Decarbonisation options of existing thermal power plant burning natural gas

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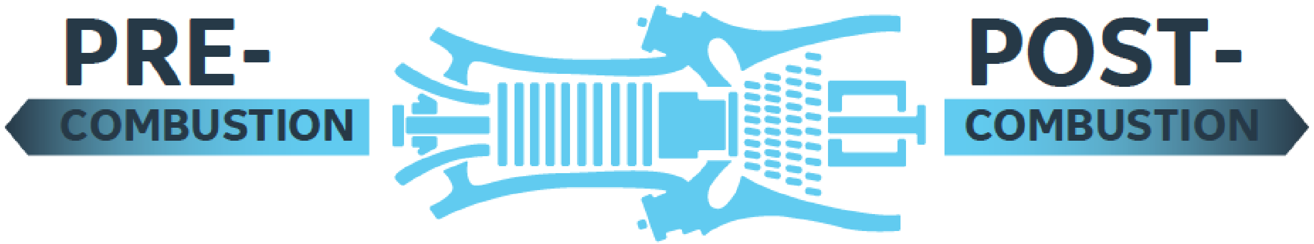
Decarbonisation options of CCGT



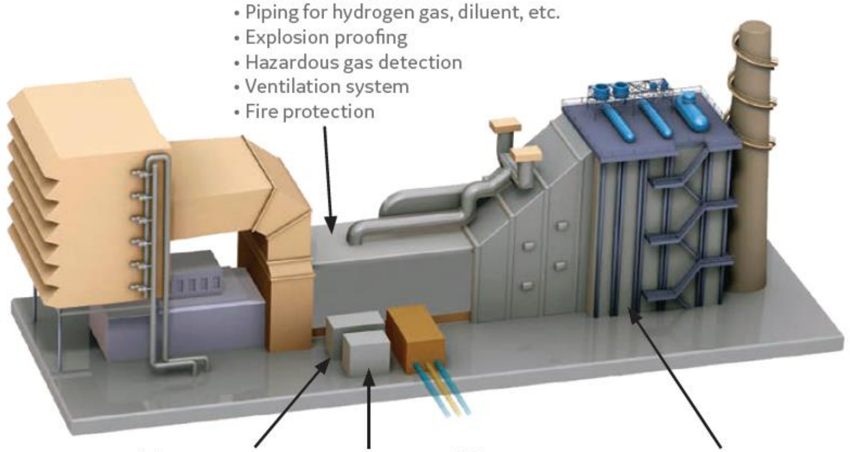
USE A ZERO OR CARBON NEUTRAL FUEL
- Hydrogen (blue, green, pink)
- Synthetic (renewable) methane
- Biofuels
- Ammonia (NH_3)

REMOVE CARBON FROM THE PLANT EXHAUST
- Carbon capture (liquid solvents)
- Carbon capture (solid sorbents)
- Oxy-fuel cycles

Start of operations - 1973
Electrical capacity - 832 MW (in cogeneration mode), 881 MW (in condensation mode)
Thermal capacity - 1,124 MW
Energy source - natural gas

- ❑ Option 1. Replacement of natural gas with alternative gases.
- ❑ Option 2. Carbon capture and underground storage (CCS) in geological formations.
- ❑ Option 3. Carbon capture, liquefaction and export.
- ❑ Option 4. Carbon capture and utilisation (CCU).

Option 1. Replacement of natural gas with alternative gases



$$E'_{CO_2} = \frac{C^d \times M_{CO_2} \times 1000}{Q_z^d \times M_C \times 100} \times \rho$$

Where

E'_{CO2} – CO_2 emission factor (t_{CO2}/TJ)

C^d – carbon content of fuel by mass (%)

M_{CO2} – CO2 molecular weight (44.0098 g/mcl)

M_C – C molecular weight (12.011 g/mcl)

Q_{zd} – lower heating value (LHV) of fuel mixture (GJ/1000m3)

1000 – conversion from GJ to TJ

100 – conversion to percentage (%)

