Carbon Storage and Management

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Why the Measurement and Allocation of CO2 in the CCUS is rather complicated?

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Introduction

- Accurate CO_2 flow measurement and allocation along the process chain from capture, transport and storage is extremely critical to safeguard every parties' interest in any CCS project.
- Attributes of a good allocation system:
  - ✓ Fair and equitable principle – no parties is disadvantaged either in short and/or long-term stance
  - ✓ Transparent, understandable algorithm within a sustainable system
  - ✓ Fit for purpose, scalable and technically robust
- Presentation objectives:
  - ✓ Share concerns around potential CO_2 measurement challenges
  - ✓ Illustrate the possible allocation challenges at various points along the CCS process chain
  - ✓ Summarize the need for a pragmatic approach while the industry progress and learn

Metering challenges

- All proven and accurate meter technologies are meant for single phase application. Physical characteristics of CO2 present a risk of multiphase flow scenarios that would significantly compromise the meter performance.
- Fluid densities – required to derive the mass flowrates – are very sensitive to concentration of contaminants and varying pressure and temperature, notably around the critical points in the phase diagram. The effect of density measurement inaccuracies are more significant in the ultrasonic flow meter (USM) and turbine meter flow calculation than orifice meter. Coriolis meter is a mass meter hence not affected.
- CO2 molecules are known to attenuate USM acoustic signals.
- In the presence of water, CO2 can be corrosive to carbon and alloy steel – increasing the risk of accelerated wear and tear on the moving parts in meters e.g., turbine meters.

