IANOS
SUSTAINABLE SOLUTIONS
for islands' decarbonisation

D5.2

Ameland UCs equipment engineering and laboratorial validation

(T5.1)

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Executive Summary

This document presents IANOS Deliverable 5.2 - *Ameland UCs equipment engineering and laboratorial validation* under Task 5.1 - *Technologies Engineering and System Dimensioning (advancement of TRLs*). It supports with the necessary specifications of the systems and equipment that will be commissioned in T5.3. This deliverable sets out the laboratorial validation of the Ameland UCs equipment within T5.1 with the goal to validate the possible assets of Ameland's pilot components prior to their deployment and demonstration. The document first gives an overview of the equipment and IT components that are included in the use cases, specifically because some equipment and IT components are demonstrated in multiple use cases.

Following the initial overview, each use case on Ameland is explored in more detail, including an overview of the assets. Each use case chapter also provides an overview of validation and next steps. The next steps per use case is especially important as the timing of the deliverable precedes full deployment. The deliverable therefore represents a snapshot in the ongoing developments on Ameland and several aspects of the use case developments will continue after submission of this deliverable.

Another reason for keeping the equipment and IT components apart, is that some IT components and equipment are used overarchingly, e.g. iVPP which will play a role in almost all use cases. The integration with the assets has yet to be done on the island, therefore only limited test results can be discussed in this deliverable. The deliverable wraps up with an overview of next steps and further conclusion of the use cases.

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3 Abbreviations

AHPD	Auto generative High-Pressure Digester
aFRR	Automatic Frequency Restoration Reserve
BBB	Bio Based Battery C1
BESS	Battery Energy Storage System
CEM	Customer Energy Manager
CHP	Combined Heat and Power
CHPS	Combined Heat and Power System
CoP	Coefficient of Performance
dEF-Pi	Distributed Energy Flexibility Platform and Interface
DSM	Demand-Side Management
DSO	Distribution System Operator
ESB	Enterprise Service Bus
ESS	Energy Storage System
EV	Electric Vehicle
FC(s)	Fuel Cell(s)
FCR	Frequency Containment Reserves
FFR	Firm Frequency Response
GOPACS	Grid Operator Platforms for Congestion Solutions
HDD	Horizontally directed drilling
HHP	Hybrid Heat Pump
HPD	High Pressure Digester
HVAC	Heating, Ventilating and Air Conditioning
ICT	Information and Communications Technology
IT	Information Technology
IoT	Internet of Things
iVPP	Intelligent Virtual Power Plant
LEC	Local Energy Communities
LH	Light House
NAM	Nederlandse Aardolie Maatschappij
NG	Natural Gas
PTO	Power take off
PV	Photovoltaic
RES	Renewable Energy Sources
TRL	Technology Readiness Level
TSO	Transmission System Operator
TT	Transition Track

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UC	Use Case
V2G	Vehicle-to-grid
WT	Wind Turbine

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4 Introduction

4.1 Purpose and Scope

This deliverable is the final deliverable for T5.1, which focussed on assessing the TRL levels of the components that will be deployed on Ameland, one of the LH islands within the IANOS project. The deliverable is being submitted at an early stage of the project, and therefore shows a snapshot of ongoing developments. The different use cases will be further developed as time progresses to demonstrate the full scope.

Some of the components, such as the TidalKite by SeaQurrent or the Bio Based Battery C1 from SuWoTec focus on the integration of these components within the IANOS project, while other aspects are developed outside of the IANOS project. Furthermore, there are not only physical components developed and demonstrated within IANOS, but also software components, e.g., iVPP and the use of the ReFlex platform. These components are also described in this deliverable, however, are also part of other work packages and tasks, therefore the information provided here is less detailed and can be found in the correlating deliverables (see list of references).

4.2 Structure

The structure of the deliverable first provides an overview of the different assets and IT components, which are part of the use cases. Their current status and details are described separately from the use cases, as they are not isolated per use case but also have overarching aspects to their deployment.

The information on the equipment and IT components has strong overlaps with other deliverables within the IANOS project and relevant information for this deliverable has been consolidated to maintain a readable structure, rather than referring to different deliverables. For more detailed information on different equipment or IT components those deliverables can always provide more detailed information and are listed in Chapter 4.3 Relation to other deliverables.

4.3 Relation to other deliverables

As mentioned above, some of the information contained in this deliverable can be found in greater detail in other deliverables. These deliverables are:

- D2.2 Report on Islands Requirements Engineering and Use Case Definitions
- D2.10 IANOS Islands Decarbonisation Master Plan
- D4.7 The iVPP Centralized Dispatcher
- D5.1 Initial TRL Assessment and Development of Ameland Technologies Roadmaps.1

- D5.3 Ameland's Use Cases Preliminary iVPP Integration Tests
- D5.4 Ameland UCs Deployment Plan Report

It is also important to mention that for the other LH island Tercereia there will be a relation with D6.2.

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5 Equipment and IT components

This chapter provides an overview all of the equipment and the IT components that are part of the Ameland use cases.

5.1 intelligent Virtual Power Plant (iVPP)

As an overarching connecting element, the intelligent virtual power plant (iVPP) will be installed and connected to all assets that either already are or will be installed on Ameland. The iVPP is a joint effort between partners involved in the IANOS project and the functional architecture of the iVPP can be seen in Figure 1.

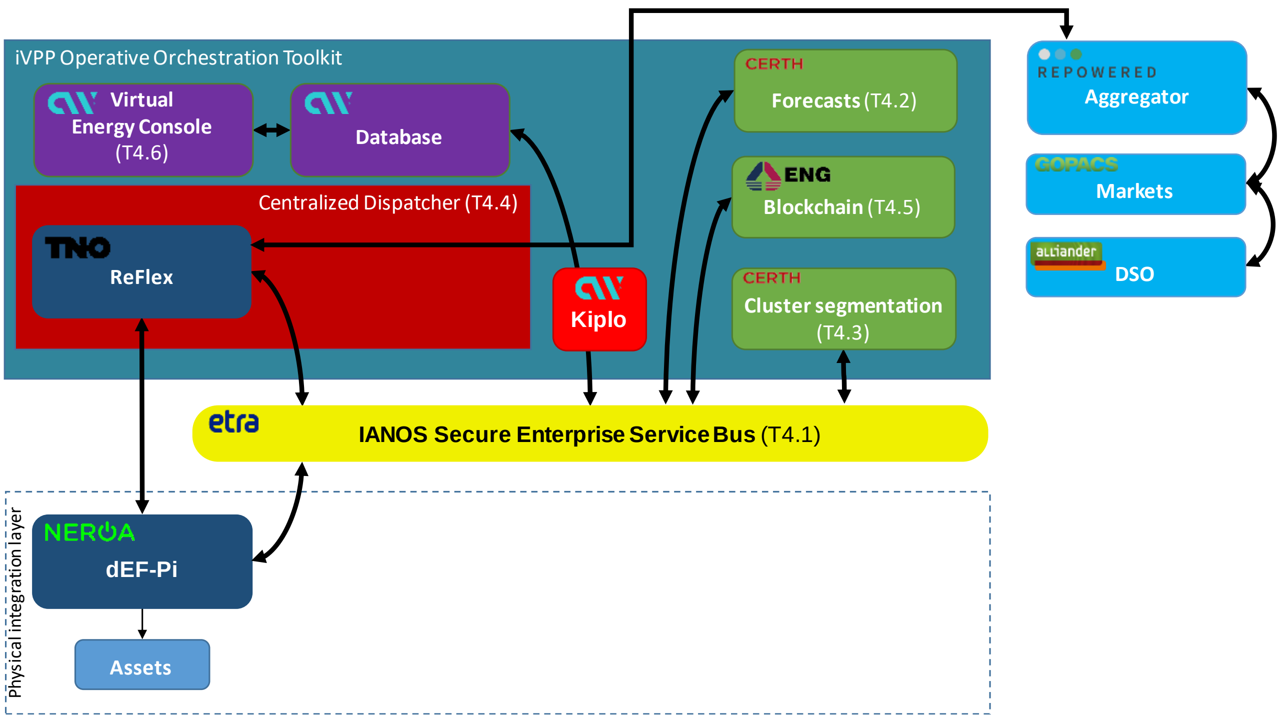

Figure 1: Deployment view for Ameland demonstration

The iVPP represents the intelligent central system which will optimize the energy flow in the system based on the parameters set by the aggregator/operator. The iVPP sets out to optimize the energy flow and can do this based on the required energy, available energy and forecast of energy to be produced or converted. Based on the asset, the iVPP will have either measure or control functionalities.

Measurements only (for assets that cannot be controlled):

- Residential solar panels
- Solar farms
- Tidal kite

Controllable assets (for power supply, storage, conversion or usage):

- Battery pack at the Ballumerbocht solar farm
- Bio Based Battery C1
- Electrolyser

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- Fuel cell at Klein Vaarwater
- Micro-CHP 's
- Private Methane Fuel Cells

5.1.1 Forecast integration test

The iVPP has a number of features including the ability to forecast the production or consumption of assets. This forecast is important as it will be the basis for the centralized dispatcher to calculate how much energy will be produced and/or consumed in the future. Without these forecasts, no planning could be created.

