Case Studies
Common Data & Data Sources
EDF, April 11, 2018

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Data sources

- **Technology data related to energy types** heating/cooling, transport, electricity, gas/fuel
  - specific CAPEX & O&M
  - efficiency, availability
  - installed fleet (incl. storage)
  - regional limits / forced capacities
- **Simplified cross-border electricity exchange**
- **Demand for 'Useful Energy' per region** projection annual demand from 2020 to 2050)
- **Generation profiles Wind/PV/Solar per region**
- **Weather data** (incl. climate change projections) Demand load profiles, generation profiles for RES, and inflows to hydro power
  … are dependent on the weather conditions
- **Projection of GDP and population per region**
- **Statistical building & socio-demographic data**

Potential External Sources (to be checked for feasibility)

Heating Cooling	→ Heat Roadmap Europe 2050 (HRE4)
Transport	→ EU Reference Scenario 2016
Industry	→ DECHEMA 2017 "Low carbon energy & feedstock for the European chemical industry"
Installed Base PP	→ entso-e
Electric Grid	→ entso-e (TYNDP), eHighway 2050
Gas Grid	→ entso-g ??
Weather	→ EU Copernicus ECEM (+ climate change) or generation profiles: www.renewables.ninja
GDP, Population	→ Projection of EU Reference Scenario 2016
Building data,	→ Digital data service
Socio-demographic data	→ Digital data service

List of technologies
All case studies

Tech Data: Installed capacities, specific CAPEX+OPEX, efficiencies, availability, limits & forced fleet (incl. projections from 2015 – 2050)

El. Generation Utility & Industry
- Steam PP Coal/Gas/Oil/Lignite
- GT PP Oil / Gas
- CCGT PP Oil / Gas
- Nuclear PP
- CHP Engine (large)

Renewables
- Run-of-River
- Run-of-River w/ reservoir
- Solar PV (large farms)
- Wind Onshore,
- Wind Offshore
- Geothermal
- Waste
- Biomass / Biogas

Generation - decentral
- Rooftop PV (small)
- Small scale wind
- Micro CHP
- Fuel cells (incl. CHP)

Grids
- Electric (Transmission) Grid

Transport (electricity only)
- E-Mobility (→Charging)
  - eCar, eTruck, eHighway
  - eAircraft, eShip [1)]

Storage (electricity only)
- Pumped Hydro
- Batteries

- Electrolyseur (H_2)

List of technologies
All case studies + additions for Multimodal Investment Model

Tech Data: Installed capacities, specific CAPEX+OPEX, efficiencies, availability, limits & forced fleet (incl. projections from 2015 – 2050)

El. Generation Utility & Industry
- Steam PP Coal/Gas/Oil/Lignite
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Renewables
- Run-of-River
- Run-of-River w/ reservoir
- Solar PV (large farms)
- Wind Onshore,
- Wind Offshore
- Geothermal
- Waste
- Biomass / Biogas
- Solar thermal

Generation - decentral
- Rooftop PV (small)
- Small scale wind
- Micro CHP
- Fuel cells (incl. CHP)
- Rooftop Solar Heat

Grids
- Electric (Transmission) Grid
- District Heating
- District Cooling [1)]
- Gas Grid [2)]

Transport (Mobility)
- Classic Mobility (Road/Ship/Air) [1)]
- Fuel Cell Cars / Trucks [1)]
- E-Mobility (→Charging)
  - eCar, eTruck, eHighway
  - eAircraft, eShip [1)]

Transport Demand (short/long distance)
- Passenger
- Freight (large/small)

Heating – temperature levels
- LT <100 °C
- MT 100°C – 150°C
- HT 150°C– 500°C
- VHT >500°C

Heating - decentral
- Small Boiler
- Small Electric
- Micro CHP
- Heat Pumps (Air / Water)

Heating - central
- Large Boiler
- Heating rod (electric) LT / MT
- Heating rod (electric) HT /VHT
- Arc Furnace (electric) VHT
- Furnace VHT
- Heat Pump (LT / MT)

Cooling - central / decentral
- Compression Chiller [1)]
- Compression Chiller HVAC [1)]
- Absorption Chiller (large) [1)]

