Challenges of Small Modular Reactors

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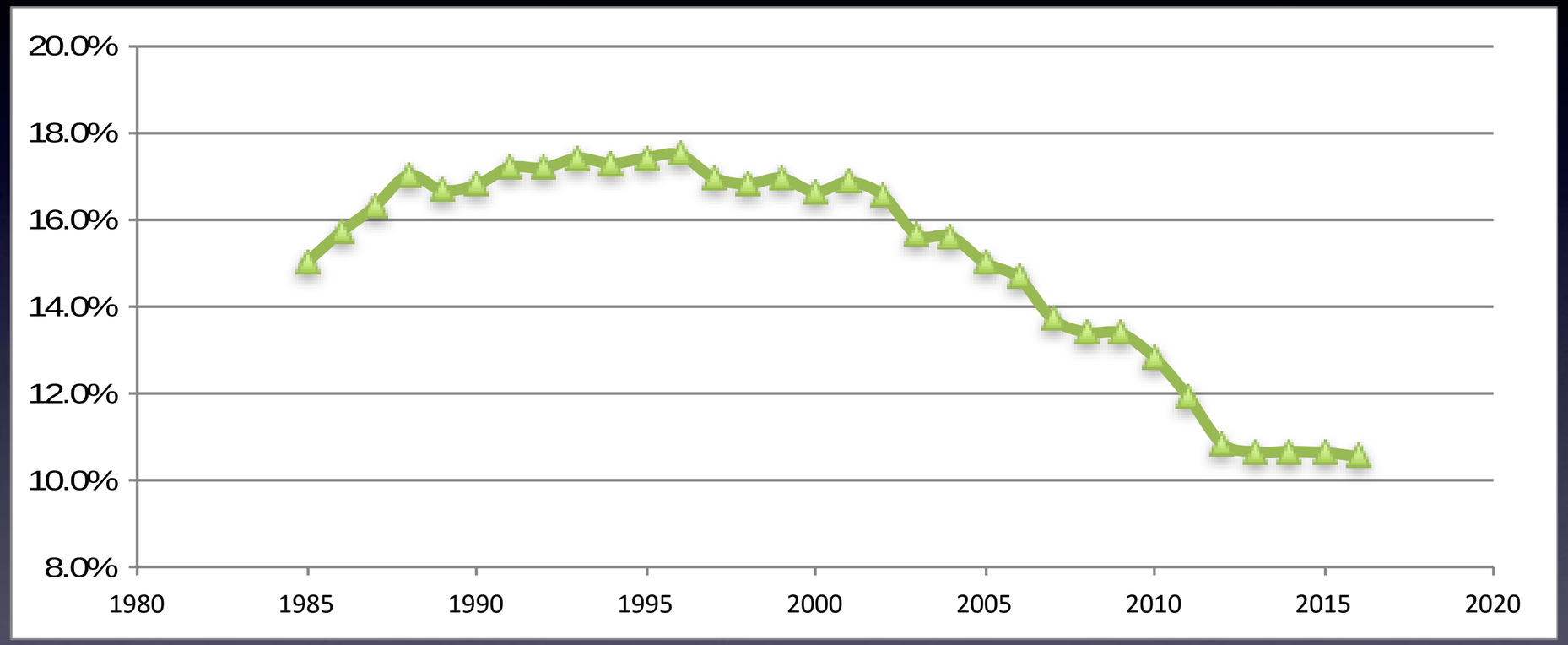
27 October 2017

