Fails to meet criteria	Not promising	Meets in some respects	Potentially meets criteria	Meets criteria

* For explanation of criteria see Box B, page 22

ASSESSMENT TABLE: **Oil and gas**

	Credible			Capable		Compelling			Priority approach
	Maturity	Economic viability	Social acceptability	Fit for purpose	Net-zero pathway potential	To critical stakeholders	Related costs and benefits	Economic development opportunities	
Oil and gas production (non-oilsands)									
Methane emission reduction	Well developed technologies to reduce fugitive emissions	Depends on context	High	High	Only as part of an integrated strategy to get to net zero.	To industry incumbents when faced with regulatory or cost pressures	Adds costs for abatement but may generate revenue through reduced methane wastage. Reduces GHG intensity of product (foreign market access)	Growing market for specialized oil and gas equipment	Medium. Necessary as long as fossil fuel extraction continues.
Machinery equipment and vehicles	Emerging. Electric or hydrogen fuel cell	Varies but more expensive than diesel	No particular problems	Yes.	Only as part of an integrated strategy to get to net zero.	To industry incumbents when faced with regulatory or cost pressures	Reduction of air pollution	For equipment or vehicle manufacturers	Low to medium Important as long as fossil fuel extraction continues
Oilsands production									
Equipment and vehicles	Developed or emerging	Varies but more expensive than diesel	No particular problems. But increasing public concern over oil sands	Yes. But limited compared to overall emissions	Only as part of an integrated strategy to get to net zero	To industry incumbents when faced with regulatory or cost pressures	Reduction of air pollution	For equipment or vehicle manufacturers	Medium. (small part of overall GHG production footprint)
Low carbon electricity for SAGD or other approaches	Multiple low carbon options including electricity from low carbon grid, renewables, small modular nuclear reactors.	Much more expensive than natural gas now. Might make sense faced with tight regulations and high carbon price	Varies by generation technology (see power table Section 5.1)	Yes, depending on circumstances	Only as part of an integrated strategy to get to net zero.	Depends on cost, regulatory environment, oil market conditions.	Potential energy and cost savings. Reduced air pollution. Danger of further stranded assets as oil demand declines.	For suppliers of alternative energy technologies	Low to medium. Option while oil extraction continues
Alternative extraction approaches	Multiple possibilities at R&D and demo stage including solvents and radio frequency heating	Expensive but potential cost savings when mature from reduced energy use	Unknown	Yes, in principle but not tested at scale	Only as part of an integrated strategy to get to net zero. Data on performance closely held by companies so impossible to verify real emission reduction potential	Yes, oil producers. Depends on costs, regulatory environment, oil market conditions.	Potential energy and cost savings. Reduced air pollution.	For suppliers of alternative extraction technologies	Low to medium. Option while oil production continues
Artificial intelligence & machine learning									
	Technology still emerging and oil and gas applications under development	Unclear. Depends on context	No particular problems	Yes, in principle	Only as a small part of an integrated strategy to reduce emissions	Yes. Current industry enthusiasm to reduce costs and raise efficiencies	Increases recovery rates and reduces cost. Could threaten some jobs	Could creates demand for skills that can be transferred to other sectors	Low priority for substantial de-carbonization

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Carbon capture and storage (CCS) across the industry									
For energy production, bitumen upgrading, hydrogen production, refining, etc.	At large demo stage	Depends on application, more development required to reduce costs	No organized opposition today, some concerns about leakage	Yes. But adds costs and complexity to operations	Depends on application. Must be supplemented with offsets to reach net zero.	Yes, in appropriate context. Can be applied to existing facilities	Creates a feedstock of CO_2 for storage or industrial use	Potential to be linked to hydrogen economy development	High. Potentially useful in multiple contexts.
Negative emissions technologies									
To offset residual emissions. Direct air capture, afforestation, agricultural practices, BEECs, etc.	Technologies at different stages of development	Highly variable: tree planting cheap, air capture expensive, etc.	No organized opposition	In principle. But many uncertainties about permanence, effectiveness, costs, scalability	In principle. But questions about permanence, and scale available to offset residual emissions from fossil fuel production and use - because of offset required elsewhere in the economy and eventual need shift entire economy to net negative.	Some offsets in use to meet existing carbon pricing schemes	Allows continues production of fossil fuels with the costs and benefits this entails	Potentially, if adopted at scale	Low to medium (varies with approach). R&D and demos to gain experience and understanding
Hydrogen production (as an alternative energy carrier)									
Steam-methane reforming (NG feedstock) **without CCS**	Well established technology	Economic technology producing hydrogen for many industries	Some concerns about hydrogen safety	Yes	Not net zero. Only as a transitory path of low emission hydrogen production	Increasing interest in hydrogen across multiple sectors	Produces abundant GHGs.	Transition to hydrogen economy	Not net zero compatible
Steam-methane reforming (NG feedstock) **with CCS**	Hydrogen established. Hydrogen production with CCS: large scale demos already underway	Currently expensive	Some concerns about hydrogen safety	Yes	Potentially net zero if offsets for NG extraction and transmission	Yes	Fossil energy producers as hydrogen emerges as a viable energy carrier	Transition to a hydrogen economy	Medium high To accelerate low carbon hydrogen deployment
In-situ gas wells	Still at experimental stage	Unknown: too early in development	Some concerns about hydrogen safety	In principle	Potentially. With sequestration of emissions and offsets to mop up residuals	Not appealing while gas production possible, and hydrogen demand undeveloped	Maintain revenue stream from mature oil and gas reservoirs. Uses existing pipeline infrastructure Reduces air pollution	Energy production/ exports in a decarbonizing world.	Medium high Potential net zero hydrogen production
In-situ oil sands	Still at experimental stage	Unknown: too early in development	Some concerns about hydrogen safety	In principle	Potentially. With sequestration of emissions and offsets to mop up residuals	Not appealing while oil production possible and hydrogen demand undeveloped	Maintains revenue stream from bitumen resource. Reduces air and water pollution	Energy production/ exports in a decarbonizing world.	Medium high Potential net zero hydrogen production

Fails to meet criteria	Not promising	Meets in some respects	Potentially meets criteria	Meets criteria

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Geothermal Electricity									
Utility-scale power generation	Demonstration scale in Canadian context	Not cost competitive today	No problems today. For some technologies local concern over fracking and seismic activity	Yes, in principle. Continuous baseload power	Yes	No strong constituency yet, but emerging	Geographic overlap between geothermal resources and oil and gas areas	Some, helps transition away from oil and gas extraction	High as alternative development trajectory in Alberta
Non-combustive uses for bitumen									
Activated carbon, vanadium, carbon nanotubes, carbon fibre	Varies according to materials	Not commercially attractive today. Longer term prospects unclear	Concerns remain re: bitumen extraction (tailings, emissions, liabilities, land disturbance)	High	Possible if extraction and processing emissions are avoided, captured and/or offset	Yes	Increasing demand for carbon nanotubes/ fibre and vanadium as decarbonization deepens	Possibly but cost unclear and many competing sources	Medium. Possible diversification strategy for Alberta
Lithium									
Direct extraction from oilfield wastewater	Under development	Expensive today (no commercial operations)	No particular problems	Yes, in principle	Yes with net zero extraction	Potentially, if profitable	Growing demand for lithium, does not require mining	Depends on growth of demand, and there are many potential competing sources.	Low. Possible diversification strategy for Alberta.