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Croatian Low Emission Development Strategy - Power System Perspective

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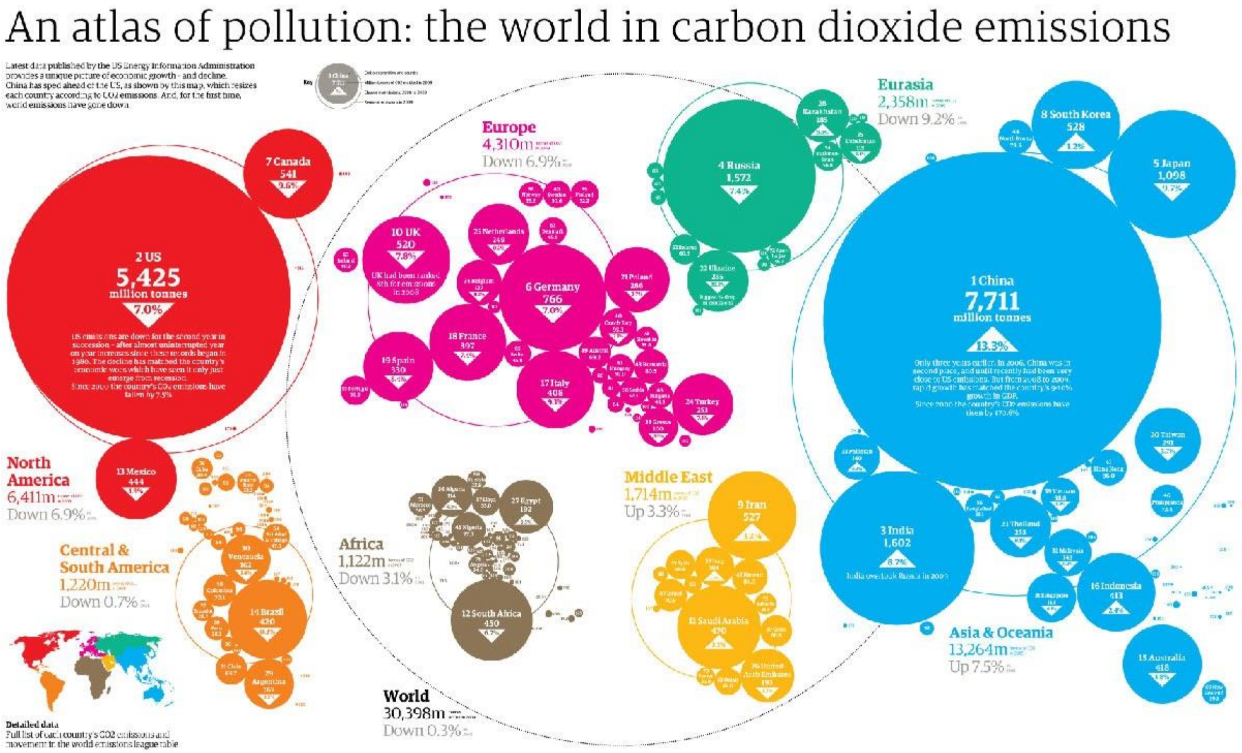
Some background…

http://www.lahistoriaconmapas.com/atlas/country-map158/kyoto-protocol-participation-map-2013.htm



Kyoto Protocol

- 1992. Rio, Brasil - UN Framework Convention on Climate Change – EARTH SUMMIT
- CO_2 emissions are affecting planet (global warming)
- Goals:
  - Taking care of ecosystems regarding climate change
  - Security of food production
  - Sustainable economic development
- Result: a document that should be amended in future

Kyoto Protocol

- COP3: 1997., Kyoto, Japan - representatives from 160 countries agreed to limit emissions of greenhouse gases
- Target: to reduce **developed** nation emissions to 5% below 1990 levels during 2008-2012
- Most countries need significant reductions (i.e. -18% reduction in BAU by 2008)
- Post Kyoto and low carbon development

Why LEDS?

https://www.armstrongeconomics.com/tag/global-warming/

Low carbon development

- Low carbon development - becoming increasingly important
- The United Nations Framework Convention on Climate Change - UNFCCC
- **COP21** in **Paris** - a legal binding agreement on climate and to keep global warming below 2°C above pre-industrial levels
- Low Emission Development Strategies - **LEDS**

What is LEDS?

http://www.iisd.org/story/iisd-and-the-sustainable-development-goals/

LEDS

- Highlights **disadvantages** and **prioritizes** activities for founding on the national level
- LEDS can be **integrated** and build on existing strategies
- Strategic plan:
  - promoting development pathway towards a low-carbon **sustainable** development
  - taking into account the **socio-economic** development **priorities** of the county

LEDS development process

- **Political** support
- Important interested groups and **stakeholders**
- Institutional framework and cross-sectoral **coordination** body
- **Collection and analysis of data**
- Identification of:
  - greenhouse gas emission **scenarios** and **projections**
  - climate change mitigation policies and measures
- Climate change measures **application** and **monitoring**.

…and what about Croatian LEDS?

REPUBLIKA HRVATSKA

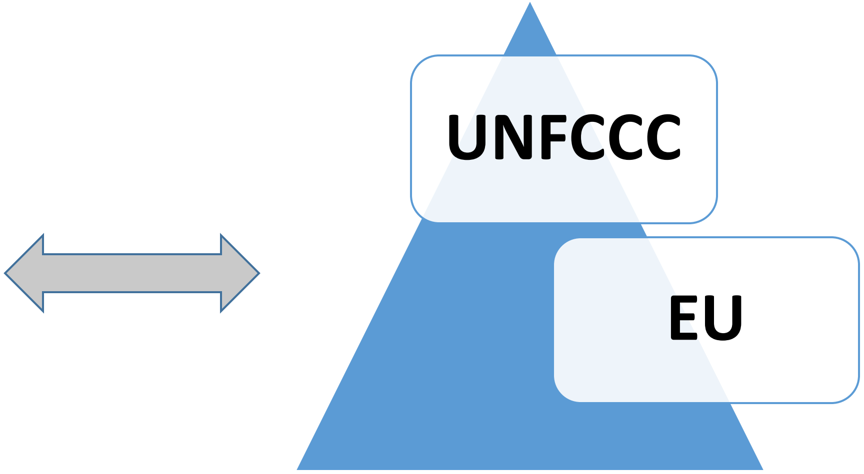
MINISTARSTVO ZAŠTITE OKOLIŠA I ENERGETIKE

The criteria and standards for determination of targets of Croatia

Low-Carbon Development Strategy of Croatia Goals

- sustainable development,
- competitive economy,
- employment,
- efficient use of resources,
- improve security of supply, sustainability of energy supply,
- reducing energy dependence,
- reducing impact on the health,

Benefits



Solidarity and commitment

Unska 3, HR-10000 Zagreb Tel: 01/ 6129 907, Fax: 01/ 6129 890 E-mail: zvne@fer.hr URL: http://www.zvne.fer.hr/

Croatian LEDS

- **Fundamental** document in the field of climate change mitigation
- Economic, development and environmental aspects
- Objective: to achieve a competitive **low carbon** economy by 2050 in line with relevant guidelines
- Contains three scenarios:
  - **NUR** - **referent** scenario
  - **NU1** - scenario of the **gradual** transition
  - **NU2** - scenario of the **strong** transition

Croatian LEDS:

Available technical measures

- **Energy efficiency** of residential and non-residential buildings
- **Smart grids**
- New **CHP** and central heating systems (**CHS**)
- Increase share of **RES**
- **Alternative fuels** for transport
- **Electrical** vehicles
- **Afforestation**
- ...

Croatian LEDS:

Available non technical measures

- Implementing climate policy in **sectoral strategies**
- Establishing **central body** for coordination
- Necessary **legal adjustments**
- New **educational** curriculum
- **ETS** adjustments
- Efforts to encourage **behavior change**
- …

Power system options

- Increasing **energy efficiency**
- Increased use of **RES**
- Increased use of **CHP**
- Switching to fuels with lower GHG production rate
- **Nuclear** option
- **CCS** technologies
- Reduction of losses in transmission and distribution systems

Croatian power system model

- Modelled in the „**PLEXOS for Power Systems**“
- Time horizon: **until year 2070.**
- Power plants (existing and **expansion candidates**)
- **CCS** technologies
- Electricity and heat **load** for each scenario
- Projections of future RES (especially **wind** and **photovoltaic**) capacity

Croatian power system model cont'd

- Power plants **outages** and new **entries**
- **Heat** and **steam** demand:
  - Cogeneration power plants
  - Heat boilers
  - Heat storage tanks
- System reserve capacity margin
- **Secondary reserve** providers:
  - Thermal power plants (gas) and
  - Hydro power plants

Scenarios

NUR → REFERENT → Continuation of the current practice under the existing regulations

NU1 → LOW CARBON → Scenario of the gradual transition

NU2 → LOW CARBON → Scenario of the strong transition

- **NURa, NU1a, NU2a** - without electricity exchange after 2030 (without imports)
- **NURb, NU1b, NU2b -** - with electricity exchange

Input data and settings

Scenario			NURa	NU1a	NU2a
RES	Hydropower >10 MW	2020.	According to the plan of HEP	According to the plan of HEP	According to the plan of HEP
		2030.	According to the plan of HEP	According to the plan of HEP+ 2 candidates for PHES	According to the plan of HEP+ 4 candidates for PHES
		2050.	According to the plan of HEP	According to the plan of HEP+ 2 candidates for PHES	According to the plan of HEP+ 4 candidates for PHES
	Hydropower <10 MW	2020.	66	66	66
		2030.	100	120	140
		2050.	100	140	140
	Solar power <100 kW (MW)	2020.	56	200	300
		2030.	250*	700	1300
		2050.	250*+candidates	700+candidates	1300+candidates
	Solar power >100 kW (MW)	2020.	candidates	candidates	candidates
		2030.	candidates	candidates	candidates
		2050.	candidates	candidates	candidates
	Wind (MW)	2020.	744	744	744
		2030.	744 + candidates	1200 + candidates	2000 + candidates
		2050.	744 + candidates	1200 + candidates	2000 + candidates ti
	Biomass power plants (1:1 ratio of electricity and heat for the CTS in CHP mode)	2020.	120	120	120
		2030.	120 + candidates	150 (140 Plexos)	200 (170 Plexos)
		2050.	120 + candidates	150 (140 Plexos)	280 (220 Plexos)
	Biogas (do not contribute to heat)	2020.	70	70	70
		2030.	70 + candidates	90	100
		2050.	70 + candidates	90	120
	Geothermal power plants (do not contribute to heat	2020.	30	30	30
		2030.	30	35	40
		2050.	30	40	50

Input data and settings

Scenario	NURa	NU1a	NU2a
The investment cost for the development of the network due to new capacity RES **	75 EUR/kW	75 EUR/kW	75 EUR/kW
Projections for price reduction of technologies for the renewable energy sources, according to the reference ***	YES	YES	YES
Electricity Market	The projection of hourly prices	The projection of hourly prices	The projection of hourly prices
Exchange capacity (after deduction of Krško NPP)	1,3 GWh/h	1,3 GWh/h	1,3 GWh/h
Price of CO2 units in the EU ETS (EUR/EUA)	15 EUR/EUA, constantly	According to EUREF 2016	According to EUREF 2016
The limit for CO2 emissions	NO	NO	**YES, -54% 2030. (1.725 kt co2,) -85% 2050. (260 kt co2) in compare to 1990 levels**
Power and heat consumption	According to projections for the NUR	According to projections for the NU1	According to projections for the NU2

