Energy and Climate Crises: winners and losers and the role of nuclear power

2023-11-28 NRG Briefing on COP28

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Chair, CIGS Study Group on Next Generation Nuclear Energy Utilization
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Executive Director Emeritus, the IEA
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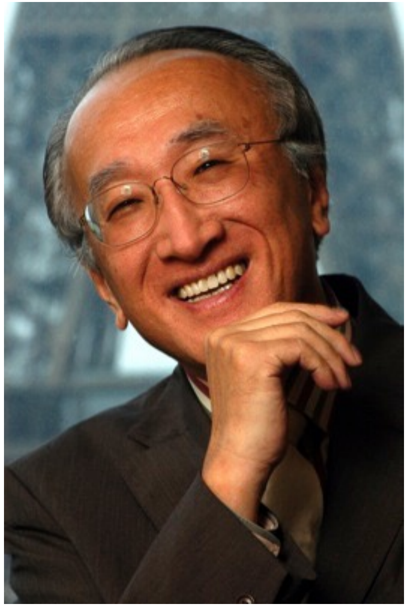
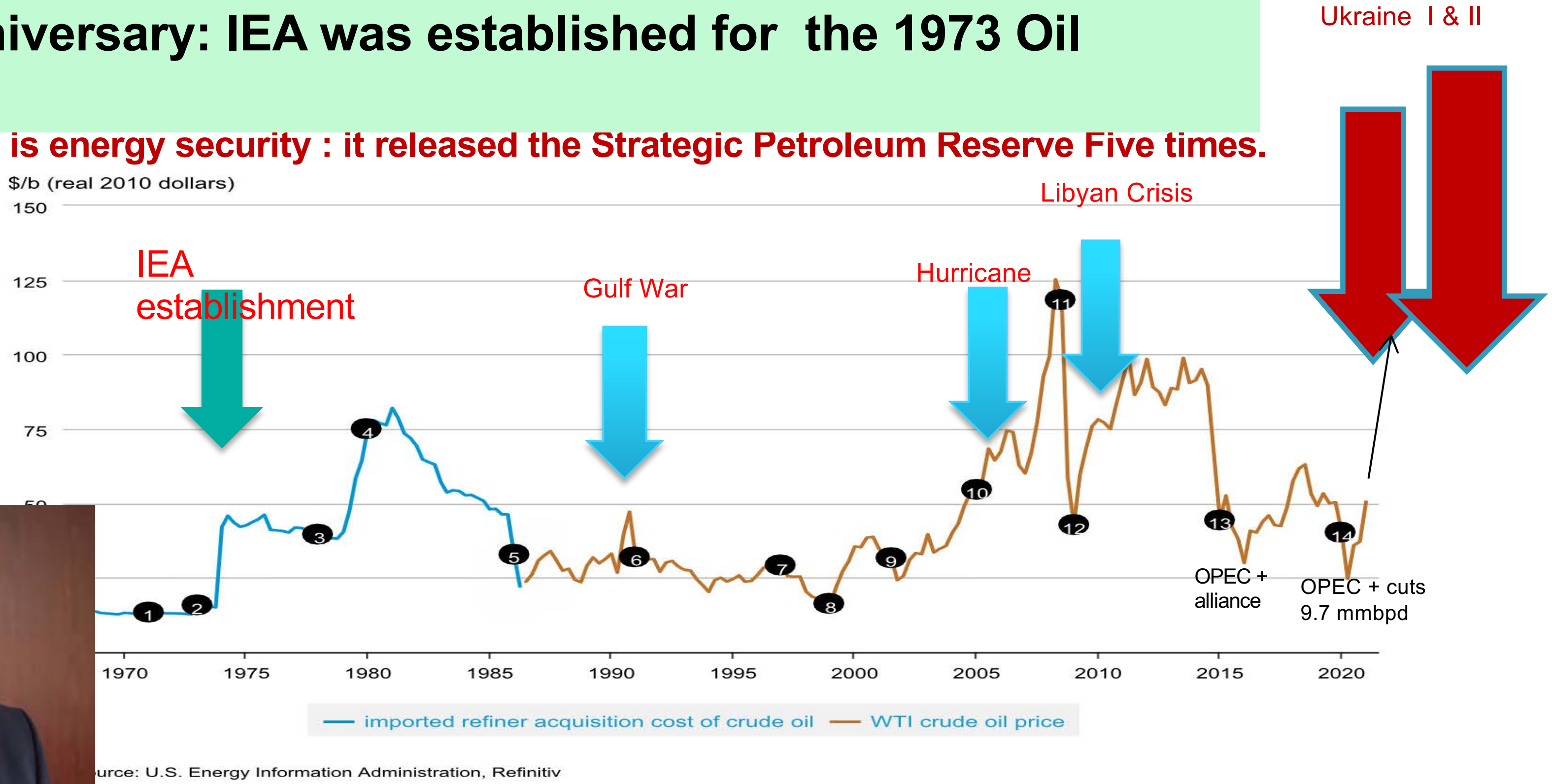


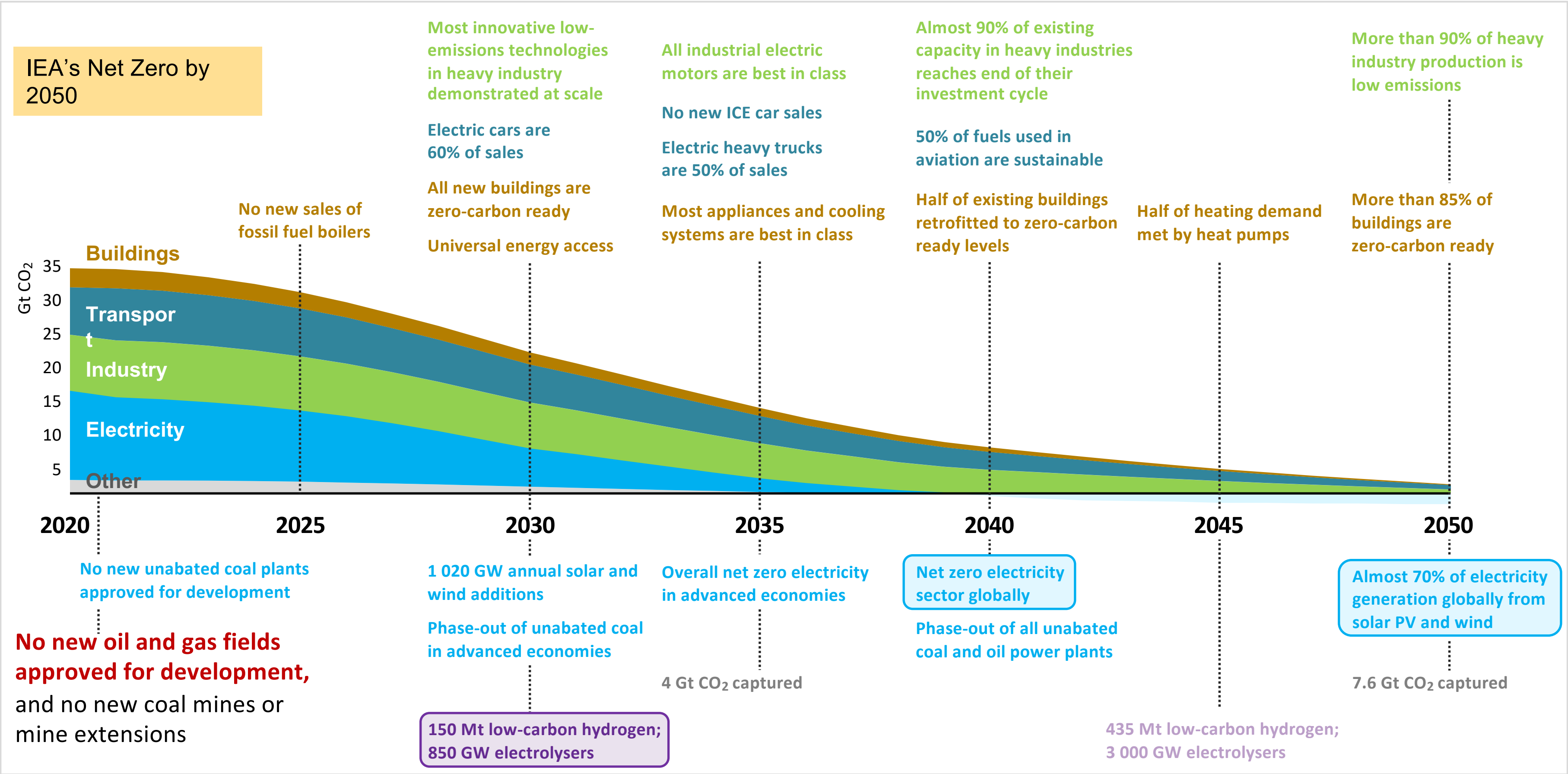
50th Anniversary: IEA was established for the 1973 Oil Shock

IEA's mission is energy security : it released the Strategic Petroleum Reserve Five times.



Dr. Fatih Birol, Executive Director of IEA says that we are in the middle of the "first truly global energy crisis".

“Net Zero by 2050” surprised OPEC and Oil Majors: The IEA Shock!



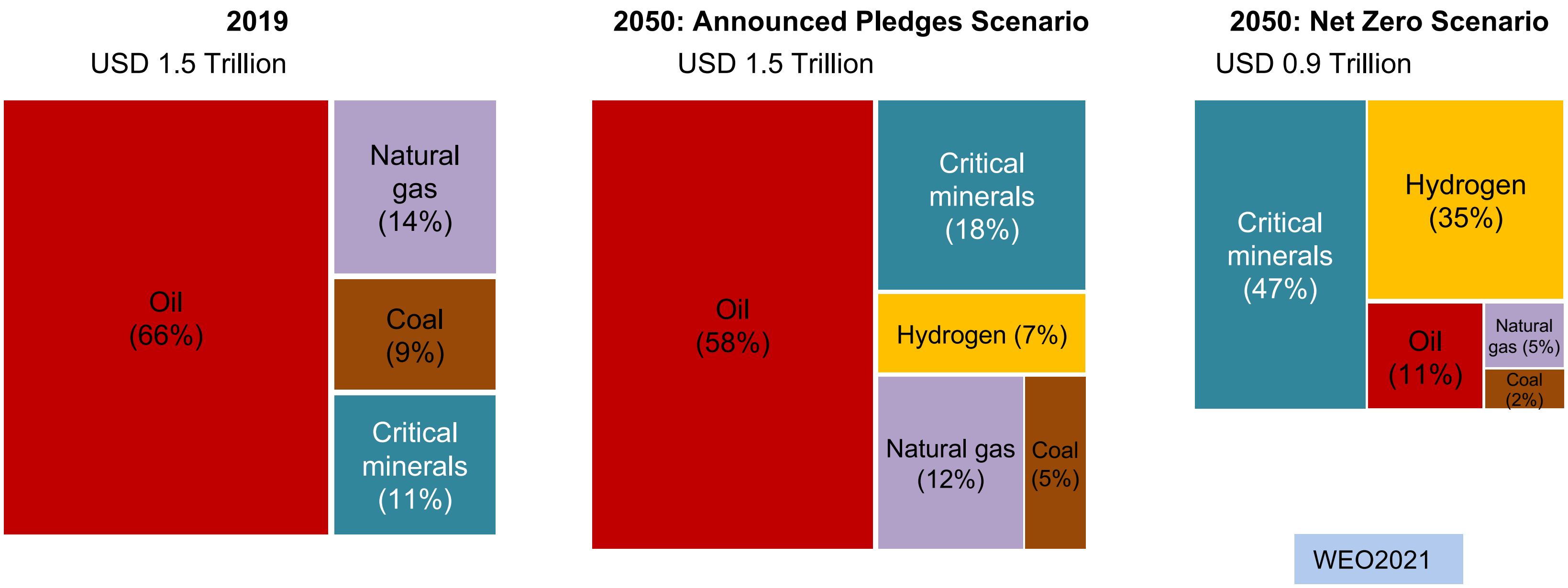
Net Zero by 2050 sets near-term milestones to get on track for long-term targets. (Back-casting)

