

SMRは原子力業界の 救世主になれるか

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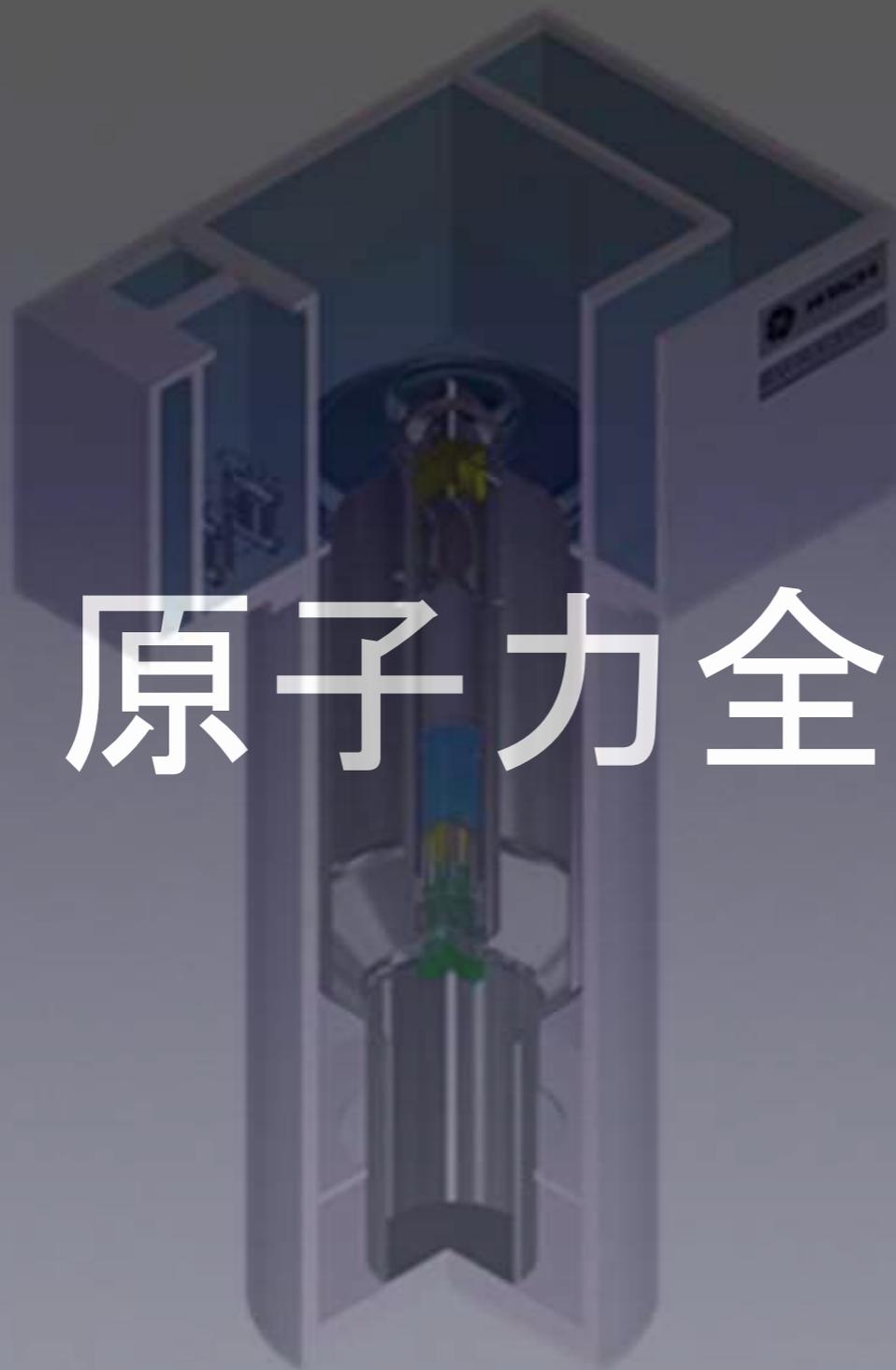


