CO_2 logistics in Finland

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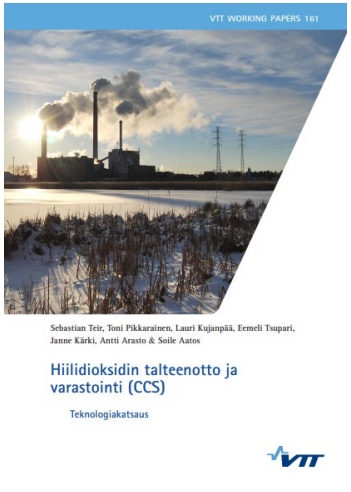
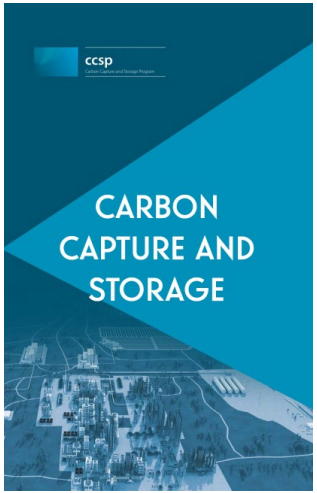
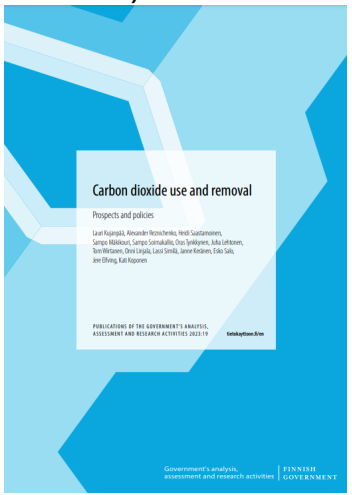
Background and past studies on CO_2 logistics in Finland

VTT's past public studies on CO_2 logistics in Finland

- CCS Finland (2008-2011)
- CCSP (2012-2016)
- CO_2 use and removal: Prospects and policies (2022-2023)
- Technological carbon sinks in Finland (2023)

