Defining Development Schemes for CO_2 Transportation Network Growth

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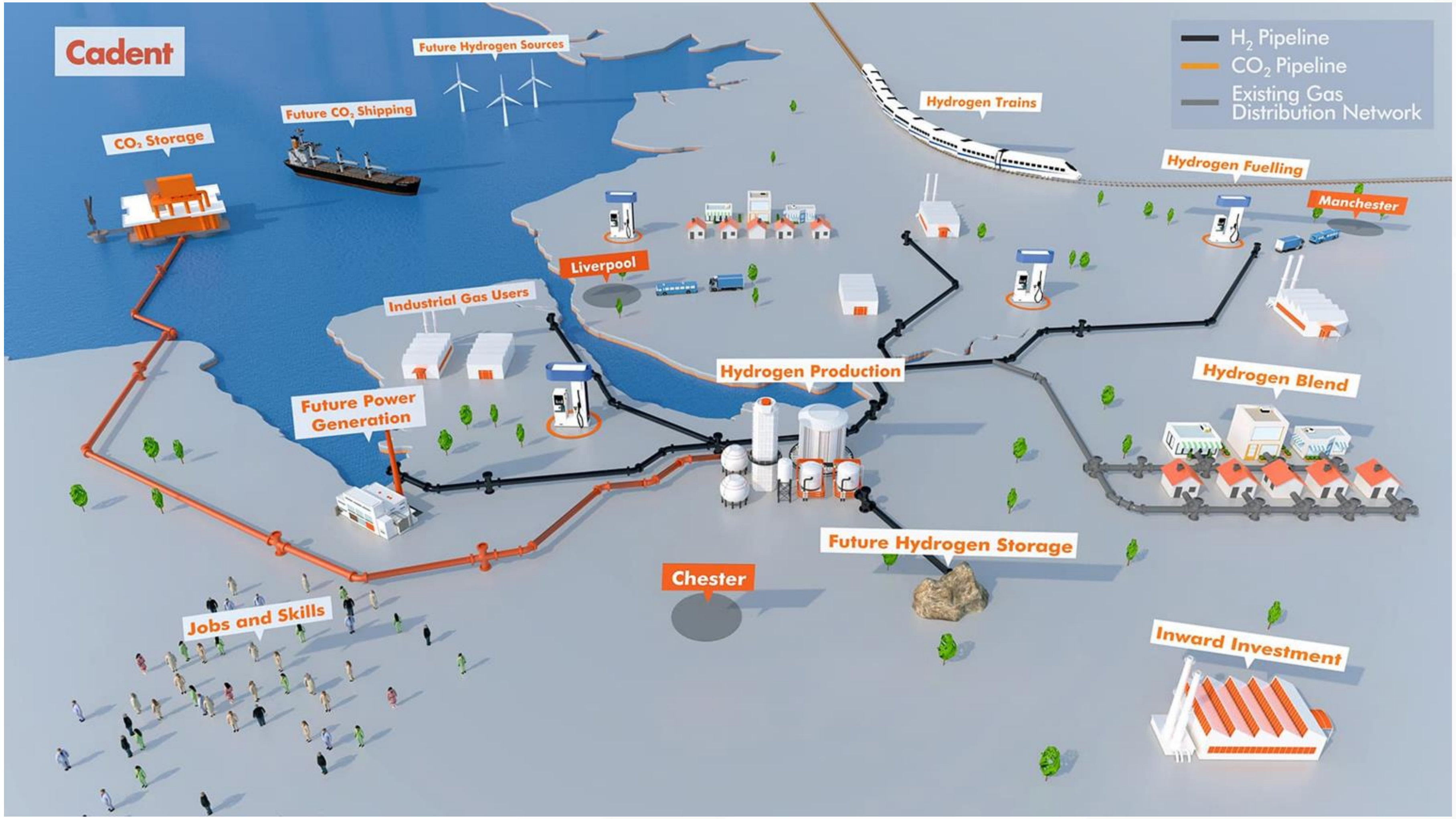
HyNet

