
Global Variable
Dockside Storage Characteristic
Transport Vessel Characteristic
Regulation Characteristic
Carbon Capture at Source Characteristics
Injection Unit Characteristic
Environmental or Locational Characteristic
Ground Transport Characteristics
What determines the profitability an offshore carbon sequestration operation?
Expenses
Revenue ($$$) is determined by the lifespan of the unit, the value of CO2, and the rate of injection
CO2 Value ($$$/MtCO2) is dependent on regulatory value, and the addtional value that may come from the CO2 capturing industry
Carbon Credit Value ($$$/MtCO2) is determined by regulation, and therefore the home port/location of carbon capture
Injection Unit Expenses ($$$) are the total expense of producing and operating a new-build injection unit
Lifetime OPEX ($$$) is a function of the various components of operating expenses, and the lifespan of the vessel
On-Site Storage OPEX ($$$/time) is the cost associated with storing liquefied CO2, and is determined by the required onboard storage capacity
Fuel costs ($$$/time) are determined by the required installed generator capacity
Generator Maintenance Costs ($$$/time) are determined by the required installed generator capacity
Site Change Cost ($$$/time) is the cost of moving the injection unit to a new field
On-Site power generation needs (MW) are determined by the size of the unit, onboard and subsea equipment, storage refrigeration requirements, and whether any power is being provided from a transport vessel
Drilling and Wellhead Installation ($$$/time) is determined by the frequency of new wellheads and the cost of opening one for production
Site Change Downtime Cost ($$$/move) is a function of how long it takes to move, and how much revenue could have been made during this time
Site Change Downtime (time) is based on the speed of the transit (whether by tug or self-prop), and the distance to the new site
Site Mooring/Installation Costs ($$$/move) is a function of first, the type of platform, and then mooring system, the water depth, and what support units may be required to complete the process
Mooring (Y/N) is a possible method of station keeping for an FPSO, and its use is determined by the water depth and weather
Dynamic Positioning (Y/N) is a possible method of station keeping for an FPSO, and its use is determined by the water depth and weather
Leg Jacking (Y/N) is a possible method of station keeping for a fixed platform, and its use is determined by the water depth and weather
Tugboat/Support vessel (Y/N) is whether or not support or tug boats are needed during installation and deployment, and is based on the self-propulsion capabilities and station-keeping method of the unit
Unit Lifespan (time) How long the unit is expected to last. Generally, 40+ years
Site Change Frequency (moves/time) is a function of how quickly the primary field is depleted and the capacity of nearby fields
Mobile or Fixed Platform? This is a key decision variable which is based on the site change frequency, and the unit lifespan.
Field Depletion Rate (Field/time) is a function of the number of sands per field and the sand depletion rate
New wellhead frequency (# New Wellheads/time) is a function of the depletion rate of sands, the number of wellheads for a new sand, and how many sands there are at a field
New wellhead installation cost ($$$/wellhead) is primarily a function of the cost of hiring a drillship and installing new subsea equipment
Drillship Cost ($$$/Wellhead) is the cost of hiring a drillship for opening a new wellhead. This is a function of the water depth, well depth, the market value of drillships, and field location
Subsea Equipment CAPEX ($$$/Wellhead) is determined by the capacity of the equipment and the operating depth
Day Rate of Drillships ($$$/time) is dependent on market forces and location
Sand Depletion Rate (#Sands/time) is a function of the injection rate at the wellhead, the number of wellheads per sand, and the size of sands at the primary reservoir
Operating Water Depth Range (m) is a property of the primary and secondary oil and gas fields
Topside Injection Support Equipment (compressors, cooling equipment, brine processing) is sized based on the injection rate of the operation, storage conditions, and reservoir pressures
Subsea Equipment Capacity (MtCO2/time) is the injection rate of the subsea equipment, and is determined by the injection rate at the wellhead, but also provides limitations to the wellhead rate.
