A 100 % Renewable Energy System In Belgium by 2050

Assessment of Different Long Term Trajectories to Transform the Current Belgian Energy System into a 100% Renewable Energy Mix

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- Definition of the scenarios
- The challenge of intermittent renewable energy
- Modelling approach: how we used the TIMES model
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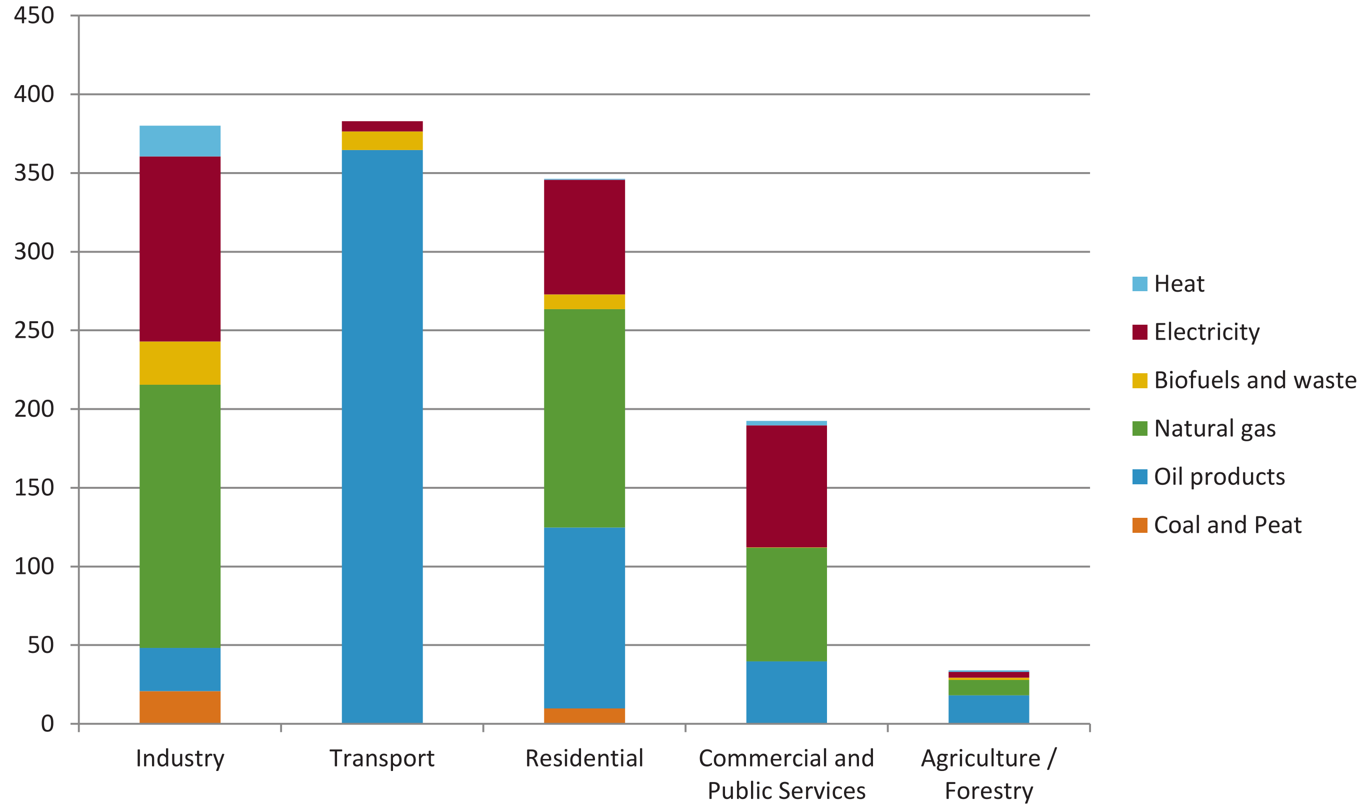
- Special results

Purpose of the project (and limits)

- Study ordered end 2011 by 4 energy ministers
- The study defines different trajectories that can lead to an energy system exclusively based on renewable energy sources
  - How to achieve a 100% renewable target in 2050 (electricity, heating and cooling, transport except aviation and sea transport)?
  - What technologies are needed?
  - What are the costs of these solutions?
- The study has to be perceived as a feasibility study
  - To be completed by other analyses

100 % What : energy is more than electricity !

(as we all know - but sometimes forget)



- Energy balance Belgium; Final energy consumption (PJ, IEA, 2009)

Background information

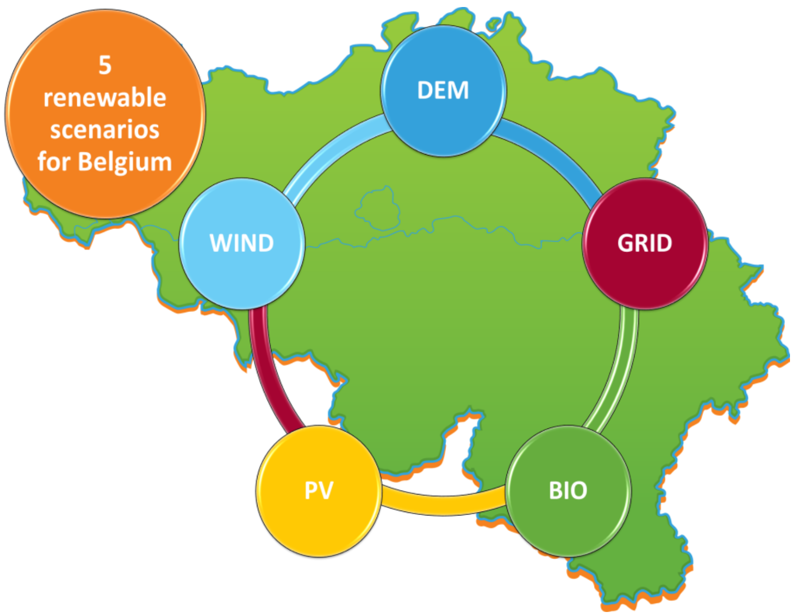
Surface: 30.000 km^2
Population: 11 million (330p/km2)
GDP: 350 billion €
Final energy consumption: 1800 PJ
Per capita final energy consumption:
150 % EU27 average or 75 % US
Hydro limited to 120 MW
Domestic fossil energy supply = 0 (1992)

Basic principles of TIMES model

- Partial equilibrium (energy) model
- Bottom-up optimisation model of the national energy system
- Detailed representation of energy-material flows and technologies (broad sense)
- Various alternative technological choices
- Up to 2050
- <u>Driving factor</u>: fulfilment of **energy service demand** (≠ energy demand)

Definitions of scenarios

REF Fossil Benchmark scenario



DEM

Limited RES potentials in DEM Scenario

- Wind
  - 8 GW offshore on the Belgian EEZ
  - 13 GW offshore on other EEZ's
  - 9 GW onshore
- Solar (PV)
  - 50 GW on Belgian soil
- Biomass
  - 100 PJ domestic production
  - 200 PJ import
- Geothermal
  - 4 GW domestic
- Electricity import 5.8 TWh
- Hydro 120 MW

End use of energy: Buildings – heating and appliances, Industry, Transport, Agriculture

