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Title: Affordable and Secure Nuclear Energy Development: DOE Investments and Laboratory R&D Challenges - A Review

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# Affordable and Secure Nuclear Energy Development:

## DOE Investments and Laboratory R&D Challenges – A Review

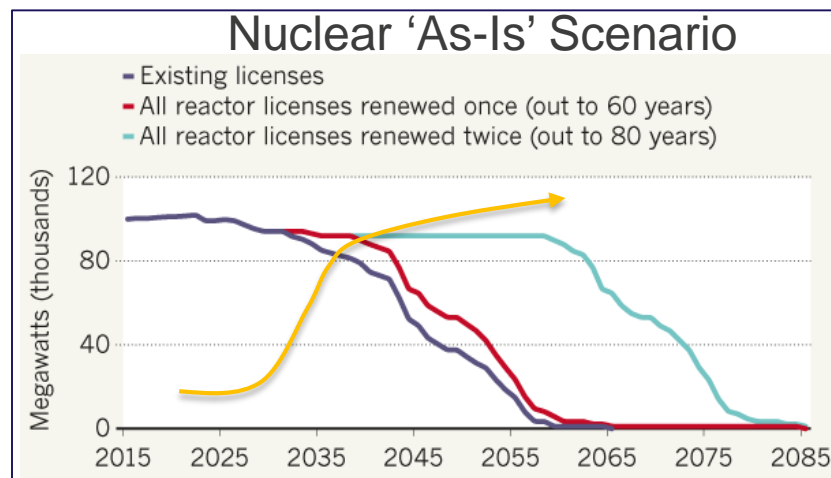
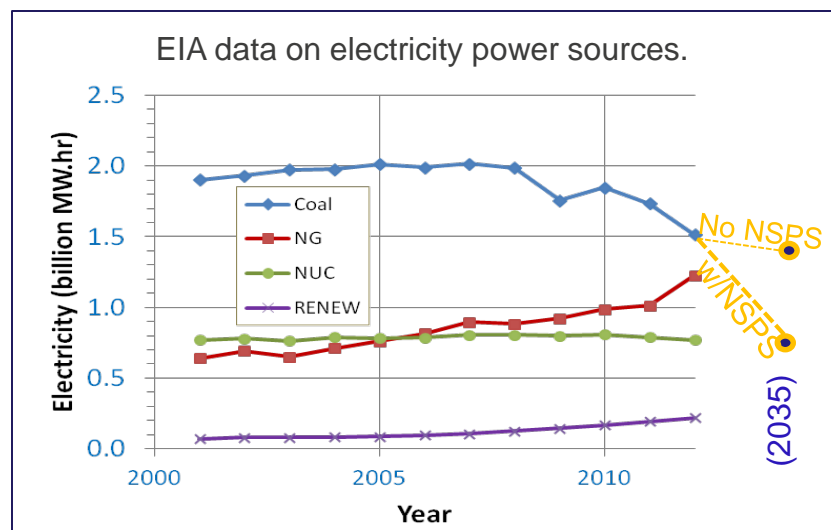
Dasari V. Rao, Program Director  
Civilian Nuclear Power Office

12/1/2016

# BACKGROUND

## OPTIONS FOR BASELOAD

- **Coal electricity has steadily declined since 2008**
  - Emissions regulations and fracking
  - EIA projected coal to stabilize @ 1.5 billion MW.hr
- **EPA New Source Performance Standard (NSPS) impacted this**
  - It limits CO<sub>2</sub> to 1000 lbs per MW.hr
  - Existing coal plants don't meet this standard without major refits
- **Three 'Scalable' Options exist**
  1. Super Critical IGCC Coal plant with Carbon Capture and Sequestration for higher efficiency (overnight capital \$5000 per kWe)
  2. Replace plants with Natural Gas Combined Cycle that can achieve EPA target (@ \$1107 per kWe); couples with Solar PV; halves water use
  3. Increase generation capacity with Nuclear units.
- **Nuclear must be made affordable**
  - National Academies
  - Sec of Energy Advisory Board
  - Aspen Institute
  - IEA/OECD Economics Forum



