Report on the evolution of the ideal transport combination

CETP CO2RR – Deliverable 2.1 [*interim*]

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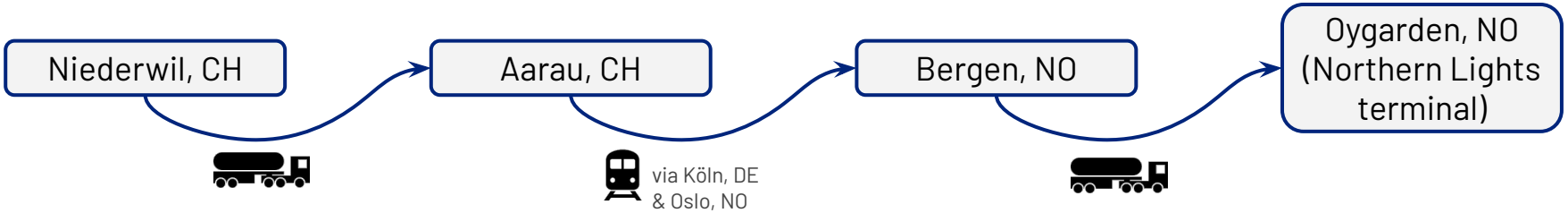
Identifying and evaluating levers that will influence the price of CO_2 transport

Transport scenario analysis

TRANSPORT

Base transport scenario

Currently envisaged transport option for Niederwil



- The estimated cost for the base transport scenario is ~**CHF 229 /tCO_2, based on an average of a number of quotes from transport providers**.
- The cost estimations to compare transport options are made for storage with Northern Lights, as a storage contract would be for a minimum of 10 years.
- *Note:* **At this point, costs presented are subject to change and are not final**.
  - Based on financial quotes received by logistics providers and Airfix assumptions.
  - Due to the current geopolitical context, we cannot assume energy prices will be the same as today.
  - Pre-feasibility study numbers are preliminary, detailed feasibility study will deliver more clarity.

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Isotainer on truck

<table>
<tr><td colspan="2">Description: Often necessary for first- and last-mile transport, liquefied CO_2 in small quantities is stored in isotainers and loaded on trucks.</td><td rowspan="2">Expected availability:
Very likely</td><td rowspan="2">Expected timeline:
already available</td></tr>
<tr><td colspan="2">Key stakeholders and service providers: Chemoil, Hoyer, Bofort, Eurotainer</td></tr>
<tr><td colspan="2">Key terms & conditions:
Very low entry threshold – individual isotainers have 20 tCO_2 capacity
CHF 30–60 per tCO_2 for short distances (20–100 km) in Switzerland; (5–10x cost of train per km)
Can be used to connect point of capture to next transport option – high flexibility
Long holding time (~70 days)
Appropriate for shorter distances and smaller volumes only</td><td>Price impact compared to base scenario:
Neutral / negative</td><td>-</td></tr>
<tr><td colspan="2">Transport scenarios and assumptions:
Included in base scenario

Recommended to keep to absolute minimum (first and last mile only, as necessary) as high cost and environmental impact.</td><td colspan="2">Intermediate infrastructure and requirements:
Intermediate storage at capture site
Additional intermediate infrastructure needs depend on combined transport modalities
Need to lease or purchase isotainers</td></tr>
<tr><td colspan="4">CO_2 emissions and environmental considerations:
High CO_2 impact (~10x more than transport by rail)
Contributes to road congestion and local air pollution</td></tr>
<tr><td colspan="4">Additional comments:
The use of e-trucks or biofuel trucks is currently limited, but could be a potential option to improve impact efficiency of value chain</td></tr>
<tr><td colspan="4">Airfix activities:
Assess route options to optimise use of trucks to transport CO_2
Negotiate with logistics providers for first- and last-mile transport</td></tr>
</table>

Source: Airfix exchanges with transport companies

TRANSPORT

Isotainer on train

Description: Suitable for long-distance ground transportation across Europe, isotainers can be loaded onto trains, with possibility of dedicated trains.