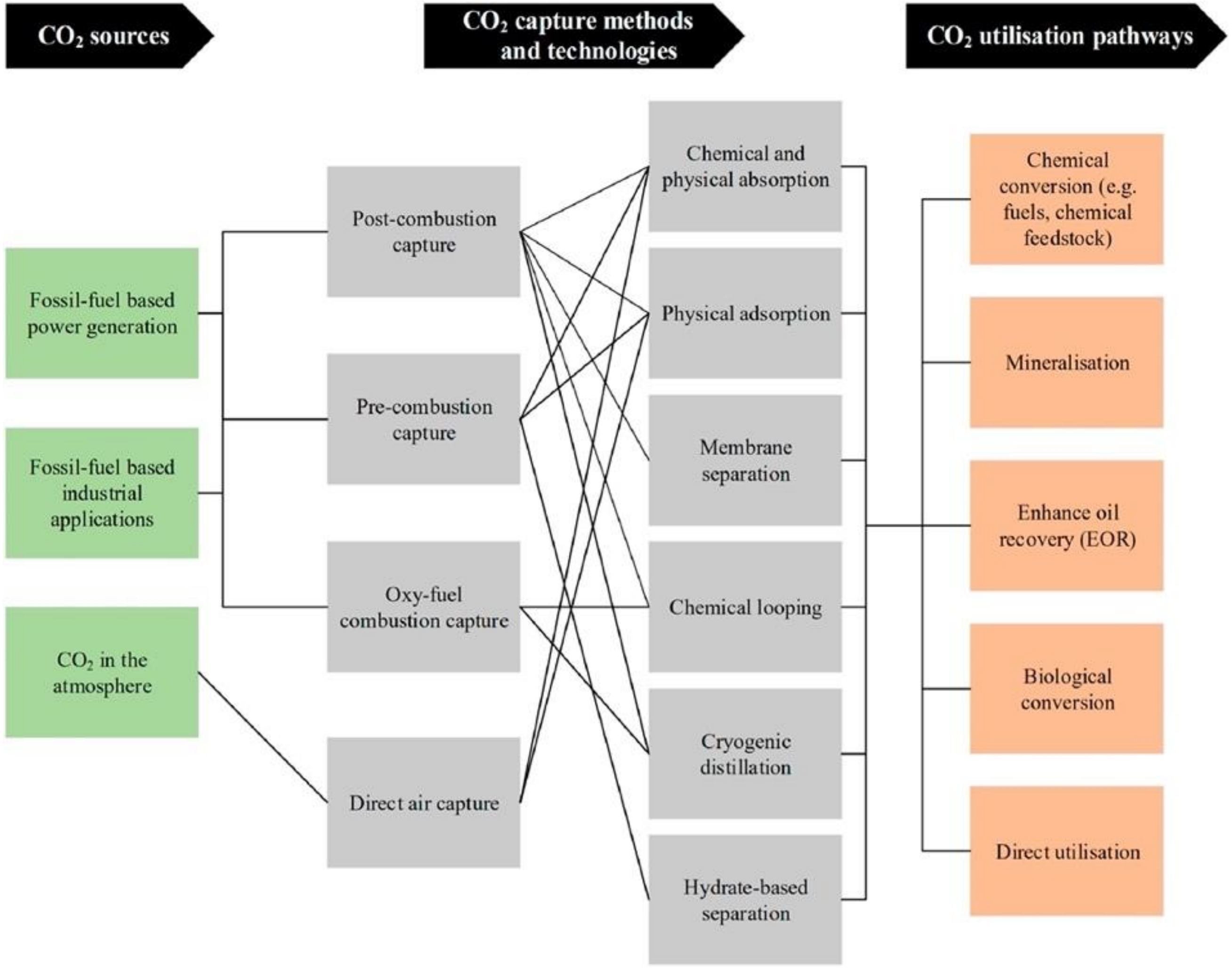
ρ – density of fuel mixture for transition from volume to mass

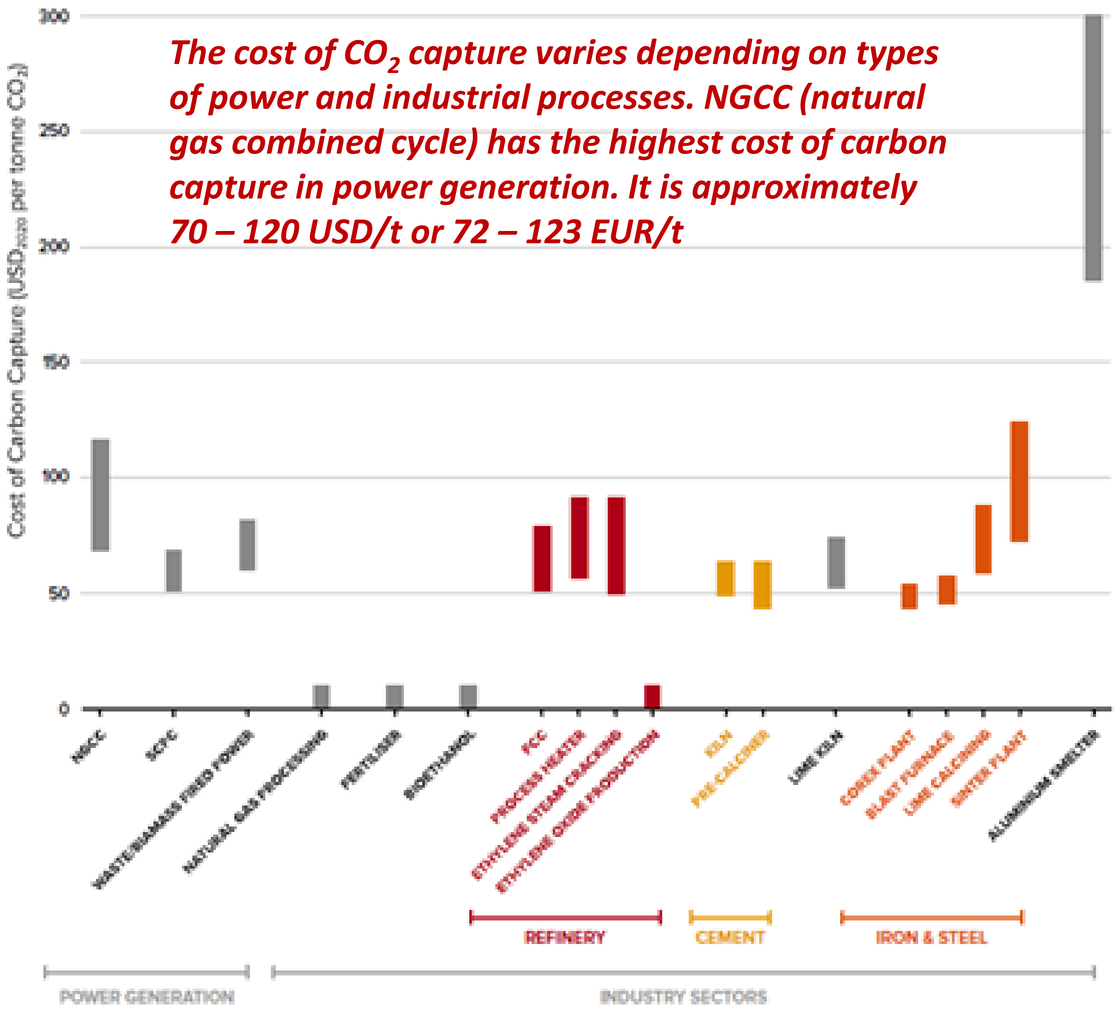
H_2 share in the mixture (%, volume)	0%	1%	3%	5%	10%	30%	50%	70%
H_2 share in the mixture (%, mass)	0.00%	0.16%	0.49%	0.83%	1.74%	6.38%	13.73%	27.08%
Density of the mixture (kg/m³)	0.523	0.518	0.510	0.501	0.479	0.391	0.303	0.215
LHV of the mixture (MJ/nm³)	34.08	33.84	33.38	32.91	31.75	27.09	22.44	17.78
Emission factor (g[CO_2]/MJ)	41.87	41.74	41.47	41.19	40.45	36.87	31.80	24.07
CO_2 emission reduction (%)	0.0%	0.3%	1.0%	1.6%	3.4%	12.0%	24.1%	42.5%

