SMALL MODULAR REACTOR PROGRAM

# Small Modular Reactors (SMRs)

## *Presentation to the Nuclear Energy Advisory Committee*

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# SMRs & Advanced Reactor Concepts

*Evolutionary and Transformative Technologies*

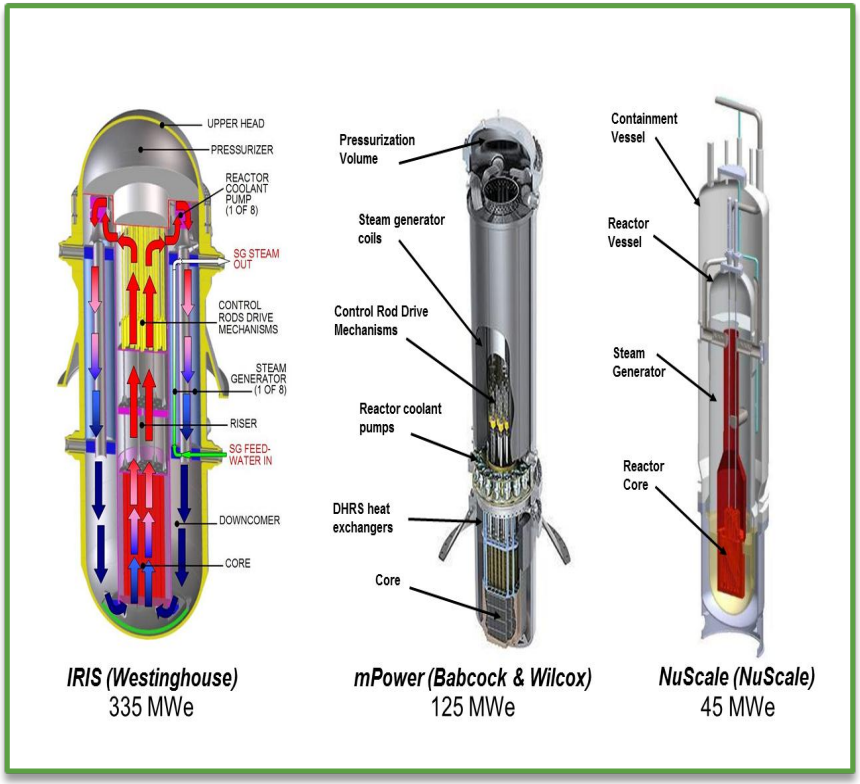
- SMRs and advanced reactor concepts can be grouped into two sets based on (a) design type, (b) estimated licensing and deployment schedule, and (c) maturity of design.
  - First-to-market Light Water Reactor (LWR) based designs
    - 5-10 years
  - Advanced, mostly Non-LWR designs
    - 10-25+ years

- Note: DOE currently defines SMRs as those reactor designs that are ≤300MWe, and fabricated in modules that are transportable from the factory to the site by rail or truck.

# Small Modular Reactors

## *Near-Term LWR Designs*

- Well-Understood Technology
  - LWR based designs
  - Standard <5% UO2 fuel
  - Regulatory and operating experience
- Commercial Interest
  - At least 2-3 credible LWR vendors
  - Vendor/Utility coalitions forming
- Manufacturing industry mobilizing
  - Revitalize US nuclear infrastructure & Navy shipbuilding industry
- Potential for operation by 2020, NRC licensed
- DOE and DoD as customers for SMR electricity
  - Private consortium constructs, owns and operates