# TWIN GOALS OF ADVANCED NUCLEAR ENERGY

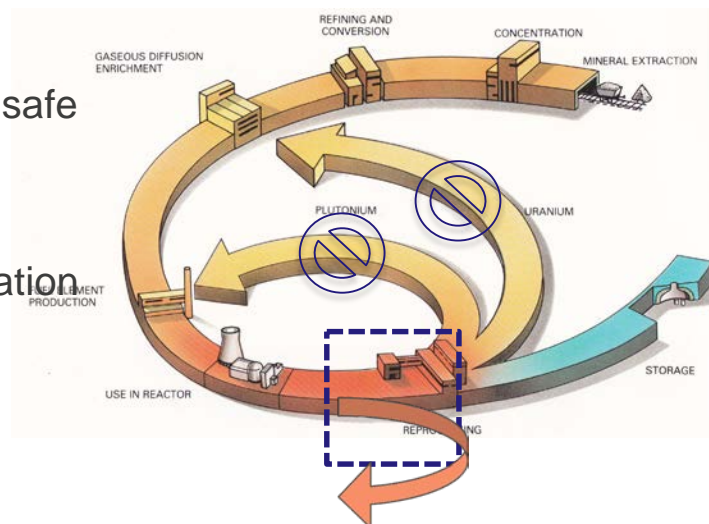
## URGENT ALIGNMENT OF THESE OFTEN COMPETING GOALS IS REQUIRED

### What is needed for sustainable nuclear energy?

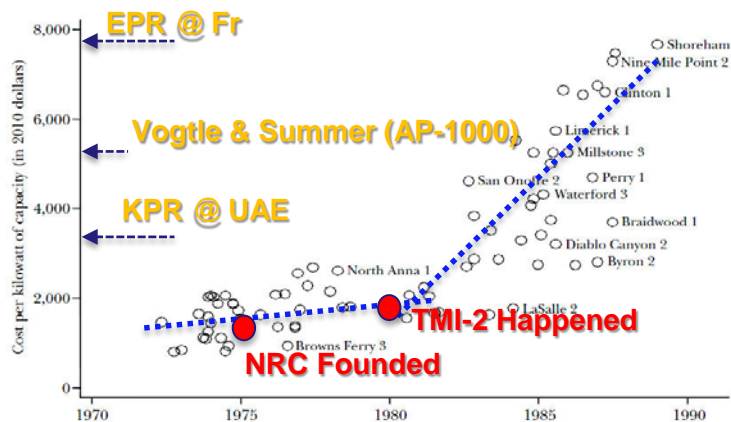
- New reactor and fuel designs that are more **economical** (less capital intensive) and inherently safe
  - Affordable approaches to development
- New countries and regions to counter GHG
- New separation technologies to increase fuel utilization

### What is Needed for secure nuclear energy?

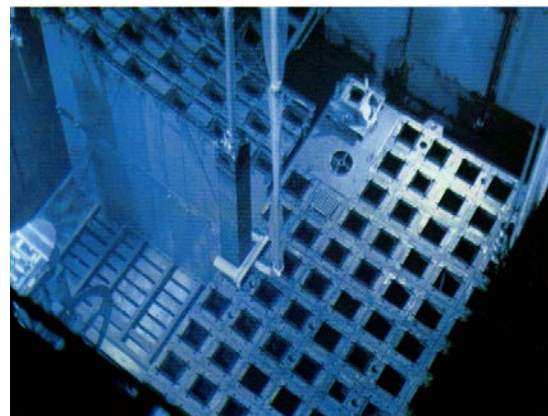
- Advanced architecture for real-time 'full' duty-cycle wide awareness of the fuel
- Multi-Scale Science Based Safeguards



