

What Are We Doing Here?

Rachel Slaybaugh

ARPA-E Workshop

May 15, 2019

Outline

- ▶ Motivation of this topic area:
 - Forward-looking design of advanced reactor operations and maintenance (O&M)
 - O&M cost reduction by $> 5x$
- ▶ How ARPA-E workshops work
- ▶ Why the agenda is the way it is
- ▶ Questions

But First: Thanks to a Great Team!



Joel Fetter, T2M



Curt Nehr Korn,
Tech SETA



Geoffrey Short,
Tech SETA



Lakshana Huddar,
Fellow



Victoria Chernow,
Fellow



Zara L'Heureux,
Fellow

But First: Thanks to a Great Team!



Colleen Nehl,
Tech SETA



Caitlin Zoetis,
Proj. Manag. SETA

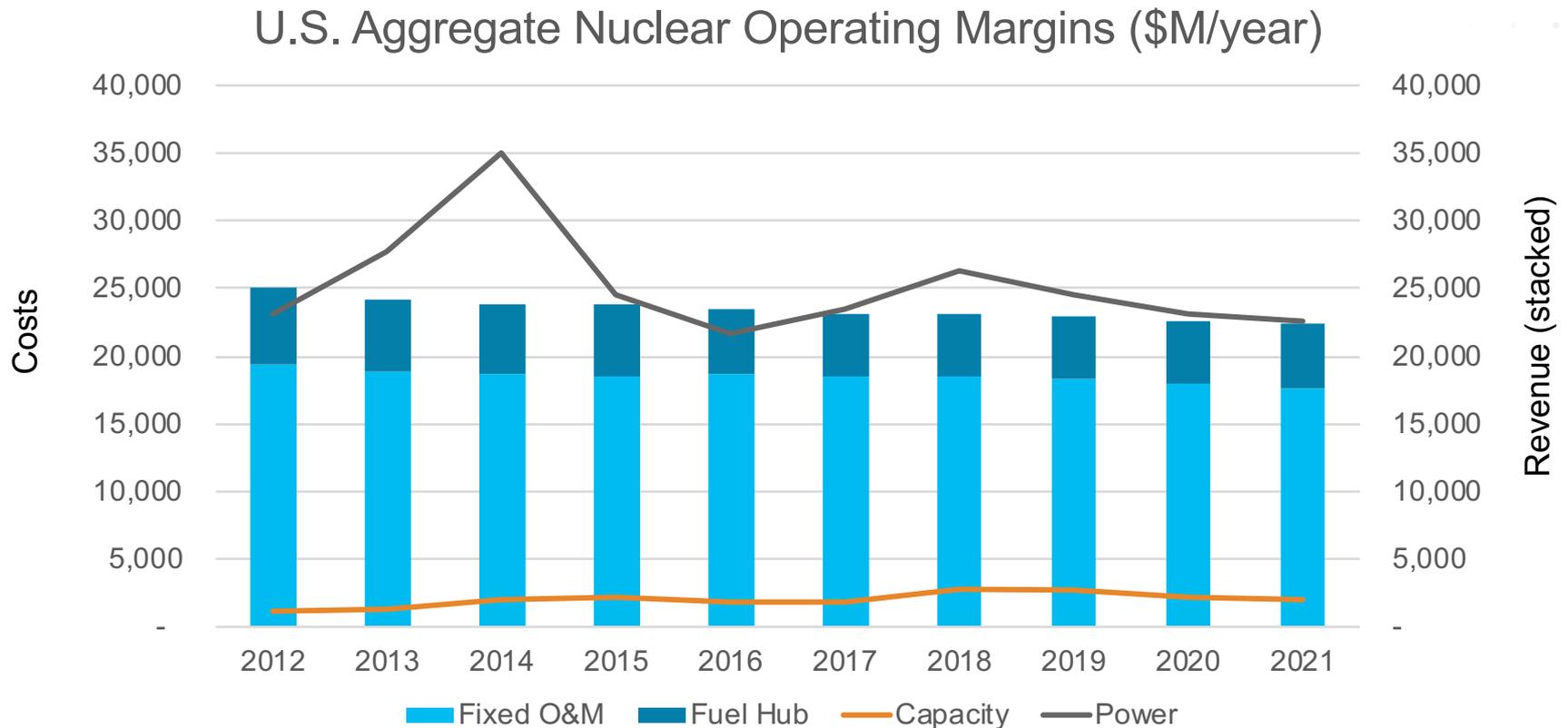


Danielle Weingarten,
Meeting Organizer

Nancy Hicks,
Meeting Organizer

U.S. Reactors are Shutting Down

- 5 reactors closed in the last 5 years
- 14 more scheduled to close by 2025



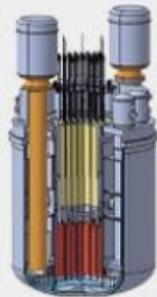
But We Need Reactors!

