Stormy Energy Future (WEO2016)

Innovation for De-carbonization

Role of the Sustainable Nuclear Power

2016-11-30 the Canon Institute for Global Studies

Former Executive Director, IEA
President, the Sasakawa Peace Foundation
Nobuo TANAKA

International Energy Agency
Secure Sustainable Together

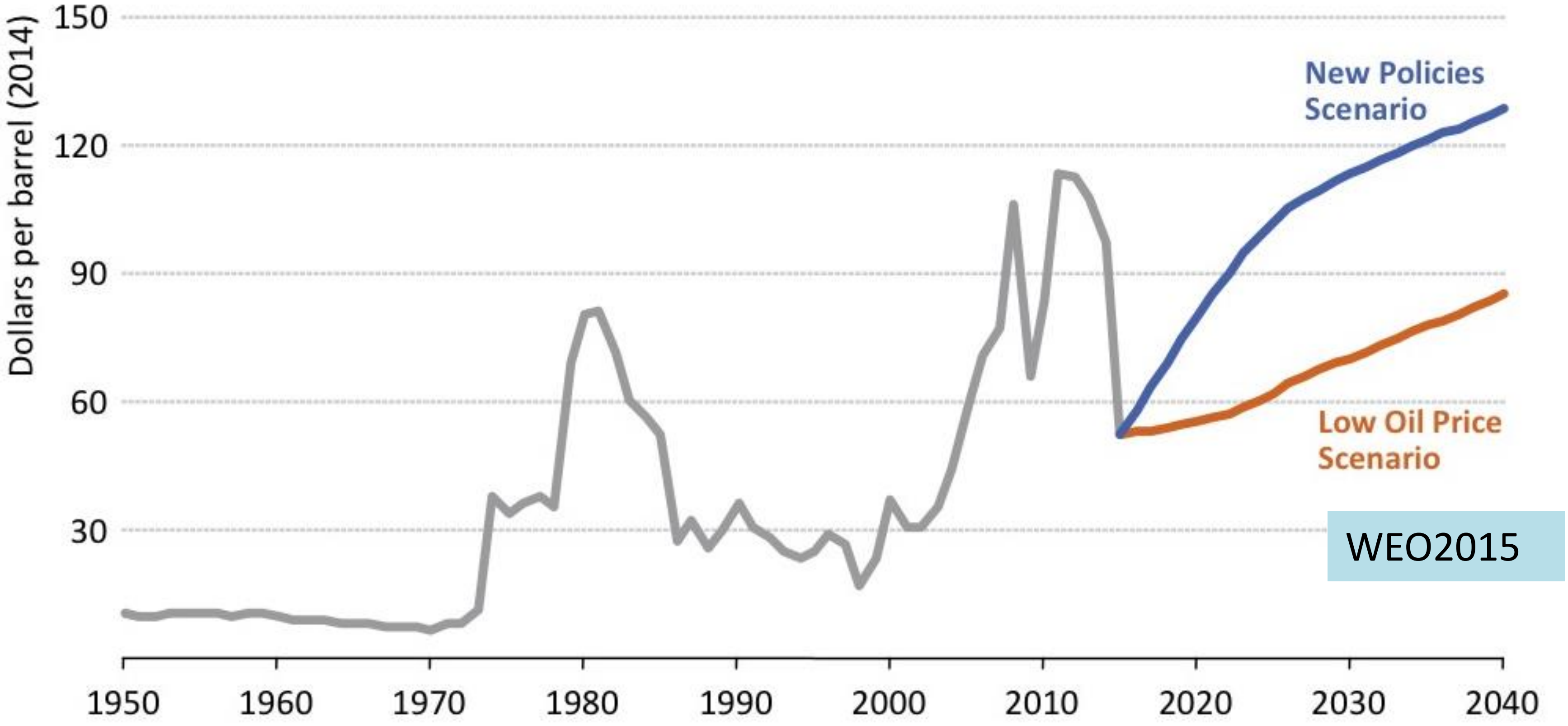
World Energy Outlook 2016

2016年11月25日　東京

本文書の原文は英語であり、IEAは本和訳が原文に忠実であるよう あらゆる努力をしているが、多少の相違がある可能性もある。

Low Oil Price Scenario

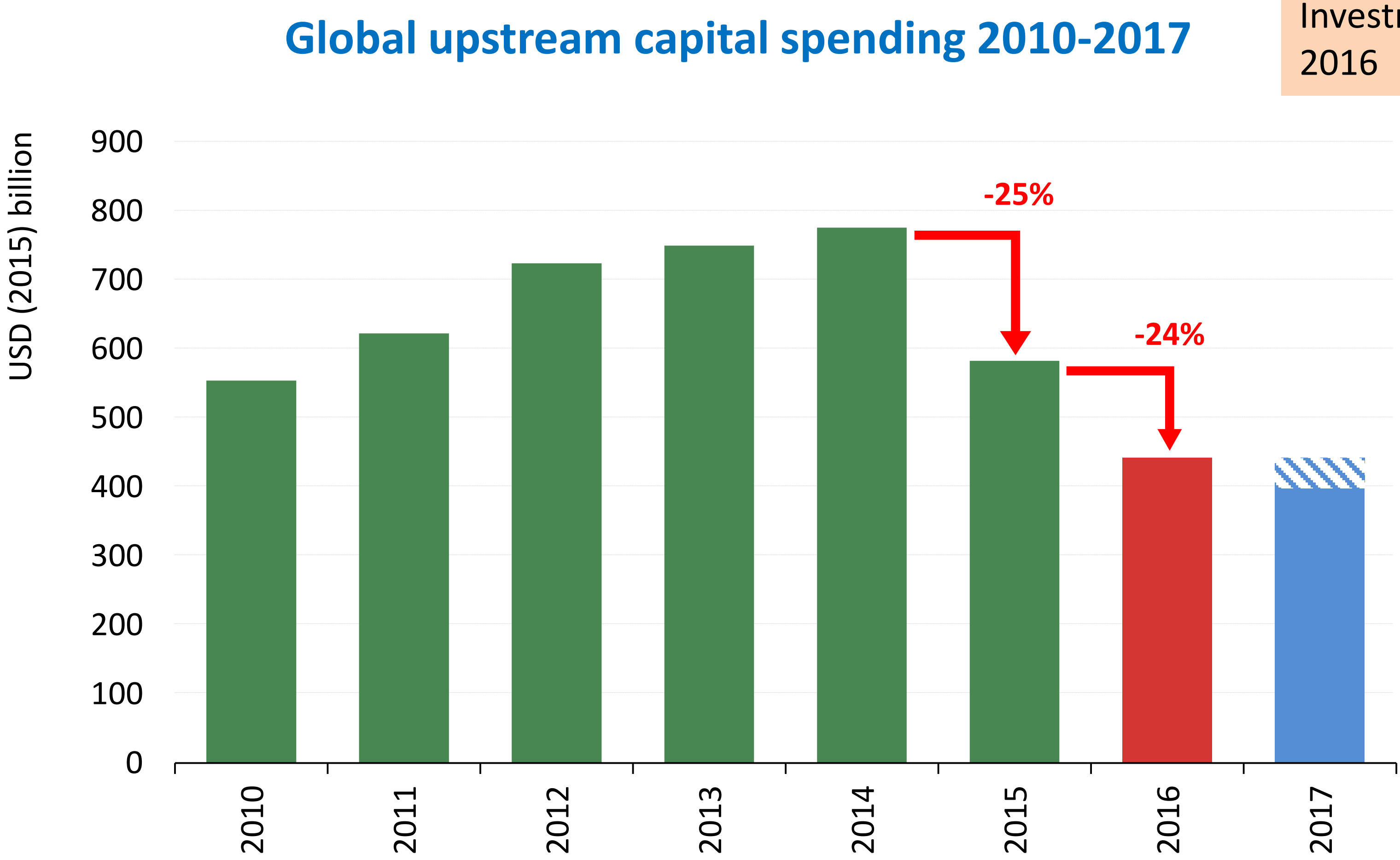
Figure 4.1 ▷ Average IEA crude oil import price by scenario



What will happen if Oil Price of $50 per barrel continues well into 2020s?

Unprecedented wave of investment cuts in the upstream oil and gas industry

World Energy Investment 2016

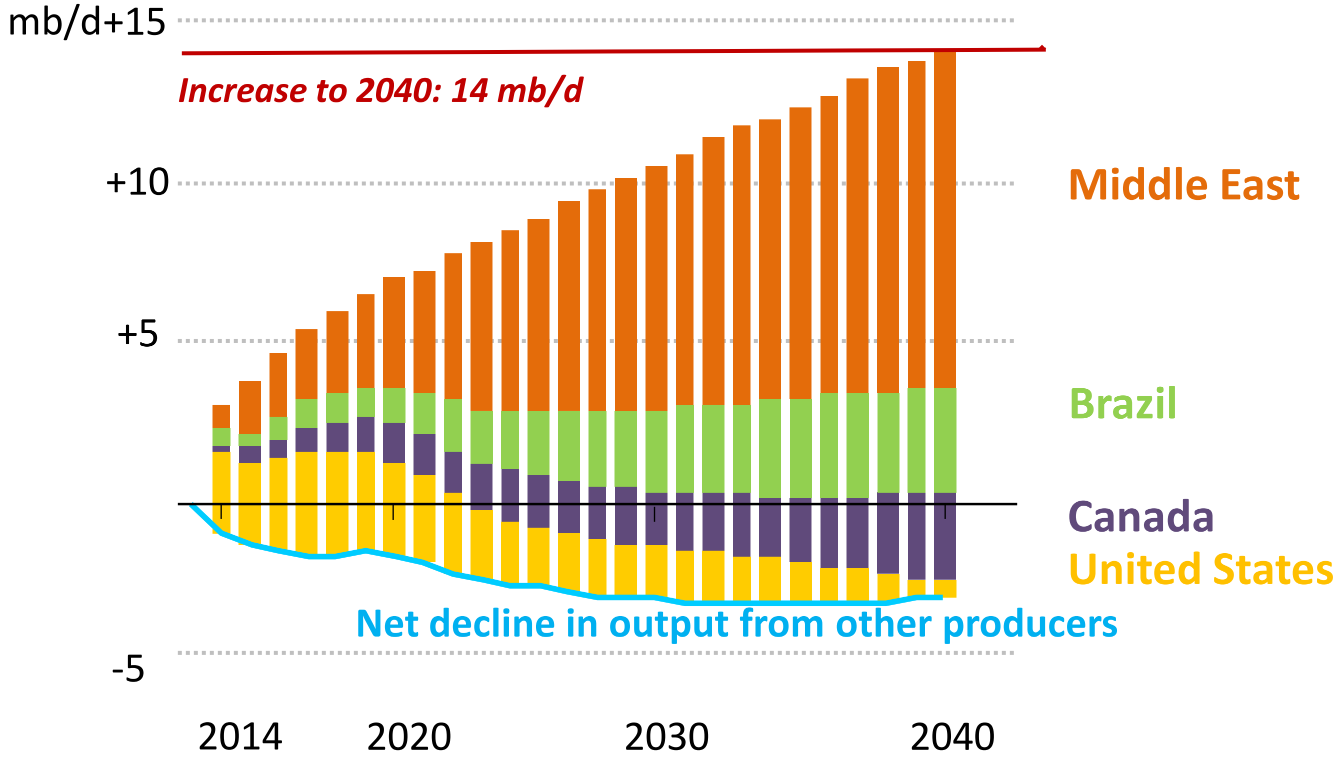


Cost deflation, efficiency improvements and reduced activity levels might lead for the first time to three consecutive years of investment decline

Instability in the Middle East a major risk to oil markets

IEA data

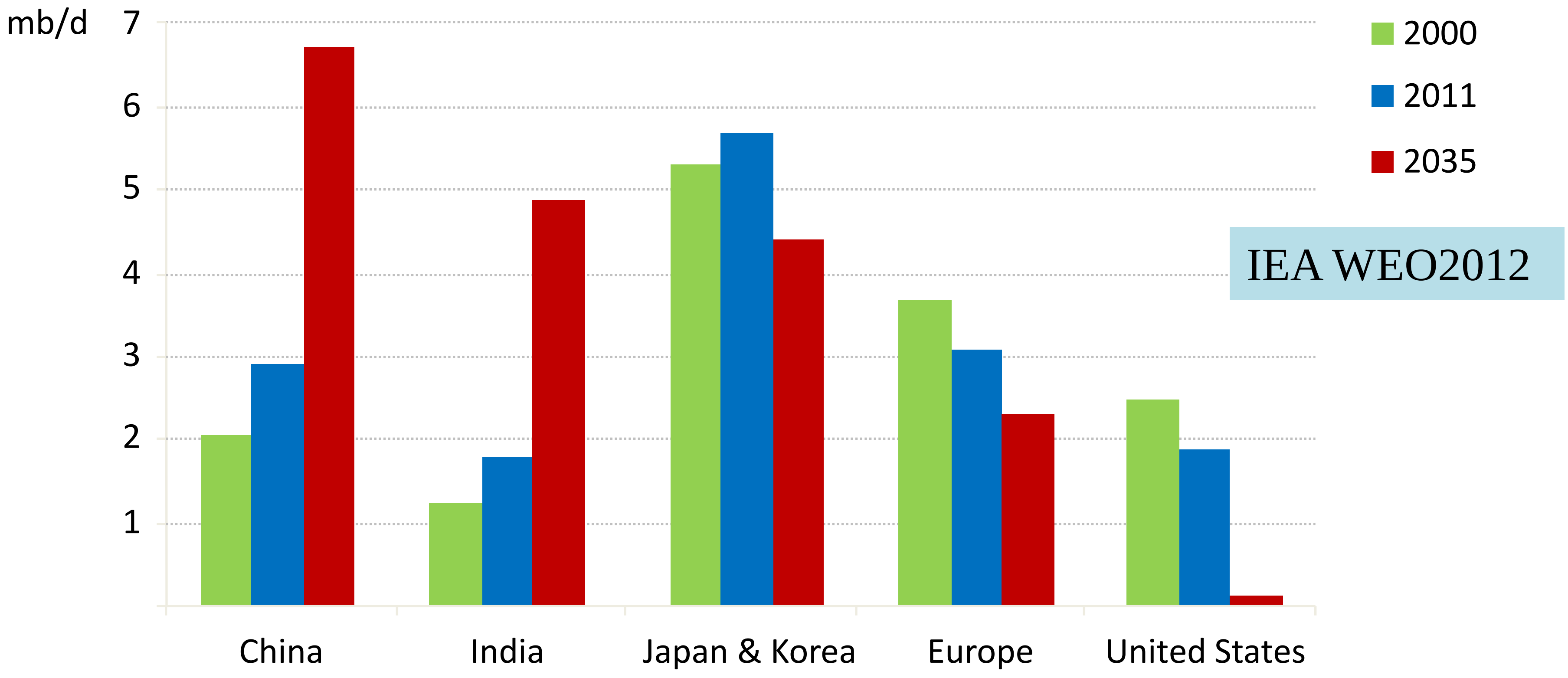
Oil production growth in United States, Canada, Brazil & the Middle East



The short-term picture of a well-supplied market should not obscure future risks as demand rises to 103 mb/d & reliance grows on Iraq & the rest of the Middle East

North American Energy Independence and Middle East Oil to Asia: a new Energy Geopolitics

Middle East oil export by destination



By 2035, almost 90% of Middle Eastern oil exports go to Asia; North America's emergence as a net exporter accelerates the eastward shift in trade

A new 'fuel' in pole position

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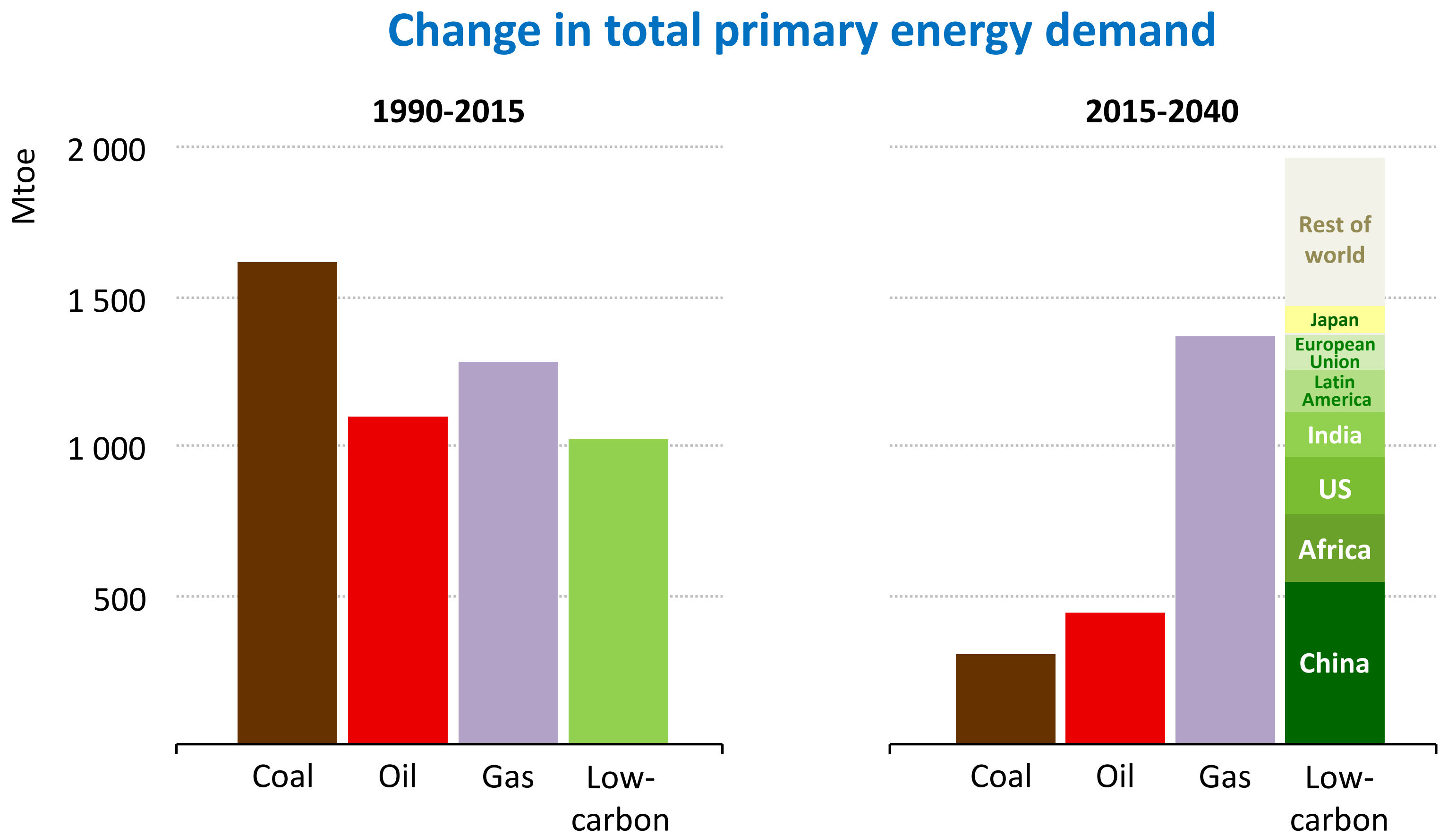

Low-carbon fuels & technologies, mostly renewables, supply nearly half of the increase in energy demand to 2040

A suite of tools to address energy security

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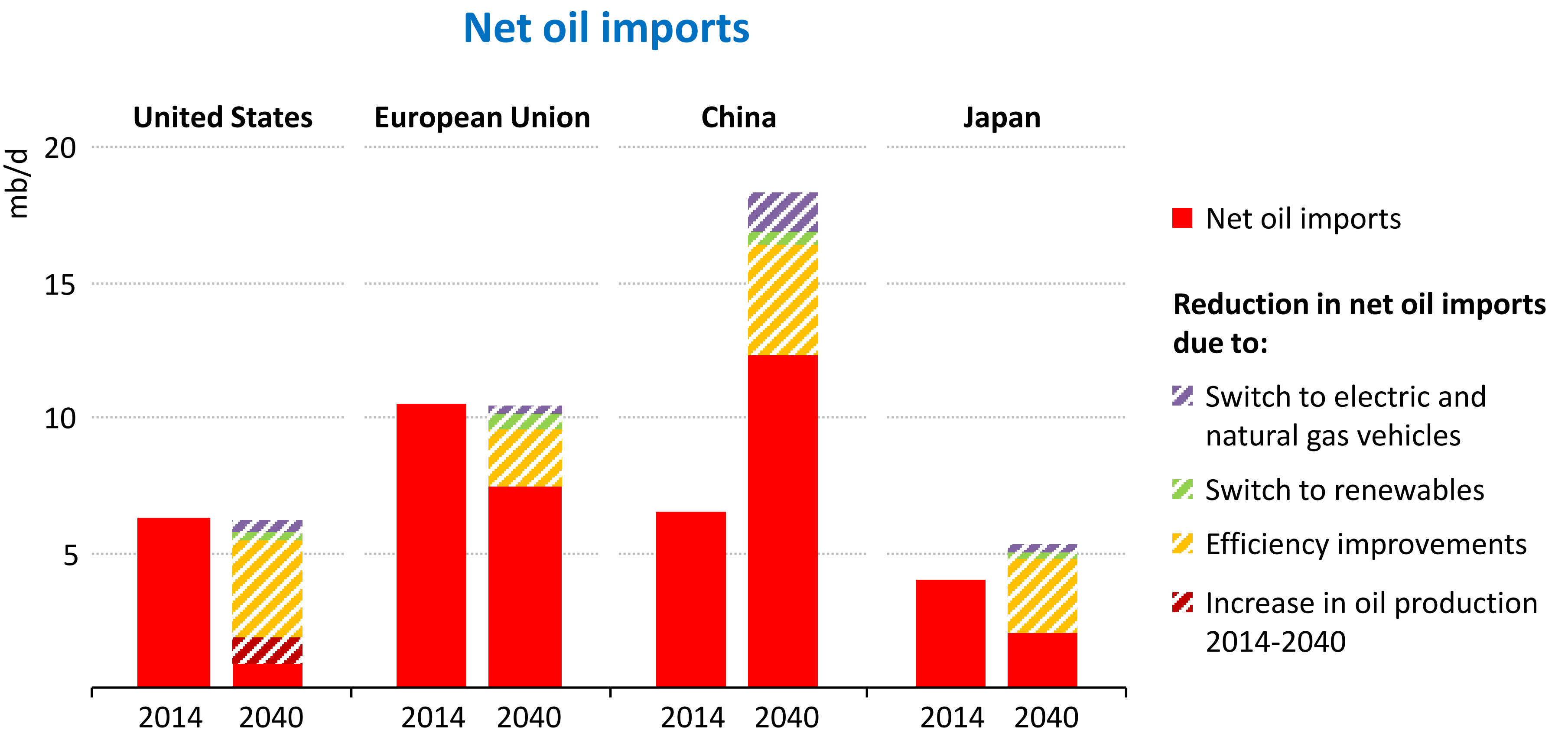

The energy transition provides instruments to address traditional energy security concerns, while shifting attention to electricity supply

