IANOS
SUSTAINABLE SOLUTIONS
for islands' decarbonisation

D5.1 Initial TRL assessment and development of Ameland technologies roadmaps

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Executive Summary

The deliverable D5.1 – Technologies Engineering and System Dimensioning (advancement of TRLs) – details a first Technology Readiness Level (TRL) assessment of the solutions that are installed at the Ameland Island demonstrator. On Ameland there are three technologies/solutions that will be developed further during the IANOS project: the Tidal Kite by SeaQurrent, the Power Battery System by SuWoTec and the High Pressure Digester by Bareau. Although these are not the only solutions that will be featured in the use cases on Ameland, these solutions will be actively developed further within the IANOS project, whereas other solutions are already more or less commercially available. In addition to the three technologies mentioned above the deliverable also discusses the iVPP software that is being used on Ameland: Reflex.

The TRL assessment takes both the current as well the target TRL levels into consideration. The deliverable also provides insight into the technology roadmaps that are envisioned to reach targeted TRLs. It is important to realize that only part of the development roadmap will fall within the scope of the IANOS project. To avoid confusion, the document explicitly indicates for each roadmap which part falls under the responsibility of IANOS. The document concludes with a high level presentation of each roadmap's timelines.

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1 Introduction

1.1 Objectives and Scope

This D5.1 deliverable is the first deliverable of task 5.1 which is mainly concerned with assessing the TRL levels of the components that are to be deployed as part of the Ameland LHI demonstrator. The deliverable will not only consider the current TRL levels, but also look at the target TRL levels towards the end of the IANOS project. For each component a road map will be described that defines the necessary steps that need to be taken to reach the desired TRL level.

The main components that are described in this deliverable are the TidalKite by SeaQurrent, the Power Battery System by SuWoTec and the High-Pressure Digester by Bareau. Although these are not the only components that will be featured in the use cases on Ameland, the integration of these components will be actively developed further within the IANOS project, whereas other components are already more or less commercially available. In addition to these physical components, the software behind the iVPP implementation on Ameland – the Reflex platform – is also discussed.

1.2 Relation to other activities

D5.1 serves a input for the remainder of task 5.1 in which the interface between the components and the iVPP will be defined and pre-pilot testing will be conducted.

There are also relations with T5.2 (Deployment Plan and Risk Management), T5.3 (System Integration, Implementation & Commissioning) and T5.4 (Use case operation, optimization and performance monitoring). All of these tasks are dependent on the realization of the TRL advancements that are described in this deliverable.

1.3 Structure of the deliverable

Chapter 2 of this deliverable describes the current status of the components/technologies. The development plan that explains for each technology how it will reach its desired TRL level is the subject of chapter 3. The technical specifications and dimensions are listed in chapter 4 and the document concludes with an overview of the implementation plan in chapter 5.

1.4 Methodology

The information presented in this deliverable has been gathered through interviews with project partners SeaQurrent, SuWoTec and Bareau. During these interviews the “Technology Readiness Level: Guidance Principles for Renewable Energy technologies” report [1] was used as it contains specific TRL level requirements for a variety of renewable energy technologies.

In addition to the interview sessions, product documentation - where available - has been consulted to complete the picture.

2 Status of the technologies

In this section, the solutions to be further developed and explored within IANOS project, and later integrated at the Ameland LHI demonstrator, will be identified and briefly introduced. The pilot context in which the different solutions will be integrated, commissioned and operated will also be summarised.

2.1 TidalKite (Seaqurrent)

2.1.1 *Solution identification*

The TidalKite is one of the renewable technologies that is further explored in the Ameland demonstration site. It is part of use case #6, which focuses on supporting the decarbonization process of the (near) offshore AWG natural gas platform.

The TidalKite test setup near Ameland consists of a monopile mooring that anchors the TidalKite system and a grid connection cable (10kV power cable) to the Ameland electricity grid as operated by Liander. The grid connection will be realised by means of a horizontally directed drilling (HDD) under the sea dike to place a tube in which the electricity cable can be placed.

After the installation, system tuning and commissioning of the TidalKite unit, the SeaQurrent operations team will make production forecasts based on the testing activities, water velocities and TidalKite power curve. The associated data files will be shared with the Ameland central dispatcher. Realtime production numbers will be available from the grid connection metering point as accessible for the grid operator (Liander). Ramping ability will be discussed and investigated considering site restrictions based on water velocity and marine environmental impacts (to be investigated).

2.1.2 *Solution description*

The SeaQurrent TidalKite technology is developed to harness energy from tidal flows. It consists of an underwater kite that makes it possible to cover a large energy harvesting area perpendicular to tidal flows. This ability makes it possible for the TidalKite to be deployed in shallow, near-shore waters that have lower water velocities, but which are located close to electricity grids and demand. The technology can also be used in deeper sites with higher water velocities.

The TidalKite technology produces fully renewable electricity, with no emission of pollution (e.g., GHG, noise). No significant impact was also found on marine life. It is a reliable technology, with a high level of predictability with regard to the expected production profile, without seasonality nor volatility. Whilst robust and high tech, the TidalKite is a relatively cheap technology that can be deployed at affordable price level.

