This research is funded by the European Union
(EIC, Pathfinder Programme, G.A. 101046937)

Deep U-tube heat exchanger breakthrough: combining laser and cryogenic gas for geothermal energy exploitation

Regulatory, Environmental & Health & Safety

Deep U Final Conference

EGC2025 – Zurich Convention Centre

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www.deepu.eu

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Outline

- Legislative and Regulatory Processes around Drilling
- Assessment of DeepU Processes
- Considerations of Environmental Impacts at drill sites
- How the conventional drilling regulatory system compares with innovative drilling technologies
- Recommendations for Technology development

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Legislation, Regulation & Standards

Aspects Considered:

- What is unique or novel about DeepU from the perspective of a regulator?
- What are the fundamental EHS risk management principles that will frame how a regulator will view the technology?
- What are representative examples of existing regulatory processes and at what point in the process could there be a misfit of DeepU technologies and the requirements?
- What would be the requirements if the technology was deployed?
- What are the consequences for project delivery in a real-world scenario that may need to be mitigated?

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Legislation, Regulation & Standards

DeepU Critical Elements

- Technology deployment and standards compliance challenges

Legislation & Regulation Principles

- Determine High Level Compliance Challenges

Existing Market Example

- EU regulatory and legislative overview on deep Drilling

Deep U Recommendations

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Legislation, Regulation & Standards

DeepU Challenges:

- Use of an industrial laser in an uncontrolled and/or changing operational environment.
- Cryogenic fluid as part of the drilling process gas to flush cuttings out of the wellbore
- Deep drilling (>4km) and maintain hole integrity over the life-time of the project with limited casing or external material applied to the wellbore wall
- Integration of new technologies with established exploration and formation evaluation practises, existing drilling equipment, practises and skill sets to ensure widespread deployment in a commercial manner.

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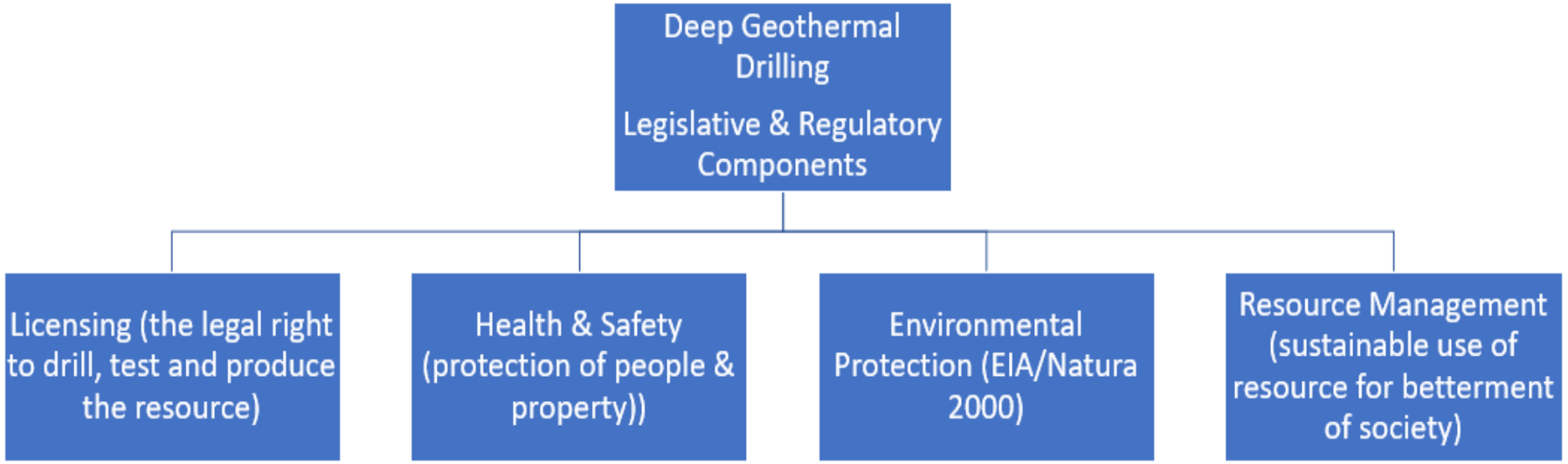
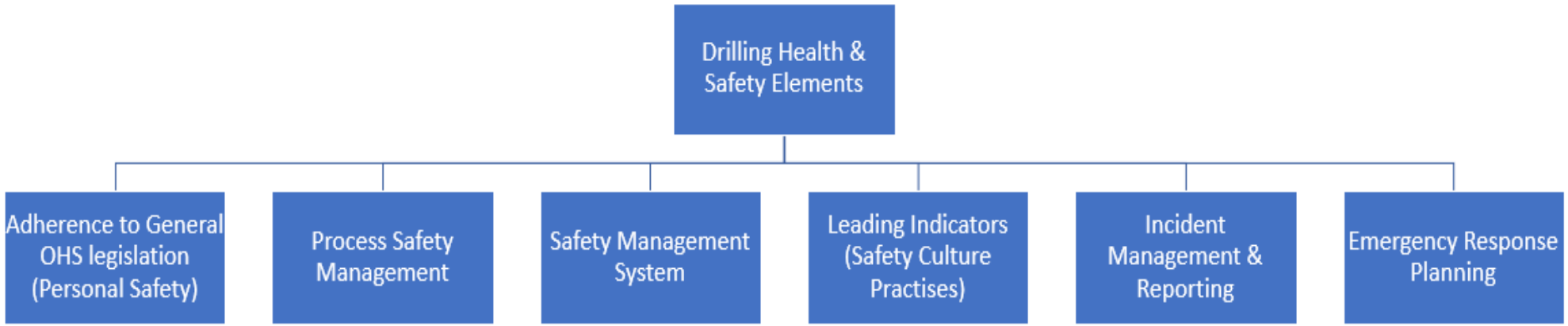
Legislation, Regulation & Standards