Storage
- Pumped Hydro
- Batteries
- Air compression (small, large)
- Heat Storage HT (small, large)
- Heat Storage MT (small, large)
- Heat Storage LT (small, large)
- Cold Storage H_2O (small, large) [1)]
- Cold Storage Ice (small, large) [1)]
- Electrolyseur (H_2) [2)]
- Power2Gas (CH4) [2)]
- Power2Synfuel (Liquid Fuel) [2)]
- Hydrogen Storage [2)]
- Gas in Cavern (NG/H_2) [2)]
- Pressurized Vessel (NG/H_2) [2)]
- Pipeline Segment (NG/H_2) [2)]

Industry Demand correlated to P2G [2)]
- Steam Methane Reforming [2)] ??
- Oil refineries H_2 Demand [2)] ??
- Chemical Industry H_2 Demand [2)] ??

1) CS1: Step 1 not considered in Step 2
2) CS1: Step 1 & Step 2-C, not considered in Step 2 A&B

Sub-country resolution clusters

- Use standardized regional clustering, e.g. NUTS to enable import from external data sources

Challenges:

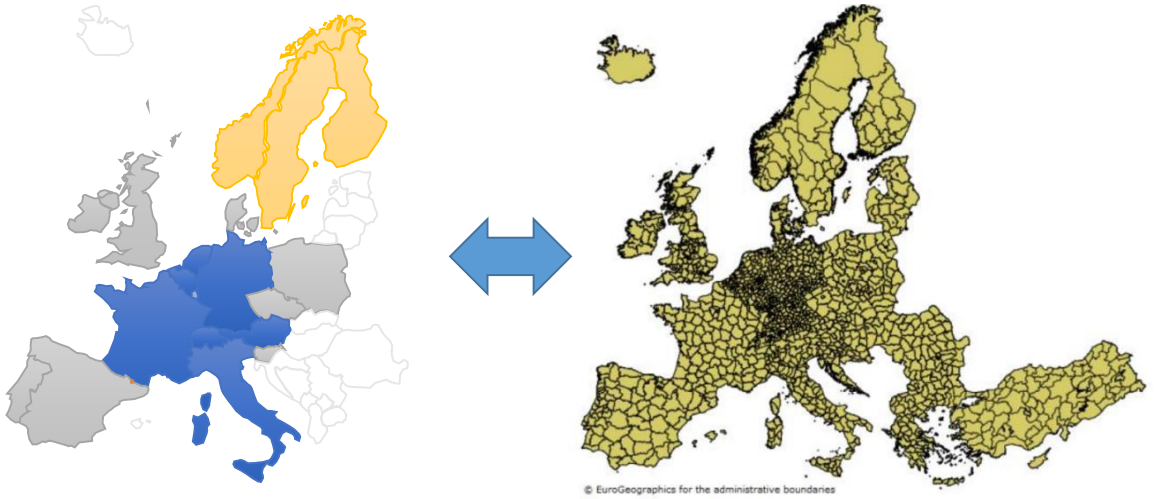
- Several European countries are modeled in parallel in sub-country resolution & along the pathway→ massive optimization problem
- Ensure data quality on all spatial resolutions

→ Adapt scope and cell sizes level according to available data quality and limiting requirements from modeling & analysis

→ Algorithms to aggregate or break down data and results between cell sizes level

Arguments for usage of NUTS Classification of regions:

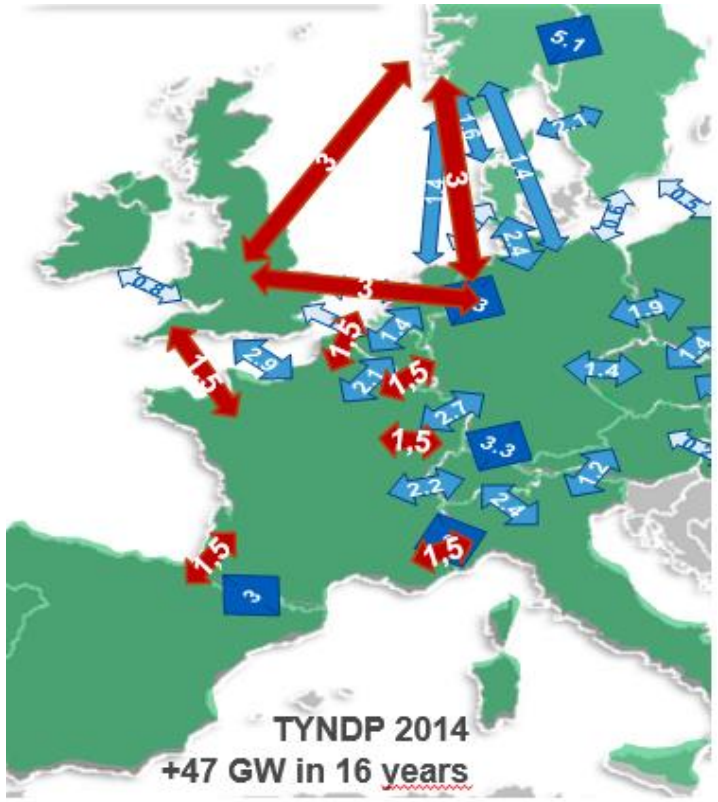
- *cover all the countries that need to be clustered;*
- *boundaries are clearly defined and available for any interested stakeholder;*
- *enable to use European databases defined at this level.*



Country NUTS-3

Simplified cross-cell energy exchange model

- Energy exchange by a simplified transmission grid (Cluster Model)



simplify

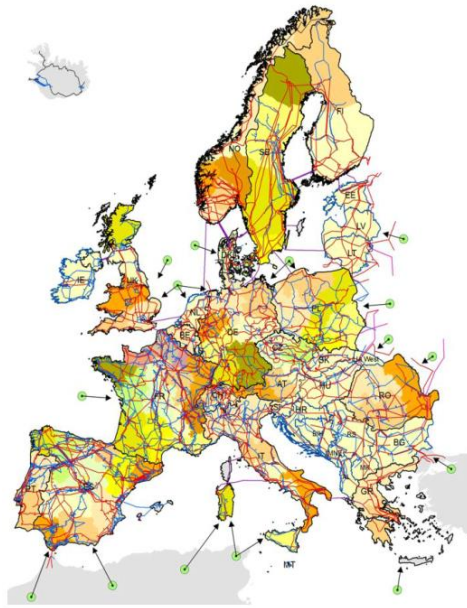


Figure 20: Geographic clustering

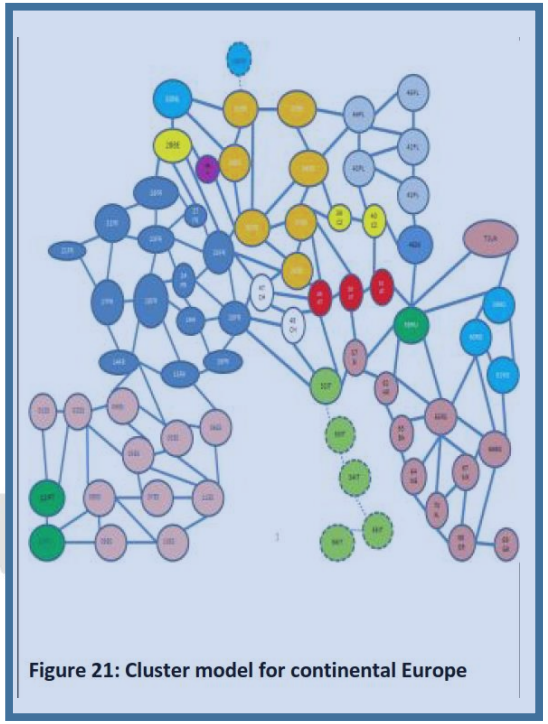


Figure 21: Cluster model for continental Europe

Note:
In Case study #1, no optimization of the transmission grid capacity or detailed consideration is done. Instead we use a simplified model considering a maximum cross-cell energy exchange which reflects the given transport capacity restrictions between cells of the chosen spatial resolution based on the existing and projected transmission grid.