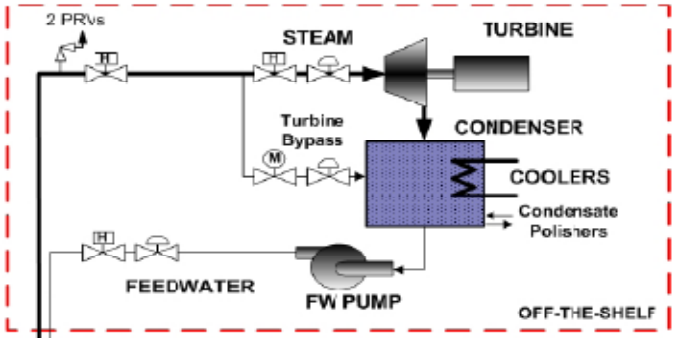
# Advanced Reactor Concepts

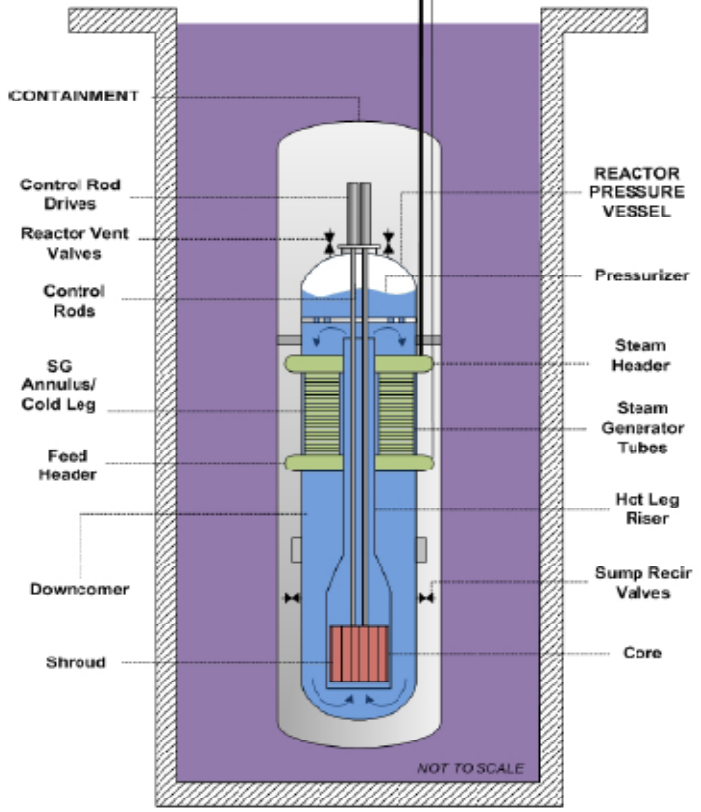
*Longer-Term SMRs*

- New innovative technologies
  - Mostly non-LWR based designs
  - Goal: Extended applications for nuclear energy
  - Characteristics: Safer, simpler, extended fuel life, proliferation resistant, higher temperature
- Broader applications
  - Distributed power production
  - Process heat applications
    - Oil refining and extraction
    - Desalination
    - Chemical and hydrogen production
    - Biofuel & Synfuel production
- Nuclear Fuel Management
  - Respond to Blue Ribbon Commission recommendations
  - Support advanced fuel cycles

# Power Module

45 MWe




- **Simple and Robust Design**
  - Integrated Reactor Vessel enclosed in an air evacuated Containment Vessel
  - Immersed in a large pool of water
  - Passively safe – natural circulation
  - Located below grade
  - Utilizes off-the-shelf turbine-generator set
  - Multiple fission product barriers
  - Air and water cooled options
- **Operating 1/3-scale test system**
- **Design Reference Plant = 12 Modules (540 MWe)**

generation mPower

# B&W mPower High-Level Requirements

- 125 MWe plant gross output per module & 60-year plant life
- NSSS forging diameter allows domestic forgings, unrestricted rail shipment
- Passive safety requirements – emergency (diesel) power is not required
  - Minimize primary coolant penetrations, maximize elevation of penetrations
  - Large reactor coolant inventory
  - Low core power density
- Standard fuel (less than 5% enriched U-235)
- Long fuel cycle, 4+ year core life
- Spent fuel storage on site for life of plant
- No soluble boron in primary system for normal reactivity control
- Conventional / off-the-shelf balance of plant systems and components
- Accommodate air-cooled condensers as well as water-cooled condensers
- Flexible grid interface (50 Hz or 60Hz)
- Digital instrumentation and controls