HITACHI

Webinar hosted by
Citizens' Nuclear Information Center, Tokyo

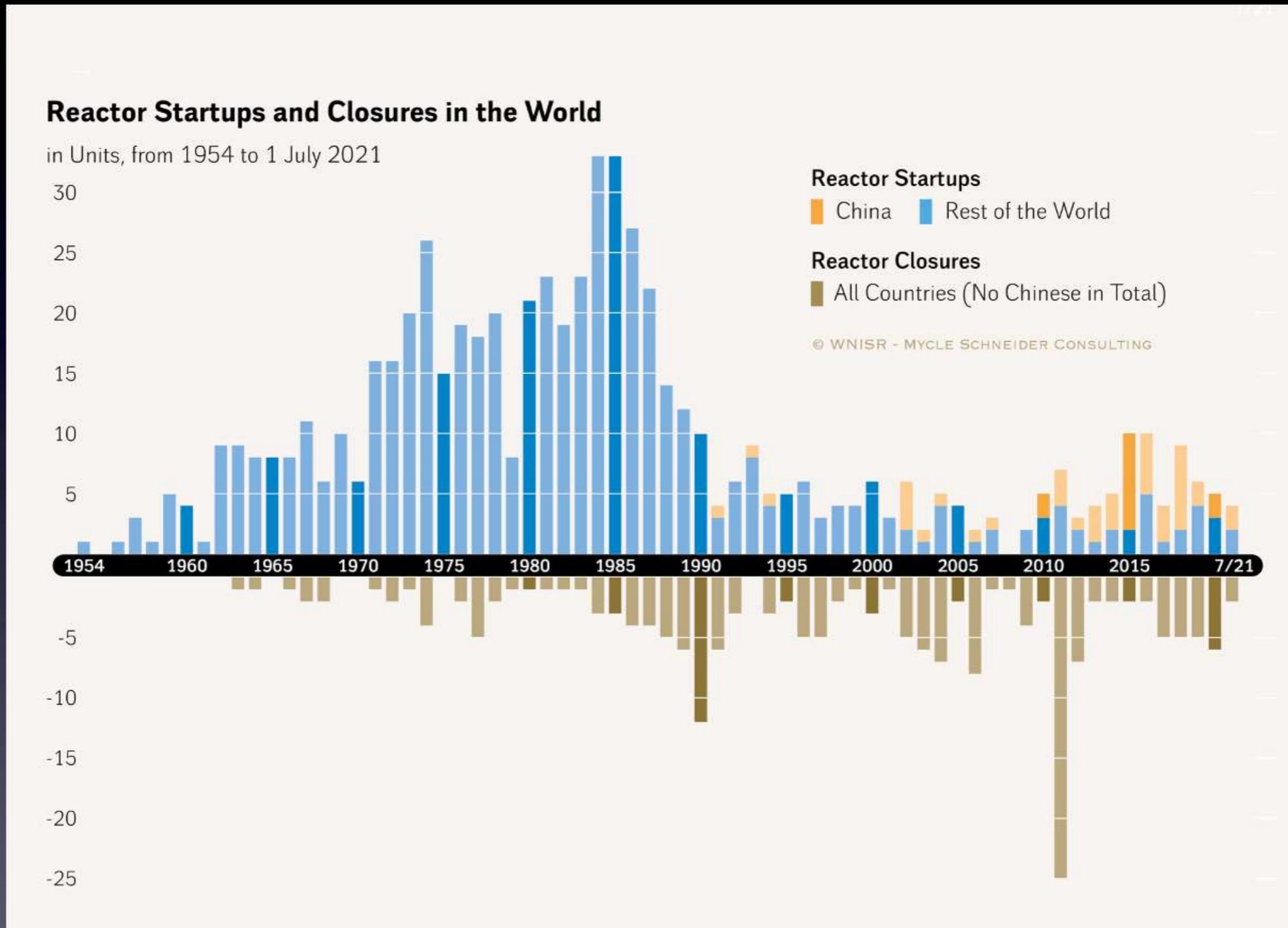
March 2022

原子力全体の背景



HITACHI

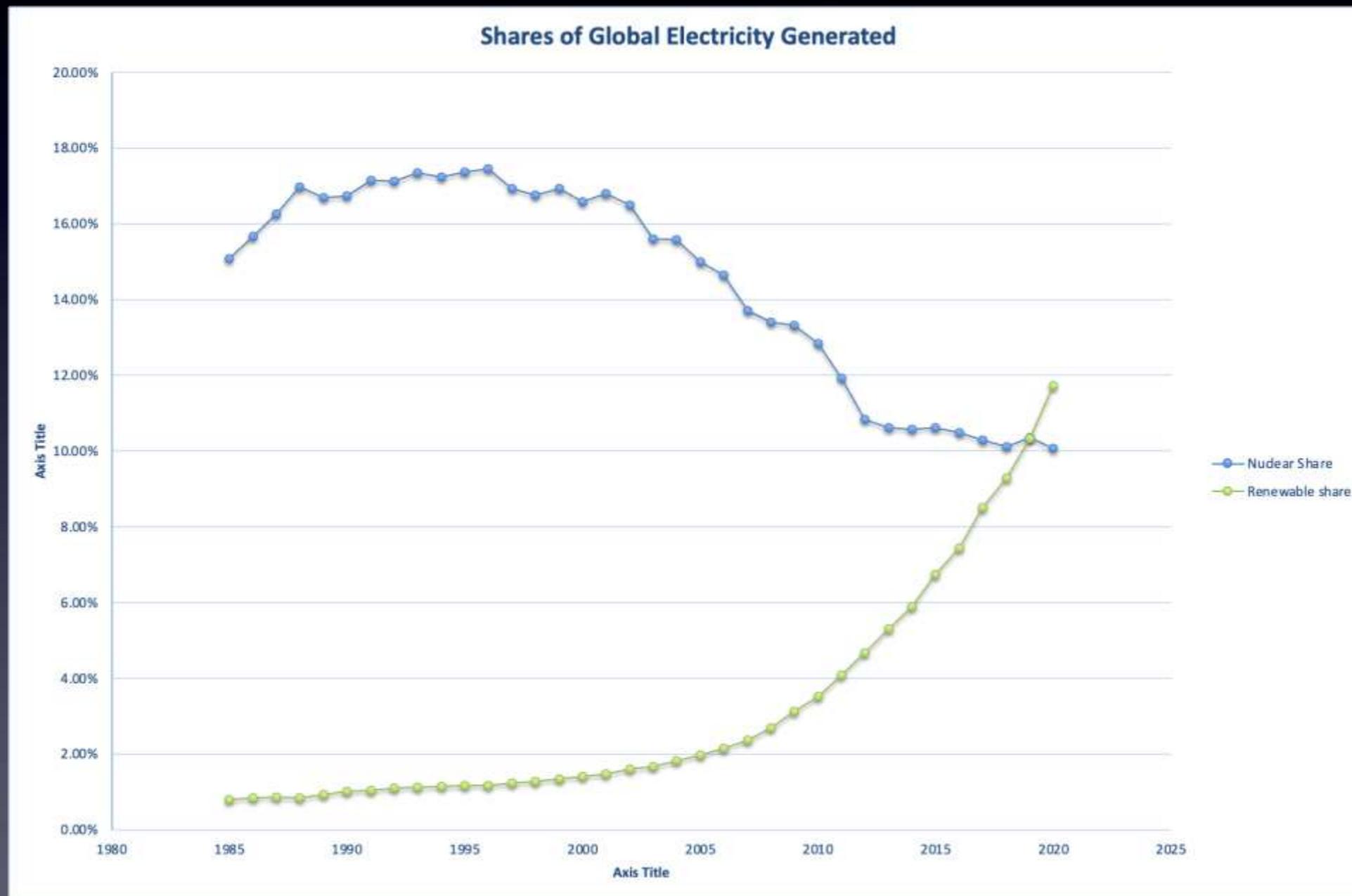
原発建設の最盛期は30年以上前に終わっている



Source: World Nuclear Industry Status Report, 2021, Mycle Schneider Consulting.