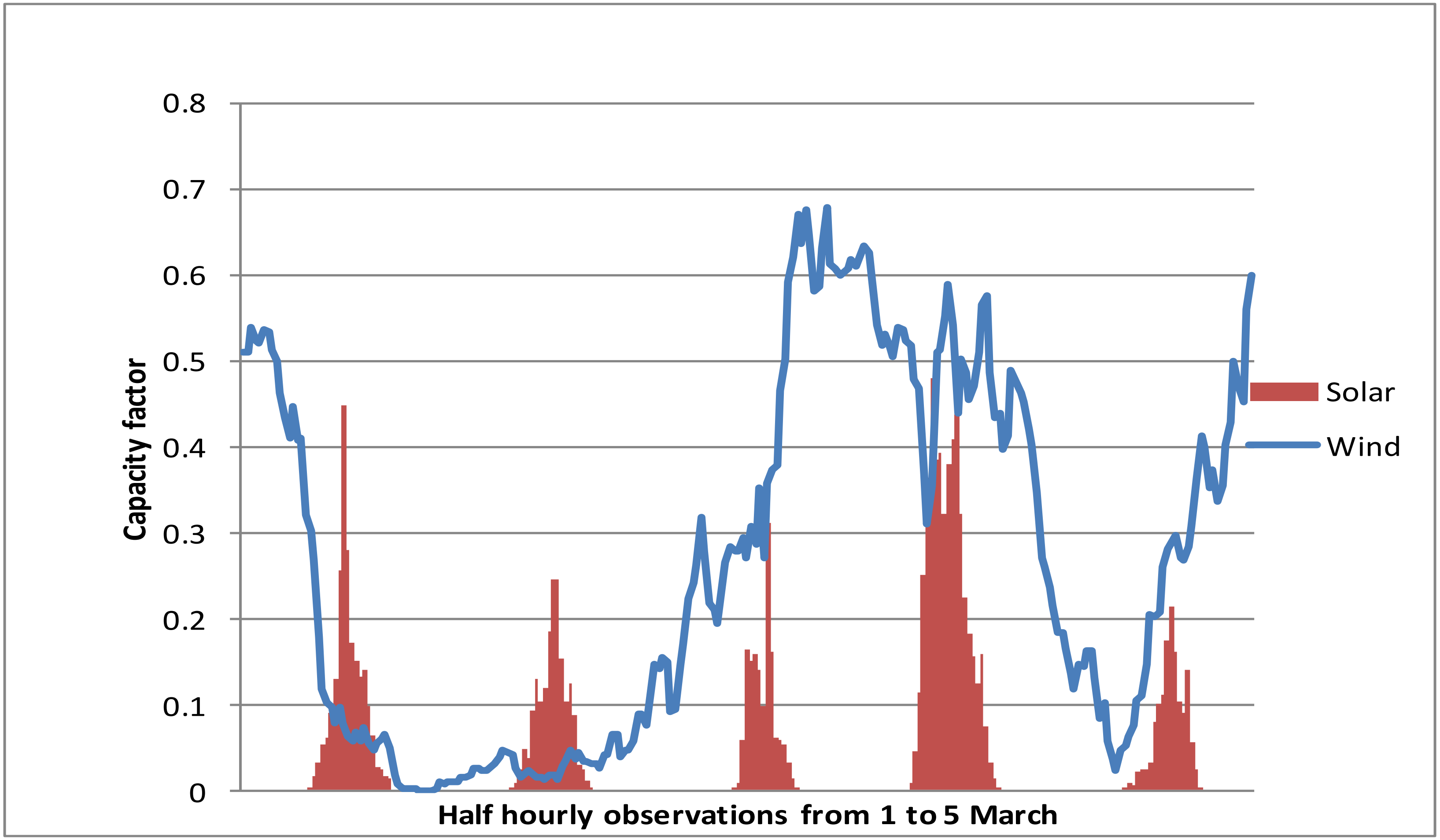
GRID Allows more Elec import → in 2050, 44 TWh is being imported

BIO Allows more biomass import → in 2050, 570 PJ is being imported

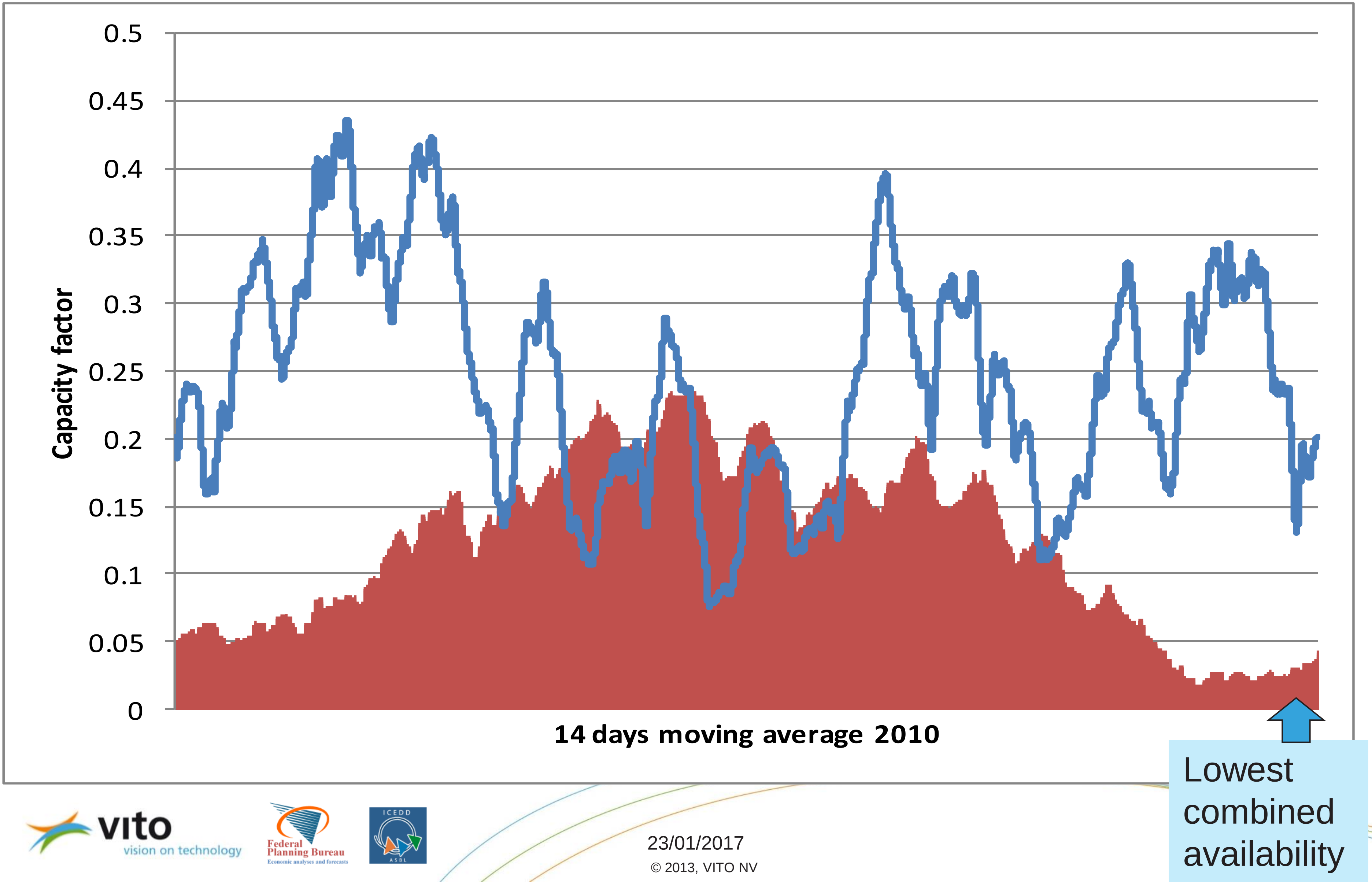
PV Allows more PV → in 2050, 170 GW is being installed

WIND Allows more wind → in 2050, onshore: 20 GW offshore: 47 GW

Challenges of intermittent renewable energy
Daily fluctuations



Challenges of intermittent renewable energy
Longer perspective



Modelling approach: How we used the TIMES model

- Security of supply
  - Extending the temporal resolution to 78 periods in one year = 26 periods of two weeks x 3 periods a day
  - Reserve capacity requirement (sum of nominal power of biomass plants, geothermal and storage facilities)
  - Constraint to assure that BE can be self sustained for 14 consecutive days without counting on wind and solar
- Day-night and seasonal electricity and hydrogen storage options
- Transmission and distribution network capacities determined by model
- Price sensitivity for end uses
- Option for large scale industrial demand management (steel sector)
- Curtailment

Assumptions

- Belgian GDP: increases at an AAGR of 1.8% in 2010-2050
- Fuel prices: from the Energy roadmap 2050, Reference scenario, crude oil to some 127 $'08/bbl in 2050
- Biomass: price of imported biomass increases to some 157 $'08/bbl in 2050
- Carbon price: 15 €/tCO_2 in 2020, 51 €/tCO_2 by 2050
- CCS technologies: not allowed
- Nuclear: 2012 legislation on the phasing out of the nuclear power plants
- Electricity imports: limited to 5.8 TWh (average Belgian net imports 2003-2010)
- Targets: 35% of primary energy in 2030, 65% in 2040, 100% in 2050