# Drivers for SMRs

- U.S. Economy and Environment
  - Provides a carbon-free energy source
  - Domestic manufacturing jobs
  - Global competitiveness
- Utility Demands
  - Reduce the capital cost and improve affordability
  - Repower aging fossil plants with non-emitting baseload electricity
- Federal Agency Needs
  - E.O. 13514 – Reduce emissions 28% by 2020; 83% by 2050
  - Mission cannot be curtailed to meet target
- Department of Defense Mission Surety
  - Meet strategic sustainability performance goals
  - Pursue energy security through a diversified energy portfolio
  - Surety, survivability, supply, sufficiency and sustainability
    - "Islanding" option which includes good neighbor policy

# Reducing Financial Risk

*Economies of Small and Modular*

- Manufacturing Economies
  - Assembly line replication optimizes cost, schedule, and quality through greater standardization of components and processes
  - Analysis of shipbuilding validates "*nth*" of a kind optimization
- Production "Skill of the Craft" Economies
  - Economic learning through replication
  - Increased skilled workforce retention with order backlog and diverse jobs
- Construction "Plug and Play" Economies
  - Prefabrication optimizes on-site construction schedules and quality
  - NRC inspection at factory (ITAAC) reduces on-site inspection
  - Parallel construction of reactor building, NSSS and BOP increases labor productivity
  - Increased labor productivity reduces project management costs
  - Reduced schedule and cost uncertainties

# SMR Industry Benefits

*Creating an Industry for Growing Markets*

- Overarching
  - Support domestic economic, energy security and environmental goals
  - Respond to increasing energy demands
- Secondary
  - Establish a U.S. supply chain infrastructure for emerging SMR technology
  - Create high-quality manufacturing, construction, and engineering jobs
    - Prototypical (100 MWe) SMR has the potential to (*):
      - Create 7,375 manufacturing/operating jobs
      - Generate $1.4 billion in sales
      - $695 million value-added
      - $431 million in earnings (payroll)
      - $44 million indirect business taxes
  - Global leader in SMR technology based on mature nuclear infrastructure and NRC certified designs
  - U.S. industry exporting to meet global demand

**The Energy Policy Institute – Economic and Employment Impacts of Small Modular Nuclear Reactors; June 2010*

# DOE SMR Program

*Responding to the Market*

- Program Mission (Beginning in FY2011):
  - Conduct research, development, and demonstration (RD&D) activities supporting the deployment of small modular reactors (SMRs)
  - Support technologies that enable the accelerated licensing and deployment of near-term light water based SMR designs
  - Support continued R&D activities for innovative, longer-term designs
- Key Program Objectives:
  - Build financial assistance partnerships with industry with a goal of certifying, licensing and deploying at least 2 LWR-based SMRs by FY2020
  - Establish a RD&D program that supports the licensing and deployment of both near- and long-term SMR designs
  - Establish domestic fleet manufacturing capability
  - Collaborate with NRC and Standards Developing Organizations (SDO's) to address gaps in codes and standards to support SMR designs
  - Conduct evaluations of advanced SMR designs for commercialization potential
  - Consider SMR first movers for DOE/DoD siting

# SMR Cost-Share Focus Area

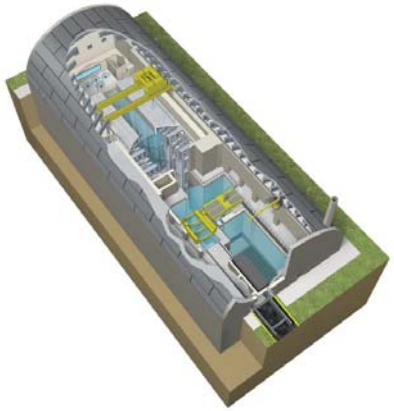
- Industry Partnerships
  - Cost-share first-of-a-kind (FOAK) development and licensing costs to advance at least two LWR SMR designs toward Design Certifications and Operating Licenses
  - Pursue business model(s) that promise a return on investment or other value proposition to the U.S. Government
    - Proposed TVA/B&W/ORNL example discussed in subsequent slides
    - Cost-shared first-mover SMRs are a performing asset that will return value to the Government
    - Cost-shared projects advance U.S. strategic missions and goals
  - Pursue business model(s) that advance U.S. commercial interests

