EnergyVille

BBL / Greenpeace / IEW Sensitivity Study

Summary

31/01/2018

Contents

The Project

Overall Objective

- Sensitivity analyses of cost optimal scenarios in the framework of the EnergiePact discussions.

EnergyVille

Scenario definitions and assumptions

Scenario overview

The different scenario's

- EV2017: EnergyVille 2017 study ordered by Febeliec (see http://energyville.be/nieuwsbericht/energyville-introduceert-objectieve-vooruitblik-op-de-belgische)
- UP18: Update base scenario
  - Gas prices aligned with World Bank 10/2017
  - Updated existing gas power plant capacities (source EDF Luminus 2017)
- UP18-Nuc: Update base scenario + 2 GW nuclear extension of 10 years (2025-2035)
  - Investment cost 1000 EURO/kW (as in EV2017)
  - Availability 2025-2035: 80 % on average, either 0%, 50% or 100%

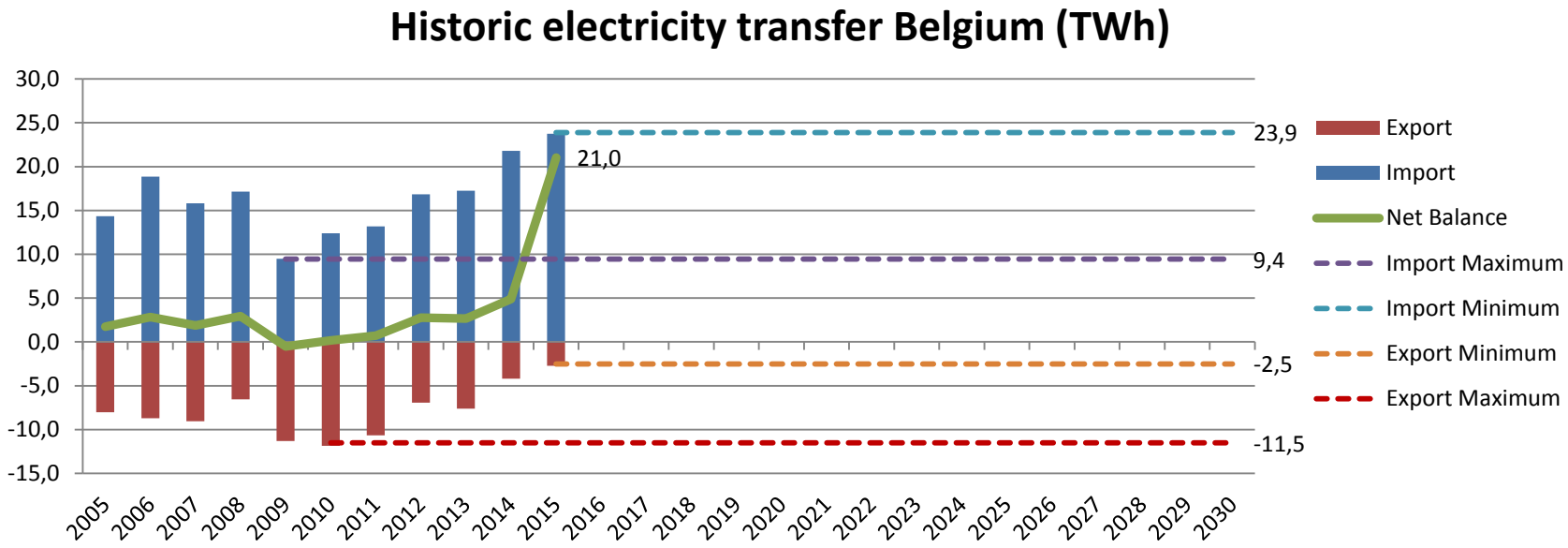
Interconnectivity

- All scenario's
  - 2020: cf ELIA report (Adequacy 2017-2027), maximum import capacity of 6,500 MW will be used.
  - 2030: maximal simultaneous import capacity will increase up to 6,500 MW, because of the
    - interconnection to Germany (ALEGrO: 1,000 MW DC),
    - interconnection to the UK (NEMO: 1,000 MW),
    - the project to Luxembourg, and the enforcements in the North of Belgium (Brabo II and III) and to France.

Interconnectivity

Electricity Trade

- For existing capacity (3.5 GW) upper and lower limits



Policy and targets

All scenario's

	RE % Central case	Carbon price €/ton
2020	13	17
2030	13	33
2040	13	50
2050	13	90

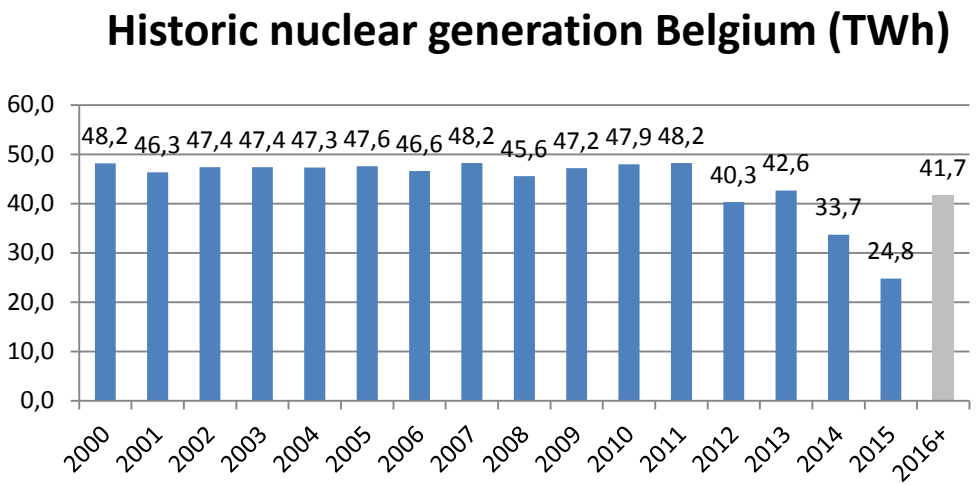
Existing gasplants (capacity in GW)

- The assumptions for the capacity of existing gas power plants have been updated (Source: EDF Luminus 2017)

Existing gas power plants (GW)	EV2017	UP18 and sensitivity scenarios
2016	4,54	3,72
2020	4,54	2,53
2030	1,83	1,85
2040	/	0,69

