NUCLEAR ENABLED HYDROGEN CO-GENERATION: SAFETY AND REGULATORY INSIGHT

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NATIONAL NUCLEAR LABORATORY

Introduction

Radiological and Chemical Hazards assessors at UK National Nuclear Laboratory (NNL).

We work across all aspects of the nuclear project lifecycle including fuel enrichment, production, and reprocessing facilities throughout the UK and internationally.

Historically, our background has mainly been fuel manufacture, which involves significant quantities of high hazard chemical including hydrogen and hydrofluoric acid.

More recently working on Small Modular Reactors, Advanced Modular Reactors and on Co-Generation safety, with particular emphasis on hydrogen/chemical production. This forms the basis of this presentation.

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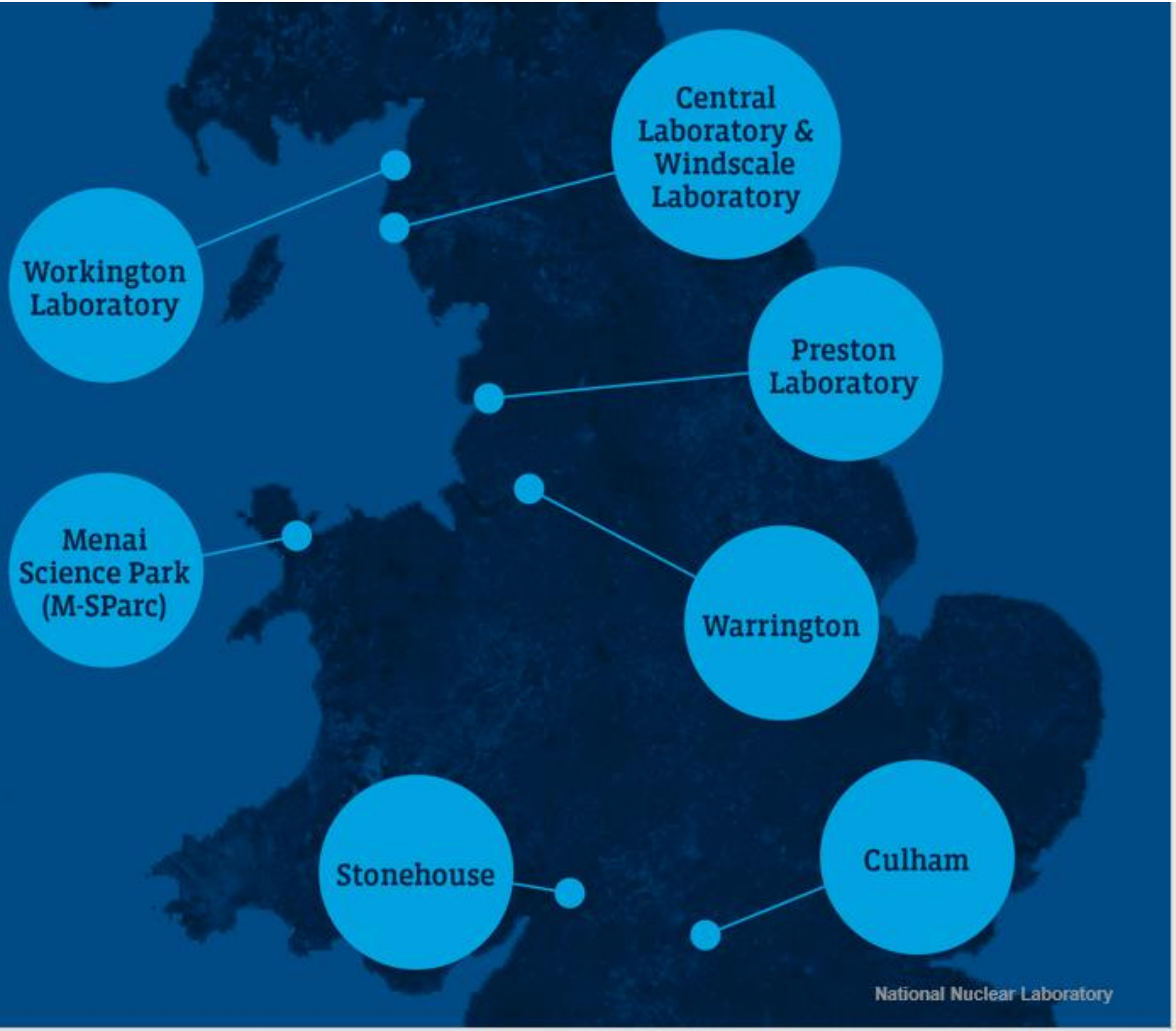
World-leading facilities

