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Call Order 4: Transport & Staging Analysis

Technical Assistance for the Daures Green Hydrogen Project:
Energy Transport & Staging Study Phase 2+

Enersense Energy Namibia (Pty) Ltd

ENGINEERING CONSULTING

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Disclaimer

List of Abbreviations

Abbreviation	Description
ASU	Air Separation Unit
BES	Battery Energy Storage
DWT	Deadweight Tonnage
ESIA	Environmental and Social Impact Assessment
EYA	Energy Yield Assessments
H_2	Hydrogen
ISBL	Inside the Battery Limit
KOH	Potassium Hydroxide
kTPA	Thousand Tons Per Annum (Year)
LCOA	Levelized Cost of Ammonia
LCOE	Levelized Cost of Electricity
LCOH	Levelized Cost of Hydrogen
MW	Mega Watt
N_2	Nitrogen
NH_3	Ammonia
OEM	Original Equipment Manufacturer
OSBL	Outside the Battery Limit
PFS	Prefeasibility Study
PtX	Power-to-Anything
PV	Photovoltaic
WTG	Wind Turbine Generators

1 Executive Summary

Enersense Energy Namibia and its partners are developing Daures Green Hydrogen Village, a first of its kind in Namibia, producing green electricity, green hydrogen, green ammonia, and green ammonia sulfate.

Within this call order, the following details have been considered:

- Energy yield assessment (EYA) with a strong focus on wind turbine selection,
- Port assessment,
- Carrier transport assessment,
- Optimization of the overall system (using Fichtner's H2-Optimizer),
- Project staging considerations, and
- Cost reduction potential by delaying FID decision.

1.1 Introduction

Table 1 shows the proposed hydrogen (H_2) and ammonia (NH_3) production capacities aimed to be produced until 2032. Phase I of the projects aim to kick-start the ammonia production within Namibia as well as to initiate a training and research center for hydrogen and ammonia to train local people for the upcoming phases (not limited to the proposed site here under evaluation). The initial use of ammonia will be to convert it into fertilizer. Phase II aims to enhance local supply while Phase III and IV are aiming to provide ammonia for regional and finally also for global use.

Phase	Year	Solar PV [MWp]	Wind [MW]	Electrolysis [MW]	Production [kTPA(H2)]	Production [kTPA(NH3)]
I	2022 - 2023	1.5	-	0.5	0.150	0.182
II	2024 - 2025	12	18	12	3.6	10.5
III	2026 - 2028	41	60	42	12.0	35.0
IV	2029 - 2032	420	590	420	121.0	352.0

Abbreviations: MW: Megawatt | MWp: Megawatt peak | kTPA: thousand tons per annum

Table 1: Proposed project phases (Source: Enersense Energy Namibia).

1.2 Energy Yield Assessment

Figure 1 (top for solar photovoltaic, bottom for wind) show the high resource quality at the proposed site west of the mountain Brandberg. Based on the available excellent resources the proposed site is strongly recommended to be assessed further and developed towards the planned full-scale project.

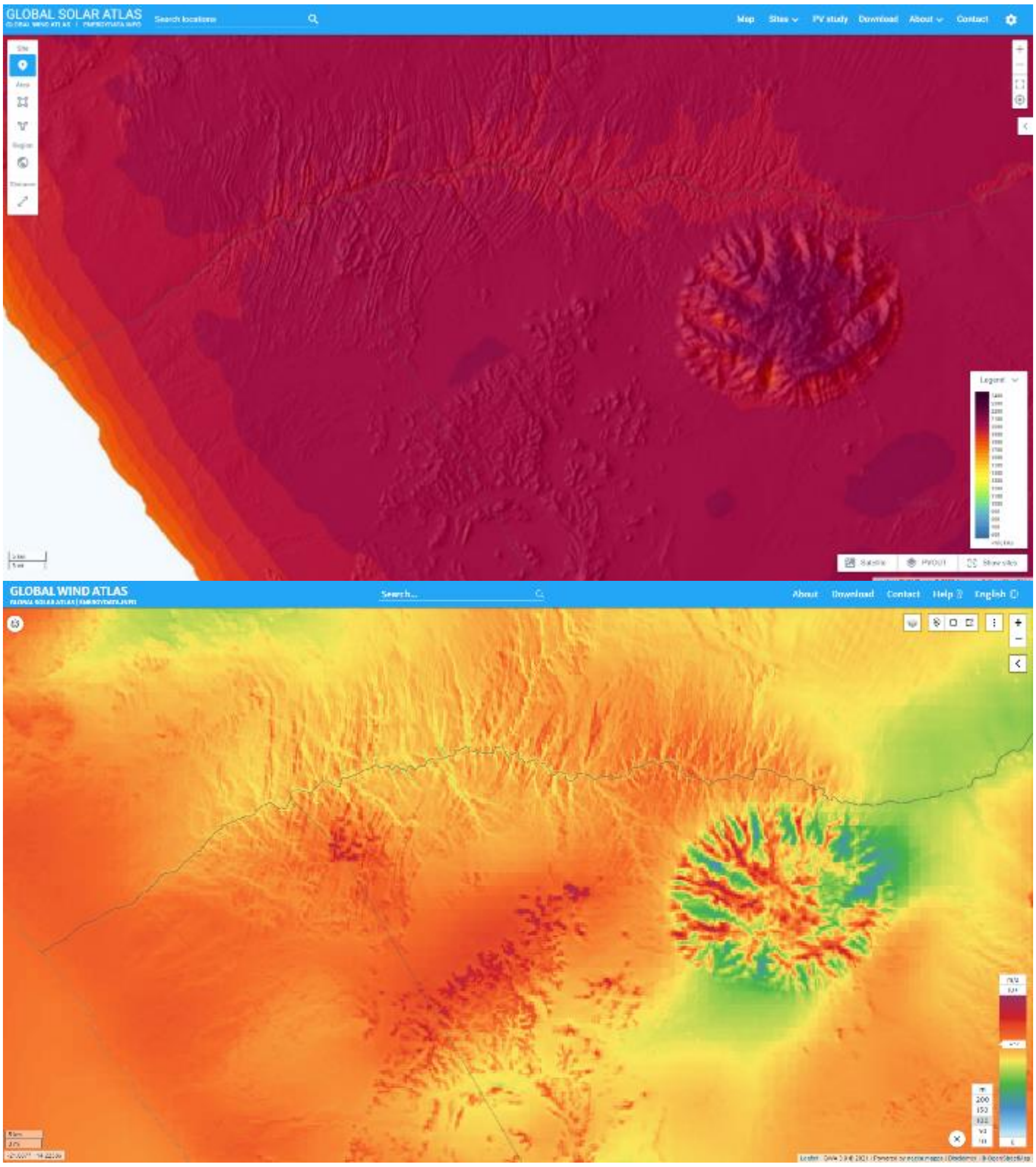

Figure 1: Regional solar photovoltaic & wind power density potential.

As typical for solar PV energy yield assessments (EYA), the assessment was based on using Solargis data[1] and using the simulation tool PVsyst[2].

