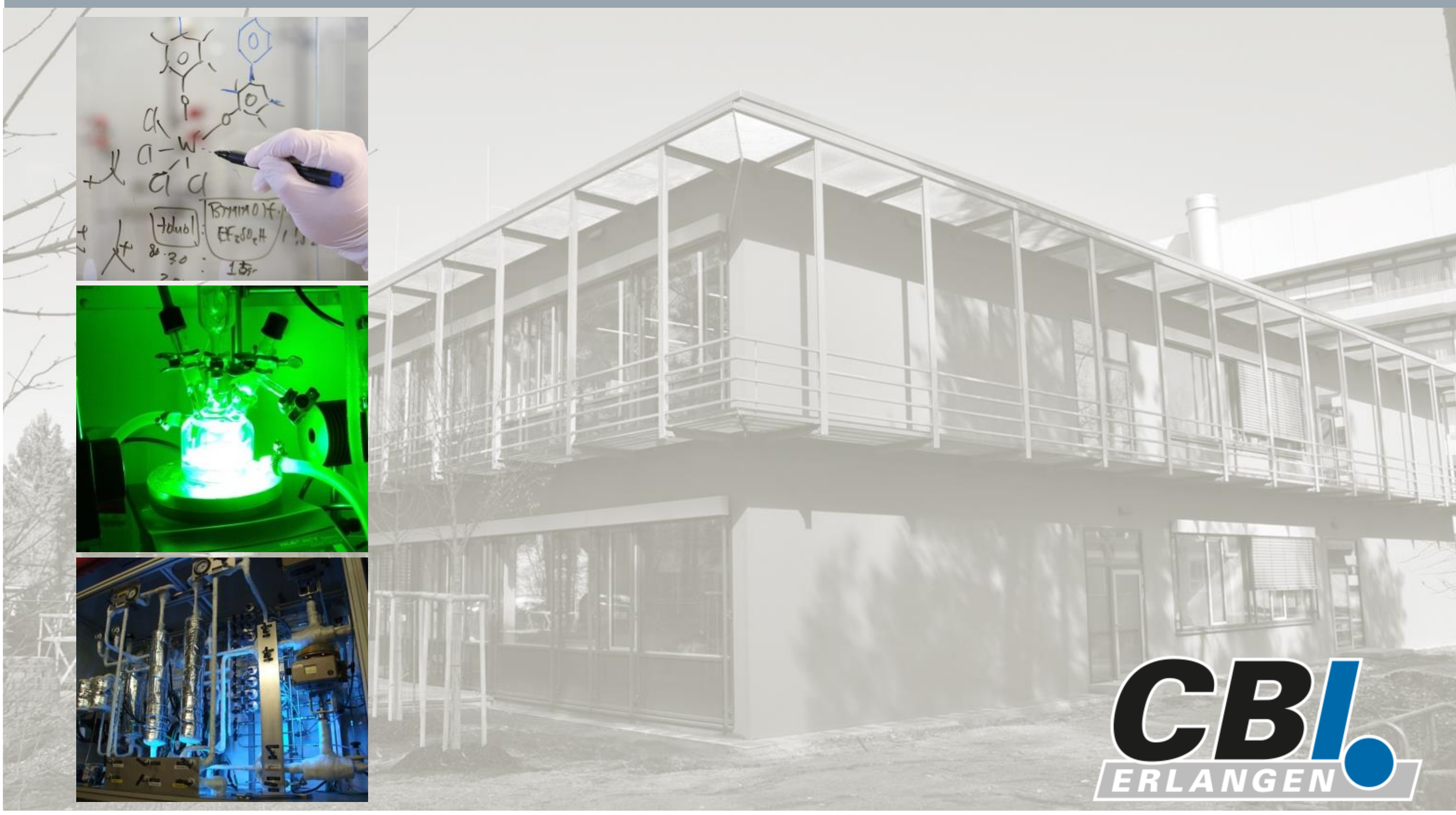
FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Offshore Hydrogen Storage

Partner project with Hydrogenious Technologies GmbH

CBI Project Course

Winter Semester 2019



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Outline

The project course is a curriculum event of no commercial interest organized by the *Department Chemie- und Bioingenieurwesen* (CBI) of *Friedrich-Alexander-Universität Erlangen-Nürnberg* (FAU) in cooperation with an industrial partner. The industrial partner of the CBI project course in spring 2019 is Hydrogenious Technologies GmbH, located in Erlangen, Germany. Hydrogenious Technologies was founded in 2013 and is a company which focuses on developing hydrogen storage system based on **liquid organic hydrogen carrier** (LOHC) materials.

