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EVALUATION OF DIFFERENT ROUTES FOR E-DIESEL AND E-KEROSINE SUPPLY IN THE PORT OF ROTTERDAM

EXTENSION TO CHAIN PROJECT

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INTRODUCTION

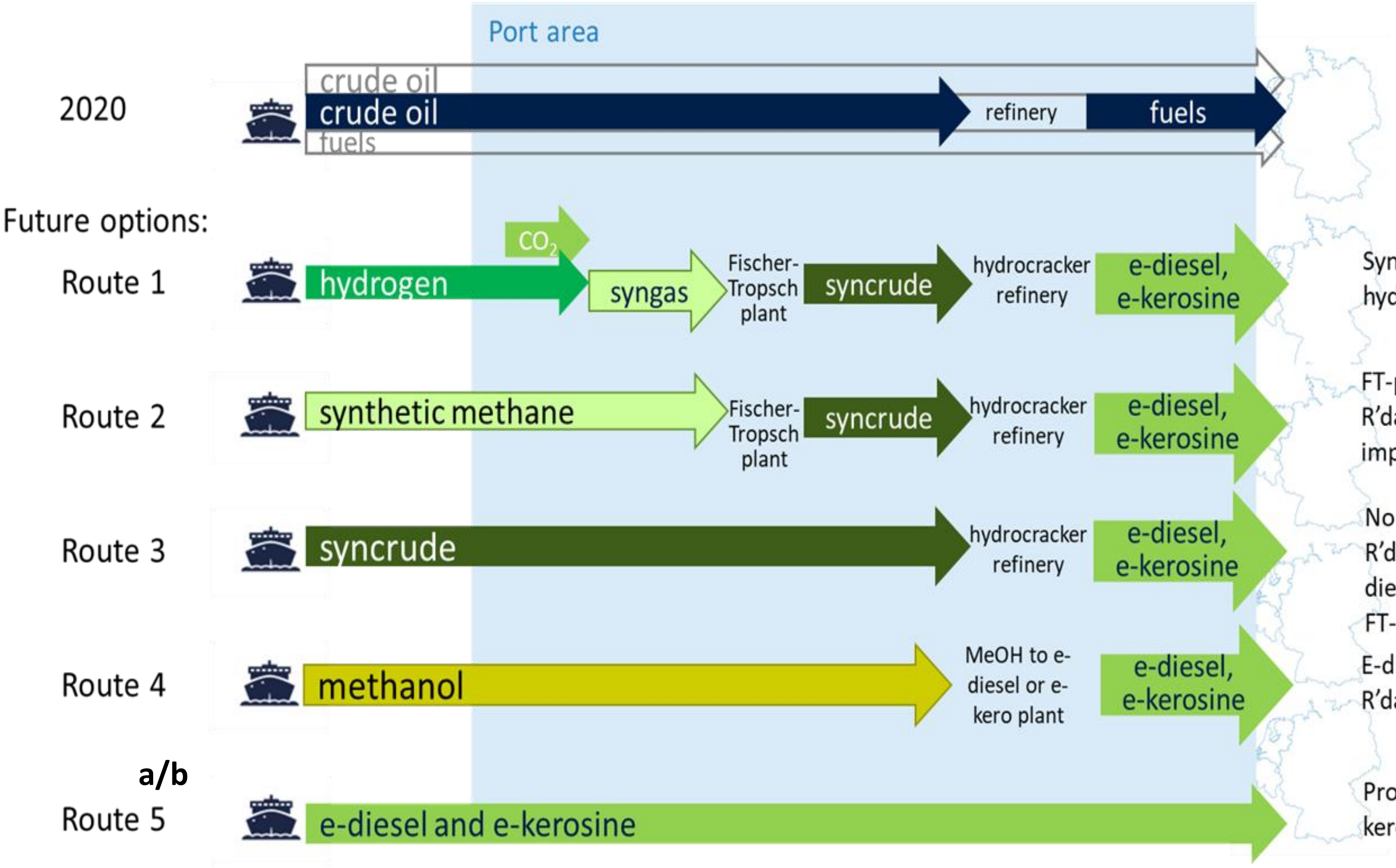
- In the CHAIN project, we answer the question what the transition to e-fuels in the Rotterdam port area could look like. How can companies maintain their current position? What new opportunities are there to strengthen this position? And what does the time path with the necessary steps to achieve this look like?
- The e-fuels identified as most relevant in the Power2Fuels project, namely e-methanol, e-diesel, e-ammonia, e-LNG and e-kerosene, in addition to green hydrogen, also form the scope of the CHAIN project. In CHAIN an economic analysis is done of import chains for green hydrogen by means of LOHC and liquid hydrogen. The import of ammonia and methanol is also being analyzed. Based on these analyses a strategy will be drawn up for the transition to e-fuels in the Rotterdam region.
- For the region, an important aspect is to maintain economic activity around the production of fuels. It is therefore important to also consider chains in which raw materials and/or intermediate products are imported and the final fuels are produced in Rotterdam: what are the possibilities for this and how would they fit into the strategy for the transition? In particular, e-diesel and e-kerosene are candidates for this.
- In this extension of the CHAIN project, routes for the production for e-diesel and e-kerosene are analyzed, with part of the production process taking place in the Rotterdam region. This involves the routes as presented on the next slide.