PROGRESSIVE ENERGY



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HyNet CCUS Phase 1

- Phase 1 is to develop the CCUS infrastructure to capture CO_2 emissions from industry and transporting CO_2 offshore for storage in the Liverpool Bay depleted gas fields.
- Takes advantage of existing facilities for gas transportation which will be repurposed for CO_2 transportation
- Currently about to enter into FEED

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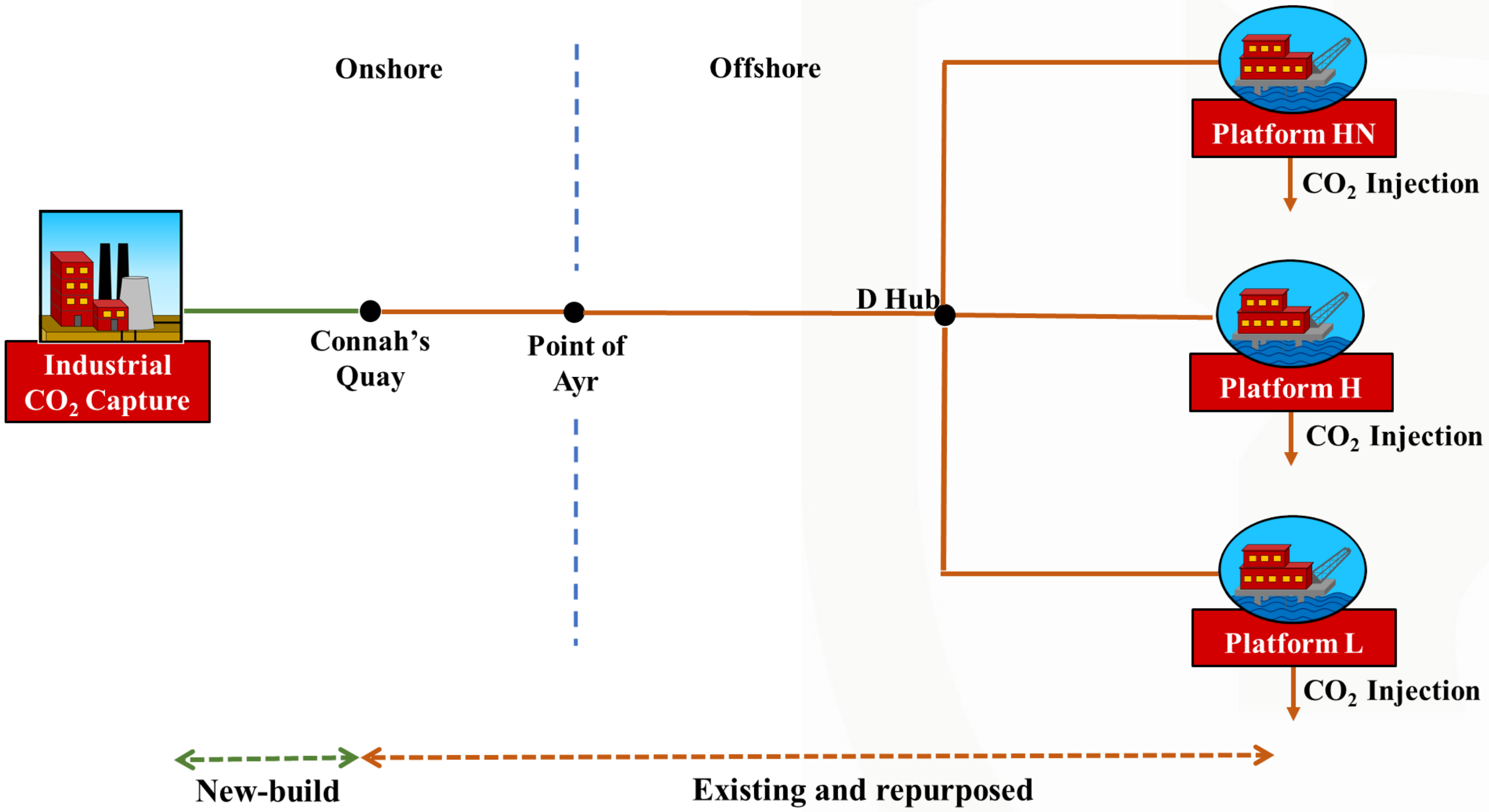
Full-Chain Transport/Injection System