Input data and settings

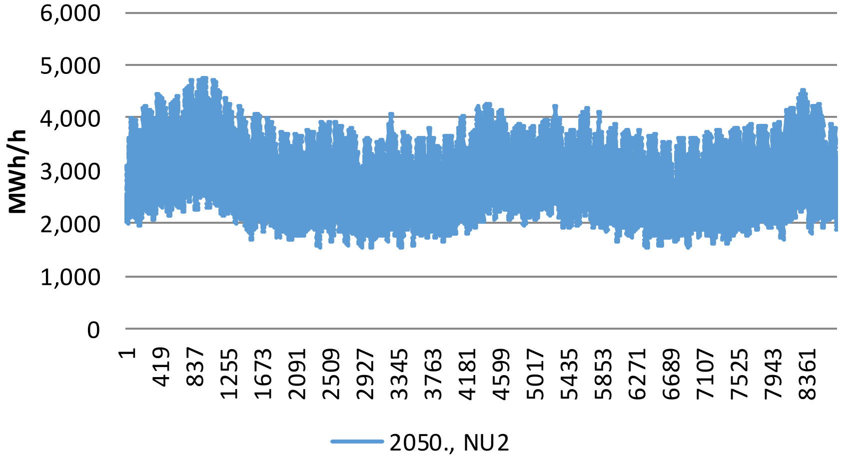
Scenario	NURa	NU1a	NU2a
Price of fossil fuels	According to EUREF 2016	According to EUREF 2016	According to EUREF 2016
Flexible demand	Heat storage, simple adjustment of the curve of charging electric vehicles	Heat storage, simple adjustment of the curve of charging electric vehicles	Heat storage, simple adjustment of the curve of charging electric vehicles
Net imports of electricity	30% of the net consumption by 2020, linear decrease to 0 from 2030	30% of the net consumption by 2020, linear decrease to 0 from 2030	30% of the net consumption by 2020, linear decrease to 0 from 2030
Reserve	As until now	As until now	As until now
The annual limit for the construction of new RES (MW/year)	3*100 for Wind, for SE 50 MW by 2030 100 MW by 2050 The ratio integrated:high 1:2	3*150 for Wind, for SE 100 MW by 2030 200 MW by 2050 The ratio integrated:high 1:2	3*200 for Wind, for SE 150 MW by 2030 300 MW by 2050 The ratio integrated:high 1:2:2
Candidates - Construction depends on profitability in the simulation of market without incentives			
* assessment of market development on the principle of net metering			
** Douring optimization it is accounted as addition to the investment cost of the new RES, except the small solar systems <100kW for their own consumption, source RoadMap 2050 EWIS, according to HOPS (Croatian Transmission System Operator) estimates			
*** The JRC-EU-TIMES model Assessing the long-term role of the SET Plan Energy technologies, JRC, 2013., COST AND PERFORMANCE DATA FOR POWER GENERATION TECHNOLOGIES Prepared for the National Renewable Energy Laboratory, Black and Veatch, 2012., PV LCOE in Europe 2015-2050 (Vartiainen, Masson & Breyer, 31st EU PVSEC, 2015), Data from the Danish Energy Agency and Energinet.dk, 2014			
**** selection on the basis of prospective solutions according to information from HEP			

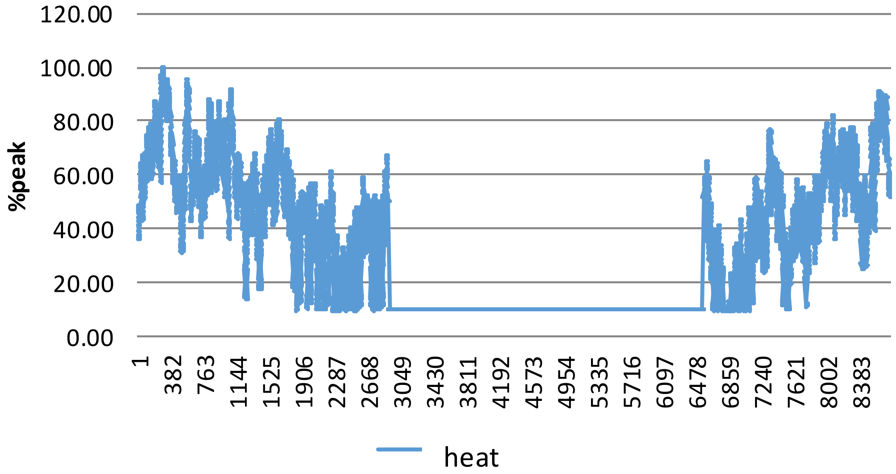
Input data and settings

- Other scenarios:
  - NURb, NU1b, NU2b
    - enable imports to 30% of the net consumption or 5 TWh/year, reserve 0% above the maximum consumption
  - NURa CO2
    - as NURa, but with the increase of prices of CO2 according to the EU REF 2016
  - NU1b_plin
    - as NU1, but with lower gas price for 30%
  - NU2a_260
    - stricter limit for the CO2 emissions in NU2a scenario (-93% emissions by 1990)
  - NU2a_EV
    - limit for the CO2 emissions as NU2a scenario (-85% emissions by 1990) + advanced (wise) use of batteries in electric vehicles

Input data and settings

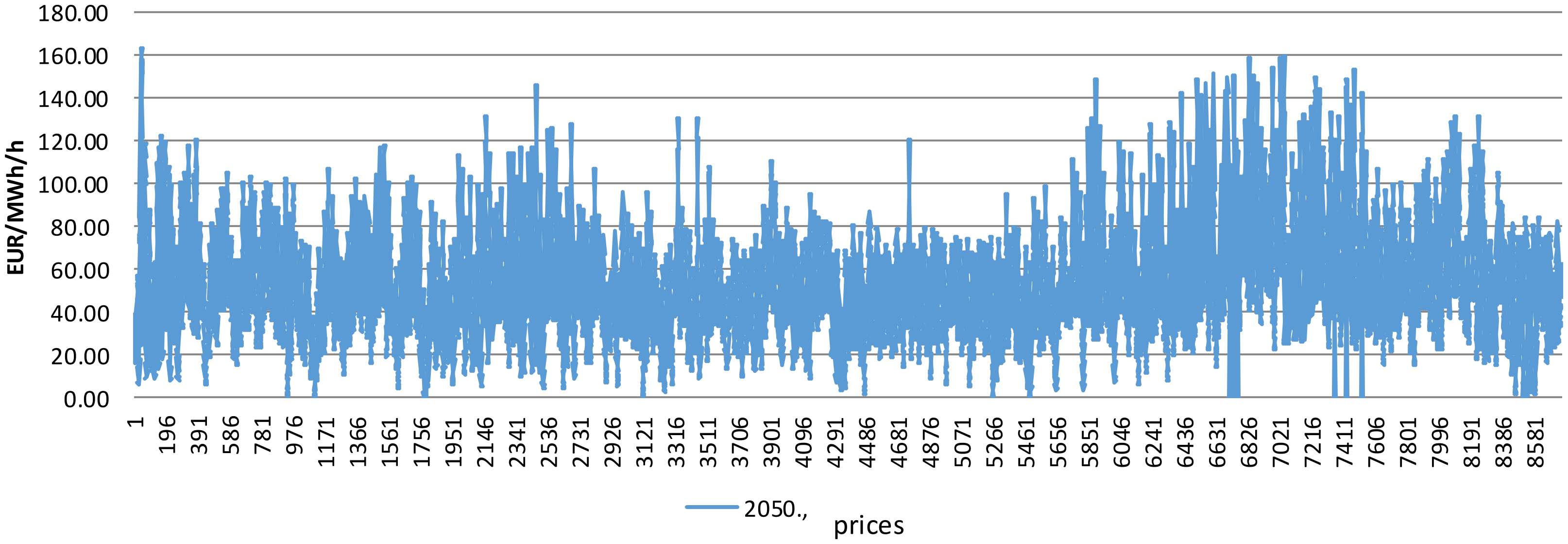
- Hourly projections of consumption of electricity and heat





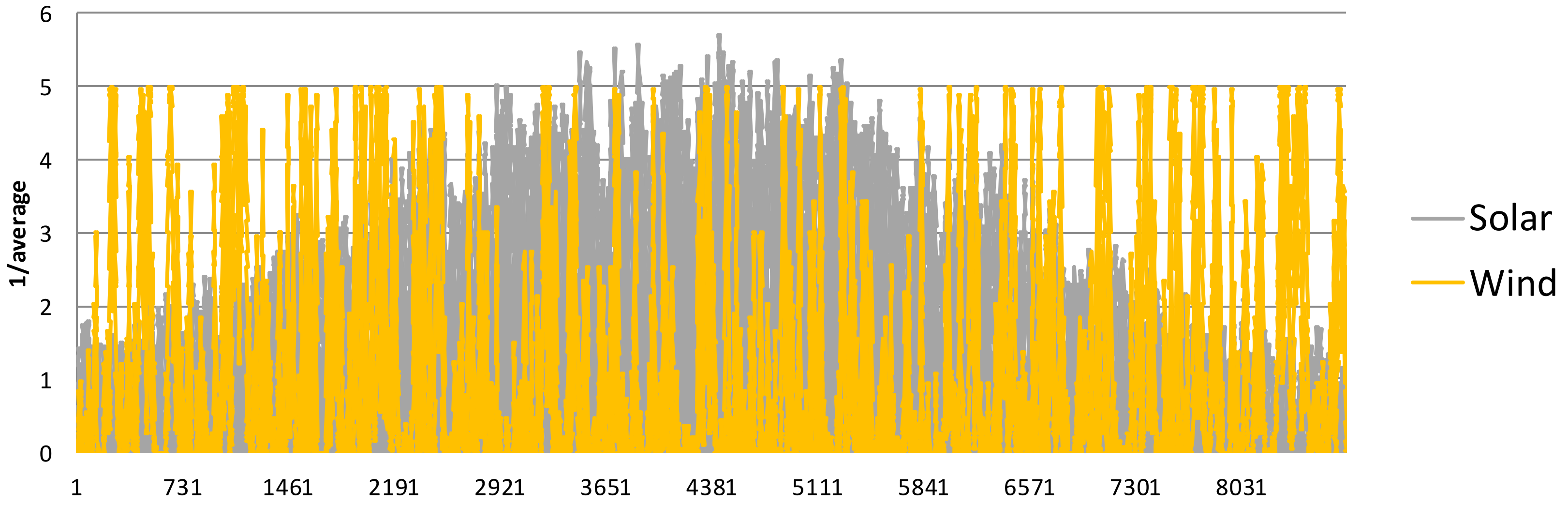
Input data and settings

- Hourly projections of electricity prices on the market



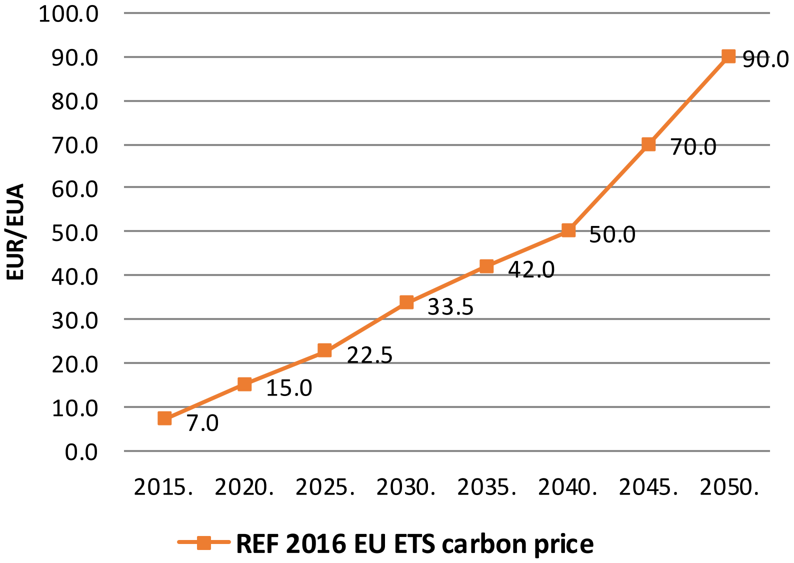
Input data and settings

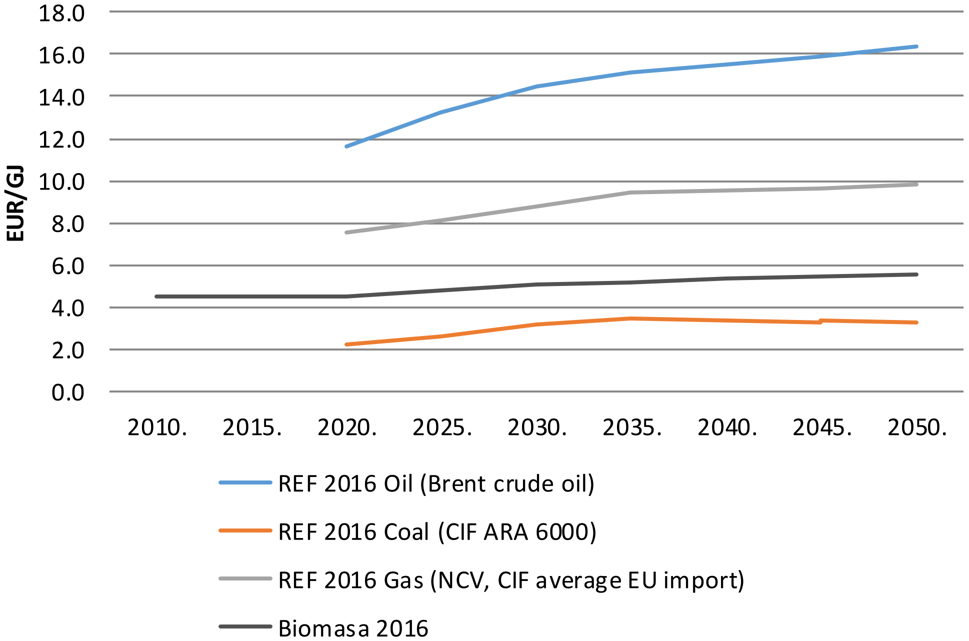
- Hourly projections of electricity produced from solar and wind