- Fundamentals of Drilling Legislation and Regulation



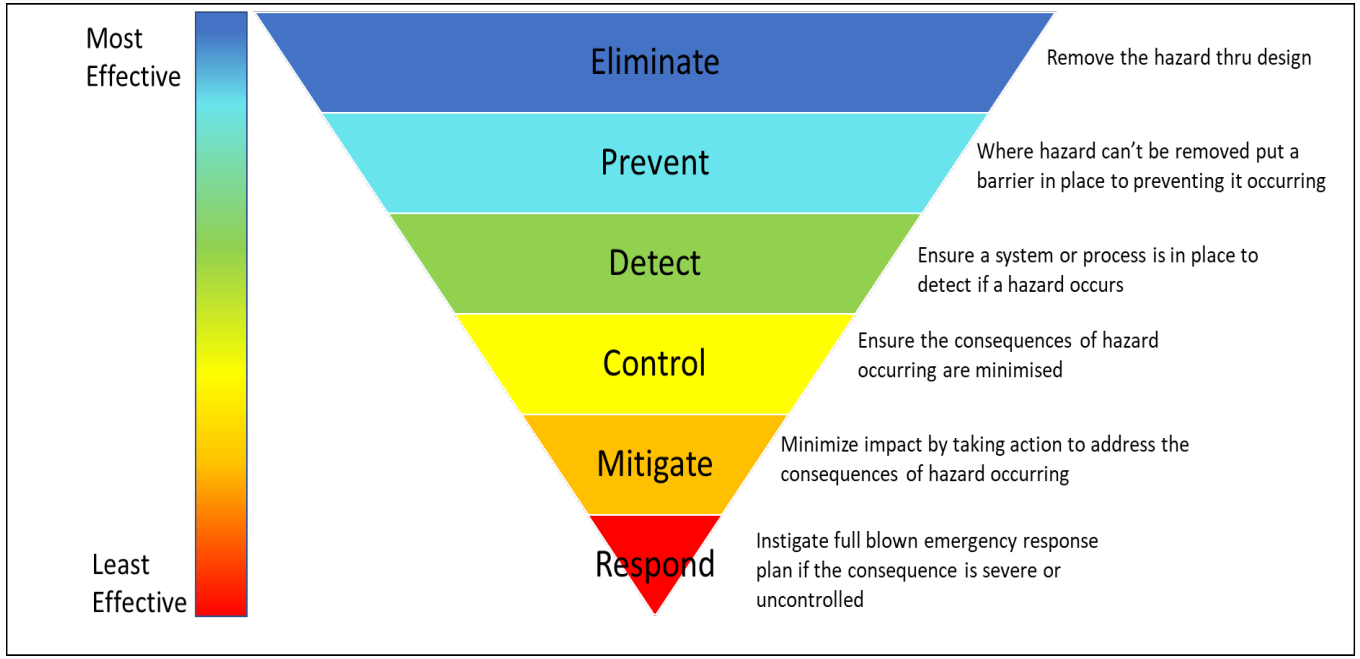
Legislation, Regulation & Standards

- Health & Safety elements with respect to Deep Drilling Legislation, Regulation & Standards