The overall concept of this year`s project course is to **design and engineer an offshore plant** which converts offshore **wind energy into hydrogen** chemically stored in the form of LOHC. A 300 MW offshore wind-park in the North Sea (German coastline) will deliver energy for the offshore plant. On the platform, seawater will be purified and split in H_2 and O_2 via electrolysis. The dried hydrogen gas is then used to hydrogenate dibenzyltoluene (Marlotherm SH), the hydrogen-lean form of LOHC (LOHC-D). The hydrogen-rich form of LOHC (LOHC-H) will be stored in a tank on the platform and pumped into tank ships in regular time intervals, where it will be transported to a port. The LOHC-H will be stored in a tank at an onshore site and from there it can be distributed to customers via tank trucks. The dehydrogenated LOHC-D will then be returned to the onshore site, where it will first be purified and shipped back to the offshore platform. Figure 1 shows the flow chart of the whole process.

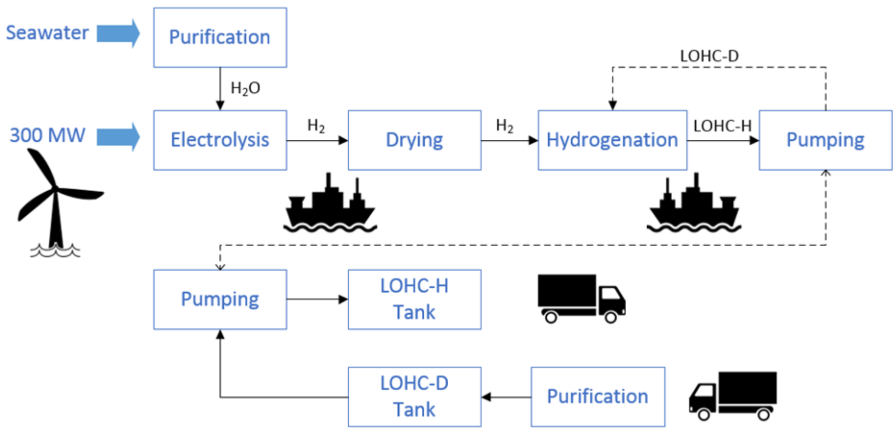

Figure 1. Block flow scheme of offshore LOHC technology.

The design and engineering of the offshore plant includes reactor design, separation systems, apparatus construction, logistics, piping system, heat management, automation, legal and safety, life cycle assessment and cost management.

Results

Based on the block scheme in Figure 1, students were assigned to the individual teams which can be categorized as generalists and specialists. The generalists include Management, Legal and Safety, Logistics, Piping, Apparatus construction, Heat management, Automation, Life Cycle Assessment and Cost calculation. The specialists include those groups responsible for a particular step in the process, namely Seawater purification, Electrolysis, Hydrogen purification, Hydrogenation and LOHC-H / -D purification.

Management

The main task of the management group is to ensure a smooth cooperation between the individual groups in terms of data exchange and problems clarification. Apart from that, the tasks of the management group also include setting a three-week **time line** (see Figure 2) for the project, organizing and compering interim and final presentation of the plant design.

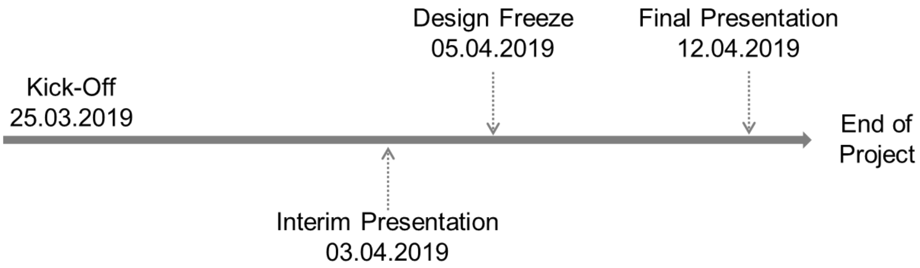

Figure 2: Time line for the project course spring 2019.