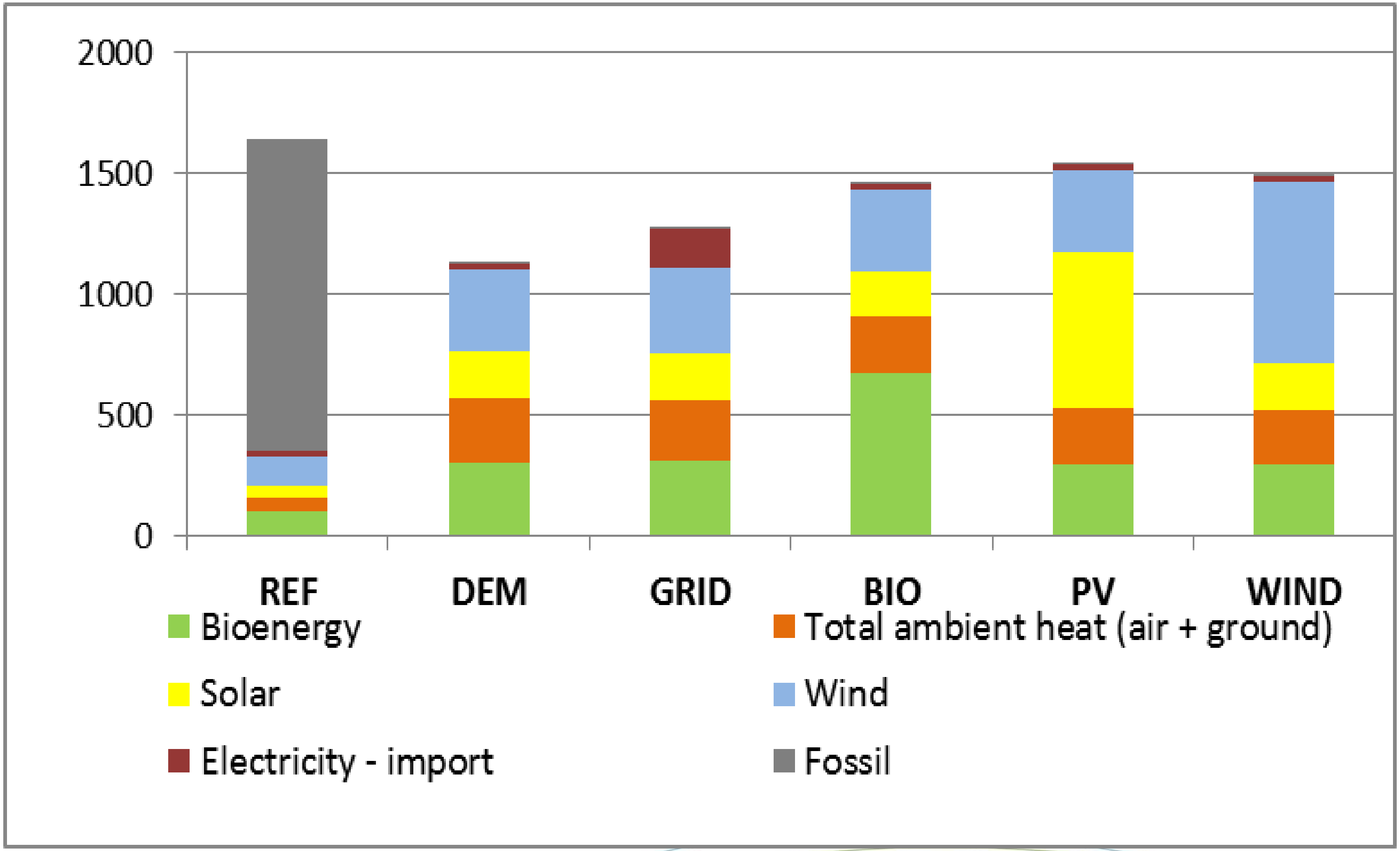
Assumptions on renewable costs

	CAPEX 2020	CAPEX 2050	FIXOM 2020	FIXOM 2050	Lifetime
Geothermal with ORC HDR	6248	5742	207	153	25
Geothermal with ORC	4166	3828	157	119	25
PV Roof panel High Price	1000	1000	10	10	25
PV Roof panel Low Price (standard runs)	1000	500	10	5	25
PV Roof panel Very Low Price	500	371	5	4	25
Wood - Steam turbine	1396	1236	50	50	30
Wind Offshore close	1807	1441	68	68	20
Wind Offshore far	1988	1585	68	68	20
Wind Offshore very far	2711	2161	68	68	20
Wind Onshore	1031	862	22	18	20

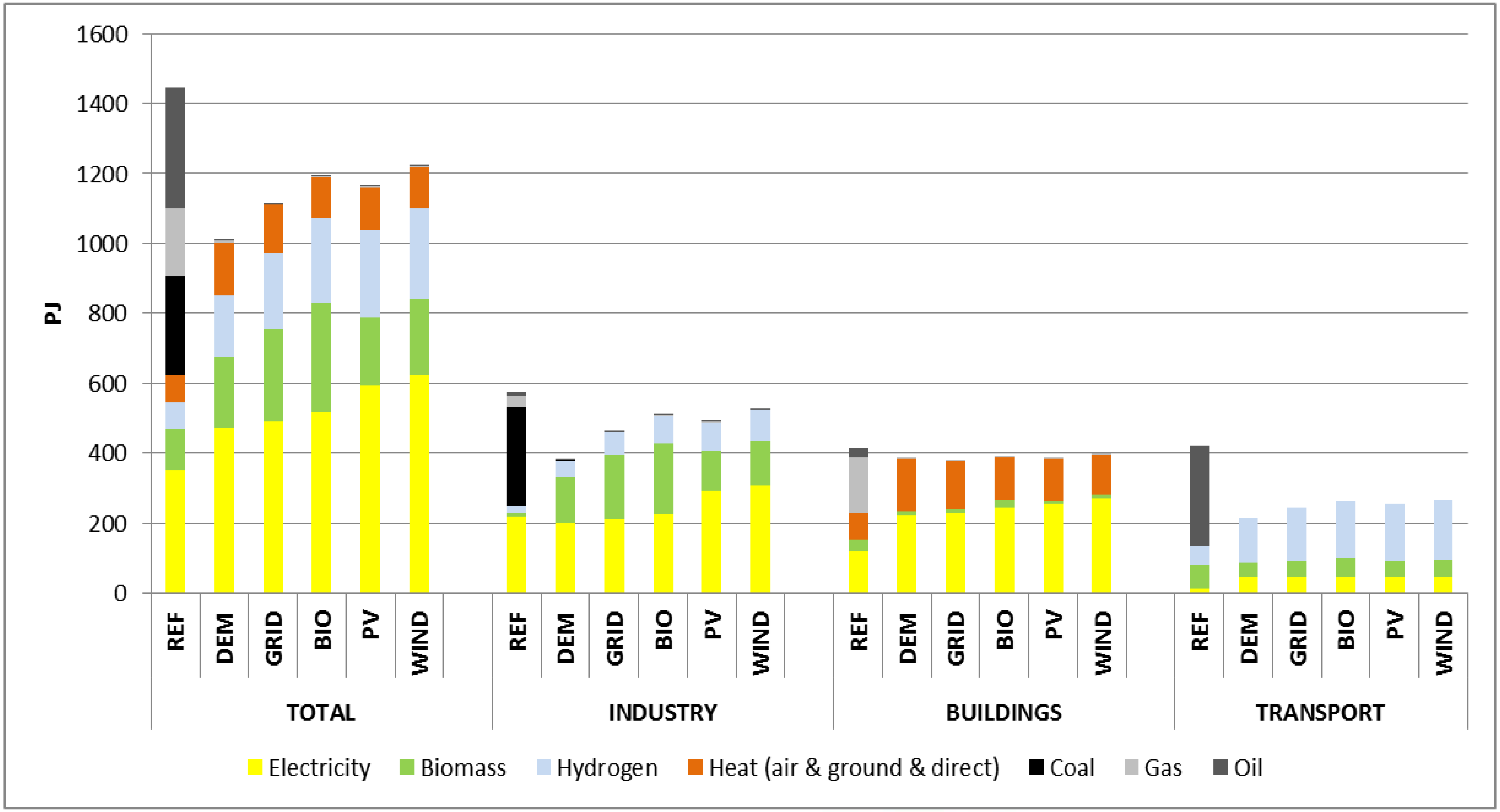
Assumptions on electricity storage costs

			Investment €/kWh			
	Efficiency	C -rate	2010	2050	Life	Max -Cap
High efficiency Day-Night	0.9	0.3	500	400	10	
Low efficiency Day-Night	0.7	0.3	200	160	5	
High efficiency -seasonal	0.95	0.03	500	400	10	
Low efficiency - seasonal	0.55	0.03	20	10	10	
Smart grids	0.98	0.03	53	53	10	15 GWh
Pumped storage	0.74	0.25	N.A.	N.A.	50	5 GWh

