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Nuclear Energy Use for Industrial Assets

Presented to the

Consultancy Meeting on Considerations for Coupling of Nuclear Cogeneration Facilities

Hosted by the International Atomic Energy Agency

Vienna, Austria

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NUMARK is a technical support contractor assisting nuclear regulatory authorities and private sector clients worldwide in the safety, environmental, and security areas. Our services include the development of regulatory infrastructure; review of license applications and amendment requests; training and procedure development; regulatory research supporting both advanced reactors and existing light water reactors; inspection support; and licensee performance assessment.

NUMARK has served as a Technical Support Organization to the US Nuclear Regulatory Commission since 2007 and the UAE Federal Authority for Nuclear Regulation since 2010. In parallel with its nuclear related services, NUMARK supports global development projects addressing Clean Energy, Energy Poverty, Energy Sector Governance and Reform, and Energy Security.

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Presentation based on ARPA-E Workshop and Input from Two Potential Users

User Objective: Assets Decarbonization

- Pledge to decarbonize processes by 2050
- Potential Paths
  - direct electrification
  - H_2 firing
  - Carbon Capture
  - Nuclear high temperature steam or gas
- Understanding how to integrate nuclear reactors into existing industrial facilities is key

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Non-negotiables for industrial investment in nuclear

- Timing for industrial asset end-of-life
  - Must be delivered on same timeline as alternatives
- Budget – capital cost
  - Clear
  - Competitive
  - Constant
- Fuel Assurance
  - Available at agreed start date and through plant life
  - Predictable cost

Steam from nuclear as a heat carrier in manufacturing applications

- First step
  - Replacement of gas-fired boilers with steam from nuclear plants could deliver significant decarbonization in existing assets
- Design and de-risk an integrated system that could
  - Fully decouple nuclear facility from the users
  - Efficiently respond to variable heat loads
  - Operate in tandem with gas generation and renewable storage
  - Potentially deliver auxiliary services (co-generation mode)
  - Provide simple and reliable services comparable to a package boiler or a co-generation unit

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Reactor Technology Selection for applications beyond baseload electricity market

- A potential new user must assess and select a reactor with very limited real-world data, in particular for technologies other than PWR, BWR
- Isolated locations both on-shore and off-shore could offer deployment opportunities for micro and small reactors
- Reaching 96+% availability requires careful integration with other generation and storage technologies
- Needed:
  - Evaluation tools to minimize risks for first movers and allow quality decisions
  - Confidence on scalability of the nuclear solution
    - Reactor manufacturability
    - Supply chain assessment

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Market may not have today a single reactor design that fits most of the industrial user requirements

- Size in MW
- Load following capabilities – fluctuation in energy demand
- Black Start capabilities – when far from the grid
- Weight and dimension - transportation and “real estate” constraints

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Regulatory hurdles for a first mover

- Cost and schedule for regulatory approval
  - Regulatory agencies do not charge per MW installed
  - Cost and schedule should reflect risk (size)
- Need clear boundaries between the nuclear facility and non-nuclear users and clarity in responsibility between industrial users, operators, and owners
- May need Standards for measurement of radioactive content of high temperature steam or gas released for unrestricted use in processes
- Nuclear liability covering applications outside large baseload power generation
  - key for insurability
- Regulator agreement that reactor can be designed for adjacent industrial hazards

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Potential Industrial Facility Accidents That Might Require Special Nuclear Facility Design Considerations

- Fire
  - High heat fluxes/smoke
  - Jet fire
- Liquid Spills (Dependent on topography)
- Explosion
  - Reflected pressure (overpressure)
  - Dynamic (drag) pressure
- Blast-induced ground motion
- Blast-generated missiles
- Flammable vapor cloud
- Explosion from vapor cloud
- Flash fire (deflagration)
- Toxic Chemicals

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Radioisotopes of concern and measurement techniques depend reactor design and on the heat transfer medium

- water-cooled
- gas-cooled
- molten salt fueled
- molten salt cooled
- liquid metal cooled
- heat-pipe energy transport

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Other Potential Issues

Return of chemically contaminated steam condensate from the industrial facility to the nuclear facility

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International Standards

- Define needed standards
  - Level of detail below IAEA Standards/Guidance
- Reconcile National Standards
- Top-down: develop ISO standards with IAEA input on priorities

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