A wave of LNG spurs a second natural gas revolution

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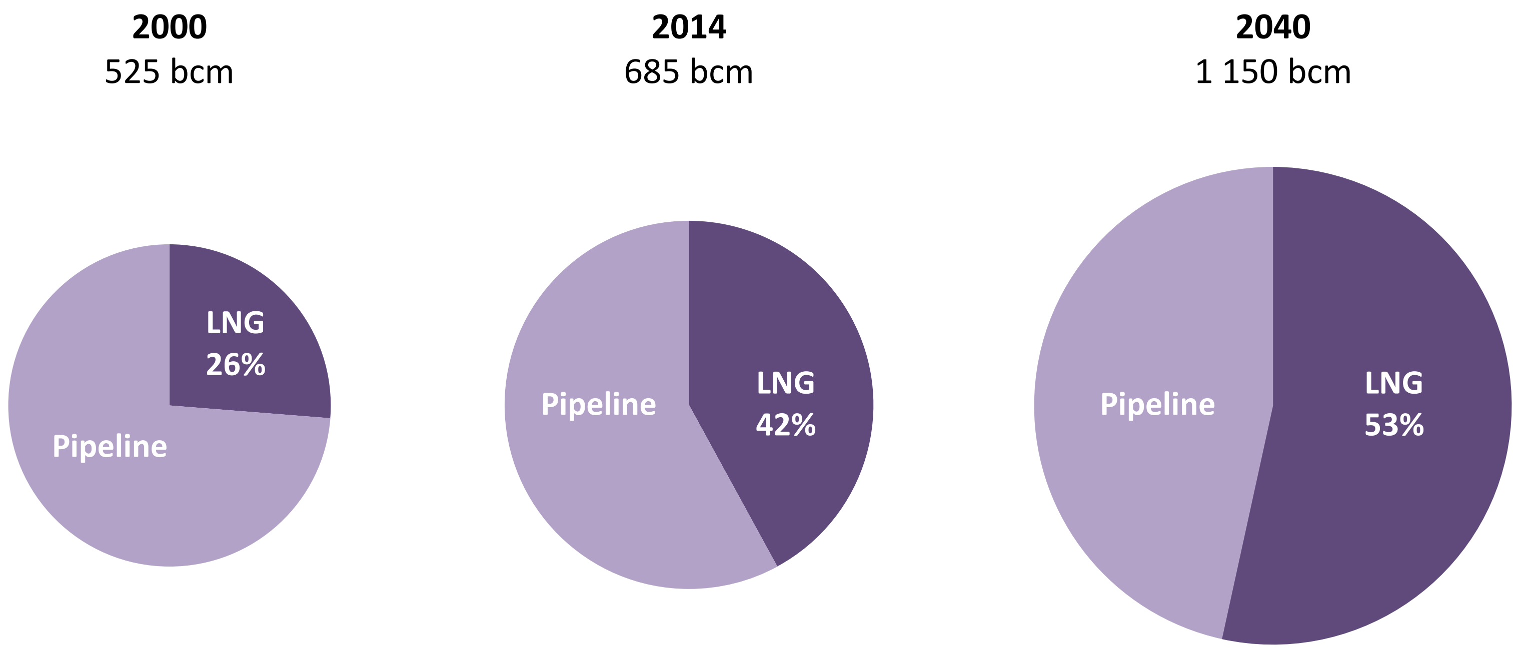
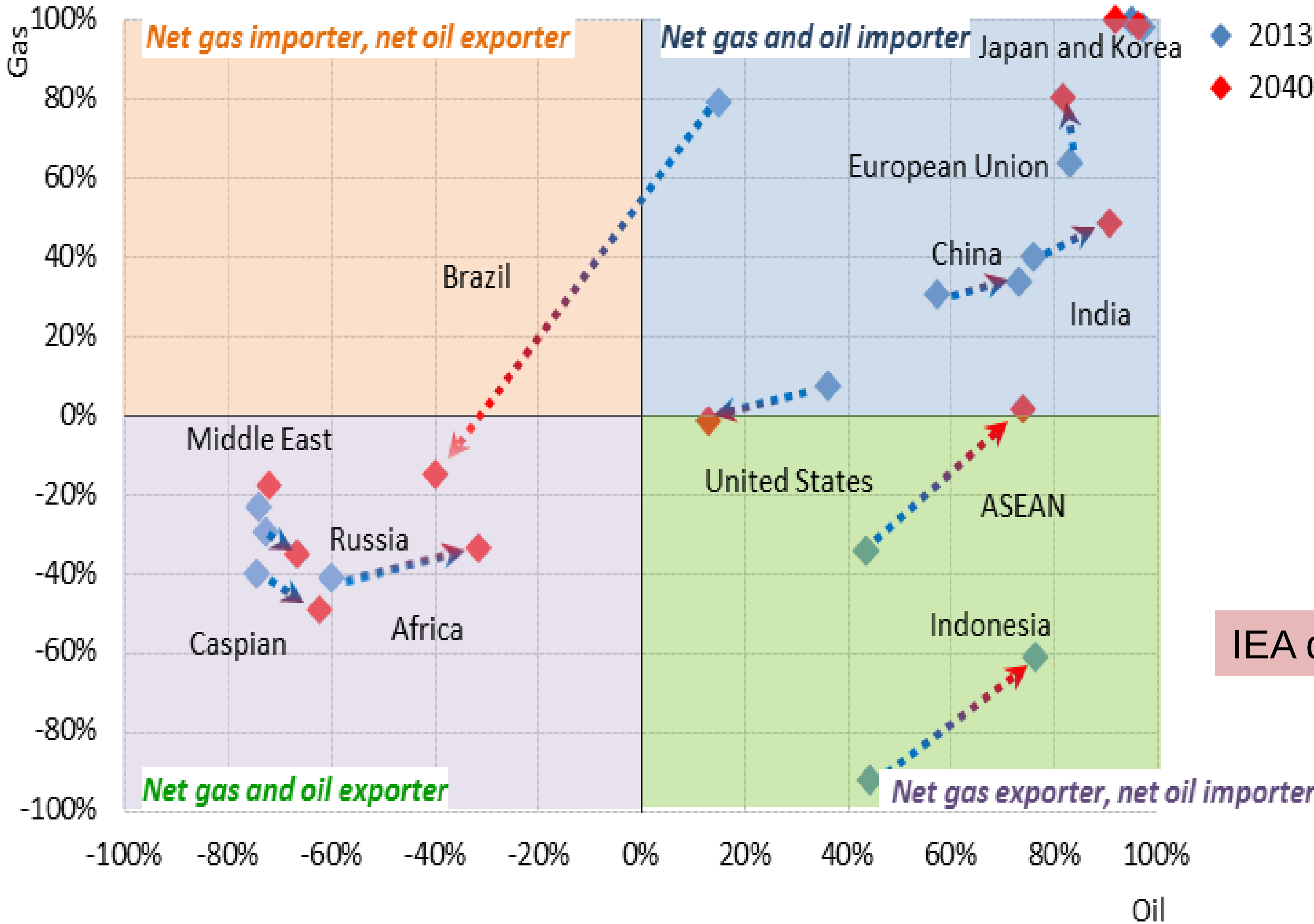
Share of LNG in global long-distance gas trade



Contractual terms and pricing arrangements are all being tested as new LNG from Australia, the US & others collides into an already well-supplied market

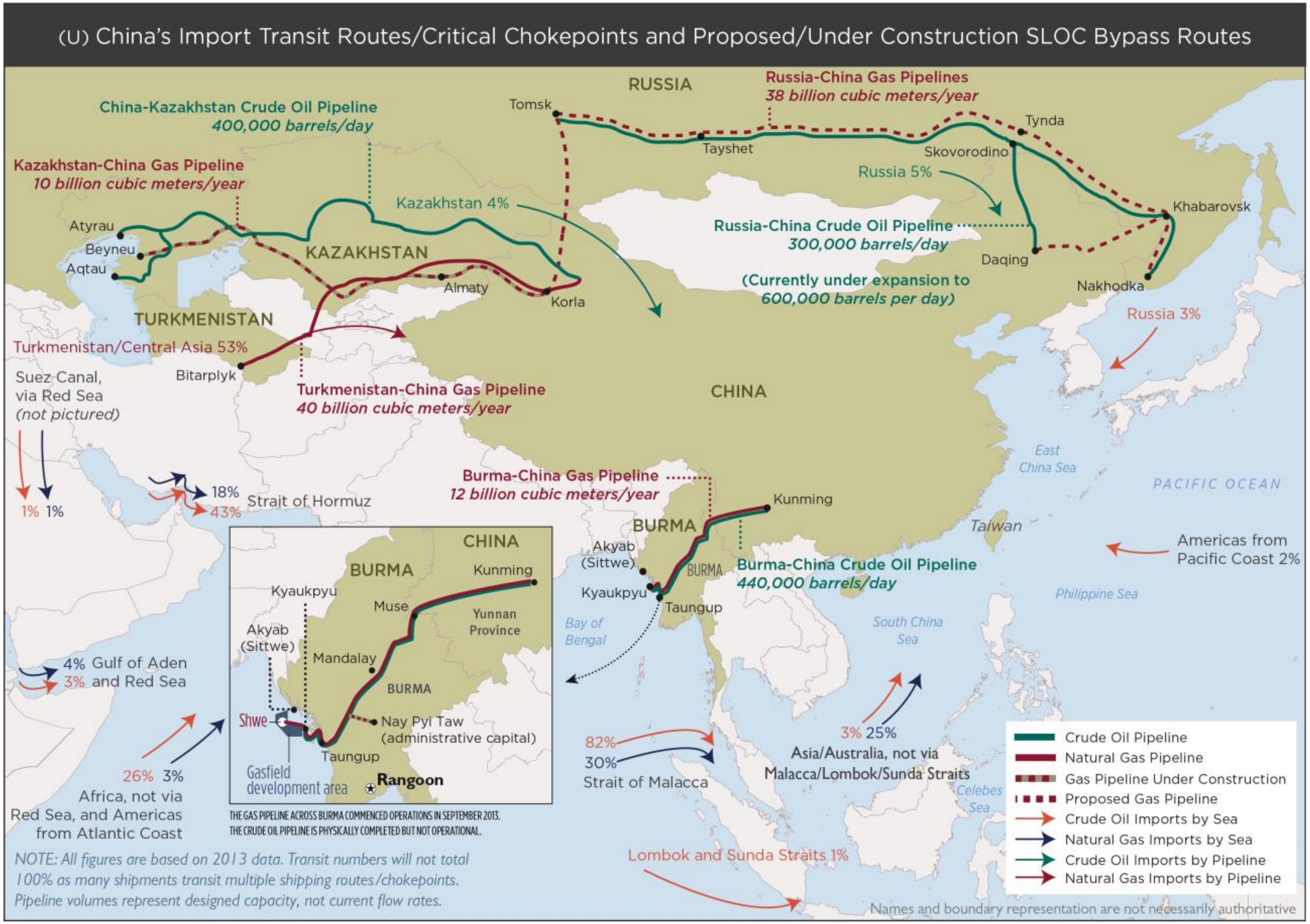
Geopolitics of the Shale Revolution: Strategic Positioning of Oil / Gas exporters and importers.



IEA data

China's Oil and Gas Import Transit Routes:

One Belt and One Road（一带一路）



USDOD China Report 2015

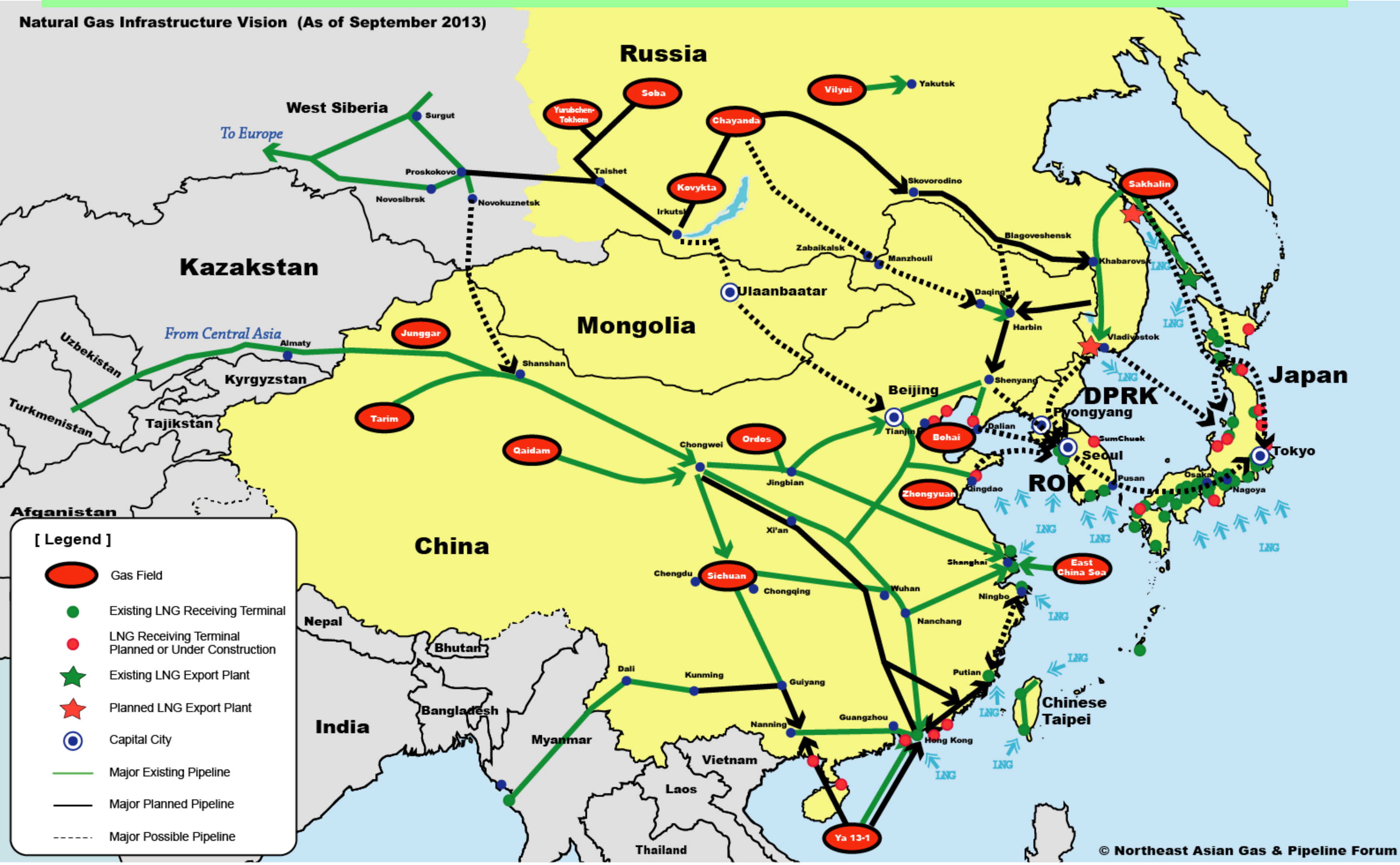
Russian Gas Pipelines Will Extend to the East: Recent China Deal

Russian Gas Infrastructure

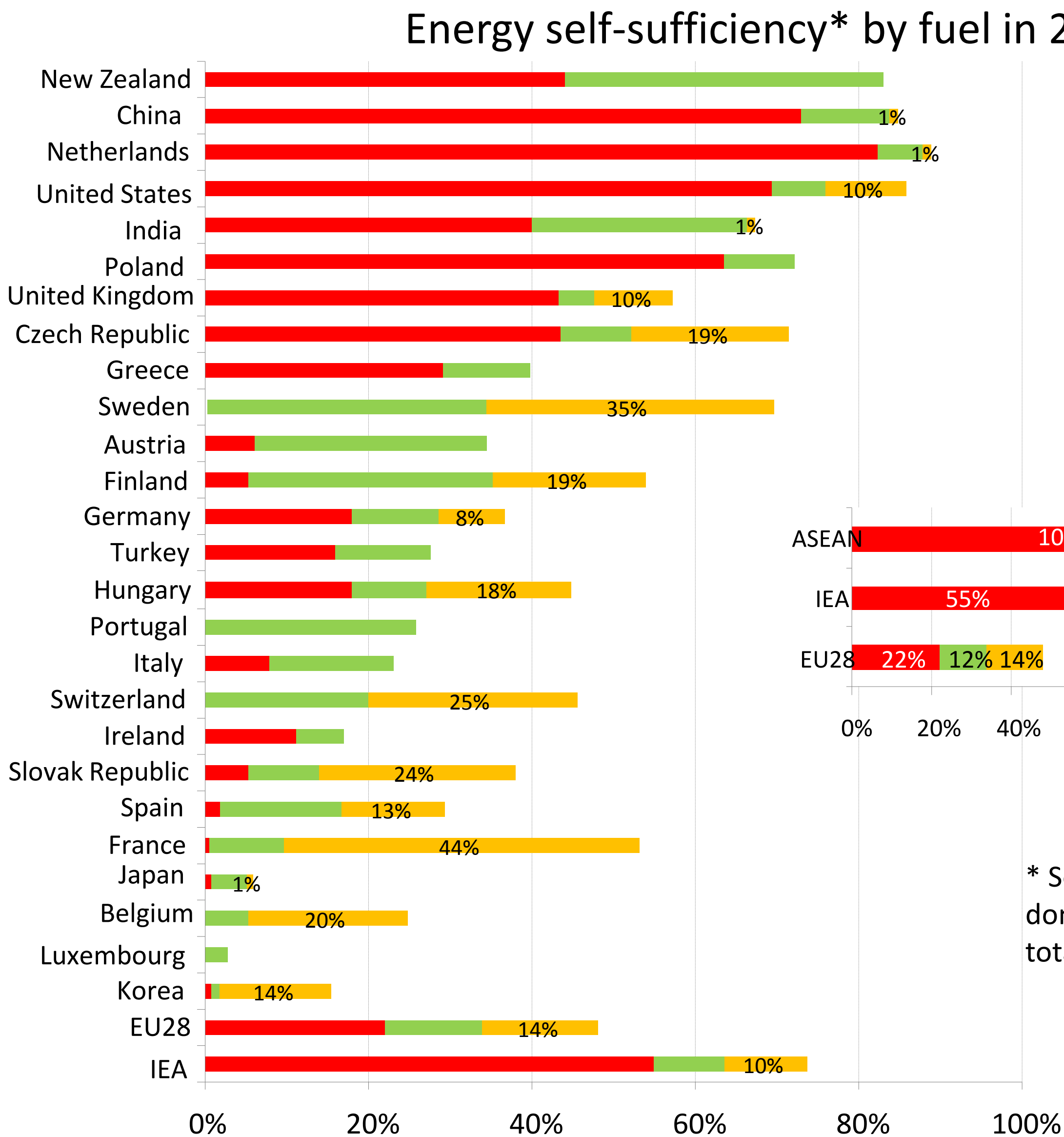
Source: IEA

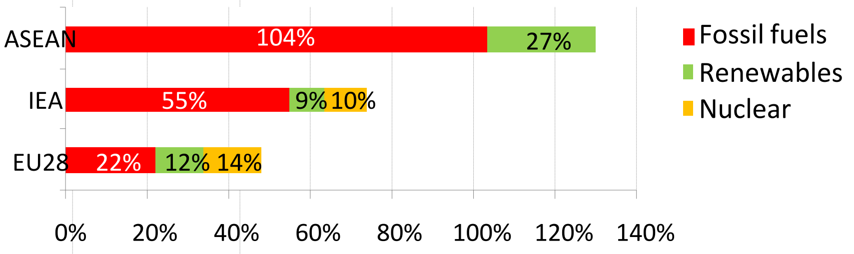
Mid-Term Oil & Gas Market 2010, IEA

Blue Print for North East Asia Gas & Pipeline Infrastructure: Dr. Hirata's Concept



Collective Energy Security and Sustainability by Diversity, Connectivity and Nuclear





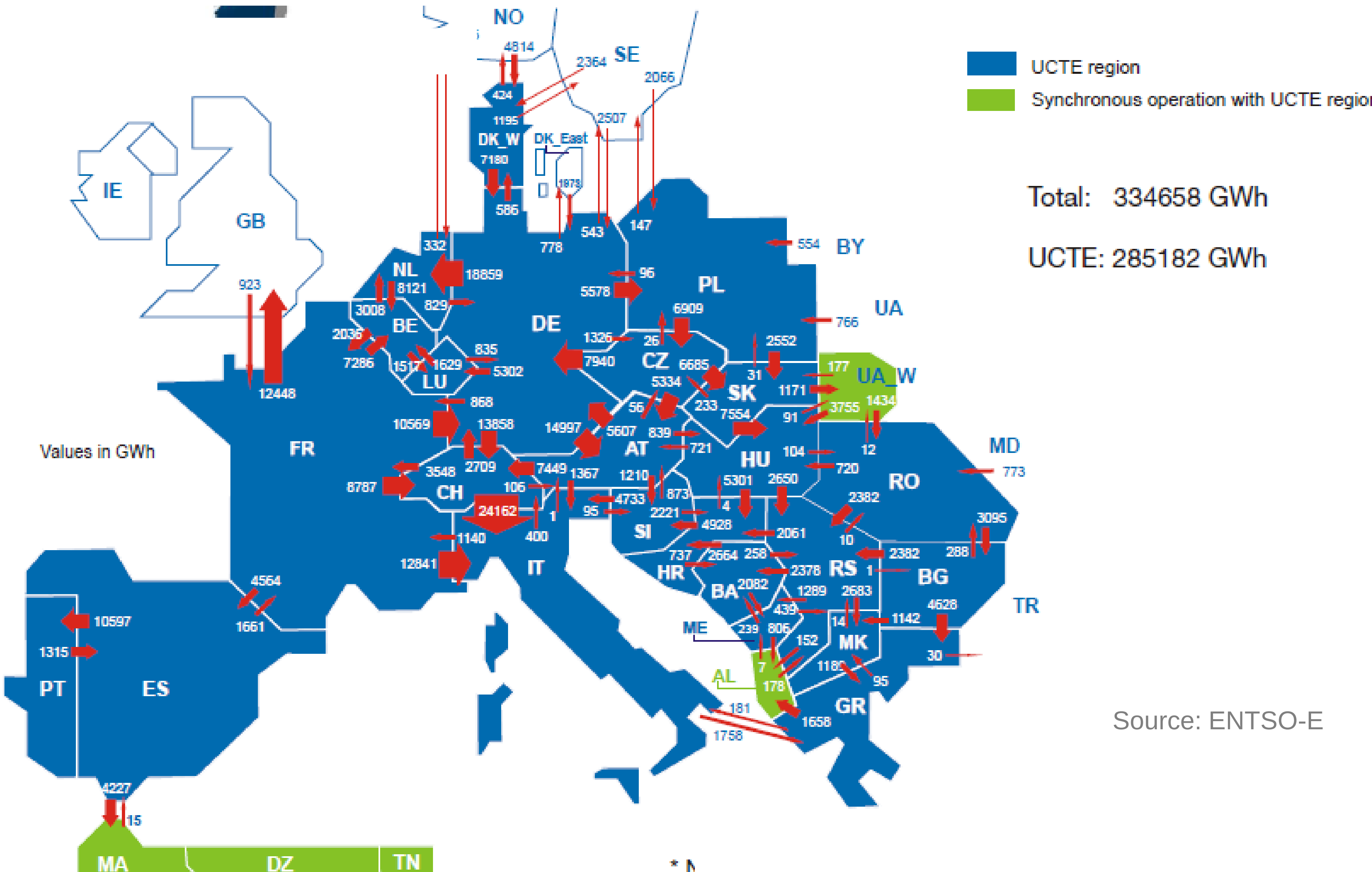
* Self-sufficiency =
domestic production /
total primary energy supply

Source: Energy Data Center, IEA.

Note: Does not include fuels not in the fossil fuels, renewables and nuclear categories.

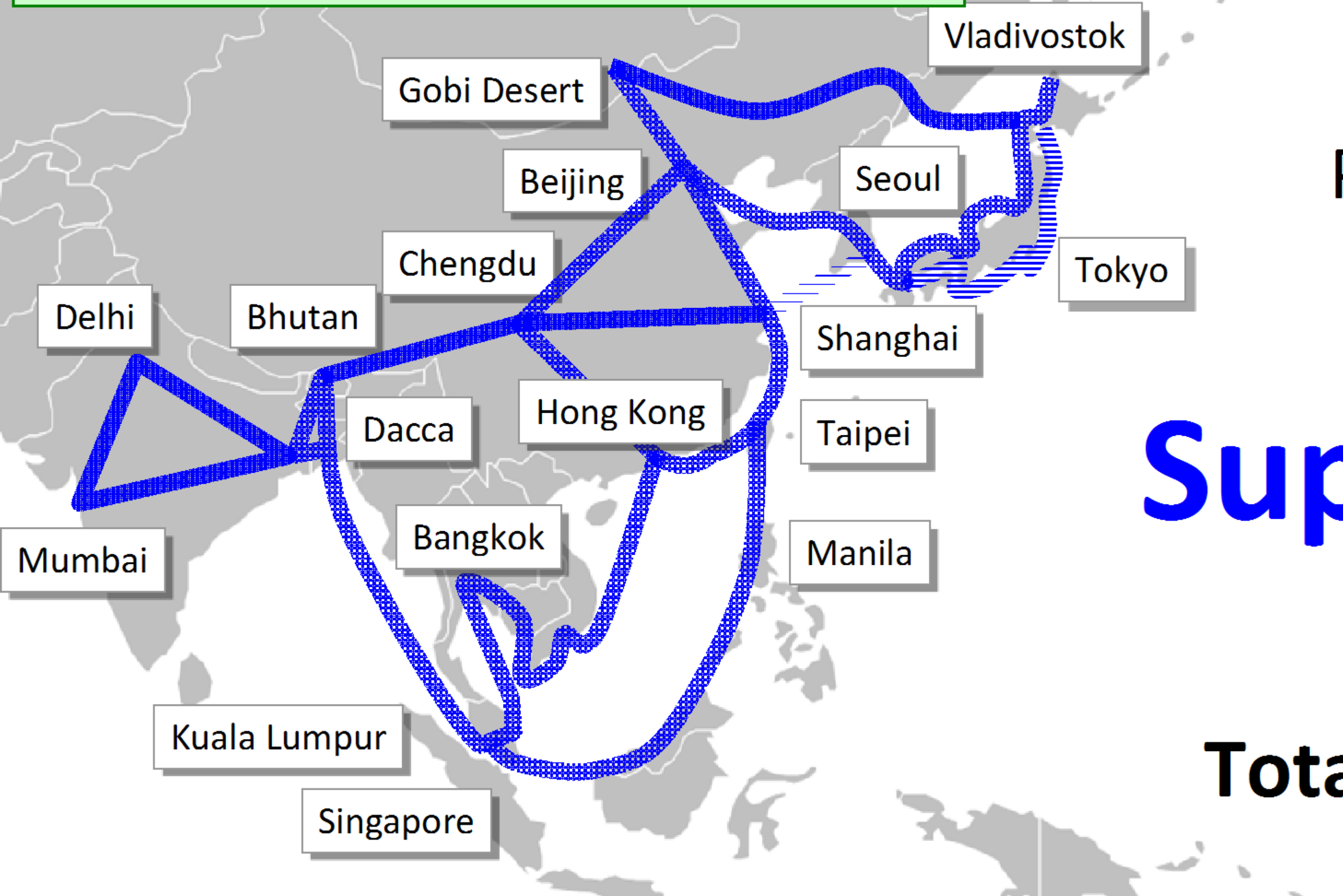
Power Grid Connection in Europe: Collective Energy Security and Sustainability

Physical energy flows between European countries, 2008 (GWh)



"Energy for Peace in Asia" New Vision?