Modeling of cross-border energy exchange

- Simplified Model for Electric Networks, e.g. as used in eHighway2050

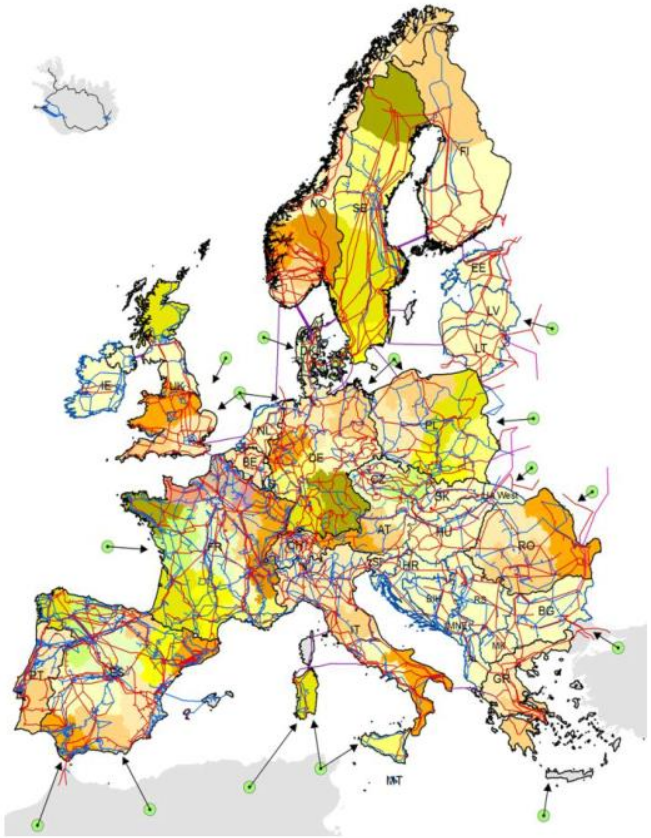


Figure 20: Geographic clustering

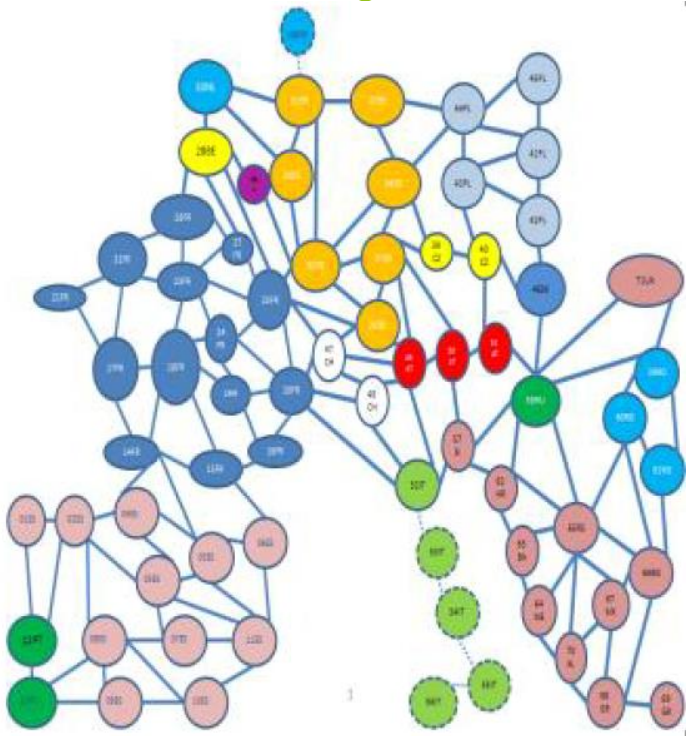


Figure 21: Cluster model for continental Europe

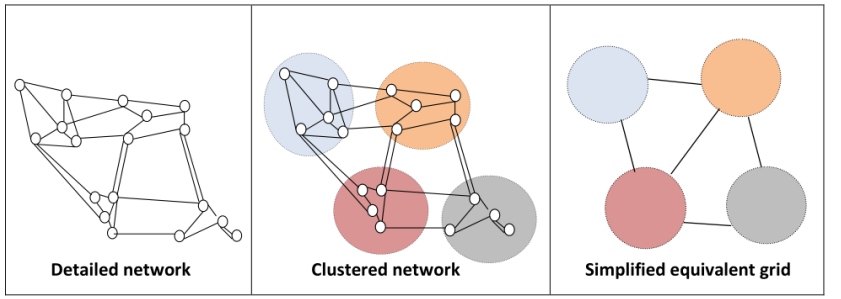