Challenges

- H_2 as main impurity
- Restrictive design/material conditions of existing infrastructure
- Potential to extreme Joule-Thomson cooling and expensive/high carbon footprint mitigation
- Complex operation due to parallel injection to 3 fields (different storage size, pressures, distances)

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Design Aims

- Develop strategy to start operation and determine what and when modifications are required
- Determine safe, robust & flexible operating envelope within the system, environmental & expenditure constraints

Design Philosophy & Drivers

- The system is designed to be operated in single phase (either gas or liquid). Two-phase flow (during normal operation) is to be avoided as reasonably possible.
- Safe, robust and flexible operation
  - Trade-offs
  - Honour design (qualification) limits of existing facilities; acknowledge facilities will be operating beyond original design life (upgrades/modifications will be required over time)
  - Environmental constraints
  - Integrity management is key
- Cost (and emissions/energy consumption) minimisation

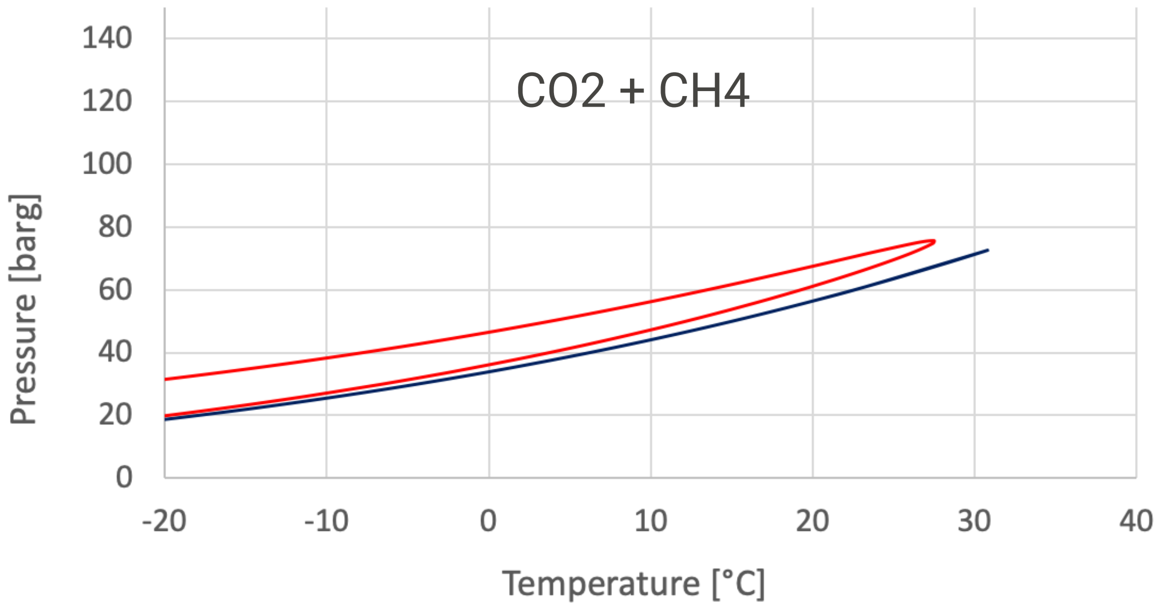
- HyNet will initially operate in gas phase (low pressure) to minimise CAPEX. After some time, the offshore section will switch to liquid (high pressure) and a new onshore pipeline will be installed (onshore section always in gas phase)

