The Belgian electricity landscape in the context of the nuclear phase-out

Stakeholders presentation

14th of March 2017

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Agenda

I. The Belgian Energy Transition in a global and European context

II. The cost of RES-based electricity is coming down faster than expected

III. The Electricity system can handle RES integration at bearable costs

IV. The drawbacks of the existing nuclear plants

I. The Belgian Energy transition in a global and European context

A. The European context and its implication for Belgium

Global context

- Paris agreement (COP21) to limit global temperature rise to well below 2 °C and to pursue efforts to limit this temperature increase to 1.5° C
- All countries design their Nationally Determined Contribution (NDC)
- IPCC report expected by 2018 with an update on the required GHG reductions

European context

- Emission reduction commitments of 80 to 95% by 2050 w.r.t. 1990
- Recent clean energy package of the European Commission reinforcing existing trends (EE, RES, higher flexibility)

Belgian federal and regional context

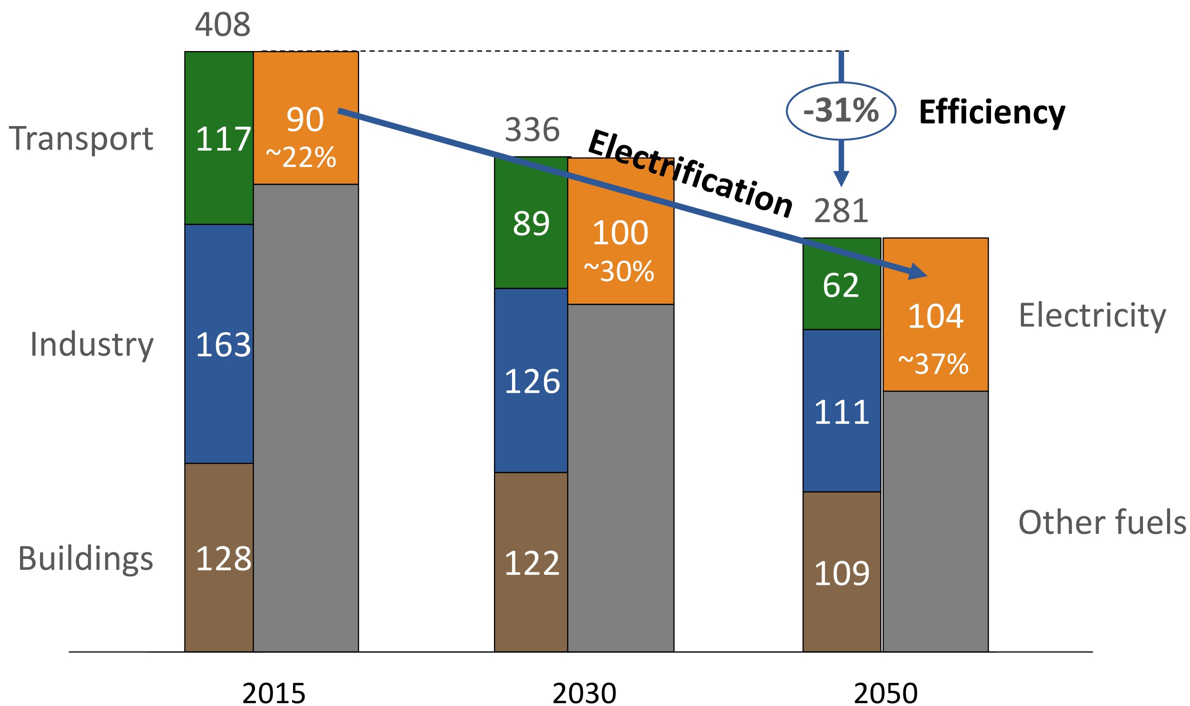
- Institutional complexity : Energy jurisdiction is shared between the federal and regional entities
- 6 GW of nuclear capacity to be retired between 2022 and 2025

Source: Climact

I. The Belgian Energy transition in a global and European context

Aa successful decarbonisation of the economy requires high levels of demand reduction, energy efficiency and high levels of electrification of demand

Total energy consumption in TWh, in Belgium by sector and by source in a scenario reaching -80% GHG



NOTE: Figures based on the CORE scenario (-80% GHG) from the Belgian low carbon scenarios

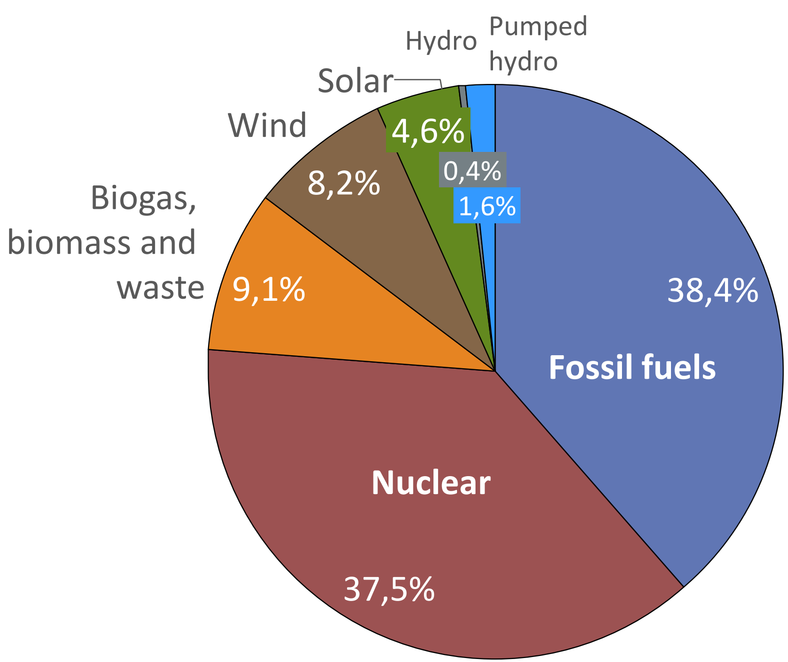
Source: Climact

I. The Belgian Energy transition in a global and European context

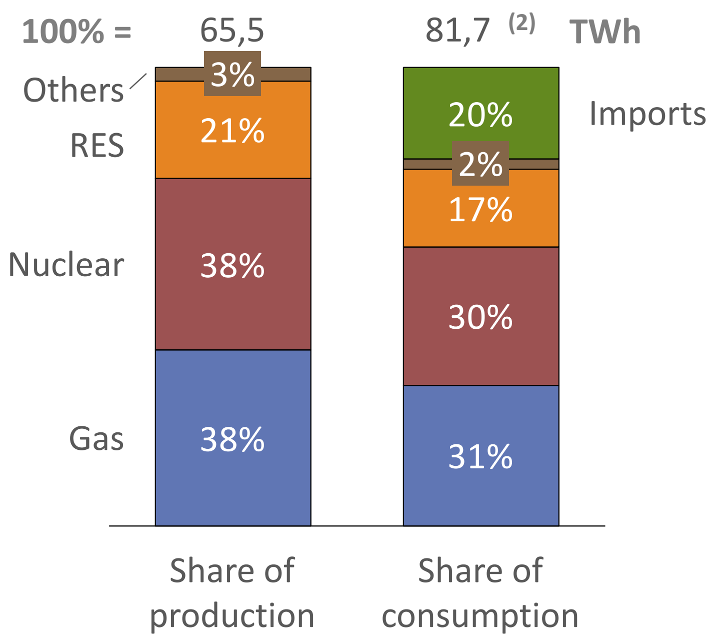
Belgium produced 65,5 TWh of electricity in 2015, importing ~20%

RES production represents ~17% of final electricity consumption

Total net electricity production in Belgium by source in 2015, in TWh (1)



Belgium 2015 (1)



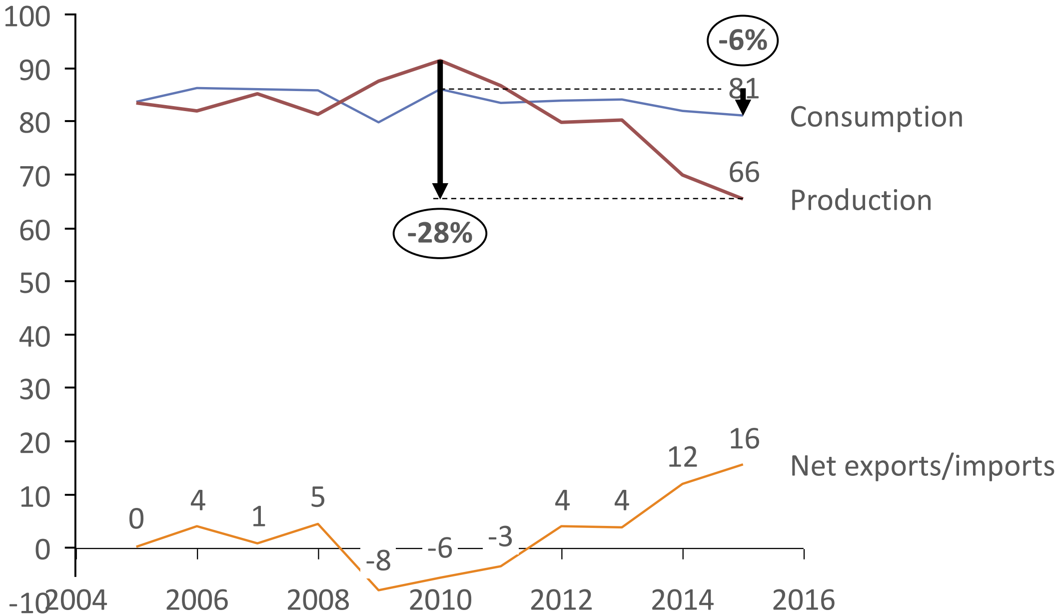
Sources: (1) Annual report FEBEG 2015, figures excluding own consumption from power plants (2) SPF Economie et Energie

I. The Belgian Energy transition in a global and European context

Belgium produced 65,5 TWh of electricity in 2015, importing ~20%

RES production represents ~17% of final electricity consumption

Evolution of electricity consumption and production in Belgium, TWh



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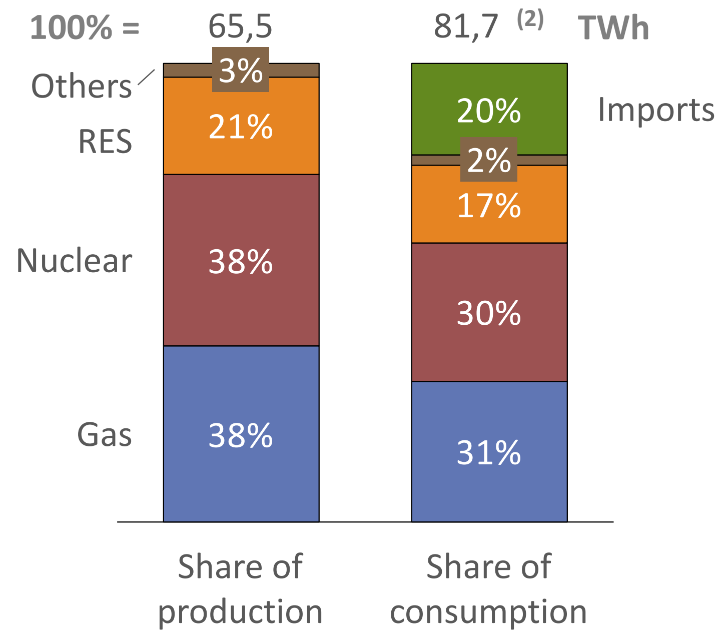
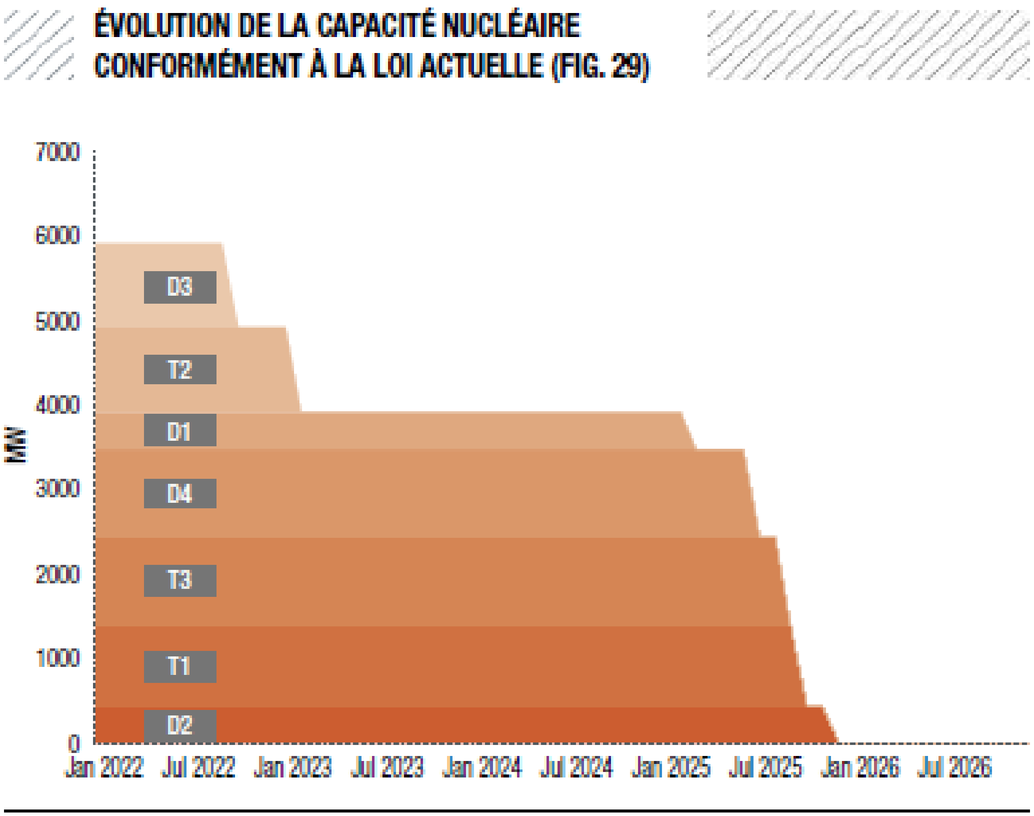