Legislation, Regulation & Standards

- Hierarchy of Controls in Process Safety Management



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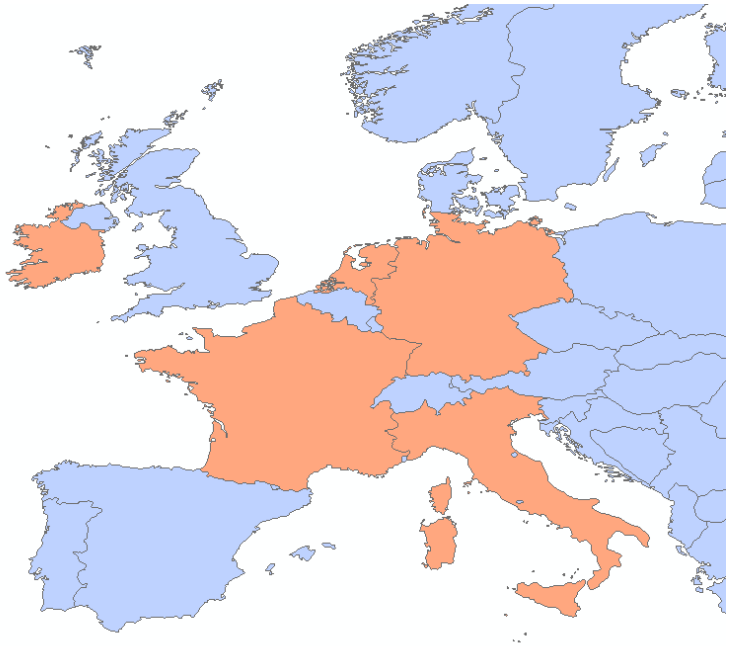
Legislation, Regulation & Standards

- Analysis of Several Jurisdictions in Europe as examples of the licensing system:
  - Ireland
  - Italy
  - France
  - Germany
  - The Netherlands