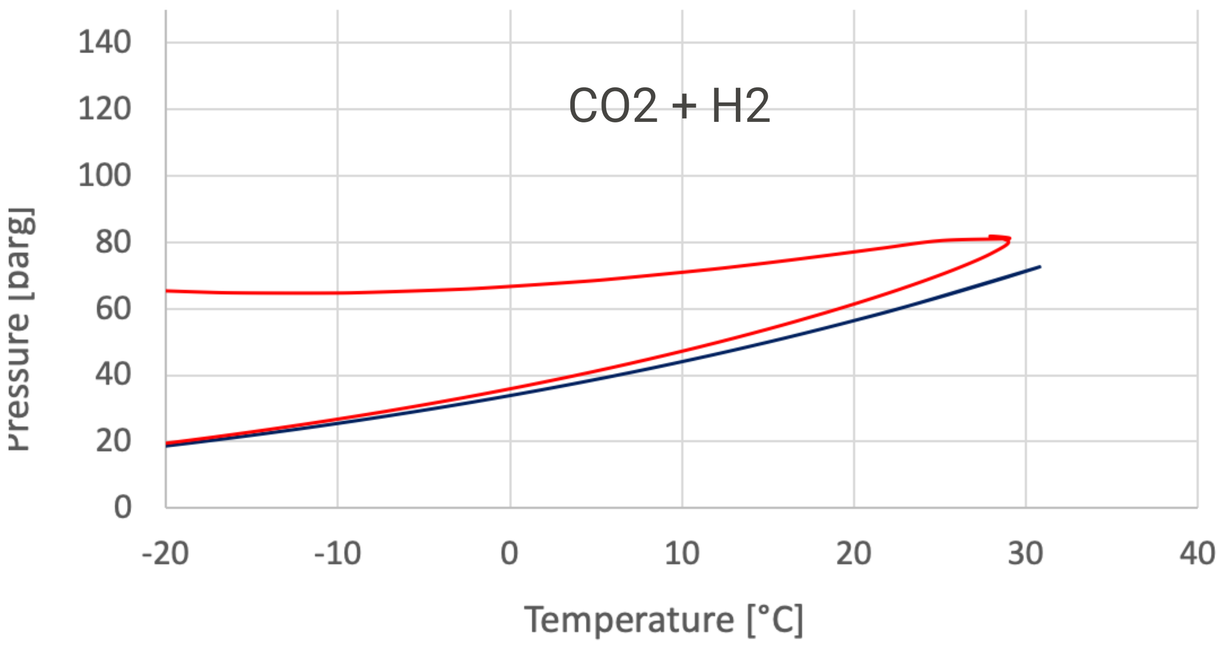
Connect the source to the endpoint

- Who are the suppliers of CO_2
  - Foundation supplier(s)
  - Others, known & unknown
- What impurities are likely
  - H_2, CH_4, CO, N_2, Ar, H_2O
  - Purer CO_2 = higher cost for the suppliers
- Properties of target reservoir(s)
  - Capacity
  - Injection rate

Impact of impurities in CO_2 streams

- Presence of impurities can lead to flow assurance, metallurgical, safety, processing, economic, storage challenges
- Increase uncertainty in fluid properties estimations
- Thermodynamics is very important (assume pure CO_2 at your peril!). There are options but more development/experiments needed.





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Major cost items

- Infrastructure is all about cost!
- Major items are:
  - Post-capture items (i.e. metering)
  - Onshore & Offshore transport
  - Pressure boosting
  - Utilities (Heating/Cooling)
  - Wells
- But also keeping in mind that
  - Minimise embodied carbon
  - Minimise GHG emissions inherent to the CCS chain