Sources: (1) Annual report FEBEG 2015, figures excluding own consumption from power plants (2) SPF Economie et Energie

I. The Belgian Energy transition in a global and European context

In parallel to the low carbon transition, Belgium has laws clarifying the phase-out of its ageing fleet of nuclear power plants between 2022 and 2025



Source: Elia adequacy report

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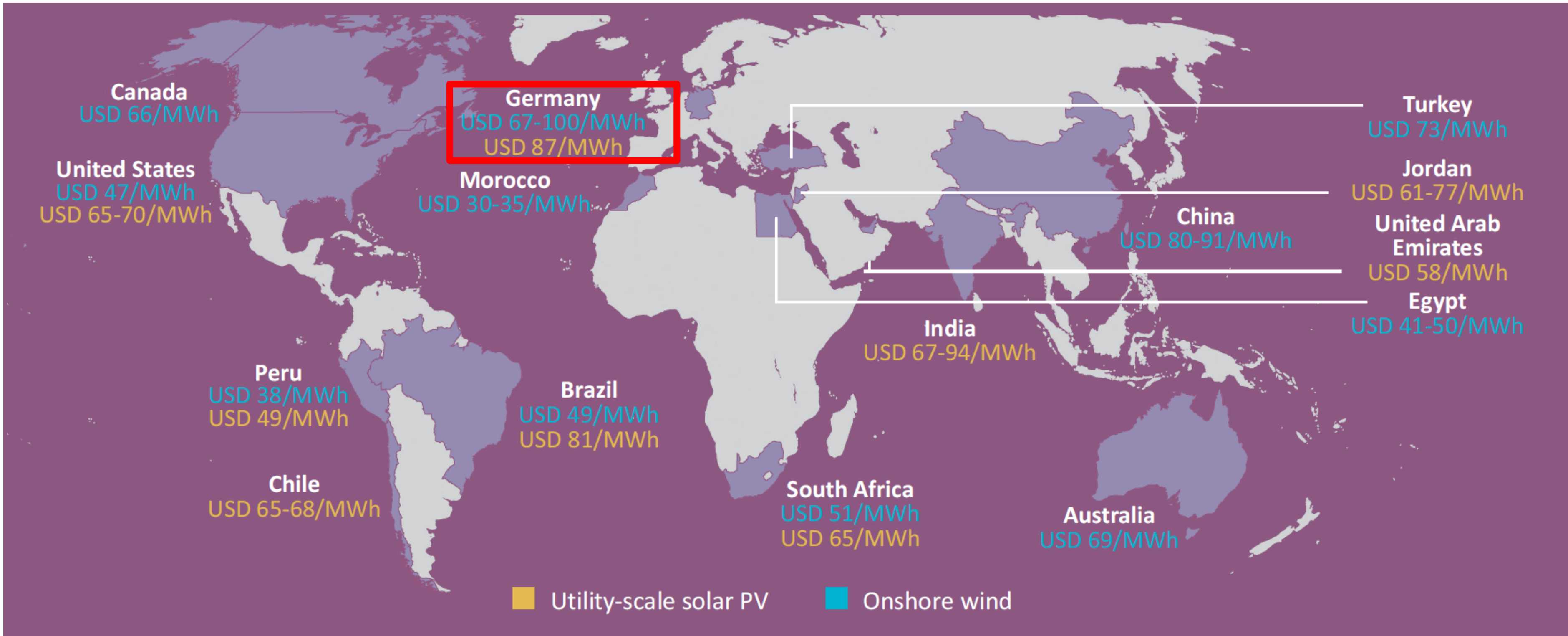
II. The cost of RES-based electricity is coming down faster than expected

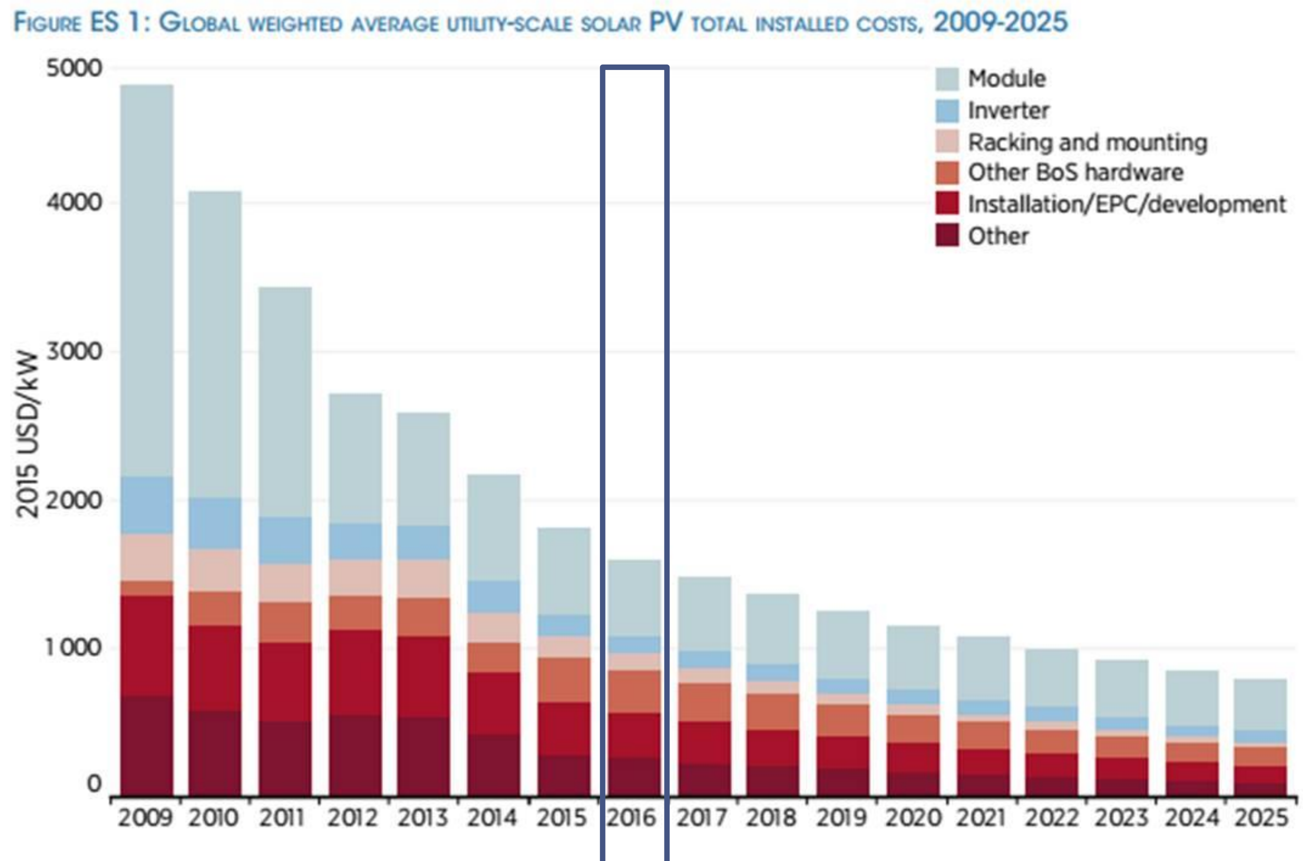
Recent long-term remuneration contract prices for 2016-19 project commissioning (e.g., auctions and FITs)



Source: IEA Tracking Clean Energy Progress 2016

II. The cost of RES-based electricity is coming down faster than expected

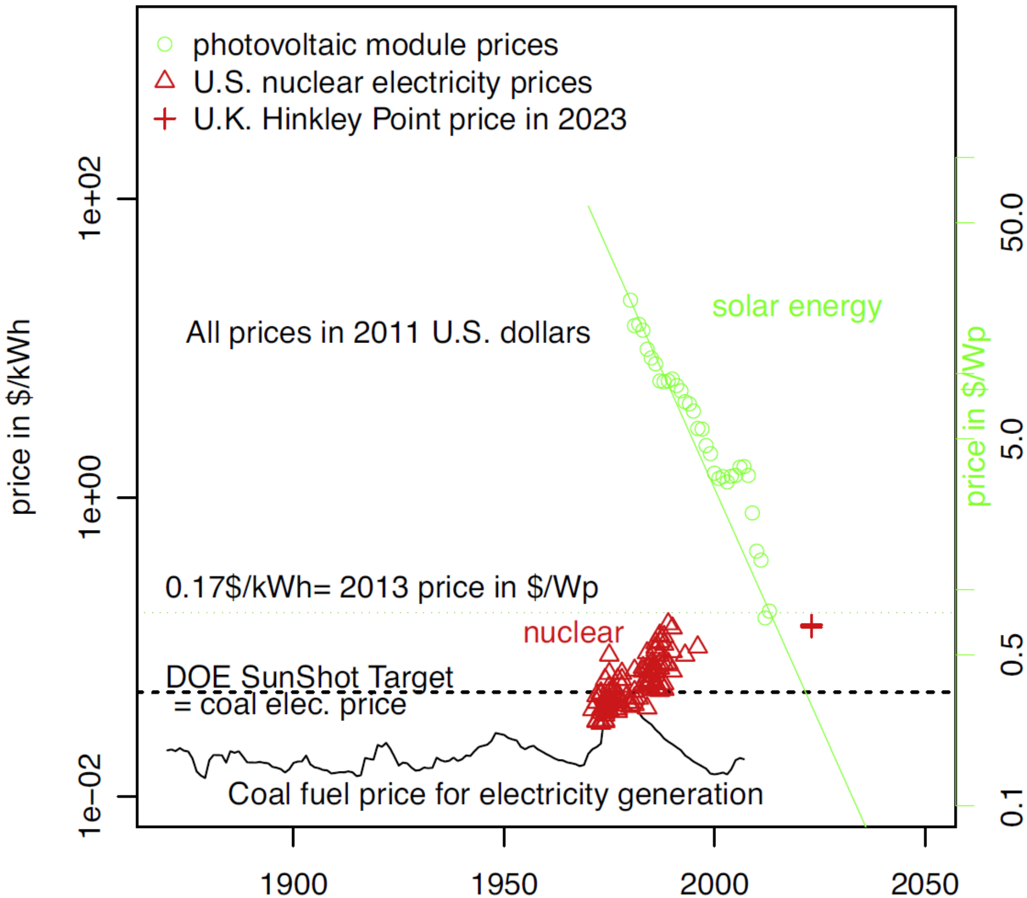
IRENA's solar study assumes ~1600 USD/kw in 2016, while it is being built at 1000 eur/kw in Belgium



Source: IRENA THE POWER TO CHANGE: SOLAR AND WIND COST REDUCTION POTENTIAL TO 2025 (2016)

II. The cost of RES-based electricity is coming down faster than expected

However, the historical trend shows an increase in nuclear costs and no sign of cost reductions