Input data and settings

- The reference price of energy sources and CO2

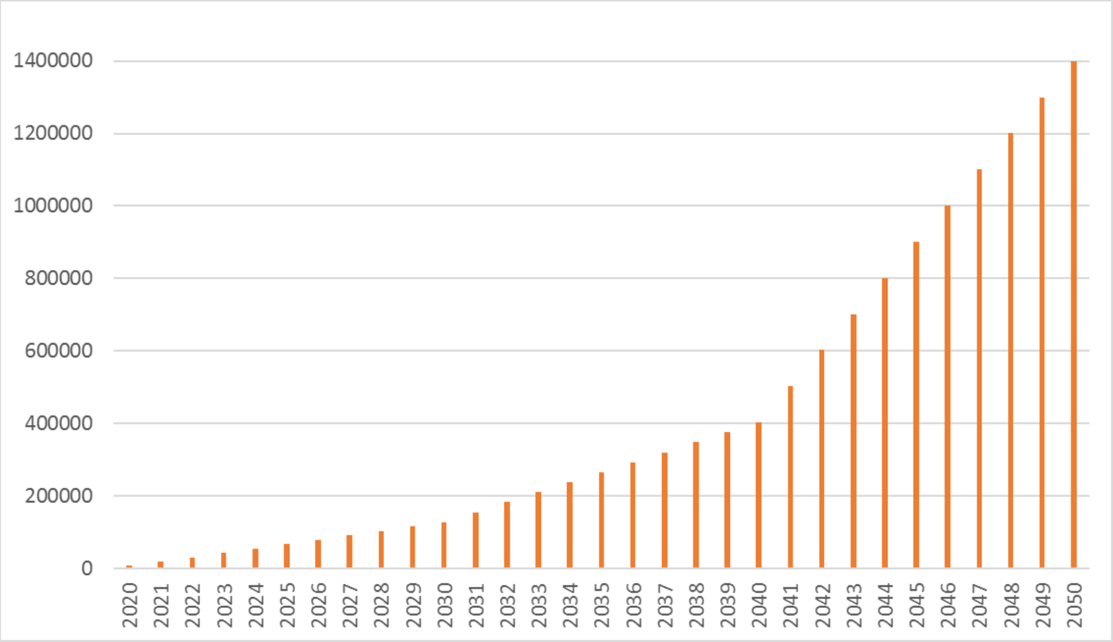




EV modeling - Covered Issues

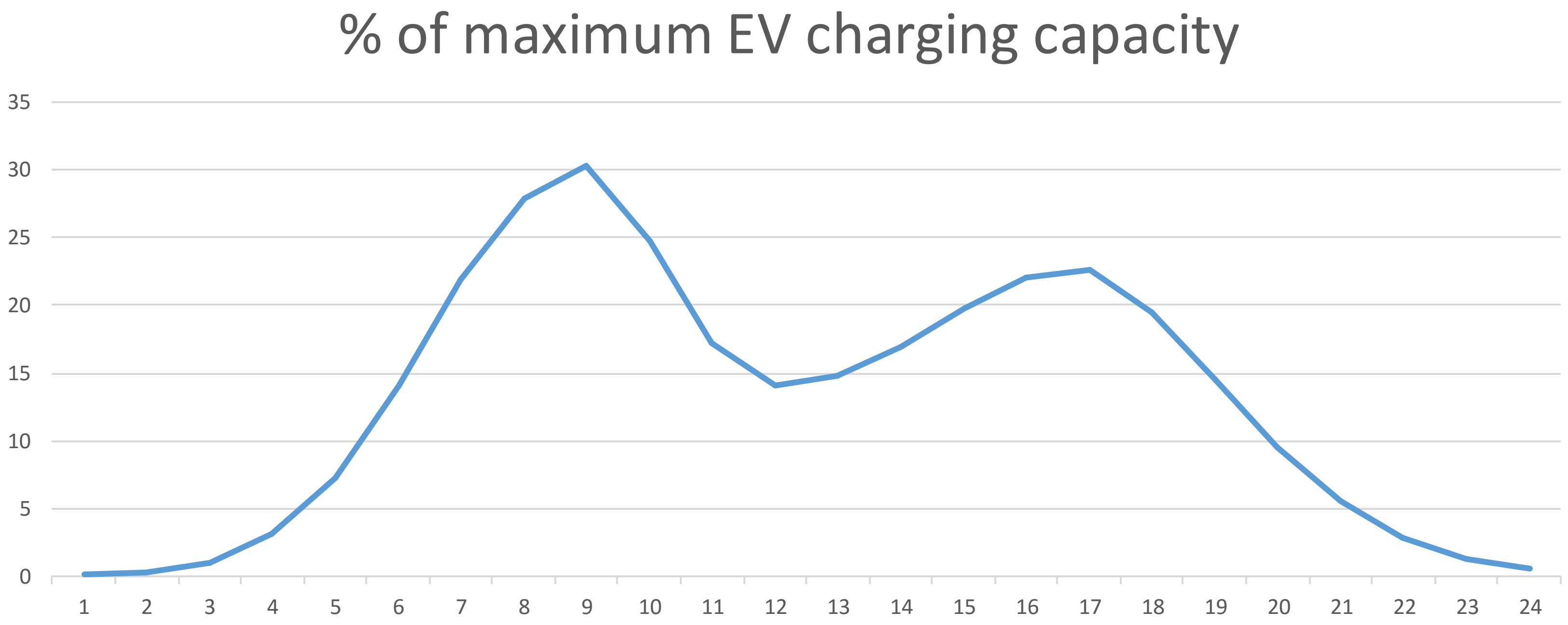
- Number of EVs
- Load profile
- Batery capacity and charge power
- Avalilable capacity for V2G
- Additional flexibility provided by EVs - examples

Predicted number of EVs

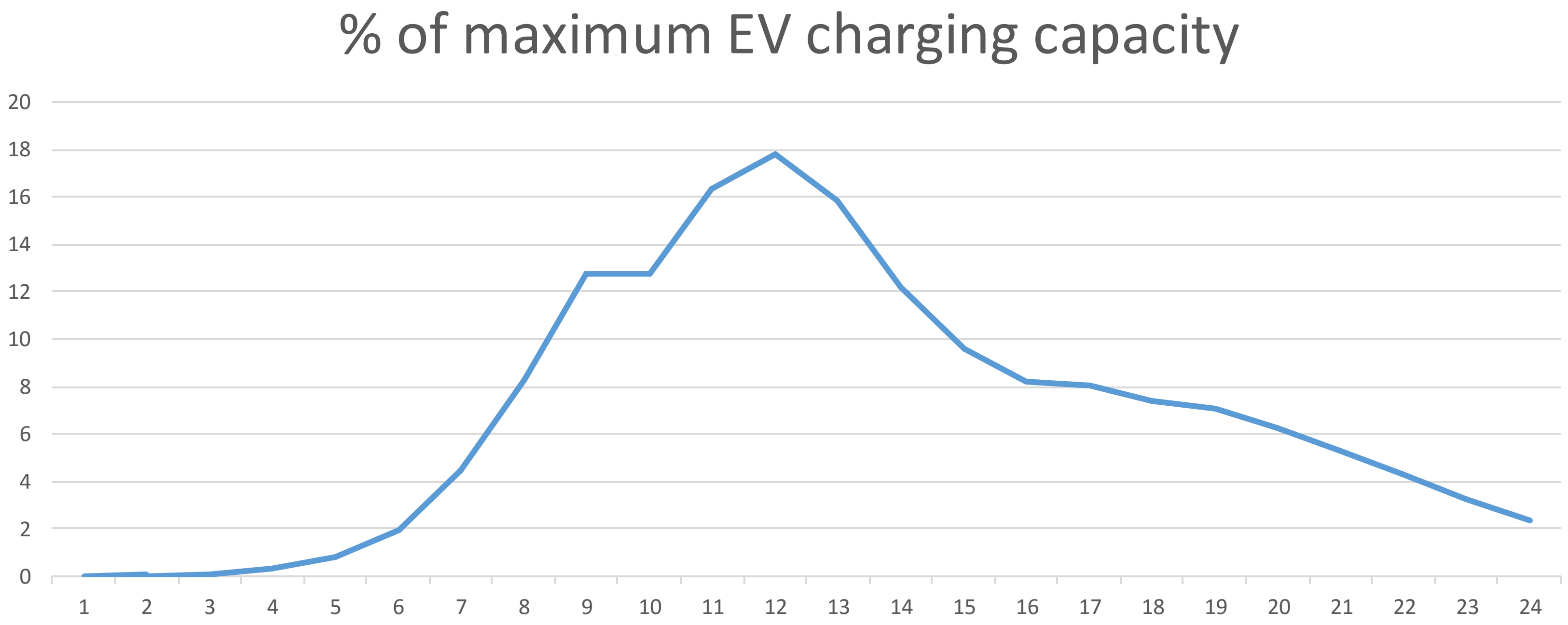


- Target: 1,4 million by 2050.

EV load profile – week day

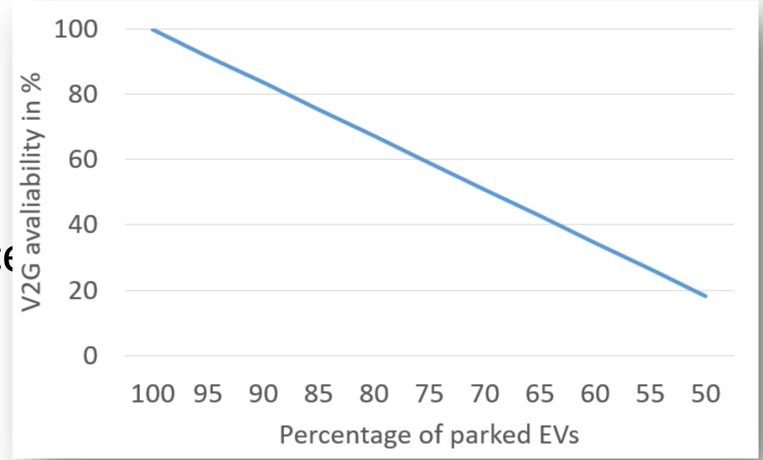


EV load profile – weekend day



Available V2G capacity

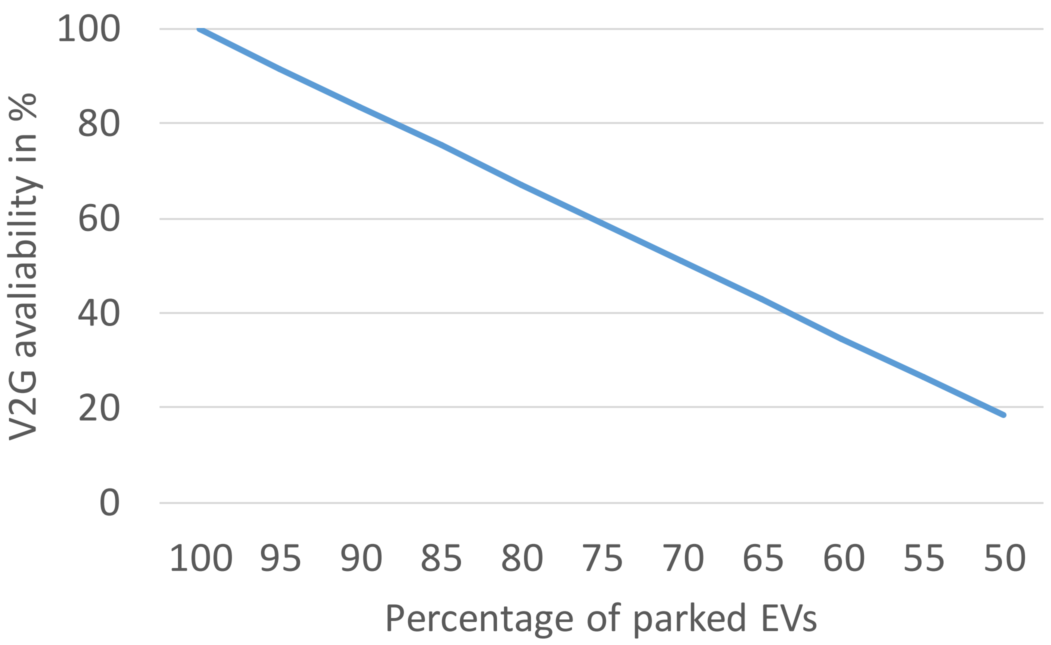
- Depends on:
  - Number of **parked** EVs (not moving)
  - Number of parked EVs on parking place