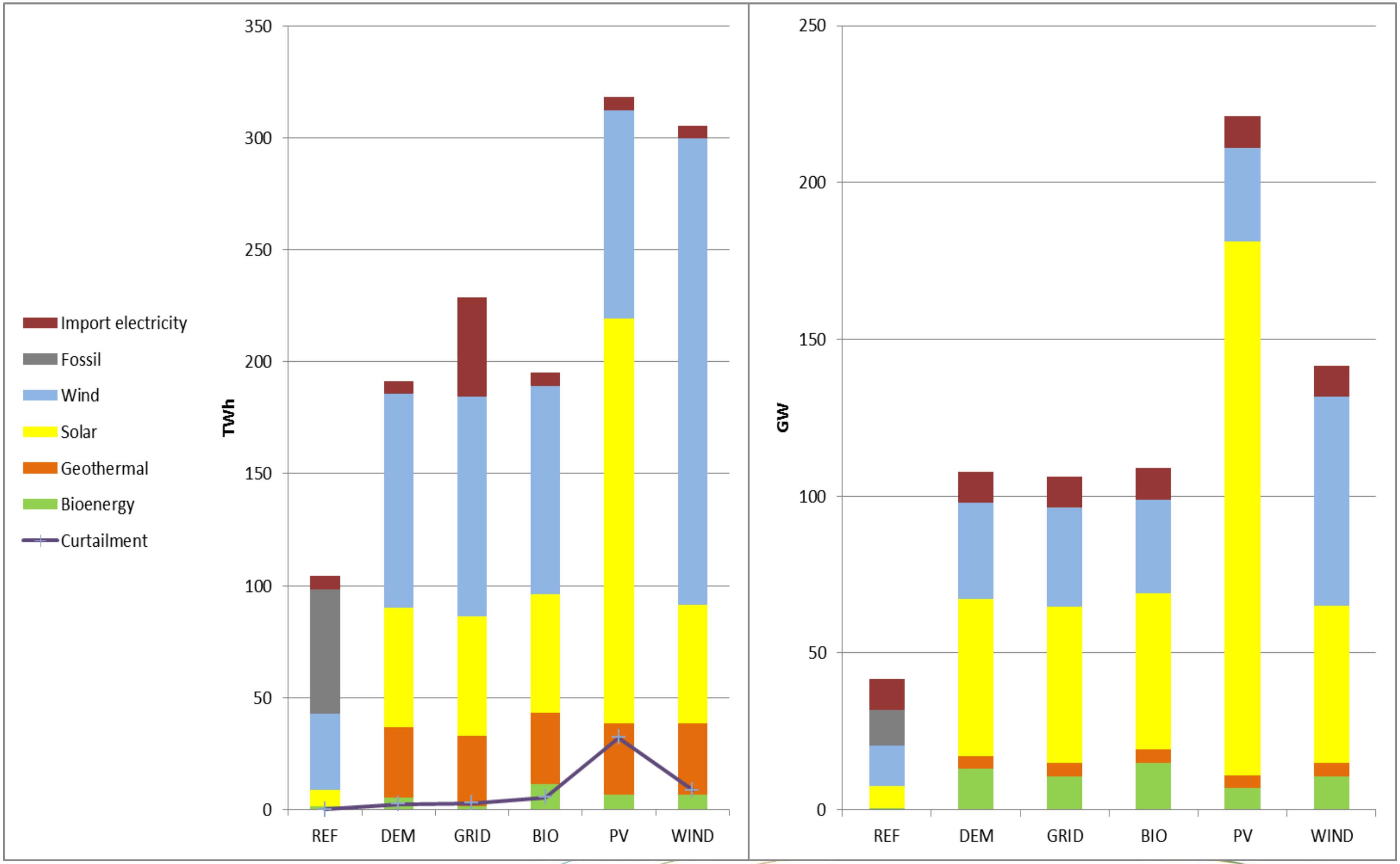
Primary energy supply in 2050



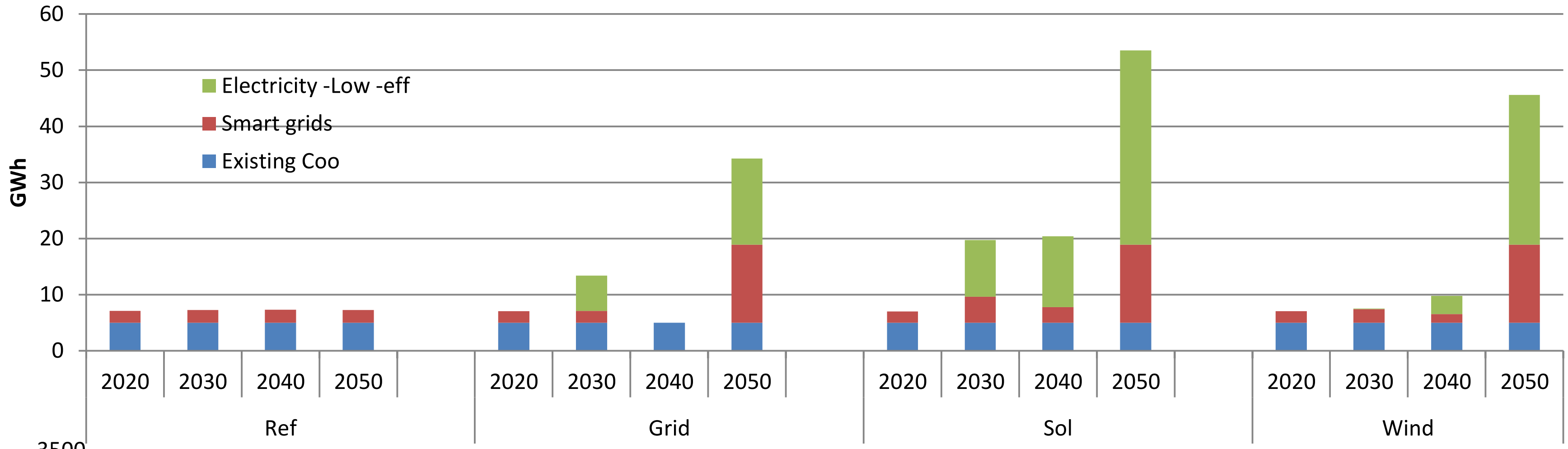
Final energy consumption

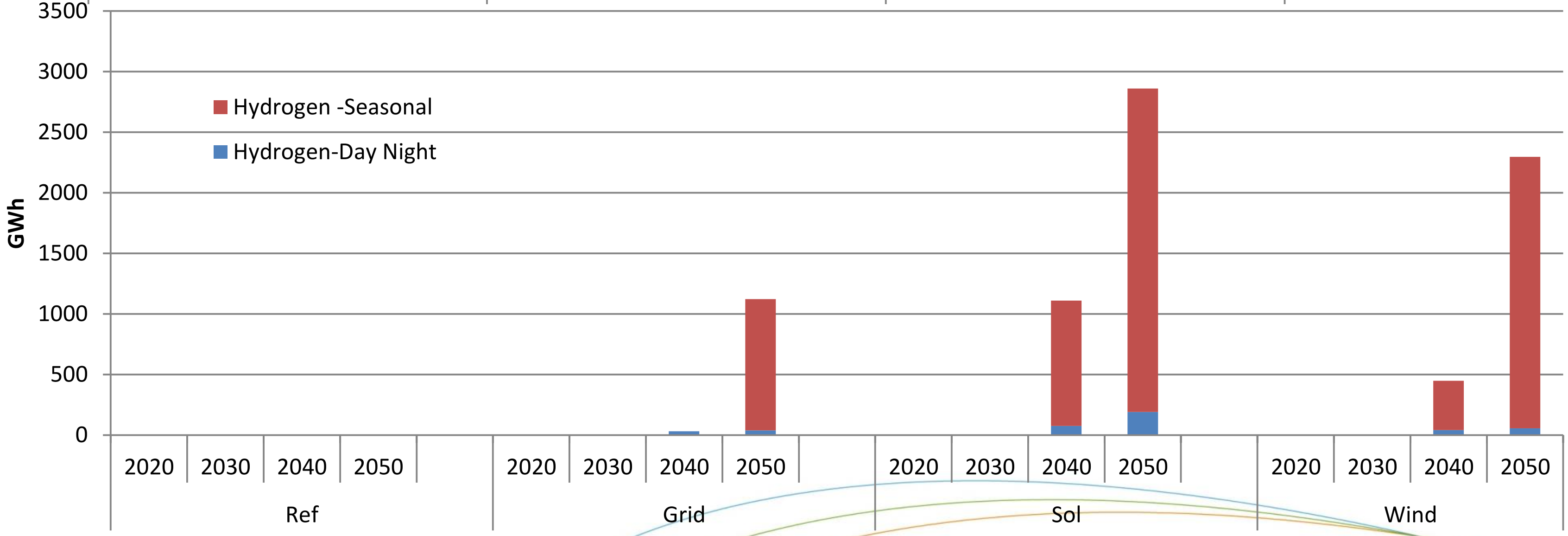


Electricity production (LHS) and capacities (RHS)