- CCGT plant does not require any modernisation, if H_2 share in CH_4-H_2 mixture does not exceed 5% (volume).
- For higher blending of hydrogen, such aspects as higher flame speed (270 cm/s for H_2, 30 cm/s for CH_4), high adiabatic flame temperature, higher flashback risk, lower explosion limit, lower Wobbe index (40.90 MJ/Nm³ for H_2, 48.17 MJ/Nm³ for CH_4), higher volume flowrate (3.3 times higher than for CH_4), lower density (0.09 kg/Nm³ for H_2, 0,717 kg/Nm³ for CH_4).

It requires a serious upgrade of gas turbine fuel system: air and fuel supply systems, compressors, burners, combustion chambers (multi cluster DNL or diffusion combustors), materials, sealing, gas leakage monitoring systems, fire protection, combustion monitoring systems.

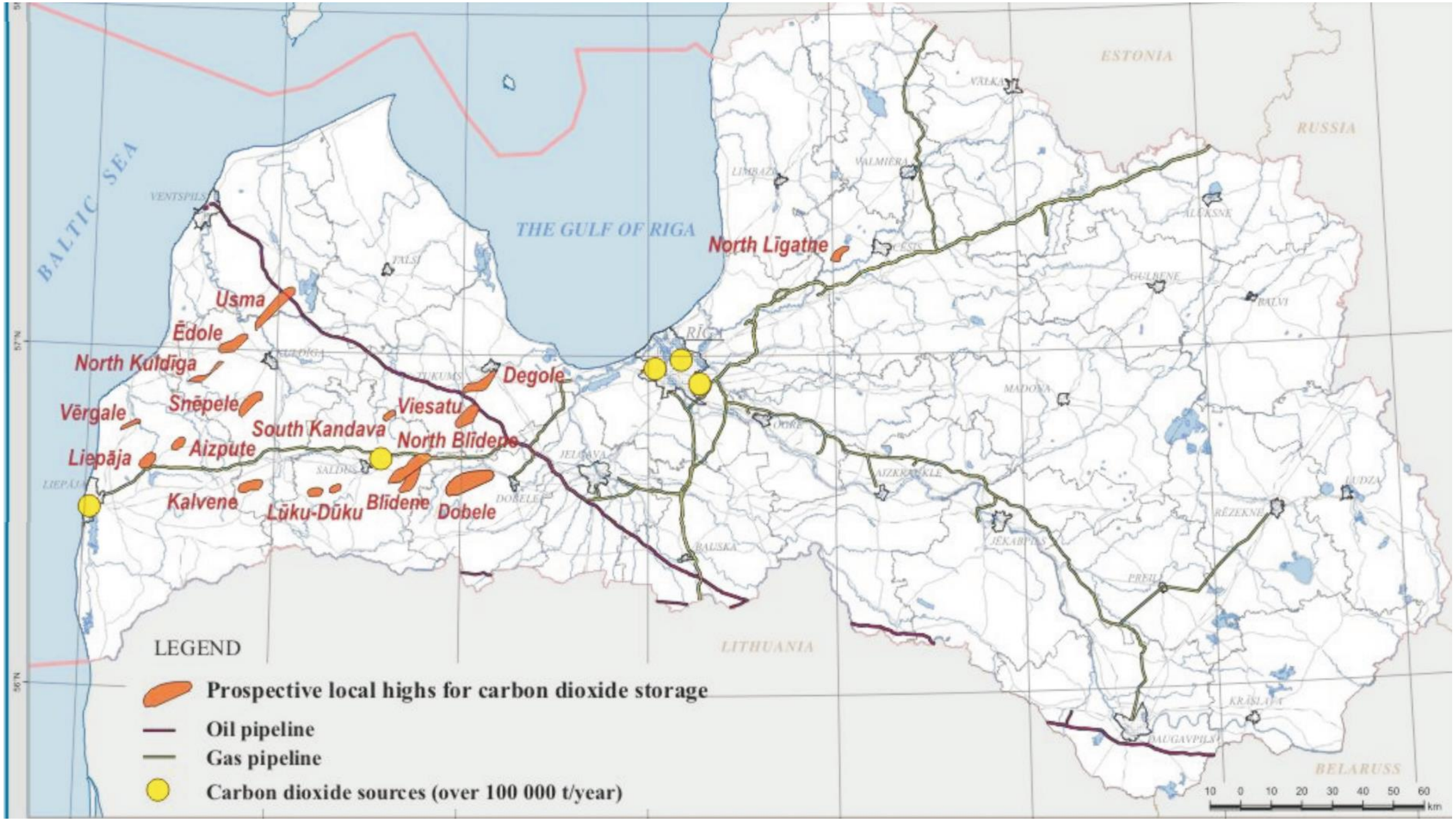
Option 2. Carbon capture and underground storage (CCS) in geological formations