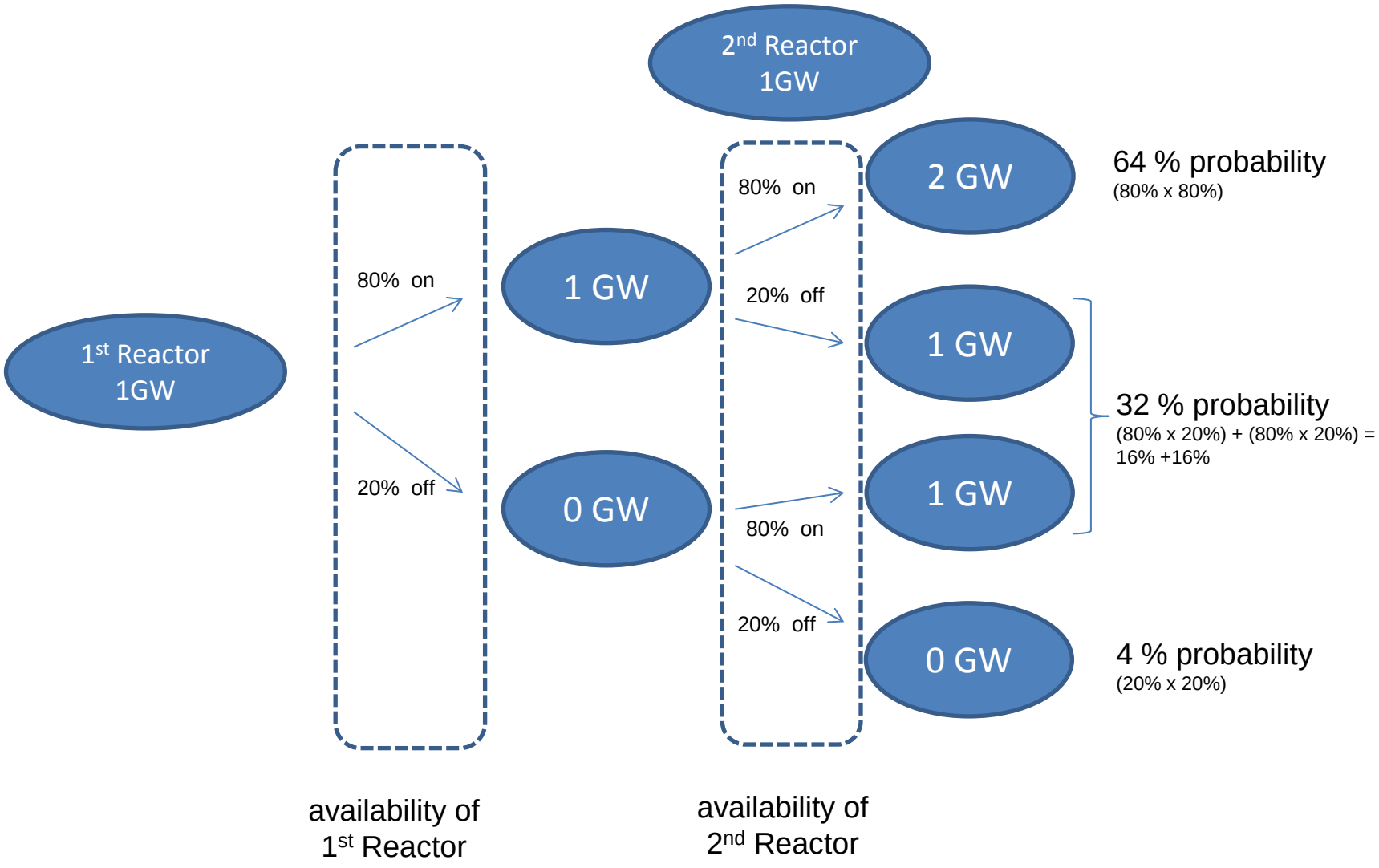
Nuclear generation

MWe	UP18	UP18-Nuc UP18-NucCritical
2014	4.810	4.810
2020	5.929	5.929
2030	0	2.000 *
2040	0	0

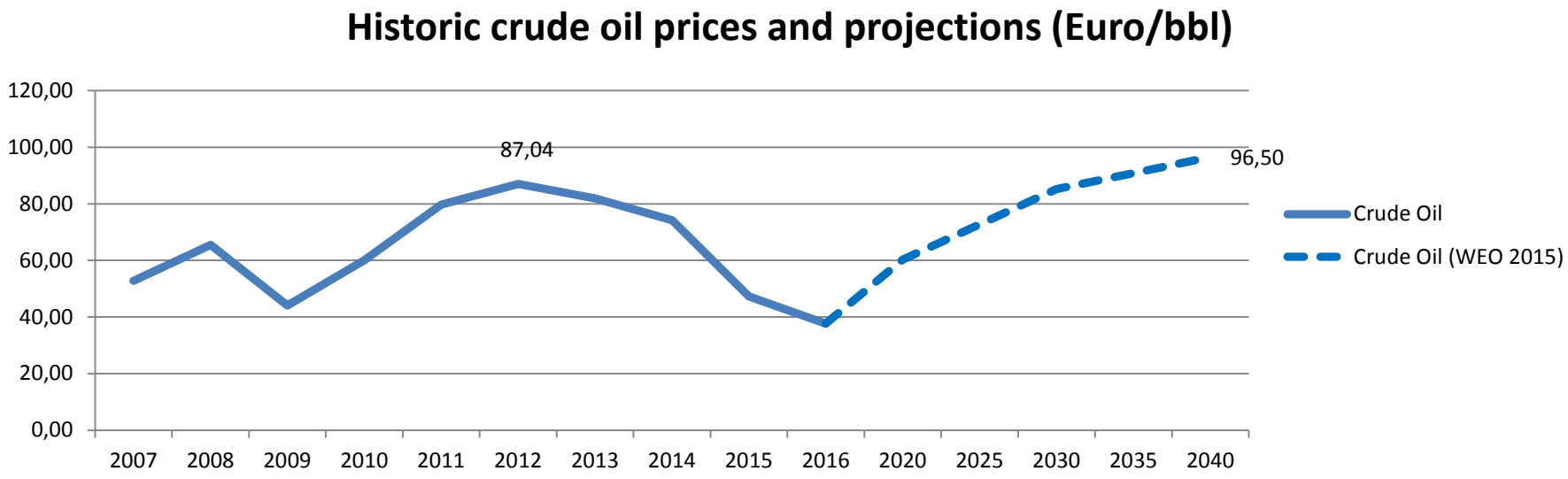


- Sensitivity 'UP18-Nuc'
  - Availability factor
    - till 2025: 80% on average (range from 50-100%)
    - 2025-2035: 80 % on average (either 0%, 50% or 100%)

Nuclear generation with 2 reactors

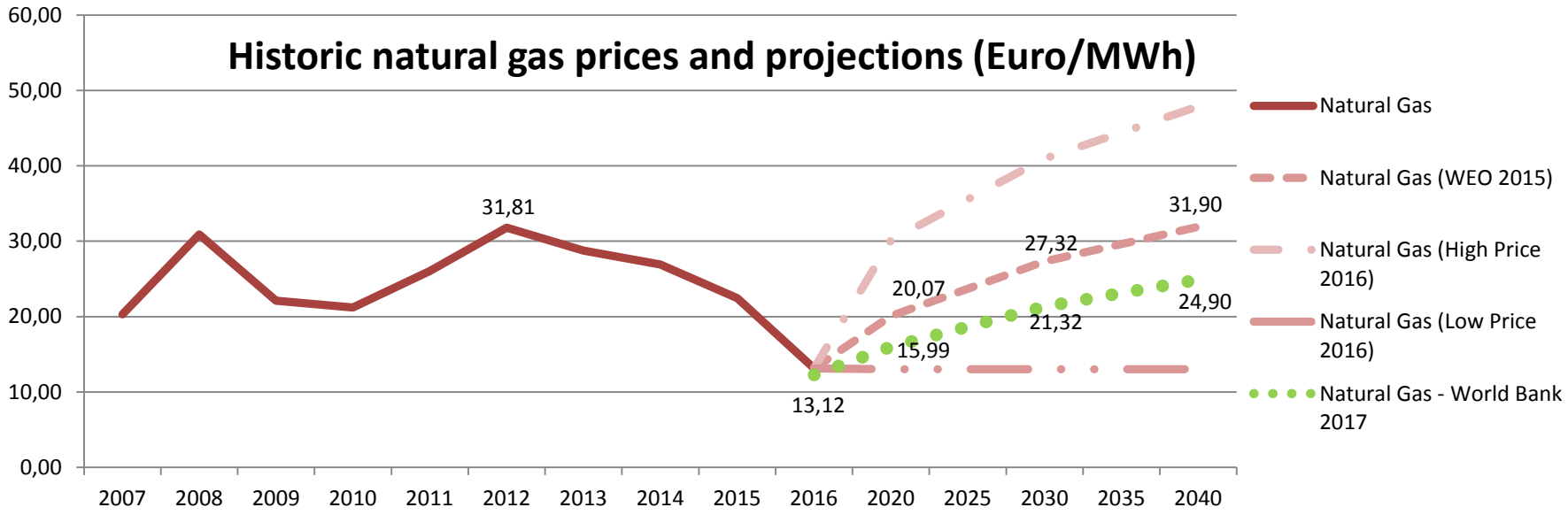


Fossil fuel prices - Oil



- All scenarios: WEO 2015 price projections for all sensitivity scenarios

Fossil fuel prices – Natural gas



- EV2017 Central Scenario: WEO 2015 price projections
- UP18 and all sensitivity scenarios: Aligned with World Bank 10/2017