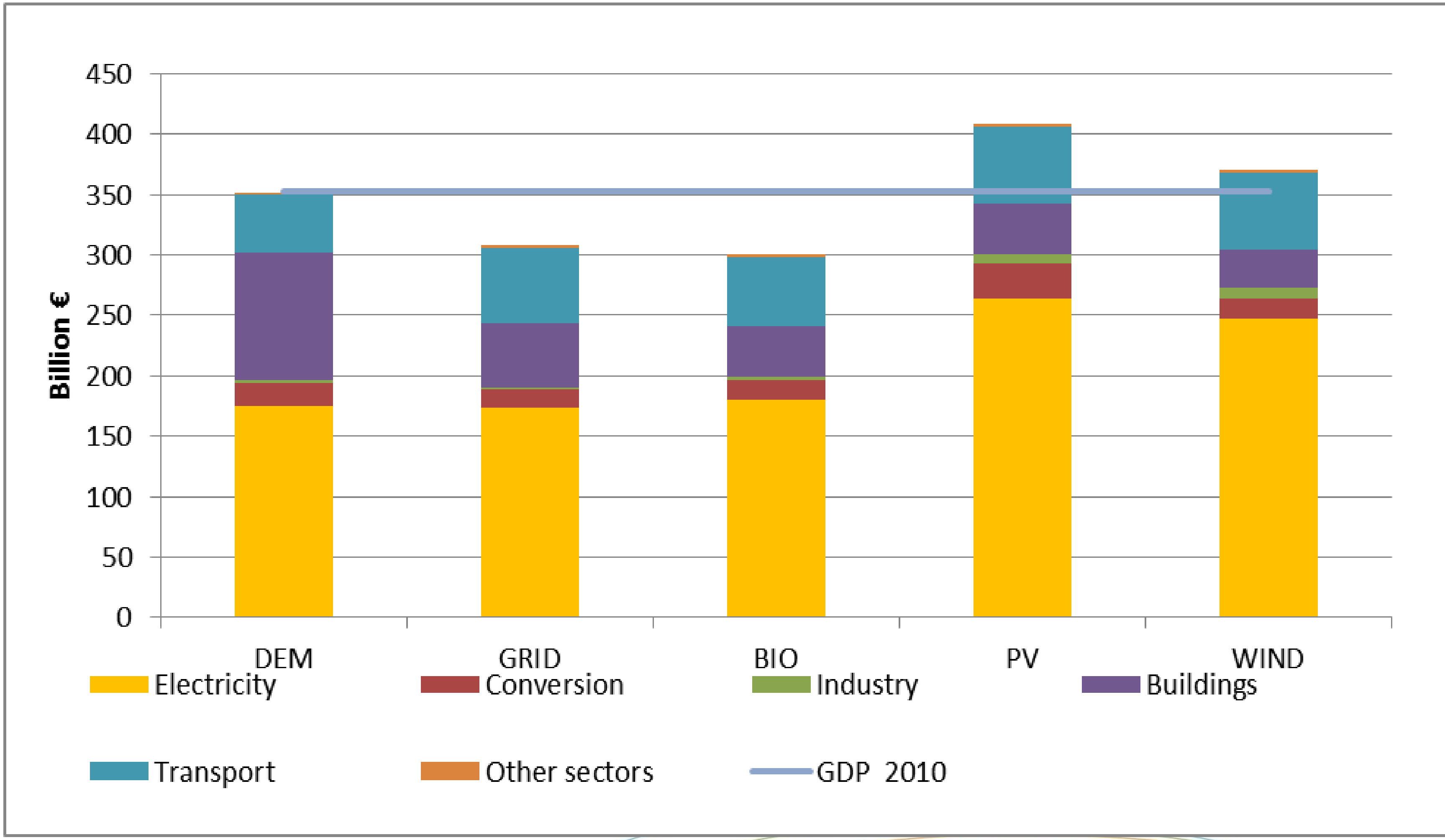


Storage technologies

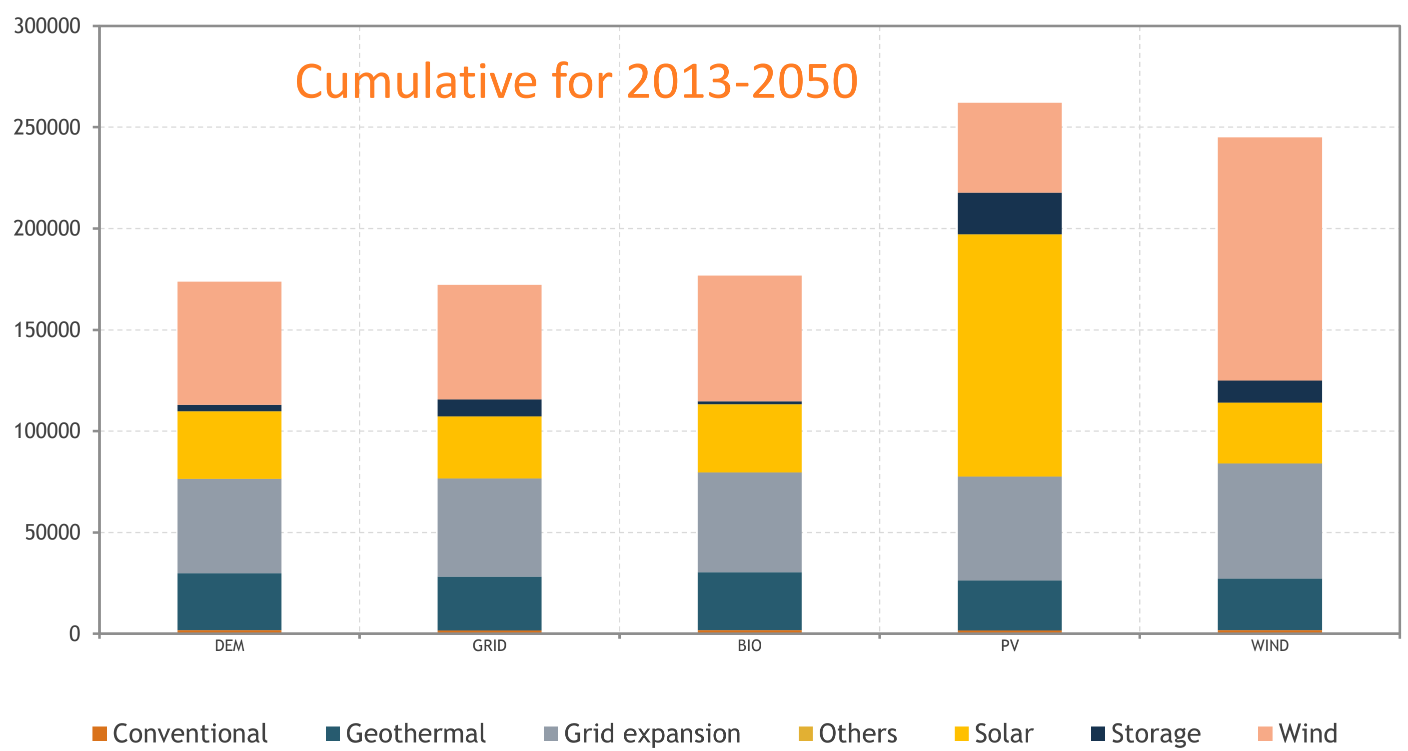




Cumulative investment requirements (2013-2050)