Winners and Losers

Country	Short term	Long Term
Russia	- - Lost EU market, less revenue, more war expenses	- - Loss of tech, investment, brain drain
EU	- Gas Shortage & high price. Risk of complacency.	++ RE Power EU and CBAM H2 pipeline
US	+Shale gas boom, +IRA invites investment	++ IRA for CCS,EV,H2, Megatech to lead RE100
China India	+ Cheap Russian gas & oil	++ RE super power, - risk of supply chain + H2 super power
Saudi Arabia	++ High Oil price, ? OPEC+ vs US	? Blue H2 CCS, Green H2 solar, Mid East Geopolitics
Japan/ Korea	- High gas price. Russian retaliation?	? Sustainable nuclear, Clean H2 supply chain
ASEAN	- High gas price	? H2 supply chain, regional grid, JCM

Hydrogen by MCH/LOHC may replace SPR in the Net Zero Scenario

Value of international energy-related resource trade



In all scenarios, but especially in the net zero pathway, critical minerals and hydrogen-based fuels are on the rise

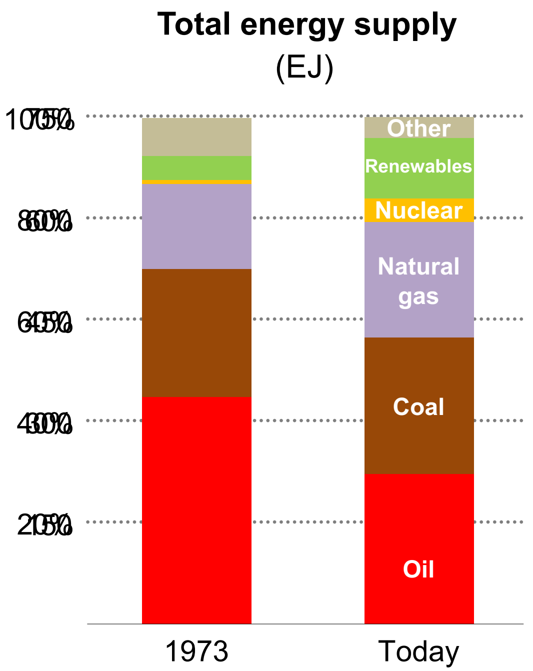
International Energy Agency

World Energy Outlook 2023

24 October 2023

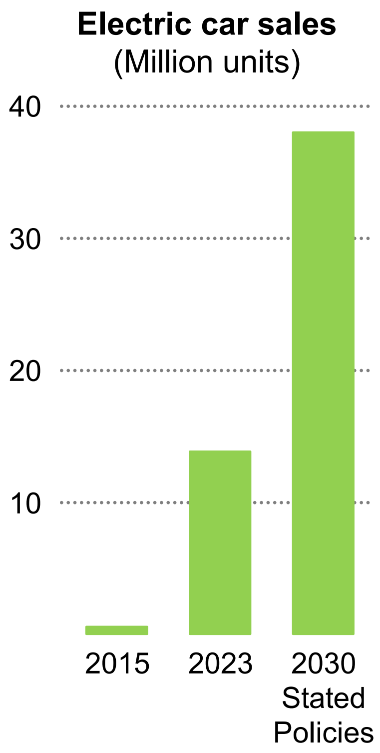
Fifty years on from the first oil shock

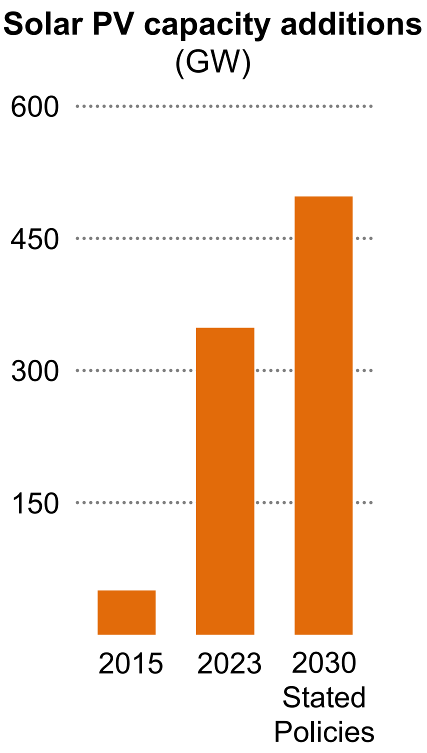
WEO2023

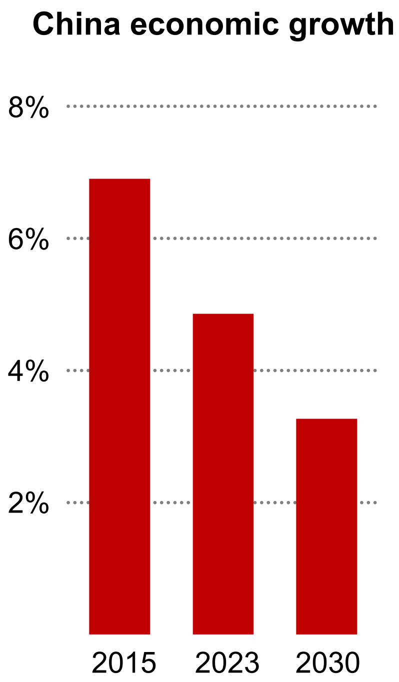


The world still faces acute energy security vulnerabilities,
but also has more tools than ever to change the outlook for global energy

Major structural shifts reshape the new *Outlook*





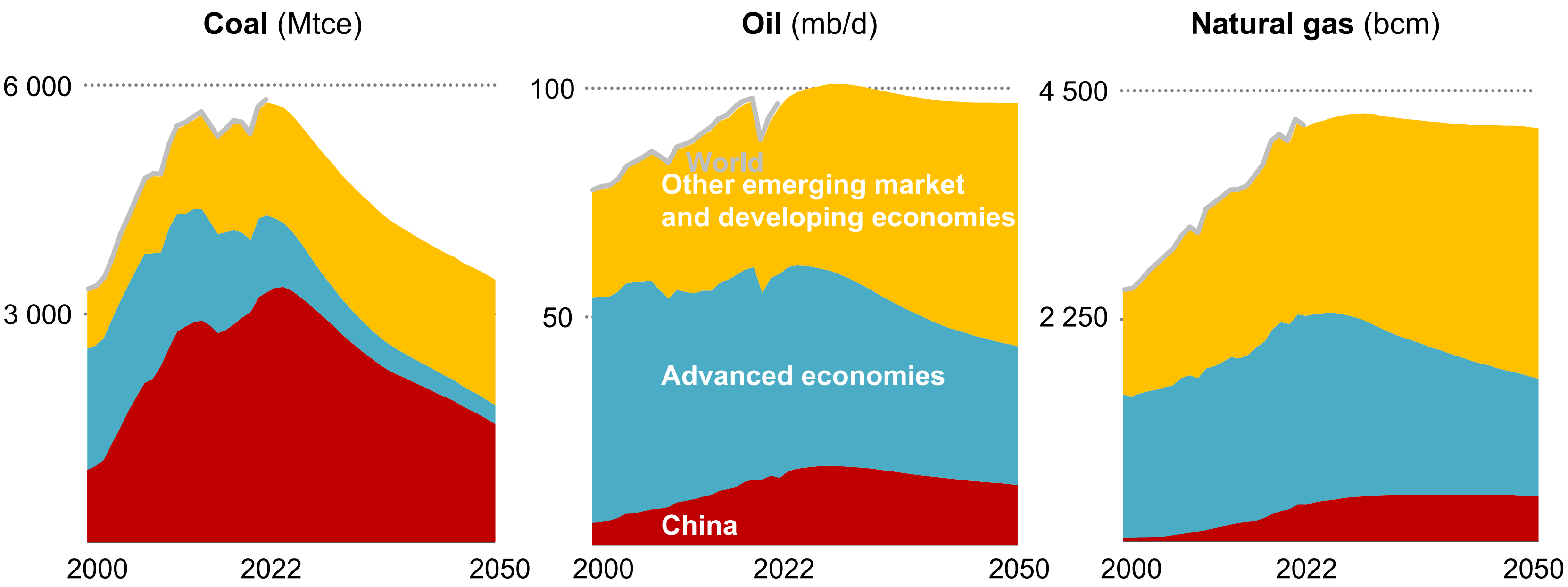


The huge surge of clean energy technologies such as electric vehicles and solar PV, combined with a rebalancing in China's economy towards a cleaner development model, change the trajectory for the global energy system

On track for a peak in all fossil fuels before 2030

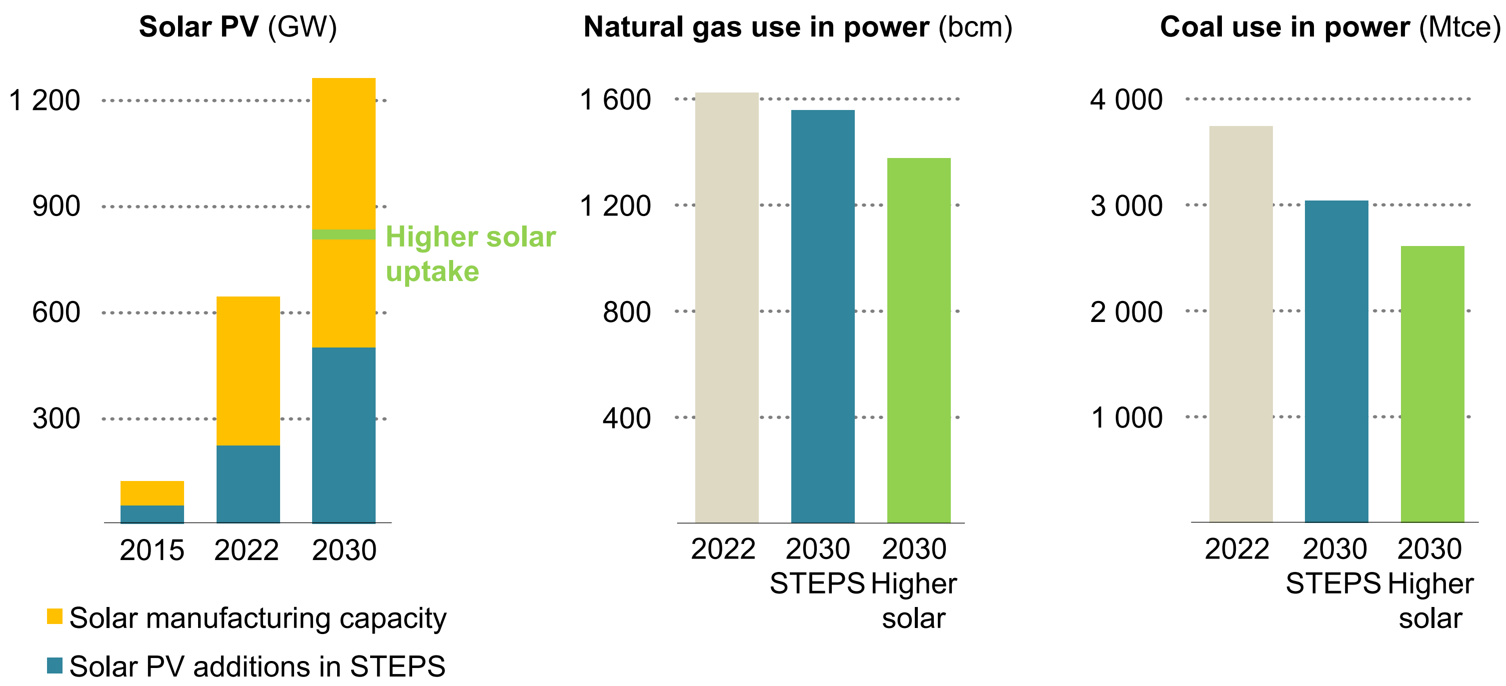
WEO2023

Fossil fuel demand in the Stated Policies Scenario (STEPS)