To ensure that the project course finishes on time, a smooth transition between specialist and generalist groups was required. Hence, a **design freeze** was set at two weeks after the project start. By then, the design and processes planned by the specialists had to be finalized and therefore eased the jobs of the generalists. **Communication** platforms such as StudOn (a well-established platform from the university) and Dropbox were used for information exchange and data management between groups. In addition, a daily meeting (**Jour-Fixe**) was held with respective team leaders to share updates on the progress of individual groups.

Legal and Safety

A **suitable offshore site** for H_2 production and LOHC loading as well as an **appropriate onshore site** for LOHC storage and purification had to be identified. As offshore location, an area declared for wind energy plants in the German Bight was selected within the Extraordinary Economic Zone (EEZ). As onshore site, the port of Brunsbüttel was chosen due to the advantages of a short transport route, nautical conditions suitable for large tankers, well established infrastructure for chemical companies and available properties for lease or purchase. Next, clarifying the necessary **authorization and approval process** with its corresponding fees was targeted. The offshore site requires a plan approval procedure according to sections 2 and 6 of the Offshore Installations Ordinance as well as an environmental impact assessment and an approval for H_2 storage according to section 1 subsection 1 number 1 of the Act on the Assessment of Environmental Impacts. The expenses were estimated to approximately 100,000 to 200,000 €. Onshore only involves a building permission with costs of roughly 0.5 % of the building costs for the LOHC purification unit, whereas the pipeline from the mooring point to the purification unit requires a suitability test by the authorities as described in section 63 of the German Federal Water Resources Act. Furthermore, the **plant safety** had to be evaluated. Especially explosion prevention and fire safety regulations have to be meticulously implemented due to the large explosive range of H_2 with air (4 - 77 vol-%) and the latent danger of auto-ignition. For example, fire barriers and fire alarm systems have to be incorporated and explosion pressure resistant construction as well as leakage and explosion detection is required. Occupational safety measures include a Helipad and life boats for the crew in case of emergencies. Finally, the **deposition of waste** products had to be planned. Therefor three important waste categories were identified: hazardous waste will be disposed in a hazardous waste incinerator, disposable waste will be deposited in a hazardous waste deposit and lastly, recyclable material will be utilized in a recycling depot or exploited through thermal utilization.

Logistics

The main task of the logistics group was to find an adequate way of **transporting LOHC** (loaded/unloaded) to and from an offshore platform in the North Sea. Principally, two scenarios were discussed to handle the production capacity of 43 $m^3\ h^{-1}$ of hydrated LOHC from the platform and returning the dehydrated form to the platform: **ISO tank containers** and tankships. After careful evaluation, containers were excluded due to the difficulties of handling ca. 1000 containers in the whole supply chain. Thus, the **tankship** option was selected, resulting in the following aspects to be addressed:

- The change of **viscosity of dibenzyltoluene** over temperature is significant, especially the hydrated form. Therefore, storage tanks should be insulated sufficiently to overcome the heat loss. There is no need for heating in case of proper insulation.
- The two forms of LOHC should be stored in **dedicated storage tanks** over the cycle of the offshore platform, ship and onshore station to ensure the prevention of any possible mixing and reduces the need for purification.

- **Cavitation of pumps** can be problematic. The Net Positive Suction Head must be taken into account.
- For loading and unloading of the tankship, **dedicated hoses** are required, which should meet several conditions (resistance against aromatic content, flow rate, flexibility).

Seawater purification

The seawater purification has the goal to provide the water that is needed for the electrolysis. In order to fulfill the requirements for **water quality and purity** for the electrolysis, the raw seawater has to go through some treatment processes. The purity required for electrolysis is referred to as "ultra-pure" quality, which according to the American Society for Testing and Materials (ASTM) is divided into different classes according to different parameters. The highest purity between Type I and Type II is required for the electrolysis. To ensure this quality, impurities such as planktons, microorganisms, salts and other components must be removed from the untreated seawater.

The seawater purification is done according to the following steps.

