UP Montélimar 5 Mai 2022

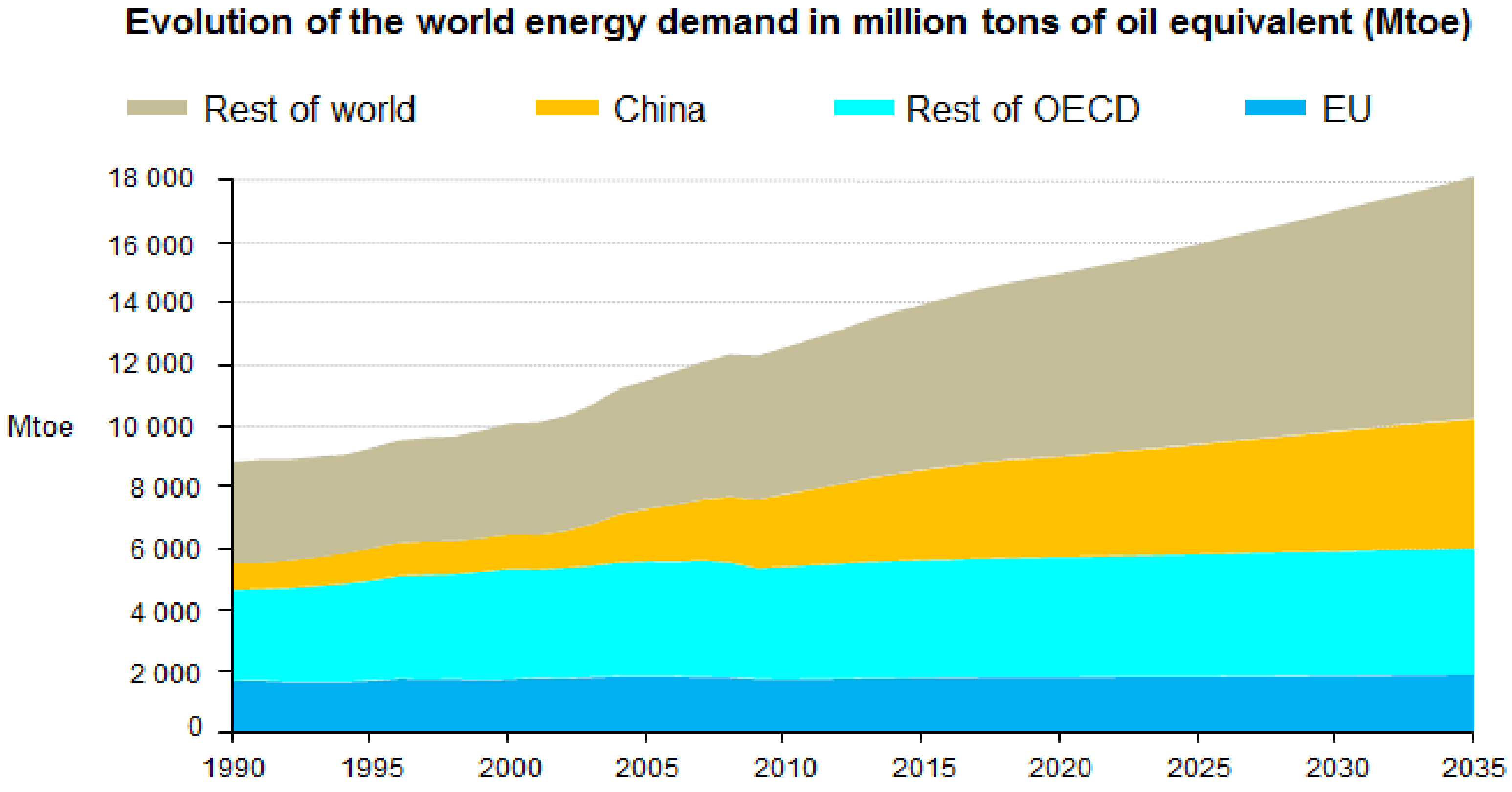
Politique Européenne de l'Energie… oui… mais…

Marc Deffrennes

Topics

- Brief history EU energy policy
- EU Green Deal… Taxonomy… REPowerEU…
- Sustainability ?
- LCOE and beyond: energy system costs…
- Market Reform ? How ?
- Discussion… Myths and Realities…

Background for Energy Policy…
BAU - Rising Global Energy Demand



Source: International Energy Agency

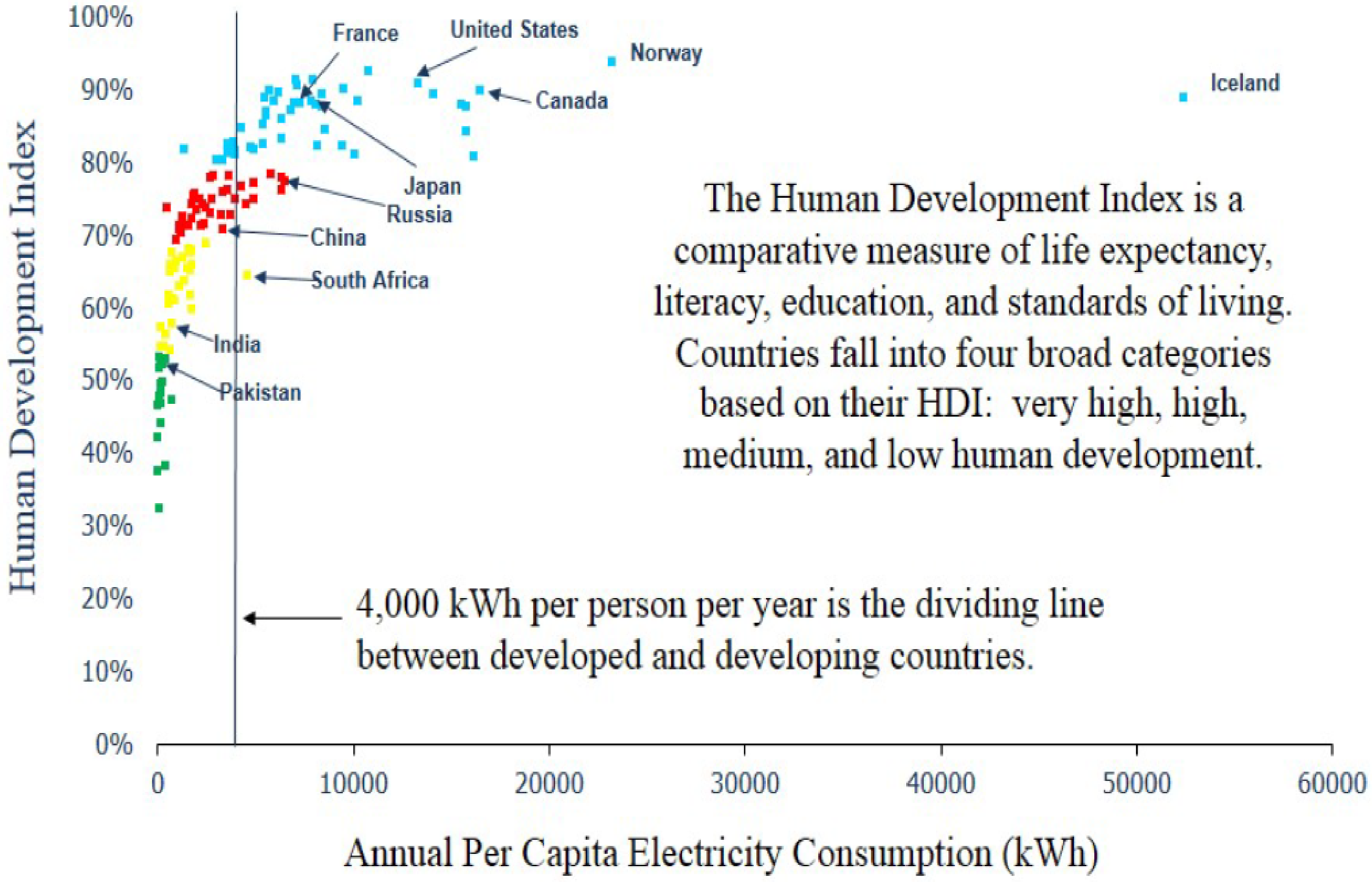
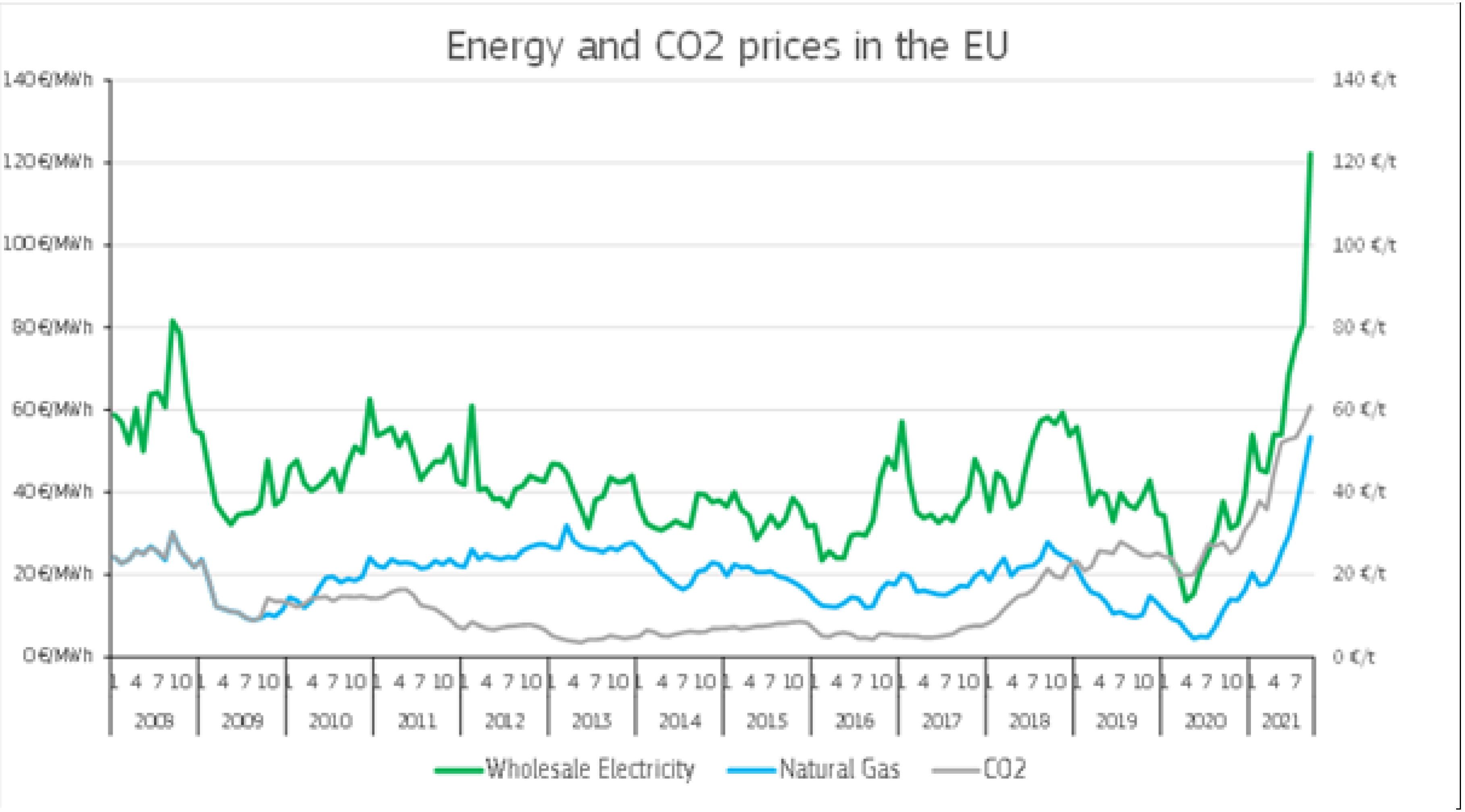


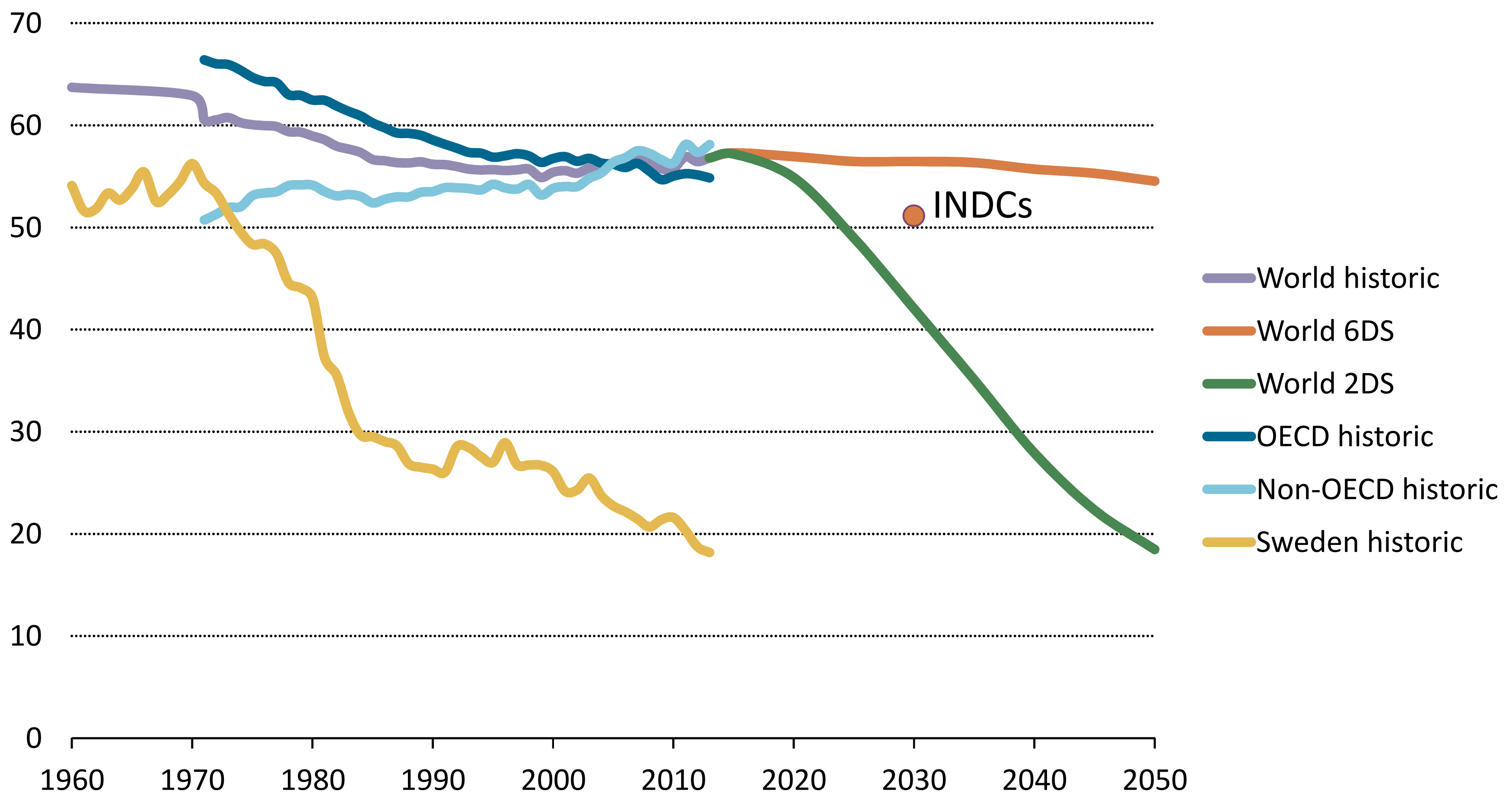
Fig. 1.1. Human Development Index versus Annual Per Capita Electricity Consumption

Current situation of the power market



EC communication on “Tackling rising energy prices: a toolbox for action and support” - COM(2021) 660 final

2°C requires a drop in the carbon intensity of primary energy (tCO2/GJ)



...which has been stable on a global level over the last 50 years.