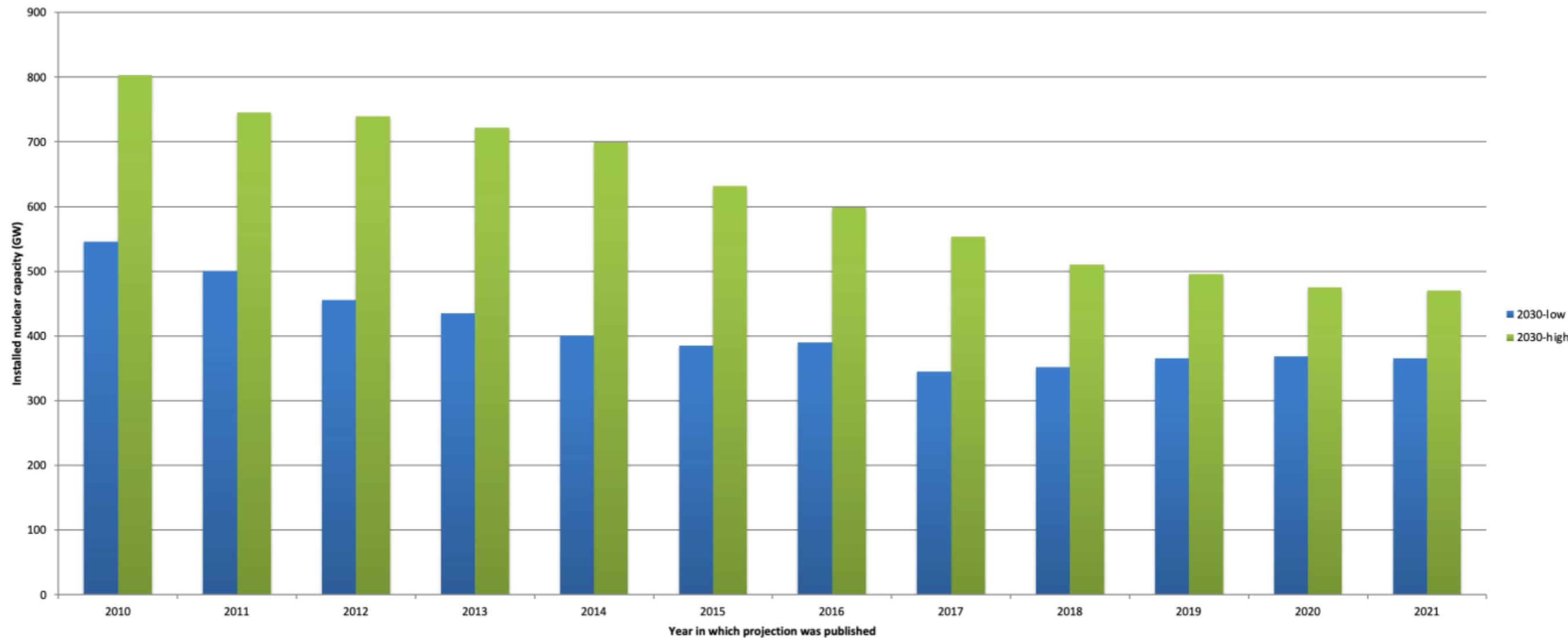
発電電力量シェア

過去の最大値である1996年の17.6%を約40%下回る



Source: Calculations using data from BP's Statistical Review of World Energy 2021

IAEAの予測



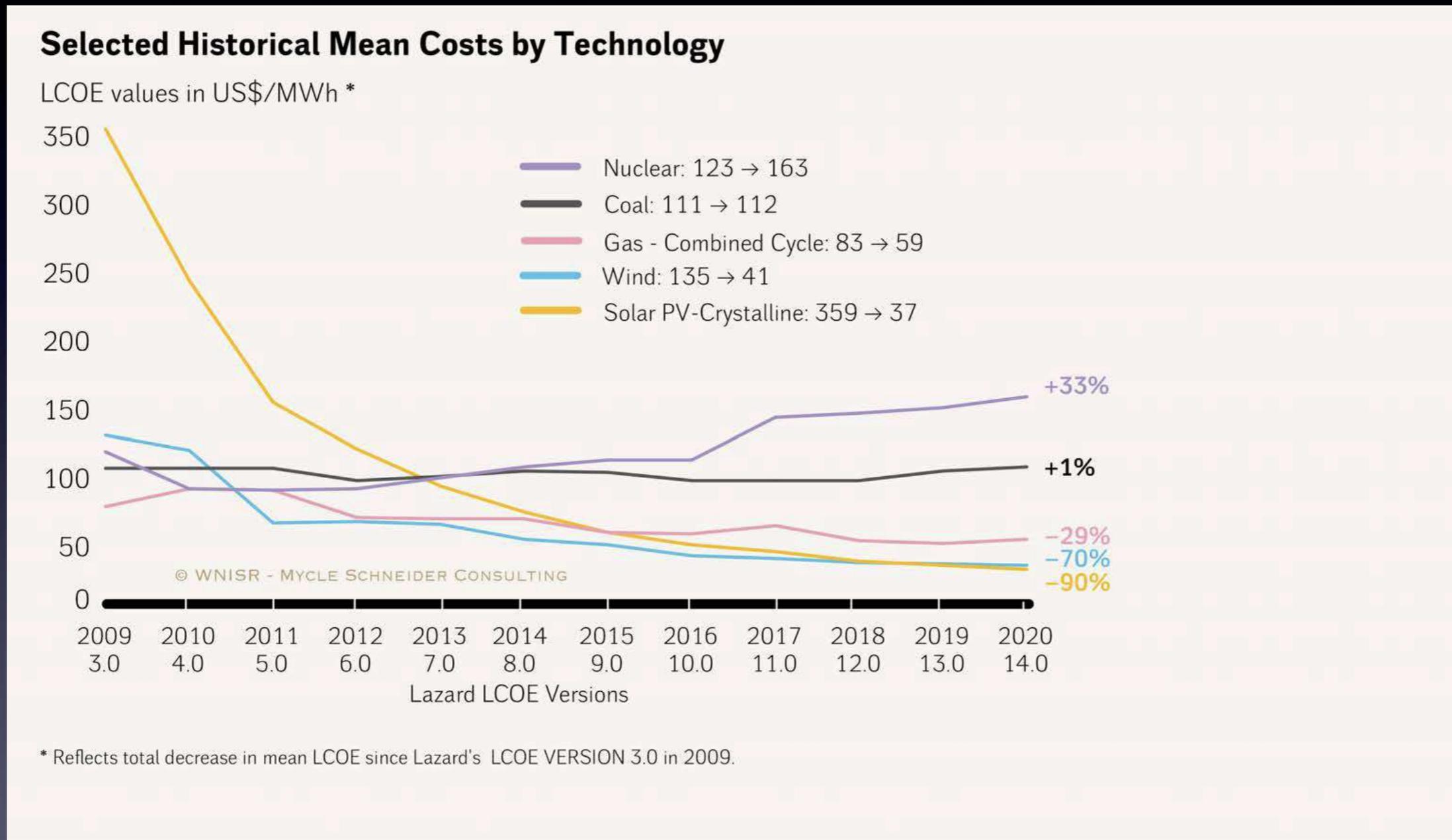
IAEA (2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021) Energy, Electricity and Nuclear Power Estimates for the Period up to 2050. Vienna, International Atomic Energy Agency.

なぜこの傾向？

原子力発電は経済的な競争力がない
原子炉の建設コストが高すぎる

他の電源は安い...

そしてもっと安くなりつつある



Source: data from Lazard, as plotted in World Nuclear Industry Status Report 2021

高い運転コストと安価な代替により、いくつかの原子炉が停止している

Another Reactor Closes, Punctuating New Reality for U.S. Nuclear Power

As Vermont Yankee shuts down, the U.S. has yet to address industry issues that span decades.

By **Christina Nunez**, [National Geographic](#)

PUBLISHED JANUARY 01, 2015



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Sweden's Oskarshamn 1 and 2 reactor units to close

14 October 2015

German utility Eon has decided that units 1 and 2 of the Oskarshamn nuclear power plant in Sweden will be shut down permanently. Unit 3 is unaffected by the decision, which was announced today by OKG AB, of which the EOn group is the major shareholder.