- Availability of parked EV capacity
- Approach and **assumptions**:
  - During night hours most of parked EVs are also available for V2G
  - During peak traffic hours avaliability of parked EVs for V2G is lowest
  - Availability for V2G is **inversly proportional** to number of moving EVs

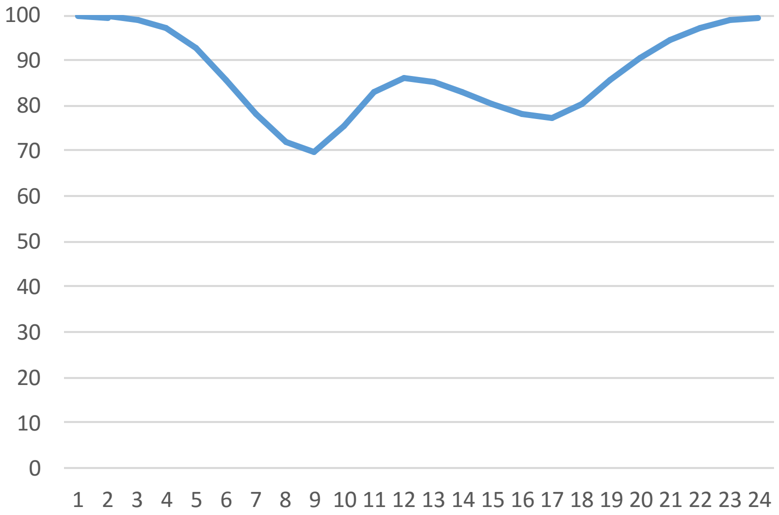
V2G availability function

- If all EVs are parked availability is 100 %
- During peak trafic hours availability is 50 %
- It is assumed that alt least 70% of EVs are always parked

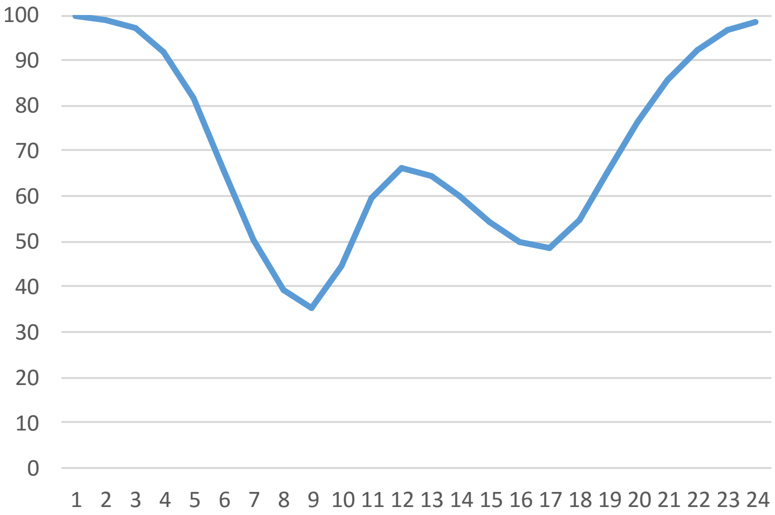


V2G availability – week day

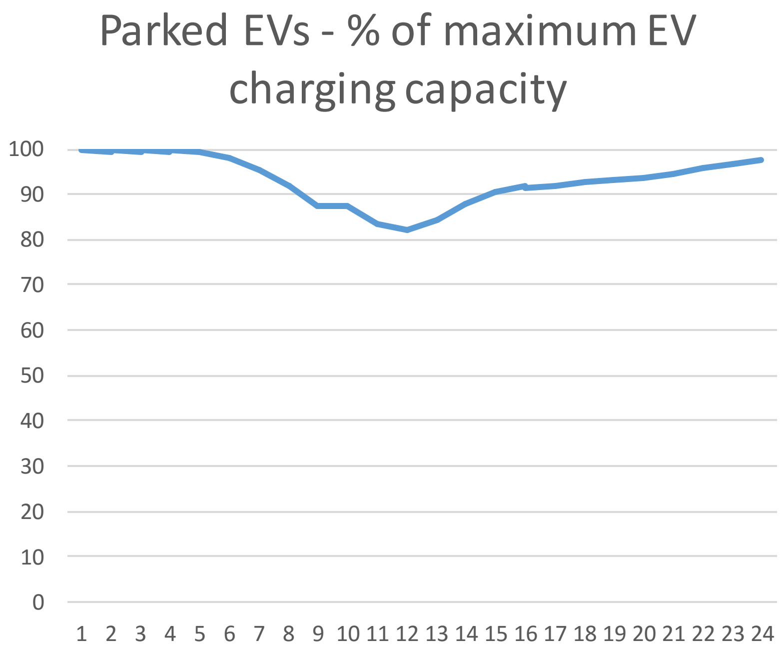
Parked EVs - % of maximum EV charging capacity