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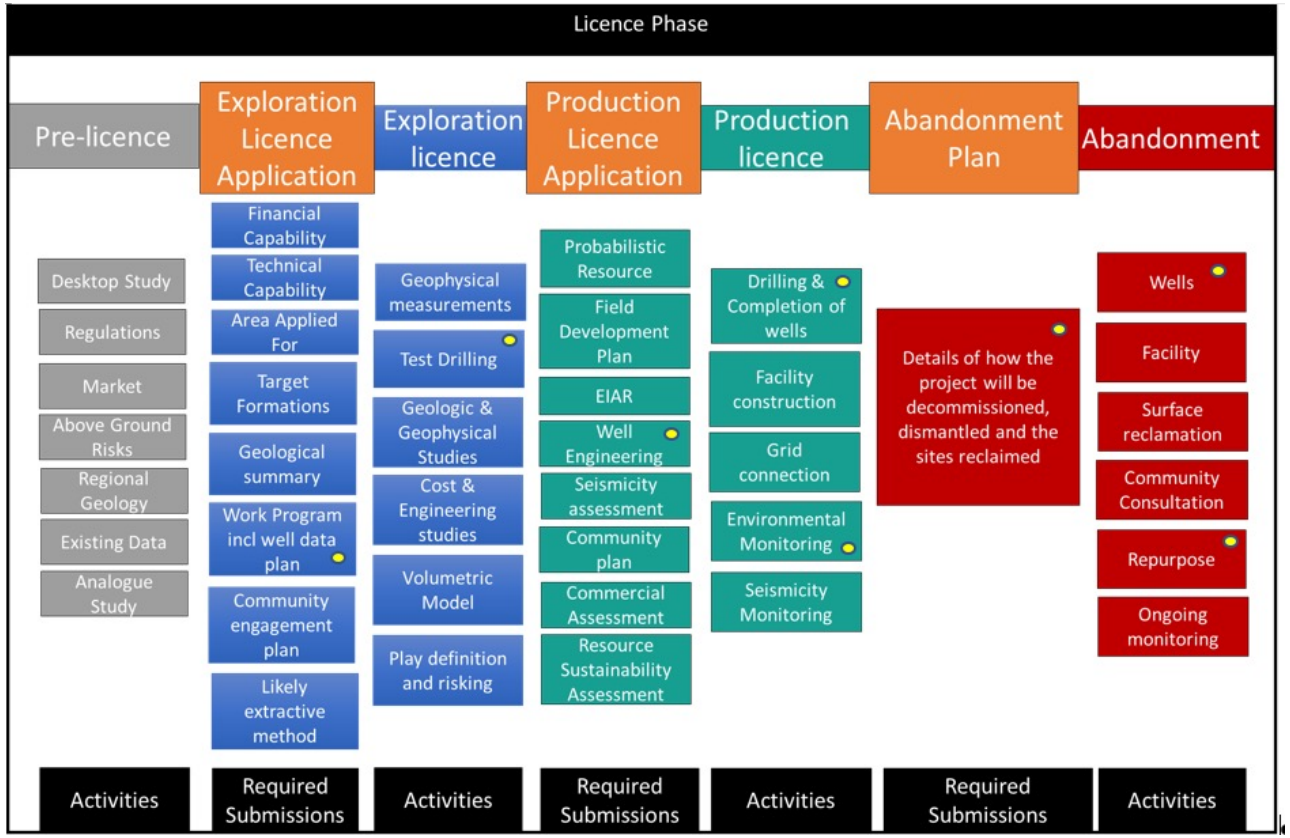
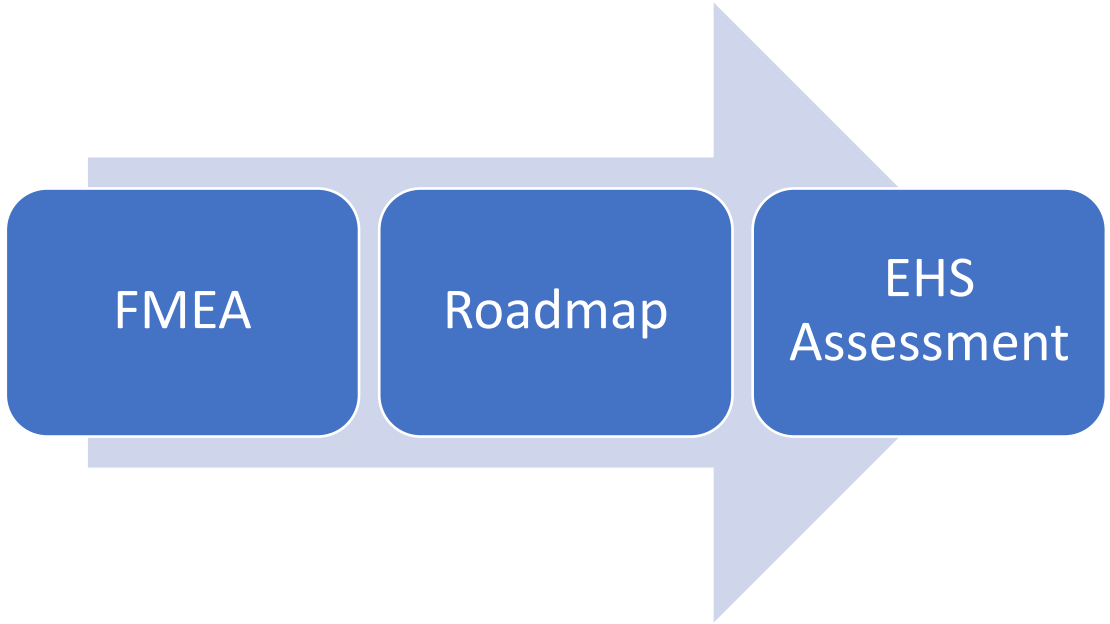
Legislation, Regulation & Standards

