The Energy Transition

— overall perspective —

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Driver of the Energy Transition

- Thé objective of the current Energy Transition should be:

  decarbonization by mid century

- Without too many other ‘targets’ / ‘constraints’, like:
  - x% efficiency improvement
  - y% RES share
  - z% electrolyzers…

- But with essential condition:
  - of guaranteed / assured energy provision (SoES)
  - at affordable societal cost

How fast the Energy Transition?

A fundamental question:

"How fast should we move towards decarbonization?"

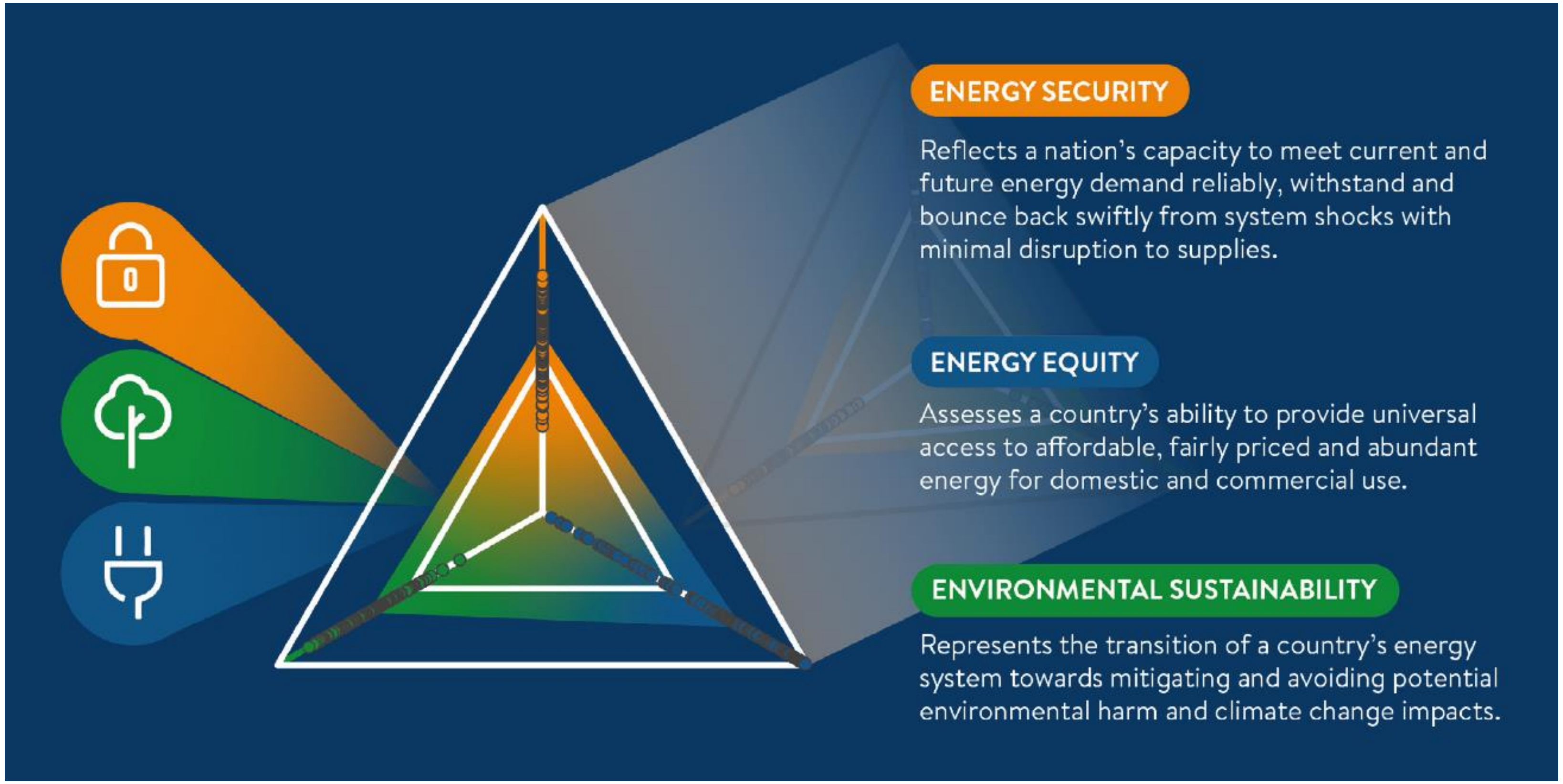
EU by 2050? China by 2060? India by 2070? RoW (a.o., Africa) by ???

- Current annual EU CO_2 emission ~7 % of global emissions (2021)
- Overall historic cumulative CO_2 emission EU ~ 17% (2022)

- We have a historic responsibility,
  should set the example, and
  help create the conditions

→ **energy technology progress**

The Energy Trilemma



The WEC's Energy Trilemma

The Energy Trilemma

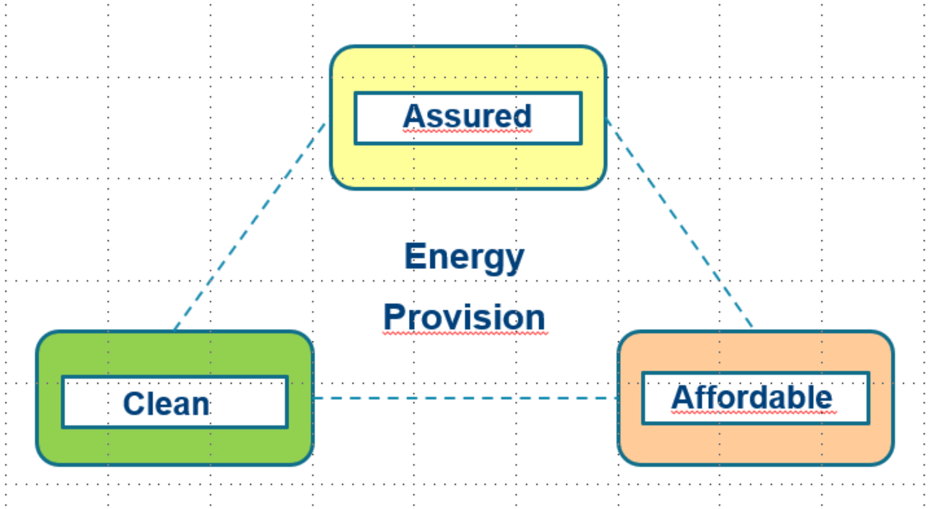
The Energy Transition

is actually a full system Transformation / a Revolution!

The current energy *'triangle'* is far from balanced:

E-E-E (Energy – Environment – Economics)

The final aim by ~ 2050 should be a balanced energy triangle



The Energy Trilemma

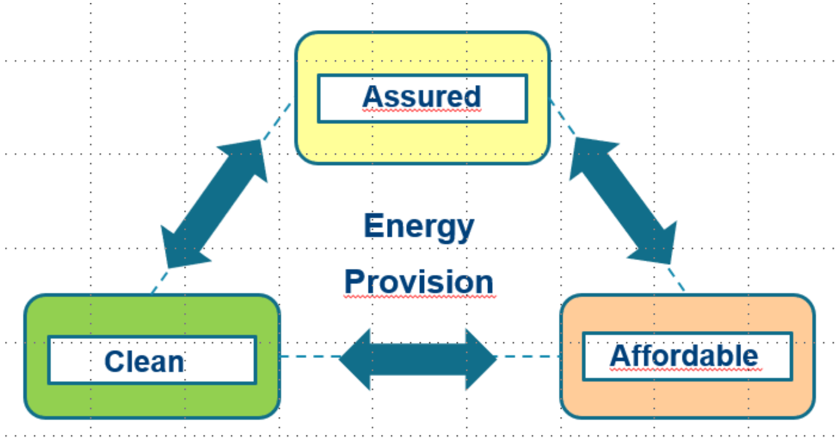
At present, the Energy Trilemma is not just an energy ‘triangle’

Recall the meaning of a ‘*dilemma*’ … similar for a *‘trilemma’*

The energy transition via the trilemma:

is a difficult exercise in managing the trade-offs;

in a moving system context / continued adaptation required



The Energy Trilemma

Throughout the period ~ 2010 - 2020

almost all attention went to decarbonization…

with energy security and affordability merely as *'footnotes'*…

As of Feb 24, 2022

more attention to **SoES** and **Affordability / Competitiveness**

Now also realization of *vulnerability* for

raw materials (rare-eath minerals),

supply chains and manufacturability

The Energy Trilemma

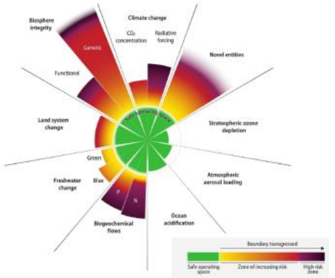
Geopolitical
context changing;

post-globalisation;