Total CO2 Injection Rate (MtCO2/time) is a determined by the number of active wellheads and the injection rate at each of them
Active Wells (# Wellheads) is a function of the number of sands within immediate vicinity of the injection unit, the size of these sands, and the rate of injection that is achieved at each wellhead
Immediate Sand Cluster Capacity (MtCO2) is the total sand capacity within proximity of the injection site, and is a property of the primary O&G field
Number of Wellheads per Sand (# Wellheads/Sand) is a function of the sand capacity and the injection rate of the wellhead
Injection Rate at Well Head [MtCO2/(time-wellhead)] is a function of the capacity of the initial reservoir's sands, but also limited by the capabilities of "off the shelf" subsea and topside injection equipment, and geological conditions
Brine Processing Equipment (MtCO2/time) is the required capacity for brine handling during CO2 injection.
Travel Distance from old to new site (distance) is a property of the nearby field locations
Geological Conditions of Reservoir (fracture pressure, initial pressure, drilling depth, permeability, porosity, brine presence) are properties of the primary reservoirs, and impact the injection rate and its variability
Size of sands within proximity (MtCO2/Sand) is a property of the primary O&G field
Number of stacked & nearby sands within proximity of injection unit (# Sands/Field) is a property of the primary O&G field
BOEM Lease Price ($$$) is determined by the primary and secondary O&G fields that would be in use
Nearby Field Location (-) is a property of the nearby oil and gas fields
Capacity of nearby fields (MtCO2) is a property of the nearby oil and gas fields
Nearby Depleted Oil/Gas Fields are a result of the location of the primary O&G field
CAPEX ($$$) of the injection unit encompasses the one-time costs of the unit
Decommissioning Costs ($$$) are primarily determined by the size of the vessel and regulatory constraints
Construction Labor Costs ($$$) are mostly a function of the size of the unit
General Acquisition & Material Costs (Hull, Basic Outfitting) ($$$) is primarily a function of the size of the injection unit, and may be influenced by local regulations
Engineering Costs ($$$) are primarily determined by the size of the unit, which encompasses the complexities of equipment integration
Generator Acquisition Costs ($$$) are determined by the required onboard power generator needs
Injection Equipment Costs ($$$) are a function of the topside injection equipment
Refrigeration Power Demands (kW) is a function of the injection rate, storage conditions, and storage quantity, and local requiremenets regarding CO2 boiloff
Size of Injection Unit (tonne & m^3) is determined by the onboard equipment, storage, and the operating sea state
CO2 Storage Tanks & Onloading Equipment (Product) is determined by the required capacity, storage conditions, and limitations from pre-fab solutions
Tank and Onloading Equipment Size (m^3 & tonne) are the space and weight impacts on the vessel, and are determined by the required equipment
Self-Propulsion Equipment (Y/N) is primarily based on the frequency of moves and the distance of those moves, the risk of severe weather and how permanent of a mooring solution is used, and whether it is a mobile or fixed platform
Compression Equipment Power Demands (kW) is a function of the injection rate, storage conditions, and formation conditions
Tank and onloading equipment capacity (MtCO2 & MtCO2/time) is determined by available products, and by the required onsite CO2 storage and vessel offloading rate
Storage conditions (Pressure, Purity, Temp) are a global variable, and is determined by the required storage capacity on the injection unit and transport vessel
Injection Variability (Cv) is determined by the rate of new wellhead installation, the reliability of the injection and subsea equipment, reservoir geology, and the number of active wellheads
Continuous injection? decision variable on whether injection will be made continuously or intermittently
Inventory buffer needed (MtCO2) is determined by the variability of injection and CO2 arrival
Onloading Variability (Cv) is determined by the operating window for CO2 onloading and the arrival variability of the CO2 transport vessels
Operating Window for Onloading Ops (% time) is how frequent operations can be underway, and is a function of the local environment and transport size. The unit does not impact because it is assumed to be larger or more motion resistaned than the vessel
Injection equipment reliability (Cv) is based on general equipment performance, MTTR, MTTF
CO2 Arrival Variability (Ca) is the variability of shipments to the injection unit. This is mostly a function of the vessel's transit time, frequency, and the local weather
