Flexible Heat and Power, connecting heat and power networks by harnessing the complexity in distributed thermal flexibility

D4.3 Ecovat validation

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

Executive summary

The FHP concept is to use distributed thermal flexibility, such as provided by heat pumps in buildings, or large thermal storage solutions, such as the one provided by the Ecovat system, to make most effective use of available renewable energy, and to create the conditions to increase the amount of such renewable energy sources also at distribution system level.

The project has two pilot sites, one in Uden, the Netherlands and one in Karlshamn, Sweden.

This report focuses on the site in Uden, which consist of an Ecovat to which various power-to-heat systems are connected. The site is located in the electrical grid of the DSO Enexis.

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Published in the framework of:

FHP[1] **F**lexible **H**eat and power, **C**onnecting heat and power networks by harnessing the complexity in distributed thermal flexibility

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[1] **Disclaimer:**

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Glossary

Acronym	Full name
AGR	Aggregator
AWHP	Air Water Heat Pump
BRP	Balancing Responsible Party
DCM	Dynamic Coalition Manager (extension/specialization of Aggregator)
DM	Day ahead Market
DER	Distributed Energy Resource
DSO	Distribution System Operator
ISP	Imbalance Settlement Period
PBC	Pluggable Business Component
P2H	Power To Heat
PTU	Program Time Unit
RES	Renewable Energy Source
TSO	Transmission System Operator
USEF	Universal Smart Energy Framework (www.usef.energy)
WWHP	Water Water Heat Pump

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1 Introduction

1.1 About the FHP Project

The FHP project[2] – *Flexible Heat and Power: connecting Heat and Power networks by harnessing the complexity in distributed thermal flexibility* – was submitted under the call *LCE-01-2016-2017: Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network*, more specifically under the *Synergies between Energy Networks* area.

[2] See http://www.fhp-h2020.eu/ and http://cordis.europa.eu/programme/rcn/700614_en.html

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2 Ecovat Pilot Site Description

This section provides a summary of the pilot site in Uden, the Netherlands. A detailed description is provided in D4.1 Pilot Definition.

2.1 Premise

The Ecovat is a large subterranean and insulated vessel for thermal energy storage. Heat is exchanged by running hot or cold water through tubes inside the surrounding concrete elements, and the vessel is equipped with sensors to monitor the temperatures of the individual layers. The facility is located at President Kennedylaan 28 in Uden, the Netherlands.

Figure 1: Ecovat pilot site during construction

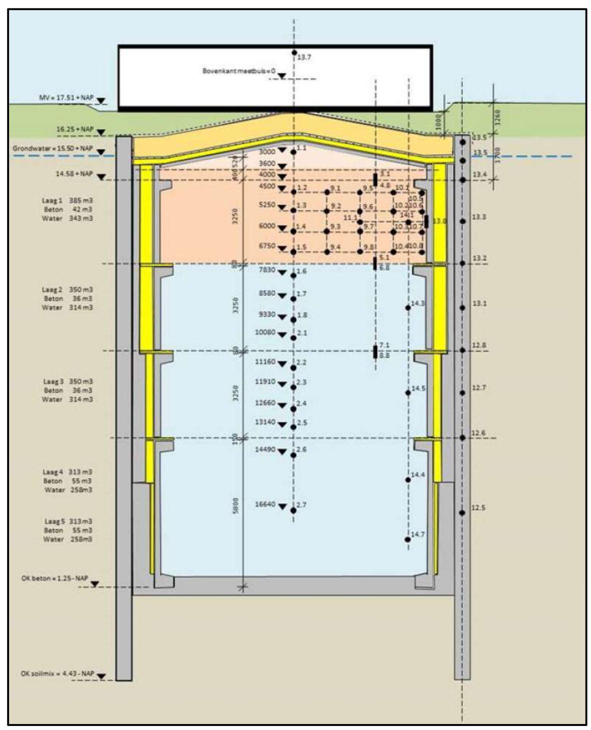

Figure 2: Intersection of the Ecovat pilot site

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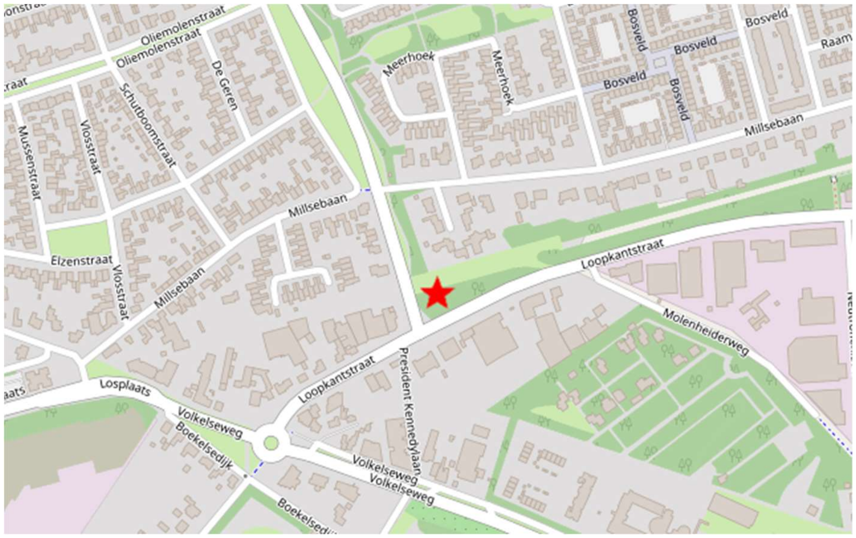

Figure 3: The Ecovat is located at President Kennedylaan 28 in Uden, the Netherlands.

The Ecovat system can roughly be divided into a number software and hardware components, marked in green and red in the figure below.

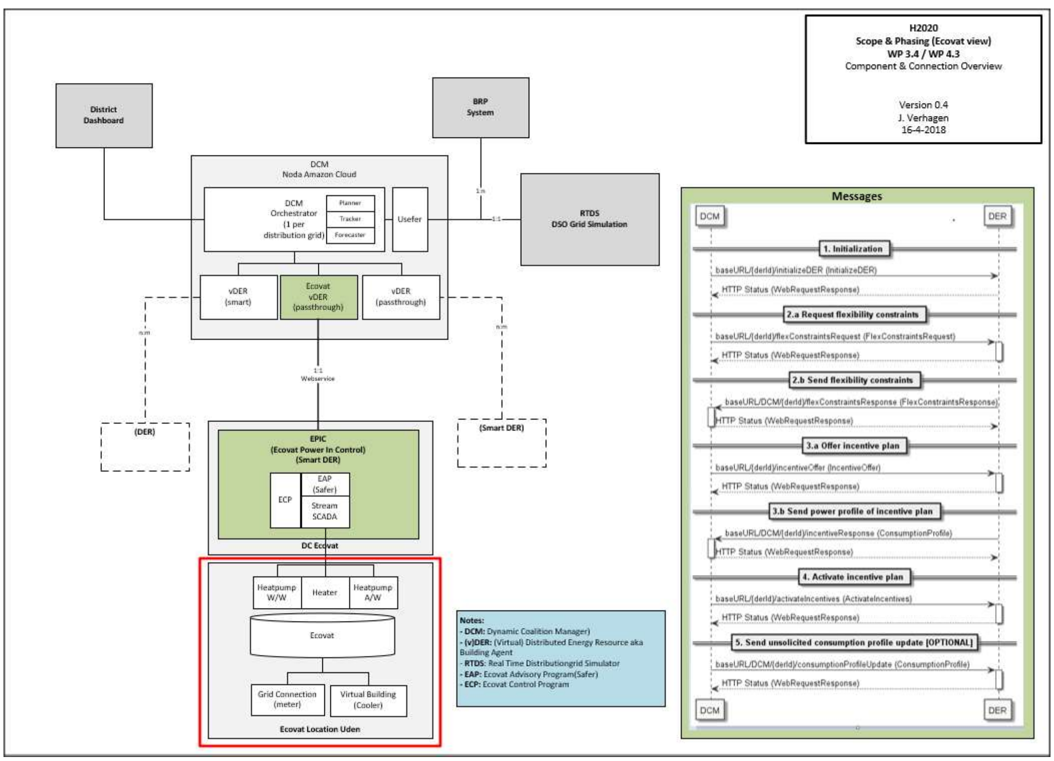

Figure 4: The software and hardware components are marked in green and red, respectively.

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2.2 The Ecovat Vessel

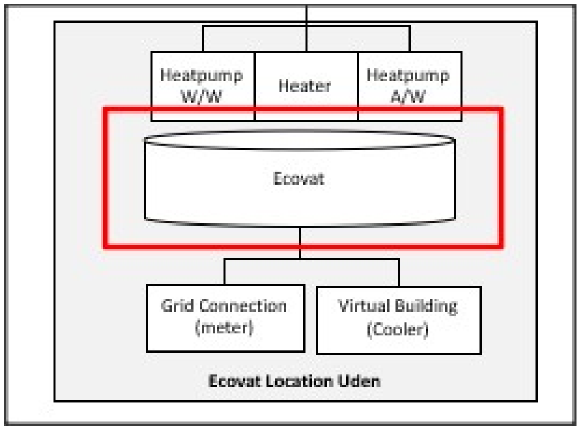

Figure 5: Ecovat vessel

Measurement	Quantity	Unit
Diameter of water column	11	m
Outside diameter	13	m
Height of water column	15.5	m
Number of thermal layers	5	
Number of elements per layer	11	
Maximum temperature	90	°C

Table 1: Characteristics of the Ecovat pilot site

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2.3 Water Water Heat Pump

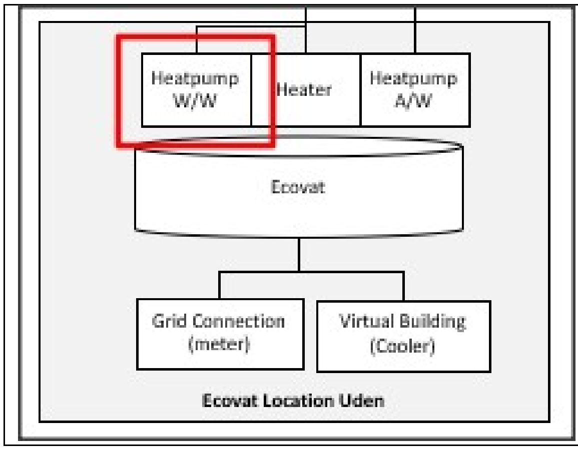

Figure 6: Ecovat water water heat pump

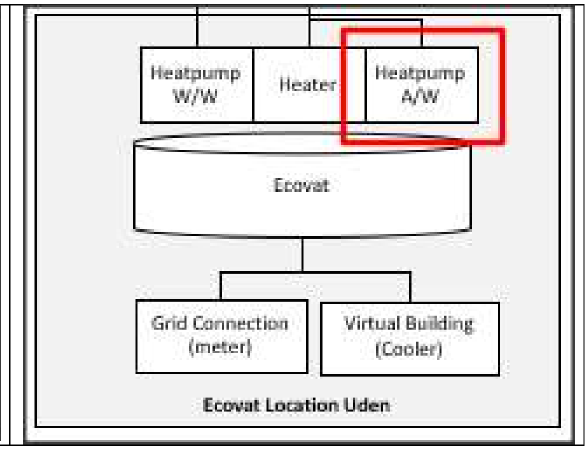

Figure 7: Ecovat air water heat pump

The Ecovat is equipped with two heat pumps, one NIBE F1155-12 and one NIBE F2120-12.