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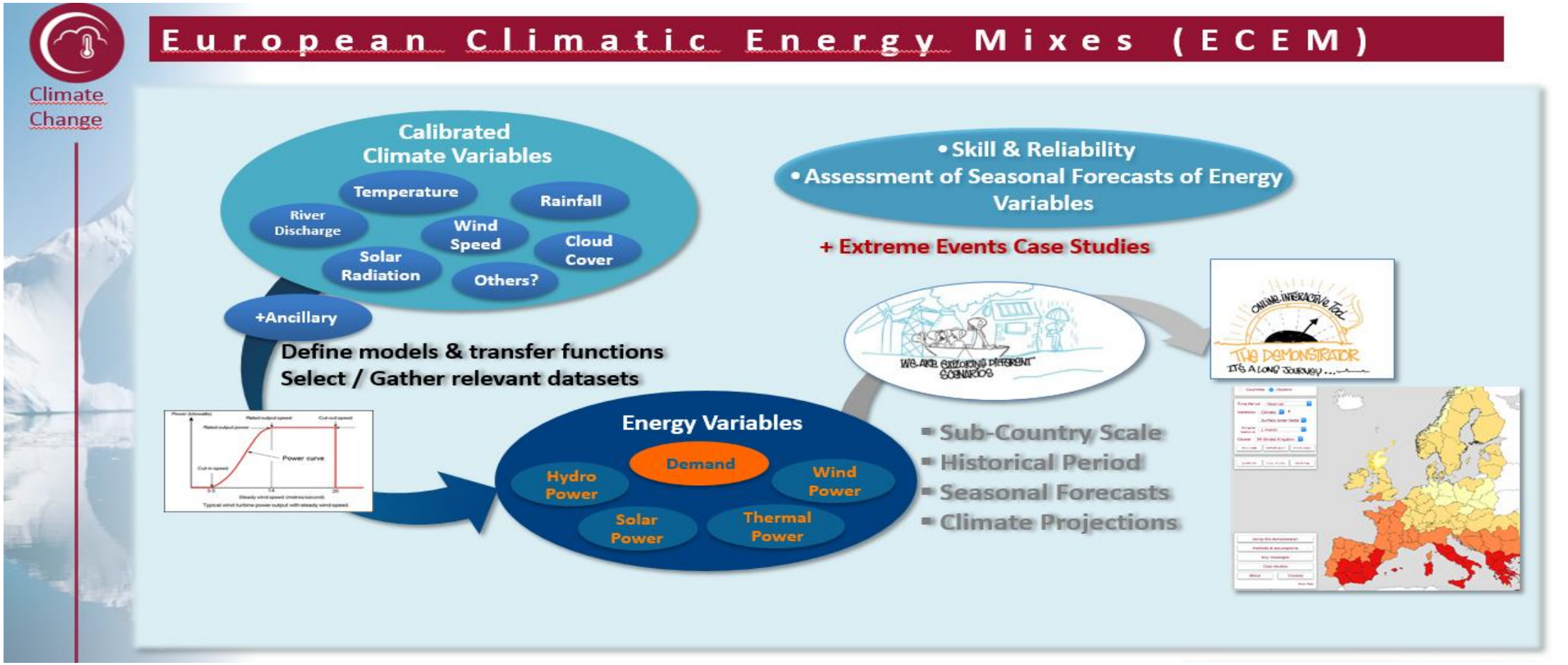
Figure 16: Illustration of steps in grid reduction

Case Study 1 & 3
A simplified model of the electric transmission grid representing maximum possible cross-border electricity exchange per cell (analog to NTC but with higher resolution) is probably sufficient.