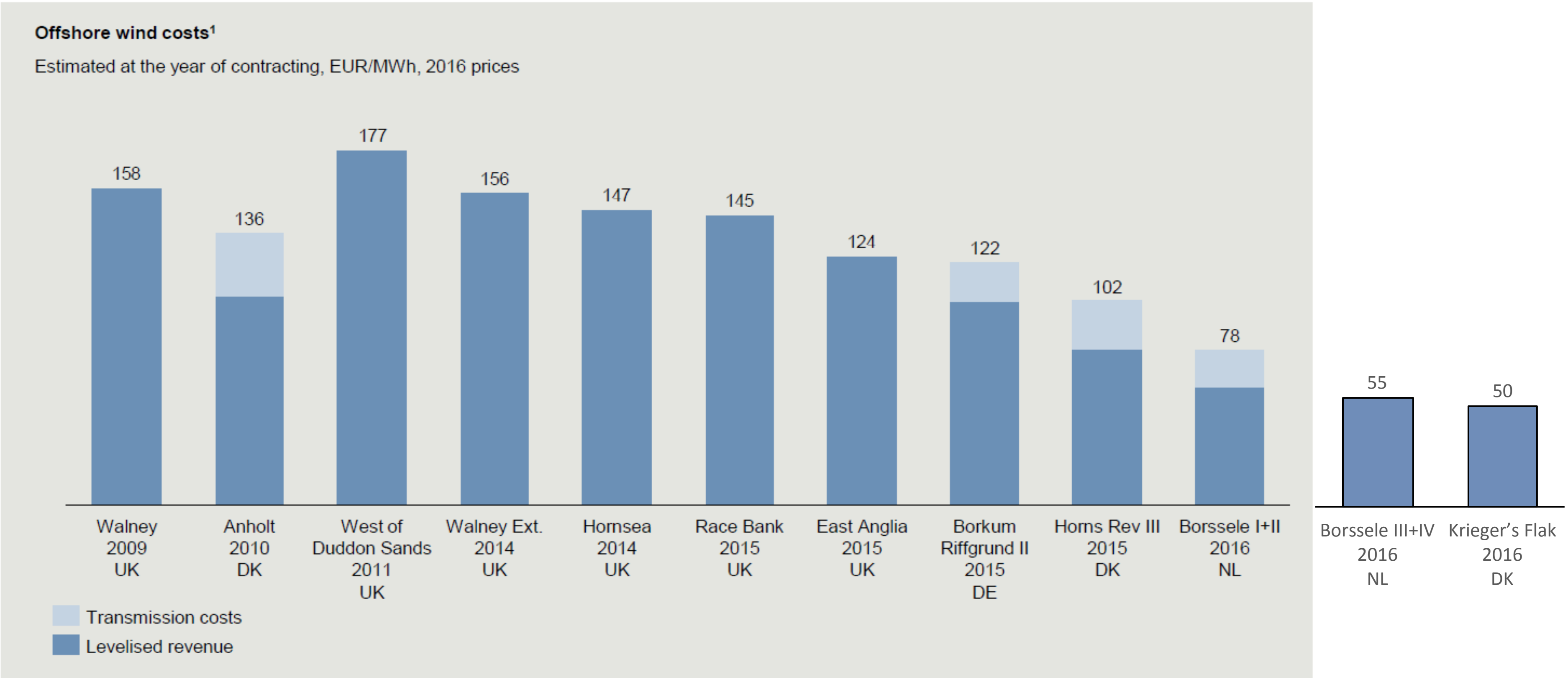


The world nuclear association highlights how the cost of new nuclear facilities has been rising since the 60's in Europe, **from USD 1,500/kW in the early 60s to above USD 5,000/kW in 2010**

Source : Farmer and Lafond, "How predictable is technological progress?" Research Policy 45 (2016) 647–665

II. The cost of RES-based electricity is coming down faster than expected

Offshore wind is also seeing fast reductions



1: Average price for the electricity over the lifetime of the plant used as proxy for the levelised costs of electricity. It consists of a subsidy element for the first years and a market income for the remaining years of the 25 years lifetime. Discount rate of 3,5% used to reflect society's discount rate. Market income based on country specific wholesale market price projections at the time of contracting

Note: Exchange rate on July 7 2016 has been used. Adjustment of costs to account for the fact that the 2012 target was set for a UK project which primarily incl. costs of transmission and extra development costs.

Source: DECC; Danish Energy Agency; Energinet.dk; NEV, Dong

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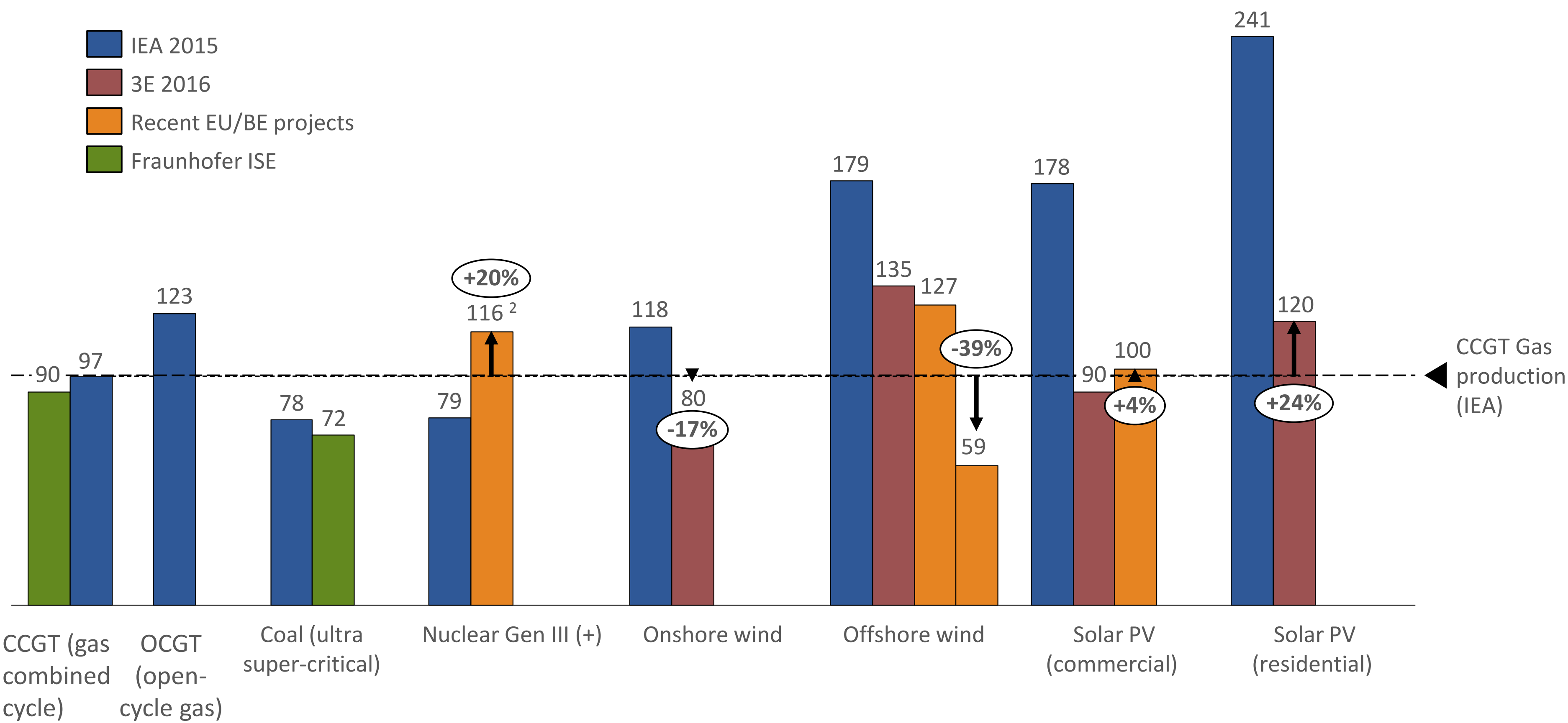
II. The cost of RES-based electricity is coming down faster than expected



Sources: IEA-NEA "Projected Costs of Generating Electricity" (2015), Fraunhofer ISE "Levelized cost of electricity renewable energy technologies" (2013), 3E "Crucial energy choices in Belgium - an investigation of the options" (2016), various company/business websites

Agenda

III. The Electricity system can handle RES integration at bearable costs

RES integration at bearable costs RES Integration will require system adaptations, but at a bearable cost

System integration costs categories	Overview of Intermittent-RES integration costs for Belgium towards 2030 (KULeuven, 2016)
Grid costs: transmission and distribution infrastructure reinforcement	1.6 – 2.2 €/MWh_{IRES} (transmission excl. interconnection and internal reinforcement) 2.4 – 3.1 €/MWh_{IRES} (transmission incl. interconnection and internal reinforcement) 2.5 – 9 €/MWh_{IRES} (distribution)
Balancing costs : costs for balancing deviations of actual generation from the forecasted generation	2 – 5 €/MWh_{IRES}
Back-up costs (or utilization effect) : represents the impact of RES production on existing conventional power plants.	3 - 8 €/MWh_{IRES}

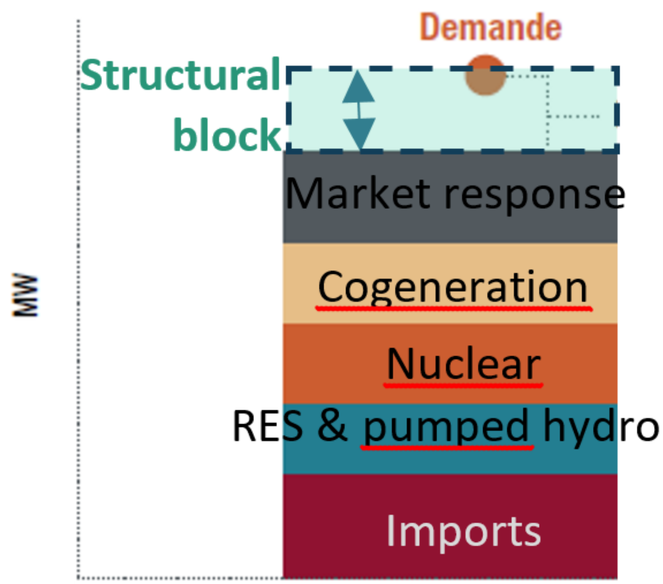
Summing up these estimates leads to a relatively wide range of 9 to 25 EUR/MWh_{IRES} by 2030

Souce: KULeuven, http://www.creg.info/pdf/ARCC/161019-KULeuven.pdf

III. The Electricity system can handle RES integration at bearable costs

Although challenging, the nuclear phase out is feasible

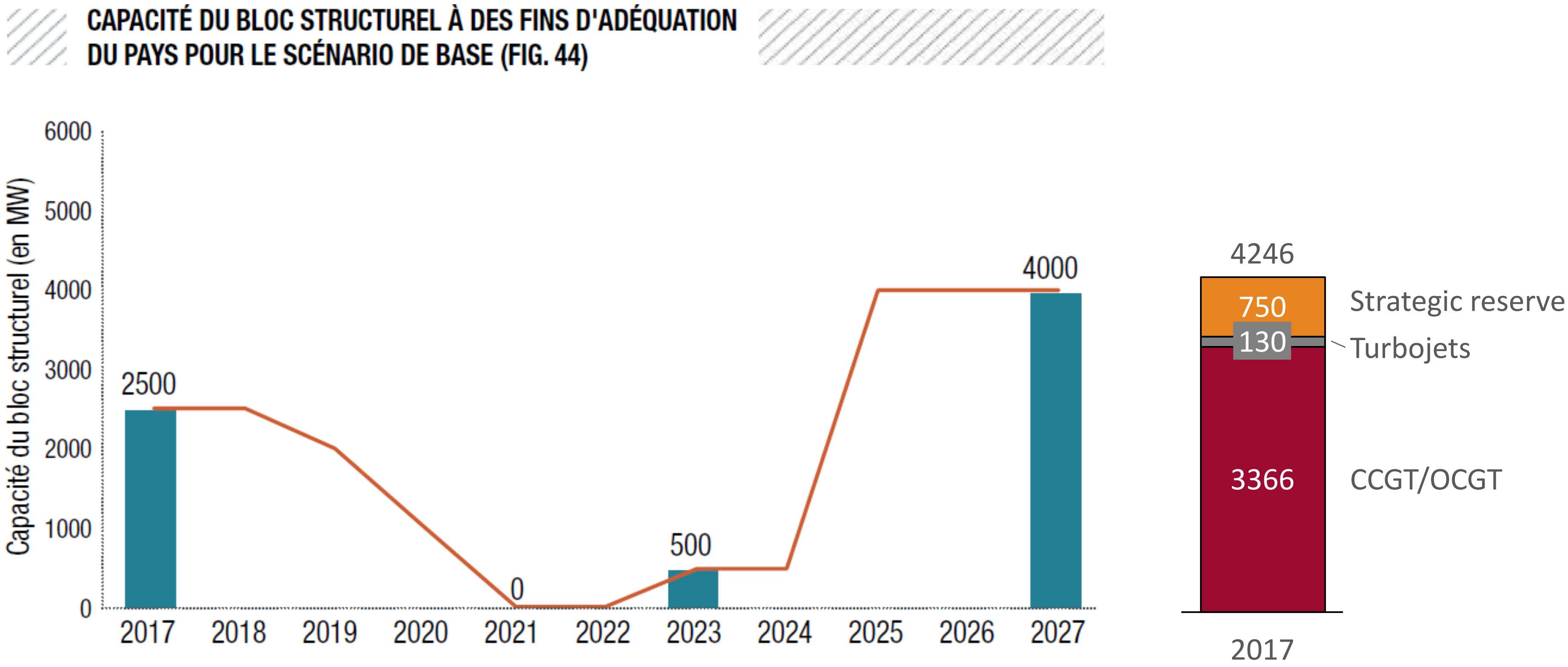
Definition of the "structural block", on top of other options