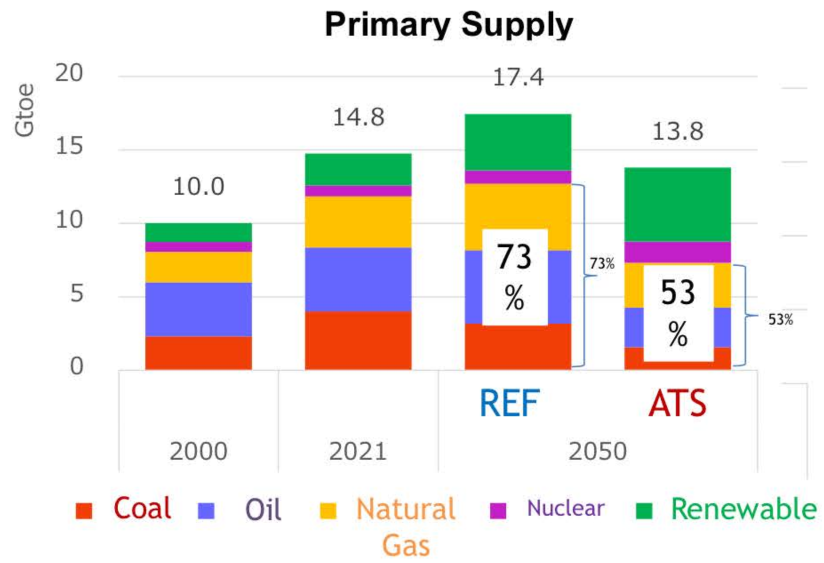
For the first time, today's policy settings are strong enough to generate peaks for coal, oil and natural gas this decade; the share of fossil fuels starts to edge downwards from 80% today to 73% in 2030

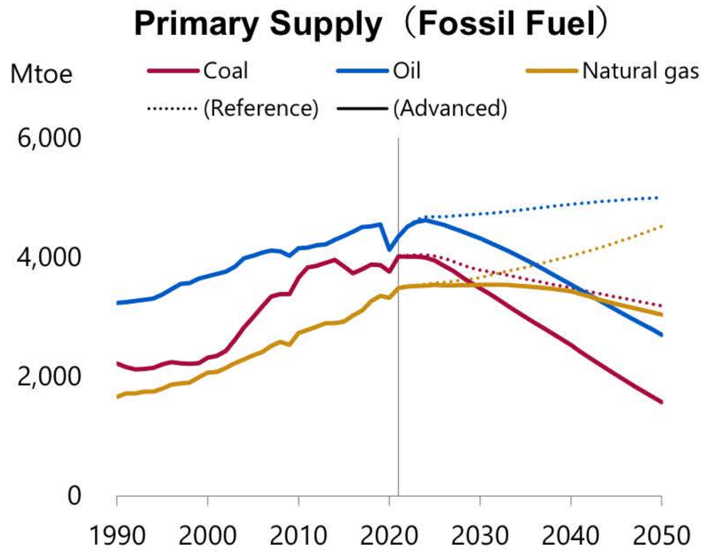
A solar boom could accelerate the shift away from fossil fuels



Ample global manufacturing offers considerable upside for solar.
Effectively integrated, this would further cut natural gas and coal use, making the declines steeper.

Primary oil and gas supply increases in Reference, and decreases in Advanced Tech..





- **(REF)** Primary supply in 2050 increases 1.2 times that of 2021, 73% of which will be fossil fuels. Oil demand increases 1.2 times and gas 1.3 times, while coal decreases 0.8 times.
- **(ATS)** Half of the primary supply is fossil fuels, and the other half is renewable and nuclear.

  Oil and coal supply peaks in the 2020s because of a decrease in transportation demand for oil and power generation demand for coal. Gas supplies remains flat until the 2030s and begin to decline before 2040.

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IEA WEO vs IEEJ Outlook：GDP growth assumptions

GDP Growth Assumptions

IEA

	Compound average annual growth rate			
	2010-2022	2022-2030	2030-2050	2022-2050
North America	2.0%	1.8%	2.0%	1.9%
United States	2.1%	1.9%	1.9%	1.9%
Central and South America	1.2%	2.3%	2.4%	2.4%
Brazil	0.9%	1.8%	2.3%	2.1%
Europe	1.7%	1.8%	1.4%	1.5%
European Union	1.5%	1.6%	1.1%	1.3%
Africa	2.9%	3.8%	4.0%	4.0%
South Africa	1.2%	1.3%	2.7%	2.3%
Middle East	2.5%	3.0%	3.1%	3.0%
Eurasia	1.9%	1.0%	1.4%	1.3%
Russia	1.4%	0.1%	0.6%	0.4%
Asia Pacific	4.8%	4.1%	2.9%	3.3%
China	6.5%	3.9%	2.4%	2.8%
India	5.7%	6.4%	4.3%	4.9%
Japan	0.6%	0.7%	0.5%	0.6%
Southeast Asia	4.3%	4.6%	3.3%	3.7%
World	3.0%	3.0%	2.5%	2.6%

Note: Calculated based on GDP expressed in year-2022 US dollars in purchasing power parity terms.
Source: IEA analysis based on IMF (2023) and Oxford Economics (2023).

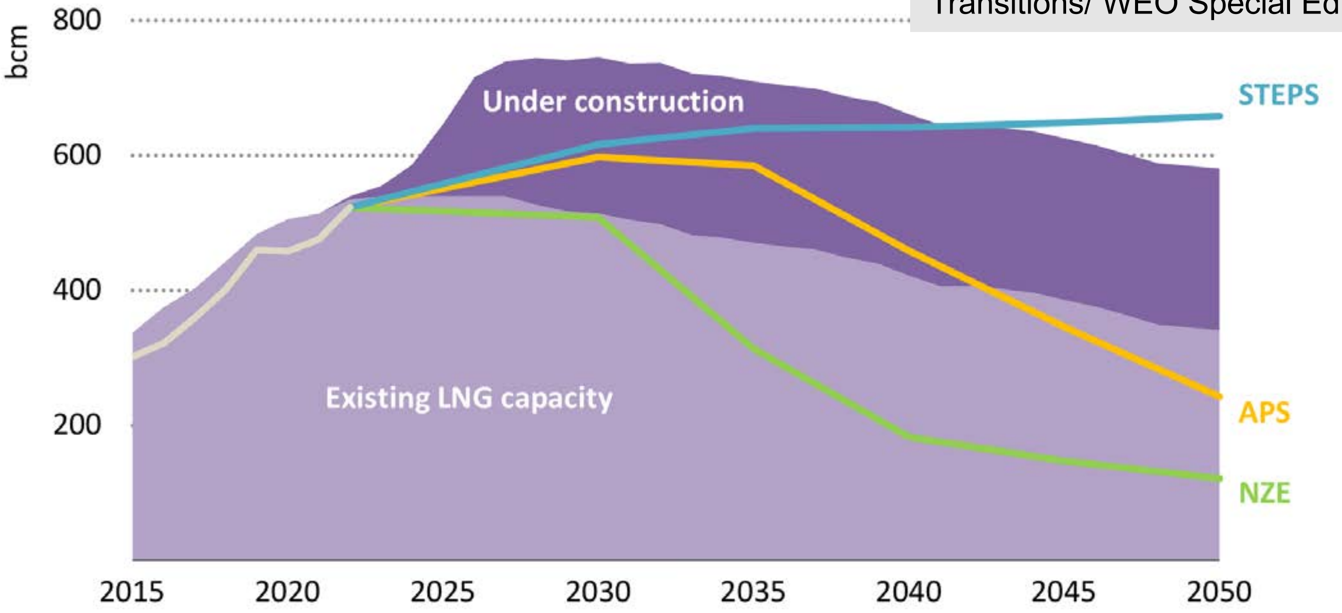
IEEJ

Region	2021/2030	2030/2050	2021/2050
North America	1.9	1.9	1.9
Central South America	2.5	2.8	2.7
Europe	1.8	1.4	1.5
Africa	4.1	4.7	4.5
Middle East	3.3	2.7	2.9
Eurasia	1.8	2.2	2.1
China	3.9	3.5	3.6
India	6.2	5.4	5.6
Japan	0.8	0.8	0.8
ASEAN	4.7	4	4.2
World	2.7	2.7	2.6

IEA's assumption is lower in Emerging Economies relative to IEEJ

Figure 1.18 ▷ Existing and under-construction LNG liquefaction capacity and LNG trade by scenario

The Oil and Gas Industry in Net Zero Transitions/ WEO Special Edition



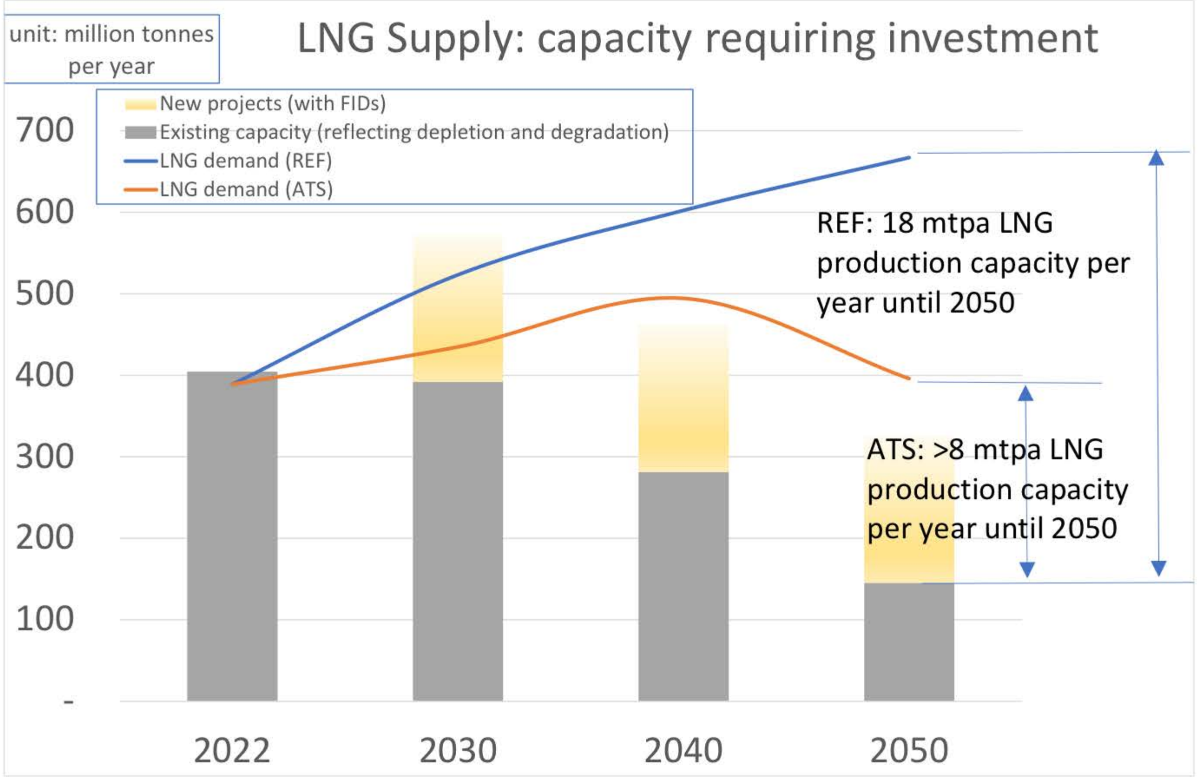
In the NZE Scenario, LNG projects currently under construction are not necessary. In the APS, trade peaks by 2030 and the capacity utilisation of plants would drop significantly.