As typical for wind EYA's, the assessment was based on Vortex data[3] and using the simulation tool WindPro[4]. As basis for the yield calculations Fichtner purchased for each location one Vortex LES (Large Eddy Simulation) Wind Time Series. These high-res (100 m) modeled virtual datasets consist of one year of 10-minute time series for a region of 6.25 km^2 around the initial set coordinate and for any height between 50 m and 300 m above the ground with reanalysis data (ERA-5, CFSR or MERRA2) serving as input data. Output parameters are horizontal and vertical wind speed, wind direction, temperature and air pressure as well as 3-second gusts and the Richardson number. The LES-one-year time series data has been long-term adjusted using ERA5 reanalysis time series data. The resulting wind data time series is used to calculate the energy output of a single turbine at hub height 120 m on an hourly basis over a

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[1] https://solargis.com/

[2] https://www.pvsyst.com/

[3] https://vortexfdc.com/

[4] https://www.emd-international.com/windpro/

period of 20 years. This can be used to determine the optimal setup of a combined renewable energy power supply in the context of the envisaged hydrogen and ammoniac production plants.

Figure 2 shows the monthly mean days for solar PV and wind as well as the expected monthly power generation throughout the reference year.

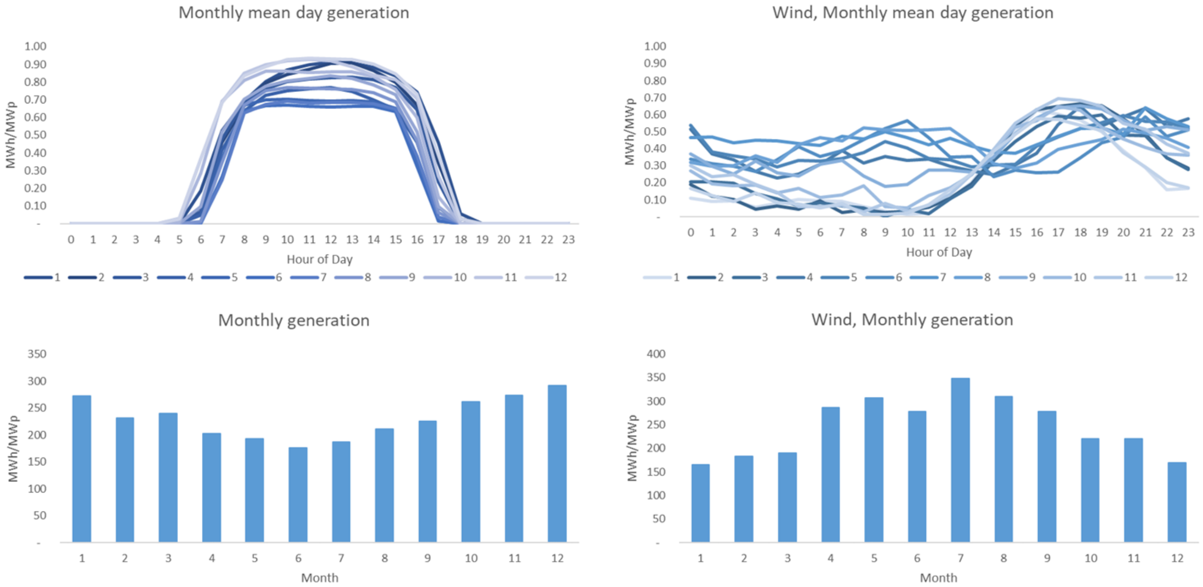


Figure 2: Expected monthly mean days and monthly generation of solar PV and Wind (based on Solargis, Vortex, ERA5).

1.3 Port of Walvis Bay

Ammonia shipping needs designated terminals. Those terminals handle potentially hazardous or poisonous cargo and need designated buffer zones, experienced port authorities and educated first responders. Establishing in an ammonia terminal in a port with existing liquid bulk handling might be easier than a new port area, were fishing and general cargo are exclusive uses.

Based on heat losses in pipelines, a terminal should be near to the ammonia production facility or a separated storage. A distance of 5 km should be the threshold for a pipeline from electrolyzer/storage to the manifold of the gas carrier.

Proportionality means that import and export locations are dependent from each other. All must agree on one transmission standard and transport units or transport vessels. For this report we consider the following standards:

- Transmission standard for liquid ammonia: fully refrigerated (≈100 kPa, ≈ -50°C)
- Transport standard: LPG/ammonia carrier with 16" manifolds

Today, ammonia carrier are usually multi-purpose carrier with a tank size of up to 90,000 m^3, but ships will be limited by deadweight tonnage (DWT). Ammonia is much denser than LPG or LNG which leads to a weight-based capacity of approximately 50,000 t cargo volume. Since ammonia shipping is a solution to provide green carbon neutral fuel, ammonia shipping requires larger vessel sizes. Namura shipbuilding announced to build an 87,000 DWT ammonia carrier (appr. 80,000 t cargo) and a further development can be anticipated. A future class of ships will emerge with cargo volumes of 100,000 t and more. The limit for LNG is the Q-max class which tanks would hold ~160,000 t of ammonia.

Currently, the Port of Walvis Bay can host ships with 60,000 and 90,000 DWT's. The current assumption for this project is a target output of 0.35 MTPA liquefied ammonia per year or 1.000 TPD. Therefore, marine ammonia terminals are required in the port. Ammonia terminals have a similar layout to an LNG or LPG terminal on the seaside. LNG terminals can be repurposed as ammonia terminals with minor adjustments according to the different material requirements of LNG and liquefied ammonia if the landside equipment is also adjusted appropriately. Terminals should meet the basic PIANC requirements for small to midsize LNG-Terminals (PIANC 172-2016), as there are no specific guidelines for large LNG or ammonia terminals. Adaptation for large gas carriers is possible.

The Port of Walvis Bay has a liquid bulk terminal. The utilization of the port is not clear. As such a new jetty is recommended to be considered as it seems feasible to build a new one. Please note that construction works might cause interruptions in a single berth setup. The berth construction part would cost around 20 to 30 million USD. It is likely that the port authority covers the CAPEX for infrastructure and will lease it to the operator, but this is considered as CAPEX for comparison reasons. OPEX of a port depends on several considerations:

- terminal lease
- tugboat service
- general maintenance crew

A crew of 10 people is needed, which leads to crew costs of up to 0.4 mn USD/a and 1.0 mn USD/a for services (tugboat services etc.).

In addition, 2% of the overall investment is applied to cover maintenance, repair, and improvements which leads to an overall OPEX of ~2.0 mn EUR/a.

Figure 3 shows an exemplary sketch of a jetty including the individual components.

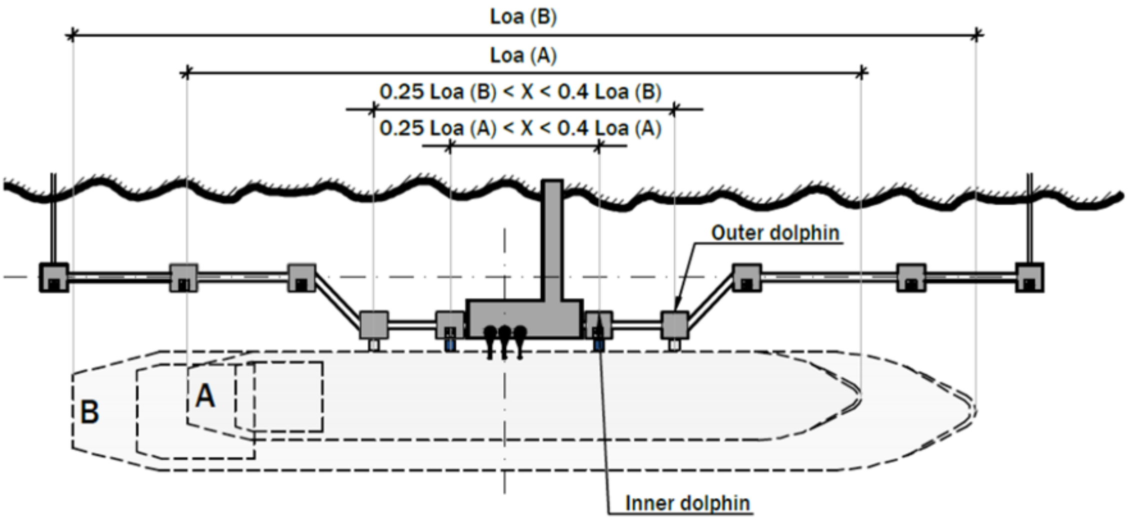


Figure 3: Exemplary Jetty layout.