# SMR Technical Focus Areas

- Advanced SMR RD&D – Will focus on development of technologies that address issues unique to SMRs:
  - SMR Instrumentation and Control/Human Machine Interface
    - Develop techniques to improve measurements, diagnostics and controls for SMR-specific environments (e.g., low flow, inaccessible internals, multiple modules, etc.)
  - SMR Assessment Methods
    - Develop PRA capability to verify reduced risk of simpler, safer designs
    - Advanced economic models for near and long-term needs
    - Integrated visualization tools for site screening studies
  - SMR Materials, Fuels and Fabrication Technologies
    - Examine ways to achieve higher fuel burn up with less dependence on control rods and boron injection
    - Support a project to advance integrated manufacturing of SMR module
    - Examine potential for coolant blockage of SMR fuel elements under unique operating conditions

# Technical Focus Areas (continued)

- Advanced SMR Research and Development (cont.)
  - SMR Regulatory Technology Support
    - Conduct evaluation and analysis on issues related to SMR source term quantification, decay heat curves, and human factors impacts
    - Address issues identified in Nuclear Regulatory Commission SECY10-0034
      - Collaborate with the NRC, Nuclear Energy Institute (NEI) and American Nuclear Society (ANS) committees
    - Develop advanced design tools and techniques for security integration
  - SMR Advanced Concept Evaluation
    - Identify and assess the characteristics, capabilities, technologies and economic viability of advanced SMR designs
    - Early focus on co-generation and load-following capability



# FY 2010-11 Budget Summary

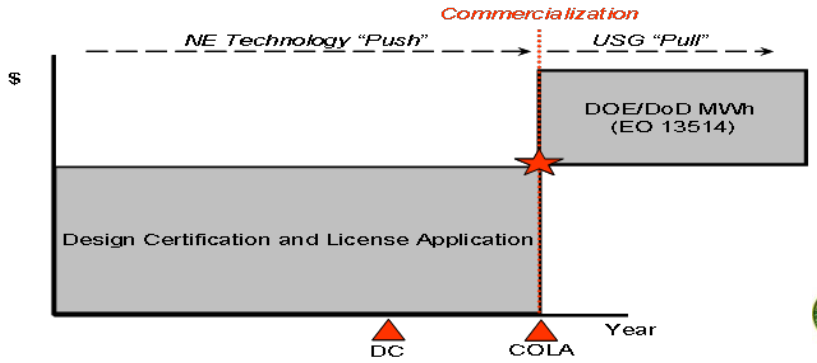
*dollars in thousands*

| Activity/Sub-Activity | FY 2010 Approp. | FY 2011 Request | FY 2011 House | FY 2011 Senate |
|---|---|---|---|---|
| **Management and Integration** | **0** | **600** | | |
| **Light Water Reactor SMR Cost Share** | **0** | **20,000** | | |
| **Advanced SMR Research and Development** | **0** | **18,840** | | |
| **SBIR/STTR** | **0** | **560** | | |
| Total – Small Modular Reactors | 0 | 40,000 | 55,000 | 50,000 |

