Generic Risk Assessment & Siting Guidance

Flexible Plant Operations and Generation (FPOG)

March 19, 2025

0910 -0925 MST

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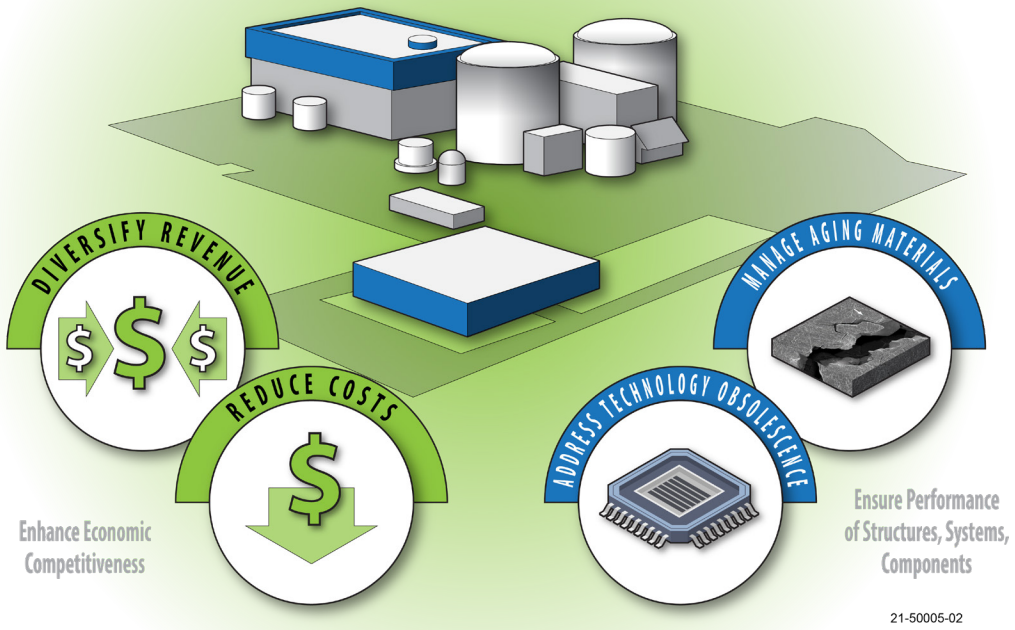
Meeting Purpose and Objectives

Purpose: Industry update on Industrial Process-NPP hazards analysis and separation distance research findings

- Related to research conducted by the Flexible Plant Operations and Generation Pathway (FPOG) on nuclear integrated hydrogen production.
- To inform future FPOG high temperature electrolysis (HTE) hydrogen integration research and to support LWRS and NRC collaboration.
- To inform future FPOG industrial process integration research and to support LWRS and NRC collaboration.



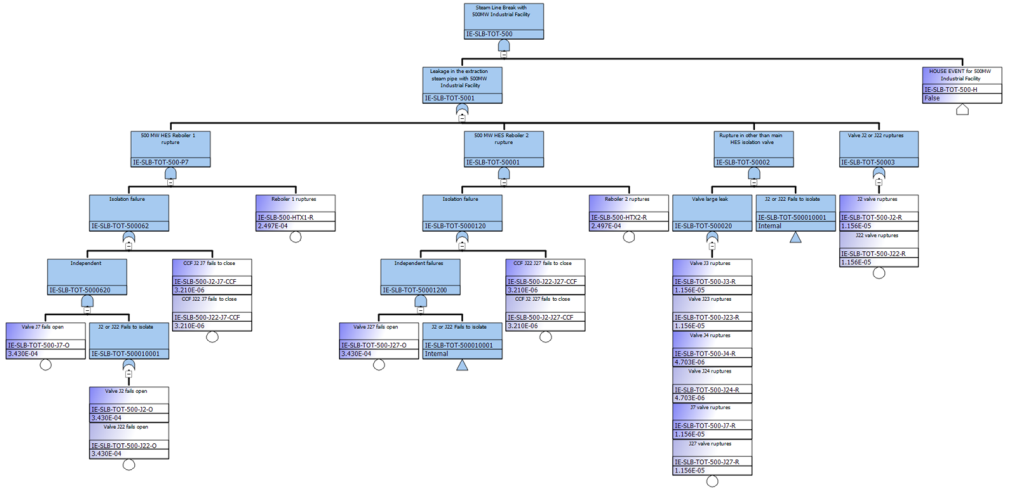
Deterministic Hazards Assessments of Industrial Customers