The following equipment must be planned for a jetty:

- *Bridge*: The bridge connects the jetty with the shore, where the length depends on the depth conditions / water depth (at the level of breasting dolphins there should be the draft of 14 m). On the bridge runs an access road and the pipe rack. Therefore, the bridge must be dimensioned for the expected traffic.
- *Loading platform*: The platform must be dimensioned for the traffic. A common size of the platform is 40,00 m x 34,50 m. A second escape route should be available in case of emergency
- *Mooring dolphins*: Number and dimension of the mooring dolphins depend on the size of the ship. They should be designed for the intended design carrier. Different ship sizes should be considered (up to Q-max) so that the dolphins do not have to be replaced and ships of different sizes can berth. The number of mooring dolphins can be subsequently expanded.
- *Breasting dolphins*: Dimension of the breasting dolphins depend on the size of the ship. They must be designed for all intended vessel sizes so that the dolphins do not have to be replaced and ships of different sizes can berth.
- *Walkways* between the dolphins for the mooring maneuver can be uses as well as escape routes if there is a second or third walkways to the shore.
- *Loading arm set*: located on the loading platform and the number of arms depends on the intended discharge. Standard manifolds have a diameter of 16 inch.

1.4 Carrier Transport

Figure 4 shows an general overview of the locations involved in the project. The project area is where the renewable energy generation ("RE site") will happen. The water source indicates the location where the seawater desalination will happen. The export habour reflects the location of the Port of Walvis Bay which is planned as the place where the export of the final product is planned at.

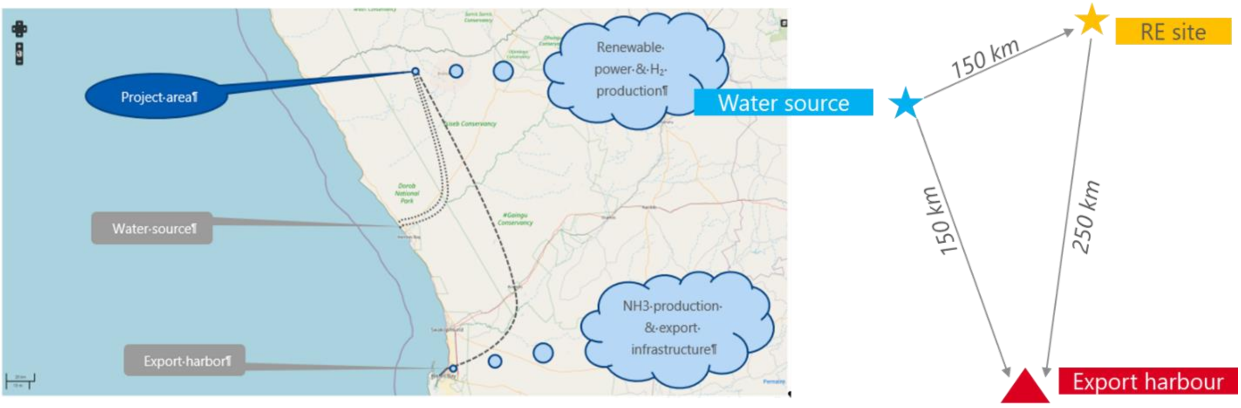


Figure 4: Overall project layout.

For a transparent assessment of several options are available. Basically the following options remain for this project (see also Figure 5):

1. Water piping, hydrogen and ammonia production, and delivering ammonia;
2. Water piping, hydrogen production, delivering hydrogen, and ammonia production,;
3. Water piping, delivering power, and hydrogen and ammonia production;
4. Power transmission, hydrogen production, delivering hydrogen , ammonia production, and delivering ammonia;

5. Power transmission, hydrogen production, delivering hydrogen, and ammonia conversion;
6. Power transmission, hydrogen and ammonia production, and delivering ammonia.

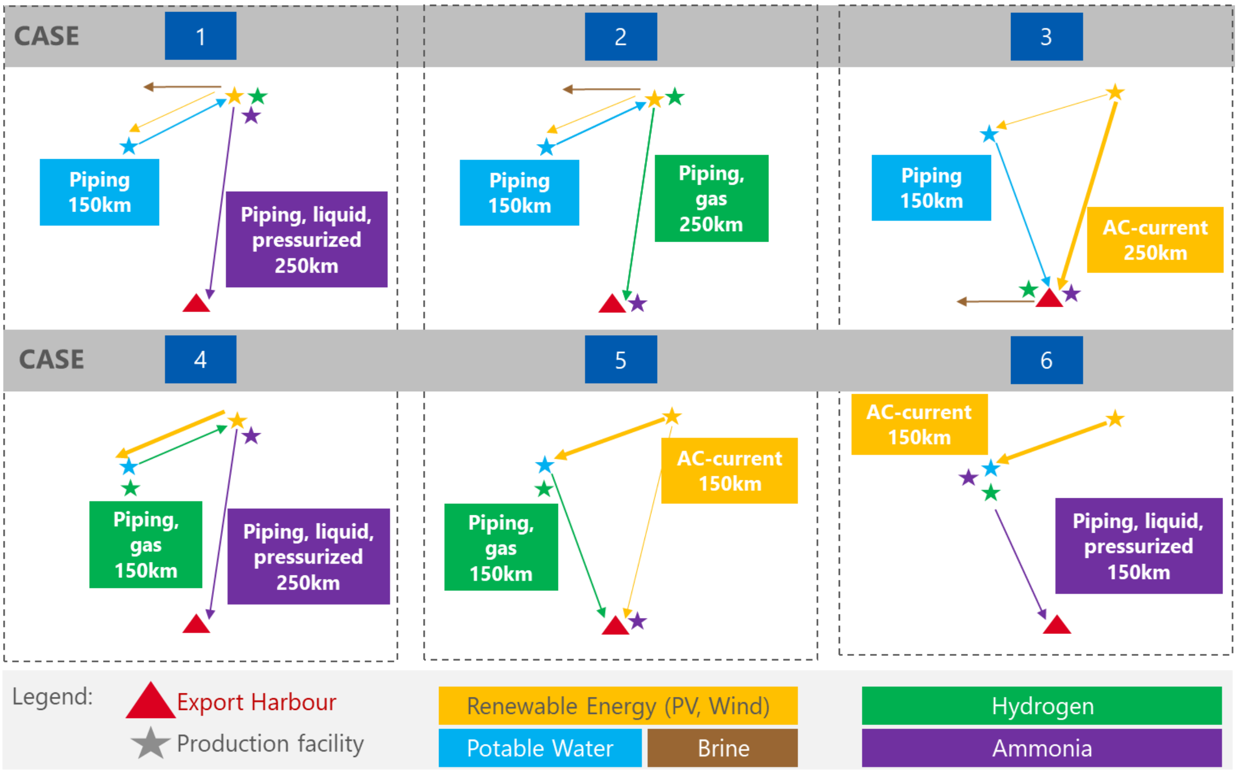


Figure 5: Possible energy carrier transport options.