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2.4 Resistor

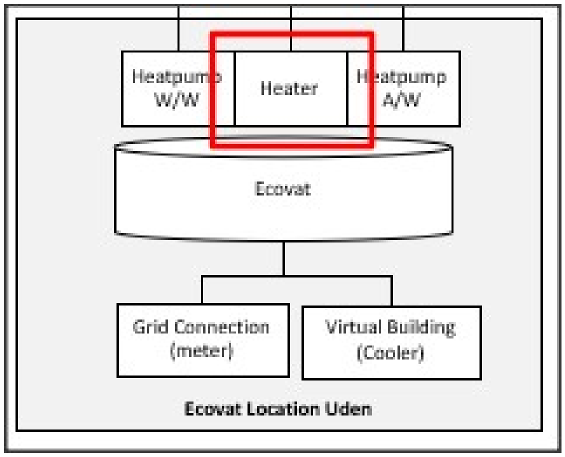

Figure 8: Ecovat resistor

Measurement, 6 x E-Tech W 28 tri	Quantity	Unit
Capacity (total)	13	L
Max operating temperature	85	°C
Max service pressure heating (primary)	3	bar
Weight (empty)	45	kg
Output power max (80/60°C)	28.8	kW
Output power min (80/60°C)	14.4	kW
Voltage	3 × 400 (+N)	V
Protection IP	43	
Electrical power	14.4 / 28.8	kW
Number of heating elements	6	
Electrical Resistance	2 × 2.4	mg/kWh
Capacity expansion tank(s)	10	L

Table 2: Resistor characteristics

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2.5 Grid Connection

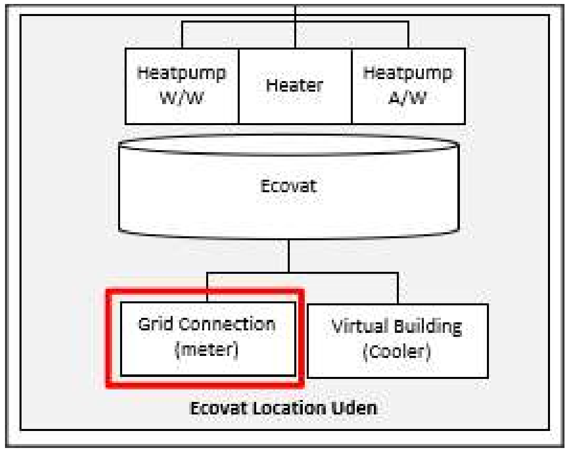

Figure 9: Ecovat grid connection

The Ecovat is connected to the grid through 3 × 250 A feeders through a medium to low voltage substation.

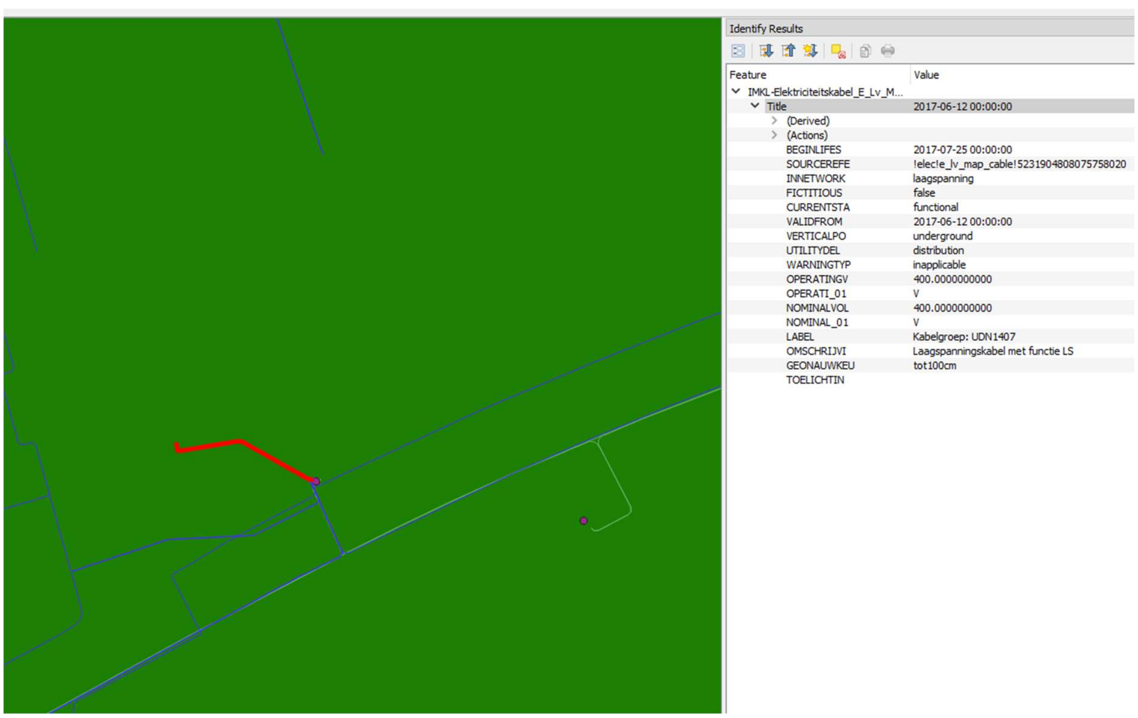

Figure 10: Ecovat grid connection layout

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2.6 Virtual Building

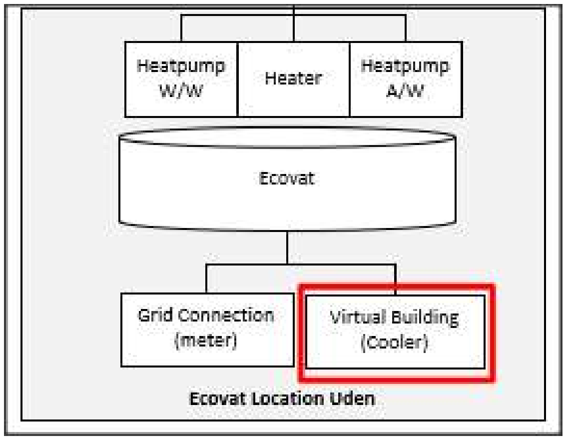

Figure 11: Ecovat dry cooler

The heat demand is simulated by means of a Horizontal Thermofin Drycooler with 2 × 910 mm fans.

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2.7 Software, ECOVAT Power in Control

2.8 ECOVAT Power in Control

The ECOVAT Power in Control (EPIC) system consisting of the ECOVAT Control Program (ECP), the ECOVAT Advice Program (EAP), and the Stream SCADA system.

2.8.1 ECOVAT Control Program

The ECOVAT Control Program (ECP) receives commands from the Stream SCADA system and responds with control signals targeting the hardware. ECP prevents the hardware from operating beyond its envelope.

2.8.2 ECOVAT Advice Program

The ECOVAT Advice Program (EAP) serves to compute optimal control actions with respect to the state of the Ecovat and exogenous variables such as weather forecasts and energy prices.

2.8.3 Stream

The Stream SCADA system is a high-level monitoring and control system connected with the ECP and the EAP.

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3 Validation of the FHP solution at Ecovat

3.1 Overall Test Plan

Test	Sub-test	Completed
Sensor/Actuator STREAM Communication Test	Digital Inputs	30-8-2018
	Digital Outputs	30-8-2018
	Analog Inputs	30-8-2018
	Analog Outputs	30-8-2018
	Counters	30-8-2018
	Inputs	30-8-2018
Control Vector Test		5-10-2018
DCM Connection Test		26-2-2019
Heat Pump Characterization test		31-10-2019

Table 3: Overall test plan

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4 Sensor/Actuator STREAM Communication Test

After the installation of the hardware and software, the connection between the sensors/actuators and STREAM is tested in order to make sure the state of the Ecovat can be logged and to make sure the Ecovat can be controlled.

4.1 Digital Inputs

Goal

To determine if the values measured by the digital sensors can be read by STREAM.

Method

The test was executed by comparing states locally with values received by STREAM. E.g. the state of a valve (open, closed) is compared with the most recent value logged by STREAM.

Test

Based on the final design of the pilot site, a list of all digital inputs was generated. For every digital input its value was compared with the corresponding sensor value.

Digital inputs
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RepNo	RtuNo	Address DI	Name	Akkoord	Opmerkingen
4	1	1	TT-COMM	V	
4	1	2	HTHP0301_STATE	V	
4	1	3	AWHP0501_STATE	V	
4	1	4	SPARE_DI0004	–	
4	1	5	SPARE_DI0005	–	
4	1	6	SPARE_DI0006	–	
4	1	7	SPARE_DI0007	–	
4	1	8	SPARE_DI0008	–	
4	1	9	SPARE_DI0009	–	
4	1	10	COMM_010101	V	
4	1	11	COMM_010102	V	
4	1	12	COMM_010201	V	
4	1	13	COMM_010202	V	
4	1	14	COMM_010301	V	
4	1	15	COMM_010302	V	
4	1	16	COMM_010401	V	
4	1	17	COMM_010501	V	
4	1	101	CV010101_OPEN		
4	1	102	CV010101_CLOSED		
4	1	103	CV010103_OPEN		
4	1	104	CV010103_CLOSED		
4	1	105	CV010104_OPEN		
4	1	106	CV010104_CLOSED		testen
4	1	107	CV010105_OPEN		→ Zie DO
4	1	108	CV010105_CLOSED		
4	1	109	CV010106_OPEN		
4	1	110	CV010106_CLOSED		
4	1	111	CV010107_OPEN		
4	1	112	CV010107_CLOSED		
4	1	113	CV010108_OPEN		
4	1	114	CV010108_CLOSED		
4	1	115	CV010109_OPEN		

Table 4: Digital inputs, part 1

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FepNo	RtuNo	Address DI	Name	Akkoord	Opmerkingen
4	1	116	CV010109_CLOSED		
4	1	117	CV010110_OPEN		
4	1	118	CV010110_CLOSED		
4	1	119	CV010201_OPEN		
4	1	120	CV010201_CLOSED		
4	1	121	CV010203_OPEN		
4	1	122	CV010203_CLOSED		
4	1	123	CV010204_OPEN		
4	1	124	CV010204_CLOSED		
4	1	125	CV010205_OPEN		
4	1	126	CV010205_CLOSED		
4	1	127	CV010206_OPEN		
4	1	128	CV010206_CLOSED		
4	1	129	CV010207_OPEN		
4	1	130	CV010207_CLOSED		
4	1	131	CV010208_OPEN		testen
4	1	132	CV010208_CLOSED		zie DC
4	1	133	CV010209_OPEN		
4	1	134	CV010209_CLOSED		
4	1	135	CV010210_OPEN		
4	1	136	CV010210_CLOSED		
4	1	137	CV010211_OPEN		
4	1	138	CV010211_CLOSED		
4	1	139	CV010301_OPEN		
4	1	140	CV010301_CLOSED		
4	1	141	CV010303_OPEN		
4	1	142	CV010303_CLOSED		
4	1	143	CV010304_OPEN		
4	1	144	CV010304_CLOSED		
4	1	145	CV010305_OPEN		
4	1	146	CV010305_CLOSED		
4	1	147	CV010306_OPEN		

Table 5: Digital inputs, part 2

FepNo	RtuNo	Address DI	Name	Akkoord	Opmerkingen
4	1	148	CV010306_CLOSED		
4	1	149	CV010307_OPEN		
4	1	150	CV010307_CLOSED		
4	1	151	CV010308_OPEN		
4	1	152	CV010308_CLOSED		
4	1	153	CV010309_OPEN		
4	1	154	CV010309_CLOSED		
4	1	155	CV010310_OPEN		
4	1	156	CV010310_CLOSED		
4	1	157	CV010311_OPEN		
4	1	158	CV010311_CLOSED		
4	1	159	CV010312_OPEN		
4	1	160	CV010312_CLOSED		
4	1	161	CV010401_OPEN		
4	1	162	CV010401_CLOSED		
4	1	163	CV010403_OPEN		
4	1	164	CV010403_CLOSED		zie DC
4	1	165	CV010404_OPEN		
4	1	166	CV010404_CLOSED		
4	1	167	CV010405_OPEN		
4	1	168	CV010405_CLOSED		
4	1	169	CV010406_OPEN		
4	1	170	CV010406_CLOSED		
4	1	171	CV010407_OPEN		
4	1	172	CV010407_CLOSED		
4	1	173	CV010408_OPEN		
4	1	174	CV010408_CLOSED		
4	1	175	CV010409_OPEN		
4	1	176	CV010409_CLOSED		
4	1	177	CV010410_OPEN		
4	1	178	CV010410_CLOSED		
4	1	179	CV010411_OPEN		

