Clean Nuclear Energy for Industry

April 16, 2020

10:00 a.m. – 12:00 p.m. MDT

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Gateway for Accelerated Innovation in Nuclear

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Webinar Details

- Thank you for joining!
- If you have technical issues, please submit them through the *"Chat"* option on the GoToWebinar control panel
- Please enter all questions for speakers using the *"Questions"* option on the GoToWebinar control panel; questions can be entered throughout the webinar
- We will address questions after each set of speakers, followed by a general discussion session at the end of the webinar
- The webinar is expected to run approximately 2 hours, but the line will stay open an additional hour for discussion if necessary

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Opening Remarks

Dr. Rita Baranwal

Assistant Secretary for Nuclear Energy
U.S. Department of Energy

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Webinar Goals

- Introduce energy “end users” to the potential of nuclear energy systems in meeting various energy demands
- Summarize the concept of “integrated energy systems”
- Allow industry leaders to share progress on non-electric applications of nuclear energy
- Initiate a discussion on requirements, considerations and concerns for energy system planning at “end use” facilities

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Introduction to Integrated Energy Systems

Dr. Shannon Bragg-Sitton

Lead, Integrated Energy Systems
Nuclear Science & Technology
Idaho National Laboratory

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DESIGNING OUR FUTURE ENERGY SYSTEMS

What goals are we trying to achieve?

How will energy be used?

What role(s) can each energy source fill?

IES
Integrated Energy Systems

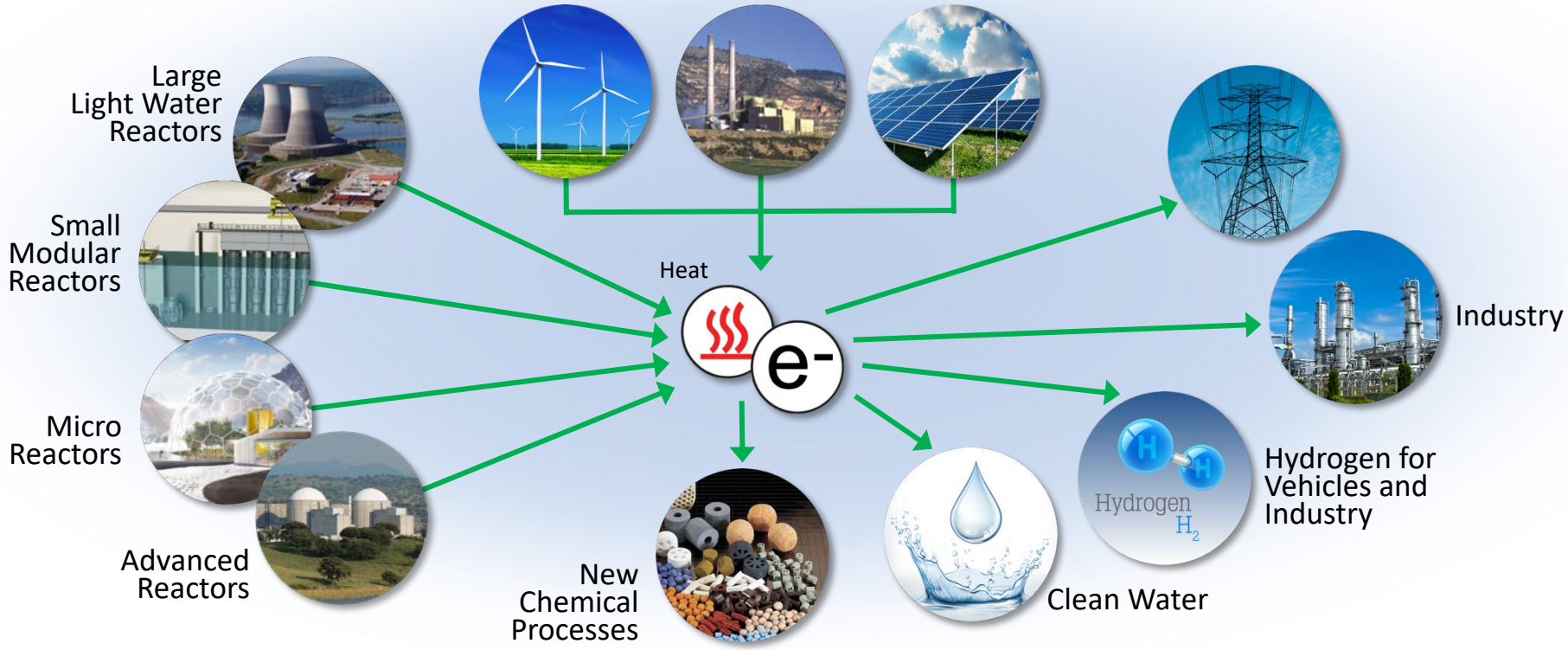
Integrated Energy Systems: A Key Opportunity

Today

Electricity-only focus

Potential Future Energy System

Integrated grid system that maximizes contributions from carbon-free energy generation for electricity, industry, and transportation

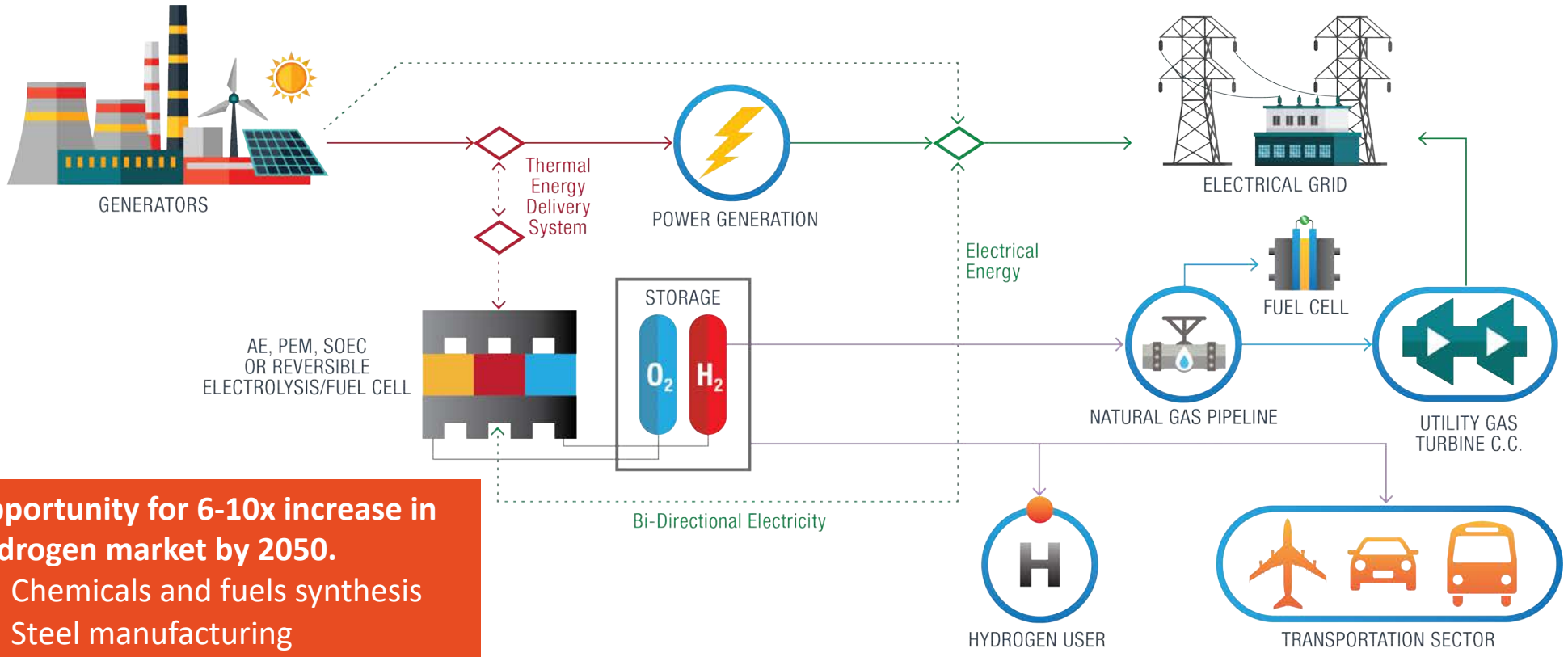


Flexible Generators ❖ Advanced Processes ❖ Revolutionary Design

IES
Integrated Energy Systems

Demonstrations coming soon!

Hydrogen Production via Electrolysis



Opportunity for 6-10x increase in hydrogen market by 2050.

- Chemicals and fuels synthesis
- Steel manufacturing
- Ammonia-based fertilizers

H_2 demonstration projects at current fleet LWRs awarded via public–private partnerships.

Demos hosted by:

- Exelon Corporation (nuclear plant in U.S. Midwest)
- Energy Harbor (Davis-Besse Nuclear Power Station)

1) Provides second source of revenue
2) Provides energy storage, for electricity production or hydrogen user
3) Provides opportunity for grid services, including reserves and grid regulation

IES Integrated Energy Systems

Meeting future **CLEAN** energy needs

Image courtesy of GAIN and ThirdWay, inspired by *Nuclear Energy Reimagined* concept led by INL.

Download this and other energy park concept images at:
https://www.flickr.com/photos/thirdwaythinktank/sets/72157665372889289/

Overview of Nuclear-Industrial Integration Demonstrations

Ugi Otgonbaatar, Ph.D.