Beside the general project setup options several options of different transport options do exist. This is shown in Figure 6.

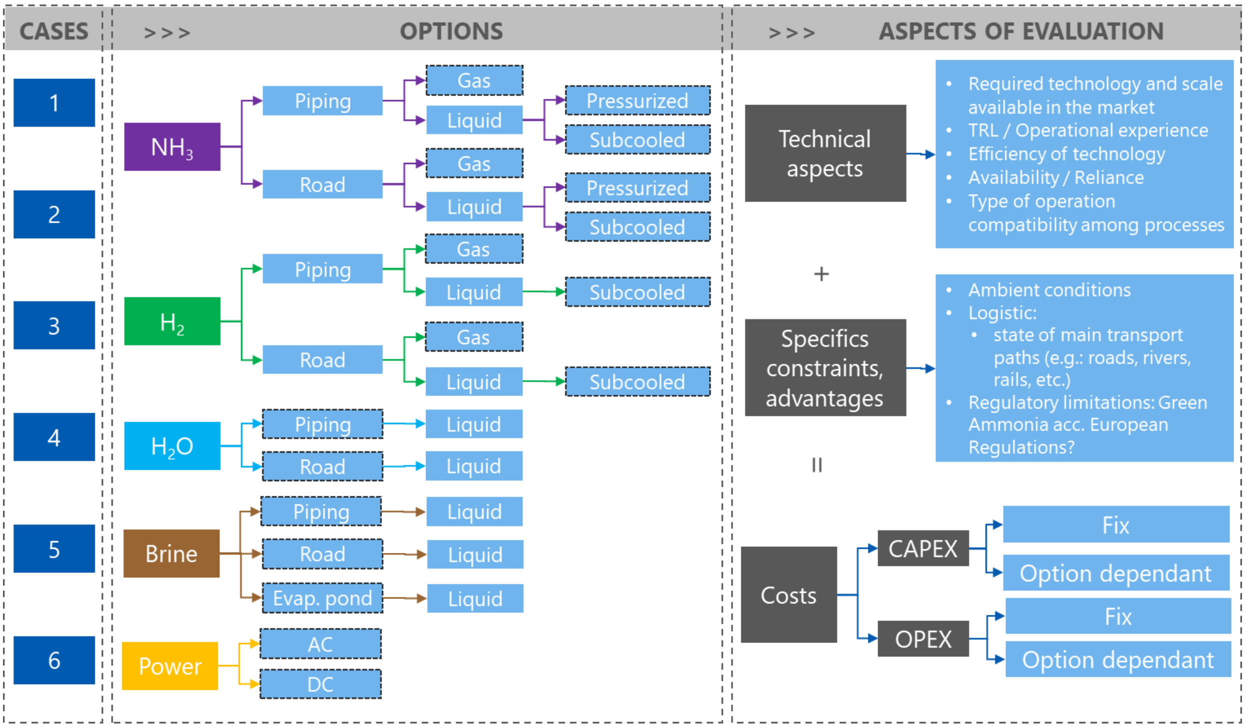


Figure 6: Detailed energy carrier transport assessment.

To limit the general transport options for the individual energy carriers, the following transport ways have been considered within this work:

- Transport of pressurized Hydrogen in gas state via pipeline
- Transport of pressurized Ammonia in liquid state via pipeline
- Transport of potable water via pipeline
- Transport of AC- Current for transport of main electrical energy required for electrolysis

Truck transport was excluded based on the complex logistics as well as the aimed distances and necessary capacities to be transported. Hydrogen pipelines in liquid state was excluded because of the continuous need of cooling combined with the distance necessary to transport hydrogen. Ammonia pipeline in gas state was excluded because of the very low mass transport possibility combined with the necessary distance to transport ammonia. DC current has not been considered based on the necessary distance and required amount of power to transport.

Figure 7 shows the overall economics of the mentioned six (6) options in the case of 0.35 MTPA of ammonia. The expected transportation cost range of the preferred options (1 and 2) is 135 to 150 USD/t(NH3). Other options (e.g., 4) even can reach transportation costs in the range of 250 USD/t(NH3).

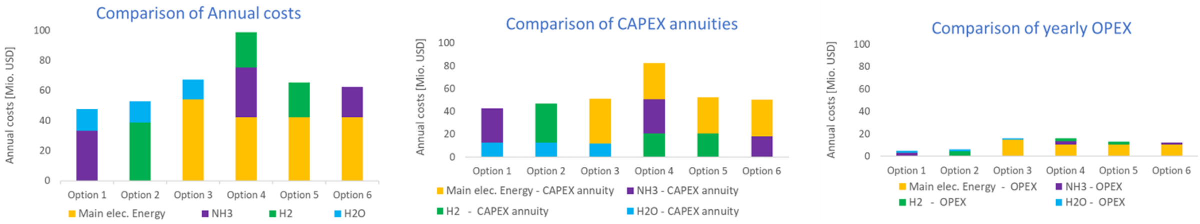


Figure 7: Results of the 0.35 MTPA energy carrier transport cases.

While option 1 is cheaper than option 2, option 2 would have the flexibility to decide at the export facility if all hydrogen shall be converted into ammonia or if some parts shall remain as hydrogen. Within option 1 an additional component, the ammonia cracker, would be necessary to convert ammonia back into hydrogen.

Figure 8 shows the overall economics of the mentioned six (6) options in the case of an increase planned output of 0.75 MTPA of ammonia. The expected transportation cost range decreases by 40-50 % and results in costs of 70 to 90 USD/t(NH3).

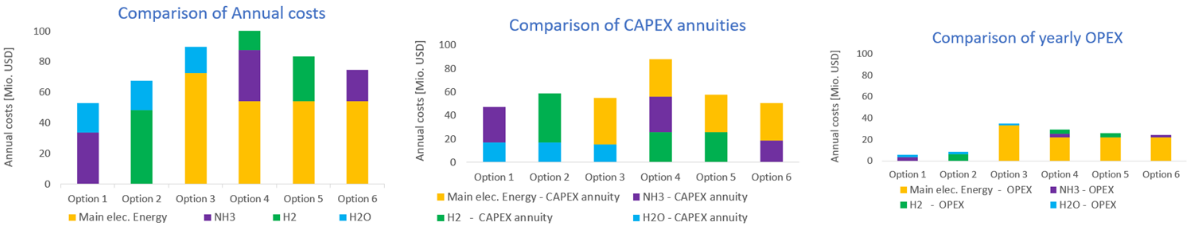


Figure 8: Results of the 0.75 MTPA energy carrier transport cases.