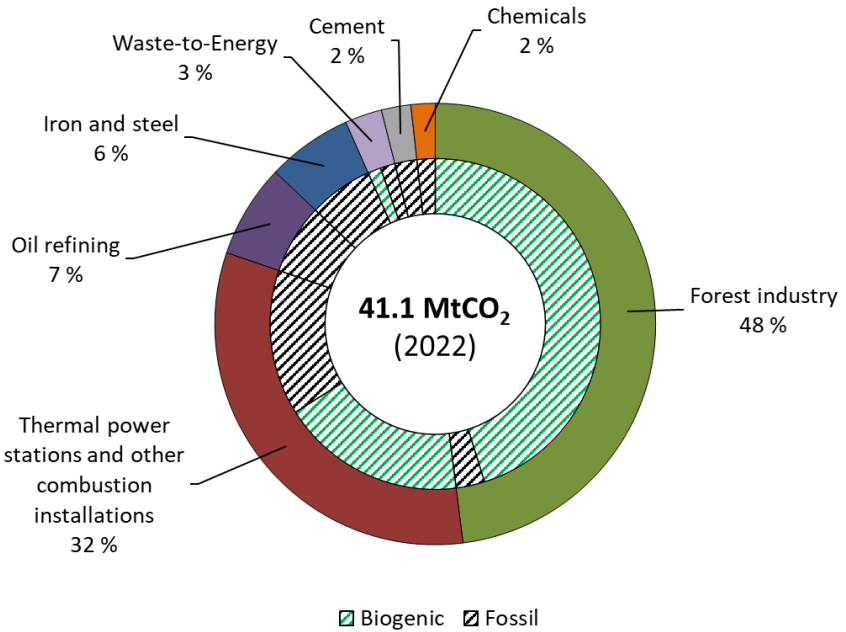




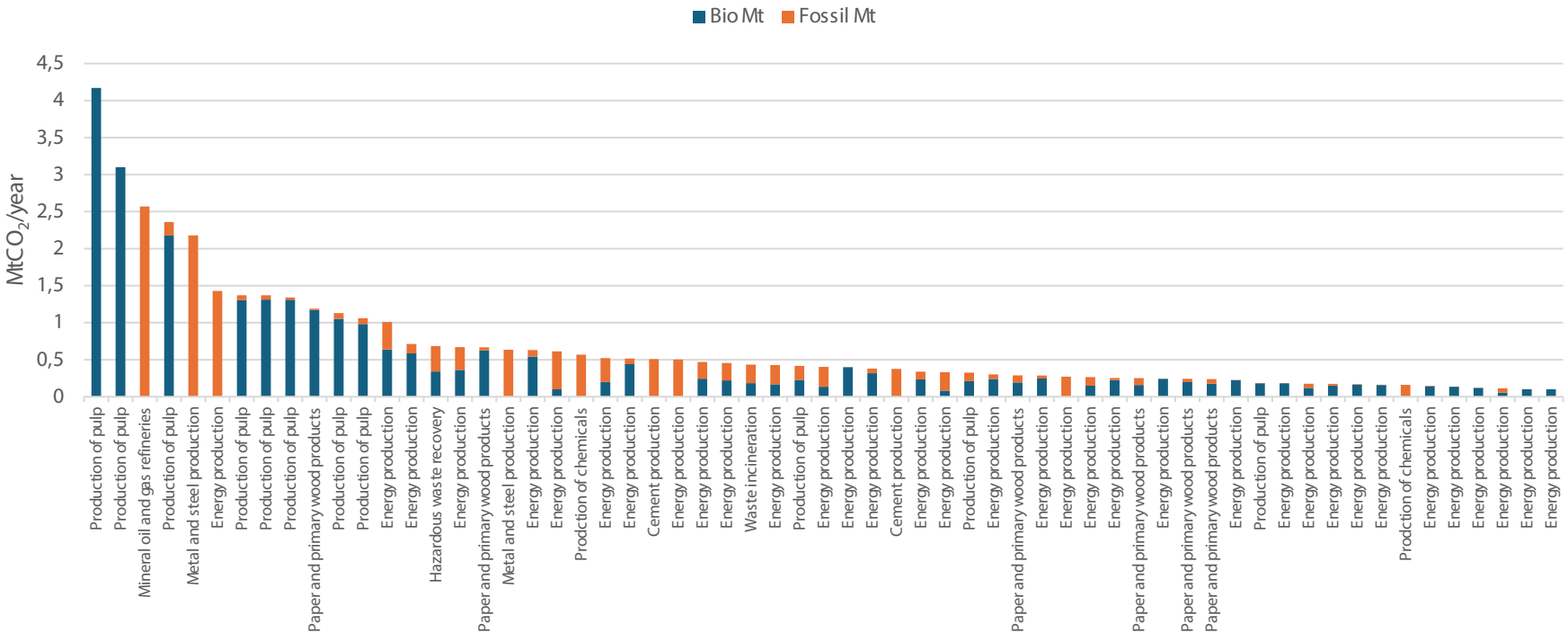


Why BECCUS? - Industrial CO_2 emissions in Finland

- According to EU's 2040 climate targets, industrial removals amount to 50-70 $MtCO_2$/year by 2040.
- Major part of industrial CO_2- emissions in Finland are biogenic, around 26,5 $MtCO_2$/year (EEA, 20.12.2023).
  - Including installations with an emission reported over 100 $ktCO_2$
  - Forest industry dominates
  - Over 7 $MtCO_2$ from large bioenergy facilities
- The combined biogenic CO_2 emissions from independent commercial heating and cooling was 14,6 $MtCO_2$ in 2021.
  - Double compared to only large thermal power stations and other combustion installations.