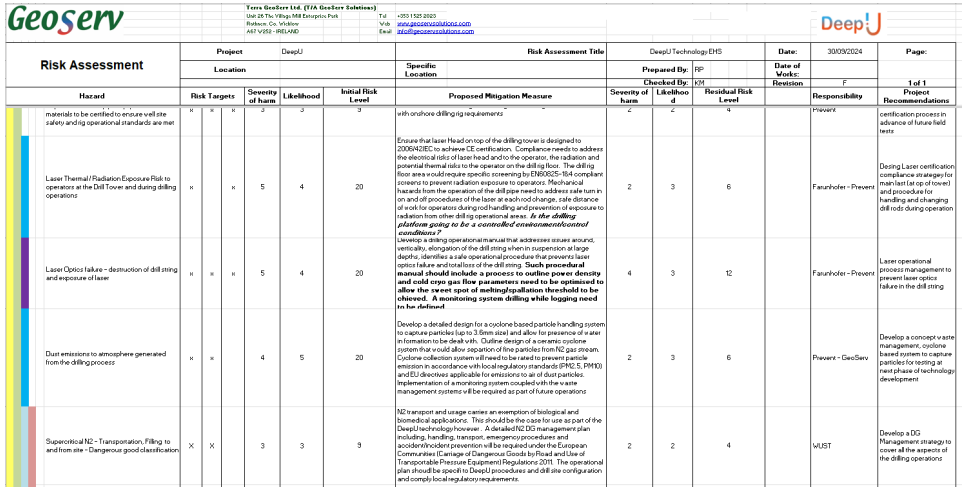
- Generalised Summary of the main licensing process
- Yellow dots highlight topics for DeepU technology requirement



EHS Evaluation

- 3 Main tools Used to Complete EHS Evaluation





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DeepU

Risk Assessment	Project	DeepU	Risk Assessment Title	DeepU Technology EHS	Date:	30/09/2024	Page:
	Location		Specific Location	Prepared By: RP	Date of Works:		
				Checked By: KM	Revision	F	1 of 1

Hazard	Risk Targets			Severity of harm	Likelihood	Initial Risk Level	Proposed Mitigation Measure	Severity of harm	Likelihood	Residual Risk Level		Responsibility	Project Recommendations
materials to be certified to ensure well site safety and rig operational standards are met	x	x	x	3	3	9	with onshore drilling rig requirements	2	2	4		Prevent	certification process in advance of future field tests
Laser Thermal / Radiation Exposure Risk to operators at the Drill Tower and during drilling operations	x		x	5	4	20	Ensure that laser Head on top of the drilling tower is designed to 2006/42/EC to achieve CE certification. Compliance needs to address the electrical risks of laser head and to the operator, the radiation and potential thermal risks to the operator on the drilling floor. The drilling floor area would require specific screening by EN60825-1:14 compliant screens to prevent radiation exposure to operators. Mechanical hazards from the operation of the drill pipe need to address safe turn in on and off procedures of the laser at each rod change, safe distance of work for operators during rod handling and prevention of exposure to radiation from other drilling operational areas. ***Is the drilling platform going to be a controlled environment/control conditions ?***	2	3	6		Faunhofer – Prevent	Desing Laser certification compliance strategey for main last (at op of tower) and procedure for handling and changing drill rods during operation
Laser Optics failure – destruction of drill string and exposure of laser	x	x	x	5	4	20	Develop a drilling operational manual that addresses issues around, vertically, elongation of the drill string when in suspension at large depths, identifies a safe operational procedure that prevents laser optics failure and total loss of the drill string. **Such procedural manual should include a process to outline power density and cold cryo gas flow parameters need to be optimised to allow the sweet spot of melting/spallation threshold to be obtained. A monitoring system drilling while logging need to be defined**	4	3	12		Faunhofer – Prevent	Laser operational process management to prevent laser optics failure in the drill string
Dust emissions to atmosphere generated from the drilling process	x	x		4	5	20	Develop a detailed design for a cyclone based particle handling system to capture particles (up to 3.5mm size) and allow for presence of water in formation to be dealt with. Outline design of a ceramic cyclone system that would allow separation of fine particles from N2 gas stream. Cyclone collection system will need to be rated to prevent particle emission in accordance with local regulatory standards (PM2.5, PM10) and EU directives applicable for emissions to air of dust particles. Implementation of a monitoring system coupled with the waste management systems will be required as part of future operations	2	3	6		Prevent - GeoServ	Develop a concept waste management, cyclone based system to capture particles for testing at next phase of technology development
Supercritical N2 – Transportation, Filling to and from site – Dangerous good classification	X	X		3	3	9	N2 transport and usage carries an exemption of biological and biomedical applications. This should be the case for use as part of the DeepU technology however . A detailed N2 DG management plan including, handling, transport, emergency procedures and accident/incident prevention will be required under the European Communities (Carriage of Dangerous Goods by Road and Use of Transportable Pressure Equipment) Regulations 2011. The operational plan should be specific to DeepU procedures and drill site configuration and comply local regulatory requirements.	2	2	4		WUST	Develop a DG Management strategy to cover all the aspects of the drilling operations