Table 6: Digital inputs, part 3

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FepNo	RtuNo	Address DI	Name	Akkoord	Opmerkingen
4	1	180	CV010411_CLOSED		
4	1	181	CV010412_OPEN		
4	1	182	CV010412_CLOSED		
4	1	183	CV010501_OPEN		
4	1	184	CV010501_CLOSED		
4	1	185	CV010503_OPEN		
4	1	186	CV010503_CLOSED		
4	1	187	CV010504_OPEN		
4	1	188	CV010504_CLOSED		
4	1	189	CV010505_OPEN		
4	1	190	CV010505_CLOSED		
4	1	191	CV010506_OPEN		
4	1	192	CV010506_CLOSED		
4	1	193	CV010507_OPEN		
4	1	194	CV010507_CLOSED		
4	1	195	SPARE_DI0195		
4	1	196	SPARE_DI0196		
4	1	197	CV0201_OPEN		→ Zie Do
4	1	198	CV0201_CLOSED		
4	1	199	CV0202_OPEN		
4	1	200	CV0202_CLOSED		
4	1	201	CV0301_OPEN		
4	1	202	CV0301_CLOSED		
4	1	203	CV0302_OPEN		
4	1	204	CV0302_CLOSED		
4	1	205	CV0501_OPEN		
4	1	206	CV0501_CLOSED		
4	1	207	CV0502_OPEN		
4	1	208	CV0502_CLOSED		
4	1	209	CV0503_OPEN		
4	1	210	CV0503_CLOSED		
4	1	211	CV0504_OPEN		

Table 7: Digital inputs, part 4

FepNo	RtuNo	Address DI	Name	Akkoord	Opmerkingen
4	1	212	CV0504_CLOSED		
4	1	213	CV0505_OPEN		
4	1	214	CV0505_CLOSED		
4	1	215	CV0801_OPEN		
4	1	216	CV0801_CLOSED		
4	1	217	CV3101_OPEN		
4	1	218	CV3101_CLOSED		
4	1	219	CV0901_OPEN		Zie Do
4	1	220	CV0901_CLOSED		
4	1	221	CV0902_OPEN		
4	1	222	CV0902_CLOSED		
4	1	223	SPARE_DI0223		
4	1	224	SPARE_DI0224		
4	1	225	SPARE_DI0225		
4	1	226	SPARE_DI0226		
4	1	227	SPARE_DI0227		
4	1	228	SPARE_DI0228		

Table 8: Digital inputs, part 5

Results

The digital inputs to register the state of the valves were not used. The spare digital inputs were not used. The digital inputs that were used, transmitted the correct values.

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4.2 Digital Outputs

Goal

To determine if the values sent resulted in expected control actions.

Method

The test was executed by comparing the commands sent from STREAM with the resulting state of the devices locally.

Test

Based on the final design of the pilot site, a list of all digital ouputs was generated. For every digital ouput, its value was compared with the corresponding actuator state.

Digital outputs 30-08-2018
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FepNo	RtuNo	Address	Name	Akkoord	Opmerkingen
4	1	1	HTHP0301_BLOCK_Heating	V	
4	1	2	HTHP0301_BLOCK_Compressor	—	
4	1	3	AWHP0501_BLOCK_Heating	V	
4	1	4	AWHP0501_BLOCK_Compressor	V	
4	1	5	DC3101	V	
4	1	6	SPARE_DO0005	—	
4	1	7	SPARE_DO0007	—	
4	1	8	SPARE_DO0008	—	
4	1	9	EB0901	V	
4	1	10	EB090101	V	
4	1	11	EB090102	V	
4	1	12	EB090103	V	
4	1	13	EB090104	V	
4	1	14	EB0902		
4	1	15	EB090201		
4	1	16	EB090202		
4	1	17	EB090203		
4	1	18	EB090204		
4	1	19	EB0903		
4	1	20	EB090301		
4	1	21	EB090302		
4	1	22	EB090303		
4	1	23	EB090304		
4	1	24	EB0904		
4	1	25	EB090401		
4	1	26	EB090402		
4	1	27	EB090403		
4	1	28	EB090404		
4	1	29	EB0905		
4	1	30	EB090501		

Table 9: Digital outputs, part 1

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FepNo	RtuNo	Address	Name	Akkoord	Opmerkingen
4	1	31	EB090502		
4	1	32	EB090503		
4	1	33	EB090504		
4	1	34	EB0906		
4	1	35	EB090601		
4	1	36	EB090602		
4	1	37	EB090603		
4	1	38	EB090604		
4	1	39	SPARE_DO0039	-	
4	1	40	SPARE_DO0040	-	
4	1	101	CV010101	V	
4	1	102	CV010103	→	niet gecodeerd.
4	1	103	CV010104	V	
4	1	104	CV010105	V	
4	1	105	CV010106	V	
4	1	106	CV010107	V	
4	1	107	CV010108	V	
4	1	108	CV010109	→	geen open contact. fout config
4	1	109	CV010110	V	
4	1	110	CV010201	V	
4	1	111	CV010203	V →	niet gecodeerd
4	1	112	CV010204	V	
4	1	113	CV010205	V	
4	1	114	CV010206	V	
4	1	115	CV010207	V	
4	1	116	CV010208	V	
4	1	117	CV010209	V	
4	1	118	CV010210	V	
4	1	119	CV010211	V	
4	1	120	CV010301	V	
4	1	121	CV010303	V	
4	1	122	CV010304	V	

Table 10: Digital outputs, part 2

FepNo	RtuNo	Address	Name	Akkoord	Opmerkingen
4	1	123	CV010305	V	
4	1	124	CV010306	V →	Open contact komt niet binnen
4	1	125	CV010307	V	
4	1	126	CV010308	V	
4	1	127	CV010309	V	Niet gecodeerd.
4	1	128	CV010310	V	
4	1	129	CV010311	V	
4	1	130	CV010312	V	
4	1	131	CV010401	V	
4	1	132	CV010403	V	niet gecodeerd
4	1	133	CV010404	V	
4	1	134	CV010405	V	
4	1	135	CV010406	V	
4	1	136	CV010407	V	
4	1	137	CV010408	V	
4	1	138	CV010409	V	
4	1	139	CV010410	V	
4	1	140	CV010411	V	Niet gecodeerd.
4	1	141	CV010412	V	
4	1	142	CV010501	V	
4	1	143	CV010503	V	
4	1	144	CV010504	V	
4	1	145	CV010505	V	
4	1	146	CV010506	V	
4	1	147	CV010507	V	
4	1	148	SPARE_DO0148	-	
4	1	149	CV0201	V	
4	1	150	CV0202	V	Niet gecodeerd
4	1	151	CV0301		
4	1	152	CV0302		Doet niets NA
4	1	153	CV0501	V	
4	1	154	CV0502	V	

Table 11: Digital outputs, part 3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

FepNo	RtuNo	Address	Name	Akkoord	Opmerkingen
4	1	155	CV0503	V	
4	1	156	CV0504	V	
4	1	157	CV0505	V	
4	1	158	CV0801	V	
4	1	159	CV3101		Doet niets N/A
4	1	160	CV0901	V	
4	1	161	CV0902	V	
4	1	162	SPARE_DO0162	–	
4	1	163	SPARE_DO0163	–	
4	1	164	SPARE_DO0164	–	

Table 12: Digital outputs, part 4

Results

Flipping each digital output resulted in the correct state for the corresponding actuator.

4.3 Analog Inputs

Goal

To determine if the values measured by the analog sensors can be read by STREAM.

Method

The test was executed by comparing states locally with values received by STREAM. E.g. the state of a temperature sensor is compared with the most recent value logged by STREAM.

Test

Based on the final design of the pilot site, a list of all analog inputs was generated. For every analog input its value was compared with the corresponding sensor value.

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Analog Inputs 30-08-2008
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FepNo	RtuNo	Address AI	Name	Akkoord	Opmerkingen
4	1	1	NA_CV010101_RETURN		
4	1	2	NA_CV010103_RETURN		
4	1	3	NA_CV010104_RETURN		
4	1	4	NA_CV010105_RETURN		
4	1	5	NA_CV010106_RETURN		
4	1	6	NA_CV010107_RETURN		
4	1	7	NA_CV010108_RETURN		
4	1	8	NA_CV010109_RETURN		
4	1	9	NA_CV010110_RETURN		
4	1	10	NA_CV010201_RETURN		
4	1	11	NA_CV010203_RETURN		
4	1	12	NA_CV010204_RETURN		NA is niet aanwezig.
4	1	13	NA_CV010205_RETURN		
4	1	14	NA_CV010206_RETURN		
4	1	15	NA_CV010207_RETURN		
4	1	16	NA_CV010208_RETURN		
4	1	17	NA_CV010209_RETURN		
4	1	18	NA_CV010210_RETURN		
4	1	19	NA_CV010211_RETURN		
4	1	20	NA_CV010301_RETURN		
4	1	21	NA_CV010303_RETURN		
4	1	22	NA_CV010304_RETURN		
4	1	23	NA_CV010305_RETURN		
4	1	24	NA_CV010306_RETURN		
4	1	25	NA_CV010307_RETURN		
4	1	26	NA_CV010308_RETURN		
4	1	27	NA_CV010309_RETURN		
4	1	28	NA_CV010310_RETURN		
4	1	29	NA_CV010311_RETURN		
4	1	30	NA_CV010312_RETURN		
4	1	31	NA_CV010401_RETURN		
4	1	32	NA_CV010403_RETURN		

Table 13: Analog inputs, part 1

FepNo	RtuNo	Address AI	Name	Akkoord	Opmerkingen
4	1	33	NA_CV010404_RETURN		
4	1	34	NA_CV010405_RETURN		
4	1	35	NA_CV010406_RETURN		
4	1	36	NA_CV010407_RETURN		
4	1	37	NA_CV010410_RETURN		
4	1	38	NA_CV010411_RETURN		
4	1	39	NA_CV010412_RETURN		
4	1	40	NA_CV010501_RETURN		
4	1	41	NA_CV010503_RETURN		
4	1	42	NA_CV010504_RETURN		
4	1	43	NA_CV010505_RETURN		
4	1	44	NA_CV010506_RETURN		
4	1	45	NA_CV010507_RETURN		
4	1	46	SPARE_AI0046	–	
4	1	47	SPARE_AI0047	–	
4	1	48	SPARE_AI0048	–	
4	1	49	TT0201	V	
4	1	50	TT0202	V	
4	1	51	TT0203	V	
4	1	52	TT002	V	
4	1	53	TT0303	V	
4	1	54	TT0501	V	
4	1	55	TT0502	V	
4	1	56	TT0503	V	
4	1	57	TT0801	V	
4	1	58	TT0802	V	~~NA~~ Nu ruimte temp.
4	1	59	TT0803		NA
4	1	60	TT0804		NA
4	1	61	TT3101	V	
4	1	62	TT3102		NA
4	1	63	TT3103	V	
4	1	65	TT0901	V	

Table 14: Analog inputs, part 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

FepNo	RtuNo	Address AI	Name	Akkoord	Opmerkingen
4	1	66	TT0902	√	
4	1	67	TT0903	√	
4	1	68	TT0904	√	
4	1	69	TT0905	√	
4	1	70	TT0906	√	
4	1	71	TT0907	√	
4	1	72	TT0908	√	
4	1	73	SPARE	–	
4	1	74	NA_CV0201_RETURN		
4	1	75	NA_CV0202_RETURN		
4	1	76	NA_CV0301_RETURN		
4	1	77	NA_CV0302_RETURN		
4	1	78	NA_CV0501_RETURN		
4	1	79	NA_CV0503_RETURN		
4	1	80	NA_CV0504_RETURN		
4	1	81	NA_CV0505_RETURN		
4	1	82	NA_CV0801_RETURN		
4	1	83	NA_CV3101_RETURN		
4	1	84	NA_CV0901_RETURN		
4	1	85	NA_CV0902_RETURN		
4	1	86	SPARE_AO0086	–	
4	1	87	SPARE_AO0087	–	
4	1	88	SPARE_AO0088	–	
4	1	89	SPARE_AO0089	–	
4	1	601	CP0501OperationStatus	√	
4	1	602	CP0501WarningError	√	
4	1	611	CP3101OperationStatus	√	
4	1	612	CP3101WarningError	√	
4	1	621	CP0907OperationStatus	√	
4	1	622	CP0907WarningError	√	

Table 15: Analog inputs, part 3

Results

The control valves were replaced late in the building process. Therefore the CV_xxxxx_RETURN were not used. The spares were not used. The analog inputs that were used returned the values observed at the site.