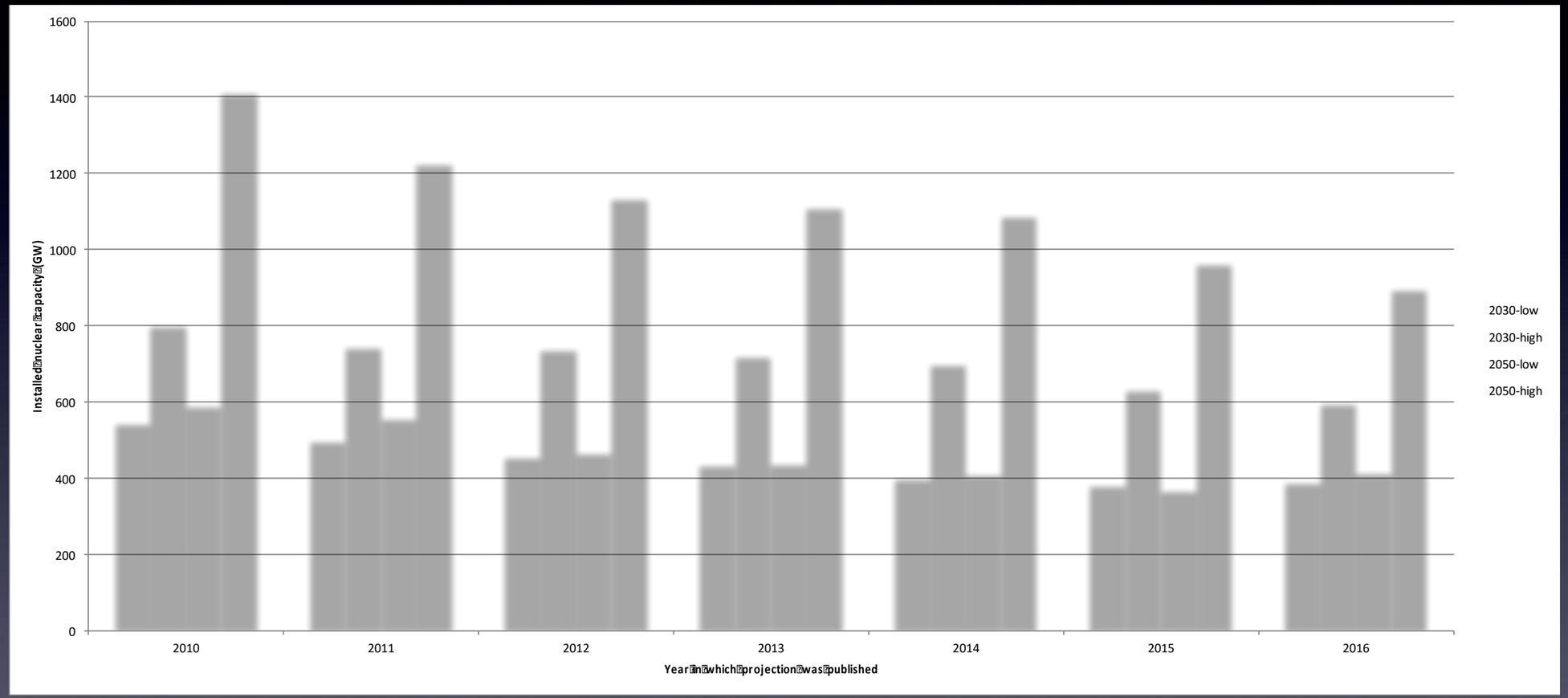
Nuclear Share

About 40 percent below historical maximum of 17.5 percent in 1996



Source: Calculations using Data from BP's Statistical Review of World Energy 2017

Future Projections



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

MIT Study - 2003

“The limited prospects for nuclear power today are attributable, ultimately, to four unresolved problems”:

- Costs
- Safety
- Proliferation
- Waste

theguardian

This new technology could save the troubled nuclear power industry

Small nuclear reactors, funded by investors like Bill Gates, are emerging in the US as cheaper, safer alternatives to traditional nuclear power plant designs

Supported by
Debbie Carlson
Sunday 16 October 2016 1

THE STRAITS TIMES

By Invitation

A floating nuclear power plant - off Singapore?

Lim Soon Heng For The Straits Time

PUBLISHED OCT 4, 2016, 5:00 AM SGT

The Republic could be a world leader in building small reactors deployed at sea, including in nearby waters

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American Elect	62.30	-0.23	-0.37%	OTTR	33.49	-0.29	-0.86%	PG&E Corp	59.80	-0.57	-0.94%
Honeywell Inte	109.00	+0.74	+0.68%	GXP	27.17	-0.19	-0.69%	PNM		-0.18	

Home » Nuclear Test » Small Module Nuclear Reactors Could Power the UK by 2030

Small Module Nuclear Reactors Could Power the UK by 2030

Sep 30, 2016

What are Small Modular Reactors?