PRODUCTION ROUTES

1. Green hydrogen (import) and CO_2 → e-syngas (production in NL) → production of syncrude in a Fischer-Tropsch plant (in NL) → production of e-diesel and e-kerosene (in existing, to be adapted, hydrocracker in NL)
2. e-LNG (import) from green hydrogen and CO_2 → production from syncrude in a Fischer-Tropsch plant (in NL) → production of e-diesel and e-kerosene (in existing, to be modified, hydrocracker in NL)
3. Syncrude (import), produced in a Fischer-Tropsch plant from e-syngas based on green hydrogen and CO_2 → production of e-diesel and e-kerosene (in existing, to be adapted, hydrocracker in NL)
4. E-methanol (import), produced on the basis of green hydrogen and CO_2 → production of e-diesel and e-kerosene
5. Import of e-diesel and e-kerosene, produced
    a. in a Fischer-Tropsch plant with hydrocracker, from e-syngas based on green hydrogen and CO_2
    b. from e-methanol, produced on the basis of green hydrogen and CO_2

We also compare these results with the results obtained for the other carriers (LH_2, NH_3, LOHC, MeOH) that are analysed in the CHAIN project.

ILLUSTRATION OF ROUTES



Syngas plant and FT-plant in R'dam; hydrogen imported

FT-plant in R'dam, no syngas plant in R'dam; FT-crude produced from imported synthetic methane

No syngas plant and no FT-plant in R'dam; hydrocrackers produce e-diesel and e-kerosine from imported FT-crude

E-diesel and e-kerosine plant in R'dam; e-methanol imported

Production of e-diesel and e-kerosine in renewable hotspots

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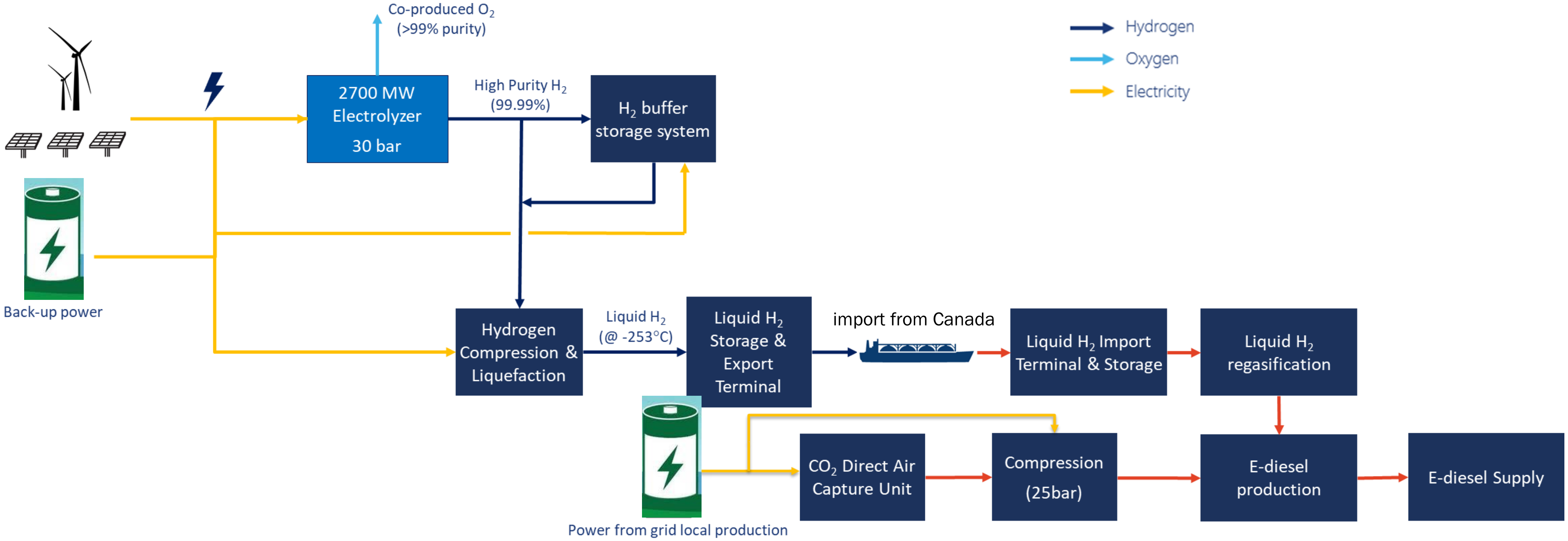
APPROACH AND ASSUMPTIONS

- Routes are divided into process blocks, such as electrolysis, syngas generation, FT synthesis, e-methanol (MeOH) production, transport, storage, reconversion, etc, and all finish with delivery of e-diesel (e-kerosene) in Rotterdam.
- Costs (CAPEX and OPEX) are calculated per process block and based on global estimates.
- The costs of all included process blocks within a value chain sum up to the total costs of the route.

- Assumptions for studied routes are consistent with those made for evaluation of other carriers (LH_2, NH_3, LOHC, MeOH) in the CHAIN project.
- The Fischer-Tropsch process operates at diesel (and kerosene) mode (less waxes and naphtha).
- *Kerosene and diesel are considered to have the same costs* (fractions can be tuned depending on process conditions).
- The analysis is performed for imports from Canada (relatively low LCOE and enough CO_2 from biomass).
- The location will be taken into account when determining the OPEX (and in particular the LCOE). Specific CAPEX for the Netherlands and abroad is kept the same. The discount value is, however, country specific.