Location Environmental Conditions
Regulations
Travel Distance for Transport Vessels (distance) is determined by the location of the primary field and the home port location
Home Port Location(s) can theoretically be anywhere but is influenced by the primary field location
Location of Primary O&G Field is a property of the primary field
Primary Depleted Oil/Gas Field can be anywhere
Vessel Expenses ($$$) is the total cost of the vessel over its lifetime
Lifetime OPEX ($$$) is an output of the various operating expenses of the vessel over its lifetime
CAPEX ($$$) is an output of the up front cost of the vessel
Of Vessels/Fleet size (# vessels) is a global decision variable that can be optimized around
Vessel Lifespan (time) How long the ship is expected to last. Generally, a constant around 20-30 years
Crew Costs ($$$/time) depends on number of crew and required pay
Fuel cost ($$$/time) is an output of the fuel type, engine SFC, and current fuel price
Maintenance Cost ($$$/time) is an output of the reliability of engines, tanks, and onboard equipment, which can be classified by mean time to repair, mean time to failure, and cost of maintenance
General Acquisition & Material Costs (Hull, quarters, machinery, etc.) ($$$) depends primarily on the size and complexity of the ship
Engineering Cost ($$$) depends primarily on the complexity of the design
Labor Cost ($$$) depends primarily on the size of vessel and yard it is built in
Size of Crew (# of people) is generally a function of the required work on the vessel, and class requirements and vessel size
Final hull displacement (tonnes) is determined by all of the required equipment, and is an indicator of structural construction costs
Vessel EEXI/EEDI (g/t*nm) depends on fuel type, engine power, engine SFC, PTO, efficiency measures, auxiliary power, correction factors based on ship type, and conversion factors
Required auxiliary power (kW) is an output of the power demand from the injection unit, ship service loads, and offloading equipment
Required propulsion power (kW), engine, SFC (g/kW*hr) is derived from emissions regulations and required power. Some fuel types may also have lesser efficiencies (i.e. Diesel Electric)
Fuel Type depends on available engines, current and future emissions regulations, and
Vessel Continuously Docked to Provide Storage and Power? (Y/N) is a global decision variable that can be optimized around
Required EEXI/EEDI (g/t*nm) depends on regulations for vessel class
Offloading equipment depends on the available equipment, and may determine the offloading rate if not custom equipment
Onloading equipment depends on the available equipment, and may determine the onloading rate if not custom equipment
Vessel Speed (kts) is an output of the transit time and distance, and is impacted by the vessel size
Onloading Rate (onto vessel) (MtCO2/time) may depend on available equipment, and is an influenced by the required transport rate and required round trip time
Storage Equipment (tanks and refrigeration) depends on the amount of CO2 that needs to be stored and the conditions that it must be stored in
Vessel Offloading Rate (MtCO2/time) is determined by the required transport rate and trip time, but constrained by available equipment
Vessel size class (tonnage) is a function of the required capacity of the vessel. However, it is constrained by the home port and sea state, which may impact the capacity
Transit Time (time) is set based on the required trip time and the transport distance
Storage conditions (Pressure, Purity, Temp) are a global variable, and is determined by the required storage capacity on the injection unit and transport vessel
Round Trip Time (time/trip - vessel) is determined by the required frequency of shipments, and whether the vessel must remain continuously docked at the injection unit
Station Time (time) is the time required for the vessel to be at the injection site
Vessel Continuously Docked to Provide Storage and Power? (Y/N) is a global decision variable that can be optimized around
Vessel Capacity (MtCO2/trip) is the amount of CO2 carried by the vessel in a single trip, and is a function of round trip time and required transport rate
Trip Frequency (trips/time) is the frequency of deliveries to the injection unit, and is dependent on the capacity of the transport vessels. Both of these must satisfy the total delivery rate required
Of Vessels/Fleet size (# vessels) is a global decision variable that can be optimized around
Average CO2 Transport Rate (MtCO2/time) is an output of the injection unit sizing and the main input to the vessel function
Dockside Storage Expenses ($$$)
CAPEX ($$$)
Lifetime OPEX ($$$)