Categories

	Capacity
Small	< 300 MWe
Medium	300 - 700 MWe

Modularity

- Assembled from factory-fabricated modules
- Each module represents a portion of finished plant
- Current large nuclear plants require substantial amount of field work

SMRs Estimated Timeline of Deployment

IAEA 60 Years

Immediate Deployable

CAREM — Argentina
HTR-PM — China
KLT-40S — Russian Federation

Near-term Deployable

ACP100 — China
SMART — Republic of Korea
NuScale — USA

Mid to Longer-term Deployable

UNITHERM — Russian Federation
HTMR100 — South Africa
SMR160 — United States of America

Under Construction

- **CAREM-25**
  CNEA, Argentina
- **KLT-40S**
  OKBM Afrikantov, Russian Federation
- **HTR-PM**
  INET, China

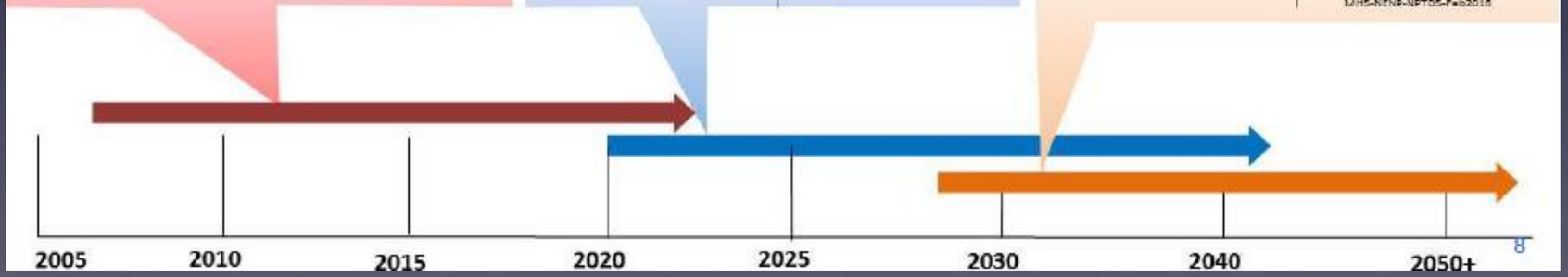
Certified or at Advanced Design Stage

- **SMART**
  KAERI, Republic of Korea
- **RITM-200**
  OKBM, Russia
- **PRISM**
  GE-Hitachi, USA
- **PBMR-400**
  PBMR, South Africa
- **BREST300-OD**
  NIKIET, Russia
- **4S**
  Toshiba, Japan
- **ACP100**
  CNNC, China
- **NuScale**
  NuScale Power, USA
- **mPower**
  B&W, USA
- **GTHTR300**
  JAEA, Japan
- **SVBR-100**
  AKME Engineering, Russia
- **ABV-6M**
  OKBM, Russia