The three-unit Oskarshamn plant (Image: OKG)

Related Stories

- EOn supports early closure of Oskarshamn units
- Court leaves Swedish nuclear tax unchanged

WNA Links

- Oskarshamn 1
- Oskarshamn 2
- Oskarshamn 3
- Nuclear Energy in Sweden

Related Links

- EOn
- OKG

80

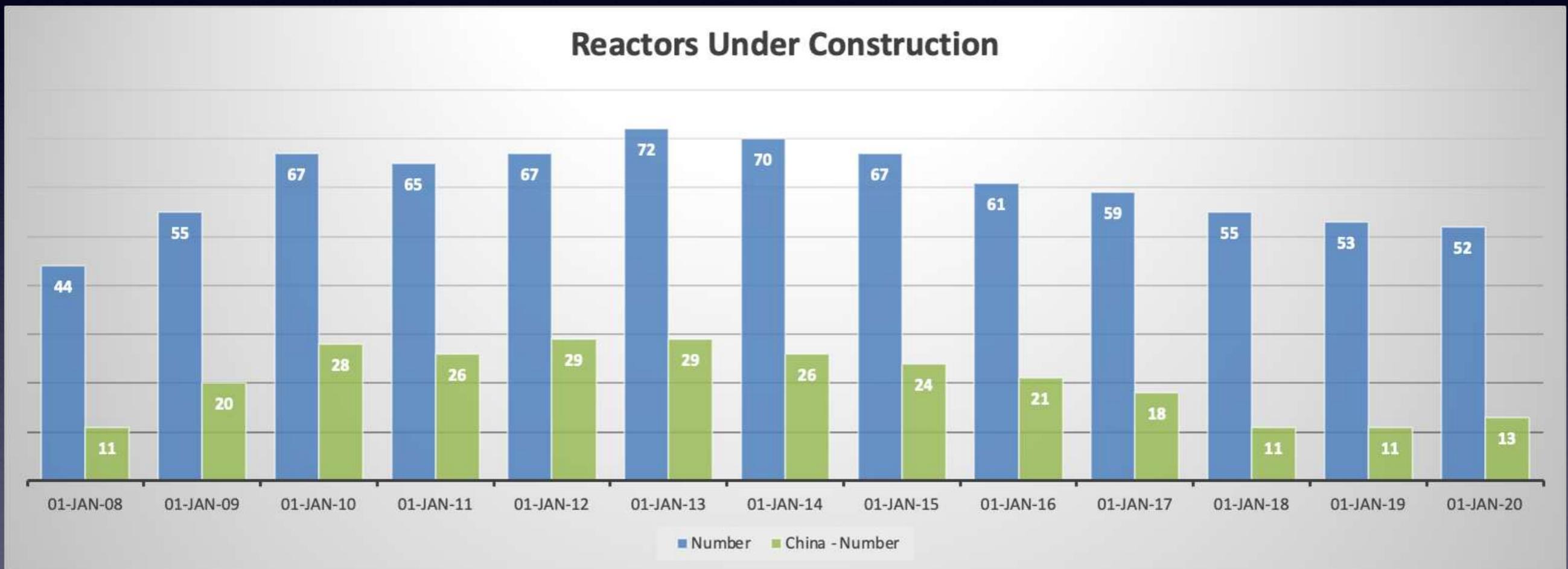
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原子力ネットワークサンス？