more fragmented
world…

The Energy Trilemma – meaning apexes

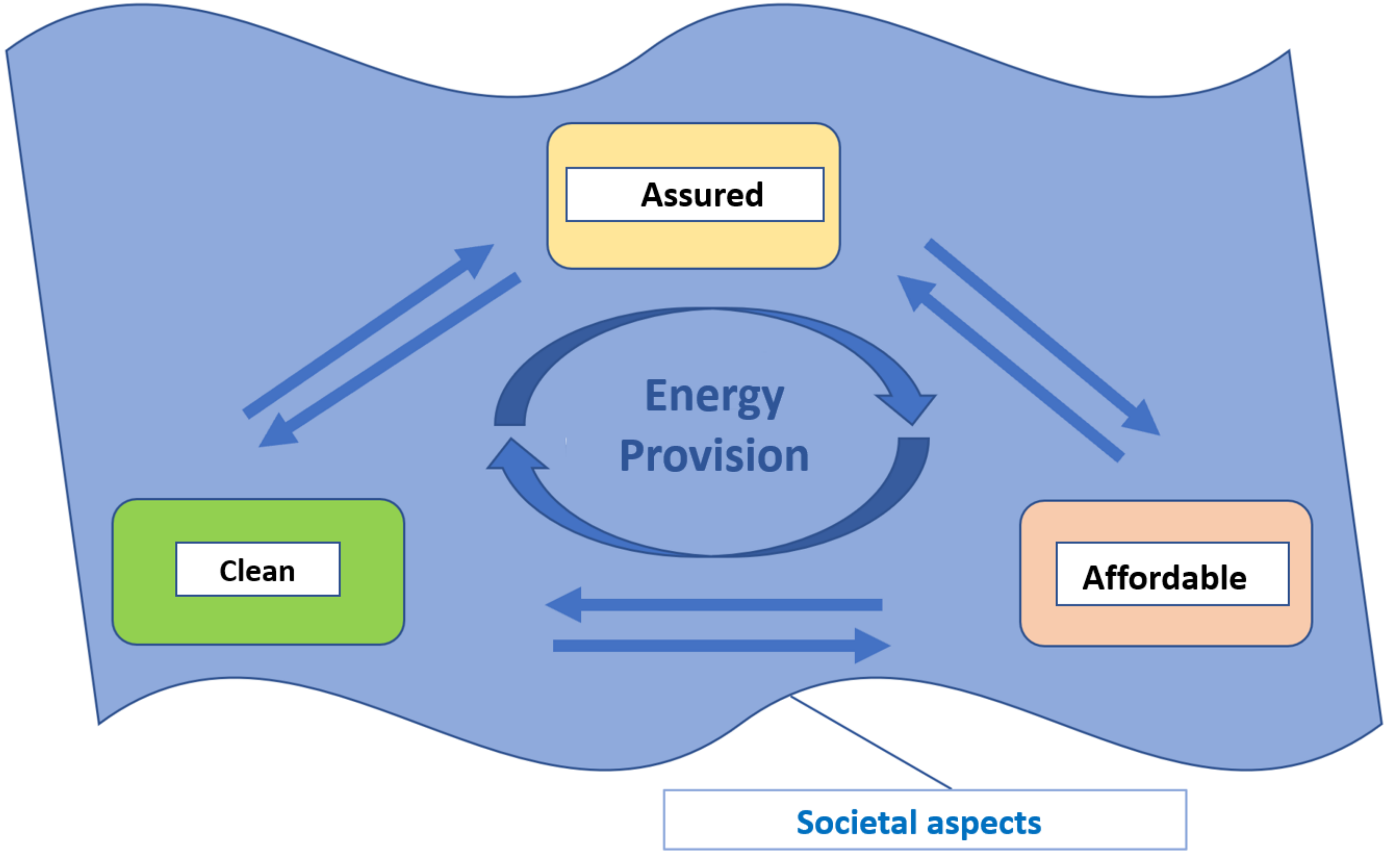
- SoES
  - Accessibility first & foremost!
  - Fundamental principle: diversity of supply / redundancy
    - Strategic SoS (primary energy / geopolitics)
    - Adequacy – timely investments
    - Security / Reliability / Resilience (avoiding blackouts)
- Affordability
  - Reasonable prices for retail consumers
  - Acceptable prices for businesses (competitiveness)
  - Acceptable <u>cost to society</u> / but <u>prices are signals</u> of scarcity
- Environmentally friendly
  - GHG emissions, planetary boundaries, …
  - But also <u>safety</u> (avoiding accidents) and <u>health</u>



The Energy Trilemma

- Don't have illusions or be naive…
- The trajectory to mid century will be <u>difficult</u> (for many years…)
- Must be <u>target-oriented, effective and efficient</u>:
  - *clear objective*,
  - *no technology preferences*,
  - let *total social cost* (private costs + external costs) be *decisive*
- **!! But do not forget <u>societal support</u> / <u>public acceptance</u> !!**

The Energy Trilemma including society



The Energy Trilemma

- Don't have illusions or be naive…
- The trajectory to mid century will be difficult
- Must be pragmatic;
  - clear objectives,
  - no technology preferences,
  - let total social cost (private cost + external costs) be decisive
- **!! But do not forget societal support / public acceptance !!**
- Success means that trilemma becomes balanced 'triangle'

Energy Provision

Guaranteed
Environment

Environment
Guaranteed

Budget / Bargain

Societal Support

Societal Support

The EU Targets

- Recall 20-20-20 targets… (nice sounding, effective but not efficient)

- Post COP-21 decision by 2030
  - - 40% GHG emissions w.r.t. 1990
  - 32% RES of final energy demand (with stat transfers)
  - - 32.5% energy efficient w.r.t. REF2007

- Fit for 55 (ff55) by 2030 (only 6 years from now)
  - - 55% GHG emissions w.r.t. 1990
  - 40% RES of final energy demand (with stat transfers)
  - - 36% energy efficient w.r.t. REF2007 (or -9% w.r.t. REF2020)

- REPowerEU (May 2022)
  - 42.5% RES of FED mandatory (45% RES aspiration)
  - - 11.7% energy efficient w.r.t. REF2020

The EU Targets – 2040 (?)

- Newly proposed target for 2040 by current Commission (Feb 2024)

EUROPEAN
COMMISSION

Strasbourg, 6.2.2024
COM(2024) 63 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Securing our future

Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society

{SEC(2024) 64 final} - {SWD(2024) 63 final} - {SWD(2024) 64 final}

The EU Targets – 2040 (?)

- Newly proposed target for 2040 by current Commission

- In summary:

  *“The Communication presents a **90%** net GHG emissions reduction w.r.t. 1990 as the recommended target for 2040.”*

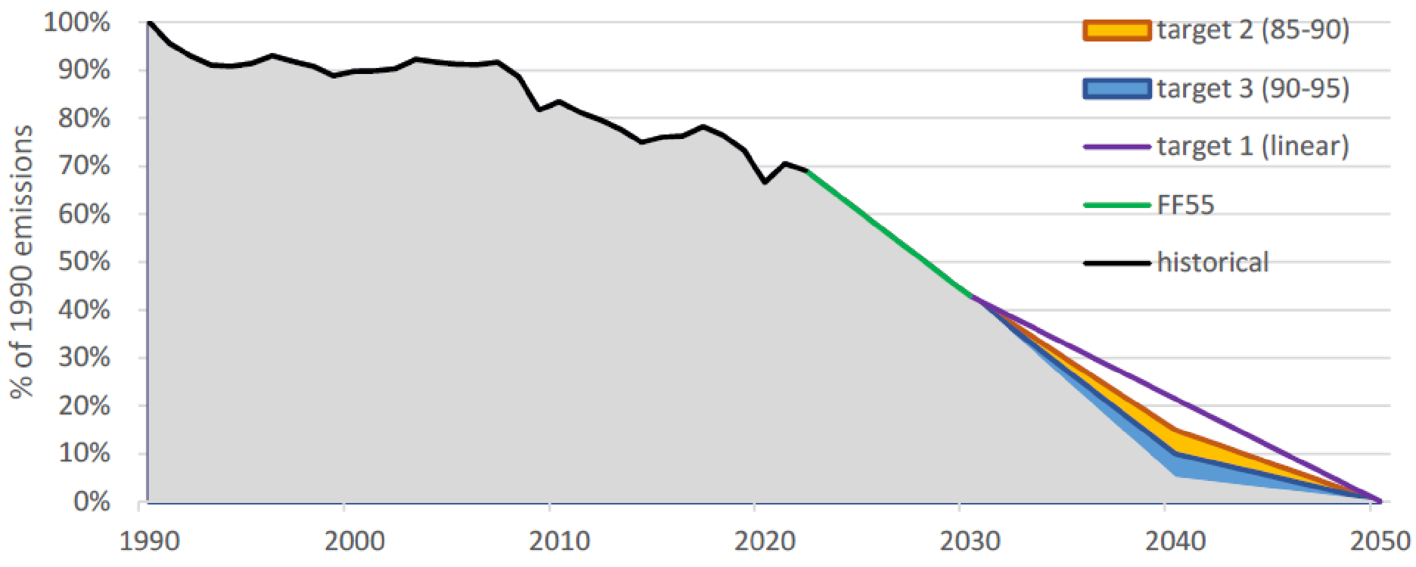
- Based on a ‘thorough’ impact assessment (exploring 3 scenarios):

  - Option 1, a reduction of up to 80% compared to 1990, consistent with a linear trajectory between 2030 and 2050 (9);
  - Option 2, a reduction of 85-90%, compatible with the level of net GHG reduction that would be reached if the current policy framework were extended to 2040 and
  - Option 3, a reduction of 90-95%.

The EU Targets – 2040 (?)

- Newly proposed target for 2040 by current Commission

Figure 4. Profile of the net GHG emissions over 1990-2050



The EU Targets – 2040 (?)

Table 10: Summary of key energy indicators

	2030	2040			2050
		S1	S2	S3	S3**
Policy relevant indicators					
Energy-related CO2 reductions vs 2005	-58%	-83%	-90%	-94%	-103%
RES share in Gross FEC	42.4%	65%	72%	75%	89%
FEC reduction vs 2015 (55)	-19%	-34%	-34%	-36%	-40%
Energy indicators - Supply					
Gross Available Energy (Mtoe)	1160	1022	1021.	1018	1032
- Fossil fuels	663	375	311	275	150
- of which for non-energy use	*96*	*96*	*96*	*96*	*80*
- of which captured	*1.8*	*11.5*	*13.2*	*13.3*	*24*
- Nuclear	139	129	129	129	142
- Renewables	328	482	544	613	691
Net imports (Mtoe)	572	347	298	267	153
Import dependency (%)	50%	34%	29%	26%	15%
Hydrogen production (Mtoe)(56)	9	60	76	100	185
e-Fuels production (Mtoe)	2	15	27	37	60
Energy indicators – Power generation					
Gross electricity generation (TWh)	3362	4563	4899	5212	6922
Net installed power capacity (GW)	1617	2181	2377	2525	3256
- Fossil fuels	238	172	164	156	142
- Nuclear	94	71	71	71	71
- Renewables	1285	1939	2142	2298	3027
Storage and flexibility options (GW)	172	213	254	275	238
Final Energy					
Final Energy Consumption (Mtoe)	764	622	614	604	555
Electricity share in FEC	33%	48%	50%	51%	62%
e-Fuels share in FEC	0%	1%	3%	5%	7%

New nuclear commitments not yet taken into account (see Box p 44).