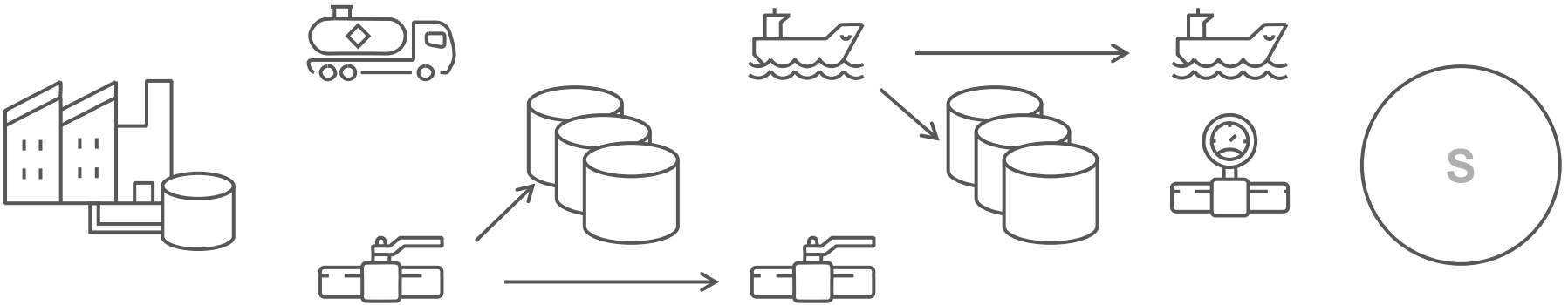


Over 100kton CO_2 emitting facilites in Finland



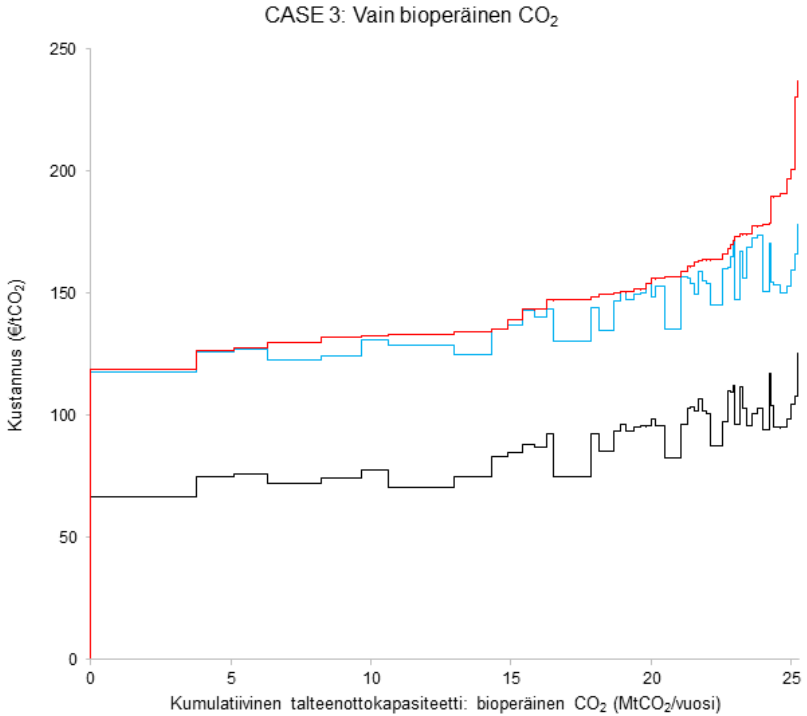
Based on past studies, ships are needed to reach geological CO_2 storage sites from Finland

CO_2 capture, pressurization	Transport by truck or train to harbour terminal or CO_2 pipeline	Liquefaction, intermediate storage for transport by ship	CO_2 transport by ship or pipeline	Liquefaction, intermediate storage in final terminal	CO_2 transport by pipeline to storage site. Ship can be unloaded at the storage site at sea.	Permanent geological storage (or mineralisation)