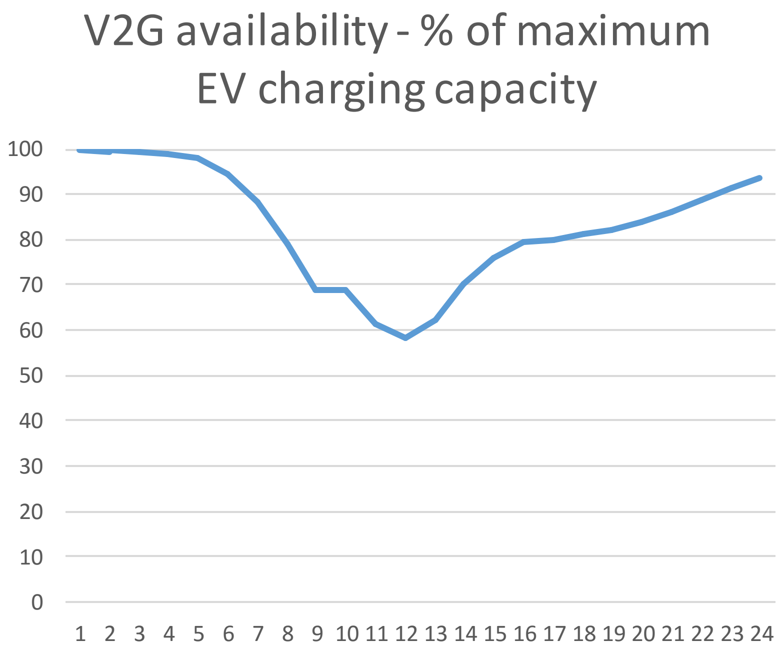


V2G availability - % of maximum EV charging capacity



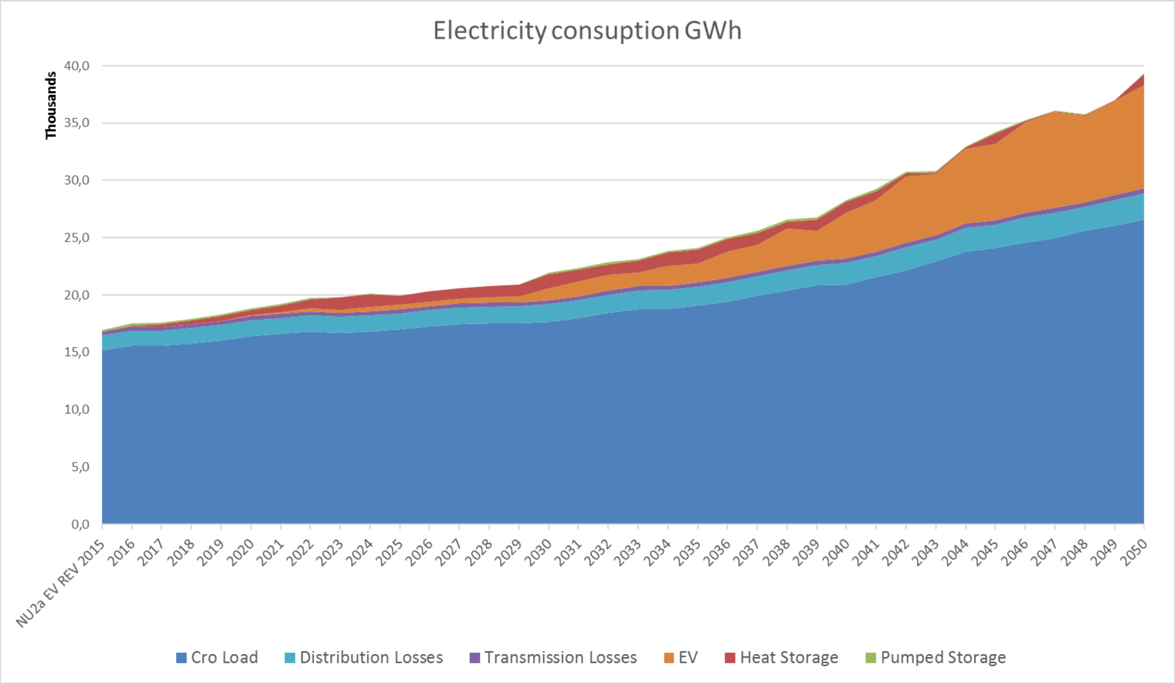
V2G availability – weekend day



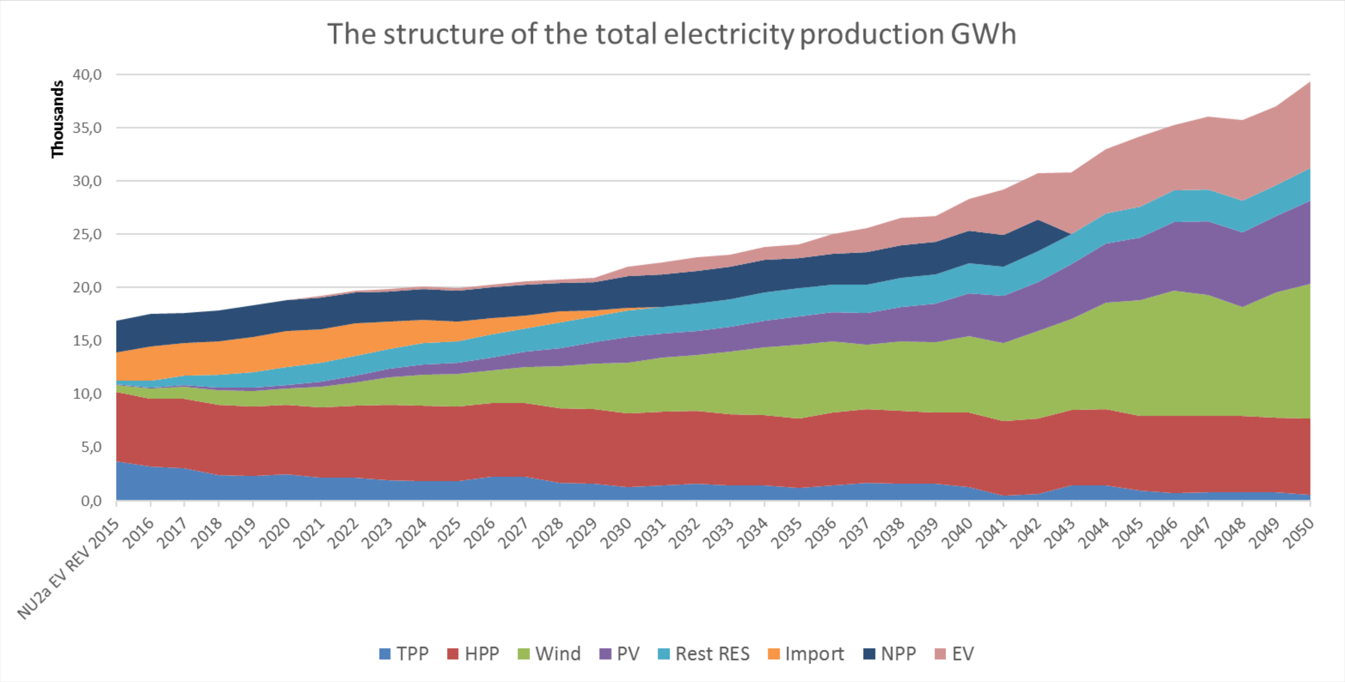


Results of scenarios

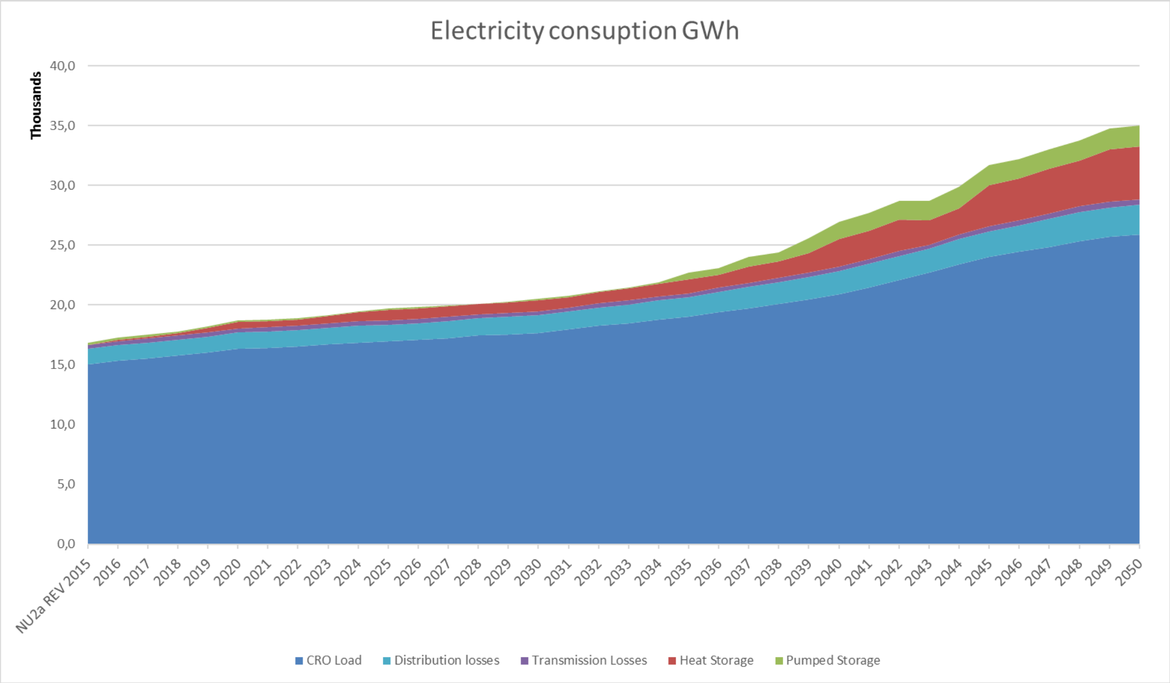
Results with EVs modeled



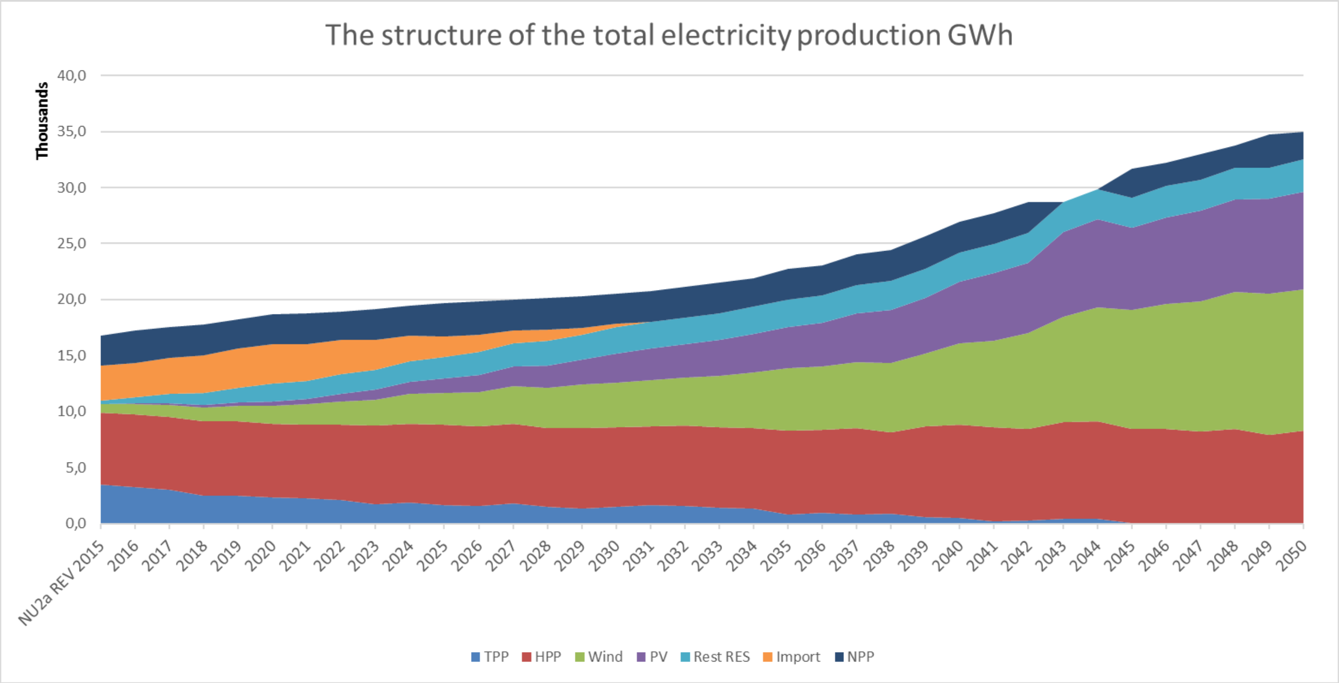
Results with EVs modeled



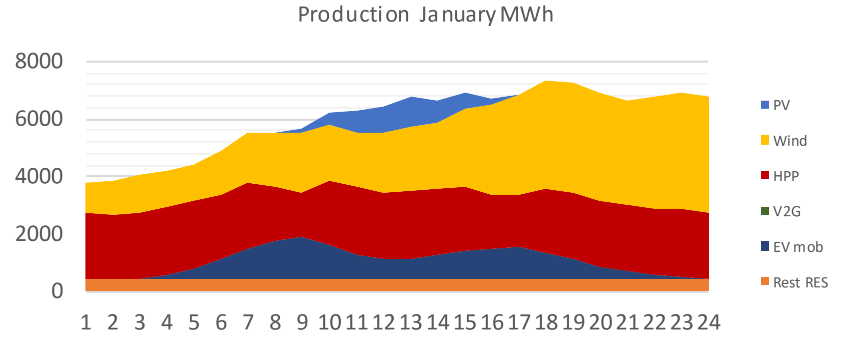
Results without EVs modeled

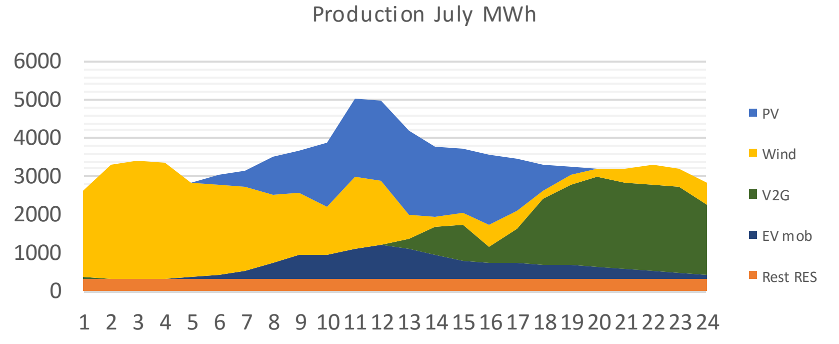


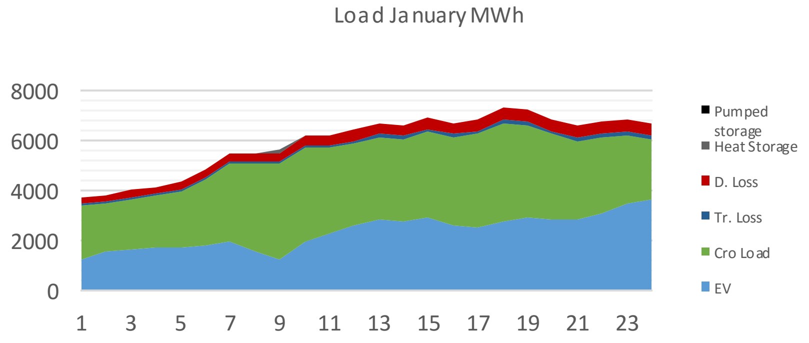
Results without EVs modeled

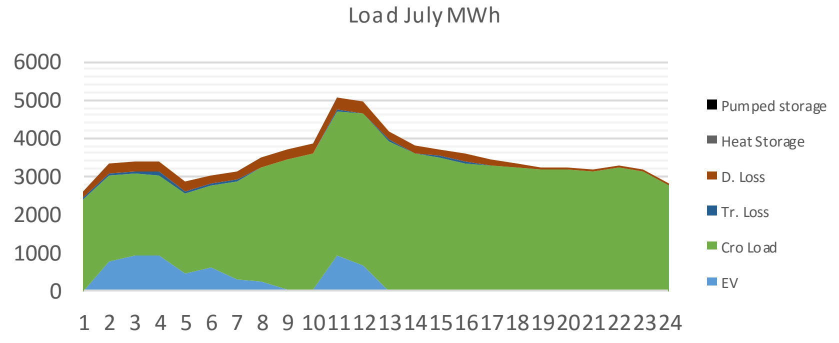


EV: electricity consumer or producer?





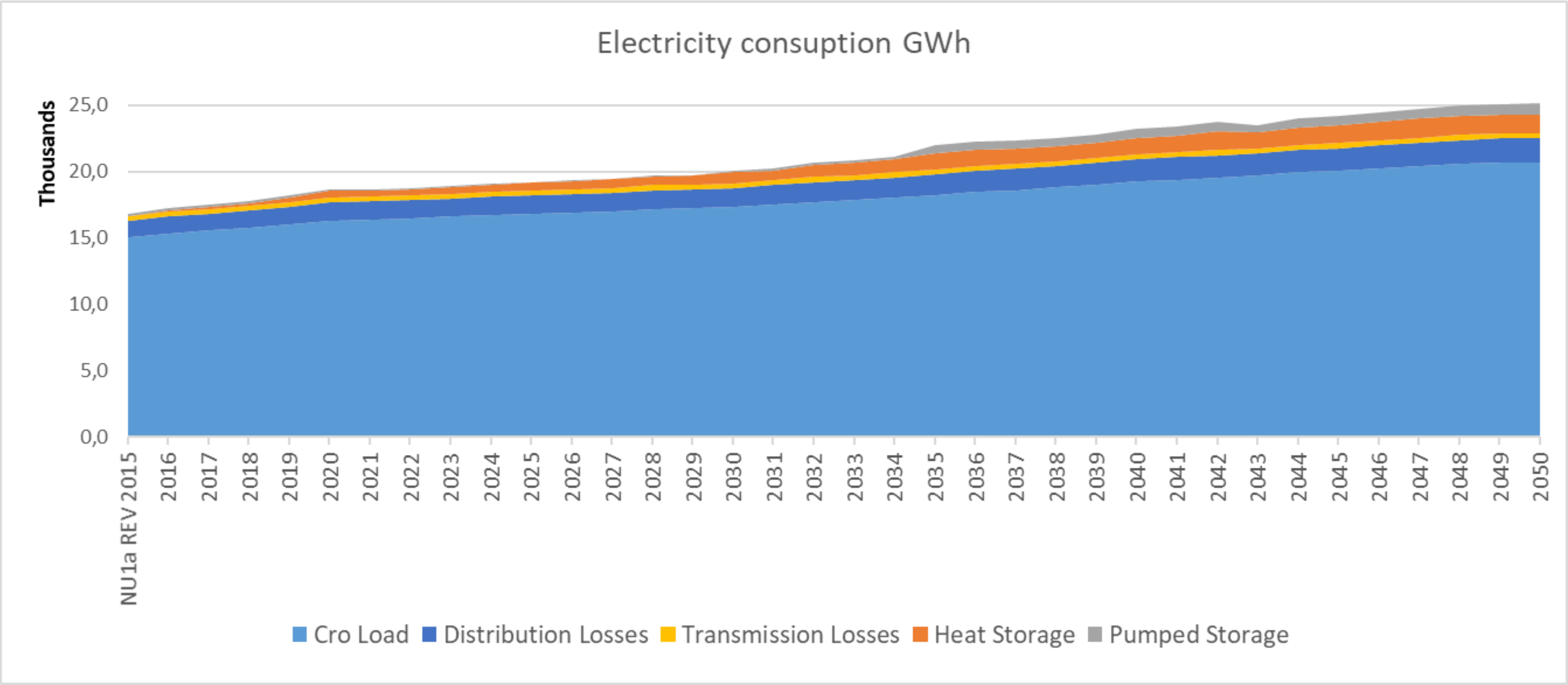




Additional flexibility

- EVs in 2050. will consume around 4,5 TWh
- It is estimated that additional EV electricity consumption for V2G will be also around 4,5 TWh in 2050.
- That is significant additional flexibility added to system
- With chargers larger than 3,5 kW (highly possible) this flexibility will be even larger
- Network issues?
    - Just in terms of costs