Demand Leveling (Time Zone & Climate Difference)
Stable Supply (through regional interdependence)
Fair Electricity Price



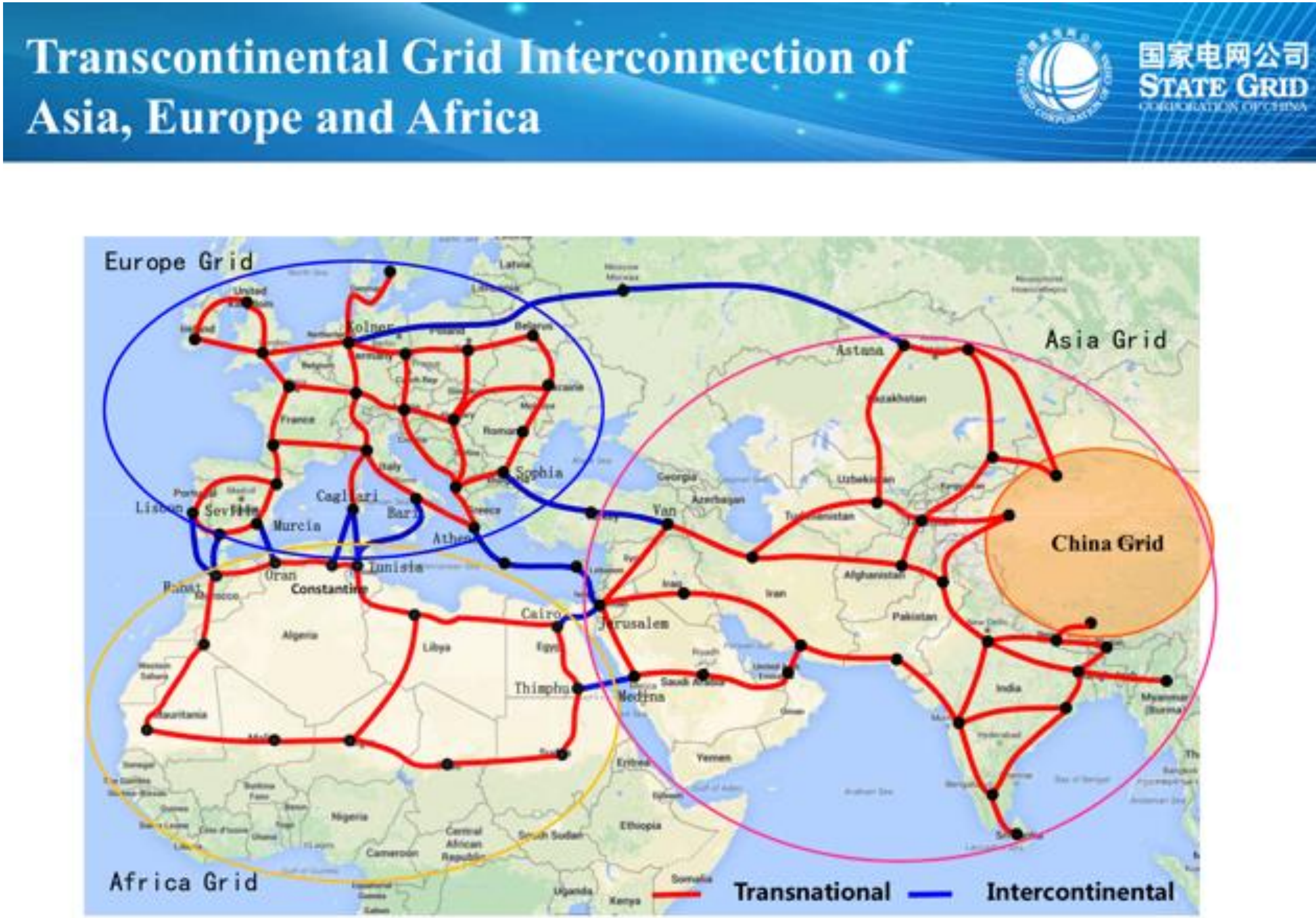
Phase 3

Asia Super Grid

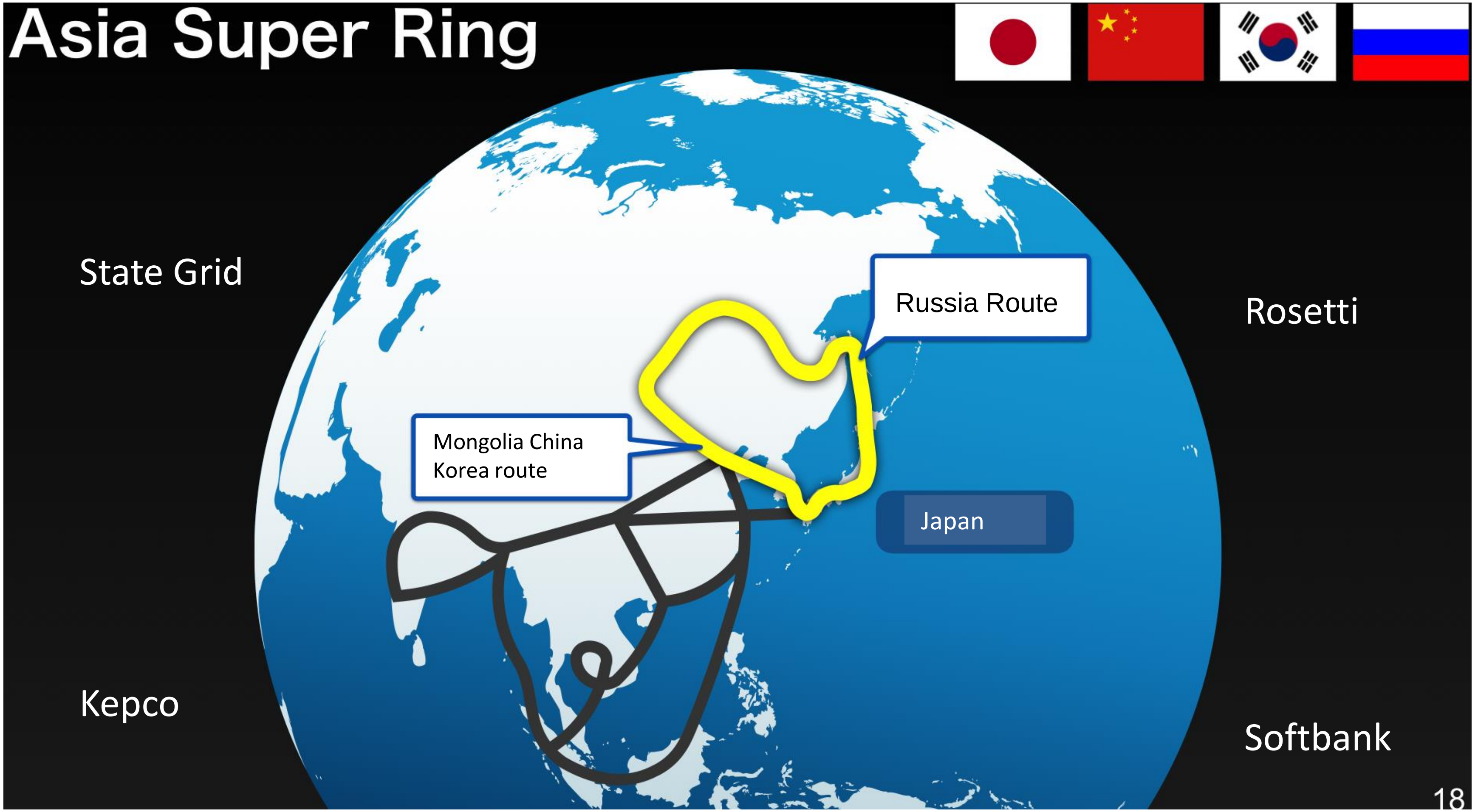
Total 36,000km

Presentation by Mr. Masayoshi SON

Global Energy Interconnection

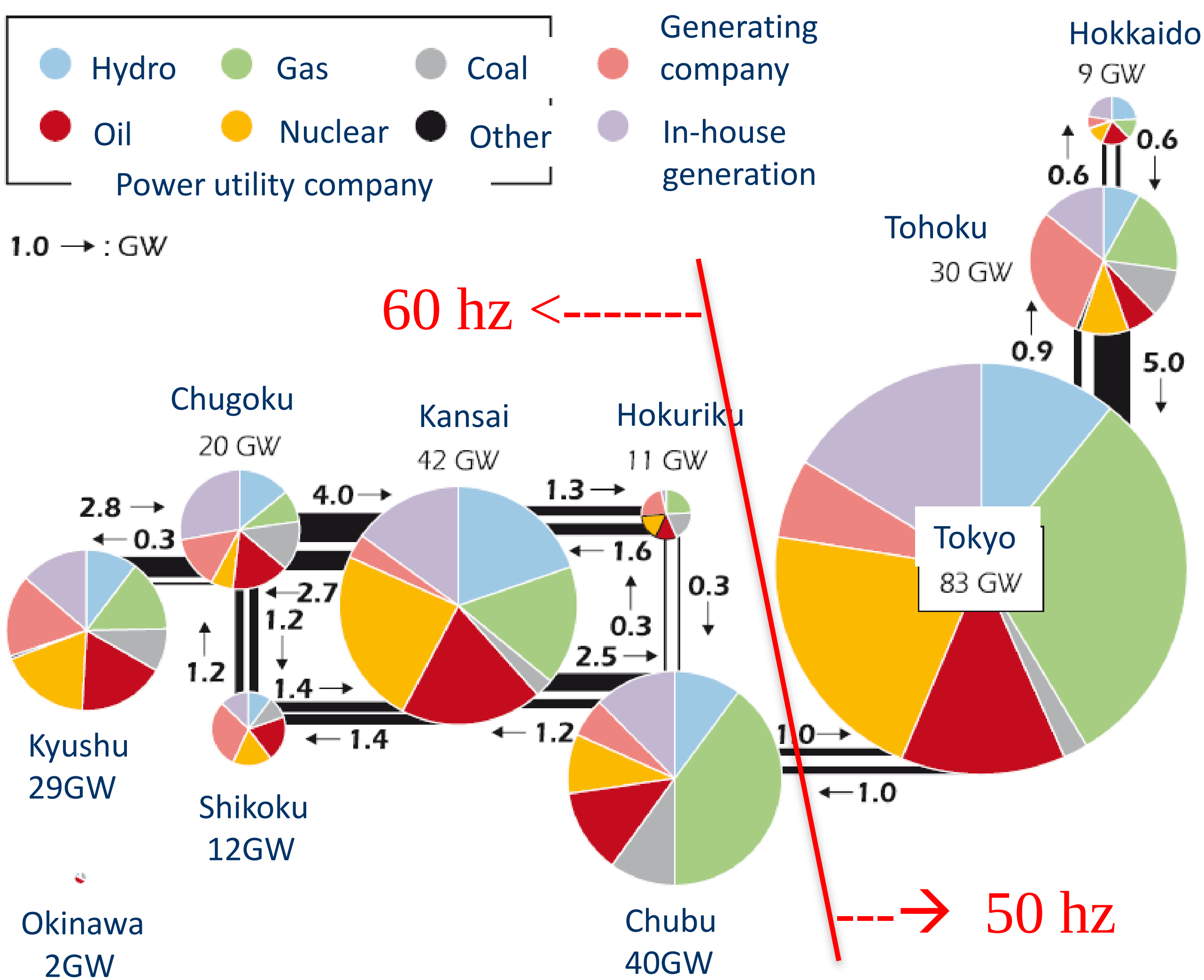


Asia Super Ring



Masayoshi SON's proposal

Lack of Grid connectivity in Japan



Source: Agency for Natural Resources and Energy, The Federation of Electric Power Companies of Japan, Electric Power System Council of Japan, The International Energy Agency

私見卓見 OPINION

原子力事業、関西電力に集約を

笹川平和財団理事長・元国際エネルギー機関事務局長 田中伸男

原子力発電所の再稼働はなかなか進まず、日本はエネルギーの9割を中東に依存する状態が続く。万が一、ホルムズ海峡が通航停止になれば国内は大混乱に陥るが、新潟県知事選の結果を見ると、東京電力は福島第1原発の事故から5年が過ぎた今も国民の信頼を回復できていない。

温暖化ガス削減の国際的枠組みであるパリ協定は各国の約束のレベルこそ低いが、今後のピアレビュー（相互評価）で削減圧力が強まろう。再生可能エネルギーの利用拡大が必要だが、思ったほど発電が伸びない状況だ。

一方、アジアの地政学はエネルギーを巡る構図を一変させる可能性がある。ロシアのプーチン大統領は最近、中国、モンゴル、ロシア、韓国、日本を電力線で結んでロシアの電力を輸出する構想への支持を表明した。サハリンと北海道を海底ケーブルでつなぐ構想はこの一部になる可能性がある。ロシアは日本と連携しつつ、中国をハブとする国際連携を目指す中国に対抗しようとしているのだ。

こうしたなか、日本はどんなエネルギーの将来図を描くべきなのか。

原子力事業の再編に関する報道が出ているが、信頼を失った東電は原子力事業を関西電力に売却し、関電を原子力中核会社として人材を集約したらどうだろう。原子力は廃炉や廃棄物対策、新型炉の開発などを進めるために人材や知識の共同活用が必要だ。

東電には発送電の法的分離の次の段階で送電会社を統合する。日本は電力の周波数が東の50ヘルツ、西の60ヘルツと分かれており、地域独占の9電力会社の連携が弱い。これが再生可能エネルギーの利用拡大が進まない理由にもなっている。統合すれば系統連携への投資が進むはずだ。東電の株価は上がり、国の出資も回収できる時が来るだろう。

ガスの調達も共同で行う必要がある。すでに東京電力と中部電力はガスの調達を共同して行う共同出資会社JERAを作り、そこに火力事業を集約しようとしている。

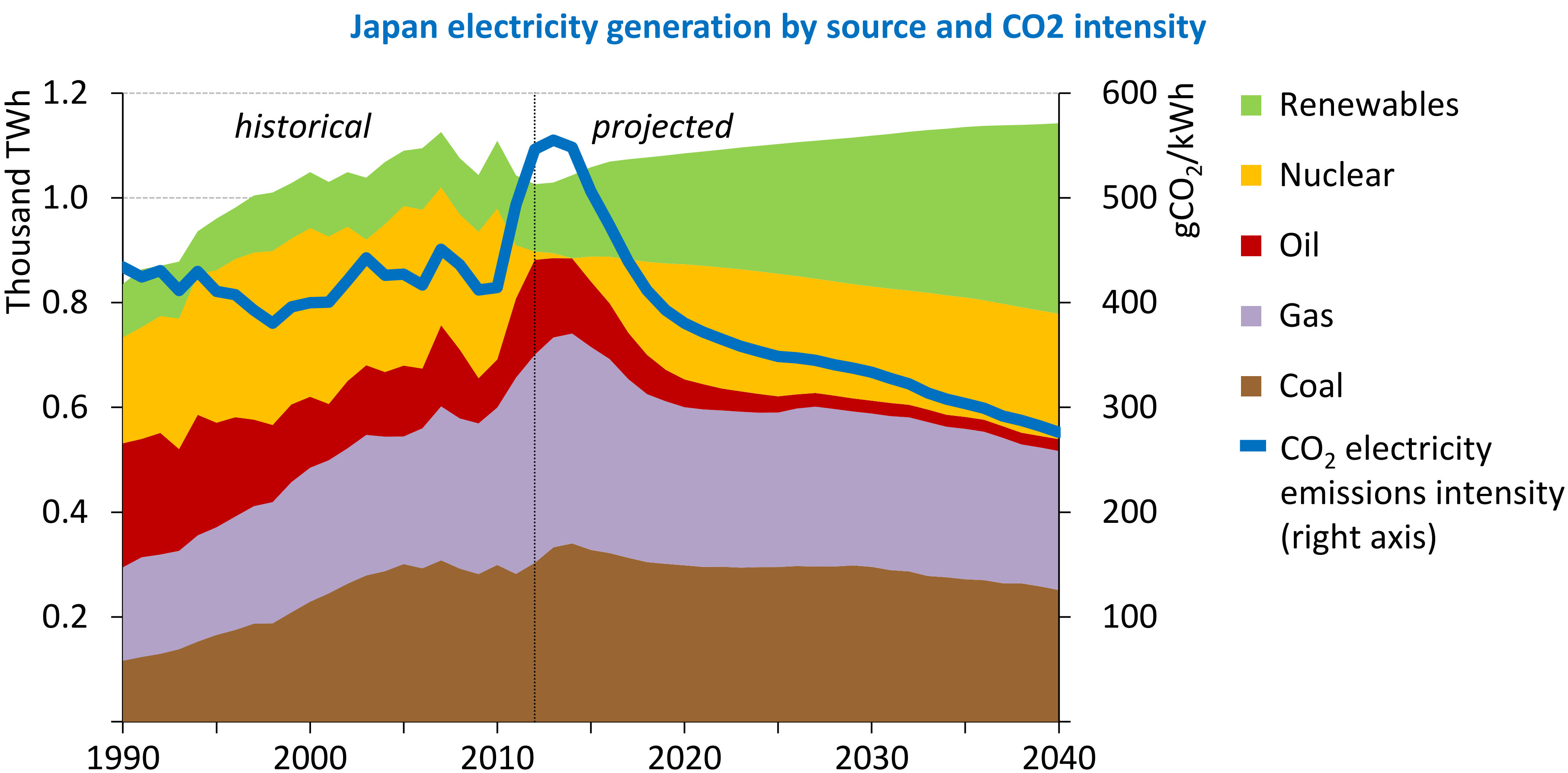
他の電力会社は風力、太陽光を中心とする発電に注力したら良い。隣国と系統線を結んでアジア広域市場ができても、それぞれが得意とする分野に特化することで勝ち残る強い電力会社ができる。

エネルギーはグローバルで動く。国内事情だけで小手先の解決先を探るのではなく、アジアの市場を見ながら大きなビジョンを描くことが答えを書く近道ではないか。

2016-10-28
日経新聞

Japan’s power system: moving to a more diverse & sustainable mix

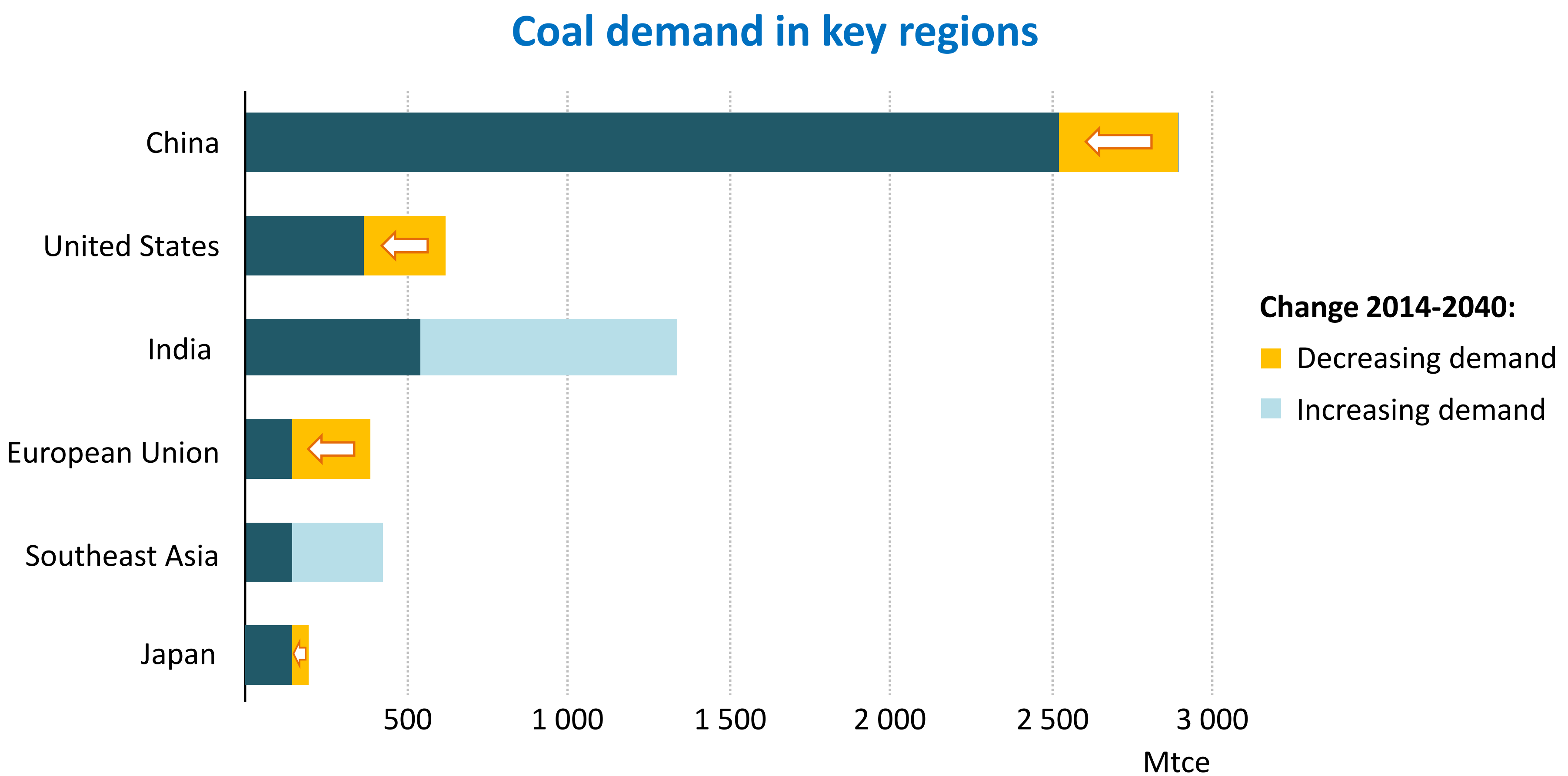
WEO2014



With nuclear plants expected to restart & increased use of renewables, Japan’s electricity mix becomes much more diversified by 2040
(Renewables 32%, Nuclear 21%, gas 23%, coal 22%)

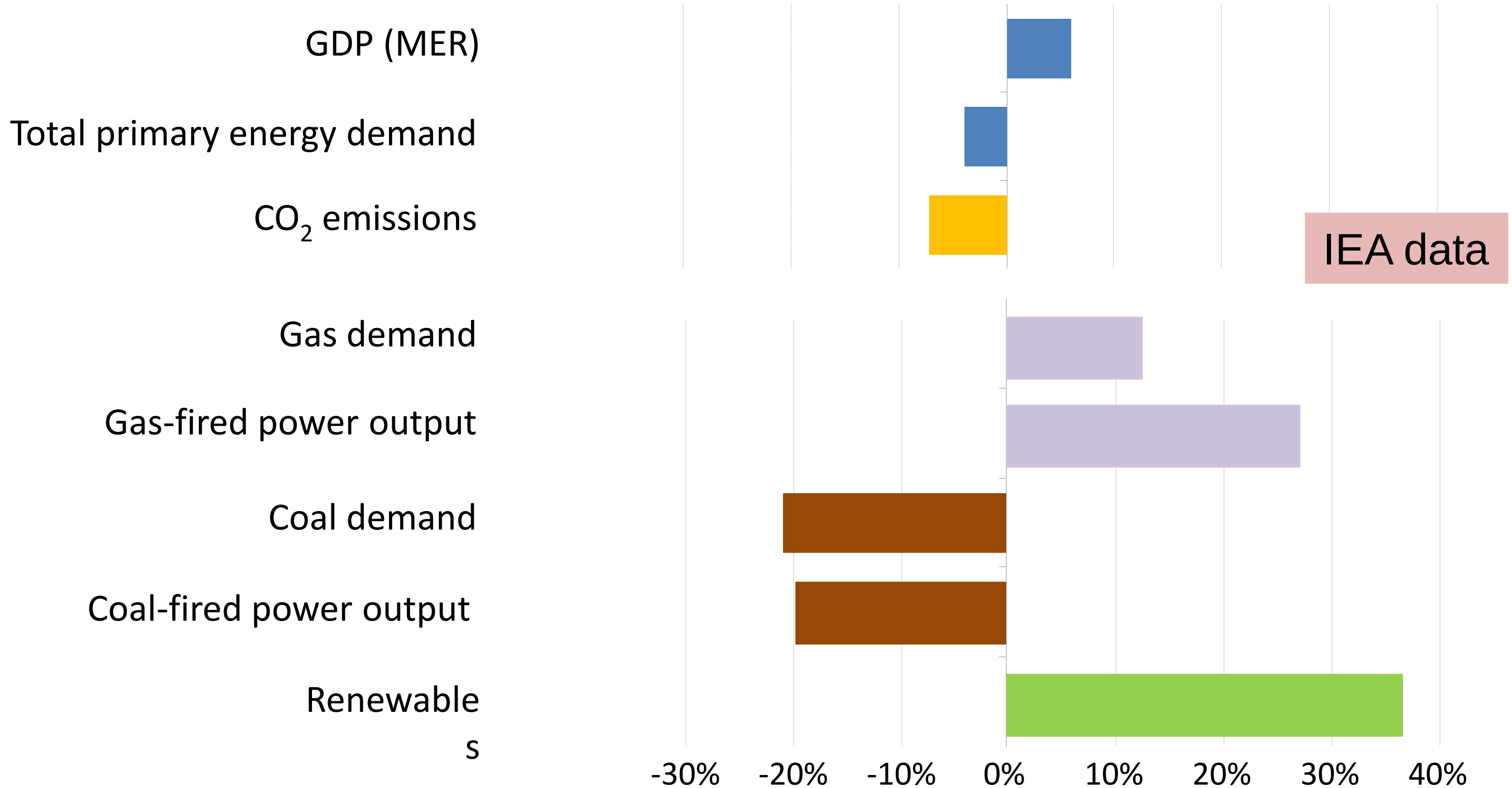
Coal: a rock in a hard place

WEO2016



The peak in Chinese demand is an inflexion point for coal; held back by concerns over air pollution & carbon emissions, global coal use is overtaken by gas in the 2030s

The Shale Gas revolution in the US achieved Win-Win-Win.
The US is the sole winner of the energy market.