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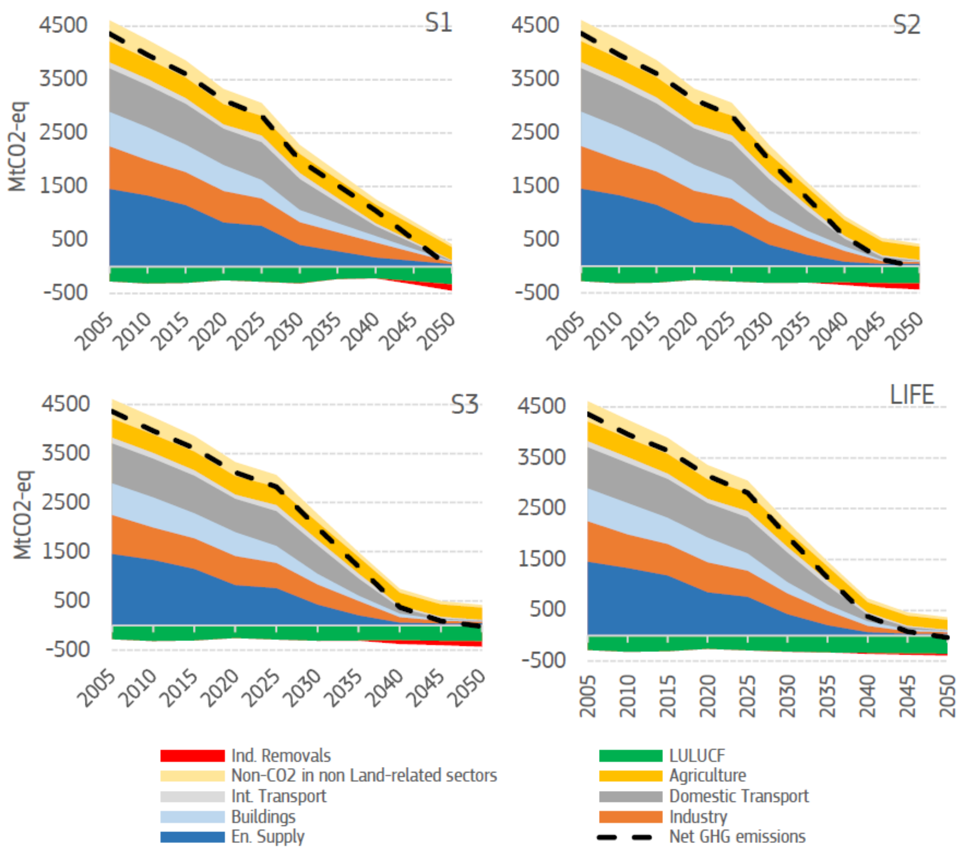
The EU Targets – 2040 (?)

Figure 5: Economy-wide GHG emission pathways



The EU Targets – 2040 (?)

Figure 6: Energy and Industry net CO2 emissions

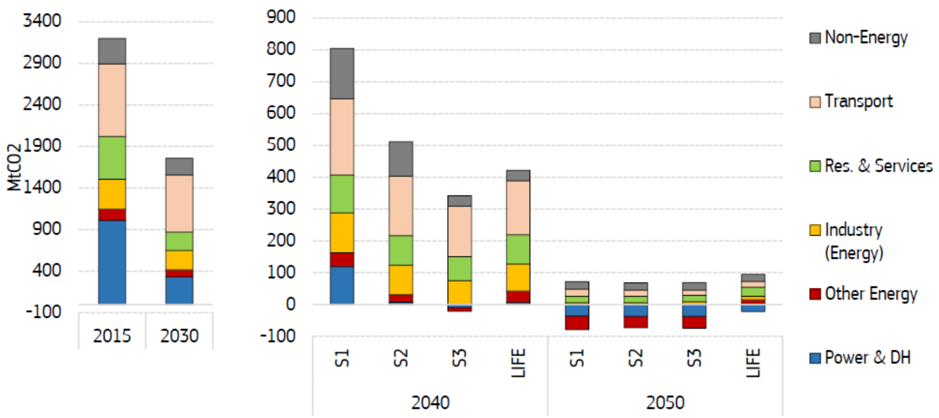
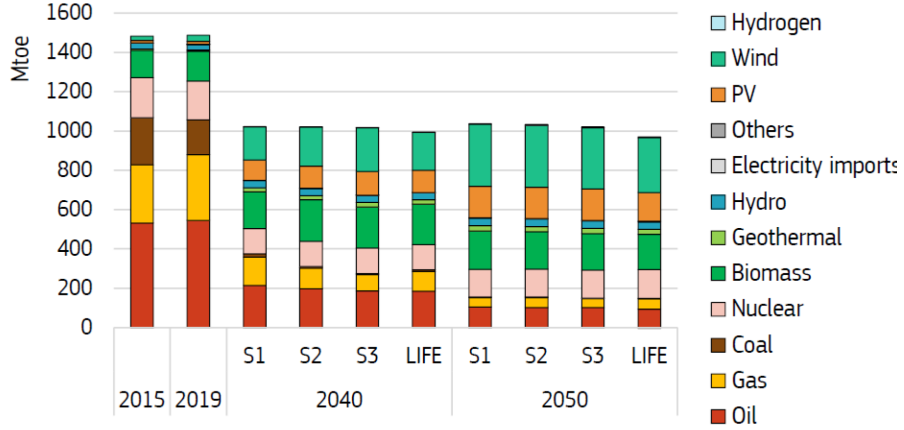
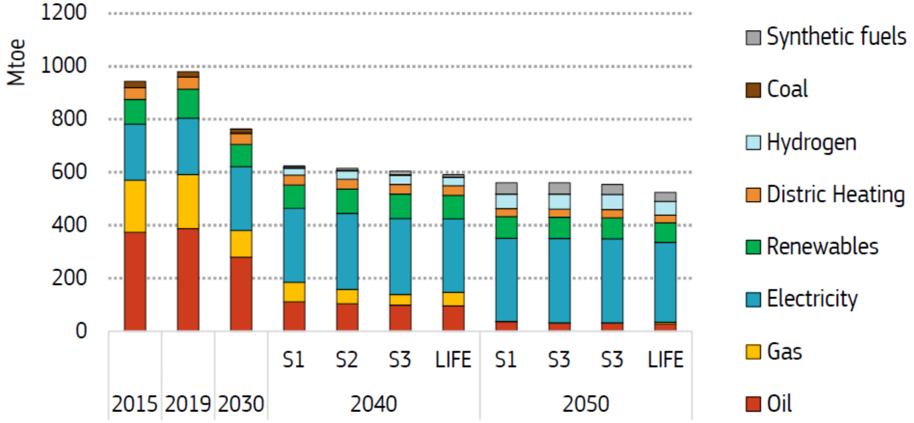


Figure 14: Gross Available Energy by energy vector, 2015-2050



Note: Biomass and waste include non-renewable waste. Natural gas includes also manufactured gas.

Figure 32: Final Energy Consumption by fuel, 2015-2050



SWD(2024) 63 final – Part 3 p 16, 27, 42

The EU Targets – 2040 (?)

Figure 18: Final electricity consumption by end-use sector

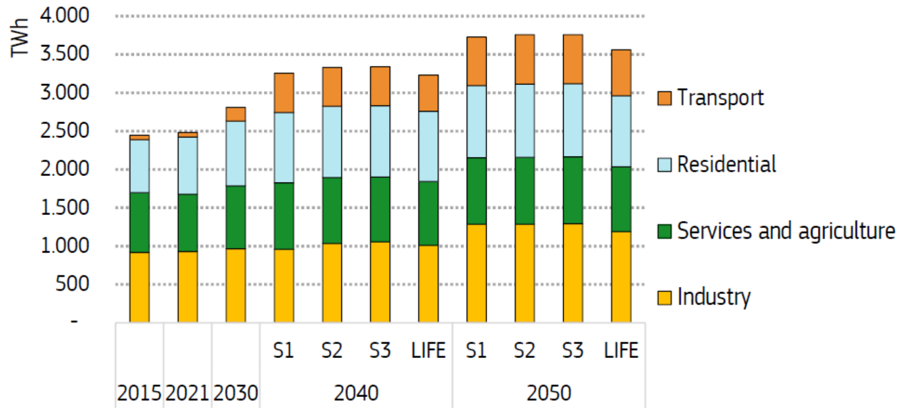


Figure 19: Electricity generation by energy carrier, 2015-2050

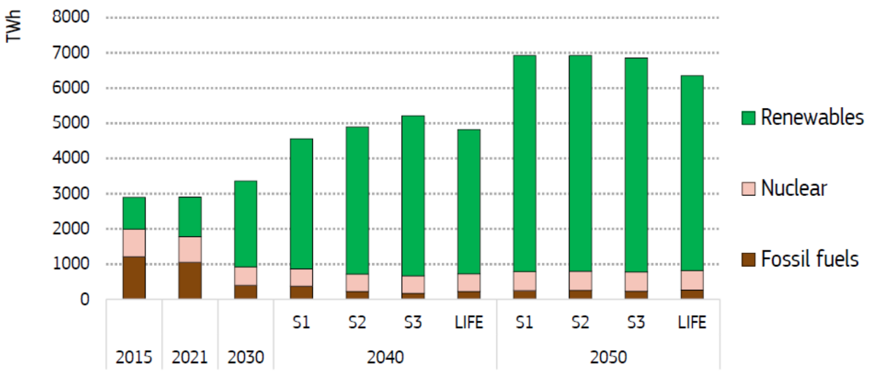
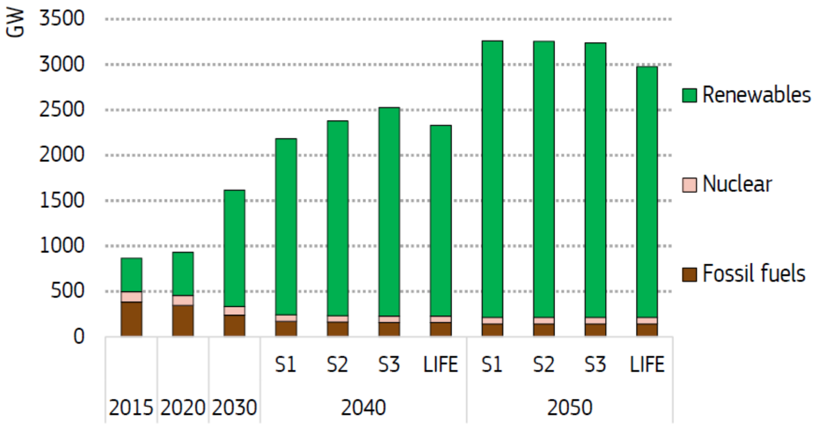


Figure 21: Net installed capacity by energy carrier, 2015-2050



The EU Targets – 2040 (?)