The TidalKite system is composed of five main components shown in Figure 1. These include:

- A TidalKite that captures kinetic energy from the water flow and converts it into traction force,
- A tether that transfers traction force to the PTO,
- A power take-off (PTO) that converts the traction into electricity,
- A seabed anchoring (mooring) that anchors the system to the seabed,
- An export cable that connects to the grid and feeds it electricity.

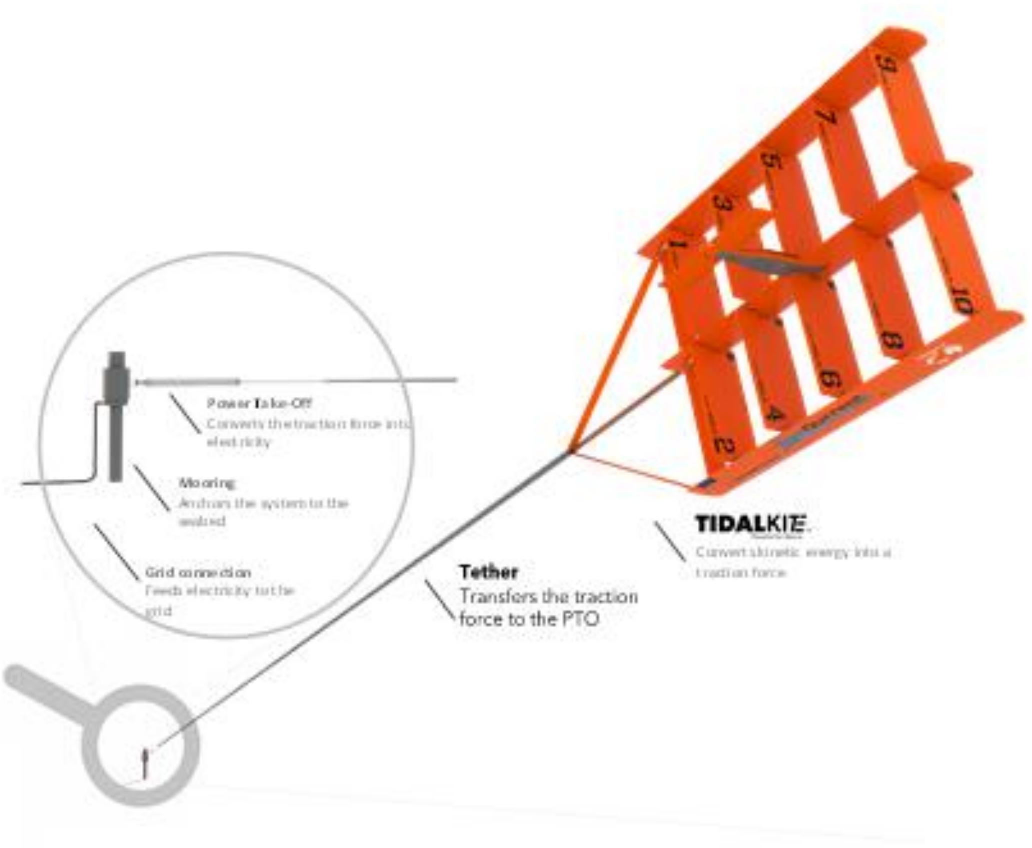

Figure 1: An overview of the Tidal Kite System

2.2 High Pressure Digester (Bareau)

2.2.1 Solution identification

The Autogenerative High Pressure Digestion (AHPD) technology is at the heart of use case #7 on Ameland. In this use case the focus lies on utilizing waste streams by converting them into green gas. One of the unique aspects of the AHPD technology is that the digestion process takes place under high pressure. This process bears a great similarity with brewing beer, which is the reason why Bareau also refers to their digester as a green gas brewery.

The installation that will be built on Ameland will be using sewage sludge from the wastewater treatment plant as its main input (later in the project restaurant waste will also be used) and convert it into green gas (biomethane at natural gas quality) , which will be injected into the local natural gas grid. Of course the produced biomethane is an important part of the business model of the green gas brewery, but it is not the only one. The sewage sludge that is used as input is considered a chemical waste stream which correponds to high costs for wastewater treatment plants. During the AHPD process the amount of sewage sludge is reduced to 10-15% of the original input, leading to significant cost reductions for wastewater treatment plants. Phosphates are another by-product of the green gas brewery, these will be re-used on Ameland.

In addition to the characteristics described above, the installation on Ameland has an important additional feature. Besides the organic waste (sewage sludge in the case of Ameland) it can also process hydrogen as its input, this technology is appropriately called AH$_2$PD. The injection of hydrogen leads to an increase in the production of methane, and to a reduction of CO$_2$ emission. The interesting part about this is that the hydrogen does need to be provided in a steady stream, but can be fed in with peaks. The methane production, however, will still be following a predictable baseline. This mechanism can be used to reduce peaks or imbalances in the electricity grid; in case of excess renewable electricity production this can be transformed into hydrogen using an electrolyser and then be fed into the AH$_2$PD.