Injection Plan

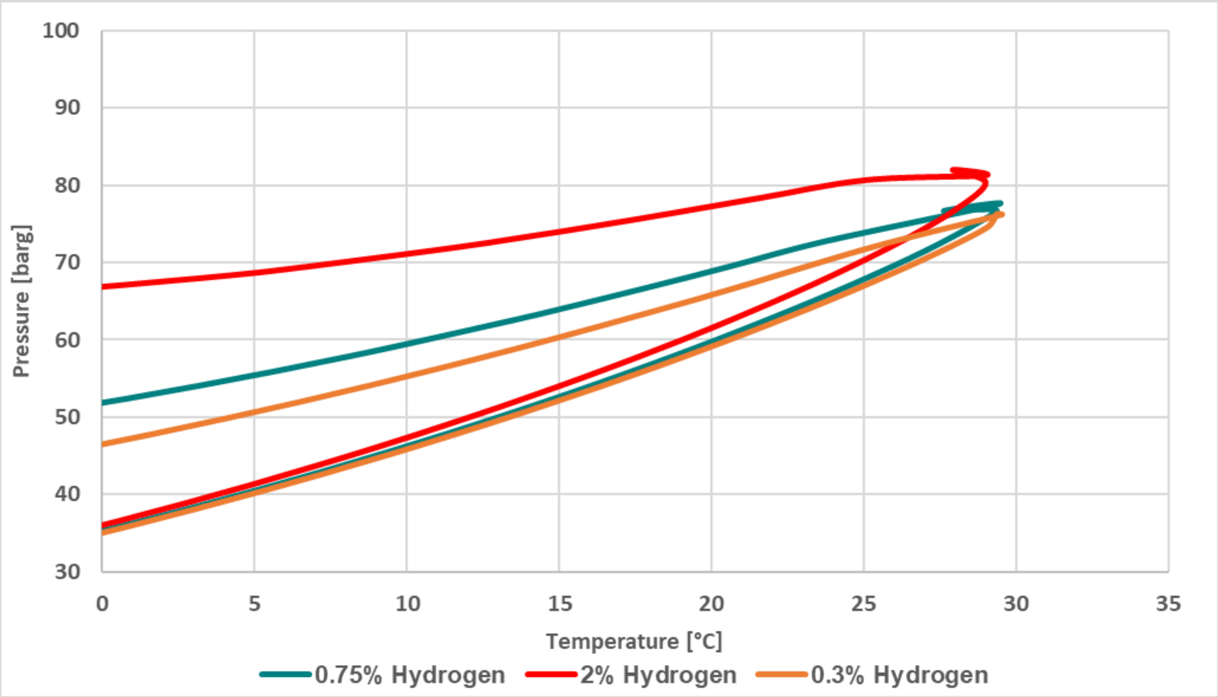
- Ultimate project building blocks defined
- Must delay investment (reuse of existing infrastructure)

- Injection pressure starts low and ends high
  - Typically from < 10 bara to > 120 bara
- Flowrates start low and end high
  - Starting flowrate typically 1-5% of maximum flowrate

- And…

…CO_2 transitions from gas to liquid in this range

- The size of the two-phase regions varies depending on impurities.
- Predictions of fluid properties in this region are pretty poor.
  - especially around the bubble point.
- Our engineering software is not well equipped to model behaviour in this region.
- And generally, multiphase flow creates a few problems.
- When do we (*have to*) switch? How do we switch?



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Design / Operating Limits – Pipelines

	Gas	Rationale
MAOP	35 barg	To avoid liquid dropout
Minimum Normal Operating Pressure	5 barg	Minimum start reservoir pressure
Maximum Velocity	20 m/s	Reduce risk erosion and vibration (some debris in used pipelines at start of operation). High velocity promotes increased JT cooling
Maximum Operating Temperature	20°C	Environmental Constraint
Minimum Operating Temperature	-10°C	No margin on minimum design temperature

	Liquid	Rationale
MAOP	125 barg	To honour design presssure
Minimum Normal Operating Pressure	97 / 84 barg	To avoid gas breakout after extended shutdown (high / low H_2 content)
Maximum Velocity	5-12 m/s	Unlikely to be high – it won't be an issue
Maximum Operating Temperature	20°C	Environmental Constraint
Minimum Operating Temperature	-10°C	No margin on minimum design temperature (unlikely to reach low temperatures as minimum JT cooling expected)