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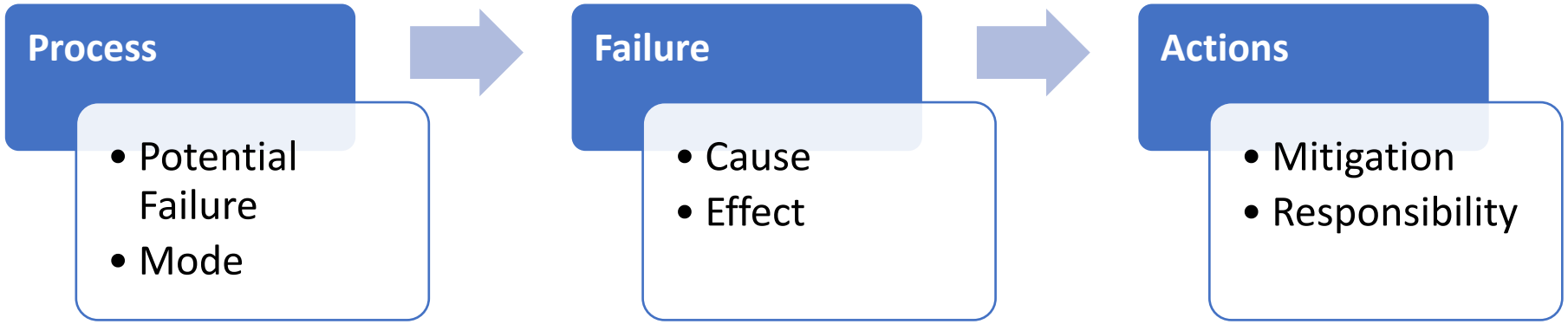
EHS Evaluation – FMEA Structure

- **Failure Mode & Effects Analysis (FMEA) Workflow:**



- Assesses the project technologies and processes
- Identifies potential failures and causes
- Proposes Process Changes and Recommendations to avoid failures

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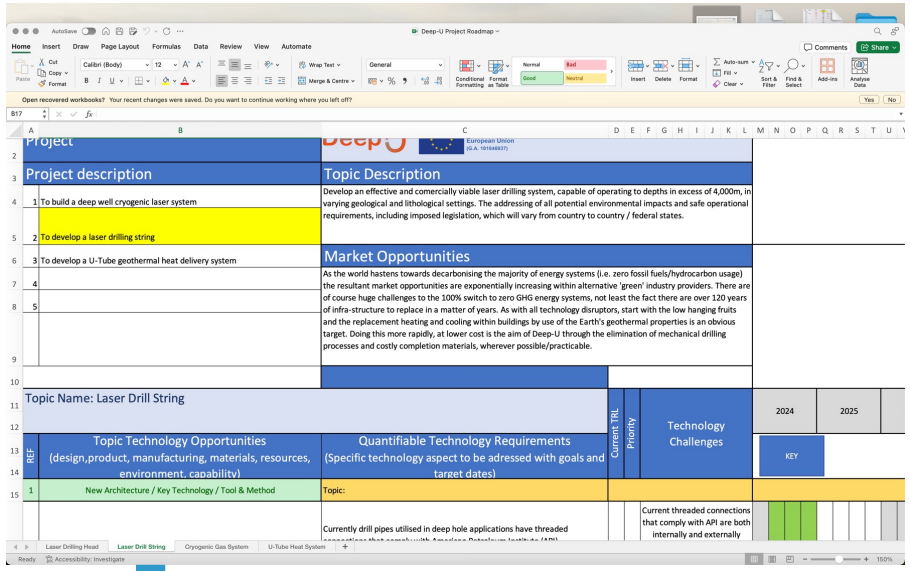
Completed Roadmap