Corporate Strategy Manager
Exelon Corporation

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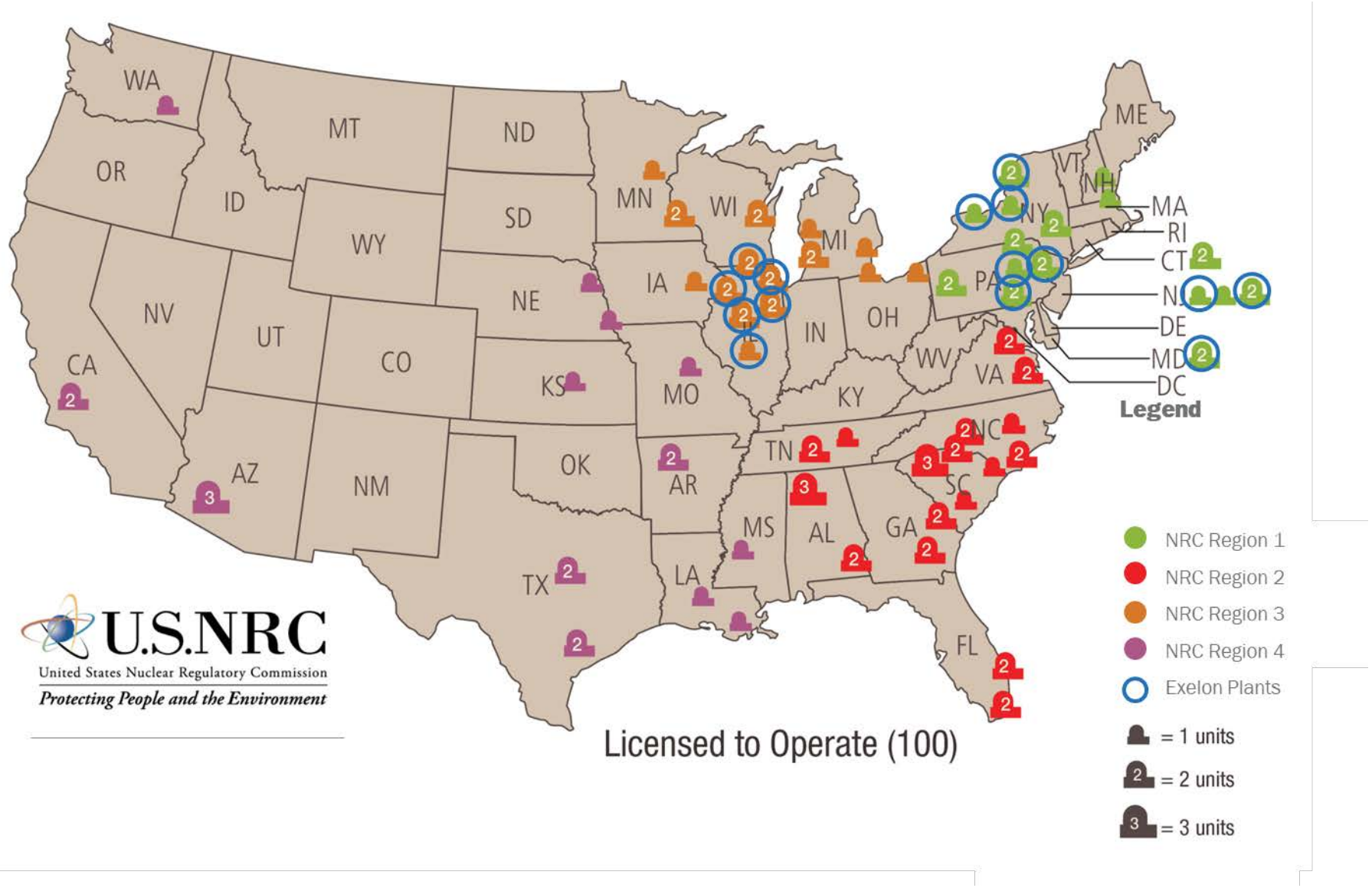
Value propositions of hydrogen generation for flexible operation of nuclear plants

GAIN-EPRI-NEI webinar
Clean Nuclear Energy for Industry

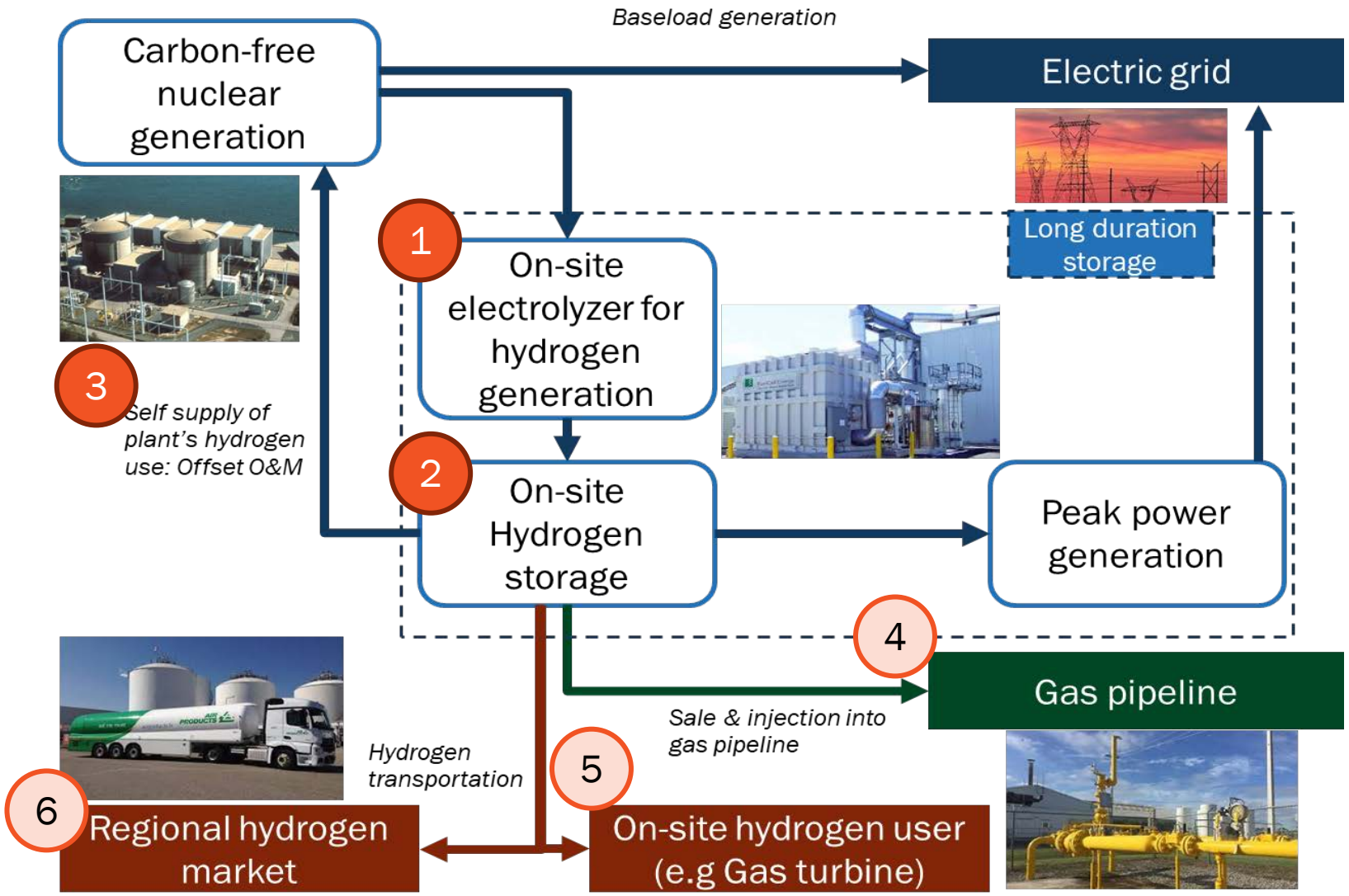
Exelon®

Exelon overview

Exelon nuclear plants are located in competitive electricity market regions



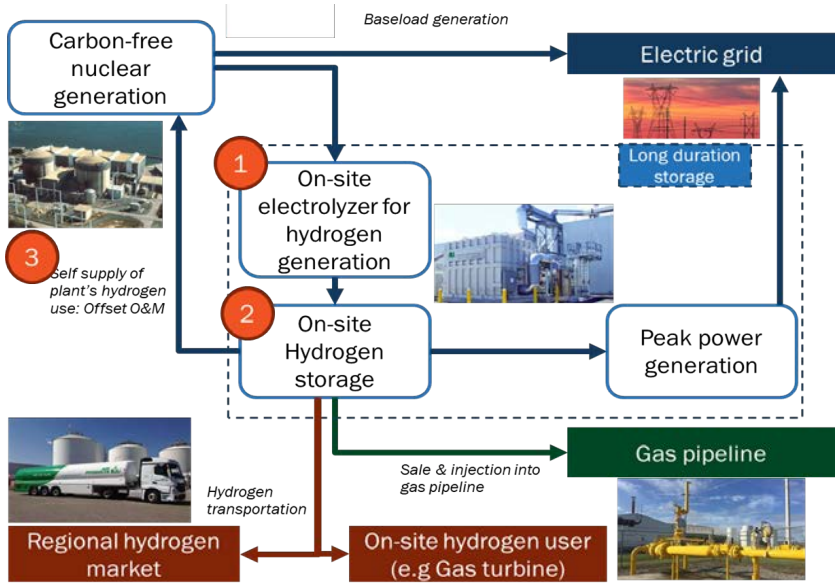
Repurposing Nuclear Plants using Hybrid Hydrogen Approach



Demonstration of electrolyzer operation at a nuclear plant (DOE grant)

Project overview

- Exelon and partners will install a 1MW PEM electrolyzer at one of Exelon's operating nuclear plants to demonstrate dynamic production of hydrogen from nuclear electricity



Team, scope

- **Partners:** Exelon, Nel Hydrogen, ANL, INL, NREL
- **Period of Performance:** 2020-2023
- **Initial budget estimate:** $7.2MM
- **Key Milestones/deliverables**
  - Site selection, regulatory review
  - Engineering design, installation
  - Steady state and dynamics operation

Challenges, Questions

Site Selection

- What are the criteria for site selection?