The cost of CO_2 capture varies depending on types of power and industrial processes. NGCC (natural gas combined cycle) has the highest cost of carbon capture in power generation. It is approximately 70 – 120 USD/t or 72 – 123 EUR/t

Potential geological structures for CO_2 / H_2 storage, oil and gas infrastructure



https://www.meteo.lv/lapas/geologija/zemes-dzilu-resursi/perspektivie-resursi/co2/co2?id=1496&nid=494

Potential CO_2 / H_2 storage volumes in geological structures

Structure	Stratigraphic unit, Formation	Lithology	Top depth (m)	Permeability (mD)	Porosity	CO_2 density (t/ m^3)	Storage efficiency factor	Area, km2	Reservoir volume, MMm3	Theoretical capacity, Mt	Capacity, Mt *(optimistic values)*	Capacity, Mt *(conservativ values)*
Aizpute	M. Cambrian, Deimena Fm.	Sandstone	1120	300	0.21	0.720	0.40	51	587	72.8	31	**14**
Blidene	M. Cambrian, Deimena Fm.	Sandstone	1168	300	0.21	0.730	0.40	43	2091	259.3	112	**58**
N.Blidene	M. Cambrian, Deimena Fm.	Sandstone	1041	300	0.21	0.710	0.40	95	2655	329.2	142	**74**
Degole	M. Cambrian, Deimena Fm.	Sandstone	1094	300	0.21	0.720	0.40	41	782	97.0	41	**21**
Dobele	M. Cambrian, Deimena Fm.	Sandstone	1058	300	0.22	0.720	0.40	67	2000	248.0	105	**56**
Edole	M. Cambrian, Deimena Fm.	Sandstone	975	300	0.20	0.720	0.40	19	283	35.1	16	**7**
Kalvene	M. Cambrian, Deimena Fm.	Sandstone	1133	300	0.22	0.730	0.40	19	525	65.0	27	**14**
Liepaja	M. Cambrian, Deimena Fm.	Sandstone	1102	300	0.21	0.720	0.40	40	660.0	73.0	31	**6**
Luku-Duku	M. Cambrian, Deimena Fm.	Sandstone	1024	300	0.22	0.720	0.40	50	1440	179.0	75	**40**
N. Kuldiga	M. Cambrian, Deimena Fm.	Sandstone	1034	300	0.20	0.720	0.40	18	490	61.0	21	**13**
N. Ligatne	U.-M. Cambrian, Cirma Strata	Sandstone	700	300	0.22	0.560	0.40	30	810	100.4	41	**23**
S.Kandava	M. Cambrian, Deimena Fm.	Sandstone	1053	300	0.20	0.720	0.40	69	1573	195.1	82	**44**
Snepele	M. Cambrian, Deimena Fm.	Sandstone	1067	300	0.22	0.720	0.40	26	602	74.6	31	**17**
Usma	M. Cambrian, Deimena Fm.	Sandstone	1000	300	0.21	0.710	0.40	20	180	9.0	5	**2**
Vergale	M. Cambrian, Deimena Fm.	Sandstone	993	300	0.22	0.710	0.40	10	194	24.1	9	**5**
Viesatu	M. Cambrian, Deimena Fm.	Sandstone	1070	300	0.21	0.720	0.40	19	424	52.6	21	**10**
										1875.2	790	**404**

According to existing legislation, CO2 geological storage in Latvia is forbidden.

https://www.meteo.lv/lapas/geologija/zemes-dzilu-resursi/perspektivie-resursi/co2/co2?id=1496&nid=494