GAS COOLED TECHNOLOGY



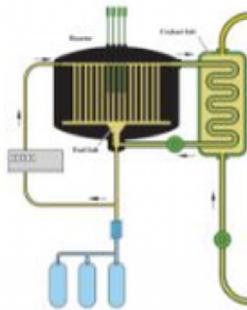
GCR

MOLTEN METAL COOLED TECHNOLOGY



SFR

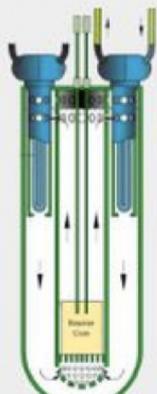
MOLTEN SALT COOLED TECHNOLOGY



MSR



GFR



LFR



SMR

- ▶ Review of 40 studies: having firm zero carbon power available reduces costs and risks in achieving a zero carbon grid, especially as reductions move $> 50\%$
- ▶ Nuclear is a strong (the strongest?) candidate
- ▶ Advanced Nuclear can solve challenges and potentially provide process heat
- ▶ There are additional geopolitical motivations

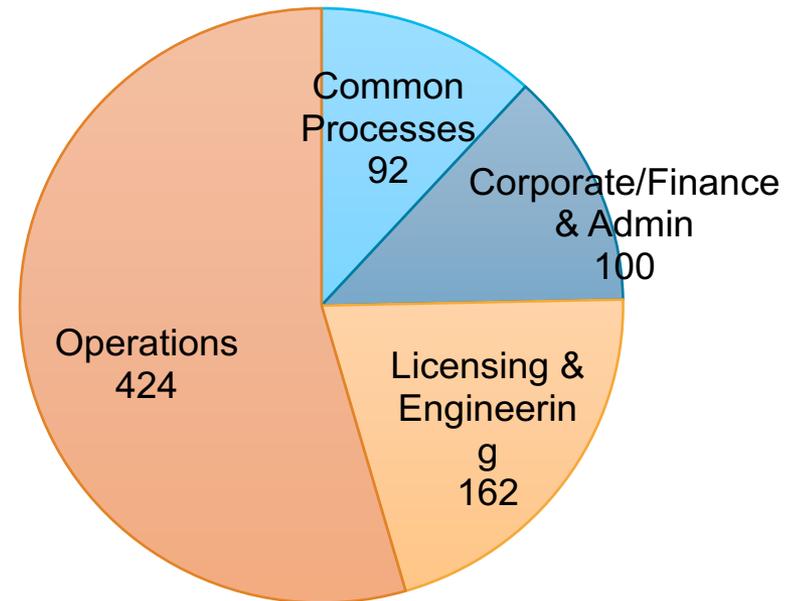
<https://www.iaea.org/newscenter/news/iaea-launches-new-version-of-advanced-reactors-database>

Why Are They Shutting Down? O&M is Too High

Category	Fuel	Capital	Operating	Total
All U.S.	6.44	6.64	20.43	33.50
Single-Unit	6.42	8.92	27.32	42.67
Multi-Unit	6.44	5.99	18.46	30.89