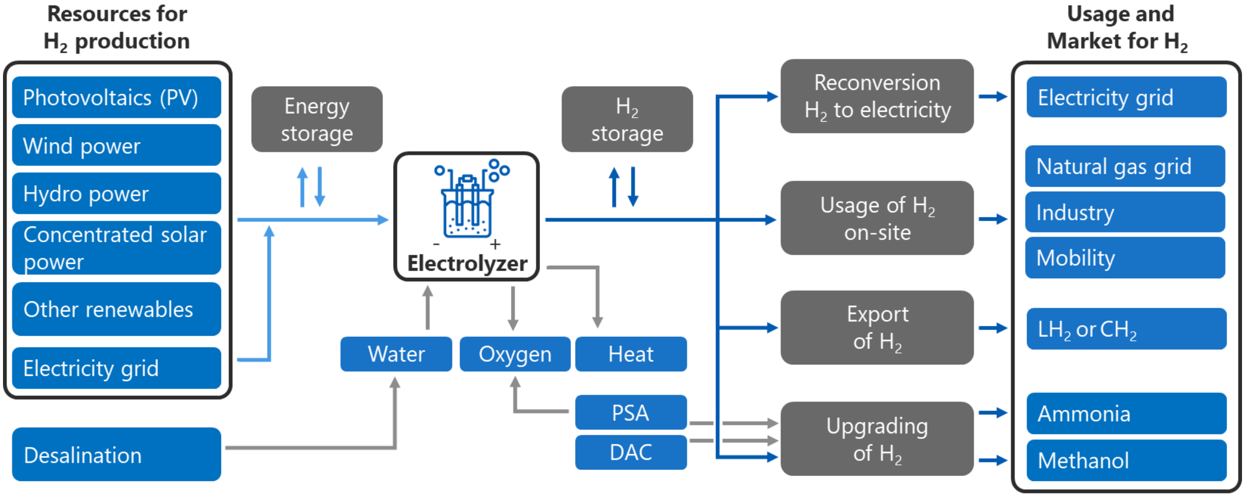
A general overview over all assessed energy carrier transport scenarios is provided in Table 2. This includes the overall economics for the 0.35 and 0.75 MTPA(NH3) production targets as well according pro’s and cons’ for the individual options.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Description	• Water to Daures • NH_3 to Port	• Water to Daures • H_2 to Port	• Water to Port • Power to Port	• Power To Desal • H2 to Daures • NH_3 to Port	• Power to Desal. • H_2 to Port	• Power to Desal. • NH_3 to Port
0.35 MTPA LCOA* (USD/t) / $\%_{lowest}$	**~135** 100%	**~150** 111%	~190 141%	~285 211%	~190 141%	~180 133%
0.75 MTPA LCOA* (USD/t) / $\%_{lowest}$	**~70** 100%	**~90** 129%	~120 171%	~155 223%	~110 157%	~100 143%
Main carrier transport needed	• Water • Ammonia	• Water • Hydrogen	• Water • Power	• Power • Hydrogen • Ammonia	• Power • Hydrogen	• Power • Ammonia
"Industrial" sites to develop	• Desalination • REN+H2+NH3 • Port	• Desalination • REN+H2 • Port+NH3	• Desalination • REN • Port+H2+NH3	• Desalination+H2 • REN+NH3 • Port	• Desalination+H2 • REN • Port+NH3	• Desal.+H2+NH3 • REN • Port
Pro	• Processes at one location	• Flexible offtake (H2 and NH3) • H2 pipeline use as storage	• Processes at one location • Flexible offtake (H2, NH3, and power) • Simplest transport sys.	• Easy water handling • No need of water pipeline	• Easy water handling • No need of water pipeline • Flexible offtake (H2 and NH3) • H2 pipeline use as storage	• Easy water handling • No need of water pipeline • Processes at one location
Contra	• Ammonia pipeline • NH3 refrig. at the port • If H2 needed at the Port, NH3 cracking necessary	• Unproven large-scale carrier transport	• Unproven large-scale carrier transport	• Ammonia pipeline • NH3 refrig. at the port • If H2 needed at the Port, NH3 cracking necessary • Complex transport sys.	• Unproven large-scale carrier transport	• Ammonia pipeline • NH3 refrig. at the port • If H2 needed at the Port, NH3 cracking necessary

Table 2: Summary of proposed energy carrier transport options including high-level assessment.

1.5 Optimization

The overall system optimization was conducted with Fichtner's H2-Optimizer (see Figure 9).



Abbreviations: H_2 - Hydrogen | LH_2 – Liquid Hydrogen | CH_2 – Compressed Hydrogen | PSA - Pressure Swing Adsorption | DAC - Direct Air Capture

© Fichtner H2-Optimizer, v2022.1

Figure 9: Fichtner's H2-Optimizer - overall system overview.

The list below mentions the most important details about Fichtner's H2-Optimizer:

- Techno-economic evaluation of entire H2/PtX value chain, use cases and business models,
- Concurrent optimization of sizing and operation (MILP using CPLEX/Gurobi),
- Considering all main components of H2/PtX value chain,
- Validated and project specific inputs (e.g., time series, costs),
- Explicit consideration of technical characteristics of the system com-ponents (e.g., such as part-load behavior, ramp rate), and
- Extendable as requirements enhance.

As special focus within the optimization process was put onto the assessment of different wind turbine generators (WTG). Figure 10 shows the assessed 31 WTG's as ratios to the largest WTG given in rotor diameter and rated power per WTG.

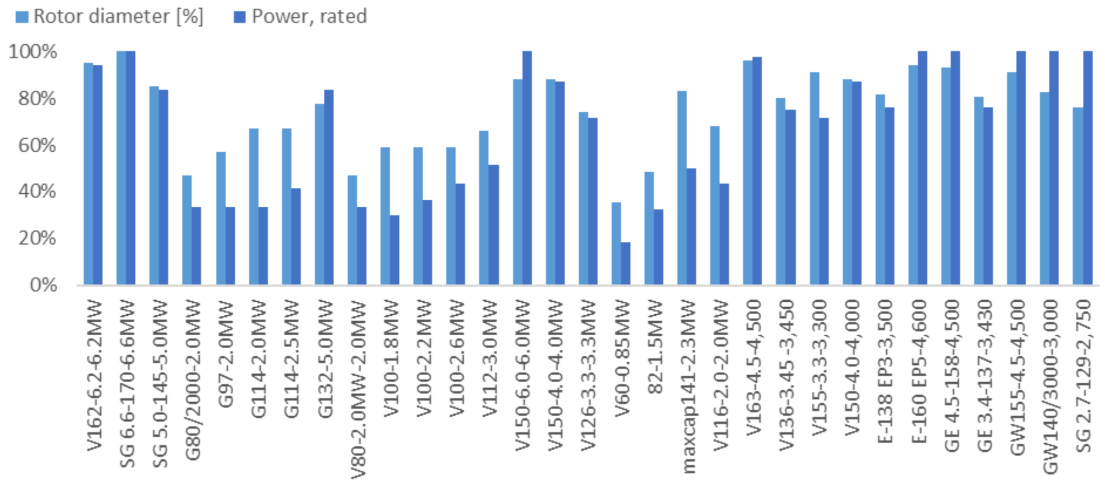


Figure 10: WTG comparison (rotor diameter, rated power) in percent.

An important remark is regarding costs: for the optimization specific costs of wind turbines is considered. Different sizes of turbines will result in (slightly) different specific costs while for all turbines are assumed to be mounted at a level of 120 m hub height. The current assumptions for wind turbines is 1.1 mn USD per MW for large WTG's such as the Siemens Gamesa 6.6 MW (RD160) turbine. A economy of scale factor of 0.5 is used which results in 1.9 mn USD per MW for small WTG's such as the maxcap 2.3 MW (RD140) turbine.

Figure 11 shows the results for the assessed scenarios. The most economical solution results in a LCOA of 931 USD/t(NH3) with the Vestas163 turbine (4.5 MW). An alternative solution using the windwise maxcap 141 (2.3 MW) results in LCOA's of 958 USD/t(NH3). As an extreme, the most expensive solution ends up at 1,118 USD/t(NH3). As such, the spread of LCOA's is between 930 and 1,120 USD/t(NH3). For the 350 kTPA(NH3) case, expected pipeline and transmission costs of about 135 to 150 USD/t(NH3) needs to be considered. For the 750 kTPA(NH3) case, the expected costs might be in the range of 70 to 90 USD/t(NH3). The transportation distance between Namibia (Port of Walvis Bay) and Europe (e.g., Port of Rotterdam, Netherland) is about 5,500 nautical miles (or 10,186 km). This results in expected shipping costs in the range of 100 to 120 USD/t(NH3).

