ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE	SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#1	**Energy efficiency in offshore operations** The ambition is to reduce operational greenhouse gas emissions by 50% in 2030 vs 2005 levels, and to near zero by 2050 (Konkraft, 2021). Over 90% of the NCS' present CO_2 emissions relate to the generation of energy (NOROG, 2020). Improved efficiency in the demand and supply of energy is critical to meeting these targets.	Water injection is a common drainage philosophy on the NCS, where produced water and/or seawater replace produced volumes to maintain the reservoir pressure. The energy demand to pump water to injection pressure is usually very large, and the NCS as a mature basin continues to see growth in its water-to-oil ratio (NPD, 2019). Preventing formation water from leaving the reservoir or removing water from the well stream as close to source as possible, would significantly reduce the energy demand for fields supported by water injection.	• Reservoir technologies for less water production. (see water management in section 4.4). • Well completion technologies that reduce water production. (see water management in section 4.4). • Downhole or subsea water separation and reinjection.
		Subsea tie-backs to existing topside facilities are projected to be the dominant means of producing new volumes on the NCS (NPD, 2019). Longer distance tie-backs will incur higher temperature and pressure losses along the flowlines, which are typically reintroduced at the host facility. Flow assurance issues (hydrates, wax) usually become more challenging with lower temperatures/pressures, and the solutions typically add to the energy demand or result in increased flaring.	• Subsea boosting. • Cost-competitive flowline insulation techniques. • Low emission flow assurance philosophies. (e.g. low dosage hydrate inhibition, cold-flow technologies).
		New topside facilities will be few and far between; existing topsides will be utilised and life-extended. Brownfield modification of major energy consumers and suppliers is often challenging in terms of layout, weight and cost.	• Increased efficiency of local power generation. (e.g. combined cycle gas turbines, dual fuel engines). • Low/zero carbon fuels (e.g. hydrogen, ammonia, blends). • Heat integration (recovery of heat within the process systems) without bulky piping or heat exchangers (e.g. heat pumps). This is an enabler for electrification (below).

---

[3] These are examples. Other solutions addressing the prioritized technology areas should also be sought and developed.

[4] Noting that chemicals which are eventually discharged to sea also represent an environmental impact.

ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE		SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#2	**Reduced cost of electrification** Electrification has to date been the preferred approach for large scale removal of upstream CO_2 emissions; favoured since it does not interfere with the reservoir or processing systems, and carries low risk. It is, however, often a costly mitigation and continues to face technical and physical limitations. Here, electrification refers to import and production of power either from shore or from other offshore sources.	Minimising the need for topside equipment to support electrification would improve the viability of electrification, in particular for brownfield applications.	Direct current (DC) transmission is most suited to longer cable lengths (typically >200 km depending on load and cable design) or higher loads (>200 MW), but requires power converters at either end of the cable which are large and heavy.	• Subsea HVDC converter. • Floating HVDC facility, noting that this incurs some of the dynamic cable issues discussed below. • Wet-mate high voltage connectors to reduce the complexity of installing subsea equipment. • Pressurised power electronics.
			Alternating current (AC) transmission avoids power converters, however it continues to see limitations in its transmission capacity and distance.	• Increase the viable range (cable length) by: - mid-point compensation. - low frequency transmission. - series capacitor. • Place electrical equipment subsea (frequency converter, transformers, reactors). - Wet-mate high voltage connectors to reduce the complexity of installing subsea equipment.
		The static cable(s) between the power source and the offshore facility are often the largest contributor to capital expenditure for electrification projects.		• Wet design high voltage cables currently qualified up to 36 kV. Areas of research include: - Degradation by water treeing. - Water condensation in the insulation at reduced load. - Water diffusion along the cable into connecting components.
		The dynamics associated with floating facilities present further challenges for electrification.	Dynamic cables (between static cables/equipment on the seabed and the floating topside facility) are currently qualified for 145 kV / 100 MW (per cable) AC transmission.	• Qualify dynamic cable for HVDC: - Termination from subsea static to dynamic section. - Dynamic influence on space charge / field inversion.
			For turret-moored (weather vaning) facilities there are currently swivels qualified up to 52 kV power transfer.	• Qualify space-efficient swivels for higher voltages.

ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE	SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#2 cont.		Most electrification schemes in operation or under development supply power to an individual facility or field. In principle, electrification hubs serving several facilities/fields, or even a region, would be more cost-efficient and reduce technical and physical limitations. Furthermore, larger grid systems improve the potential for the integration of renewable power sources and energy storage systems. The mixture of frequencies (50/60 Hz) used at differing facilities must be overcome, where applicable.	• Improved understanding of practical issues that affect the overall viability of hubs: - Collate key data characterising individual NCS facilities (forecast load profiles, frequency etc.) that can be used for preliminary technical assessment. - Research the organizational viability (multiple licenses, cash flow, cost allocation, ownership etc.). - Integration of renewable energy sources (e.g. wind) and gas power with carbon capture and storage (see below). - Energy storage opportunities (e.g. batteries, fuel cells).
		Electrification from low carbon or renewable power production offshore can be a supplement to, or a replacement of, conventional offshore power generation or power from shore.	• Technologies for alternative energy sources offshore.
#3	**Offshore carbon capture, utilization and storage (CCUS)** CCUS is widely recognised as group of technologies that will have a significant role in the energy transition, notably serving 1) fossil-fuel grid power, 2) blue hydrogen and 3) sectors with hard-to-abate emissions (IEA, 2020). Each of these three groups could be represented offshore. (for sequestration of CO_2 captured outside of upstream activities, see section 4.4)	Exhaust gas capture technologies are not yet proven offshore, but are available in the market using conventional technology at abatement costs which have been found to be competitive against power from shore. Nonetheless, current capture and CO_2 injection modules require a sizable footprint, height and weight, and are therefore highly challenging for brownfield applications. Injected CO_2 reaching production wells (known as "back-production") is a significant risk due to corrosion – enhanced material selection is expensive.	• Reduced size, weight, and cost to further improve competitiveness. • Improved understanding of the behaviour of injected CO_2 in the reservoir. • Cost-effective techniques for storage/utilisation of CO_2 (in the order of 10^5 tonnes per year) which does not involve the producing reservoir.
		Gas is expected to continue to increase its share of NCS production while the regional demand for gas is predicted to fall (Rystad Energy, 2021). Alternative techniques to monetise gas resources in a low carbon society could be performed offshore with the help of carbon capture and local storage.	• Offshore blue hydrogen production (see also section 5 discussing new energy markets). • Offshore gas power generation, exporting power to the onshore grid (also known as "gas-to-wire").

ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE	SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#4	**Lifecycle assessments** LCAs enable environmental impacts beyond only the operational phase of an asset to be evaluated in design. LCAs need to enable a broad range of environmental indicators. For emissions, Scope 3 aspects should also be included.	Upstream facilities are complex in their components and supply chains and rely on specialist yards and vessels. Early design phases offer the greatest opportunity to affect key decisions which might influence lifecycle environmental impacts, but the least information upon which an LCA could be based.	• Toolkit aimed at the early design phases of upstream facilities to enable coarse LCAs to be established, commensurate with the information that is available. • Methods for risk assessment related to handling of contaminated waste from obsolete offshore materials (e.g. decommissioning),
#5	**Leak detection and mitigation** Unplanned releases of hydrocarbons or chemicals to the marine environment erodes trust in and the reputation of the industry. Improved detection of leaks is therefore important to reduce business risk as well as environmental risk.	Conventionally, sensing devices are static and are limited to covering either a point source (e.g. a valve) or an area (e.g. ambient seawater surrounding a subsea facility). Remote and rapid pin-pointing of a leak point within a complex/congested facility is hence challenging, and likely to limit the effectiveness of the immediate response.	• Sensors mounted on autonomous mobile devices (e.g. AUVs, drones) permanently stationed at the facility may allow fewer sensors to be used for greater coverage/ accuracy. • Further effort is needed to demonstrate and implement available sensor technologies, to reduce cost of the technologies, and to understand how the technologies can be utilized and optimized for different purposes (i.e. environmental risk factors in general)
		In design, it is often challenging to justify measures for the detection and (where relevant) containment of leaks. This is particularly true for, but not limited to, smaller leak scenarios (typically which do not carry a significant safety or asset risk).	• Develop a framework for performance standards and/or functional requirements to support the selection of leak detection strategies for smaller leak scenarios.
		In operation, it can be challenging to quickly detect smaller leaks using process (in-pipe) instruments, especially where there are frequent changes in process conditions.	• Detection techniques which accurately monitor the ambient environment, to complement process instrumentation. • Artificial intelligence, data-analytics and physical models for faster and more reliable detection. • Review whether there are opportunities for better calibration data (in test facilities or in-situ) to help tune the above tools.

ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE	SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#5 cont.		Lack overview of reported NCS leak events which can be used by the industry for experience transfer and could in the future form the basis for statistical analysis supporting risk assessments.	• Along the lines of the UK's Hydrocarbon Release Database (HCRD) (UK HSE, 2020), Norwegian authorities are recommended to publish a leak database detailing the fluid type and properties, volume, rate, duration, cause etc. This should cover chemicals as well as hydrocarbon fluids. • Better understand the connection between fracture mechanisms and leakage rate to better predict the risk of leakage as well as leakage rate development over time.
#6	**Environmental risk assessment and management** Discharges to the marine environment from petroleum activities are risk assessed using the DREAM model to predict the Environmental Impact Factor (EIF). This predominantly covers discharges with produced water, injection water and drill cuttings. All natural compounds (from oil and gas production) and added chemicals are included. Chemicals are classified into colour-coded groups according to their properties (i.e. environmental hazards). These properties are an input to the EIF model.	EIF models are considered to have been highly successful at minimising the impact/risk from discharges to the marine environment. However the industry may be overlooking the holistic risk provided by EIF models and instead focusing on reducing individual chemicals' hazards (by substitution). Substitution is one tool to minimise the environmental risk of discharges to the marine environment, but it is not the only solution. Managing the holistic risk is foreseen to offer a better environmental performance compared to managing the hazards of individual chemicals.	• Wider-spread use of EIF models/results for decision making (both in design and operation) and for periodic regulatory reporting. • Improved knowledge/understanding of techniques which avoid chemical injection, or target reduced injection volumes (e.g. chemical combinations, low-dose chemicals). • Improved information availability/sharing concerning chemical properties (e.g. partitioning and toxicity) – collaboration between vendors and operators, inclusion in chemical databases.
		Future production on the NCS is expected to be characterised by new wells and IOR techniques within existing fields, whereas the numerous smaller discoveries are likely to be developed as tie-backs to existing facilities.	• Discharge philosophies/practices for drilling of production/injection wells. • Chemical development should focus on the industry trends (e.g. drilling, IOR chemicals, hydrate inhibitors, corrosion inhibitors, drag reducers, chemicals supporting produced water treatment and techniques to treat injected seawater). • Compatibility issues created by mixing produced waters from different fields.
		A prerequisite for the O&G industry is to demonstrate sustainable activities for the regional fauna and ecosystems. This is particularly important for vulnerable areas.	• Improved knowledge, models and tools supporting good effect and risk evaluation of environmental impact on marine ecosystems.

ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE	SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#7	**Oil spill contingency** It is a prerequisite for the industry that oil spills are avoided. However, if they occur, they must be detected early and the consequences need to be minimized through efficient oil spill response.	Subsea dispersion of oil reduces the environmental impact by decreasing the concentration and increasing natural decomposition. It also reduces the risks for response teams attempting to work at the surface near the spill site. However, there is limited experience of these techniques at full-scale.	• Further technology development and large scale testing of subsea dispersant injection (SSDI) and subsea mechanical dispersion (SSMD) to lift to higher TRL level.
		The efficiency numbers used for different oil spill response technologies, in oil spill response analysis and planning, are often questioned. Especially for mechanical recovery.	• Increased knowledge and documentation on efficiency and effects for different oil spill response technologies is needed.
		Oil spill response equipment and techniques may not be suitable for the cold climate in the high north.	• Test conventional equipment and techniques in winterized conditions. • Adapt equipment and techniques where required. • Train response teams to understand the different equipment and techniques required in cold conditions.
		Tools used for spill modelling and response rely on accurately predicting the fluid's behaviour. Wax rich crude oils and condensates with high pour point may not be accurately predicted with the tools used today.	• Further development of modelling tools to compensate for reduced initial spreading and increased oil thickness for oils that may solidify on the surface in≈contact with cold sea water.
		Shoreline clean-up knowledge and tools are typically based on heavy fuel oils which will behave differently to NCS fluids (crude oils and condensates).	• Increased knowledge and documentation on behaviour of different crude oil types in contact with different shoreline substrates. • Improve the basis for estimation of resources requirements adapted to crude oil releases. • Improvement of shoreline clean-up technologies for crude oils.

ID.	TG1 PRIORITIZED AREA	PROBLEM STATEMENT / CHALLENGE	SUPPORTING TECHNOLOGY & KNOWLEDGE INNOVATIONS[3]
#8	**Environmental performance data** Increased public scrutiny of the petroleum industry's environmental impacts should be proactively met by offering enhanced transparency.	A significant amount of information is publicly available, offering an insight into historic volumes of pollutants at field-level. However, the information is dispersed and generally inflexible (not centralised or in a format to allow ease of interrogation), and there is significant room for improved disaggregation of data.	• A single-source, publicly accessible environmental data hub which can be flexibly interrogated and exported. - Facilitates maximum available disaggregation (e.g. by facility, emission equipment, chemical functional group etc.). - Functionality to collate data by processing hub[5]. - Includes production/injection data for normalisation.
		There is no overview of upstream energy consumption, which is crucial to support strategy and research which targets greenhouse gas emissions.	• Annual reporting of energy (GWh) which separates between: - Demand by main use (e.g. oil separation, gas compression, water injection etc.). - Supply by type (electrical, mechanical, thermal) and source (e.g. turbine, engine, boiler, WHRU, imported power etc.). • Fuel consumed by source (gas, diesel).
		Data are collected on emissions and for environmental monitoring. A significant amount of data is available but not sufficiently coordinated across different platforms and needs for optimal total utility.	• Utilize all available emission and environmental data for improved prediction of effect of activities on ecosystems and biodiversity.

---

[5] For example, emissions/discharges from Field X support production from Field Y in addition.