EXAMPLE OF ROUTE 1

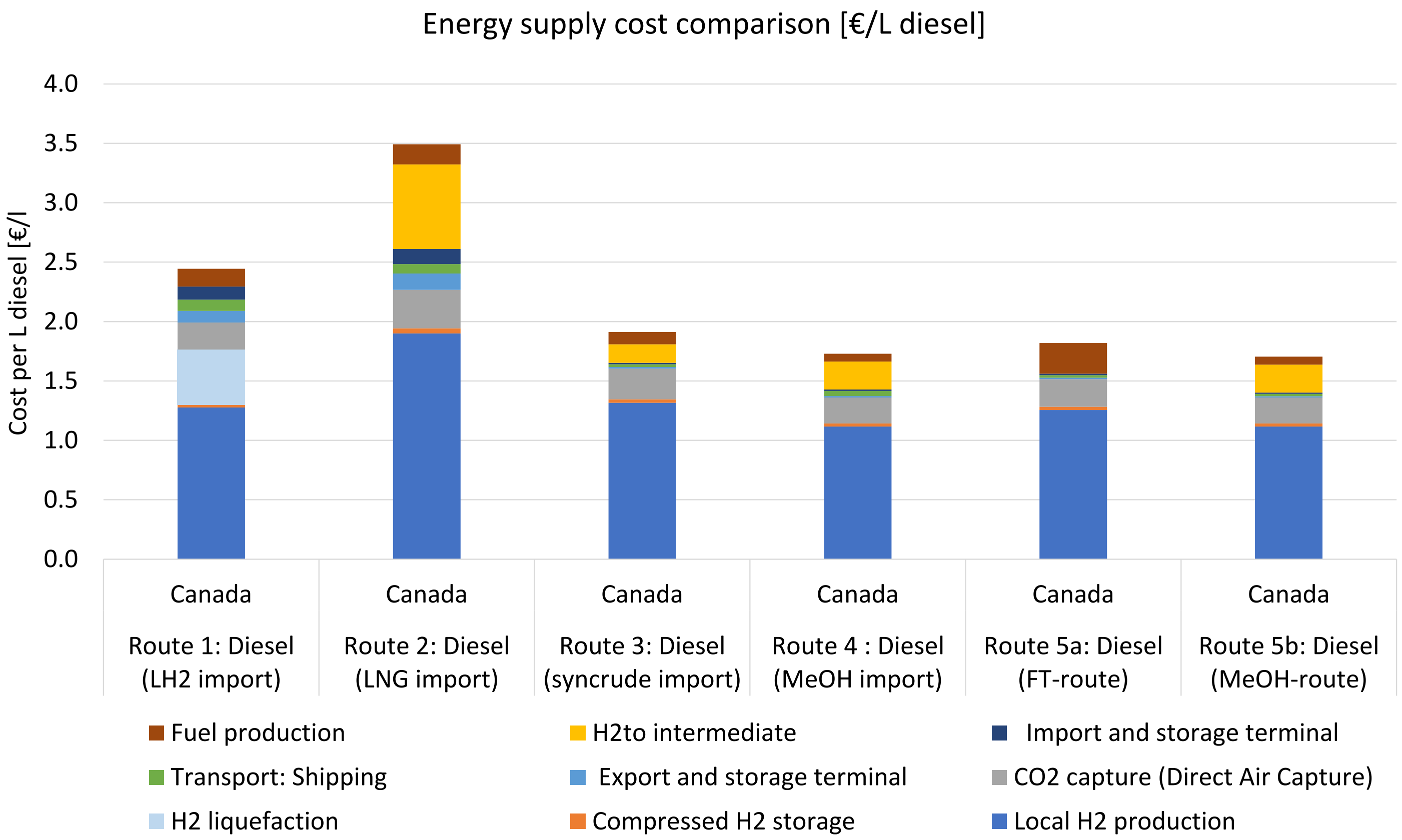


Back-up power share to the total power costs:

- 4.7%

See Appendix for the other routes

COMPARISON ROUTES



- Lowest production costs for diesel are found via the MeOH route (diesel import from Canada), mainly thanks to the high chain efficiency (Route 5b)
- Route 2, LNG import followed by FT diesel production in Rotterdam is most expensive due to high H_2 demand for the CH_4 synthesis, resulting in lower overall chain efficiency

NB: uncertainty in cost estimates may be up to ~50% per process block. However, since assumptions for each of the routes are the same, the overall comparison between routes is more accurate.