- Report INL/RPT-24-80742 performed hazards assessments on representative industrial customers offsite of an LWR.
  - Oil or chemical refinery
  - Methanol plant
  - Hydrogen plant
  - Wood pulp and paper mill

- Hazards assessments included:
  - Accidentology – what has gone wrong
  - Hazards Identification – what can go wrong
  - System level failure modes and effects analysis (FMEA)
    - Akin to a HazOps and HazID
  - Toolbox of existing assessment methodologies

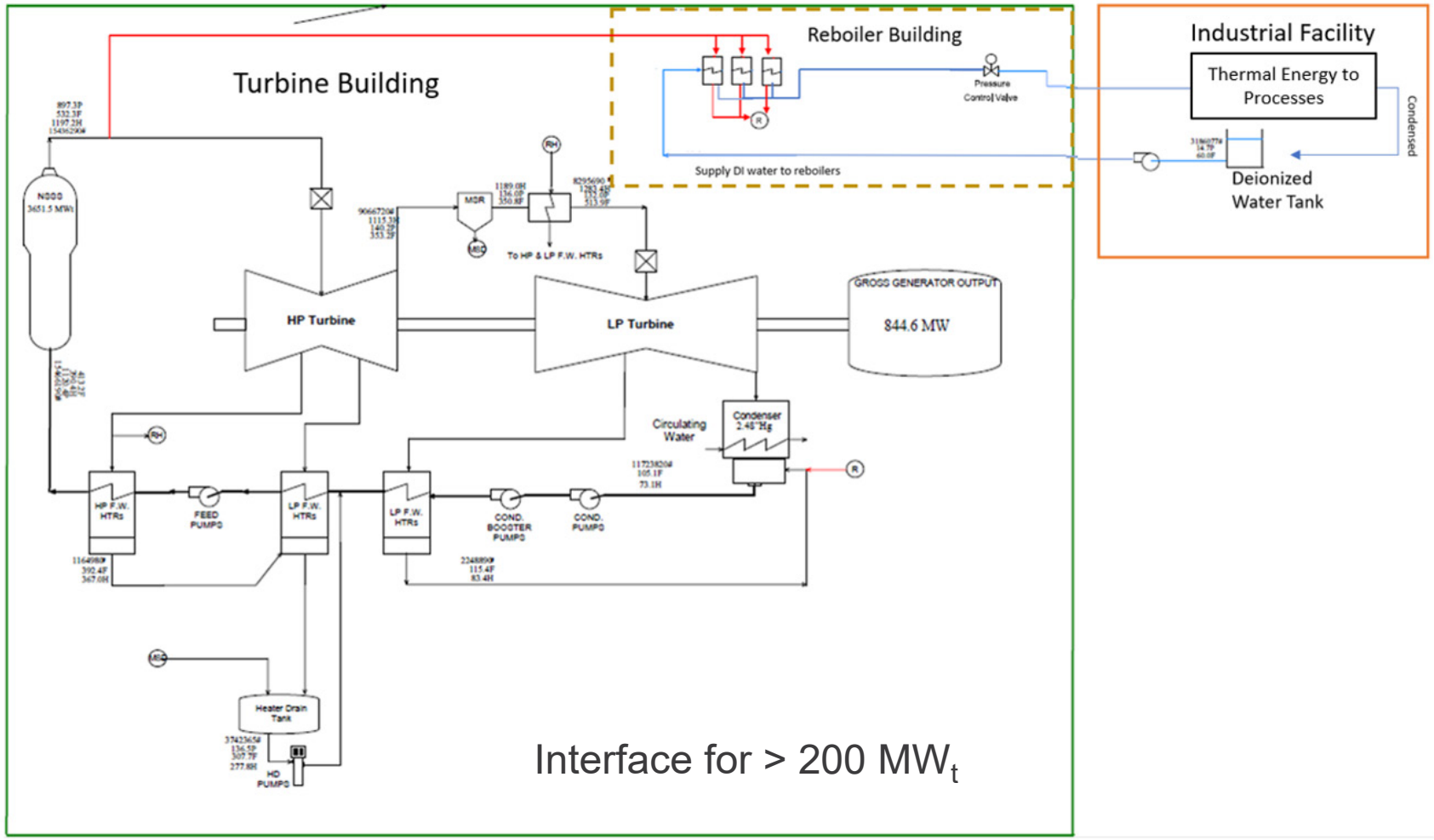
Nuclear Integrated Industrial Facilities Risk Results

- PRA
  - Initiating event (IE) frequency increases of internal events based on plant modifications are minimal
  - IE frequency of external events from the industrial customer facility must be limited by one or both:
    - Safe separation distance through siting
    - Engineered barriers



LWR Modifications for Customer Steam Delivery (PRA)

- Thermal Extraction Safety
  - Internal IE frequency increases of internal events
    - Steam line break (MSLB)
    - Can tap steam off of cold reheat for <200 MW_t
  - Insignificant increases in IE MSLB @ 7.7% max of all the cases we studied.