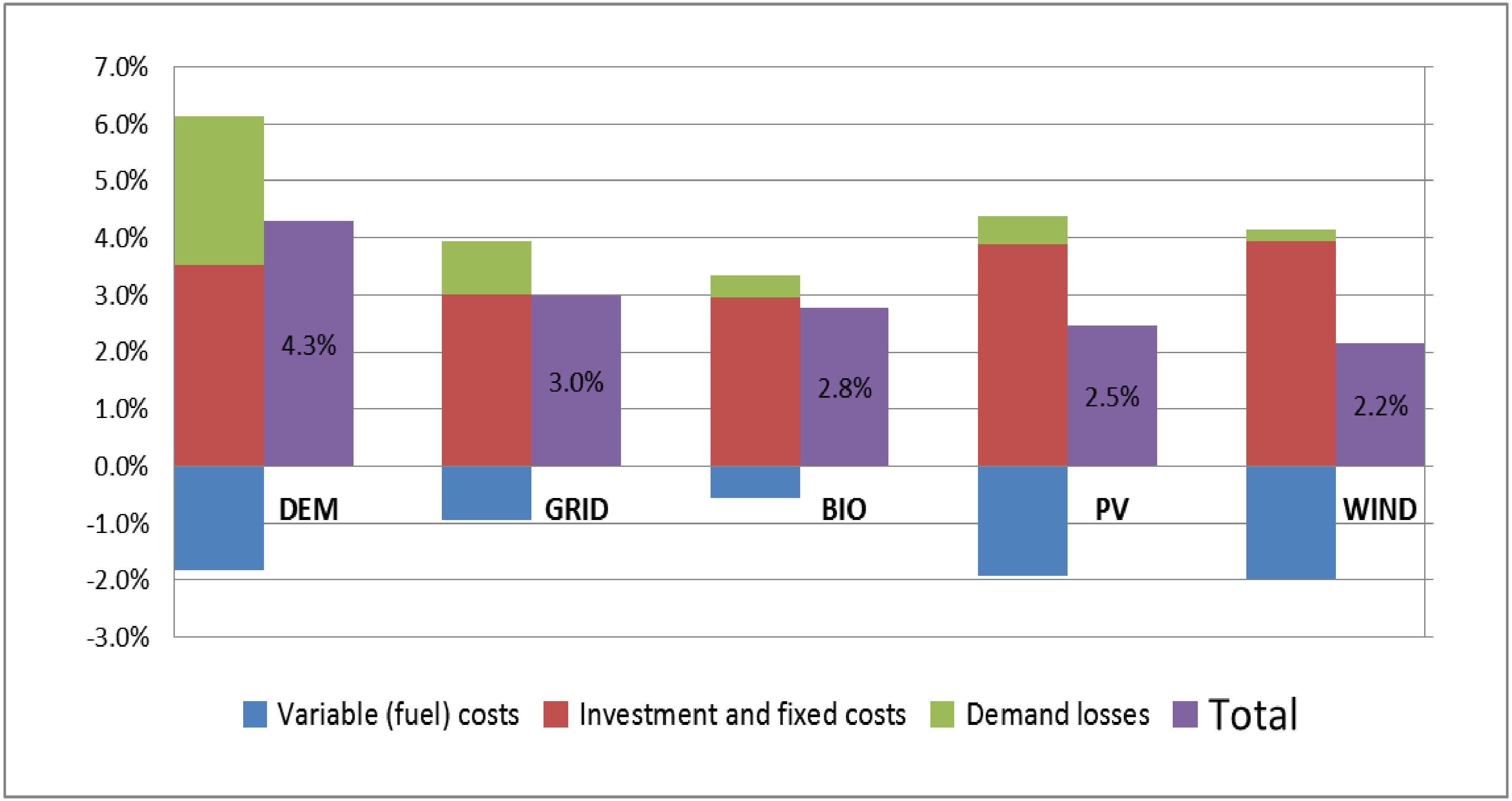


Costs: Cumulative additional investment expenditures in the electricity sector (M€2005)



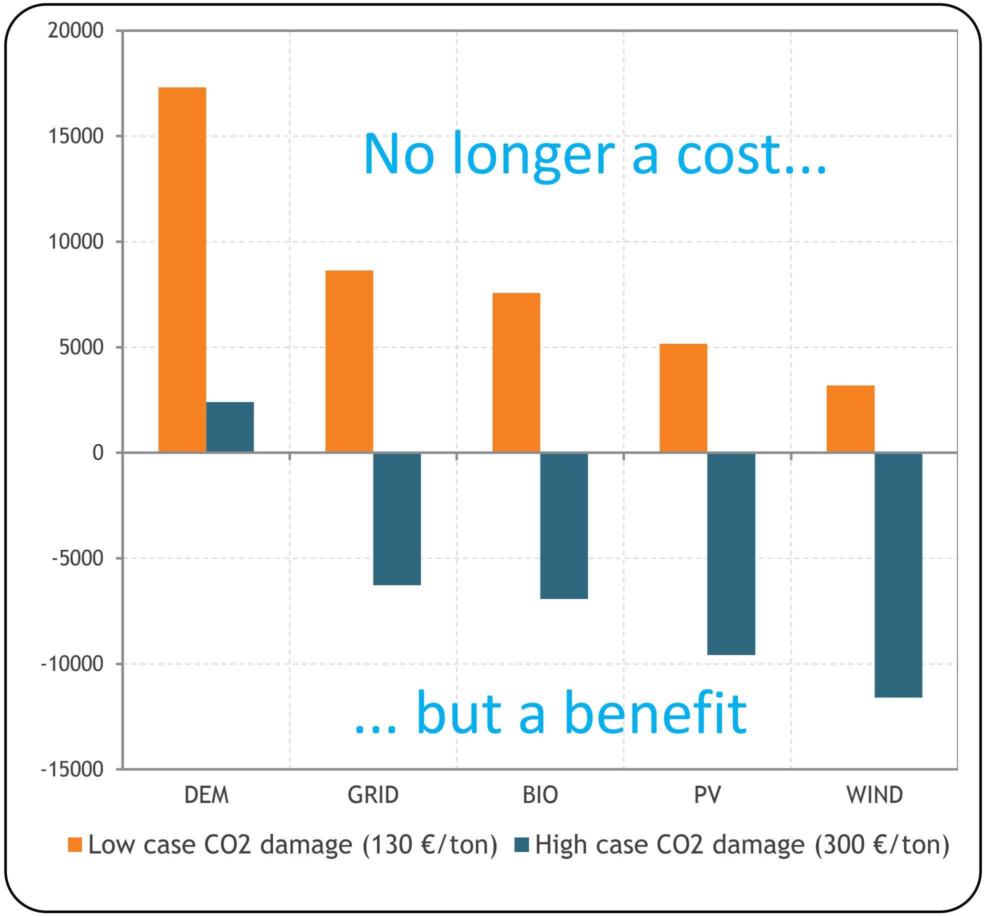
Source: TIMES.

Cost of renewable energy scenarios (in % GDP 2050)