4.4 Analog Outputs

Goal

To determine if the values sent resulted in expected control actions.

Method

The test was executed by comparing the commands sent from STREAM with the resulting state of the devices locally.

Test

Based on the final design of the pilot site, a list of all analog outputs was generated. For every analog output its value was compared with the corresponding actuator state.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

Analog outputs. 20-08-2018

Alle I/O getest Etienne Hilgen

FepNo	RtuNo	Address AO	Name	Akkoord	Opmerkingen
4	1	1	NA_CV010101		
4	1	2	NA_CV010103		
4	1	3	NA_CV010104		
4	1	4	NA_CV010105		
4	1	5	NA_CV010106		
4	1	6	NA_CV010107		
4	1	7	NA_CV010108		
4	1	8	NA_CV010109		
4	1	9	NA_CV010110		
4	1	10	NA_CV010201		
4	1	11	NA_CV010203		
4	1	12	NA_CV010204		NA = Niet aanwezig.
4	1	13	NA_CV010205		
4	1	14	NA_CV010206		
4	1	15	NA_CV010207		
4	1	16	NA_CV010208		
4	1	17	NA_CV010209		
4	1	18	NA_CV010210		
4	1	19	NA_CV010211		
4	1	20	NA_CV010301		
4	1	21	NA_CV010303		
4	1	22	NA_CV010304		
4	1	23	NA_CV010305		
4	1	24	NA_CV010306		
4	1	25	NA_CV010307		
4	1	26	NA_CV010308		
4	1	27	NA_CV010309		
4	1	28	NA_CV010310		
4	1	29	NA_CV010311		
4	1	30	NA_CV010312		
4	1	31	NA_CV010401		
4	1	32	NA_CV010403		

Table 16: Analog outputs, part 1

FepNo	RtuNo	Address AO	Name	Akkoord	Opmerkingen
4	1	33	NA_CV010404		
4	1	34	NA_CV010405		
4	1	35	NA_CV010406		
4	1	36	NA_CV010407		
4	1	37	NA_CV010408		
4	1	38	NA_CV010409		
4	1	39	NA_CV010410		
4	1	40	NA_CV010411		
4	1	41	NA_CV010412		
4	1	42	NA_CV010501		
4	1	43	NA_CV010503		
4	1	44	NA_CV010504		
4	1	45	NA_CV010505		
4	1	46	NA_CV010506		
4	1	47	NA_CV010507		
4	1	48	SPARE_AO0048		
4	1	49	NA_CV0201		
4	1	50	NA_CV0202		
4	1	51	NA_CV0301		
4	1	52	NA_CV0302		
4	1	53	NA_CV0501		
4	1	54	NA_CV0502		
4	1	55	NA_CV0503		
4	1	56	NA_CV0504		
4	1	57	NA_CV0505		
4	1	58	NA_CV0801		
4	1	59	NA_CV3101		
4	1	60	NA_CV0901		
4	1	61	NA_CV0902		
4	1	62	DC3101_SETPOINT	V	
4	1	63	SPARE_AO0063	–	
4	1	64	SPARE_AO0064	–	

Table 17: Analog outputs, part 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

FepNo	RtuNo	Address AO	Name	Akkoord	Opmerkingen
4	1	601	CP0501SetValue	√	
4	1	602	CP0501PumpCommand	√	
4	1	603	CP0501OperationMode	√	
4	1	611	CP3101SetValue	√	
4	1	612	CP3101PumpCommand	√	
4	1	613	CP3101OperationMode	√	
4	1	621	CP0907SetValue	√	
4	1	622	CP0907PumpCommand	√	
4	1	623	CP0907OperationMode	√	

Table 18: Analog outputs, part 3

Results

The control valves were replaced late in the building process. Therefore, the CV_xxxxxx were not used. The spares were not used. Setting the analog outputs that were used resulted in an expected state locally.

4.5 Counters

Goal

To determine is the values stored by the counters are correctly transferred to STREAM.

Method

Compare the values locally with the values registered by STREAM.

Test

Based on the final design of the pilot site, a list of all counters was generated. For every counter its value was compared with the corresponding actuator state.

Counters 30-08-2018
Alle I/O getest Etienne Hilgen

FepNo	RtuNo	Address CI	Name	Akkoord	Opmerkingen
4	1	601	CP0501PowerConsumption	√	
4	1	602	CP0501OperationHours	√	
4	1	611	CP3101PowerConsumption	√	
4	1	612	CP3101OperationHours	√	
4	1	621	CP0907PowerConsumption	√	
4	1	622	CP0907OperationHours	√	
4	1	701	QT010101HeatEnergyE1	√	Modbus
4	1	702	FT010101VolumeV1	√	
4	1	711	QT010102HeatEnergyE1	√	
4	1	712	FT010102VolumeV1	√	
4	1	721	QT010201HeatEnergyE1	√	
4	1	722	FT010201VolumeV1	√	
4	1	731	QT010202HeatEnergyE1	√	
4	1	732	FT010202VolumeV1	√	
4	1	741	QT010301HeatEnergyE1	√	
4	1	742	FT010301VolumeV1	√	
4	1	751	QT010302HeatEnergyE1	√	
4	1	752	FT010302VolumeV1	√	
4	1	754	FT010401VolumeV1	√	
4	1	761	QT010401HeatEnergyE1	√	

Table 19: Counters

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

Result

For every counter the value observed locally corresponded with the value observed in STREAM.

4.6 Additional Inputs

Goal

In the vessel 96 temperature sensors are installed to monitor the state of the Ecovat. In the pipes from and to the power-to-heat systems, temperature and flow sensors are installed. This test determines of the measurements conducted by those sensors are correctly transmitted to STEAM.

Method

Compare the values, expectations or estimations locally with the values registered by STREAM.

Test

Based on the final design of the pilot site, a list of sensors was generated. For every sensor its value was compared with the corresponding actuator state.

Real Inputs Alle uitgetest 30-08-2018 Etienne Hilgen

FepNo	RtuNo	Address RI	Name	Akkoord
4	1	1	TT000101	√
4	1	2	TT000102	√
4	1	3	TT000103	√
4	1	4	TT000104	√
4	1	5	TT000105	√
4	1	6	TT000106	√
4	1	7	TT000107	√
4	1	8	TT000108	√
4	1	9	TT000109	√
4	1	10	TT000110	√
4	1	11	TT000111	√
4	1	12	TT000112	√
4	1	13	TT000113	√
4	1	14	TT000114	√
4	1	15	TT000115	√
4	1	16	TT000116	√
4	1	17	TT000117	√
4	1	18	TT000118	√
4	1	19	TT000201	√
4	1	20	TT000202	√
4	1	21	TT000203	√
4	1	22	TT000204	√
4	1	23	TT000205	√
4	1	24	TT000206	√
4	1	25	TT000207	√
4	1	26	TT000208	√
4	1	27	TT000209	√
4	1	28	TT000210	√
4	1	29	TT000211	√
4	1	30	TT000212	√
4	1	31	TT000213	√
4	1	32	TT000214	√

Table 20: Additional inputs, part 1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

4	1	33	TT000215	√
4	1	34	TT000301	√
4	1	35	TT000302	√
4	1	36	TT000303	√
4	1	37	TT000304	√
4	1	38	TT000305	√
4	1	39	TT000401	√
4	1	40	TT000402	√
4	1	41	TT000403	√
4	1	42	TT000404	√
4	1	43	TT000501	√
4	1	44	TT000502	√
4	1	45	TT000503	√
4	1	46	TT000504	√
4	1	51	TT000119	√
4	1	52	TT000120	√
4	1	53	TT000121	√
4	1	54	TT000122	√
4	1	55	TT000123	√
4	1	56	TT000124	√
4	1	57	TT000125	√
4	1	58	TT000126	√
4	1	59	TT000127	√
4	1	60	TT000128	√
4	1	61	TT000129	√
4	1	62	TT000130	√
4	1	63	TT000131	√
4	1	64	TT000132	√
4	1	65	TT000133	√
4	1	66	TT000134	√
4	1	67	TT000135	√
4	1	68	TT000136	√
4	1	69	TT000216	√

Table 21: Additional inputs, part 2

4	1	70	TT000217	√
4	1	71	TT000218	√
4	1	72	TT000219	√
4	1	73	TT000220	√
4	1	74	TT000221	√
4	1	75	TT000222	√
4	1	76	TT000223	√
4	1	77	TT000224	√
4	1	78	TT000225	√
4	1	79	TT000226	√
4	1	80	TT000227	√
4	1	81	TT000228	√
4	1	82	TT000229	√
4	1	83	TT000230	√
4	1	84	TT000306	√
4	1	85	TT000307	√
4	1	86	TT000308	√
4	1	87	TT000309	√
4	1	88	TT000310	√
4	1	89	TT000405	√
4	1	90	TT000406	√
4	1	91	TT000407	√
4	1	92	TT000408	√
4	1	93	TT000505	√
4	1	94	TT000506	√
4	1	95	TT000507	√
4	1	96	TT000508	√
4	1	500	TT000100_AVG	– PVC
4	1	501	TT000200_AVG	– PVC
4	1	502	TT000300_AVG	– PVC
4	1	503	TT000400_AVG	– PVC
4	1	504	TT000500_AVG	– PVC
4	1	601	CP0501FlowRate	√ modbus

Table 22: Additional inputs, part 3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

4	1	602	CP0501Speed	√
4	1	611	CP3101FlowRate	√
4	1	612	CP3101Speed	√
4	1	621	CP0907FlowRate	√
4	1	622	CP0907Speed	√
4	1	701	FT010101Flow1	√
4	1	702	QT010101ActualPower	√
4	1	703	TT010101	√
4	1	704	TT010102	√
4	1	711	FT010102Flow1	√
4	1	712	QT010102ActualPower	√
4	1	713	TT010103	√
4	1	714	TT010104	√
4	1	721	FT010201Flow1	√
4	1	722	QT010201ActualPower	√
4	1	723	TT010201	√
4	1	724	TT010202	√
4	1	731	FT010202Flow1	√
4	1	732	QT010202ActualPower	√
4	1	733	TT010203	√
4	1	734	TT010204	√
4	1	741	FT010301Flow1	√
4	1	742	QT010301ActualPower	√
4	1	743	TT010301	√
4	1	744	TT010302	√
4	1	751	FT010302Flow1	√
4	1	752	QT010302ActualPower	√
4	1	753	TT010303	√
4	1	754	TT010304	√
4	1	761	FT010401Flow1	√
4	1	762	QT010401ActualPower	√
4	1	763	TT010401	√
4	1	764	TT010402	√

modbus

Table 23: Additional inputs, part 4

4	1	771	FT010501Flow1	√
4	1	772	QT010501ActualPower	√
4	1	773	TT010501	√
4	1	774	TT010502	√

Table 24: Additional inputs, part 5

Result

All sensors transmitted their values to STREAM. The sensors with tag TT000x00_AVG were not present and therefore not tested.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

5 Control Vector Test

A control vector is a set of single control actions. E.g for charging the top layer with the resistors, multiple actuators have to be controlled, i.e. the resistor itself, a pump and multiple valves.

Goal

To check that each control vectors controls the right actuators.

Method

After activating a control vector, the state of each actuator is observed.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731231.