Source: My calculations, based on IAEA PRIS data

原子力ネットワーク USA

期待されたこと

約30基の受注

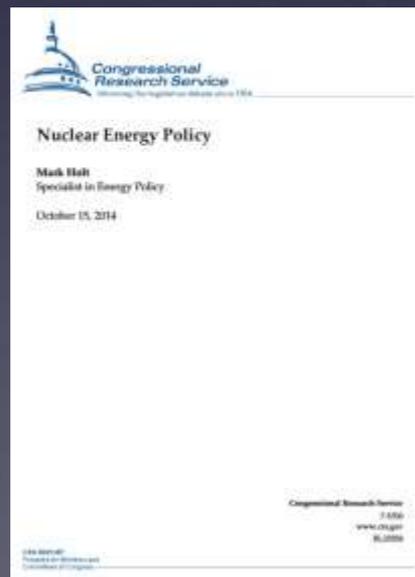
2021年までに15GW近くの新規設備

実現したこと

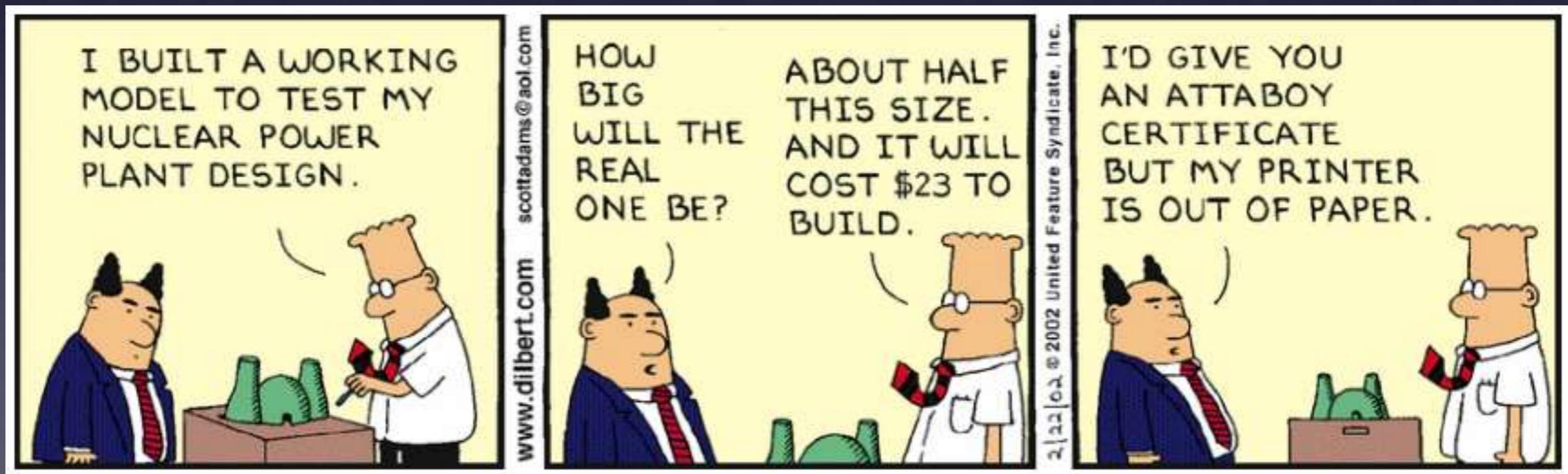
4基しか着工しない

2基の原子炉は90億ドルを費やした後、放棄された

何が残っている？

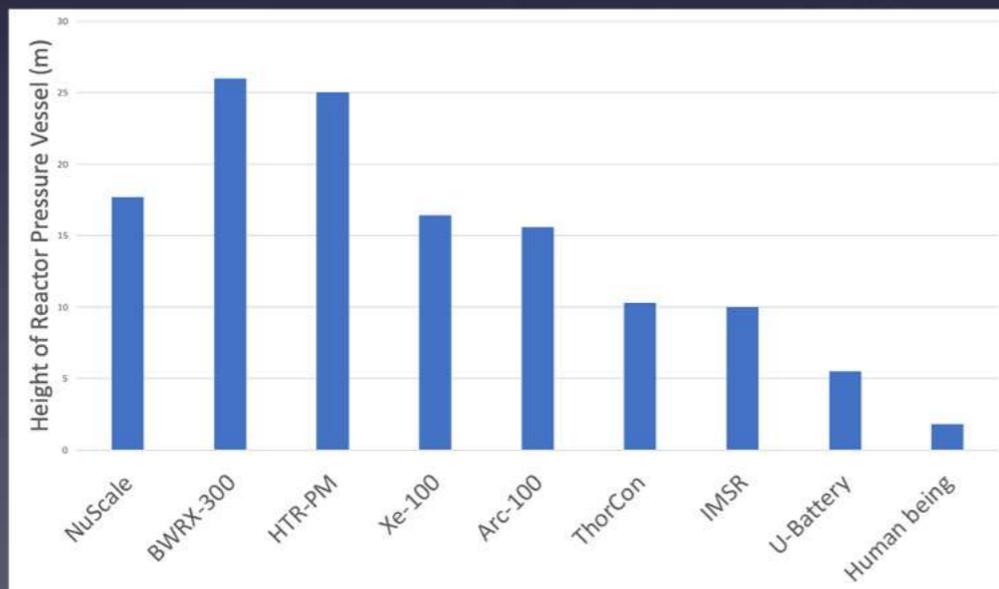


小型モジュール 原子炉とは？



小型モジュール原子炉とは？

	容量
小	< 300 MWe
中	300 ~ 700 MWe



工場生産されたモジュールから組み立てる

各モジュールは、完成した発電所の一部を構成する

カナダでのSMR

多くのメディアで注目される

公的資金

有利な規制

2018年: SMRロードマップのための連邦政府資金

2020年: 連邦政府が行動計画を発表

2020年10月 テレストリアル・エナジー社に連邦政府から2000万カナダドル（1600万米ドル）の資金提供

2021年3月 モルテックス社に連邦政府から5000万カナダドル（4000万米ドル）の資金提供

2021年12月 オンタリオ州電力がGE日立と共同でBWRX-300をカナダに展開すると発表



SMRは原子力の問題を解決するのか？

BULLETIN OF THE ATOMIC SCIENTISTS
2021, VOL. 77, NO. 4, 207–214
<https://doi.org/10.1080/00963402.2021.1941600>

 **Routledge**
Taylor & Francis Group

OTHER FEATURES

 Check for updates

Can small modular reactors help mitigate climate change?

Arjun Makhijani and M. V. Ramana 

IEEE Access
Multi-Disciplinary | Rapid Review | Open Access Journal

Received February 28, 2021, accepted March 5, 2021, date of publication March 9, 2021, date of current version March 22, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3064948

INVITED PAPER

Small Modular and Advanced Nuclear Reactors: A Reality Check

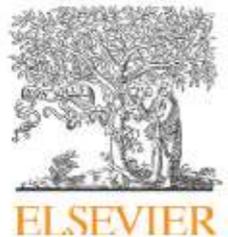
M. V. RAMANA 

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一つの炉型ですべての属性は実現できない

Energy Research & Social Science 2 (2014) 115–124

Contents lists available at [ScienceDirect](#)

 **Energy Research & Social Science** 

journal homepage: www.elsevier.com/locate/erss

Original research article

One size doesn't fit all: Social priorities and technical conflicts for small modular reactors

M.V. Ramana*, Zia Mian

Nuclear Futures Laboratory and Program on Science and Global Security, Princeton University, United States

 CrossMark

小型だと...

コストが高くなる

$$\frac{K_1}{K_2} = \left(\frac{S_1}{S_2} \right)^{0.6}$$

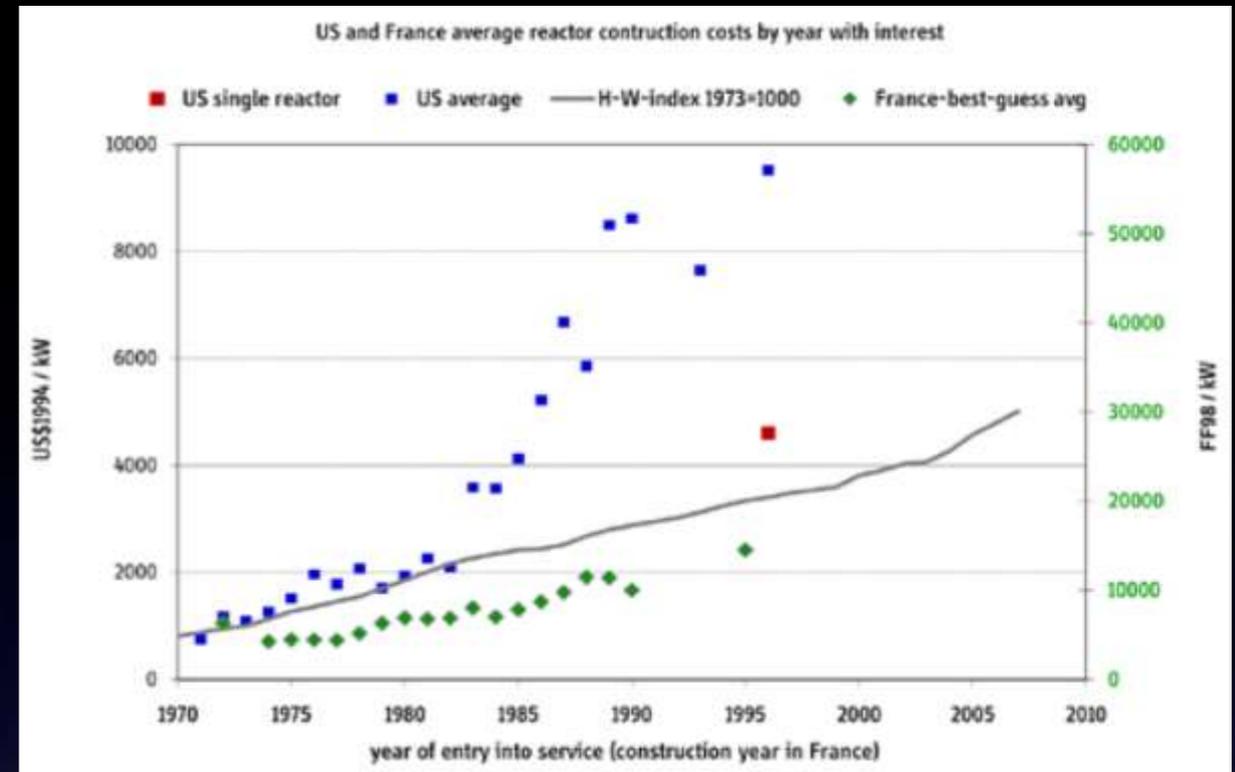
使用済燃料/廃棄物/核拡散リスクの増加

RESOURCE REQUIREMENTS AND
PROLIFERATION RISKS ASSOCIATED
WITH SMALL MODULAR REACTORS

ALEXANDER GLASER,* LAURA BERZAK HOPKINS, and M. V. RAMANA

NUCLEAR TECHNOLOGY VOL. 184 OCT. 2013

“学習”はSMRのコストを上げる可能性もある

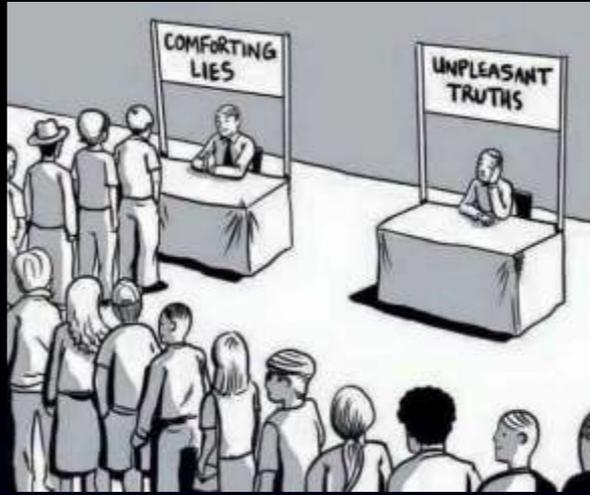


Grubler, Arnulf. 2010. "The Costs of the French Nuclear Scale-up: A Case of Negative Learning by Doing." *Energy Policy* 38 (9): 5174–88.