As part of this deliverable, the validation of the integration between the following software components took place:

- *ReFlex* (TNO): This is the centralized dispatcher which can create optimized plannings for the assets available in the cluster.
- *IANOS Secure Enterprise Service Bus* (ETRA): The communication bus through which software components can communicate with other software components.
- *Forecaster* (CERTH): Produces the forecast for any asset type within scope of the IANOS project.

For this integration we have not included the physical assets and control software (dEF-Pi) as the partner NEROA is still creating a working system. All these components are shown in Figure 2 where the physical assets of the architecture have been greyed out to denote that the physical assets are not part of this integration test.

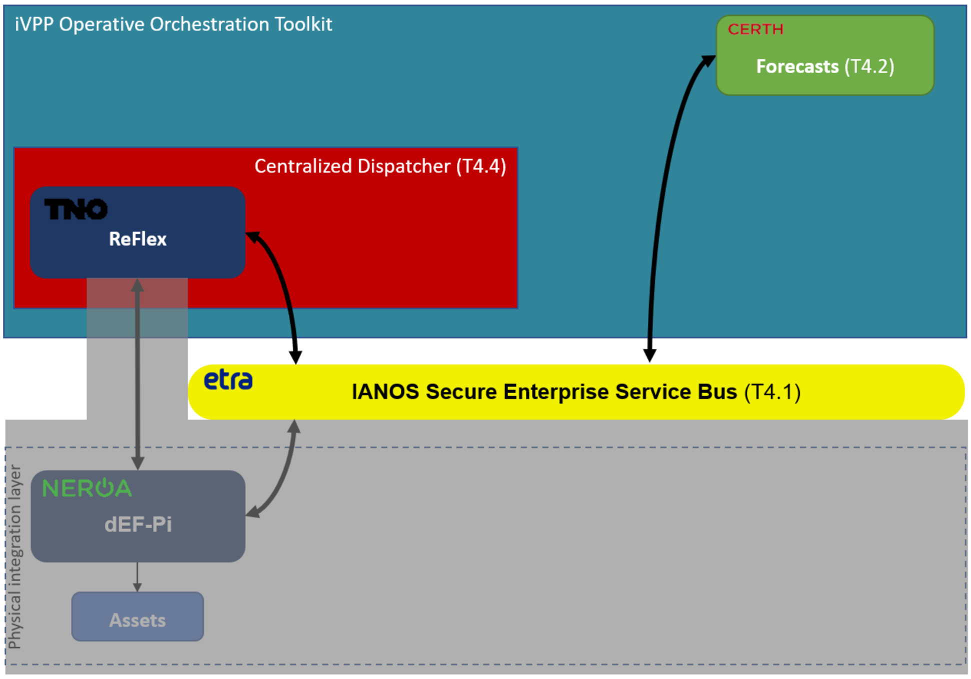

Figure 2 Partial architecture which is included in the integration test. The physical assets have not yet been included which is denoted with the greyed-out area.

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5.1.1.1 Integration design

The integration between the ReFlex and Forecaster software components utilizes the Enterprise Service Bus (ESB). The ESB is a 'message broker' which allows publishers to send messages to any interested subscribers. Any message is sent to a topic name and any subscriber can listen to one or more topics. By decoupling publishers and subscribers through topics, it is unnecessary to configure all the subscribers at the publisher. The publisher does not need to know which components need to receive the messages it publishes. The ESB uses the RabbitMQ technology for this.

RabbitMQ may be configured with a number of messaging protocols and formats. Within the IANOS project it has been decided to proceed with the MQTT messaging protocol. The 'retain' feature of MQTT has been utilized to save the latest, published forecast by the Forecaster component at the ESB. If a subscriber connects or reconnects, it will immediately receive the latest forecast.

The Forecaster component is configured to create new forecasts when possible and it will publish the latest forecasts on the ESB. The ReFlex component subscribes to the forecasts and will receive the latest forecast whenever it (re)connects to the ESB or when a new forecast is published.

5.1.1.2 Integration test

In order to perform the integration test the Forecaster component is configured to publish the forecasted production profile for the solar farm in Ameland, Ballum. The forecast spans three days and is updated every 15 minutes. The forecast takes the latest weather forecasts and previously measured production values into account. ReFlex is configured to subscribe to the ESB for the published forecasts.

The integration test is successful when:

- An initial forecast is sent by the Forecaster.
- The initial forecast is received successfully by ReFlex.
- ReFlex shows the correct forecast in its dashboard.
- The forecasts are submitted in a single MQTT message which is retained by the ESB.
- An updated forecast is sent by the Forecaster after 15 minutes.
- ReFlex overwrites the previous forecast in favour of the new forecast.

5.1.1.3 Integration test results

The integration has been tested successfully. Initially, a forecast was published by the Forecaster and received by ReFlex as is shown in Figure 3. The values have been checked manually and they were correct.

Figure 3 The initial forecast received by ReFlex from the Forecaster using the ESB. Values have been verified manually.

These forecast was sent and retained as a single MQTT message as is shown in Figure 4.