Regulatory

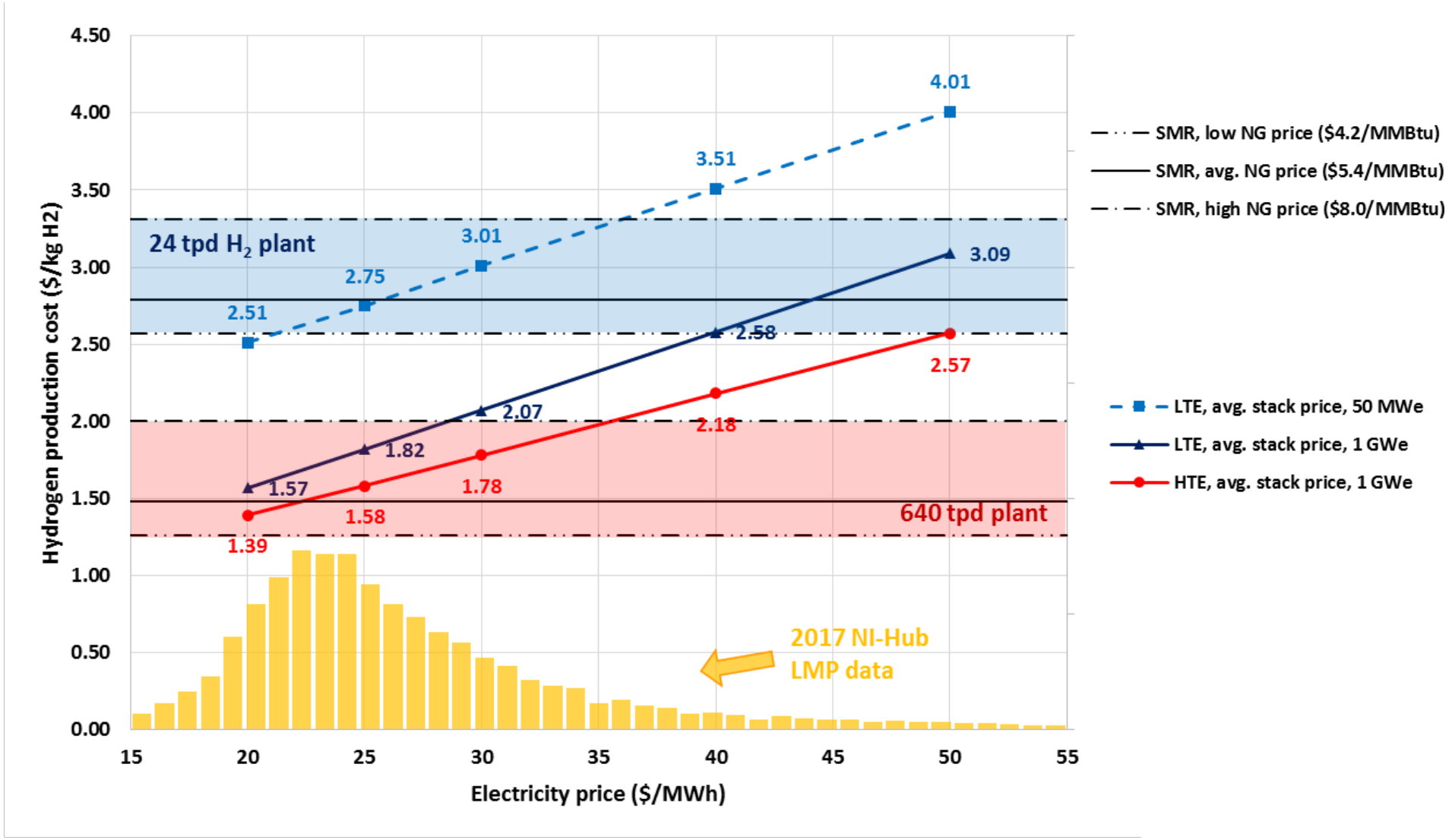
- What are the relevant regulations that affect nuclear hydrogen production?

Market-related

- What is the effective electricity price that the electrolyzer pays?

Exelon

H_2 Production Cost Results Summary- Steady State (2019$)



Exelon

Overview of Nuclear-Industrial Integration Demonstrations

Alan Scheanwald

Project Manager
Strategic Engineering
Davis-Besse Nuclear Power Station

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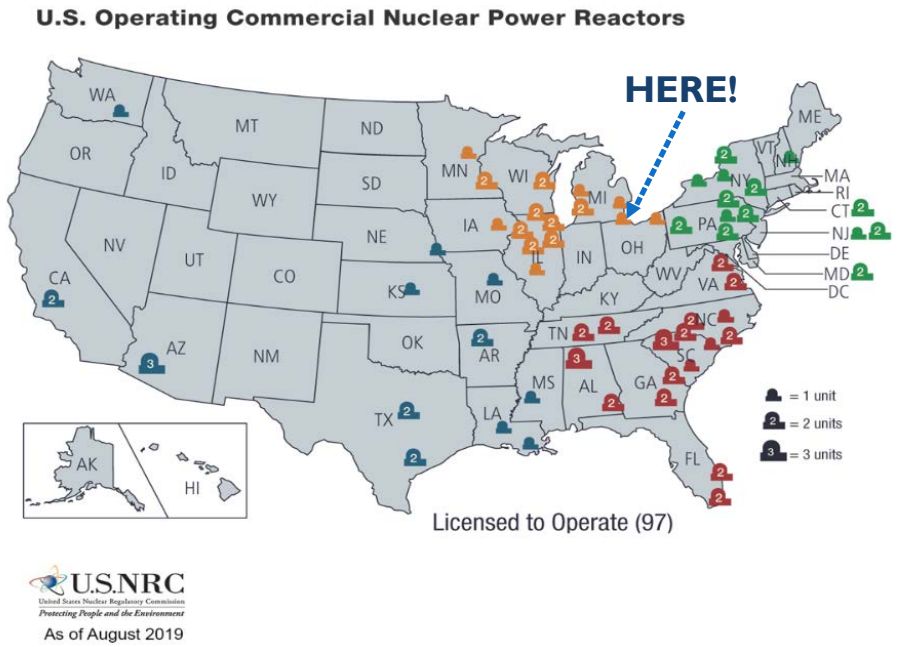
WHY DAVIS-BESSE?

The objective is to diversify and increase the revenues of nuclear plants facing increased competition from renewables and low-cost natural gas.

Benefits of operating at the Davis-Besse Nuclear Power Station (DBNPS):

- Electrical power is taken at plant output and prior to the switchyard. Reduces electricity costs.
- Inputs for hydrogen production are electricity and water. Uses existing facilities.
- Plant's relative proximity to key markets are ideal for reducing transport distances.
- Hydrogen will be generated from a "carbon-free" source.



GRANT PROPOSAL STATUS

- Received notification to begin award negotiations on 09/10/2019.
- Received pre-award authorization of funding on 11/26/2019.
- Still in negotiations for complete award.

- Project Collaborators Include:
  - Idaho National Labs (INL)
  - Arizona Public Service - Palo Verde
  - Xcel Energy – Monticello & Prairie Island

- Project duration is 24 months from entry into the period of performance.

HYDROGEN SKID SELECTION

- Equipment to be used is Low Temperature Electrolysis (LTE) using Polymer Electrolyte Membrane (PEM) technology.
  - Using a proven technology to minimize risk for the project.
- Equipment is to be containerized.
  - "Turn-key" solution will help to reduce additional engineering efforts and project risk.
- Requires roughly 2 MW of electricity and 2,400 gallons of water per day at maximum operating capacity.

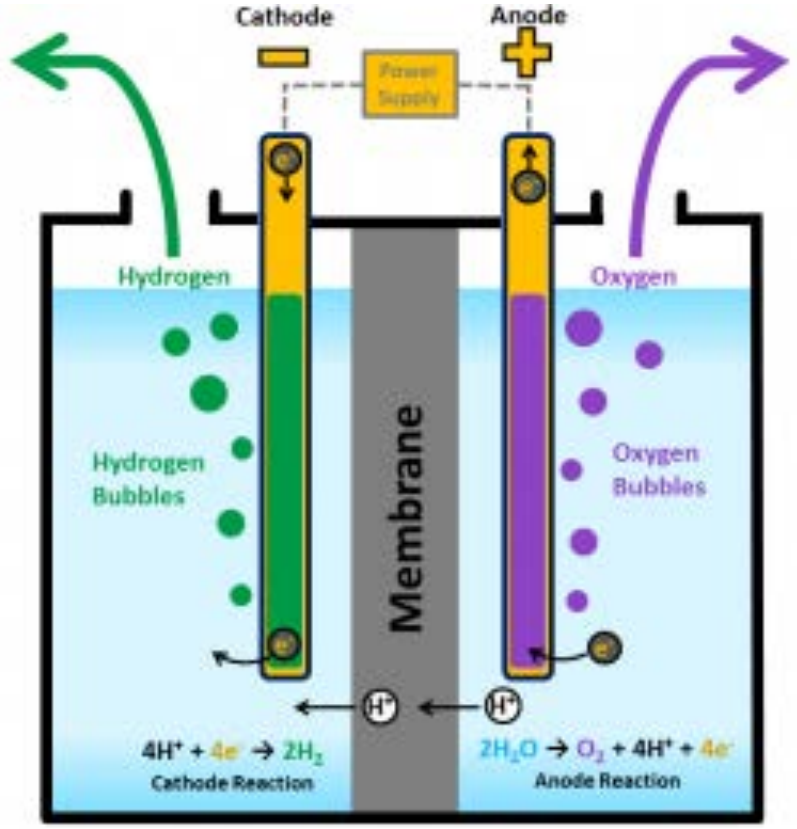
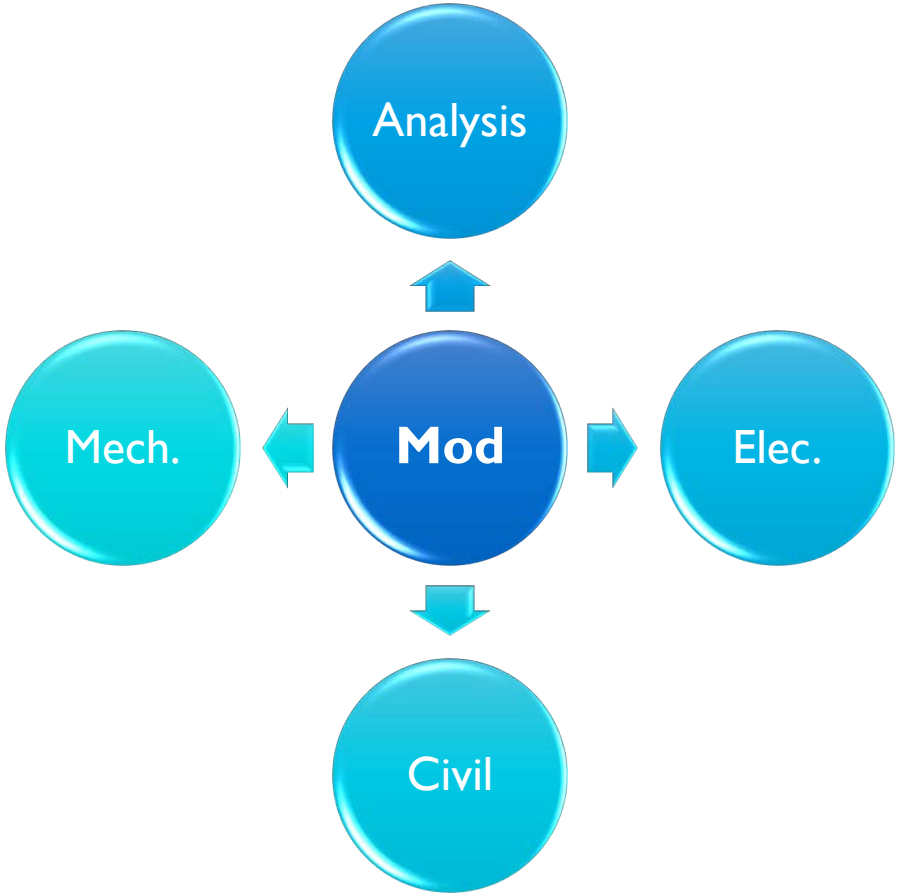