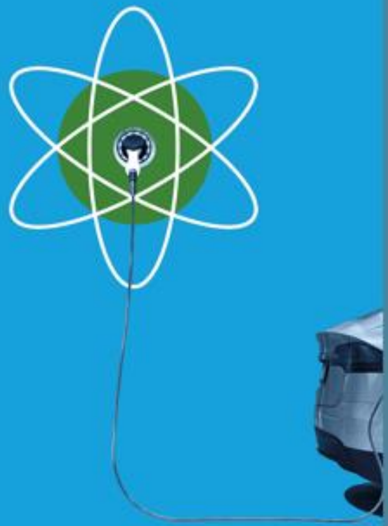
£1.5bn

the value of the nuclear facilities we manage



Four Focus Areas

Clean Energy



Environmental Restoration

Health and Nuclear Medicine

Security and Non-Proliferation

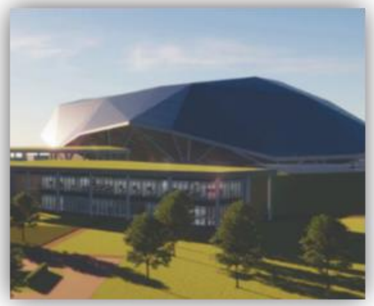
Nuclear Power and Co-Generation in United Kingdom

A massive revival of nuclear power is underway, placing the UK at the forefront of a global race to develop cutting-edge technologies to rapidly deliver cleaner, cheaper, more secure energy.

- Construction of first new nuclear power plant in many years is underway at Hinkley Point C.
- Development of Small Modular Reactors (SMRs), which can be constructed in factories.
- Funding for the further development and design of a type of Advanced Modular Reactor (AMR) and next generation fuel.

AMRs operate at a higher temperature than SMRs and as a result they could provide high temperature heat for hydrogen and other industrial uses alongside nuclear power.

The aspiration is to locate these new reactor types in proximity to industrial hubs, and population centres.



UK Hydrogen Policy

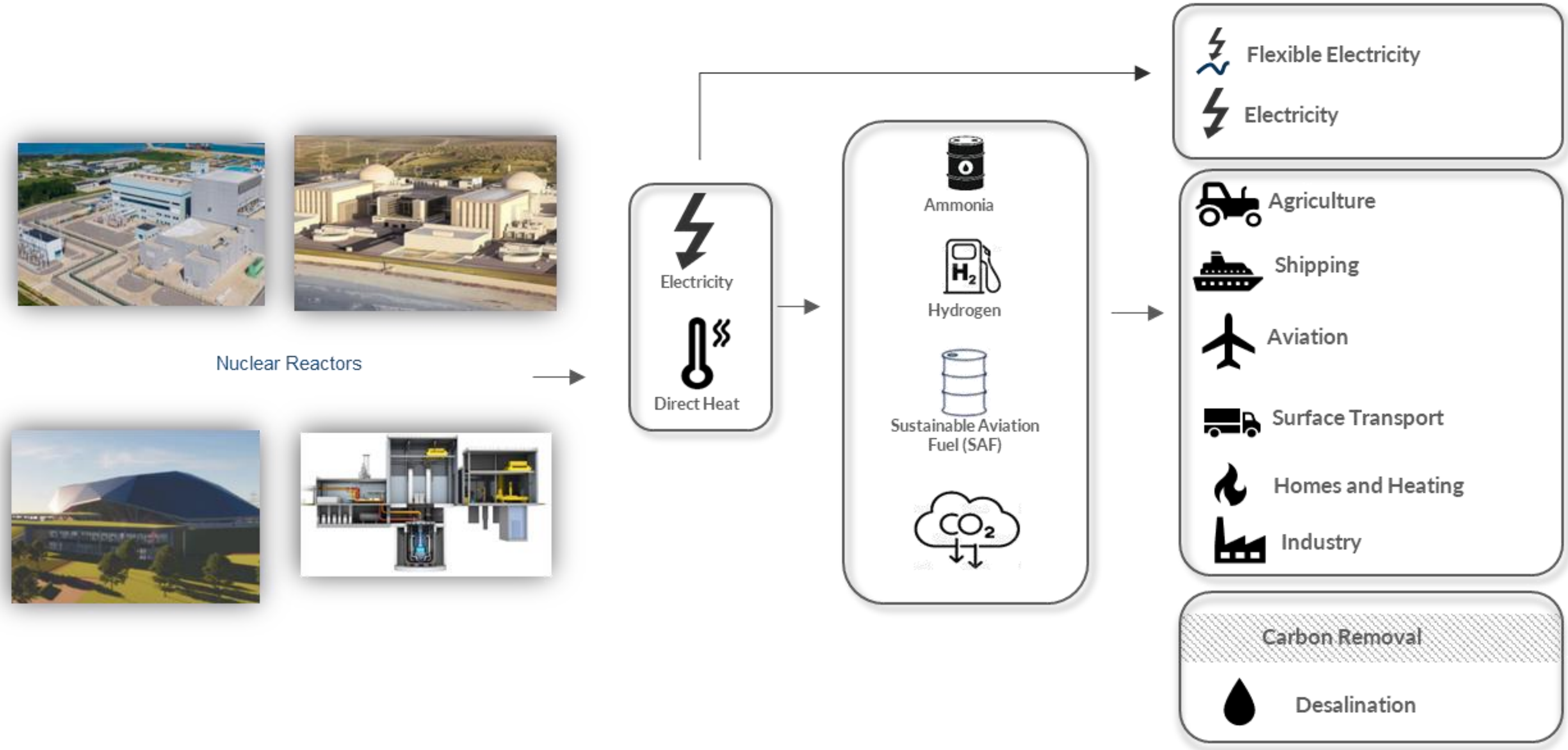
UK Government has expressed commitment to developing the UK's low carbon hydrogen economy

Hydrogen is considered critical to delivering energy security and decarbonisation targets and presents a significant growth opportunity.