*

# Dual Government Role for SMRs

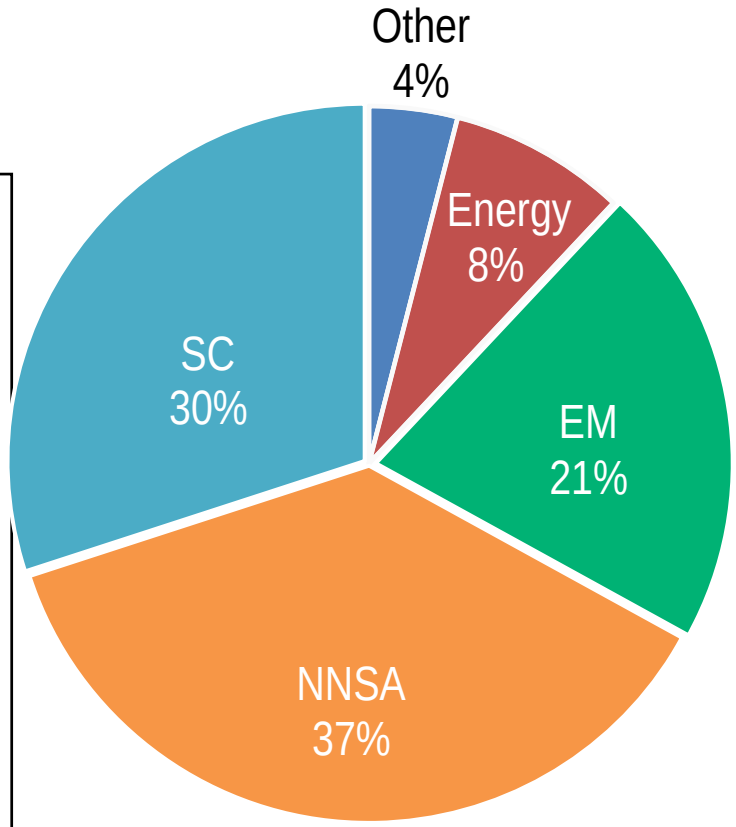
- Technology Push (NE)
  - Support a public/private partnership program that will accelerate commercialization of at least two LWR SMR designs
  - Cost-share FOAK development and licensing activities
    - Design certification, license application, early site permits
- Technology Pull (DOE, DoD)