Conceptual Design for Future Deployment

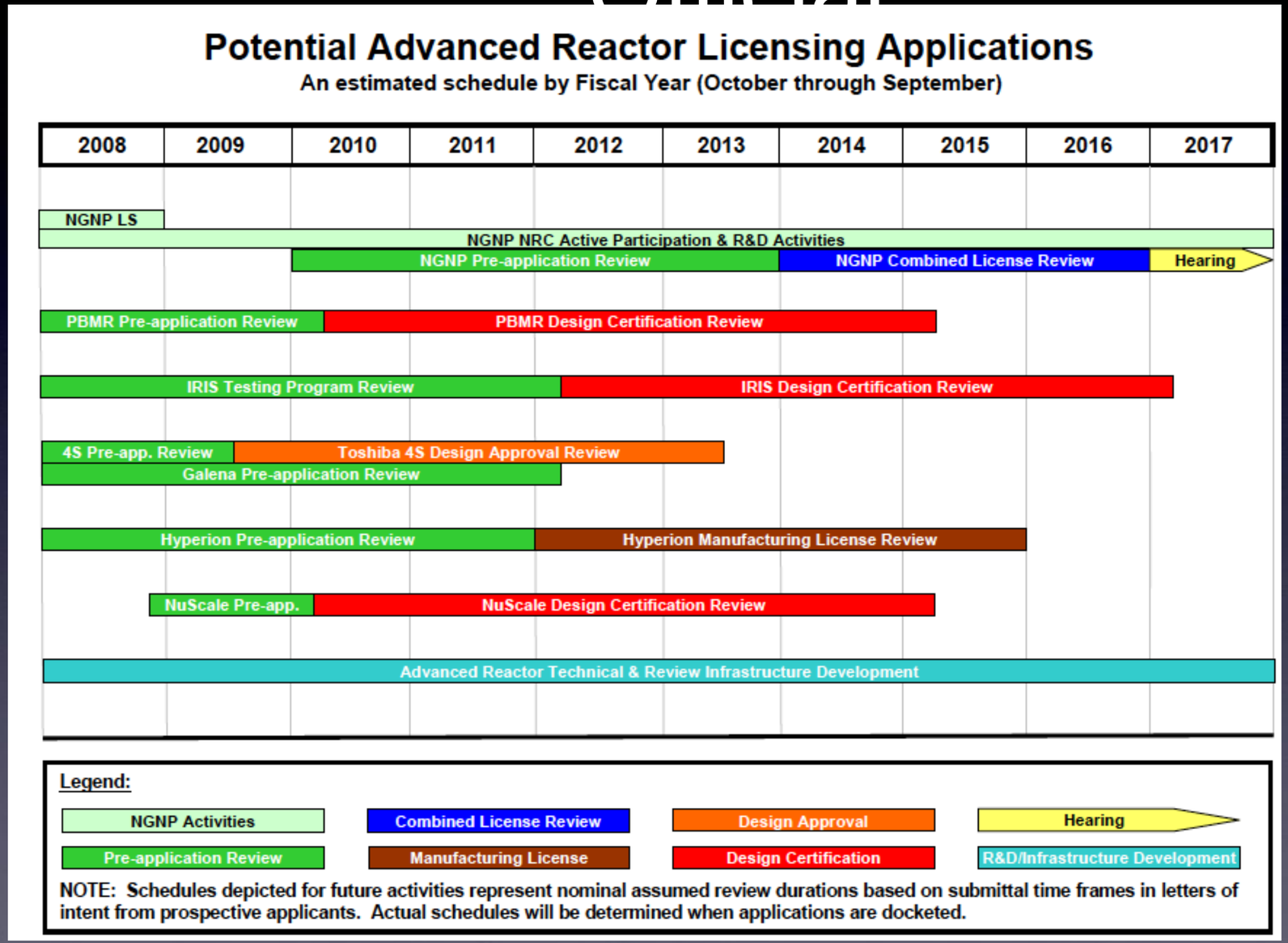
- **AHWR300**
  BARC, India
- **Flexblue**
  DCNS, France
- **IRIS**
  IRIS International Consortium
- **DMS**
  Hitachi-GE, Japan
- **IMR**
  MHI, Japan
- **VVER-300**
  OKB Gidropress, Russia
- **Westinghouse SMR**
  Westinghouse, USA
- **SMR160**
  Holtec, USA
- **VK-300**
  NIKIET, Russia
- **Th-100**
  STL, South Africa
- **SC-HTGR**
  AREVA, France
- **G4M**
  Gen4 Energy, USA

MHS-NENP-NPTDS-Feb2016



Subki, M. Hadid. “Small Modular Reactors: Update on International Technology Development Activities.” presented at the The 13th INPRO Dialogue Forum on Legal and Institutional Issues in the Global Deployment of SMRs, Vienna, Austria, October 18, 2016. https://www.iaea.org/INPRO/13th_Dialogue_Forum/007_Advances_in_Small_Modular_Reactor_Technology_developments.pdf.

Prognosis in 2008 by NRC Official



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

The Importance of Licensing

Ensuring safety in design and operations

Facilitating Exports

“Choosing a nuclear reactor design that is finalized and frozen, particularly one that has undergone licensing review in other countries, can minimize project uncertainties. While some modifications may be needed due to local regulatory requirements or due to the special characteristics of a site, a complete design helps to ensure that the project will be within budget and schedule”

Technology Options for a Country’s First Nuclear Power Plant International Atomic Energy Agency; 2012

The main conclusions in regard to safety and licensing of SMRs are as follows:

- Many newcomers have expressed interest in SMRs, but are still in favour of 'proven' technology; so they want SMR technology to be first deployed in the country of origin to minimize licensing and performance risks.
- Nine countries are developing several new SMR designs with a large diversity of designs, applications, and range of unit power, and in different stages of development. In the light of the Fukushima accident the technology users paid particular attention to the implications of multi-module plants in relation to extreme natural events.
- Since many innovative SMRs contain a certain degree of 'first-of-kind' engineering systems and components, licensing and regulatory issues must be addressed.