It can play a pivotal role in the transition to a future based on renewable and nuclear energy while ensuring that natural gas used during this transition is from reliable sources including from North Sea production.

Can provide clean energy for a variety of uses.

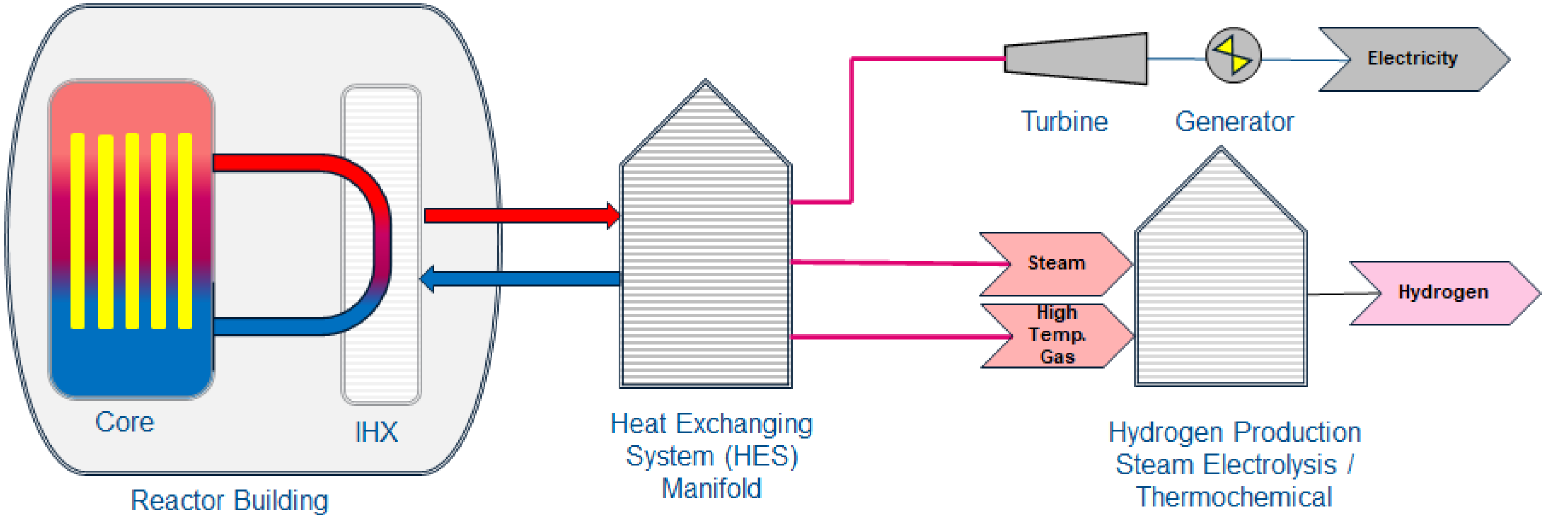
Nuclear Energy: Beyond Electricity and In Policy



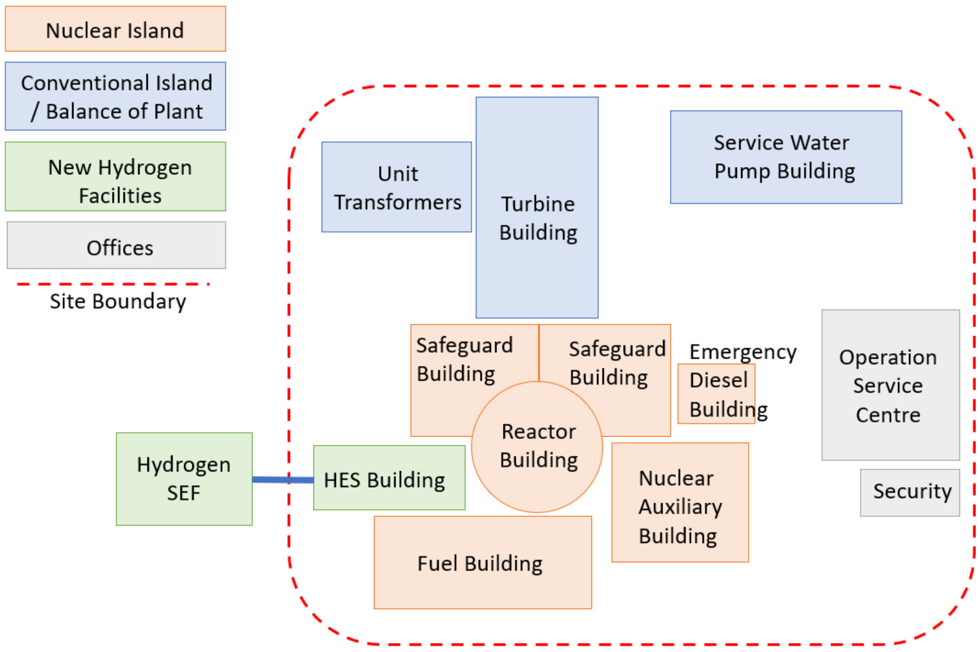
Co-Generation Nuclear Facility

What would a Co-Generation Nuclear Facility Look Like?