Investment is needed to meet incremental LNG demand, as well as replace depleting existing LNG production capacity

- Investment is needed in 8 - 18 mtpa LNG production capacity per year until 2050
- Required additional capacity investment means the gap between projected LNG demand and decreasing existing production capacity, to be filled by the followings:

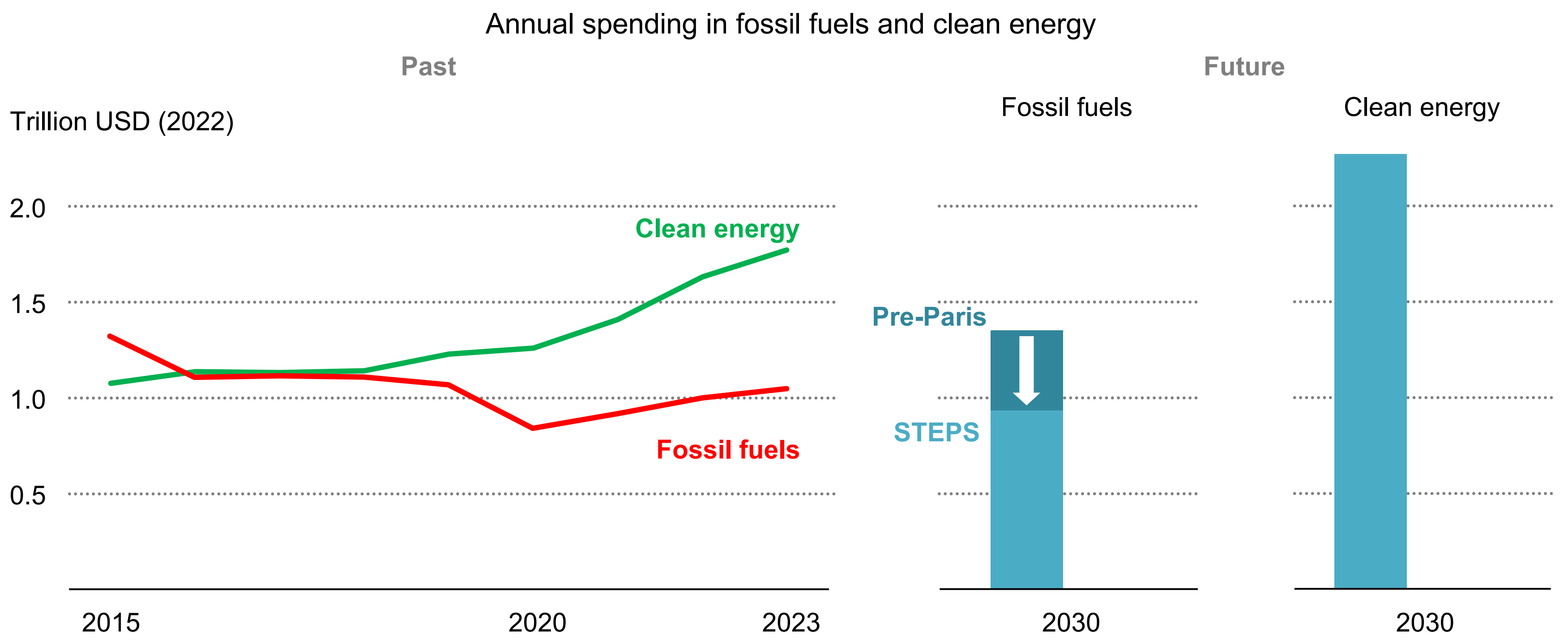
1. Greenfield project investment
2. Alternative new field development (backfill) investment
(the yellow stack indicates already sanctioned projects)
3. Investment in existing fields to offset production decline
4. Rejuvenation of existing liquefaction facilities

✓ *Those projects already greenlighted (included in the yellow stacks) may entails uncertainty with possible delays and failures to materialise



New dynamics for energy investment

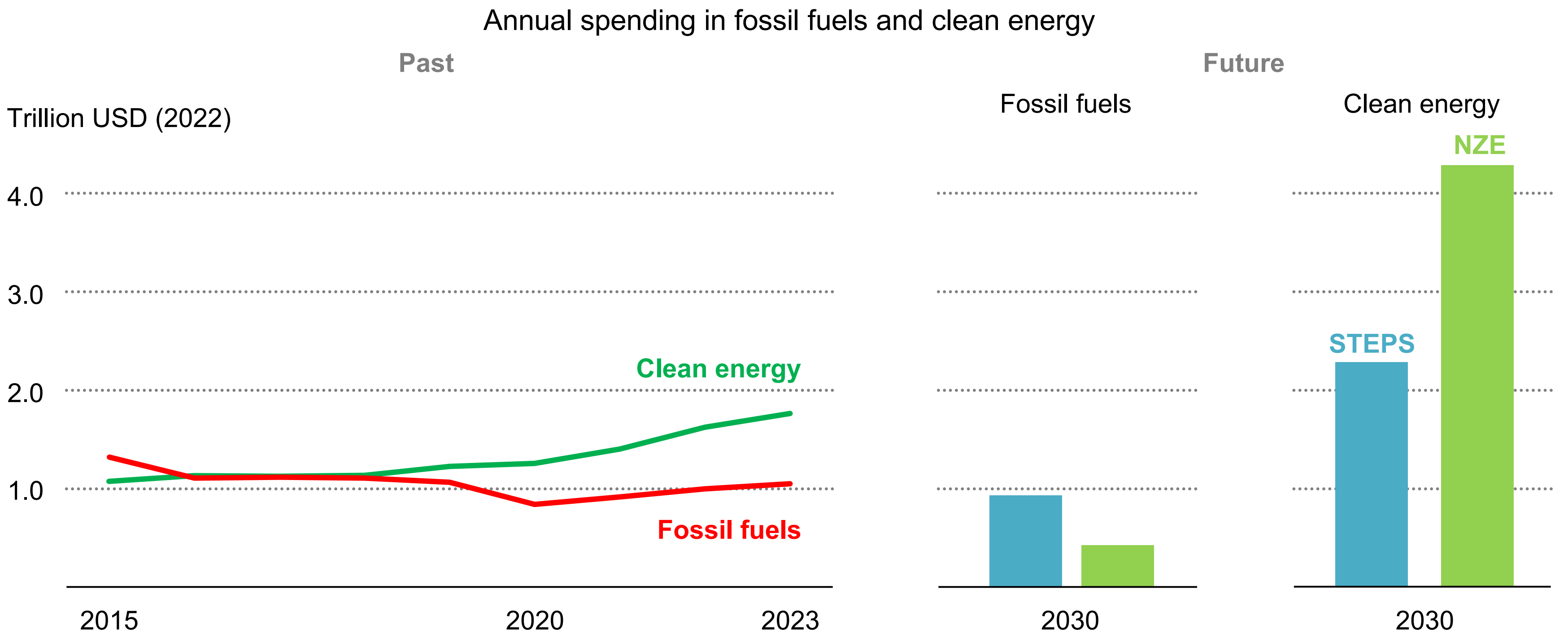
WEO2023



Fossil fuel investment today is in line with levels needed in the STEPS.
Today, every dollar spent on fossil fuels sees USD 1.8 spent on clean energy.

New dynamics for energy investment

WEO2023

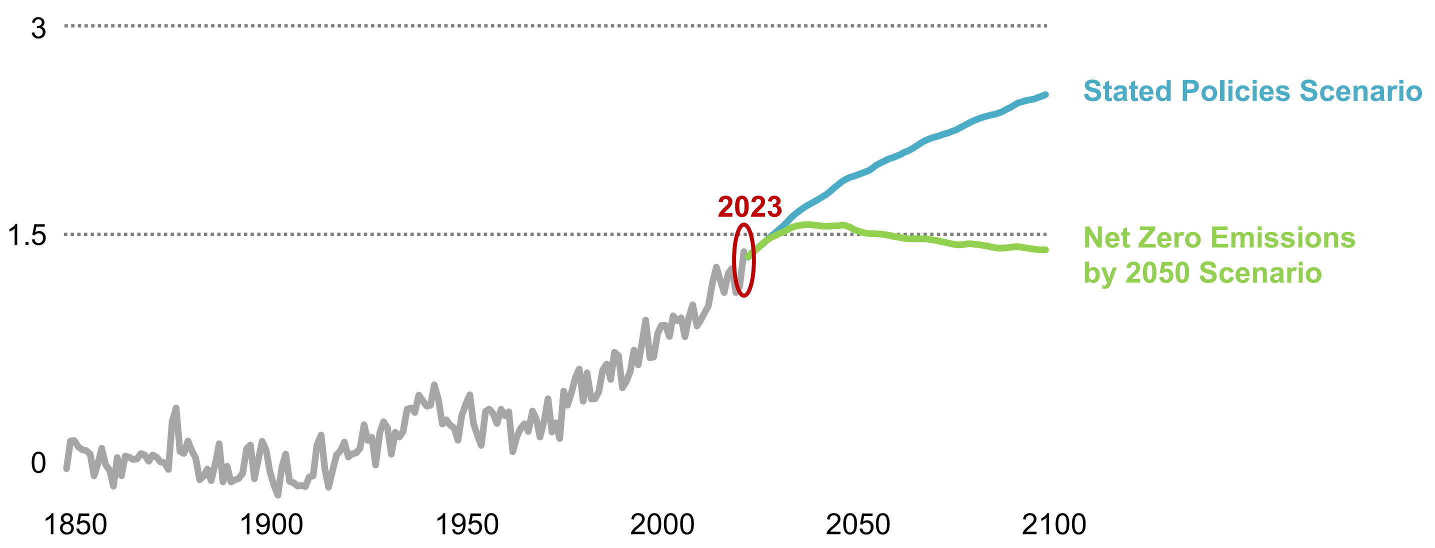


Fossil fuel investment today is in line with levels needed in the STEPS.
Today, every dollar spent on fossil fuels sees USD 1.8 spent on clean energy. This rises to USD 10 in 2030 in the NZE.

Today's choices will determine future warming

WEO2023

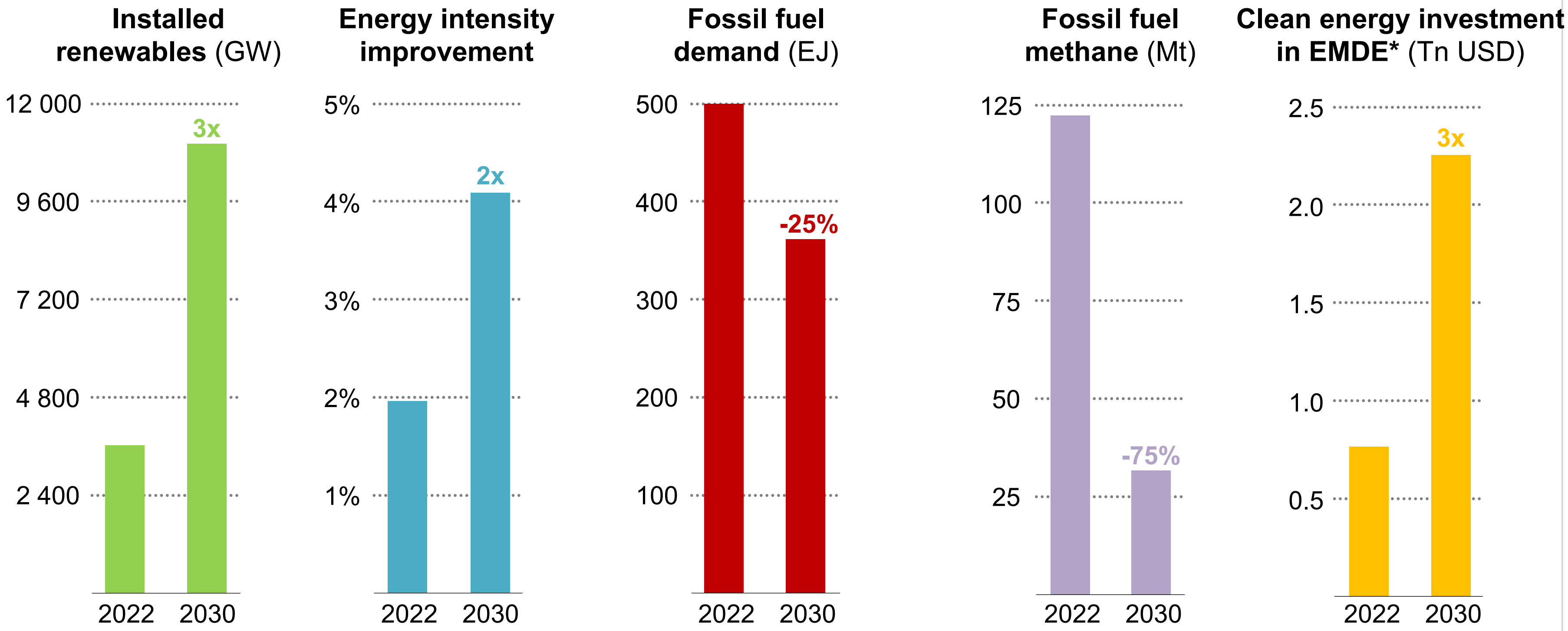
Change in global average surface temperature from pre-industrial levels (°C)



Emissions are set to peak by 2025 under today's policy settings, but temperatures would continue to rise; proven policies and technologies are available to keep the door to 1.5 °C open

Historical temperature data from HadCRUT.5.0.1.0

Five pillars to keep 1.5 °C alive



A comprehensive energy package for COP28 needs to drive the growth in clean energy, support emerging and developing economies in the transition, and recognise the need to reduce fossil fuel demand

* EMDE = emerging market and developing economies

International Energy Agency

The Oil and Gas Industry in Net Zero Transitions

23 November 2023

A moment of truth is coming for the oil and gas industry. Will the oil and gas industry be part of the solution?

