's for 2020 and 2030 scenario's; CO_2 estimate for 2030 from Thomson Reuters

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3. Assumptions – CO2 emission factors

- CO_2 intensity [t_{CO2}/MWhprim] for each fossil fuel category

Category	CO_2 intensity [t_{CO2}/MWh_{prim}]
Coal fired	0,34
Gas fired	0,21
Oil fired	0,27

- Other categories – no CO_2 emissions

Sources: Andreas Schröder, Friedrich Kunz, Jan Meiss, Roman Mendelevitch and Christian von Hirschhausen, "Current and Prospective Costs of Electricity Generation until 2050", 2013, available www.diw.de/documents/publikationen/73/diw_01.c.424566.de/diw_datadoc_2013-068.pdf

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4. Model input and output data

Inputs

- Hourly profiles of demand and hourly profiles of renewables (Task 3)
- Fuel and CO_2 prices (Task 5)
- Installed generation capacity per generation technology (Task 3)
- Technical and economic parameters per generation technology
- Network topology (transmission system matrix) and transmission lines capacity (Task 5)
- Imbalance volumes - forecast errors (Task 5)
- Amount of smart appliances (Task 2, utilized in Tasks 6 and 7)
- Hourly profiles of smart appliances flexibility (per group) and average shifting times (Task 3, utilized in Tasks 6 and 7)

Model

- Constrained optimization (Task 5)

Outputs

- Total system costs
- Marginal prices per hour
- CO_2 emissions per hour
- Production mix per hour
- Optimal utilization of flexibility from smart appliances per hour (in Tasks 6 and 7)

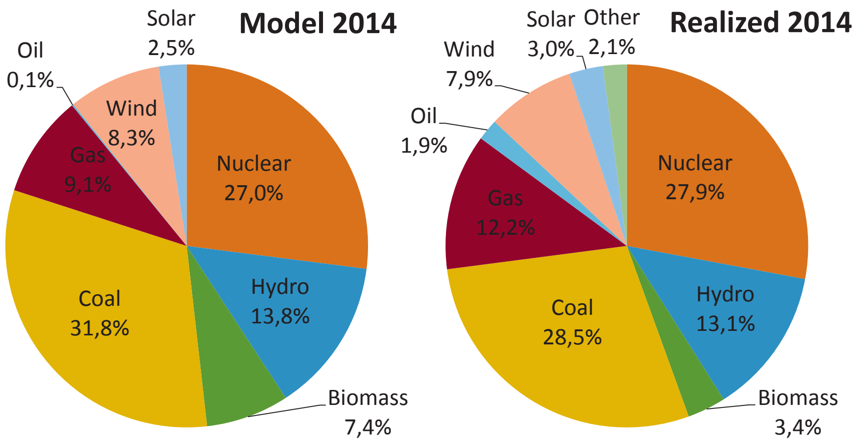
5. Computation of KPIs

» KPI1: Economic value – total system costs [€/MWh]

» KPI2: Total amount of CO_2 emissions over the considered period [Mt]

» KPI3: Energy efficiency of the utilized generation mix over the considered period [%]
(defined as produced electrical energy divided by the total primary energy utilised to produce the electrical energy)

5. Model and data validation



Comparison of the outcome of the model for input data defined for 2014, and the realized generation mix (electricity production by source) in 2014 in EU-28 area

5. Base case – day-ahead market use case

- System costs increase significantly in 2030, driven by increased prices of CO_2 emissions and fuel prices
- Small decrease in CO_2-emissions, due to increase of installed capacity in RES
- Increase efficiency generation mix: higher share of RES

Day ahead use case	KPI1 (total system costs) [M€]	KPI2 (CO_2 emissions) [Mt]	KPI3 (efficiency of the utilized generation mix) [%]
2014	63.614	803	54
2020	75.079	736	58
2030	115.504	699	61

5. Base case – imbalance/reserve use case

- System costs for imbalance increase significantly in 2030, driven by increased costs of CO_2
- Net impact on CO_2 emissions is limited due to opposing trends:
  - Higher imbalance due to e.g. increase of RES
  - More equal distribution of positive and negative imbalance
- Increase efficiency generation mix over the years: higher share of RES

Day ahead use case	KPI1 (total system costs) [M€]	KPI2 (CO_2 emissions) [Mt]	KPI3 (efficiency of the utilized generation mix) [%]
2014	7,2	1,56	54
2020	11,2	1,65	58
2030	143,76	1,78	61

6. Conclusions

- Assumptions for 2014, 2020 and 2030 scenario based on verified references
- Utilized model and data are validated against the realized data → gives confidence for further analysis
- Analysis of base case shows the impact of increasing demand, RES and CO_2 prices on the KPIs (system costs increase, CO_2 emissions decrease, and primary energy efficiency increases)
- Analysis of base case indicates a potential increasing need for flexibility over the coming years