The green gas brewery on Ameland will not feature an electrolyser and will therefore not be integrated with the electricity grid. Instead the AH$_2$PD will be demonstrated for a limited period, by using hydrogen supplied by a fuel truck.

2.2.2 Solution description

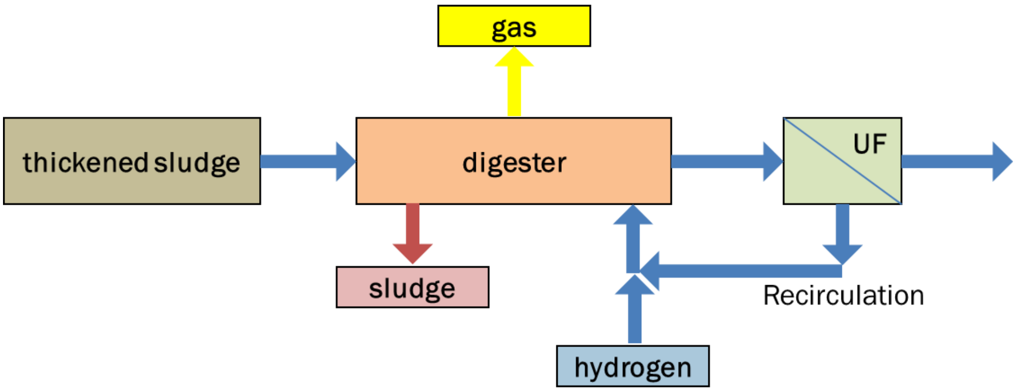

Figure 2: Simplified process flow diagram of the AH$_2$PD technology used on Ameland

Figure 2 depicts the process flow of the green gas brewery on Ameland. The main input for the digester is the thickened sewage sludge that is a waste stream of the wastewater treatment plant on Ameland.

The digester itself is an airtight vessel in which pressure is built up autogeneratively, by gas producing bacteria. This process can be started by simply bringing the reactor vessel up to temperature. The operational pressure amounts to roughly 20 bar, while the temperature ranges from 36 to 60 degrees Celsius. Due to the high pressure, CO$_2$ will dissolve in water, but the methane (CH$_4$) remains as a gas and can be retrieved as biomethane from the top of the reactor. The green gas contains more than 90% CH_4, even without hydrogen addition, and can be directly injected into the natural gas grid because of its high quality.

The primary green gas makes up 89 percent of the gas in the reactor, the remaining 11 percent is secondary gas that is released from the pressurized water phase, by reduction of the permeate after the integrated UltraFiltration (UF); this secondary gas will be used to feed the heater, that is required to keep the process on the right temperature. The permeate (‘AHPD beer’) is treated to recover phosphate and to remove ammonium.

The thickened sludge that forms the fuel of the digester cannot be fully converted, typically 10 - 15% of the sludge remains; a very significant reduction of what is considered a harmful waste stream.

If available hydrogen can be injected into the recirculation mechanism (crossflow) of the green gas brewery. This can lead to a doubling of the green gas production. This process also requires CO_2 which is already present in the reactor. In case the amount of CO_2 is insufficient, additional CO_2 could be injected as well. Hydrogen and carbondioxide are not directly transferred into methane; formic acid is probably being used as an intermediate step[1]. The formic acid seems to act as a buffer in this biological process. It is this buffer that makes it possible for the hydrogen to be supplied in peaks, while the methane production remains at a constant level. This is a very useful feature for dealing with renewable production peaks on the electricity grid. During these peaks hydrogen can be produced with an electrolyser, which can then be injected into the green gas brewery.

The installation on Ameland will be facilitating both the wastewater treatment plant and the gas grid. An electrolyser is not part of the installation, therefore there is no direct integration with the electricity grid. A fuel truck supplying hydrogen will be used to test the hydrogen injection process.

2.3 Power Battery System (SuWoTec)

2.3.1 Solution identification

The Power Battery System (PBS) is a completely recycle battery that does not contain lithium, ion or cobalt. In addition to the use of fully recyclable materials, the main innovation of the PBS is its flexibility in charging and discharging which can be done simultaneously. There are multiple charging and discharging methods (both AC and DC) as well as a fast discharging mode for charging EVs.

Within the IANOS project the main use of the PBS will be to smooth out the capricious nature of most renewable energy production. As such it will be installed in between a renewable energy source and the connection to the grid. On Ameland the PBS will be part of two use cases: use case #1 which is about the maximization of self-consumption on the island and use case #4 where the PBS supports congestion management and the improvement of the power quality.

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[1] This is subject of a PhD research at Groningen University (2021).

The PBS will be built close to a new construction with 13 houses in the city of Nes. The houses will have solar panels and the PBS will be used to balance this system to avoid undesirable PV production peaks on the grid and at the same time optimize self-consumption by the involved households.

2.3.2 Solution description

There are multiple versions of the Power Battery System; the version that is going to be installed on Ameland is the 120 kWh version. As mentioned before the PBS features two major innovations: the use of completely recyclable materials and its flexibility in charging and discharging.