Image taken from https://www.energy.gov/eere/fuelcells/

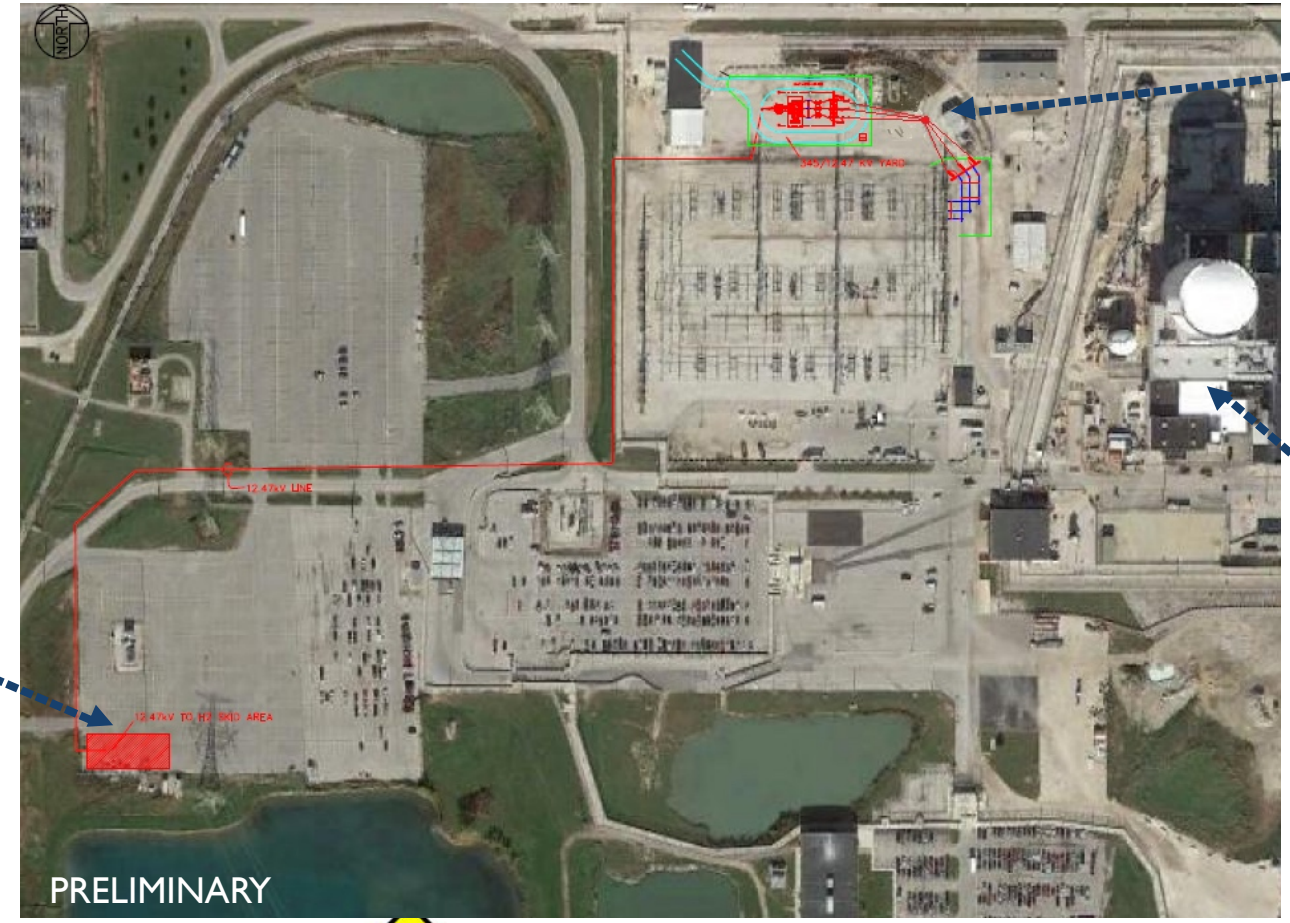
DESIGN & ANALYSIS



- **Analysis** – Determine the effect the skid and supporting equipment will have on plant operation, design and the licensing basis.
- **Electrical Design** – Develop the safest and most efficient means to connect the equipment to the plant's electrical distribution system.
- **Mechanical Design** – Select and design for the optimal water source.
- **Civil Design** – Design foundations, supports, and structures necessary for skid installation.

MODIFICATION IMPLEMENTATION

Design & locate the equipment such that the effect on the design and licensing basis it mitigated (to the extend practical).



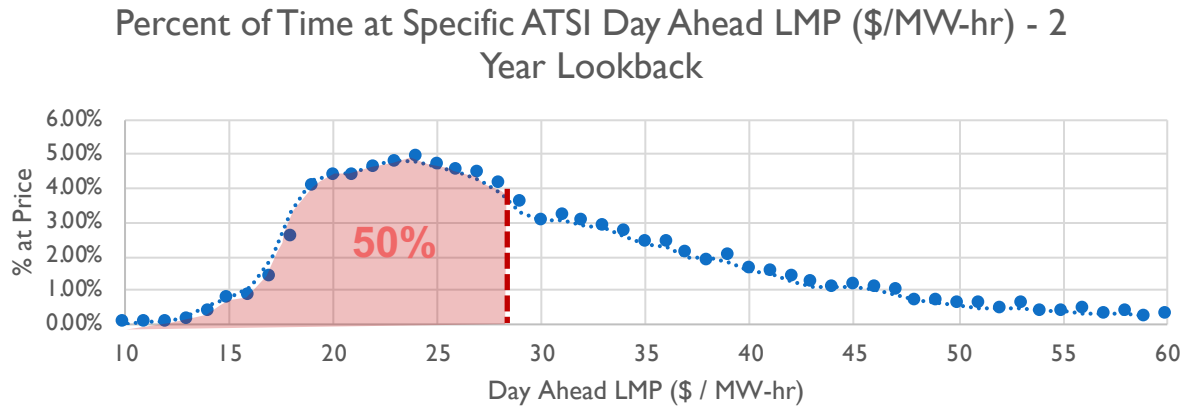
Electrical Tie-In

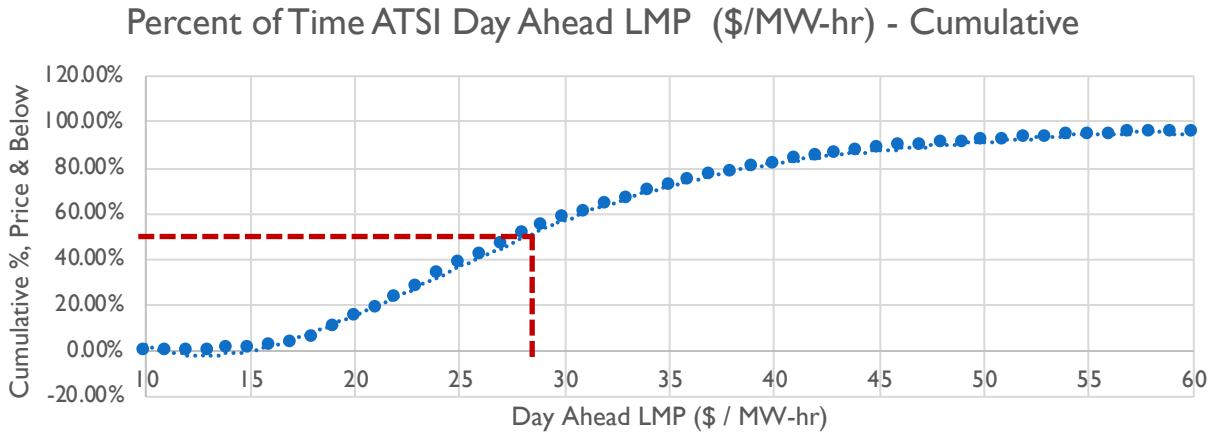
Power Block

Hydrogen Production Area

COMMISSIONING & TESTING

- Control software will be able to modulate H_2 output based on input variables .
- Control software will interface with Programmable Logic Computer (PLC) on vendor supplied H_2 skid.