Source: Energy Technology Perspectives, 2016

EU Energy Policy: Brief History

- 1951 **CECA**; 1957 **Euratom Treaty: a promotional energy Trea**ty as a « project » to implement the vision of the European Communities… a model…
- 1987 The Single Act: assembling all three Treaties and Communities under one Framework focused on open liberalised market policies… towards the **electricity market**…
- **Kyoto** Protocol Signed1997/EiF2005 – **EU target GHG minus 8% vs 1990 for 2012**
- 2005 EU Emission Trading Scheme **ETS**… towards a **carbon market**…
- 2007 **Lisbon Treaty: energy policy becomes a shared EU/MS competence but each MS keeps the right to choose its energy mix (Art 194 TFEU)**
- 2007: Launch of SET Plan and SNETP; Creation of ENEF – among a number of Energy Fora…
- **2010 Climate and Energy Package:**
  EU Energy Strategy for a « competitive, sustainable, secure » energy
  3x20 targets: 20% GHG reduction vs 1990, 20% RES, 20% EE – in 2020
  Binding at EU level and translated into national binding targets for all MS

EU Energy Policy: Brief History

- **2011 Energy Roadmap 2050: 80-95% GHG reduction in 2050 vs 1990**
  « NOTED » by Council (Presidency – no full consensus)
  « Adopted » by EP
  7 Scenarios mixing EE, RES, Nuclear, and CCS – reduction of global energy consumption but increased electricity demand – **ENER D analysis made for PINC: nuclear 140 GW in 2050**…
- Preparation/Adoption Budget 2014-2020 – the Fukushima effect on Euratom FP H2020…
- 2014 Start Juncker Commission – « La Commission de la dernière chance »… Financial Crisis GR PO ES reshuffle the priorities…
- **2014 EU Energy Strategy 2030** + EU Energy Security Strategy (recurring gas crisis)
  40% GHG reduction binding EU and MS, 27% RES + 27% EE binding EU not MS: Governance Mechanism
  + 10% Interconnexions helping security of supply of electricity and grid stability…

EU Energy Policy: Brief History

- 2015 « Energy Union » Package
  Security of Supply, Energy Market Integration, Energy Efficiency, Emissions Reduction, Research and Innovation (reinforce SET Plan)
- **End 2015 COP Paris Agreement: Max + 2°C – target + 1.5°C in 2100**
- 2017 Publication Euratom **PINC: 100 GWe nuclear in 2050** (based on MS plans)
- **2018 « A Clean Planet for All »… « CLEAN »**
  New roadmap scenarios 2050:
  Comm Canete(Energy): **RES will be the backbone of the EU electricity mix with nuclear… 80% and 15%.... (this last figure in line with PINC)**
  Therefore 2030: 40% GHG Reduction, 32% RES and 32% EE, 15% Interconnexion
  National Energy and Climate Plans NECPs (EE, RES, GHG, Interconnect, R&I) to be finalised and reviewed by EC for 2020
- **2019 EC Proposal « EU Green Deal »… « GREEN »:** very wide embracing all policies of EU:
  « Carbon Neutrality » for 2050

EU Energy Policy: Brief History

- 2019 von der Leyen Commission – «A more geopolitical EU »
- **2019 « EU Green Deal » (resp: EC VP Frans Timmermans)**
  Carbon Neutrality in 2050 : Council – but Poland / Adoption EP
- 2019 EC Budget Proposal 2021-2027: 1000 Billion Euros
- **Financing mechanisms and tools (EC VP V Dombrovskis)**
  ex: InvestEU (post Juncker Plan), Modernisation and Innovation Fund (post NER300), Structural and Regional Funds, Just Transition Fund, Research Framework Programme, EIB Lending Policy,… **nuclear most of the time excluded**…
- « **Taxonomy <u>Sustainable</u> Financing** «: TEG… Adoption by Council and EP… nuclear left oustide initially (mainly because HLW mgmt « not demonstrated »)… ref to potential role for «energy transition »…

EU Energy Policy: Brief History

- 17 September 2020 State of the Union Speech vdL at the EP :

  2030 Climate Target Plan:
  - EC Communication Stepping up Europe's 2030 Climate Ambition
  - Based on Accompanying Impact Assessment and EU-wide Assessment of the NECPs
  - **Draft European Climate Law with target of at least minus 55% GHG emission by 2030 (vs 1990)**: is realistic and feasible – but requiring investment boost: green recovery post COVID…

30% of the overall Budget to be climate-relevant (noting an estimation of needed investment for 2021-2030: Annually 350 billion more than previous decade – 180 billion)

Announcing numerous Implementation Actions (Directives and Regulations):
By June 2021: EU ETS, Effort Sharing Reg, Land Use Reg, EE Dir, RES Dir, CO_2 cars/vans Reg
Later: Energy Buildings Reg, Ecolabel Dir, legislation to roll out TEN-E TEN-T, Alternative Fuels Infrastructure Dir, Reg on Governance Energy Union and Climate Action…

EU Energy Policy: Brief History

... 2020… 2021…

- **Increased financing means (Covid impact): Budget + Next Generation EU (Recovery Package 750 billion)**
  Proposal by the EC under discussion by Council and EP (on equal footing)
  Total order of 1.8 trillion…
  Nuclear still excluded from a number of financing tools… ia Green Bonds...
- **Taxonomy** : Implementation by EC through Delegated Acts helped by a Sustainable Finance Platform (Commitology) + Dedicated review of nuclear sustainability by the JRC and other environmental experts (Art 31 and DG SANTE – radiation protection perspective…)
- EU Energy System Integration Strategy + **Hydrogen Strategy for a Climate neutral Europe (creation of the European Clean Hydrogen Alliance)**

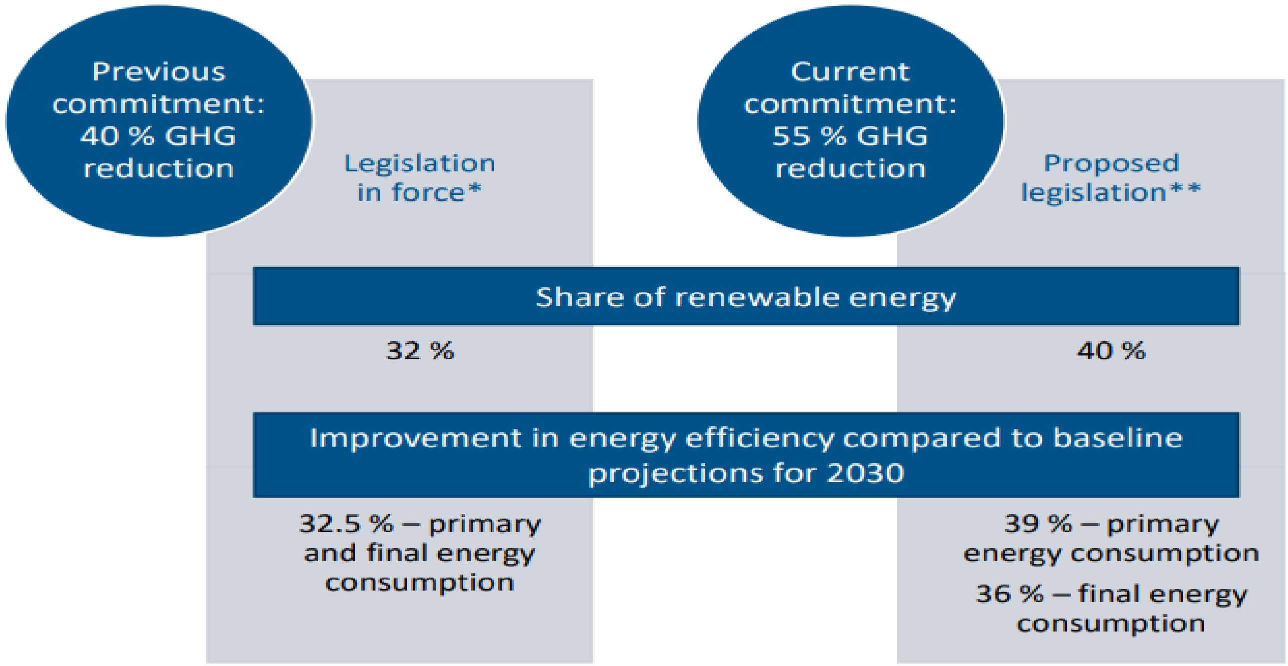
EU Energy Policy: Brief History

Where are we today ???

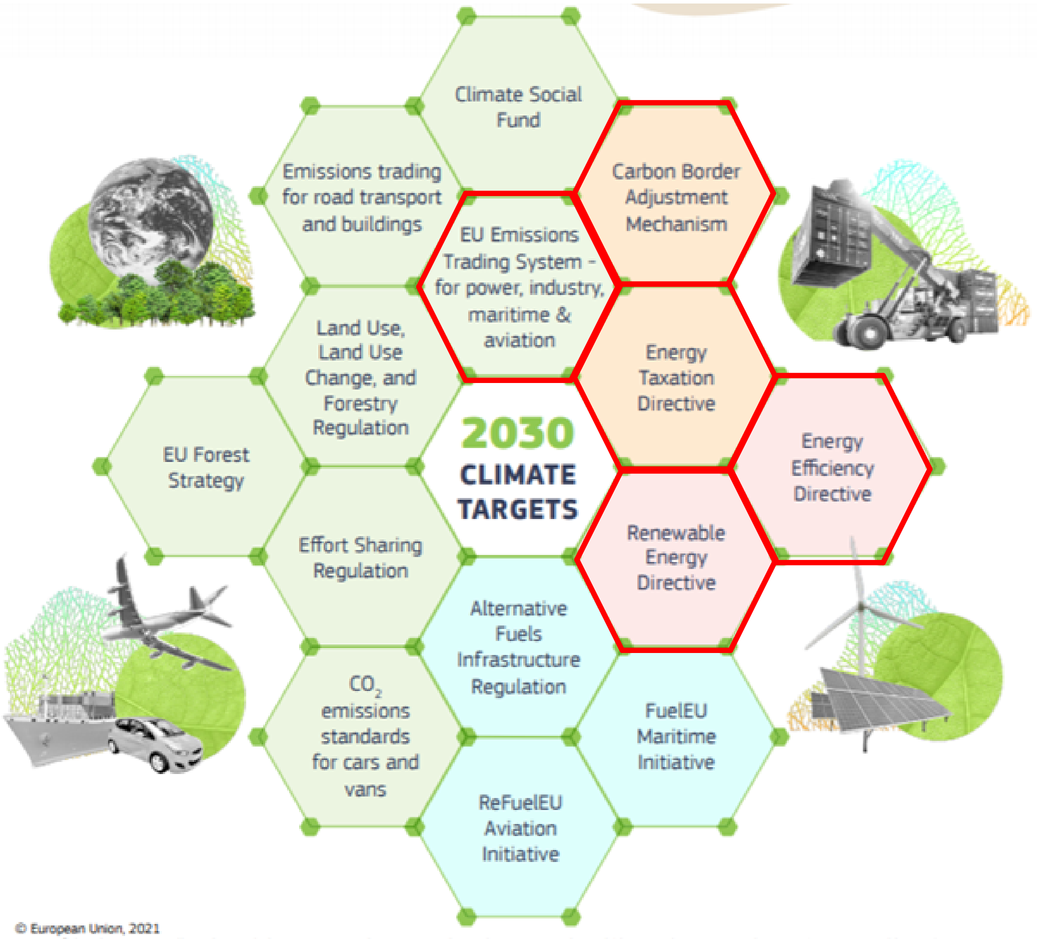
- EU Green Deal ? **FIT FOR 55 Package**…
- **Taxonomy** for Sustainable Financing… 1st DA approved end 2021 and Complementary DA for nuclear and gas – for the transition – to be approved ???
- Gas crisis – supply and prices - **REPowerEU**
- **Hydrogen** ???

EU Green Deal

Figure 2 – Updates to climate targets



Fit for 55 package



- **Renewable Energy Directive review**
  - Validity of guarantee of origin of renewables energy
  - Renewable/Clean hydrogen production forecast

- **Energy Efficiency Directive review**
  - Following the issue of the Primary Energy Factor (PEF) for nuclear (more details can be found in FORATOM’s reaction to the “Clean Energy for All Europeans” package – April 2017)

- **EU-ETS**
  - Any measure that will lead to increasing the carbon price is welcome
  - Stability of the price is also needed

- **Revision of the Energy Taxation Directive**
  - Guarantee affordable access to low-carbon energy for the competitiveness of the European industry and for all European citizens

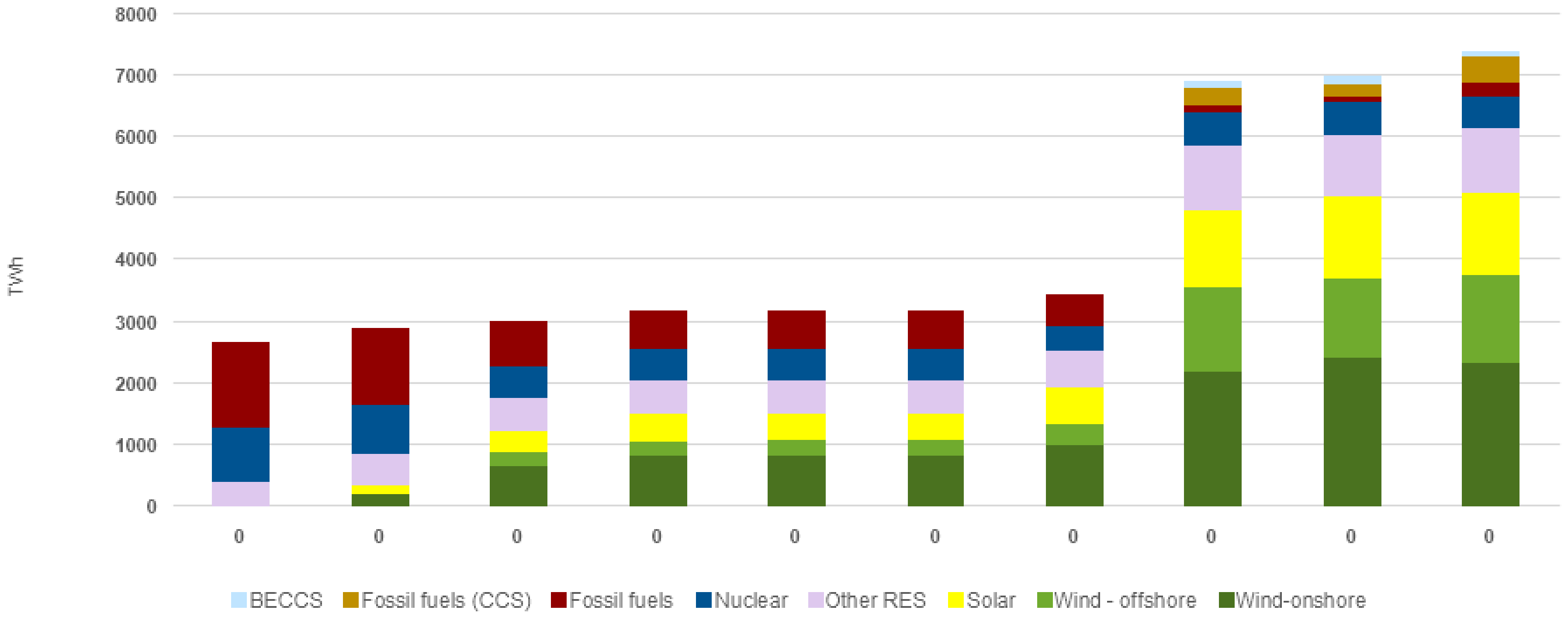
- **Carbon Border Adjustment Mechanism**
  - Potential opportunity for the non-EU FORATOM members

REPowerEU

1. Urgent Actions on prices
   - Keep retail energy prices in check
   - Guidance for temporary tax measures on windfall profits
   - State Aid measures
   - Market actions to improve elec market design
2. Refilling gas storage for next winter
   - Legislation on mininum gas storage
   - Coordination gas refilling operation
   - Investigation into behavior by operators (Gazprom)
3. RepowerEU to cut dependance on Russian gas
   - More renewables (solar, windpower, reduce time for permitting)
   - More heat pumps and energy savings
   - Diversify gas supplies
   - Decarbonise industry by electrificaton and renewable hydrogen for processes
   - Doubling biomethane
   - Create an Hydrogen Accelerator

NO MENTION OF… NUCLEAR !!! Business as usual for nuclear at EU level !!!