The choice for using fully recyclable materials instead of rare and expensive materials such as lithium, ion or cobalt allows for a large reduction of battery costs once the product has been fully developed and production has been scaled up.

With its flexible charging/discharging behaviour the PBS can be used in a variety of applications. It can combine AC and DC charging/discharging as well as single and 3 phases. One example would be to charge the PBS with a single phase grid connection and then (simultaneously) discharge on 3 phases to devices that support this. This feature could be very useful for fast EV charging through a limited single phase connection. In this scenario the PBS would be placed in between the grid connection and the EV charging station. During the day the battery can be charged with a single phase grid connection and when the EV arrives at home it can be charged fast by utilizing 3 phases from the battery to the EV or even more directly using DC. The PBS can be charged with a maximum of 12 kW, discharge power levels can be in excess of 15 kW.

The PBS weighs in at 3600 kg for the 120 kWh version, which makes it only suitable as a stationary battery system as it would be too heavy for EV applications.

In order to monitor and control the operation of the PBS, a battery management system will be developed that also allows for remote control of the battery unit by third parties so that it can be fully integrated in a variety of demand response scenarios.

2.4 iVPP (TNO/Repowered)

2.4.1 Solution identification

The iVPP on Ameland will be implemented using the Reflex technology. The Reflex platform facilitates the aggregator (which on Ameland is Repowered) in optimizing the value of the flexibility resources in its portfolio. Normally this would involve a lot of manual analysis on the side of the aggregator which is now automated by Reflex. Reflex enables an aggregator to test a variety of scenarios during the planning phase to learn how the flexible assets in its portfolio will react.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nº 957810

The flexibility of the Reflex platform helps to support the variety of use cases that will be demonstrated on Ameland.

2.4.2 Solution description

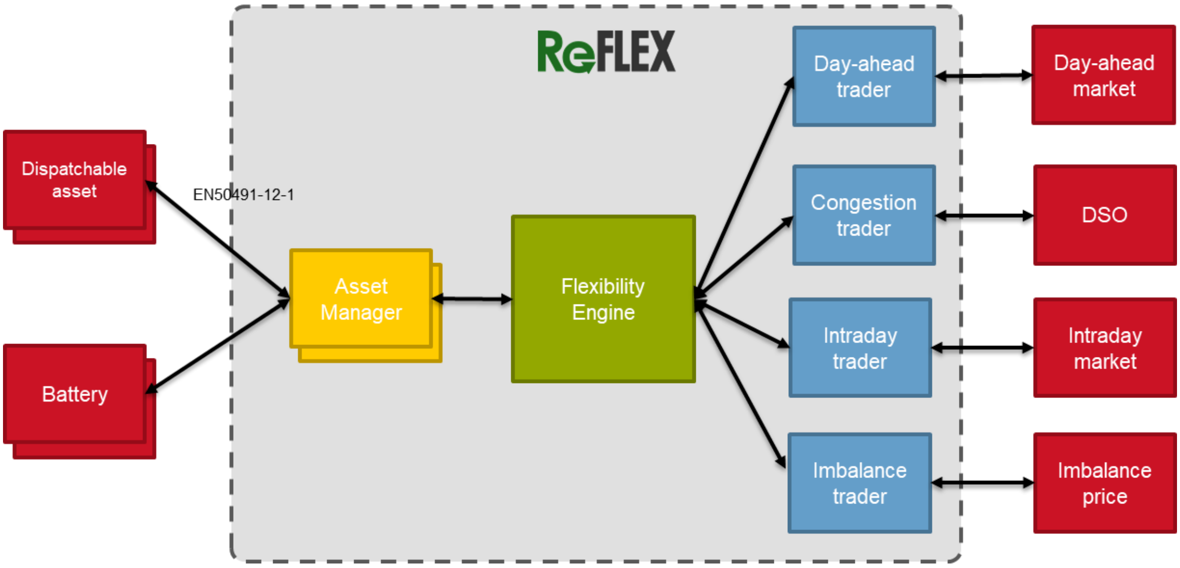

Figure 3: Architecture of the Reflex platform

The Reflex platform is depicted in Figure 3 and consists of the following components: Asset Managers, the Flexibility Engine and Traders.

- The Asset Managers receive the flexibility information from all connected flexible assets in the portfolio of the aggregator, such as batteries, EV's, heat pumps, etc. The protocol that is being used to communicate the flexibility information is S2 which is defined in the European prEN50491-12-2 standard. There is no specific requirement for the frequency with which the flexibility information is exchanged. It is up to the flexible asset to decide when updated information will be sent to the asset manager.
- The Flexibility Engine is used to determine the behaviour of the entire cluster. It is able to consider a wide range of scenarios in order to determine the most optimal one for a given optimization objective or a combination of multiple objectives. It uses the flexibility of the assets as input, but also the constraints of different markets that might take advantage of the available flexibility.
- The traders communicate their optimization objective/constraints to the Flexibility Engine so that it can take these into account while trying to find the most optimal solution. There is a different trader within Reflex for each market that the aggregator is active on.