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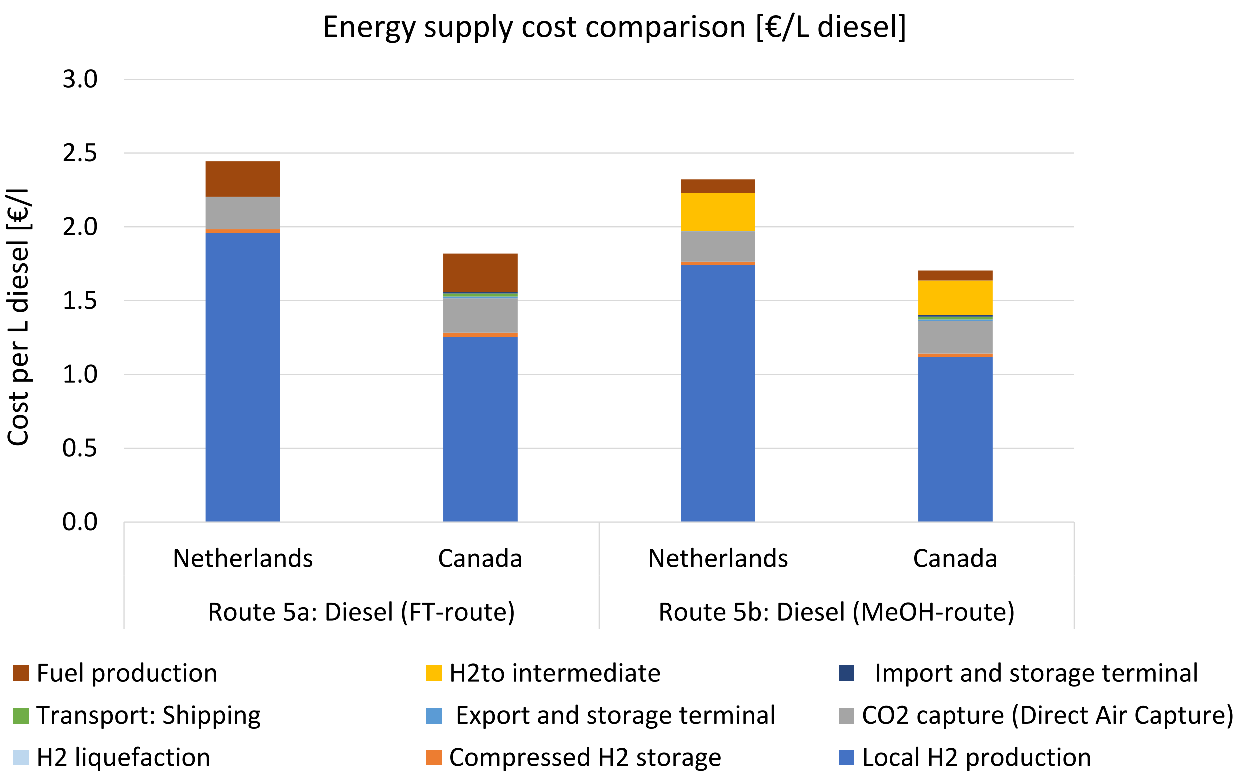
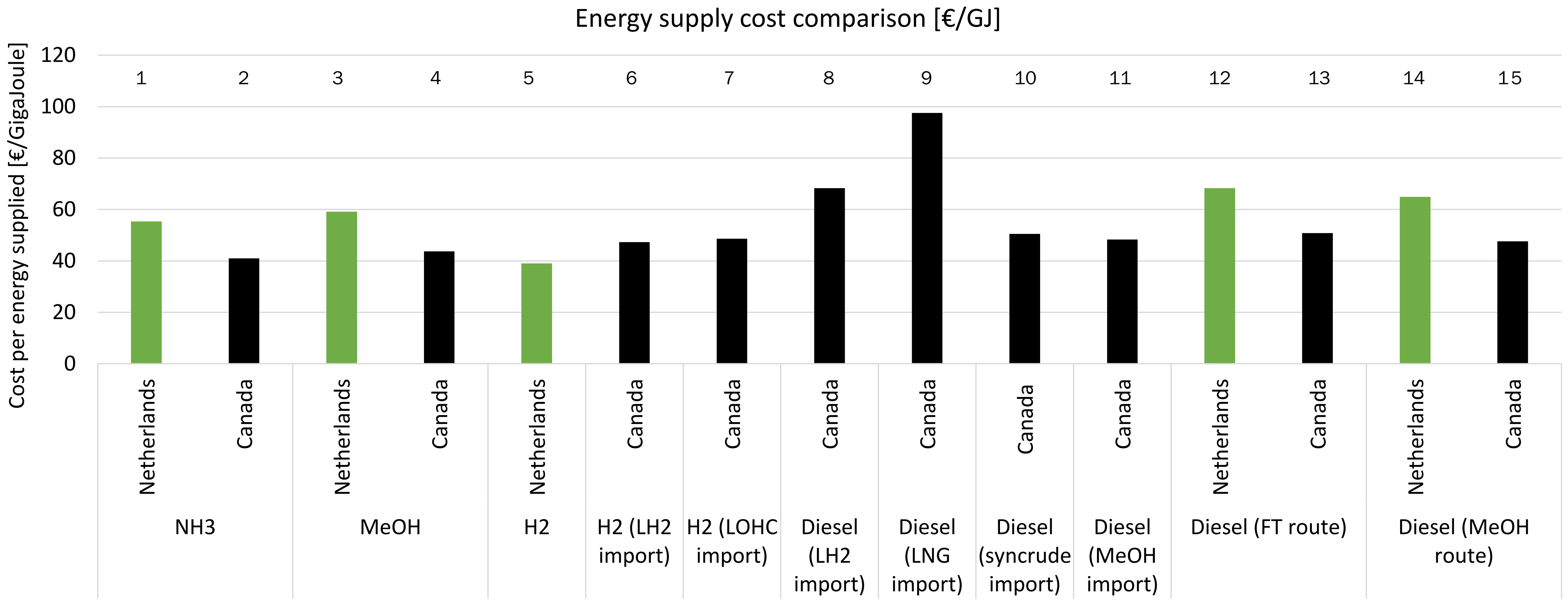
COMPARISON OF IMPORT AND LOCAL PRODUCTION