External Event Hazards to LWR from Customer Facilities (Deterministic)

- Overpressure
  - Detonation *
  - Deflagration *
  - Vapor Cloud Explosion
  - Boiling Liquid Expanding Vapor Explosion (BLEVE)
- Heat Flux
  - Jet Fire *
  - Pool Fire
  - Fire Ball
- Toxicity
  - Chemical Effects
  - Asphyxiant
- Non-Toxic Pollutants
  - e.g., Spillage that fouls shared water source intakes
- The hazards are well-defined by customers
  - Each industry has accepted methodologies for evaluation and mitigation
- All on-site and off-site hazard assessment methodologies must be resolved within the NRC's accepted methodologies and mitigations for impacts on NPP SSCs

* Applicable to Hydrogen Production

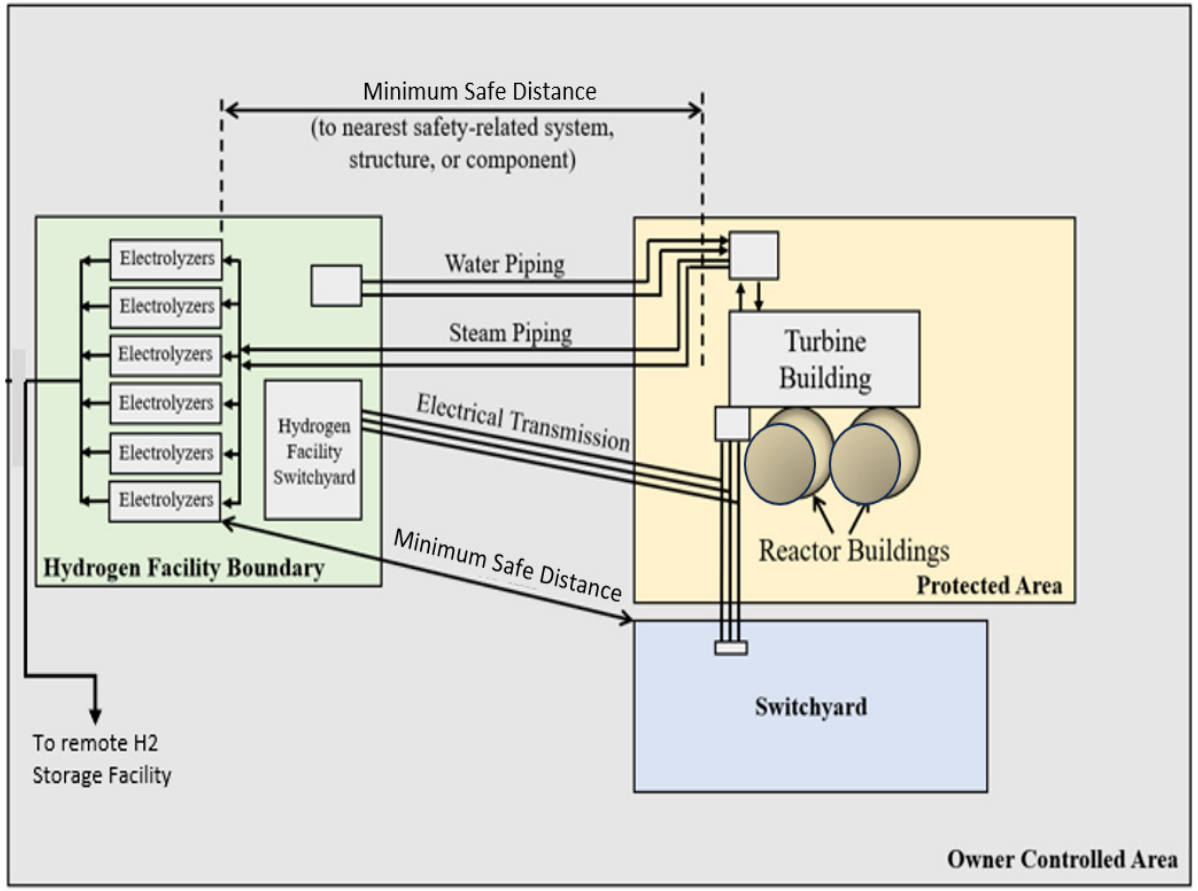
Generic Nuclear Integrated Hydrogen Plant Layout