Cost abatement curve: CO_2 capture, transport and storage from Finland

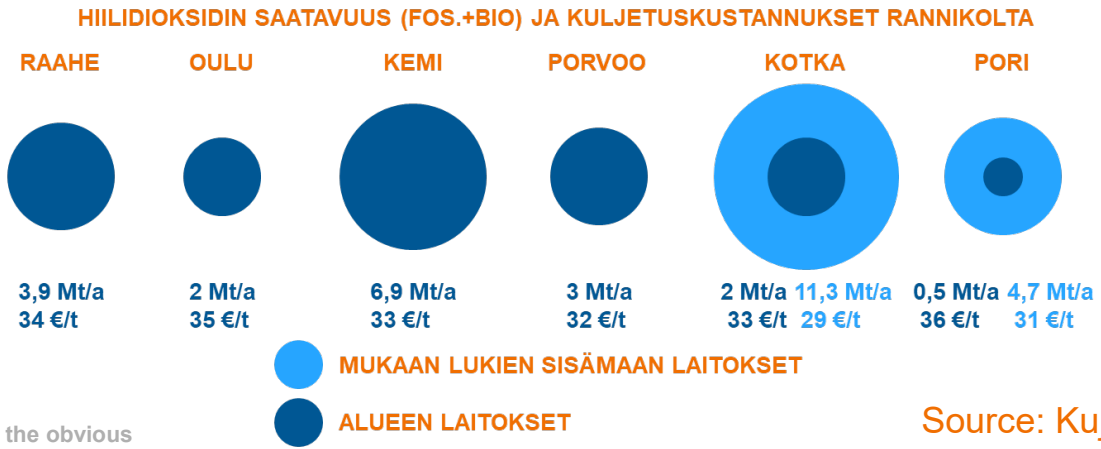
- Based on Kujanpää et al. 2023, unit costs of BECCS in Finland would be within the range of:
  - 119—237 €/tCO_2 (no shared logistic)
  - 117—178 €/tCO_2 (with shared logistic).
  - Shared logistics mean that two or more CO_2 sources use the same transport infrastructure.
- Sharing logistics benefits the smallest capture facilities the most.
- However, major uncertainties in the presented transport unit cost from inland sites to ship terminals: **limited accounting of route planning, alternative transport modes or seasonal fluctuations**.



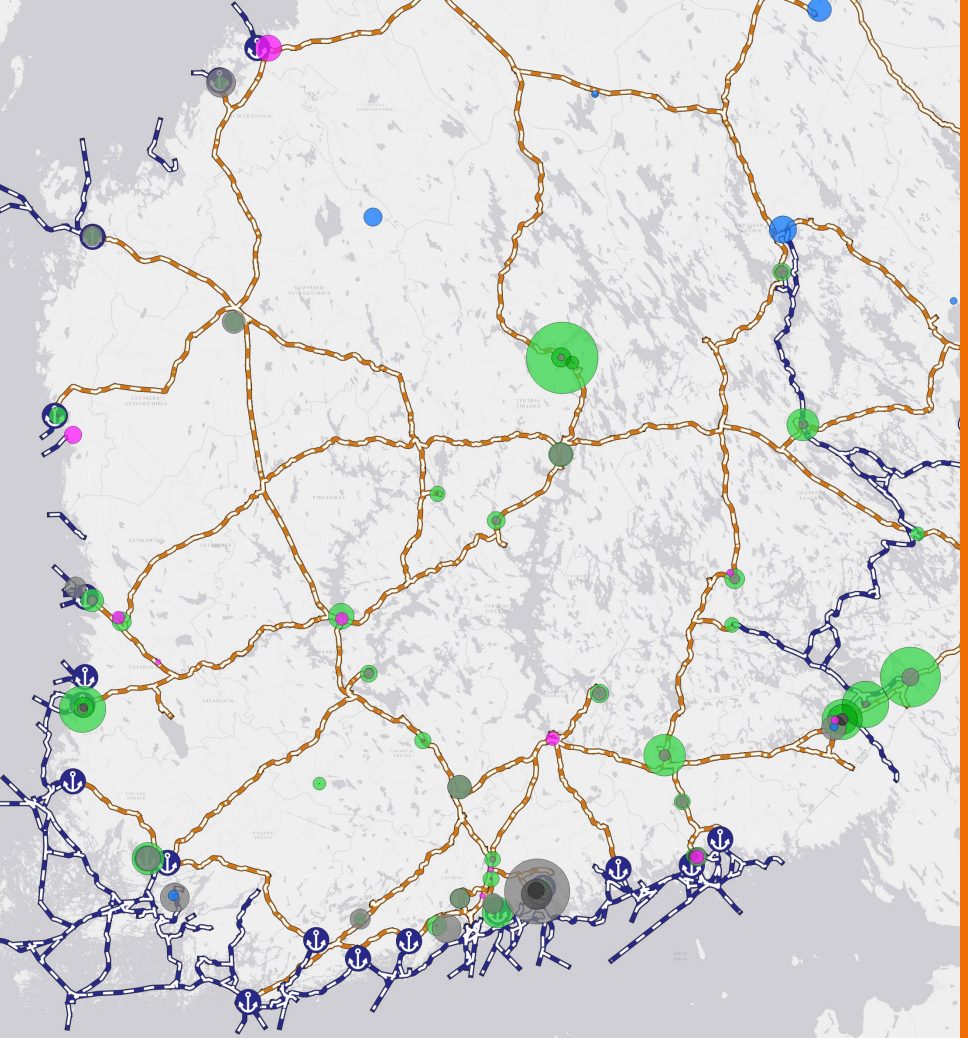
Cost of capture, transport and storage (no shared logistics)
Cost of capture, transport and storage (with shared logistics)
Cost of capture and compression