- The industry's engagement with clean energy transitions will be a key topic at COP28.

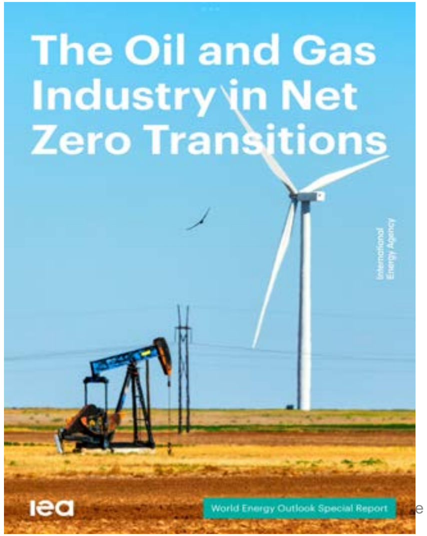
- Most oil and gas companies are watching energy transitions from the sidelines. Oil and gas producers account for only 1% of total clean energy investment globally.

- The first-order task is to slash emissions from company operations. Commit to reduce 60% of CO_2 emission by 2030.

- Transitions will hurt the bottom line for companies focused on oil and gas. Oil and gas investment is needed in all scenarios, but the demand trajectory in a 1.5 °C world leaves no room for new fields.

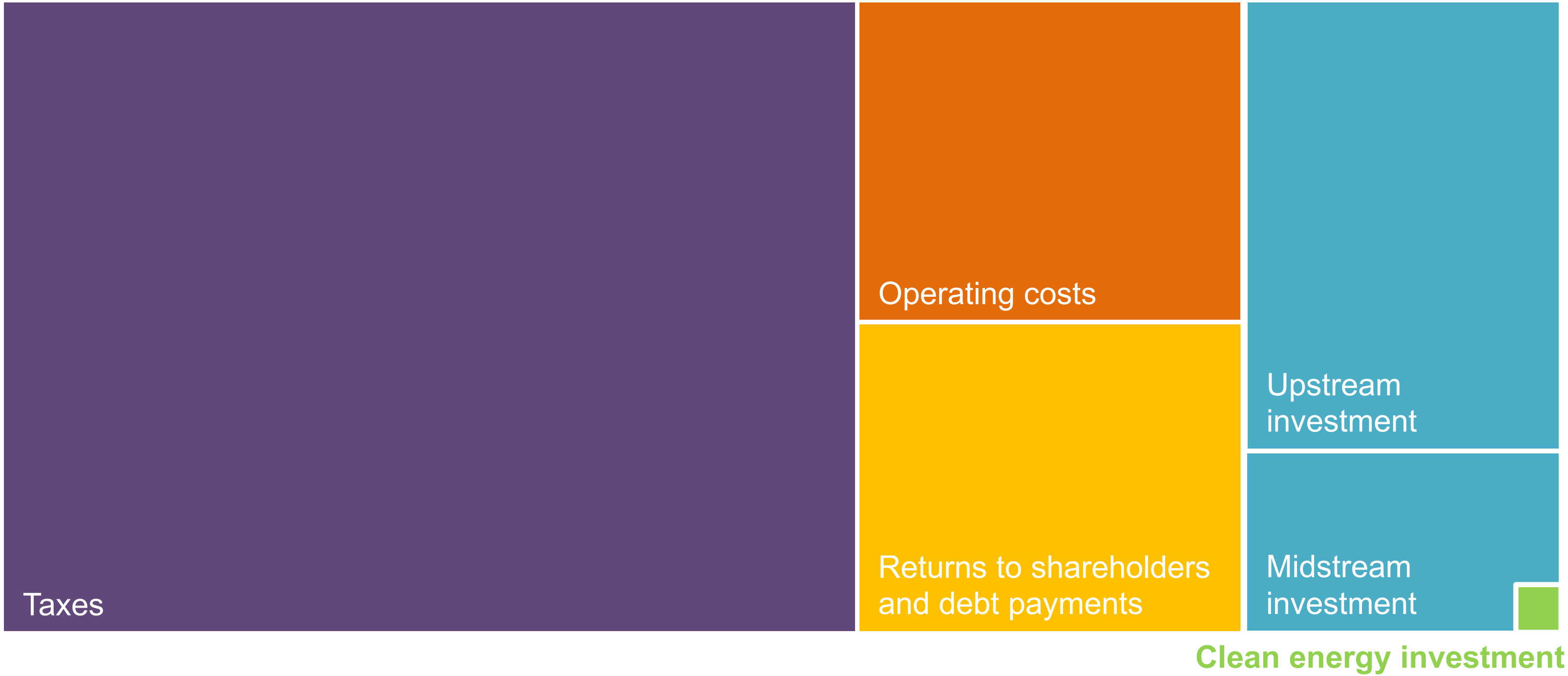
- The oil and gas industry is well placed to scale up some crucial technologies for net zero transitions … but this requires a step-change in the industry's allocation of investment . Commit to increase investment for clean technology from 2.5% of total capital expenditure now to 50% by 2030.

- CCUS is very important but it is pure fantasy to compensate everything.



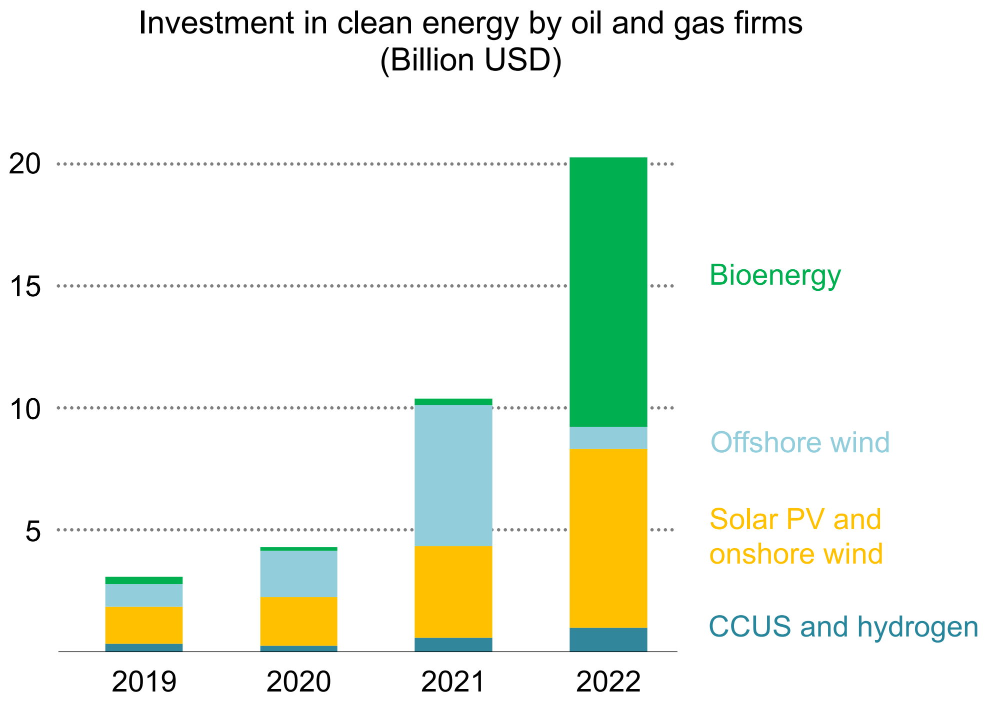
Where does the money go?

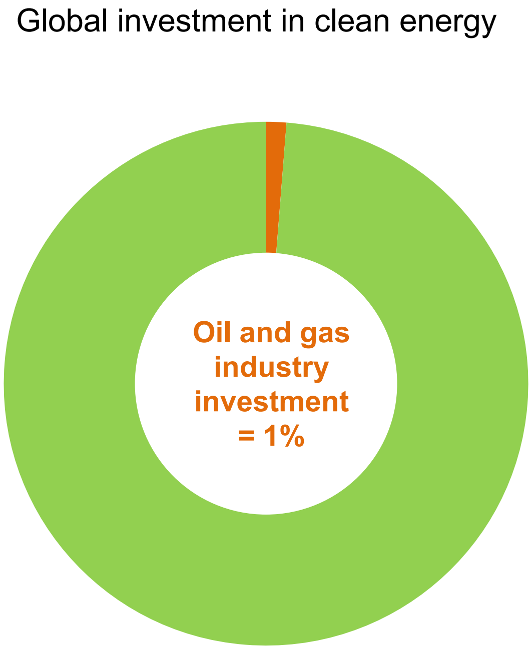
Revenue from oil and gas sales in 2022



Oil and gas companies have generated around USD 3.5 trillion each year on average in recent years. The largest share goes to governments: only a tiny proportion goes directly to the clean energy economy

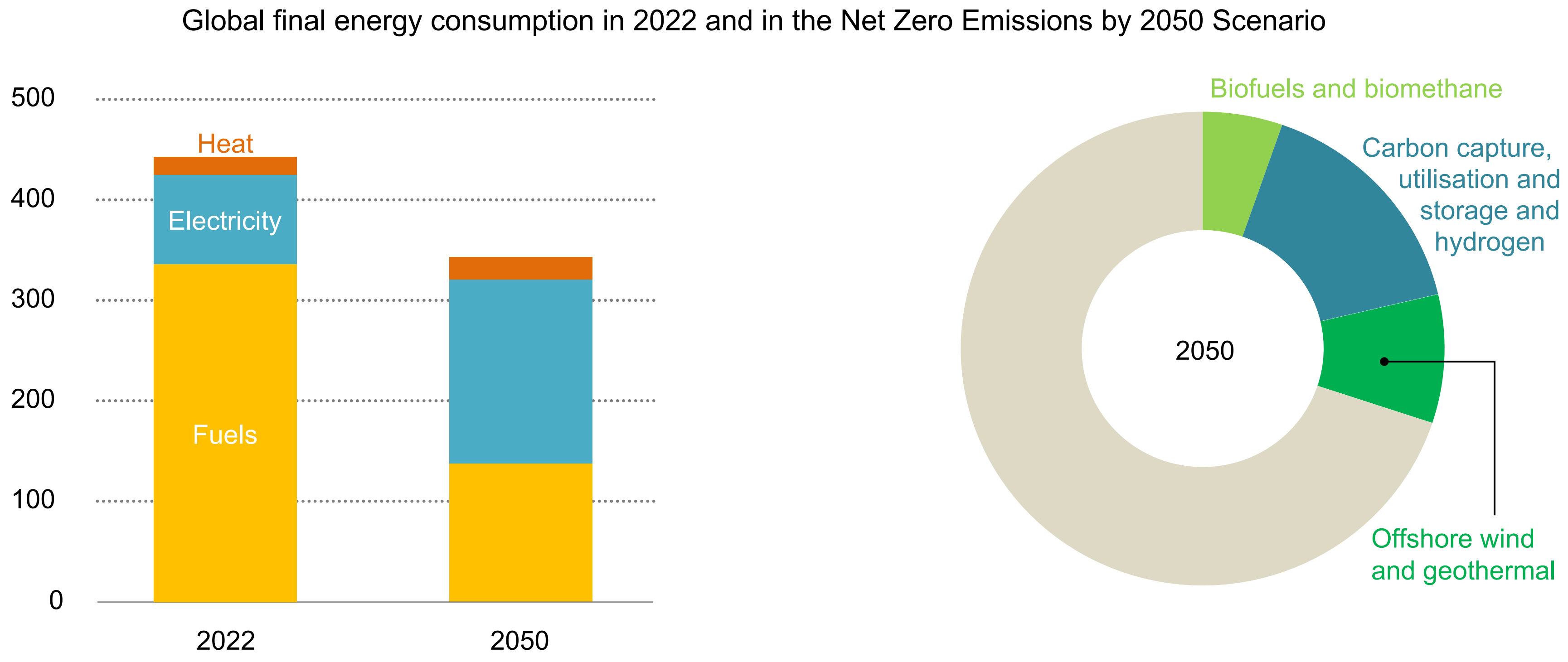
The oil and gas industry invests in a range of clean energies