TIMES Model Parameters

Renewable Energy Generation Sources (RES)

Fuel	Technology	Size (MWe)	Investment Cost (€$_{2010}$/kW)				Fixed O&M (€$_{2010}$/kW)				Average Availability Factor/Year (%)
			2016	2020	2030	2050	2016	2020	2030	2050	
Solar	Solar PV roof (> 2 MW)	<0,1 MWp	1.000	800	800	800	46	46	46	46	9,7%
	Solar PV roof Commercial (> 2MW)	>10MW	800	600	547	520	46	46	46	46	9,7%
Wind	Wind Onshore	-	1.200	1.200	1.190	1.100	27	27	24	21	22%
	Wind Offshore (< 2,2 GW)	-	2.000	2.000	1.800	1.500	80	80	63	63	40%
	Wind Offshore (> 2,2 GW)		2.500	2.300	2.000	2.000	80	80	63	63	40%

- 40% min. share of small scale/residential solar within total PV
- Wind offshore above 2,2 GW capacity requires investments in transmissions lines (=> higher investment costs)

EnergyVille

Energy system model – TIMES

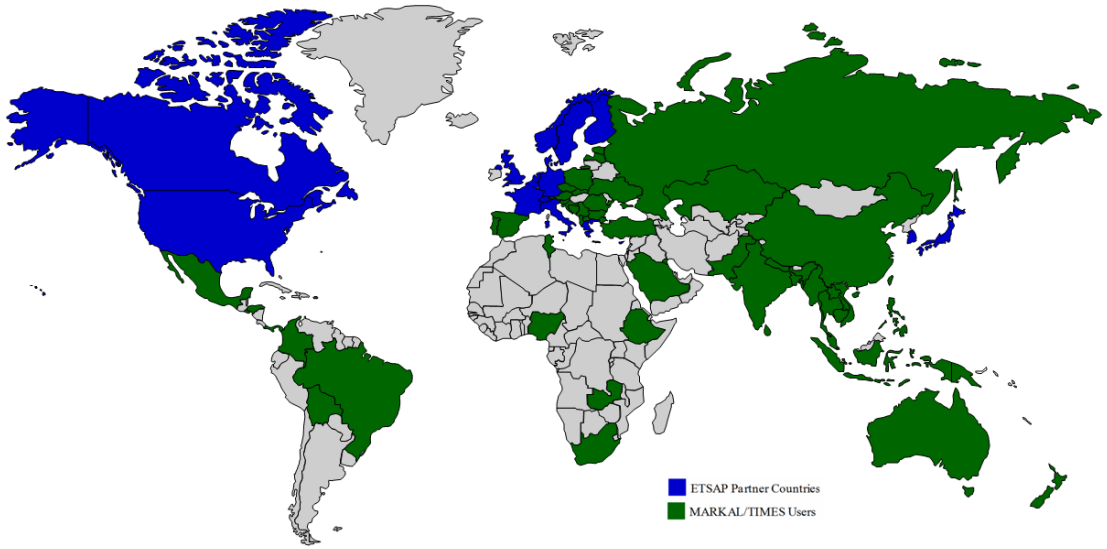
Energy system model – TIMES

Background

TIMES is a Model Generator for
'techno-economic energy system models'

Developed by the

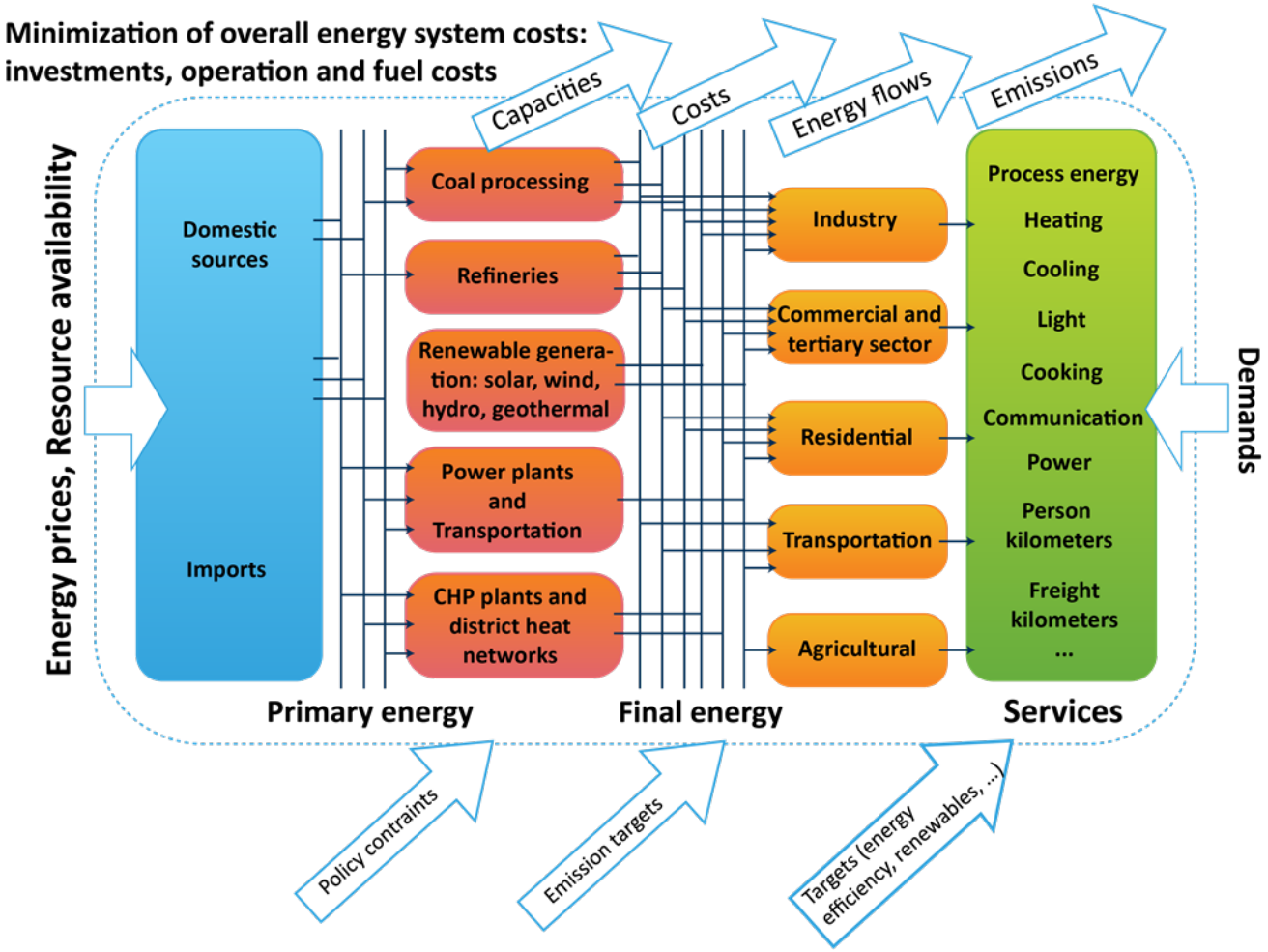
- Energy Technology Systems Analysis Programme (**ETSAP**)
- Coordinated by the **IEA** (International Energy Agency, Paris)
- Members of ETSAP and TIMES (or MARKAL) users all over the world
- **VITO is a contracting partner** of ETSAP for over 20 years!
- More information under http://www.iea-etsap.org



Energy system model – TIMES

Background

- Simple representation ‘reference energy system’ (by process)



Energy system model – TIMES

Background – What can you expect from TIMES?