Figure 23: Net installed storage and new fuels production capacity, 2015-2050

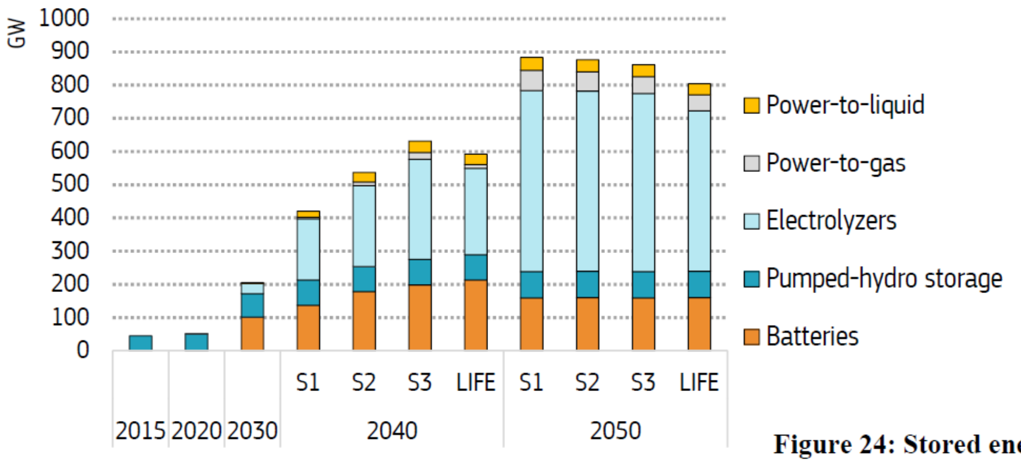
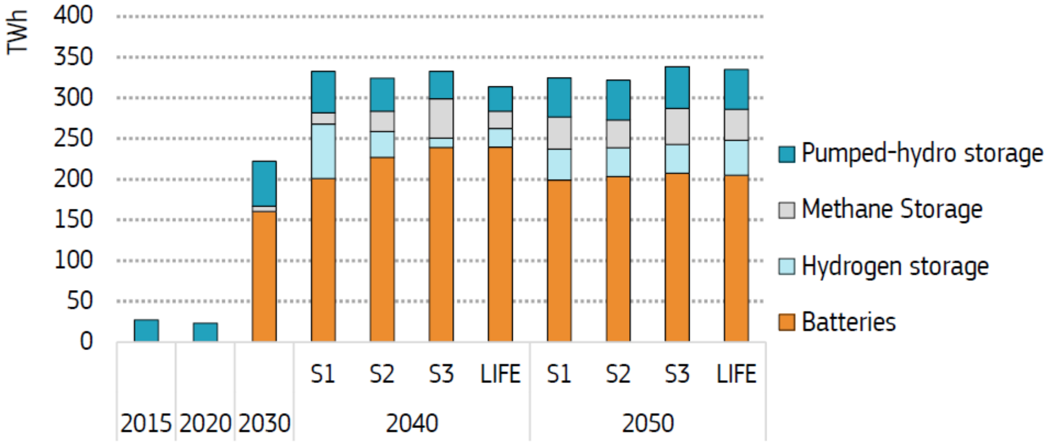


Figure 24: Stored energy by technology, 2015-2050



The EU Targets – 2040 (?)

- Does one realize the difficulties with these 2040 targets?
- How about public acceptability?
- How about the overall system costs?

A target of 90% will require greater focus and effort to ensure a just transition than for less ambitious target options, as the transition is somewhat accelerated. While the difference across options in costs for households is limited (notably thanks to higher energy efficiency in Option 3 that limits energy purchases), the post-2030 policy framework should include adequate policy measures to ensure affordable energy prices and access to decarbonised solutions. Redistributive measures will be essential to address social impacts so that no one is left behind.

The resulting energy system costs ([13]) are also similar across options, ranging from 12.4% (Option 1), 12.7% (Option 2) to 12.9% of GDP (Option 3) in 2031-2040, a moderate increase compared to the 11.9% of GDP spent in 2011-2020, and then fall to about 11.3% for 2041-2050. The cost of fossil fuel imports decreases significantly under Option 3, to less than 1.4% of GDP by 2040 and less than 0.6% in the last decade (against 2.3% over 2010-2021 and 4.1% in 2022 during the recent energy crisis), saving about €2.8 trillion over 2031-2050.

The EU Targets – 2040 (?)

Actual targets

to be defined by the

new Commission, Council & EU Parliament…

Stay tuned…

Nuclear – Quo Vadis?

Possible role of nuclear in future energy systems?

Nuclear – Quo Vadis?

- Currently (esp. after Feb 24, 2022) new ‘renaissance’ of nuclear in EU; several decisions taken by EU governments (and globally)

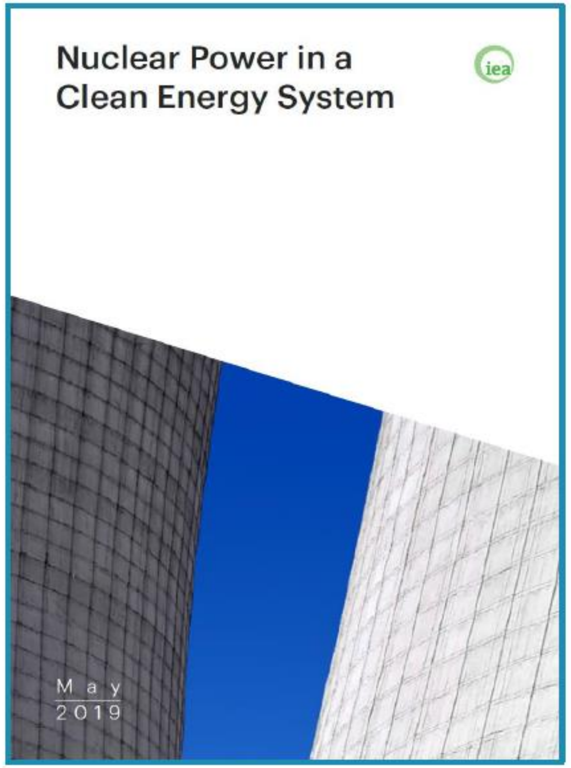
- Important distinction:
  - Long Term Operation (LTO) of existing safe plants
  - New Build
    - Classical big reactors (EPR, AP1000, …)
    - Small Modular Reactors (SMRs)

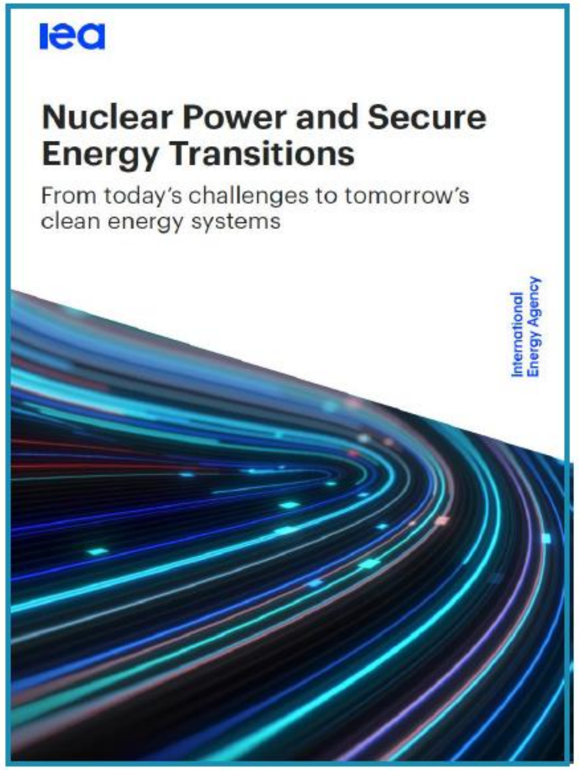
- Next 10-15 years, much LTO and some new build / pilot plants with ample government support…

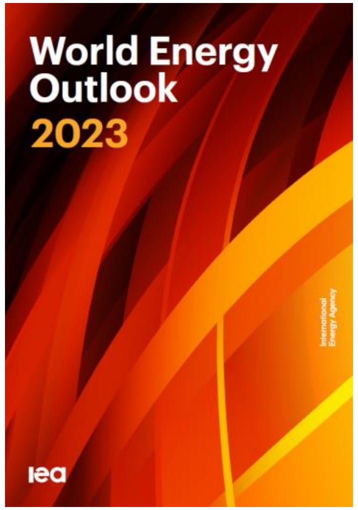
- But long-term success? ***Proof of the pudding is in the eating***…

Nuclear – Quo Vadis?

Interesting references







And for general context,
→ IEA WEOs…

Nuclear – Quo Vadis?

- Important preliminaries:
  - *New* meanig of ‘baseload’ (actually 3 different concepts)
  - NPPs are able to participate in load following (perhaps after study)
  - LTO? A system has no a-priory technical lifetime;
    Only economic lifetime or political lifetime

Nuclear – Quo Vadis?

'Composition' & behavior of the electricity generation system will depend on:

- Geography (location e.g., near sea, elevation, …) & meteorology
- governmental policies: exogenously 'imposed' constraints on the system – cfr DE
- and imposed targets (e.g., share of renewables, green hydrogen, EVs, heat pumps, …)
- further reductions cost PV, wind & batteries expected
  (even in fragmented non-global world with technological 'strategic autonomy)
- expect ample VRE into the energy system / huge installed VRE capacities / increased electrification
- behavior depends on 'flexibility' options (with evolution over next 10…:30 years):
  - Flexible thermal generation (CCGT or OCGT with CCS, or biogas, …)
  - Electrical transmission
  - Active demand response / participation; sector coupling
  - Energy storage (PHS, batteries, …)

Nuclear – Quo Vadis?

'Composition' & behavior of the electricity generation system:

- ../..
- with realistic 'obstacles' (permitting, licensing, BANANA, …) LT VRE share ~ 70…90%
- because LT storage (seasonal / Dunkelflaute), most analyses 'find' gap-filling technology:
  CCGT+CCS, H_2, NPPs, geothermal
- future of nuclear will largely depend on investment cost
- realistic contribution elec *energy* share nuc ~ 10-20-30% depending on the above…
- but, may need 'substantial' installed *capacity* nuclear power plants!

Nuclear – Quo Vadis?

- Latest record for new build in EU and USA abysmal…
  - Finland, France, UK, USA
  - However UAE quite succesful

- How about SMRs?

SMRs are a ‘business concept’; with various technologies

from evolutionary ‘downscaled’ Gen iii reactors (AP 300) to *Gen iv* or *v* advanced reactors with new fuel cycles.