  - Agencies enter into Power Purchase Agreements (PPA) for low-GHG electricity produced by SMRs
  - PPA enables financing for a utility to construct and operate SMRs on or near federal sites



# DOE Goal for Reducing Greenhouse Gas Emissions

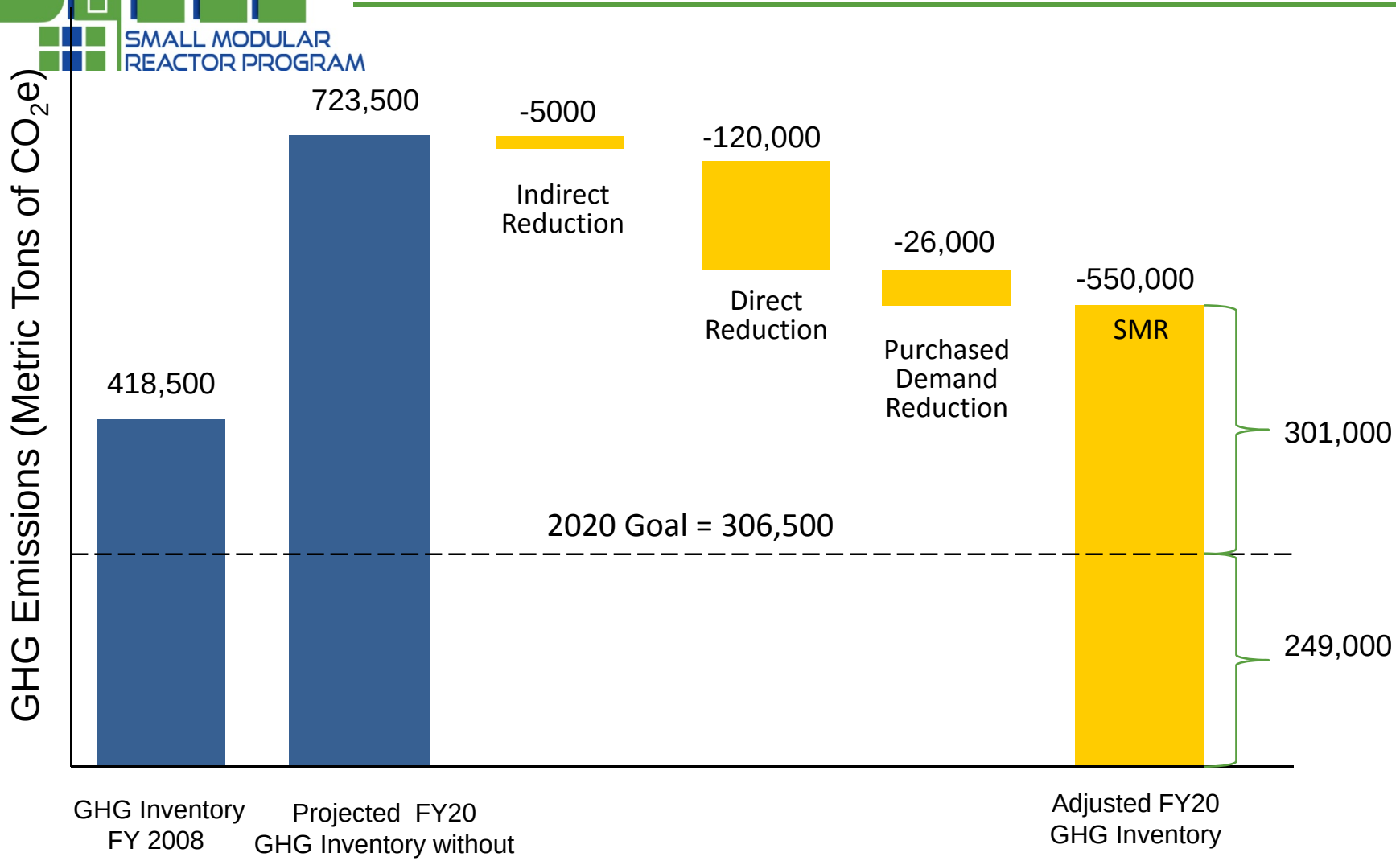
- Preliminary 2008 baseline: 4,600,000 $MtCO_2$
- DOE goal for 2020 (28% reduction): 1,290,000 $MtCO_2$