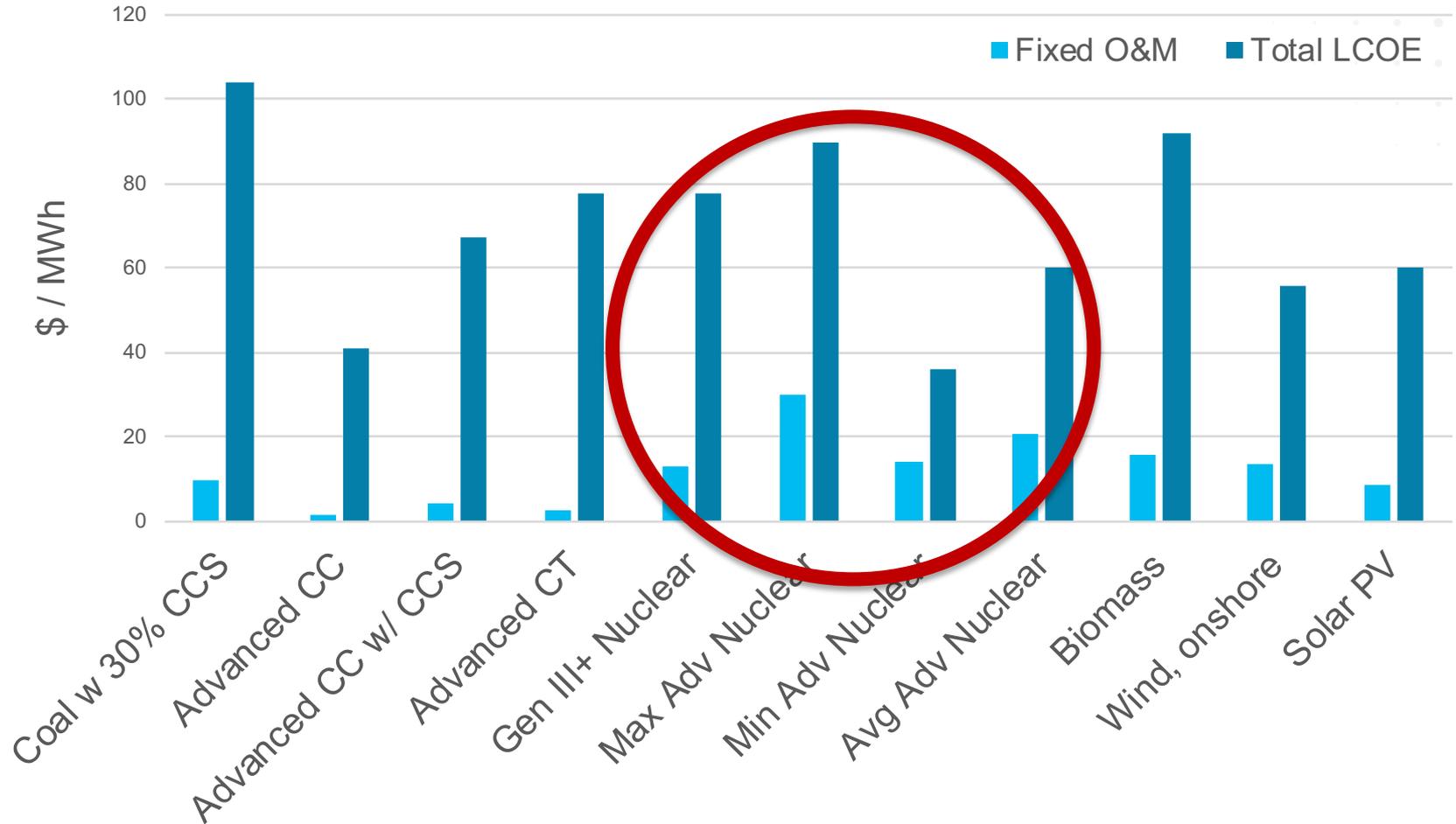
- ▶ Table in 2017 \$/MWh
- ▶ Minimal staffing across best performing plants: ~750 FTEs
- ▶ Operations and Maintenance are the largest addressable categories

FTEs at a 1 GWe Reactor



What about Gen III+ and Advanced?

LCOE and Fixed O&M



Key Points + Caveat

- ▶ For Gen III+, fixed O&M is $< 1/5^{\text{th}}$ of LCOE
 $> 2/3^{\text{rd}}$ is capital cost recovery
- ▶ Current studies indicate Advanced Reactors look pretty similar to Gen III+ in cost structure
 Though O&M might be more like $1/3^{\text{rd}}$ of LCOE
- ▶ HOWEVER, little concrete detail for advanced O&M
- ▶ People have focused on capital and schedule reduction
- ▶ Even though ARs will need different technologies, and there's tremendous opportunity in starting from scratch

What Is the Current State of Reactor O&M?

- ▶ Deterministic
 - Standards-based
 - Hesitation to adopt new technologies or change approach
 - Driven almost exclusively by physics-based models
- ▶ Human-work driven (e.g., physically inspect items, take readings, etc.)
- ▶ Data collection is difficult and use is inefficient



Mark Bugnaski / Kalamazoo Gazette

What Might “Optimal Operations” Mean?