Gross electricity generation in the EU



	2030				2050			
Scenario	**REF**	**REG**	**MIX**	**MIX-CP**	**REF**	**REG**	**MIX**	**MIX-CP**
Gross electricity generation by nuclear (TWh)	**519**	**512**	**515**	**513**	**404**	**532**	**545**	**511**
Share of nuclear electricity production	**17.3%**	**16.2%**	**16.3%**	**16.3%**	**11.8%**	**7.7%**	**7.8%**	**6.9%**
Nuclear installed capacity (GW)		**93.9**			**55**	**≈ 50**	**≈ 60**	**≈ 70**
Capacity factor (%)	**44**	**40**	**41**	**41**	**40**	**37**	**31**	**23**

Source: Impact Assessment of the revised Renewable Energy Directive - SWD(2021) 621 final

EU Green Deal: myths or realities: Hydrogen ?

- Why Hydrogen now ? Recurring « spike » or real opportunity for a low carbon future ?
- Hydrogen is a noble product, expensive to produce (cheaper methane reforming (CO_2!) vs expensive electrolysis) and not so easy to handle/transport – presently used as feed for industrial chemical processes
- Some visions/ideas on the table for the future:
  - Feed for additional industrial uses: ia steel making, synth fuels…
  - Fuel for transportation: synth fuels, EV fuel cells, « hydrogen » motors (also NH_3)…
  - P2P: Green Hydrogen = Renewable Hydrogen – storing intermittent electricity
  - CCUS: CO_2 + Hydrogen = CH_4
- Public sector support and financing commitments : initiated by DE, followed by FR, strong push at EU level (ia Next Generation EU – post covid Recovery Package) – intense lobbying for subidies…
- Strong coalition between the RESi (going hydrogen to justify high deployment of RESi - by reducing curtailment through selling excess low value electricity, and by providing storage of electricity) and the gas sector (greening gas, ensuring usage of gas infrastructures, providing backup power for RESi)… towards an Hydrogen Market… another Energy Vector Market… !
- Risk and Opportunity for nuclear energy…

Infrastructure for renewable and low-carbon gases

34th Madrid Forum (Gas Sector)

- The Forum invites the Commission to design enabling market rules for the deployment of hydrogen, including by removing barriers for efficient hydrogen infrastructure development (e.g. via repurposing) and ensuring access to liquid markets for hydrogen producers and customers, as expressed in its Hydrogen Strategy. The rules should accommodate the various pathways of renewable and low-carbon gases deployment, such as industrial demand in clusters efficiently linked by hydrogen backbones – including in combination with the scale up of renewable electricity generation – and connected to storage as well as decentralised production for local demand, including blending in the grid to guarantee broader availability of renewable and low-carbon gases for end-users.

- The Forum further invites the Commission to consider the need for a more integrated and flexible energy system and the role of hydrogen infrastructure, including storage and import terminals in this context, when revising the TEN-E Regulation.

- The Forum also invites the Commission and national regulatory authorities to consider how to fairly allocate costs of the hydrogen infrastructure (newly built or repurposed).

- https://ec.europa.eu/info/events/34th-madrid-forum-2020-oct-14-15_en

EU Green Deal: myths or realities: Hydrogen ?

- JJ Delmée PDG ENECO interviewed by Fran Herpelinck Dec 2020
- Les plans énergétiques fédéraux prévoient une sortie du nucléaire, mais aussi la construction de nouvelles centrales au gaz pour compléter l'approvisionnement en énergie solaire et éolienne. Le think tank britannique Ember prévient que d'ici 2030, la Belgique sera l'un des pays d'Europe qui émettra le plus de CO2. Comment Eneco voit-il ces centrales électriques?
- «Les centrales au gaz font en effet partie de la solution, en ce sens qu'elles sont une source d'énergie pour une période transitoire. Pour l'instant, ces centrales fonctionnent toujours au gaz traditionnel. Cependant, elles sont tout à fait prêtes pour un passage total à l'hydrogène. Le surplus d'énergie renouvelable est stocké et réutilisé dans une centrale électrique que vous pouvez facilement allumer ou éteindre selon les besoins. Le passage à l'hydrogène ne sera pas non plus long à venir. Bien sûr, je comprends le scepticisme, mais de telles centrales sont essentielles pour devenir un monde dans lequel nous pouvons générer et stocker une énergie verte abondante, de sorte que nous n'ayons plus à utiliser ces mêmes centrales électriques alimentées au gaz fossile. Le choix entre les centrales à gaz et les centrales nucléaires est (aujourd'hui) facile.

EU Green Deal: myths or realities: Hydrogen ?

- BE PM Alexander De Croo… interviewed 22 Nov RTBF by C Deborsu: « … les centrales au gaz à construire pour sortir du nucléaire vont engendrer une pollution supplémentaire… »

- Answer of PM : « *Oui, mais, toujours suivant Elia, il s'agit d'une nouvelle génération de centrales au gaz qui pourra, à terme, on parle de 10 ans, brûler de l'hydrogène. Le virage sur une économie basée sur l'hydrogène, çà, c'est le futur et la Belgique va être à la pointe de la technologie* »

EU InDepth Energy Review IEA/NEA

- What are IDRs ??? Last EU IDR was in October 2019 – Report released in June 2020
- 2019: minus 23% GHG vs 1990 (but stable since 2014, before covid)
  2017: Electricity: 30% RES (incl hydro), 25% Nuclear, 21% Coal, 20% Nat Gas
  2019: Carbon Intensity of electricity 240gr CO_2/kWh = 35% of CO_2 emissions of primary energy (30% transport, 35% other uses)
- **EU emissions reduction are NOT on trajectory** to mins 80/95% in 2050 and may not reach minus 40% in 2030… « be realistic »…
- **Electricity Adequacy is at risk**: gas will substitute coal and nuclear phase outs – with an increased risk of security of supply

EU InDepth Energy Review IEA/NEA

- **IDR messages to EU:** *« GET PRIORITIES RIGHT… »*

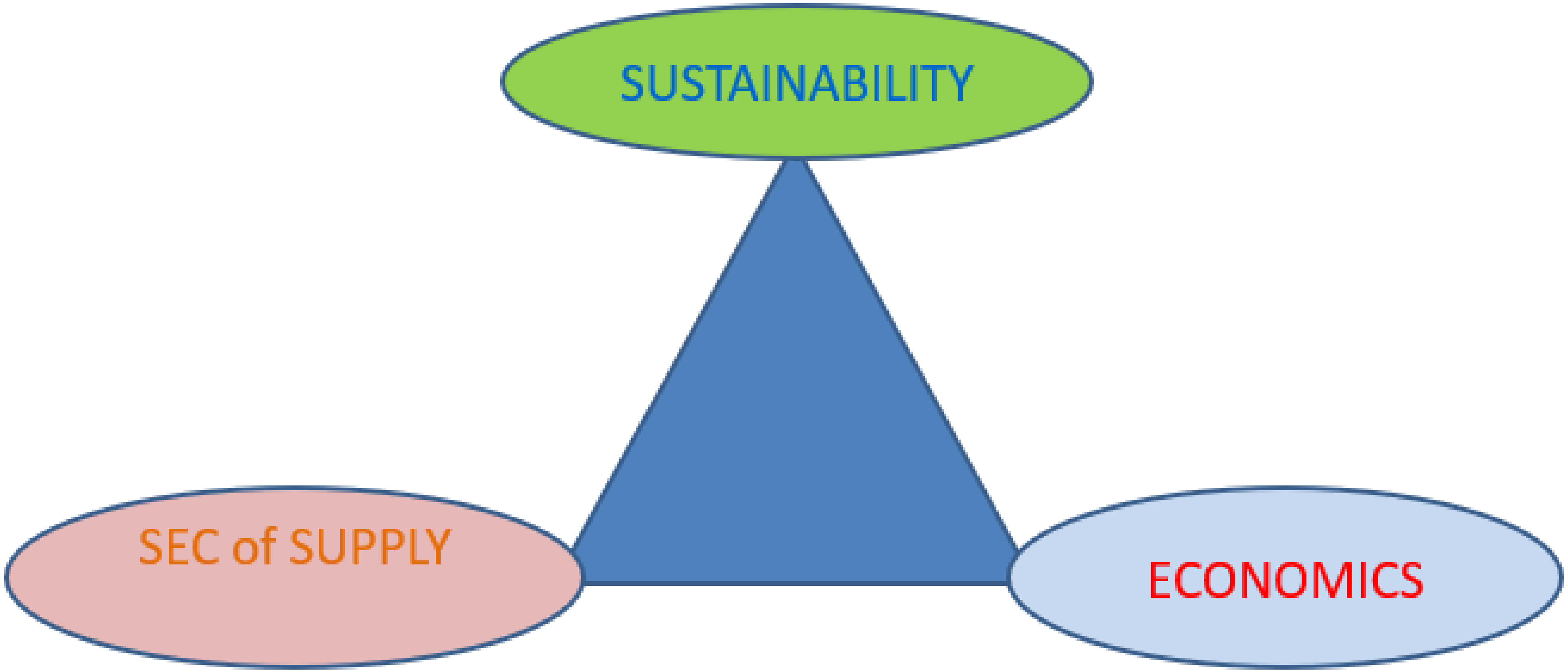
1. Operationalise Energy Efficiency first
2. Improve use of low carbon fuels in buildings, transport and industry
3. Use an Energy System approach and integration
4. Expand clean energy innovation

… **Nuclear Chapter:** main message: ensure consistency between high level policy documents and implementation tools based on a low carbon technology neutral approach… + LTO ! (IEA Report 2019 on Nuclear Energy: LTO in EU cheapest way to produce electricity…)

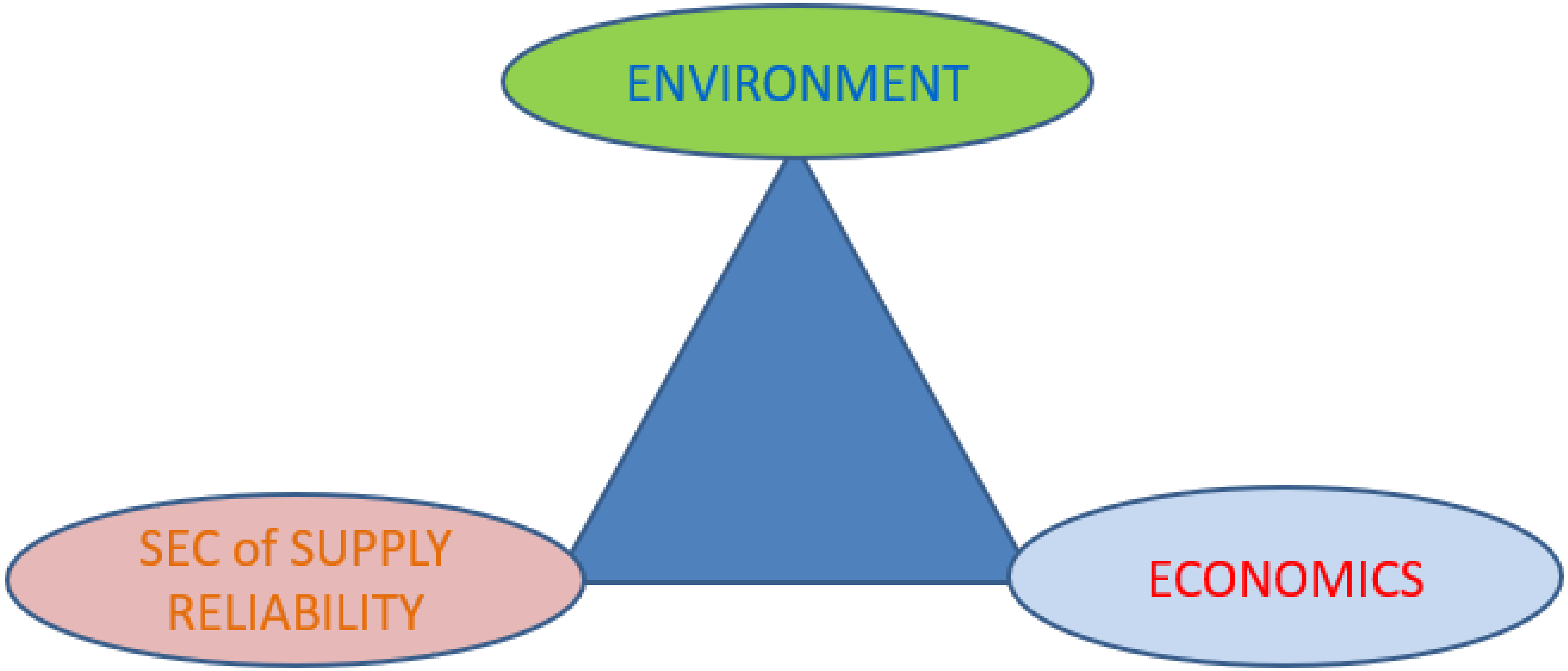
Sustainability… (and weCARE)

- Concept has been at the core of weCARE's creation (2019) and Logo
- Sustainability has recently become the MOST CRITICAL ISSUE for (energy) policy making at EU level – **Taxonomy Sustainable Finance**
- Storyline to be used by weCARE for interactions with EU Institutions… **SUSTAINABLE IS NOT EQUAL TO GREEN**… but much more… by the way green is a color and nothing else… avoid non sense « green electricity », « green hydrogen »,…
- Storyline in line with Brundlandts concept – **Societal Sustainability** – Sustainable for Society – beneficial for society of today and not penalizing for society of tomorrow
- 4 next slides = storyline on sustainability - leading to **C A R E –**
  Clean Affordable Reliable Energy
- From LOGO TO MOTTO:
  weCARE for a Clean Affordable Reliable Energy system for a Sustainable Society

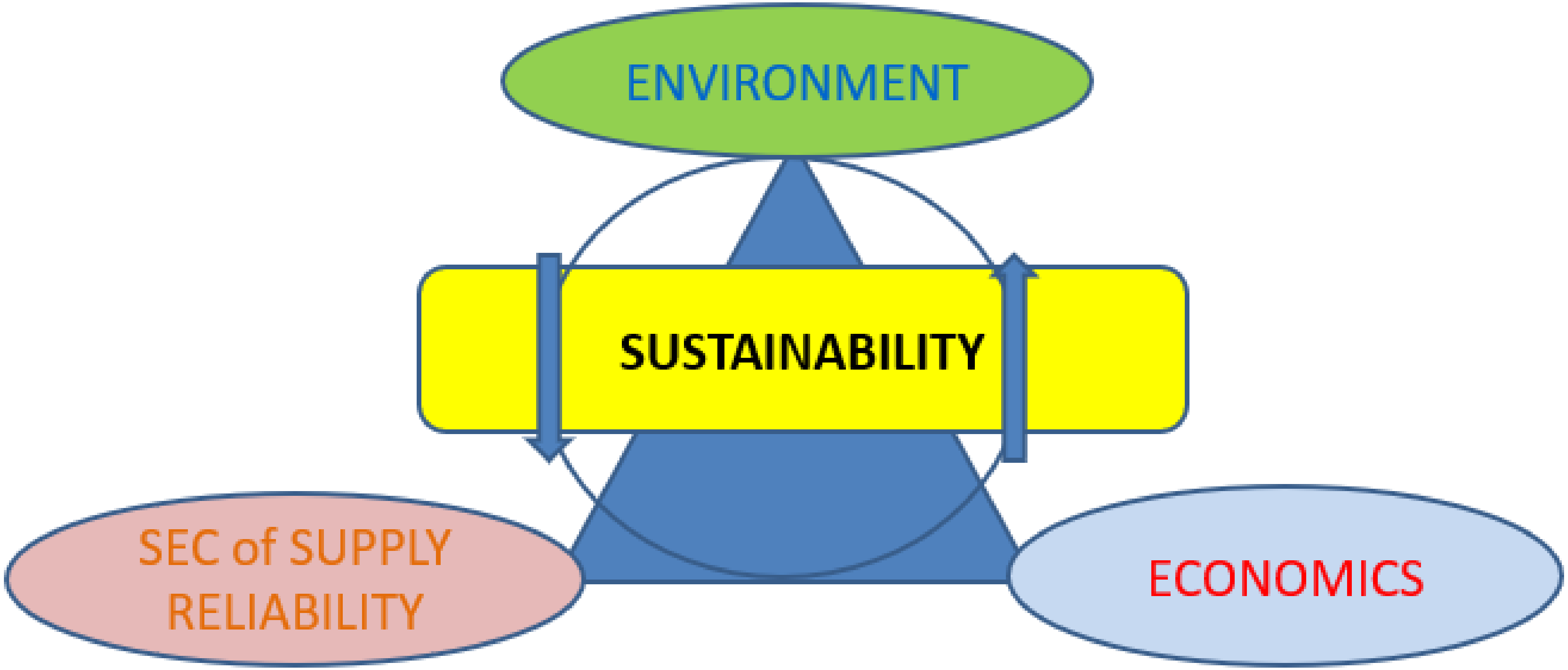
Beyond CO2… Global Challenges
The triangle of Energy Policy