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```
{
  "asset_id": "ameland/Ballum/pvField",
  "measurements_message": [
    {
      "measurement_name": "pv_forecast",
      "measurement_unit": "kWh",
      "measurements": [
        {
          "value": 0.085,
          "timestamp": "2023-01-25T13:30:00.000000Z"
        },
        {
          "value": 0.069,
          "timestamp": "2023-01-25T13:45:00.000000Z"
        },
        {
          "value": 0.057,
          "timestamp": "2023-01-25T14:00:00.000000Z"
        },
        … other entries are skipped …
        {
          "value": 0.0,
          "timestamp": "2023-01-27T22:15:00.000000Z"
        },
        {
          "value": 0.0,
          "timestamp": "2023-01-27T22:30:00.000000Z"
        },
        {
          "value": 0.0,
          "timestamp": "2023-01-27T22:45:00.000000Z"
        },
        {
          "value": 0.0,
          "timestamp": "2023-01-27T23:00:00.000000Z"
        }
      ]
    }
  ]
}
```


Figure 4 The initial forecast formatted as an MQTT message.

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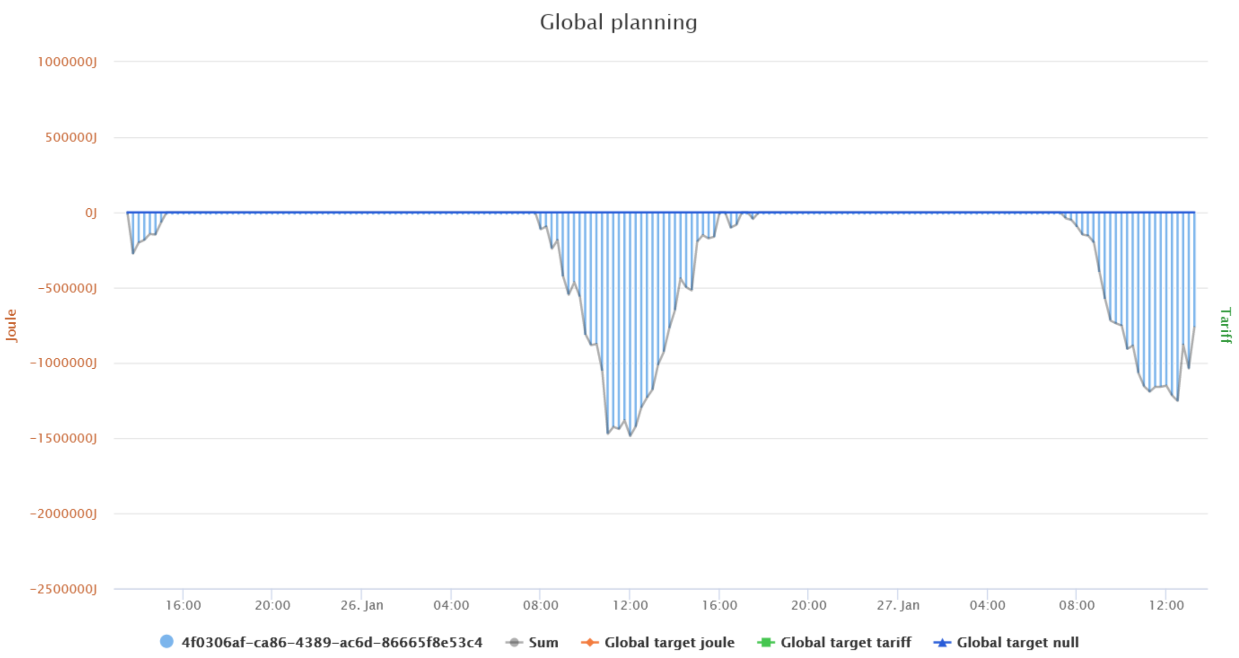
After 15 minutes, an updated forecast was calculated which is shown in Figure 5. The values have again been checked manually and they were correct.

Figure 5 The second forecast received by ReFlex from the Forecaster using the ESB. Values have been verified manually.
Time is in UTC



5.2 Residential solar panels

Residential solar panels will be installed as part of demonstration use case 1 on Ameland. Approximately 1MW solar panels on 400 individual residential and tertiary rooftops are planned.

5.3 Solar Farm (Airport)

February 2016 marked the start of the 6MWp solar park on Ameland. Since the beginning the solar park has, on average, produced 6600MWh per year. The park is owned by Ameland, Eneco and the Amelander Energy Cooperative, representing the first ground based solar park in the Netherlands. Within the solar farm, there are 23,000 REC 260PE solar panels installed together with 165 ABB TRIO 27.6 TL OUTD inverters. The electricity is transformed to 10KV by three transformers. The electricity produced there runs from the solar park in Ballum to the distribution in Nes by a 6 km cable and dispersed to the households on Ameland.

5.4 Tidal Kite

Within the IANOS project the integration of the TidalKite into the Ameland grid and in the central dispatcher will take place.

The SeaQurrent TidalKite aims to harness the kinetic energy produced by tidal and ocean currents. The TidalKite technology allows to generate clean electricity from shallow and deep low velocity currents. It is made up of an underwater kite, a single rigid, buoyancy-neutral and hydrodynamic device, consisting of a frame with multiple wings. This underwater kite allows to cover a larger energy harvesting area, perpendicular to the flow[1].

The TidalKite test setup in the Waddenzee around Ameland consists of the following system illustrated below, comprises a TidalKite (1) that is connected by means of a (high tech cable) tether (2) to a power take off (PTO) (3). The PTO is fixed to the seabed by means of a Mooring Structure (4) and electricity is distributed to shore by an underwater electric export cable (5).[2]

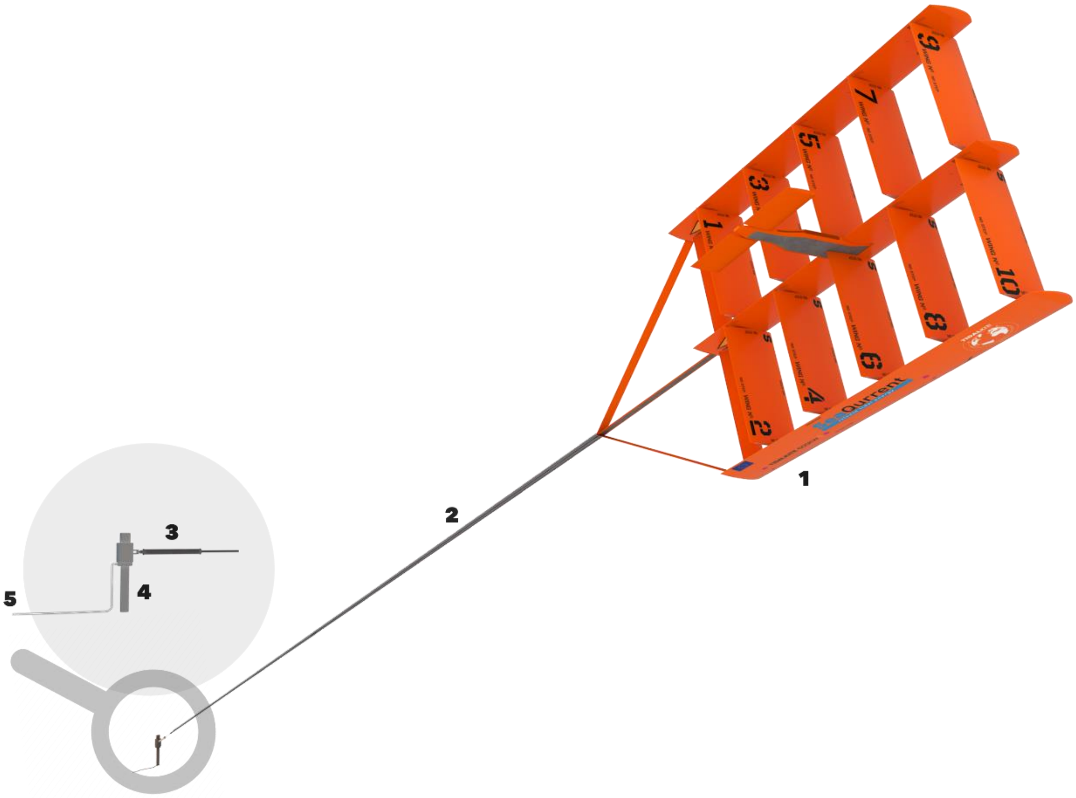


Figure 6: TidalKite System

Included in the TidalKite setup will be a grid connection cable (10kV power cable) connected to the Ameland electricity grid as operated by Liander. The grid connection will be established by a HDD (horizontally directed drilling) under the sea dike to place a tube which will house the electricity cable. The total length of the TidalKite system is approximately 100 meters long. A standard TidalKite has a capacity of 500kW and it is connected to the grid via a 10kV power cable.3 SeaQurrent is working on the 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.

The TidalKite developments which SeaQurrent will work on within the IANOS project are:

- the connection of the technology to the grid (integration of the TidalKite to the Ameland grid and central dispatcher)

[1] The next generation tidal energy plants based on the principle of kiting; accessed 29 August 2022 - [Home - SeaQurrent]
[2] ibid
[3] ibid

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- the integration of the technology with the iVPP to be part of the Ameland UCs
- the development of the technology's remote monitoring and control system

Most of the development and testing of the TidalKite is executed outside of the IANOS project. Only the integration with the iVPP is part of the IANOS project. The TidalKite will not be actively controlled by the iVPP but its production will be used to match with IANOS assets that can provide flexibility.

5.5 Micro-CHP

Within UC1 on Ameland, there will be three (3) houses equipped with a battery pack of 3.5kWh, solar panels (1kWe) and micro-CHP of 5.5kWth. These will be based at multiple locations on Ameland.

5.6 Bio Based Battery C1/BESS

In the proximity to a new construction with 13 houses in the city of Nes, SuWoTec will deliver the 120kWh Bio Based Battery C1. This unique concept battery is developed for electricity storage in a simple, safe and affordable way. This Bio Based Battery C1 (BBB) does not contain lithium, ion or cobalt and is a completely recyclable battery. The key innovations of the BBB are that it has a unique natural self-cooling system and therefore no energy loss for process cooling. It is safe in use and there is no risk of fires and thermal runaways. It is very flexible and mobile and can be transported and assembled on remote sites, Is flexible for input and output AC and DC. There is no need for high-capacity grid connections and fits easily in existing infrastructure. The Bio Based Battery C1 is available in 120 kWh modules and can be extended to multiple MWh. The focus within the IANOS project will be to work out the volatile attributes of most renewable energy production. The BBB will be installed in between a renewable energy source and or the grid connection and the end user.

Local Energy Harvesting → Local Energy storage → Local Energy use

Product specifications

- Nominal voltage: 576 V
- Storage capacity: 120 kWh
- Maximum charging capacity: 15 KW
- Maximum discharging capacity: > 50KW
- Load efficiency: > 97% @ 20 °C
- Discharge efficiency: > 96% @ 20 °C
- Dimensions (L x W x H): 2,170mm x 1,654mm x 1,560mm
- Weight: 4,200 KG

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Figure 7: Demonstration of SuWoTec BBB C1

5.7 Hybrid Heat Pumps

There are already 135 Hybrid Heat Pumps (HHP) installed in residential houses on Ameland. The HHP are equipped with a 20kWth gas boiler and a 1.1kWe/5kWth heat pump each. Therefore, the HHP can alternate between natural gas and electricity, independently adapting to weather conditions. Additionally, the HHPs are also capable of running on biogas.

To support the final set up of the Hybrid Heat Pumps on Ameland, a test set-up has been prepared in the HESI lab. This is a combination of a heat pump and a gas boiler. The combination allows for the hybrid heat pump to use the heat pump as much as possible to fulfil the heat demand of a house, while the gas boiler will only be turned on when the heat demand is higher than the maximum thermal power that the heat pump alone can deliver. If the outside temperature is too low for efficiently using the heat pump, it is also possible for the gas boiler to be switched on. This would be based on the Coefficient of Performance (CoP) of the heat pump to be too costly to operate in comparison to the gas boiler.

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Figure 8: Hybrid Heat Pump set up in HESI lab (Elga heat pump, left; gas boiler, right)

The possibility to switch between heat pump and gas boiler also can be used for flexibility reasons. In the case of congestion management in the electricity distribution grid, the set up can be used to switch from hybrid heat pump to gas boiler, using the Smart Grid Ready Protocol, during peaks in the electricity distribution grid. The reason behind is, that a heat pump uses a significant amount of electricity compared to the gas boiler only using gas. Of course, the consumers would need to be compensated for the higher costs associated with gas when this type of flexibility is being used.