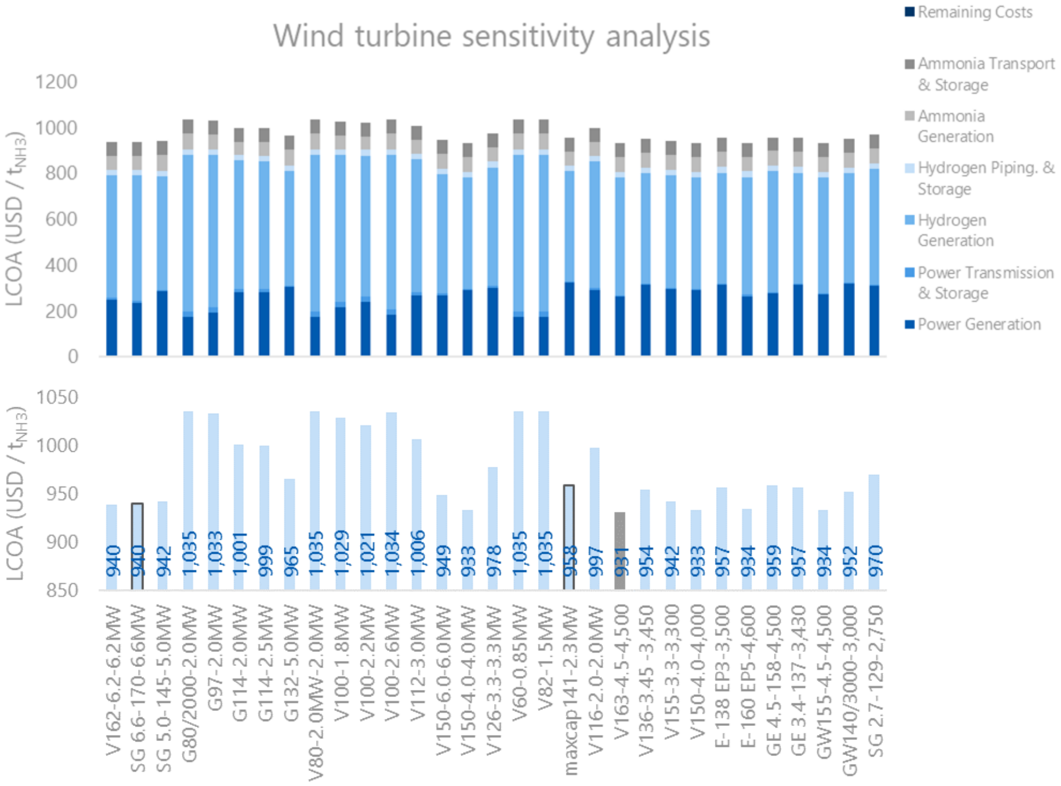


Figure 11: Expected LCOA's for all assessed WTG's.

Based on the WTG selection the maximum size of the overall project can be adjusted. For example, by using the maxcap WTG the 350 kTPA(NH3) case uses already the entire area available for wind turbines. Moving to e.g. V163 the available land can be used to up to 750 kTPA(NH3) (see Figure 12). Turbines such as the G80/2000, V80, V60, and V82 have not been found economical compared with power from solar photovoltaic.

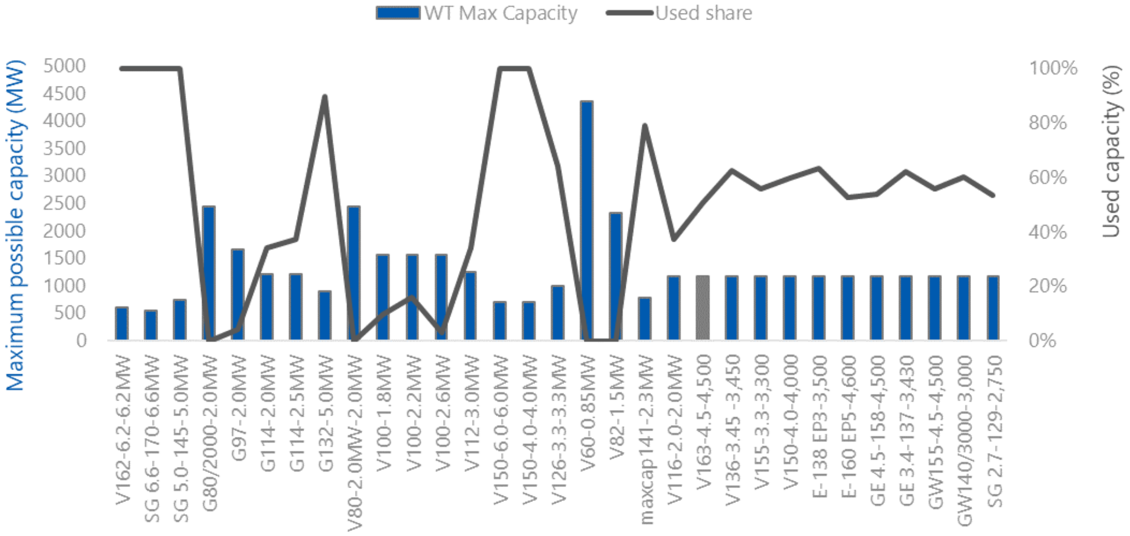
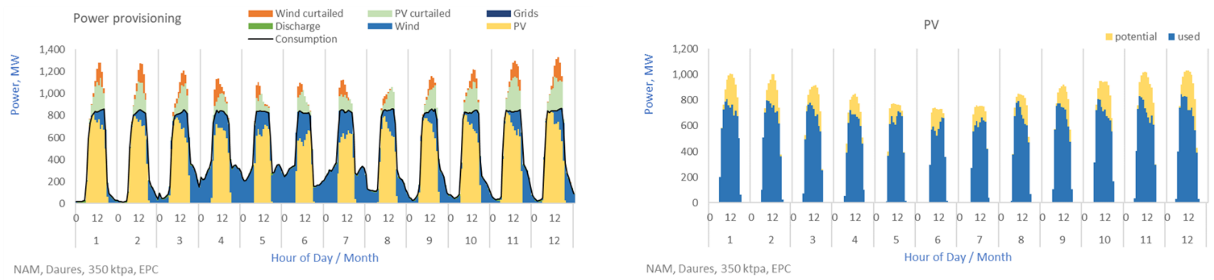


Figure 12: Used wind area land (in percent).

A final WTG selection shall also consider supply chain constraints to make sure that the proposed OEM is able to deliver the necessary wind turbines.

Figure 13 shows some examples of the optimal case including the overall power provisioning, and power curtailment separated into solar PV and wind including usage and curtailment.