Immediate Challenges for SMRs

1. **Economics / Competitiveness**
   - VRE-dominated electric system → low Capacity Factor
   - Small size → no scaling effect per $MW_{installed}$

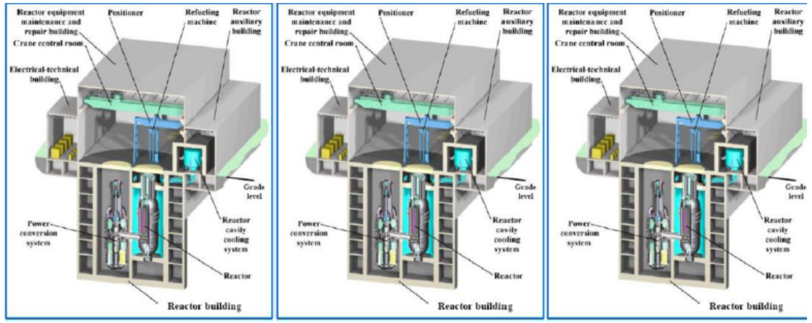
     → need large number of units manufactured

     → but now ~ 90 different 'designs'…

Immediate Challenges for SMRs

2. **Get novel / revolutionary SMR concepts approved by *Nuclear Regulators***
   - Must prove safety & acceptable back-end fuel cycle
   - How to bring regulators up to speed on new concepts?
     - Timely ‘education’ of, and knowledge transfer, to regulators
     - Pre-licensing trajectories recommended (learning by doing)
     - Need new ‘generation’ of nuclear students & graduates (familiar with e.g. fast-spectrum reactors)

What is an SMR?

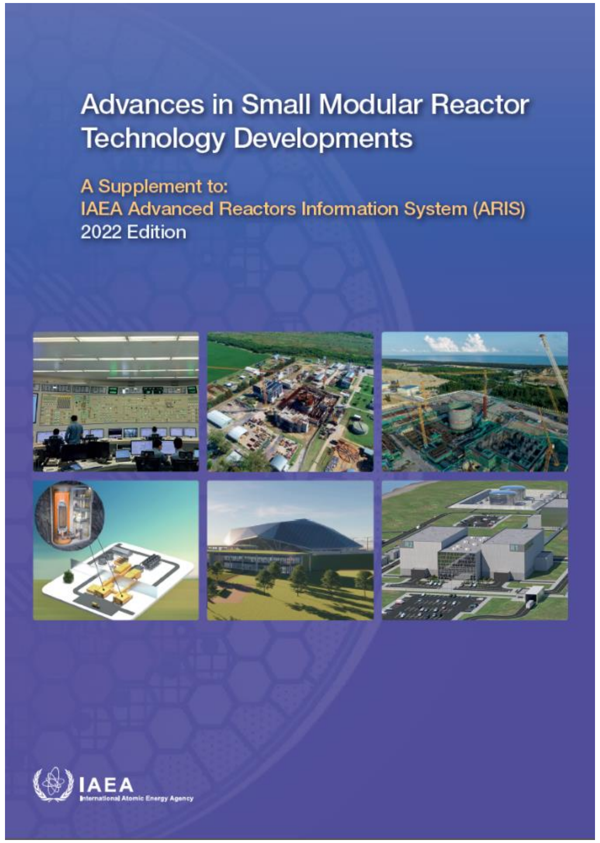


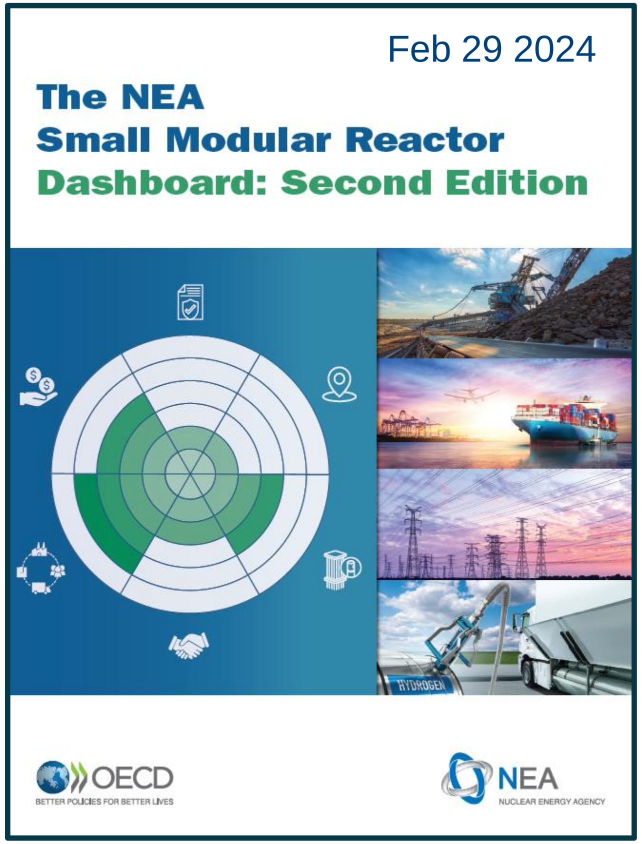
The *'modular'* in SMRs stands for two meanings:

1. Many small identical reactor units, sited next to each other as independent modules, making a power plant with bigger output.
   - Many of these identical modules could be placed at different sites at different locations around the world.
   - Extreme example: a reactor fitting in a container.

2. The major parts of a particular reactor of whatever size are built in a workshop, that will be brought to the site and assembled (klicked together) there.
   - Like IKEA or LEGO… / kind of **'prefab' construction**
   - Much less onsite work!

What is an SMR?





Future of SMRs?

SMRs *may* provide a potentially interesting nuclear technology

- A reasonable amount of R&D support is warranted
- Several different designs should be kept
- Give breathing space to small start-up companies
- When companies start using their own money, it looks interesting

- Important aspect will be standardization of nuclear regulatory aspects!
- A stable policy & investment environment is necessary

- **It is up to the 'nuclear fission community' to prove that they can make it work!**

Wrap up – Key Takeaways

- The Energy Transition is not to be underestimated!
- Do not forget the societal aspects (pace of transition?)
- Reflect upon taxes (polluter pays; ETS) versus subsidies (IRA)
- Much can be helped via expansion transmission network
- But permitting, permitting and permitting???

- Uncertainties:
  - Geopolitics / EU politics
  - Role of Natural Gas, CCUS, DAC, Hydrogen, Bioenergy
  - Which technology has priority on the grid?

- **Remain optimistic, but realistic: be a *‘possibilist’*;**
  be transparent about the costs and difficulties.

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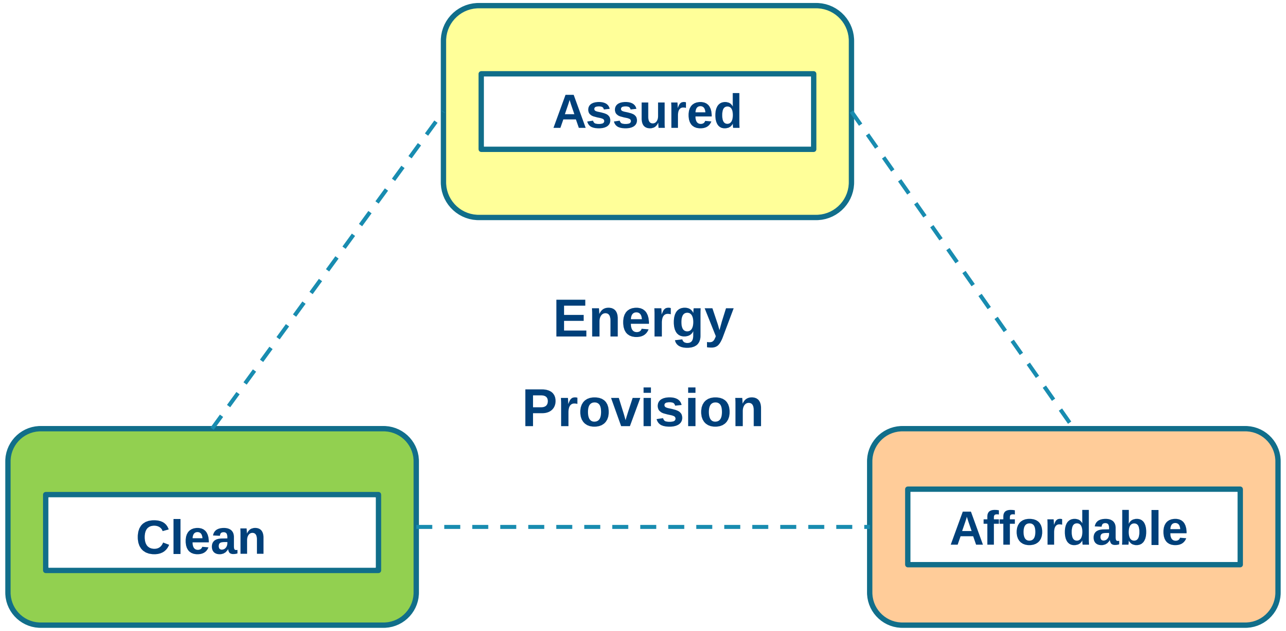
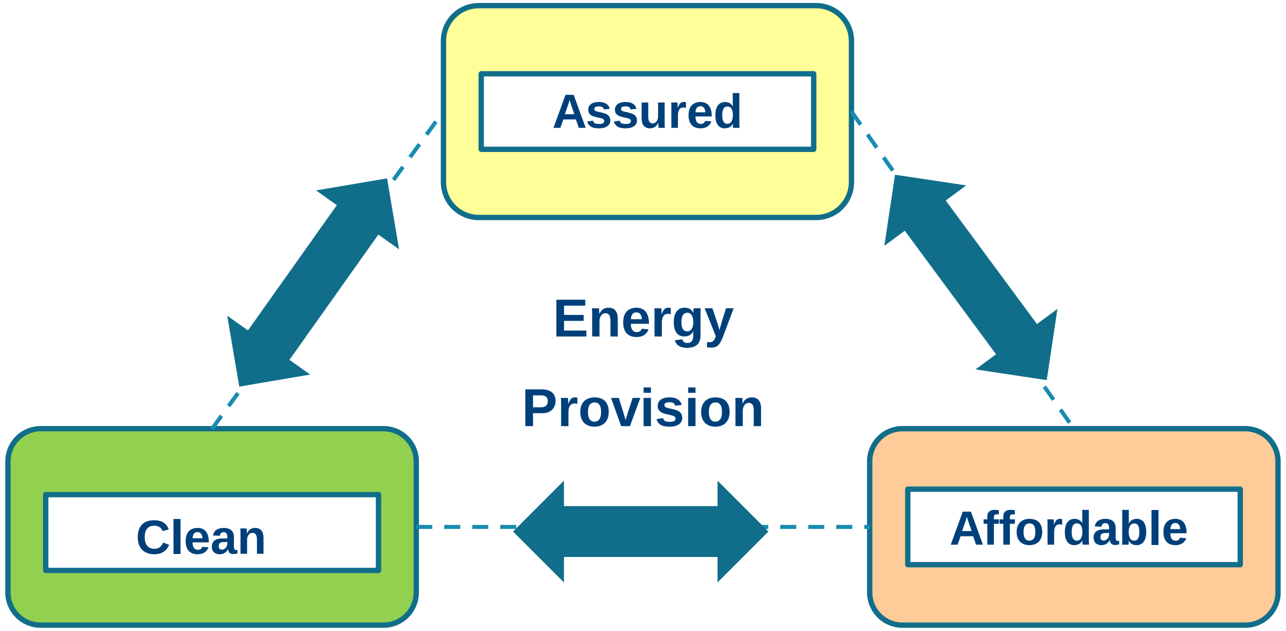
Backup slides