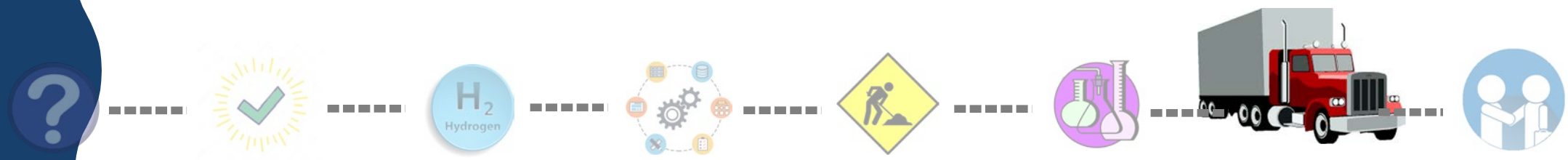




TRANSPORT & CONSUMER BASE

"Need to identify existing and help cultivate emerging markets"

- INL Technical Economic Assessment (TEA)
  - Written for DBNPS by the Idaho National Laboratories (INL)
  - Discusses business case for bulk hydrogen distribution in the Toledo, Ohio area (fuel cell vehicles, petroleum refineries, iron-ore plants, fertilizer production facilities, etc.)
- Local/Regional Partnerships
  - Transportation costs are a significant portion of the expected price of our product. Reducing the transportation distances is important to the success of the project and future scale up activities.
  - Can leverage production facility's proximity to major transportation corridors and potential consumer base.



SCALE-UP / PROJECT CONCLUSION

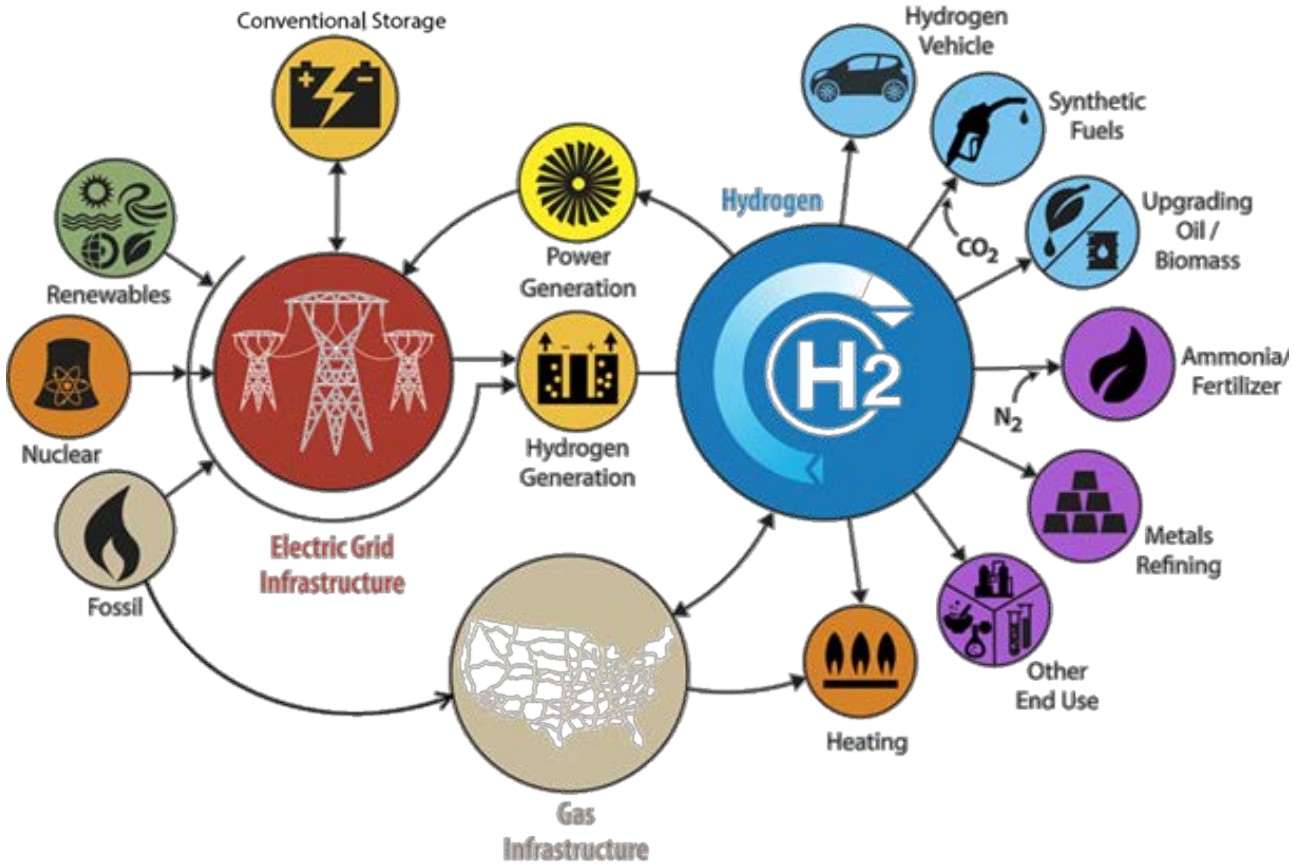


Image taken from https://www.energy.gov/eere/fuelcells/h2scale

At maximum operating capacity, the pilot plant is expected to produce 800-1,000 kg-H_2 / day, and consume roughly 2 MWe.

DBNPS has a nominal output of 925 MWe (2,817 MWt).

Preliminary estimates show a positive return on investment if future scale-up activities are pursued.

Overview of Nuclear-Industrial Integration Demonstrations

Molly Strasser

Innovation Manager (Nuclear)
Xcel Energy

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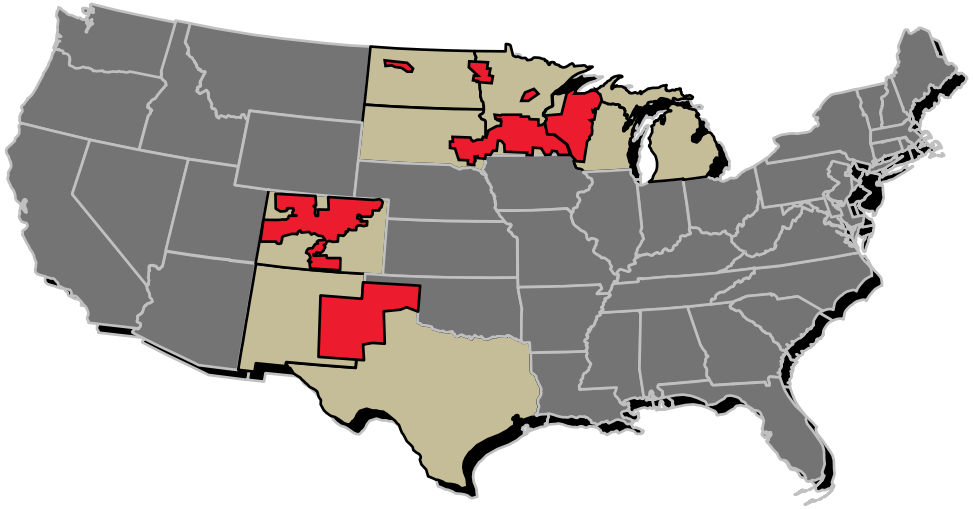
Xcel Energy: Path to Carbon-Free Energy

April 16, 2020

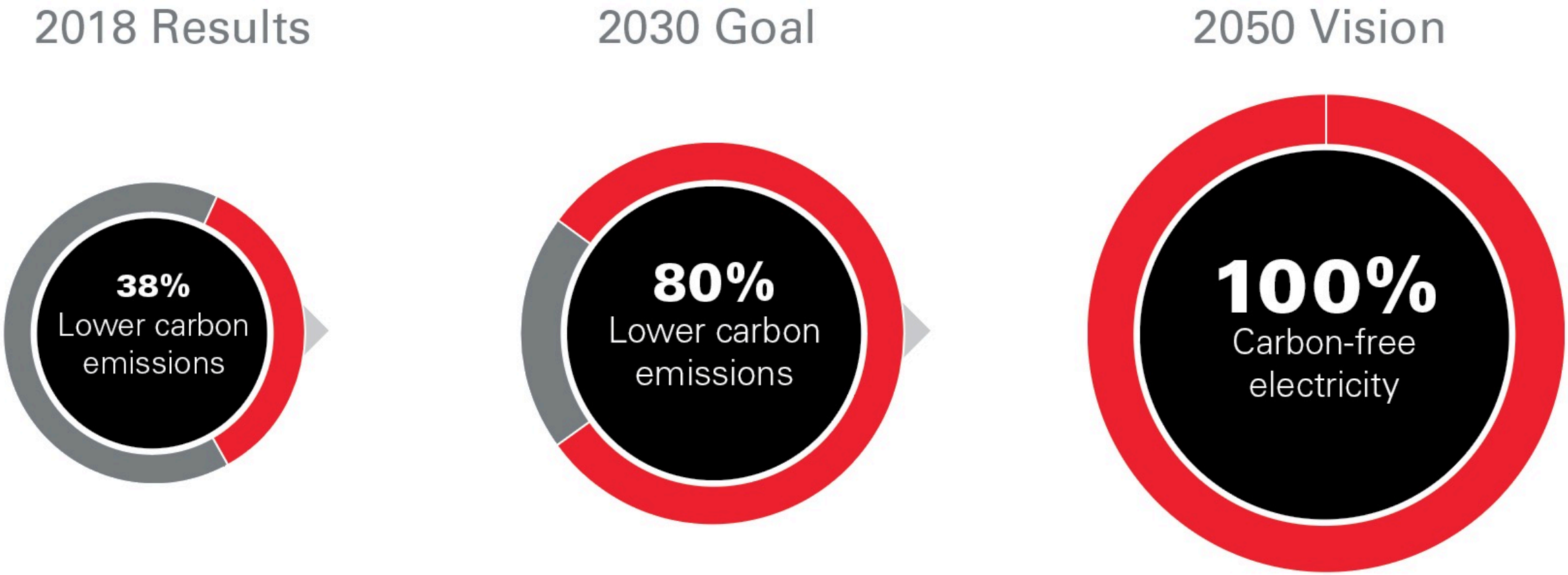
Company Profile – Xcel Energy

Xcel Energy is an electric and natural gas company that is committed to the clean energy transition. Based in Minneapolis, Minn., we have regulated operations in eight Midwestern and Western states, and provide a comprehensive portfolio of energy-related products through four operating companies.