- Overall power provisioning
- PV potential and used



- Power curtailment
- Wind potential and used

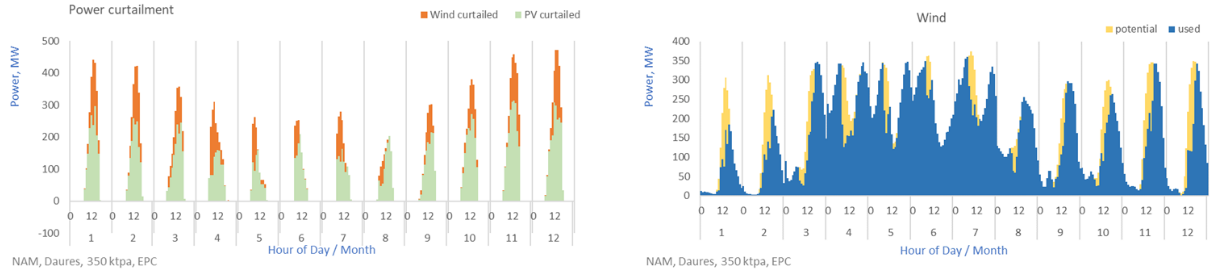
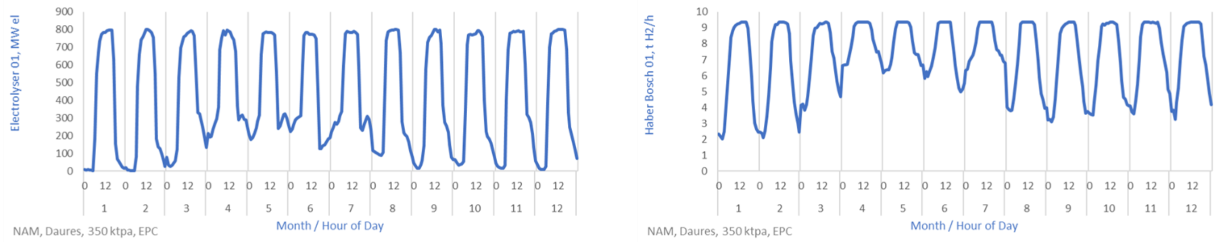


Figure 13: Exemplary Fichtner's H2-Optimizer results, focus power.

Figure 14 shows exemplary results of the optimal case on how "for an average day" a month the operation of hydrogen, nitrogen, and ammonia production units might look like.

- Electrolyser operation
- Haber Bosch operation



- Air separation unit operation
- Haber Bosch operation, exemplary period

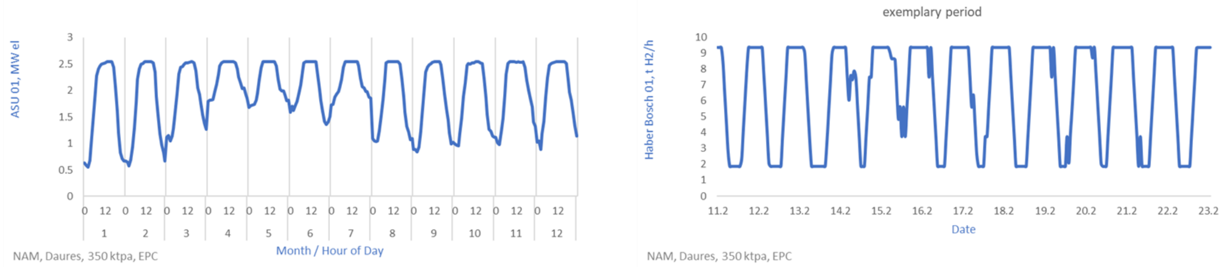


Figure 14: Exemplary Fichtner's H2-Optimizer results, focus hydrogen, nitrogen, and ammonia.

As the figure above shows, for the Haber Bosch process as well as the air separation process a 20 % minimum load requirement has been introduced as both processes are not start- and stoppable in short period of times.

1.6 Learning Rate

An very important detail to be considered is when the financial investment decision (FID) will happen. In all costs and LCO's mentioned up to know, the assumption is a FID in 2023. As such the latest available cost blocks have been considered. If the FID is expected to happen several years in the future, this calls for the consideration of cost improvement (cost reduction) opportunities. This kind of opportunities are basically considered in the well-established learning rate (LR) method.

The LR method is based on several assumptions:

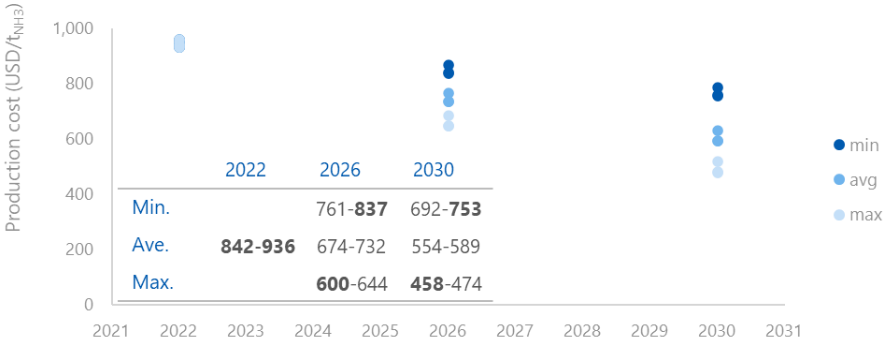
- increasing (doubling) the installed capacity of a given technology is able to reduce the specific cost per installed unit,
- the materialized historical cost improvement will continue in a similar manner as they did the last decade or two, and
- the LR effects are based on long-term expectations and might differ significantly within a short period of time.

Therefore, Table 3 shows the considered annual cost improvements for the technologies battery, electrolysis, solar PV, and wind. As this comes with high uncertainty, three LR scenarios have been considered.

(%/a)	Minimum LR	Average LR	Maximum LR
BES	2	5	8
Ely	2	5	8
PV	5	8	11
Wind	1	2	3

Table 3: *Considered learning rates (%/a).*

Using the LR method, Figure 15 shows to be expected ammonia production costs considering a FID in 2026 and 2030. Based on the significant differences in LR assumptions, shown in Table 3, the expected ammonia production cost for 2026 has a spread of 237 USD/t(NH3) and is expected between 600 and 837 USD/t/NH3). For 2030, the expected spread is 295 USD/t(NH3) and a range between 458 and 753 USD/t(NH3). On average, a CAPEX reduction from ~3.8 bn USD towards 3.3 bn USD (for 2026) and 2.8 bn USD (for 2030) seams feasible for the 350 kTPA(NH3) case.



	2022	2026	2030
Min.		761-**837**	692-**753**
Ave.	**842-936**	674-732	554-589
Max.		**600**-644	**458**-474

Figure 15: *Projected ammonia production costs.*

Figure 16 shows a comparison on how DECHEMA sees the production cost of hydrogen in Europe in different regions (R1 - Southern Europe: Italy, Spain and France; R2 - Western Europe: Austria, Belgium, Germany and Netherlands; R3 - Northern Europe: Norway; R4 - Central Europe: Croatia, Hungary and Slovakia)[5] compared with the expected ammonia production cost of the Daures Green Hydrogen Village (shown in blue dots for 2022, 2026, and 2030 in different shapes of blue for minimum, average, and maximum reduction expectations). This figure shows clearly the potential of the green ammonia production in the Daures Green Hydrogen Village project and the opportunity to deliver it to the European markets. On top of the production costs up to 200 USD/t(NH3) has to be added for the local and international transportation as mentioned above (see Section 1.5). The line in blue shows the high end of the expected production cost while the grey line above indicates the overall cost including local and international transportation towards Europe (Port of Rotterdam, Netherlands).