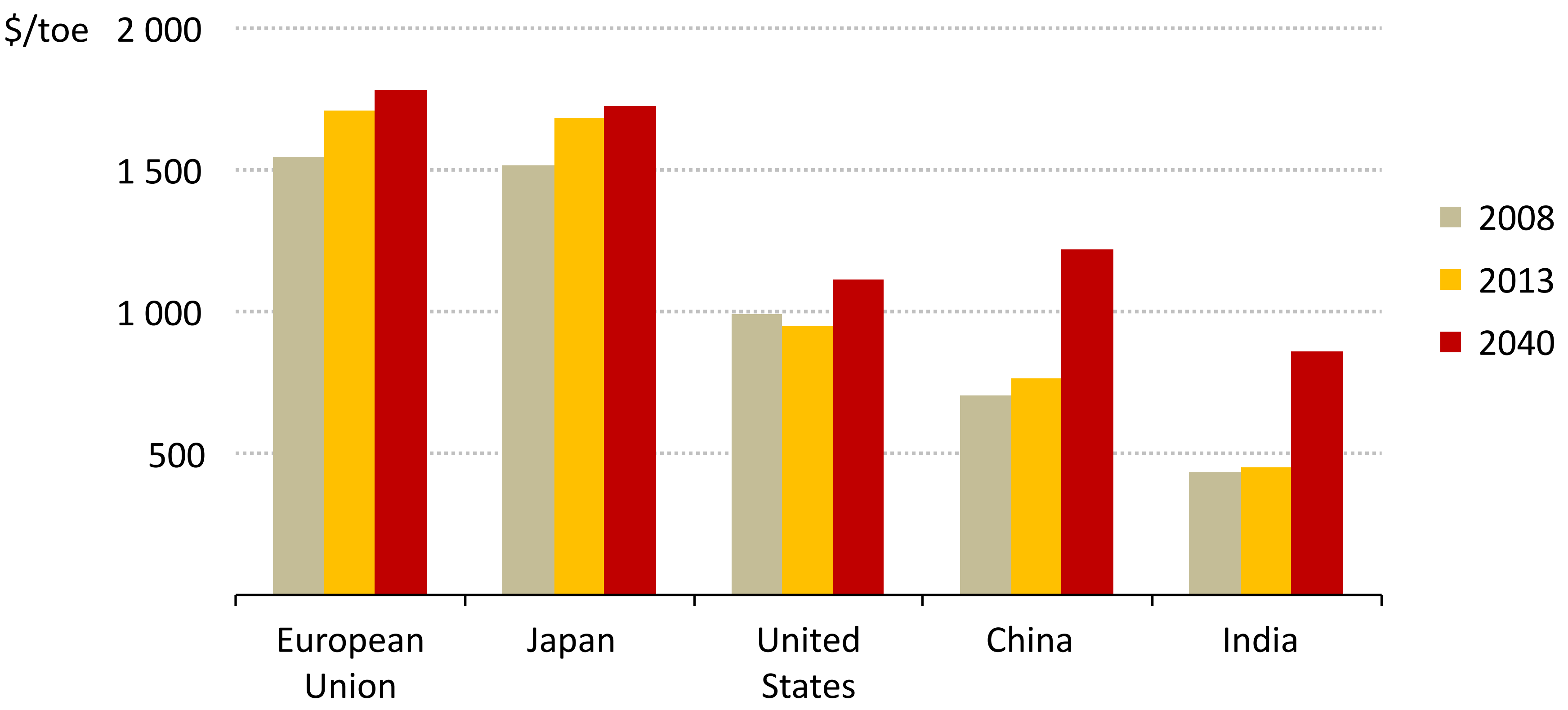


From 2008-2013, United States CO_2 emissions went down by 7% due to coal-to-gas fuel switching, power generation efficiency gains & increased renewables output

United States holds a strong position on energy costs

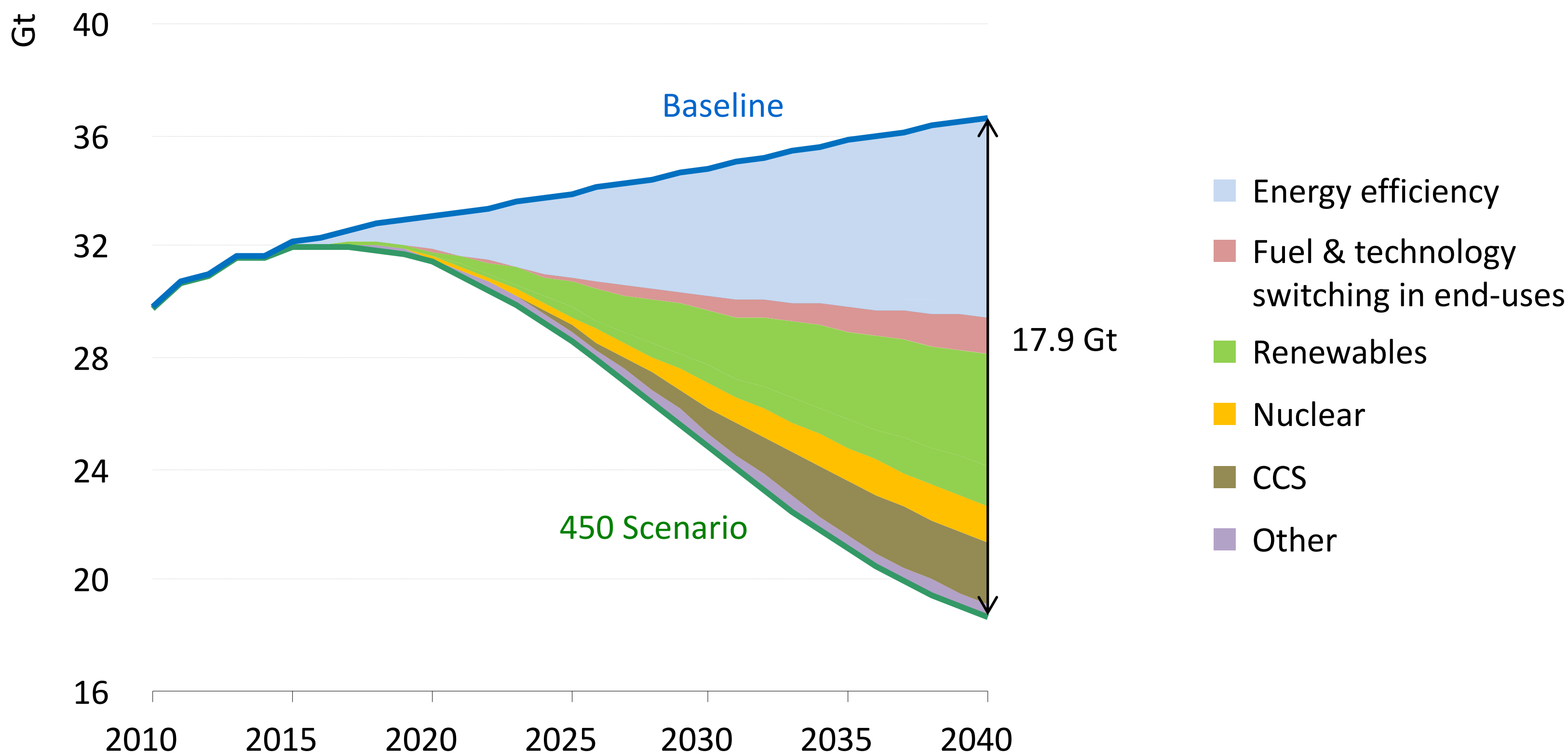
WEO2014

Weighted average cost of energy paid by consumers



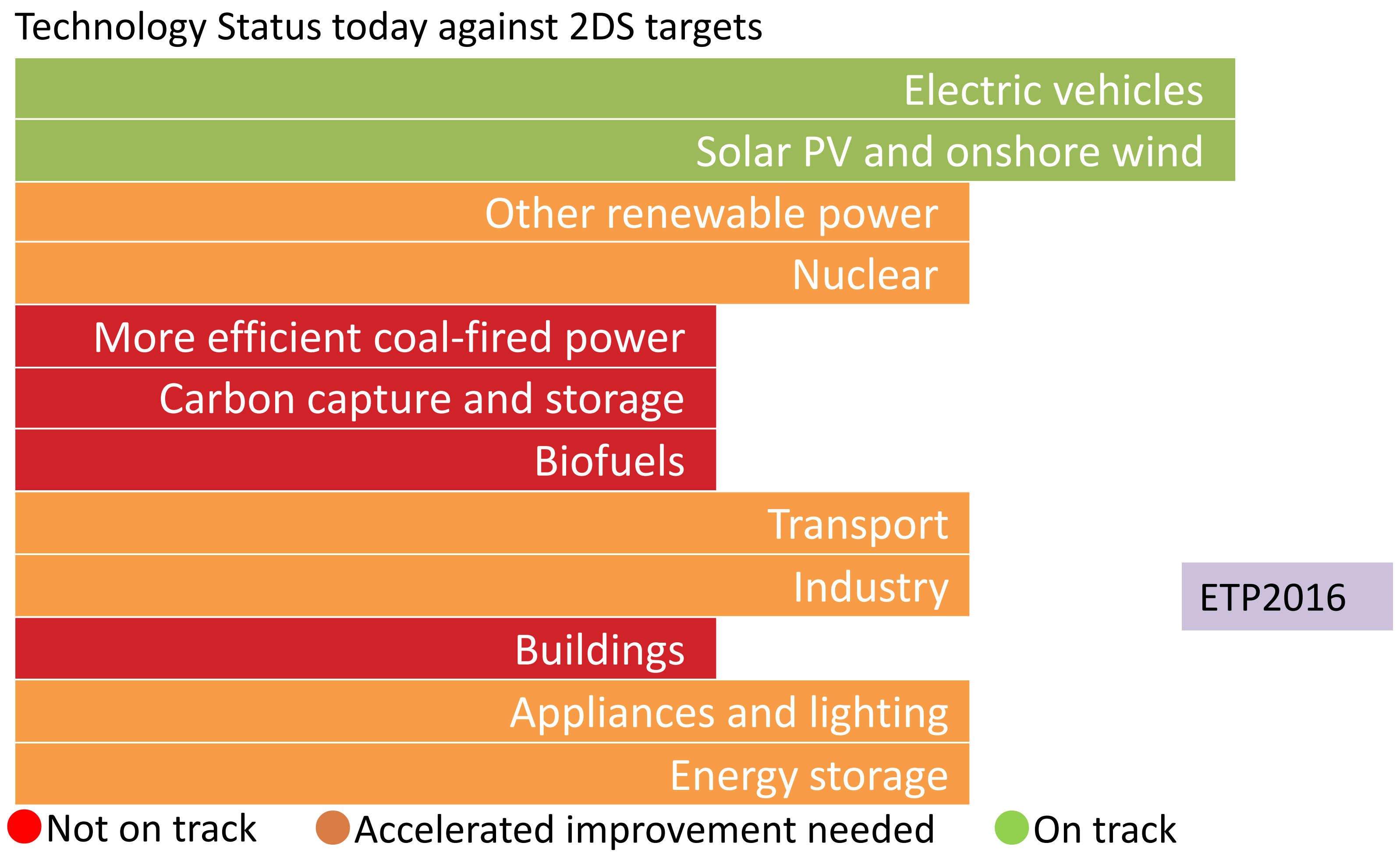
Economies face higher costs, but the pace of change varies: China overtakes the US, costs double in India & remain high in the European Union & Japan

A 2° C pathway is still some further efforts away



A peak in emissions by around 2020 is possible using existing policies & technologies; technology innovation and RD&D will be key to achieving the longer-term goal.

Global progress in clean energy needs to accelerate

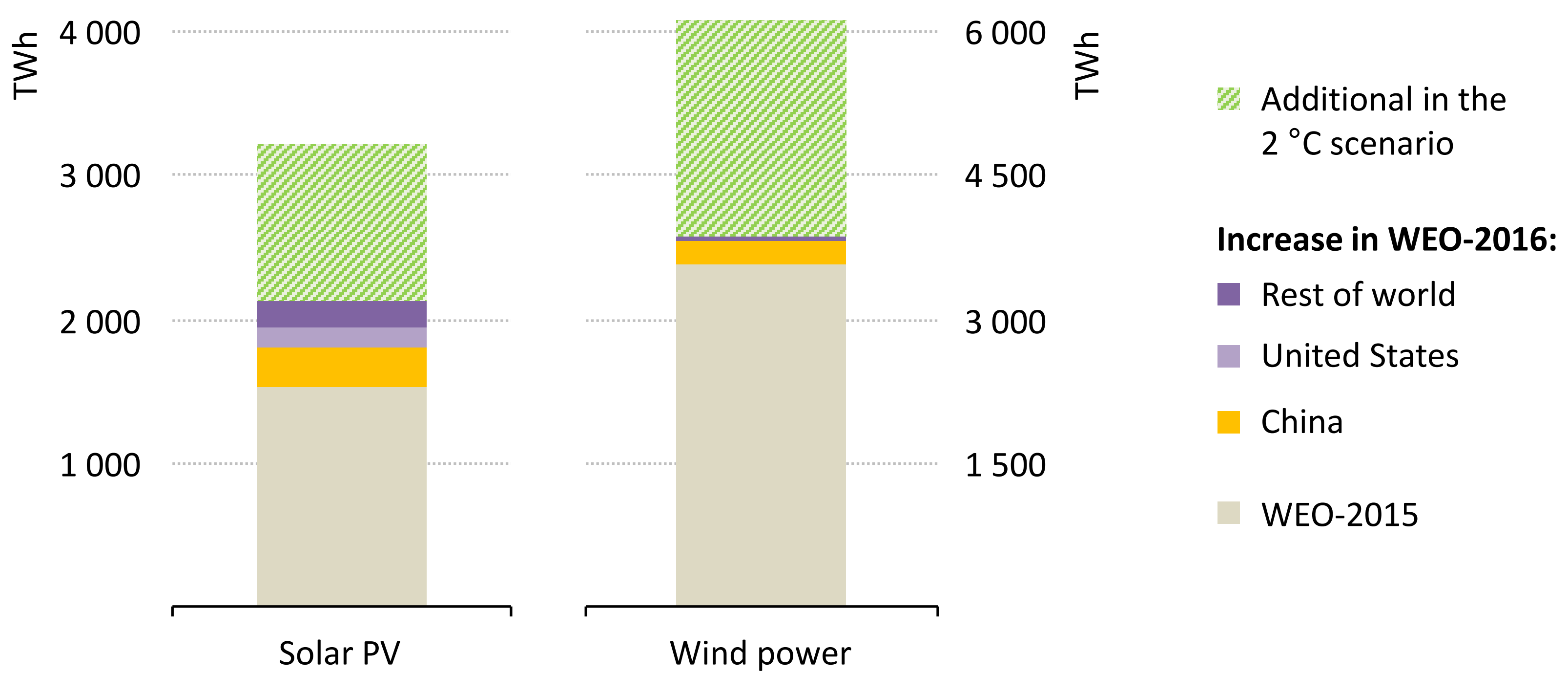


Global clean energy deployment is still overall behind what is required to meet the 2°C goal, but recent progress on electric vehicles, solar PV and wind is promising

Greater policy support boosts prospects for solar PV and wind

WEO2016

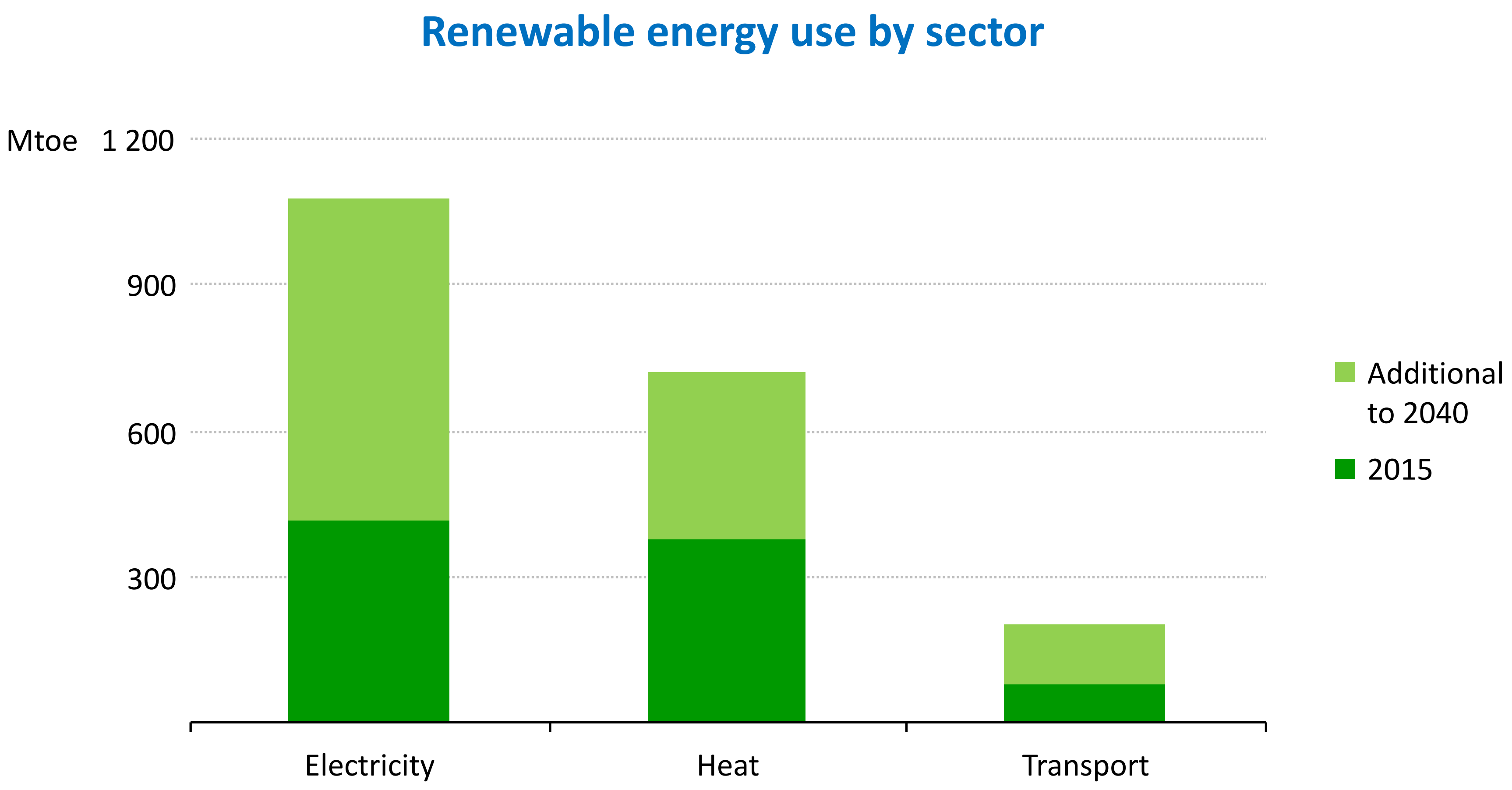
Solar PV and wind generation, 2040



Stronger policies on solar PV and wind help renewables make up 37% of electricity generation in 2040 in our main scenario – & nearly 60% in the 2 °C scenario

The next frontiers for renewables are heat and transport

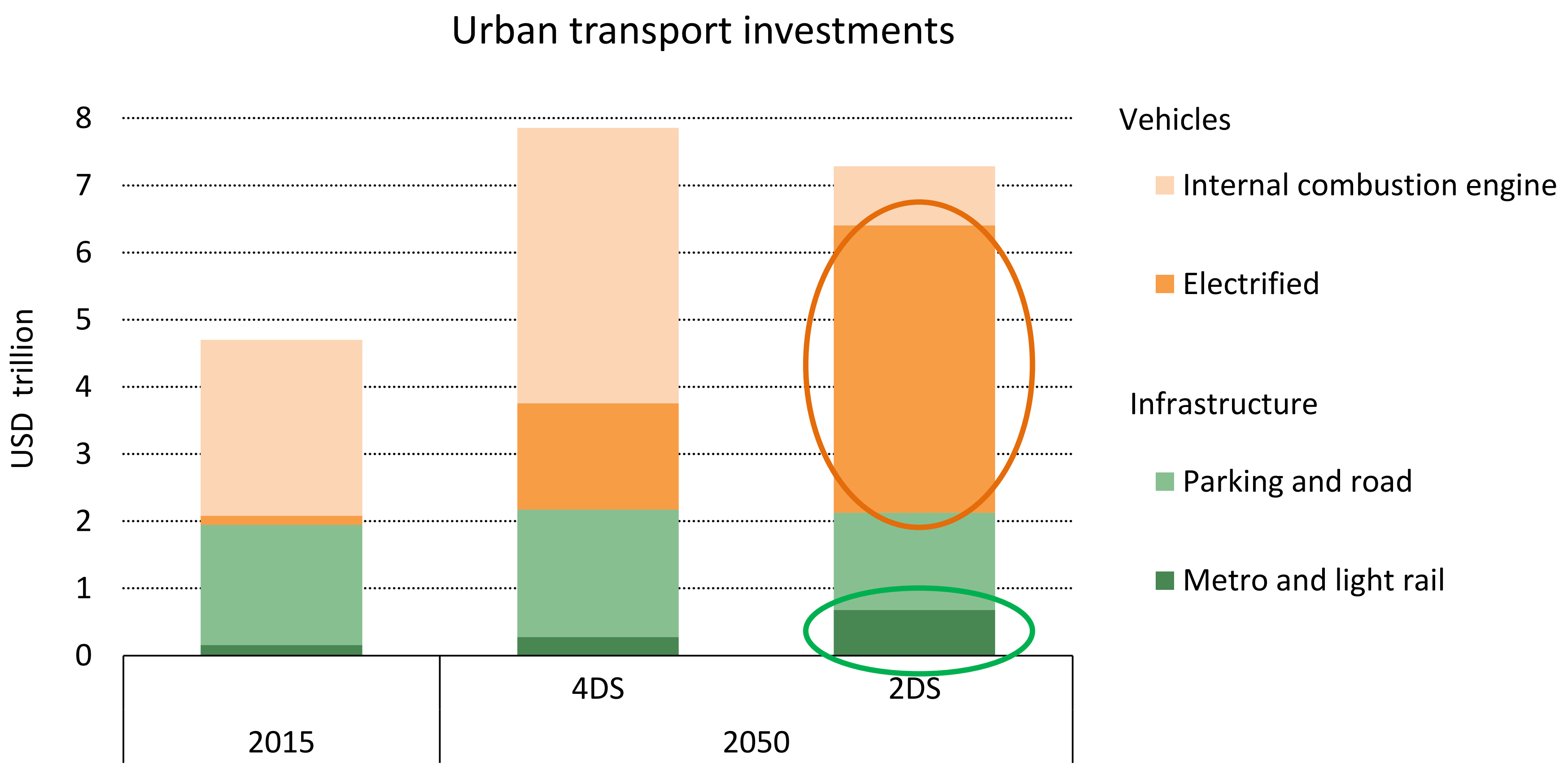
WEO2016



Today renewables in electricity and heat use are nearly at par; by 2040, the largest untapped potential lies in heat and transport

Sustainable transport systems: a cheaper way to provide service

ETP2016

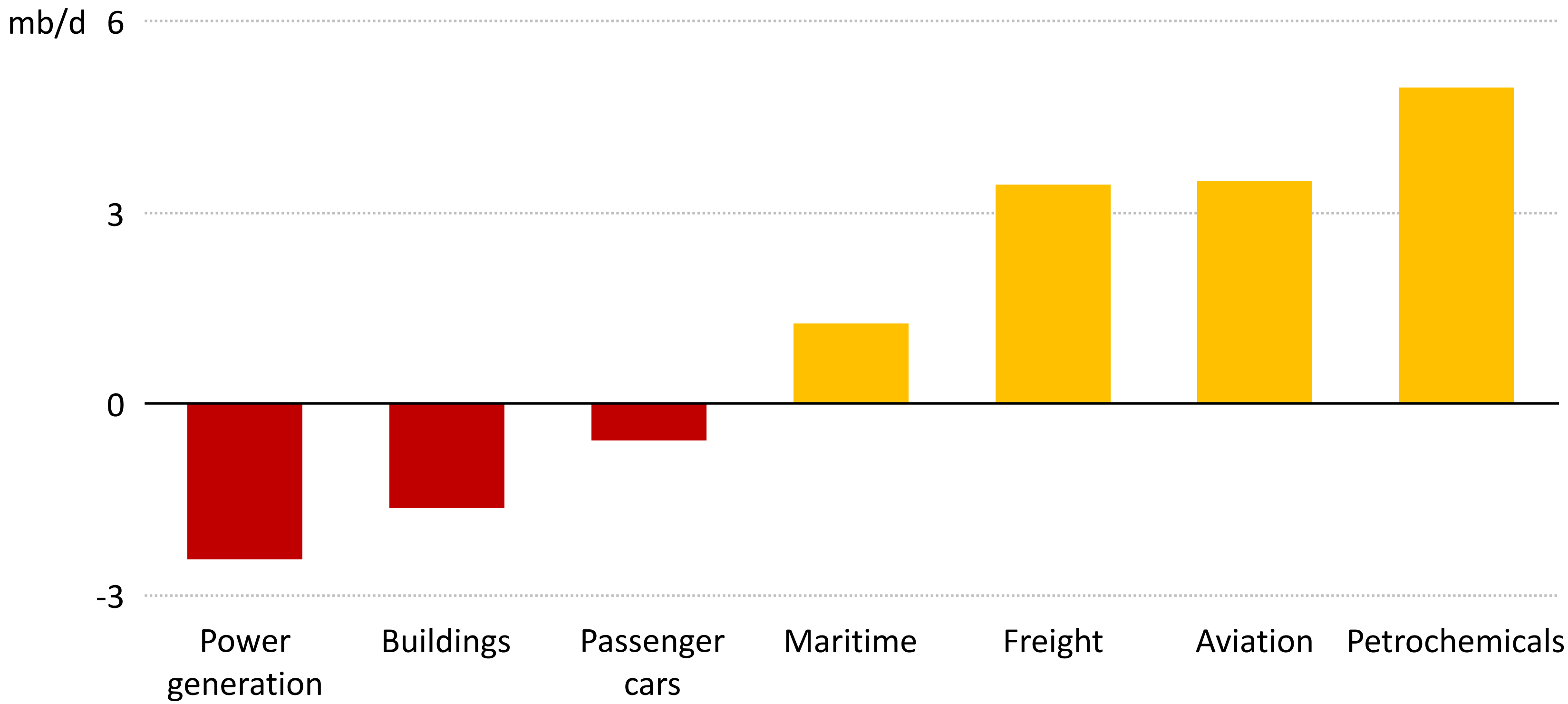


In the 2DS, by 2050 one billion cars are electric vehicles while public transport travel activity more than doubles

No peak yet in sight, but a slowdown in growth for oil demand

WEO2016

Change in oil demand by sector, 2015-2040



The global car fleet doubles, but efficiency gains, biofuels & electric cars reduce oil demand for passenger cars; growth elsewhere pushes total demand higher