Better cost efficiency in CO_2 logistics could be gained through CO_2 hubs

- A possibility for smaller plants to benefit from scale in hubs.
- At costal area of Finland, emission hubs (Kemi, Oulu, Pori, Rauma, Vuosaari, Kotka) could provide in the order of 10 Mt biogenic CO_2 or more if CO_2 also transported from inland.
- To complement past studies of CO_2 logistics in Finland, however, especially studies on the inland transport networks are needed.



Source: Kujanpää et al. 2023



The new study ”Outlook of CO_2 logistics in Finland”

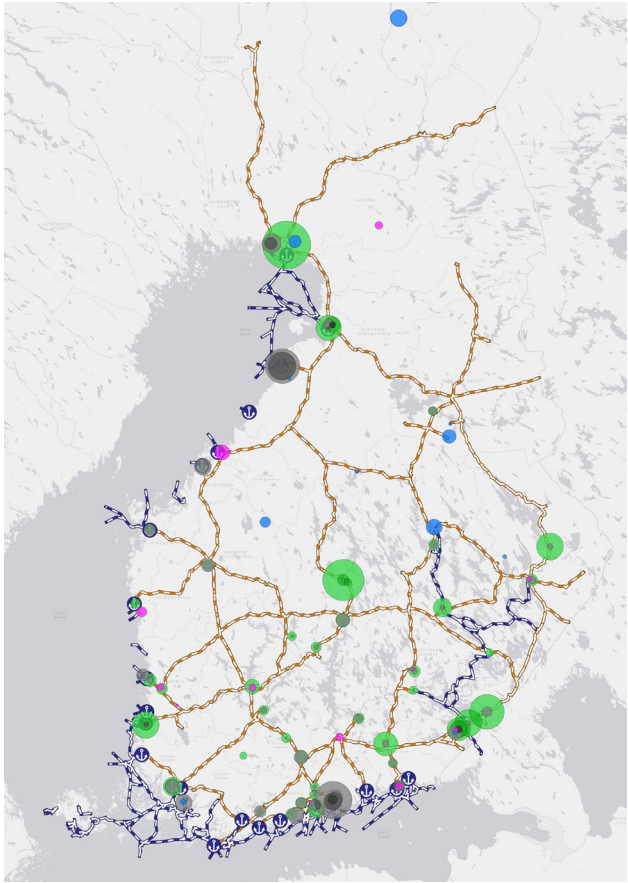
Introduction to the project ”Outlook on CO_2 logistics in Finland”

- VTT is conducting a new study on the outlook of CO_2 logistics in Finland, together with Bionergia Ry:s network of partner companies.
  - Work in progress - Results will be ready by August 2024.
- The goal is to assess alternative technologies and networks for CO_2 logistics, focusing on the investment and unit costs of CO_2 transport.
- The study consists of:
  - Outlook on large CO_2 point sources, CO_2 terminals and inland hubs
    - Creation of development scenarios how the logistic networks could look like in 2040.
  - Finding optimal modes of transport and their costs
    - Definition and application of unit cost estimation method
  - Assessment of required investments per mode of transport, type of infrastructure and development scenarios.