### Economies of Scale: Bigger is Better! (70's economics)



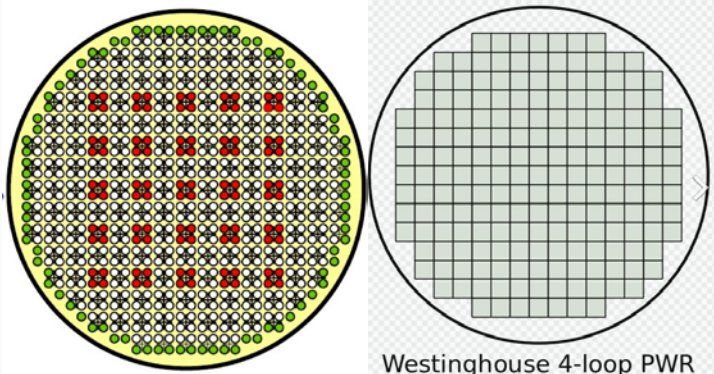
### No YMP: Large Used Fuel Inventory



# GLOBAL NUCLEAR LANDSCAPE IS UNDERGOING A MAJOR CHANGE

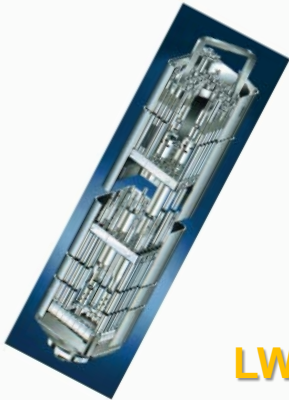
DRIVEN BY ECONOMICS AND PUBLIC-PRIVATE SPONSORSHIP TECHNOLOGY IS EVOLVING

## Workhorses of Present & Near Future Deployment in US/OECD Countries

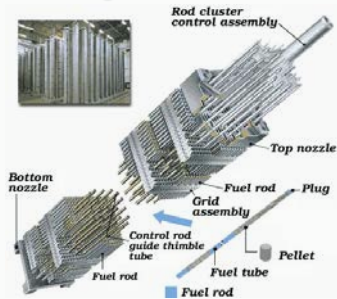


Westinghouse 4-loop PWR

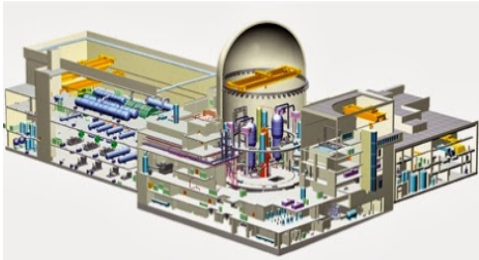
## GE-BWR Design



## Westinghouse Bundle



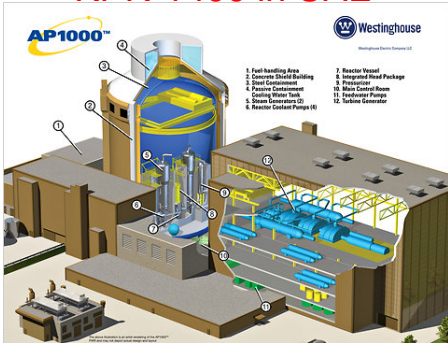
## LWR Sustainability (DOE)



KPR-1400 in UAE



EPR-1200 Fr, UK(?)



AP-1000: US (4),  
China (8), and India (6)  
**Loan Guarantee**  
**Prod Tax Credit**  
**Six to 8 years**  
**Cost: \$5300 per KWe**

## Accident Tolerant Fuels (DOE)



U<sub>3</sub>Si<sub>2</sub>.UN



U-Th-Zr Metal



# WHAT'S NEEDED FOR *NUCLEAR RENAISSANCE*?

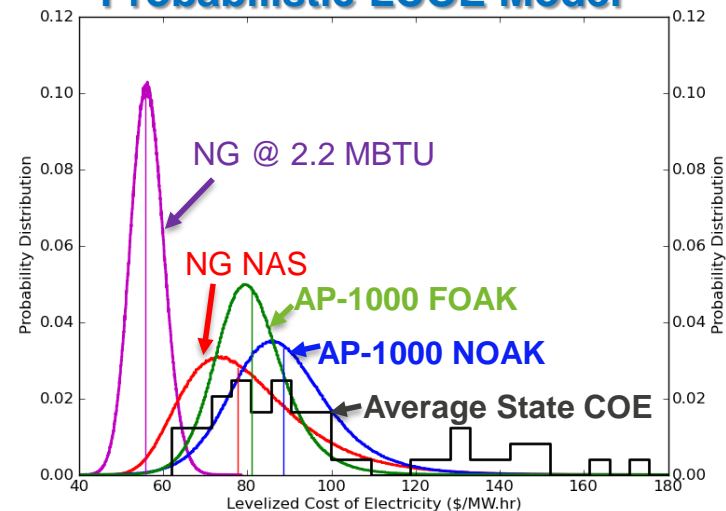
## COST CONTROLS AND REGULATORY SIMPLIFICATION

- **AP-1000 (Vogtle & Sumner)**
  - Construction costs (EPC): \$ 3700-4000 per kWe
  - Regulatory (Q&A Costs): \$ 750 per kWe
  - Financing on Capital: \$1600 per kWe
  - Total: \$ 6050 per kWe
- **Key**
  - Reduce length of construction
  - Reduce number of systems for Regulation and QA
  - Reduce EPC with simpler systems