**Purchased electricity is the biggest contributor to DOE GHG emissions**

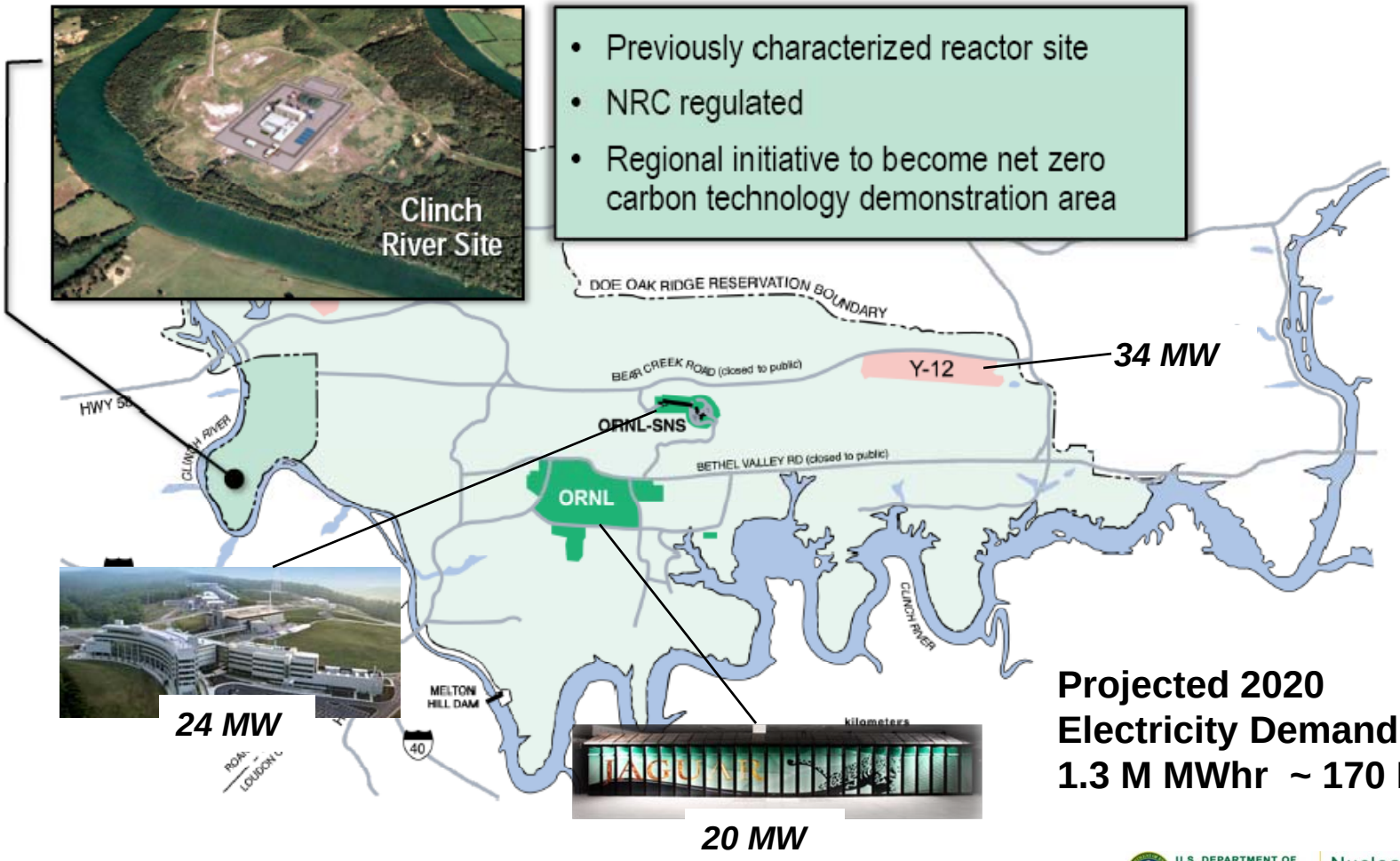



DOE GHG emissions: FY08 baseline

# ORNL can Meet/Exceed GHG Goal in 2020 with 125MWe SMR



# TVA/Oak Ridge Potential DOE First Mover




**Projected 2020 Electricity Demand: 1.3 M MWhr ~ 170 MW**

# Business Case for Cost-Share Recovery

***Assumption: One SMR unit (2 modules) in Oak Ridge, Tennessee***

| Option and description | Electricity cost, $/MWh* | Total** projected electricity cost, $M | DOE FOAK investment, $M | Savings relative to base case*** | | | DOE investment recovery period |
|---|---|---|---|---|---|---|---|
| | | | | Per MWh, $ | Per year, $M | Total, $M | |
| Base Case: SMR Consortium designs and builds; no DOE investment | $128 | $5,149 | N/A | N/A | N/A | N/A | N/A |
| Case 1: DOE funds 50% FOAK costs; Consortium funds 50% FOAK costs and 100% construction cost | $105 | $4,224 | $350 | $23 | $30.8 | $575 | 11.3 years |
| Case 2: DOE funds 100% FOAK costs; Consortium funds 100% construction cost | $81 | $3,259 | $700 | $47 | $63.0 | $1,166 | 11.5 years |

*Estimated—subject to negotiation
**Cumulative site power cost for 2020-2050
***Based on simple payback method