NU1a & NU2a_EV



Electricity consuption GWh
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NU1a REV 2015
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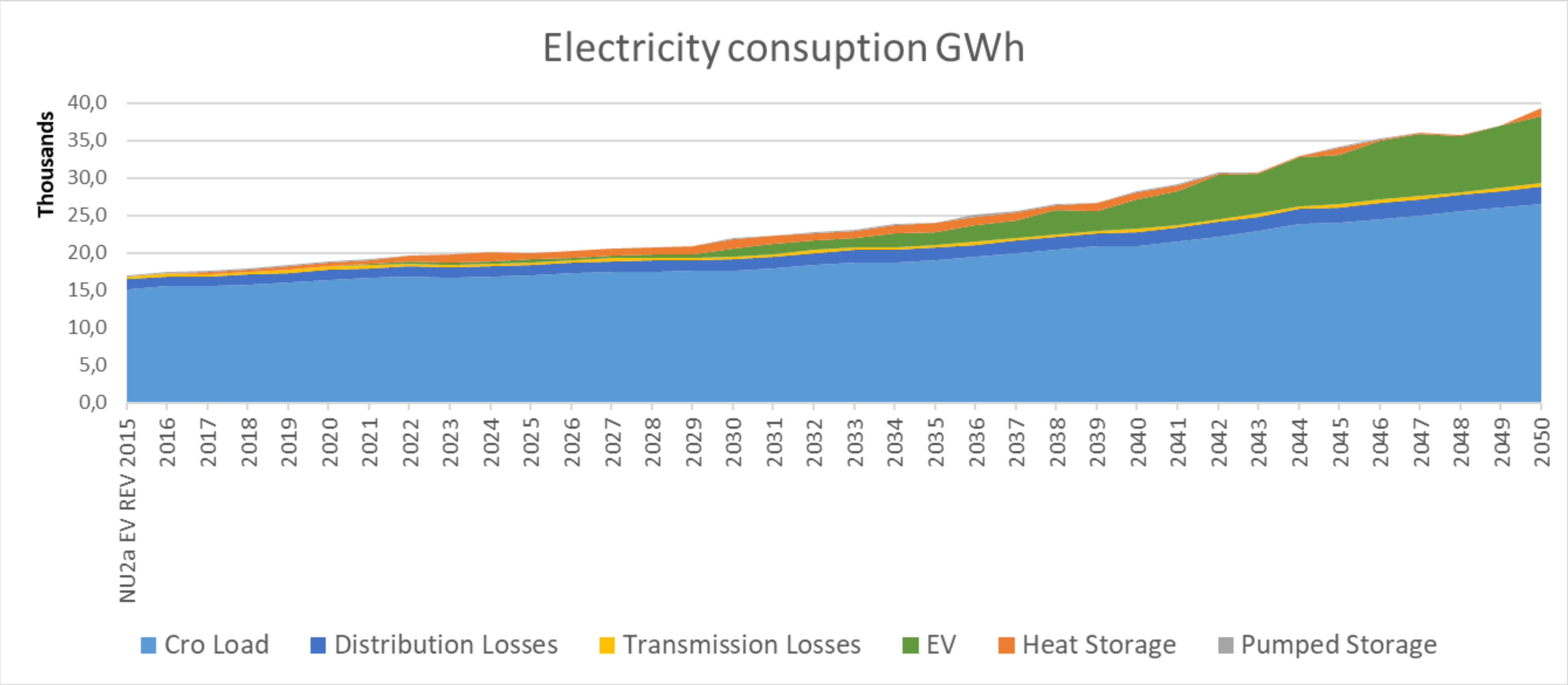
Cro Load
Distribution Losses
Transmission Losses
Heat Storage
Pumped Storage

NU1a & NU2a_EV



Electricity consuption GWh
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NU2a EV REV 2015
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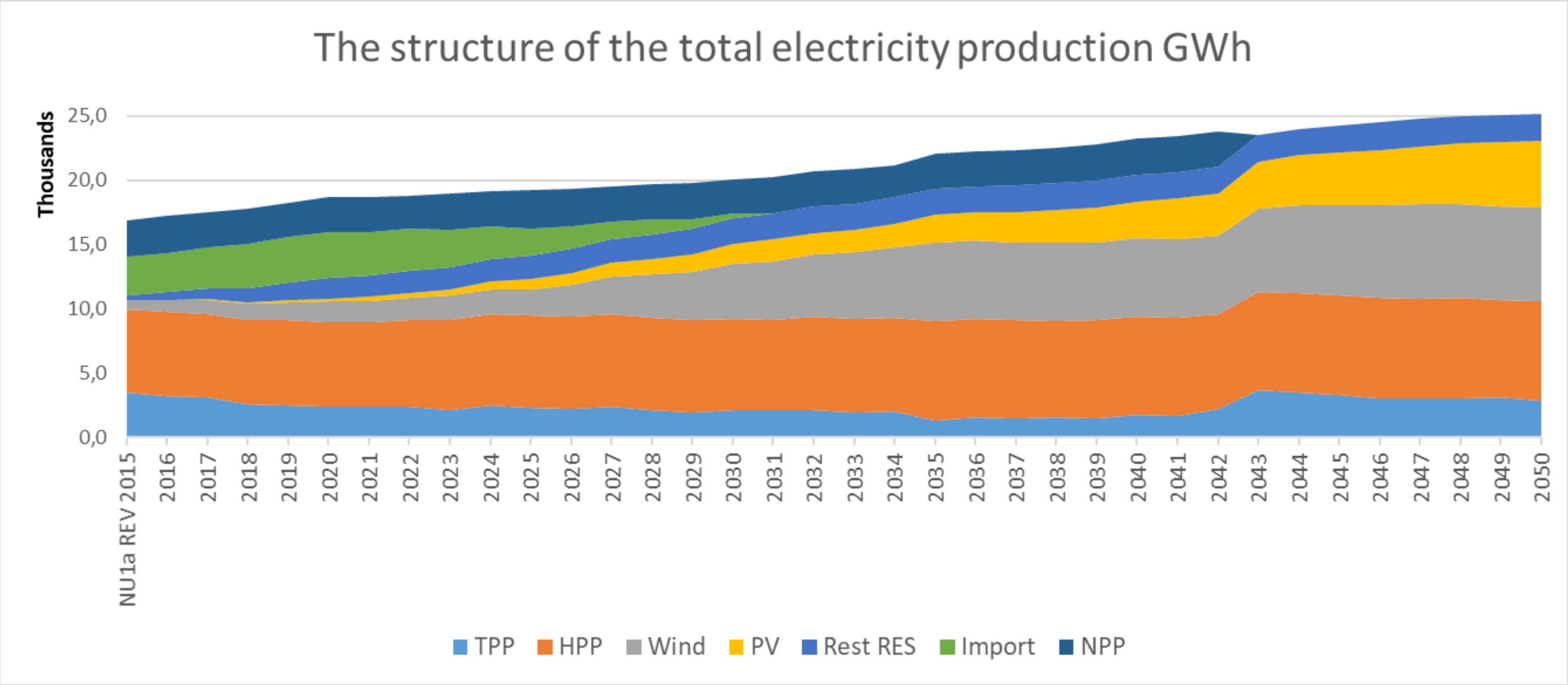
Distribution Losses
Transmission Losses
EV
Heat Storage
Pumped Storage

NU1a & NU2a_EV


The structure of the total electricity production GWh
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NU1a REV 2015
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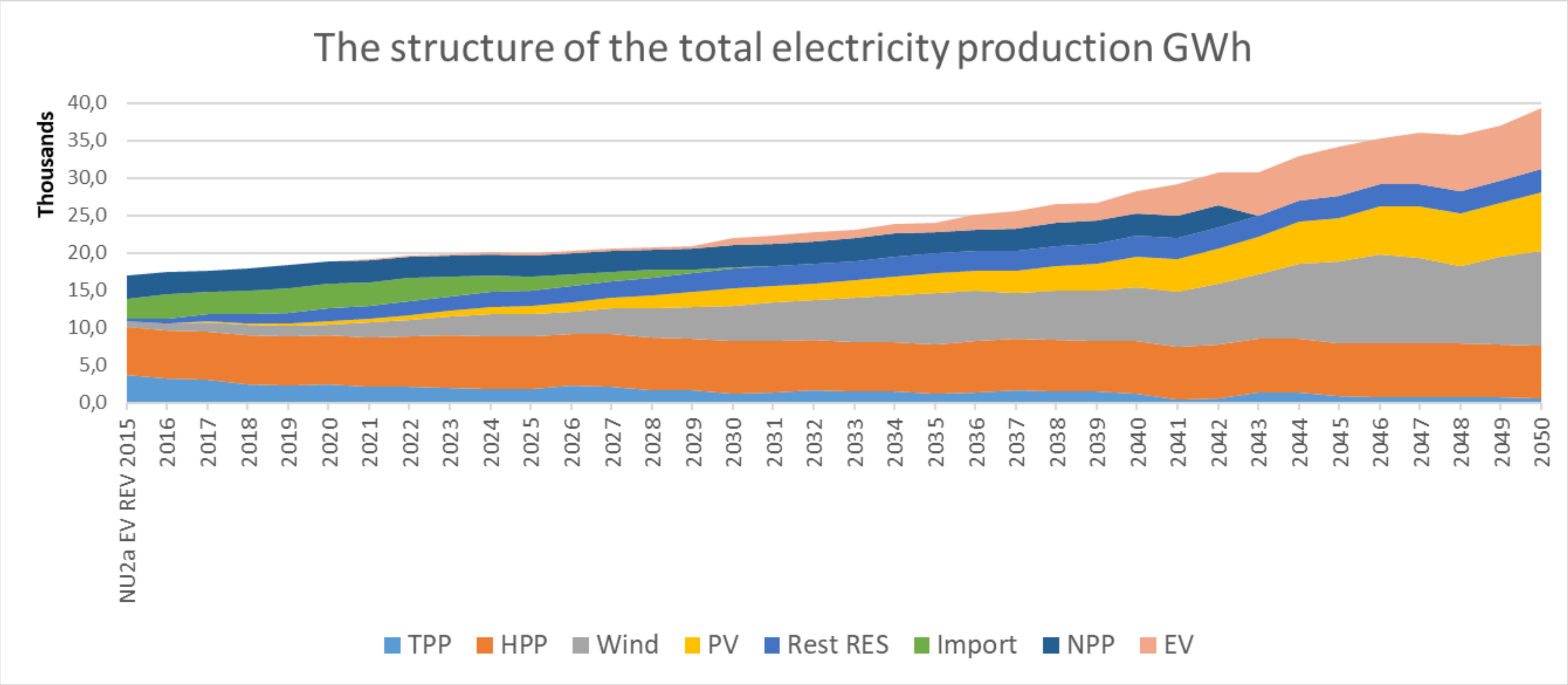
TPP
HPP
Wind
PV
Rest RES
Import
NPP