IAEA Workshop on Technology Assessment of Small and Medium-sized Reactors (SMRs) for Near Term Deployment, December 2011

Domestic deployment in technology-developers' countries is very important to encourage newcomer countries to adopt SMR (i.e. operability/safety record, provenness)

M. Hadid Subki, "Global Development Trends, Prospects and Issues for SMRs Deployment", 23rd TWG - GCR Meeting, IAEA Headquarters, Vienna, 5 - 7 March 2013

Licensing rules currently applied for certifying reactors have almost all been developed for relatively large reactors

SMR designs are novel with features not deployed in currently prevalent reactors

Integral designs with steam generators within reactor core, steam generator(s), and pressurizer into a single common pressure vessel

Use of passive recirculation modes with low coolant flows under operational and accident situations

Source: http://ansnuclearcafe.org/wp-content/uploads/2013/03/hauling-NuScale-502x200.png

What is the market outlook for SMRs?

Economical challenge for SMRs: Lower up-front cost, higher per kW/kWh cost

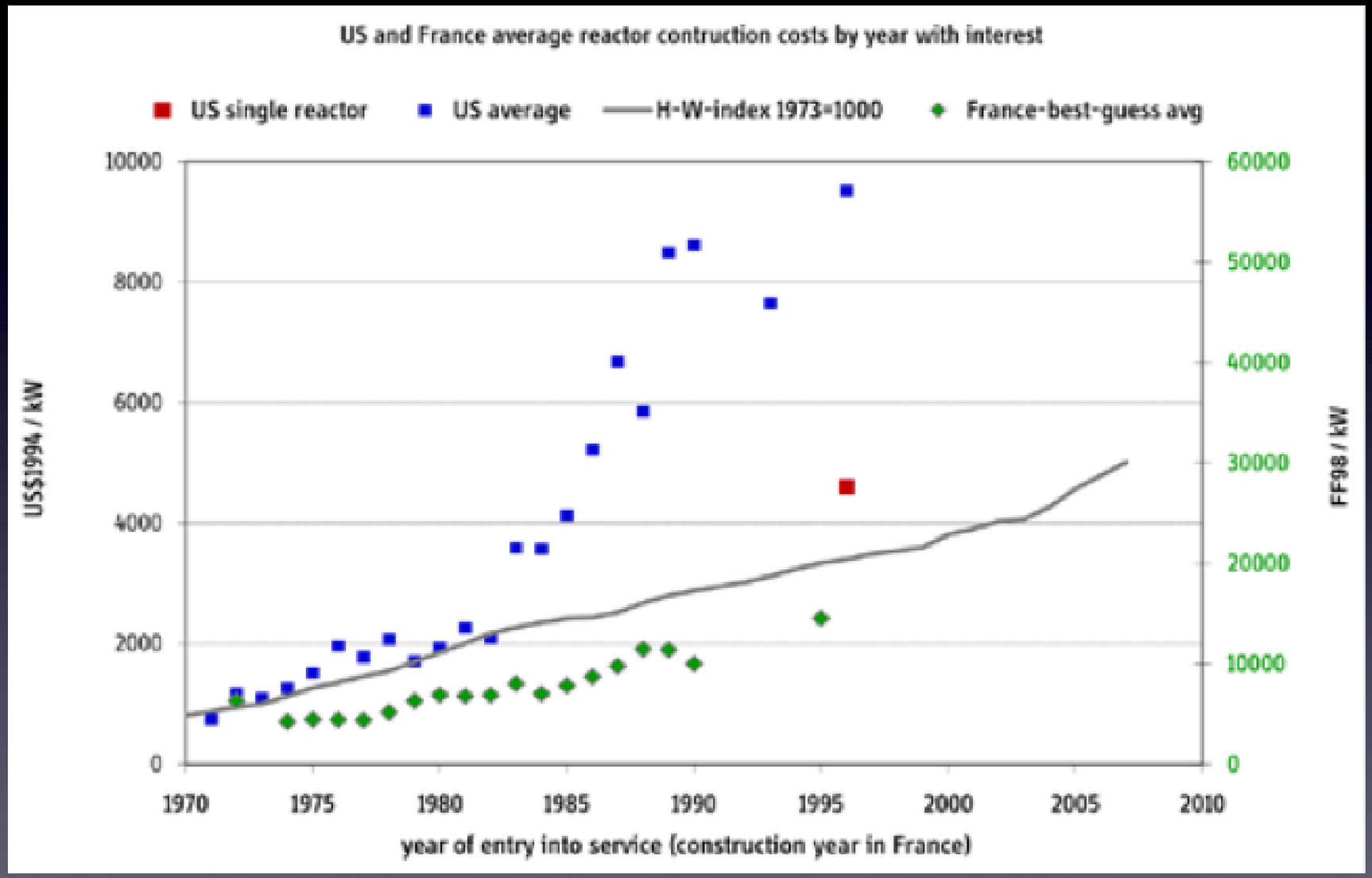
$$\frac{K_1}{K_2} = \left(\frac{S_1}{S_2}\right)^{0.6}$$