- 44 processes assessed in the FMEA:
  - Drilling Process Components
  - Cryogenic Gas System
  - Laser Operation
  - Formation Interaction
  - Completions
- Development of a Technology Roadmap
- Mapping out technology challenges to be addressed during the project and in future technology developments



Recommendations

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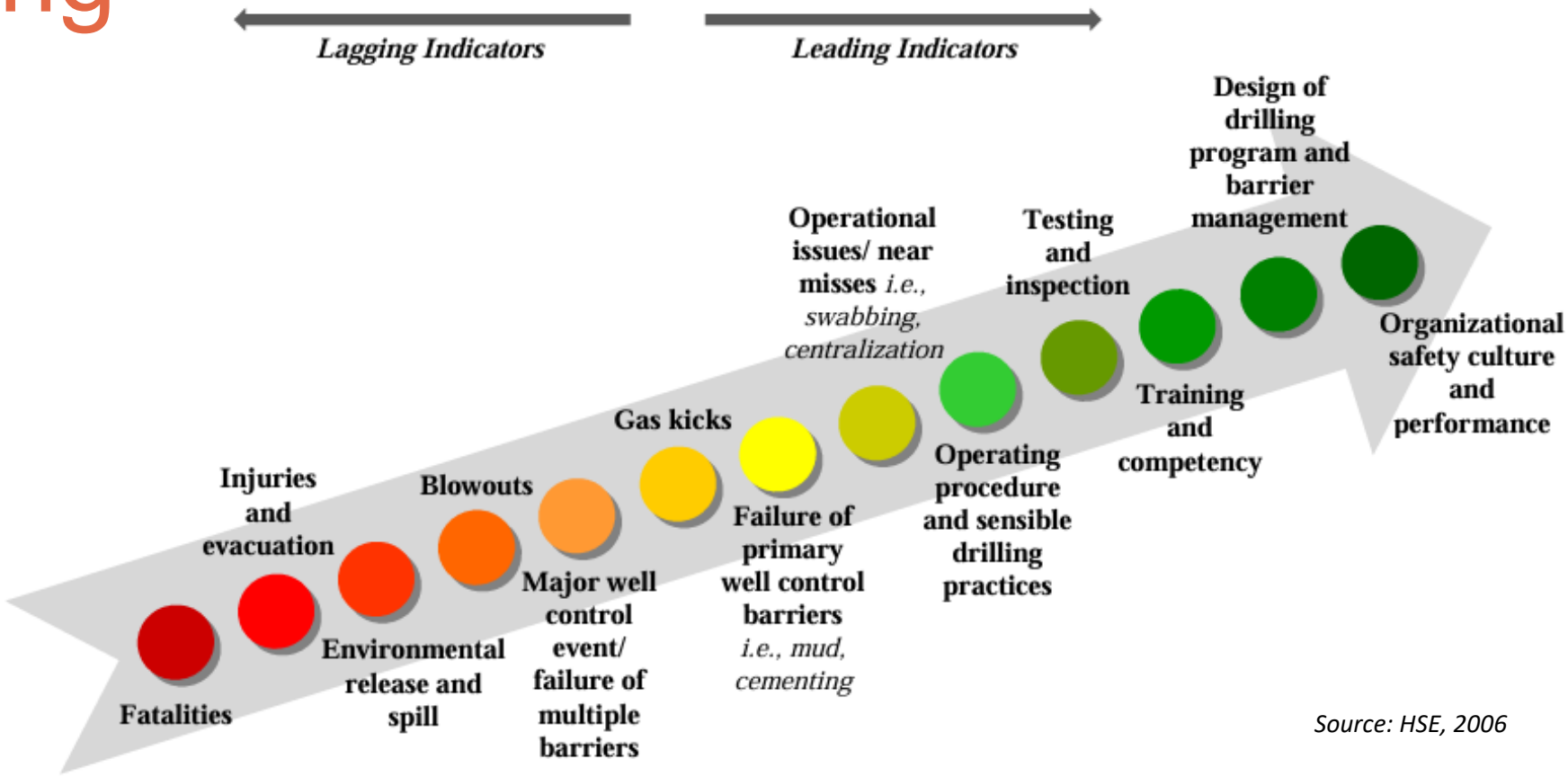
EHS Indicators for Conventional Drilling