学習があったとしても、あまりにも多くの損する「ロスリーダー」を作らなければならない

Diseconomies of Scale Exponent

	0.6	0.8
10%	700	80
5%	60,000	780



これまでの経験～
同じことの繰り返し

実際のプロジェクトでは遅延 や、業績悪化が起きている

アルゼンチン：Carem-25は2014年着工だが2020年11月レポートは「物理的完成度は70%」、完成時期は不明となっている

中国：HTR-PM 2012年建設開始、2017年発電開始予定、最近臨界に達した（4年遅れ）

ロシア KLT-40Sは2007年着工、2010年10月運転開始予定だが2020年5月にやっと運転開始。IAEA PRISデータベースによると、2020年のツインユニットの負荷率load factorsはわずか29%と16%である。

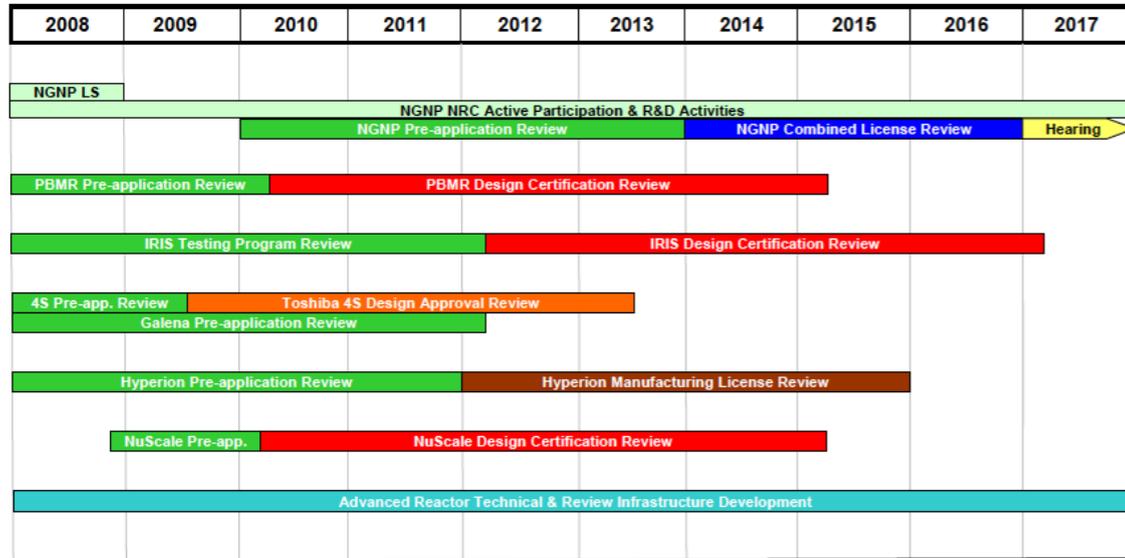
Source: <https://zh-prod-1cc738ca-7d3b-4a72-b792-20bd8d8fa069.storage.googleapis.com/s3fs-public/inline-images/190626175935-arctic-nuclear-2-exlarge-169.jpg>



NuScale

Potential Advanced Reactor Licensing Applications

An estimated schedule by Fiscal Year (October through September)



Legend:



NOTE: Schedules depicted for future activities represent nominal assumed review durations based on submittal time frames in letters of intent from prospective applicants. Actual schedules will be determined when applications are docketed.

Source: Edward Baker, "NRC's Advanced Reactor Program," 16 October 2008, <http://web.mit.edu/ans/www/documents/seminar/F08/baker.pdf>, accessed 19 May 2015

NUSCALE'S INCREASING COST PROJECTIONS COMPARED TO ACTUAL SMR COSTS



"Without clarity on the steam generator integrity, it would be **premature to conclude that the NuScale design ensures adequate protection of public health and safety.**"

Advisory Committee on Reactor Safeguards Member Vesna B. Dimitrijevic, March 2020

We identified a boron dilution issue that remains open. We are concerned that this class of events **could lead to a potential reactivity insertion accident and core damage.**"

Advisory Committee on Reactor Safeguards letter, June 2020

Ramana, M. V. "Eyes Wide Shut: Problems with the Utah Associated Municipal Power Systems Proposal to Construct NuScale Small Modular Nuclear Reactors." Portland, OR: Oregon Physicians for Social Responsibility, September 2020. https://www.oregonpsr.org/small_modular_reactors_smrs.

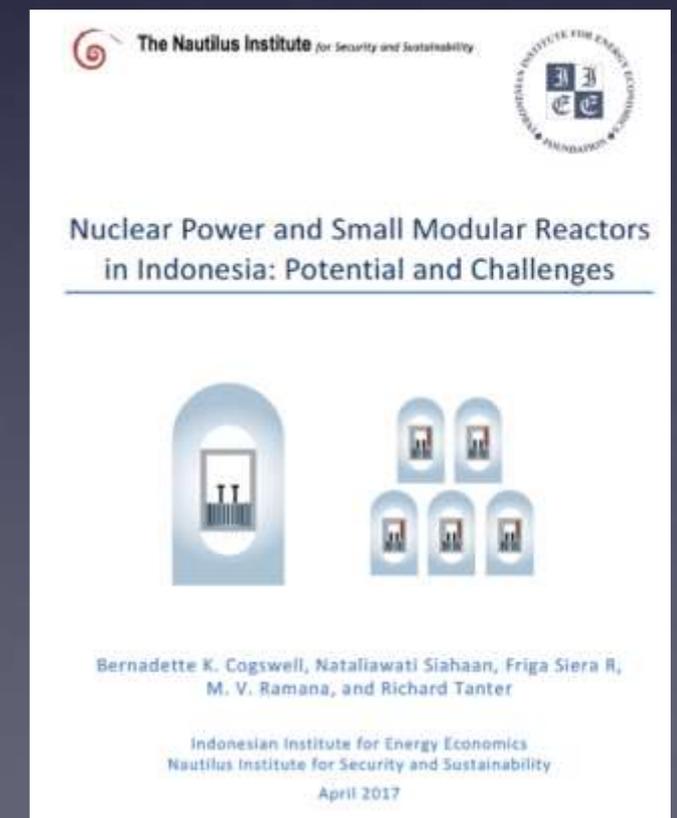
Douglas O. Hunter: Why the world is watching Utah's Carbon Free Power Project

[sttrib.com/opinion/commentary/2021/11/23/douglas-o-hunter-why](https://www.sttrib.com/opinion/commentary/2021/11/23/douglas-o-hunter-why)