- Diesel production in the Netherlands via both the FT- and MeOH-route is more expensive than import from Canada via identical production routes
- The cost difference is dominated by higher hydrogen costs for production in the Netherlands due to a higher levelized cost of electricity (LCOE) in the Netherlands in comparison to the LCOE in Canada

COMPARISON WITH OTHER ENERGY CARRIERS



- Lowest production cost per GJ of fuel are via H_2 production in NL (39 €/GJ H_2), column 5.
- Lowest production cost per GJ of fuel imported are via NH_3 supply (41 €/GJ NH_3), column 2.
- Lowest cost to supply e-diesel (column 8-15) is via the methanol route with e-diesel import (48 €/GJ Diesel), column 15.
- Lowest e-diesel supply costs are 9% higher per GJ fuel compared to MeOH import from Canada (column 15 vs column 4).

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EVALUATION OF THE ROUTES

Next to costs, other aspects, such as added value, economic activity, and reuse of existing assets in the Rotterdam area, are important in the analysis of novel value chains around e-diesel and kerosene supply to the Port of Rotterdam. The following aspects should be taken into account:

- Route 1 (LH_2):
  - Import of novel carriers, such as LH_2 and LOHC, requires new process routes and infrastructure.
- Route 3 (syncrude import):
  - Current economic activity and assets largely remain when syncrude, a similar type of carrier as crude oil, is imported.
  - Syncrude is different from crude oil and possibly more difficult to transport (precipitation of paraffinic solids). Upgrading to diesel is likely to be done before export, also to benefit from the added value.
- Route 5a (FT): no experience at larger scale with Reverse-Water Gas Shift reactor, FT-synthesis is commercial technology.
- Route 4, 5b (MeOH to diesel):
  - CO_2 to MeOH is proven at larger scale (CRI, Iceland), for route 5b MOGD demonstrated at 100 barrels/day.
  - MeOH can also function as a platform molecule for the chemical industry, which is a benefit for the methanol route
- All routes will require CO_2 from a biogenic source or direct air capture to be CO_2 circular. Biogenic CO_2 might be scarce and DAC is still low TRL and requires significant amounts of energy and space.
- For the production routes in the Netherlands supply of sustainable CO_2 and H_2 results in significant space requirements (both for novel technology and renewable energy supply). This might be challenging in a highly populated country like the Netherlands