Impact of 450 ppm Scenario on Oil Market

WEO 2013

Figure 2.5 ▷ World primary energy demand by fuel in the New Policies Scenario

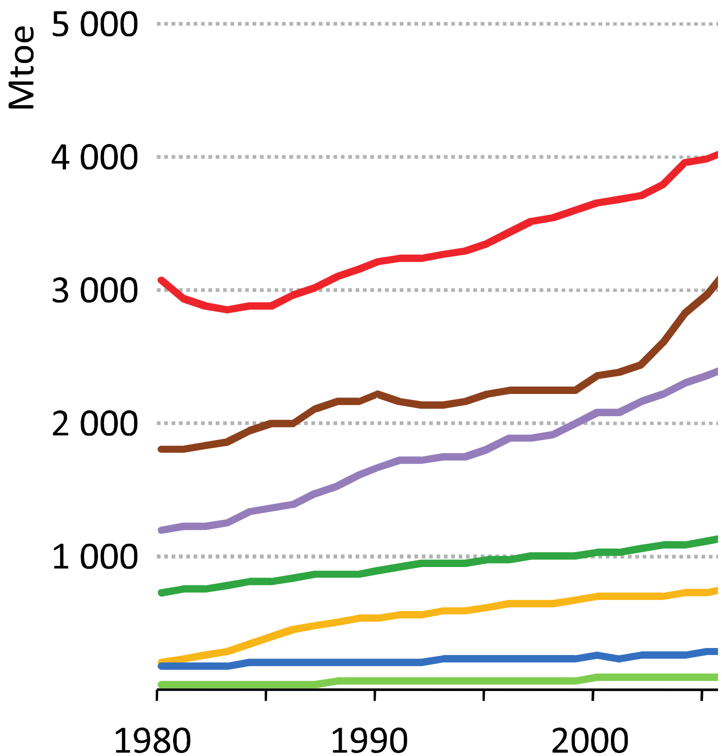
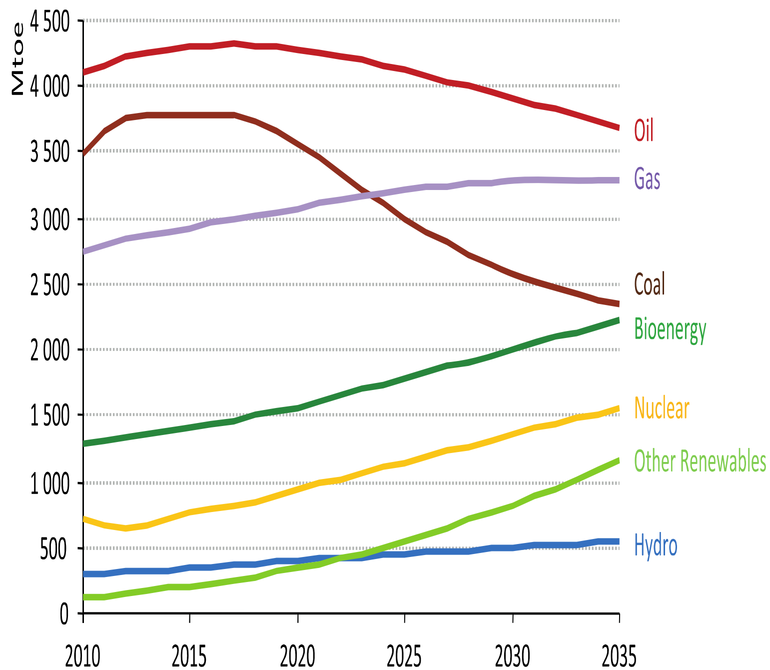


Figure 8.5 ▷ Primary energy demand in the 450 Scenario by fuel

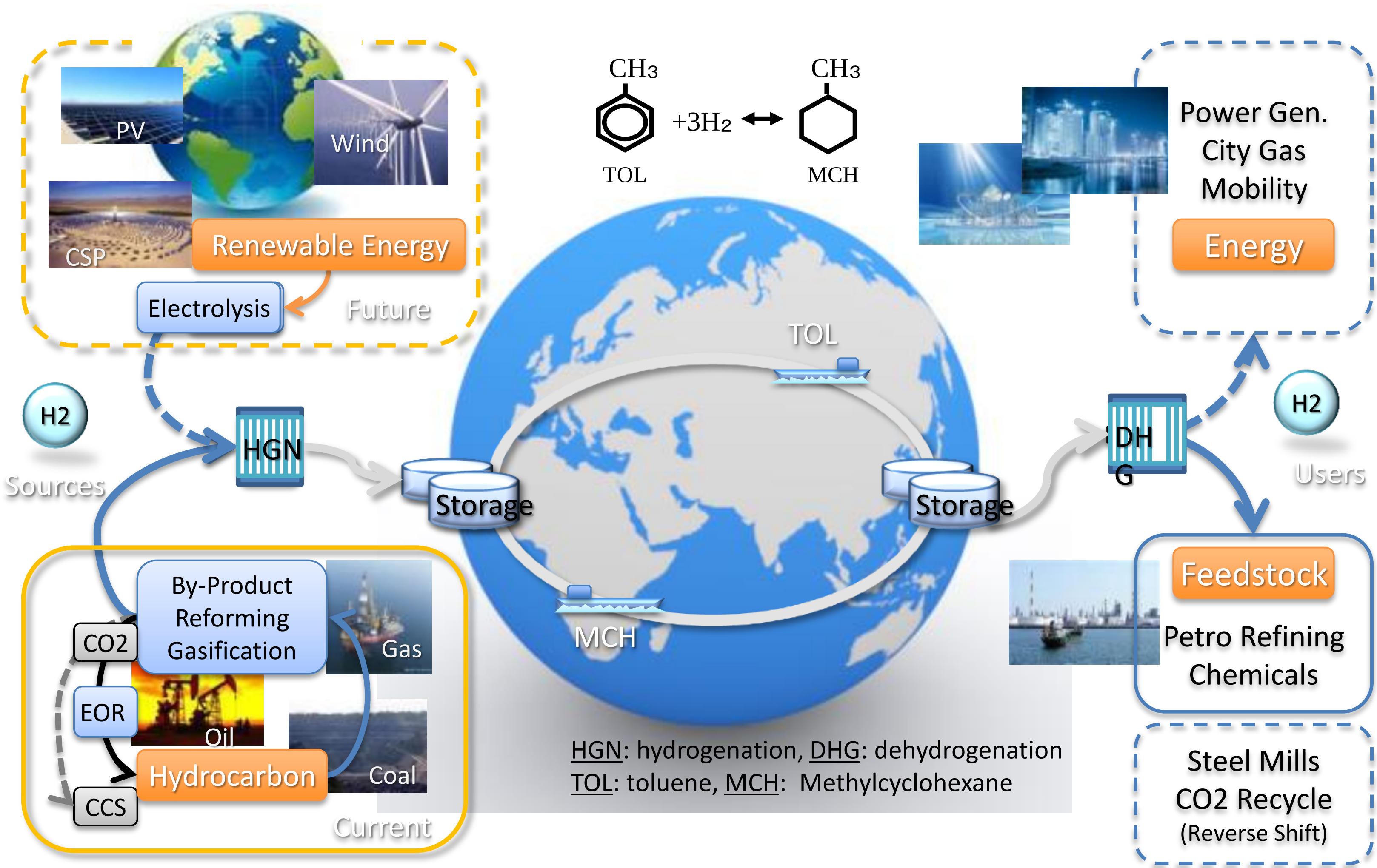


newables

The Stone Age didn't end because we ran out of stones.

Hydrogen as solution: Chiyoda's Supply Chain Proposal

- Chiyoda established a complete system which enables economic H2 storage and transportation.
- MCH, an H2 carrier, stays in a liquid state under ambient conditions anywhere.

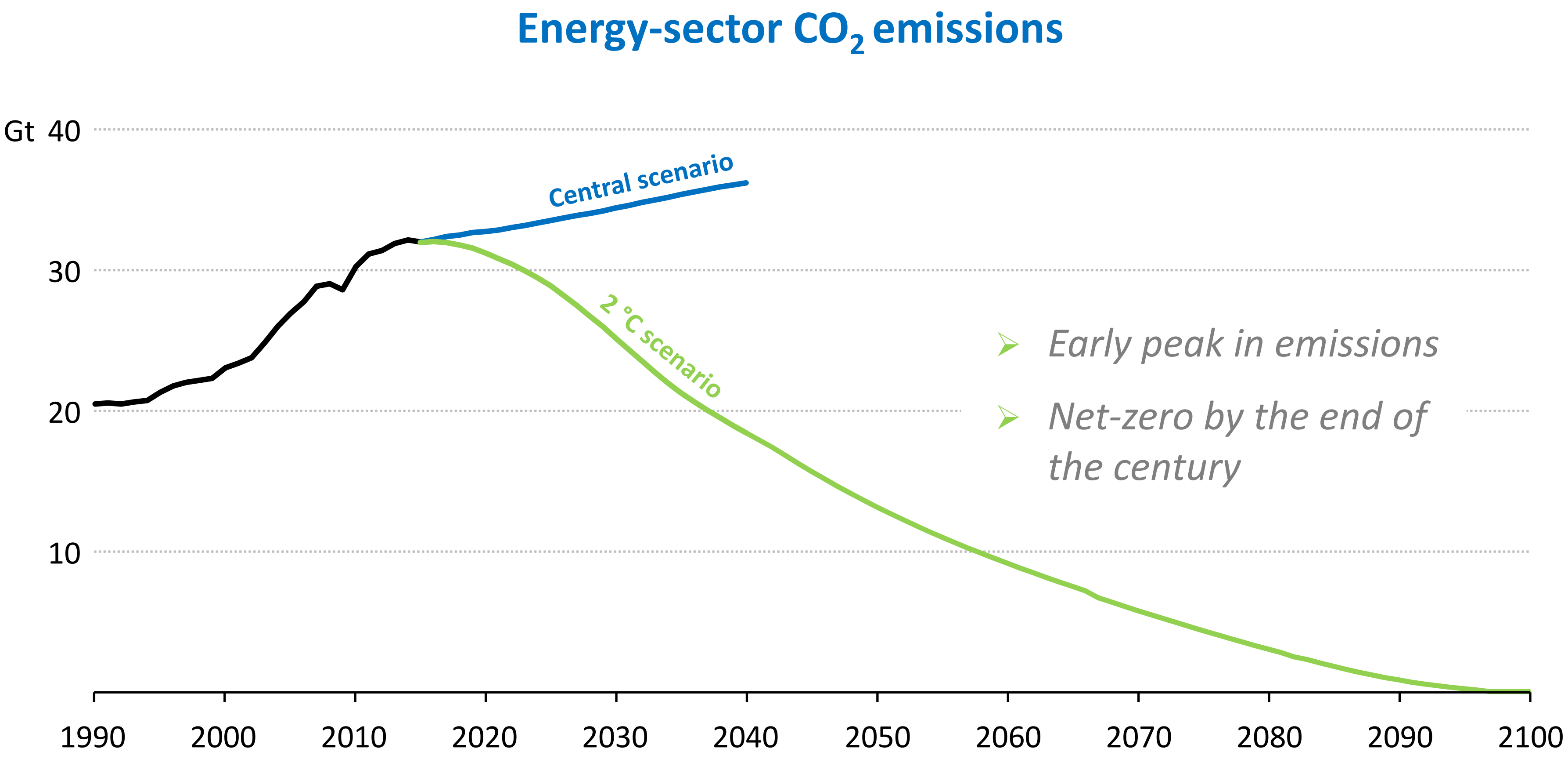


- H2 Supply of a 0.1-0.2mmtpa LNG equivalent scale (M.E. to Japan) could be feasible.

CHIYODA CORPORATION

Still a long way from a pathway to energy sector decarbonisation

WEO2016



Current pledges fall short of limiting the temperature increase to below 2 °C; raising ambition to 1.5 °C is uncharted territory

Sustainable Nuclear Power

Figure 1.7 Global electricity generation mix in the 2DS, 2013-50

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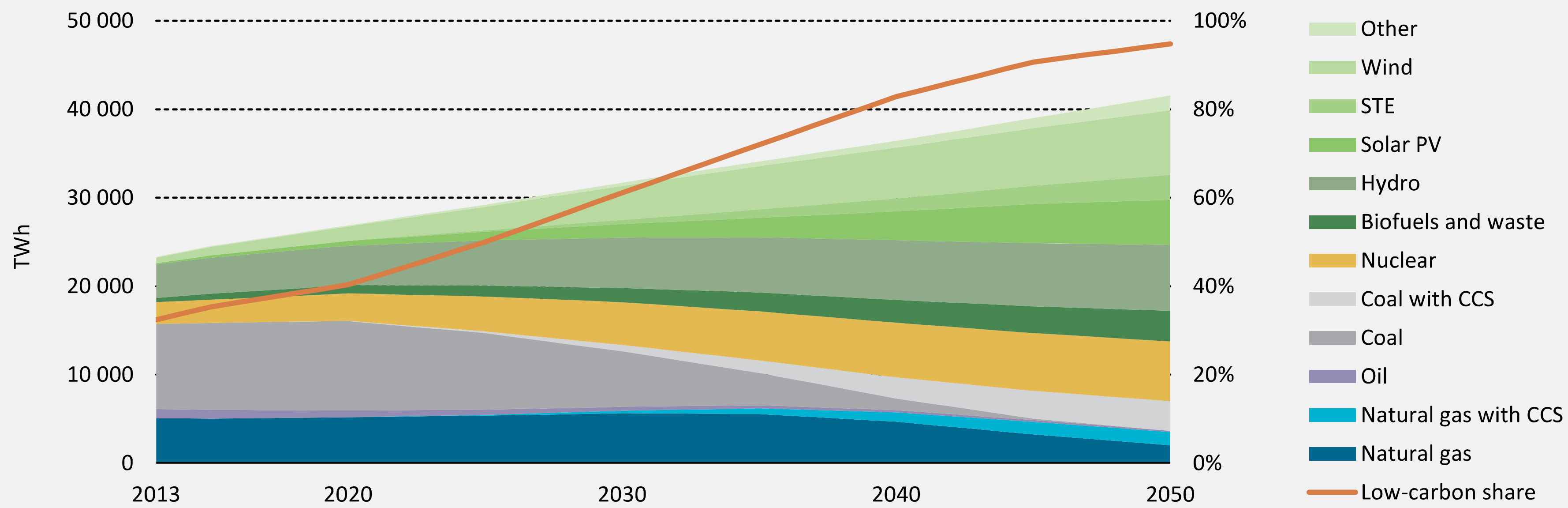


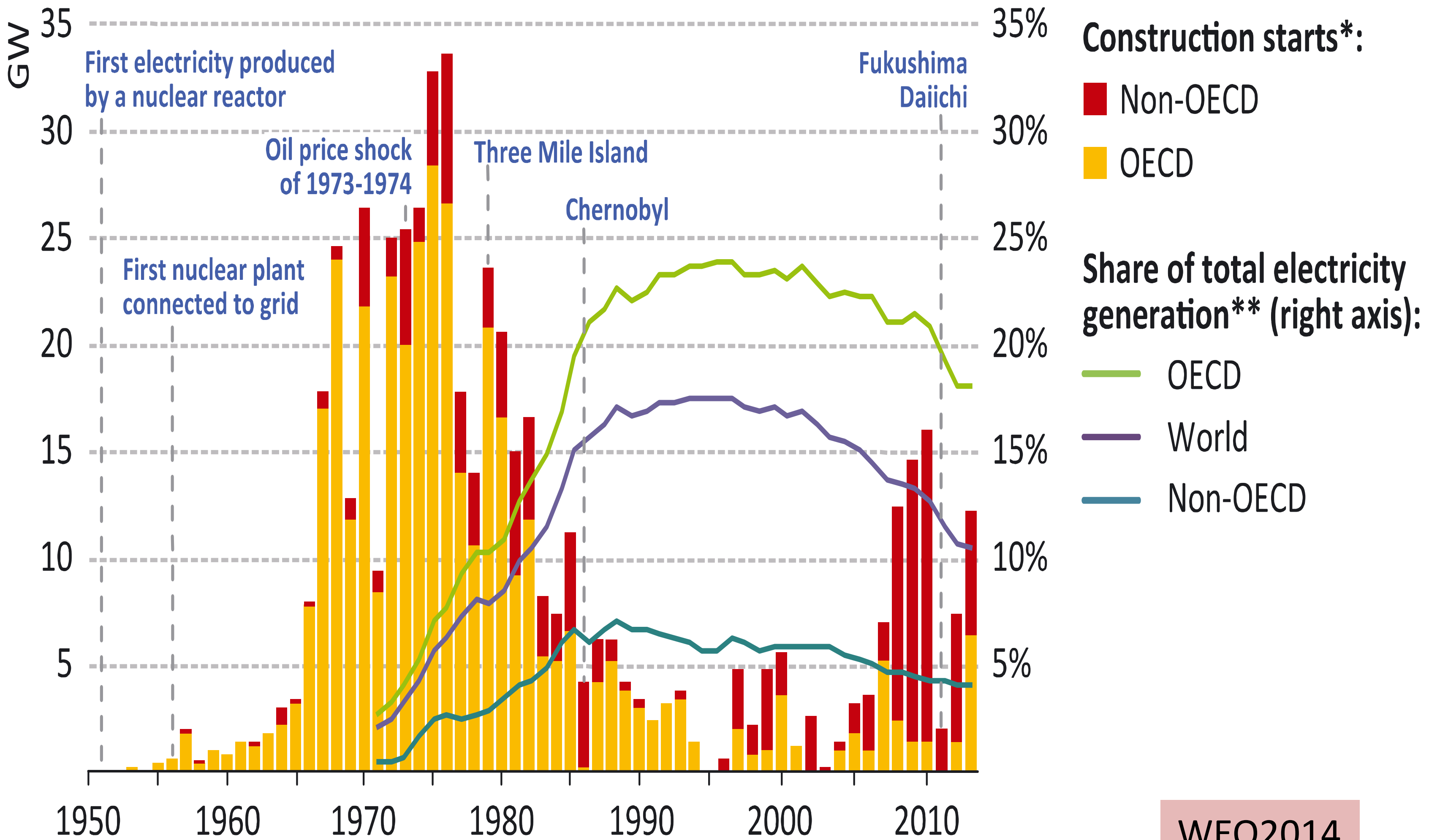
Notes: STE = solar thermal electricity. Low-carbon share refers to the combined share of the generation of electricity from renewables, nuclear and CCS.
Source: IEA analysis and IEA (2015f), *World Energy Statistics and Balances*, www.iea.org/statistics.

Key point *Today fossil fuels dominate electricity generation with 68% of the generation mix; by 2050 in the 2DS, renewables reach a similar share of 67%.*

- 2013 Generation share
  - Fossil fuels: 68%
  - Renewables: 22%
  - Nuclear : 11%

- 2DS 2050
  - Renewables: 67%
  - Fossil fuels: 17% (CCS12%)
  - Nuclear : 16%

History of Construction of Nuclear Reactors



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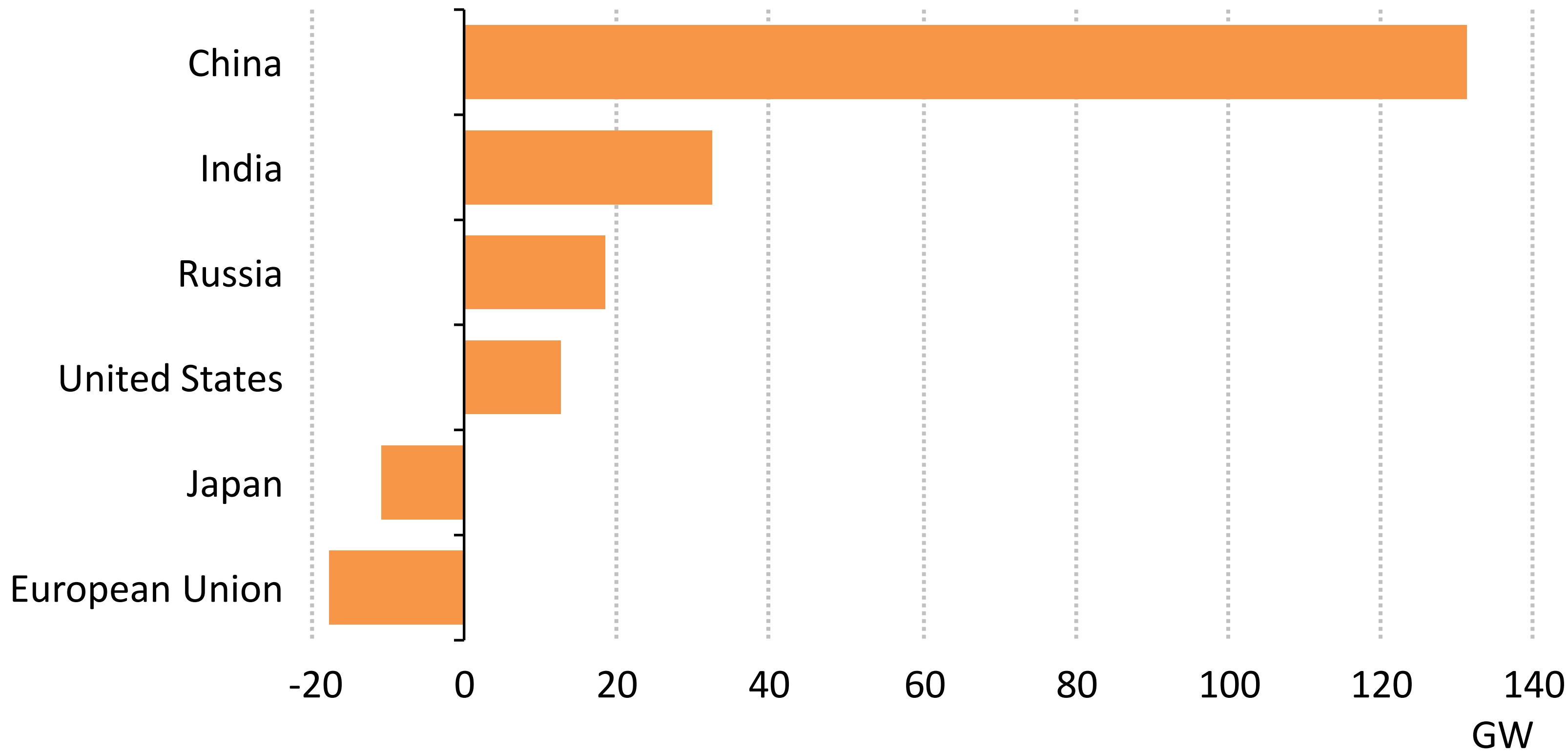
Nuclear capacity grows by 60%, but no nuclear renaissance in sight

WEO2014

Net capacity change in key regions, 2013-2040



Capacity grows by 60% to 624 GW 2040, led by China, India, Korea & Russia; yet the share of nuclear in the global power mix remains well-below its historic peak

Generations of Nuclear Energy

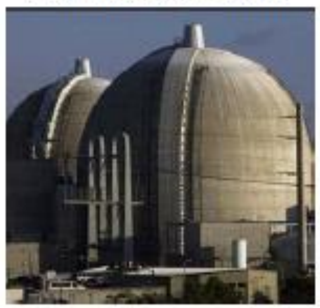
Generation I

Early Prototypes

- Shippingport
- Dresden
- Magnox

Generation II

Commercial Power



- PWRs
- BWRs
- CANDU

Generation III

Advanced LWRs

- CANDU 6
- System 80+
- AP600

Generation III+

Evolutionary Designs

- ABWR
- ACR1000
- AP1000
- APWR
- EPR
- ESBWR

Generation IV

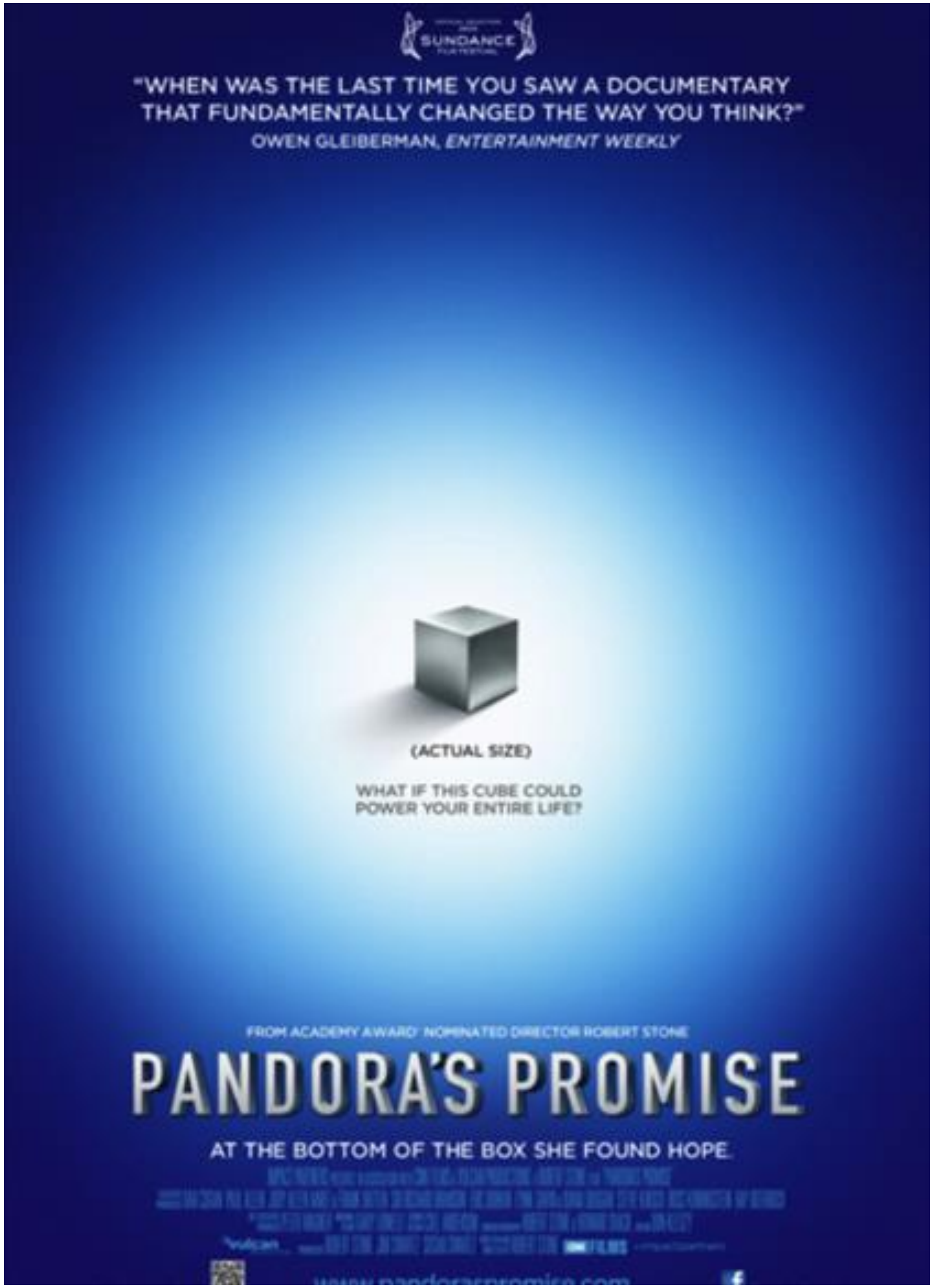
Revolutionary Designs

- Safe
- Sustainable
- Economical
- Proliferation Resistant and Physically Secure