5.8 NAM (Nederlandse Aardolie Maatschappij) Platform

The NAM platform is already operational for Ameland and currently uses the gas it produces for gas compression totaling up to 410 TJ per year. Within 2022 the compressor will be replaced by a 6 MW electrical compressor. This will increase the energy flow from the island to the NAM-platform with up to 180 TJ/year.

5.9 Solar Park (Ballumerbocht)

This solar park with a capacity of 3MWP will be realized in the first half of 2023.

5.10 Battery Storage

The solar park Ballumerbocht will be combined with a large battery to enable local balancing of the PV production. The battery can also be used to perform ancillary services with such as FCR and aFRR. The exact capacity of the battery still has to be determined.

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5.11 Electrolyser

The electrolyser is planned to be realized near the solar farm and battery at the Ballumerbocht. The further purchase, installation and exploitation is initiated by the Municipality of Ameland. Koninklijke Van Twist is developing a new electrolyser and plans to install a 400V version on Ameland. The outcomes of the tests will determine if a larger version will be bought.

5.12 Fuel Cell

5.12.1 Methane Fuel Cells

Within the IANOS project 35 (CH4) privately owned Fuel Cells (FCs) will be used, these are fed by the CH4 district grid to 35 individual homes. These fuel cells deliver 2.3 kW of electrical power and 0.6 kW of thermal power. The fuel cells are already in operation and were funded by the National Project Slimme Stroom. Software has already been developed to allow remote control of the methane fuel cells so that their flexibility can be controlled.

5.12.2 Hydrogen Fuel Cell

A large hydrogen fuel cell with an electrical capacity of 500kW is placed on the recreational park Klein Vaarwater. The electricity that is being produced by the fuel cell is dispatchable which makes this asset very flexible.

5.12.3 Combined Heat Power System (CHPS)

A Combined Heat Power System will be used as one of the sources for a heat grid that is used to heat recreational houses. The CHP can deliver 75kW of electrical power and 110kW of thermal power.

5.13 Hydrogen Fueled Vehicles

The ambition is to demonstrate hydrogen (H2) fueled vehicles (most likely as water taxis) within the IANOS project. The hydrogen water taxis have not been designed yet and further information is not known. As an alternative to the hydrogen water taxis, alternative usage of hydrogen is being explored. These alternatives are municipal vehicles, the heat grid in Nes and seasonal storage at Klein Vaarwater recreational park.

5.14 Auto generative High-Pressure Digester (AHPD)

BAREAU will not further develop the High-Pressure Digester (HPD) within the IANOS project as the initial scope of this innovative solutions could not meet the requirements. As a mitigating measure, to compensate for the loss of the HPD solution alternatives are being explored. This could be in the form of an alternative centralized digester or by deploying multiple smaller

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digesters at restaurant locations. The Municipality of Ameland is exploring alternatives to reach the target of reducing CO2 emissions on (bio)waste management.

5.15 Wind turbines

The placement of 2 smaller wind turbines - with a capacity of 15kWe each - is still being analyzed.

5.16 Smart Charging of EV batteries

New charging stations will be installed on Ameland at the beginning of next year. There is not much detailed information available about these new charging stations yet. The aim is to control the flexibility of the charging stations through backoffice integration with the charging station operator.

5.17 ReFlex and dEF-Pi[1]

The ReFlex technology supports the implementation of the iVPP on Ameland. The ReFlex platform supports the aggregator on Ameland (Repowered) to optimize the value of the flexibility resources available in its portfolio. The optimization of the flexibility resources usually involves manual analysis on the aggregator side, where the ReFlex technology is able to automate this process. In addition, the ReFlex technology allows the aggregator to run a variety of scenarios during the planning phase, testing how flexible assets in its portfolio will react.

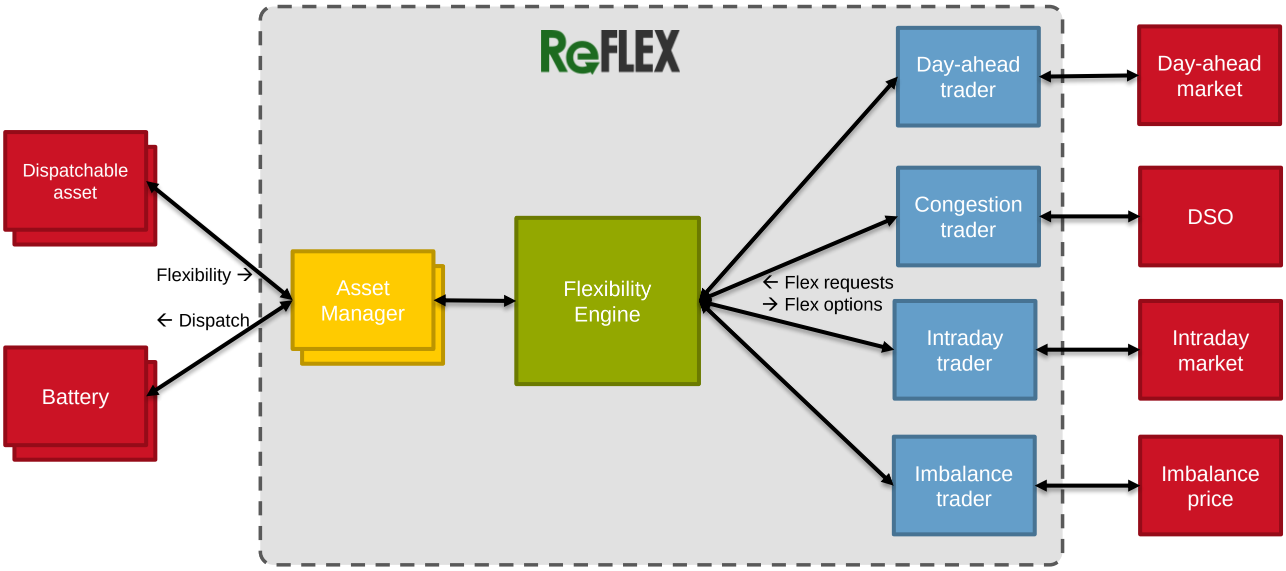

Figure 9: ReFlex high-level architecture

The high level architecture of ReFlex is depicted in Figure 3, showing the Asset Managers, the Flexibility Engine and Traders.

- The Asset Managers get the flexibility information from connected flexible assets in the portfolio of the aggregator (e.g. batteries, heat pumps, EV's). Via the S2 protocol the

[1] For more detailed information on ReFlex and dEF-Pi can be found in IANOS deliverables: D4.7, D5.1, and D5.3.

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flexibility information is then shared. The S2 protocol is defined in the European prEN504911-12-2-standard. The flexible assets decide when updated information is sent to the asset manager, as there is no specific requirement regarding the frequency of exchanging flexibility information.

- The Flexibility Engine determines the behaviour of the whole cluster. By considering a wide range of scenarios, it can determine the most optimal for a given optimization objective or multiple objectives. It does so by using the flexibility of the assets as input, considering constraints of different markets that could take advantage of the available flexibility.
- The Traders communicate the optimization objectives or constraints to the Flexibility Engine. The Flexibility Engine can then take the objectives or constrains into consideration to find the most optimal solution. For each market the aggregator is active in, a different trader within ReFlex exists.

The Distributed Energy Flexibility Platform and Interface (dEF-Pi) sets out to develop an interoperable platform. This platform will be able to connect to multiple assets and support a host of Demand Side Management (DSM) approaches. Within the IANOS project dEF-Pi will come to use to host the Resource Manager for the hybrid heat pump installation and will enable communication to ReFlex.

6 Use cases and Requirements

The Use Cases demonstrated on Ameland revolve around existing RES and new development plans on the island. There are 9 Use Cases, of which UC1 through UC8 are connected with the iVPP. The UCs are grouped in 3 Energy Transition Tracks (TT), depending on the goals and exploitation opportunities. The overview is the following:

Transition Track 1 (TT1) – Energy efficiency and grid support for extremely high RES penetration: Included in TT1 are UC1, UC2, UC3 and UC4 and uses the iVPP to reduce energy curtailment and supporting a high RES usages in the energy system.

Transition Track 2 (TT2) – Decarbonization through electrification and support from non-emitting fuels: Included in TT2 are UC5, UC6, UC7 and UC8 and focuses on demonstrating the potential of electrification as a way to decarbonize different sectors and cross-resource integration of non-emitting fuels utilization and circular economy.

Transition Track 3 (TT3) – Empowered Local Energy Communities: Only UC9 is part of TT3 and focuses on engaging and involving citizens in the decarbonization transition and effort on the island. This UC will not be addressed in this deliverable as there are no technical assets included.

The below Figure provides an overview of the demonstration areas on Ameland and where assets are installed or will be installed.

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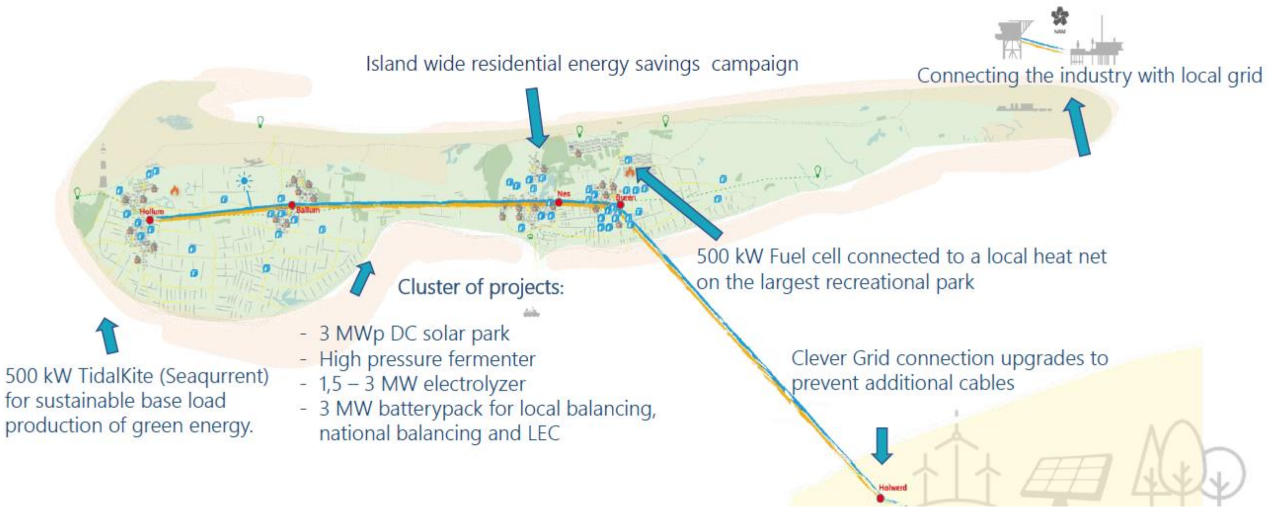

Figure 10: Overview of Ameland island and demonstration areas

The following chapters will provide an overview of the use case and the equipment involved.

6.1 Use Case 1: Community demand-side driven self-consumption maximization