Previous geological studies of Dobele structure

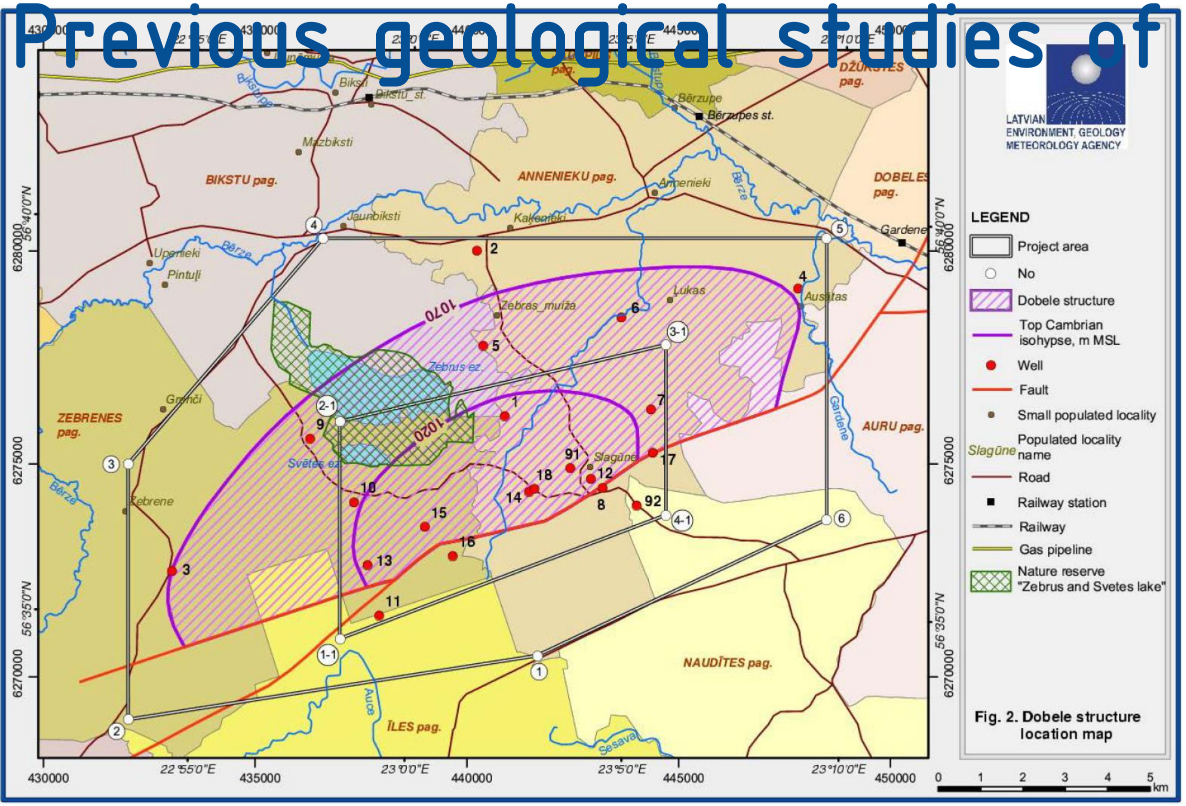
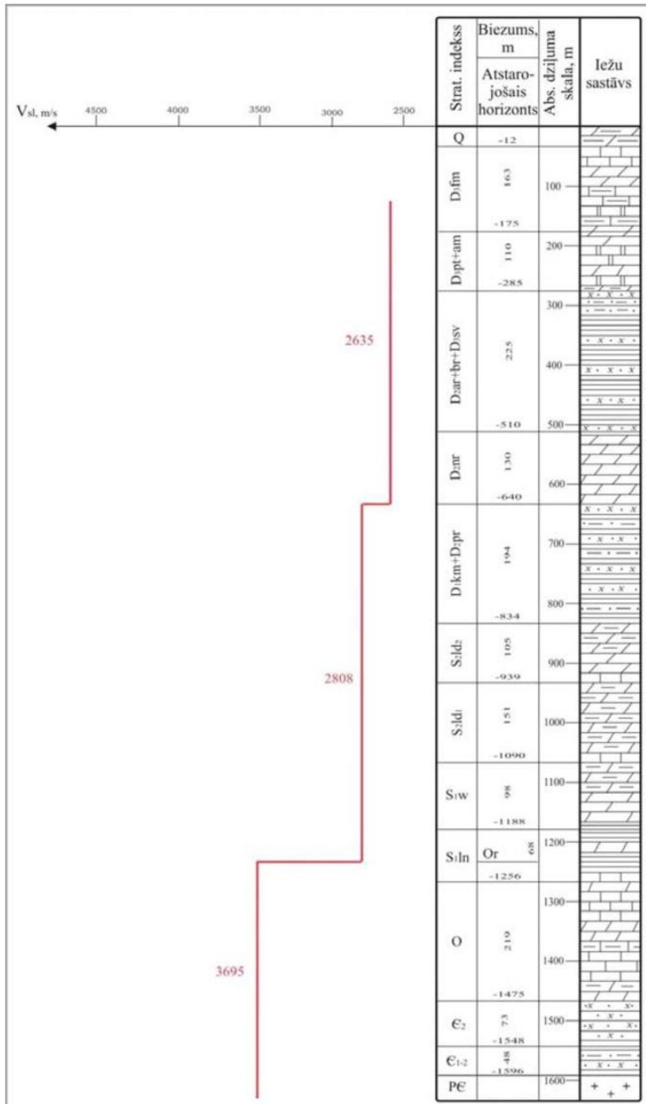
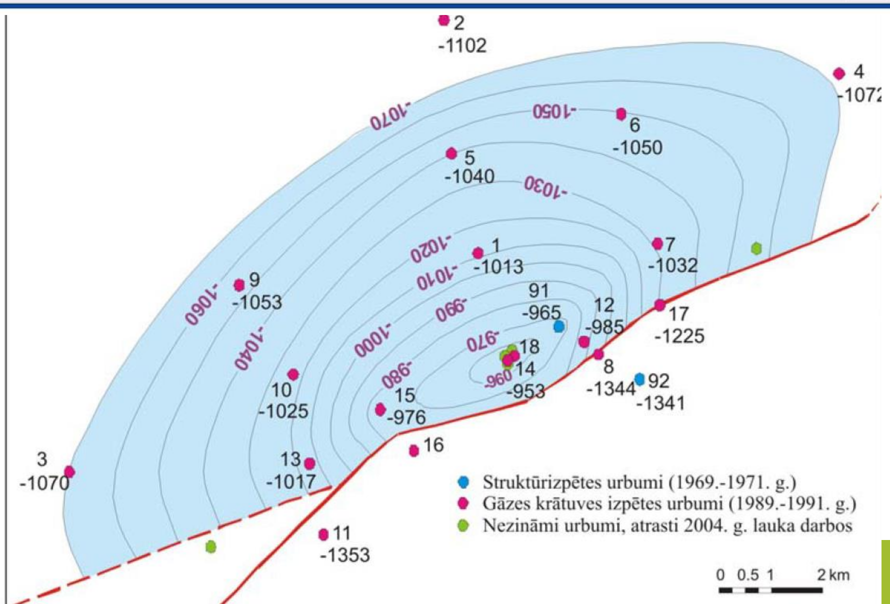
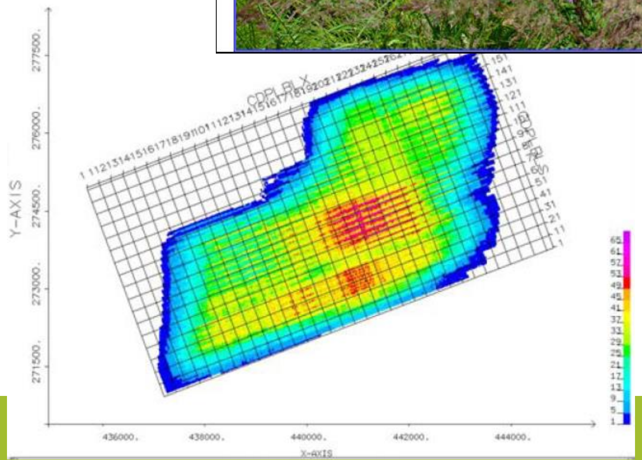