SOURCE : Elia, adequacy study 2017-2027

III. The Electricity system can handle RES integration at bearable costs

Although challenging, the nuclear phase out is feasible



SOURCE : Elia, adequacy study 2017-2027

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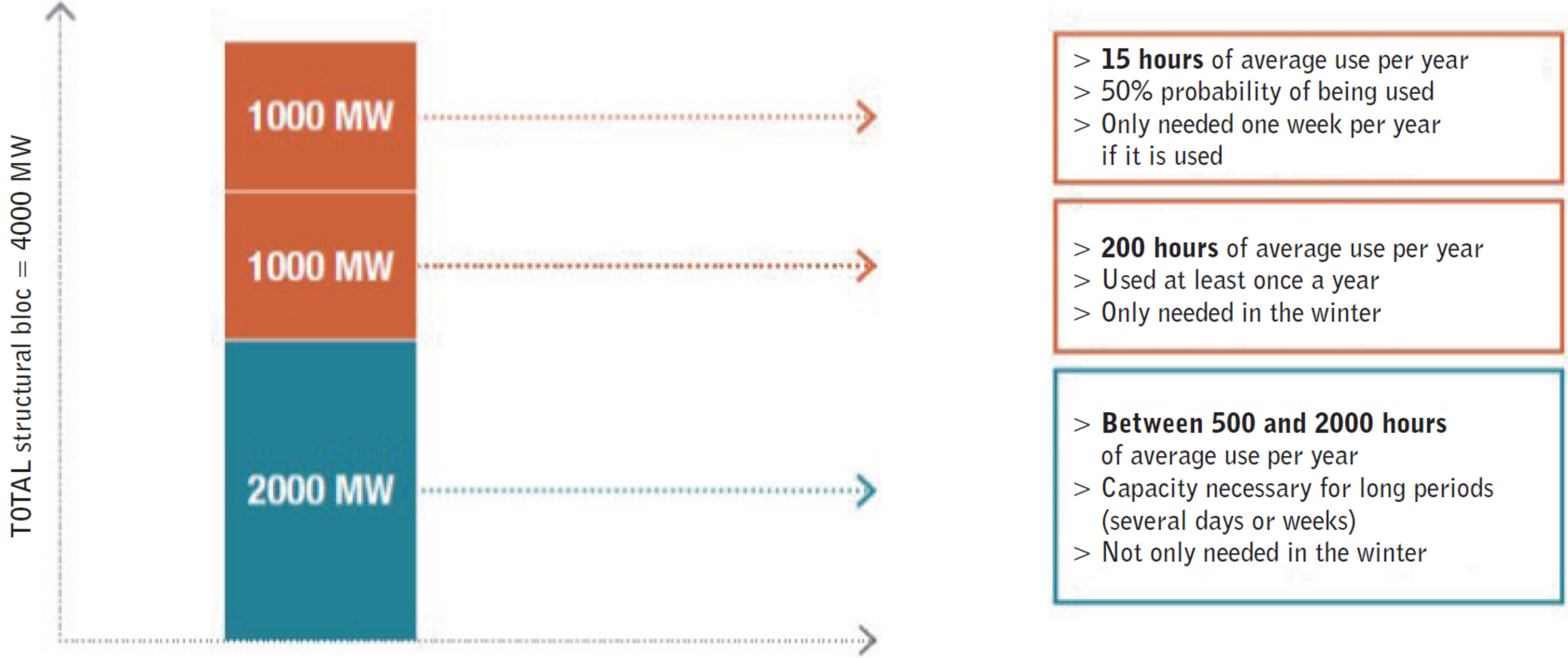
Although challenging, the nuclear phase out is feasible

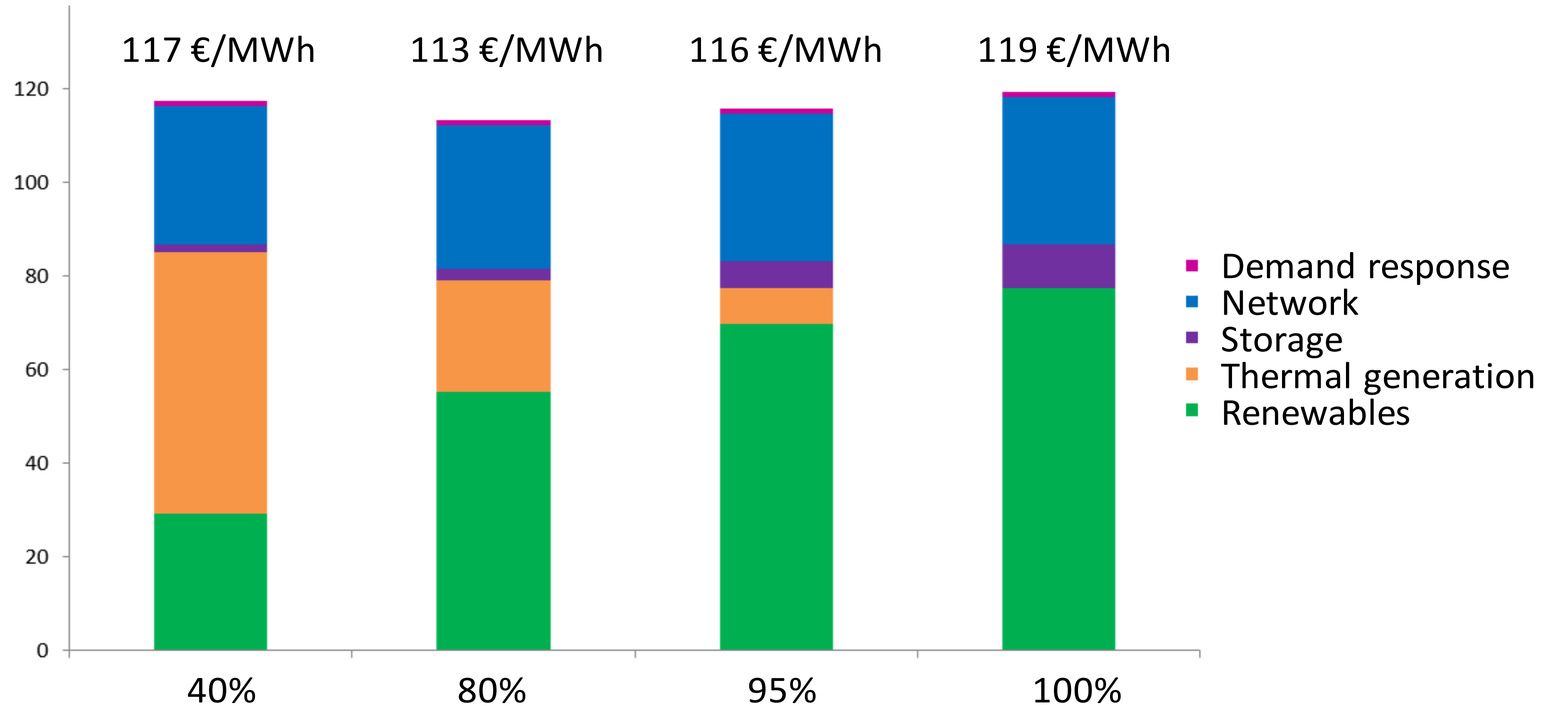
Characteristics of major blocks of the structural block in 2027 in the base scenario



SOURCE : Elia, adequacy study 2017-2027

III. The Electricity system can handle RES integration at bearable costs

In the longer term, detailed grid analysis show that large RES penetration can be integrated



Source: France: Un mix électrique 100% renouvelable ? Analyses et optimisations (Octobre 2015, ADEME et ARTELYS)

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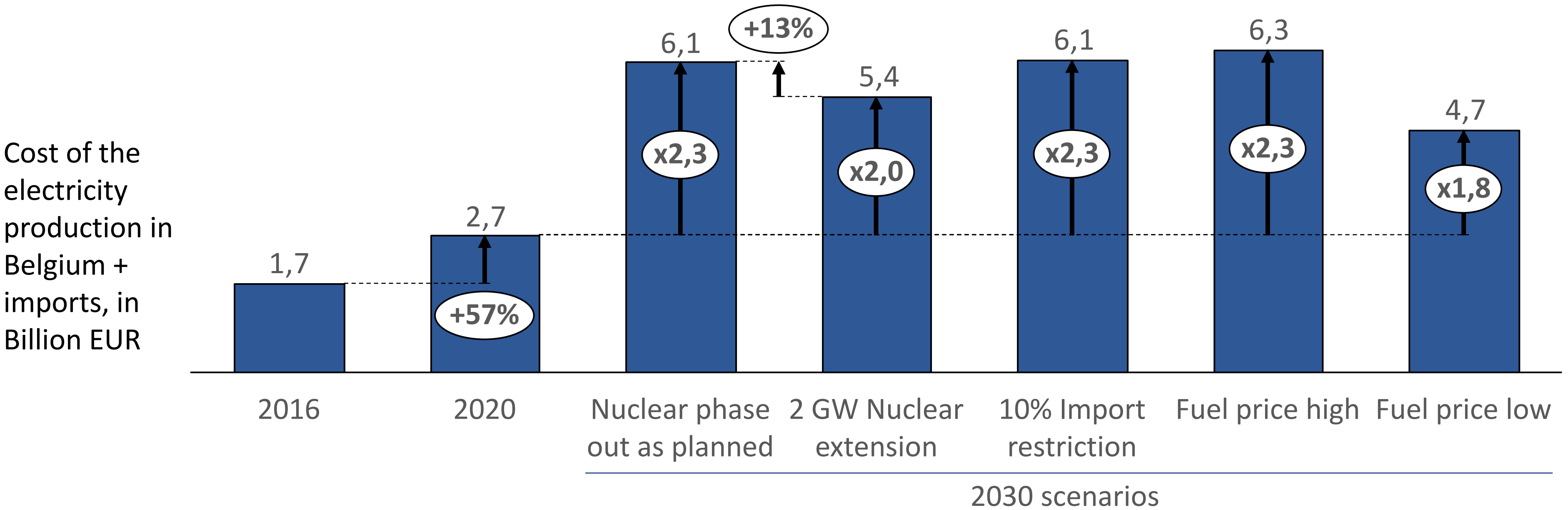
IV. The drawbacks of the existing nuclear plants
The cost dimension