- Co-generation is a way to use a single source of energy efficiently to produce power and useful thermal energy
- Use rejected heat for the second production plant
- Wasted energy to produce useful outputs such as direct heating and/or production of hydrogen
- High temperature steam, i.e. > 300 to 1000 °C, to drive efficiency and greater yields of hydrogen



Nuclear Co-Generation and Siting

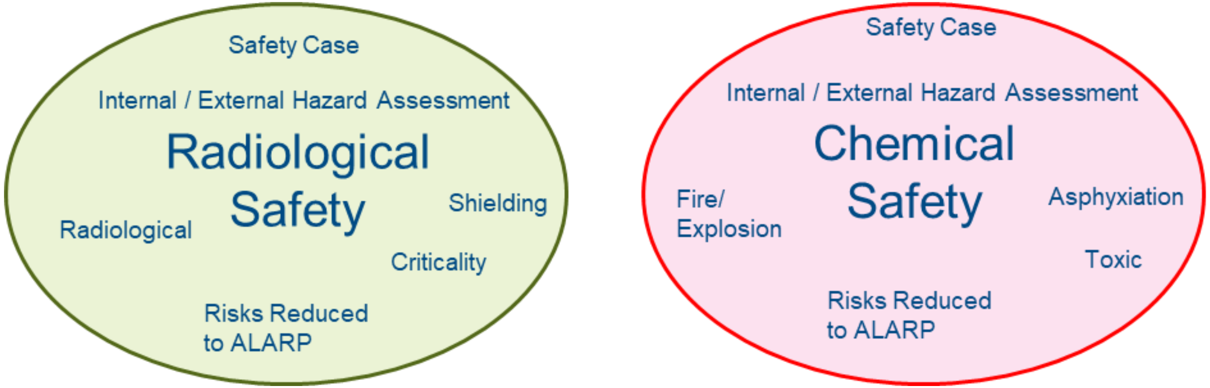


Initial engagement with nuclear regulators has identified significant benefits in locating hydrogen production outside of nuclear site boundary:

- Easier modification
- Reduced deployment/ decommissioning costs

Remains requirement to consider potential for impact upon adjacent nuclear site.

Nuclear Derived Hydrogen Safety



Radiological Safety - Legal Requirements – Regulations, Standards and Guidance

Radiological Safety

IAEA Safety Standards and Guidance;

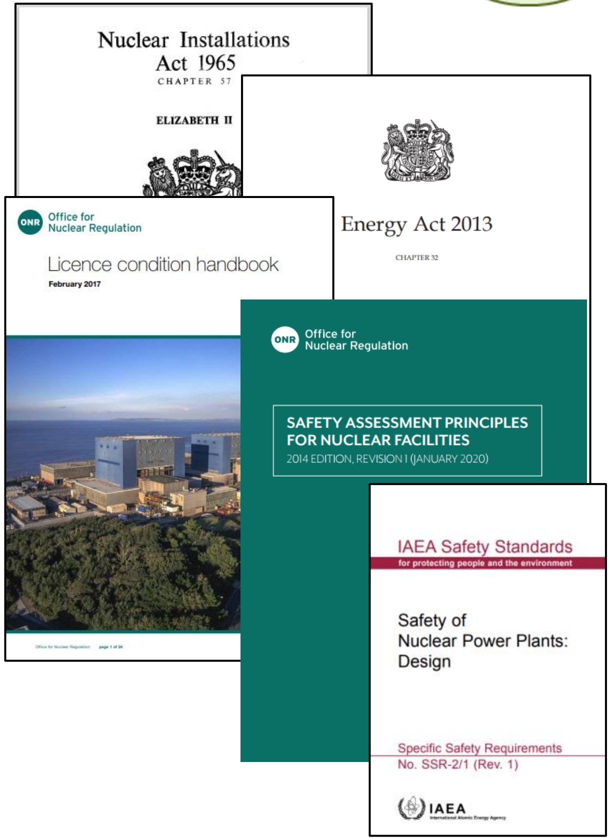
UK laws: **Nuclear Installations Act**, **Health and Safety at Work etc. Act** and **Energy Act**.

Office for Nuclear Regulation (ONR): Nuclear License Conditions (LCs), Safety Assessment Principles (SAPs) and Technical Assessment Guides (TAGs).

Other Regulations:

- The Ionising Radiations Regulations (IRR),
- The Radiation (Emergency Preparedness and Public Information) Regulations (REPPIR),

A fundamental requirement cited in UK legislation is that risks be reduced to **ALARP**. This principle provides a requirement to implement proportionate measures to reduce risk where doing so is reasonable.



Safety Designations to Meet Safety Requirements

- Identify Safety Functions necessary to achieve safety objectives, protecting people and the environment from harmful effects of ionising radiation:
    - **Control of Reactivity,**
    - **Residual Heat Removal,**
    - **Confinement of Radioactive Materials.**
- Safety Functions to be delivered within a nuclear facility, both in normal operation and in fault / accident conditions, should be categorised in a graded manner based on their significance to Nuclear Safety to include consideration of Defence in Depth (DiD).
- A typical graded DiD approach involves:
    - High consequence, high frequency events, requiring two high integrity measures.
    - Low consequence events, requiring one lower integrity measure.
- **The ONR permissions key activities through the licensee Safety Case**.