- **Employees**: 11,865
- **Natural gas operations**
  - Customers: 2.0 million
  - Transmission: 2,209 miles
  - Distribution: 35,112 miles
- **Electricity operations**
  - Customers: 3.6 million
  - Transmission and Distribution: 219,841 miles



Bold carbon-reduction goals

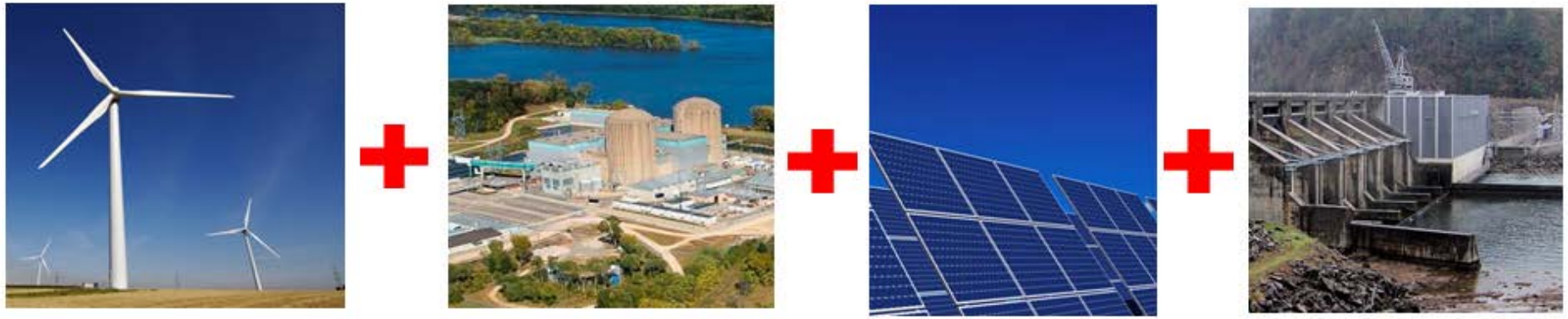


Company-wide emissions reductions from the electricity serving our customers, compared to 2005

Safe ▪ Clean ▪ Reliable ▪ Affordable

Flexible Power Operations

An innovation that enables 80% carbon-free by 2030



- Both Plants in MISO day ahead market
- Evaluating hybrid operations – Hydrogen
  - Integrated Energy Systems

LWRS Funding Opportunity Announcement (FOA)

- US Department of Energy released FOA to support Light Water Reactor Sustainability (LWRS)
  - Significant government partnering funding available
  - Purpose of FOA is to advance nuclear power, both improved advanced nuclear reactor and improvements of existing domestic fleet
- Production of hydrogen identified as opportunity for demonstrating link between existing nuclear fleet and renewable energy sources
  - Flexible Power Operations – Monticello and Prairie Island
  - Applicable to multiple reactor design type

LWRS Funding Opportunity Announcement (FOA)

DOE Announcement for Advanced Nuclear Technology - 9/10/2019

- Industry consortium (3 partners) with National Labs

LWRS LIGHT WATER REACTOR SUSTAINABILITY

- Xcel Project Scope – Technical Economic Assessment
  - Evaluation of future electric / hydrogen markets to determine potential
  - Determine how to navigate hybrid operations (H2) in a regulated market
  - Strengthen the Nuclear Power Plant Image
    - Provide analysis to show power is “green”, clean, carbon free, etc...
  - Produce Carbon Free H2 – Help Meet Xcel 2030 / 2050 Goals
    - Evaluate use of ‘green’ hydrogen in current Xcel generation units
  - Pioneer New Area

Summary and Xcel's Future Steps

- Complete the Technical Economic Assessment and Investor Grade Report
- Evaluate implementation of H2 pilot at Xcel nuclear facility
- Begin building framework for implementation
  - Plant Connections
    - Technical / Regulatory Requirements
  - PUC / State / Local Community Support
- Develop partnerships for future pilots with downstream users


ZERO EMISSIONS
1715
SARTA
SARTA
H2 H2O

Overview of Nuclear-Industrial Integration Demonstrations

Jeff Brown

Senior Consulting Engineer
Strategic Business Services
Palo Verde Generating Station
Arizona Public Service

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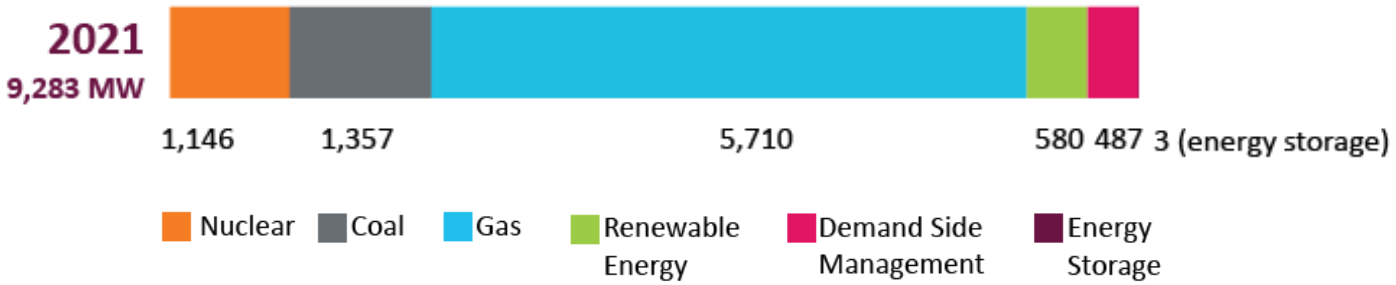
PaloVerde™
GENERATING STATION

aps

Integrated Energy Systems to Support Long Term Sustainable Carbon-Free Generation for Arizona

- Arizona's largest and longest-serving energy provider
- Arizona Public Service generates clean, reliable and affordable energy for 2.7 million Arizonans
- 6,300 dedicated employees power our vision of creating a sustainable, carbon-free energy future for Arizona.
- Operating owner of the Palo Verde Generating Station (29.1%)
- Total generation (peak capacity):

PINNACLE WEST
CAPITAL CORPORATION

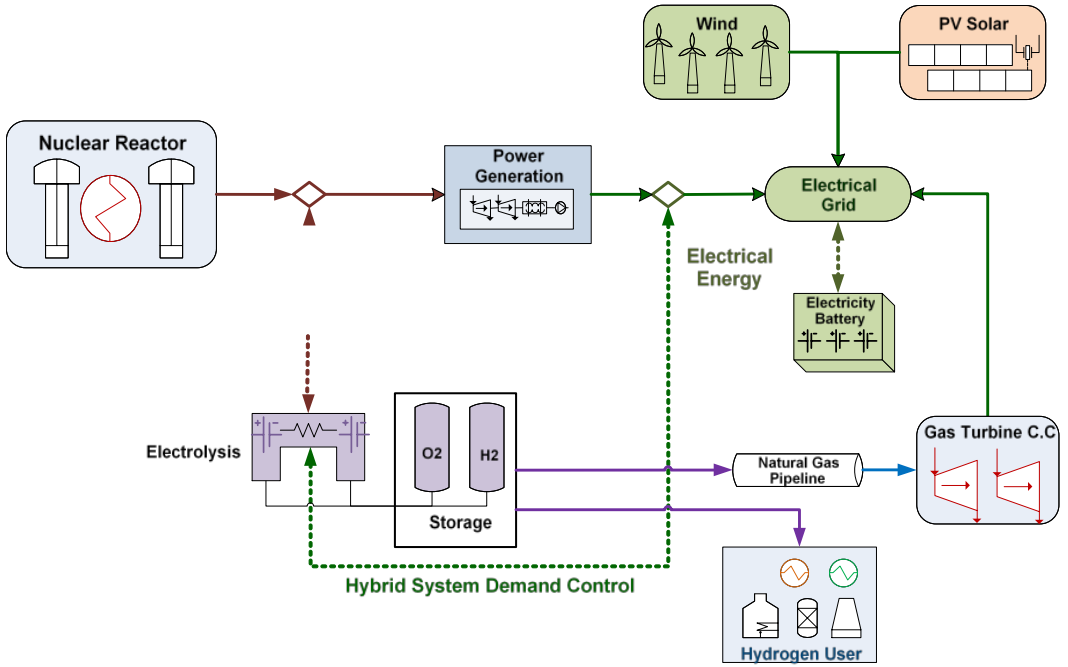


Palo Verde Nuclear Generating Station

- Largest nuclear generating plant in the U.S. (4200 MWe)
- Seven participating owners
- Provides power to Arizona, California, New Mexico, and Texas
- 2019 Generation – 31,100,000 MW-hr carbon-free power