Beyond CO2… Global Challenges
A better Triangle for Energy Policy

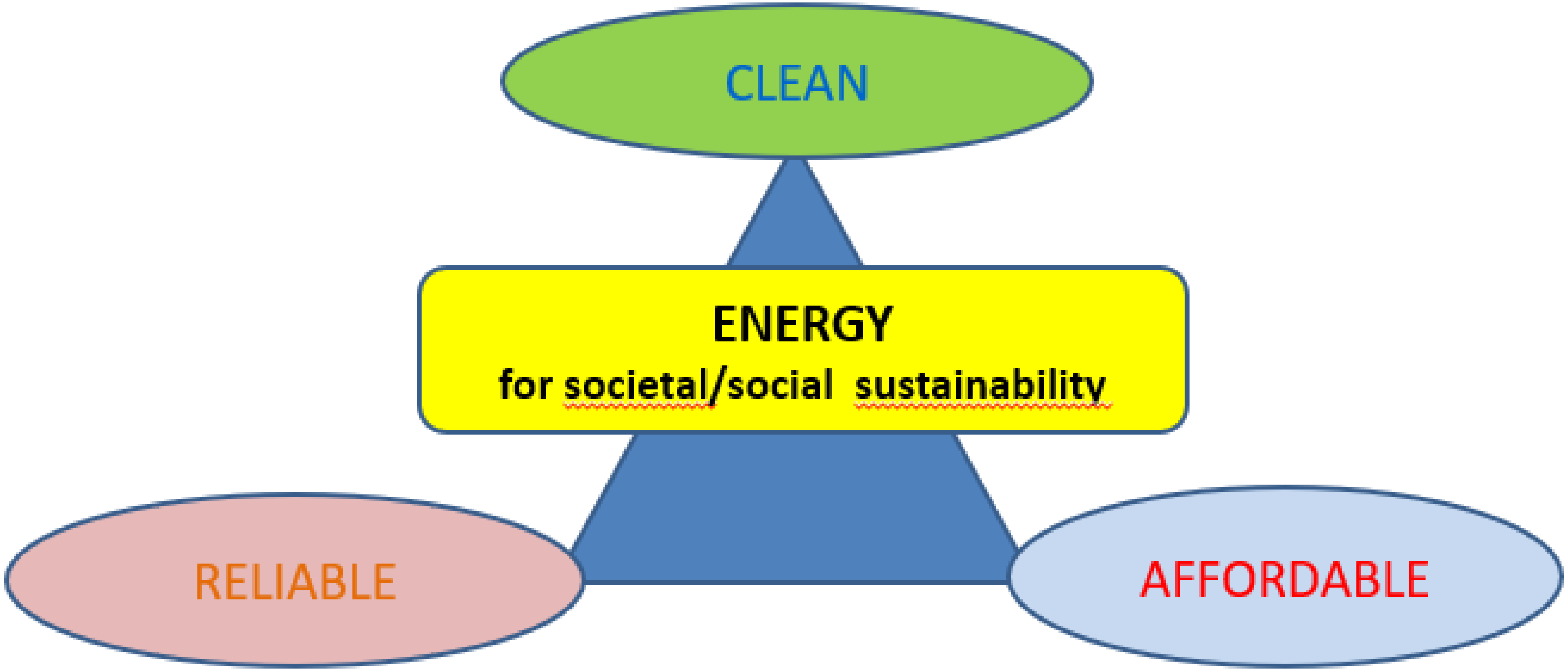


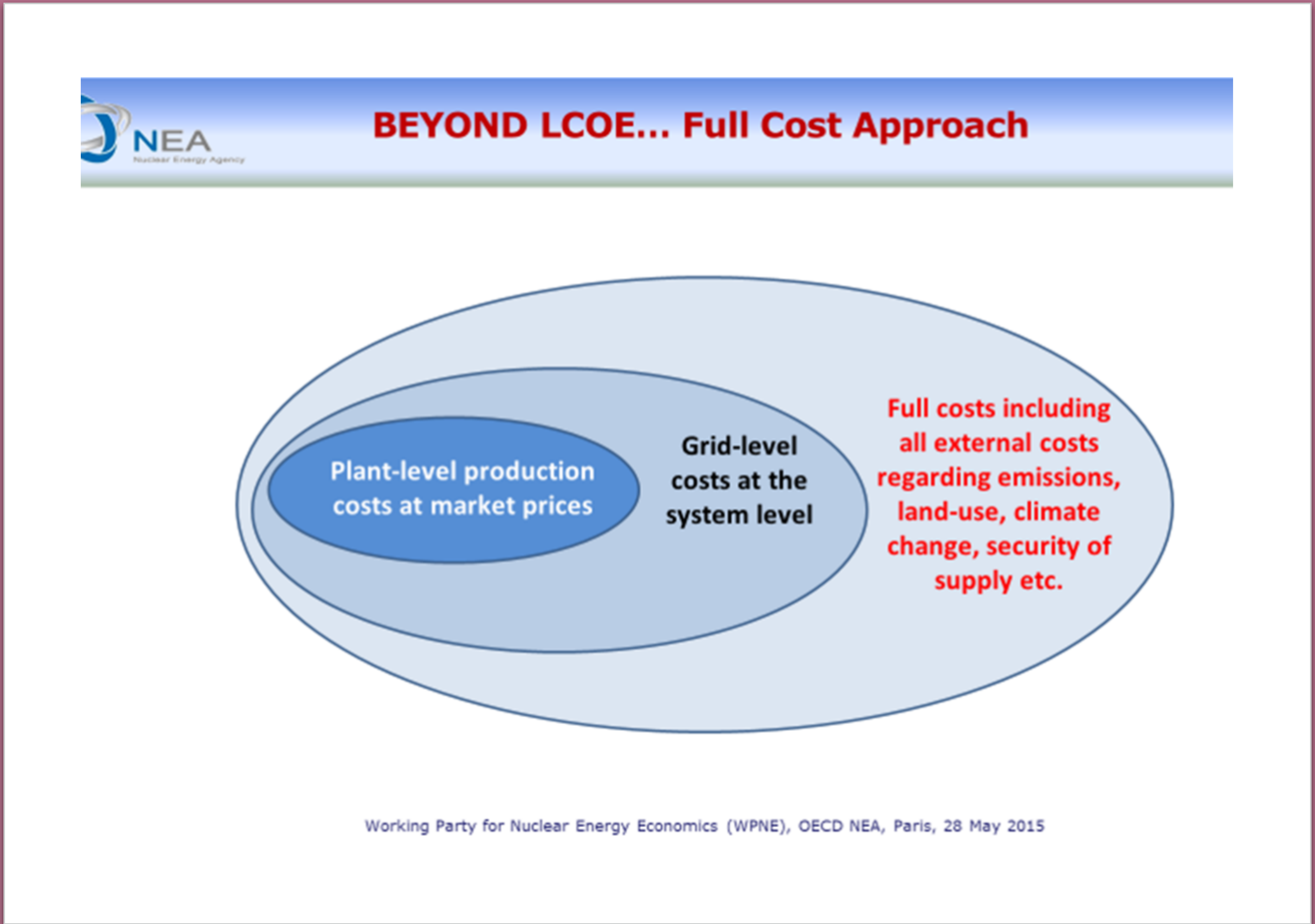
Beyond CO2… Global Challenges
A better Triangle for Energy Policy



Beyond CO2… Global Challenges

A better Triangle for Energy Policy – weCARE https://www.wecareeu.org



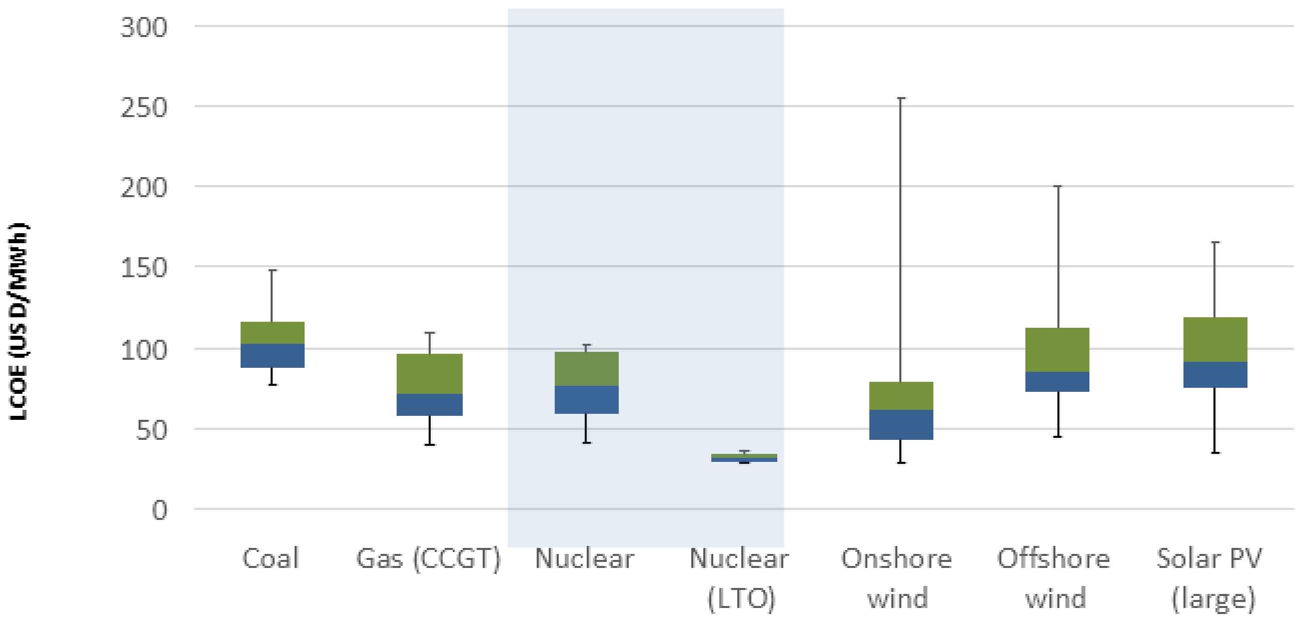


Economics : Beyond LCOE...

Fostering system affordability and investment efficiency

- LTO is the **most competitive low-carbon option** in many regions
- **VRE integration and external cost reductions** associated with dispatchability, air pollution and climate change benefits
- **Additional time** to smooth investment trends and optimize industrial plans and policies

LCOE by technology, 2025



Note: Coal includes lignite plants. Discount rate of 7% and carbon price of USD30/tCO2
Source: IEA/NEA (2020)

A low LCOE does not necessarily mean that existing markets reflect the **system value of LTO**.
Predictable policy frameworks are also key to sustain these cost trends.

ECONOMICS: LTO OCC (NEA 2020)

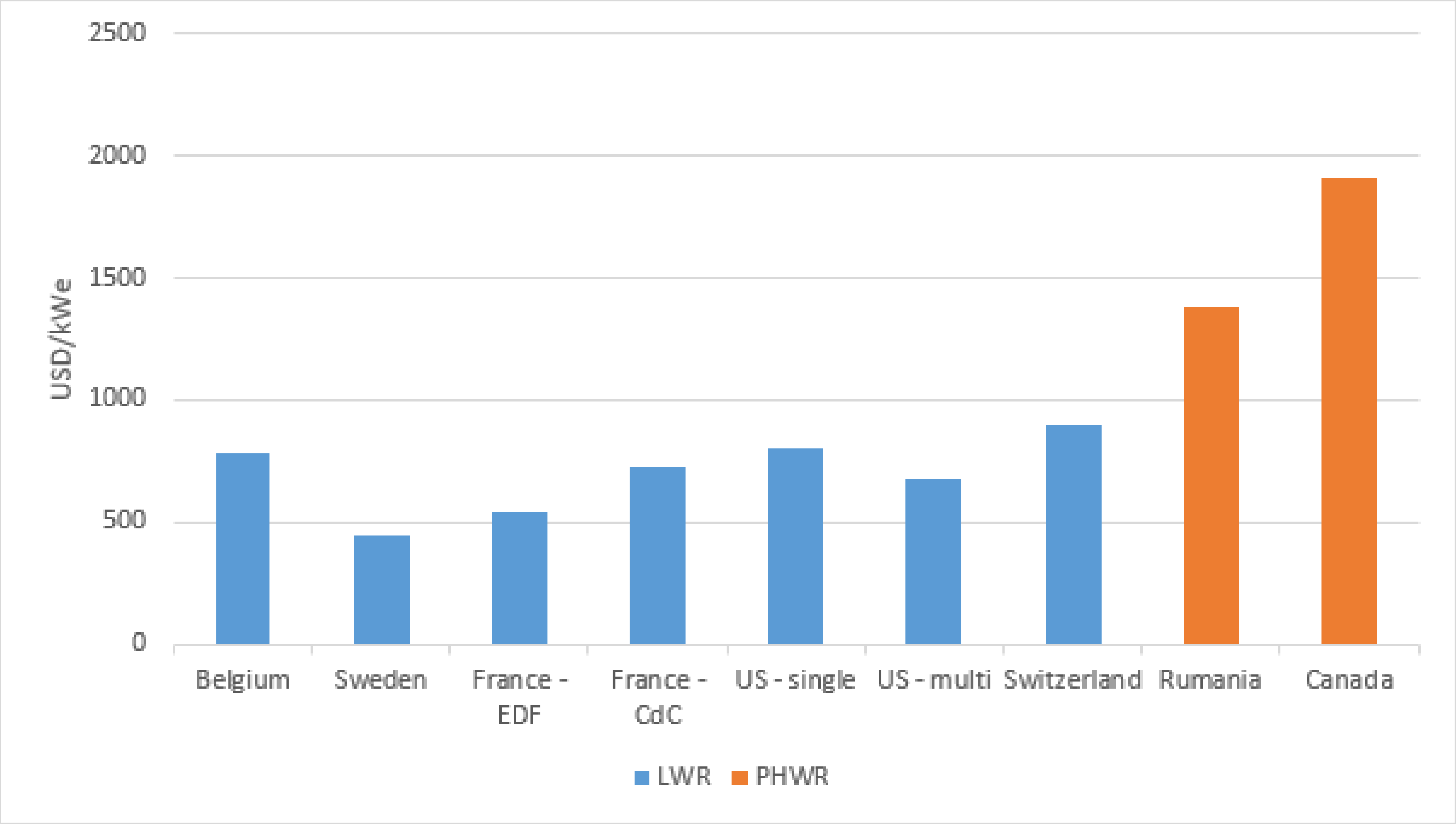
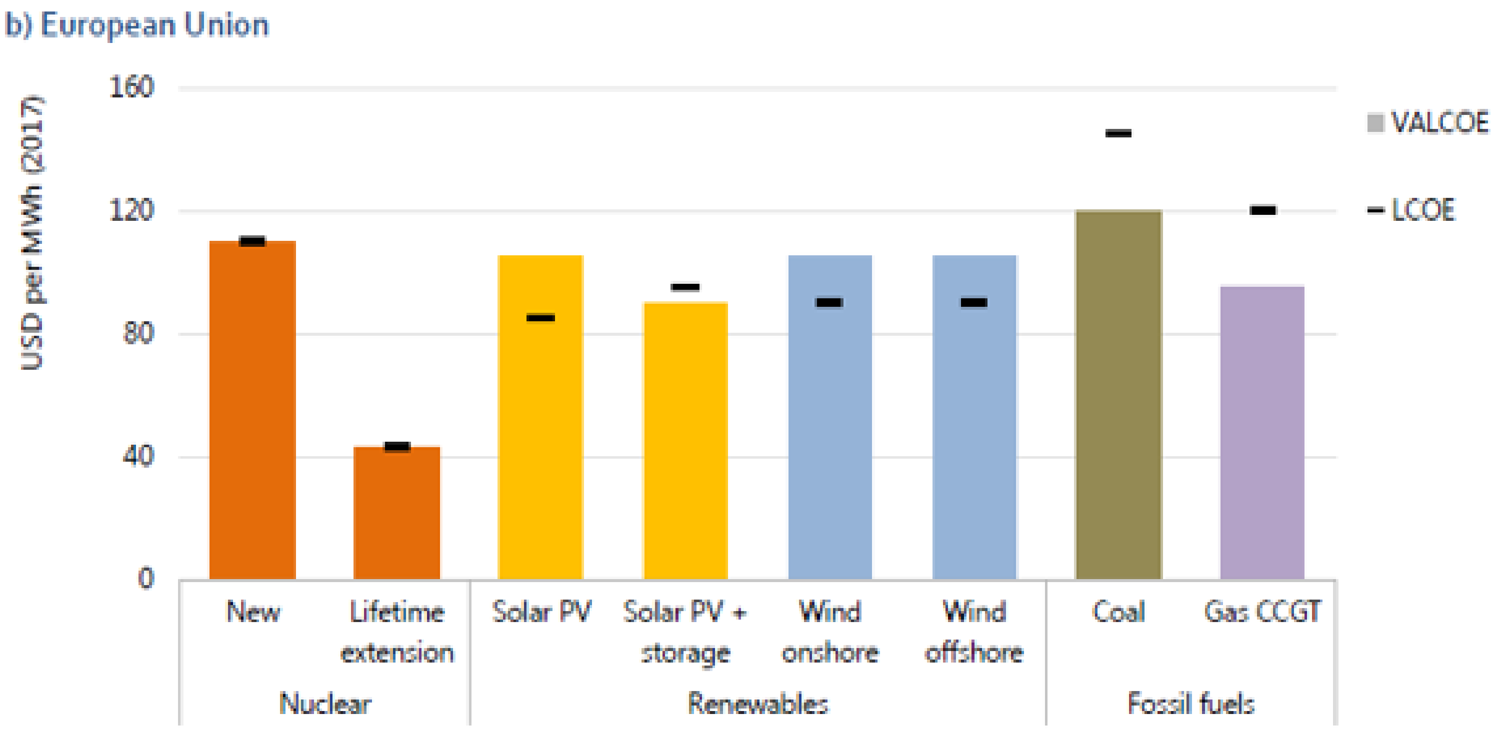