Assured
Energy
Provision
Clean
Affordable



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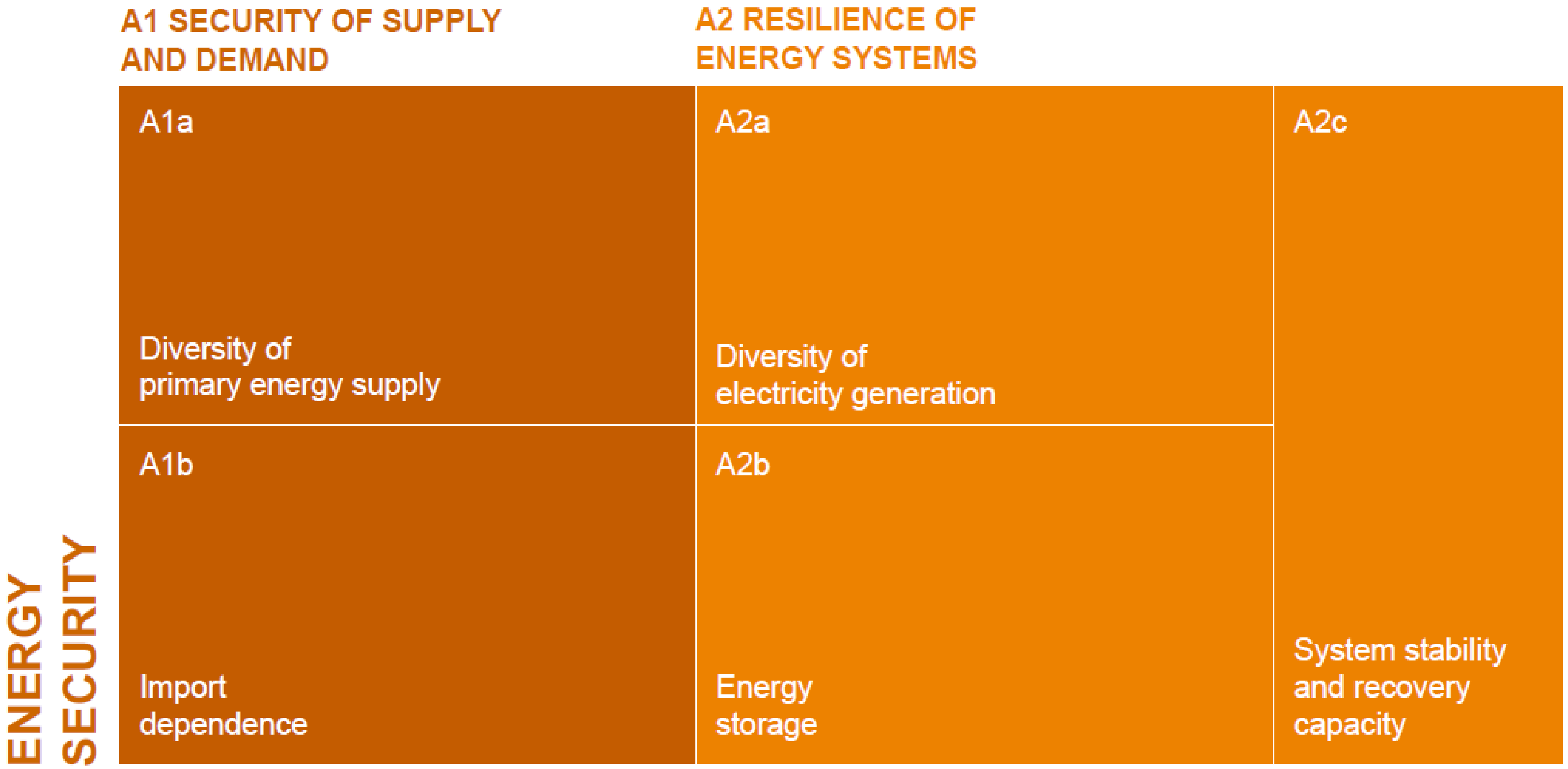
Energy Trilemma Index structure and weighting of the indicators



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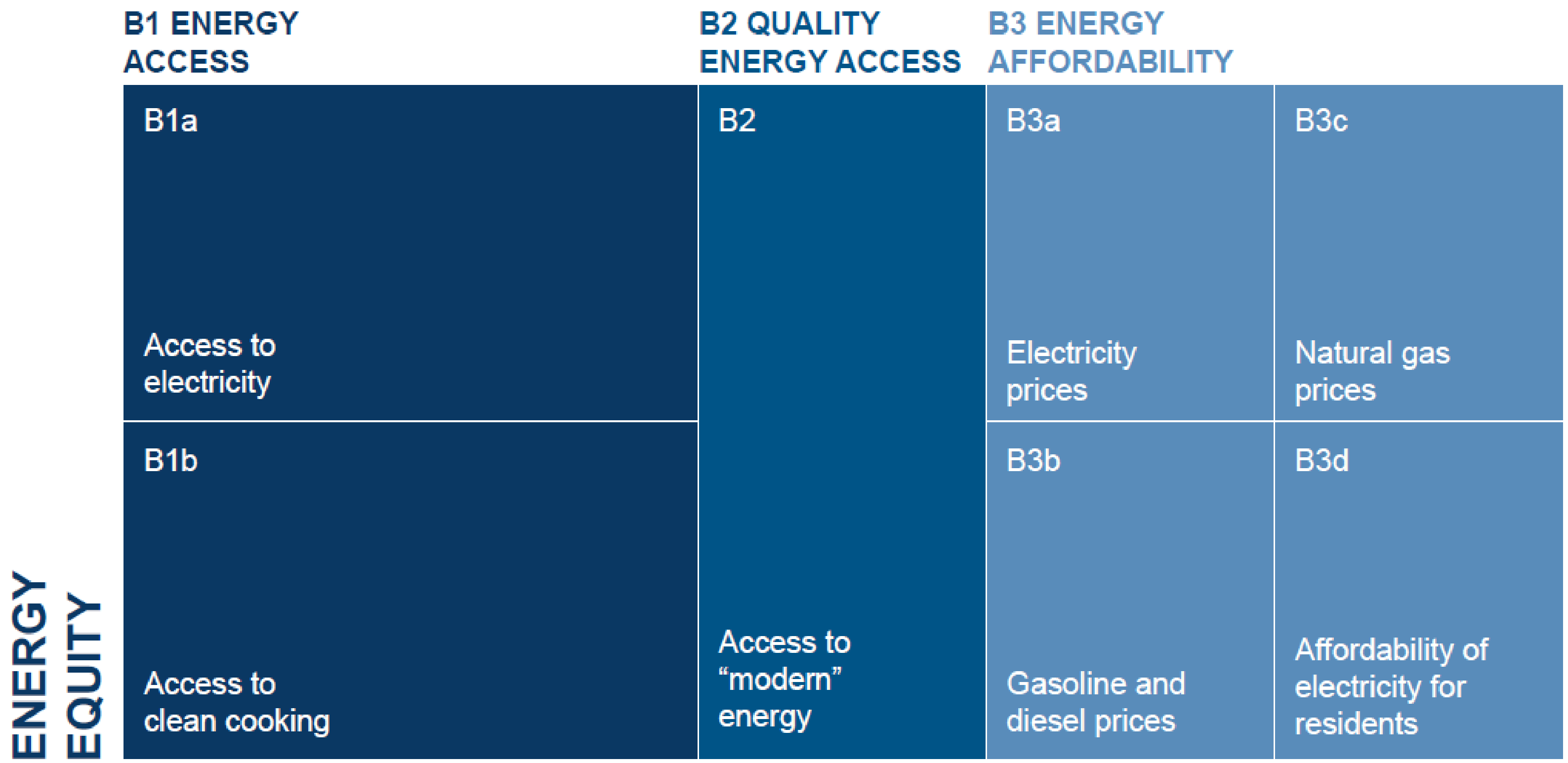