An Evolving Grid

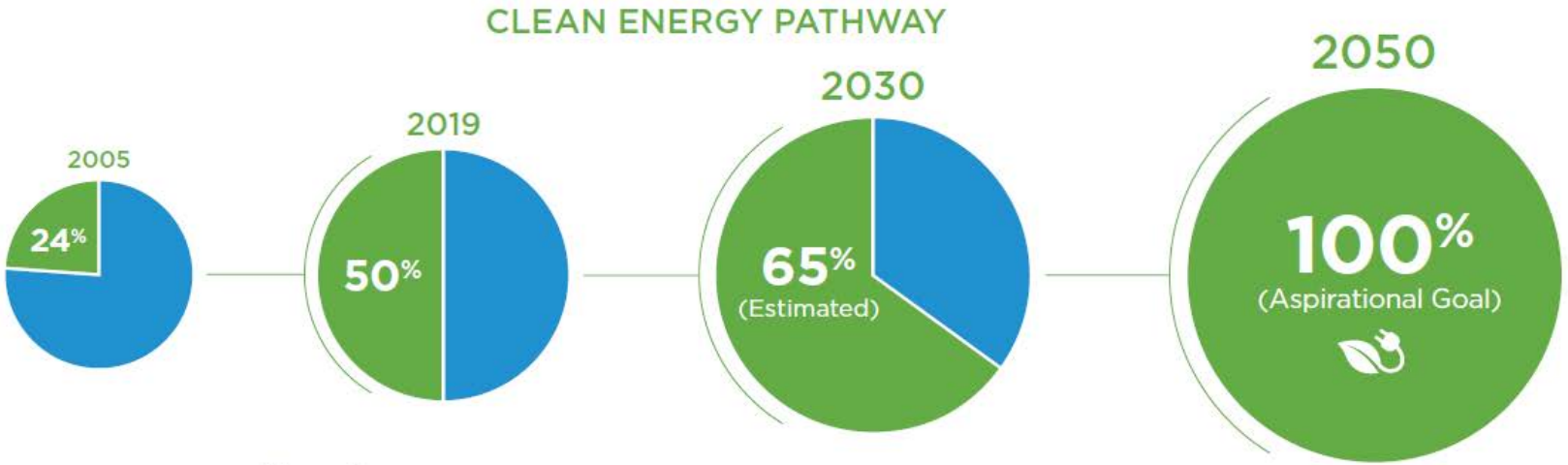
- APS is experiencing the impacts of growing renewable energy in the dessert southwest
- Increasing frequency of low and even negative hub pricing increases pressure on Palo Verde to curtail power during seasonal conditions



Integrated Energy Systems

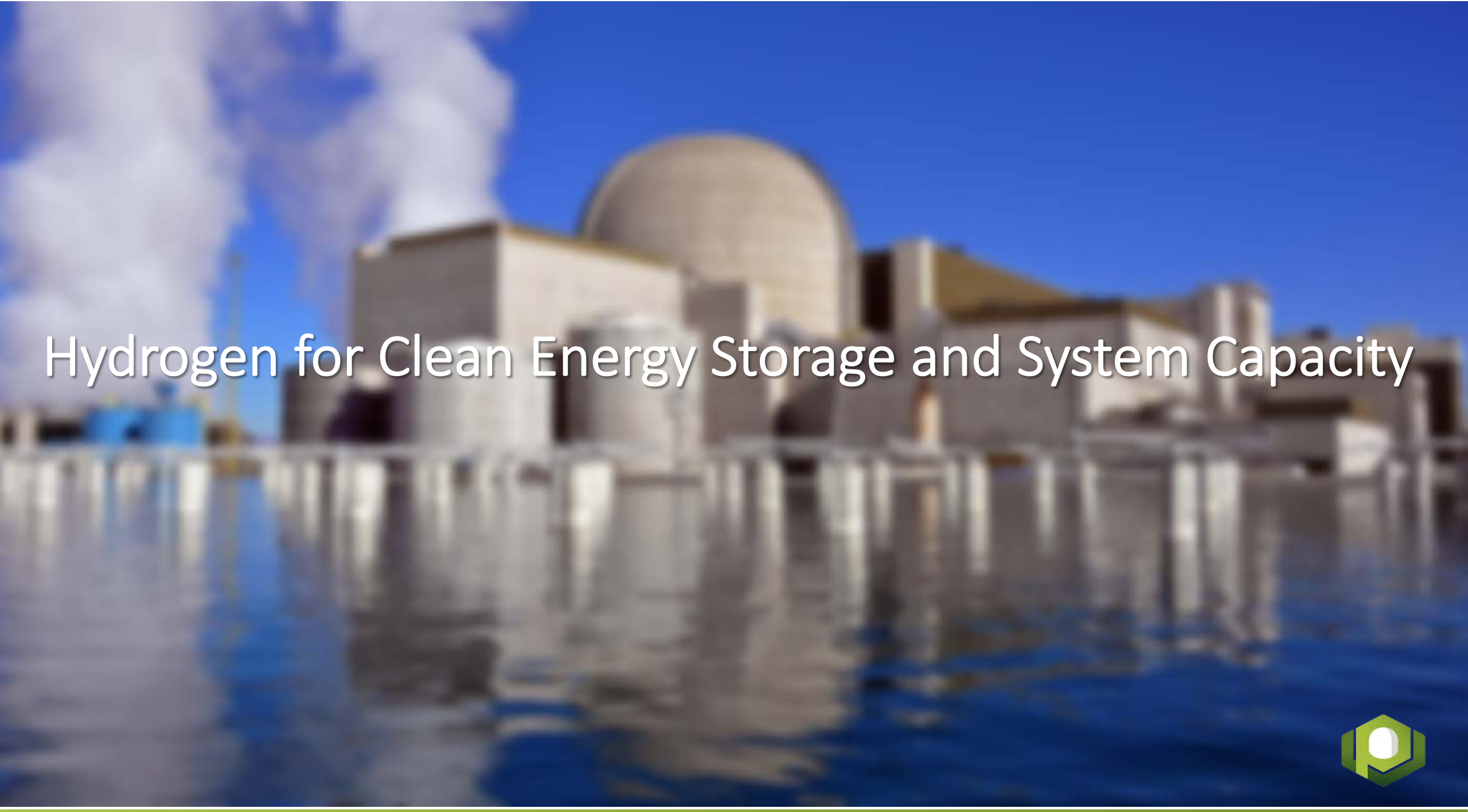
- Integrated Energy Systems (IES) may provide large scale capacity and an alternative to curtailment
- IES may also provide for alternate energy market opportunities

APS Clean Energy Commitment



Clean energy commitments

- 100% clean, carbon-free electricity by 2050
- 65% clean energy by 2030 with 45% renewable energy
- Eliminate coal by the end of 2031

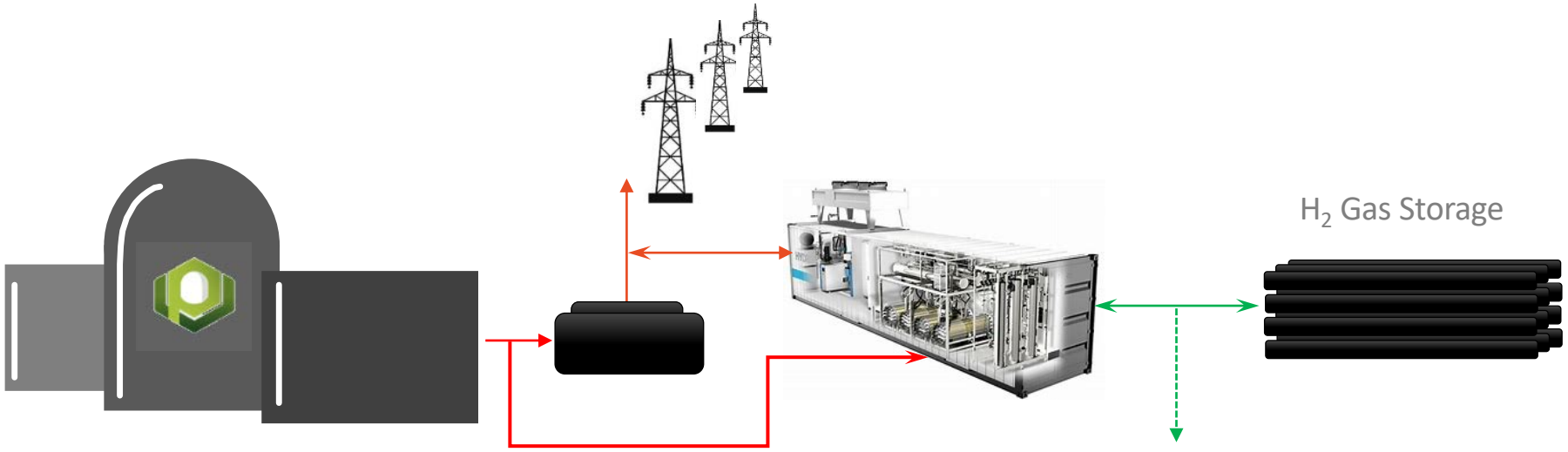

Hydrogen for Clean Energy Storage and System Capacity

Industry Efforts

- Nuclear utility collaboration with Idaho National Labs / Light Water Reactor Sustainability (LWRS) program
  - Program funding – DOE Office of Nuclear Energy, DE-FOA-0001818
- Technical Economic Analyses for regional hydrogen markets
- Technology Demonstrations
  - Advance electrolysis technology and scale
  - Safe integration with nuclear power
    - Generation and storage hazards analysis
    - Systems impacts
- Palo Verde demonstration – Reversible High Temperature Steam Electrolysis
  - Advance technology to support grid capacity as an option to curtailment

Reversible High Temperature Steam Electrolysis

- Integrated high temperature solid oxide electrolysis cell (SOEC) uses plant thermal energy (steam) to reduce electrolysis cell potential (voltage) and improve efficiency
- Reversible system (rSOEC) uses hydrogen to generate power in the same stack



Considerations

- H2 generation capacity and cost
  - High Temperature Steam Electrolysis efficiency needed to achieve production price competitive with renewable energy
  - Significant advances in technology and commercial scale production needed
  - System flexibility necessary to react to daily demand
- Storage capability – a major consideration
- Compliance with 10CFR50, Appendix A, all licensing bases commitments , Final Safety Analysis Report, and state and local requirements
- Clean generation policies are needed

Clarifying Questions for Industry

Please enter all questions or comments using the *"Questions"* option on the GoToWebinar control panel

Additional discussion time will follow the next two speakers.