Figure 33 – LTO overnight costs in selected countries and for different technologies

ECONOMICS: LCOE… 2017 (IEA 2019)



Notes: VALCOE = value-adjusted levelised cost of electricity; LCOE = levelised cost of electricity; PV = photovoltaics; coal = coal supercritical; CCGT = combined-cycle gas turbines. Nuclear lifetime extension LCOE is based on 1.1 billion USD investment to extend operations for 20 years. Storage paired with solar PV is scaled to 20% of the solar capacity and 4-hours duration. LCOEs are calculated based on an 8% weighted-average cost of capital for all technologies. Other cost assumptions are from the World Energy Outlook 2018 and are available at https://www.iea.org/weo/weomodel/.

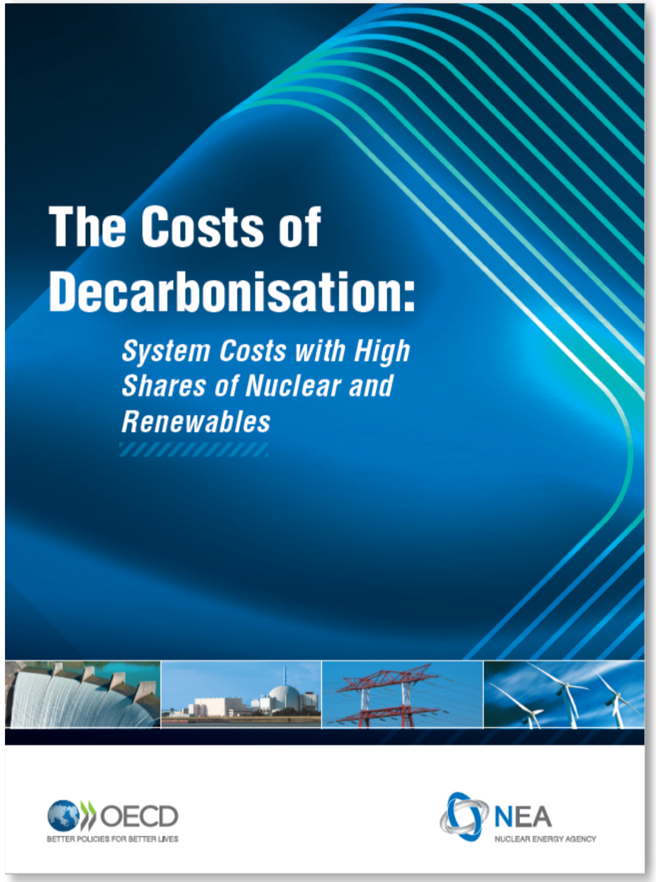
Projected Cost of Electricity Generation (LCOE)

From EC W D'Haeseleer Study 2012 – in frame of ENEF

Overnight refurbishment cost (ORC):	400, 600 and EUR_{2012} 850/MWe
Refurbishment period:	2 years, spending 50% of the ORC each year
Capacity factor after refurbishment:	85%
Lifetime extension:	20 years
Decommissioning fee:	15% of the ORC
Fuel costs (similar to a new build):	EUR_{2012} 6/MWh
O&M costs (similar to a new build):	EUR_{2012} 10/MWh
Discount rate:	5% and 10%

Sample calculation results are

With an ORC of EUR 400 (ref – 33%)	$LCOE_{LTO}$(5%)= EUR 21/MWh, $LCOE_{LTO}$(10%)= EUR 23/MWh
With an ORC of EUR 600 (reference)	$LCOE_{LTO}$(5%)= EUR 23/MWh and $LCOE_{LTO}$(10%)= EUR 26/MWh
With an ORC of EUR 600 and EUR 850 (ref + 42%)	$LCOE_{LTO}$(5%)= EUR 26/MWh and $LCOE_{LTO}$(10%)= EUR 30/MWh



THE COSTS OF DECARBONISATION

SYSTEM COSTS WITH HIGH SHARES OF NUCLEAR AND RENEWABLES

Mr Jan Horst Keppler
Senior Economic Advisor, Division of Nuclear Technology Development and Economics

Foratom Workshop on System Costs
Paris, 12 December 2019

Global System Approach: NEA « System Costs »

- **Report NEA 7299/2019**: The Cost of Decarbonisation: System Costs with High Shares of Nuclear and Renewables… (Electricity)

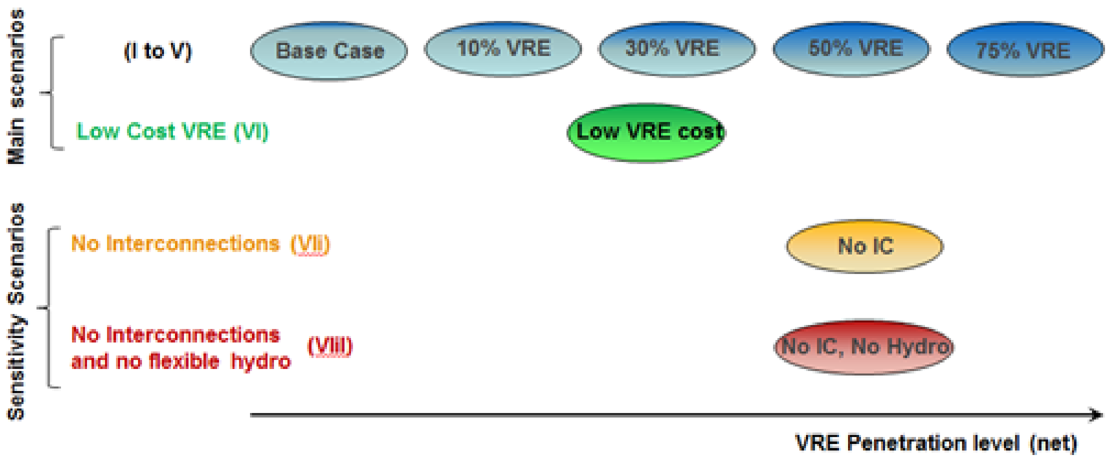
MAIN CONCLUSION:

Assuming 50gr CO2/kWh in 2050… (meaning limiting gas!!!) – going from 0 to 75% VRE…

- Going from zero to 75% VRE multiplies the necessary installed capacity by 3
- With 75% VRE System costs are increased by 50 USD/MWh
- More VRE means more volatility in electricity prices (at 75% 4000 hrs negative prices) and discourage investment
- Market value of VRE reduces with increasing shares (more for solar than wind), also discouraging investment

… there seems to be an « economic » upper limit for VRE of the order of 30 to 40%...

Eight Scenarios with identical constraint of 50gCO2 per kWh



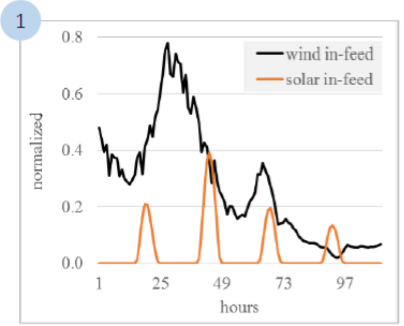
- One base case scenario with 0% VRE
- Four scenarios with *imposed shares* of 10%, 30%, 50% and 75% of VRE in generation.
- One scenario with anticipated low VRE costs
- Two sensitivity scenarios testing for the importance of hydro resources or interconnections.

- **Detailed least cost linear programming, hourly resolution, two zones, technical constraints in cooperation with group of modellers working at MIT.**
- **Identical demand curve, carbon emission target (50 gCO_2/kWh) and fixed hydro resources; realistic data for VRE loads; costs from IEA/NEA *Projected Costs* (2015).**

Assessing the total costs of electricity systems

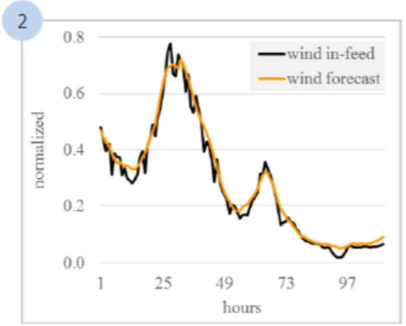
- Total system costs are the sum of plant-level generation costs and grid-level system costs
- System costs are mainly due to characteristics intrinsic to variable generation.

Source: L. Hirth



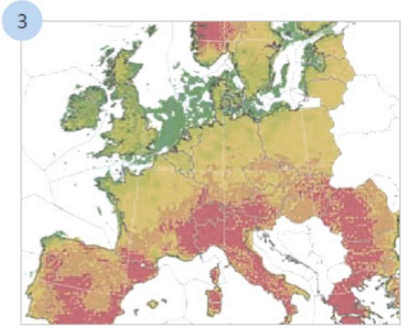
Wind does not always blow

Profile costs (Changing mix)



Difficult to predict

Balancing costs (Short-term variations)



Good sites are distant from load centers

Transmission and distribution costs

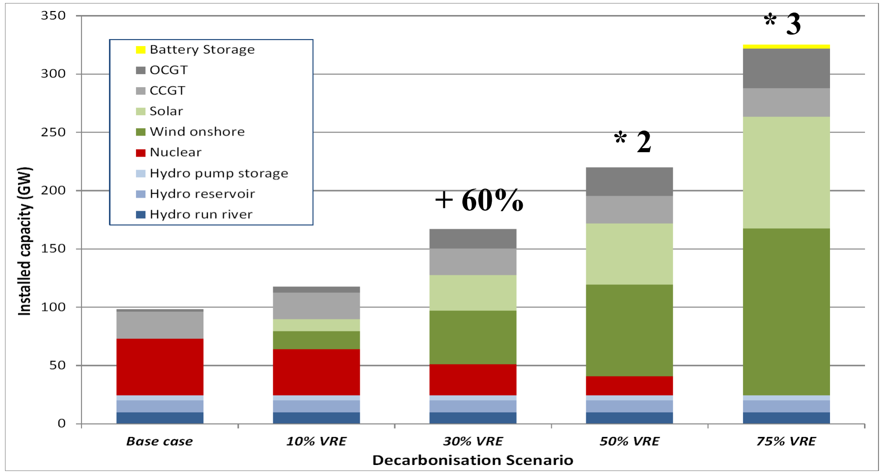
System costs depend on:

- Country characteristics and the existing mix;
- VRE penetration and load profiles;
- Flexibility resources (hydro, storage, interconnections).

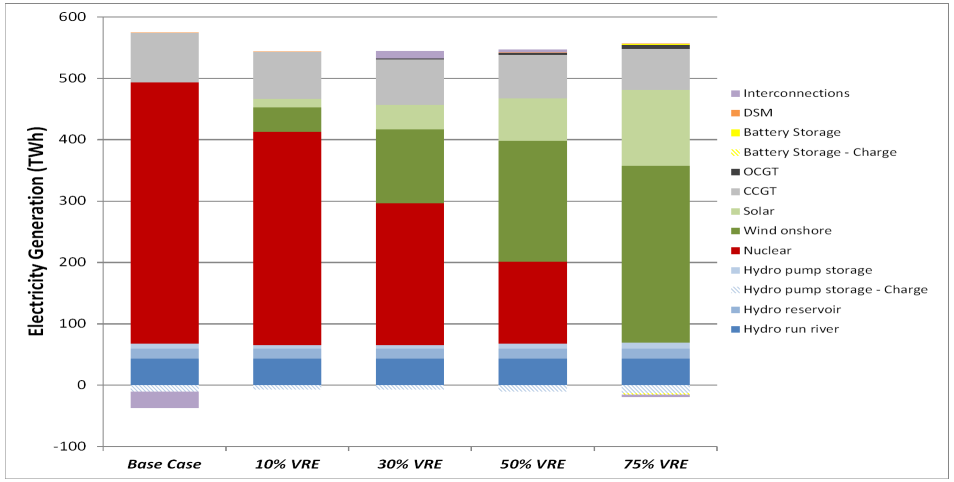
Additional impacts on load factors of dispatchable generators and prices.