Case Study 1 Step 2
Approach for gas grid model w/ P2Gas → tbd

The impacts of climate change



Population and GPD growth

Projected GDP and Population growth is differs between the European countries

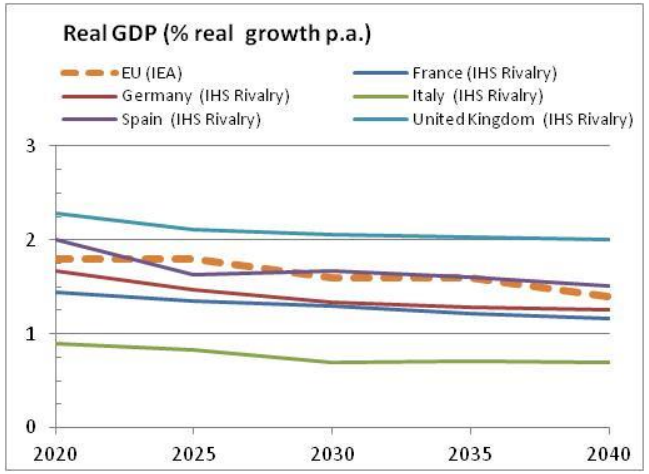
Trends in Population and GPD Growth

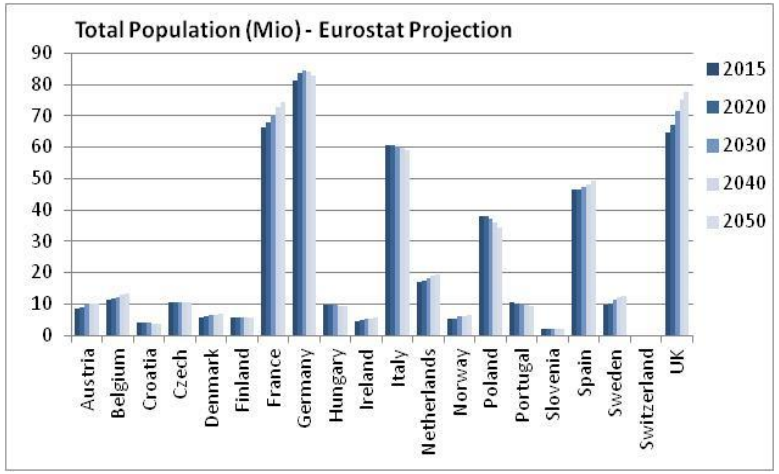
… have huge impact on the future demand of useful energy and therefore on the demand of secondary and primary energy.

… can be used for filling gaps in data sets using them

- for scale down of aggregated numbers to sub-country cells using meta data GDP and Population
- for indirect forecasting of demand of 'Useful Energy' from meta data

  e.g. calculate demand transport as f(ΔpopulationΔGDP)





Provide data set with forecasted data from 2015 – 2050 for GDP and population growth for at least for each country, if possible on sub-country level from external sources, e.g. use

• Eurostat population projection[3)]	→ Population all countries	2015-2050
• IHS Markit Rivalry[1)]	→ GDP (FR, ES, GER, IT, UK)	2015-2050
• IEA Energy Technology Perspectives[2)]	→ GDP, Population (Total EU only)	2015-2050

1) IEA: https://www.iea.org/etp/etpmodel/assumptions 2) IHS Markit Global Energy Scenarios - Rivalry (2016)
3) http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-data

Fuel prices – e.g. from EU Reference Scenario 2016

Exemplary input for fuel prices

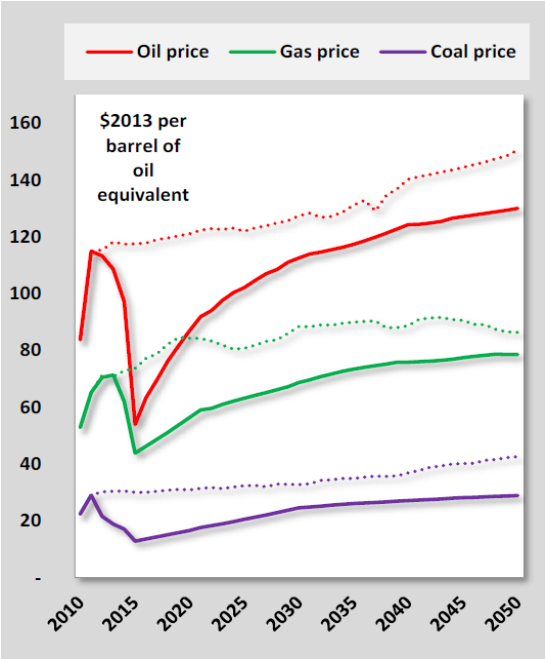
- from EU Reference Scenario 2016

… takes as exogenous assumptions the evolution of global fossil fuel prices, which have been developed independently with PROMETHEUS (global partial equilibrium energy system model).