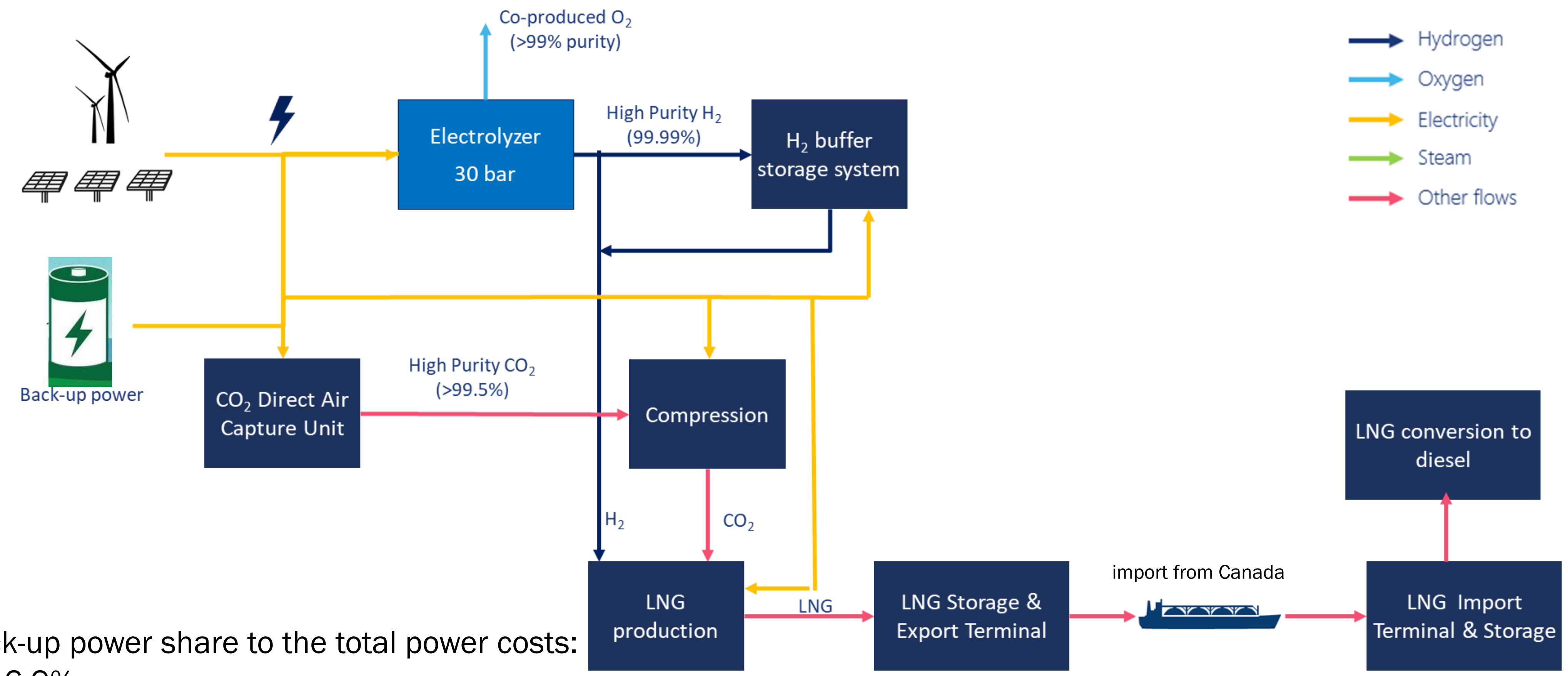
CONCLUSIONS

- Production of diesel (and kerosine) produced via the MeOH route is found most efficient and results in lowest cost. Cost of production via Fischer-Tropsch is close to cost of the MeOH route.
- Cost of production with LNG is most expensive. Local production via imported LH2 is also significantly more expensive than the MeOH and FT import routes.
- Import of diesel (and kerosine) is significantly more cost effective than local production of both intermediate and fuel, but only slightly more cost effective than producing the fuels locally from imported intermediates, such as MeOH or syncrude.
- Import of syncrude presents technical challenges. Also, the step from intermediate to diesel (and kerosine) results in a higher value product, while the additional expenses are fairly limited. It seems logical that the producer of the intermediate converts it into the final diesel (and kerosine) product. Import of green MeOH to produce diesel and kerosine seems more rational, since MeOH is also a platform molecule for the chemical industry and a global MeOH market already exists.

APPENDIX
DETAILED ASSUMPTIONS

Technology	Efficiency (LHV)	CAPEX (MEUR/kta)	Power consumption (MWh/t product)
SNG production	78%	0.80 (ref. size 60 kta)	0.14
NG liquefaction		0.28 (ref. size 28 kta)	0.5
Methanol production	83%	0.3 (ref. size 1000 kta)	0.37
FT-diesel .	71%	1.28 (ref. size 70 kta)	0.24
Syncrude	77%	0.51(ref. size 70 kta)	0.24
Methanol to diesel	95%	0.33 (ref. size 1000 kta)	0.37

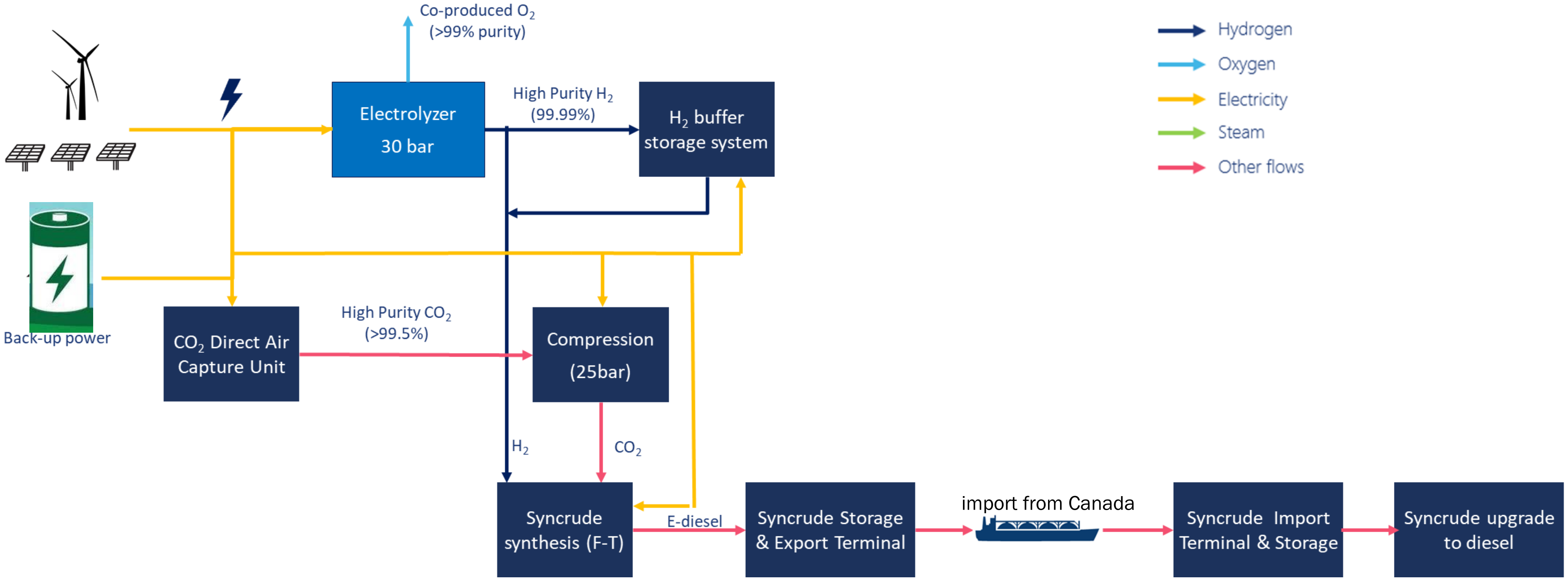
APPENDIX
ROUTE 2



Back-up power share to the total power costs:

- 6.9%

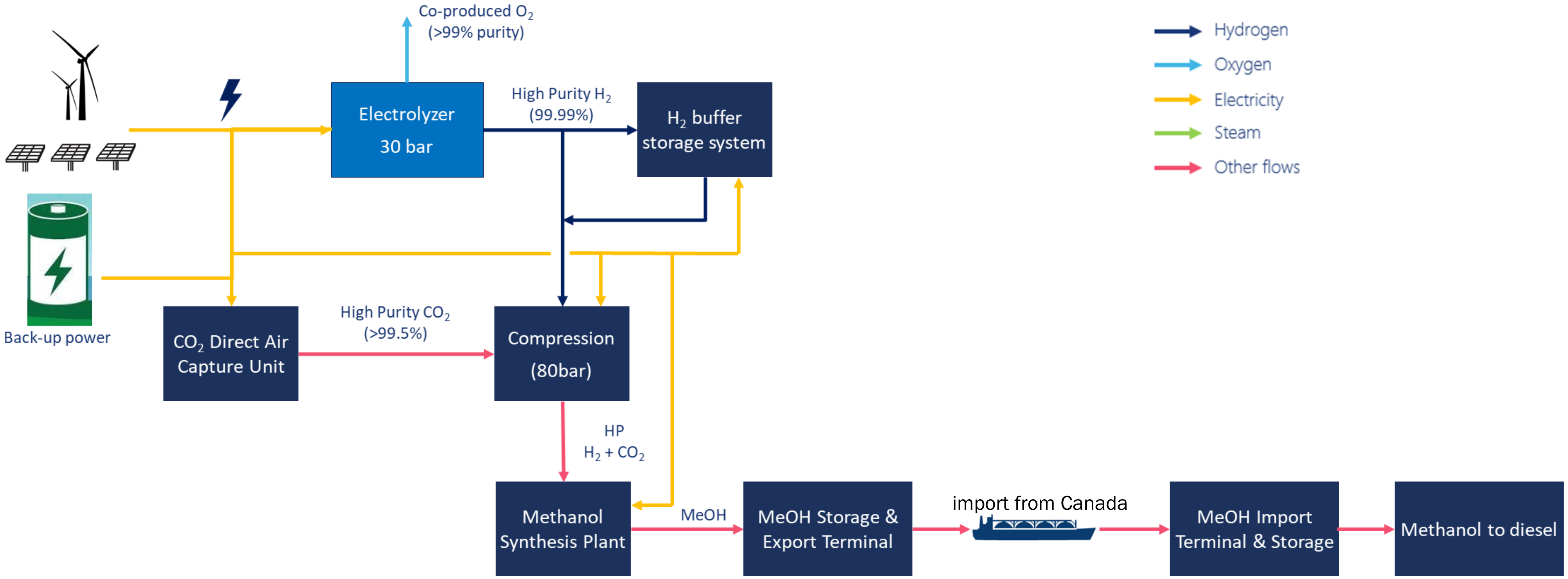
APPENDIX
ROUTE 3



Back-up power share to the total power costs:

- 3.1%

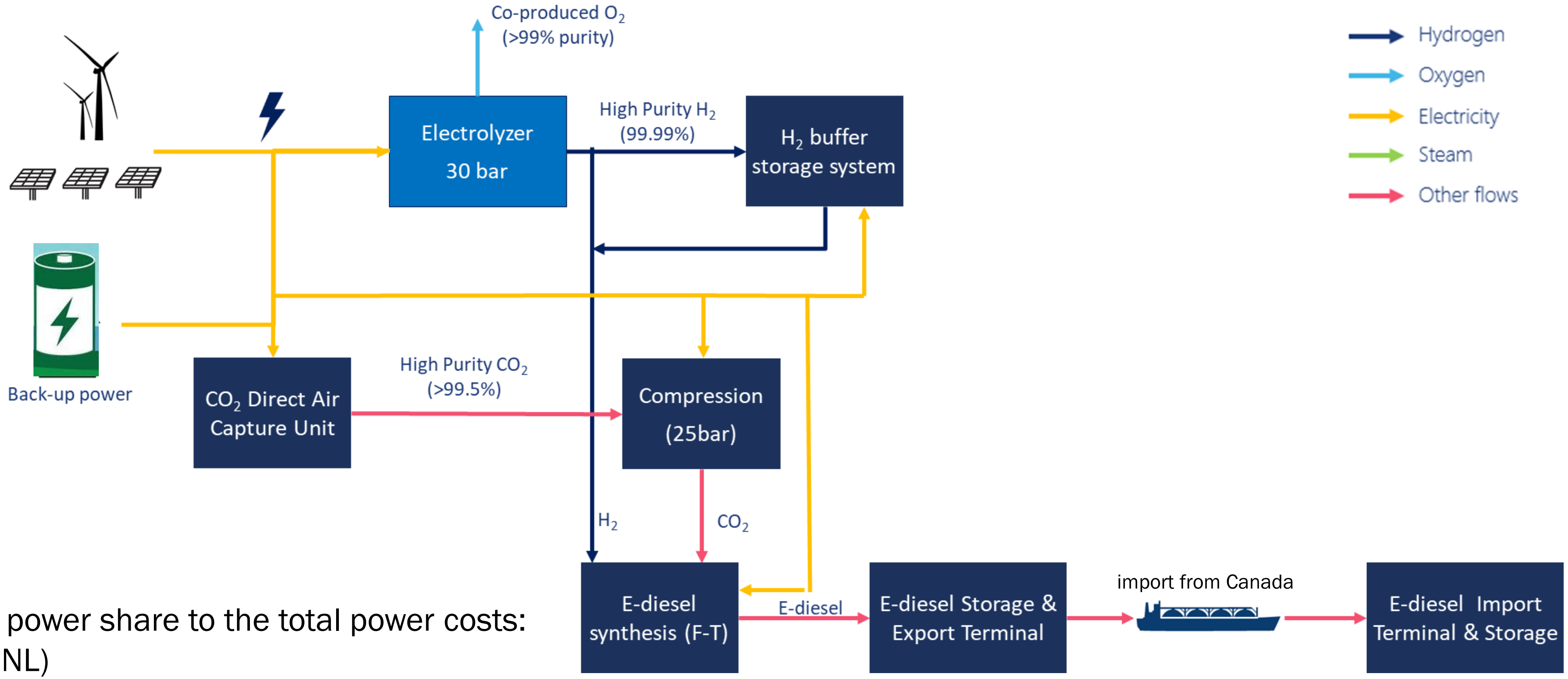
APPENDIX
ROUTE 4



Back-up power share to the total power costs:

- 3.6%

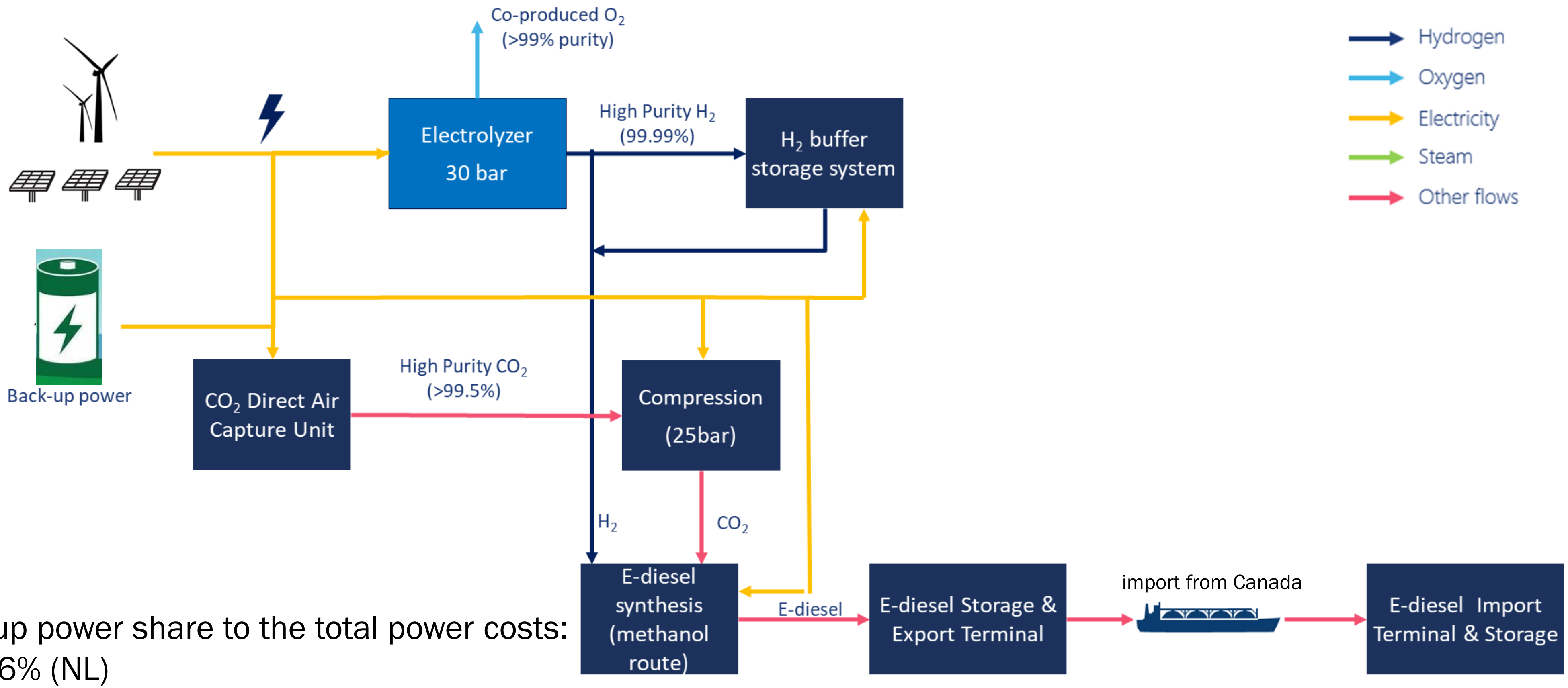
APPENDIX
ROUTE 5A



Back-up power share to the total power costs:

- 3% (NL)
- 4.9% (Canada)

APPENDIX
ROUTE 5 B



Back-up power share to the total power costs:

- 3.6% (NL)
- 6.2% (Canada)

THANK YOU FOR YOUR TIME

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