Hazard Assessment and Risk Targets

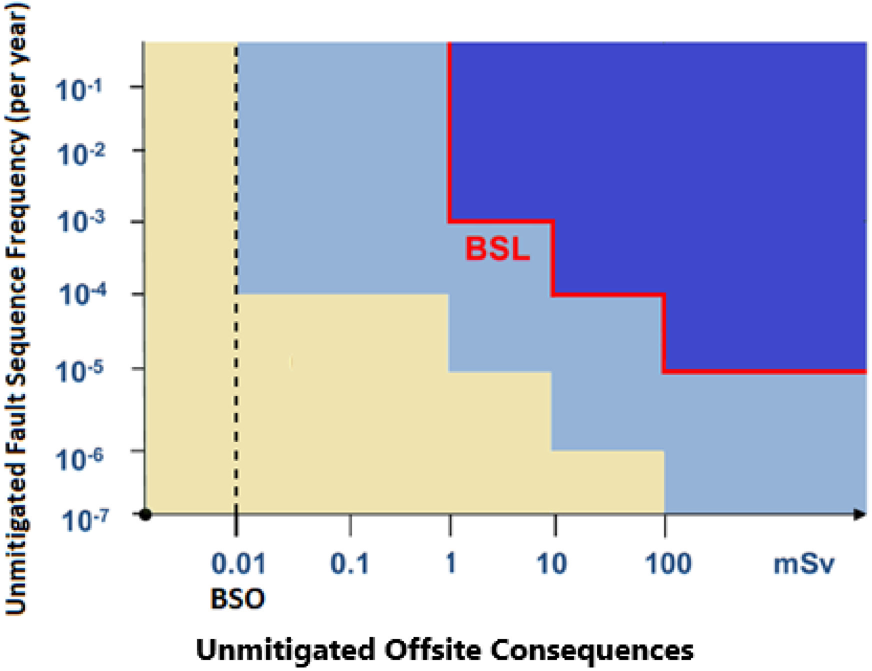
Radiological Safety

Hazard Assessment (deterministic & probabilistic) is undertaken to understand the radiological consequences and initiating event frequency for postulated faults & hazards.

These are compared to numerical targets in the SAPs for the:

- BSO: Basic Safety Objective
- BSL: Basic Safety Limit

Application of graded approach to safety and categorisation of equipment to reduce risk.

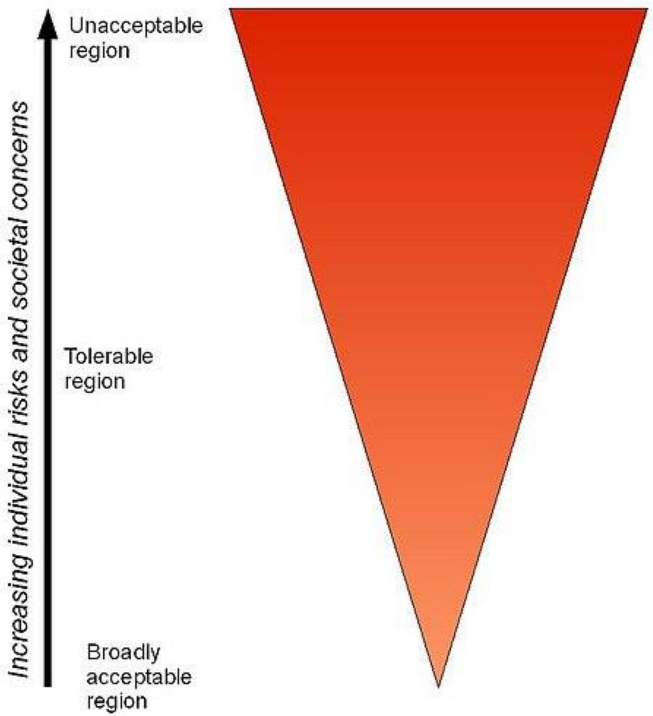


Note, the example for onsite, however, similar approach to onsite consequences.

As Low As Reasonably Practicable (ALARP)

Radiological Safety

- The BSLs / BSOs translate the Tolerability of Risk framework
- A new facility or activity should at least meet the BSLs
- Even if the BSLs are met, the risks may not be ALARP
- The designer / duty holder must reduce the risks until it is no longer appropriate to do so, applying the legal test of gross disproportion
- Duty holder should implement measures until any further improvements are grossly disproportionate to reduction in risk



Assessment Approach

Radiological Safety

Identify Hazards → Identify Hazard Management Strategies → Determine consequence(s) → Identification of safety measures → Comparison with Criteria → Comparison with ALARP

Chemical Hazards

Considerations of the following non-radiological hazards:

Toxic (Inhalation / Skin), Explosion, Asphyxiation.
Commonly referred to as chemotoxic in the nuclear industry

Legal Requirements and Regulations (overlap with those for radiological safety):