6.1.1 Background

Use Case 1 focuses on the optimisation of self-consumption of renewable energy produced on the local, neighbourhood or island wide level. In line with TT1 goals of reducing energy curtailment and increased usage of RES, the (to be) installed assets will be controlled by the iVPP to shift demands to moments that have a renewable energy generation surplus. Furthermore, the main objectives are to:

1. Increase self-consumption from renewable energy sources to optimize the asset exploitation on Ameland and to reduce future grid transport costs to the mainland as well as improve grid performance in periods of excess of renewable energy generation.
2. Increase renewable energy penetration to reduce energy curtailment
3. Avoid and reduce grid challenges due to congestion or overload

The intelligent Virtual Power Plant (iVPP) aims to control and optimize the consumption of the behind-the-meter assets in a Local Energy Community (LEC)

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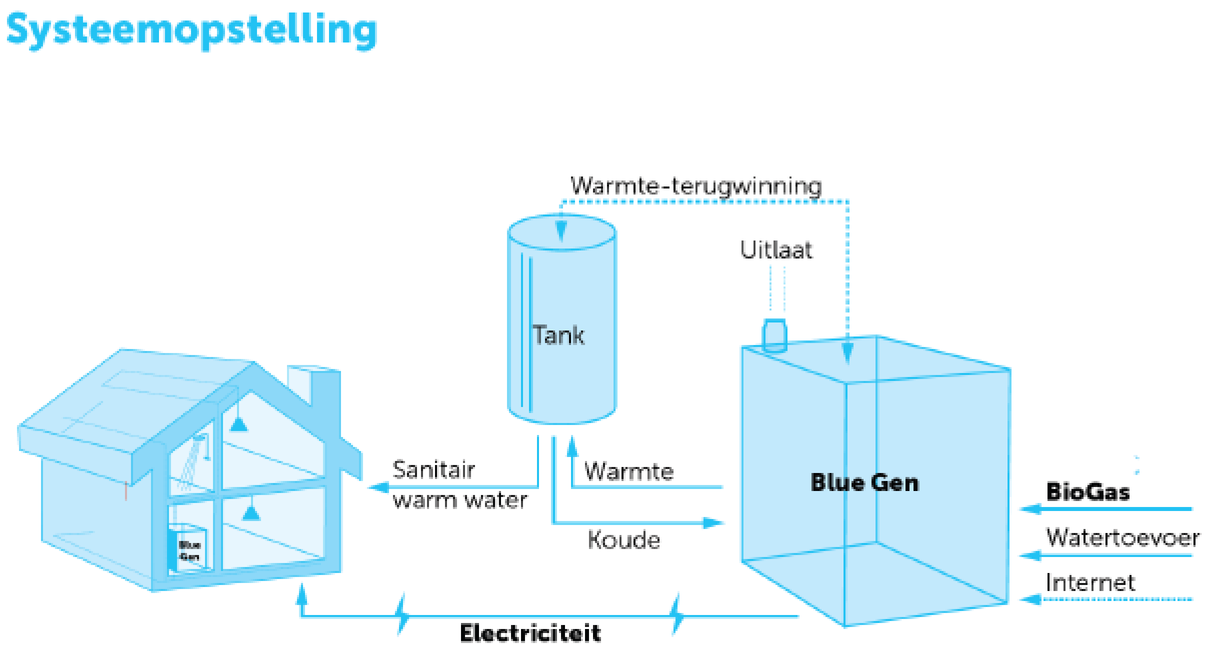

Figure 11: Example of system setup

6.1.2 Requirements

For the demonstration of this UC the devices and the devices' RES production needs to be measured and forecasted. The energy produced by the solar farm should be used as much as possible for the hybrid heat pumps to run as much as possible on electricity, in line with their default behaviour. An overview of the devices part of the Ameland UC is shown in the below table:

Device	# Assets	Existing	Main technical characteristics	S2 Type[1]
Solar Farm	1	X	6MWp, read power via backend	PEBC
Hybrid Heat Pumps	135	X	7 types on the island, of which 4 have been lab-tested. Comm. via Pi.	DDBC
Bio Based Battery C1	1		120kWh, comm. probably via backend	FRBC
Fuel Cell CH4	35	X	2kWe each	OMBC
Wind Turbines	2		15kWe each	PEBC
Residential PV	400	X	Total around 1MW. Could be monitored in 2 ways: From smart meter, or at inverter.	PEBC
Battery pack, solar panels, µCHP	3	X	Battery: 3.5 kW	FRBC, PEBC, FRBC

Table 1: Overview of devices of UC1 on Ameland and their main technical characteristics, measurable and controllable variables.

[1] S2 type refers to the control type category as defined by EN 50491-12-2 (better known as *S2* interface as described by the European Reference architecture for Smart Grids, see also Appendix A.
At Ameland this novel S2 interface is utilized to communicate energy flexibility. For each device an analysis is made to which S2 control type the device belongs.

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6.1.3 Validation and next steps in UC integration

The following steps remain to be done for this use case:

- Install all assets that are part of this use case.
- Unlock the flexibility of the assets using the dEF-Pi platform and the S2 protocol.
- Configure the correct optimization targets for the iVPP.
- Test/validate this use case.

6.2 Use Case 2: Community supply-side optimal dispatch and intra-day services provision

6.2.1 Background

Use Case 2 has set out three main goals, which are; 1) provide flexibility on the generation side, 2) reduce energy curtailment, and 3) avoid grid challenges. Using the available flexibility on the energy generation side of the utility-scale assets the UC can examine the potential of minimizing the energy curtailment during periods of surplus renewable energy generation. The iVPP can perform the day-ahead optimal dispatch and provide intra-day balancing services to the power system by computing the optimal dispatch set-point. This helps ensuring that the available capacity of the batteries is sufficient to increase RES penetration.

Through the iVPP's Utility-Scale Assets Scheduler the iVPP considers three categories of assets:

1. Dispatchable assets, including diesel engines, waste incinerators, geothermal power generators of utility-scale assets and flexibility assets;
2. Non-dispatchable assets, such as wind and solar PV generators; and
3. Large-scale BESS and Power to Fuel (H2) storage systems, e.g. electrolysers.

In order to compute the optimal dispatch set point, the information of different assets is used and is directly collected from the solar farm, which the iVPP is directly connected to.

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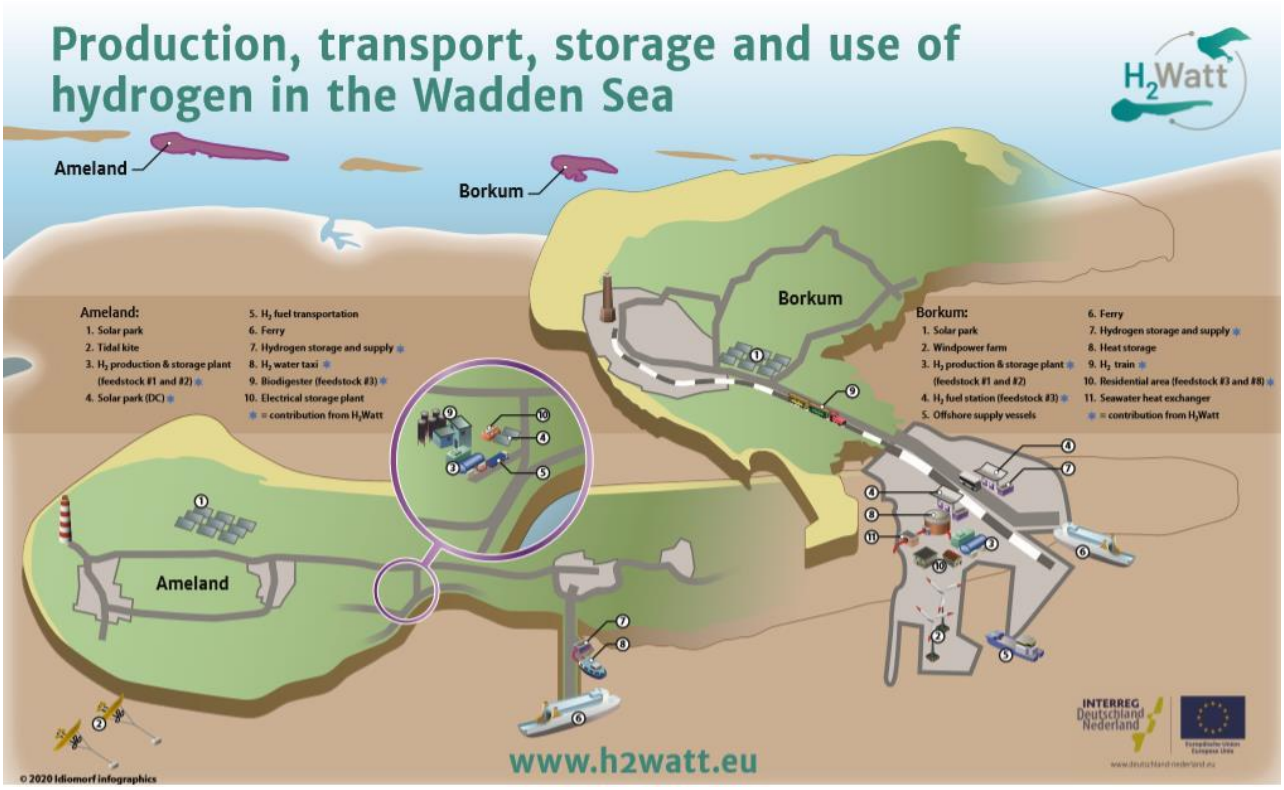

Figure 12: Overview UC2 set-up

6.2.2 *Requirements*

In order to demonstrate this UC forecasting of PV, wind turbine and load is required. Furthermore, day-ahead dispatch scheduling and the technical characteristics of energy storage systems (ESS) and PV and wind turbines are necessary. The devices part of the use case in Ameland are:

Device	# Assets	Existing	Main technical characteristics	S2 type*
Solar Farm	1	X	6 MW	PEBC
3MWh Battery	1		3 MW DC solar park	FRBC
Electrolyser	1			PEBC / OMBC
3MWh BESS				

Table 2: Overview of devices of Use Case 2 at Ameland and their main technical characteristics, measurable and controllable variables.

6.2.3 *Validation and next steps in UC integration*

The following steps remain to be done for this use case:

- The Ballumerbocht solar park needs to be realized including the 3MWh BESS and the electrolyser.
- The GOPACS platform will have to be integrated into the iVPP.
- Configure the correct optimization targets for the iVPP.
- Test/validate this use case.

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6.3 Use Case 3: Island-wide, any-scale storage utilization for fast response ancillary services

6.3.1 Background

Within Use Case 3 the focus is to capacitate the power system with distributed storage technologies having frequency and voltage control capacities allowing to improve the quality and stability of the power system. The iVPP will aggregate the different storage systems to ensure fast services to the grid, such as FFR (Firm Frequency Response) and voltage deviations. Furthermore, the iVPP will also ensure that there is a pre-defined capacity reserved for these services, which can vary depending on the status and situation forecast of the power system within a short window of time (i.e., one day).
The iVPP will make use of data from the grid to be able to calculate the set-point for storage assets supplying the energy to the grid when necessary. The set-point works as a suggestion to determine when interference is to be done with assets daily operations.

Reflex is being used as an integral part of the iVPP in all use cases. This use case is an exception to that rule as ReFlex is not fast enough for supporting FCR and aFRR services, therefore Repowered will place bids directly at the TSO (Tennet).

Figure 13: Picture of Klein Vaarwater (top), Pavilion at Klein Vaarwater (bottom)

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6.3.2 Requirements

Part of demonstrating this UC relies on having a partner with market access and the ability to control and measure battery storage at a specific time scale and precision. In addition, it will require a reservation of battery capacity for a specific market and careful positioning of batteries to best support voltage management. Devices part of the use case in Ameland are listed in the below table:

Device	# Assets	Existing	Main technical characteristics	S2 type*
3MWh battery	1			FRBC
Private CHPs	35	X	2kW	FRBC
CHP	2		75 KWe/110KWth	FRBC
Fuel cell	1		500KWe	OMBC

Table 3: Overview of devices of Use Case 3 at and their main technical characteristics, measurable and controllable variables.

6.3.3 Validation and next steps in UC integration

The following steps remain to be done for this use case:

- The Ballumerbocht solar park needs to be realized including the 3MWh BESS and the electrolyser.
- Test the correct functioning of placing FCR and aFRR bids at the TSO.

6.4 Use Case 4: DSM and Smart Grid methods to support Power quality and congestion management services

6.4.1 Background

This Use Case aims to ensure stability of the power system, reduce energy curtailment and support congestion management services by making use of demand flexibility as a measure to provide slow ancillary services to the grid (e.g., to help prevent congestion). Furthermore, the UC4 will focus on utilizing demand side flexibility to improve the overall energy system, ensure a larger inclusion of RES production.