Future work

Current data on CO_2 emissions and infrastructure

- The up-to-date CO_2 emissions (fossil and biogenic) have been mapped with rail routes and harbours.
- Estimates of CO_2 utilization volumes have been mapped based on current P2X/CCU project pipeline (in pink)
  - The estimates are unvalidated and indicative due to project uncertainties
- Locations of mines with potentially suitable tailings for mineral storage of CO_2 have also been mapped (in blue).
  - The indicated storage potentials are unvalidated middle estimates.

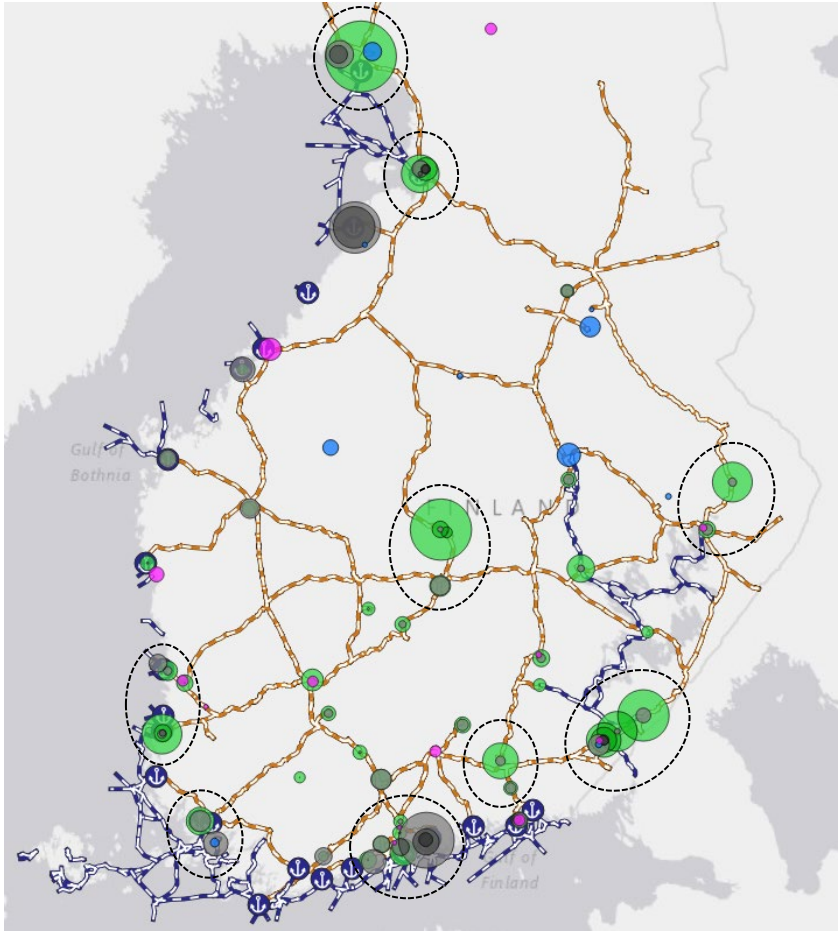


Possible hubs based on density and scale of CO_2 emitting facilities

- The CO_2 capture potential in the regions with higher density of large point sources is in total over 20 $MtCO_2$/year (bio).
- Four larger inland hubs could be formed: Jyväskylä-Äänekoski (3.5 $MtCO_2$/year), Joensuu-Uimaharju (1.5 $MtCO_2$/year), Imatra-Lappeenranta (4.8 $MtCO_2$/year) and Kouvola (1.2 $MtCO_2$/year).
- In total, roughly the same amount of CO_2 can be captured in coastal and inland hubs.