- The water is taken from the sea by means of **"fish-friendly" suction**, so coarse impurities and fish are excluded.
- Then the seawater is passed into a **sand filter** which filters bigger particles and impurities.
- An **activated carbon filte**r is then used, in order to separate e.g. dissolved chlorinated hydrocarbons and other organic substances.
- To kill microorganisms, disinfection takes place by means of **UV irradiation**. This has the decisive advantage that there is no need for chemicals on the offshore platform.
- For the desalination of the seawater, **reverse osmosis** is used.
- Finally the water has to pass through an **electron deionizer** to achieve the purity required for the electrolysis.

Electrolysis

The **Proton Exchange Membrane Water Electrolysis** (PEMWE) offers many advantages over other electrolysis technologies that make it particularly suited for renewables and off-shore use. In addition to **high hydrogen purity** it can quickly adapt to **fluctuations** and offers a broad range of possible operating points (5-160 % workload). Mild temperature and the possibility of electrochemical compression ($T \approx 10$-60 °C, $p \approx 1$-30 bar) enable smooth transitions to prior and subsequent process steps. In addition to the water that is converted to

H_2 and O_2, an extensive **recycle stream** (ratio ca. 1:50) is pumped through the electrolyzer-stacks to carry off heat and oxygen. For regeneration, the recycle stream is decompressed for degasification and subsequently led through a heat exchanger, before reentering the supply tank. The electrolysis-unit designed during this project is dimensioned for an **average workload of 75 MW** and a **maximum of 120 MW** (total number of electrolyzers: 75; water supply and hydrogen output: 15 m^3_{H2O}/h, 1646 kg_{H2}/h; 24 m^3_{H2O}/h, 2633 kg_{H2}/h for 75 MW / 120 MW respectively). PEMWE requires ultrapure water. Since slow **degradation processes** and accumulation of membrane and electrode components in the recycle stream occur, a second purifying unit is implemented in the recycle. There was no data available on the issue, but it might play a very significant role in a system that combines many cell-stacks with a singular recycle. Furthermore, PEMWE and electrolysis in general are still fields of research. Major progress is expected in regard to catalyst loading of the electrodes, overall efficiency and thereby cost. At the same time the number of plants with a scale comparable to this project will increase and offer more technical data.

Hydrogen purification

The hydrogenation reactor requires a water content of less than 10 ppm (wt.) therefore a hydrogen purification unit is needed. Since the H_2-stream exits the electrolyzer saturated at 25 to 30 bar and a temperature of 60 °C, the water content can be determined as 5.6 wt.-%. First, a **heat exchanger** is established to lower the temperature to 30 °C by which the water content is reduced to 1.59 wt.-%. After that, a two-step **pressure swing adsorption** (PSA) decreases the water content to 10 ppm (wt.). In the first column, a packing based on activated carbon is used. Since the gas is saturated, activated carbon shows a good adsorption behavior and lowers the water content to 0.15 wt.-%. For very high purifications, an adsorption with molecular sieves is added to ensure the 10 ppm (wt.) water content in the H_2-stream. For both PSAs, a realization of **four columns** has been established to ensure a **continuous operation**. For the **regeneration** of the activated carbon, a higher temperature and a lower pressure is desired. Therefore, the waste heat of the reactor can be used to heat 2 % of the pure product and return it at a pressure of 1 bar and 170 °C in the adsorber to regenerate the activated carbon. The regeneration gas will be recycled to the beginning of the purification plant. The same process will be utilized to regenerate the molecular sieves. Since higher temperatures are needed to desorb the molecular sieves, the recycle gas will be heated to 340 °C to ensure a complete regeneration.