Test

After activating a control vector, the state of each actuator is compared with a description of the control vector.

	Description	PLC base formula	Test 5-10-2018
1	R_RL_1	(Resistor.RL[1])	OK
2	R_RL_2	(Resistor.RL[2])	OK
3	R_RL_3	(Resistor.RL[3])	OK
4	R_RL_4	(Resistor.RL[4])	OK
5	HTHP_RL_1 AND HTHP_AL_5	(HtHp.RL[1] AND HtHp.AL[5])	OK
6	HTHP_RL_1 AND HTHP_AL_4	(HtHp.RL[1] AND HtHp.AL[4])	OK after modification
7	HTHP_RL_1 AND HTHP_AL_3	(HtHp.RL[1] AND HtHp.AL[3])	OK after modification
8	HTHP_RL_2 AND HTHP_AL_5	(HtHp.RL[2] AND HtHp.AL[5])	OK
9	HTHP_RL_2 AND HTHP_AL_4	(HtHp.RL[2] AND HtHp.AL[4])	OK
10	HTHP_RL_2 AND HTHP_AL_3	(HtHp.RL[2] AND HtHp.AL[3])	OK
11	HTHP_RL_3 AND HTHP_AL_5	(HtHp.RL[3] AND HtHp.AL[5])	OK
12	HTHP_RL_3 AND HTHP_AL_4	(HtHp.RL[3] AND HtHp.AL[4])	OK
13	HTHP_RL_4 AND HTHP_AL_5	(HtHp.RL[4] AND HtHp.AL[5])	OK after modification
14	AWHP_RL_1	(AwHp.RL[1])	OK after modification
15	AWHP_RL_2	(AwHp.RL[2])	OK
16	AWHP_RL_3	(AwHp.RL[3])	OK
17	AWHP_RL_4	(AwHp.RL[4])	OK
22	BH_AL_1	(BuildingHeating.AL[1])	OK
23	BH_AL_2	(BuildingHeating.AL[2])	OK
24	BH_AL_3	(BuildingHeating.AL[3])	OK
25	BH_AL_4	(BuildingHeating.AL[4])	OK
29	BC_RL_5	(BuildingCooling.RL[5])	OK
30	BC_RL_4	(BuildingCooling.RL[4])	OK

Table 25: All control vectors and test results

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	22	23	24	25	29	30
CV010101_PLC	DO	1	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CV010103_PLC	DO	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010104_PLC	DO	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010105_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CV010106_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010107_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CV010108_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CV010109_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010110_PLC	DO	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010201_PLC	DO	0	1	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
CV010203_PLC	DO	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010204_PLC	DO	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010205_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CV010206_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010207_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CV010208_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CV010209_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010210_PLC	DO	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010211_PLC	DO	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
CV010301_PLC	DO	0	0	1	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0
CV010303_PLC	DO	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010304_PLC	DO	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010305_PLC	DO	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
CV010306_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CV010307_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010308_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CV010309_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CV010310_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010311_PLC	DO	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0
CV010312_PLC	DO	0	0	0	1	0	0	1	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0
CV010401_PLC	DO	0	0	0	1	0	1	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0
CV010403_PLC	DO	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010404_PLC	DO	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CV010405_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CV010406_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CV010407_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010408_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CV010409_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CV010410_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010411_PLC	DO	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0
CV010412_PLC	DO	0	0	0	0	0	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
CV010501_PLC	DO	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
CV010503_PLC	DO	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
CV010504_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV010505_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
CV010506_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
CV010507_PLC	DO	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
CV0201_PLC	DO	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
CV0202_PLC	DO	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
CV0301_PLC	DO	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV0302_PLC	DO	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
CV0501_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
CV0502_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CV0503_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV0504_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
CV0505_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV0801_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV0901_PLC	DO	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV0902_PLC	DO	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CV3101_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CP0201 (F1155)	N/A	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
CP0301 (F1155)	N/A	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
CP0501_PLC	MOD	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
CP0801	N/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CP0802	N/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CP0907_PLC	MOD	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CP3101_PLC	MOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
CP3102_PLC	MOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
CP31002_PLC	N/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
DC3101_SETPOINT	AO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
HTHP0301_PLC	DO	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
AWHP0501_PLC	DO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0

Table 26: Incidence matrix describing the relationship between control vectors and control actions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

Result

The observed control actions were similar to the control actions in the incidence matrix.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6 DCM (VITO) and Ecovat Interaction Tests

In this series of tests, the interaction between the VITO DCM and the Ecovat was tested. This a subset of the data available in [FHP Test protocol WP4.xlsx] created by Davy Geysen (VITO).

6.1 Test with tag "ECOVAT UC1 17_12_2018"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) and the ECOVAT for 1 cycle with blocking control signals.

Test

Test was logged by Ecovat. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	17-12-2018	Davy Geysen	Success		Not available
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	17-12-2018	Davy Geysen	Success		Not available
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	17-12-2018	Davy Geysen	Success		Not available
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	17-12-2018	Davy Geysen	Success		Not available
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	17-12-2018	Davy Geysen	Success		Not available
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	17-12-2018	Davy Geysen	Success		Not available
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	17-12-2018	Davy Geysen	Success		Not available
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	17-12-2019	Davy Geysen	Success		Not available
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	17-12-2019	Davy Geysen	Success		Not available
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	17-12-2019	Davy Geysen	Failure	DCM sent an ActivateIncentives message with test flag False. Following this the control signals were not blocked and the Ecovat started running the profile and heating up.	Not available
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	Activated consumption profile is correctly followed and logged by the Ecovat	The electricity consumption measurements of the Ecovat show that the activated consumption profile is followed	17-12-2018	Wiet Mazairac	Success/Failure	The profile was followed by the Ecovat BUT it was repeated after 24 hours which is unwanted behaviour. Ecovat made changes to the code to make sure the profile will not be repeated when it's finished	See graph below
		UC1.8	Product/Service KPI Calculation							
		UC1.1.1	DA Cycle	The first cycle was correctly executed	The full cycle of UC1 was successfully executed	17-12-2018	Davy Geysen - Wiet Mazairac	Success/Failure	The cycle itself was successfully executed but the test flag of the control actions was put to False instead of True. Due to this the control signals were executed and it was found that the requested profile was repeated after 24h which was incorrect behavior	See graph below
		UC1.1.2	ID Cycle - 6/18h	NA	NA					
		UC1.1.3	ID Cycle - 12/18h	NA	NA					
		UC1.1.4	ID Cycle - 18/18h	NA	NA					

Table 27: Test with tag "ECOVAT UC1 17_12_2018"

Result

Partial success. DCM sent an ActivateIncentives message with test flag False. Following this the control signals were not blocked and the Ecovat started running the profile and heating up.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

The profile was followed by the Ecovat BUT it was repeated after 24 hours which is unwanted behaviour. Ecovat made changes to the code to make sure the profile will not be repeated when it's finished.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.2 Test with tag "ECOVAT UC1 20_12_2018"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT for 3 days with blocking control signals.

Test

Test was logged by Ecovat. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									Not available
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	20-12-2018	Davy Geysen	Success		Not available
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	20-12-2018	Davy Geysen	Success		Not available
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	20-12-2018	Davy Geysen	Success		Not available
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	20-12-2018	Davy Geysen	Success		Not available
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	20-12-2018	Davy Geysen	Success		Not available
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	20-12-2018	Davy Geysen	Success	It was seen that the IncentiveResponse always gave a flexibility of 0 kW for the Ecovat. This was not correct because the Ecovat was cold, i.e. it has flexibility to start charging. Because of this every ADMM cycle converged in only 1 iteration.	Not available
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	20-12-2018	Davy Geysen	Success		Not available
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	20-12-2019	Davy Geysen	Success		Not available
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	20-12-2019	Davy Geysen	Success		Not available
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	20-12-2019	Davy Geysen	Success		Not available
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.8	Product/Service KPI Calculation	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.1.1	DA Cycle	The first cycle of UC1 was correctly executed	The full cycle of UC1 was successfully executed	20-12-2018	Davy Geysen	Success		Not available
		UC1.1.2	ID Cycle - 6/18h	The first cycle of UC1 was correctly executed	The full cycle of UC1 was successfully executed	20-12-2018	Davy Geysen	Success		Not available
		UC1.1.3	ID Cycle - 12/18h	The first cycle of UC1 was correctly executed	The full cycle of UC1 was successfully executed	20-12-2018	Davy Geysen	Success		Not available
		UC1.1.4	ID Cycle - 18/18h	The first cycle of UC1 was correctly executed	The full cycle of UC1 was successfully executed	20-12-2018	Davy Geysen	Success		Not available

Table 28: Test with tag "ECOVAT UC1 20_12_2018"

Result

Success. The full cycle of UC1 was successfully executed. Although, it was seen that the IncentiveResponse always gave a flexibility of 0 kW for the Ecovat. This was not correct because the Ecovat was cold, i.e. it has flexibility to start charging. Because of this every ADMM cycle converged in only 1 iteration.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.3 Test with tag "ECOVAT UC1 02_01_2019"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check if the problem with the 0 kW flexibility from ECOVAT UC1 20_12_2018 was solved

Test

Test was logged by Ecovat. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									Not available
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success	It was seen that the IncentiveResponse always gave an upper and lowerbound of 172 kW for the Ecovat. This was correct because the Ecovat was cold, i.e. it has to start charging to meet the heat demand. VITO and Ecovat discussed how to deal with this in the future in order to get useful results (as a first solution it was decided to use virtual temperatures instead of real ones).	Not available
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	2-1-2019	Davy Geysen	Success		Not available
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	2-1-2019	Davy Geysen	Success		Not available
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.8	Product/Service KPI Calculation	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.1.1	DA Cycle	The first cycle of UC1 was correctly executed	The full cycle of UC1 was successfully executed	2-1-2019	Davy Geysen	Success		Not available
		UC1.1.2	ID Cycle - 6/18h	NA	NA	2-1-2019	Davy Geysen	Success		Not available
		UC1.1.3	ID Cycle - 12/18h	NA	NA	2-1-2019	Davy Geysen	Success		Not available
		UC1.1.4	ID Cycle - 18/18h	NA	NA	2-1-2019	Davy Geysen	Success		Not available

Table 29: Test with tag "ECOVAT UC1 02_01_2019"

Result

Partial success. It was seen that the IncentiveResponse always gave an upper and lowerbound of 172 kW for the Ecovat. This was correct because the Ecovat was cold, i.e. it has to start charging to meet the heat demand. VITO and Ecovat discussed how to deal with this in the future in order to get useful results (as a first solution it was decided to use virtual temperatures instead of real ones).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.4 Test with tag "ECOVAT UC1 22_01_2019"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check the results if virtual temperatures are used, new cycle started every hour (instead of every 6h)

Test

Test was logged by Ecovat and VITO. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:35:14
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success	FlexConstraintsResponse only contains 0's which is not correct.	ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:35:28
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:35:31
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:35:31
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:35:32
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:37:17
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:54:22
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:54:22
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:54:22
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	22-1-2019	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:54:24
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.8	Product/Service KPI Calculation	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.1.1	DA Cycle	The first cycle of UC1 was correctly executed	The 1st full cycle of UC1 was successfully executed	22/01/2019 12h35	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 12:54:24
		UC1.1.2	ID Cycle - 1/18h	The second cycle of UC1 was correctly executed	The 2nd full cycle of UC1 was successfully executed	22/01/2019 13h35	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 13:54:01
		UC1.1.3	ID Cycle - 2/18h	The third cycle of UC1 was correctly executed	The 3rd full cycle of UC1 was successfully executed	22/01/2019 14h35	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 14:54:16
		UC1.1.4	ID Cycle - 3/18h	The fourth cycle of UC1 was correctly executed	The 4th full cycle of UC1 was successfully executed	22/01/2019 15h35	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 15:55:17
		UC1.1.5	ID Cycle - 4/18h	The fifth cycle of UC1 was correctly executed	The 5th full cycle of UC1 was successfully executed	22/01/2019 16h35	Davy Geysen	Success		ECOVAT UC1 22_01_2019 logs @ 22/01/2019 16:54:11
		UC1.1.6	ID Cycle - 5/18h	The sixth cycle of UC1 was correctly executed	The 6th full cycle of UC1 was successfully executed	22/01/2019 17h35	Davy Geysen	Failure	No IncentiveResponse was received by the DCM from the Ecovat	ECOVAT UC1 22_01_2019 logs @ 22/01/2019 18:39:05

Table 30: Test with tag "ECOVAT UC1 22_01_2019"

Result

Partial success. No IncentiveResponse was received by the DCM from the Ecovat.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.5 Test with tag "ECOVAT UC1 29_01_2019"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check the results if virtual temperatures are used, new cycle started every 6 hours for 3 days.