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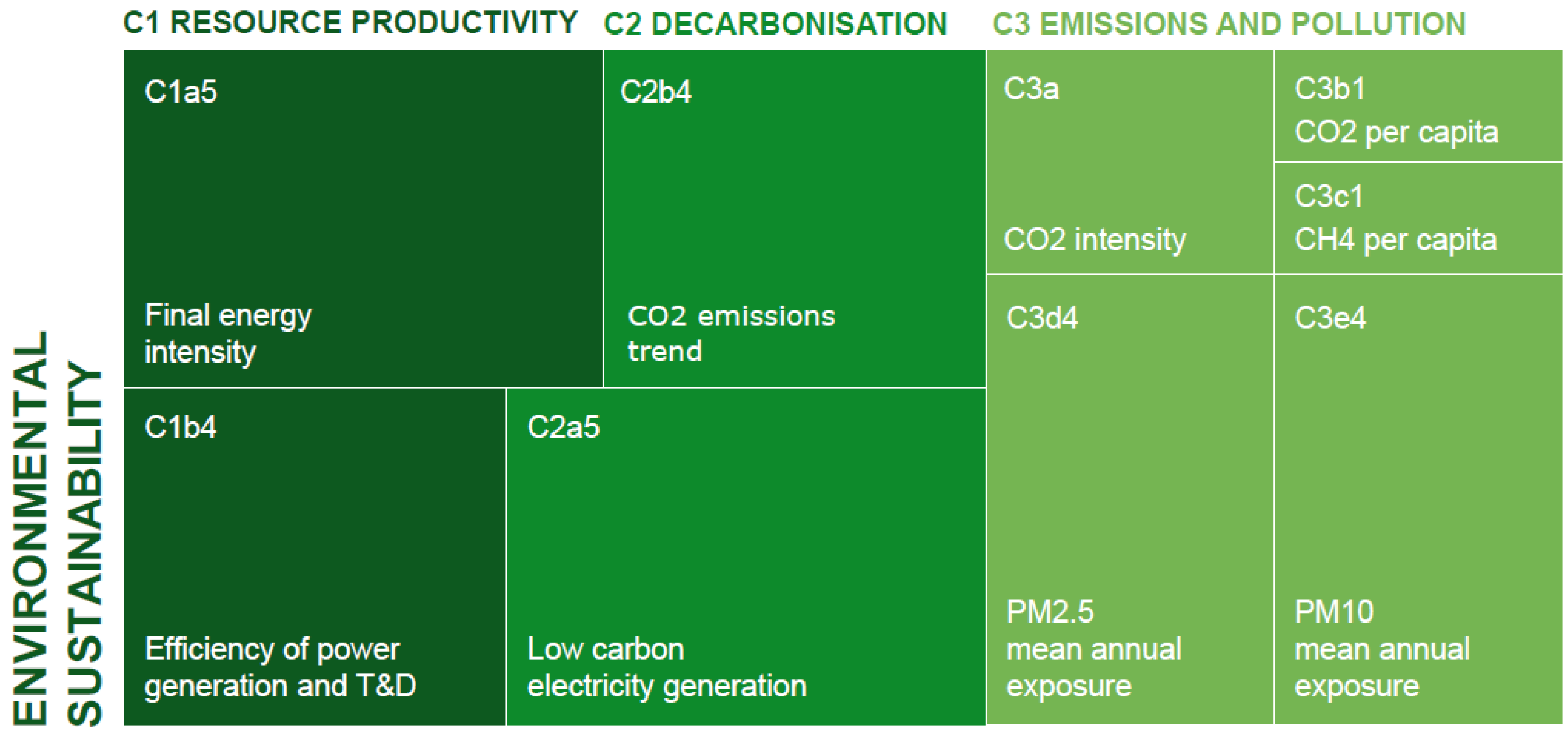

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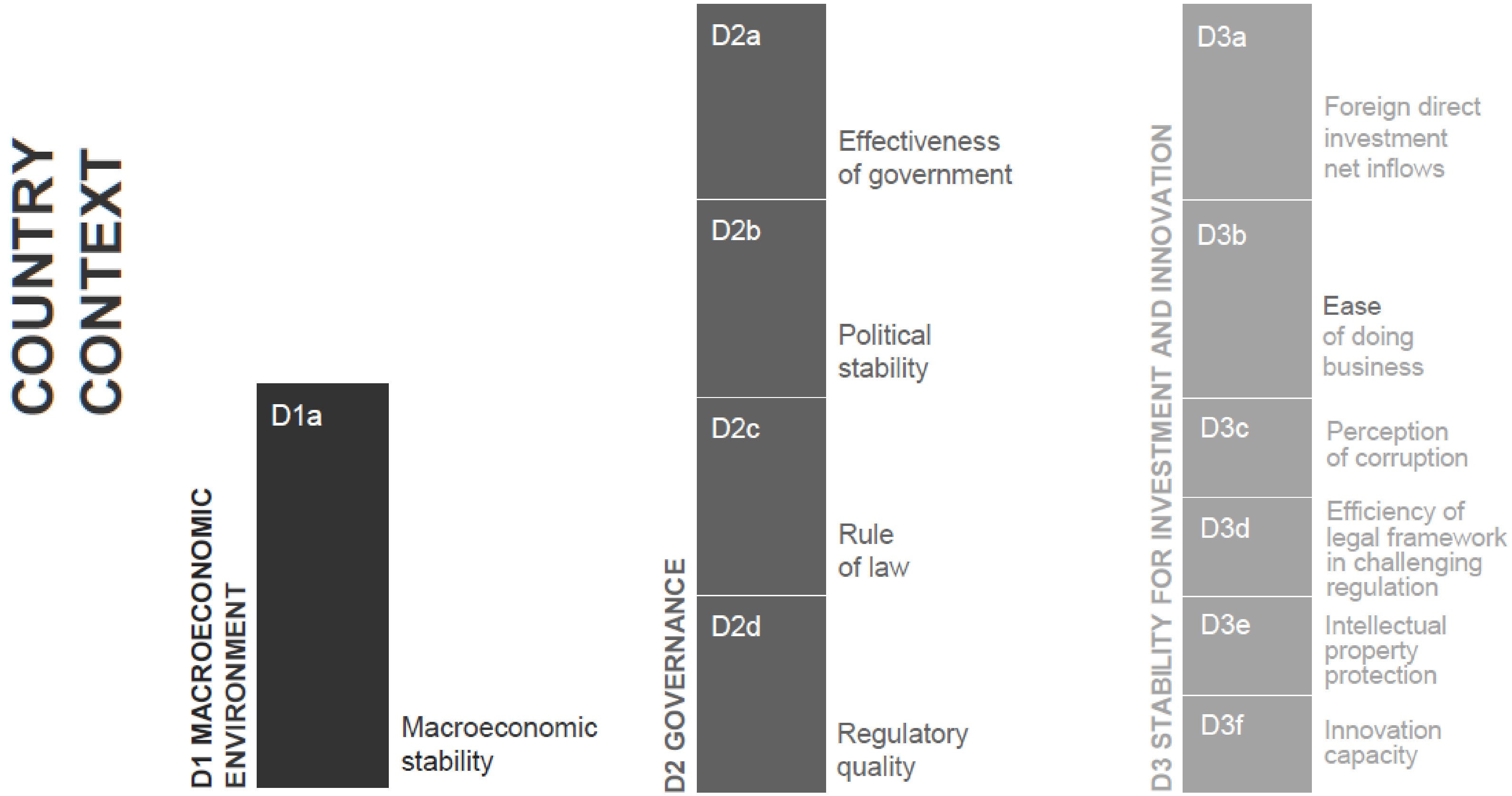

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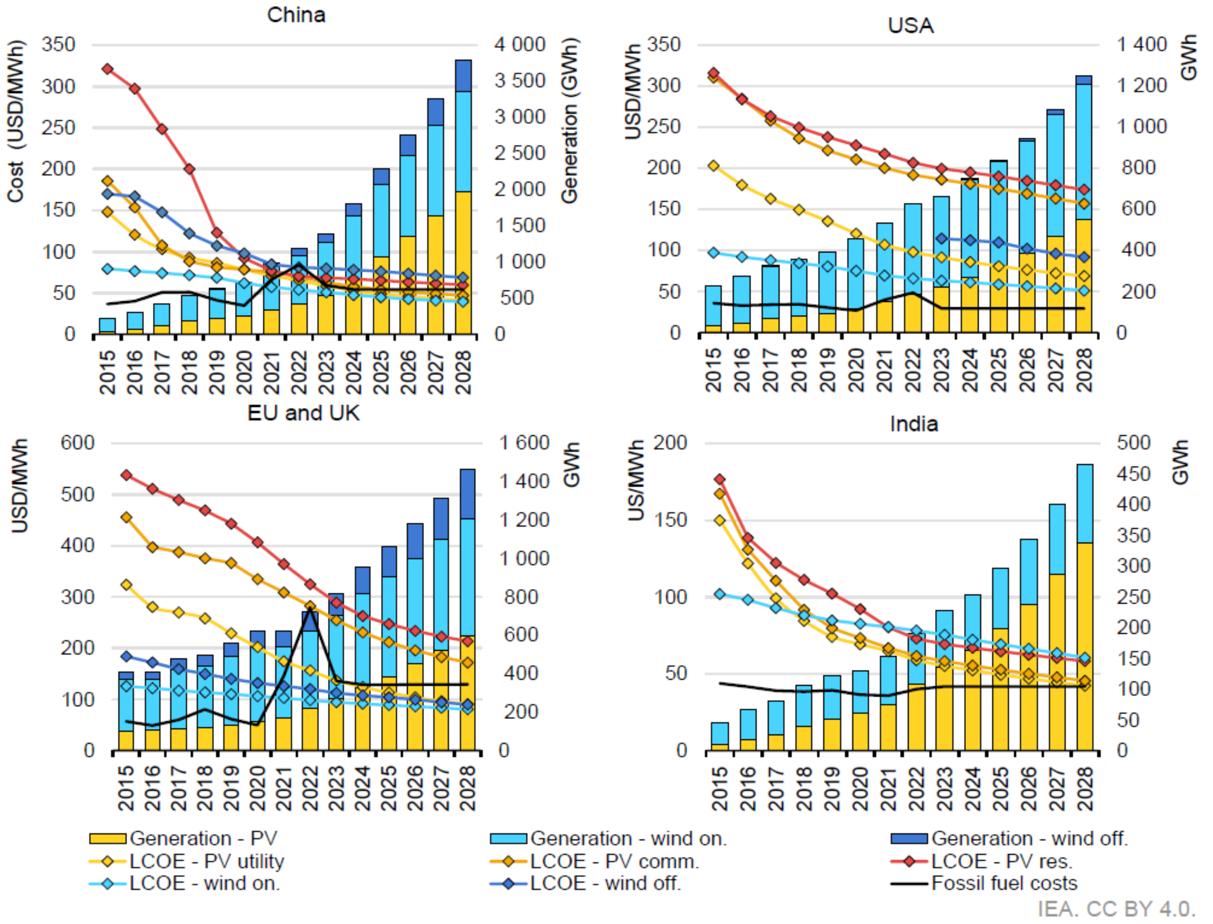
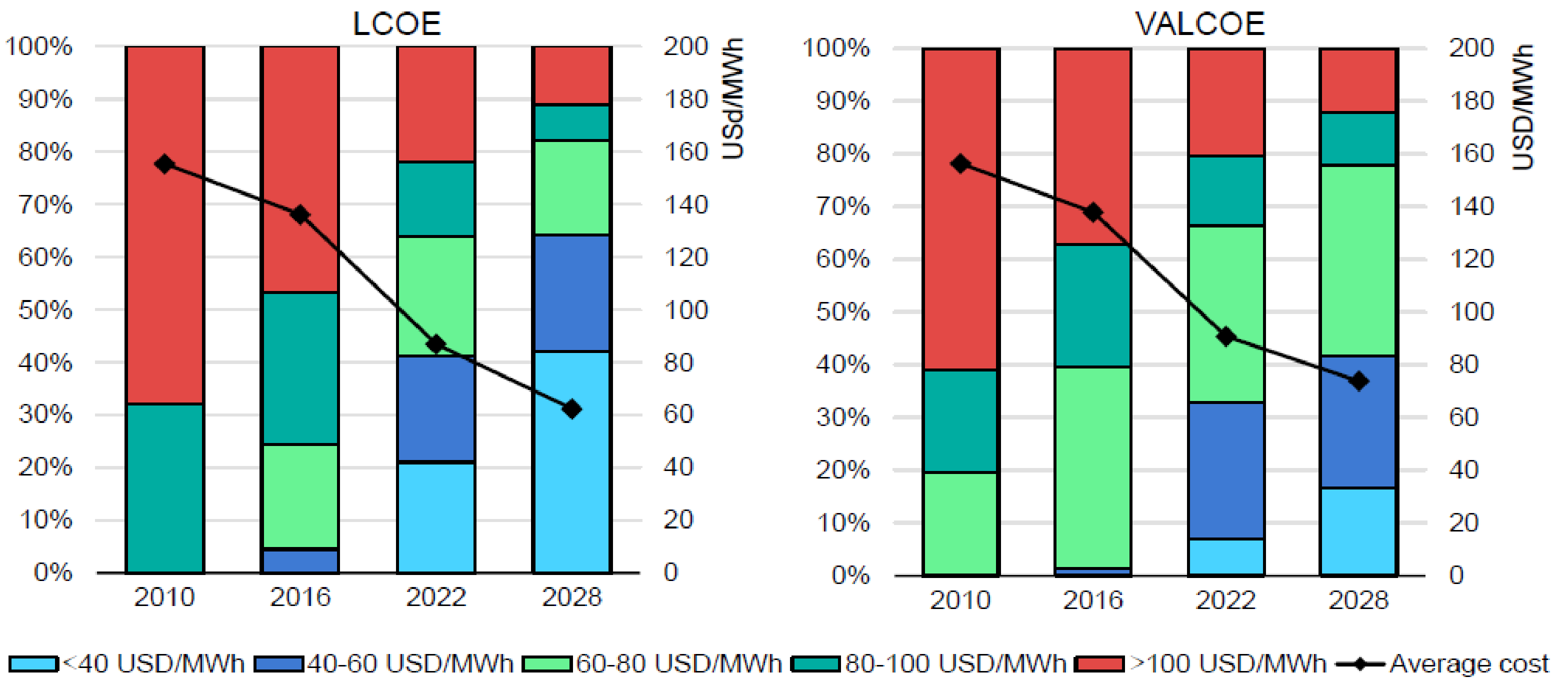