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3 Development plan

This section focuses on the current ant the target TRL levels of the different technologies that are being used on Ameland. For each technology a roadmap is proposed that explains the steps to advance the current TRL level to the desired target level that should be reached by the end of the IANOS project. Since the implementation of the roadmap is not dependent on the IANOS project alone, it is also be made explicit which part of the roadmap will be within the scope of IANOS.

3.1 TidalKite (Seaqurrent, TRL 6 → 8)

3.1.1 Development timeline

Current Status (pre-IANOS)

The TidalKite technology has been developed in multiple projects outside of IANOS, both in controlled and full sea environments. SeaQurrent tested the PTO system's capacity to deliver electricity to the grid in a workshop. In 2017 a first kite was tested in a controlled environment, the MARIN flow basins in Wageningen. Between 2018 and 2019, SeaQurrent validated the technology in a relevant environment by installing and testing a Kite and PTO prototype out at sea. In this setup, the PTO was installed on a moored barge from which the kite and tether were dispatched into the water for operation. The system was installed in isolation, not connected to the grid, to focus on flying the kite. Cost estimates for the entire TidalKite system where updated, allowing for insights into scale-up possibilities. The technology's environmental impact was also researched in various studies, including the impact of the seabed with the University of Groningen, as well as studies on seal behaviour in the Borndiep flow channel by Wageningen Marine Research. SeaQurrent also worked with the NEN expert teams to assess their technology against the 8775 NEN fish safety norm for pumps and turbines. This confirmed that the TidalKite system leads to no significant fish damage. As a result of previous projects, the technology is currently completing the TRL6 as described in the Guide's general guidelines and checkpoints for Ocean technologies. SeaQurrent is working on a new prototype in the expected commercial dimensions, with beams hosting wings covering an area of approximately 9mx12m in total, and a tether connection of 6m (total kite size of 18mx9m), with a weight of approximately 15 tons.

Developments within the IANOS scope

The TidalKite system is divided into 5 main sub-systems. Within IANOS, SeaQurrent will focus on developing some of the technology's sub-systems. This includes:

- The connection of the technology to the grid (the TidalKite will be integrated into the Ameland grid and central dispatcher).
- The integration of the technology with the iVPP so that it actively be involved in the Ameland use cases.
- The development of the technology's remote monitoring and control system.

3.1.2 Associated risks

The risks discussed in this chapter relate to the IANOS scope for the SeaQurrent TidalKite. Risks related to the development of the TidalKite and its physical operation will thus not be treated here. The main risks within the scope of IANOS include:

1. Grid connection not working
2. Instable power output of the TidalKite
3. Data connection for dynamic dispatch unstable
4. Limitations in ramping ability of the TidalKite

3.1.3 Mitigation measures

1. Grid connection not working: The grid connection is being realised. Close contact with the grid operator (Liander) is kept. A subcontractor is used that is pre-qualified to work with and on Liander assets. Timely installation of the hardware and commissioning of the connection is implemented, to leave ample time to cater for delays.

2. Instable power output of the TidalKite: The PTO buffers pressurised hydraulic fluid that is used for power generation in the hydromotors and connected generators. Robust transformer and grid cable, place in a protective tube are used. This secures the connection. The buffering step adds control and steering of fluid for power generation, to stabilise its output profile and delink it from volatility in water velocity. The kite can be dynamically and real-time be positioned in the (vertical direction) of the water column, towards the best position for stable, constant traction forces and consequently stable electricity production.

3. Data connection for dynamic dispatch unstable: The data connection will be routed via the power cable in the tube. An additional backup option is to add communication via a buoy and the wireless network.

4. Limitations in ramping ability of the TidalKite: A study is anticipated to be executed in relation to the impact on sea life of (IANOS-desired) re-dispatch possibilities. This together with technical limitations will be reviewed and implemented during TidalKite tuning and testing.

3.2 High Pressure Digester (Bareau, TRL 7 → 9)

3.2.1 Development timeline

At the start of the IANOS project the AH_2PD technology was at TRL level 7. A prototype of the technology has already been operational since 2010 at the premises of Bareau in

Heerenveen. During this 10 year period the prototype has been operated almost continuously.

Another requirement for TRL 7 is that “compliancy with relevant environment conditions, authorization issues, local / national standards is guaranteed, at least for the demo site”. This is the case for the AH_2PD technology. The technology is very similar to water treatment technology, therefore a lot of the regulation for water treatment also applies to the green gas brewery. All the necessary permits required to build the Ameland AHPD installation are expected shortly (August 2021).

The facilitation of the wastewater treatment plants has been verified and validated as well as the integration with the gas grid and the injection of hydrogen. The manufacturing process of the AH_2PD has also been defined. All of the green gas brewery components, with the exception of the high pressure reactor, are commercially available. The high pressure reactor itself is manufactured specifically for Bareau by a third party, but there are many suppliers that would be capable of producing the reactor according to Bareau’s specifications. Bareau integrates all the components into a complete solution.