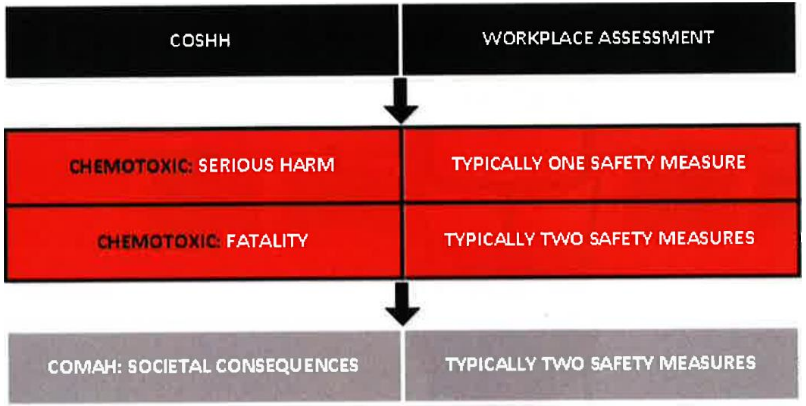
- Health and Safety at Work Act etc.
- The Classification, Labelling and Packing of Chemicals Regulations
- Control of Substances Hazardous to Health (COSHH) Regulations
- The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)
- Confined Space Regulations
- The Control of Major Accident Hazards (COMAH) Regulations

Regulated by HSE usually, but ONR undertake this responsibility for a nuclear licensed site.

Springfields site was the first nuclear site to produce COMAH case in the UK.

Assessment of Chemical Hazards

- Demonstrate that hazards presenting **harm to health**, **physical harm** or **asphyxiation** can be safely **managed** and the **risk** is **reduced to ALARP**.
- Hazards are identified in a **structured** and **systematic** way (e.g. HAZard and OPerability HAZOP studies) and Hazard Management Strategies (HMS) identified to prevent or adequately manage them. Based on severity (i.e. unmitigated consequences and initiating event frequency).
- Safety Measures assigned which are proportional to risk.



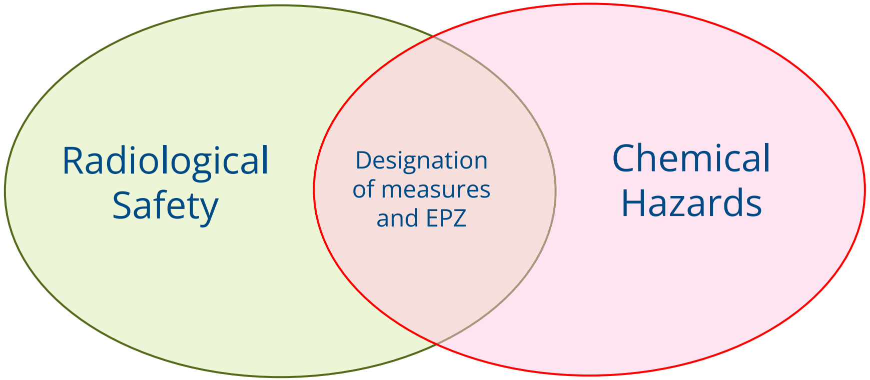
Hierarchical approach to safety measures, which eliminate or minimise the exposure to hazards where possible.

Reconciliation of Measures

COMAH and The Radiation (Emergency Preparedness and Public Information) Regulations both assign **Emergency Planning Zones (EPZ)** based on nature and consequence of the hazard.

Can be conflicting needs (e.g. chemical requires dispersion and radiological requires confinement).

Clear overlap in the approach for radiological safety and treatment of chemical hazards.

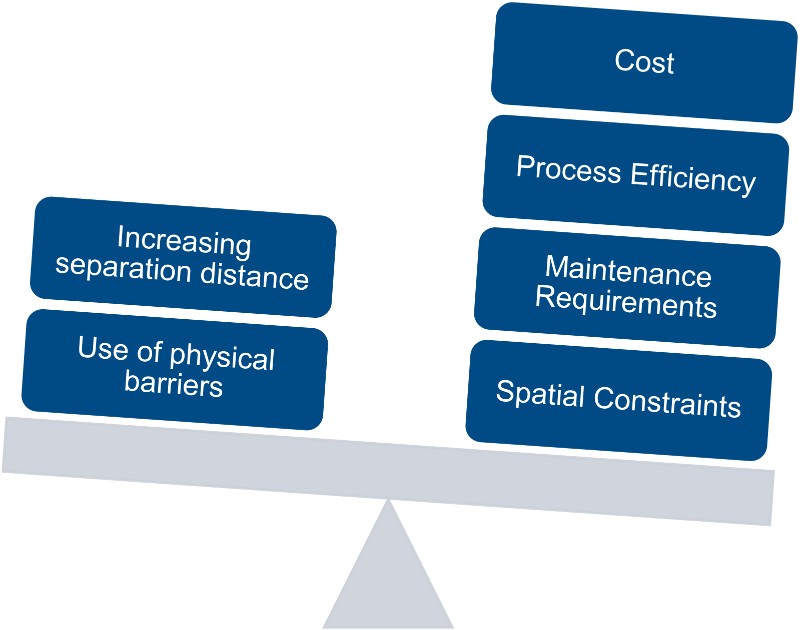


Nuclear Co-Generation Considerations

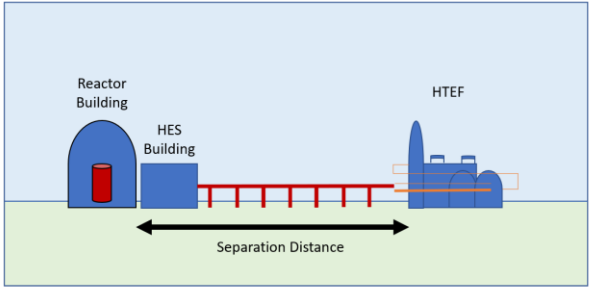
Co-Generation Risk Reduction Strategies

Safety against the consequences from an explosion and chemical release hazard can generally be reduced by:

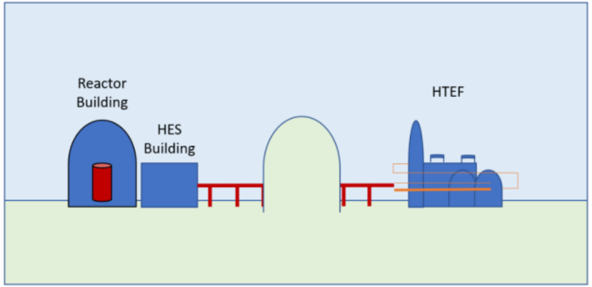
But there can be disadvantages:



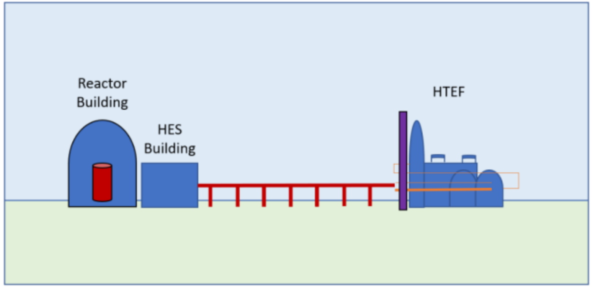
Potential Design Strategies to Reduce Risk to Nuclear Island Buildings



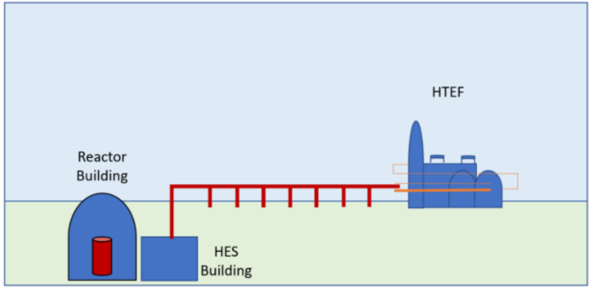
Increase separation distance between the reactor and electrolysis facility



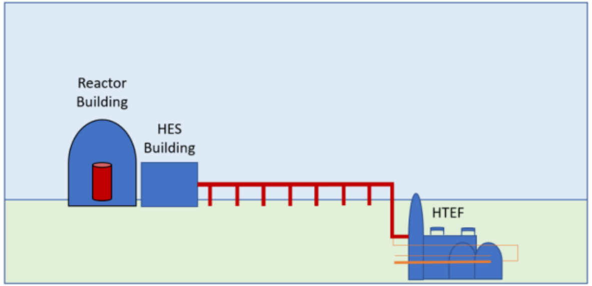
Introducing a raised land barrier between the facilities