Figure 14: SuWoTec Bio Based Battery C0

Figure 15: Demonstration of SuWoTec BBB C1

6.4.2 Requirements

For the demonstration of UC4 load and production forecasts, controllable load and real-time measurements are required. The devices part of the use case in Ameland are:

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Device	# Assets	Existing	Main technical characteristics	S2 type*
3MWh Battery	1			FRBC
CHP	2	X	75KWe/110KWth	FRBC
500KWe Fuel cell	1			OMBC
Hybrid Heat Pumps	135	X	7 types, of which 4 are tested on Smart-Grid-Readyness	DDBC
Bio Based Battery C1	1		120 kWh	FRBC
Private CHPs	35	X	2kW	FRBC

Table 4: Overview of devices of Use Case 4 at Ameland and their main technical characteristics, measurable and controllable variables.

6.4.3 *Validation and next steps in UC integration*

The following steps remain to be done for this use case:

- The Ballumerbocht solar park needs to be realized including the 3MWh BESS and the electrolyzer.
- Realize the Biobased battery.
- Unlock the flexibility of the assets using the dEF-Pi platform and the S2 protocol.
- Configure the correct optimization targets for the iVPP.
- Test/validate this use case.

6.5 Use Case 5: Decarbonization of transport and the role of electric mobility in stabilizing the energy system

6.5.1 *Background*

Use Case 5 focuses on the decarbonization roadmap of the transport sector on the islands. For Ameland this includes installing EV chargers and exploring their potential for expansion with V2G and smart charging schemes to increase the use of RES. The EV charging stations will be connected to the iVPP, which will control their charging and discharging modes.

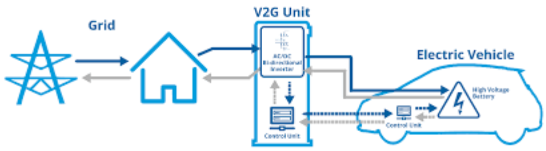

Table 5: Overview of V2G utilization

Moreover, this Use Case will also study the potential of hydrogen fuelled vehicles, to support the decarbonization of the transport sector, taking advantage of the hydrogen produced from the electrolyser in the case of Ameland (UC#2).

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6.5.2 *Requirements*

To demonstrate this UC it will be necessary to control the charging and discharging behaviour of EVs as well as have information on the usage, charging duration and time. The devices that are part of the UC are listed in below table.

Device	# Assets	Existing	Main technical characteristics	S2 type*
Charging Station EV	10		Spread across the island, only 1 type of charging station. comm. will be established through backend	PEBC
Municipal EV vehicles	3	X		
Electric buses (public transport)	6	X		
Electric bikes (for tourists)	1000	X		
EV vehicles (for tourists)		X		

Table 6: Overview of devices of Use Case 5 at Ameland and their main technical characteristics, measurable and controllable variables.

6.5.3 *Validation and next steps in UC integration*

The following steps remain to be done for this use case:

- Install the charging infrastructure for the EVs, electric buses and electric bikes.
- Acquire 3 municipal vehicles.
- Integrate the charging infrastructure through the back office of the charging station operator(s) using the S2 protocol.
- Configure the correct optimization targets for the iVPP.
- Test/validate this use case.

6.6 Use Case 6: Decarbonizing large industrial continuous loads through electrification and locally induced generation

6.6.1 *Background*

The objectives of Use Case 6 are to further explore the decarbonization of large industrial sites, by maximising consumption of local RES. Ameland project partners will integrate a large-scale industrial load, with available RES (6MWp community owned solar farm) and newly to be installed RES (3MWp solar farm, a 500kWe tidal-kite, 2*15kWe wind turbines, a 500kWe fuel cell, 2*75kWe CHPs).

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Figure 16: Context: The (near) offshore natural gas platform owned by the NAM

6.6.2 Requirements

In order for this UC to be demonstrated, the measurements of data consumption of the large industrial load to identify fluctuations in consumption is necessary. The key devices that are part of the UC are listed in below table.

Device	# Assets	Existing	Main technical characteristics	S2 type*
Solar Farm 6MW	1	X		PEBC
Solar Farm 3MW	1			PEBC
500kW Tidal Kite	1		Communication will be done via backed.	PPBC / PEBC
NAM Drilling Platform	1	X	Monitoring will be done via backend.	-
Mainland connection	1	X		-
Fuel Cell	1	X	500kWe	OMBC
Wind Turbines 15KWe	2			PEBC
CHP	2		75kWe/110KWth	FRBC
H2 storage				

Table 7: Overview of devices of Use Case 6 at Ameland and their main technical characteristics, measurable and controllable variables.

6.6.3 Validation and next steps in UC integration

The following steps remain to be done for this use case:

- The Ballumerbocht solar park needs to be realized including the 3MWh BESS and the electrolyser.
- Install the tidal kite.

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- Install the wind turbines.
- Unlock the flexibility of the assets using the dEF-Pi platform and the S2 protocol.
- Configure the correct optimization targets for the iVPP.
- Test/validate this use case.

6.7 Use Case 7: Circular economy, utilization of waste streams and gas grid decarbonization

6.7.1 Background

The ambition of this Use Case is to decarbonize the island by re-using waste streams to produce green energy. At this moment alternatives are being explored to the Auto-Generative High-Pressure Digester.

6.7.2 Requirements

Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*
Electrolyser	1			-
Digester	1			PEBC / OMBC

Table 8: Overview of devices of Use Case 7 at Ameland and their main technical characteristics, measurable and controllable variables.

6.7.3 Validation and next steps in UC integration

The following steps remain to be done for this use case:

- Realize the digester or multiple smaller units as an alternative to the large digester
- No active iVPP control is foreseen for this use case.

6.8 Use Case 8: Decarbonisation of heating network

6.8.1 Background

The ambition of this Use Case is to decarbonize the existing heat grid on Ameland and result in the monitoring of four decarbonized heating solutions. To achieve this residential hybrid heat pumps will be installed, including the establishment of the connection to the iVPP. Furthermore, the holiday park Klein Vaarwater will have an integrated 500kWe fuel cell, H2 storage and additional heat pumps for peak demands.

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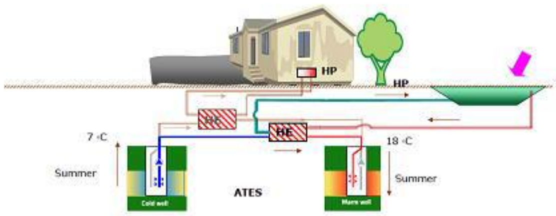

Figure 17: Example of an aqua thermal energy setup with seasonal storage

6.8.2 Requirements

For this UC it is required to control heat production facilities and have the load profiles of demand in heat networks. The devices that make up the UC are listed in the below table.

Device	# Assets	Existing	Main technical characteristics	S2 type*
Fuel Cell	1		500KWe	OMBC
Heat Grid Nes	1		Planned to be driven by heat pumps to exploit energy from surface water in 40 households	?
Heat Grid Klein Vaarwater	1	X	Is driven by the CHP on Klein Vaarwater & have some regular HR-boilers as a back-up for the system	?
Bio Based Battery C1	1		120kWh	FRBC
Hydrogen Storage	1		Dimensions of this storage are to be researched	
Hybrid Heat Pumps	135	X	7 types, of which 4 are tested on Smart-Grid-Readiness	DDBC

Table 9: Overview of devices of Use Case 8 at Ameland and their main technical characteristics, measurable and controllable variables.

6.8.3 Validation and next steps in UC integration

The following steps remain to be done for this use case:

- The Ballumerbocht solar park needs to be realized including the 3MWh BESS and the electrolyser.
- Realize the Bio Based Battery C1.
- Realize the fuel cell.
- Realize the hydrogen storage.
- Realize the heat grid in Nes.
- No active iVPP control is required for this specific use case, although most of the assets are also part of other use cases and will be controlled for their electricity flexibility.