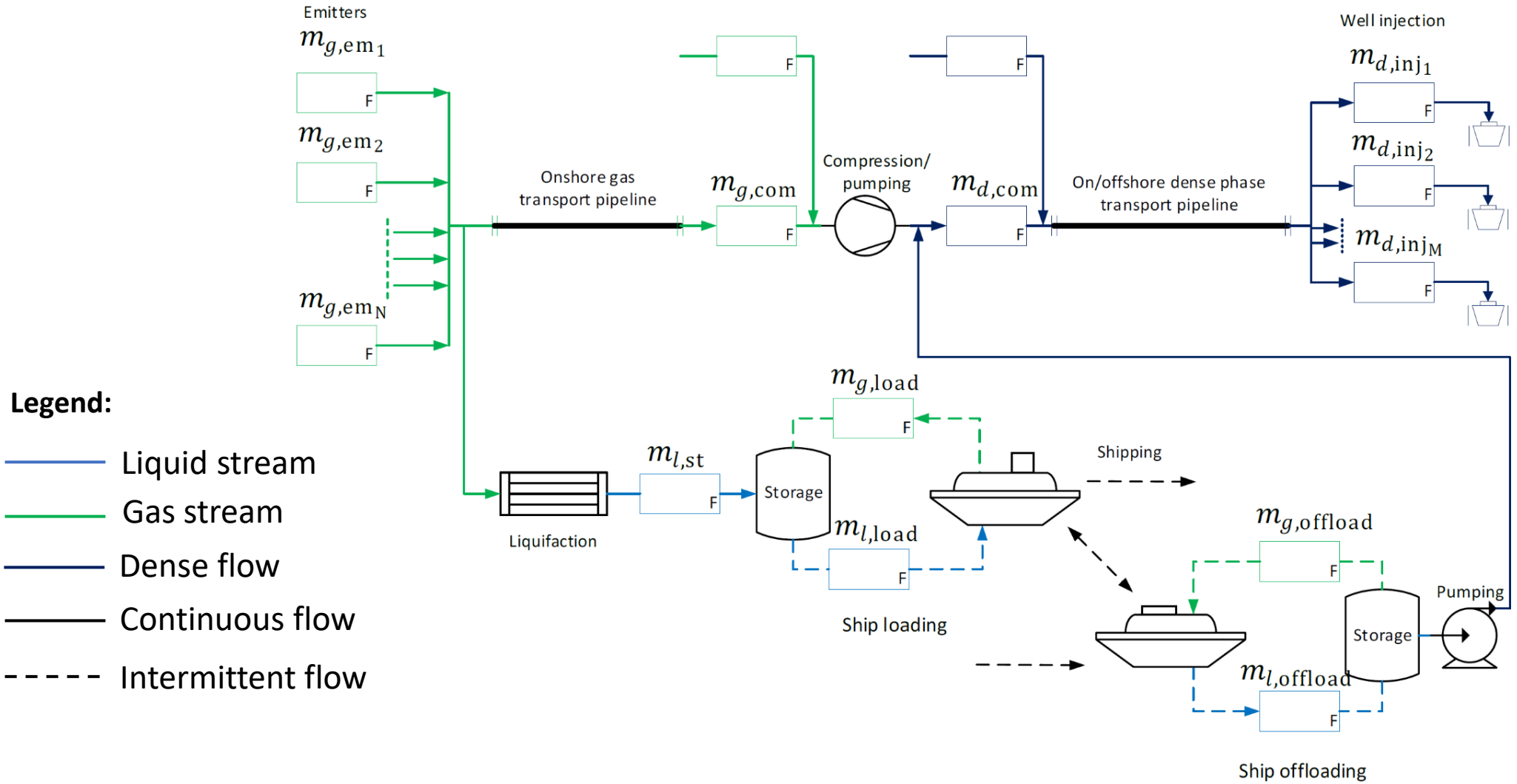
Other metering considerations

- Availability of the calibration facility for CO2 or CO2-rich flow meters with adequate size and pressure ranges
- CAPEX consideration – optimum meter count, adequate sizing, placements and material compatibility
- OPEX considerations – Logistical accessibility and maintainability during operation
- Quality measurement – online and/or offline sampling alone is sufficient or require process simulation with proven equation of state

Allocation challenges

- Allocation principles are the crucial building blocks in any commercial agreements, including in CCS developments. Extensive collective experience in traditional oil and gas allocation can be leveraged to set a strong foundation for CCS as we progress in the decarbonation journey.
- Each CCS network may be unique. A typical CCUS network diagram from a technical paper by DNV in the 2023 Global Flow Measurement Workshop (GFMW) is used to illustrate the allocation challenges in a CCUS network in this presentation.
- While the list may not be exhaustive, it is important to note that not all concerns are applicable in all CCS development.