$$c(t) = c_0 \left(\frac{K(t)}{K_0}\right)^{\lambda}$$

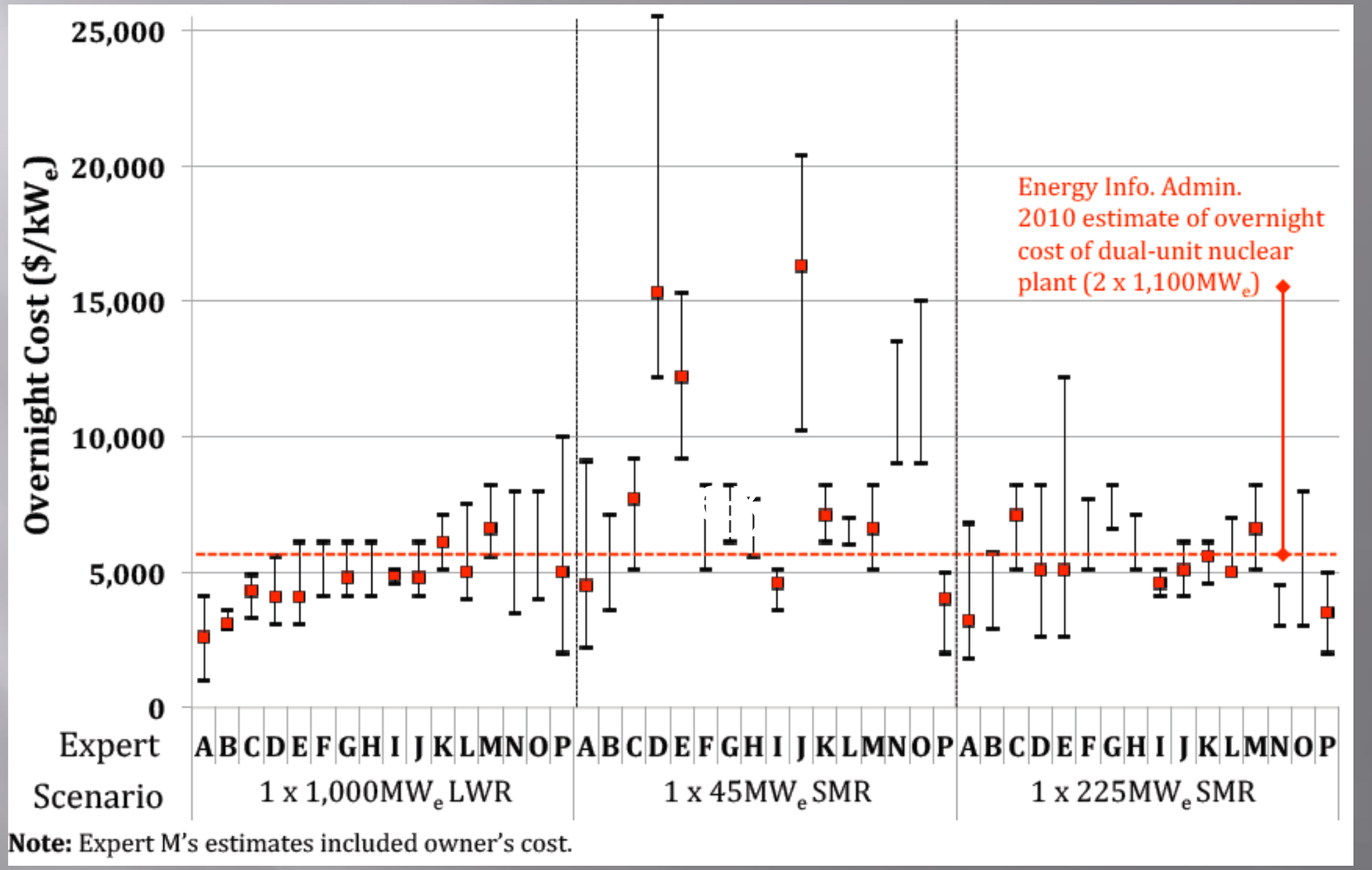
Diseconomies of scale vs accelerated learning