Notes: LCOE = levelized cost of electricity. Wind on. = Wind onshore. Wind off. = Wind offshore. PV comm. = PV commercial. PV res. = PV residential.

Share of global PV and wind electricity production by generation costs, LCOE (left) and VALCOE (right) approach, 2010-2028



Notes: LCOE = levelized cost of electricity. VALCOE = value-adjusted LCOE.

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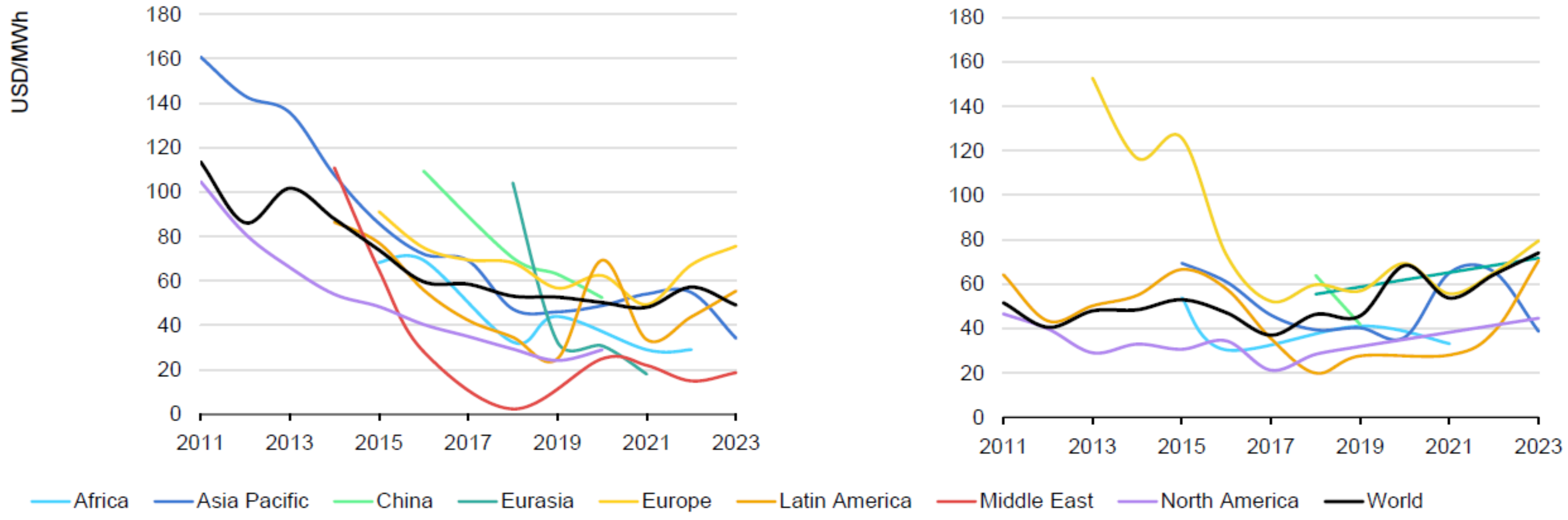
Average auction prices by region for solar PV (left) and onshore wind (right)



Note: Asia Pacific excludes China.

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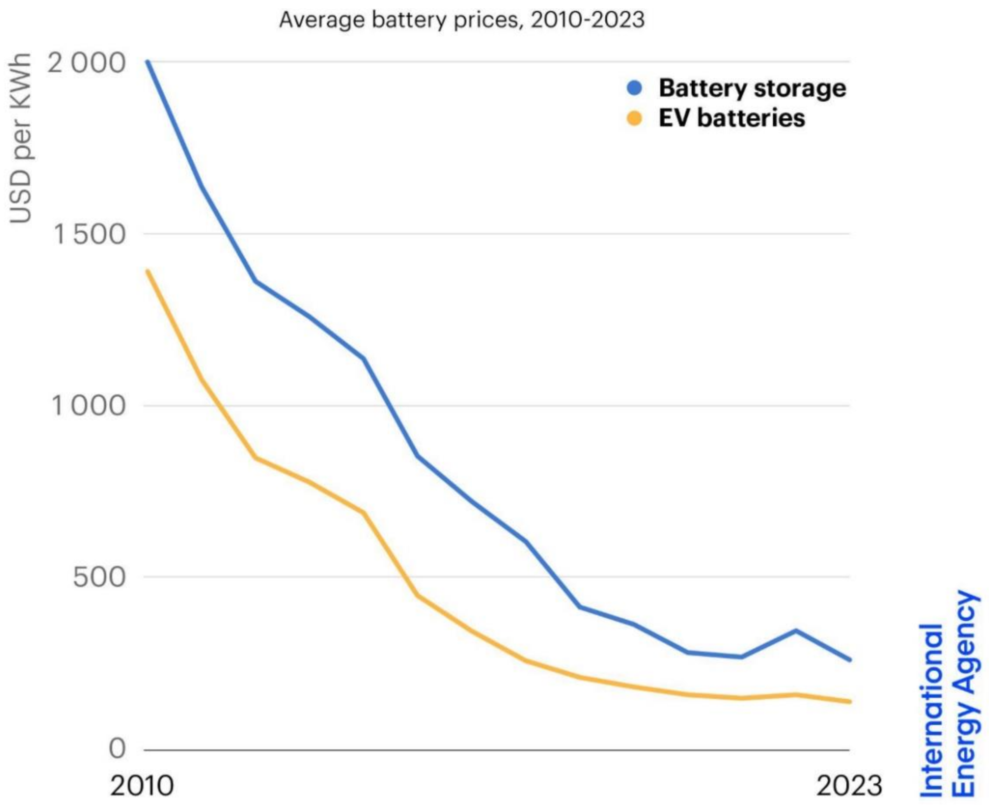
In less than 15 years, battery costs have fallen by more than 90%, one of the fastest declines ever seen in clean energy technologies



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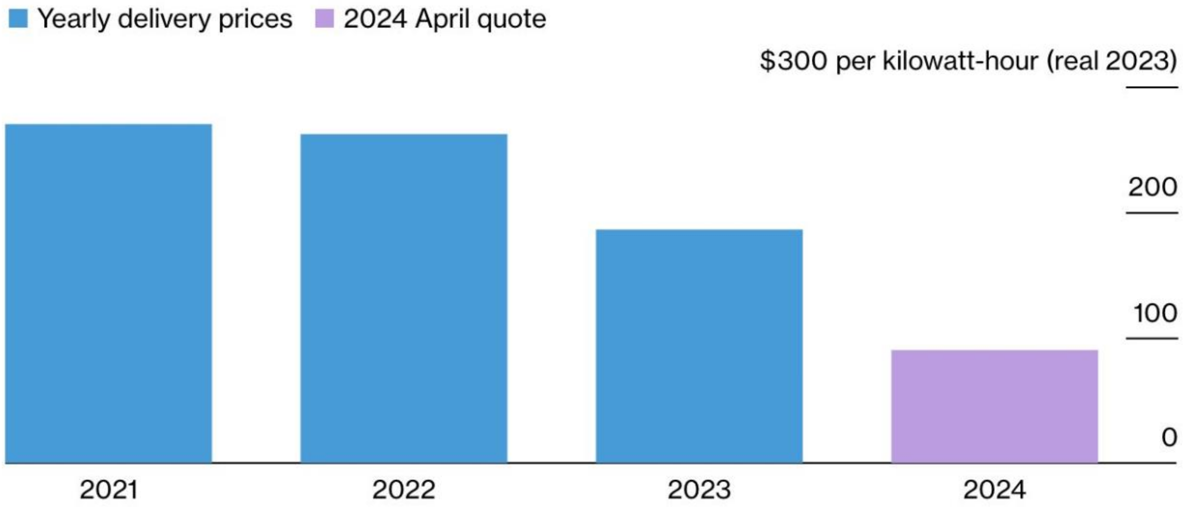
Energy Storage System Prices Drop in China

Quoted China energy storage system prices more than halve in 2024



Source: BloombergNEF, participants at the 12th Energy Storage International Conference and Expo (ESIE).

BloombergNEF