Fig. 2. Dobele structure location map

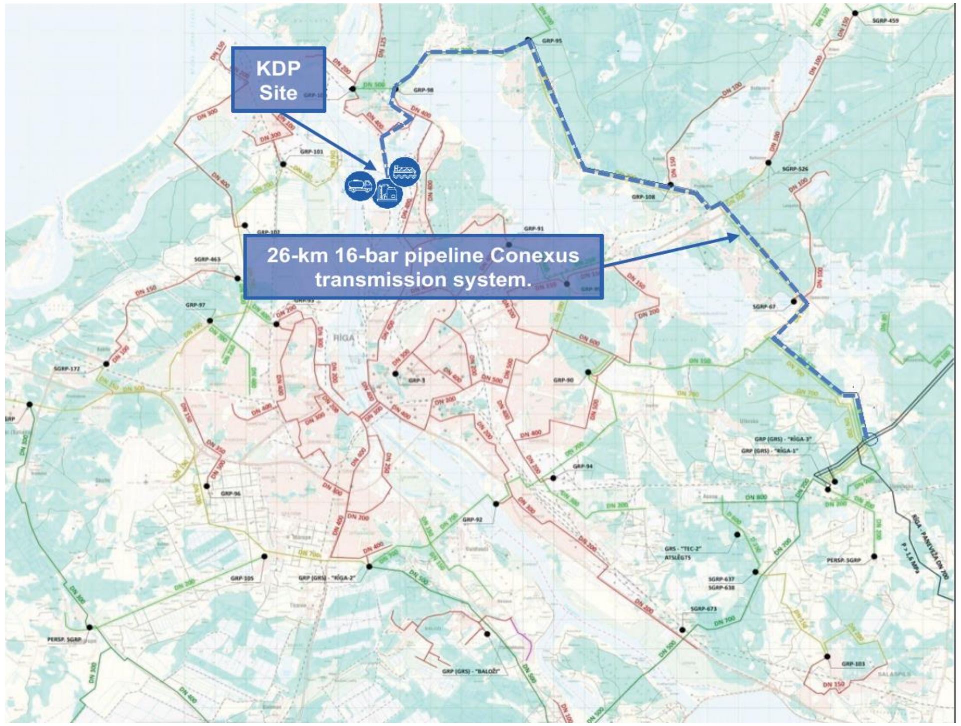


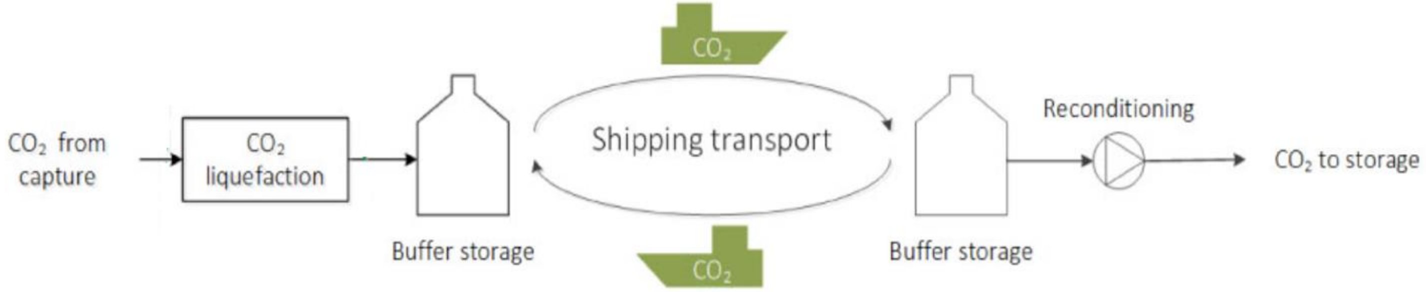




Option 3. Carbon capture, liquefaction and export

- The CO2 shipping chain starts after the CO2 capture and lasts until storage. The chain involves liquefaction, buffer storage, loading/unloading, shipping transport and reconditioning. In practice, the CO2 could be transported under different transport conditions (temperature and pressure)