Reference Nuclear Plant

- Westinghouse 4-loop PWR
  - 1200MW$_e$ / 3,700MW$_{th}$ / SWYD: 345kV
  - Typical for 1/3 of operating US NPP Units
- New Hydrogen Steam/Water Supply
- New Behind the Meter Electric

High Temp Electrolysis (HTE) Facility

- 500MW$_{DC}$
- Thermal Load – 100MW$_{th}$
- Hydrogen Production
  - 300 tons/day @ 1500 psi

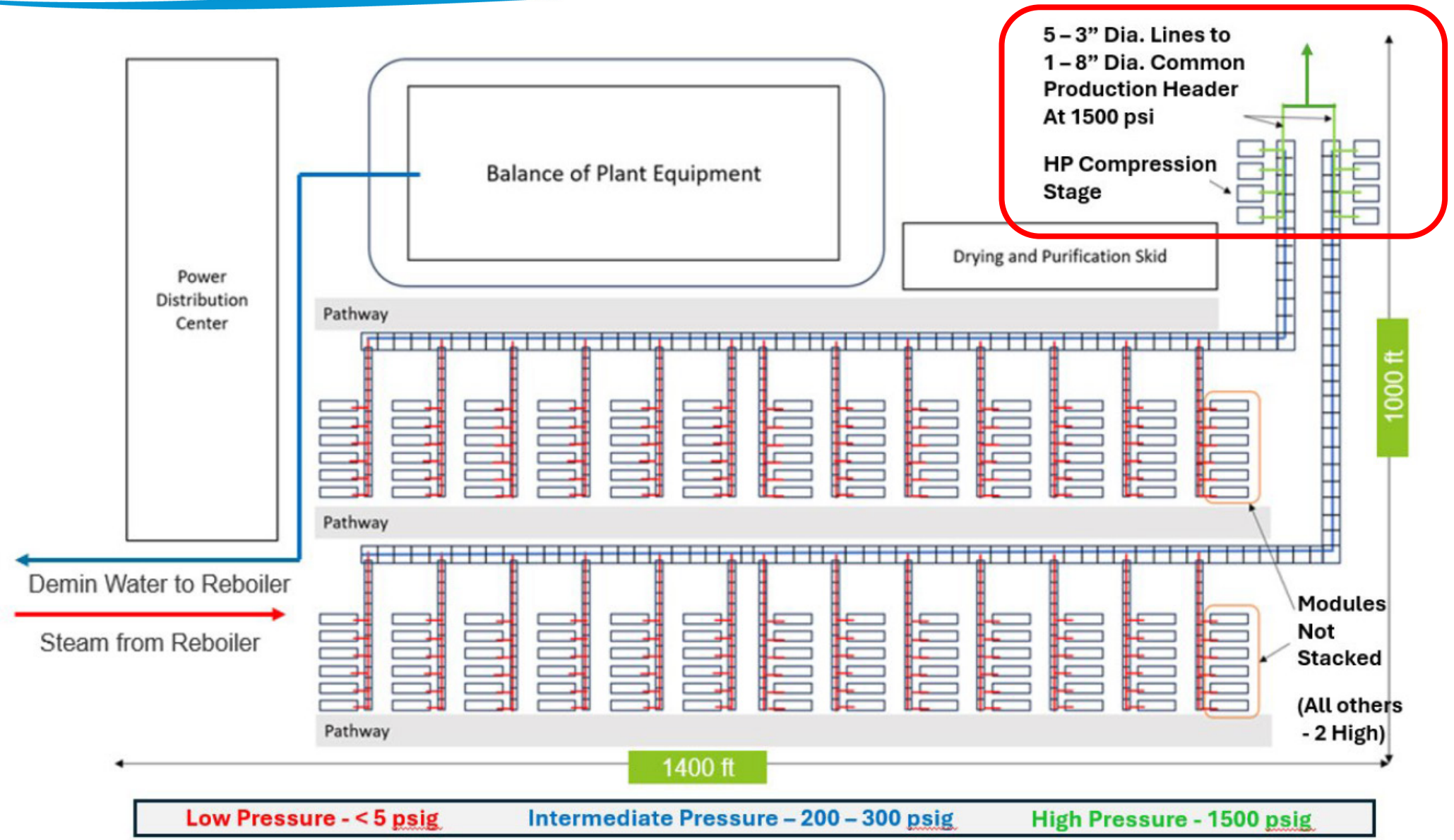


Hazards of Hydrogen vs Other Industrial Facilities

- Hydrogen is relatively benign and a good candidate for placement inside the NPP owner-controlled area (OCA)
  - Fire protection NFPA codes dictate placement within the OCA under Fire Protection Engineering Evaluation

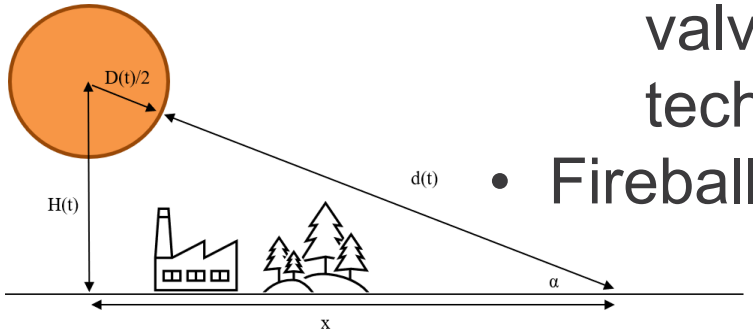
- Hazards at other industrial facilities are outside the OCA
  - Each industry has accepted methodologies for evaluation and mitigation
    - Chemical-specific methodologies are often used.
      - e.g., heavy hydrocarbons are not evaluated for their full TNT equivalence due to their low vapor pressure
    - Safe siting distance and/or engineered barriers are used for mitigation

Example 500 MW_{DC} Hydrogen Facility



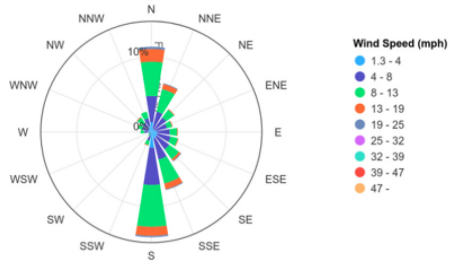
Hazards Toolbox For All Industrial Processes

- Report INL/RPT-24-80742 explored existing methodologies for common industrial hazards
  - Vapor cloud dispersion analysis for toxic and/or explosive mixtures
  - Blast analysis other than hydrogen-specific methods
  - Blast mitigation strategies
    - Barriers, explosive isolation valves, suppression techniques
  - Fireball heat flux analysis



Fireball Diagram

Combination SynGas Toxic Cloud and HTEF Overpressure Analysis



10-year Wind Rose for Generic River Site

Siting Considerations

- Report INL/RPT-24-80742 listed siting considerations for safety