Learning Rate	Diseconomies of Scale Exponent 0.6	0.8
10%	700	80
5%	60,000	780

Not much evidence of “Learning”



Experts Expect Higher Costs

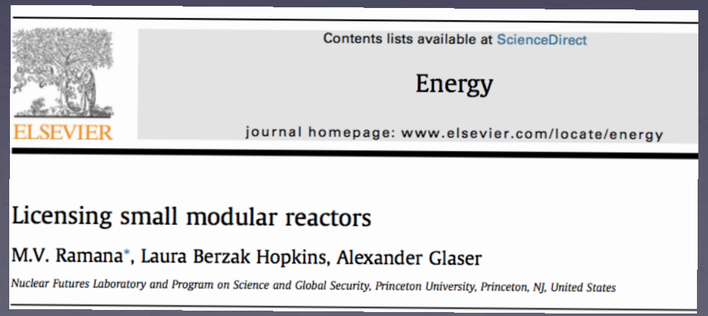


Note: Expert M's estimates included owner's cost.

Source:Abdulla, Ahmed, Inês Lima Azevedo, and M. Granger Morgan. 2013. "Expert Assessments of the Cost of Light Water Small Modular Reactors." Proceedings of the National Academy of Sciences 110 (24): 9686–91.

Licensing might pose safety requirements that could drive up operating costs

Several unresolved issues: Use of Probabilistic Risk Assessment in the Licensing Process for SMRs; Appropriate Source Term, Dose Calculations, and Siting for SMRs; Offsite Emergency Planning (EP) Requirements for SMRs;…



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Licensing small modular reactors

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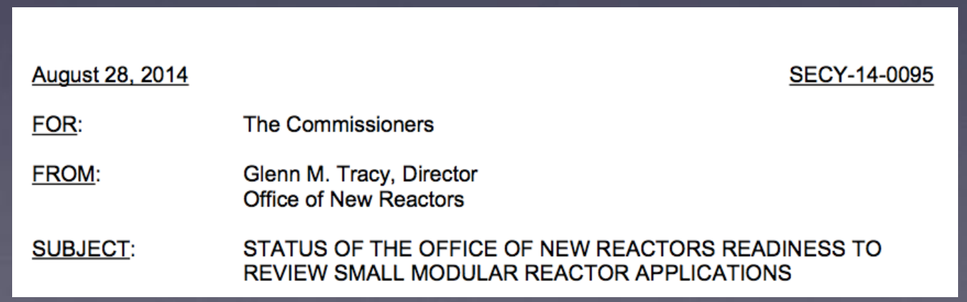