NU1a & NU2a_EV


The structure of the total electricity production GWh
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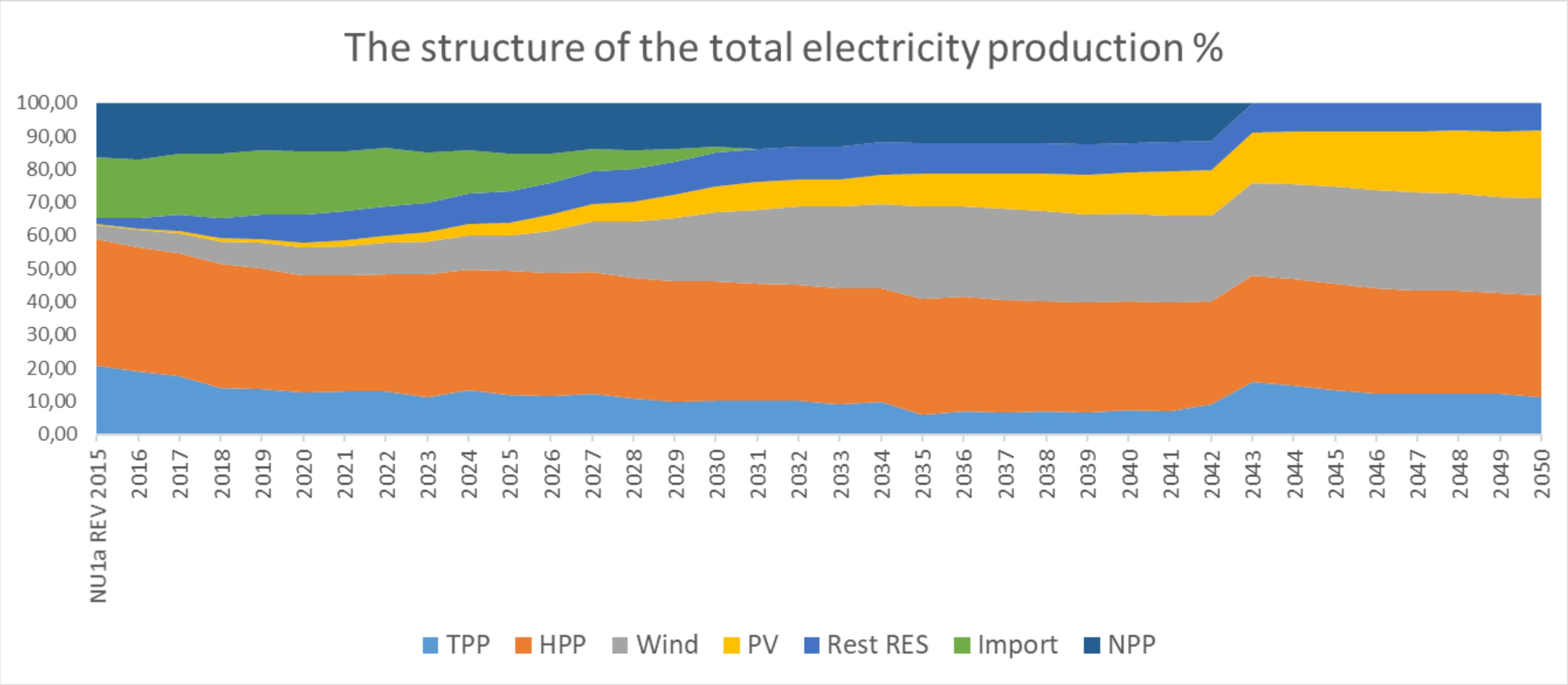
NU1a


The structure of the total electricity production %
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NU1a REV 2015
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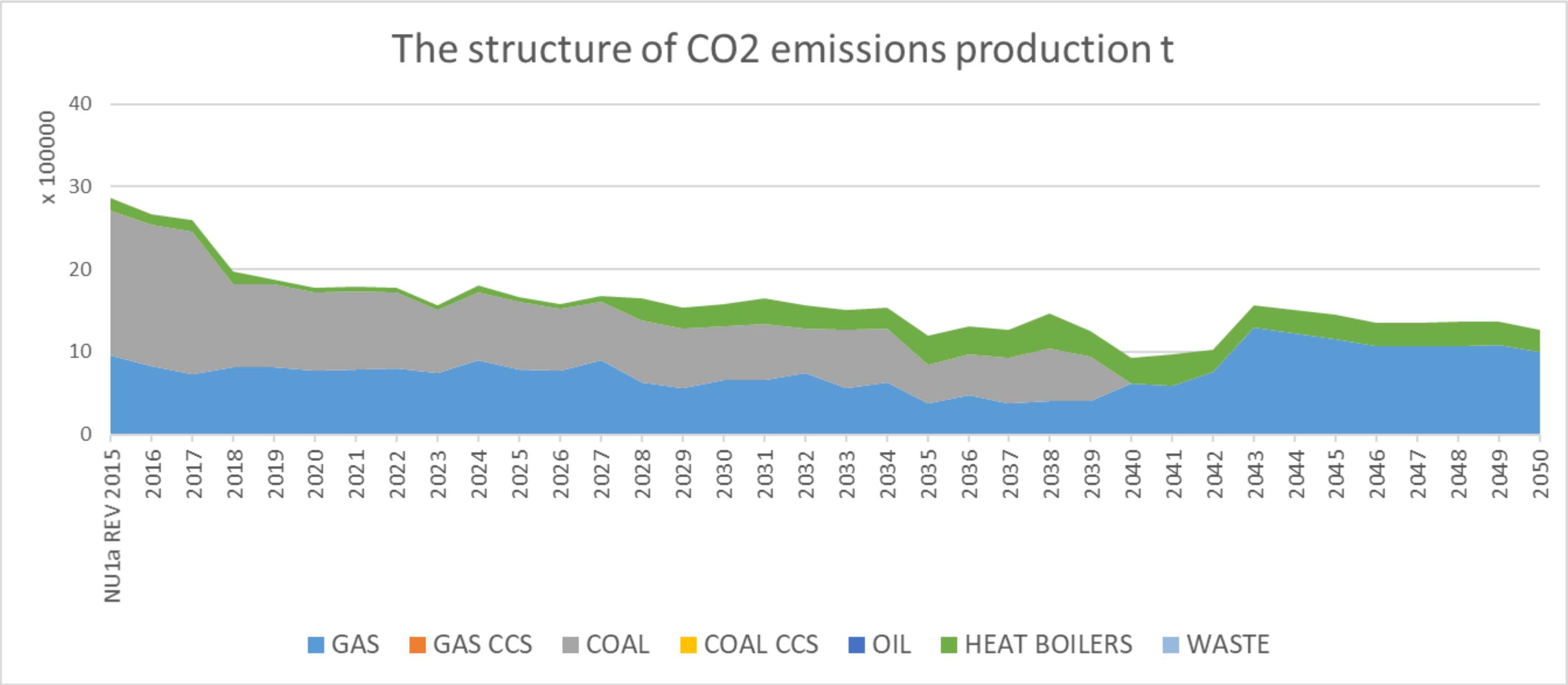
NU1a


The structure of CO2 emissions production t
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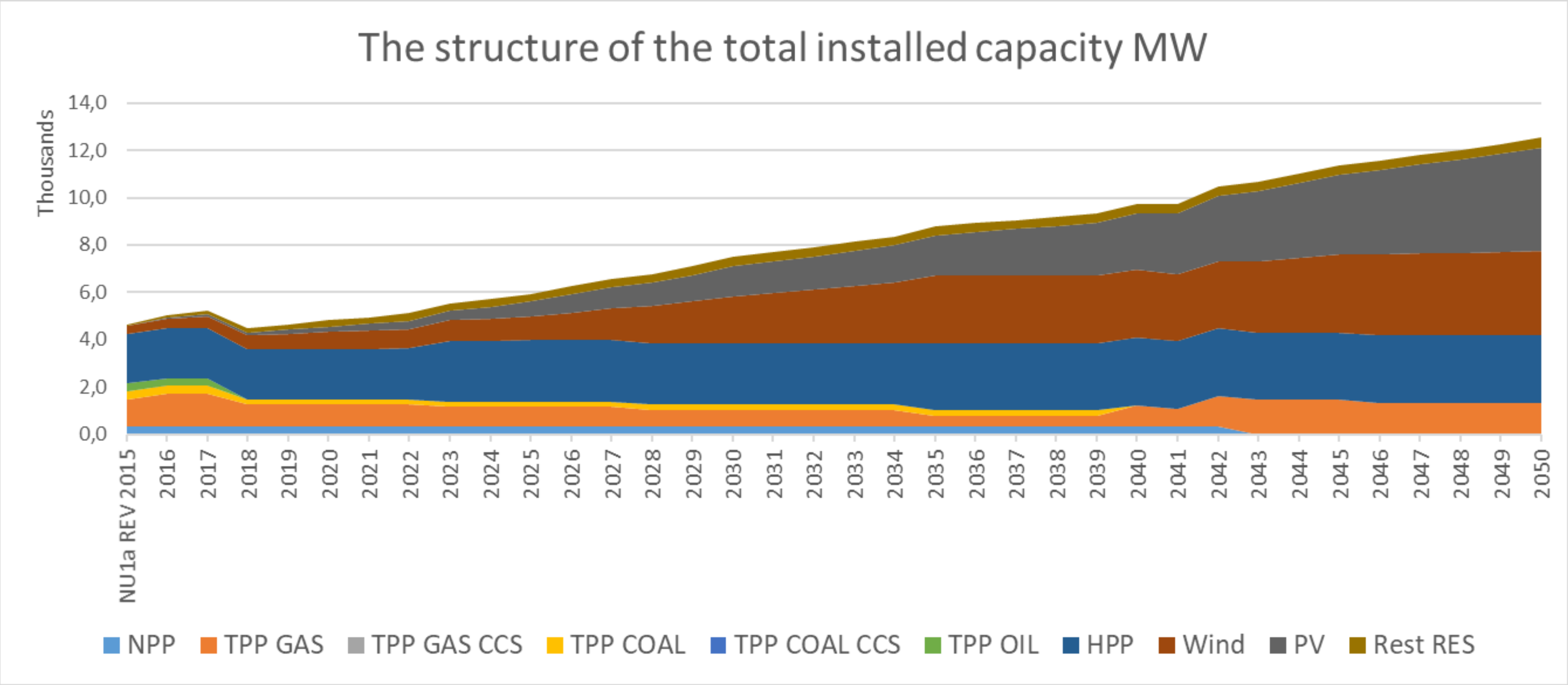
WASTE

NU1a



The structure of the total installed capacity MW
Thousands
14,0
12,0
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2,0
0,0
NU1a REV 2015
2016
2017
2018
2019
2020
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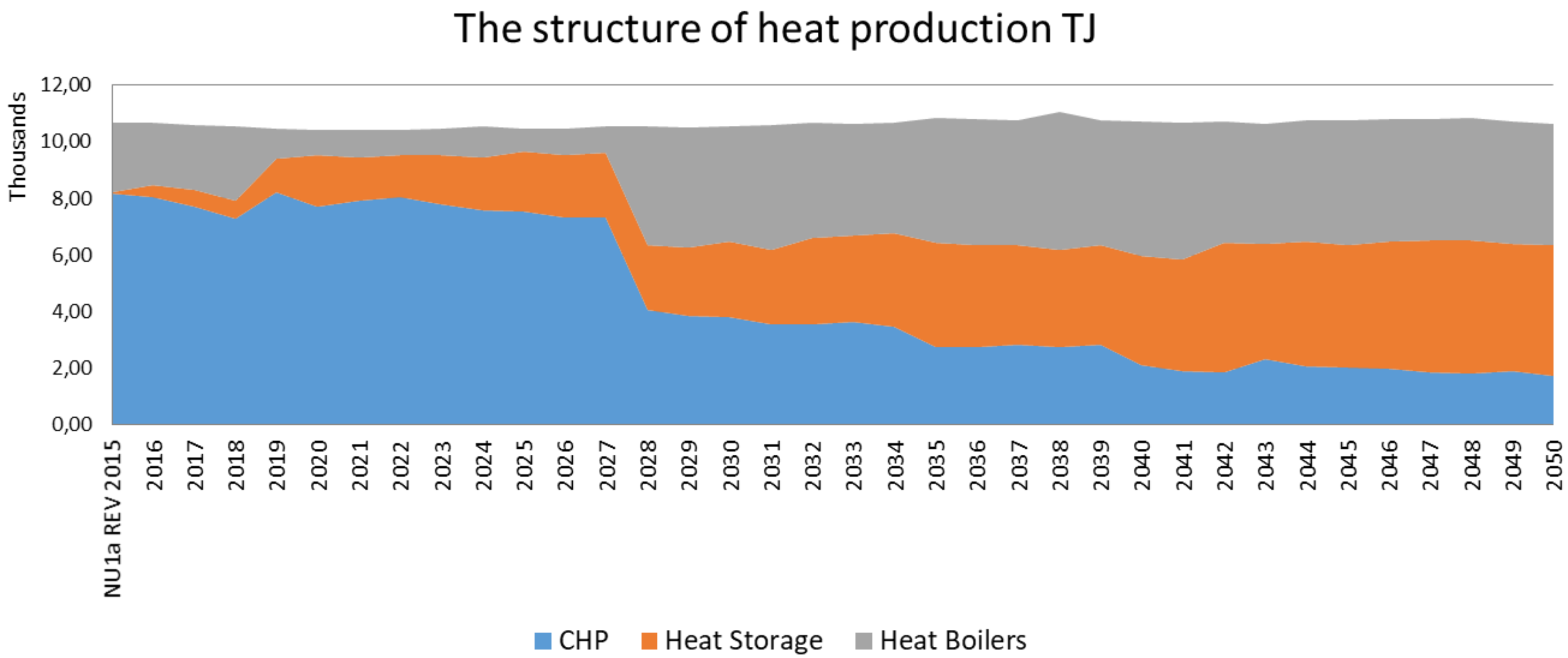
2050
NPP
TPP GAS
TPP GAS CCS
TPP COAL
TPP COAL CCS
TPP OIL
HPP
Wind
PV
Rest RES