Result 1: Considerable excess capacity needed to meet demand

Installed Capacity



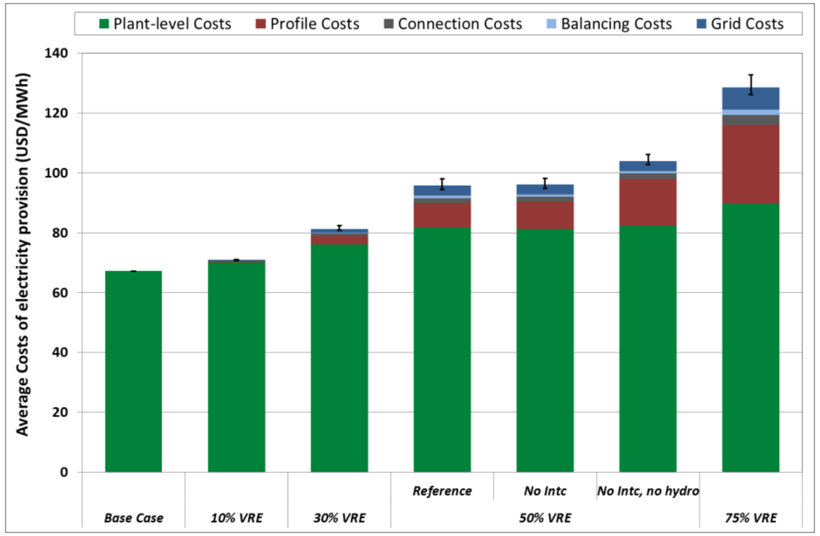
Electricity Generation



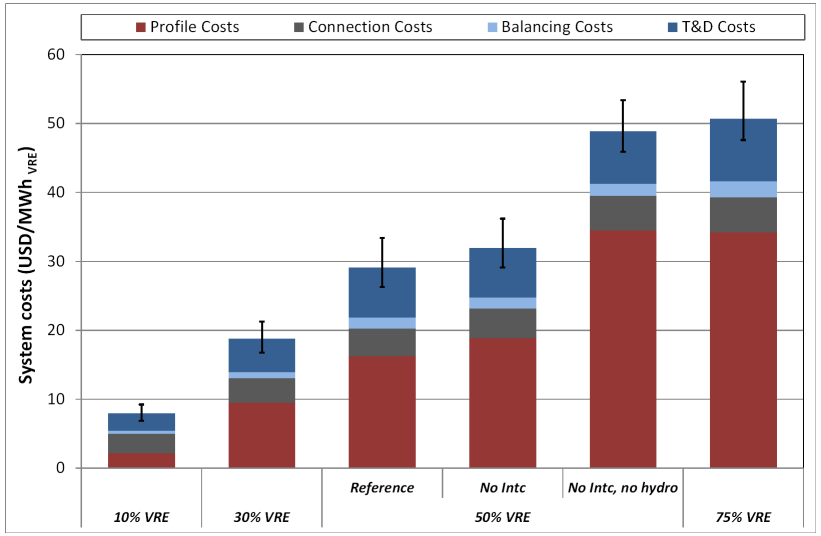
- Rising VRE share results in significantly larger capacity needs.
- Due to carbon constraint, coal no longer included, but gas provides flexibility. Battery storage deployed only at high VRE penetration levels.

Result 2: As VRE share increases system costs become a concern

Total Costs



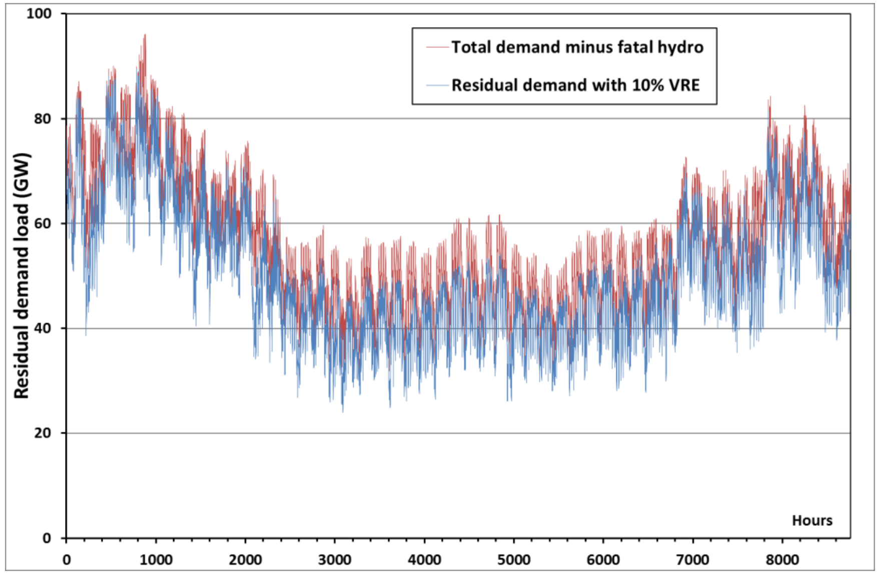
Breakdown of System Costs



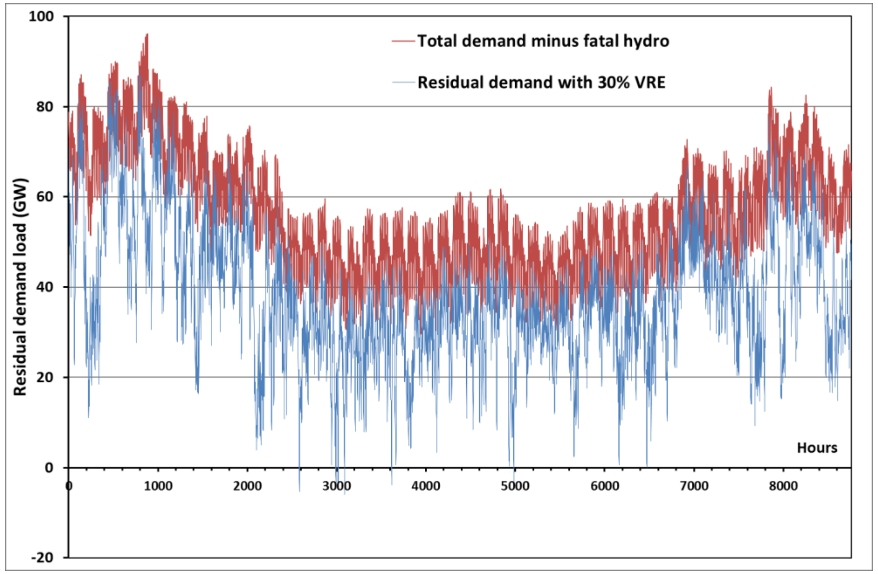
- Estimate of system costs with data from literature (T&D, connection and balancing).
- System costs are large and increase with VRE generation share.
- Profile costs are the dominant component, especially at high VRE generation share.

High VRE share de-structures the remainder of the system I

10% Variable Renewables



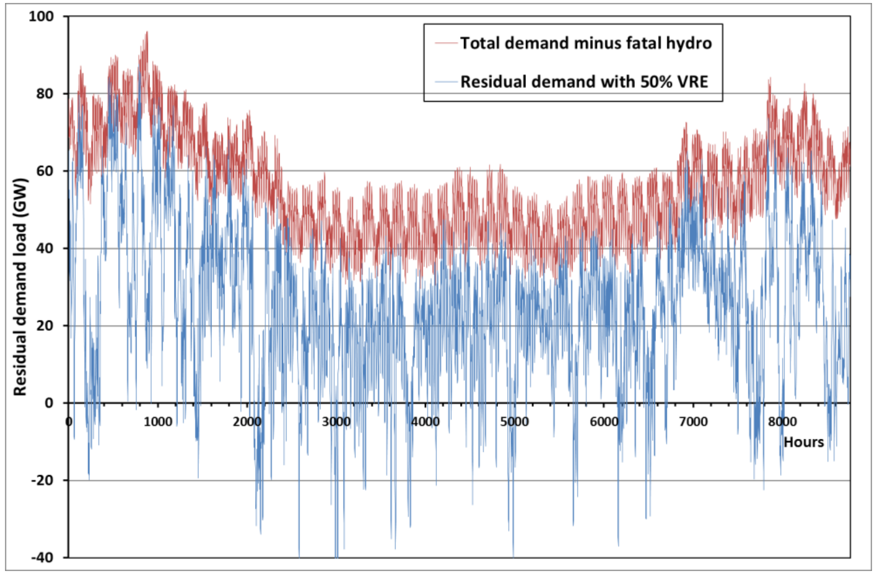
30% Variable Renewables



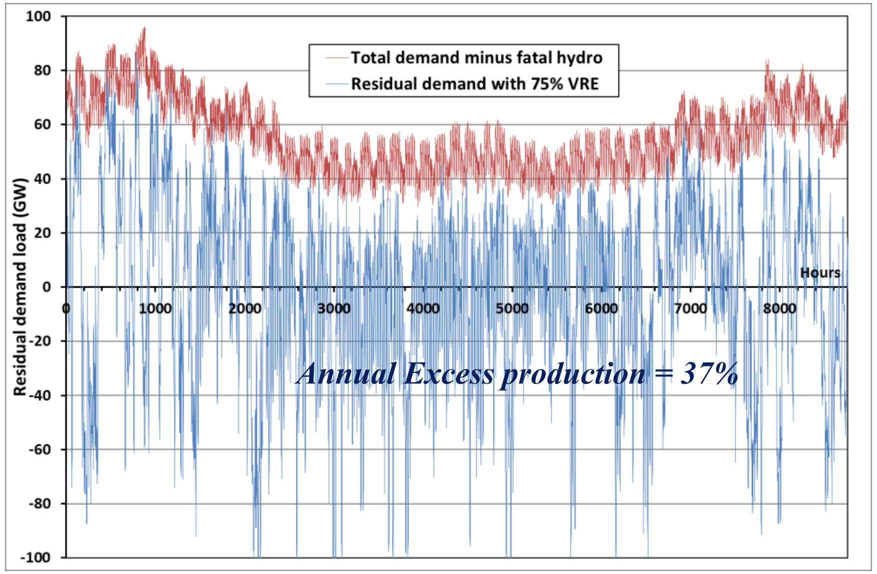
- High VRE shares result in challenges for system management.

High VRE share de-structures the remainder of the system II

50% Variable Renewables

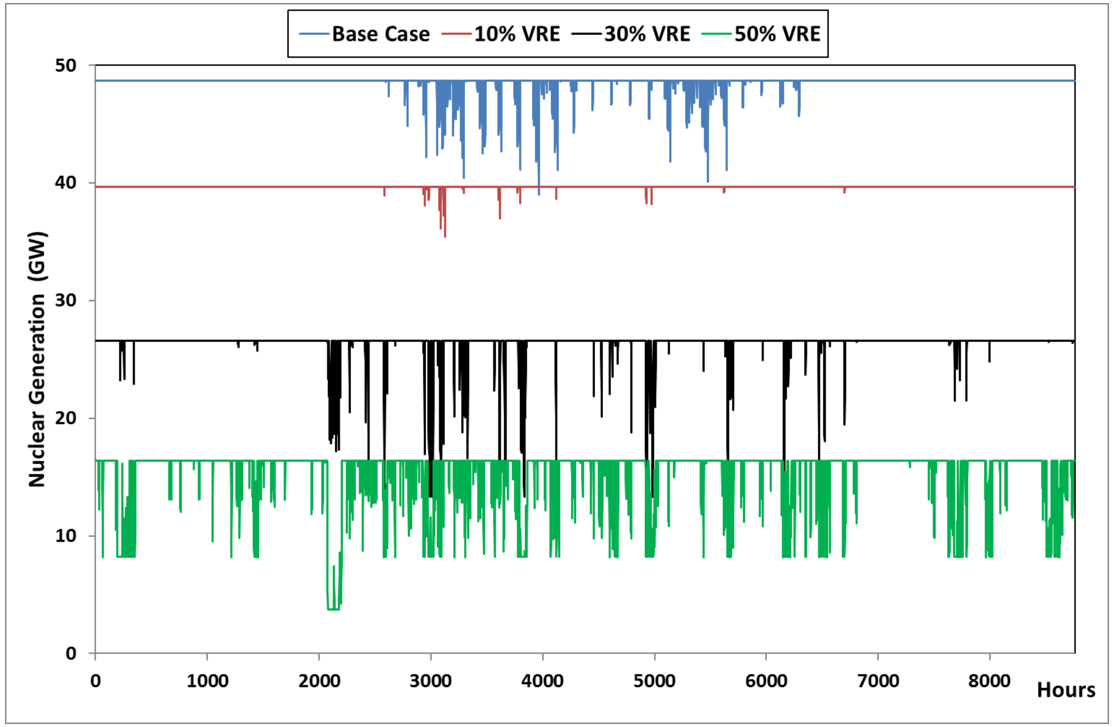


75% Variable Renewables



- Residual demand for dispatchable thermal operators loses its characteristic daily, weekly and seasonal patterns and becomes more volatile and unpredictable.

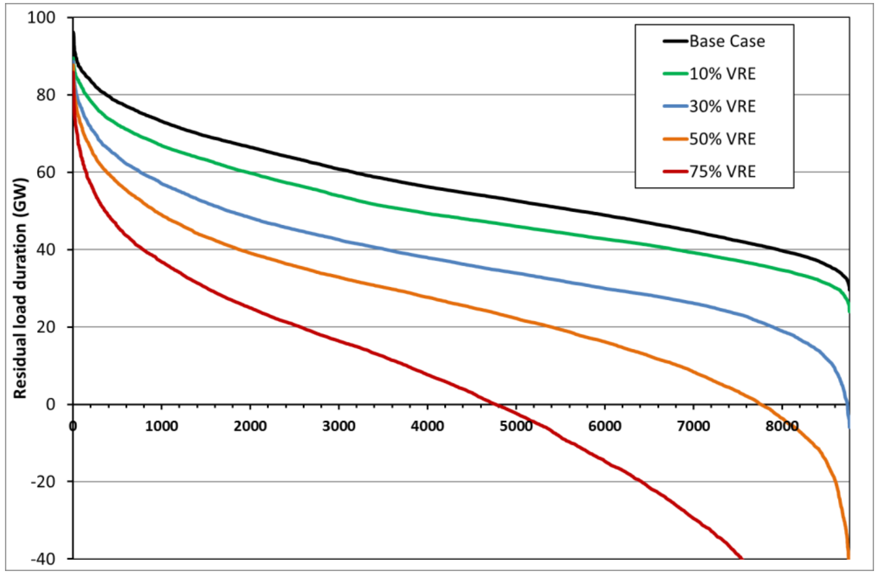
Result 4: Increasing demand on flexibility of nuclear power plants



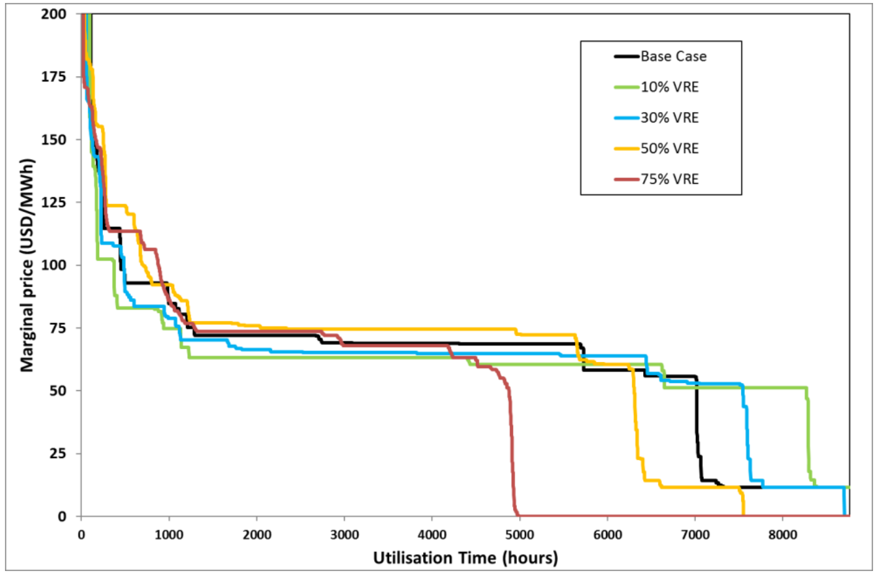
- With increasing VRE shares nuclear capacity declines.
- The number and steepness of the ramps for load following (cycling) increases.
- This poses the question of sector coupling, *i.e.*, combining electricity generation with the production of another "storable" product (heat, desalination, hydrogen…).