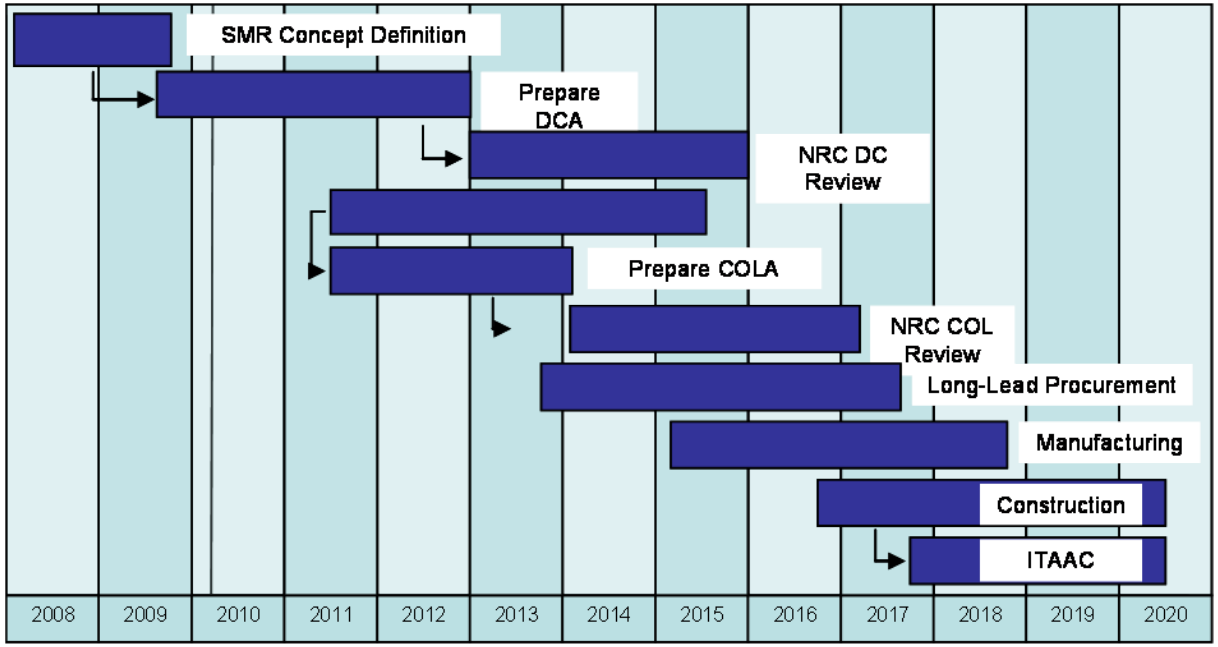
# Federal Role in SMR Commercialization

*Value Proposition in a Private-Government Proposal*

| Department of Energy | Vendor | Federal Facility | Public Utility |
|---|---|---|---|
| ▪ Achieves substantial progress in meeting its complex-wide GHG reduction goal<br>▪ DOE: Exceeds its GHG reduction goal with additional room for mission growth<br>▪ DOE-NE: Demonstrates commercial viability of SMR design and deployment models<br>▪ Reduces risk of volatility in electrical rate for high energy mission specific facilities | ▪ Achieves accelerated demonstration of SMR design<br>▪ Demonstrates fully domestic supply chain<br>▪ Demonstrates economy-of-replication business model<br>▪ Builds strong position for domestic and international markets | ▪ Substantially reduces carbon footprint to support DOE GHG reduction goals<br>▪ Demonstrates site-wide net-zero energy model<br>▪ Provides test-bed for power islanding technologies<br>▪ Secures long-term predictable power costs | ▪ Increases mix of clean energy generation<br>▪ Demonstrates viability of incremental capacity model for future generation growth<br>▪ Demonstrates viability of SMRs for repowering of fossil sites |

# Deployment by 2020

## *Nominal SMR Licensing Schedule*




- NRC responding to SMR interest
  - SECY 10-0034 identified issues with SMR licensing
  - Office of New Reactors includes SMR certification & licensing
  - FY2011 budget request calls for doubling NRC staff to support SMR review and licensing
  - NRC and industry (NEI) currently working on SMR licensing/regulatory issues

# Summary

- Nuclear power remains a key element of U.S. energy strategy
- U.S. Government incentives and programs are designed to “jumpstart” the U.S. commercial nuclear industry
- Challenges still remain for nuclear energy to be successful in the U.S.
  - Licensing and deployment schedule
  - Affordability (total capital cost)
  - Cost competiveness ($ per kWe)
  - Manufacturing/fabrication capabilities
  - Public acceptance
- DOE is committed to address challenges and will continue to support advanced and innovative nuclear reactor designs and technologies
  - Support Administrations GHC Goals
  - Respond to U.S. energy needs