During the IANOS project the green gas brewery will advance to TRL level 9. To reach this level the following steps will be taken.

The first step is the deployment of the technology in its final form in real world conditions. The installation on Ameland will be fully operational and facilitate the wastewater treatment plant on Ameland as well as the natural gas grid on the island. Another requirement is that there is a stable manufacturing process for entering a low rate production. As already described earlier, the necessary components are not scarce and are/will be fully certified, therefore it is expected that Bareau can start building multiple installations of their green gas brewery during the lifetime of the IANOS project. The necessary training and maintenance documentation are being developed already.

Finally the business model behind the green gas brewery will be refined further. The challenging part here is that three stakeholders that traditionally do not have a lot to do with each other will have to work together in a new constellation; wastewater treatment plants, gas grid operators , renewable electricity producers and electricity grid operators. The lessons that will be learned with the installation on Ameland are crucial to demonstrate to all involved stakeholders how they can profit from this innovative technology.

Developments within the IANOS scope

The developments that are described to reach TRL level 9 for the AH_2PD technology will mostly take place outside of the IANOS project. The contribution of the IANOS project will focus primarily on demonstrating the hydrogen injection into the green gas brewery, which can potentially lead to a doubling of the production of green gas (provided that sufficient hydrogen is available for injection).

3.2.2 Associated risks

With respect to the high pressure digester the following main risks have been identified:

- **The AHPD plant might not be ready in time.** In order to be able to test the hydrogen injection (AH2PD) the AHPD plant on Ameland must be realized in time.
- **Transport of hydrogen by truck to the island may not be allowed.** Naturally hydrogen must be transported to the AHPD plant on Ameland to test the hydrogen injection (AH2PD). Since there is no local hydrogen grid yet, this will have to be supplied by a fuel truck for which permission by local authorities is required
- **The AHPD might fail to secure the necessary funding to complete the project.** BAREAU's AHPD plant is privately financed and therefore needs to secure the necessary funding to be viable.

3.3.3 Mitigation measures

The following mitigation measures will be taken to counter the risks identified above:

- The AHPD plant will be realized in a separate project and will therefore not depend on the IANOS project itself. In addition he hydrogen test on Ameland is planned towards the end of the project which should provide ample time to realize the plant.
- The hydrogen transport by fuel truck will be planned carefully and timely so that any eventualities can be tackled in time.
- Different alternatives are being assessed for the case the AHPD is not able to secure financing. The different solution can be in the form of an alternative centralized digester on the island or by deploying multiple smaller digester at locations such as restaurants. At this moment the municipality of Ameland is looking into alternative to meet the goal od reducing CO2 emissions of (bio)waste management.

3.3 Power Battery System (SuWoTec, TRL 5 → 7)

3.3.1 Development timeline

The current TRL level of the Power Battery System is 5. The system has been tested at the Entrance facility in Groningen. The cells of the battery have been tested and are ready to be deployed on Ameland. A simulation of the full system has been conducted and now the electrical connections between the cells will have to be realized.

In order to advance the PBS to TRL level 6 several steps need to be taken. First of all the prototype will have to be demonstrated in a relevant environment. This has already been done for the battery cells but the battery management system still needs fine tuning, which is expected to be completed in 2021. A second step is to verify that the performance of the PBS matches the simulation results and that the system is reliable. Another issue that has to be addressed to reach TRL 6 is to demonstrate the interoperability of the PBS with other connected technologies. This will be achieved through the development of a management and control system for the PBS. The last step is the definition of a manufacturing approach for the PBS.

During the IANOS project the PBS is expected to reach TRL 7. This means that, in addition to the TRL 6 requirements, a full scale pre-commercial system has to be demonstrated in an operational environment. This will be the 120 kWh version of the PBS that will be installed on Ameland. Also the integration with other connected technologies will have to be verified and validated.

Developments within the IANOS scope
The developments that are described above are necessary to reach the target TRL level 7. However, most of these developments are not realized within the IANOS project itself, but are part of the broader SuWoTec roadmap for the Power Battery System. Only the development of the management and control system for the PBS will fall within the scope of the IANOS project.

3.3.2 Associated risks

3.3.3 Mitigation measures

3.4 iVPP (TNO/Repowered)

3.3.1 Development timeline

Reflex is currently at TRL level 6 and will be advanced to TRL level 8 within the IANOS project. The following steps will be taken to reach the desired TRL level:

- Reflex optimizes currently on power profiles. Reflex will be extended to support market price forecast profiles (e.g. for day-ahead and intra-day).
- Integrate with an actual energy supplier. Some of Reflex' price-based market activities are currently simulated. In IANOS a energy supplier is partner and we will extend Reflex to integrate with them to test and validate value stacking in a real-life situation.
- Support optimization at a higher frequency than the 15min time frames it currently supports.
- Test and validate Reflex in a real-life situation with multiple heterogeneous assets by utilizing DefPi to gather the required flexibility information.