Dockside Equipment Lifespan (time)
Vessel Docking Infrastructure ($$$) are mostly a function of the vessel's size
Land Cost ($$$) is based on the storage size and the location
Engineering Costs ($$$) are generally based on the size and capacity of the system
General Acquisition & Material Costs ($$$) are determined by the storage and transfer equipment size
Maintenance Frequency/Cost ($$$/time) is primarily a function of the storage and transfer equipment size
Utility Cost ($$$/time) is determined by the equipment power demands, and the local energy rate (determined by location)
Vessel Docking Expenses and Personnel ($$$/time) can be generalized to the vessel's size and voyage length
Dockside Power Requirements (kW) are determined by the required equipment for vessel onloading, and for the storage tanks and condition of storage
Storage Size (MtCO2) is a function of the required inventory buffer for injection operations, the density of CO2 as determined by storage conditions, and constrained by the space constraints of the site
Storage conditions (Pressure, Purity Temp) are a global variable, and is determined by the required storage capacity on the injection unit and transport vessel
Port - Vessel CO2 transfer capacity (MtCO2/time) is determined by the required onloading rate for the vessel
Storage conditions (Pressure, Purity Temp) are a global variable, and is determined by the required storage capacity on the injection unit and transport vessel
Space Constraints (km^2) are determined by the location of the home port, and influence the storage capacity of the site
The Required Inventory Buffer (MtCO2) is a function of the injection rate of CO2, and the variability of the storage input from the CO2 sources
Storage Input Variability (Cv) is determined by a combination of the arrival variability (Ca), the cargo capacity of the vessel, storage conditions, and the onloading variability
Onloading Equipment Variability (Cv) is a property of the vessel-shore transfer equipment
Transport Arrival Variability (Ca) is a function of travel distance from source to dockside, the mode of transport, and the frequency of shipments
Travel Distance (km) is a function of the source and port locations
Onshore Transport Expenses ($$$)
CAPEX ($$$)
Lifetime OPEX ($$$) is a function of the fuel, crew, and maintenance costs, and the lifespan of the units
Acquistion Cost ($$$) is a function of the transportation type and the number of transport units and their capacity
Transport Units is determined by the required frequency of trips and the transport type
Fuel Cost ($$$/time) is a function of the transport type, frequency of trips, and travel distance
Crew & Maintenance Costs ($$$/time) are a function of the transportation type
Lifespan of Transport Units (time) is a property of the transport type
Shipment Frequency (trips/time) is determined by the transportation mode type, the capacity per trip, and the total transfer rate required
Transit Time (time) determined by the travel distance and average speed
Average Transit Speed (km/time) is a property of the transportation mode
Transportation Capacity (MtCO2/trip) is a function of the required output capacity and the type of transportation
Infrastructure Cost ($$$) is a function of the transportation type
Transportation Mode (type) should be a function of the distance to travel, the quantity of CO2 transported, the variability of CO2 production, and the port/source locations
Source Locations are a property of the carbon sources
Source CO2 Output Rates (MTCO2/time) is a property of the carbon source
Seasonality of Carbon Sources (Cv) are a property of the carbon sources, and can impact the decision of whether to use the source or not
Carbon Sources should be determined by the required injection rate and the port location, and should be influenced by the seasonality and dependency of the source
Cost of CO2 Capture ($$$)
CAPEX ($$$)
Lifetime OPEX ($$$)
Lifespan of Source (time) is a property of the source
CO2 Capture Equipment Acquisition and Installation Costs ($$$) are a function of the source type, CO2 condition, and rate of capture
Source Storage Equipment Costs ($$$) are determined by the quantity of CO2 needed to store, and the condition of CO2
Maintenance and Personnel Costs ($$$/time) can be observed as a function of the source type, storage size, and capture rate
Source Storage Requirements (MtCO2) are determined by the CO2 production variability, the CO2 production quantity, and the frequency and capacity of transport
Storage conditions (Pressure, Purity Temp) are a global variable, and is determined by the required storage capacity on the injection unit and transport vessel
CO2 Source Variability (Cv) is a property of the carbon source and it's seasonality