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Senior Technical Advisor
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Everett Redmond II, Ph.D.

April 16, 2020

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Department of Energy Advanced Reactor Demonstration Program – New in FY 20

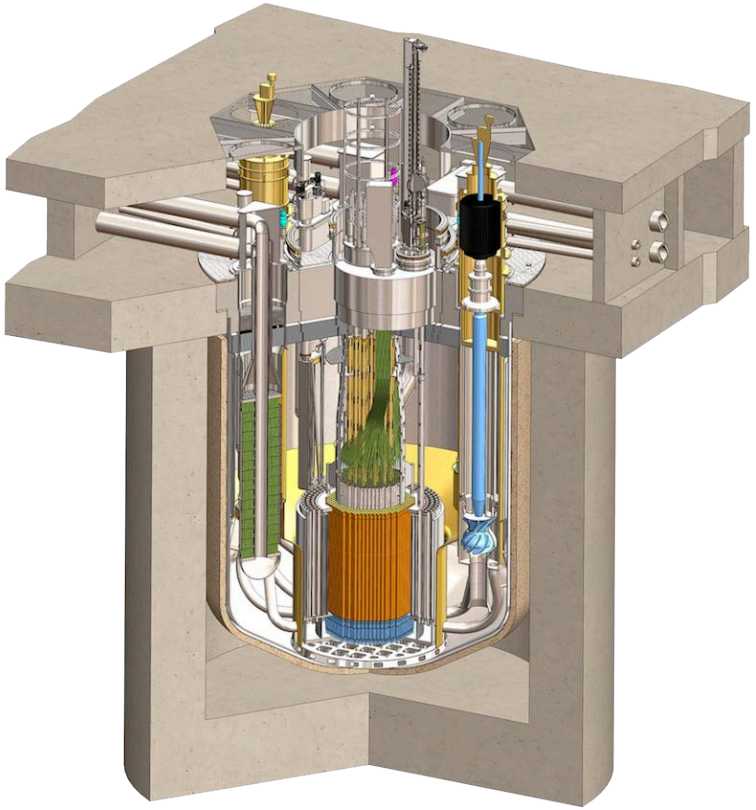
Advanced Reactor Demonstrations

- $160 million (M) for first year of funding for two advanced reactor demonstrations
- Technical feasibility that the demonstration can be operational in five to seven years

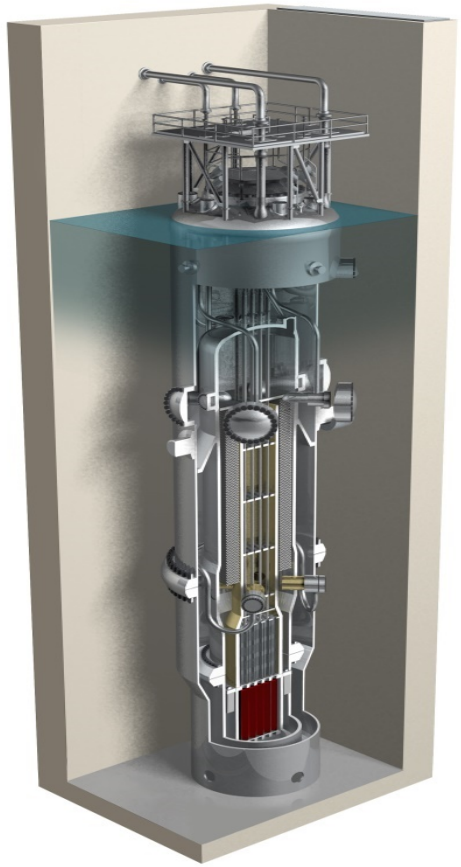
Risk Reduction for Future Demonstrations

- $30M to address technical risks for 2 to 5 reactor designs not selected for the first two demonstrations

Range of Reactor Sizes Coming



Greater than
300 Megawatt Electric



Less than
300 Megawatt Electric

1-10 Megawatt Electric

NuScale and UAMPS

- NuScale Reactor
  12 modules each
  60 MWe
- NRC approval of Design Certification late in 2020

- Utah Associated Municipal Power Systems (UAMPS) plans to construct and operate a NuScale reactor at Idaho National Lab around 2026

Micro-Reactors for Remote Locations and Mobile Micro-Reactors

Mobile micro-reactor demonstration being planned by DOD for Idaho National Lab around 2024

Oklo Aurora Fission Battery

- Application with Nuclear Regulatory Commission (NRC)
- Heat and electricity
- 1.5 MWe
- 10+ years before refueling
- Demonstration at Idaho National Lab around 2024

THE FUTURE OF CLEAN ENERGY WILL BRING NEW REACTOR DESIGNS AND NEW APPLICATIONS

By Third Way, GENSLER

Commercializing Advanced Reactors

Andrew Sowder, Ph.D.

Senior Technical Executive
Advanced Nuclear Technology
Electric Power Research Institute

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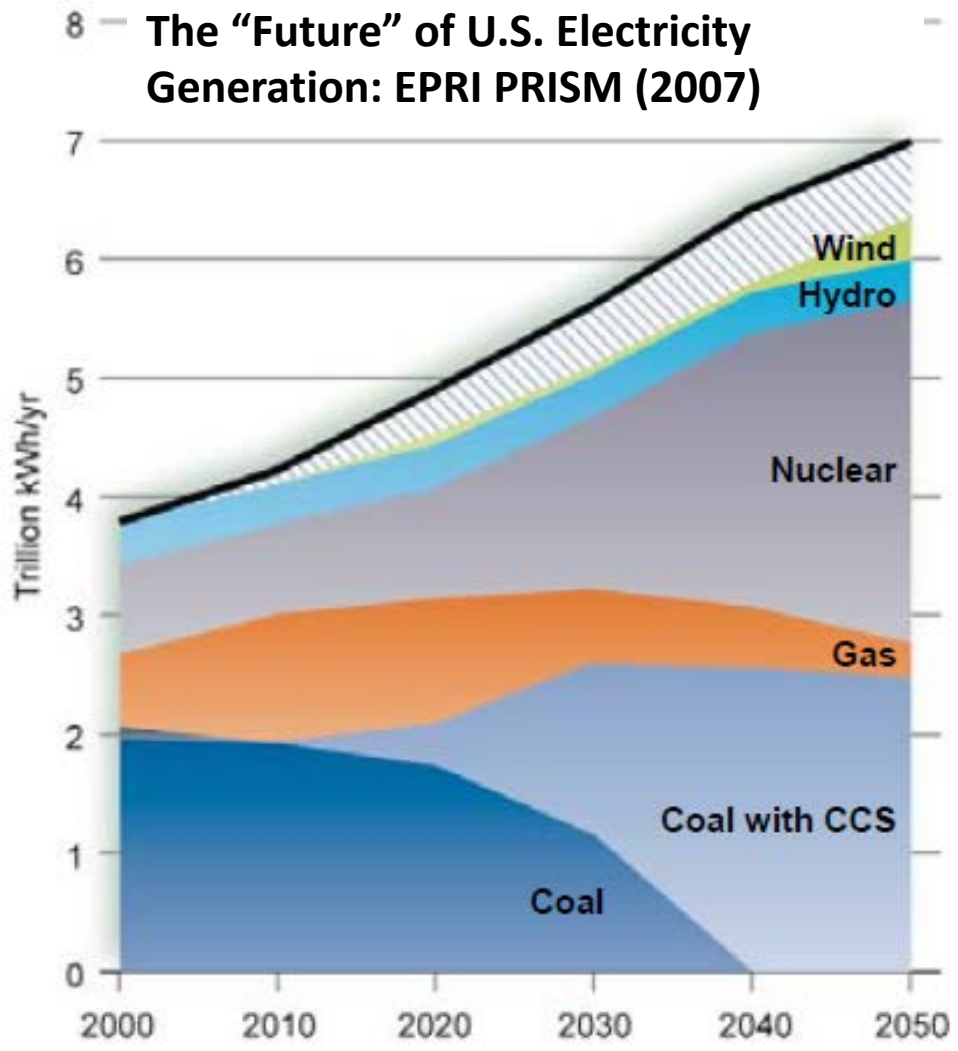
Commercializing Advanced Reactors for New Customers and an Uncertain Future

Andrew Sowder, Senior Technical Executive
Advanced Nuclear Technology

GAIN-EPRI-NEI Webinar: Clean Nuclear Energy for Industry
April 16, 2020

Global Context for Future of Nuclear: Uncertainty

- What will price of natural gas be?
- What will price of carbon be?
- What will technology competition be?
  - Natural gas with CCS?
  - Renewables with grid-scale energy storage?
- "Unknown unknowns" … *i.e., the next shale gas revolution*



EPRI 2007. The Power to Reduce CO2 Emissions: The Full Portfolio.

What will it take to commercialize advanced reactors?

- Technologies that are:
  - Mature
    - ✓demonstration
  - Compelling
    - ✓new attributes and capabilities
  - Competitive
    - ✓cost and value
- Customers who:
  - Understand
    - ✓informed and engaged
  - Believe
    - ✓evidence of performance
  - Need
    - ✓business case

Closing

- Technology developers need to understand customers and markets for their products

- Customers and other primary stakeholders:
  - have an interest in understanding technology landscape and horizon
  - have a role to play early in design process

- Advanced reactors (AR) must offer compelling options to compete
  - with other technology solutions
  - within uncertain and changing energy markets

EPRI AR Owner-Operator Requirements Guide (ORG) Rev. 1 [3002015751]

Questions and Discussion

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- We will address as many questions as possible during the webinar, and will follow-up later to address additional questions
- At the end of the webinar, please submit ideas for the next webinars in this series, so they can be tailored to fit your interests

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