- ▶ Lower direct personnel costs
- ▶ Eliminate radiation to workers
- ▶ Reduce cost / amount of maintenance
- ▶ Reduce risk of human error
- ▶ Increase operational excellence
- ▶ Increase margin / safety envelope

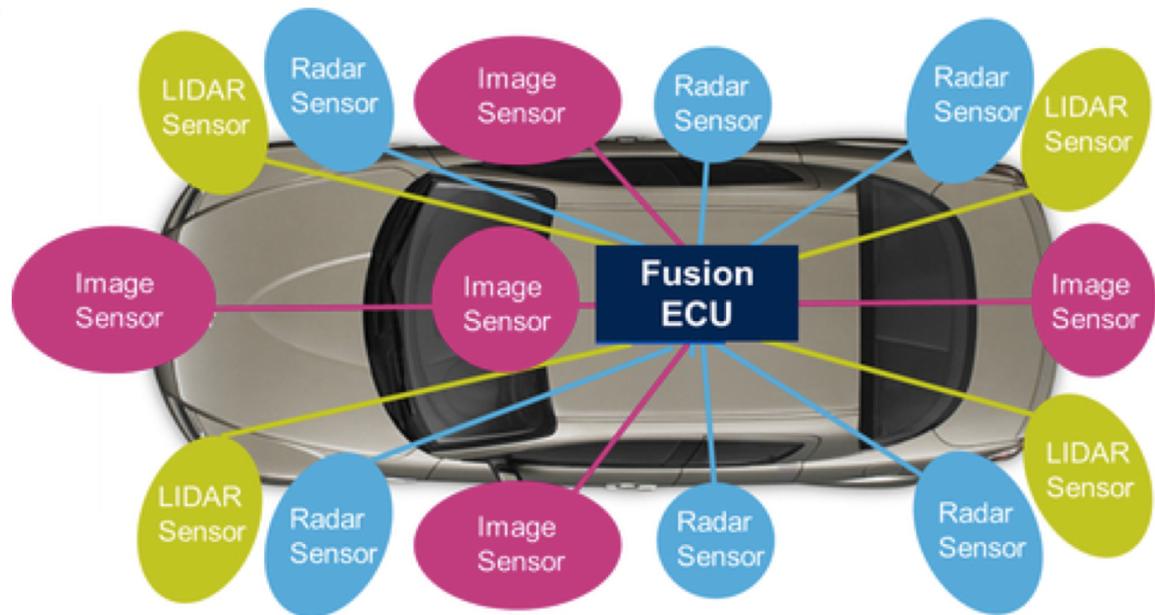


However,

- ▶ Increase cost of sensors / equipment / software?
- ▶ Shift problems and cost from one place to another?
- ▶ Increase need for certain highly specialized staff?
- ▶ How do we get the relevant innovators to think about nuclear?

Why Is Now the Time To Sort This Out?

- ▶ The AR fleet is only just starting to think about this problem (Any cited improvement in O&M comes from inherent plant safety, not adoption of new O&M tech)
- ▶ But thinking **now** about what *will be needed* is essential
- ▶ We need to know the tech gaps so we can fill them in time
- ▶ We need to know how to build the plants
- ▶ We want to avoid redesign / retrofiting



How Do ARPA-E Workshops Work?

Goals: ARPA-E's workshops have two main goals

1. We gain information and feedback from you on our potential new program idea
2. You start thinking about the possible program so you'll be ready to apply if we should have a program in this area

We'll go over a bunch of content to give you context for the technology we're interested in

We'll have discussion sessions where we can hash out the what's what and brainstorm what matters

You Said Content? What Are All These Talks?

- ▶ You'll notice we have a bunch of talks designed to cover the space we think might be relevant for a future program in this area:
 - Current and Advanced reactor operations and monitoring
 - Autonomy and Automation
 - Asset Performance Management (e.g., selective controlling of data, extrapolative forecasting, and predictive maintenance)
- ▶ The first two breakouts will be to
 - Get a handle on the state of the art
 - Talk about where the gaps and biggest needs are
- ▶ Then we'll spend tomorrow talking about what a program might look like

What is Possible Now That Wasn't Before?

- ▶ From 1985: “Future nuclear power plants are projected to be highly modularized, with the possibility of several plants being operated from one control room. AI-based diagnostics and control systems can make this possible by taking over the mundane day to day oversight tasks that the operators must perform to keep the plant running.”



Additional Context

- ▶ Tomorrow we'll hear from the Office of Nuclear Energy about any related initiatives – they are a critical partner in taking anything we do further
- ▶ Feel free to send me any ideas after the workshop.