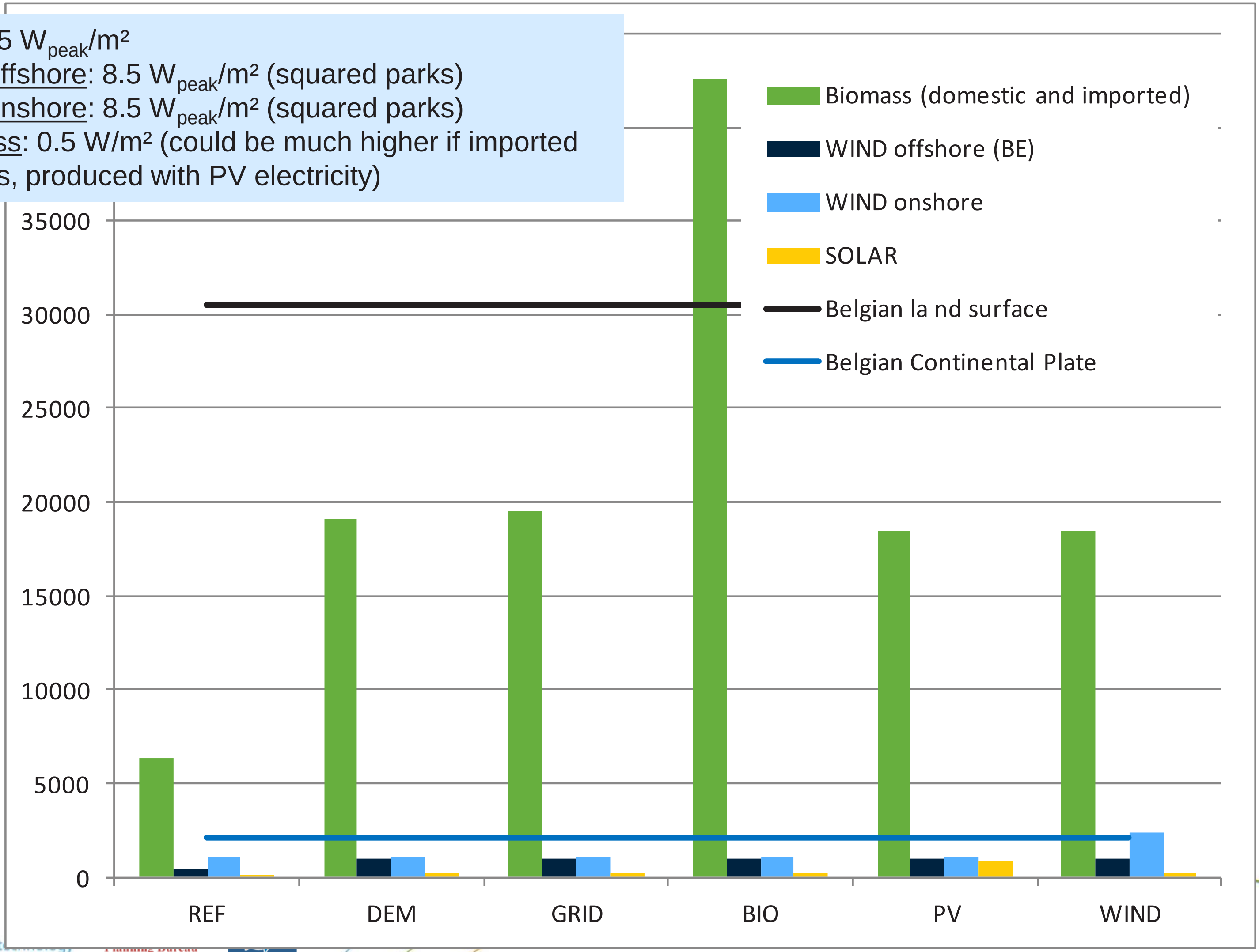
Costs: Additional cost incl. avoided GHG damage cost (M€2005), 2050

- Total annual add. cost wrt REF, when (global) benefit of avoided GHG in 2050 is included



Space requirement (2050) (km²)

PV: 205 W_{peak}/m^2
Wind offshore: 8.5 W_{peak}/m^2 (squared parks)
Wind onshore: 8.5 W_{peak}/m^2 (squared parks)
Biomass: 0.5 W/m^2 (could be much higher if imported biofuels, produced with PV electricity)



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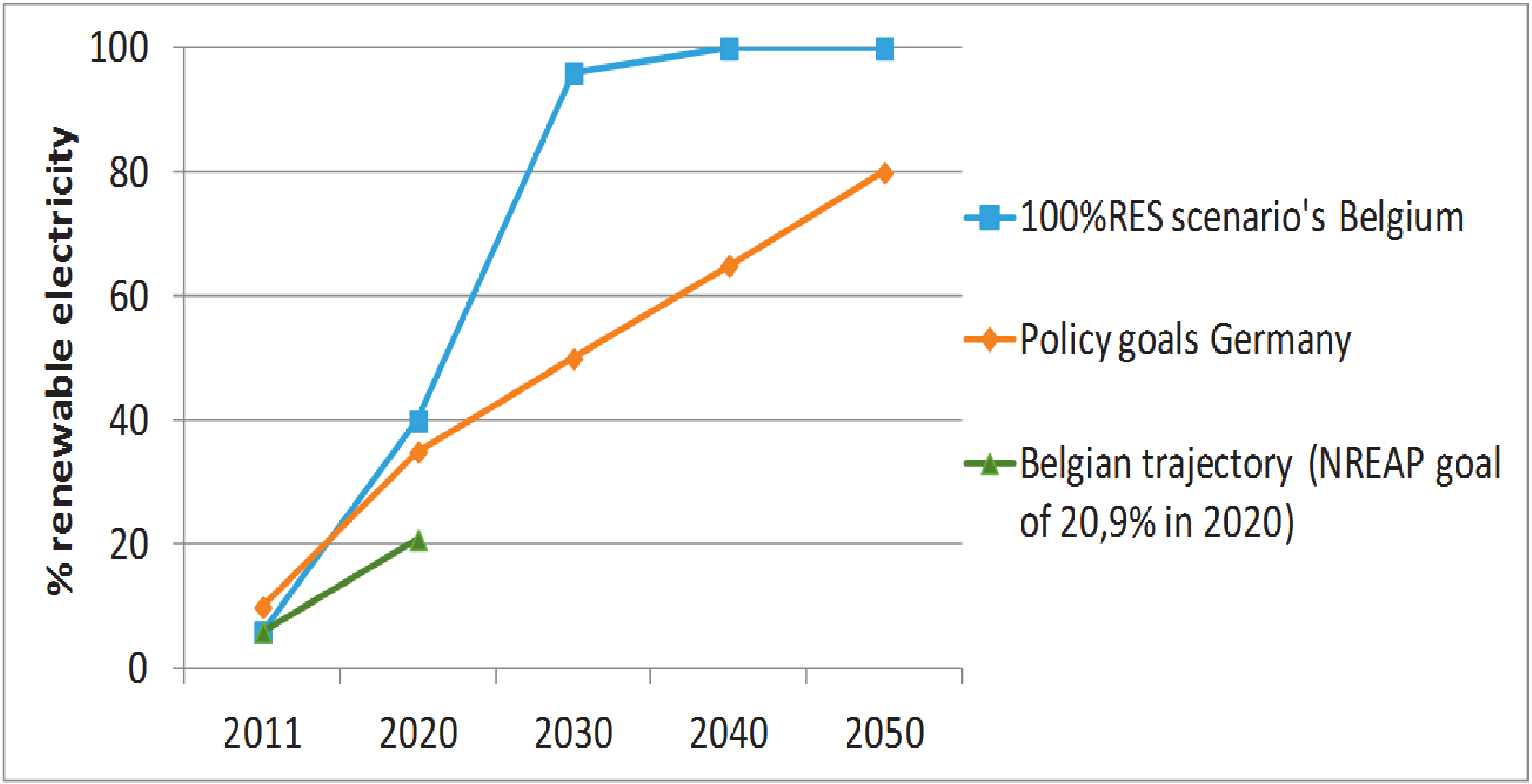
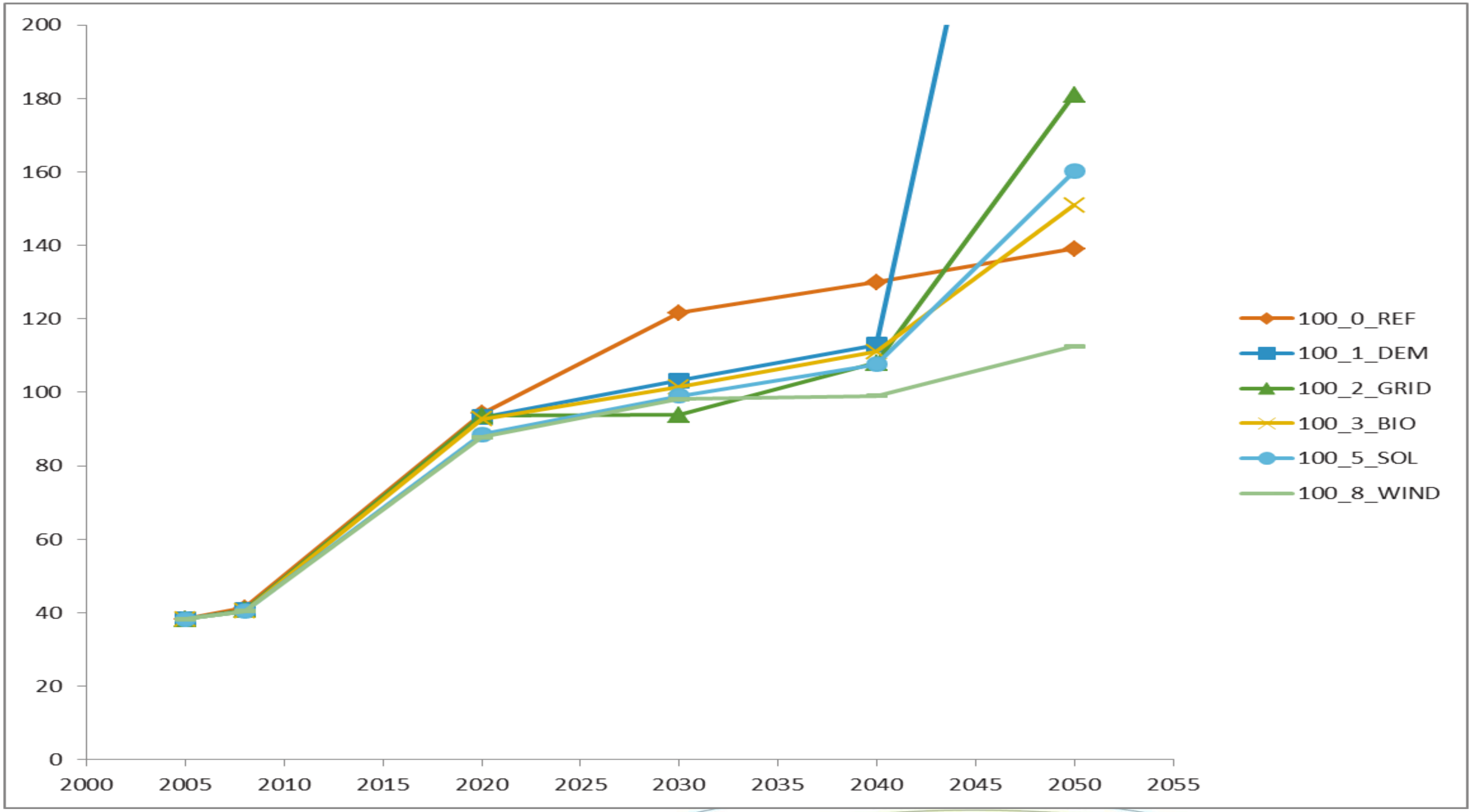
Special results: Renewables penetration in electricity sector