Hydrogenation

First, the decision concerning the catalyst was made. **Platinum** was chosen as the active metal to reach the given target for the **degree of hydrogenation** (DoH) at the end of the reactor (DoH_{out} = 95 %). A 0.3 Pt-wt.-% eggshell catalyst with alumina as supporting material (as produced by CLARIANT) was chosen. For the first design, a productivity was determined with an effectiveness factor. This factor was calculated by correlating results of a semi batch reactor from Jorschik et al.[1] and a **Dead End trickle bed reactor** from Müller[2] for ruthenium (Ru) at 30 bar and 210 °C. Assuming that the effectiveness factor is constant and also valid for the platinum catalyst, the productivity of the platinum catalyst can be calculated in the trickle-bed reactor using the data of the semi batch reactor for Pt in Jorschick et al.[1]. With this productivity and the mass flow of hydrogen that has to be converted, a catalyst volume and thus a first number of pipes can be derived. For further consideration of the hydrogenation and the temperature profile, a **kinetic model** was determined using the same data.[1] The application of the derived kinetic in a one-dimensional PFTR model showed that the reaction is **highly temperature sensitive**. Therefore another design had to be developed. With a new effectiveness factor of 60 % that was given by Dr. P. Preuster from HI ERN (unpublished data), the heat production per axial volume element increased even more. Since the productivity and thus the heat production in the first segment of the pipe is the highest, the **reactor is divided into two sections** with different catalyst dilutions and different cooling temperatures. The first section has a length of 3 m, a wall temperature of 220 °C and an overall mass of particles in the reactor to catalyst mass ratio of 14.5, which is called the dilution factor. The dibenzyltoluene is hydrogenated from a degree of hydrogenation of 0.05 up to 0.5 in this segment. The second section is 7 m long with a wall temperature of 240 °C. The dilution factor in this section is 9 and the DoH of the dibenzyltoluene increases up to 0.95. With this model and a pipe diameter of 17.3 mm, the number of pipes can be calculated. For the hydrogenation, 22000 pipes are needed for the multi-tube reactor. The LOHC-H will then be stored in big offshore tanks, waiting to be shipped to the onshore site.

LOHC-D purification

The LOHC-D returning from the customers contains 500 ppm (wt.) water. The **water content** after purification must be below 10 ppm (wt.). Neither rectification nor membrane processes can achieve such low water concentration, at least not with reasonable effort. For this reason, we propose a **drying process via adsorption** on molecular sieve (zeolite 4Å). The mass

[1] H. Jorschick, A. Bulgarin, L. Alletsee, P. Preuster, A. Bösmann, P. Wasserscheid, ACS Sustainable Chem. Eng. 2019, 7, 4186.
[2] Michael Müller, Dissertation, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, 2018.

stream of LOHC-D to be dried is about 37 t h^{-1}. The zeolite is estimated to have an equilibrium water load of approx. 8 wt.-%. Adsorption is an exothermic process and hence should be conducted at low temperatures. Since the **high viscosity** of DBT (0.05 Pas at 20°C) provides an additional diffusion resistance, a **long contact time** (1h empty bed contact time) is required. Therefore, **two identical adsorbers** with a total height of 15.5 m and a diameter of 3 m have been designed to purify the LOHC-D stream. Each apparatus is filled with 37.5 tons of zeolite resulting in a bed height of 8.2 meters. With this technical configuration, each adsorber can operate for 4 days before it must be regenerated. The **regeneration process** consists of three steps. First the apparatus is heated up to 330°C with superheated steam flowing through a heating coil inside the adsorber. During this step most of the remaining LOHC-D will leave the column due to its reduced viscosity. Afterwards a nitrogen stream is led through the adsorber column for about 12 hours to purge desorbing water and remaining LOHC-D from the zeolite. To prevent air pollution, the water and LOHC-D in the nitrogen stream will be removed in a heat exchanger by cooling down the gas stream to ambient temperature. The last step of the regeneration is the cooling of the apparatus back to adsorption conditions by flooding it with LOHC-D using it for its original purpose as heat carrier oil. As the whole regeneration process takes about 3 days, there is a buffer time of 24 hours by a 4 days on stream cycle assuming a weekly cycle.

Piping

The task for the piping group was subdivided into two major tasks. One major task was to create an **assembly plan** of the offshore and the onshore facility (see Figure 3). The ideas where visualized with the program *Sketch Up*. The program has implemented libraries with graphical 3D Symbols for the different apparatus of the facility. It was possible to implement them in a true scale arrangement drawing. This drawing made it possible to guess the critical consumption of space for the offshore and onshore site. Moreover, the length, branching and curvatures of the pipes could be calculated. The second great task was to **construct the piping system** of the whole facility. First the material of the pipes was selected. The materials were selected by the critical characteristics of the fluid which is transported by each pipe. As the contact with seawater is unavoidable in the whole plant, all material has to be chlorine resistant. The thermoplastic PVDF was selected as a possible material for pipes with a pressure of less than 6 bar. For pipes that exceeds a pressure limit of 6 bar, stainless steel was selected. Another critical characteristic that is not avoidable is hydrogen embrittlement. Therefore special steel with high amount of chrome and molybdenum were selected. The nominal diameter was calculated due to the maximum speed of the fluid in the pipe. These values are listed in different norms. With the flow rate and speed, the nominal diameter was calculated.