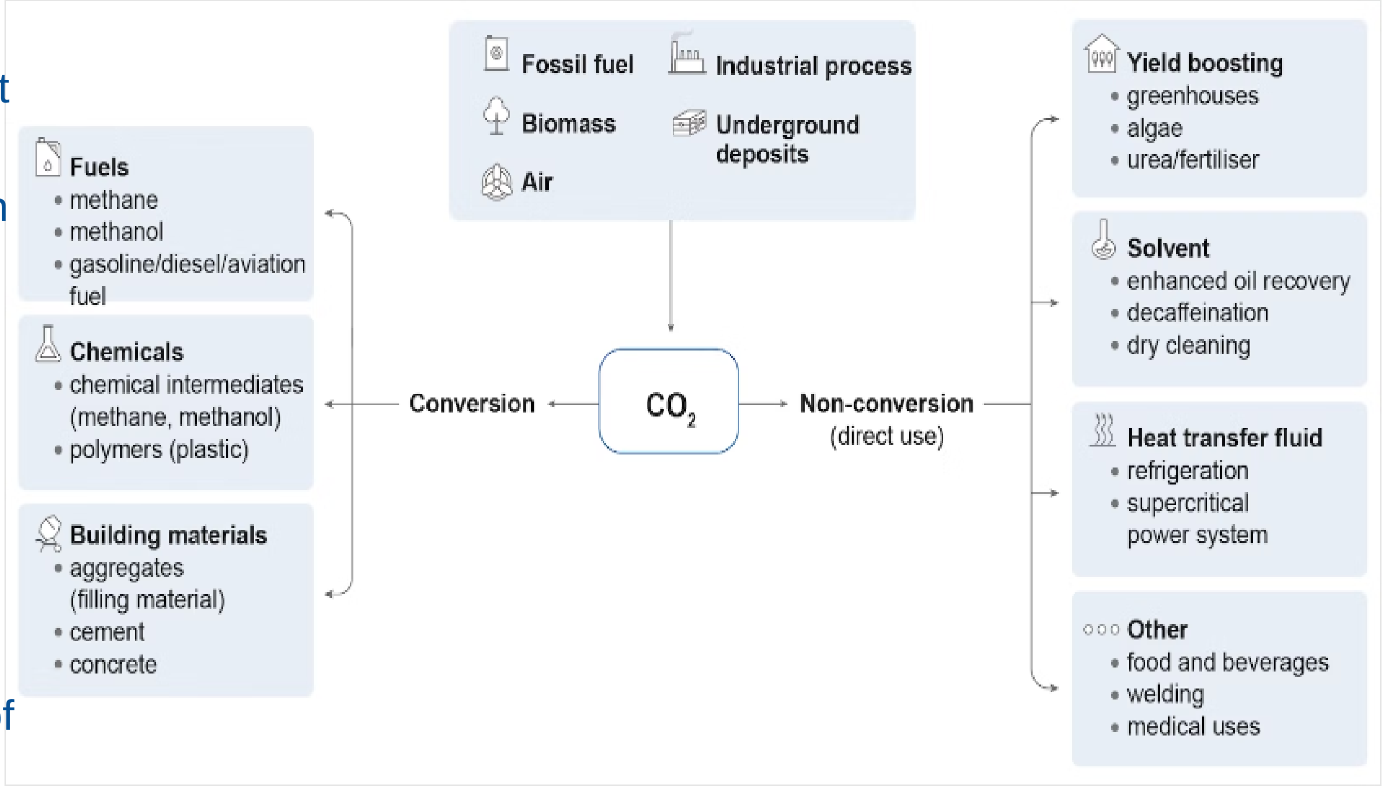
Value chain component	Estimated cost range / €
Carbon capture (cement kiln)	50-90
Carbon compression and dehydration	10-20
CO2 transport pipeline @ 150-300 km	5-25
CO2 transport by ship @ 150-1500 km	15-20
CO2 injection and geological storage	5-20
Monitoring of geological storage	5
Total	75-180

- *For Riga TPP-2 one of the possible options could be transportation of CO2 to the port of Riga (the area of Kundziņsala) through the 25-30 km long CO2 pipeline, CO2 liquefaction, loading to CO2 transport ships and transporting it to the final disposal area, for example, to depleted oil and gas fields in the Northern Sea. For example, such CO2 storage area is developed by Equinor, Shell and TotalEnergies in the Norwegian shelf, the project is known as Northern Lights*

Option 4. Carbon capture and utilisation (CCU)

- On 24 January 2022 mentioned partners received the invitation from Tallinn University of Technology (TTU) and Kaunas University of Technology (KTU) to apply to the European Commission's "Horizon" call HORIZON-CL5-2022-D3-01 (Decarbonising industry with CCUS) in order to implement the research project "CCUS Baltics".
- Within the scope of this study it was planned to implement CCUS demonstration as following:
- AS “Latvenergo” in cooperation with the Latvian Hydrogen Association installs a PEM electrolyzer in Riga TPP-2 within the above mentioned pilot project.
- CO2 delivery to the pilot project is provided from the Achemas Grupa factory in Lithuania, for example using the railway infrastructure or road transport.
- As part of the "CCUS Baltics" project, AS “Latvenergo” install equipment for the production of synthetic fuel (for example, methanol) at Riga TPP-2 production plant.
- Test injections of CO2 are made by Conexus on the site of Incukalns underground gas storage.

- The range of potential CO2 use applications is very large and includes direct use, by which CO2 is not chemically altered (non-conversion) and the use of CO2 by transformation (via multiple chemical and biological processes) to fuels, chemicals and building materials (conversion).