November 23, 2021

462MWeで53億2000万ドル⇒11,515ドル/kW＝建設開始時のVogtleより80%アップ

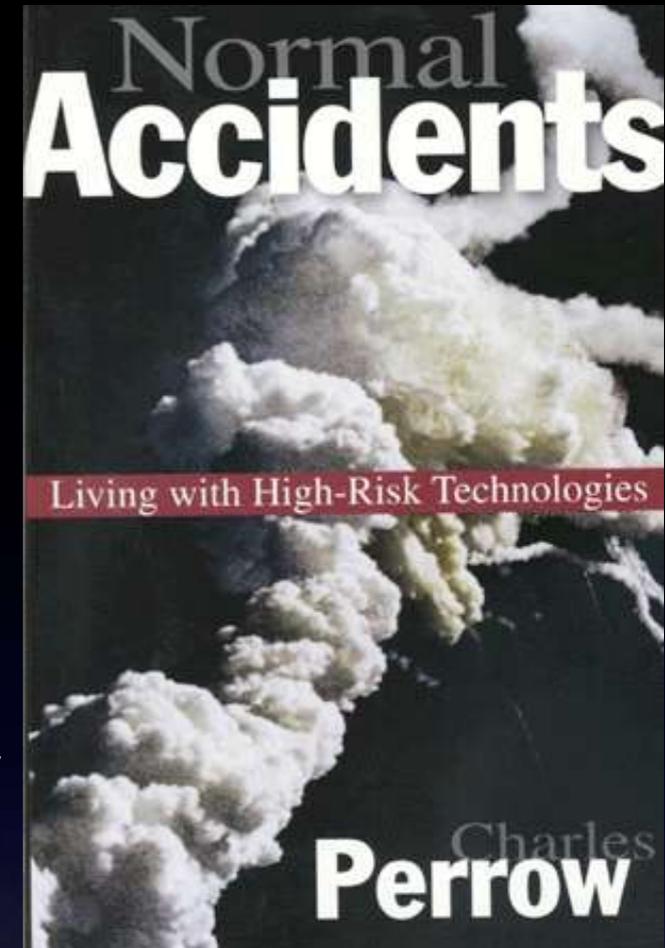
顧客見込み先国が買わない 3つのケーススタディ ガーナ、ヨルダン、インドネシア



小型原子炉もニューク
リアである⇒事故を
起こす可能性がある



Charles Perrow: 相互作用の複雑さと緊密な結合は、重大な事故を必然的に引き起こす

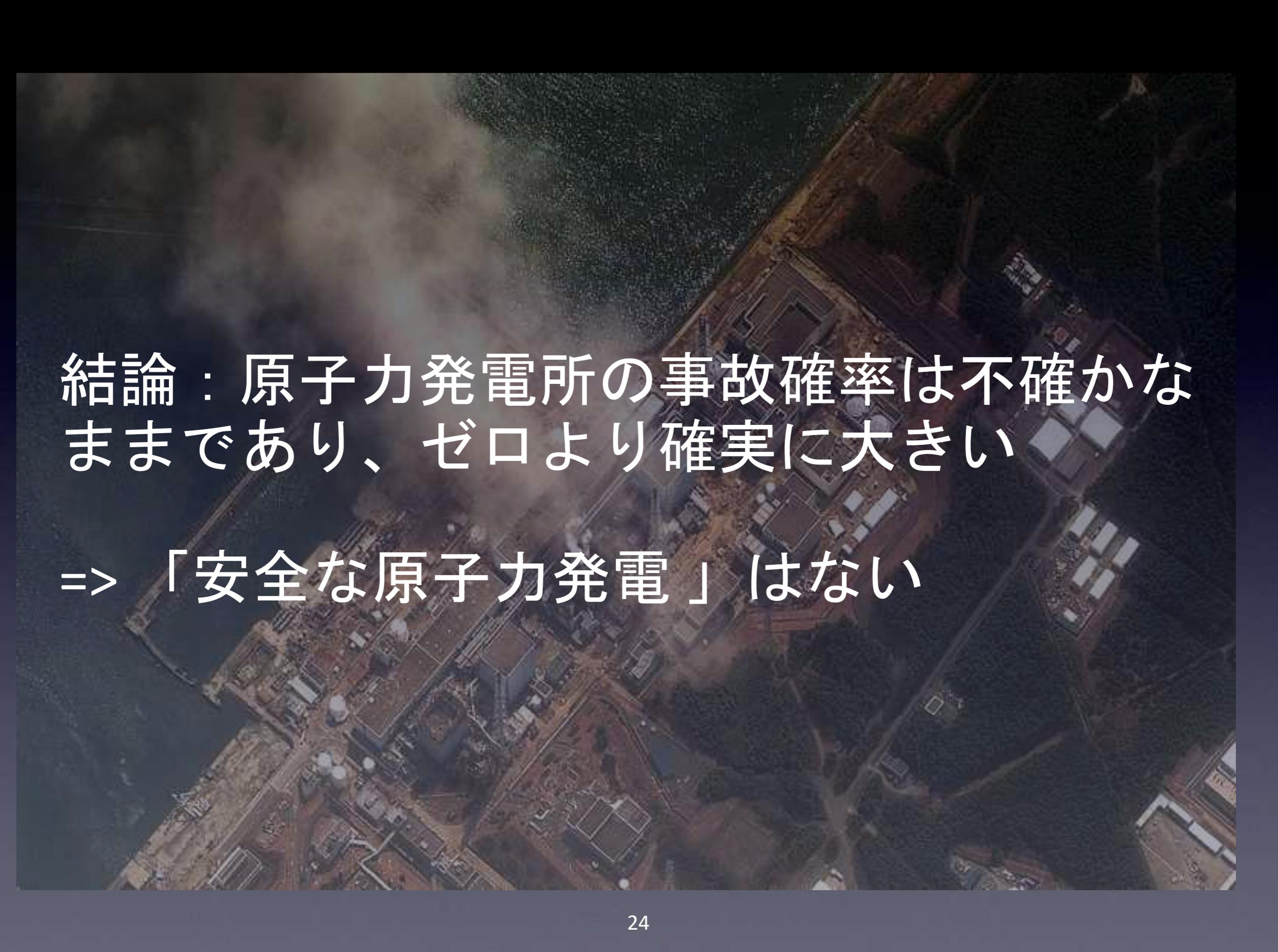


Berkeley HRO Group: このような技術を管理しなければならない組織は、非常に厳しい要求があり、それを満たすことは困難である

JOURNAL OF CONTINGENCIES AND CRISIS MANAGEMENT

High Reliability Organizations: Unlikely, Demanding and At Risk

Todd R. La Porte*

An aerial photograph of a nuclear power plant facility, showing various buildings, piping, and structures. A large plume of white smoke or steam is rising from the central part of the plant, partially obscuring the sky. The surrounding area appears to be a mix of industrial and natural landscape.