	90% capture potential ($MtCO_2$/year)		
Region/Hub	**Fossil**	**Bio**	**Total**
Kemi-Tornio	0.80	3.89	4.69
Oulu	0.26	1.79	2.05
Joensuu-Uimaharju	0.07	1.47	1.54
Jyväskylä-Äänekoski	0.24	3.47	3.71
Imatra-Lappeenranta	0.36	4.83	5.19
Pori-Rauma	0.28	2.00	2.28
Vuosaari*	0.89	1.23	2.12
Naantali-Parainen	0.73	0.64	1.37
Kouvola	0.07	1.18	1.24
Total	**3.71**	**20.48**	**24.19**

*Excluding Porvoo



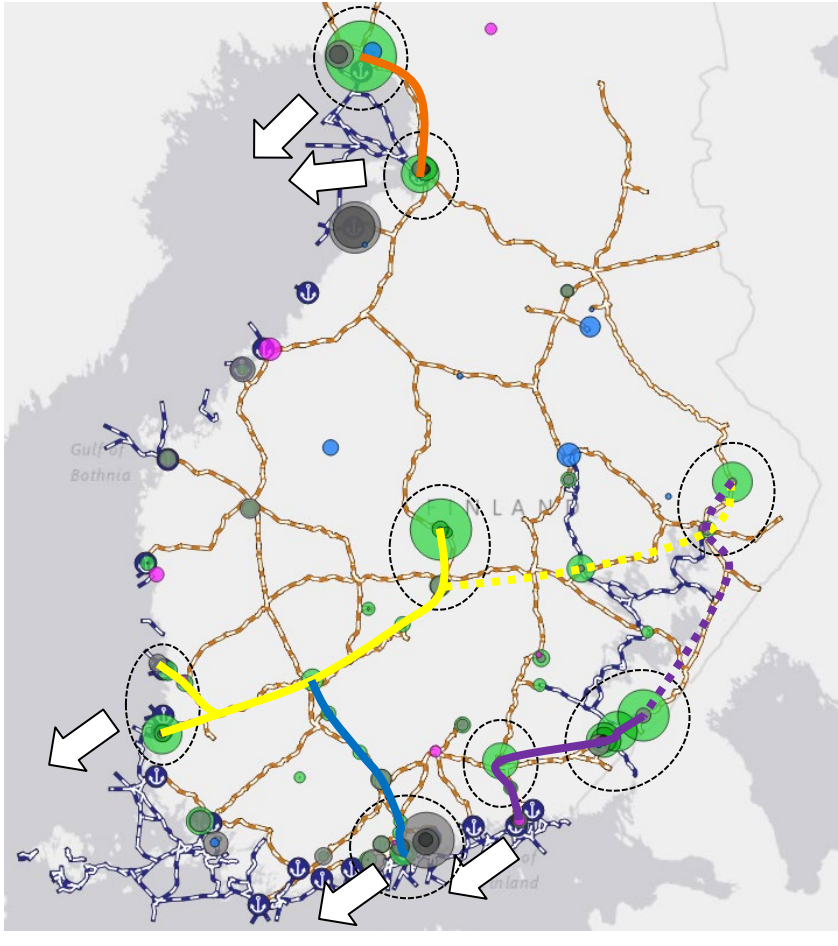
3 cases with utilisation or geological storage / export emphasis

- Temporal scope of each scenario is the same (2040) but volumes regarding utilization and storage are altered.

- **CASE A: Baseline**
  - Volumes of CO_2 for utilization and geological storage are estimated based on the current initiatives and targets of EU and Finland.
  - CO_2 hubs may emerge both inland and near the coast.