Test

Test was logged by Ecovat and VITO. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 11:45:26
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success	FlexConstraintsResponse only contains 0's which is not correct.	ECOVAT UC1 29_01_2019 logs @ 29/01/2019 11:45:26
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 11:45:26
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 11:45:27
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 11:45:26
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 11:55:50
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 13:37:19
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 13:37:19
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 13:37:20
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	29-1-2019	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 13:37:21
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.8	Product/Service KPI Calculation	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.1.1	DA Cycle	The first cycle of UC1 was correctly executed	The 1st full cycle of UC1 was successfully executed	29/01/2019 13h37	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 13:37:31
		UC1.1.2	ID Cycle - 6/72h	The second cycle of UC1 was correctly executed	The 2nd full cycle of UC1 was successfully executed	29/01/2019 19h42	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 19:42:33
		UC1.1.3	ID Cycle - 12/72h	The third cycle of UC1 was correctly executed	The 3rd full cycle of UC1 was successfully executed	29/01/2019 1h42	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 01:42:15
		UC1.1.4	ID Cycle - 18/72h	The fourth cycle of UC1 was correctly executed	The 4th full cycle of UC1 was successfully executed	29/01/2019 7h38	Davy Geysen	Success		ECOVAT UC1 29_01_2019 logs @ 29/01/2019 07:38:23
		UC1.1.5	ID Cycle - 24/72h	The fifth cycle of UC1 was correctly executed	The 5th full cycle of UC1 was successfully executed	29/01/2019 12h20	Davy Geysen	Failure	No IncentiveResponse was received by the DCM from the Ecovat	ECOVAT UC1 29_01_2019 logs @ 29/01/2019 12:20:19
		UC1.1.6	ID Cycle - 30/72h	Following cycles could not be executed because of the previous error	Following cycles could not be executed because of the previous error	29-1-2019	Davy Geysen	Failure		

Table 31: Test with tag "ECOVAT UC1 29_01_2019"

Result

Partial success. FlexConstraintsResponse only contains 0's which is not correct. No IncentiveResponse was received by the DCM from the Ecovat

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.6 Test with tag "ECOVAT UC1 06_02_2019"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check the results if virtual temperatures are used, new cycle started every 6 hours for 3 days

Test

Test was logged by Ecovat and VITO. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 07:53:47
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Failure	FlexConstraintsResponse only contains 0's which is not correct.	ECOVAT UC1 06_02_2019 logs @ 06/02/2019 07:53:47
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 07:54:32
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 07:54:33
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 07:54:34
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 08:09:38
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 9:52:55
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 9:52:56
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 9:52:57
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	6-2-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 9:52:57
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.8	Product/Service KPI Calculation	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.1.1	DA Cycle	The first cycle of UC1 was correctly executed	The 1st full cycle of UC1 was successfully executed	06/02/2019 9h52	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 9:52:57
		UC1.1.2	ID Cycle - 6/72h	The second cycle of UC1 was correctly executed	The 2nd full cycle of UC1 was successfully executed	06/02/2019 15h52	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 15:52:45
		UC1.1.3	ID Cycle - 12/72h	The third cycle of UC1 was correctly executed	The 3rd full cycle of UC1 was successfully executed	06/02/2019 22h06	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 06/02/2019 22:06:22
		UC1.1.4	ID Cycle - 18/72h	The fourth cycle of UC1 was correctly executed	The 4th full cycle of UC1 was successfully executed	07/02/2019 4h30	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 07/02/2019 04:30:35
		UC1.1.5	ID Cycle - 24/72h	The fifth cycle of UC1 was correctly executed	The 5th full cycle of UC1 was successfully executed	07/02/2019 16h16	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 07/02/2019 16:16:00
		UC1.1.6	ID Cycle - 30/72h	The sixth cycle of UC1 was correctly executed	The 6th full cycle of UC1 was successfully executed	07/02/2019 19h54	Davy Geysen	Failure	No IncentiveResponse was received by the DCM from the Ecovat	ECOVAT UC1 06_02_2019 logs @ 07/02/2019 19:54:29
		UC1.1.7	ID Cycle - 24/72h	Following cycles could not be executed because of the previous error	Following cycles could not be executed because of the previous error			Failure		

Table 32: Test with tag "ECOVAT UC1 06_02_2019"

Result

Partial success. FlexConstraintsResponse only contains 0's which is not correct. No IncentiveResponse was received by the DCM from the Ecovat.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.7 Test with tag "ECOVAT STATUS 422 04_03_2019 a"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check if it resends a FlexConstraintsRequest if ECOVAT returns a 422 status in the response

Test

Test was logged by Ecovat and VITO. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 a logs @ 04/03/2019 13:16:33
		UC1.1 a	Ecovat sends a failed (status 422) FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM and it has a 422 status in the JSON message	DCM has received the FlexConstraintsResponse (status 422) correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 a logs @ 04/03/2019 13:16:36
		UC1.1 b	DCM sends FlexConstraintsRequest again to DSO	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 04/03/2019 13:17:33
		UC1.1 b	Ecovat sends a correct FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM and it has a 200 status in the JSON message	DCM has received the FlexConstraintsResponse (status 200) correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT UC1 06_02_2019 logs @ 04/03/2019 13:19:14

Table 33: Test with tag "ECOVAT STATUS 422 04_03_2019 a"

Result

Success. Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status. DCM has received the FlexConstraintsResponse (status 422) correctly and responded with an HTTP 200 status. Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status. DCM has received the FlexConstraintsResponse (status 200) correctly and responded with an HTTP 200 status.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.8 Test with tag "ECOVAT STATUS 422 04_03_2019 b"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check if it resends a IncentiveOffer if ECOVAT returns a 422 status in the response.

Test

Test was logged by Ecovat and VITO. Logs are available.

Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
Use case 1, VITO Shaper									
	UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:35:21
	UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:35:56
	UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:35:56
	UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:35:57
	UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:35:59
	UC1.4 b	Ecovat sends a failed (status 422) IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM and it has a 422 status in the JSON message	DCM has received the IncentiveResponse (status 422) correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:36:05
	UC1.4 c	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:36:19
	UC1.4 d	Ecovat sends a correct (status 200) IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM and it has a 200 status in the JSON message	DCM has received the IncentiveResponse (status 200) correctly and responded with an HTTP 200 status	4-3-2019	Davy Geysen	Success		ECOVAT 04_03_2019 b logs @ 04/03/2019 14:46:24

Table 34: Test with tag "ECOVAT STATUS 422 04_03_2019 b"

Result

Success. Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status. DCM has received the IncentiveResponse (status 422) correctly and responded with an HTTP 200 status. Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status. DCM has received the IncentiveResponse (status 200) correctly and responded with an HTTP 200 status.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

6.9 Test with tag "ECOVAT UC1 26_02_2019"

Goal

Evaluate the full-chain integration of the VITO DSO, VITO DCM (Forecaster, Planner, Tracker) against the ECOVAT to check the results if virtual temperatures are used, new cycle started every 6 hours for 3 days (added status element to FlexConstraintsResponse and IncentiveResponse and fixed bug of lower/upperboundary of flexConstraintsRequest being 0).

Test

Test was logged by Ecovat and VITO. Logs are available.

ID	Test name	Step #	Description	Expected result	Acceptance criteria	Date	Name	Result	Comment	Evidence
UC1.1	Use case 1, VITO Shaper									
		UC1.1 a	DCM sends FlexConstraintsRequest to Ecovat	FlexConstraintsRequest is correctly received by Ecovat	Ecovat has received the FlexConstraintsRequest correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 14:09:22
		UC1.1 b	Ecovat sends FlexConstraintsResponse to the DCM	FlexConstraintsResponse is correctly received by the DCM	DCM has received the FlexConstraintsResponse correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 14:11:22
		UC1.2	DCM sends FlexConstraintsResponse to DSO as PUPrognosis	PUPrognosis is correctly received by the DSO	DSO has received the PUPrognosis correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 14:11:29
		UC1.3	DSO executes grid check and sends FlexRequest to DCM	Grid check is executed correctly and FlexRequest is received by the DCM	DCM has received the FlexRequest correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 14:11:29
		UC1.4 a	DCM sends IncentiveOffer to Ecovat	IncentiveOffer is correctly received by Ecovat	Ecovat has received the IncentiveOffer correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 14:11:30
		UC1.4 b	Ecovat sends IncentiveResponse to the DCM	IncentiveResponse is correctly received by the DCM	DCM has received the IncentiveResponse correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 14:28:11
		UC1.4	Steps 3 and 4 are repeated until the ADMM cycle converges or until the maximum iterations have been executed	ADMM cycle finished by converging or by reaching the maximum iterations	The ADMM cycle of the DCM has finished and a FlexOffer has been created	1-3-2019	Davy Geysen	Further investigation needed		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 16:42:21
		UC1.5 a	DCM sends FlexOffer to the DSO	FlexOffer is correctly received by the DSO	DSO has received the FlexOffer correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 16:42:21
		UC1.5 b	DSO sends FlexOrder to the DCM	FlexOrder is correctly received by the DCM	DCM has received the FlexOrder correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 16:42:21
		UC1.6	DCM sends ActivateIncentives to Ecovat (with test flag True to block the control signal) to activate the expected consumption profile	ActivateIncentives is correctly received by the Ecovat	Ecovat has received the ActivateIncentives correctly and responded with an HTTP 200 status	1-3-2019	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 16:42:23
		UC1.7	The Ecovat has followed the activated consumption profile and it is logged correctly	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.8	Product/Service KPI Calculation	NA (control signals are blocked)	NA (control signals are blocked)					
		UC1.1.1	DA Cycle	The first cycle of UC1 was correctly executed	The 1st full cycle of UC1 was successfully executed	26/02/2019 16h42	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 16:42:23
		UC1.1.2	ID Cycle - 6/72h	The second cycle of UC1 was correctly executed	The 2nd full cycle of UC1 was successfully executed	26/02/2019 22h38	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 26/02/2019 22:38:40
		UC1.1.3	ID Cycle - 12/72h	The third cycle of UC1 was correctly executed	The 3rd full cycle of UC1 was successfully executed	27/02/2019 04h17	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 27/02/2019 04:17:57
		UC1.1.4	ID Cycle - 18/72h	The fourth cycle of UC1 was correctly executed	The 4th full cycle of UC1 was successfully executed	27/02/2019 10h25	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 27/02/2019 10:25:03
		UC1.1.5	ID Cycle - 24/72h	The fifth cycle of UC1 was correctly executed	The 5th full cycle of UC1 was successfully executed	27/02/2019 16h25	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 27/02/2019 16:25:21
		UC1.1.6	ID Cycle - 30/72h	The sixth cycle of UC1 was correctly executed	The 6th full cycle of UC1 was successfully executed	27/02/2019 22h32	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 27/02/2019 22:32:07
		UC1.1.7	ID Cycle - 36/72h	The seventh cycle of UC1 was correctly executed	The 7th full cycle of UC1 was successfully executed	28/02/2019 04h17	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 28/02/2019 04:17:53
		UC1.1.8	ID Cycle - 42/72h	The eight cycle of UC1 was correctly executed	The 8th full cycle of UC1 was successfully executed	28/02/2019 10h27	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 28/02/2019 10:27:20
		UC1.1.9	ID Cycle - 48/72h	The ninth cycle of UC1 was correctly executed	The 9th full cycle of UC1 was successfully executed	28/02/2019 16h28	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 28/02/2019 16:28:36
		UC1.1.10	ID Cycle - 54/72h	The tenth cycle of UC1 was correctly executed	The 10th full cycle of UC1 was successfully executed	28/02/2019 22h27	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 28/02/2019 22:27:41
		UC1.1.11	ID Cycle - 60/72h	The eleventh cycle of UC1 was correctly executed	The 11th full cycle of UC1 was successfully executed	01/03/2019 04h13	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 01/03/2019 04:13:58
		UC1.1.12	ID Cycle - 66/72h	The twelfth cycle of UC1 was correctly executed	The 12th full cycle of UC1 was successfully executed	01/03/2019 10h33	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 01/03/2019 10:33:14
		UC1.1.13	ID Cycle - 72/72h	The thirtheenth cycle of UC1 was correctly executed	The 13th full cycle of UC1 was successfully executed	01/03/2019 16h23	Davy Geysen	Success		ECOVAT UC1 26_02_2019 logs @ 01/03/2019 16:23:53

Table 35: Test with tag "ECOVAT UC1 26_02_2019"

Result

Success. Cycle 1 through 13 were successfully executed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

7 Heat Pump Characterization Tests

In this series of tests, data is collected in order to be able to make a heating signature model for indirect control of heat pumps by overriding the outdoor temperature sensor.