- To provide options to decision makers regarding energy system planning:
  - Multi objective (renewable + efficiency + CO2 target + …)
  - Technically feasible
  - Specify possible courses of action with insights on their risks, costs and benefits

- Generate technology explicit future scenarios with related information on expected
  - Energy consumption
  - Material consumption
  - Costs
  - CO_2 emissions
  - etc.

- To determine what technologies are competitive, marginal or uncompetitive in each market… in a system view

- Introduce costs and a cost minimization objective
  - The ‘best’ (least cost) configuration of the complex system is proposed, taking into account multiple objectives/constraints

Energy system model – TIMES

Background – What can you expect from TIMES?

- TIMES computes an **economic equilibrium** for energy markets, from supply to the end use services
- The model computes both the **flows** of energy and their **prices**, in such a way that the suppliers of energy produce, at least, the amounts that the consumers are willing to buy.
- **Economic rational**: the total economic surplus is maximized when all markets are in equilibrium (or total system cost is minimized).
- Energy markets are competitive, with perfect foresight.
- Demands for energy services can be elastic to their own prices, capturing the main feedback from the economy to the energy system.

Energy system model – TIMES

Background – What **not** to expect from TIMES?

- TIMES is bottom-up technology rich model → technologies that are not explicitly modelled will not be present in the scenario results. For the time horizon of this study (2030) this does not necessarily need to be a problem:
  - Tidal energy is not modelled
  - Use of biomass as feedstock for chemical sector is not modelled
  - Valorisation of excess heat from industry is not modelled

- Existing support mechanisms (subsidies, green certificates, …) are not taken into account

- Exogenous assumptions have to be made on the maximum technical potential for the uptake of technologies.

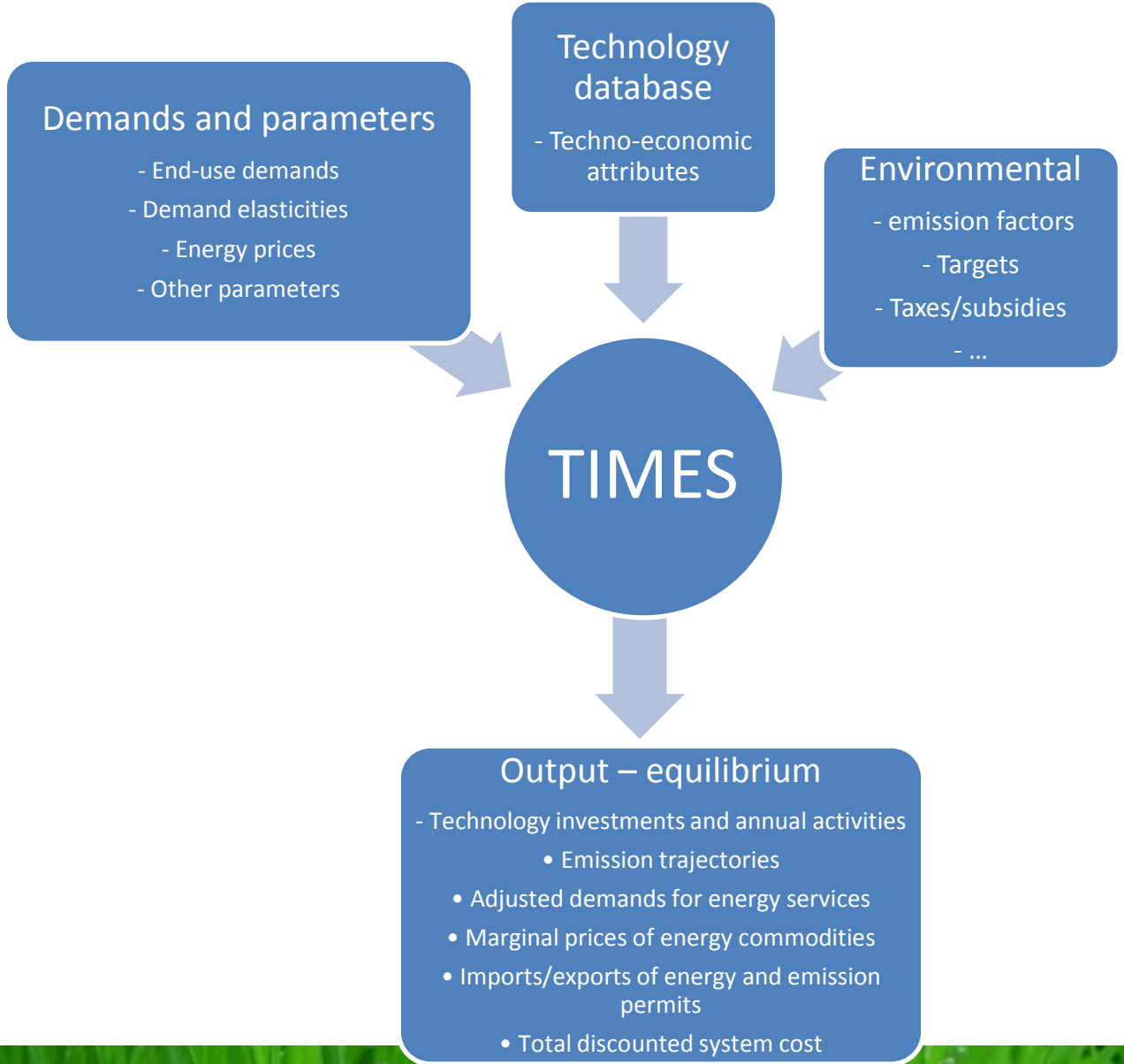
Energy system model – TIMES

Building and using a TIMES model

- Step 1: quantification of the current system
  - 4^E main dimensions
    - Energy commodity flows
    - Engineering: stock of existing and new transformation processes and end-use devices
    - Environment: GHG emissions (and air pollutants)
    - Economy: prices and values of commodities, technologies, sub-systems

Energy system model – TIMES

Building and using a TIMES model



Energy system model – TIMES

Building and using a TIMES model

Step 2: Defining targets with stakeholders

- Stakeholders define targets and assumptions
- EnergyVille calculates possible development paths (scenarios) of the system (energy fuels and technologies, costs and emissions (exploratory scenarios))
- Stakeholders adopts a scenario or ask for more analyses or define alternative targets