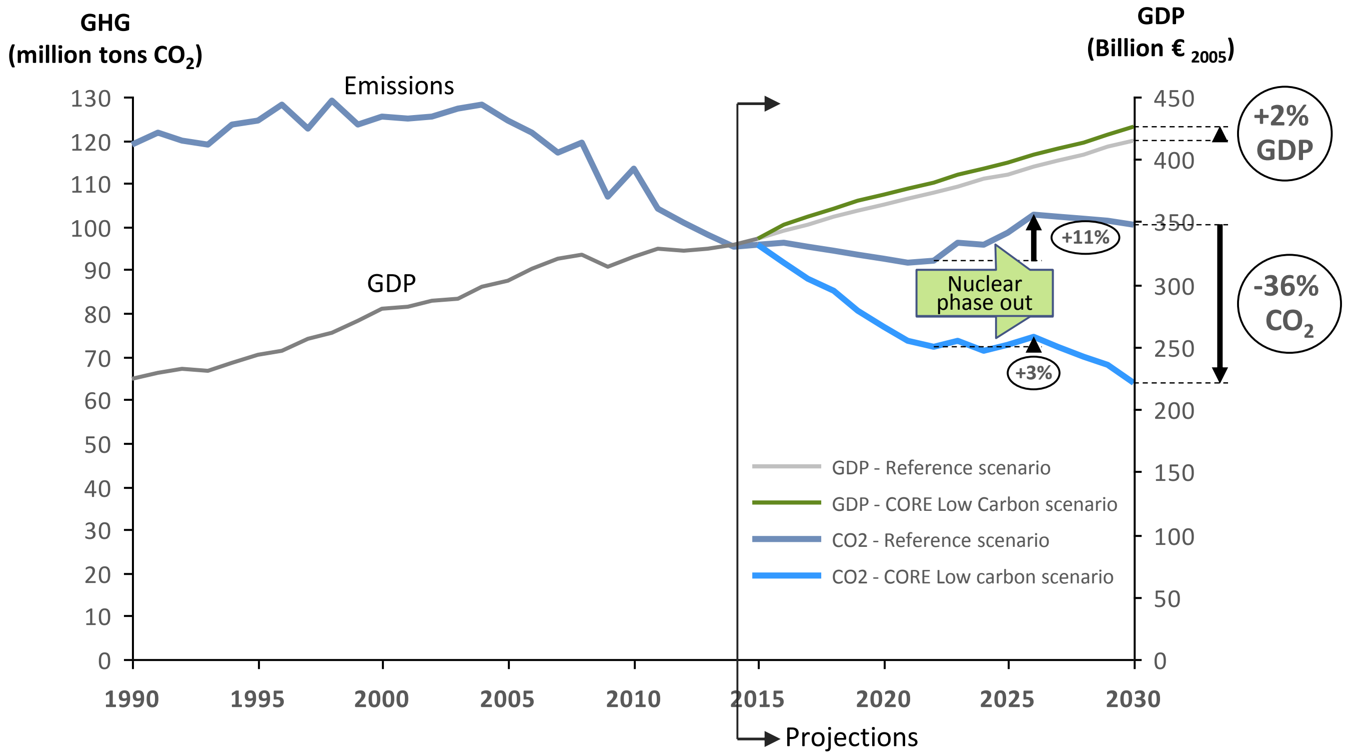
Cost converted to EUR/MWh	2016	2020	Nuclear phase out as planned	2 GW Nuclear extension	10% Import restriction	Fuel price high	Fuel price low
	20	32	70	62	71	73	55

8 eur delta = 28 eur/year for a household consuming 3500 KWh

Source : Based on the EnergyVille/Febeliec study

IV. The drawbacks of the existing nuclear plants
The GHG dimension

GDP and CO_2 emissions (Billion € 2005 / million tons CO_2 in that year)



Source : Climact, BfP : Macro economic impacts of the Belgian Low Carbon transition

IV. The drawbacks of the existing nuclear plants
The key issues

There are various major issues with nuclear

- **Accidents** : While probability of a major accident is low, the implications are extreme.

  This risk increases with older plants and with the terrorist threat.

  While costs of a major accident are clearly difficult to estimate, they are in the top ranking of the costliest disasters worldwide. Estimates of the cost of a major accident between EUR 160 (Fukushima) and 450 billion (Chernobyl).

  Additionally, there is a serious liability issue: the NPP operators are only liable until EUR 1,2 billion
- **Waste** : While this cost is being provisioned, there is still no clear view on storage. This has implications for many hundred-thousands of years, locking in future generations/civilisations.
- **New nuclear would imply a massive lock-in** : e.g., Hinkley Point = 35 years of subsidies (vs 10 to 19 years for solar and offshore wind in Belgium, respectively), and 60 years of lifetime.

This policy brief concludes with a series of recommendations in support of a coherent Belgian energy vision :

1. Giving a clear sign that the **nuclear phase-out** is going through the way it is planned
2. Continuing with **no-regret deployments** :
   - Energy efficiency
   - Demand and supply flexibility options
   - RES deployment
   - Building-up interconnections
3. **EU integration and cooperation** needs to be organised properly
4. Setting an adequate **price on carbon**
5. Looking in more detail at **alternatives to enhance flexibility** in the electricity system

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Thank you.

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We're in the middle of an energy transition, with many radical changes happening at the same time

	FROM .. The current/past energy system	**.. TO .. the FUTURE energy system**
Overall context	▪ Energy issues less at the center of geopolitical issues with lower energy prices ▪ Climate change is a marginal issue ▪ Economic growth	▪ **Complex and uncertain geopolitics affecting high fuel prices** (energy security issues) ▪ **Climate change** is an increasingly important issue ▪ **Economic crisis**, key competitiveness issues
Market and regulatory	▪ Limited pressure on fossil fuels and lower prices ▪ Limited market integration ▪ Limited regulatory constraints and trend towards liberalization	▪ High **pressure on fossil fuels** and higher prices **volatility** ▪ Increasing EU **market integration** ▪ Increasing **regulatory constraints** (e.g. ETS) and trend towards intervention
Physical Energy System	**Demand** ▪ Limited focus on Energy Efficiency ▪ Stable share of electricity and heat demand has limited impact on the electricity system ▪ Demand inelasticity **Supply** ▪ Centralized production, limited auto-production ▪ Stable electricity production (baseload system) ▪ Limited storage ▪ Little innovation in the system **Separate systems for heat, power and transport** **Limited uncertainty in the evolution of the system**	**Demand** ▪ Increasing focus on **energy efficiency** ▪ Electrification (EV, heat pumps) and more **integration** between heat/gas & electricity systems ▪ Increasing focus on **demand flexibility and elasticity** **Supply** ▪ Increasing **decentralized** (e.g., wind, small biomass) and auto-production (e.g., PV, cogeneration) ▪ Increasing share of **intermittent** production ▪ Increasing **storage** requirements (electricity and gas) ▪ Innovation and new technologies can lead to **breakthroughs** in the systems **Integration of systems** (electrification, CHP, district heating) **High uncertainty in the evolution of the system**

Objectives are set at the European level, and lead to national ones

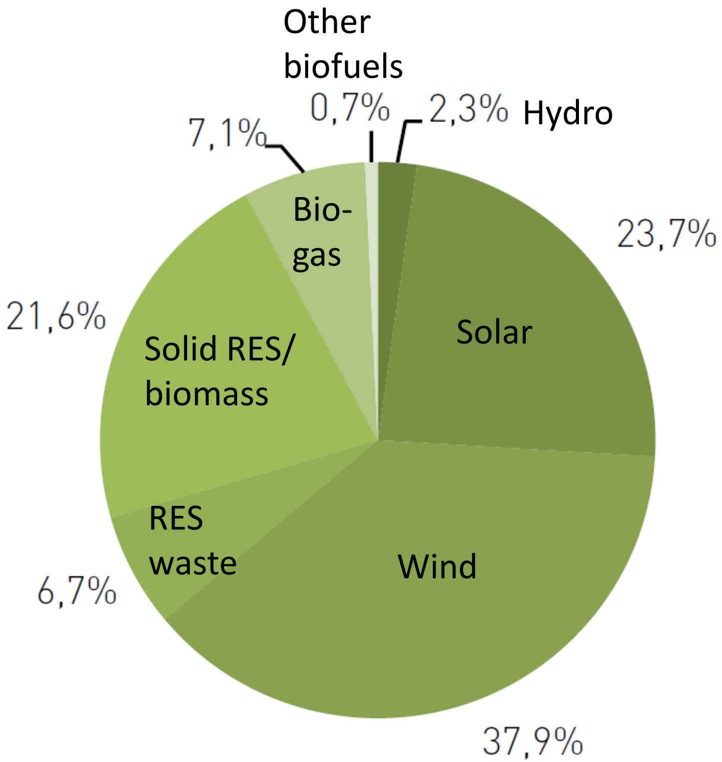
	2020	2030	2050
Energy efficiency	EU-wide: -20% vs BAU scenario	EU-wide: at least -27% vs BAU scenario	
GHG emissions	BE non-ETS: -15% vs 2005	BE non-ETS: -35% vs 2005	EU and BE: -80% à -95% vs 1990
RES	BE: 13%[1] (4,224 Mtep)	EU-wide: at least 27% RES in final consumption	

[1] Of final gross consumption

Source: SPF Environnement, European Commission

The RES share of electricity production is mostly based on solar, wind and biomass

RES-based electricity production in Belgium in 2014, %



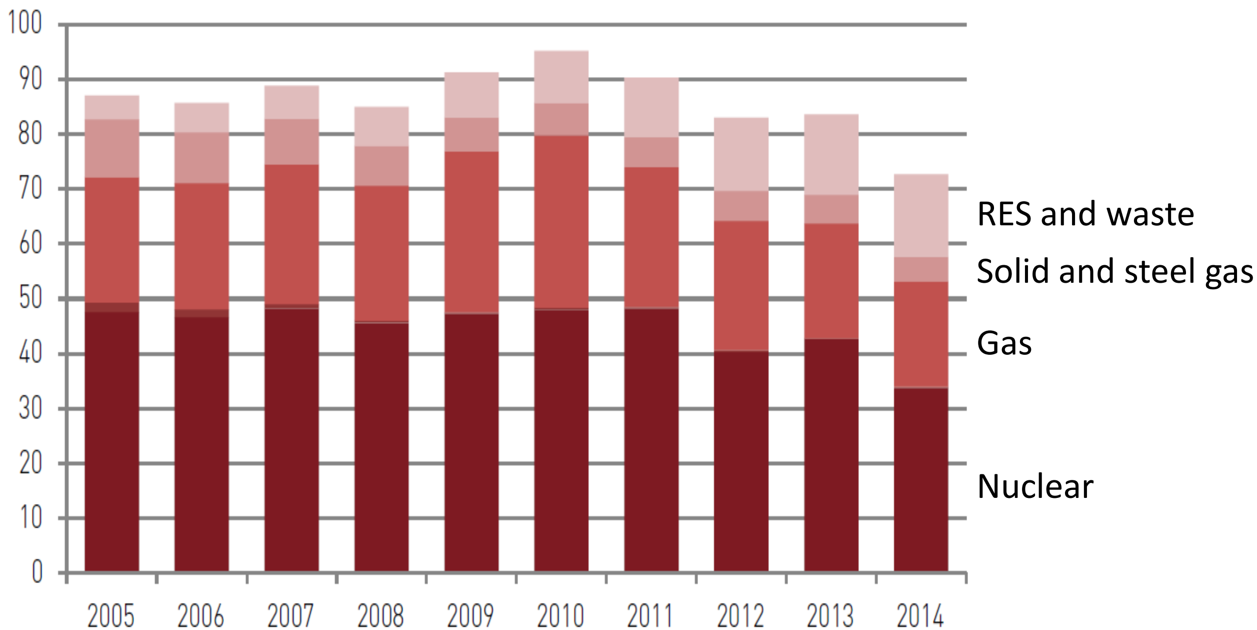
- Wind has the highest contribution (offshore wind brings 2,2 TWh of the 4,6 TWh)
- Solar is second with 2,9 TWh (with 3 GW of capacity)