RULE: No one is allowed to say
“we can't do that because of regulations”

1. The regulations for advanced reactors aren't written yet
2. We need to start by dreaming as big as we can,
then refining the idea
3. I brought the NRC here to keep you in check on this point

We're Starting From This Frame

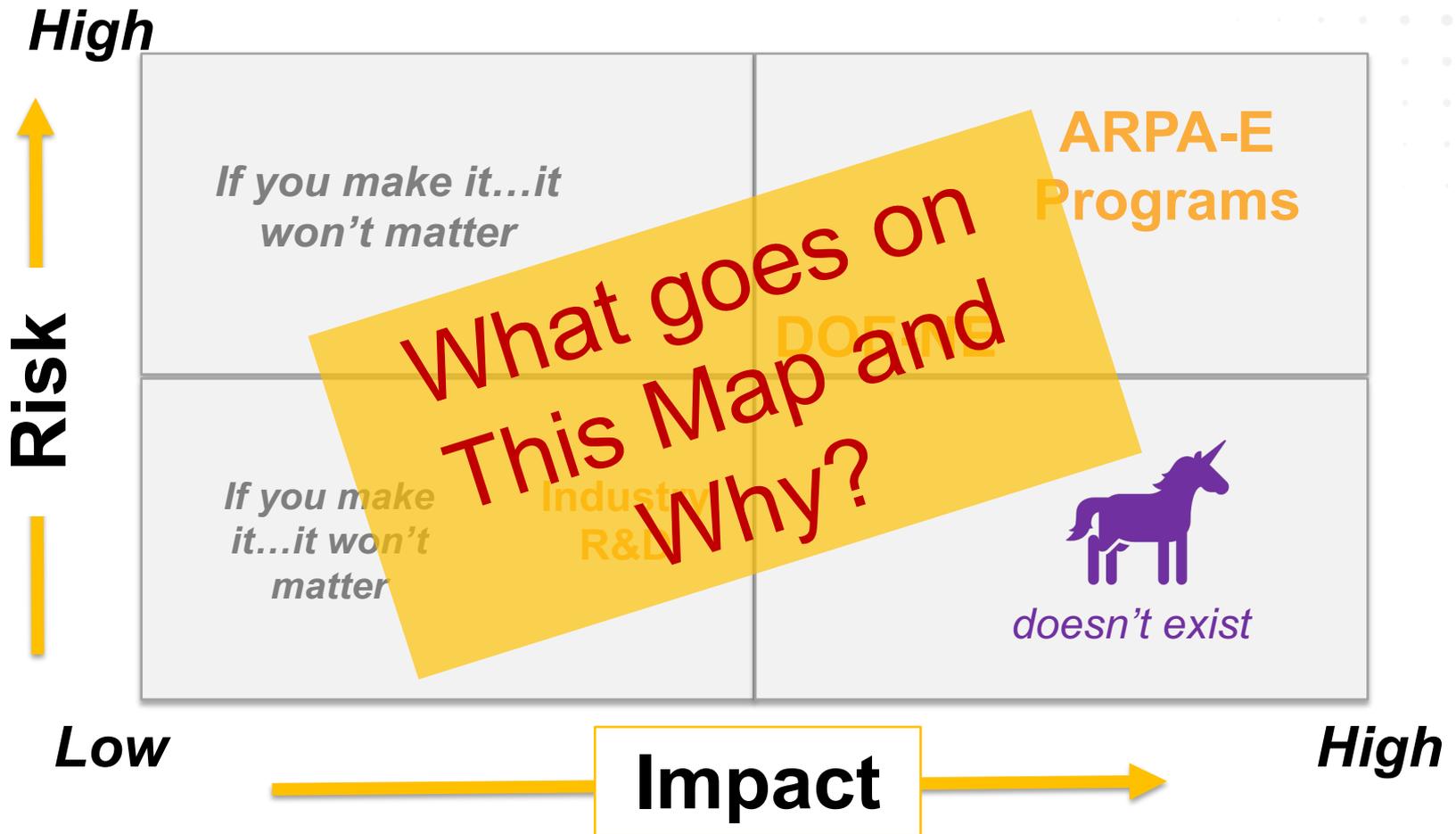
Overall goals:

1. Have a clear understanding of the technical requirements for O&M for several Advanced Reactors
2. Reduce fixed O&M cost from ~13 \$/MWh in the current fleet to ~3 \$/MWh in the advanced fleet

Most likely path:

1. Translate existing technologies to advanced reactor designs and develop technologies to fill in the gaps
2. Reduce total staffing level from ~750 FTE/GWe to ~50 FTE/GWe

What We Really Want Out of This



We would accomplish many more things if we did not think of them as impossible.

- Vince Lombardi