EnergyVille

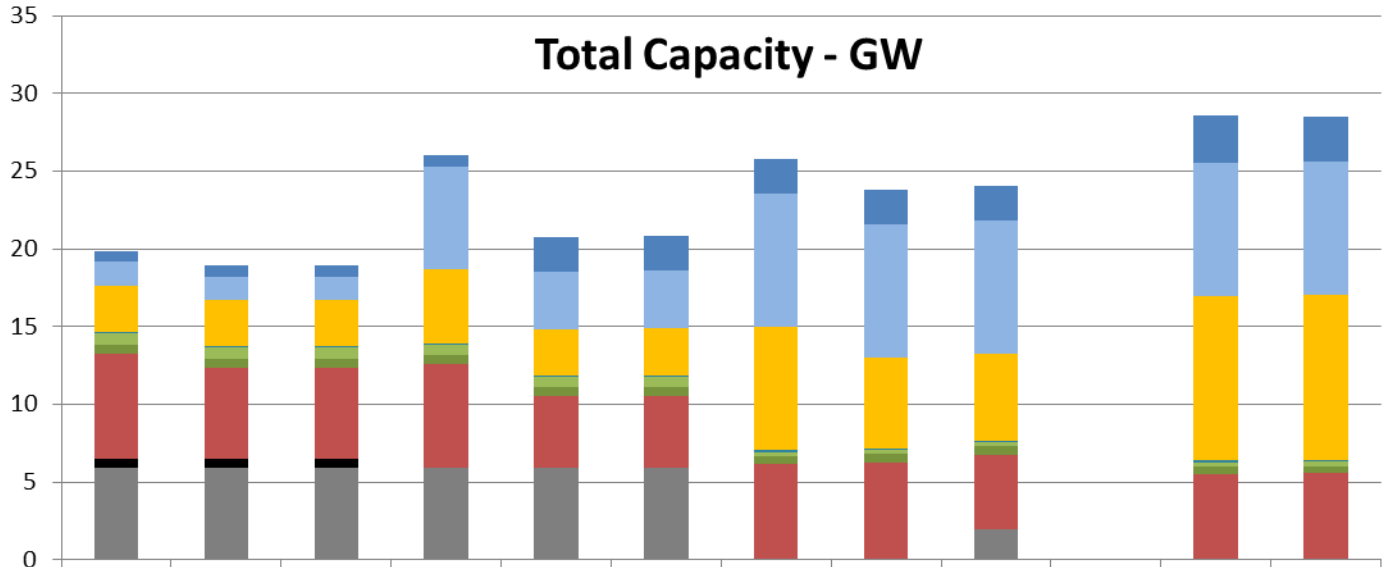
Results
31-01-2018

Scenario results

Scenario Overview

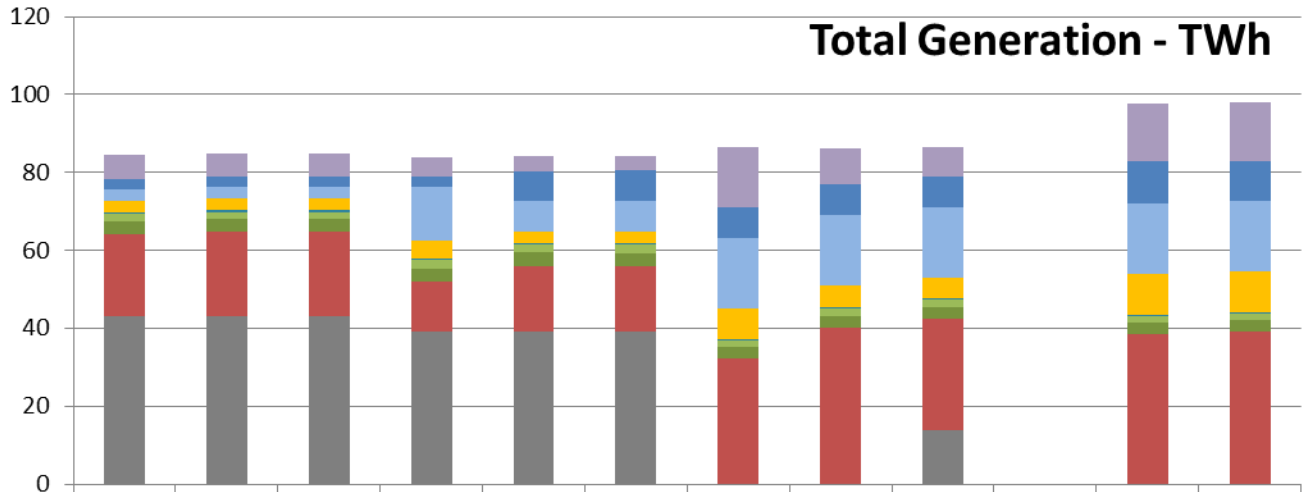
- EV2017: EnergyVille 2017 study ordered by Febeliec (see http://energyville.be/nieuwsbericht/energyville-introduceert-objectieve-vooruitblik-op-de-belgische)
- UP18: Update base scenario
  - Gas prices aligned with World Bank 10/2017
  - Updated existing gas power plant capacities (source EDF Luminus 2017)
- UP18-Nuc: Update base scenario + 2 GW nuclear extension of 10 years (2025-2035)
  - Investment cost 1000/EURO/kW
  - Availability 2025-2035: 80 % on average, either 0%, 50% or 100%
- Reporting years: 2016, 2020, 2030, 2040

Results - Power Capacity



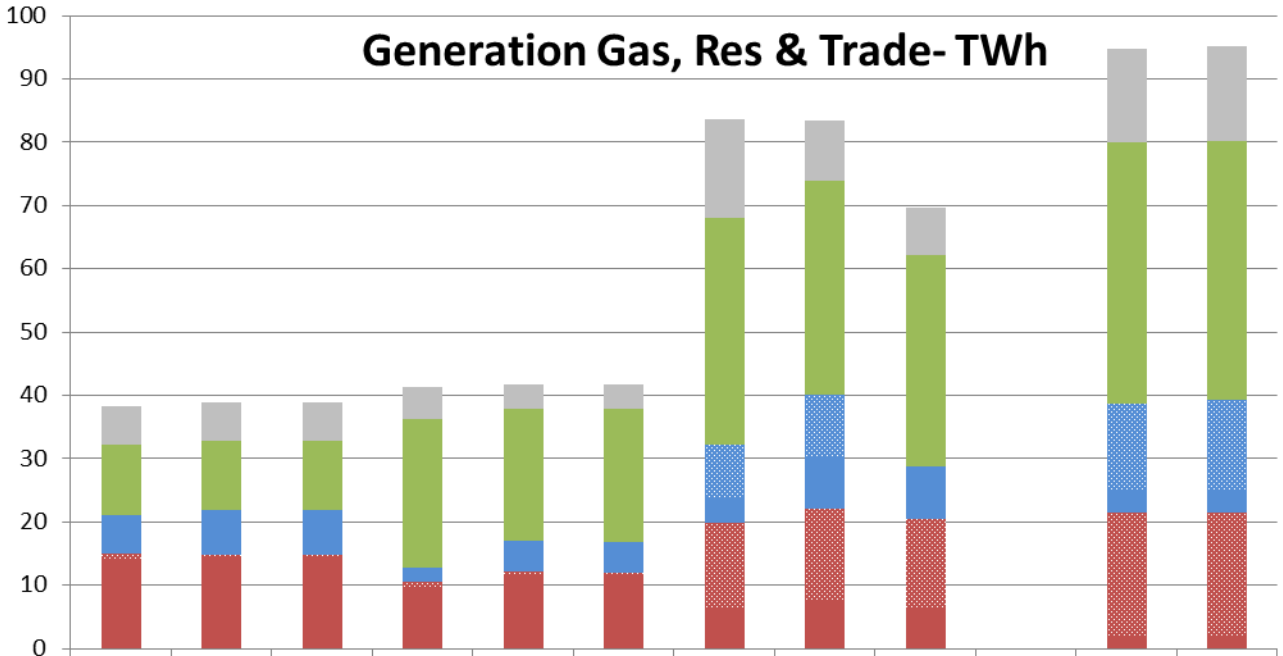
	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc
	2016			2020			2030			2040		
Wind Offshore	0,71	0,71	0,71	0,71	2,20	2,20	2,20	2,20	2,20	0,00	3,04	2,87
Wind Onshore	1,51	1,51	1,51	6,56	3,68	3,78	8,60	8,60	8,59	0,00	8,60	8,60
Solar PV	2,98	2,98	2,98	4,78	2,98	2,98	7,93	5,84	5,57	0,00	10,57	10,64
Hydro	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,11	0,11	0,00	0,11	0,11
Biomass & Other Ren.	0,75	0,73	0,73	0,67	0,65	0,66	0,27	0,26	0,27	0,00	0,25	0,26
Other Fossil	0,52	0,52	0,52	0,55	0,56	0,56	0,54	0,54	0,54	0,00	0,49	0,49
Natural Gas	6,81	5,89	5,89	6,70	4,64	4,64	6,13	6,25	4,75	0,00	5,53	5,55
Coal	0,56	0,56	0,56	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Nuclear	5,93	5,93	5,93	5,93	5,93	5,93	0,00	0,00	2,00	0,00	0,00	0,00