Source: SPF Economie et Energie

I. The Belgian Energy transition in a global and European context

Electricity production has decreased, with an increase in RES

Evolution of electricity production in Belgium, in TWh

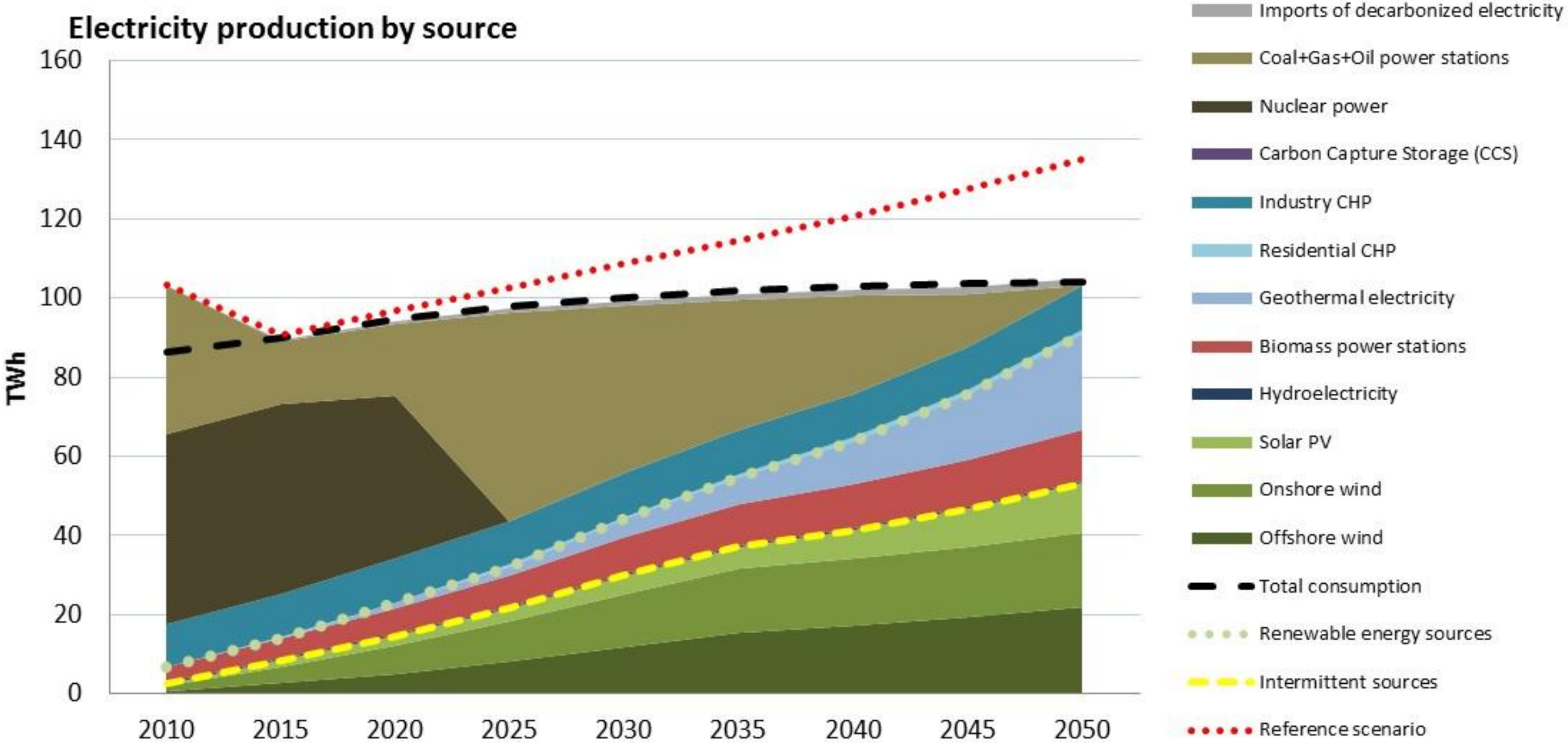


- There was a drop in electricity production of 13% in 2014 linked to temporary closures of the nuclear capacity, which was compensated with higher imports*
- RES is the only category which increased over the past 10 years
- Belgium has 21 GW of electric capacity, with nuclear making up 28% (5,9 GW) and thermal plants 41% (8,6 GW)

* Net imports of 17,6 TWh (21,5 % of electricity consumption)

Source: SPF Economie et Energie

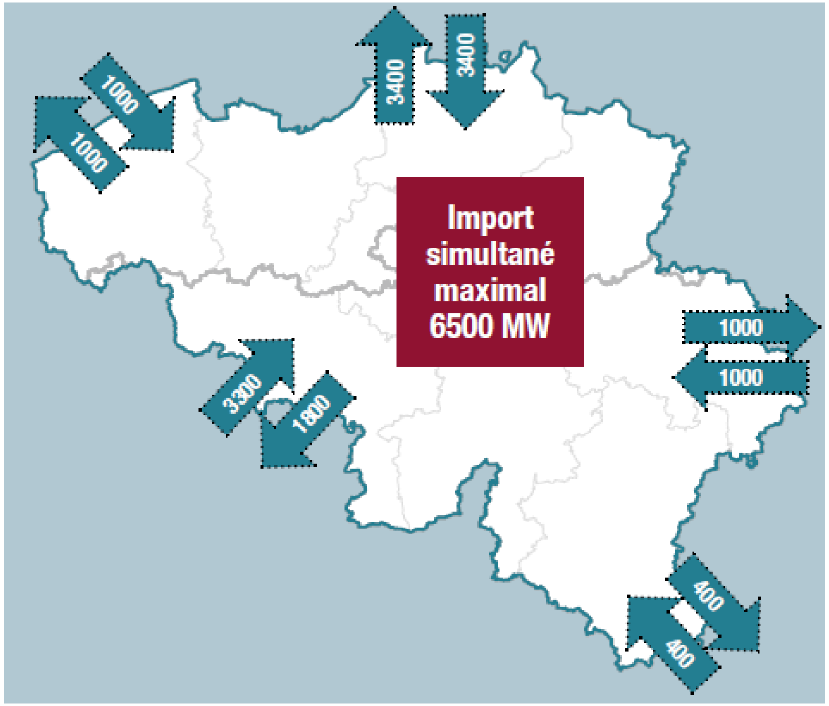
III. Evolution of the electricity generation mix in the CORE scenario



III. The Electricity system can handle RES integration at bearable costs

Although challenging, the nuclear phase out is feasible

CAPACITÉS D'ÉCHANGES COMMERCIALES MAXIMALES (EN MW) ENTRE LA BELGIQUE ET LES PAYS VOISINS POUR 2027 CONSIDÉRÉES DANS CETTE ÉTUDE (FIG. 40)



SOURCE : Elia, adequacy study 2017-2027

IV. The drawbacks of the existing nuclear plants
The risk of major nuclear accidents

While costs of a major accident are difficult to estimate, they are in the top ranking of the costliest disasters worldwide. Cost estimates should include :

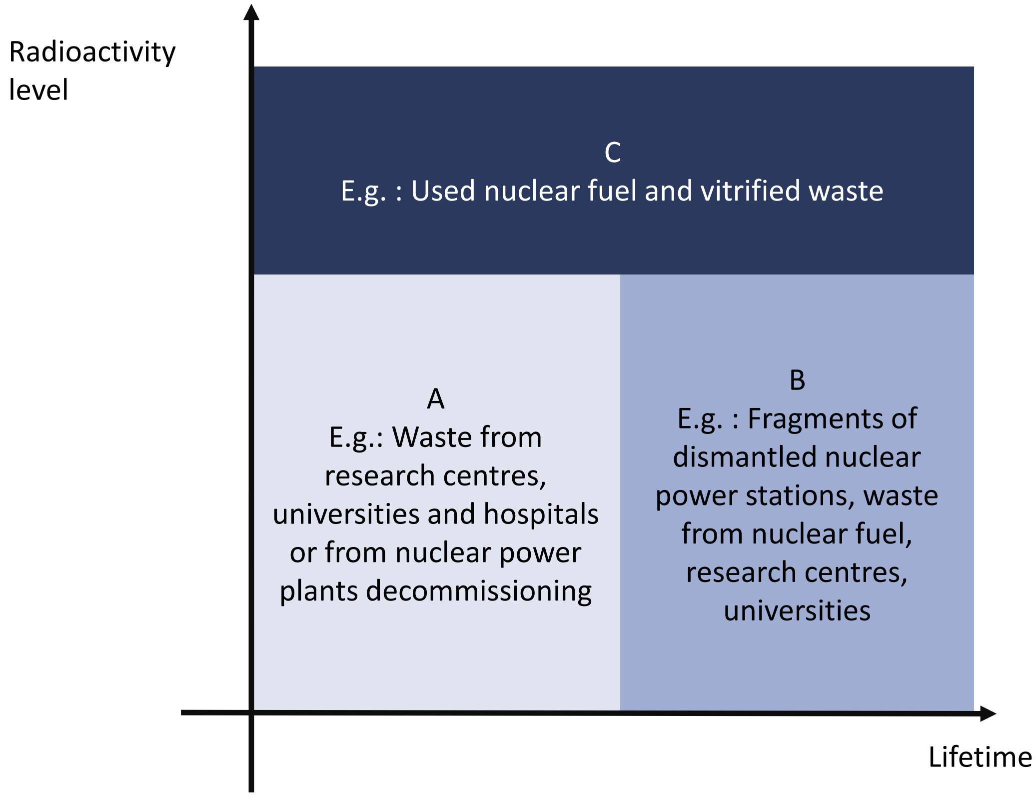
- Direct damage caused by the accident
- Expenditures related to:
  - Actions to seal off the reactor and mitigate the consequences in the exclusion zone
  - Resettlement of people and related construction of new housing and infrastructure
  - Social protection and health care
  - Research on environment, health and production of clean food
  - Radiation monitoring of the environment and decontamination
  - Disposal of radioactive waste
- Indirect losses related to the opportunity cost of removing agricultural land and forests from use and the closure of agricultural and industrial facilities

Chernobyl (1986) : Up to EUR 435 billion
Fukushima (2011) : Already estimated at EUR 160 billion

Sources :

- International Atomic Energy Agency (2006): Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts.
- Belarus Foreign Ministry (2009): Chernobyl Disaster of April 2009.
- Japan Times (2016): Cost of Fukushima disaster expected to soar to ¥20 trillion

IV. The drawbacks of the existing nuclear plants
The waste dimension



Source : Climact, based on Nuclear forum

IV. The drawbacks of the existing nuclear plants
The waste dimension

Finland launched the construction of the first permanent storage facility in a 420m-deep granite layer in Onkalo
Estimated cost **of EUR 3.5 billion.**

For **Belgium**, B&C-type of nuclear waste (long-lifetime or high-activity) are still waiting for an underground storage solution, probably in 200m-deep clay layers near Boom or Ypres.

The cost for this deep-burying solution is estimated up to **EUR 3.2 billion** and additional **EUR 360 million for R&D**.

France is studying a similar project in Bure.
Estimated cost of **EUR 20-25 billion.**

Germany is looking for a permanent storage facility and is facing significant public opposition for its project in Gorleben. **Sunk R&D costs are about EUR 1.6 billion.** At least **EUR 2 billion more is needed for research**.

Source : L'Écho, Le coût de l'enfouissement des déchets nucléaires risque de s'alourdir, 23/11/2016

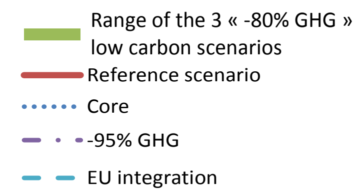
IV. The drawbacks of the existing nuclear plants
The risk of lock-in

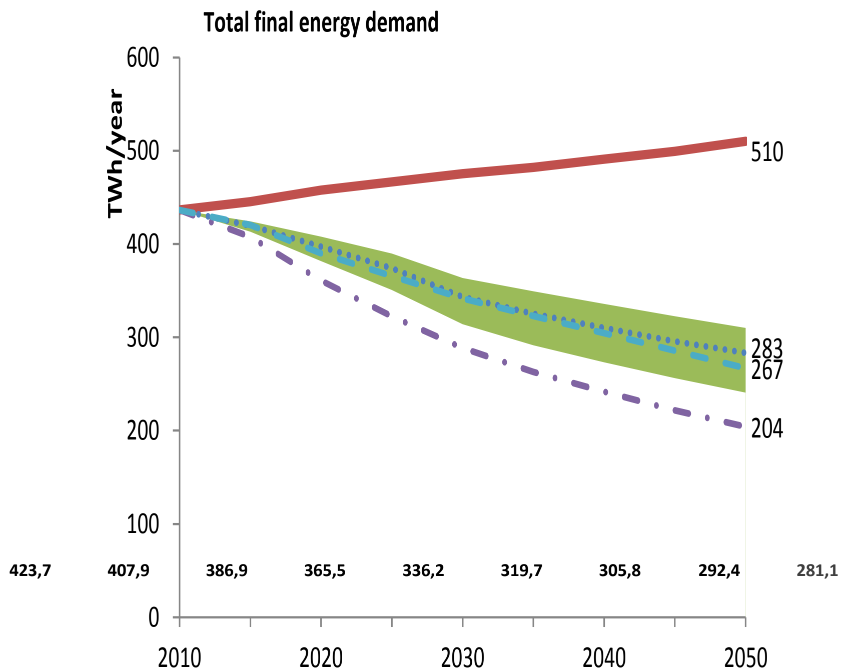
The lock-in concept refers to a situation where the existing technologies lead to inertia and tend to block the system from moving towards another situation, even if the latest is more desirable.