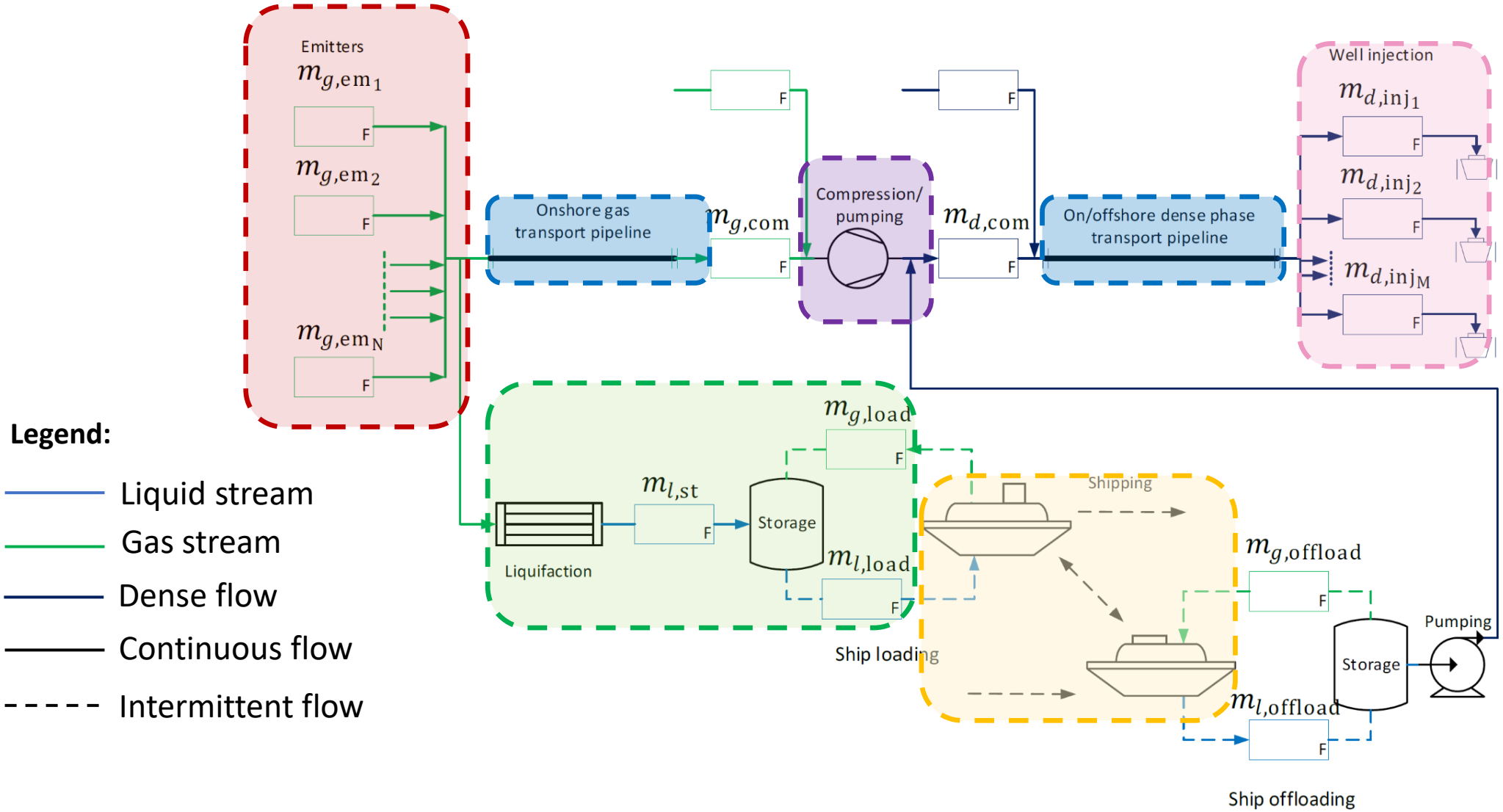
(Typical) CCS network



Legend:

- Liquid stream
- Gas stream
- Dense flow
- Continuous flow
- Intermittent flow

CCS Allocation Challenges



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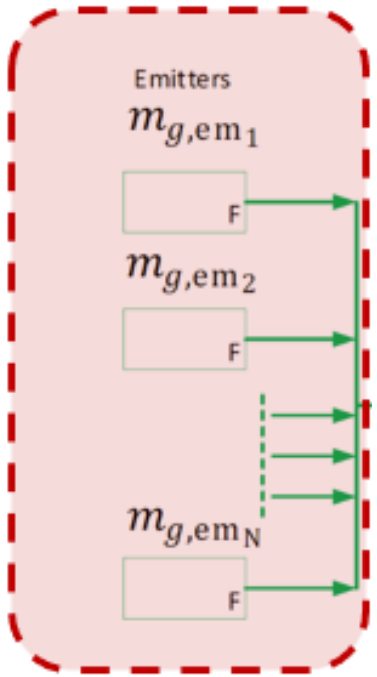
CCS Allocation Challenges *cont.*



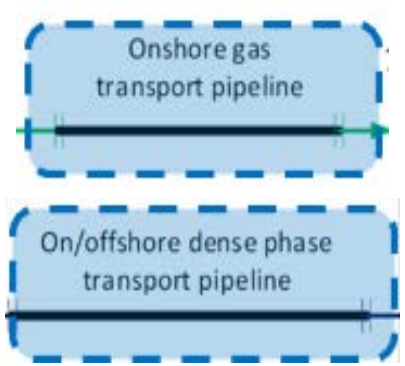
- Various sources of CO emitters:- different level of potential contaminants e.g., Nitrogen, oxygen, methane, hydrogen, argon etc
  - Adequate interval for quality determination
  - Effect of impurities to operation and allocation
  - Is there a need to track these impurities?