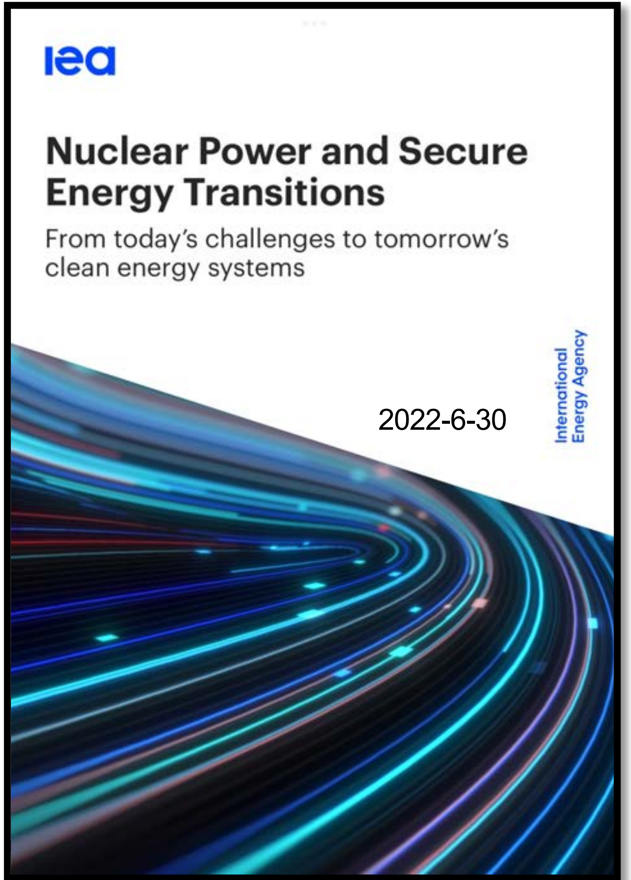
Oil and gas company investments in clean energy technologies is on the rise, reaching one third of all investment in CCUS and bioenergy, but represent just 1% of clean energy investment in 2022

Clean energy solutions requiring oil & gas skills grow in importance



A wide range of technologies are required to get the world to net zero emissions; electricity cannot do it all. Sectors with a close affinity to oil and gas company expertise make up 30% of a net zero emissions energy system

Nuclear energy could play an important role in ensuring rapid and secure energy transitions.



Russia's invasion of Ukraine and disruptions in global energy supply have made governments rethink their energy security strategies, targeting diverse and domestic supplies

Governments in over 70 countries have committed to achieving net zero emissions, covering three-quarters of global emissions and economic activity

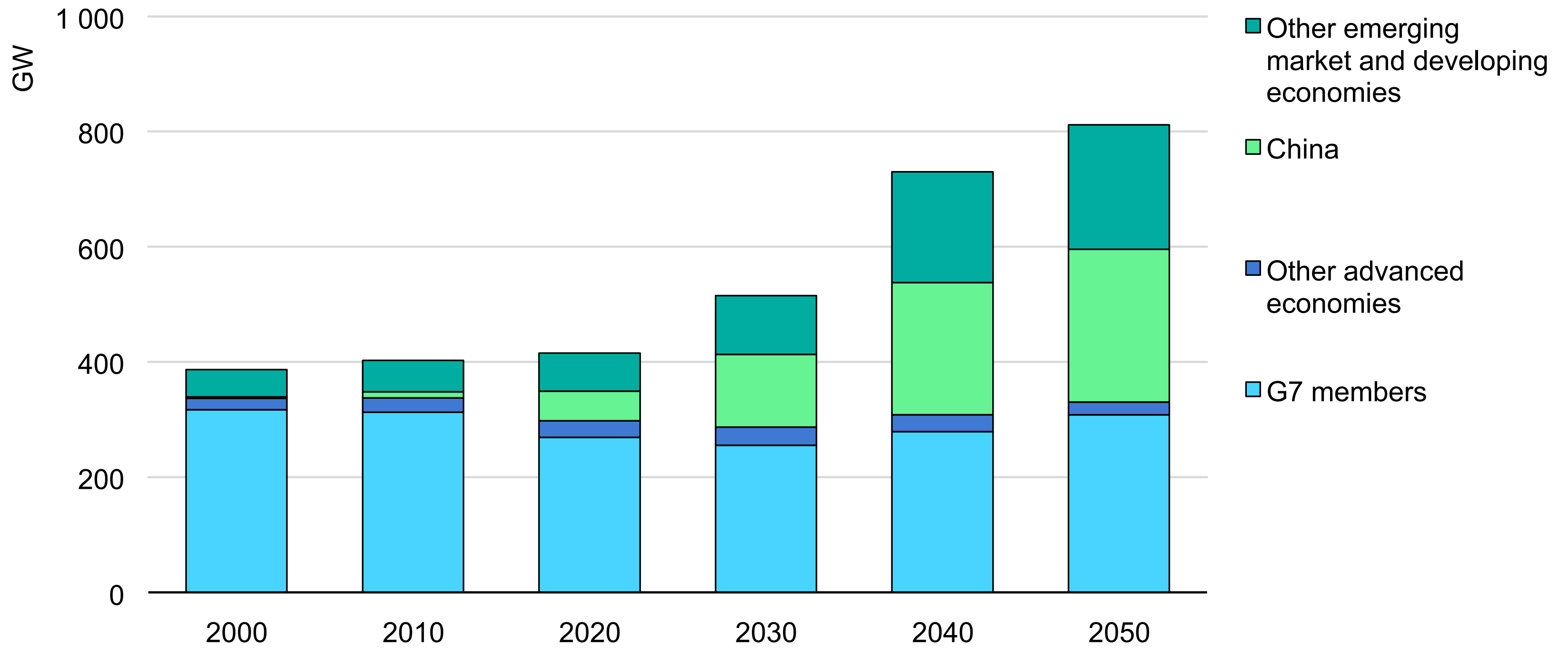
Peaking CO_2 emissions this decade and starting a long-term decline is essential to keep the door open to limiting climate change to 1.5 °C

The policy landscape is changing, opening up opportunities for nuclear to make a comeback

"NuclearPower and Secure Energy Transition" by IEA 2022-6-30

Nuclear capacity doubles to 2050 on the path to Net Zero

World nuclear power capacity in the NZE



To complement renewables in the NZE, the nuclear industry must deliver new projects on time and on budget, with projects in advanced economies needing to cut costs by almost half from ongoing projects.

“NuclearPower and Secure Energy Transition” by IEA 2022-6-30

US, UK Lead Pledge to Triple Nuclear Power by 2050 at COP28

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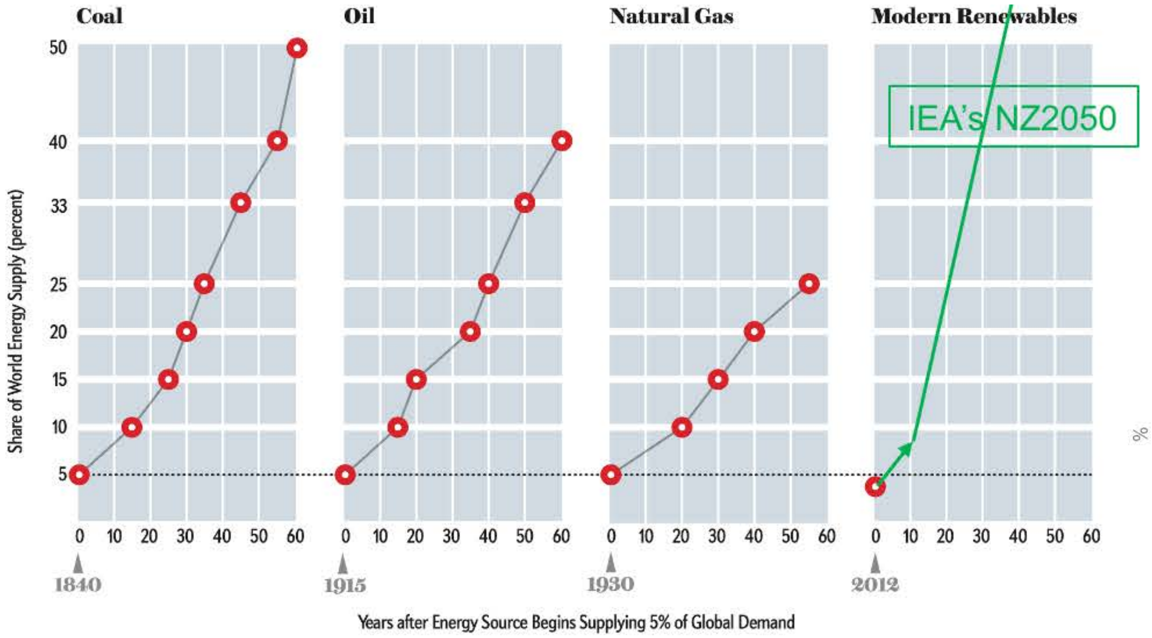
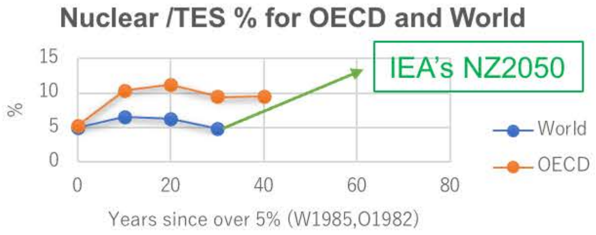
US, UK Lead Pledge to Triple Nuclear Power by 2050 at COP28

- Countries to support new tech, like small modular reactors
- Nuclear power has seen a resurgence in interest recently

- The US will lead a push at the COP28 climate summit to triple the amount of installed nuclear power capacity globally by 2050.
- The declaration will call on the World Bank and other international financial institutions to include nuclear energy in their lending policies
- The US will be joined by the UK, France, Sweden, Finland and South Korea in the pledge to be signed Dec. 1 in Dubai

Large Light Water Reactor (LWR) Paradigm is a "Successful Failure" (Vaclav Smil)





Vaclav Smil vs IEA's Net Zero by 2050

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Innovation for Cool Earth Forum (ICEF) 2022 Nuclear Session

Agreed on Four conditions for "Sustainable" Nuclear Power.

(1) SMR with passive safety
(2) Radioactive Waste Disposal
(3) Proliferation Resistance
(4) Socio-Political Sustainability

Ambassador Emanuel of the US joined as a keynote speaker.
He stressed importance of US-Japan cooperation on nuclear.

I told him IFR of Argonne National Lab is the sustainable nuclear model and should be applied to the Fukushima meltdown fuel debris solution.

Interim Recommendations of CIGS Study Group on Next Generation Nuclear Energy Utilization "Facilitating Revitalization of Nuclear Energy in Japan"

Nuclear Power Generation in the Future

We believe that nuclear power is indispensable to form an energy mix in Japan. Past experiences tell us that, in the future, Japan must take a completely different approach from the conventional path to meet the following three conditions.

1. **Risk Minimization**

Since the risk in nuclear power generation cannot be made zero, the idea of risk minimization is quite important. Even in case of a nuclear accident, smaller scale nuclear reactors with smaller fuel inventories could reduce the area affected, such as emergency evacuation zones. It is also necessary to develop technology for enhancing passive safety, so that the operation of a reactor can be stopped as safely and quickly as possible. As part of this process, if the design of the reactor can be made as locally acceptable as possible, it will help to gain the understanding of the local community where the reactor is located and encourage the participation of local residents.