3.3.2 Associated risks

The following risks with relation to Reflex have been identified:

- One of the main risks is that the development of the Reflex platform is currently performed by a relatively small team.
- Complexity of the optimization in Reflex requires too much effort.
- Integration with other partners requires too much effort.

3.3.3 Mitigation measures

The following mitigation measures will be taken to deal with the risks described above:

- The development team will be expanded so that there is more continuity in the further development of Reflex.
- Define minimum viable product (MVP) and gradually expand the complexity of Reflex.
- Identify integration efforts in an early stage (not at deployment time) and define clear interfaces between the partners’ components/technologies

4 Dimensioning, specification, testing and installation requirements

In this section, following the previously described development plans, the solutions' technical specification and the major installation requirements are identified, apart from any relevant testing protocols to consider that may be aligned with the technology providers' expectations on the field testing and commissioning procedures to implement at the LHI environment.

4.1 TidalKite

Technical specification

Capacity: A standard TidalKite has a capacity of up to 500kW and it is connected to the grid via a 10kV power cable.

Dimensions: The total system (mooring – PTO – tether – kite) is ~100m long. It covers a stretch of 100 meters perpendicular to the water flow direction during one working stroke of its kiting trajectory. After turning it takes the return stroke, ideally at a different depth. With the change of the tide and flow direction, the system rotates around its mooring and is operated at ~100m on the other side of the mooring. The kite remains in this rectangle of 200 x 100m (50 meters on either side of the mooring). It only shortly passes at 100m on one side of the mooring during the tide change turn. When installed in arrays, it is anticipated that up to 8 units can be installed in a stretch of 1 kilometer perpendicular to the water flow direction. The optimal distance between rows of TidalKites in an array/farm setup is site dependent.

Additional Testing and installation requirements

The installation of the TidayKite system is done from a towed barge with a crane on top. Divers will connect the TidalKite and secure the connections.

4.2 High Pressure Digester (Bareau)

Technical specification

Performance: The following performance specifications apply to the AH_2PD technology as it is deployed on Ameland:

- **Green gas production:**
    - **Converted organic dry matter (ODM):** 0.37 tonne of ODM/d
    - **Converted dissolved chemical oxygen demand (COD):** 66 kg COD/d
    - **Gas production (Bareau model):** 1.024 l gas/kg ODM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

    - **Operational pressure:** 18.6 bar
    - **Gas production efficiency:** 89% green gas
    - **Loss into permeate:** 11% waste gas, to be reused in a heater
    - **Methane content in green gas (ex hydrogen):** 90% CH_4
    - **Average daily primary green gas production (90% CH_4):** 300 Nm^3/d
    - **Average yearly primary green gas production (90% CH_4):** 110.000 Nm^3/y

- **Gas treatment primary gas**
    - **Production:** 12.5 Nm^3/h
    - **Methane content:** 90% CH_4
    - **Energy content:** 113 kWh/h
    - **Peak factor gas supply (winter/summer):** 0.5

When the hydrogen supply would be sufficient the yearly gas production of the installation can be doubled to 220.000 Nm^3.

The scale at which the green gas brewery is operated on Ameland is too small to be commercially viable. However, the scaling factor of the AH_2PD technology is 1.6, which enables larger installations to be profitable with relative ease.