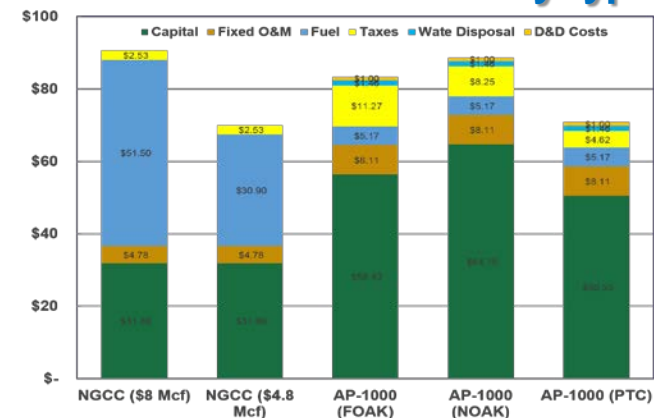


**SMRs and Gen-IV**

### Probabilistic LCOE Model

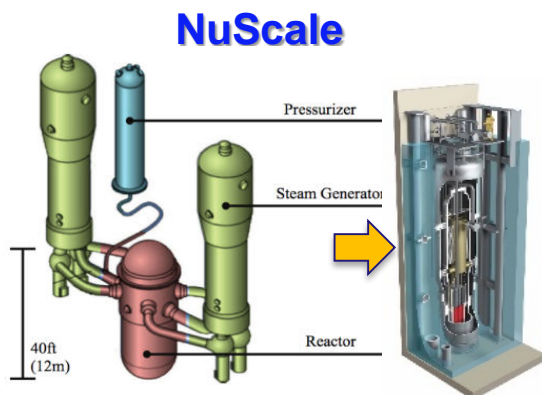


### Contribution to Costs by type



# SMALL MODULAR REACTORS

## SIMPLE, SCALABLE AND INHERENTLY SAFE

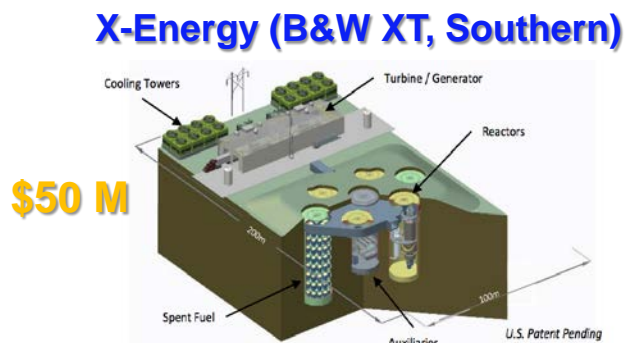


### NuScale SMR Strengths

- \$450 M Licensing Investment
- Existing NRC Regulatory Framework
- Existing Fuel Fab/Handling/ Disposal infrastructure
- SEAB recommends continued Loan Guarantee and PTC

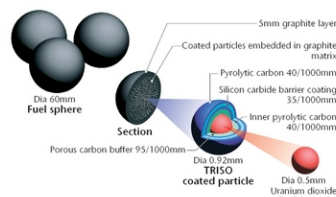
### TBD:

- NRC Licensing Burden Reduction
- Supply chain – QA and cost control

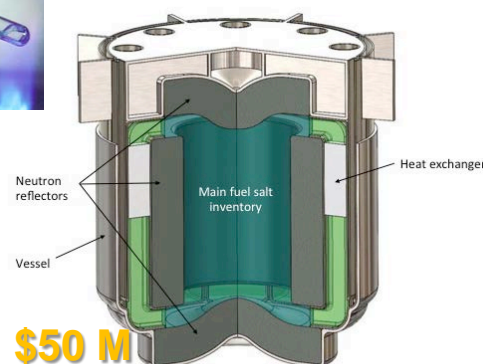
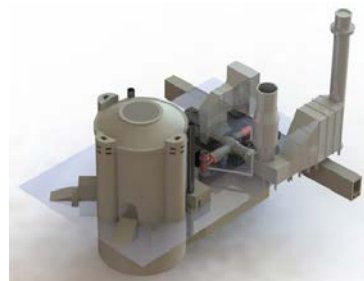


**GE: SPRISM**

### TRISO



### FLiBe (LiF.BeF<sub>2</sub>.U)



**\$50 M**

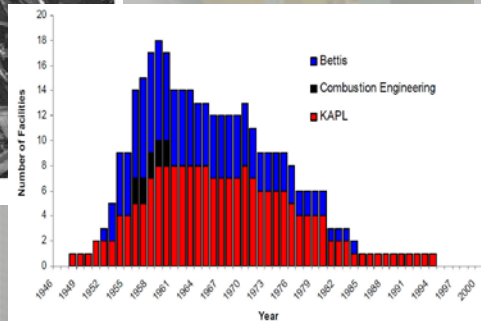
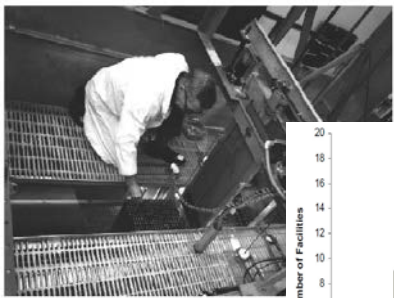
**Chloride Molten Salt Fast**