Key stakeholders and service providers: Chemoil; Hoyer; Carbon Collectors

Expected availability:
Very likely

Expected timeline:
already available

Key terms & conditions:

- Minimum volume threshold 5,000–15,000 tCO_2 per year
- CHF 100–200 per tCO_2 for distances between 800 km (Basel–Rotterdam) and 2,500 km (Basel–Bergen)
- Appropriate for small- to medium quantities of CO_2
- Possibility of dedicated trains for higher volumes of CO_2 (> 40'000 tCO_2 per year)
- Uses existing locomotives and wagons – equipment already available
- Long-term contracts required *(exact timeline tbc)*

Price impact compared to base scenario:
Neutral / positive

Option 1:
- 6.5%

Transport scenarios and assumptions:
Included in base scenario

Option 1: use of dedicated trains in base scenario likely to result to lower price [*estimate*]

Intermediate infrastructure and requirements:

- Onloading/ offloading terminal required
- Need to lease or purchase isotainers
- Potential of having dedicated trains

CO_2 emissions and environmental considerations:

- Mostly low CO_2 impact (~10x less than transport by truck)

Additional comments:

- Existing rail freight corridors provide a broad network of CO_2 transport options in Europe
- A significant part of the costs of transporting hazardous material by train are linked to loading, offloading and transfers (intermediate stops)

Airfix activities:

- Assess route options to optimise use of trains to transport CO_2
- Aggregate volumes from various projects to reach the threshold for a dedicated train
- Negotiate with logistics providers

Source: Airfix exchanges with transport companies

TRANSPORT

Isotainer on ship

Description: Isotainers can be loaded on ships, using existing shipping routes, for long-distance transportation of small quantities of CO_2.

Key stakeholders and service providers: North Sea Container Line

Expected availability:
Very likely

Expected timeline:
already available

Key terms & conditions:

- Minimum scale: 5,000–15,000 tCO_2 per year
- CHF 80–200 per tCO_2 for distances between 1,000 km (Rotterdam–Bergen) and 2,200 km (Rotterdam–Iceland)
- Ease of handling: isotainers from trains can be transferred to ships
- No flexibility on port of delivery

Price impact compared to base scenario:
Positive

Option 1:
- 13%

Option 2:
-15%

Transport scenarios and assumptions:
Option 1: transport via truck & rail to Rotterdam and then shipment to Northern Lights
Option 2: transport via truck & rail to Marseille or Genoa and then shipment to Northern Lights [*estimate*]

Intermediate infrastructure and requirements:

- Container ship loading facility
- Need to lease or purchase isotainers

CO_2 emissions and environmental considerations:

- Mostly low CO_2 impact (similar as rail)

Additional comments:

- Available today – the DemoUpCARMA project has used this option for its demonstration project

Airfix activities:

- Assess route options to optimise use of trains to transport CO_2
- Negotiate with logistics providers

Source: Airfix exchanges with transport companies

TRANSPORT

Bulk CO_2 shipping

Description: Dedicated ships – with large cryogenic tanks that can maintain the CO_2 in liquid format – can transport the CO_2 from large ports to the CO_2 storage injection sites.

Key stakeholders and service providers: Dan Unity; Northern Lights; Varo

Expected availability:
Very likely

Expected timeline:
2028–2030

Key terms & conditions:

- Volume threshold to use at full capacity: **minimum ~350,000 tCO_2/year**
- Lead time: ~28-30 months
- Option of using green methanol as fuel
- Requires a deep-sea port to load & unload CO_2
- Minimise port time due to high costs (~EUR 35k/day)
- CHF 40–100 per tCO_2 for Rotterdam–Norway and Rotterdam–Iceland
- Investment needs taken by ship owner but require long-term contracts (10+ years)

Price impact compared to base scenario:
Positive

Option 1:
- 27%

Option 2:
- 26%
(*pending quote confirmation*)

Transport scenarios and assumptions:
Option 1: transport via truck & rail to Rotterdam and then shipment to Northern Lights
Option 2: transport via truck & rail to Marseille or Genoa and then shipment to Northern Lights [*estimate*]

Intermediate infrastructure and requirements:

- Temporary storage at departure port
- If rail tanks are used, loading facility needed

CO_2 emissions and environmental considerations:

- Energy- and CO_2-efficient compared to other transport options
- Environmental impacts linked to sea freight

Additional comments:

- Linked to specific storage offerings
- Despite the minimum threshold, the significant cost reduction could make it relevant to start using the ship even below its full capacity]]
- Provides flexibility on destination as ships can be re-routed
- Existing and busy transport corridor between basel & rotterdam

Airfix activities:

- Identify offerings for bulk CO_2 ships and ports with adequate infrastructure
- Aggregate CO_2 emitters to co-commit to secure the FID on the ship, and potentially collaborate on the intermediate infrastructure

Source: Airfix exchanges with transport companies

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Bulk CO_2 inland barge (incl. bulk shipping)

Description: Inland barges provide a long-distance, large-scale option for river transportation, particularly suited for landlocked regions and emitters close to inland waterways.