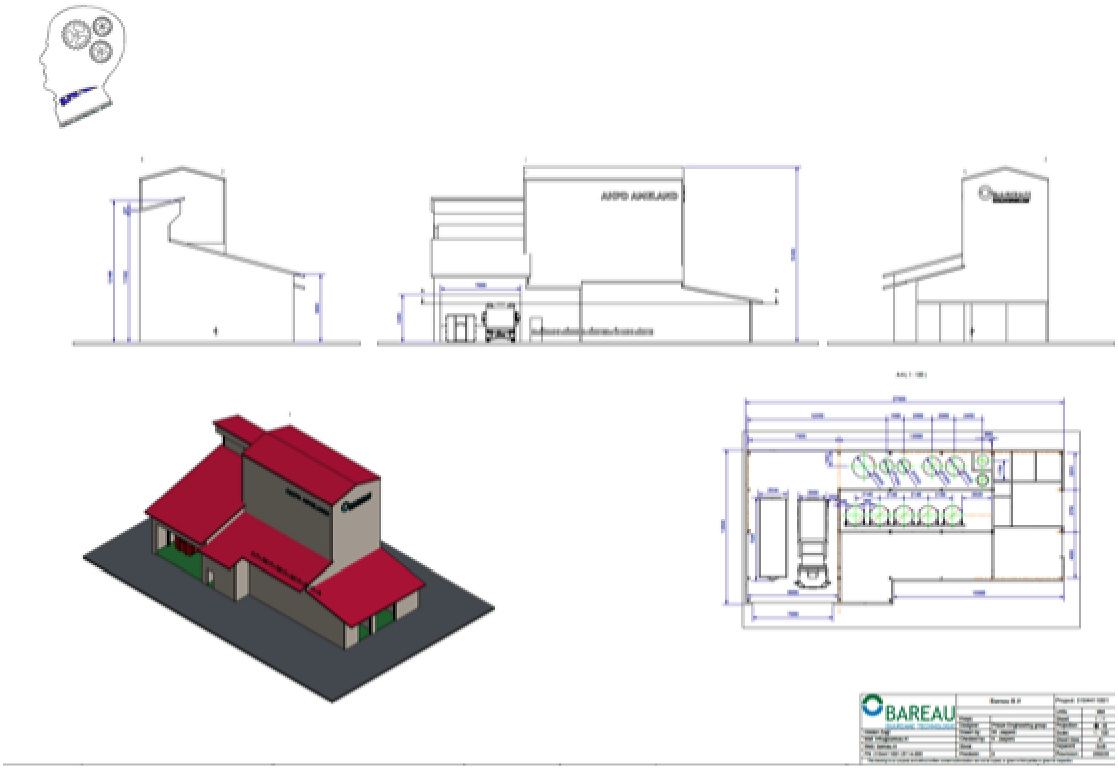

Figure 4: Design of the AH_2PD installation on Ameland

Dimensions: The building in which the AH_2PD resides is depicted in Figure 4: Design of the AH_2PD installation on Ameland and has the following dimensions: 30 * 13 * 12 meter (l*w*h).

4.3 Power Battery System (SuWoTec)

Technical specification

Capacity: The Power Battery System has a storage capacity of 120 kWh and can be charged with 12 kW. The maximum discharge power is > 15 kW. Charging efficiency is > 97%, discharging efficiency is > 96%.

Dimensions: The 120 kWh version of the PBS has a length of 2172 mm, a width of 1654 mm and a height of 1560 mm. The weight of the system is 3600 kg. The battery requires some space for cooling. This is a passive cooling system that only requires a natural air flow.

4.4 iVPP (TNO/Repowered)

Since the iVPP will be implemented through software it does not make sense to discuss technical specifications and physical dimensions.

5 Implementation Plan

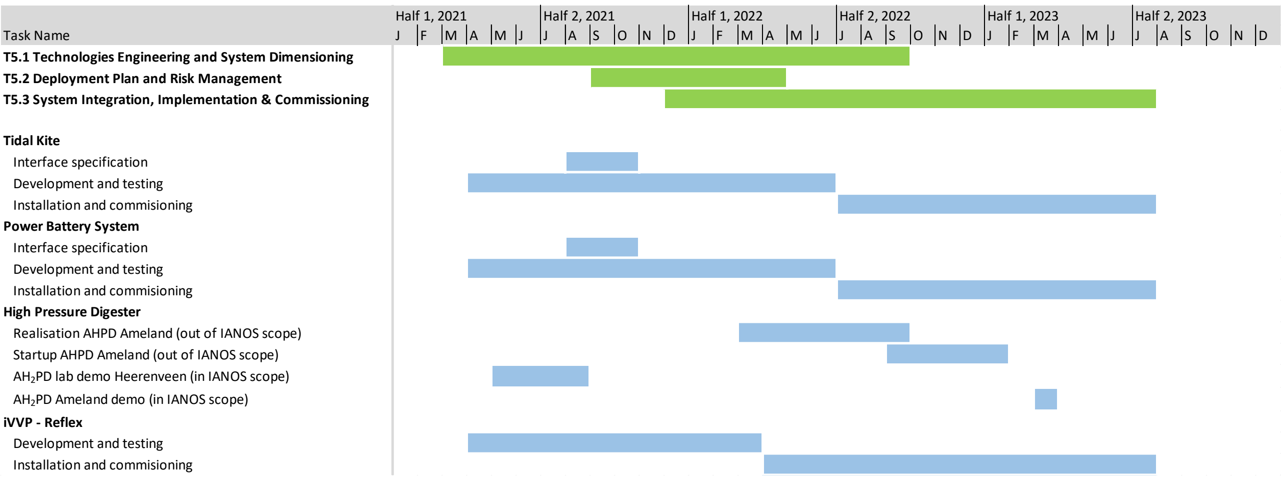

Figure 5: Implementation plan for the Ameland technologies

Figure 5 provides an overview of the implementation phases for the Ameland technologies. Each technology has an “Interface specification” phase. During this phase the interface with the iVPP will be defined. The “development” and “testing” phases have been combined into one to illustrate a more iterative approach instead of a waterfall.

It should also be noted that only a part of the “development and testing” phase can actually be attributed to the IANOS project. A lot of the development work will take place outside of the IANOS context.

6 References

[1] Directorate-General for Research and Innovation (European Commission), *Technology readiness level: Guidance principles for renewable energy technologies: annexes*, 2017-12-21, available online: <https://op.europa.eu/en/publication-detail/-/publication/1da3324e-e6d0-11e7-9749-01aa75ed71a1/language-en/format-PDF/source-search>.

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Annex I

Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

- TRL 1 – basic principles observed.
- TRL 2 – technology concept formulated.
- TRL 3 – experimental proof of concept.
- TRL 4 – technology validated in lab.
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 7 – system prototype demonstration in operational environment.
- TRL 8 – system complete and qualified.
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).

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