1950 1960 1970 1980 1990 2000 2010 2020 2030

Gen I	Gen II	Gen III	Gen III+	Gen IV

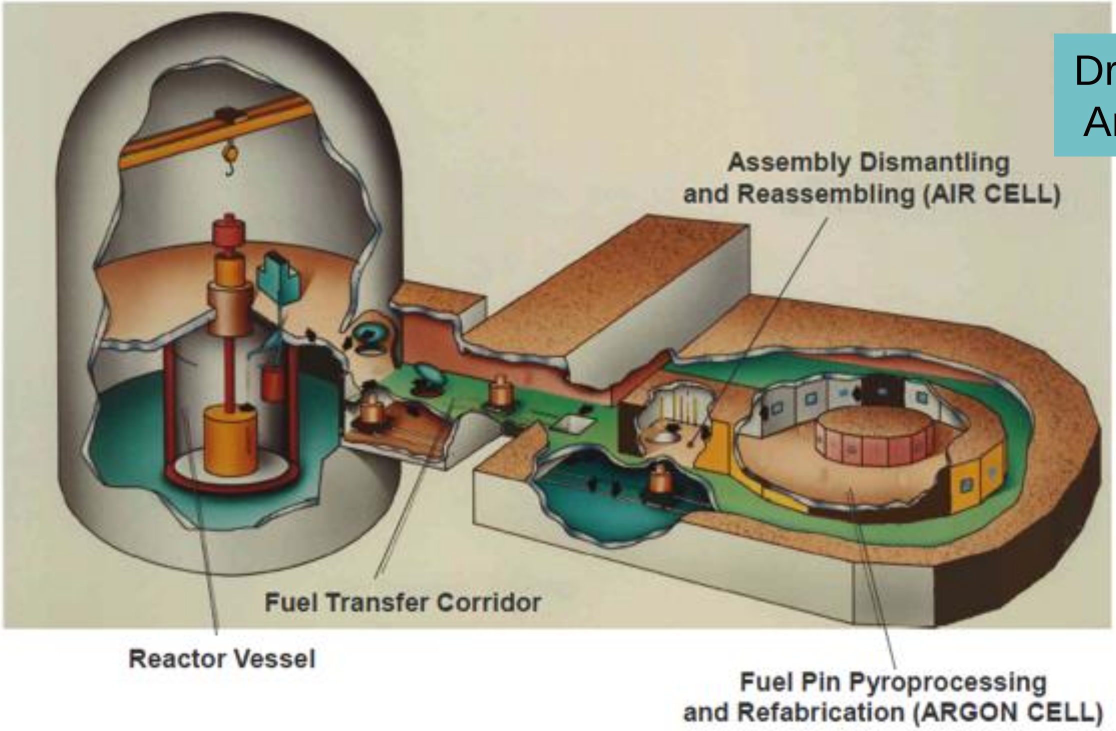
http://www.gen-4.org/Technology/evolution.htm



"Pandora's Promise", a movie directed by Robert Stone, is a documentary of environmentalists who changed their views about Nuclear Power.
IFR (EBR2) story comes up as missed opportunity.

Time for Safer, Proliferation resistant and Easier Waste Management Paradigm:
Integral Fast Reactor and Pyroprocessing

Pyroprocessing was used to demonstrate the EBR-II fuel cycle closure during 1964-69



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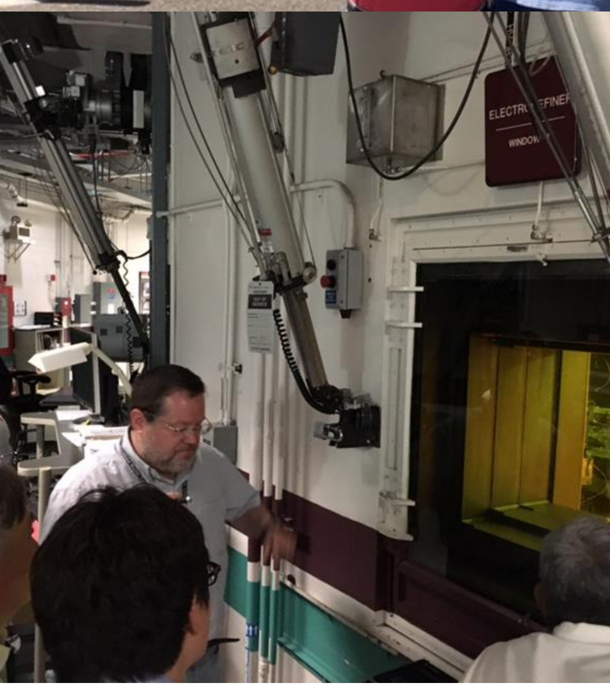
Argonne National Laboratory

IFR has features as Inexhaustible Energy Supply ,Inherent Passive Safety ,Long-term Waste Management Solution , Proliferation-Resistance , Economic Fuel Cycle Closure.
High level waste reduces radioactivity in 300 years while LWR spent fuel takes 100,000 years.

Idaho National Laboratory



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Technical Rationale for the IFR

✓ Revolutionary improvements as a next generation nuclear concept:

- Inexhaustible Energy Supply
- Inherent Passive Safety
- Long-term Waste Management Solution
- Proliferation-Resistance
- Economic Fuel Cycle Closure

✓ Metal fuel and pyroprocessing are key to achieving these revolutionary improvements.

✓ Implications on LWR spent fuel management

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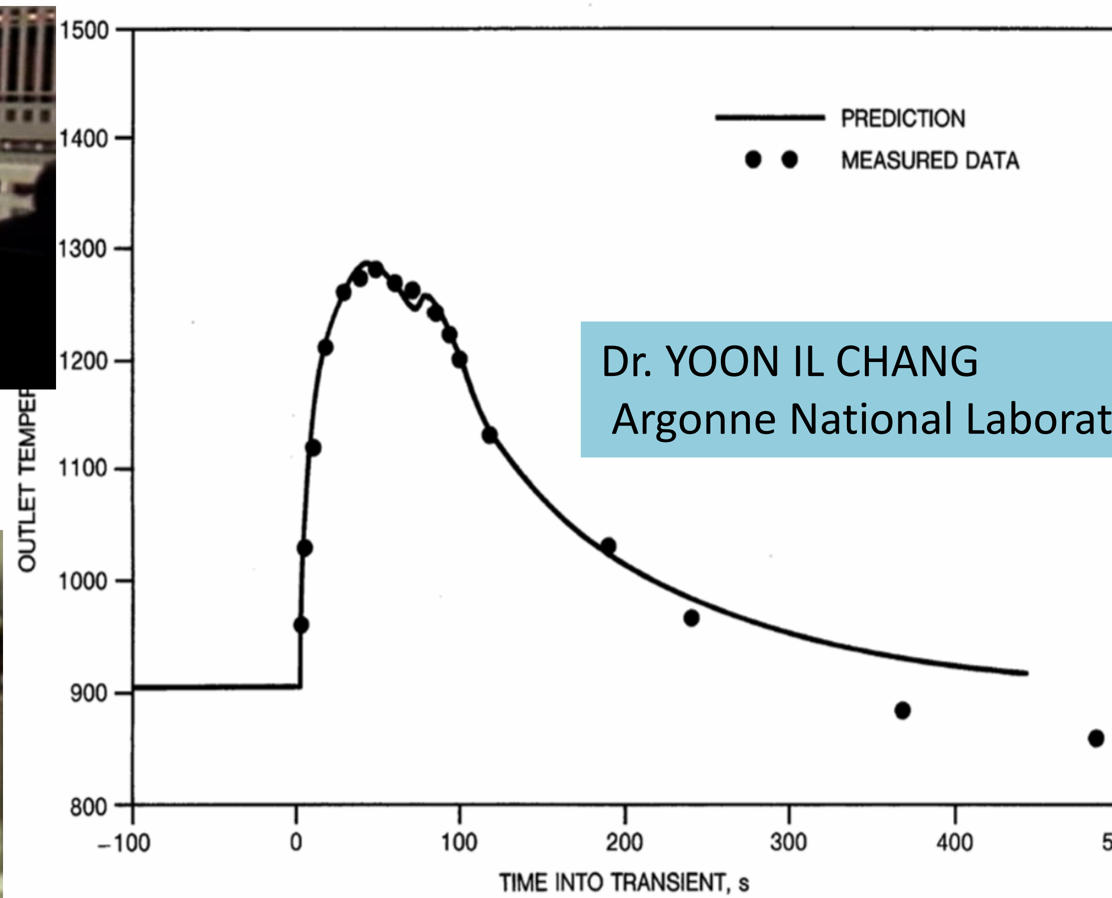
Passive Safety was proven by the 1986 Experiment very similar to the Fukushima event.

Loss-of-Flow without Scram Test in EBR-II



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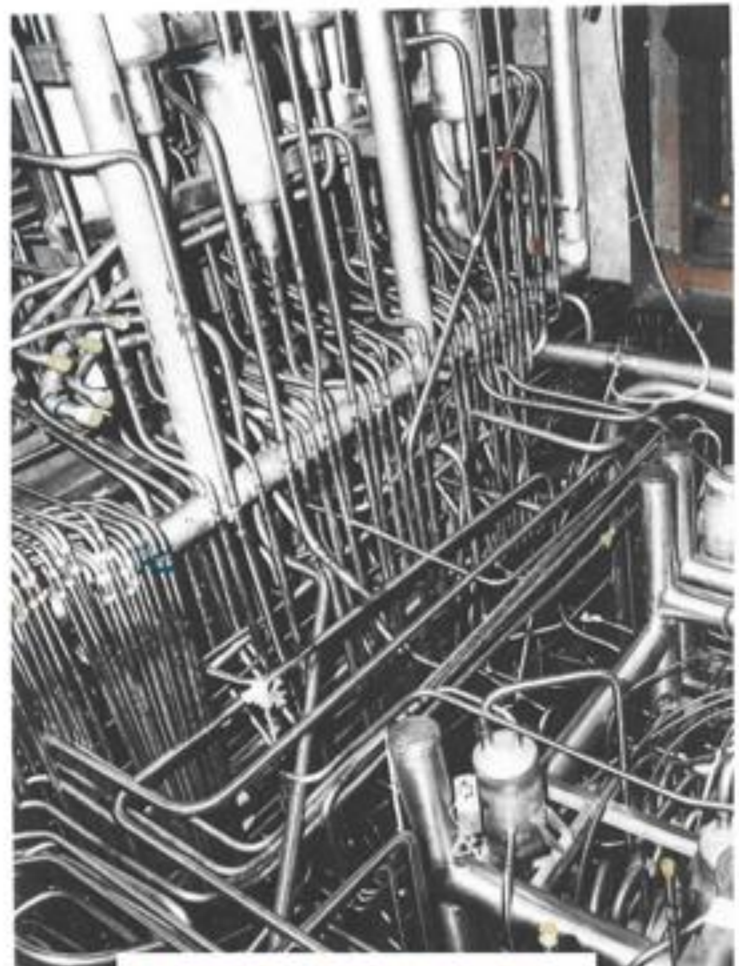
Pyroprocessing equipment and facility are compact
More favorable capital cost and economics

Pyroprocessing



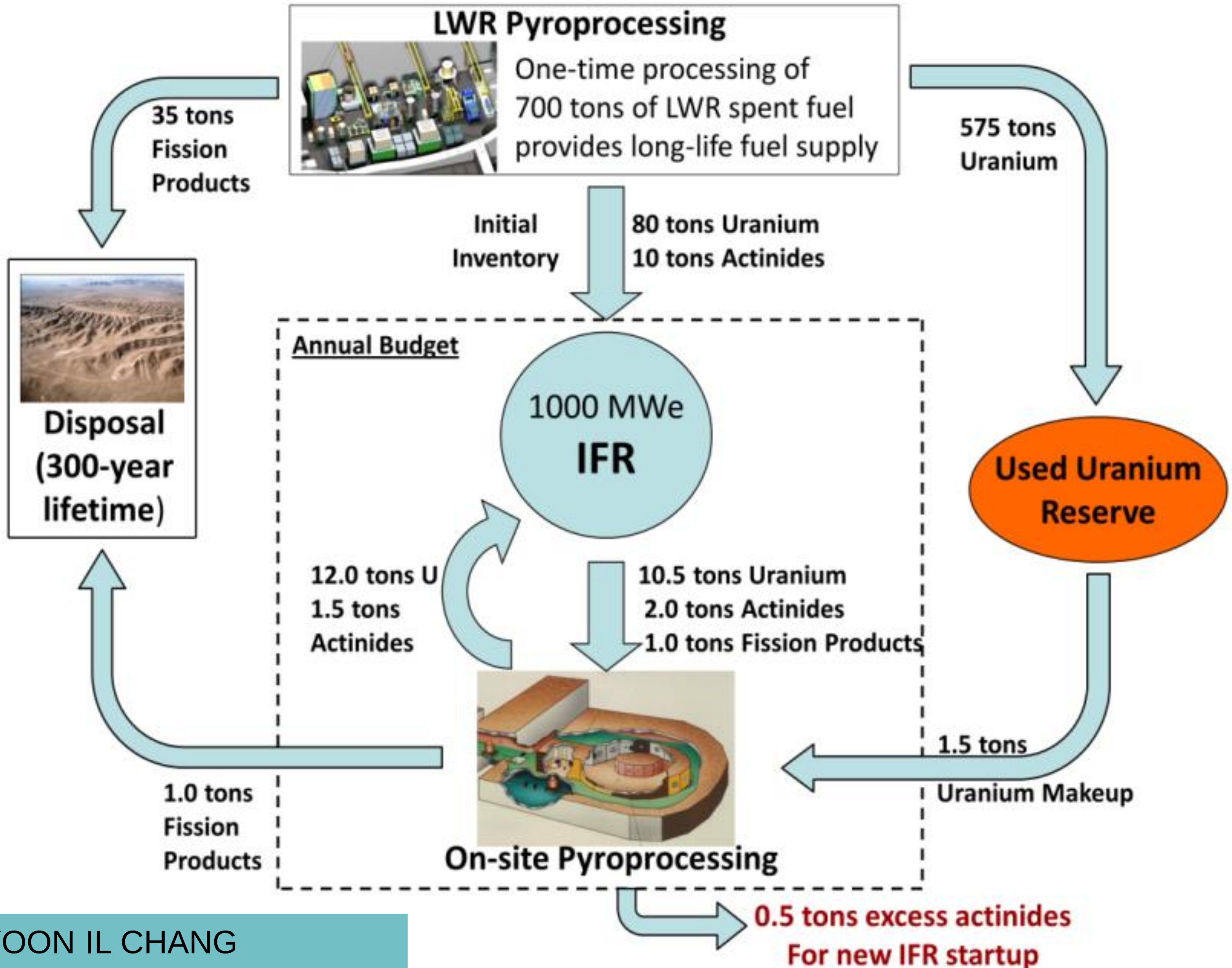
Aqueous Reprocessing

Pyroprocessing costs much less than Aqueous Reprocessing

Capital Cost Comparison ($million)
Fuel Cycle Facility for 1400 MWe Fast Reactor

	Pyroprocessing	Aqueous Reprocessing
Size and Commodities		
Building Volume, ft^3	852,500	5,314,000
Volume of Process Cells, ft^3	41,260	424,300
High Density Concrete, cy	133	3,000
Normal Density Concrete, cy	7,970	35-40,000
Capital Cost, $million		
Facility and Construction	65.2	186.0
Equipment Systems	31.0	311.0
Contingencies	24.0	124.2
Total	120.2	621.2

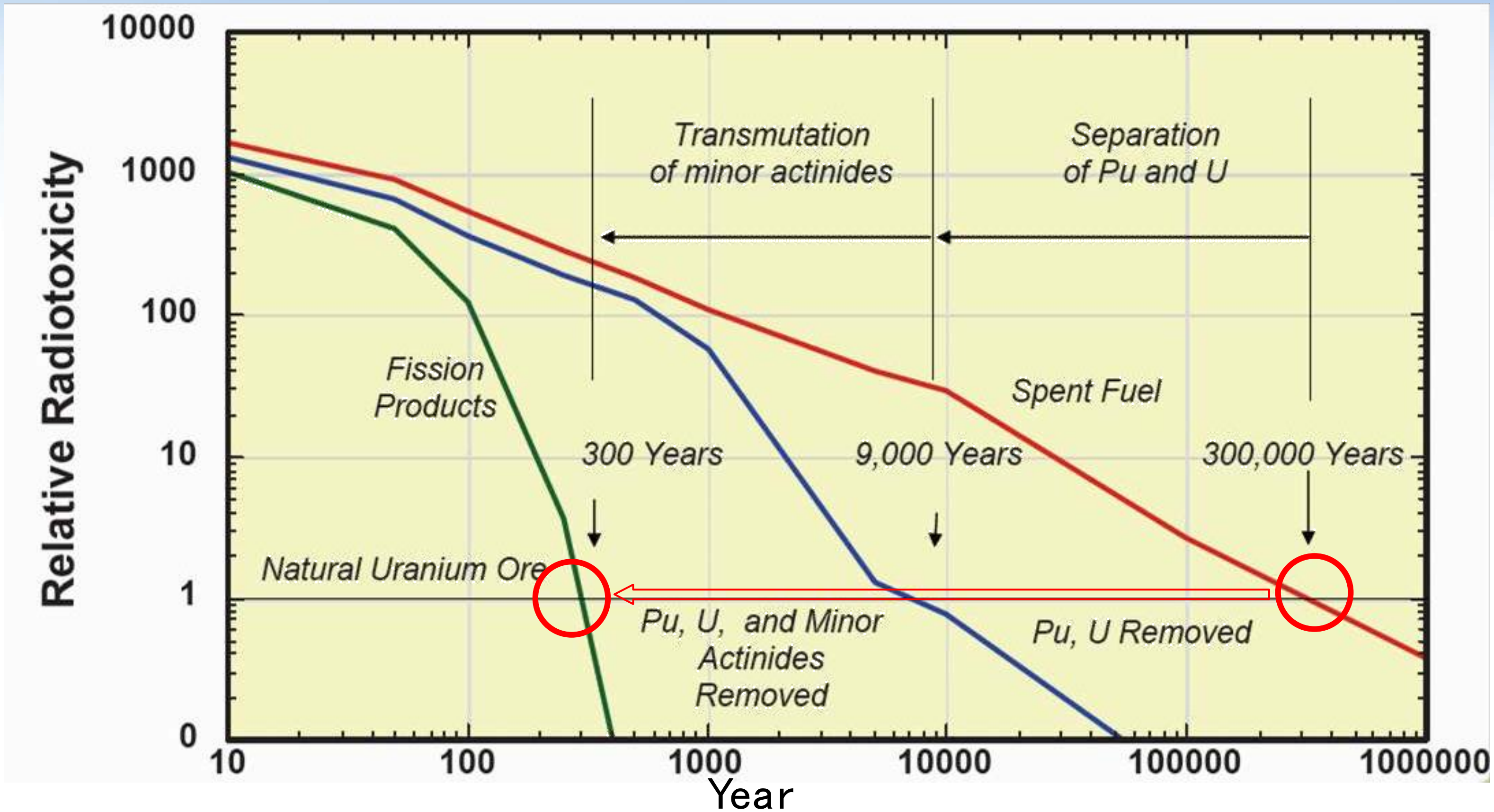
Dr. YOON IL CHANG
Argonne National Laboratory



Dr. YOON IL CHANG
Argonne National Laboratory

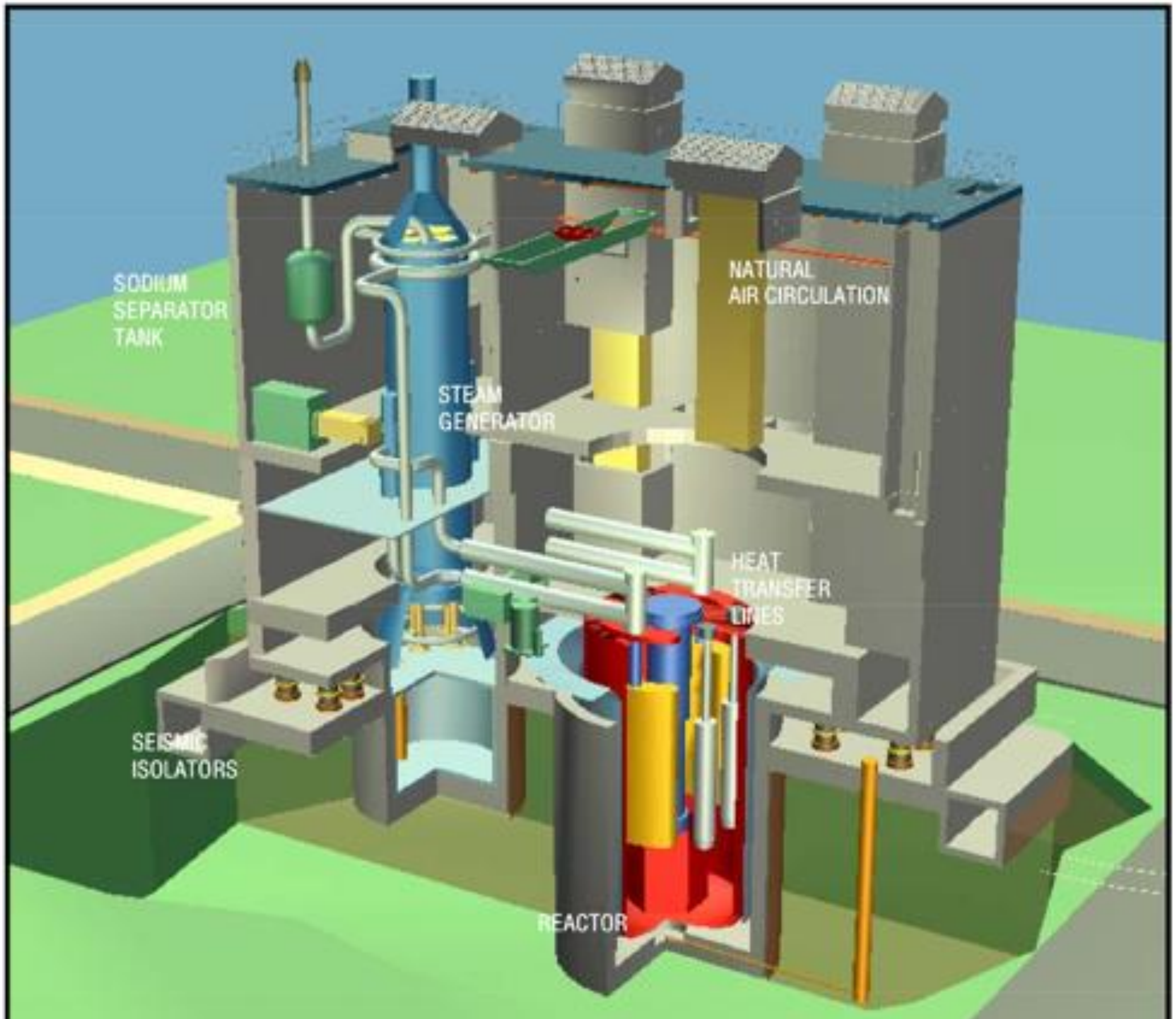
Transuranic disposal issues

The 1% transuranic (TRU) content of nuclear fuel is responsible for 99.9% of the disposal time requirement and policy issues



Removal of uranium, plutonium, and transuranics makes a 300,000 year problem a 300 year problem