The model endogenously derives consistent price trajectories for oil, natural gas and coal based on the evolution of global energy demand, resources and reserves, extraction costs and bilateral trade between regions.

Projected fuel import prices
From EU Reference Scenario 2016[1)]
see p.41

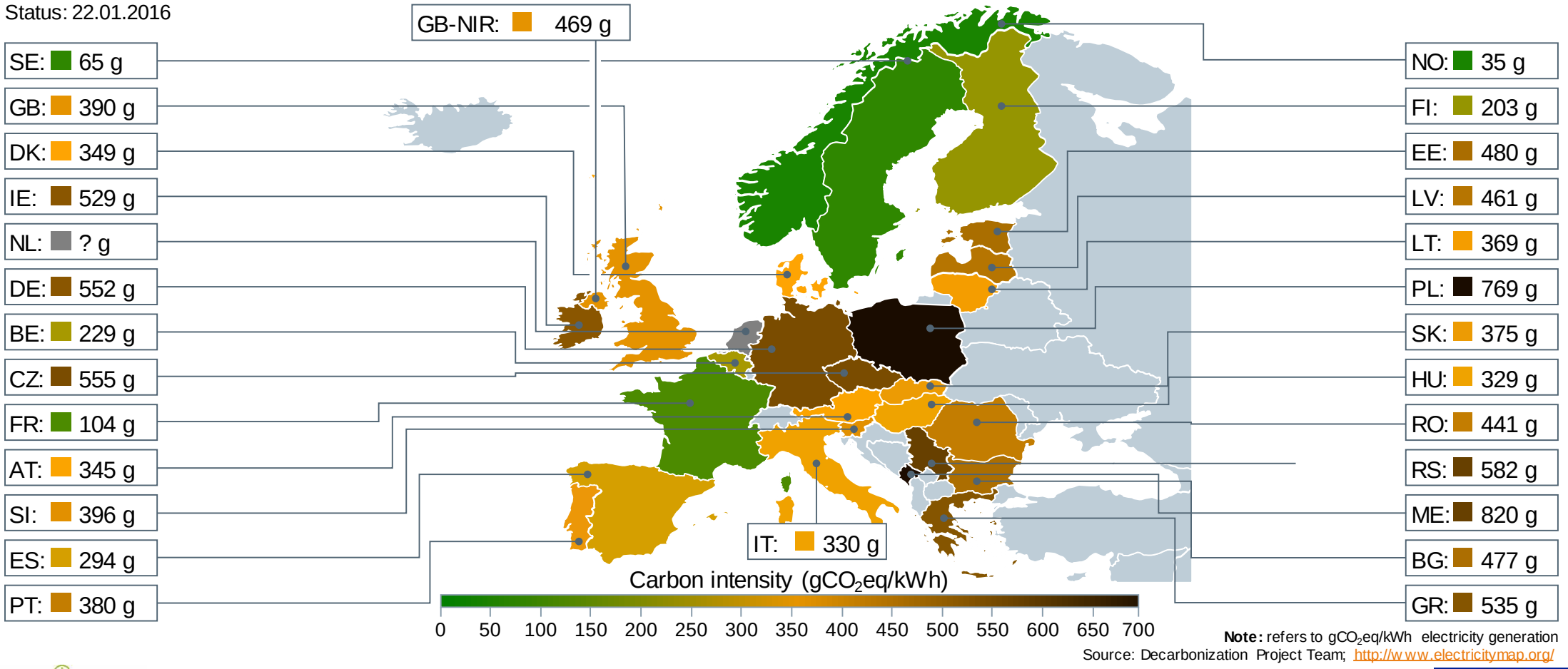
Note:
Dotted lines represent the previous EU Reference Scenario



Use import prices of fossil fuels from EU Reference Scenario 2016 [1)]
Alternative: Use Prices from IHS Autonomy or IHS Rivalry

1) https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf

CO_2 emissions of European electricity generation by country → individual reduction goals for countries and sectors?



Thank you!

Do you have any questions?