**Fluoride High Temperature**

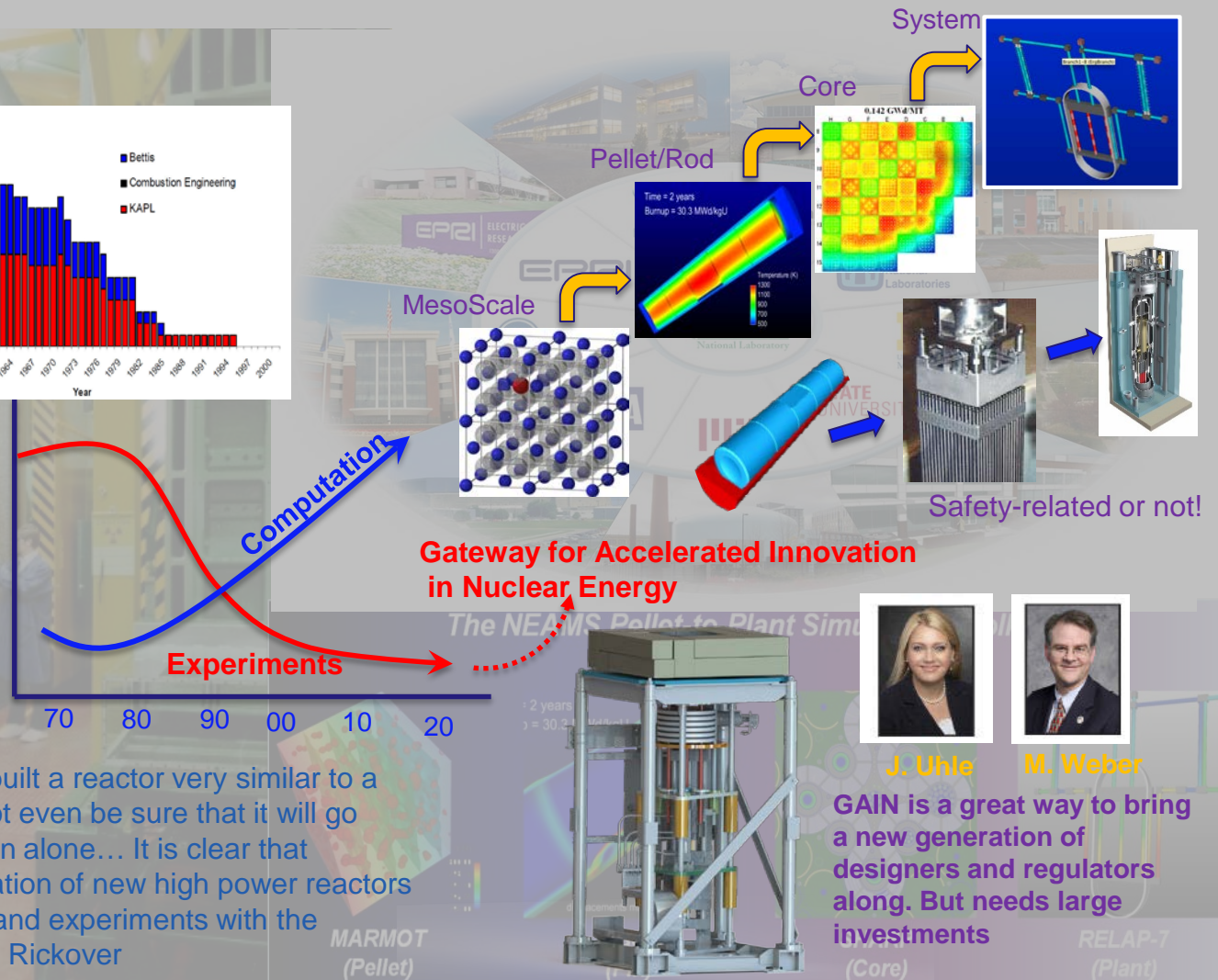


# Backup slide

- **Major investments required to make Advanced Reactors a Reality**



“...Unless one has already built a reactor very similar to a proposed design, one cannot even be sure that it will go critical – based on calculation alone... It is clear that successful design and operation of new high power reactors must rely heavily on critical and experiments with the proposed design...” -- Adm. Rickover



J. Uhle M. Weber

**GAIN is a great way to bring a new generation of designers and regulators along. But needs large investments**

(Core) (Plant)