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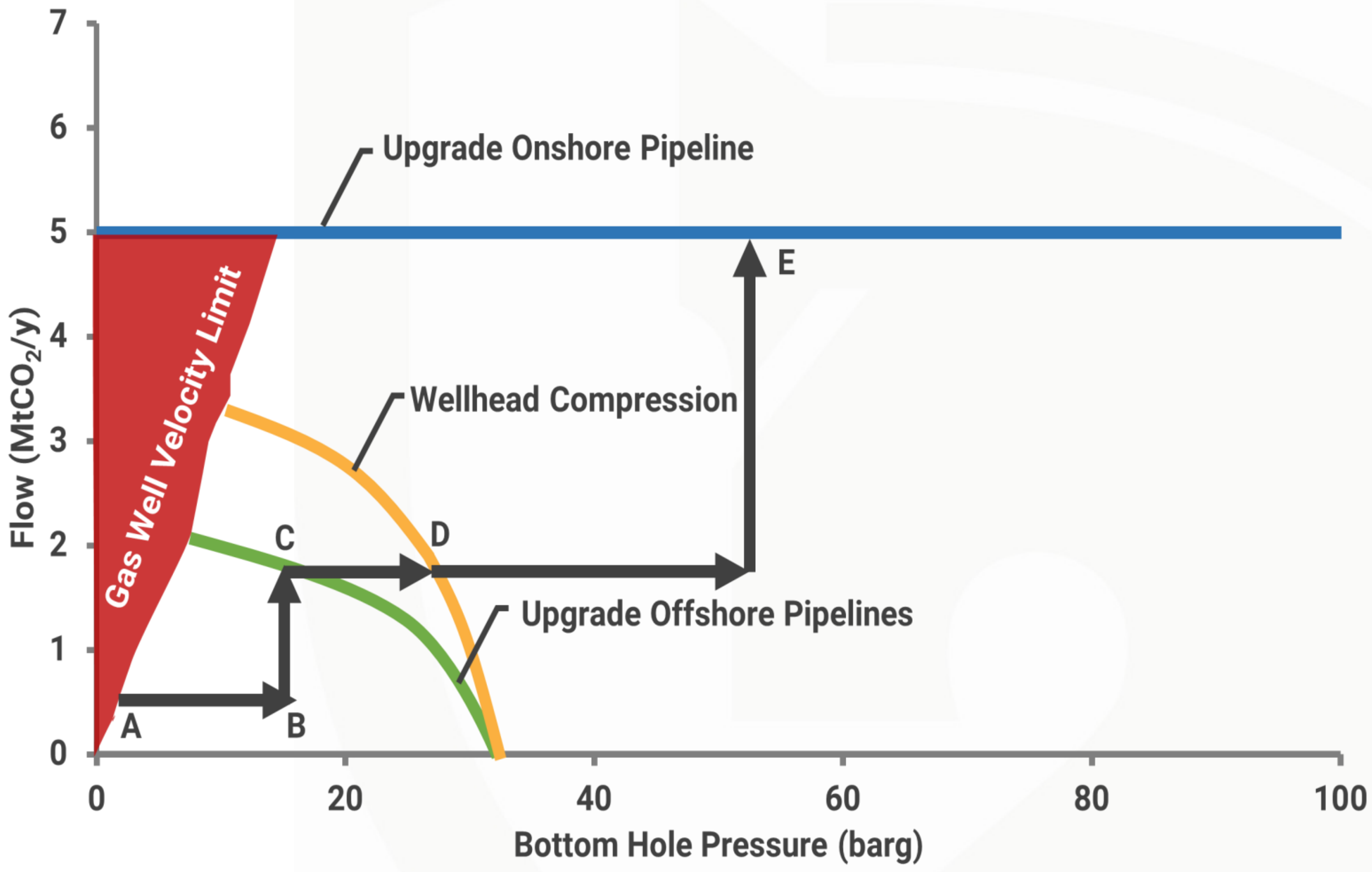
Design / Operating Limits – Wells

	Limit	Rationale
MAOP / Design Pressure	98 - 113 barg	Initial reservoir production pressure
Minimum Normal Operating Pressure	5 barg	Minimum start reservoir pressure
Maximum Velocity	20-30 m/s	Reduce risk erosion and vibration (some debris in used pipelines at start of operation). High velocity promotes increased JT cooling. Material likely to be more resistant to erosion. High velocities risk to damage formation.
Design Temperature	31 - 60 / -10°C	Reservoir Temperature and/or to match pipeline design temperature
Minimum Operating Temperature	0 / 4°C	0°C but arrival temperature at bottom hole > 4°C (damage formation)