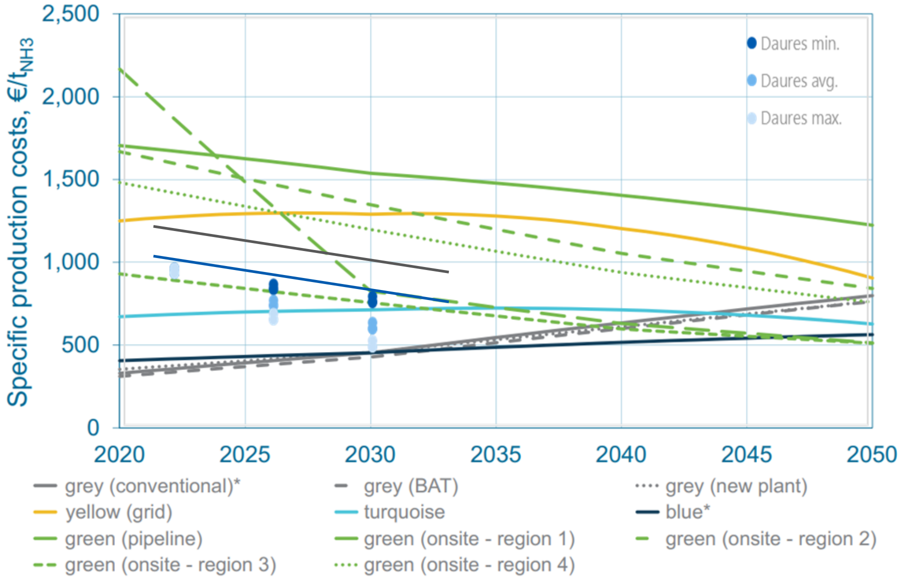
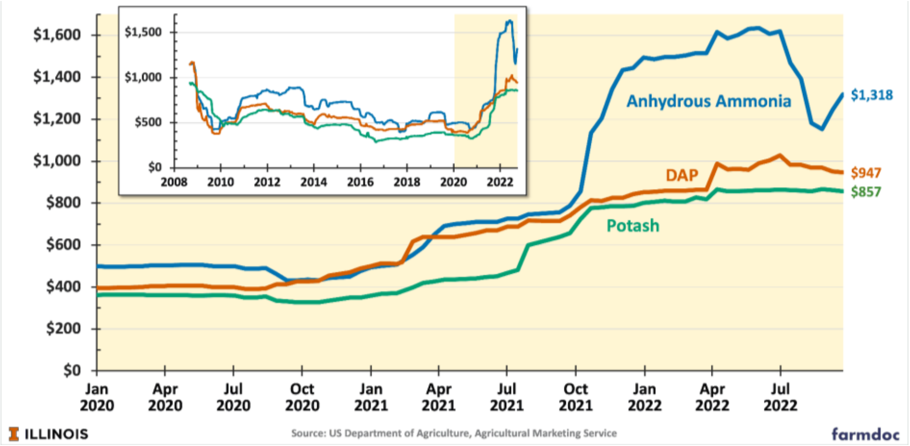


Figure 16: DECHEMA production cost curve vs. expected project costs.

Figure 17 shows the development of the last almost three years in terms of anhydrous ammonia, DAP, and potash.[6] While the very high prices went down already after an historically high prices of over 1,600 USD/t(NH3) the current level in the range of 1,200 to 1,300 USD/t(NH3) is seen as a medium term price level within the markets expectation.



Source: US Department of Agriculture, Agricultural Marketing Service

Figure 17: Historical price development of anhydrous ammonia, DAP, and potash.

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[5] https://dechema.de/dechema_media/Downloads/Positionspapiere/Studie+Ammoniak.pdf

[6] https://farmdocdaily.illinois.edu/2022/09/fertilizer-prices-rates-and-costs-for-2023.html

1.7 Next Project Phase Deliverables

The current work is based on AACE class 5 cost accuracy.[7] With that, as shown in Table 1-4, the only real deliverable is the block flow diagram (BFD).

Engineering Deliverables	AACE Cost Classes >	5	4	3	2	1
Block Flow Diagrams (BFD's)		S/P	P/C	C	C	C
Plot Plans		-	S	P/C	C	C
Process Flow Diagrams (PFD's)		-	S/P	P/C	C	C
Utility Flow Diagrams (UFD's)		-	S/P	P/C	C	C
Piping & Instrument Diagrams (P&ID's)		-	S	P/C	C	C
Heat & Material Balances		-	S	P/C	C	C
Process Equipment List		-	S/P	P/C	C	C
Utility Equipment List		-	S/P	P/C	C	C
Electrical One-Line Drawings		-	S/P	P/C	C	C
Specifications & Datasheets		-	S	P/C	C	C
General Equipment Arrangement Drawings		-	S	P/C	C	C
Spare Parts Listings		-	-	S/P	P	C
Mechanical Discipline Drawings		-	-	S	P	P/C
Electrical Discipline Drawings		-	-	S	P	P/C
Instrumentation/Control System Discipline Drawings		-	-	S	P	P/C
Civil/Structural/Site Discipline Drawings		-	-	S	P	P/C

Abbreviations: None ("-"): development of the deliverable has not begun. | Started (S): work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion. | Preliminary (P): work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals. | Complete (C): the deliverable has been reviewed and approved as appropriate.

Table 1-4: Estimate classification and engineering deliverables.

The next step within this project is to reach AACE class 4 cost accuracy and schedule level 2. To reach this, the following tasks are necessary to be started or reach preliminary status:

- Block Flow Diagrams (BFD's)
- Plot Plans
- Process Flow Diagrams (PFD's)
- Utility Flow Diagrams (UFD's)

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[7] https://www.costengineering.eu/Downloads/articles/AACE_CLASSIFICATION_SYSTEM.pdf

- Piping & Instrument Diagrams (P&ID's)
- Heat & Material Balances
- Process Equipment List
- Utility Equipment List
- Electrical One-Line Drawings
- Specifications & Datasheets
- General Equipment Arrangement Drawings

1.8 Summary

Based on the results shown and discussed above, an increase of the proposed project seams feasible and economically necessary from a carrier transport perspective (able to reduce cost from about 140 to 80 USD/t(NH3) from 350 towards 750 kTPA(NH3) production capacity). As such, Table 5 shows an extended table with an added phase V and a production target of 750 kTPA(NH3). Growth even after this point of production target could be realized with pure solar PV additions which is expected to be economical in combination with battery energy storage (BES) after 2030.

Phase	Year	Solar PV [MWp]	Wind [MW]	Electrolysis [MW]	Production [kTPA(H2)]	Production [kTPA(NH3)]
I	2022 - 2023	1.5	-	0.5	0.15	0.182
II	2024 - 2025	12	18	12	3.6	10.5
III	2026 - 2028	41	60	42	12	35
IV	2029 - 2032	420	590	420	121	352
V	TBD *	2,012	1,493	1,548	132	750 (2x 375)

Abbreviations: MW: Megawatt | MWp: Megawatt peak | kTPA: thousand tons per annum | rounded numbers
*Remark: * Phase V based on preliminary H2-Optimization results*

Table 5: Updated proposed project phases.

As such, the next proposed step is to initiate the pre-FEED for the phase IV or even phase V of the project while considering possible development options for phase II and III as intermediate steps of the project growth strategy.

The pre-FEED might be separated into smaller work packages such as (but not limited too):

- re-assess the WTG decision once the first two month of data out of the wind measurement campaign are available,
- collect the necessary assumptions for the pre-FEED,
- possible power export options for otherwise curtailed power (e.g., use in water desalination or water purification),
- initiate talks with OEM's for solar PV, wind, electrolysis, and Haber Bosch synthesis,
- support on OEM selection (e.g., electrolysis, Haber Bosch synthesis),
- support on EPC selection (e.g., solar PV, wind, electrolysis, Haber Bosch synthesis, pipelines),
- support on purchase strategy of hardware (e.g., electrolysis, Haber Bosch synthesis),
- support in tendering preparations, and
- support in additional discussion (e.g., lenders, off-takers, OEM's, EPC's) as necessary.