Results - Power Generation 1/2



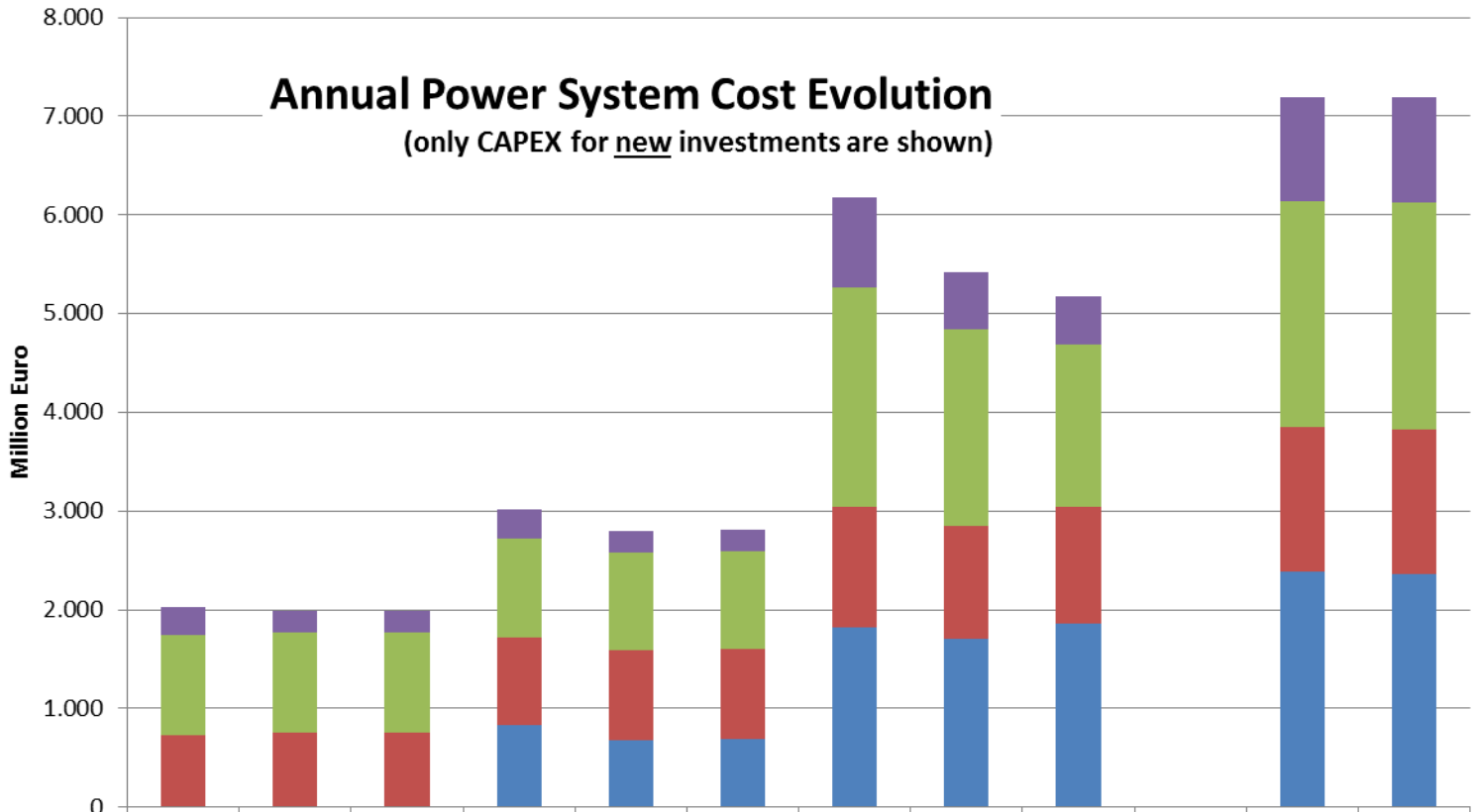
	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc
	2016			2020			2030			2040		
Net Imports	6,26	6,12	6,12	5,03	3,83	3,79	15,58	9,34	7,51	0,00	14,85	14,98
Wind Offshore	2,53	2,53	2,53	2,53	7,82	7,82	7,82	7,82	7,82	0,00	10,79	10,19
Wind Onshore	3,18	3,18	3,18	13,82	7,75	7,95	18,11	18,11	18,09	0,00	18,11	18,11
Solar PV	2,92	2,92	2,92	4,68	2,92	2,92	7,75	5,71	5,44	0,00	10,34	10,40
Hydro	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,00	0,38	0,38
Biomass & Other Ren.	1,94	1,86	1,86	2,05	2,05	2,05	1,78	1,78	1,78	0,00	1,74	1,74
Other Fossil	3,16	3,16	3,16	3,46	3,46	3,46	2,99	2,99	2,99	0,00	2,74	2,80
Natural Gas	21,13	21,85	21,85	12,82	16,91	16,75	32,15	40,17	28,67	0,00	38,62	39,26
Nuclear	43,02	43,02	43,02	39,11	39,11	39,11	0,00	0,00	13,80	0,00	0,00	0,00

Results - Power Generation 2/2



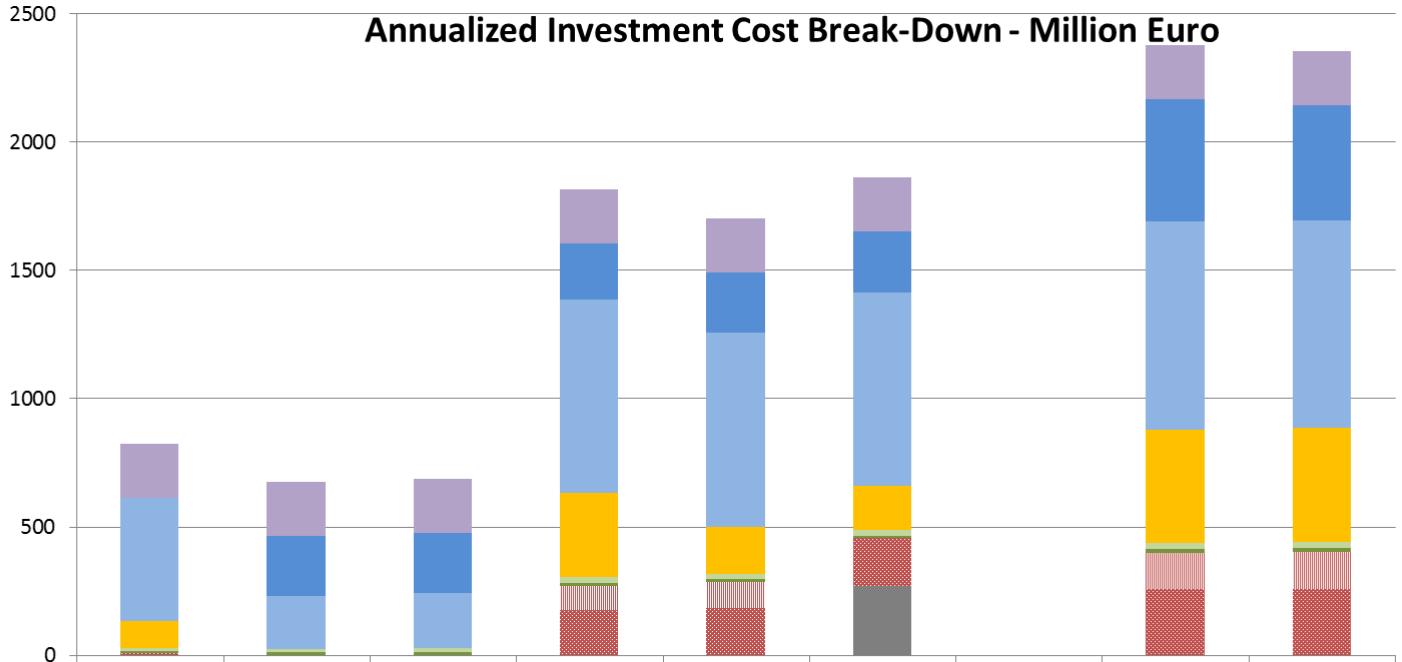
	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc
	2016			2020			2030			2040		
Net Imports	6,26	6,12	6,12	5,03	3,83	3,79	15,58	9,34	7,51	0,00	14,85	14,98
Renewables	10,95	10,87	10,87	23,46	20,92	21,12	35,84	33,79	33,51	0,00	41,36	40,82
New PP - Natural Gas	0,00	0,00	0,00	0,00	0,00	0,00	8,57	9,89	0,00	0,00	13,73	14,25
Existing PP - Natural Gas	6,17	7,03	7,03	2,21	4,85	4,74	3,74	8,26	8,24	0,00	3,45	3,60
New CHP - Natural Gas	1,04	0,25	0,25	0,80	0,51	0,51	13,34	14,35	14,07	0,00	19,58	19,56
Existing CHP - Natural Gas	13,92	14,58	14,58	9,80	11,55	11,50	6,50	7,67	6,36	0,00	1,86	1,84