NU1a


The structure of heat production TJ
Thousands
12,00
10,00
8,00
6,00
4,00
2,00
0,00
NU1a REV 2015
2016
2017
2018
2019
2020
2021
2022
2023
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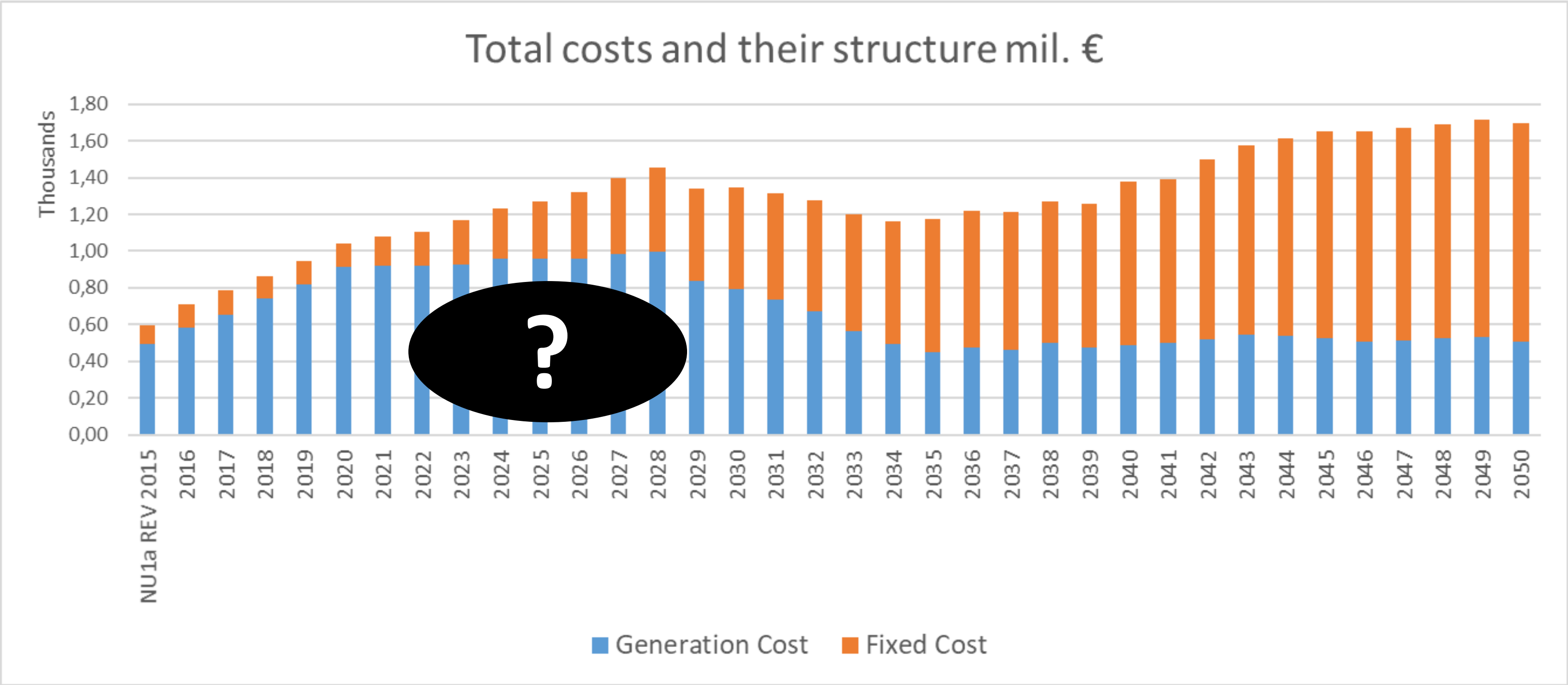
2049
2050
CHP
Heat Storage
Heat Boilers

NU1a


Total costs and their structure mil. €
Thousands
1,80
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
NU1a REV 2015
2016
2017
2018
2019
2020
2021
2022
2023
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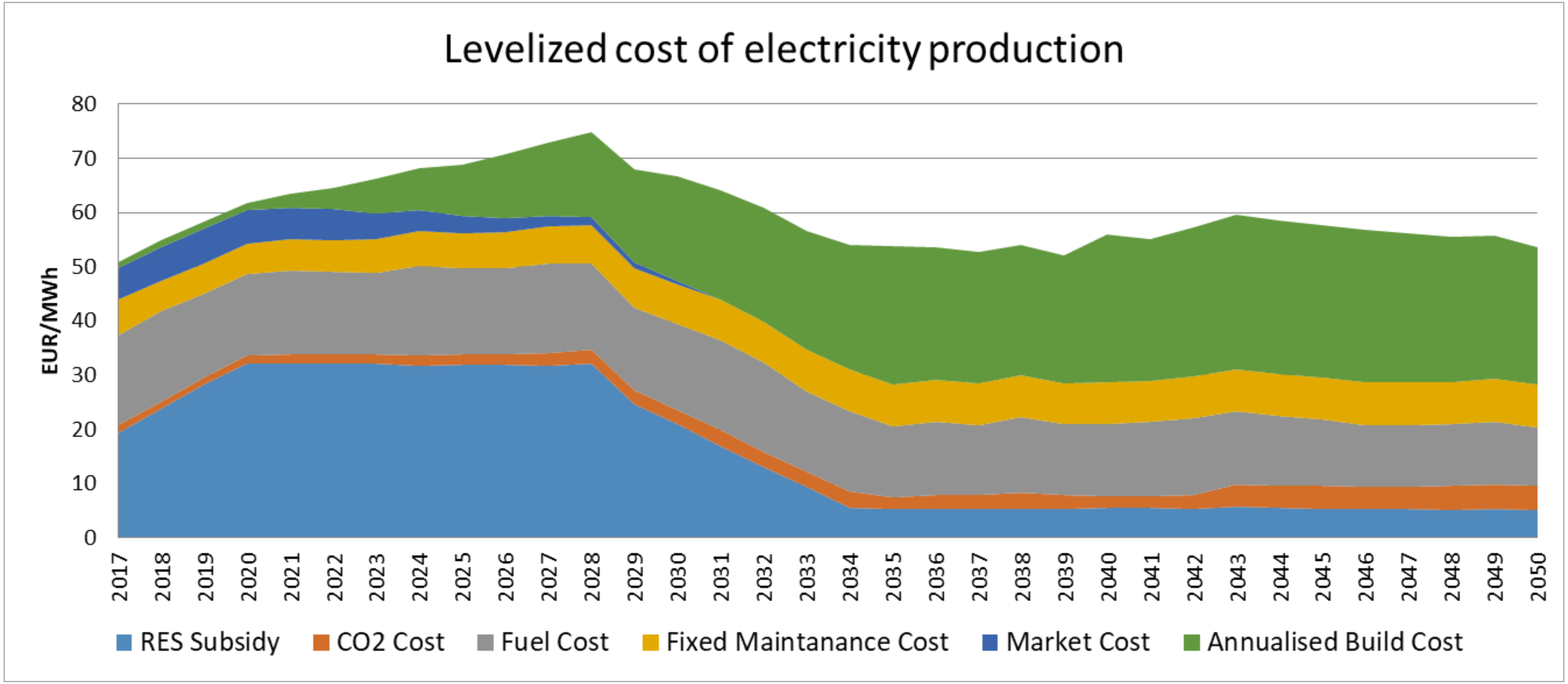
2050
?
Generation Cost
Fixed Cost

NU1a



Levelized cost of electricity production
EUR/MWh
80
70
60
50
40
30
20
10
0
2017
2018
2019
2020
2021
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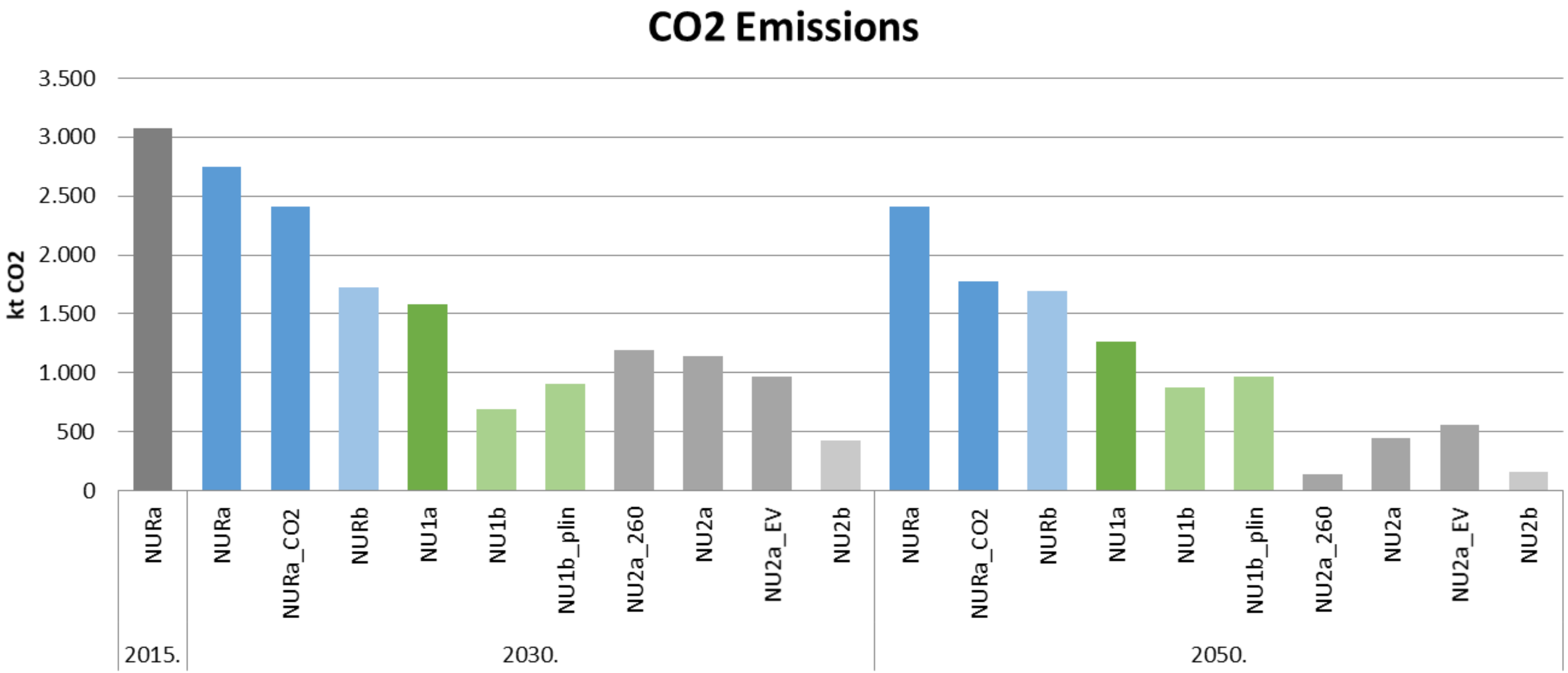
2050
RES Subsidy
CO2 Cost
Fuel Cost
Fixed Maintanance Cost
Market Cost
Annualised Build Cost

Comparison of scenarios



Comparison of the main indicators of scenarios - Range of renewables in NU1 i NU2 scenarios

		2015.	2030.	2050.
Capacity				
HPP	MW	2.095	2.609	2.609 – 3.609
Wind	MW	418	1.520 – 2.200	2.200 – 6.720
SE	MW	48	1.140 - 1860	3.299 – 6.381
Other RES	MW	88	385 - 450	410 - 530
Biomass PP	MW	25	140 - 170	140 - 220
Biogas PP	MW	27	90 - 100	90 - 120
Geothermal PP	MW	0	35 - 40	40 - 50
Small HPP	MW	36	120 - 140	140

Wind

SE

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Unska 3, HR-10000 Zagreb Tel: 01/ 6129 907, Fax: 01/ 6129 890 E-mail: zvne@fer.hr URL: http://www.zvne.fer.hr/

Conclusion

- In all scenarios **significant RES** share increase is expected especially in photovoltaic and wind power - volatile nature
- **Additional flexible** power plants/other assets should be also commissioned.
- If assumptions and measures stated in Croatian LEDS would be implemented and achieved, then Croatia will be able to develop and design its power system **in alignment with international and European requirements** regarding CO2 emissions that are set.