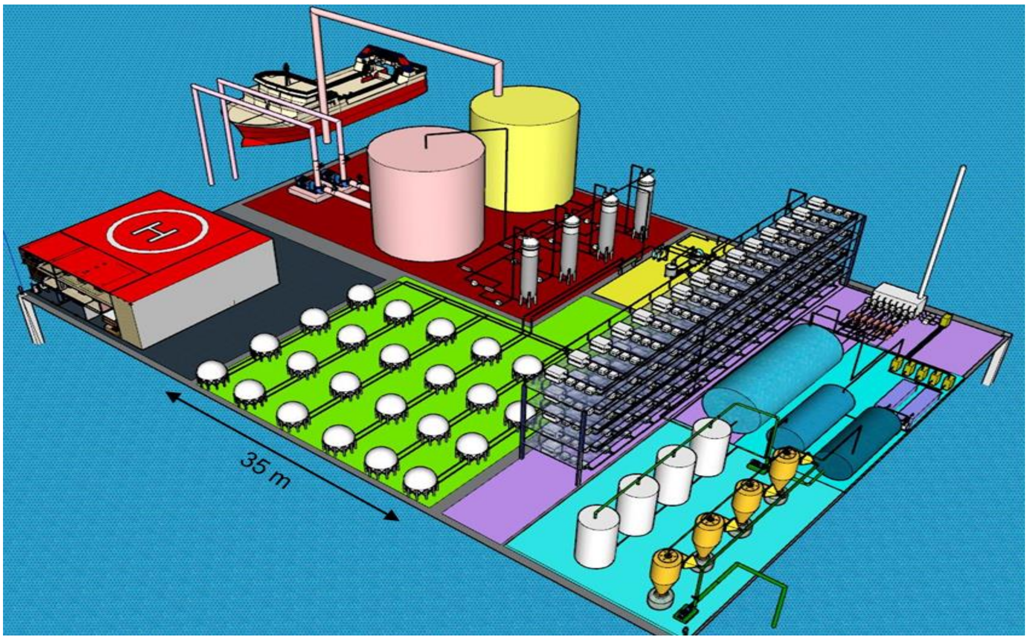

Figure 3. Installation plan of LOHC offshore site.

The least possible **pressure stage** was selected by the wall thickness that is needed for the pressure in each pipe. In the end, pressure losses, thermal expansion, pressure surges and vibrations were calculated.

Apparatus construction

The task of the apparatus construction group is the design of the apparatus, reactors and storage tanks required for the process. For this, the first step is to design the **component parts**, of which the apparatus are built, in a CAD software. In this case, *CREO Parametr*ic is used as CAD program. The main pieces of the apparatus (e.g. cylindrical walls, flanges, heads, bottoms, built-ins, etc.) are designed in CREO in a **parametrized** way, to be able to quickly adapt to design changes later. For the calculations of the parts, mainly the **AD 2000 standards** for pressure equipment are used, while certain components are based on **DIN standards** as well. After calculations, the apparatus are assembled in CREO by making use of the previously designed standard components. The main focus during this task is on the reactors, adsorption columns and hydrogen storage tanks, which are designed individually for the process requirements. After having designed the apparatus, an **estimation of overall steel mass** for the cost calculation and the life cycle assessment is made. Also, dimensions are forwarded to the piping group for the site plan. Another main focus is the **selection of suitable materials** for the apparatus, which also happens in corporation with the piping group. The choice of steel is highly depending on temperature, pressure, weldability, chemical resistance and mechanical strength. One major criterion is the contact with pressurized hydrogen. For H_2 contact and temperatures below 350 °C, the steel 1.4539 is used. Below 250 °C, 1.4410 is used due to higher mechanical stability. The rest of the apparatus, where no hydrogen is present, are to be constructed with the seawater resistant steel 1.4462.