S-PRISM Nuclear Steam Supply System



GE-Hitachi

Application of an IFR cycle to the existing Japanese nuclear fuel cycle

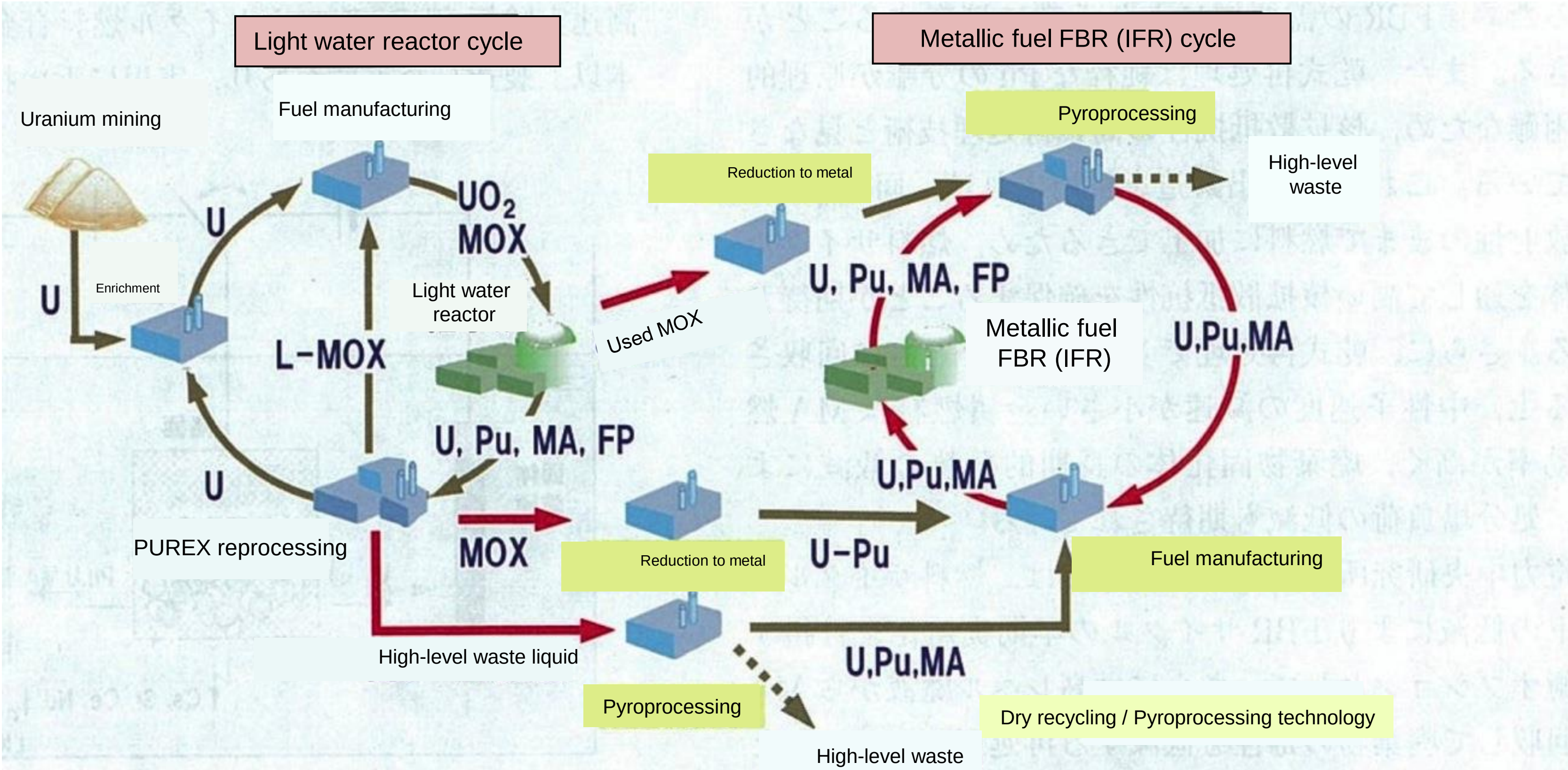
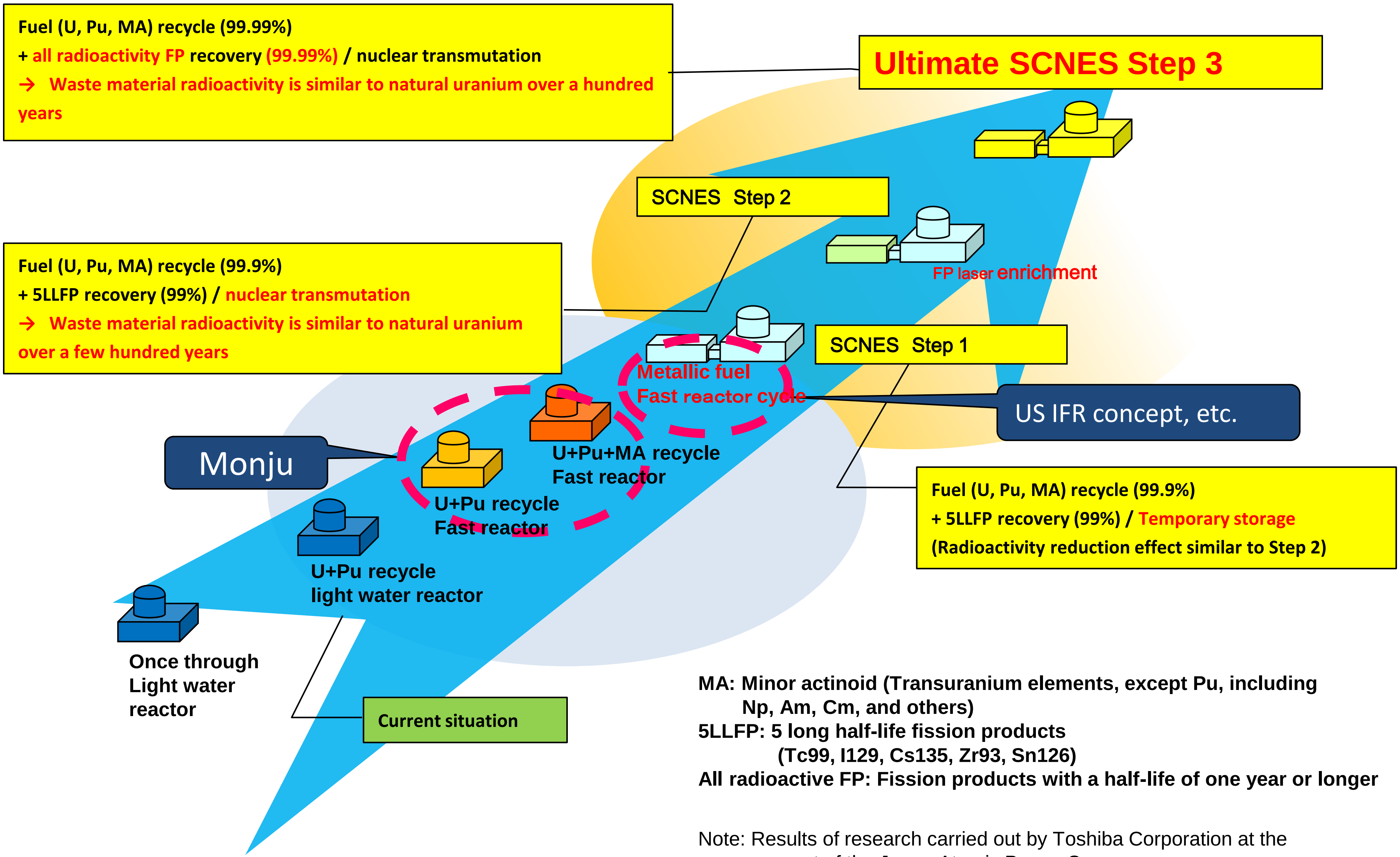


Figure 6: Fuel cycle concept using Pyroprocessing technology

(30) Journal of the Atomic Energy Society of Japan Vol. 52, No. 7 (2010)

Central Research Institute of Electric Power Industry: Tadafumi Koyama, Takanari Ogata

Stepwise approach to SCNES (Dr. Yoichi Fujiie)

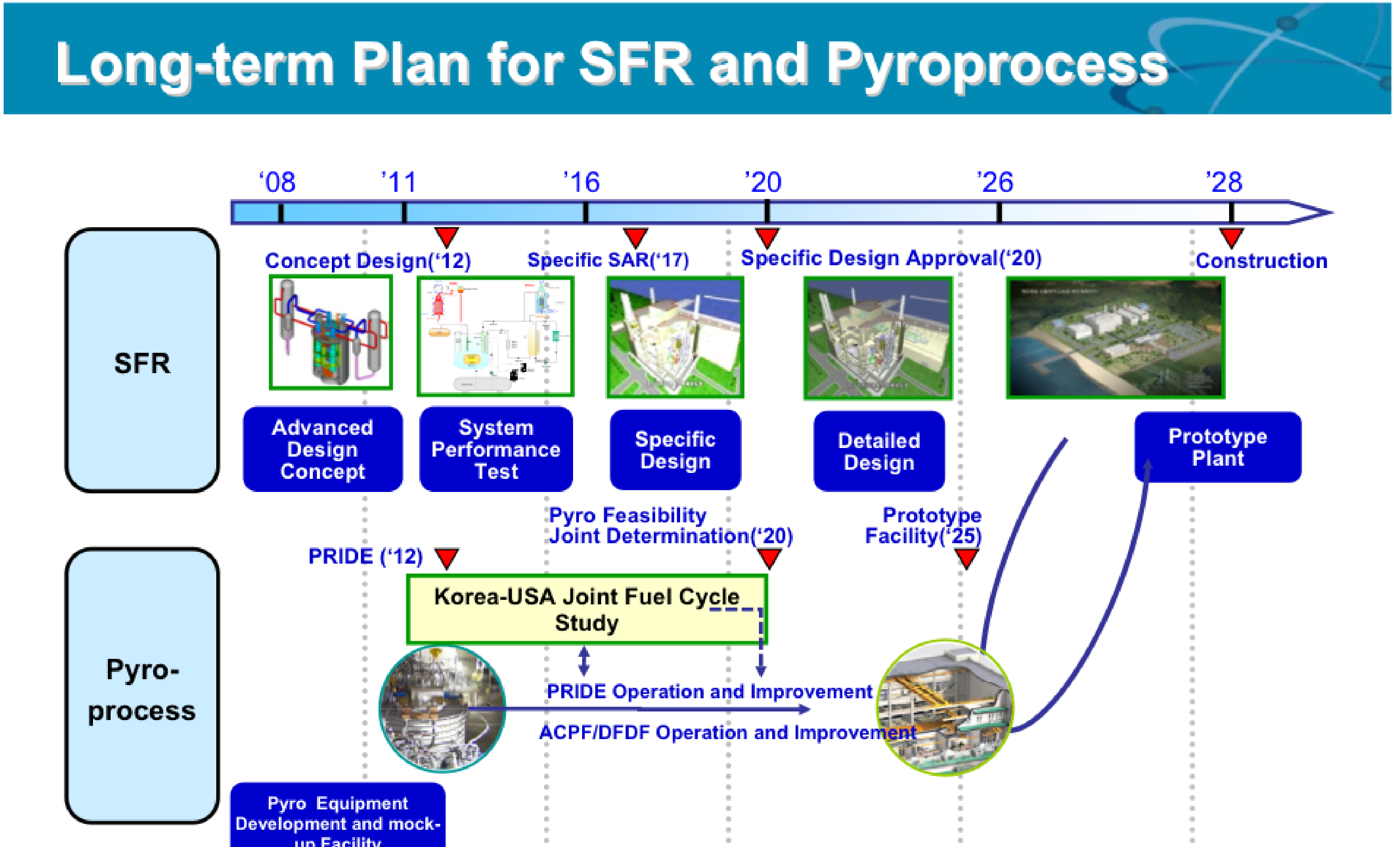


MA: Minor actinoid (Transuranium elements, except Pu, including Np, Am, Cm, and others)
5LLFP: 5 long half-life fission products (Tc99, I129, Cs135, Zr93, Sn126)
All radioactive FP: Fission products with a half-life of one year or longer

Note: Results of research carried out by Toshiba Corporation at the request of the Japan Atomic Power Company

Legend of Admiral Rickover: Success of LWR for nuclear submarine has crowded out Fast Reactors

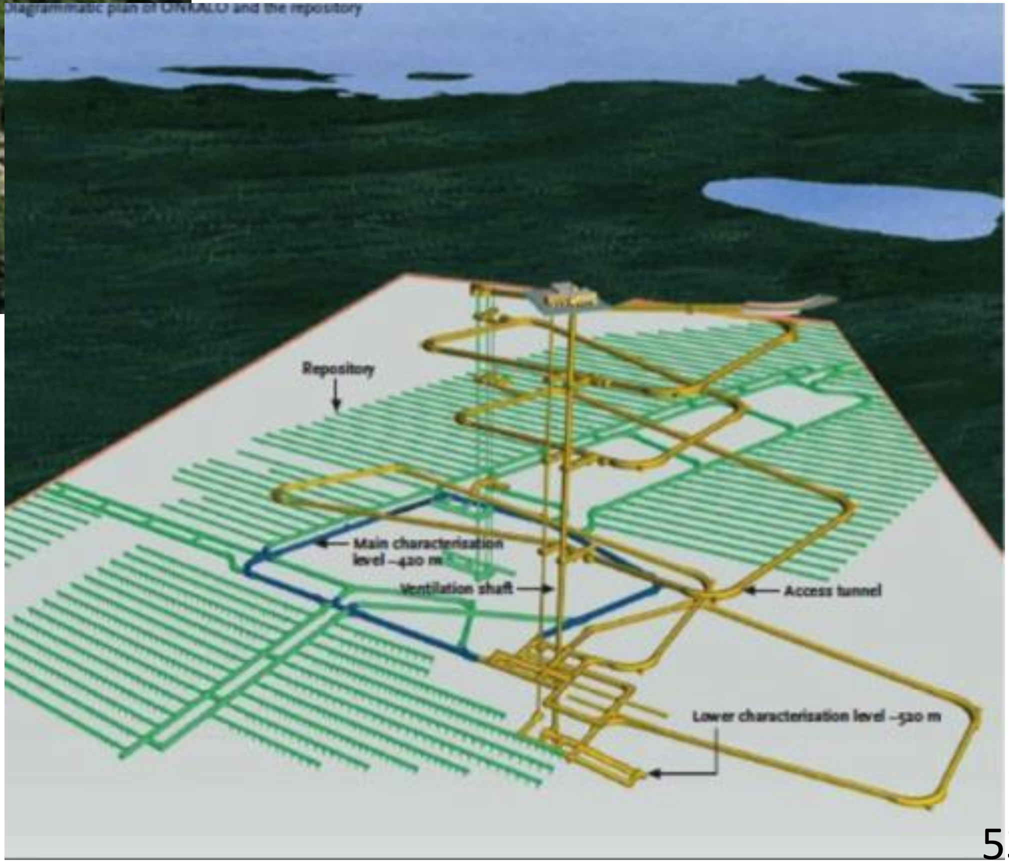
Korea is eager to build fuel cycle by IFR by revising the 1-2-3 Agreement with US



Radioactive High-level Waste Disposal or Storage

Finland Model:

Olkiluotp Nuclear Power Plant and Onkalo nuclear spent fuel repository



HQ of Teollisuuden Voima Oyj Utility which owns Olkiluoto Nuclear Power Plant exists in the Plant site.

Proposal: Japan-US Cooperation to Demonstrate IFR for the SF & Debris at Fukushima Daiichi

- Melt downed fuel debris and contaminated Spent fuels will likely stay in Fukushima, though nobody so admits.
- Pyroprocessing is the most appropriate method for treating spent fuels and debris.
- Pu and MA from Debris and Spent fuels be burned in IFR. Electricity is generated as by-product.
- High level waste of 300 years be stored rather than disposed geologically while decommissioning of units be cemented for years.
- Fukushima Daini (Second) Nuclear Plant of TEPCO is best located to demonstrate GE's extended S-PRISM.
- International joint project of Japan-US-Korea will provide complementing regional safeguard for global non-proliferation regime.
- Provides ground for extension of Japan-US 1-2-3 Agreement in 2018 by demonstrating complemental fuel cycle options.

Technical Feasibility of an Integral Fast Reactor (IFR) as a Future Option for Fast Reactor Cycles

-Integrate a small Metal-Fueled Fast Reactor with Pyroprocessing Facilities -

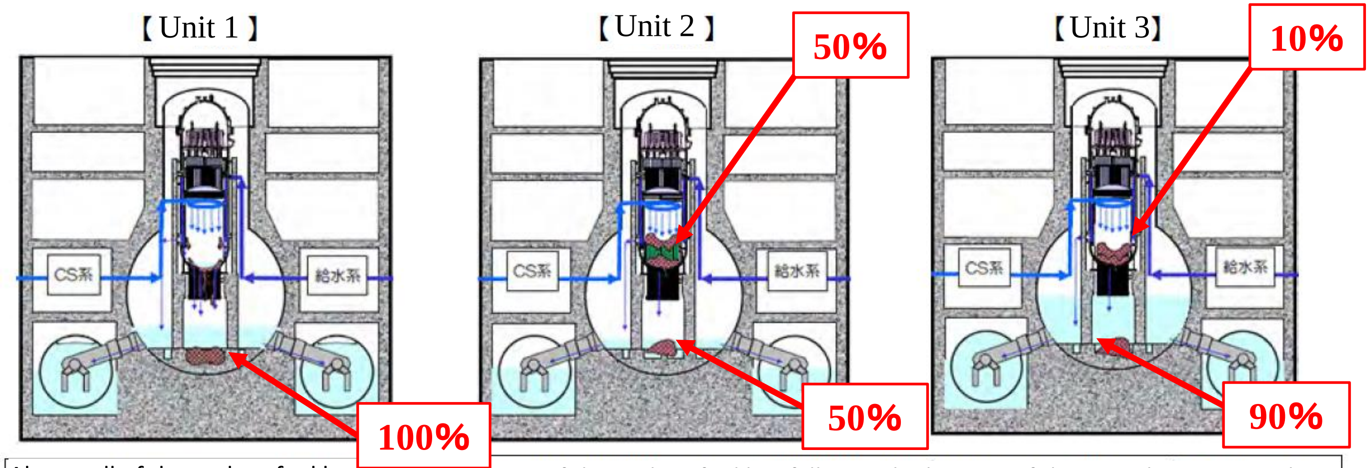
November 18, 2016

Nuclear Salon

5. Research Results

Amounts of fuel debris and nuclear materials from the TEPCO Fukushima Daiichi NPS (estimated)

The distribution fraction of heavy metals (TRU+U+FP) is estimated to be as shown by the numbers to the right in red based on analyses using the SAMPSON code[*2]



Almost all of the molten fuel has fallen to the bottom of the RPV plenum and almost none of the fuel is left in the core.

-Some of the molten fuel has fallen to the bottom of the RPV plenum or to the PCV pedestal, and some fuel still remains in the core.
-It is estimated that more fuel than originally thought has fallen to the bottom of the PCV at Unit 3

Assumed states of the Unit 1~3 cores/containment vessels[*1]

The amount of debris and primary composition has been estimated as follows based upon the amount of fuel, number of control rods, and the remaining amount[*3] of structural material in each reactor.

	[Unit 1]	[Unit 2]	[Unit 3]
Amount of core region debris (Approx. 120 tons):	0	Approx. 100 tons	Approx. 20 tons
Amount of MCCI debris (740 tons):	Approx. 260 tons	Approx. 170 tons	Approx. 310 tons

- Main composition of core region debris that fused/mixed with core structure material (SUS, Zry): $(U,Zr)O_2$, SUS-Zry alloy
- Main composition of MCCI debris that fused/mixed with concrete outside the pressure vessel: $(Zr,U)SiO_4$, $CaAl_2Si_2O_8$, etc.

● As the average fuel composition for debris in Units 1~3, we used the composition at the time when void reactivity is the most severe, a maximum minor actinide ((MA) neptunium, americium, etc.) content rate and the largest number of years since the disaster within the published data.

⇒Transuranium element（TRU：Pu+MA) mass is 1.94 tons, and heavy metal (HM) mass is 251 tons

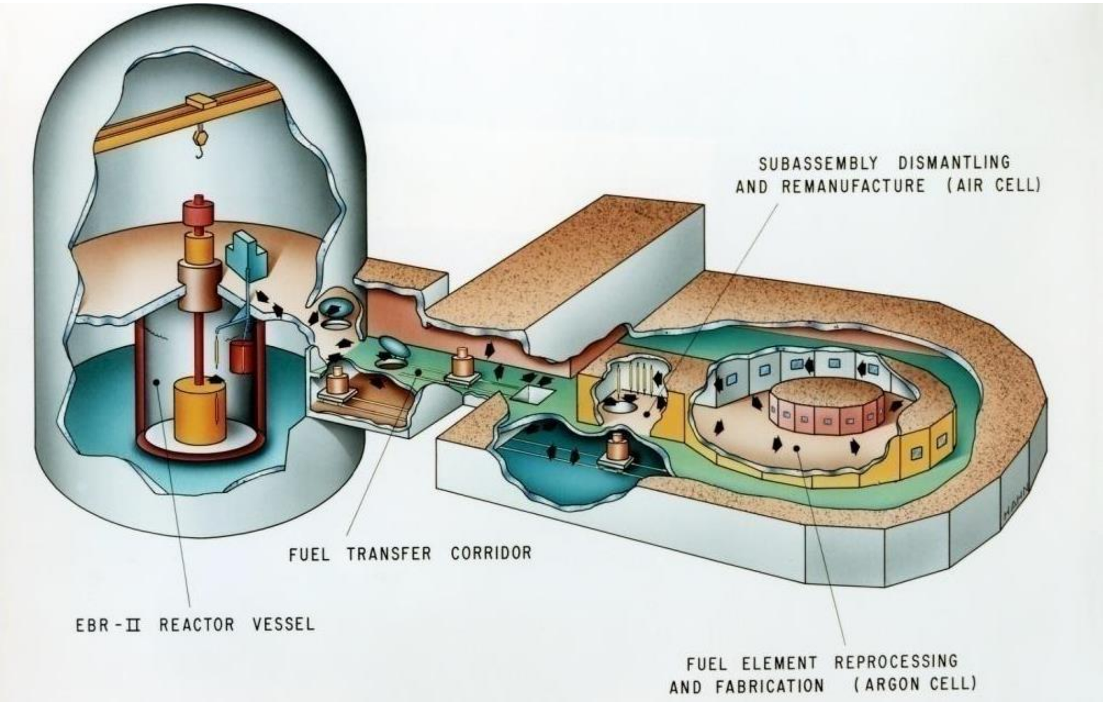
＊1：Excerpt from 1st Progress Report on the Estimate of the Status of the Fukushima Daiichi Nuclear Power Station Units 1~3 Core/Containment Vessels and the Deliberation of Unsolved Issues,"from TEPCO website.

＊2：Masanori Naito, "Analyzing Accident Event Escalation using the SAMPSON Code," Atomic Energy Society of Japan Fall Symposium, September 11, 2015.

＊3：T. Washiya et.al, Study of treatment scenarios for fuel debris removed from Fukushima Daiichi NPS, Proc. of ICONE-23, May 17-21, 2015, Chiba, Japan

Technical Feasibility of an Integral Fast Reactor (IFR)

- ✓ 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 **TRU elements account for approximately 1.9tons**.
- ✓ Configuration
  - A MF-SFR with inherent safety features (reactor output: 190MWt)
  - Application of a metallic fuel pyro-processing method that makes debris processing possible.

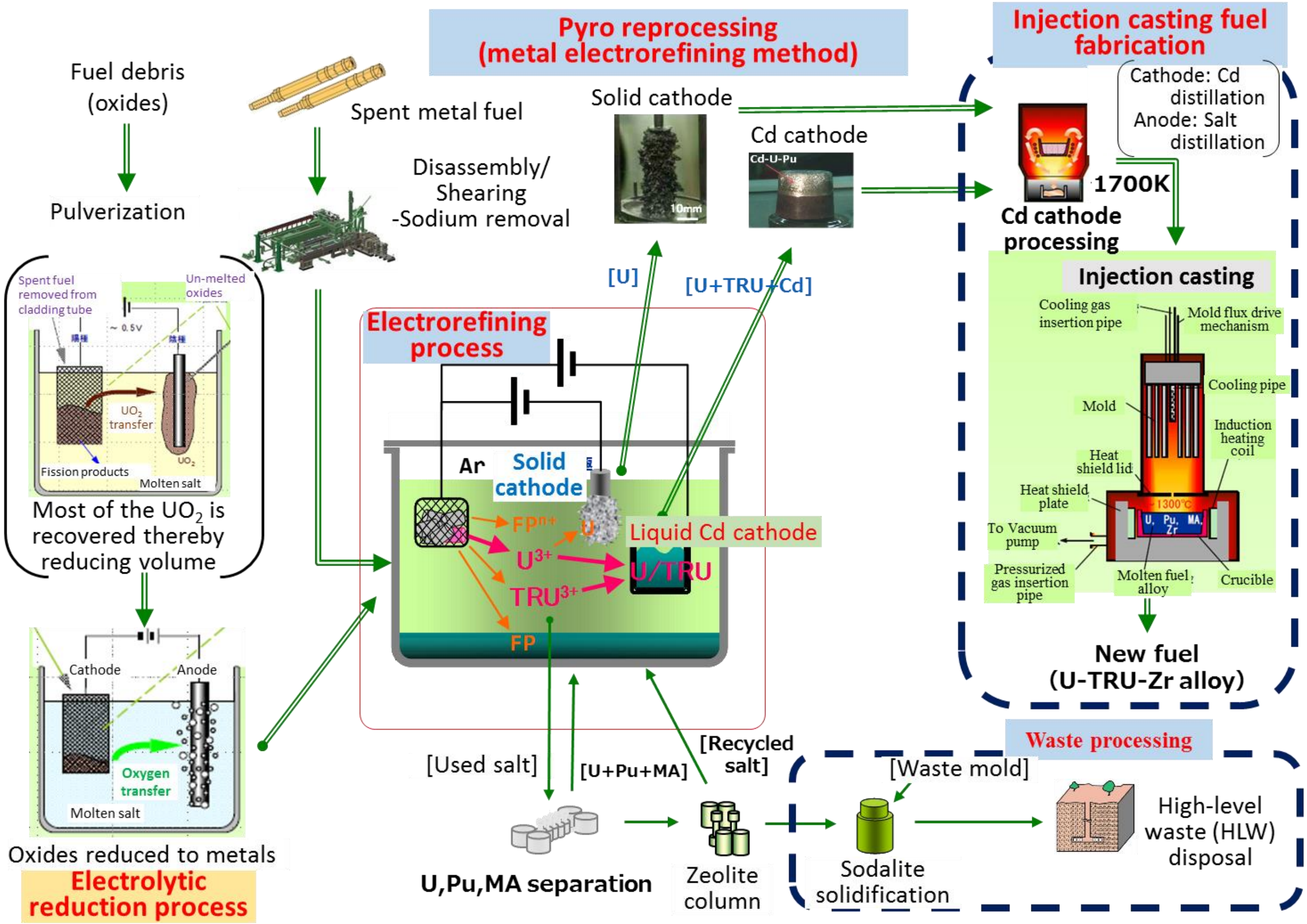


Concept diagram of an IFR that combines a fast reactor with a fuel recycling facility
(Example: Argonne National Laboratory Experimental-Breeder Reactor EBR-II and fuel cycle facility (FCF))

(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.)