Key stakeholders and service providers: Victrol; Varo

Expected availability:
Very likely

Expected timeline:
2028

Key terms & conditions:

- Minimum volume threshold of 100,000 tCO_2 per year
- CHF 30–80 per tCO_2 for Basel–Rotterdam
- Lead time of 2-2.5 years
- Investment needs mostly covered by barge owner but will require long-term contracts (10+ years)
- Possibility of isotainers on inland barge

Price impact compared to base scenario:
Positive

Option 1:
- 40%

Transport scenarios and assumptions:
Option 1: truck and train to Basel, then barge to Rotterdam and bulk shipment to Northern Lights
Option 2: Possibility of isotainers on inland barge would also be cheaper than base scenario, but necessitate Rotterdam–Northern Lights train or shipment

Intermediate infrastructure and requirements:

- Temporary storage at departure port
- Onloading/ offloading terminal required

CO_2 emissions and environmental considerations:

- Energy- and CO_2-efficient

Additional comments:

- **Barge transport is highly dependent on water levels (impact transported volumes) – with a water levels becoming more and more volatile, this solution does not appear as the most resilient one**

Airfix activities:

- Aggregate projects in Switzerland to combine volumes

Source: Airfix exchanges with transport companies

TRANSPORT

Pipeline

Description: *Pipeline are an efficient large-scale mode of CO_2 transportation across Europe, but with currently no clear operator in Switzerland and lengthy authorisation process.*

Key stakeholders and service providers: Cargo Sous Terrain; OGE (Delta Rhine Corridor); EU2NSEA; German Carbon Transport Grid

Expected availability: Likely

Expected timeline: from 2035

Key terms & conditions:

- Very high threshold for minimum volume: 1,000,000–2,000,000 tCO_2 per year
- CHF 10–40 per tCO_2 to reach main CO_2 hubs or storage sites
- Very high investment needs across Europe
- Likely limited direct access for small- and medium-sized emitters
- Extent of potential pipeline network still unknown
- Likely not available for another 10 years

Price impact compared to base scenario: Positive

Option 1: - 52%

Option 2: - 65%

Transport scenarios and assumptions:

Option 1: Truck to Basel or closest pipeline connection (e.g. Dietikon), pipeline to Rotterdam, then shipment to Northern Lights [*estimate*]

Option 2: Truck to Basel, pipeline to Northern Lights [*estimate*]

Intermediate infrastructure and requirements:

- Can partly use refurbished infrastructure
- Intermediate storage hubs needed in key locations (e.g. Basel, Rotterdam, Bergen)

CO_2 emissions and environmental considerations:

- Energy- and CO_2-efficient
- Public acceptance considerations linked to potential impacts of construction of pipeline

Additional comments:

- Other projects are being conceptualised in Scandinavia, Croatia, the south of France and Italy.
- Study on KVA Linth estimates costs of CHF ~18 per tCO_2 from Basel to Bergen;
- ETH Zurich study estimates costs of CHF 30–35 per tCO_2 for a Swiss pipeline.

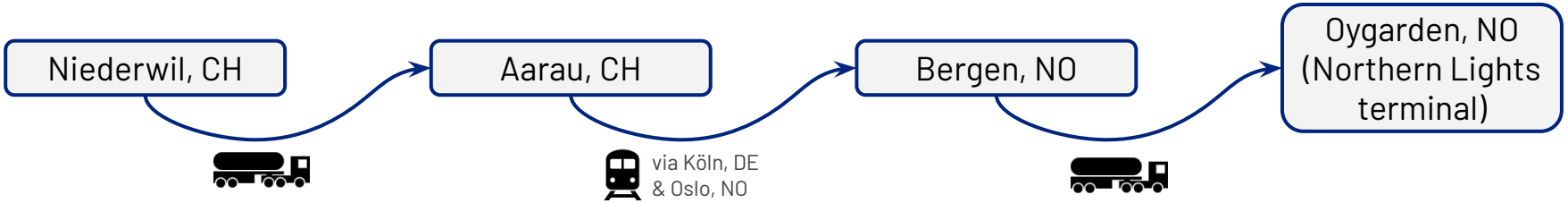
Airfix activities:

- Aggregate projects in Switzerland to combine volumes
- Works with relevant partners on feasibility of CH pipeline

Source: Airfix exchanges with transport companies

TRANSPORT

Base transport scenario



CHF 220/ tCO_2
2026-2027

Based on average from a number of quotes from transport providers and Airfix insights. The cost estimations to compare transport options will be for storage with Northern Lights, to simplify comparison.