2. **More Realistic Method of High-level Radioactive Waste Treatment**

It is a difficult issue to determine site for high level radioactive waste disposal in all countries. Because such waste must be stored in geological disposal facilities and kept isolated from the human living environment for several hundred thousand years. On the other hand, pyroprocessing technology for metal fuel cycle succeeded in shortening the isolation period of radioactive waste to 300 years by extracting plutonium and minor actinides (MA). This technology was tested using simulated fuel debris which had the same elements as TMI-2 fuel debris. Although this debris could not be reprocessed by the conventional reprocessing method, it was successfully reprocessed when this technology was applied. This means that both spent fuel that has been exposed to sea water and fuel debris that should be retrieved in the future from damaged reactors of Fukushima Daiichi Nuclear Power Plant could be reduced to radioactive substances, which merely requires isolation for 300 years. It should be noticed that the problems associated with the use of the light-water reactor system may be able to be skirted around when this technology is introduced in the future.

3. **Contribution to Nuclear Non-proliferation**

Besides the problem of high-level radioactive waste disposal, the light-water reactor system also poses difficulties when viewed from the angle of nuclear non-proliferation. The uranium enrichment technology that is essential for fabricating fuel of light-water reactors, together with spent fuel reprocessing technology, can be easily applied to development of nuclear weapons. Therefore, future nuclear power generation systems must be as unlikely as possible to produce materials that could lead to nuclear proliferation. Also, it will be necessary to review the management system of nuclear substances in line with the development of novel technologies and the associated nuclear proliferation risks.

For the purpose, the improvements of environment such as **(1) political leadership, (2) Obligation of the government, (3) Residents' Participation and Interactive Communication, and (4) Reconstruction of Fukushima and Peaceful Uses of Nuclear Energy, a**re necessary.

Members

Nobuo Tanaka (Chair)
Tomoko Murakami
Momoko Nagasaki
Reiko Fujita
Maiko Takeuchi
Atsuko Kanehara
Junko Sugaya
Mao Kurahashi
Mina Sekiguchi
Minako Fujiie
Akiko Iwata (Observer)
Chieko Nagayama (Observe
Eri Nakatani (Observer)
Yuki Hasegawa (Observer)

https://cigs.canon/en/article/20221107_7096.html

Why does CIGS setup Only Women Working Group for Advanced Nuclear system?

Nuclear Community is very male-dominant. Unfortunately most of these men are not eager to transform the current system with vested-interest orientation.
Women as outsiders can change the system which then may be acceptable for general public in japan. Women have much more strong sense of safety and security than men. **If the President of TEPCO were a woman, she could have avoided the Fukushima Accident in 2011.**

Opinion　オピニオン

元国際エネルギー機関（IEA）事務局長／前笹川平和財団会長
田中 伸男
たなか・のぶお　東大経卒、通商産業省（現経済産業省）入省。通商政策局総務課長、経済協力開発機構（OECD）科学技術産業局長などを経て07年に欧州出身者以外で国際エネルギー機関（IEA）事務局長に就任。72歳。

女性メンバーら、持続可能性訴え

次世代原子力に厳しい指摘

講壇

キヤノングローバル戦略研究所が始めた次世代原子力をめぐる研究会が中間報告を発表した。この研究会のメンバーは男性は筆者のみで、あとは女性である。なぜ女性だけなのかといえば原子力ムラの男性たちは既存のシステムにからめ取られていて変革への突破力が感じられないからである。彼女たちは手厳しい。福島事故のけじめがついていない、優れたシステムである小型モジュラー炉（SMR）や金属燃料がなぜこれまで使われなかったのかの反省がない、役所のコミュニケーションは一方的で双方向ではない、福島を特別扱いすることは差別扱いだ、原子力にはビジョンがない、政治にリーダーシップが欠けている—など舌鋒鋭い。

ロシアのウクライナ侵攻で原子力施設が危険にさらされている一方で、エネルギー安全保障上の重要性も見直されている。二酸化炭素を出さないことも重要だ。しかし原子力はそれだけでは持続可能とはいえないのではないか。これが彼女たちの原点である。

将来の原子力はさらに三つの条件を満たさなければならない。第1に事故のリスクや環境への影響をミニマムにすること。第2に放射性廃棄物の処理処分方法の確立。第3に核不拡散性能の高い技術、システムであることである。

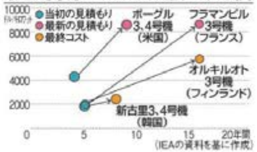
■■■

政府は革新軽水炉と称して安全性を高めた改良型大型軽水炉を古い炉のリプレース候補としているようだが、これは持続可能とは言えない。大型炉は万が一のリスクが高い。

小型炉なら避難の範囲をプラント内だけに狭めることも可能だろう。国際エネルギー機関（IEA）は大型軽水炉は建設期間の延伸で当初の2～3倍ものコスト増になるとしており（グラフ）、標準化を目指すSMRこそ本命だとしている。人材とサプライチェーン（供給網）を維持するためだけに数兆円もする将来性のない炉に投資するのはムダである。

また大型軽水炉を建てることは廃棄物処理に貢献せずむしろ処理すべきゴミを増やすだけである。この際新規の大型軽水炉はやらないと宣言し、第2の条件である廃棄物処理までのトータルシステムを非連続的発想で変革しなければならない。

最近の原子力プロジェクトの建設コストと期間



■■■

そのためには金属燃料高速炉（IFR）によりゴミの毒性を30万年から300年に落とす技術が役に立つ。この技術は米国アイダホ国立研究所ですでに確立されており、これを福島原発の燃料デブリ処理や塩水で汚染された燃料処理にも使える。福島で成功すれば他の原子炉サイトにも応用できる。

またこの技術は第3の条件である核不拡散性が高い技術でもある。小型炉は風力太陽光など変動する自然エネルギーとも共生しやすい。金属燃料なら出力調整が楽であり、余剰を熱や水素として貯蔵する技術を併用することも可能だろう。地域分散型、地産地消型原子力として地元の需要に応えるシステムなら地元の理解も得やすいはずだ。これなら2022年のイノベーション・フォー・クール・アース・フォーラム（ICEF）も提言した原子力の社会・政治的な持続可能性条件をも満たす。IFRは福島事故で日本が失った信頼を取り戻す技術として世界に先駆けて日本が実現させなければならないイノベーションである。まずは日米でこの技術がデブリ処理に使えるかの研究を開始すべきだ。

（次回は産学連携推進機構理事長の妹尾堅一郎氏です）

日刊工業新聞　2022-10-31

Key Findings: Flexible Nuclear Energy for Clean Energy Systems

- Flexibility: "*The ability of nuclear energy generation to economically provide energy services at the time and location they are needed by end-users. These energy services can include both electric and non-electric applications utilizing both traditional and advanced nuclear power plants and integrated systems.*"

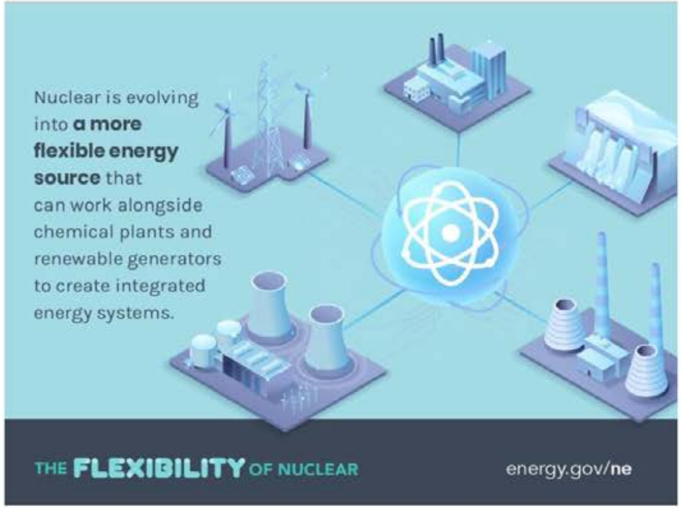
  - ***Operational* flexibility:** There is an established body of knowledge surrounding current sources of flexible nuclear energy and its constraints.
  - ***Product* flexibility:** Innovation can increase the flexibility of existing nuclear reactors to produce both clean electricity and beneficial non-electric products.
  - ***Deployment* flexibility:** Advanced reactors will present even more opportunities for flexibility in nuclear systems at various scales.

Nuclear flexibility can enable other clean energy generators.

https://www.nice-future.org/flexible-nuclear-energy-clean-energy-systems

FNC FLEXIBLE NUCLEAR CAMPAIGN FOR NUCLEAR-RENEWABLES INTEGRATION

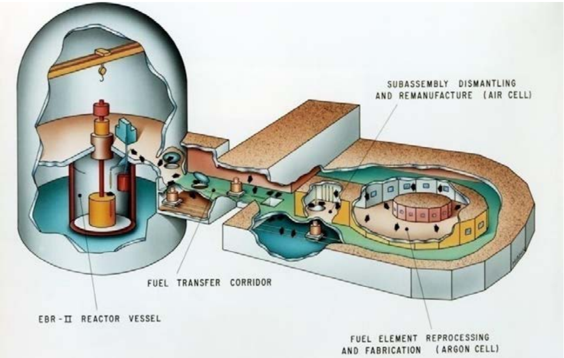
A CAMPAIGN OF THE CLEAN ENERGY MINISTERIAL



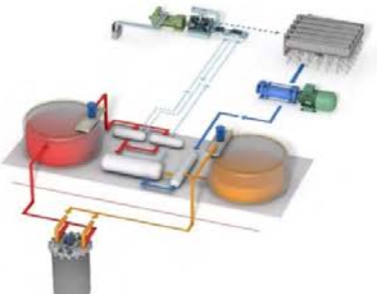
Jill Engel-Cox
Director, Joint Institute for Strategic Energy Analysis
National Renewable Energy Laboratory
Golden, Colorado, USA

NICE Future
Nuclear Innovation: Clean Energy Future
An Initiative of the Clean Energy Ministerial

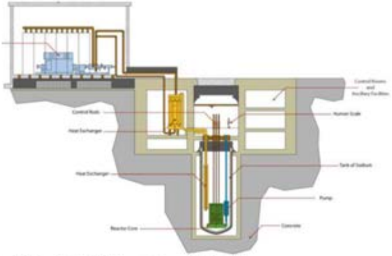
Socio-Politically Sustainable Nuclear Models?



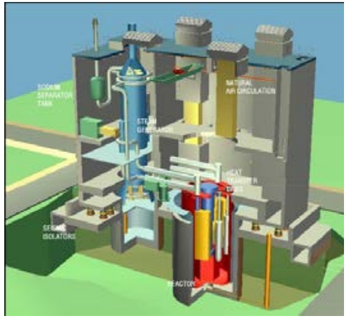
Integral Fast Reactor



Terra Power's Natrium



ARC 1000



GE-Hitachi's
PRISM

OKLO's Aurora reactor

Dow Chemical
and X-energy

Rolls-Royce UK SMR

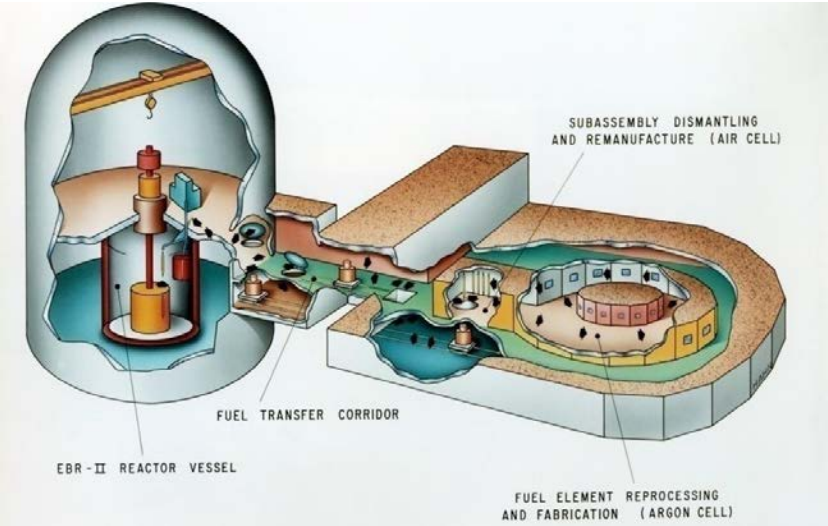
Akademik Lomonosov

Integral Fast Reactor (IFR) for Fukushima Debris Processing

✓ The concept of an integral fast reactor (IFR) consists of reprocessing the fuel debris, fabricating TRU fuel, burning it in a small MF-SFR and recycling the spent fuel by reprocessing

✓ Amount of heavy metals (HM), such as uranium, present in fuel debris: Approx. 250tons and **<u>TRU elements account for approximately 1.9tons</u>**.