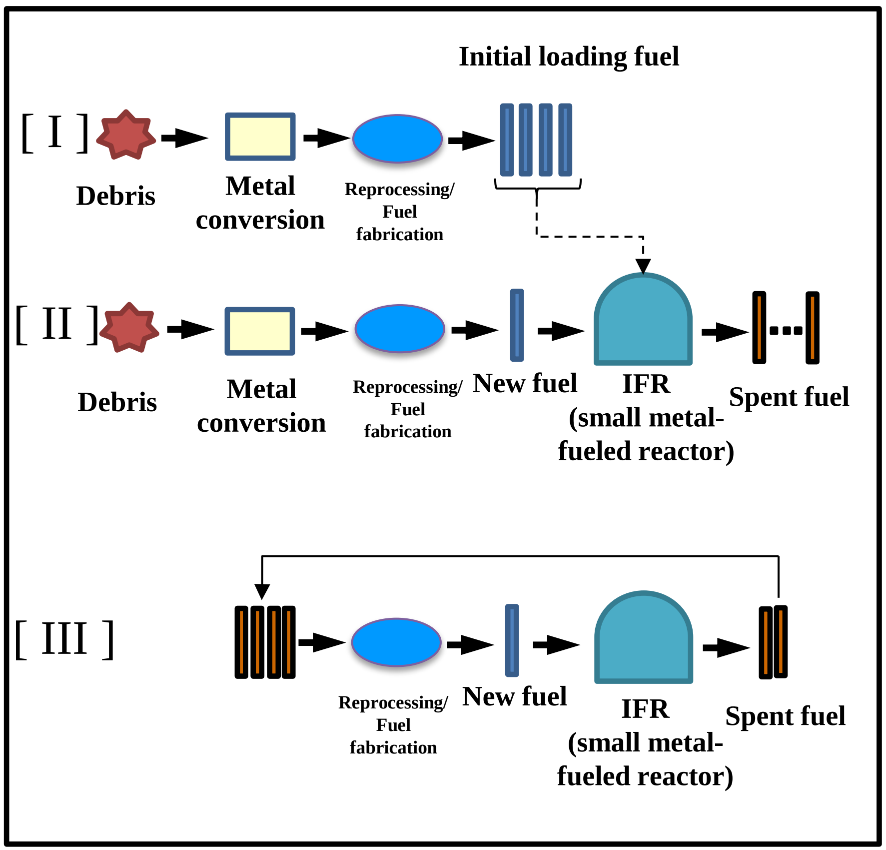
Pyroprocessing Technology (for oxide and metallic fuels)

- Spent metallic fuel is dissolved in molten salt and metal U is deposited on solid cathodes using the difference in oxidation-reduction potential. After this, metal Pu, U and MA are deposited into molten Cd cathodes and the actinides are extracted all at once.
- If the electrolytic reduction process is used for preprocessing, the process can also be used for oxide fuels.

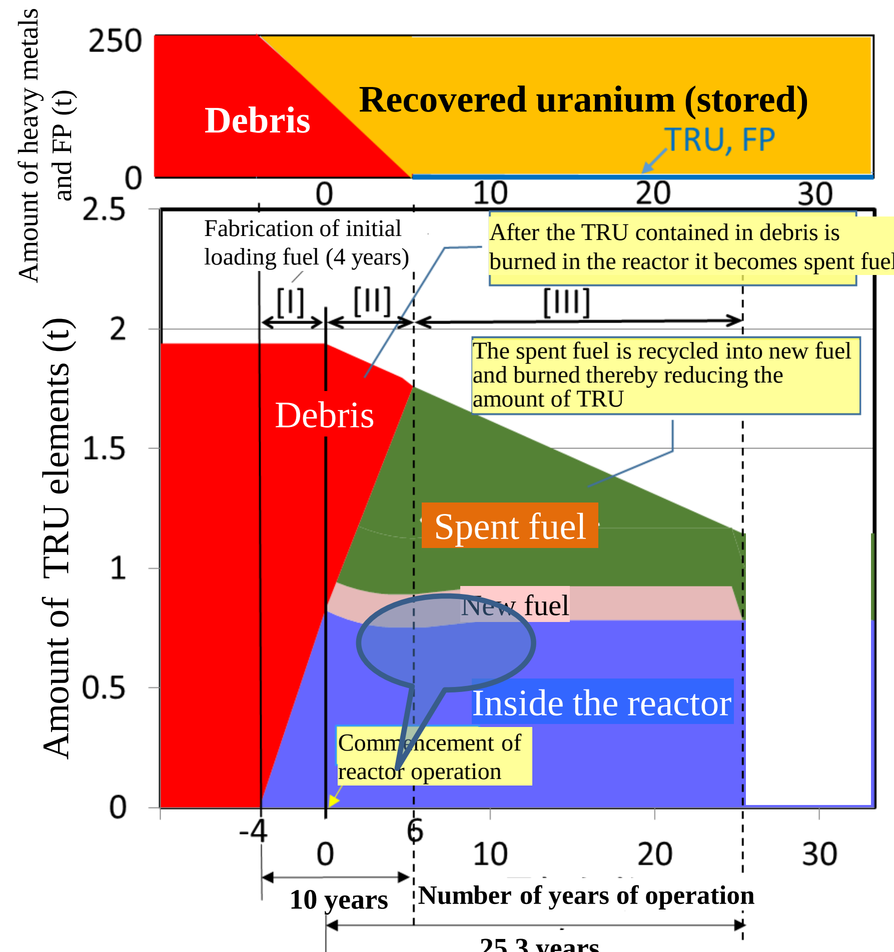


Debris Processing Scheme and TRU Reductions

- An assessment of TRU burn-up performances showed the originally estimated debris processing period of 15 years could be shortened to 10 years.
- The 1.9 tons of TRU present in the debris will be reduced to a total of 1.2 tons in 25 years after the launching the IFR including that remaining in the reactor and that existing in the spent fuel. Since the amount of TRU required to constantly fabricate fuel after this point will be insufficient, it will be necessary to procure TRU from external sources in order to continue continuous operation of the reactor.



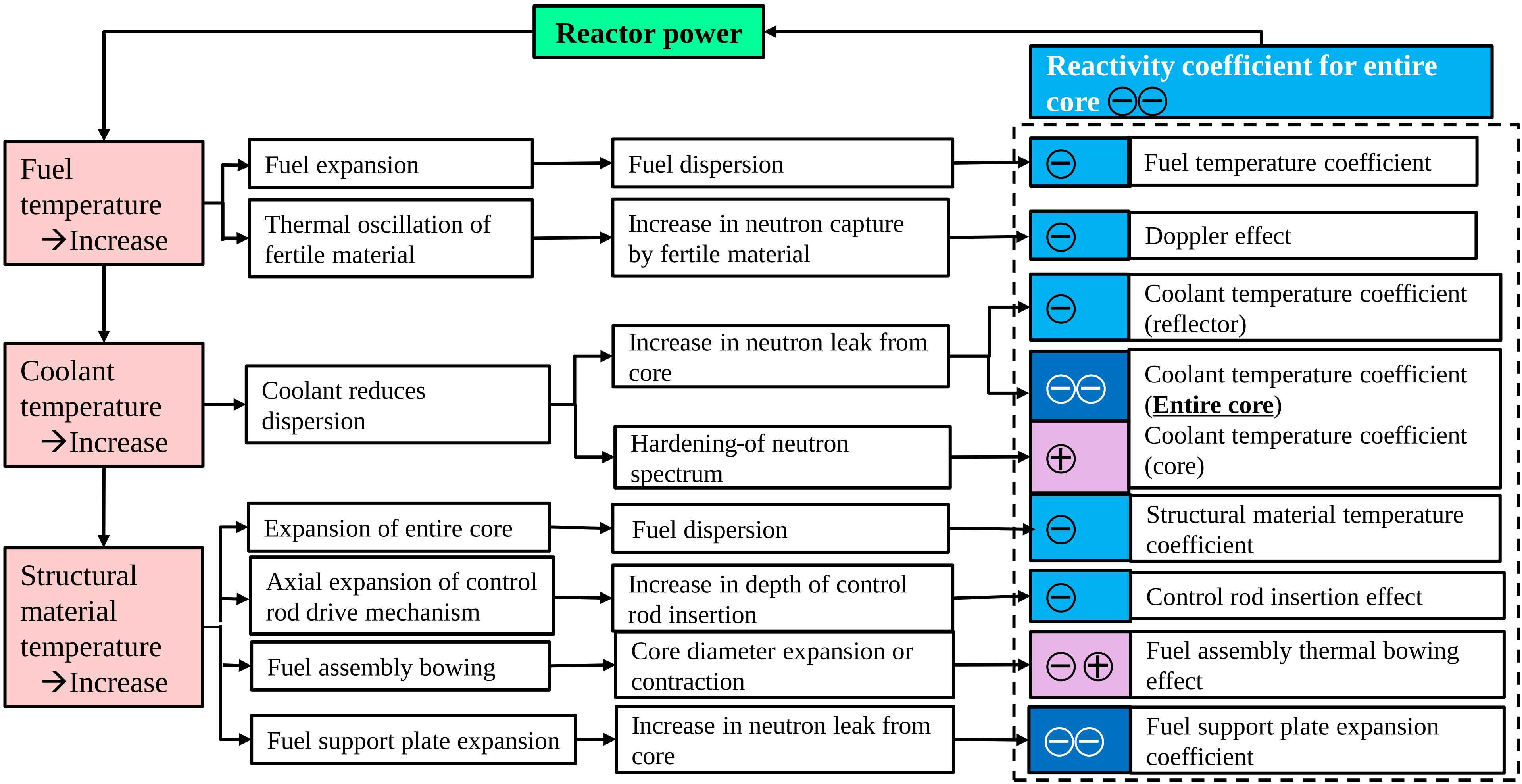
Concept diagram of debris processing scheme



IFR operation and TRU reductions

Passive Safety of Small Metal-fueled Reactors

In case reactor temperature increases, reactor power will decrease by inserting negative reactivity feedback.



In addition, passive safety features are employed:

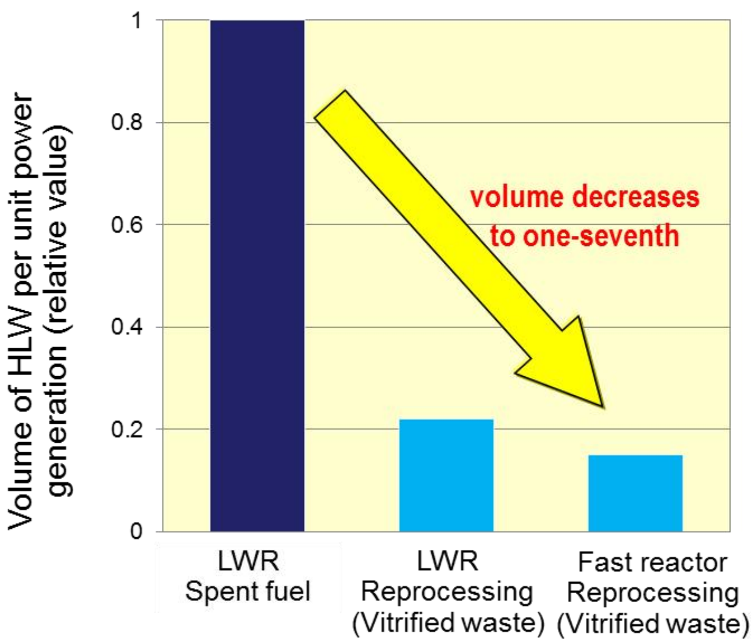
In response to loss-of-flow events, large negative reactivity effect is generated by the GEM.

In response to transient-over-power events, withdraw of the control rods is limited by the rod stop mechanism.

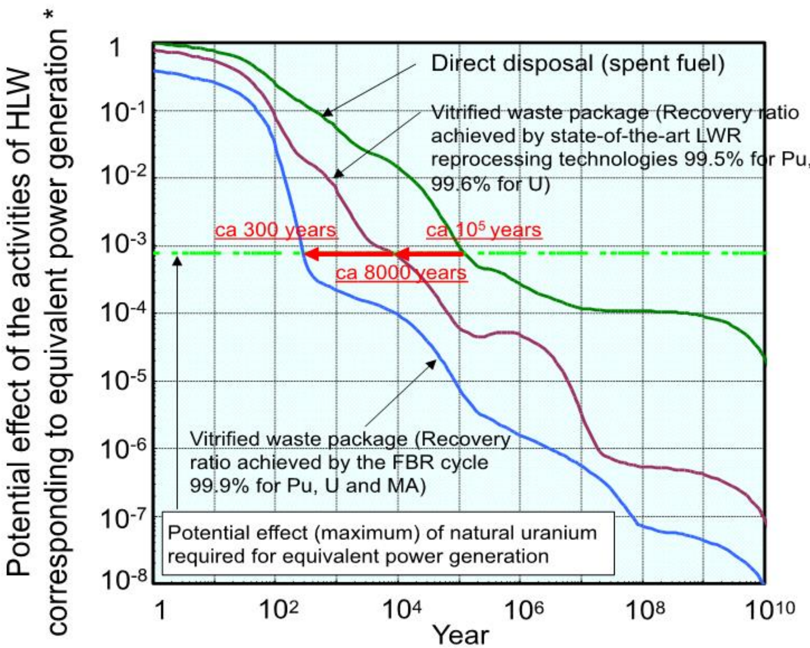
Reducing the Volume of Radioactive Waste and Decreasing Hazard Level (Radiotoxicity)

- By suitably processing fuel debris and recycling it in a fast reactor, TRU is either kept in the core or as part of spent fuel. (Surplus recovered uranium is separated/stored)
- A fast reactor cycle releases less long-lived isotopes outside the system by confining TRU in a cycle system as well as burning them, thus it has a beneficial effect on reducing the volume of waste and radiotoxicity.
  - Amount of high-level radioactive waste generated (when compared to direct disposal of spent fuel)
    LWR cycle: Approx. **22%**, Fast reactor cycle: Approx. **15%**
  - Effect at reducing hazard level (Approx. 100,000 years to fall to levels equal to natural uranium required for equivalent power generation in the case of direct disposal of spent fuel)
    LWR cycle: Approx. **8,000 years**, Fast reactor cycle: Approx. **300 years**

*) A relative value assuming that the potential effect of spent fuel at the first year is 1.



Reduction in the volume of high-level radioactive waste



Reduction in duration of potential toxicity

Evaluation of Construction Costs for Reactor and Fuel Cycle Facilities

[Reactor]

- A small MF-SFR with the **thermal output of 190MWt** (**electrical output: 70MWe**) was estimated:
  - Decision on the major plant specifications, created general main-circuit system schematics, conceptual diagrams for reactor structures, and conceptual diagrams for the reactor building layout
  - Estimated plant commodity with referencing commodity data from past designs.
  - JAEA's evaluation code for construction cost is adopted.
- Results: **Approx. 110 billion yen** (construction unit cost: Approx. **1.6 million yen/kWe**) (However, there is much uncertainty in these values since the system design has not yet been performed.)

[Fuel Cycle]

- A tentative assessment of the overall construction costs of pyroprocessing facilities capable of **reprocessing 30tHM/y** and **fuel fabricating 0.72tHM/y** was done as follows:
  - The number of pieces of primary equipment were estimated based upon the processing capacity of primary equipment after determining a general process flow and material balance.
  - A general assessment was made by referencing recycle plant cell volume and building volume from past researches
- Assessment result: Whereas the construction cost of these facilities may be able to be kept at approximately **several tens of billions of yen**, there is much uncertainty in regards to reprocessing facilities and since design aspects have not been examined, it is necessary to refer to assessment values made during other design research into facilities with similar processing capabilities.

うつくしま、福島
(Fukushima, the Beautiful)

昨日はとても勉強になりましたし、何よりも明るい気持ちになりました。福島は日本の科学技術のために使っていただいた場所なのですから。 思いがけない傷を負ってしまった福島ですが、これからも技術者たちの挑戦を見届け、世界の技術発展と人類の未来のために使っていただく地になること、それこそが福島の前向きな選択であると感じました。
5年間悲観的な感情論を山ほど聞いて、どちらに向けて顔を上げていったらいいのか、福島の人間はずっと模索してきたのだと思います。
昨夜、田中様のお話しを聞いて、私は原発が街に初めてやってきた子供の頃のことを思い出しました。田中様のお話は、私にその時と同じ気持ちを思い出させるものでした。そのようなお話を聞いたのはの初めてです。ありがとうございます。
事故の前まで、福島県のキャッチコピーは、美しい島という意味で、「うつくしま、福島」だったのです。事故後に、そのポスターも言葉も消えました。私は科学技術に尽くすという意味で、「つくすしま、福島」でいいのではないか、これは決して後ろ向きの決意ではなく、福島の誇りだと思います。是非とも実現に向けて頑張っていただきたいし、ご協力できることがあればやらせていただければ嬉しく思います。私は身体障害者ですが、自由な時間はたくさんありますので、社会のお役に立てることがあるなら、身体が動く限り何でもやってみたいと思っています。

Statement by Dr. Takashi NAGAI after Nagasaki atomic bomb. "How to turn the devil to the fortune."

Dr. Takashi Nagai, a Professor at Nagasaki University in 1945 when the atomic bomb was dropped, exemplifies the resilience, courage and believe in science of the Japanese people. Despite having a severed temporal artery as a result of the bomb, he went to help the victims even before going home. Once he got home, he found his house destroyed and his wife dead. He spent weeks in the hospital where he nearly died from his injuries. But just months after the atom bomb dropped, he said:

"Everything was finished. Our mother land was defeated. Our university had collapsed and classrooms were reduced to ashes. We, one by one, were wounded and fell. The houses we lived in were burned down, the clothes we wore were blown up, and our families were either dead or injured. What are we going to say? We only wish to never repeat this tragedy with the human race. We should utilize the principle of the atomic bomb. Go forward in the research of atomic energy contributing to the progress of civilization. Devil will then be transformed to fortune.(Wazawai tenjite Fukutonasu) The world civilization will change with the utilization of atomic energy. If a new and fortunate world can be made, the souls of so many victims will rest in peace."

Sustainable Nuclear Power

経済教室

大震災から5年 エネルギー政策 ㊦

持続可能な原子力を探れ

ポイント

- ○原油安続くと中東依存が一層高まる懸念
- ○エネルギー安全保障と温暖化回避両立を
- ○日米原子力協定改定を見据え未来図描け

田中 伸男 元国際エネルギー機関事務局長

東日本大震災から5年がたった今、エネルギー情勢は様変わりしている。

例えば石油価格。2014年の夏からみて国際石油価格は約3割の水準だ。国際エネルギー機関(IEA)が15年11月に発表した世界エネルギー見通しで注目すべきは「石油低価格シナリオ」だ。5年前に北米のシェールオイル生産が日量400万バレルを超え、天然ガスでも米国が輸出国になると予想する者はいなかった。さらに石油輸出国機構(OPEC)のリーダー、サウジアラビアが減産せず価格支配を放棄したのも驚きだ。

サウジは北米産シェールオイルがどの程度の価格弾力性を持つのか試している。原油価格低迷でシェール減産を予想する者が多かったが、リグ(掘削設備)などの価格低下、効率的な油田への資源集中により、シェールは結構しぶといことが分かってきた。

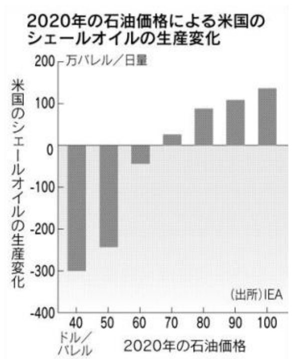
IEAはシェールオイルの価格弾力性を分析し、市場価格にあわせて素早く供給を調節する機能はOPECから北米のシェールに移ったと結論付けている(図参照)。「エネルギー新時代」の幕開けだ。

日本は震災後5年間、大半の原子力発電所が停止し、ガスと石油の輸入増で国富を流出させてきた。しかし最近の原油価格低迷が貿易収支を改善し、安倍政権の経済政策アベノミクスを支えている。これは日本にとって極めて幸運だが、一体いつまで維持できるのか。一方で、長引けば良いことばかりではなくなる。

IEAは2年連続で石油の上流投資が減るとみる。石油低価格シナリオの第1の問題は、北米やブラジルなど非OPECの高コスト生産地域で投資が減るため、将来は低コストの中東のOPEC諸国に過度に依存することになる点だ。このシナリオでは世界の石油貿易量の半分以上がホルムズ海峡経由になる。最近のサウジとイランの対立激化や過激派組織「イスラム国」(IS)によるテロの拡散など、中東情勢は予断を許さない。

日本は昨年、ペルシャ湾などでの緊急事態に対応するため安全保障法制を強化した。今後は同じく中東依存が高まる中国、インドとの安全保障協力も視野に入れるべきだ。米国からの液化天然ガス(LNG)輸入に加え中東外の大供給国、ロシアとの関係強化が重要だ。ロシアも日本との安定した取引を求めている。この際、ガスパイプラインや電力グリッド(送電網)の連係など思い切った経済連携を進めるべきだろう。

ガスパイプラインによるドイツとロシアの経済統合が、東西ドイツの再統合を可能にしたと考えれば、日ロ間のエネルギーブリッジがいずれ北方領土問題解決への一里塚になると考えられる。政府がアジアと一体のエネルギー安全保障を考え、産業界は国内市場が縮小する中で広くアジアと一体となったエネルギービジネスを考えるべきだ。



日本、米独と事情違う

原油価格低迷がもたらす第2の問題は地球環境問題への取り組みの遅延だ。温暖化ガス削減問題は5年間全く進展がなかったが、15年末の第21回国連気候変動枠組み条約締約国会議(COP21)の合意が転機となるかもしれない。

今回は米中を含む主要国すべてが参加するメカニズムができた。また各国の約束を5年ごとに見直し、徐々に目標に近づくボトムアップ・プロセスが誕生した。5年前の震災を理由にした義務免除はもう通用しないし、将来削減が一層強化される可能性がある。

IEAは再生可能エネルギーが将来石炭、天然ガスを追い越し、最大の電源になるとみている。そのためには化石燃料から低炭素エネルギーへ一挙にシフトを起こす必要がある。しかし低価格の石油、ガス、石炭はこれに水を差す。

特に石炭は今安いからといって、低効率の石炭発電設備投資をすると排出規制が強化されれば困ったことになる。解決のためには石炭ガス複合発電(IGCC)など高効率発電技術や、将来実現する二酸化炭素(CO_2)回収・貯留技術(CCS)を普及適用することが必要になる。

将来に炭素価格が高くなれば、水素技術は逆に日本のお家芸になりうる。こうしたリスクをコストとして認識するため、欧米の企業の多くは将来のCO_2価格を1トン当たり30~60ドルと想定して、投資決定のハードルレートに加えていると聞く。一方、日本企業でこうした動きはほとんどないようだ。パリ合意を受けて早く日本企業も同様の準備を始めるべきだろう。

原油安続いても原発必要

原油価格低迷の第3の課題は、原子力の将来をどう描くかだ。中東危機は千年に一度の津波より頻繁に起きる可能性が高く、原子力は準国産の電源として重要だ。原発事故から5年がたち、厳しい安全基準の下で原発再稼働が徐々に進む中で、政府は30年に原子力発電が全電源の20~22%を占めるとの目標を立てた。

これはエネルギー安全保障と温暖化ガス排出削減目標の達成を可能にする最低限の目標だ。今後も原油価格低迷が続くなら、原発は不要との声があるがそう単純ではない。

シェール革命で天然ガスが極めて安い米国では、ガスが石炭より割安になったためガス発電が石炭発電に取って代わり、CO_2排出削減と経済成長の両立が可能になった。

また米国では、シェール革命で従来の石炭に加え石油やガスが今後数十年間は豊富に生産されるので、安全保障上の理由から割高な原子力発電を進める必要性は乏しい。残念ながらシェール革命のない日本にこんな余裕はない。

ドイツが22年までに原発を順次廃止できるのも、いざとなれば隣国のフランスから原子力の電気を輸入できるからだ。さらに欧州は電力グリッドが緊密に連係して大市場を形成することで、変動する風力・太陽光の利用度を上げることも目指している。欧州はまさに集団的な連係プレーでエネルギー安全保障と持続可能性を同時に達成している。

隣国と連係がないうえ、国内の電力網すら50ヘルツと60ヘルツで東西に分断されている日本で同じことはできない。

今でもなお多くの国民が安全保障、地球環境貢献、経済性といったメリットだけでは原子力推進に賛成できないようだ。確かに、他のエネルギーよりも厳しい持続可能性条件が原子力には求められる。その条件とは、第1に万が一事故が起きても放射能がまき散らされないという原子炉の受動的安全性、第2に使用済み核燃料や高レベル廃棄物が安全に処分されること、第3に日本が途上国に技術輸出しても核兵器に転用されないという核不拡散性である。

実はこうした技術はすでに米国に存在する。アルゴンヌ国立研究所が開発した統合型高速炉(IFR)と電解型乾式(空冷式)再処理技術だ。この技術は福島第1原発の炉心で溶け落ちた核燃料(デブリ)の処理に必須である。高速増殖炉「もんじゅ」も、この炉で使う金属燃料の燃焼実験に使える。

日米原子力協定の改定が18年に迫っている。日米国民が納得する協定延長のためには持続可能な原子力システムの未来図が必要だ。この際、日米共同で炉心デブリ処理技術の実証実験を福島で進めることが近道ではないか。

震災から5年がたつが、世界のエネルギー情勢は嵐のまっただ中にある。立ち止まっているわけにはいかない。

たなか・のぶお 50年生まれ。東京大経卒、旧通産省へ。笹川平和財団理事長