6.9 Use Case 9: Active Citizen and LEC Engagement into Decarbonization Transition

This use cases is excluded from this deliverable, as it focuses on citizen engagement and does not contain devices or IT components.

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7 Conclusions

This deliverable provides an overview of the current state of the development of the Ameland use cases. The deliverable provides a current snapshot of the ongoing developments on Ameland with respect to the use case implementations and assets, as well as IT components that will be demonstrated. The main conclusions in relation to the use case development are stated below.

- The iVPP software - which in the Ameland case is composed of the SolarFlex, ReFlex, and dEF-Pi platforms and the IANOS Enterprise Service Bus – is there, but the integration with the assets still needs to be done. This is partly due to the fact that a large part of the assets still needs to be installed. However, there is also a lot of software integration work that remains to be done on the assets that have been installed already.

- Initially this deliverable was to be submitted in September 2022. However, this would have been just shortly after submission of D5.3 (Ameland's use cases preliminary iVPP integration tests) which was submitted in July 2022, reducing the amount updates that could have been communicated. In addition, integration efforts were and are still ongoing for the preparation of the full deployment of the use cases on Ameland. Although at the moment of updating this deliverable, integration efforts relating to the integration with individual assets is still ongoing, it is notable to highlight the forecast integration test that has been conducted. The forecast will be the basis for the centralized dispatcher, which is an integral component for most use cases. The successful testing of the forecast will pave the way for a smooth integration once all partner assets are installed and deployed.

- On Ameland, there is a lot of overlap between the use cases in terms of assets that are being used. Therefore, use cases will not be implemented individually but integrated in the iVPP software components, especially ReFlex. ReFlex can be fed with different target profiles that reflect the desired behaviour of each use case. Through this mechanism, the iVPP will optimize its operation across the different use cases simultaneously. The only exception is Ameland use case #3 which deals with fast response ancillary services such as FCR and aFRR. These services require very fast response times which cannot be met by the ReFlex platform and will therefore be implemented through a custom solution built by Repowered.

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8 References

Deliverable 2.2 – Report on Islands requirements engineering and Use Case definitions, 30 April 2022

Deliverable 2.10 – IANOS Islands Decarbonization Master Plan, 30 July 2021

Deliverable 4.7 – The iVPP Centralized Dispatcher (T4.4). 31 March 2022

Deliverable 5.1 – Initial TRL assessment and development of Ameland technologies roadmaps, 27 July 2021

Deliverable 5.3 – Ameland's use case preliminary iVPP integration tests

Deliverable 5.4 – Ameland UCs Deployment Plan report, 29 April 2022

The Next generation tidal energy plants based on the principle of kiting, accessed 29 August 2022; Home - SeaQurrent

Appendix A:

EN 50491-12-1 S2 ARCHITECTURE

The EN 50491-12-1 architecture focuses on the premises side of the smart grid and is mainly concerned with the communication between smart devices and the Customer Energy Manager (CEM). Figure 18 provides a logical view of the components that can be found at the premises side.

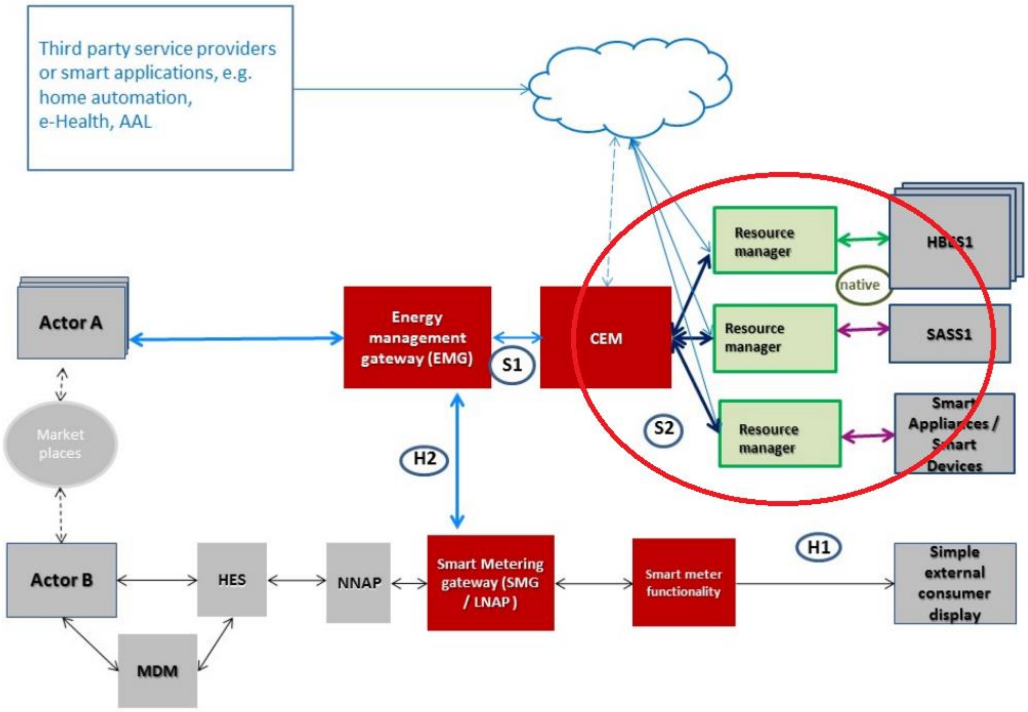

Figure 18: Logical view of a premises smart grid system

The logical view shows all of the relevant smart gird systems on the premises, the red circle outlines the scope of CEN-CENELEC's 50491-12 standard series. Within this standard series the so called S2 interface is being specified.

The S2 interface is used to communicate the energy flexibility of smart devices to the Customer Energy Manager (CEM). The CEM also uses S2 to send instructions to smart devices to exploit their flexibility in a specific way. The components involved in the S2 communication are described below.

- Smart Devices. Smart Devices can offer energy flexibility by deviating from their normal consumption/production pattern. These devices can be controlled externally so that they can be integrated into the premises smart grid system. These devices are very diverse and perform a wide range functions within a home or a building, such as whitegoods, PV, HVAC, etc. In Figure 18 this is reflected by the different terminology that is being used. Smart devices/appliances represent devices like whitegoods. The Home and Building Electronic System (HBES) are systems that are used in home or building automation and perform functions such as switching, open and closed loop control. Singe Application Smart System (SASS) are systems that are composed of a group of devices that work together for a single

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application. Think of a HVAC system that is composed of components such as fans, chillers, radiators etc. Controlling a single component within such a system for flexibility purpose might disrupt the correct functioning of the complete system. Therefore the entire system with all of its components should be treated as a single source of flexibility.

As is apparent these devices are very diverse in their functionality. This also goes for the protocols that are used to control these devices externally. Examples of such (IoT) protocols are KNX, EEBUS/SPINE, ModBus, Zigbee, Bluetooth, WiFi, Z-Wave, but also proprietary protocols. The same holds for the data models/parameters that are used. It is virtually impossible for a Customer Energy Manager to be aware of and support all possible permutations of functionality, protocols and data models. This is where the Resource Manager and the S2 interface come in.

- Resource Manager. The Resource Manager is an intermediary logical component that on one side communicates with the smart devices using its native protocol and data model and understands the functionality that the device performs. On the other side it communicates the flexibility options of the devices to the Customer Energy Manager (CEM). The CEM is only interested in the flexibility that the device has to offer, not in all of the available detailed device parameters and protocols. These would simply overwhelm the CEM and would require adaptations to be made to the CEM every time a new device would be connected.

  The Resource Manager translates the low level device information into more high level information on the energy flexibility that is offered to the CEM via the S2 interface. This is not a straightforward mapping; information that is not relevant for energy flexibility needs to be filtered out while other information needs to be enriched to make it relevant for energy flexibility. Take a thermal buffer for a example; a Resource Manager will have to understand what the capacity of that buffer is and how fast it can be heated. The S2 Control Types sections below describes in more detail which energy flexibility information is conveyed over the S2 interface. The Resource Manager will also receive instructions over S2 from the CEM to use the flexibility in a particular way.

  In providing flexibility to the CEM, the Resource Manager will also take user comfort as well as the operational boundaries/safety margins of the device into account. These aspects will also be checked if the Resource Manager receives an instruction from the CEM. If user comfort or the operational boundaries/safety margins are compromised by executing a CEM instruction it is the responsibility of the Resource Manager to reject that instruction.