Result 3: Decreased load and volatile electricity prices discourage investment

Load Duration Curves



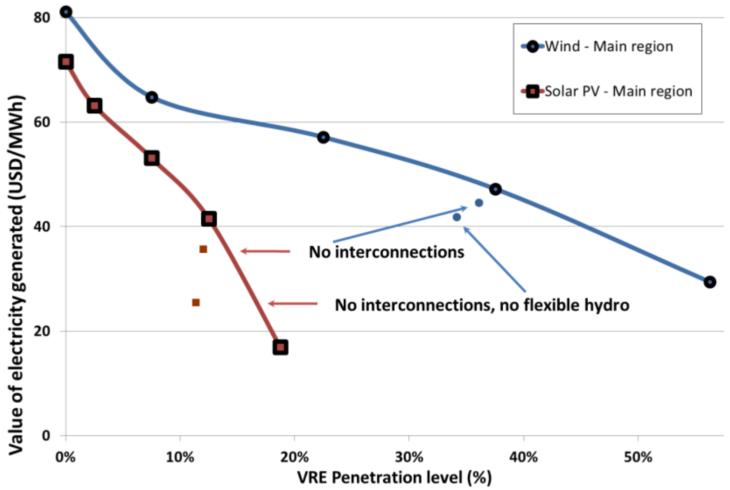
Price Volatility



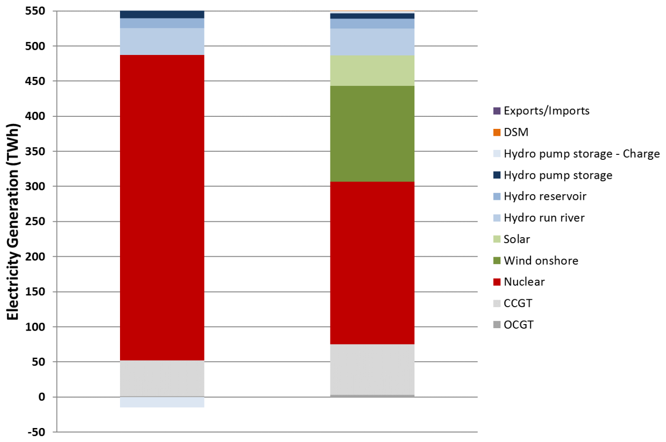
- Increase of hours with zero price (over 3750 hours *p.a.* at 75% VRE), compensated by greater number high-price hours (>100 USD/MWh).
- Price volatility increases uncertainty, investment costs and risks to capacity adequacy.

Result 5: Market-based introduction of VRE is intrinsically difficult

Declining Market Value of VRE

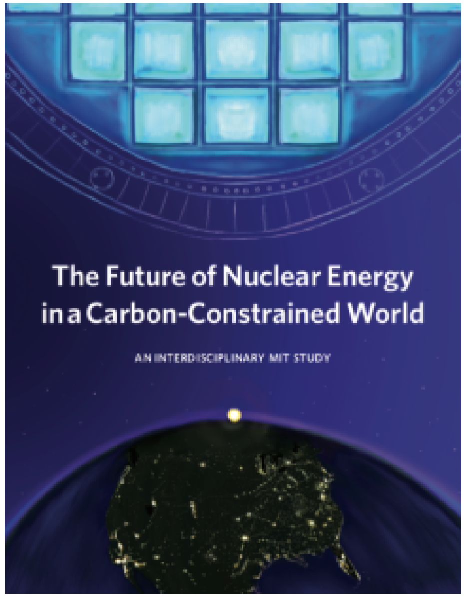


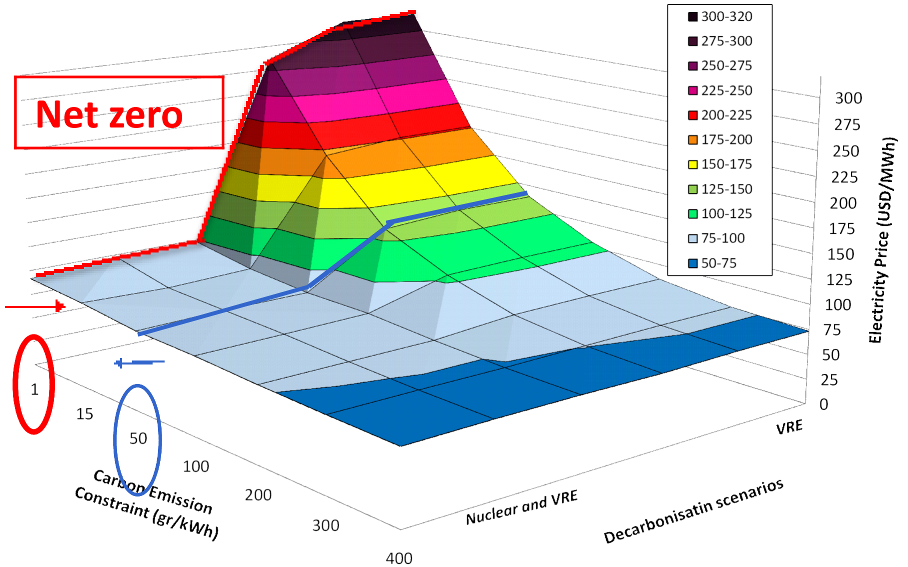
Even Low Cost VRE Limited Market Entry



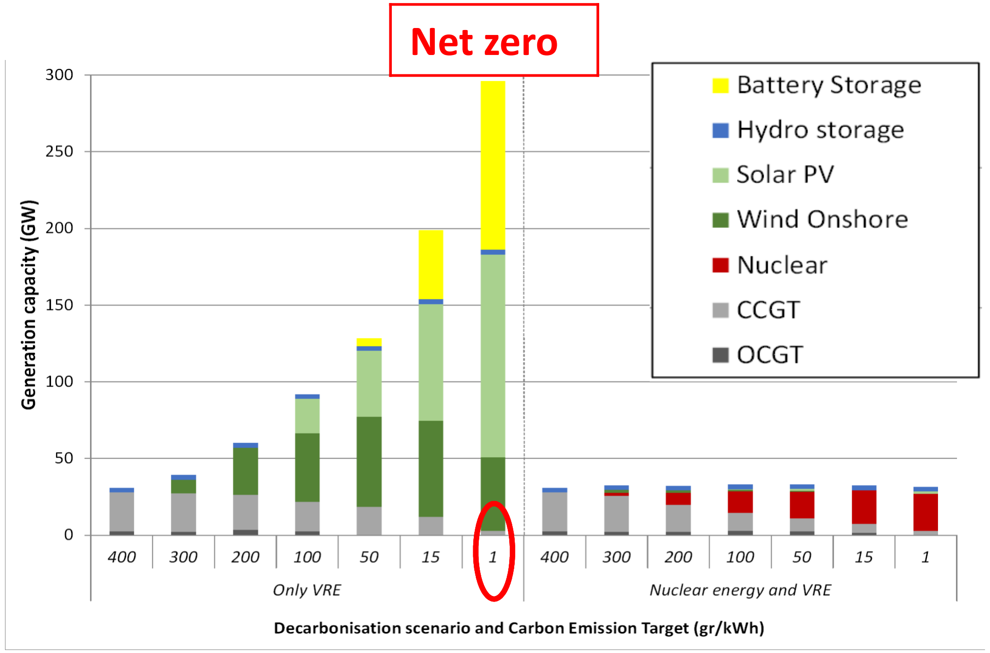
- VRE earn less than average market prices due to auto-correlation during production hours. This effect increase with their share and is larger for solar PV. Flexibility resources improve value.
- Future expected cost declines of VRE (e.g., 60% PV, 50% wind off-shore, 33% wind on-shore) will allow self-entry into the market. The level will depend strongly on local conditions.

System Costs Are a Function of Carbon Targets and VRE Targets





Source: N. Sepulveda, MIT



Key Findings:

- The average cost of electricity increases with the stringency of the carbon constraint. The increase is much more significant in scenarios where only VRE are deployed.
- The structure of the optimal generation mix changes drastically as the decarbonisation target becomes more binding.

Lessons of the NEA system cost study

The NEA study on *The Cost of Decarbonisation* compares different low carbon electricity mixes satisfying the same stringent carbon constraint cost of 50g per kWh consistent with the *Paris Agreement* and the objective to keep the rise of global mean temperatures below 2°C. In different scenarios, generation from VRE is substituted for nuclear generation 1:1. Given current technologies and costs, the study allows for the following conclusions. A higher share of VRE and a lower share of nuclear imply:

1. **Considerably higher system costs (up to USD 50/ MWh_{VRE}) as energy value of VRE declines;**
2. **Higher overall costs (under LCOE cost assumptions in IEA/NEA (2015); as VRE costs decline, future *least-cost systems* will contain both VRE *and* nuclear;**
3. **Considerably higher capacity (with implications for land-use, externalities etc.);**
4. **Higher price volatility (up to 3750h of zero prices, compensated by prices above USD 100 per MWh);**
5. **Higher technical stress for residual system (nuclear, gas) due to ramping and cycling, whose implications cannot be modelled here.**

Future low carbon systems will require considerable attention from policy-makers and regulators, both as far as investments and as far as operations are concerned.

Overall Cost – External Costs From EC W D'H Study 2012

External Costs

Without Accidents (main source EC NEEDS and PSI projects)

- External costs for nuclear-generated electricity (routine): 1 – 4 $€_{2012}$/MWh
- Compare with other means

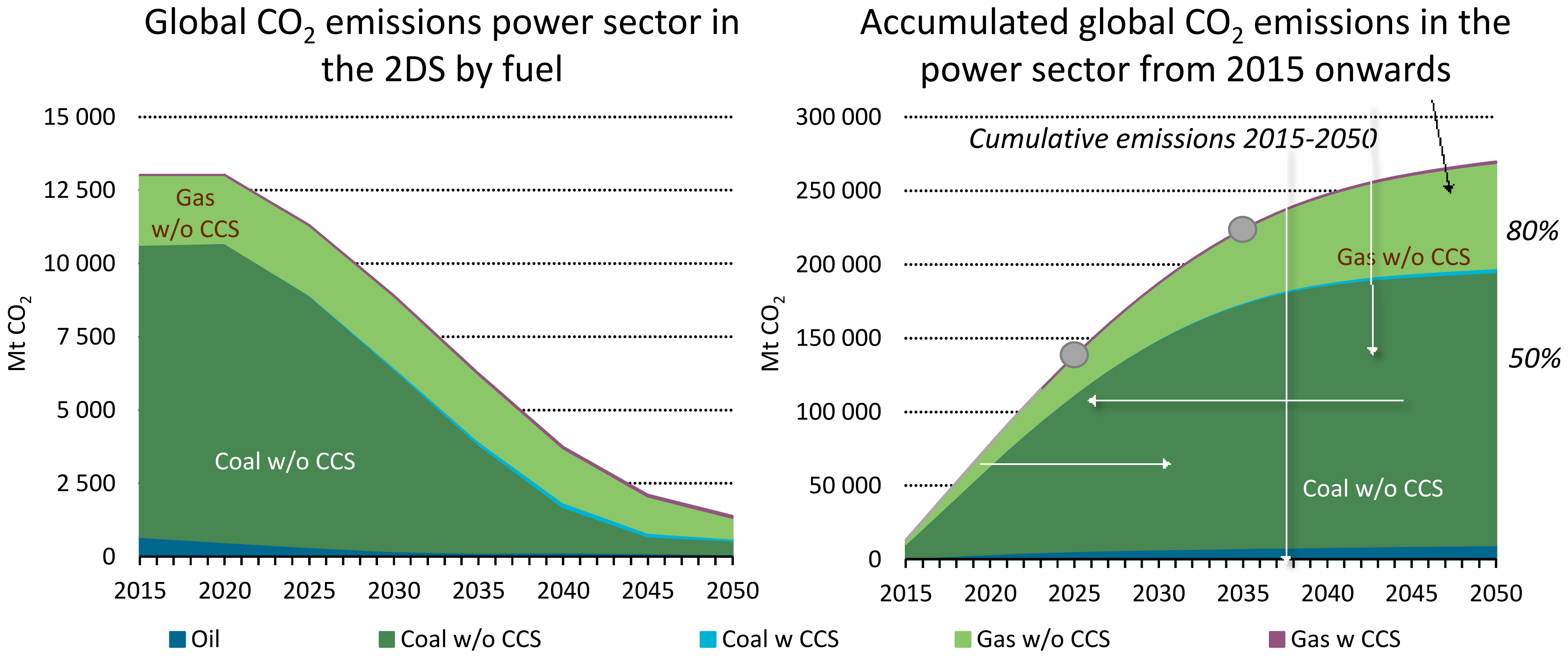
Coal	~ 40 $€_{2012}$/MWh
Gas	~ 20 $€_{2012}$/MWh
PV	~ 10 $€_{2012}$/MWh
Wind	~ 2 $€_{2012}$/MWh

Nuclear Accidents

(main source + conservative adaptation: Nuclear ON OFF – François l'Evêque – Pr Economie Mines Paris Tech)

External cost due to nuclear accidents is ~ 0.3 … 1 … 3 €/MWh

Next 20 years critical for further reductions in cumulative emissions beyond 2°C



- By 2025, already 50% of the cumulative emissions of the power sector over the period 2015-2050 have been emitted.
- By 2035, the amount increases to 80% and to 90% by 2040.

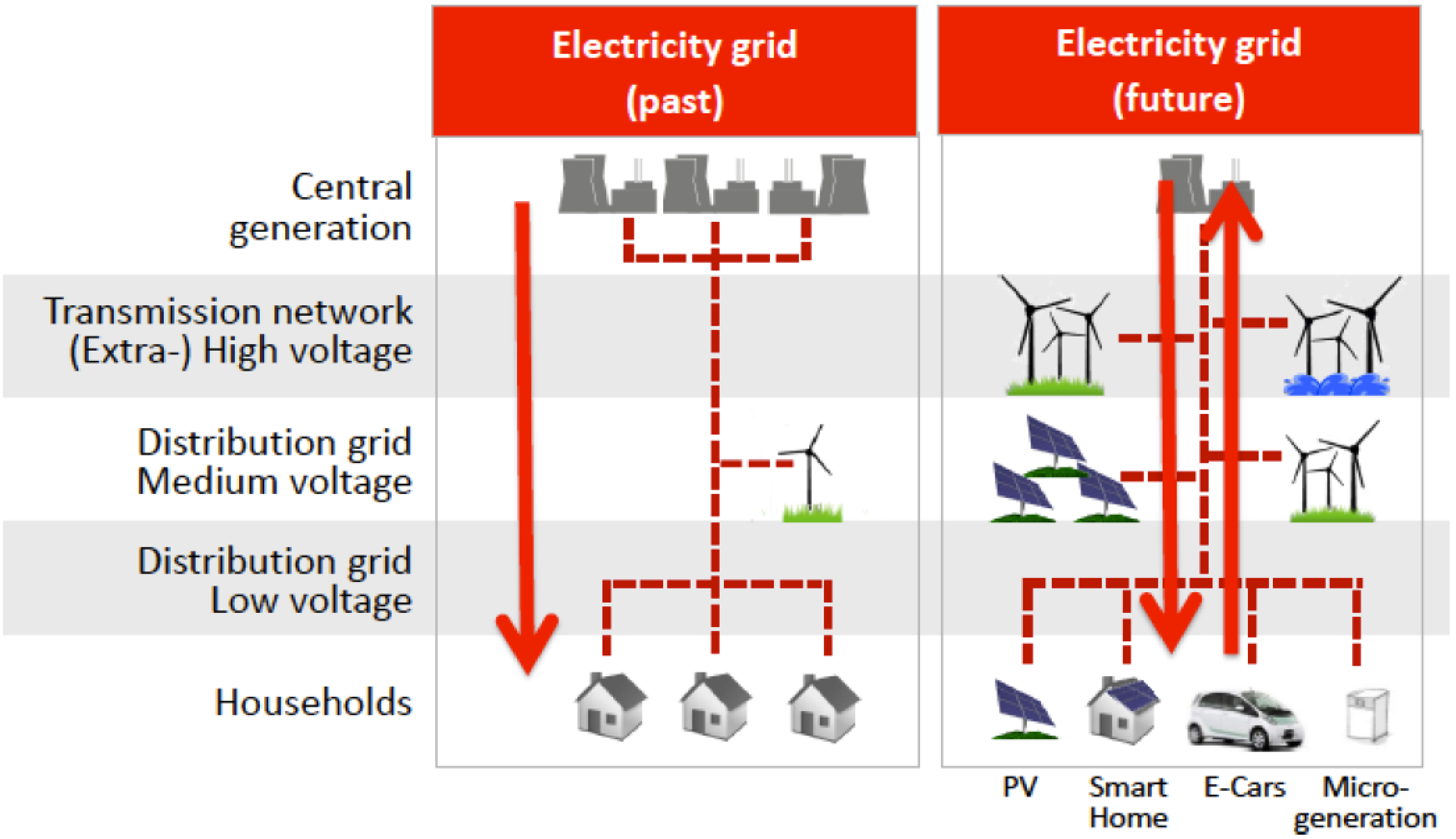


Fig. 1.3. Changing Structure of the Electricity Grid [J. Specht, E.ON, August 2014]