Results - Power System Costs



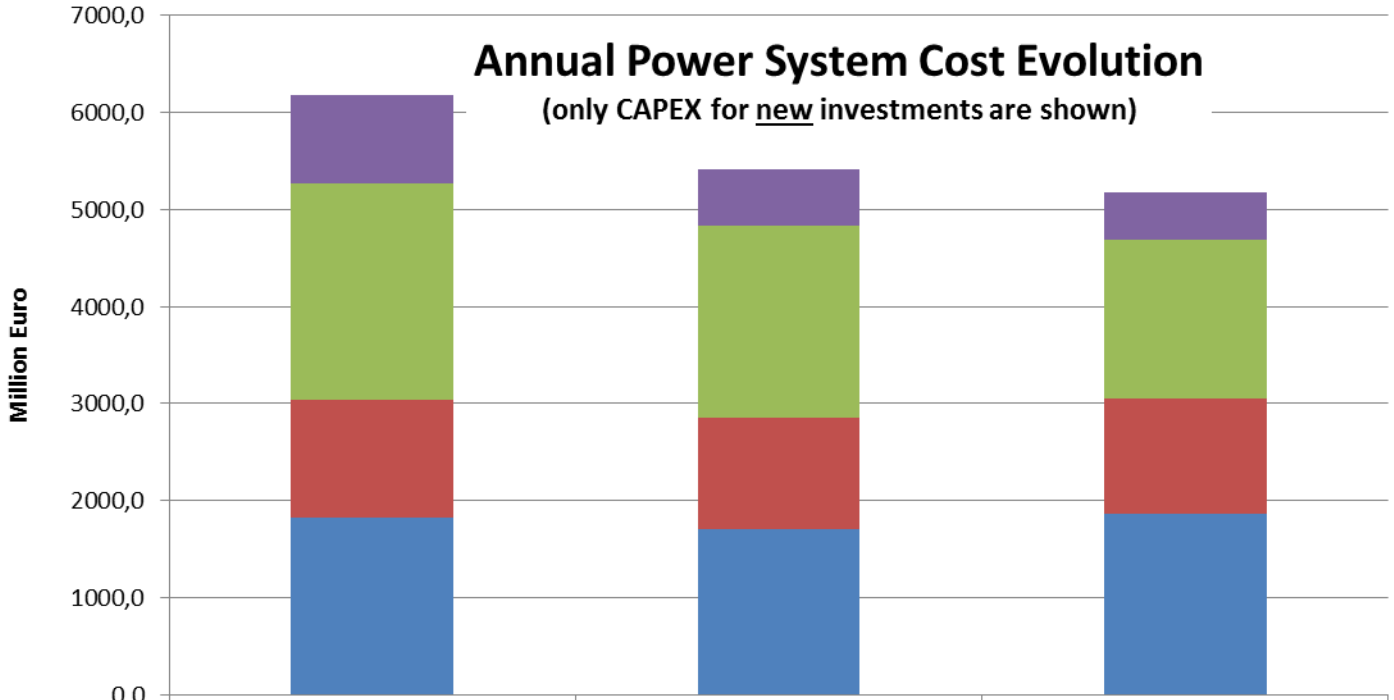
	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc	EV2017	UP18	UP18-Nuc
	2016			2020			2030			2040		
Trade	280	224	224	296	217	215	910	576	497	0	1.061	1.066
Fuel	1.012	1.011	1.011	1.005	994	989	2.230	1.989	1.636	0	2.280	2.310
O&M	721	756	756	894	908	911	1.221	1.145	1.184	0	1.472	1.463
Inv.	14	2	2	826	678	690	1.818	1.705	1.864	0	2.381	2.357
Total	2.027	1.994	1.994	3.021	2.798	2.805	6.179	5.415	5.180	0	7.194	7.196

Results - Power System Costs



	EV2017	UP18 2020	UP18-Nuc	EV2017	UP18 2030	UP18-Nuc	EV2017	UP18 2040	UP18-Nuc
Trade	212	212	212	212	212	212	0	212	212
Wind Offshore	0	234	234	217	234	234	0	477	447
Wind Onshore	478	205	214	755	754	753	0	809	809
Solar PV	105	0	0	327	184	171	0	442	445
Hydro	0	0	0	0	1	1	0	1	1
Biomass & Other Ren.	14	11	13	23	20	23	0	21	23
Other Fossil	8	10	10	10	10	10	0	16	16
Natural Gas - PP	0	0	0	96	101	0	0	142	144
Natural Gas - CHP	9	6	6	178	188	188	0	260	260
Coal	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	271	0	0	0
Total	826	678	690	1818	1705	1864	0	2381	2357