  - Safe siting distance is a primary defense to hazards presented by the customer facility and other local hazards

- Report INL/RPT-23-74311 lists considerations other than safety
  - Adherence to environmental protections
    - Local laws, codes, and zoning
  - Economic considerations
    - Long runs of steam piping cost more to build
  - Performance considerations
    - Steam quality may be affected

Preliminary Research Conclusions

- PRA and Deterministic Risk Assessments
  - Initiating event (IE) frequency increases of internal events based on required plant modifications are minimal and support 10 CFR 50.59
  - IE frequency of external events must be limited by safe separation distance through siting distance and/or engineered barriers
  - Industry accepted hazards analysis tools from specific industries will be petitioned for use to meet codes and guidance by the NRC.
- Siting the Customer Facility
  - Siting for safety
    - Determined by customer facility hazards
    - Determined by other local hazards
  - Siting for economics
    - Local zoning, geography, laws, codes
    - Costs associated with required long runs
      - Thermal losses, construction cost increases

Future Research Potential

- Probabilistic Risk Assessments
  - Leverage generation risk assessment research for advanced reactors and apply to LWRs
    - Assesses the customer's energy supply risk based on maintenance and random events and their times to recovery
    - Expand beyond static GRA to use dynamic PRA with static PRA inputs
    - Can be used as an input to economic risk
- Siting
  - Leverage FY25 work in advanced reactor siting methodologies
    - EPRI and STAND methodologies with some further suggestions.

Sustaining National Nuclear Assets

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