Constraint/Operating Map

- Generate maps for concept candidates
- Thermodynamics/FA/Process modelling
- It does not include reservoir model (pressure build-up rate)



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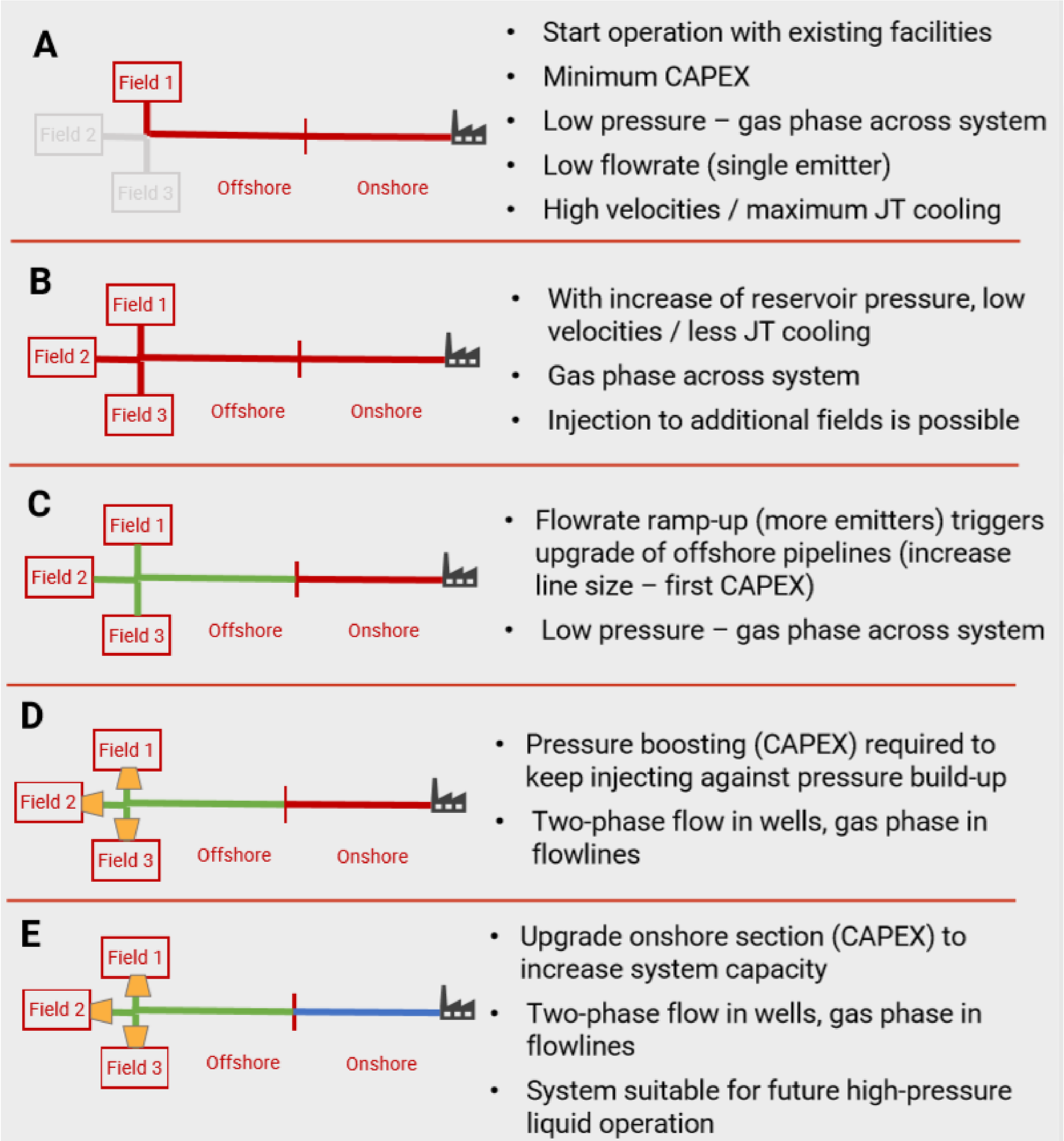
Staged Development

Pressure stages:

- Free flow from source to injection
- Gas flow only
- Transition from gas to liquid (offshore)
- Liquid (offshore)

Flowrate stages

- First supplier
- Foundation supplier(s) online
- Maximum?