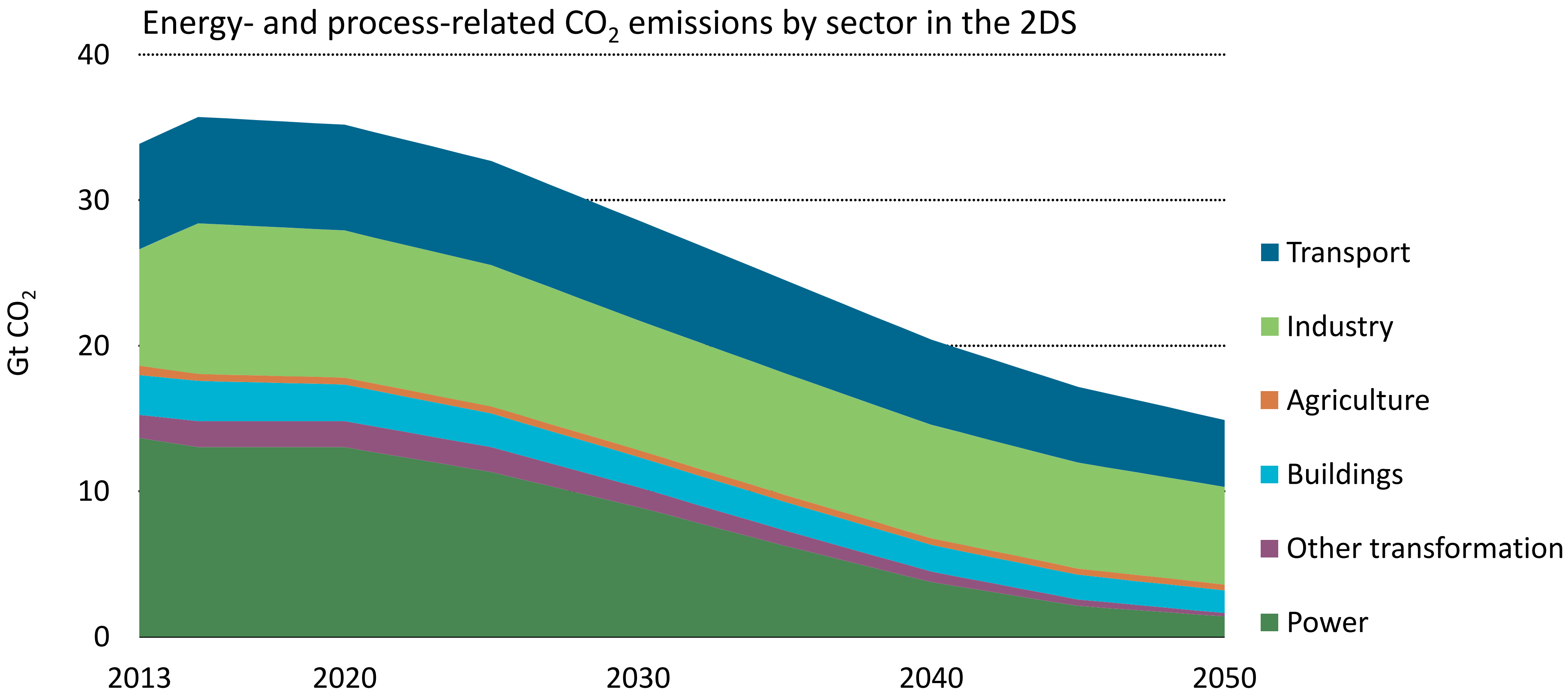
Fraction of decarbonised electricity…

Look to Sweden and France… and Germany (2015)…
Germany's Carbon Intensity for electricity decreased from 213 to 202 gr CO2/kWh over the last 10 years… cost: 300 Billions Euros… for 93 GW RES and 160TWh/y - compared to 65 GW Nuke in France and 3x more electricity…

Source : Environmental Progress, chiffres provenant du rapport "Statistical Review of World Energy" de BP

From 2 degrees to “well-below 2 degrees”

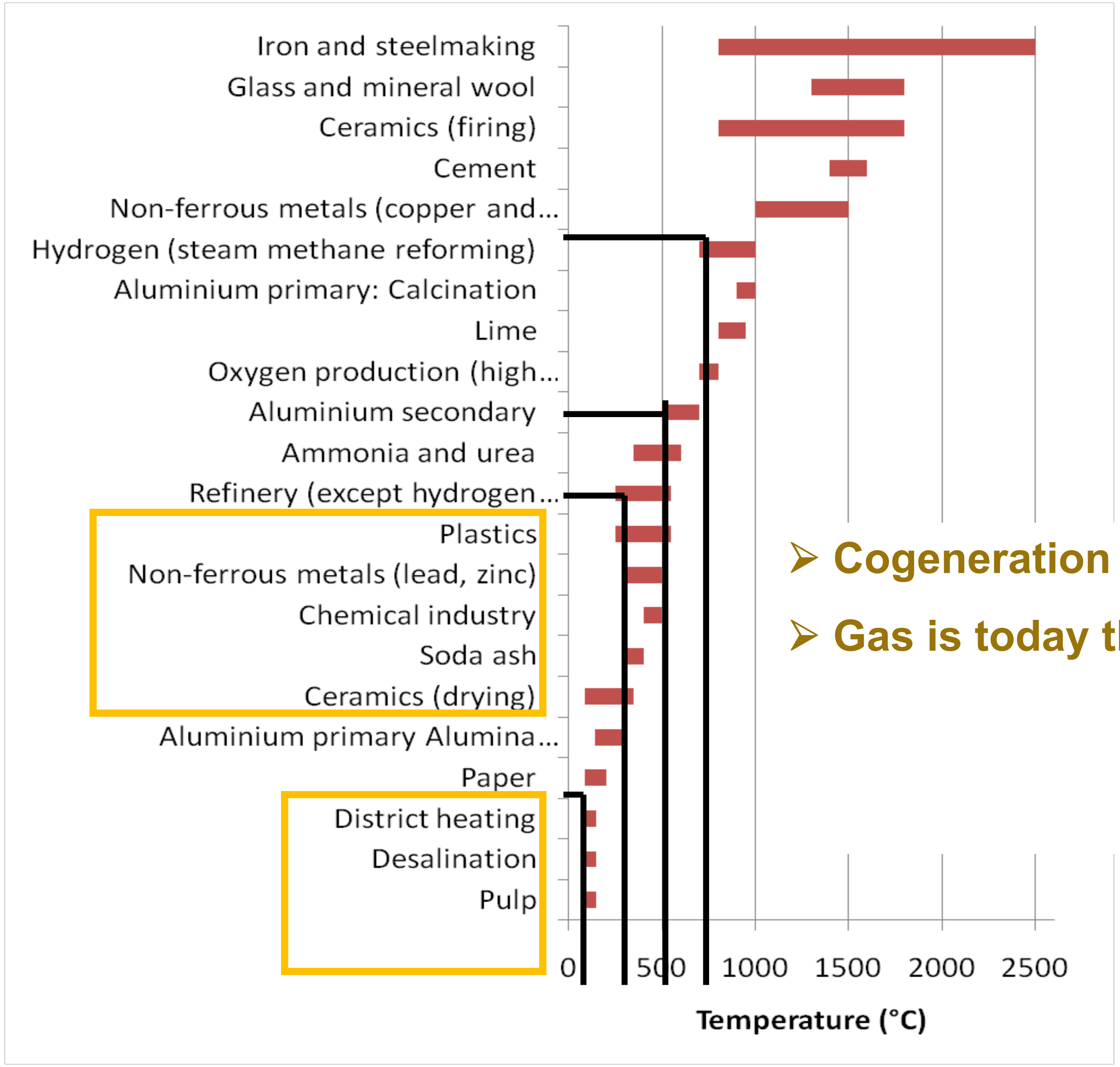
International Energy Agency
Secure Sustainable Together



Industry and transport accounted for 45% of direct CO2 emissions in 2013, but they are responsible for 75% of the remaining emissions in the 2DS in 2050.

Source: Energy Technology Perspectives, 2016

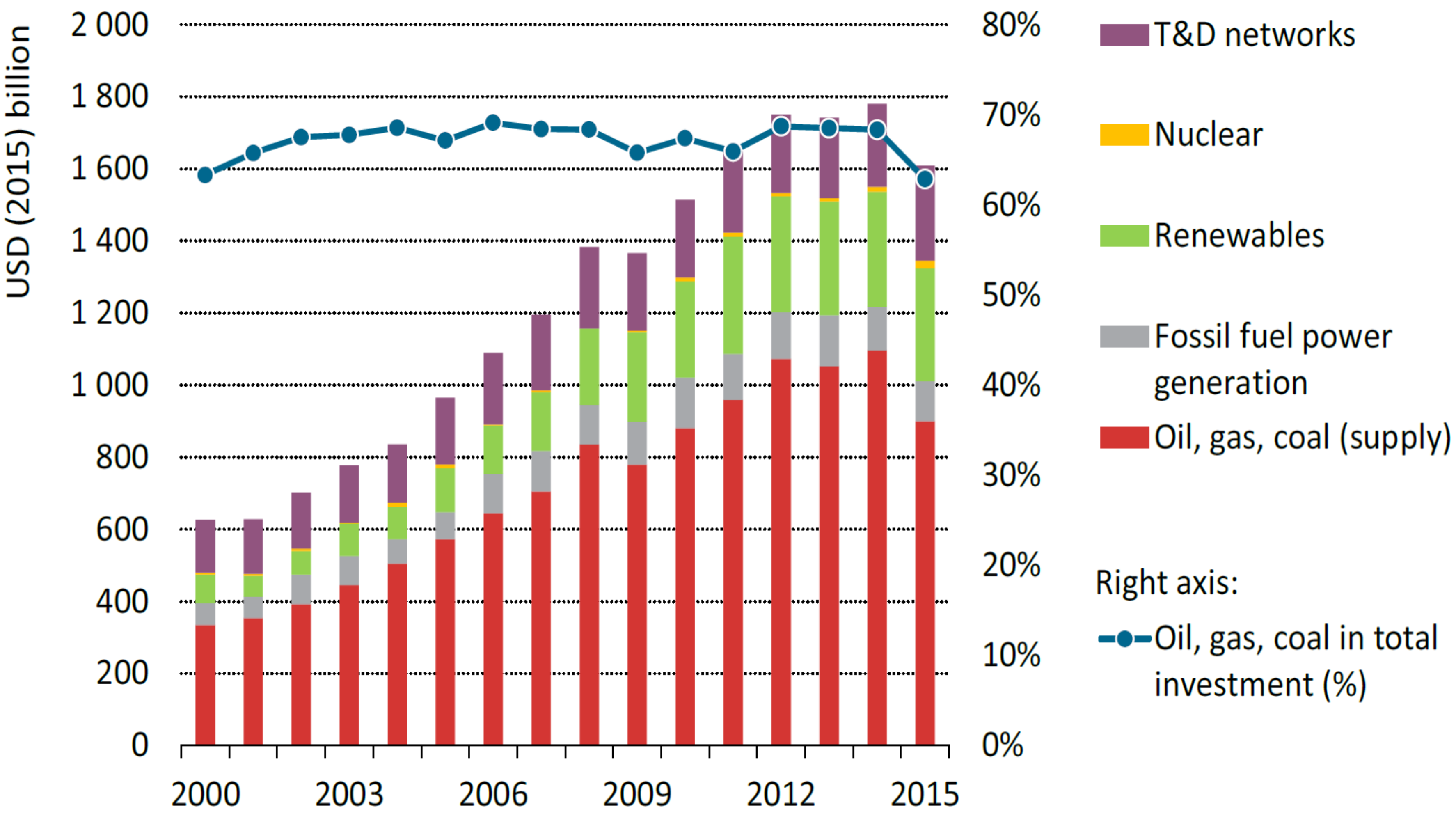
Process Temperatures



- **Cogeneration is a mature technology**
- **Gas is today the reference technology**

→ Can nuclear replace fossil fuel applications?

Investment in the global energy system

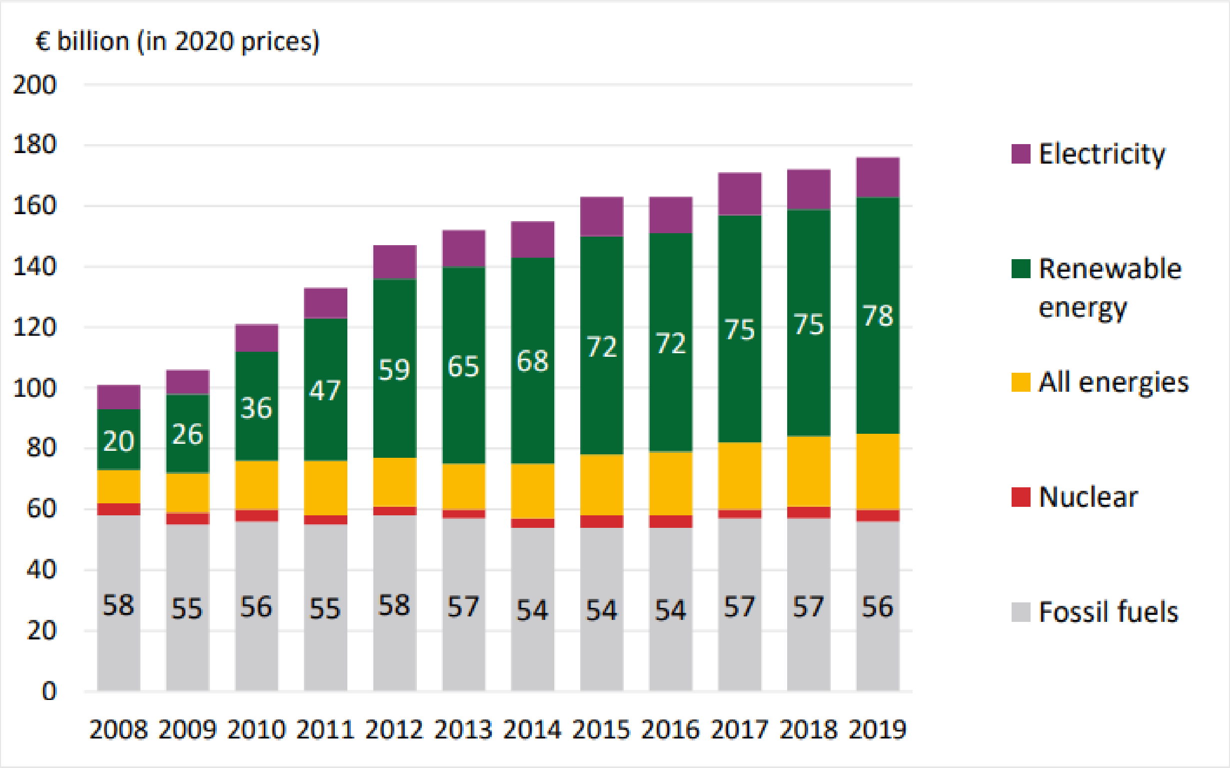


Source: World Energy Investment 2016

Energy Subsidies in EU

European Court of Auditors 2022

Figure 10 – Energy subsidies by category between 2008 and 2019



Source: ECA based on the *Study on energy subsidies and other government interventions in the European Union*, October 2021.