✓ Configuration
- A MF-SFR with inherent safety features (reactor output: 190MWt)
- Application of a metallic fuel pyro-processing method that makes debris processing possible.



Concept diagram of an IFR that combines a fast reactor with a fuel recycling facility
(Example: Argonne National Laboratory Experimental-Breeder Reactor EBR-II and fuel cycle facility (FCF))

(Source: Y. I. Chang, "Integral fast reactor – a next-generation reactor concept," in Panel on future of nuclear Great Lakes symposium on smart grid and the new energy economy, Sept. 24-26, 2012.)

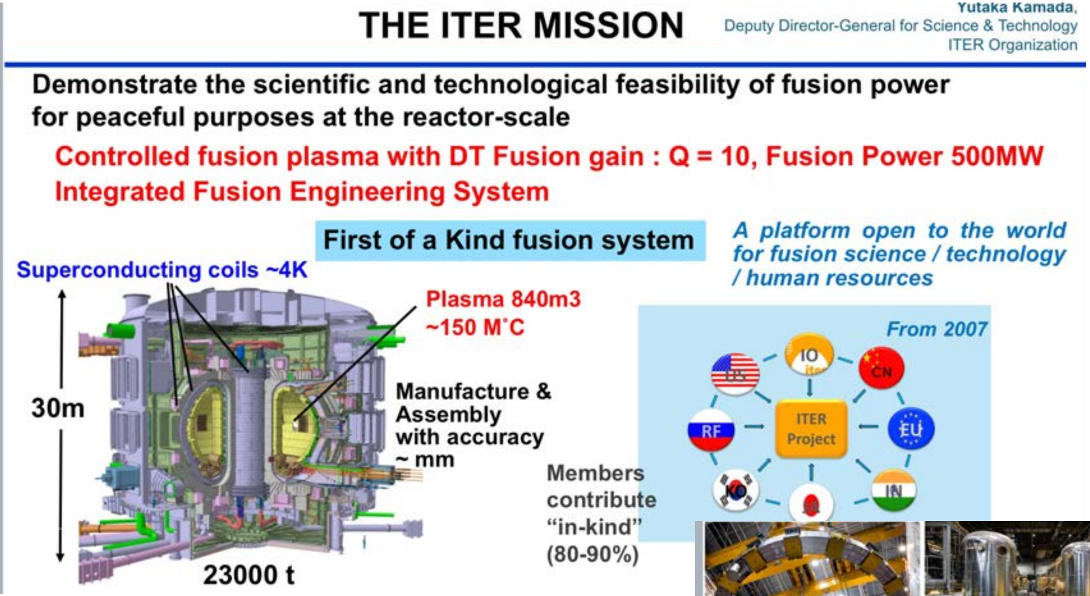
METI's Review of Advanced Reactors

CIGS's Sustainability check

	Maturity	Regulation	Supply	Economy	H2	Load Follow	Pu Economy	Waste Disposal	Non energy Sector	Safety & risk	Waste Disposal	proliferation
Advanced LWR	◎ ※既存技術を活用可	◎ ※既存規制を活用可	◎ ※既存軽水炉のサプライチェーン有	◎ ※現行の軽水炉と同水準	△	○	△	△	○	X	X	X
Small LWR (小型 海外)	○	○～◎	○～◎ ※日本が得意とする大型鍛造品が不要のケースも	◎ ※米国のガス火力並が目標	△	○ ※モジュールごとの制御により負荷追従可能なものも	△	△	○	○	X	X
Small LWR	○	△ ※基準の議論が必要	○～◎	?						Marine use、**metallic fuel**		
Fast Reactor	○	○	◎ ※常陽、もんじゅの実績	◎ ※現行の軽水炉と同水準	○	◎ ※溶融塩の蓄熱システムを組み合わせた負荷追従可能	◎	◎ ※Pu･MA燃焼可	◎ ※医療用RI製造可	◎	◎	◎
										Metallic fuel & Pyroprocessing		
HT Gas Reactor	○	○	◎ ※HTTRの実績	○⇒◎ ※コジェネで経済性向上	◎ ※高温を活用した水素製造可	◎	△	△ ※高燃焼度で処分場面積低減（○）	○ ※耐高温材料製造技術の獲得	◎	X	X
Fusion Reactor	× ※要素技術の開発段階	△	○ ※ITERで部分参加	?	◎	?	?	◎ ※高レベル放射性廃棄物発生せず	○ ※コイルがヒッグス粒子発見に貢献	◎	◎	◎

出典：総合資源エネルギー調査会原子力小委員会第29回資料3（2022年8月9日）

Nuclear Fusion at ICEF



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Fusion may be at the Inflection Point. (Scott HSU)

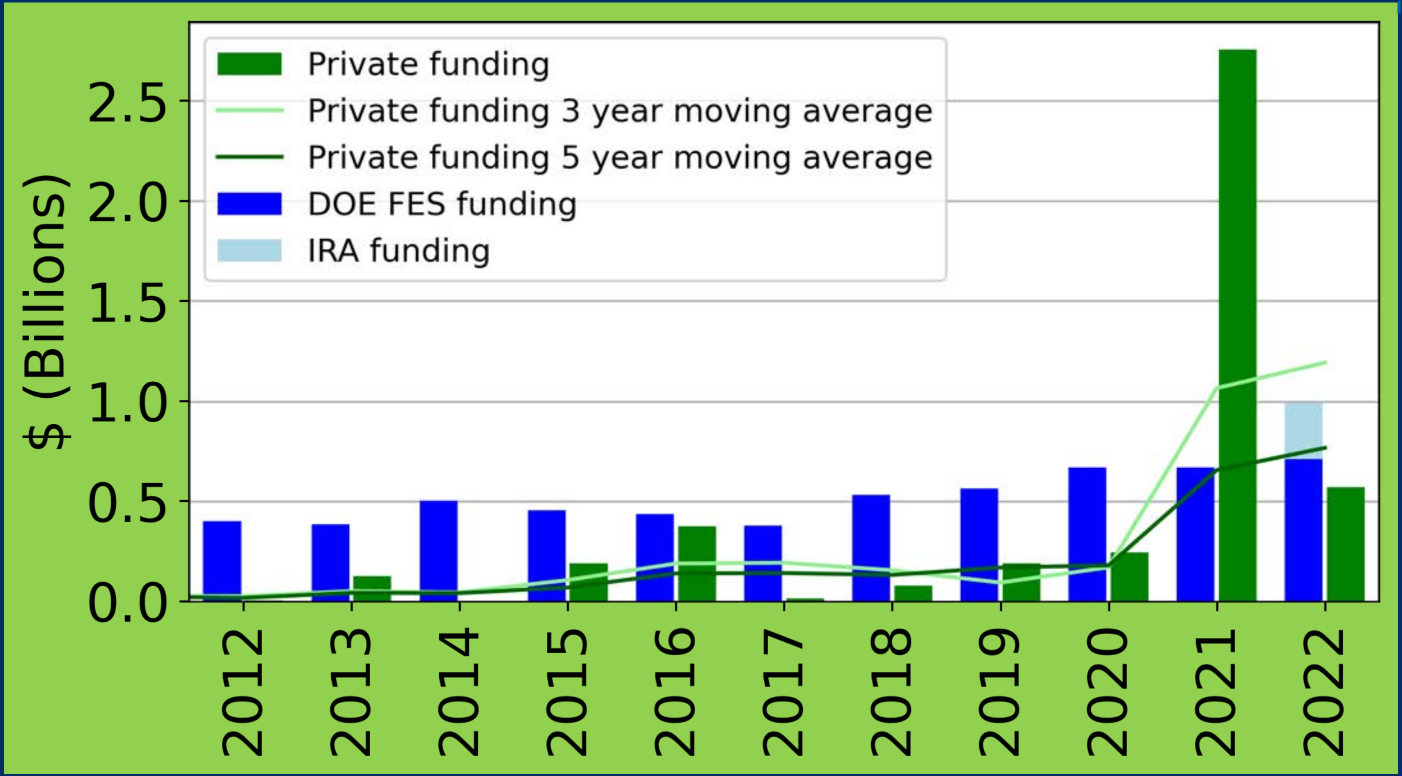
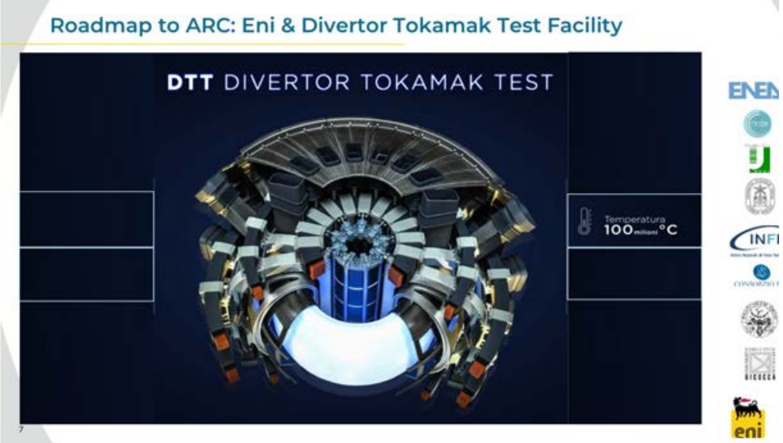


Figure credit: Sam Wurzel, DOE ARPA-E

ENI & Commonwealth Fusion

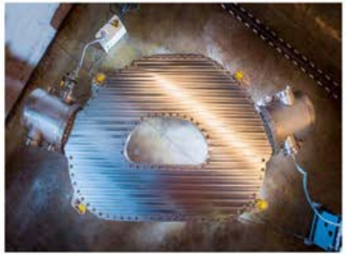


1 Eni/CFS Roadmap

Eni endorsed MIT approach: innovative technologies - known physics

2018	Eni investment in CFS → **3 phase fast-track approach** to the **first commercial compact high field tokamak** ✓
2021	**Phase 1**: 20T HTS magnetic field reached ✓
2025	**Phase 2**: SPARC First experimental tokamak for technology demonstration Q > 1
Early 30s	**Phase 3**: ARC first demonstration fusion power plant

Eni was among the first movers in the Energy Industry



Innovation for Cool Earth Forum

Helical Fusion Co.

Team

Junichi MIYAZAWA
Co-Founder, Co-CEO
Head of R&D

Takaya TAGUCHI
Co-Founder, Co-CEO
Head of Business/Finance

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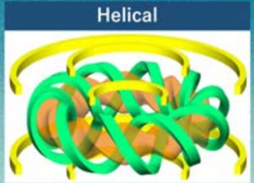
Why us? - Stable Operation

- Simple in structure, but quite difficult to operate continuously.

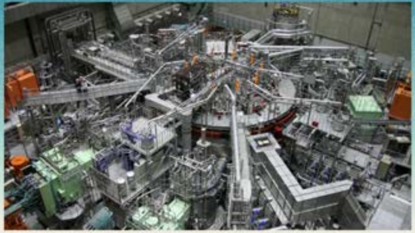


- Complex in structure, but good for operation and maintenance.
→Suitable for power generation

https://www-lhd.nifs.ac.jp/pub/LHD_Project.html 6/ 23

Why us? - Achievement

"LHD" is the only device in the world which has achieved 100 million degrees Celsius and plasma duration time for over 3,000 sec.



Large Helical Device (LHD)
at National Institute for Fusion Science (Japan)

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Our Goal

2034

the world's first steady-state fusion reactor

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Clean Planet: Solid state Fusion