Source: HSE, 2006

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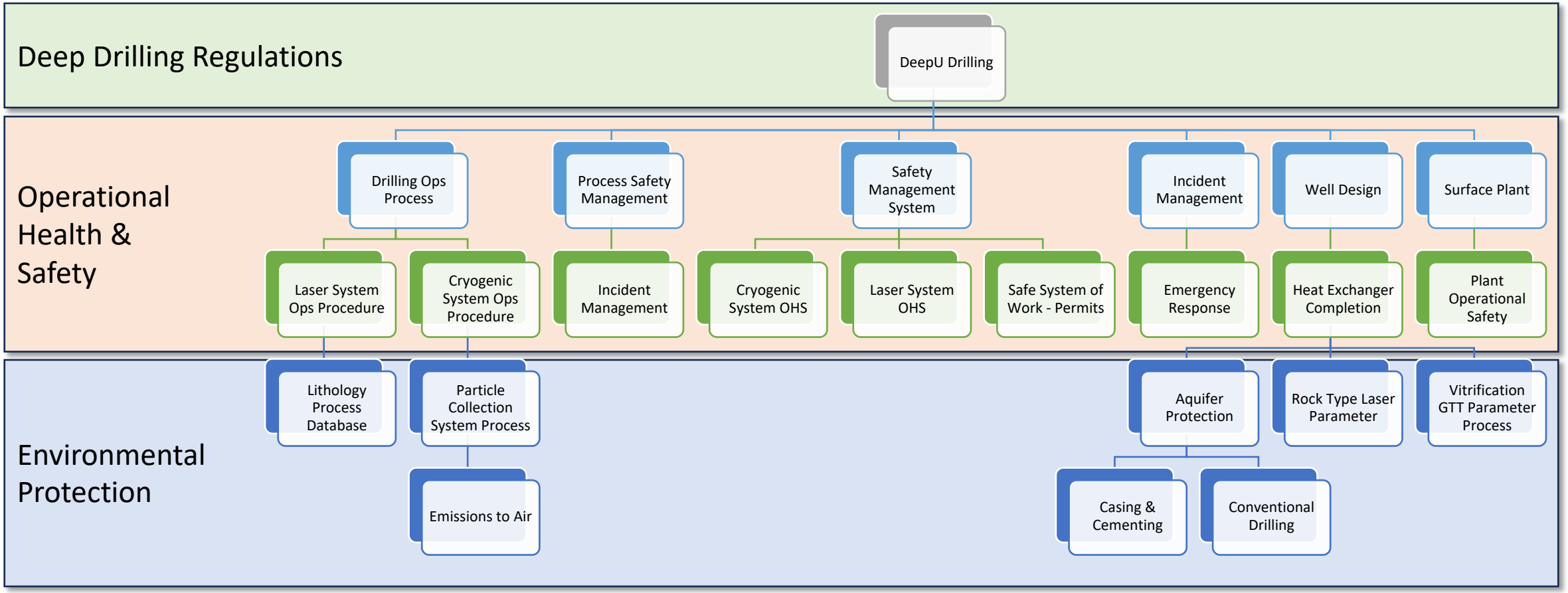
Recommendations for DeepU Drilling



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Development Recommendations

- **Laser System**
  - **Fail safe operations procedures** for industrial laser usage on a drill site – safety management system
- **Nitrogen System**
  - **Operational procedure** for use & storage – safety management system
  - **Separation from cuttings & Emissions**
- **Drill String**
  - **Drilling Depth Governed by Material and Connection specification**
  - **Certification/Standardisation**- DNV, Lloyds, API, IADC, ISO
- **Electrical Infrastructure & Total Power Supply**
- **Lithologies & Borehole Completion**
  - **Well Control Measures & Borehole Breakout**
  - **Multi-method approach** to ensure Environmental compliance & Final geothermal well structure
  - **Decommissioning** requirements
  - **Measurement, Monitoring and Verification (MMV)**

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Thank you for you attention

- **Ric Pasquali & Kevin Mallin**

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