Comparison 2030 – Power System Cost

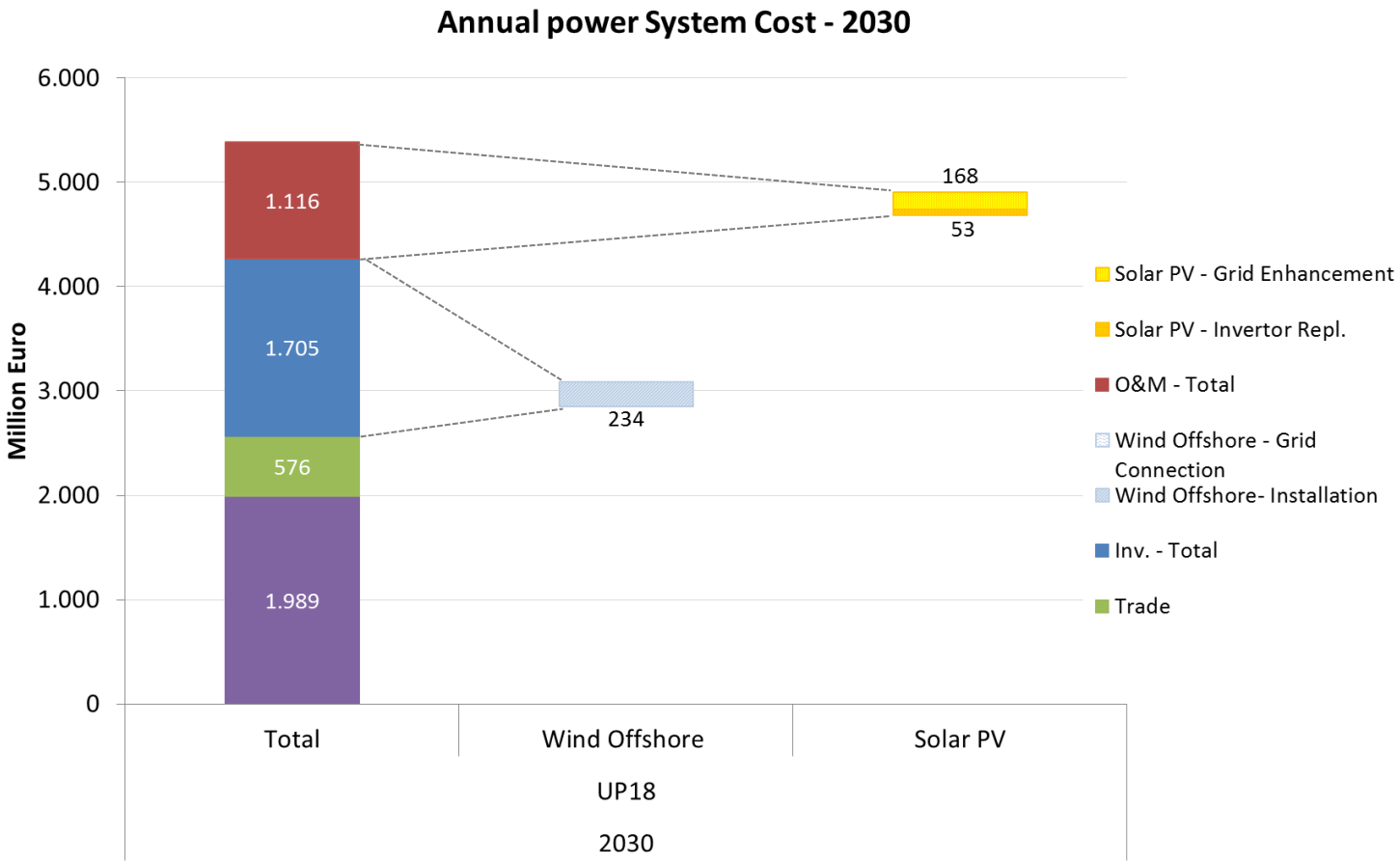


	EV2017	UP18	UP18-Nuc
	2030		
Trade	910,2	576,1	496,5
Fuel	2230,1	1989,4	1635,9
O&M	1221,0	1144,4	1184,0
Inv.	1818,0	1704,5	1863,9
Total	6179,3	5414,5	5180,3

Comparison 2030 – Grid Cost

- Remark: 'Distribution grid' enhancement cost is allocated completely to PV installation.
  - Could also be allocated to uptake of electric vehicles and heat pumps
  - EnergyVille calculated that using a PV 'grid injection limit' can lead to an uptake of up to 20GW of PV without substantial grid enhancement and with limited curtailment.
    - Paper submitted: 'Using local storage for managing PV power injection in the electricity grid, enabling a larger direct consumption of renewable energy'; Applied Energy 2018

Comparison 2030 – Grid Cost



UP18 Scenario in 2030:

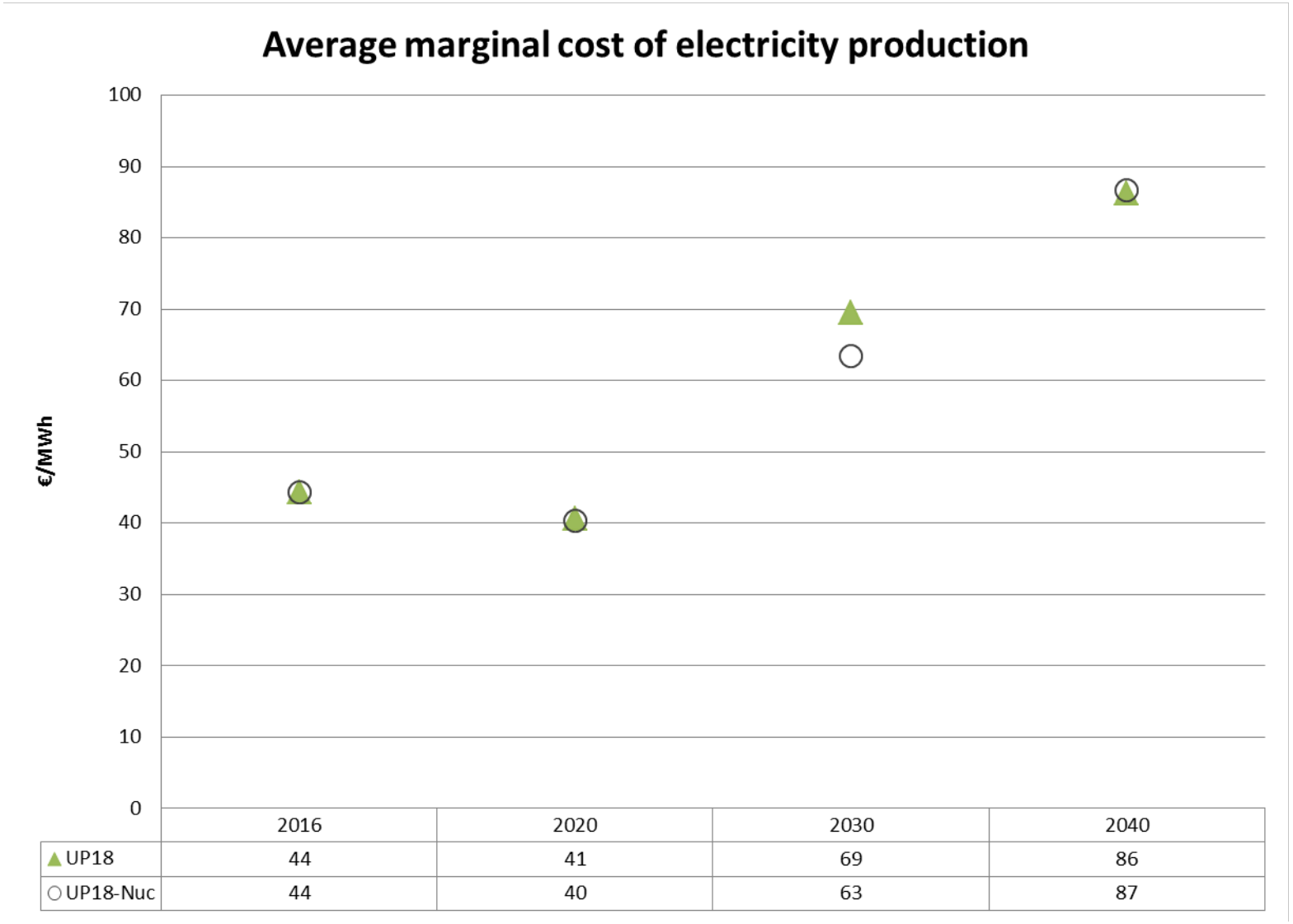
Solar PV → 221 MM Euro of total operation and maintenance costs

Grid Enhancement → 76% of total solar PV O&M

Invertor Replacement → 24% of total solar PV O&M

Wind Offshore (up to 2,2 GW) → no investment in grid connection needed

Average marginal production cost of electricity



	2016	2020	2030	2040
▲ UP18	44	41	69	86
○ UP18-Nuc	44	40	63	87

EnergyVille

More information

Website: energyville.be

Pieter.Lodewijks@energyville.be