Introducing blast panelling near the facilities

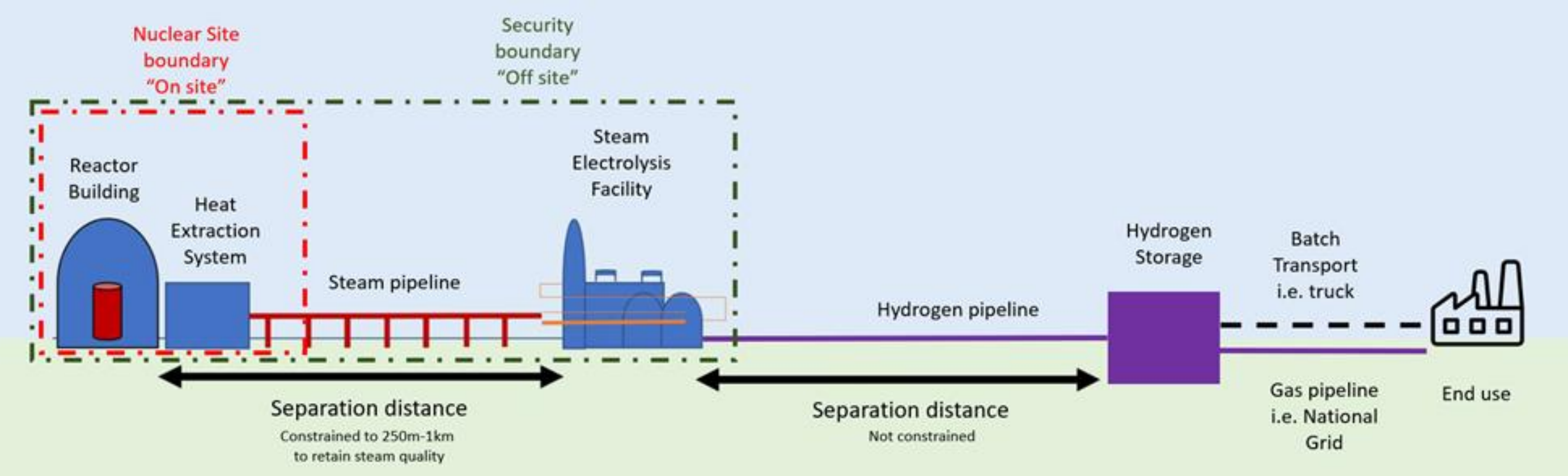


Constructing the nuclear reactor and associated safety equipment underground



Constructing the electrolysis facility underground

Route to Construction for Co-Generation



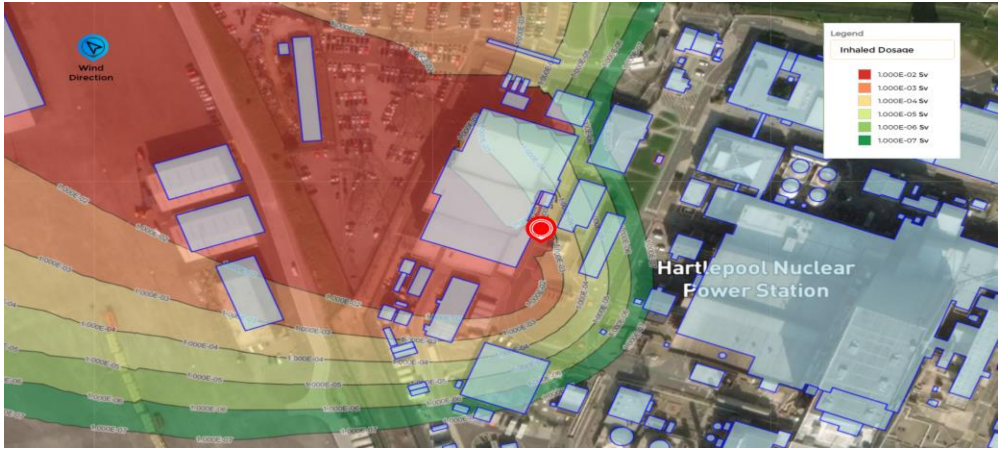
- Heat extraction system remains in the nuclear site boundary
- Limited distance to maintain high temperature steam quality
- Electrolysis facility is off the nuclear site boundary but within the security boundary
- Separations distance from nuclear island reduces risk
- Hydrogen is transported away to an off-site storage facility, keeping physical quantity by nuclear site low
- National gas transmission network transports around the country to where it is required

Developments in Dispersion Modelling

Accurate dispersion modelling allows consideration of radiological and chemical consequences arising from an incident.

This includes consideration of concurrent releases and consequential releases.

Working alongside RiskAware Limited to develop new capability.



See ‘Dynamic Dispersion Modelling to Enable Informed Decision Making in Modern Nuclear Safety Cases’ ATW International Journal for Nuclear Power Issue 04/23. H. Chapman, S. Lawton, J. Hargreaves. et. al. https://www.yumpu.com/de/embed/view/QrE0f6iT3vdtFc98

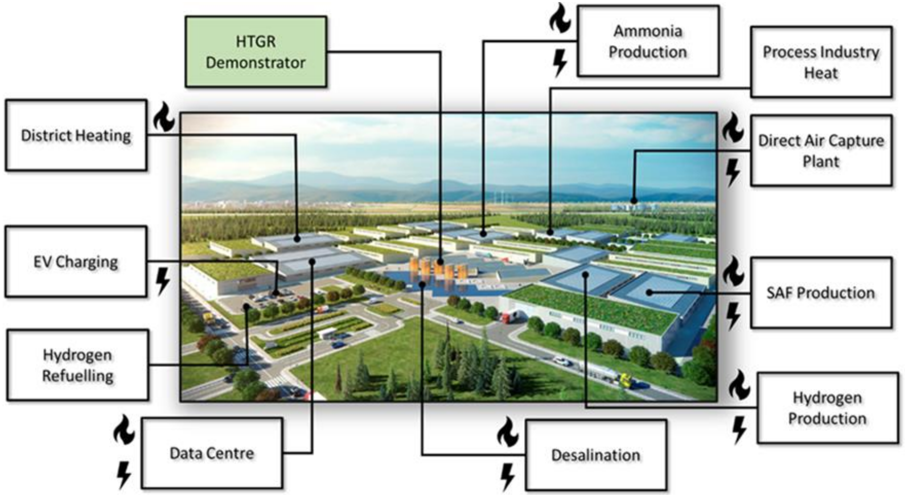
Conclusion

Generation of hydrogen from a nuclear energy source is not likely to introduce a disproportionate level of risk to the nuclear site.

Existing capabilities and methodologies are available to assess and manage the risk.

Demonstrating the safe operation of hydrogen production technologies at a nuclear licensed site will be key to enabling the deployment and successful deployment of nuclear enabled hydrogen.

Advances in dispersion modelling allow accurate modelling of releases, consideration of combined hazards and facilitate stakeholder engagement.



Thank you

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