August 28, 2014 SECY-14-0095

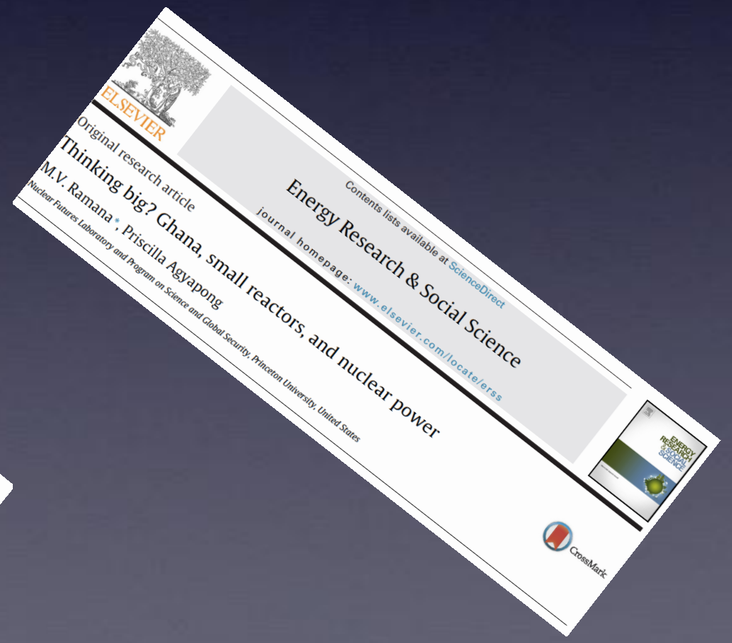
FOR: The Commissioners

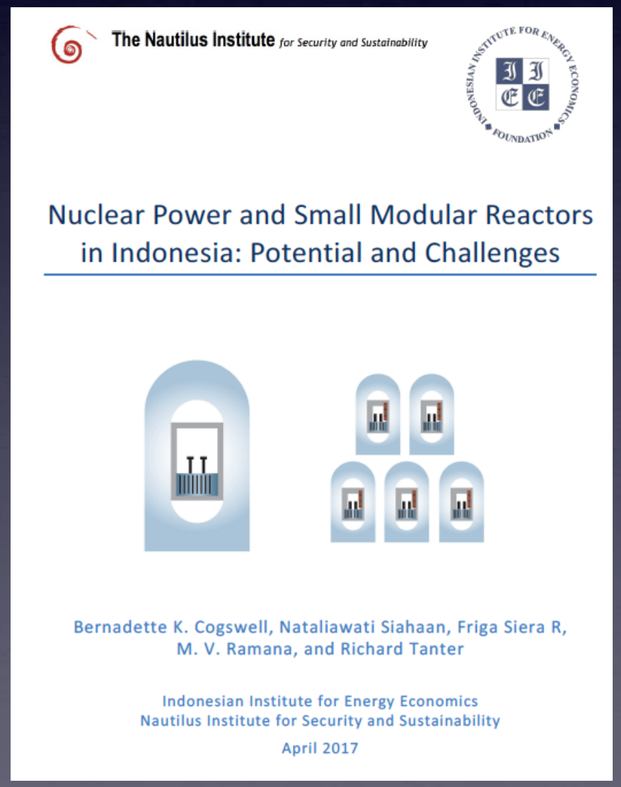
FROM: Glenn M. Tracy, Director
Office of New Reactors

SUBJECT: STATUS OF THE OFFICE OF NEW REACTORS READINESS TO REVIEW SMALL MODULAR REACTOR APPLICATIONS

Need a “full order book” before setting up manufacturing plant

Demand for these reactors is uncertain—potential customer countries not buying





Two US SMR Vendors

Christofer Mowry, Presiden
U.S. Department of Ene
of the B&W mPower

B&W Selected As Winner of DOE's Small Modular Reactor Program

November 20, 2012 03:48 PM Eastern Standard Time

CHARLOTTE, N.C.--(BUSINESS WIRE)--The Babcock & Wilcox Company (B&W) (NYSE:BWC) announced today that it has been selected as the winner of the U.S. Department of Energy's (DOE) competitively bid Small Modular Reactor (SMR) Licensing Technical Support Program. B&W will receive funding that will support accelerated development of its B&W mPower™ SMR technology.

U.S. DOE Awards Funding for NuScale Power's SMR Technology

Includes up to Five Years and $226 Million in Funding

2013

2014: B&W slashed funding on SMR R&D (over $80 mn/y to below $15 mn/y)

No investors or customers willing to contract

“At this time, the latest extension to the Cooperative Agreement [Small Modular Reactor Licensing Technical Support Program] has expired and the DOE funding has been suspended”

THE BABCOCK & WILCOX COMPANY
(Exact name of registrant as specified in its charter)

UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM 10-Q

Westinghouse also pursued SMRs for over 1.5 decades (IRIS, Westinghouse SMR)

2014: “reprioritised staff devoted to SMR development” and focus its efforts on the AP1000 reactor and “gaining new decommissioning contracts”

“The problem I have with SMRs is not the technology, it’s not the deployment -- it’s that there’s no customers” - Danny Roderick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BANKRUPTCY

Westinghouse Paid Former CEO Roderick $19 Million

Company filed for bankruptcy March 29

By Peg Brickley

Updated May 30, 2017 12:10 p.m. ET

Renowned Bankru

The Problem with Multiple Objectives

All desirable properties will likely not be realizable in a single design

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

Contents lists available at ScienceDirect

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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

Conclusion

SMRs still unproven technology

New and untested designs: not deployed in home countries

Not enough market potential to justify building factories to make SMRs