- Customer Energy Manager. The CEM takes into account the flexibility that is being provided by all Resource Managers on the premises. Based on its optimization objectives and additional external information/incentives, it will decide how to use that flexibility so that its objectives will be met as closely as possible. Examples of CEM objectives could be to optimize on dynamic energy tariffs, promote self-consumption as much as possible or to help the Distribution System Operator (DSO) alleviate congestion. After the CEM decided on how to use the flexibility, it will send an instructions to the Resource Managers over S2.

  By using S2 a lot of the implementation details of the devices are hidden for the CEM and it can focus on its core business: managing energy flexibility. This enables the CEM to connect to a wide variety of devices with little effort thus promoting interoperability.

S2 Control Types

Resource Managers are all capable (if supported by the underlying smart device) to provide power/energy measurements and forecasts. In addition to these basic and generic functions, the S2 interface features five control types that represent different types of energy flexibility. A Resource Manager will map the flexibility of the device it represents onto one of these control types. The CEM will only have to implement these control types to be able to connect to all devices via their respective Resource Managers. The control types are described below:

- Power Envelope Based Control. This control type is used for devices that cannot be controlled by the CEM to adhere to a specific value for their production or consumption. They can however be asked by the CEM to not exceed certain power limits over time. A typical example of such a device would be a PV panel. The CEM cannot directly control its production as this is dependent from the amount of sunshine, but it can ask the PV panel to not exceed a certain production limit, also known as curtailment. This feature is very useful for congestion management for example. When there is too much production for the local grid to handle, this control type can be used to limit the output of the PV panel to a manageable level.

- Power Profile Based Control. The power profile based control type is typical for devices that perform a function with a corresponding power profile that is known or can be predicted beforehand. Their main flexibility comes from the ability to change the start time of that power profile. White goods, such as a washing machine with a delayed start option, are good examples of this category. A consumer fills the washing machine with dirty clothes, selects a program and chooses the final time by which this program should be finished. The CEM can then decide what the best possible start time is, giving its optimization objectives.

  Another type of flexibility is offered by this control type is the ability to choose between multiple alternative power profiles. The heating cycle of the washing machine might have alternative profiles, e.g. one that consumes less power but requires more time to heat the water and one that consumes more power and takes less time to reach the target temperature. The CEM can then choose which one of these alternatives to use.

- Operation Mode Based Control. Devices that fall within this control type have the possibility to control the amount of power they produce or consume, without significant effects on their future flexibility options. Typical examples for this control type are diesel generators and variable electrical resistors. Such devices are often useful for balancing microgrids. Operation mode devices offer a lot of flexibility; they can assume a range of power levels at almost arbitrary moments in time. When this type of flexibility would be modelled with power profiles, as used for power profile based control, the number of possible permutations would rapidly grow beyond practical limits.

  To avoid such issues, the operation mode control type is modelled as a state machine. A resource manager can declare multiple operation modes for a device. An operation mode is a mode/state that a device can find itself in, that is associated with a specific power value. For example, a diesel generator can have three operation modes: one for being off, one for running at reduced power and one for running at full power. The `off' operation mode has a power value of 0 W associated with it, the `reduced power' operation mode has a power value of -1 800 W (a negative value denotes production), and the `full power' operation mode has a power value of -3 000 W.

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Transitions between operation modes are also explicitly specified. This way, the possible transitions between operation modes may be restricted. Transitions can also be equipped with timing constraints: a device can for example express that it needs to run for a minute in `reduced power', before it can move on to `full power'. This can be achieved by defining a 'minimum on time' timer that blocks the transition when its value is not equal to 0.

The CEM can send instructions that will tell the Resource Manager which operation mode to go to next. These instructions also contain timestamps to inform the Resource Manager on when the transition to a next operation mode should be made.

- Fill Rate Based Control. The fill rate-based control type can be used for devices that have the ability to store or buffer energy. How energy is stored or buffered does not matter, as long as there is a means to measure how full the storage or buffer is.

  There are many examples of devices that can store or buffer energy. Stationary batteries and electric vehicles are examples of devices that store energy in batteries. Heating devices such as CHPs, (hybrid) heat pumps or boilers can buffer energy in a dedicated heat buffer (typically a thermally insulated water tank), but a room with an allowable bandwidth for the temperature can also be used as a buffer.
  Finally, there are also devices that produce cold, like air conditioners, fridges and freezers. Just like heat, cold can be buffered. There are even more ways to buffer or store energy imaginable, such as storing energy in the form of hydrogen, air pressure, water pressure or angular momentum.

  The main component of this control type is the storage itself. A device shall be able to inform the CEM about its fill level, a measure of how full the storage is, and the lower and upper bounds that the fill level should remain within. If applicable it can also inform the CEM about its target fill level and by when that should be reached. This would be useful when charging an EV for instance. In addition to the storage there are also actuators that can affect the fill level of the storage. E.g. an electrical heating element in a hot water buffer.

  The behaviour of the actuators is described with a state machine, just like the operation mode based control type. In this case however the states also specify what their influence on the fill level of the buffer is.

- Demand Driven Based Control. Demand Driven Based Control can be used for systems that are flexible in the type of energy carrier they use, but are not capable of buffering or storing energy (in that case Fill Rate Based Control should be used). A typical example is a hybrid heat pump, that generates heat using either electricity (using a heat pump) or natural gas (using a gas boiler), but doesn't have a thermal buffer. The hybrid heat pump must deliver a given amount of heat (hence demand driven), but can still decide whether to generate this heat using electricity or natural gas. Typically, such systems favour the heat pump, but use the gas boiler in case the heat demand cannot be fulfilled by the heat pump alone or when there is a shortage of capacity in the electricity grid.

  Similar to the Fill Rate Based Control, Demand Driven Based Control has the concept of multiple actuators. Again the behaviour of these actuators is described using a state machine. This time the states do not specify their influence of the fill level of the buffer is, but they specify a supply rate that can be matched with the demand. The CEM can select a state for each actuator as long as the demand is being matched by their aggregated supply.