結論：原子力発電所の事故確率は不確かな
ままであり、ゼロより確実に大きい

=> 「安全な原子力発電」はない

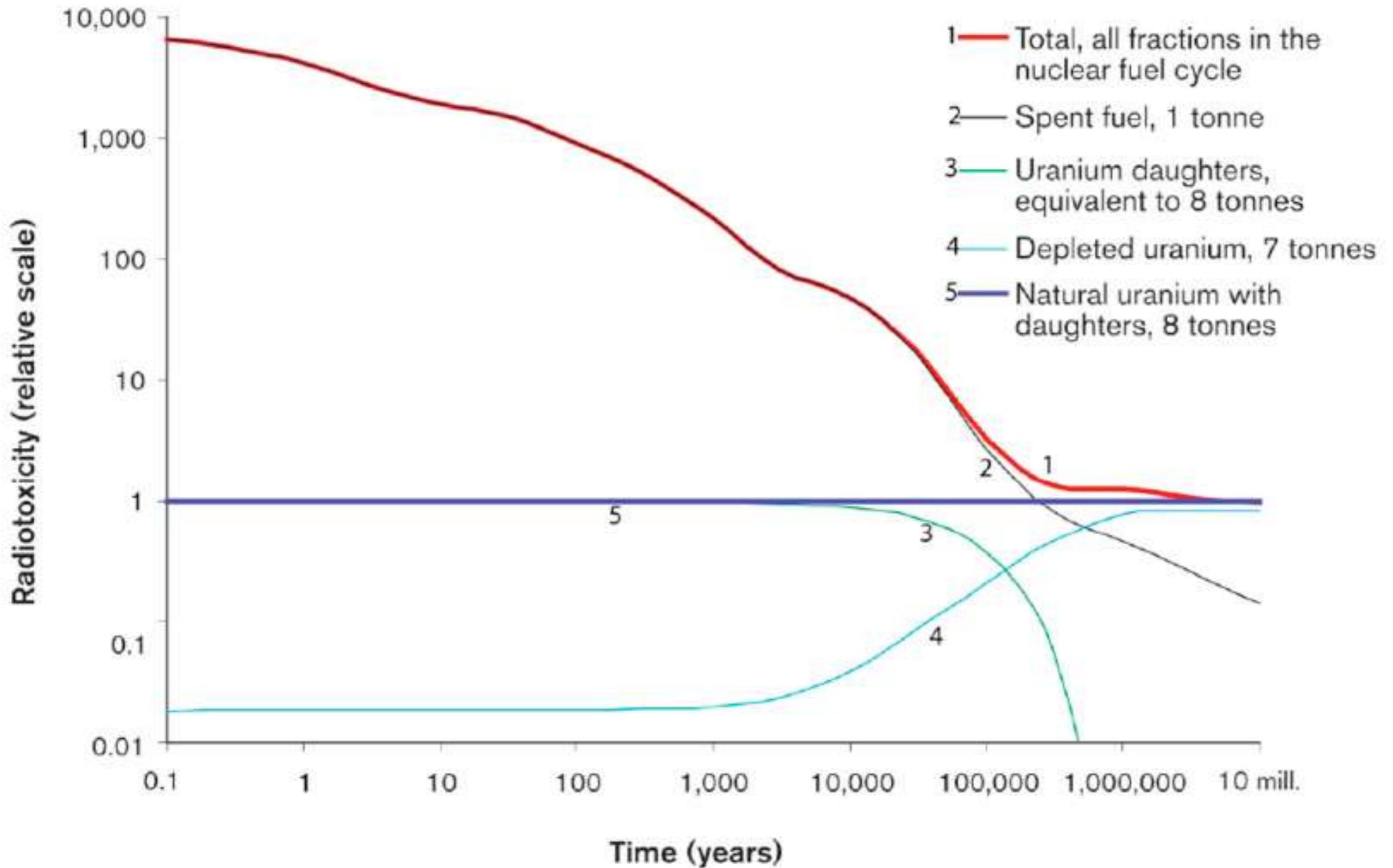


DANGER

POISONOUS RADIOACTIVE  WASTE BURIED HERE
DO NOT DIG OR DRILL HERE BEFORE A.D. 12,000



原子力発電は、数千年にわたり
有害な放射性廃棄物を発生させる。



Source: Feiveson, Harold, Zia Mian, M. V. Ramana, and Frank Von Hippel. 2011. "Managing Spent Fuel from Nuclear Power Reactors: Experience and Lessons from Around the World." Princeton: International Panel on Fissile Materials.

技術的課題と社会的懸念の結合⇒稼働中の核廃棄物処分場なし

実証されたソリューションがない

An Enduring Problem: Radioactive Waste From Nuclear Energy

BY M. V. RAMANA

Program on Science and Global Security, Princeton University, Princeton, NJ, USA



Photograph of a waste container at the Waste Isolation Pilot Plant, USA, with its lid unsealed and apparent heat discoloration taken by the U.S. Department of Energy on May 15, 2015. Source: http://www.wipp.energy.gov/wipprecovery/photo_video.html

I. GEOLOGICAL DISPOSAL: THE PROMISE AND THE REALITY

Some of the radioactive elements produced during the operation of nuclear reactors have extremely long half-lives, and have to be isolated from human contact for hundreds of thousands of years (see Fig. 1). This requirement for stewardship is unprecedented in human history. Since the 1950s, nuclear establishments have advocated dealing with these radioactive wastes by constructing an underground repository in a suitable geological medium and placing the waste there, within special containers. Much attention from the technical community has been focused on finding a suitable location because the choice of geological media (e.g., granite, volcanic tuff, or clay) will influence the behavior of radionuclides when they escape from the container [2]. The question is one of "when," not "if"; because of corrosion, radionuclides will migrate into the biosphere over the long periods of time it would take for them to decay. As Allison Macfarlane, former Chair of the U.S. Nuclear Regulatory Commission put it, no "site will...contain nuclear waste indefinitely. The goal is to select a site and engineered features, such as the waste canister, which maximize the amount of time the waste is isolated" [3, p. 84].

Nevertheless, confidence in the idea of a repository remains high. The U.S. National Academy of Sciences'

Decades after the idea was first proposed, it appears that underground repositories to manage radioactive spent fuel from commercial reactors are finally going to be constructed. In November 2015, the ruling center-right party in Finland became the first government to grant a construction license for such a repository [1]. The U.S. Department of Energy is pursuing a consent-based process to set up a similar repository. Do these developments mean that a long-sought solution to the problem of nuclear waste is imminent?

As this article will argue, there are many fundamental reasons why dealing with radioactive waste is a special and enduring challenge. Even if a repository is constructed in one or two countries, those examples are by no means generalizable. The continuing problem of radioactive waste disposal, in turn, is another reason to be wary of a large-scale expansion of nuclear power.

Digital Object Identifier: 10.1109/JPROC.2017.2641518

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Vol. 105, No. 3, March 2017 | PROCEEDINGS OF THE IEEE 415

Received: 1 October 2017 | Revised: 6 January 2018 | Accepted: 8 January 2018

DOI: 10.1002/wene.289

ADVANCED REVIEW

Technical and social problems of nuclear waste

M. V. Ramana

WILEY WIREs ENERGY AND ENVIRONMENT

Take home messages

すべてのSMRには様々な技術的課題があり、原子力が直面するすべての問題を解決できるものはない

最高の環境であっても、高価な電力を生産することになり、開発には長い時間がかかる。