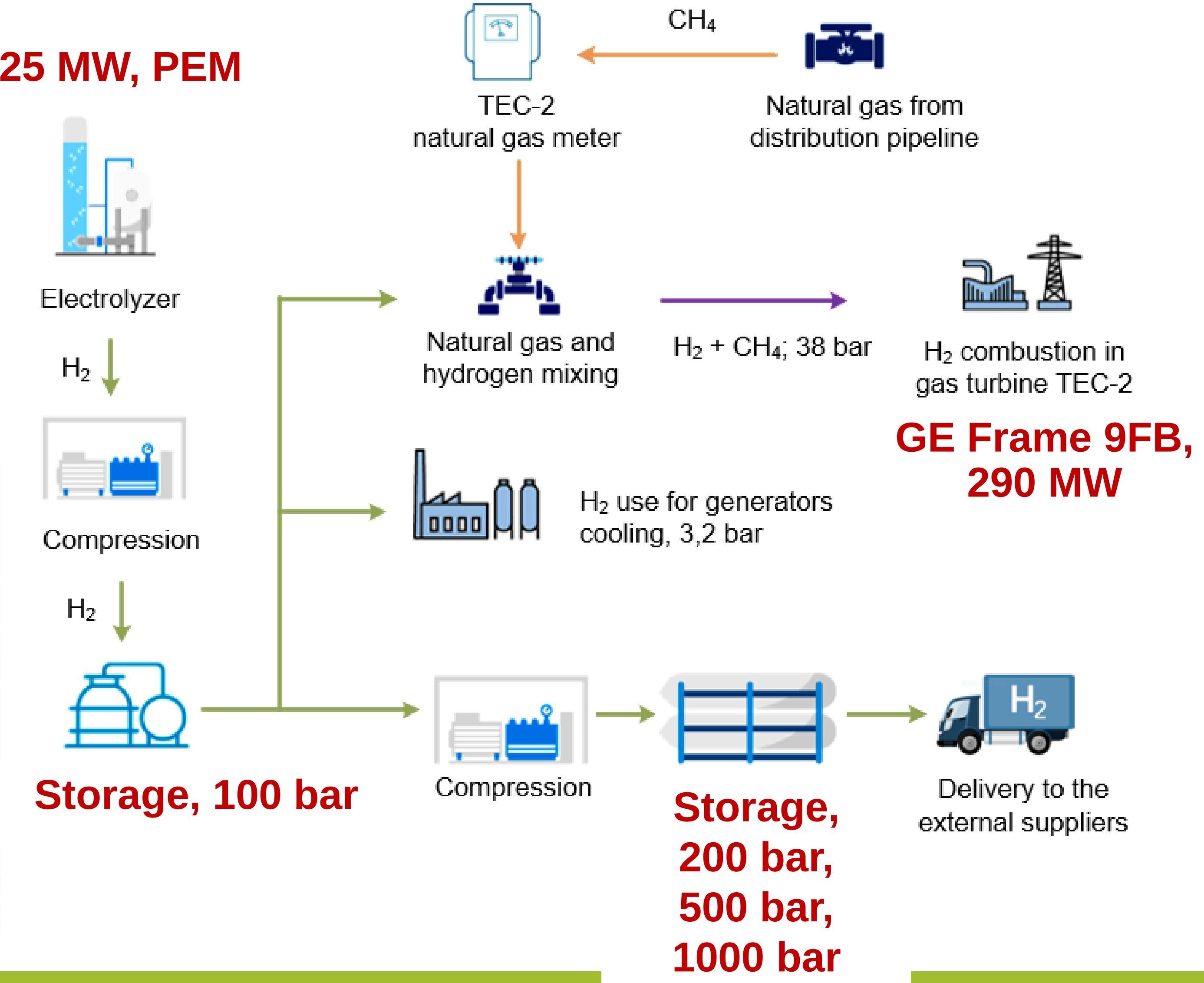


Concept and scale of hydrogen project (Riga TPP-2)

130 MW, Wind

Green energy

70 MW, Solar PV



Comparison of options (1)

Options	Advantages	Disadvantages
Option 1. Replacement of natural gas with alternative gases	a) possibility for wide use of renewable energy sources (wind and solar) in hydrogen production, b) avoidance of carbon dioxide emissions during the electricity production, c) possibility to supply a surplus of hydrogen to transport sector and industry, d) avoidance of all problems associated with CCS option, including the ban for geological storage of CO_2.	a) very high costs of hydrogen production, b) very low conversion efficiency, c) necessity to convert CCGT plant for hydrogen combustion and to install considerable wind and solar capacity.
Option 2. Carbon capture and underground storage (CCS) in geological formations	a) avoidance of carbon dioxide emissions during the electricity production, b) possibility to store CO_2 emissions, if CO_2 utilisation is not possible in full extend, c) possibility to develop national or regional infrastructure for CO_2 transportation and storage in Latvia, which would be shared among different stakeholders	a) existing ban for geological storage of CO_2 and uncertainty with future legislation, b) necessity to make full scale geological investigation to validate the suitability for storage site, c) very high costs of carbon capture, d) uncertainty on how to deliver CO_2 from the plant to storage site.

Comparison of options (2)

Options	Advantages	Disadvantages
Option 3. Carbon capture, liquefaction and export	a) avoidance of carbon dioxide emissions during the electricity production, b) not necessary to look for storage location in Latvia, c) flexibility to balance CO_2 storage and utilisation strategies	a) expansive CO_2 liquefaction and maritime transportation, b) uncertainty with storage capacity and availability of CO_2 storage site overseas. c) very high costs of carbon capture, d) uncertainty on how to deliver CO_2 from the plant to the CO2 export terminal in the port
Option 4. Carbon capture and utilisation (CCU)	a) possibility to sell CO_2 for direct use (non-conversion) b) possibility to use CO_2 (via multiple chemical and biological processes) to produce synthetic fuels, chemicals and building materials, c) synergy with green hydrogen production	a) very high costs of carbon capture, b) necessity to deliver sufficient amounts of hydrogen or nitrogen c) necessity to install complicated and expensive equipment for hydrocarbon synthesis

Conclusions

- It becomes obvious that every considered option has its benefits and drawbacks, that is why no single answer, which options is preferred does exist.
- Most likely the right approach would be using the combination of options for decarbonising of CCGT plant, which would definitely include carbon capture, storage and utilisation.
- Geological storage option depends on the removal of existing prohibition of this option in Latvian legislation and on results of geological investigation.
- The option with liquefaction and export is less preferred, but could be considered if ban for geological storage in Latvia could not be removed.

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