- Emitters can come from a single entity (least likely) or multiple entities with different level of severity/consequence for any operational trip or interruptions
  - Production Forecasting & Nomination complexities
  - Capacity over/under booking? What is the consequence of not meeting the nomination?
  - Need an agreed Constraints management philosophy

CCS Allocation Challenges *cont.*

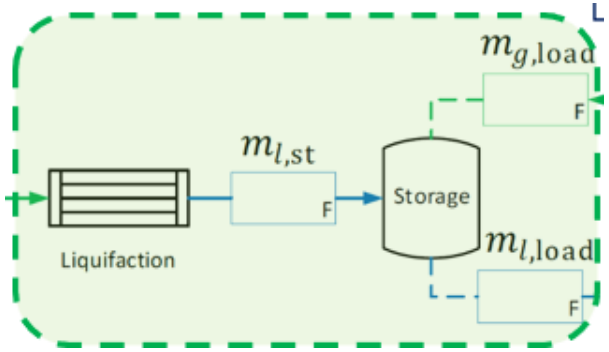
- Compression power requirement is a significant OPEX element in CCS. Fuel allocation - What is the most equitable basis?
  - Fixed via tariff?
  - Pro-rata mass throughput? What happens on compressor recycle mode?
- Is power consumption always proportional to throughput? What if density changes due to contaminants hence compression power variation?
- Analysis paralysis vs sustainable approach?

CCS Allocation Challenges *cont.*



- Line pack inventory especially in dense phase can hold a large volume relative to hourly/daily incoming flow onto the system boundary
- Selection of the correct allocation period e.g., hourly/daily/monthly is influenced by the effect of inventory variations in a long pipeline
- Allocation algorithm may or may not include the feedback mechanism to cater for line pack inventory. What is at risk?

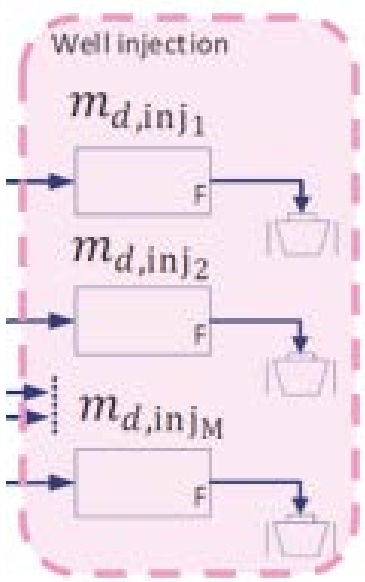
CCS Allocation Challenges *cont.*



- Risk of increased measurement uncertainty due to phase changes across various processing stages. How to measure each line/phase and how many meters are too many?
- Cost vs Benefit and Exposure Analysis

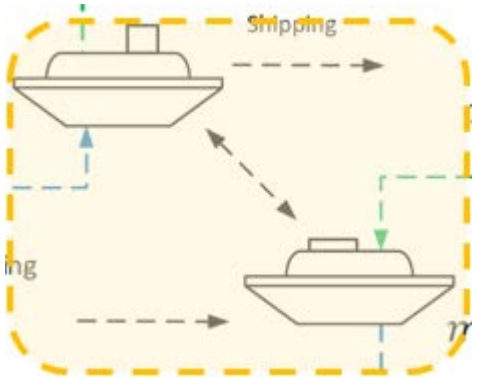
- Fugitive emissions and flare/vent allocation.
- What is a technically robust method of allocation?

CCS Allocation Challenges *cont.*



- New approach for mass balancing as introduced in the Emissions Trading Scheme (ETS) – using arithmetic average vs traditional reconciliation. How do we track bad actors? Is there a need to do that?
- Well measurement vs reservoir modelling. How much deviation in total mass is too much?
- Is actual contaminants level critical for well injection for other reasons e.g., flow assurance or well integrity? Does it need to be tracked, measured and included in the allocation system?

CCS Allocation Challenges *cont.*



- Change of ownership and transfer of risks along the CCS chain. Where are the point of transfer?
- Different standards and regulation across international / regional boundaries. Which one is binding?
- Fiscal metering systems – Validation, quality assurance and auditing rights and responsibilities.

Conclusion

- Metering and allocation challenges are expected to stay while the industry learns and grows.
- It is important for the parties involved to be aware of the potential risks and financial exposure posed by each challenges and make an informed decision to formulate a fit-for-purpose approach in CCS development.
- To enable progressive growth in CCS without delaying the decarbonization ambition, its crucial for the binding agreements to allow for retrospective adjustment within a pre-defined time limits should the substantial error is discovered down the line.

Thank you