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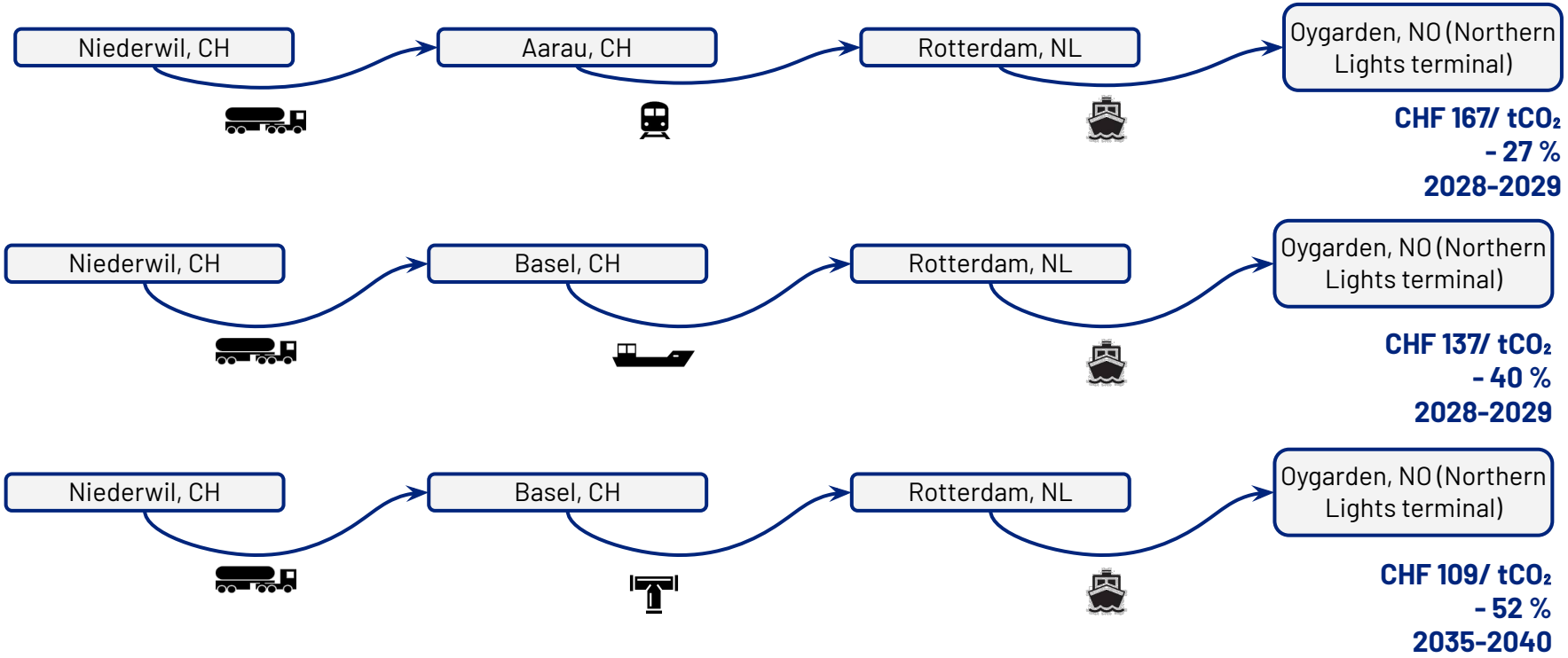
Alternative transport scenarios

Potential evolution of transport options for Niederwil



Based on average from a number of quotes from transport providers and Airfix insights. The cost estimations to compare transport options will be for storage with Northern Lights, to simplify comparison.

Key takeaways

Unlocking cheaper and more efficient transport modalities

- Transport is the largest driver of cost (over 50%) in value chain as networks are not yet fully developed.
  - However, providers are emerging and the value chain is demonstrated
  - Future transport options will unlock more efficient and cheaper transport modalities, especially for larger volumes.
- Transport costs for a Swiss emitter could go down by over 40% by 2030, with pipelines eventually allowing for decreases of 65%.
  - Note: this is for the base scenario with storage with Northern Lights. Additional storage sites may come online, closer to Switzerland, presenting different and possibly cheaper options.
- Options for cheaper transport costs:
  - Dedicated trains
  - Isotainers on ships
  - Isotainers on inland barge
  - Bulk inland barge
  - Bulk shipping
  - Pipelines
- Airfix is engaging transport and logistics providers to explore the feasibility of these potential scenarios.