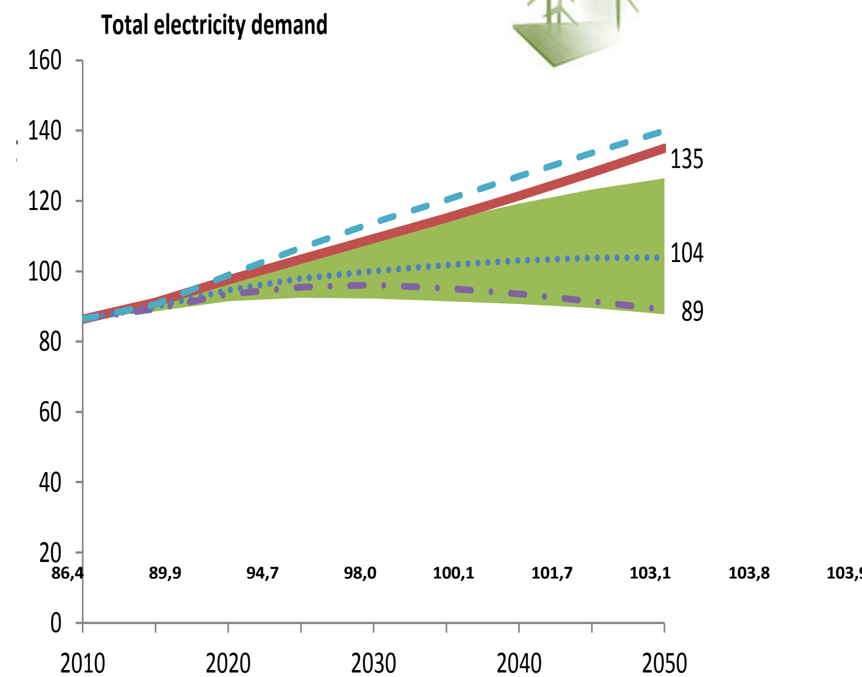
There are various potential lock-in dimensions regarding nuclear power plants in the Belgian context :

- **Energy transition** : Maintaining an overcapacity of rigid baseload power generation leads to low investments into the key elements of the energy transition (medium- and peak-load power plants, flexibility solutions and grid development).
- **Subsidies** : Hinkley Point nuclear power plant will lock the UK government in for 35 years of subsidies (vs 10 to 19 years for solar and offshore wind in Belgium, respectively
- **Waste** : Future generations/civilisations are locked in regarding nuclear waste management

#6 Lowering energy demand is key, stabilizing electricity demand

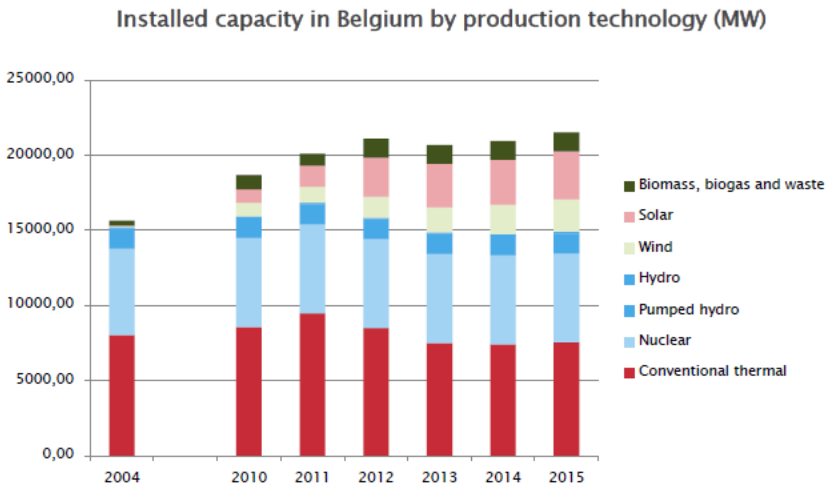


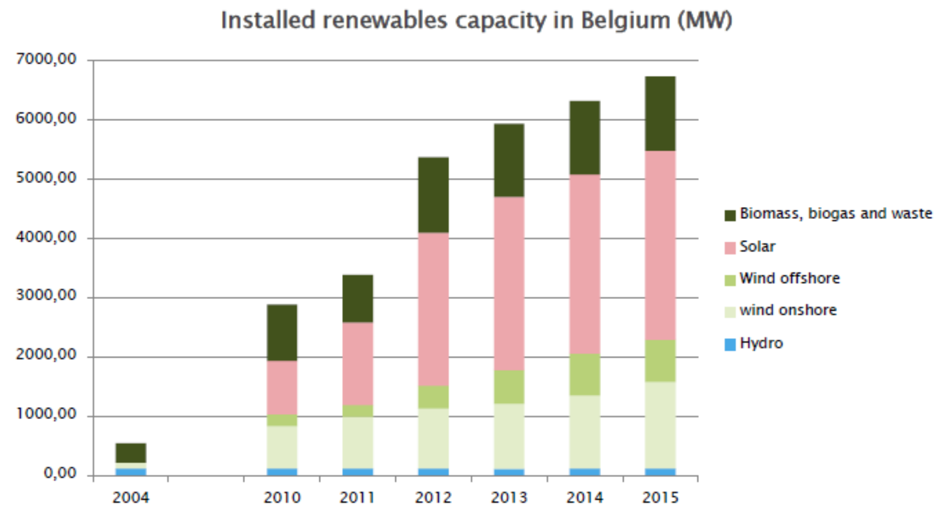




Source: Belgium OPEERA model (Climact, VITO)

Capacity slightly increased lastly up to 24 523 MW
The renewables capacity increased up to 6503 MW, the increase is mainly due to the wind (especially the offshore capacity)





Source: Annual report FEBEG 2015

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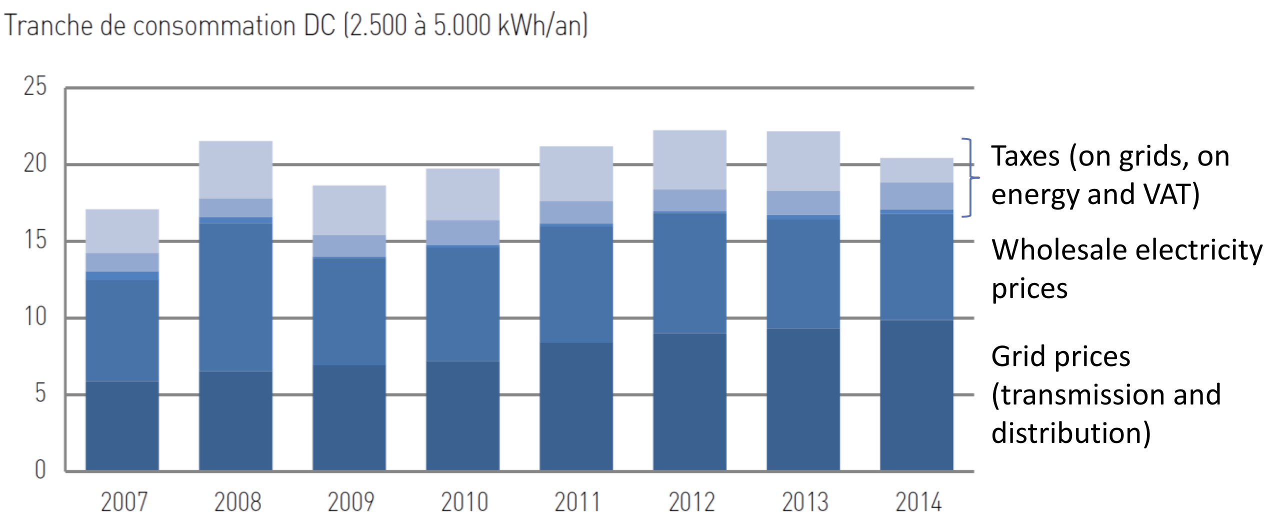
RES and Offshore wind in Belgium

- The European Union has set the goal to increase the share of EU energy consumption produced from Renewable Energy Sources (RES) to 20% by 2020
- This leads to Belgian obligations of 13% RES supply, which in turn is computed to lead to 20.9% RES in Belgian’s final consumption of Electricity
- RES production in 2015 was still only 17% of final electricity consumption
- Achieving the objective will rest on several types of RES of which offshore wind is an important one, meant to represent about 1/3 of the renewable electricity supply in 2020 (the 2,2 GW planned for 2020 would produce 8,5 TWh compared to the objective 23 TWh of RES-based electricity in the NREAP)

SOURCE : NREAP

The share of grid prices has increased by ~70% in the past 7 years

Evolution of electricity prices for the consumers, eurocents/kwh

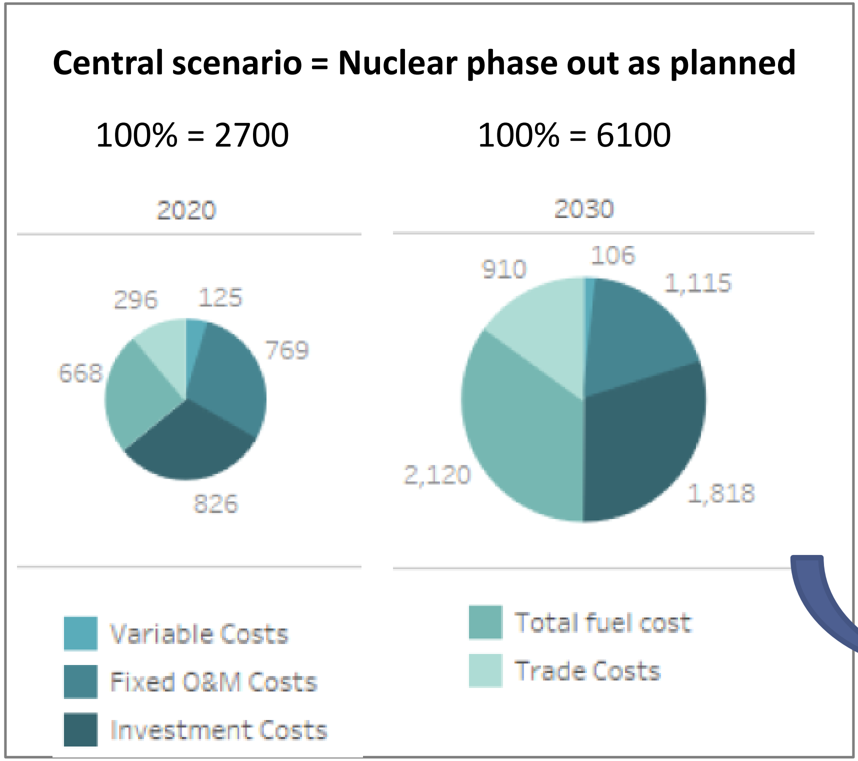


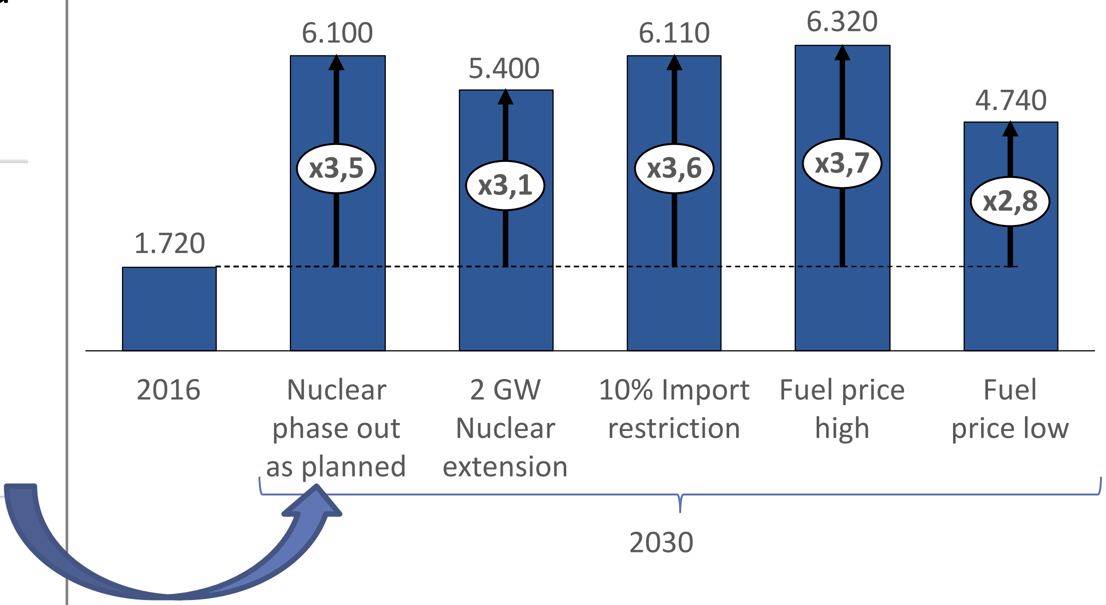
- An average residential consumer paid 20,43 eurocents/kwh for electricity in 2014
- Almost half (48%) is made of grid prices (including support to solar PV which is channeled through ELIA)
- Average wholesale electricity prices were about 1/3 of the total price
- VAT has gone to 6% in 2014 (and back to 21% in 2016)