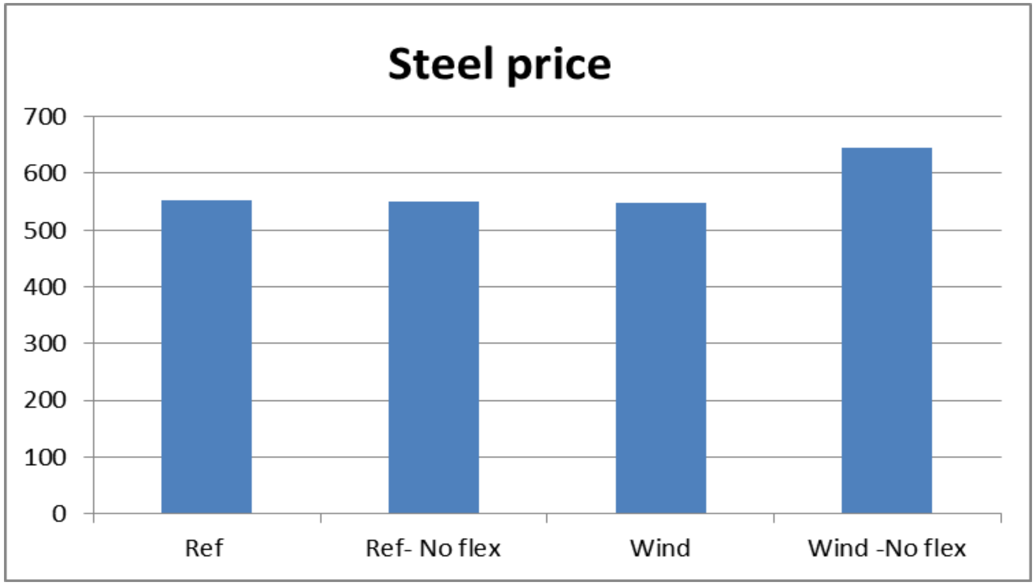
Electricity prices



Special results: Steel production

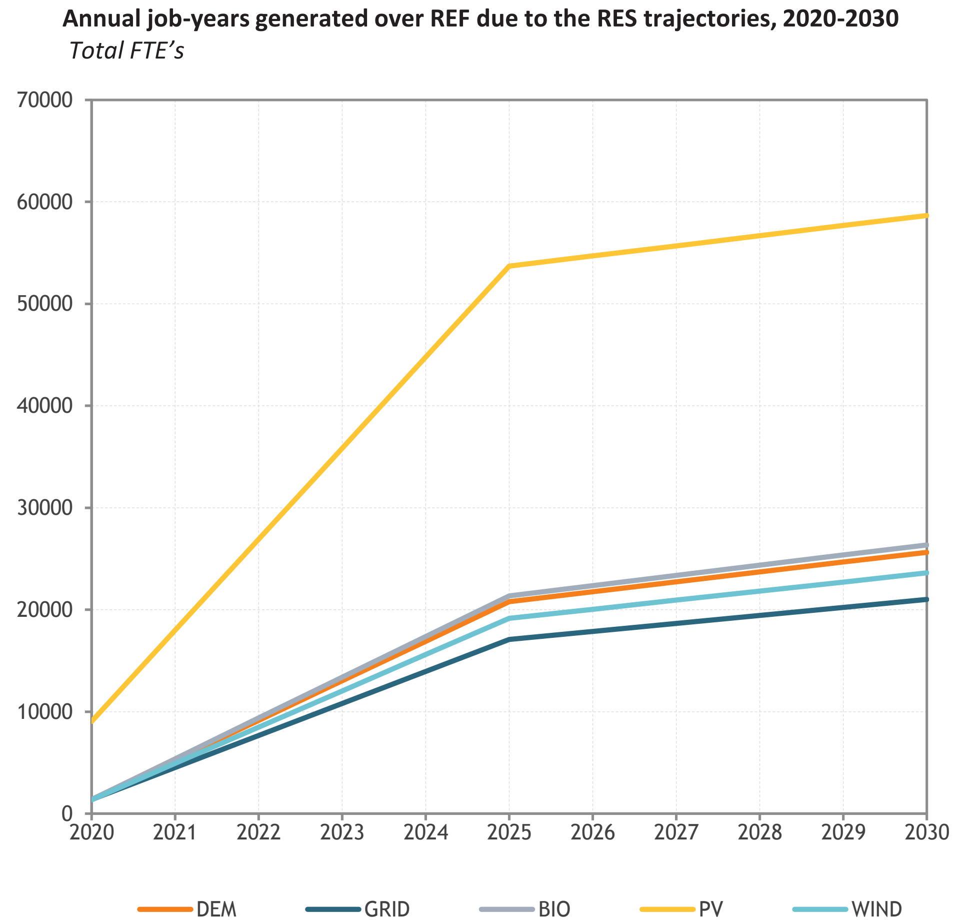
» Flexible steel production saves 600 m € in 2050 or 17% of total revenues of the sector

» Flexible steel production is competitive in wind scenario



Employment: Some estimations

- The RES trajectories all create more job-years or FTE's than REF
- REF already integrates a lot of renewables
- PV creates the most FTE's in any given year
- BIO and DEM are the second highest job generating scenarios



Source: Wei et al. (2010), Federal Planning Bureau.

Conclusions (1/2)

Technically, a 100% renewable energy system is feasible without having to change the economic paradigm.

However, such a radical society transformation implies that:

- A highly ambitious renewable target goes hand in hand with a trend towards electrification: a doubling/tripling of power production is noted, curtailment is necessary
- Energy imports strongly diminish but remain important: imports tumble from 83% (REF) to [42%-15%] depending on the scenario
- Society shifts from a fuel intensive to a capital intensive society
- It seems cost efficient to maintain overcapacities, both in industry and power generation → new paradigm in energy perception

Conclusions (2/2)

- This comes at a significant cost: in 2050, energy system costs increase by 20% wrt REF, BUT…
  - When including disutility costs, the total add. cost is even higher (30%)
  - With disutility + GHG damage → net positive effect of some scenarios +/- 10 B€/year (highly dependent on GHG damage cost assumptions)
  - 300 to 400 billion € of additional investments are needed
  - Sensitivity to fuel prices and PV costs
    - PV costs from 371 – 1000 €05/kW_p => variation of 0.5% of GDP2050
    - Variant of REF scenario with higher oil prices (250 $08/boe in 2050) → additional costs decrease
  - Creation of additional employment
    - 20 000 to 60 000 additional full-time jobs in 2030
  - Cost efficiency of adapting to energy flow variability
- Further research is certainly needed…

Thank you for your attention

Full report via Google: 100% renewable energy by 2050

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