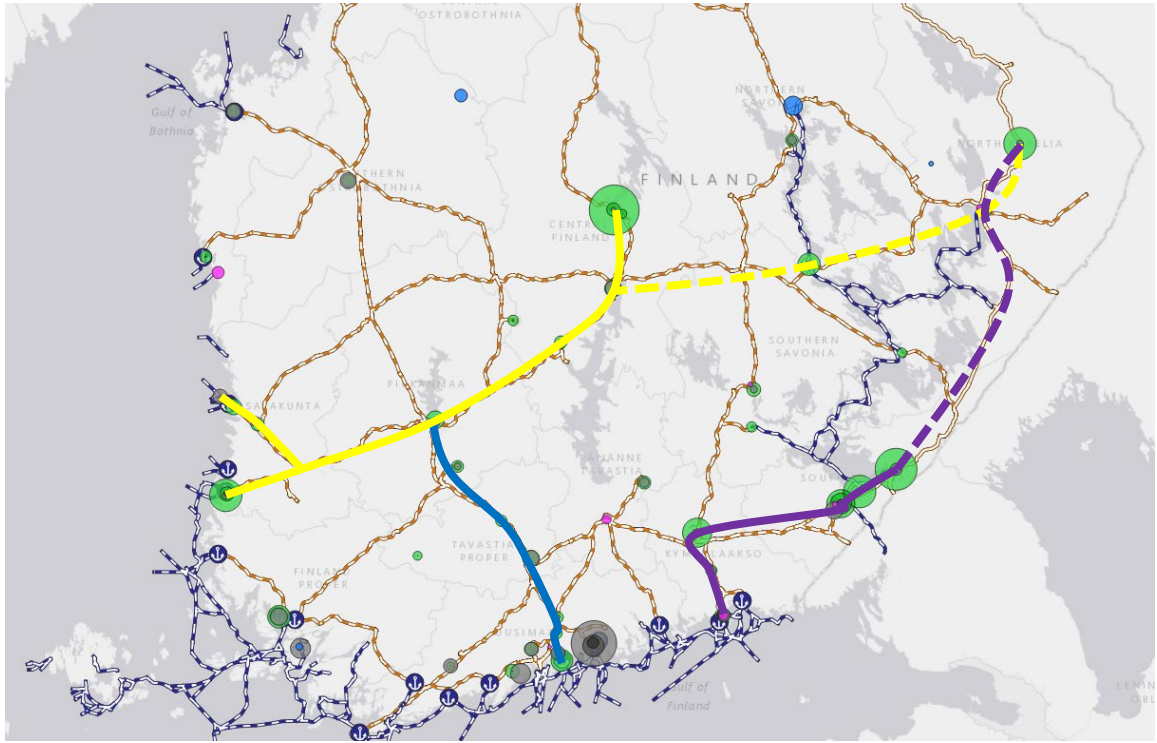
- **CASE B: Utilization emphasis**
  - Volumes of CO_2 utilization are larger compared to the baseline scenario, whereas geological storage capacity reduced in similar proportion.
  - As CO_2 utilization is more local, it is expected that there will be lower demand for designated CO_2 logistics infrastructure.
  - CO_2 hubs may emerge both inland and near the coast.

- **CASE C: Geological storage / export emphasis**
  - Volumes of geological storage of CO_2 are larger compared to the baseline scenario creating higher demand for CO_2 export logistics like shipping terminals.
  - CO_2 hubs are expected to emerge especially near merchant harbours.



Alternative trunk line options in the scenarios

- Possibility to study alternative trunkline routes to Pori/Rauma, Vuosaari and Kotka. Such as:
  - Uimaharju-Imatra-Lappenranta-Kouvola-Kotka
  - Uimaharju-Joensuu-Varkaus-Jyväskylä- Tampere-Pori/Rauma
  - Tampere-Vuosaari
- Would enable smaller capture facilities to access remote hubs and terminals.
- Gives additional indication of costs and comparison between transport modes: pipeline vs. train.



Conclusions

- The result will be an up-to-date study on the big picture of CCUS logistics in Finland.
- Major CO_2 clusters both inland and coastal regions, and capture potential within the current cluster regions is over 20 $MtCO_2$/year (bio).
  - Due to smaller scale, bioenergy facilities would benefit most from shared infrastructure.
  - Hubs are covered by the railroad network
- Three major trunkline routes can be investigated, which could give connection to smaller capture sites along the pipeline/railroad.
- Based on current project pipeline, the volume of CO_2 utilization accounts for only 1.3 $MtCO_2$/a, which still remains only a fraction of the potential.

beyond
the obvious

Thank you!

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