The purpose of these tests is to find the relation between a simulated outdoor temperature and the amount of electric power consumed by the heat pump. This is done by applying control signals (i.e. sensor override values) and observing the heatpump's reaction (i.e. changes in electricity consumption) to these control signals.

7.1 Air Water Heat Pump

7.1.1 Test with tag "2019_10_03_01_awhp_steps"

Goal

To observe a relation between the value used to override the outdoor temperature sensor and the electric power consumed by the air water heat pump.

Method

Override the outdoor temperature sensor and wait for the heat pump to stabilize. Override the outdoor temperature sensor again and monitor the electric power consumption of the heat pump.

Test

- 11h00: Test starts by overriding the outdoor temperature sensor.
- 12h15: Heat pump reacts and increases electric power consumption.
- 15h00: The value with which the outdoor temperature sensor is overwritten is changed.
- 17h30: A small increase in electric power consumption can be observed.
- 19h00: The test is ended by overwriting the value of the outdoor temperature sensor.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

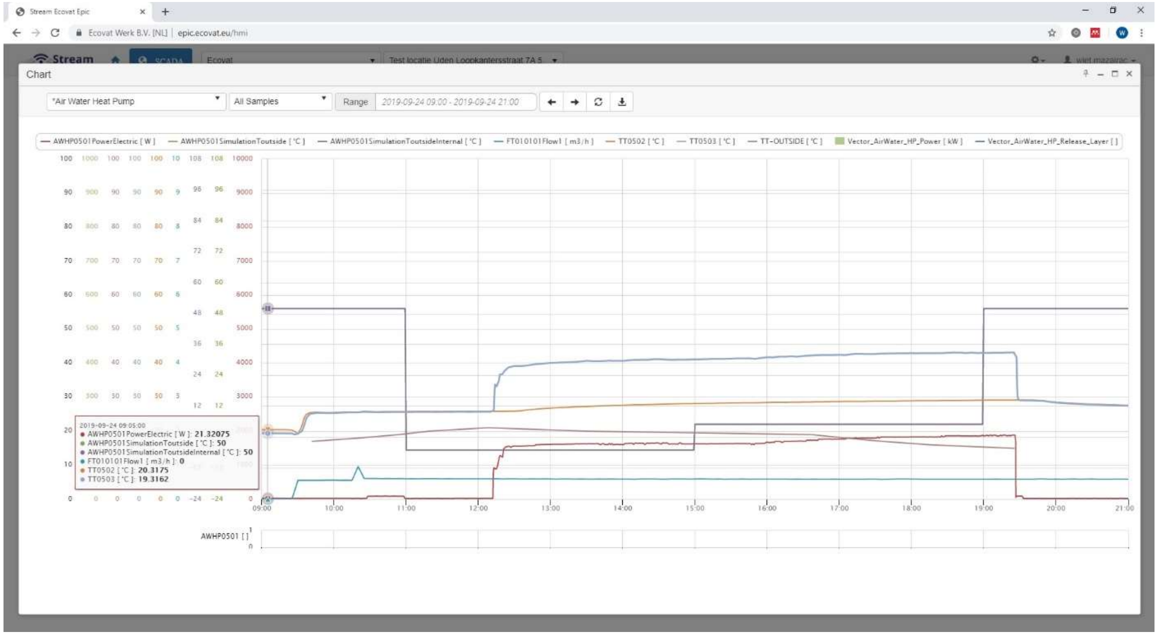

Figure 12: Test with tag "2019_10_03_01_awhp_steps"

Result

This test and other tests indicated that a clear relation between the simulated outdoor temperature and the power consumption could not be observed. The real outdoor temperature has a more significant influence on the electric power consumption. However, it is not possible to control the real outdoor temperature. Therefore, we concluded it would be more beneficial to proceed testing with the water-water heat pump instead of continuing testing with the air-water heat pump. The power consumption of the water-water heat pump does not depend on the real outdoor temperature.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

7.2 Water Water Heat Pump

7.2.1 Test with tag “2019_09_25_03_wwhp”

Goal

Goal of this test is to observe ramping as a result of an override of the outdoor temperature sensor.

Method

Override outdoor temperature sensor and measure consumed electric power of the heat pump.

Test

- 11h00: Test starts by overriding the outdoor temperature sensor.
- 11h20: The electric power consumption of the water-water heat pump increases.
- 14h00: Desired supply temperature is reached. WWHP ramps down.
- 15h00: Override of outdoor temperature sensor.
- 15h05: WWHP seems to react to the new override and ramps up. Desired supply temperature will not be reached.
- 19h00: Test stopped by overriding the outdoor temperature sensor.
- 19h30: WWHP ramps down to 0.

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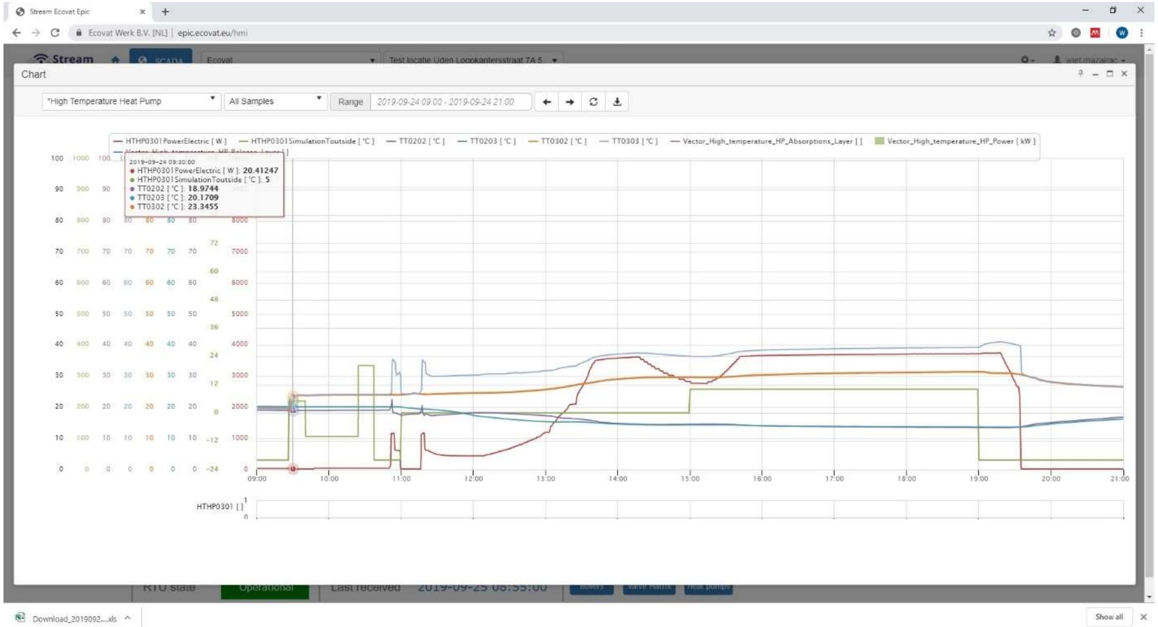

Figure 13: Test with tag “2019_09_25_03_wwhp”

Result

Ramping was observed (15h15) as a result of an override of the outside temperature (15h00). Ramping was observed at the begin and end the test.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731231.

7.2.2 Test with tag "2019_09_25_04_wwhp"

Goal

Goal of this test is to observe ramping as a result of an override of the outdoor temperature sensor. In this test a smaller temperature increase is applied.

Method

Override outdoor temperature sensor and measure consumed electric power of the heat pump.

Test

- 22h00: Test starts by overriding the outside temperature sensor.
- 23h20: The WWHP reacts. The WWHP increases its power almost instantly. And at the same time the desired supply temperature is reached.
- 23h20-01h30: A continuous cycle can be observed in which the supply temperature overshoots after which the heat pump turns of. Once the supply temperature has been decreased, the heat pump starts again. This oscillating behaviour continues until approximately 02h00.
- 02h00: The outdoor temperature value is overwritten with a new value.
- 03h00-04h30: The electric power consumption of the WWHP ramps up.
- 04h30: The desired supply temperature is reached after which the WWHP ramps down slowly.
- 05h20: Steep increase of supply temperature after which the WWHP turns off.
- 05h30: Heat pump turns on again, after which the supply temperature remains stable.
- 06h00: Outside temperature value is overwritten to end the test.
- 06h10: Heat pumps stops.

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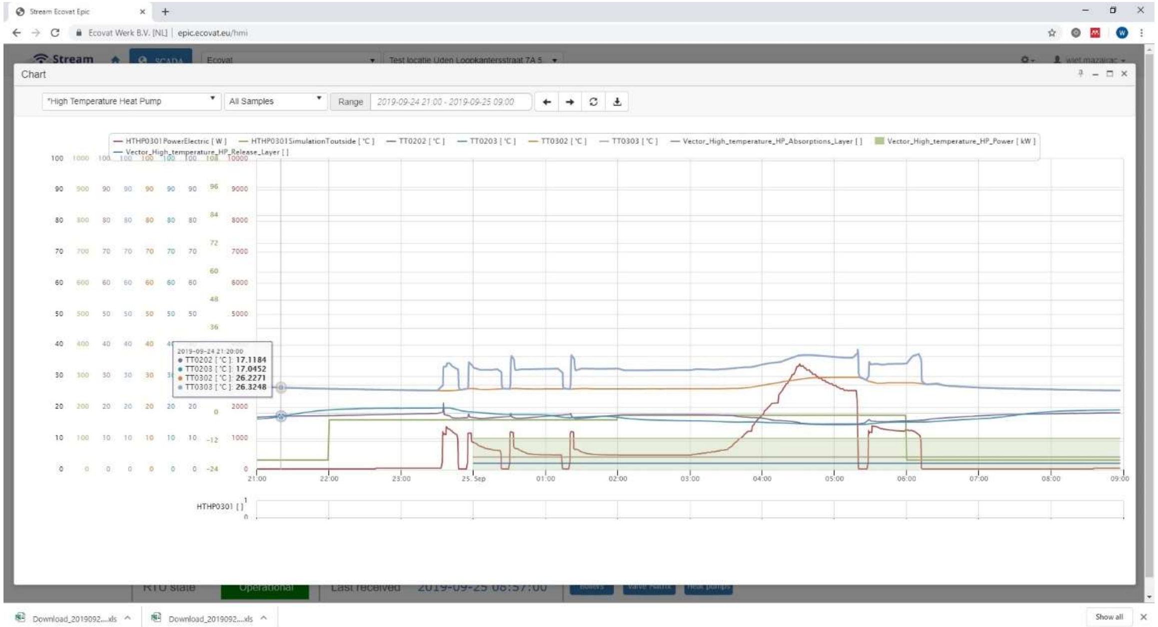

Figure 14: Test with tag "2019_09_25_04_wwhp"

Result

Ramping observed (03h00-04h30) as a result of simulated outside temperature adjustment 02h00. Ramping observed at begin and end of test.