Source: SPF Economie et Energie

As further background, the EnergyVille Times model runs for Febeliec show –

Total annual costs electricity production + import, Million EUR





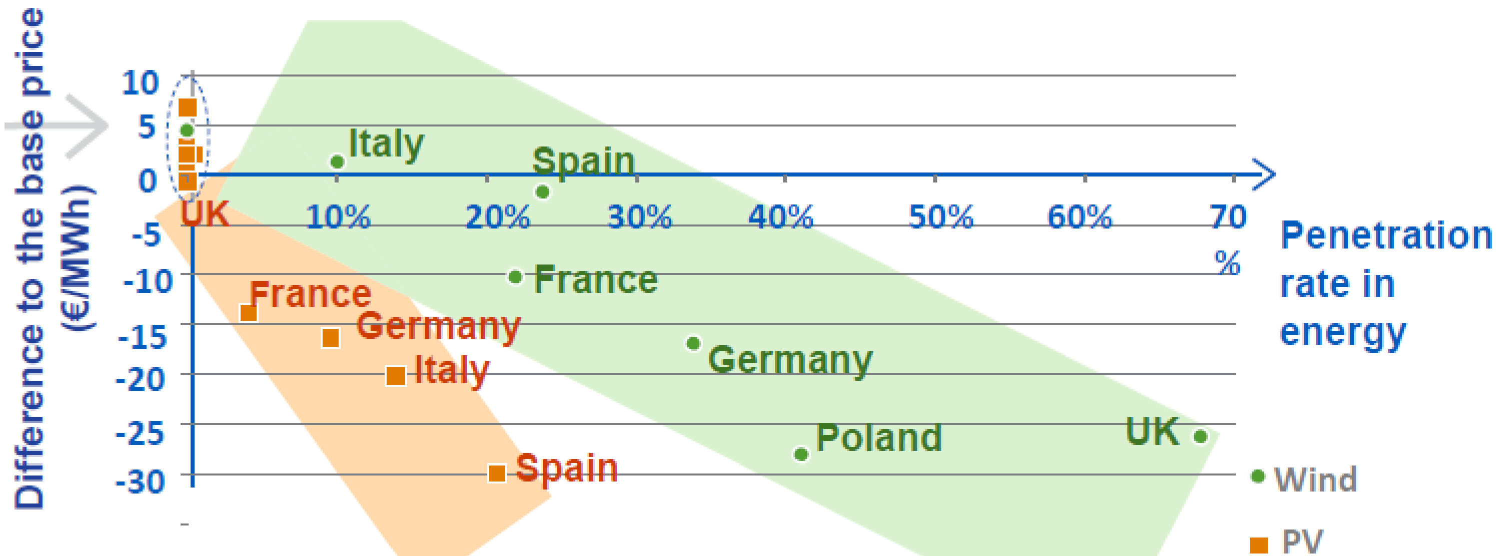
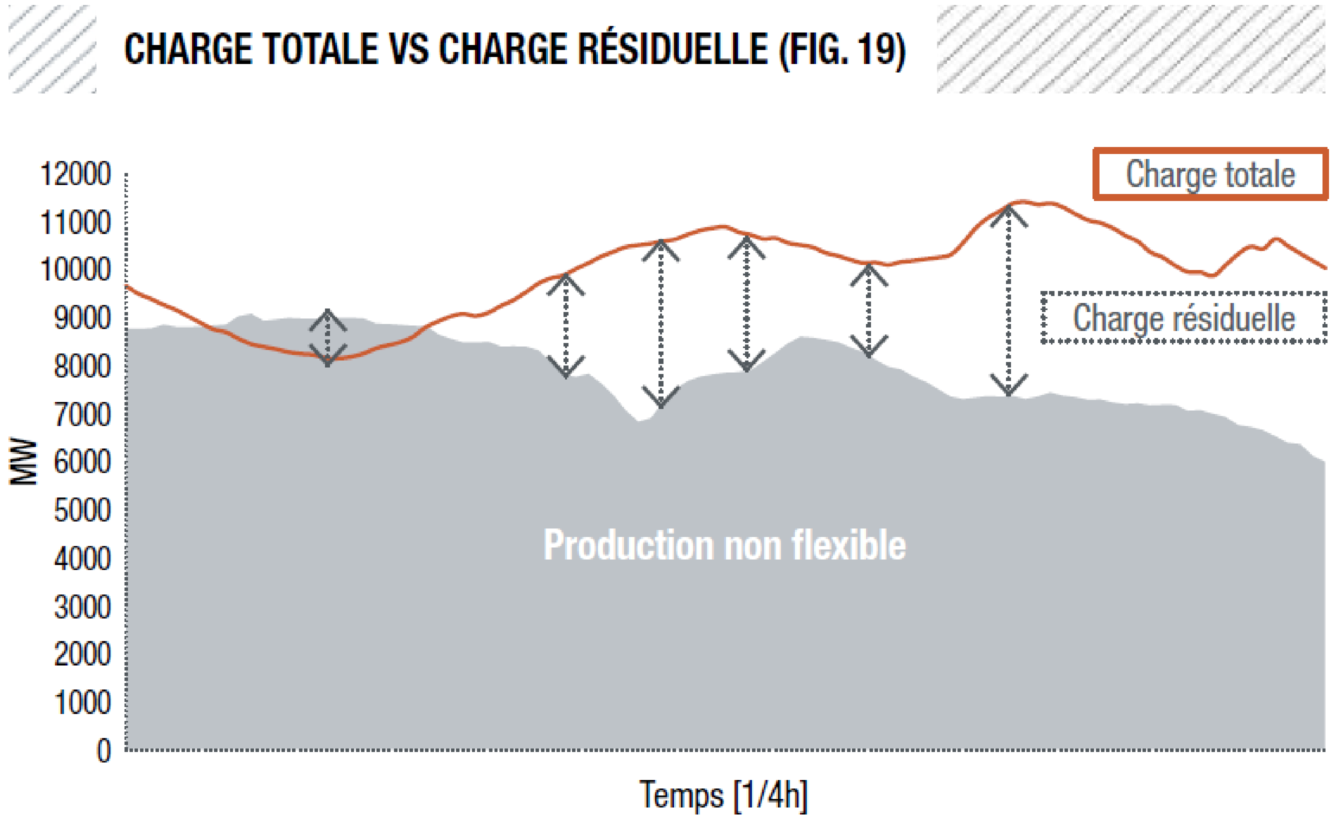

Difference to the base price (€/MWh)
10
5
0
-5
-10
-15
-20
-25
-30
UK
Italy
Spain
10%
20%
30%
40%
50%
60%
70 %
Penetration rate in energy
France
Germany
Italy
Spain
France
Germany
Poland
UK
Wind
PV

Illustration des besoins en flexibilité



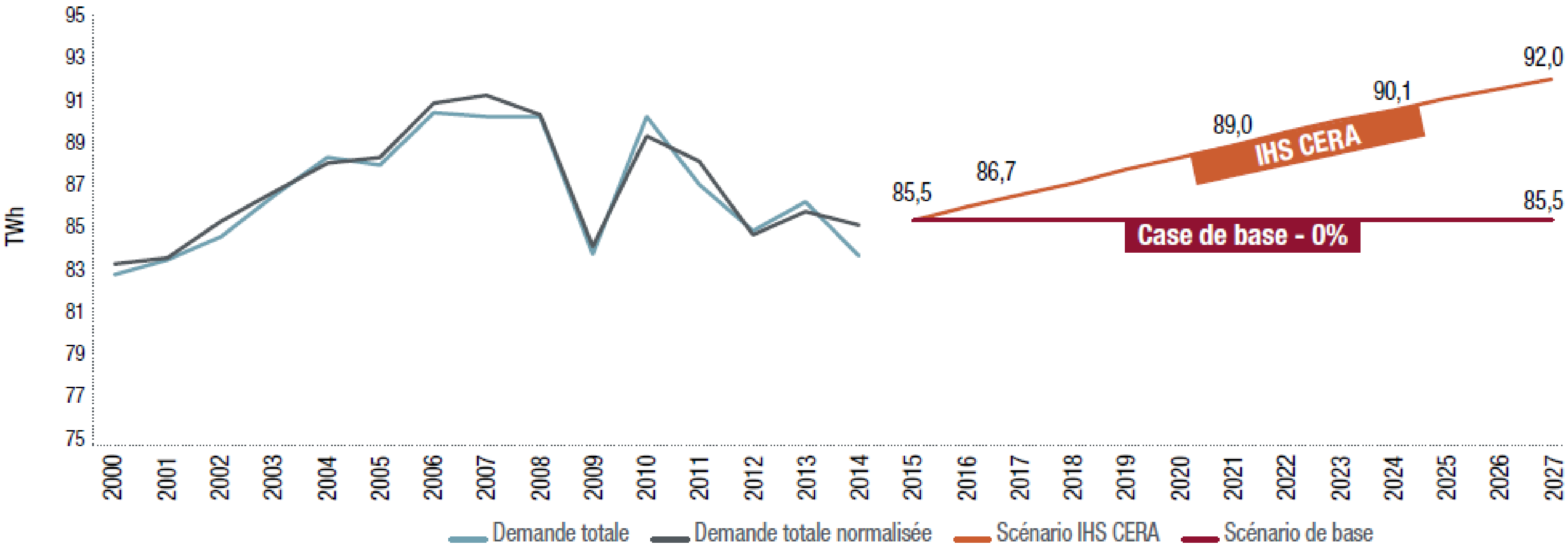
Input assumptions

RÉSUMÉ DES HYPOTHÈSES (FIG. 43)

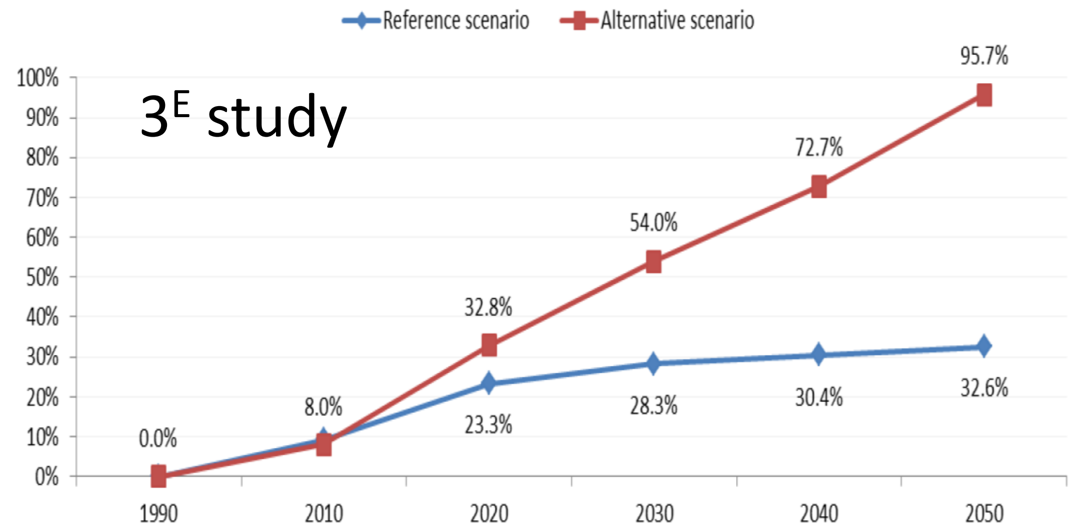
		CWE	Reste de l'UE	Sensibilité
Consommation	0% de croissance			IHS CERA (0,6%/an)
Renouvelable	Meilleure estimation	Rapports nationaux et contacts bilatéraux + SO&AF	Sur base du SO&AF (System Outlook and Adequacy Forecast)	Haute
Capacité thermique	Nucléaire selon la loi			« Coal Phase Out » et « Low Capacity » pour les pays voisins
Réponse du marché	Etude Pöyry			Sans réponse de marché en BE
Stockage	Pompage - Turbinage actuel			Avec du stockage additionnel
Interconnexions et capacité d'import	Selon le plan de développement fédéral			+2GW import BE & BE isolée
Réserves de balancing	Estimation dans cette étude			
Prix des combustibles	Forwards pour 2017 & « Current Policies » (IEA)			Scénario « 450 » (IEA)
Coûts fixes et variables des centrales	Etude ETRI de la Commission Européenne			

Hypothèses de consommation d'électricité

CONSOMMATION ÉLECTRIQUE NORMALISÉE EN BELGIQUE : HISTORIQUE ET SCÉNARIOS (FIG.33)



3^E study and PwC
RES deployment assumptions



PwC study

- Base Year : 14,2 TWh de RES (**15,7%** dont 55% intermittentes)
- 2030: 41,4 TWh (**44,3%** dont 76% intermittentes)
- 2050: 77,6 TWh (**67,4%** dont 80% intermittentes)

Source: 3^E study for Greenpeace et al. : Crucial energy choices in Belgium - an investigation of the options; PwC study for the Nuclear Forum: Réussir la transition énergétique