Heat management

Optimal usage of resources requires **heat integration and recovery**. On a remote offshore facility the limited access to utilities is a challenge. This study identifies heat sinks and sources according to flow enthalpy, temperature, as well as process continuity. Only continuous processes are considered in internal heat integration. The most important heat sinks are the desalination process (5 to 25 °C) as well as the preheating of hydrogen (30 to 240 °C) and DBT-D (25 to 240 °C) feed. Among the heat sources is the reactor excess heat (at 240 and 220 °C), the product stream leaving the reactor (260 to 50 °C) and the electrolysis (60 to 30 °C). Two **cooling cycles** were designed to enable straightforward process regulation, limit the contact with seawater and prevent fouling in the system. Cooling cycle A is mainly used to cool the electrolysis at a temperature level from 25 to 45 °C. Cooling cycle B is used to cool the reactor excess heat and ranges from 30 to 60 °C. Seawater is used as cooling utility, ranging from 15 to 35 °C. The desalination feed is heated with reactor excess heat. The feed stream to the reactor is preheated with the hot product stream leaving the reactor, as well as excess heat from the stream for reactor cooling. For **fouling prevention** the Taprogge process (flow-driven ball cleaning) is recommended. This state-of-the-art technology is frequently used in similar settings such as power stations and desalination plants.

Automation

The basic design of every sub-process is extended by the **automation of the unit operations**. Sensors to determine pressure, temperature, flow, levels, compositions, etc. are used to supervise the system and compare actual values with the defined set points. In case of deviation these devices are supposed to affect actors like pumps, heaters or valves to adjust the controlled parameters. Thus, the **control loops** serve the achieving of stable operating conditions. **Dynamic influences** need to be considered to maintain a **continuous and safe operation** mode. Concepts of how to start up or shut down the plant as well as how to intervene in the case of an emergency have to be contemplated. The **Piping and Instrumentation Diagrams** (P&ID) are developed for every individual process step with respect to the linkages and dependencies of the different units as well as of the heat exchange network. Therefore, it is examined, whether the combined process as a whole shows **operational reliability**. In addition to that, external companies are to be requested information on functionality and prices of analysis tools to be able to prepare a rough cost estimation of the required measuring devices.

Life Cycle Assessment

As the task required, the **global warming potential** over 100 year period (GWP 100a) is regarded as a main indicator to assess the impact factor of climate change for offshore hydrogen production. According to DIN EN ISO 14040, four steps are taken to complete the LCA. The **main goal** is to identify the process with the highest contribution to the GWP 100a of the plant. Additionally the comparison of the sub-processes with each other is set as a goal. The GWP 100a of the plant should then be compared to other hydrogen production technologies. The functional unit of the LCA is 1 kg H_2. The **scope** includes, that the lifetime of the plant is 20 years. The amount of LOHC-H which is produced over 20 years has been calculated from the mass flow of LOHC-H per hour with the assumption, that the plant operates stationary over its lifetime. Furthermore in the "considered hypothetical scenario" the dehydrogenation process of the LOHC-H, as well as the transportation of the LOHC-H to the dehydrogenation plant are not related to emissions, so that the GWP 100a for these two process steps are set to zero. The amount of H_2 which is ready for use over a lifetime of 20 years is been calculated with the assumption, that 0.06 kg H_2 can be obtained from 1 kg LOHC-H through the "fictive emission-free" dehydrogenation. The required data for the LCA is summarized mainly from other groups, the literature and from the database *ecoinvent*. The modelling Software used is *openLCA*. For the **cradle-to-grave assessment**, boundary conditions are defined. The processes which are included by the boundary conditions are: the production and transportation of raw materials, construction, maintenance and decommission of the plant, plant operation, storage and transportation of LOHC. For LCA by the method *ReCiPe Midpoint (H)*, the final result of GWP 100a is approximately 1.112 kg CO_2-eq per kg H_2. Meanwhile, the **climate change impact** of every process can be calculated. As a result the highest impact to the total GWP 100a has the off-shore wind park, which consist of 150 2MW wind turbines. The second highest impact on the GWP 100a comes from the installation of the hydrogen production plant, which includes the production and transportation of raw materials and the facility components as well as the installation of the components at the site. The high impact in this case is mainly caused by the production of the LOHC and its transportation to the offshore location. The most common H_2 production technology is steam reforming of methane. The comparison shows, that the GWP 100a of the offshore H_2 production plant is approximately 12 times lower. The comparison with other studies which are using electricity from wind parks and electrolysis as the H_2 production technology shows, that the magnitude of the GWP 100a in our case, with the assumptions we made, is realistic. A more detailed LCA is required to get a more indicative result.