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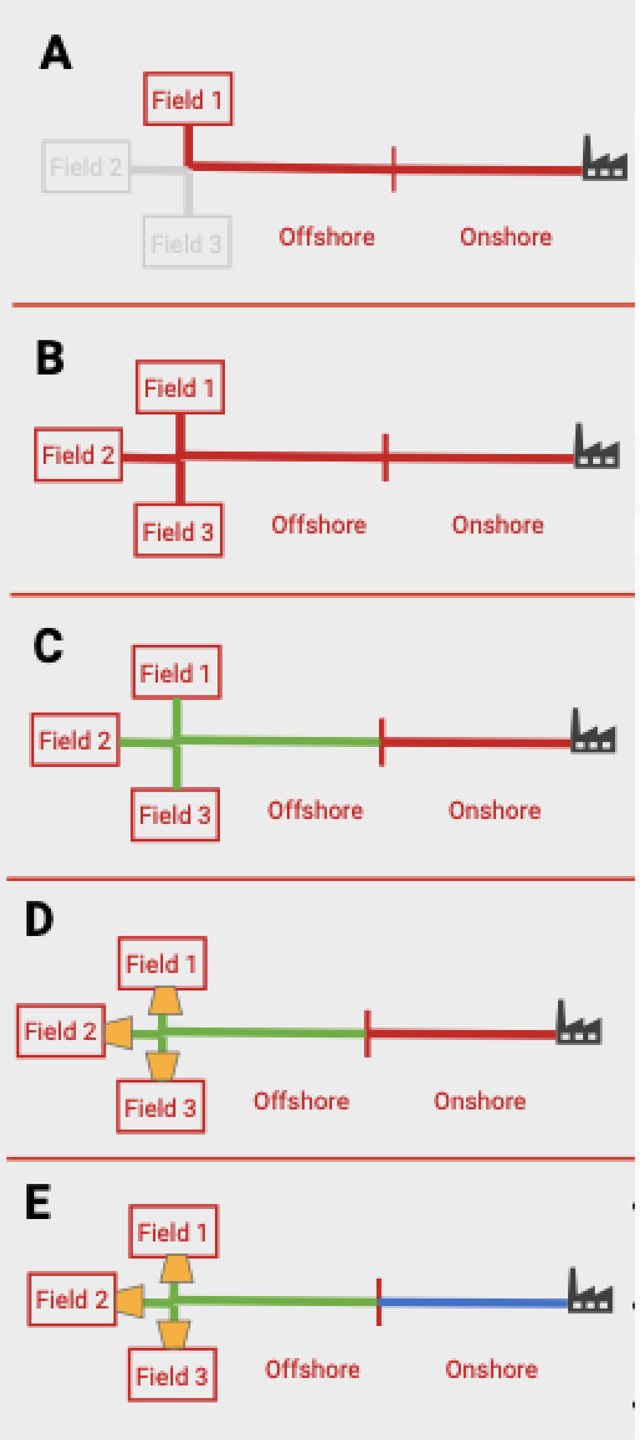
Define the stages

	Free flow	Gas	Transition	Liquid
First (0.5 MtPa)	A	B		E
Foundation (2 MtPa)		C	D	E
Maximum (10 MtPa)			E	E



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Finally, future work

- Two-phase flow in pipelines. This is a total new concept and potentially advantageous but possibly difficult to control (slugging, etc.). Feasibility study will be required.
- Significant knowledge gaps in thermodynamics
  - Development of custom-made EoS (with some experimental verification)
- Consider reducing maximum rates towards maximum injection pressure: avoid designing to “last day” conditions. Maximum flowrate & maximum reservoir pressure should not be concurrent.
- Is our approach optimal?