Cost calculation

From the **main component costs** (reactors, pumps, tank) of the individual process steps, the resulting costs are calculated and thus the total investment needs of the plant are estimated. The cost calculation takes into account process-specific materials and fittings, as well as operating costs (wages, costs, operating resources) and profitable by-products. There are different methods for estimating investments, they differ in their accuracy and content of information at different times of project planning. **Capacity methods** allow an early and rapid estimation, they serve as a basis for decisions for or against a project. Once a preliminary design is established and the design of the main components is completed, **structural methods** can be used. At the beginning of the project a capacity method by **Zevnik/Buchanan** is used for a first rough cost-estimation based on the product capacity. The total plant costs of 63.1 million Euro were estimated too low, the price for the electrolysis-unit alone is 75 million euro. The costs of all components without piping, isolation and electric material amounts to **166 million Euros**, with the process steps of electrolysis with 75 million Euro and reactor with 72 million Euro taking the main part. Knowing the total component costs, the total costs of the plant can be estimated by a structural method. In the **Guthrie method** factors are added for piping, isolation, electric material and installation of the plant, so the plant total costs amount about **600 million Euros**. The highest additional investment costs are the purchase of the LOHC for 120 million Euro and the tank ship for 85 million euro. As tribute to the off-shore location an additional one third of the total plant costs is added. If everything is summed up total investment costs of **1 billion Euros** are received. For the **annual turnover** the sale of hydrogen at filling station is considered. The current selling price of hydrogen at filling stations is 9.50 Euro per kg, it is expected to sell the hydrogen for 5.30 Euro per kg to the station. At an annual production of 17,600 tons of hydrogen per year, this leads to an **annual turnover** of 92 million euro.

Résumé

The designed plant is located on an **offshore platform** near to a wind park and the **onshore site** is chosen to be at ChemCoast Park Brunsbüttel. The shipping distance between the two sites is around 180 km. At the offshore site, seawater is drawn up and introduced to a **desalination** unit, where it will be purified and desalted. The desalinated seawater is then fed into a total of **75 electrolyzer units** and electrolyzed to hydrogen and oxygen. The hydrogen produced is then dried by a two-step **pressure-swing-adsorption** with activated carbon and molecular sieve as adsorbents. The dried hydrogen is stored in a total of **25 buffer tanks** before it is introduced into the reactors. The hydrogenation of LOHC-D is realized in **four multi-**

tubular reactors with a total of 22000 tubes filled with supported platinum catalyst. The hydrogenated LOHC-H which has a degree of hydrogenation (DoH) of 95 %, is **stored** in a tank and will be **transported** to the onshore site by ship in a 2 days interval. The dehydrogenated LOHC-D which has a DoH of 5 % is **returned** to the onshore site, whereby it will be **purified** in zeolithe adsorbers, stored in a tank and shipped back to the offshore platform. Since the dehydrogenation of LOHC-H is not within the scope of this project course, the circulation period of LOHC leaving and returning back to the offshore platform is assumed to be two weeks. **Weather fluctuation** is a main challenge for the offshore plant. The electrolyzer and drying units have a high **operation flexibility** that can handle the fluctuations in energy delivered by the wind park, whereas the reactor cannot. Due to the difference in the flexibility of these operation units, buffer tanks are built before the reactor to store the hydrogen produced from electrolyzers. Due to time constraints of the project course, the plant design did not take seasonal weather fluctuations into account, but four days of slack season into account. With respect to **heat management**, the offshore plant has a high heat production, particularly from the electrolyzer and reactor units. Since the plant has a low heating demand and no external integration is possible for an offshore plant, ca. **45 MW of waste heat** is transferred into sea. The above-mentioned plant design is the result of the three-week project course and should only serve as a first feasibility study for offshore LOHC technology.

Imprint

CBI Project course spring 2019

Offshore Hydrogen Storage - Partner project with Hydrogenious Technologies GmbH

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