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7.2.3 Test with tag "2019_09_26_01_wwhp_stabalize"

Goal

To measure the amount of time required for the WWHP to stabilize after being turned on and to determine if the increase in power is constant over time or if the WWHP overshoots first.

Method

First overwrite the value of the outdoor temperature sensor with a value which turns the WWHP off, then overwrite the sensor with a value that turns the HP on.

Test

- 09h10: WWHP is off. Value of outdoor temperature sensor is overwritten to turn on heat pump.
- 10h30: Heat pump reacts and ramps up after small spike.
- 12h00: Supply temperature overshoots and power consumption ramps down.
- 13h20: Heat pump turns off for a few minutes, turns on again and ramps up to required power.
- 15h10: Heat pump power consumption is stabalized.

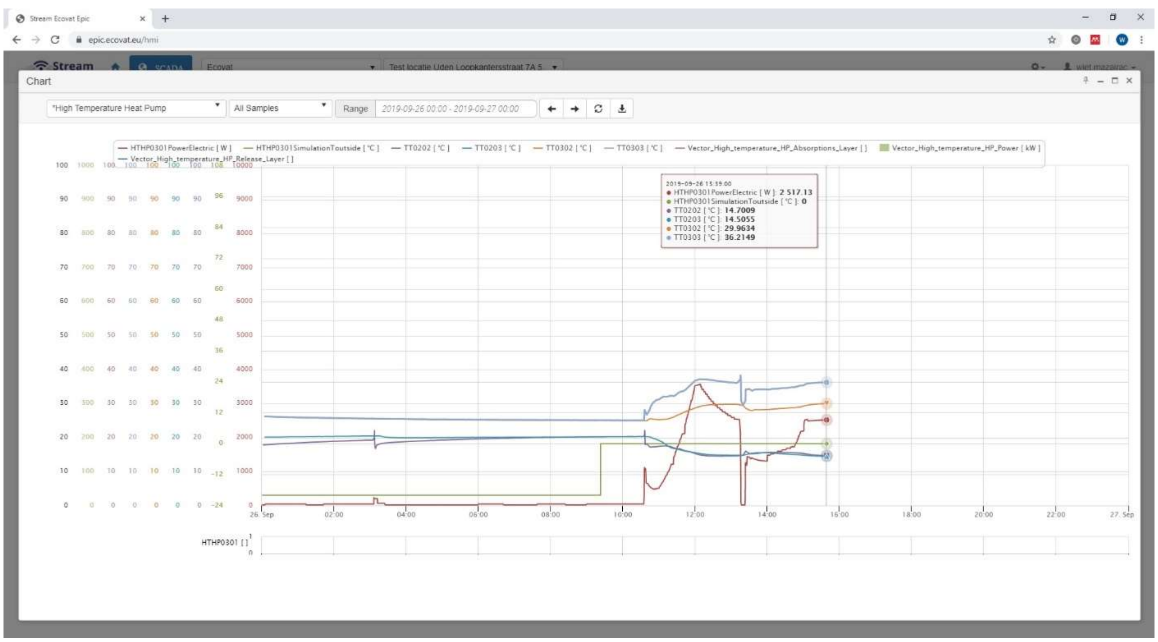

Figure 15: Test with tag "2019_09_26_01_wwhp_stabalize"

Result

Given the initial conditions and control settings, the heat pump requires 6 hours to stabilize.

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7.2.4 Test with tag "2019_09_26_03_wwhp_max"

Goal

To determine the maximum electric power capacity of the water-water heat pump.

Method

Overwrite the outdoor temperature sensor with a value to obtain a maximum supply temperature.

Test

- 12h00: Value of outdoor temperature sensor is overwritten.
- 12h30: Heat pump reacts and ramps up.
- 14h05: WWHP reaches near maximum supply temperature and maximum electrical power consumption in this test.
- 19h30: WWHP reaches maximum supply temperature and maximum electric power consumption.
- 20h00: Control signal is sent to turn the heat pump off.
- 20h50: Heat pump turns off.

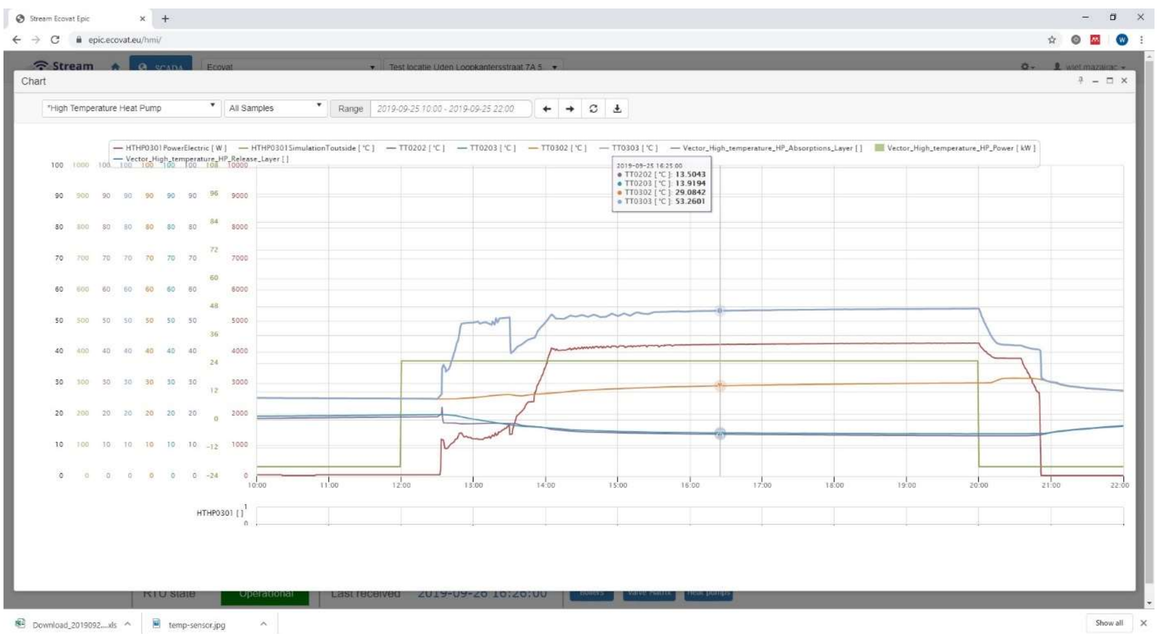

Figure 16: Test with tag "2019_09_26_03_wwhp_max"

Result

The maximum amount of power the WWHP can consume is almost 4200 [W]. The heat pump requires a little over 2 hours to reach that power. After those 2 hours a very small increase in power consumption can be observed.

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7.2.5 Test with tag "2019_10_03_02_wwhp_steps"

Goal

To determine the relation between the overwritten outdoor temperature value and the electrical power consumption of the heat pump.

Method

In this test the value of the overwritten outdoor temperature value is a step function. Every 4 hours the value is increased by 5 degrees Celsius.

Test

- 13h00: After stabilization of the heat pump the simulated outdoor temperature sensor value is increased by 5 degrees every 4 hours.
- 13h00-08h00: The amount of electric power consumed is erratic. During this period the power drops to 0 at 3 moments after which the heat pump increases its power consumption again. Every 4 hours the control signal is changed. In this period only 2 levels of power consumption can be observed (3800 Watts and 4400 Watts).
- 08h00-06h00: Every 4 hours the control signal decreases with 5 degrees Celsius. The electric power consumption of the heat pump decreases, however a step function is difficult to observe.

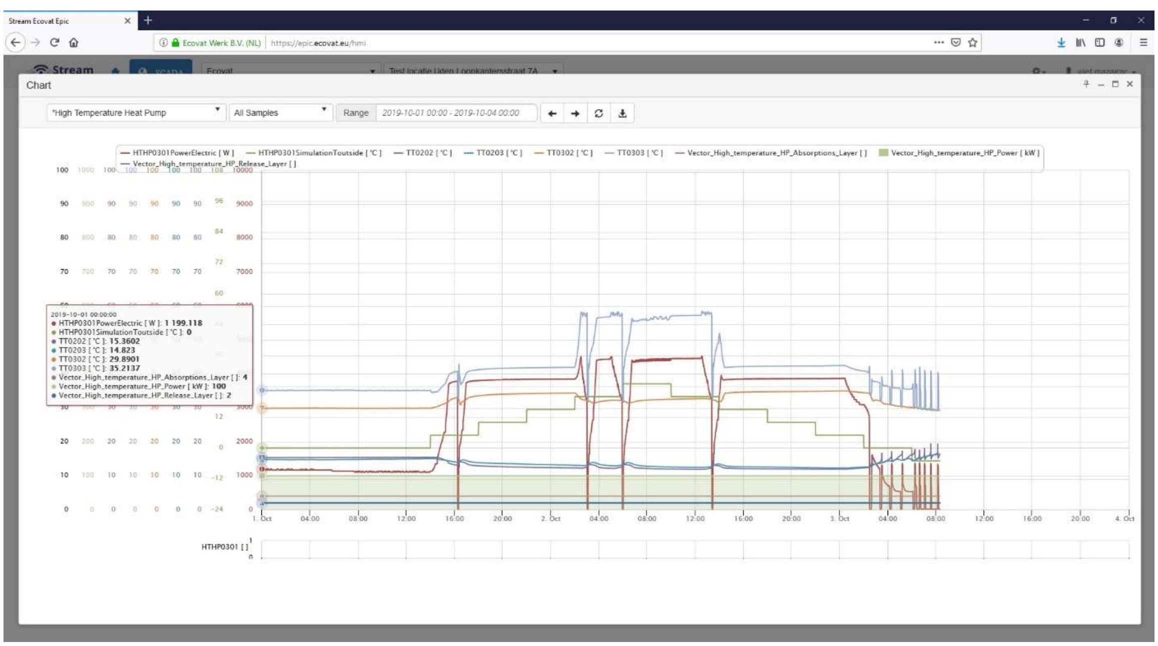

Figure 17: Test with tag "2019_10_03_02_wwhp_steps"

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Result

The water-water heat pump reacts to the control signal. It turns on when the control signal goes up and it turns off when the control signal goes down. Also, different levels of power consumption can be observed. It is not possible however to relate the exact value of the control signal with the amount of electricity consumed by the heat pump.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

7.2.6 Test with tag "2019_10_08_01_wwhp_manual_pump_speed_heating"

Goal

The goal of this test is to observe a relation between the simulated outdoor temperature and the electric power consumed by the water-water heat pump.

Method

In this test the value of the overwritten outdoor temperature value is a step function. Every hour the value is increased and decreased by 1 degrees Celsius. Also, the pump speed for the heating medium is set to manual and at a speed of 70%. This decreases the number of unknowns and therefore it will be more straightforward to control the electric power consumption of the water-water heat pump.

Test

- 10h00: The heat pump is turned off. The value of the outdoor temperature sensor is overwritten.
- 12h00: Control signal step function starts; the simulated outdoor temperature is increased by 1 degree Celsius every 30 minutes. The heat pump is still turned off.
- 13h00: The heat pump turns on and peaks. Power consumption is reduced immediately, however no stabilization occurs.
- 14h00: Electric power consumption increases by approximately 1 [kW] to approximately 1,7 [kW]
- 16h00: Electric power consumption increases by approximately 1 [kW] to approximately 2,8 [kW]
- 18h00: Electric power consumption increases by approximately 1 [kW] to approximately 3,9 [kW]
- 21h30: From this time on the simulated outdoor temperature is reduced by 1 degree Celsius every 30 minutes.
- 22h00: Although the electric power consumption decreases, it shows erratic behaviour.
- 08h00: End of test.

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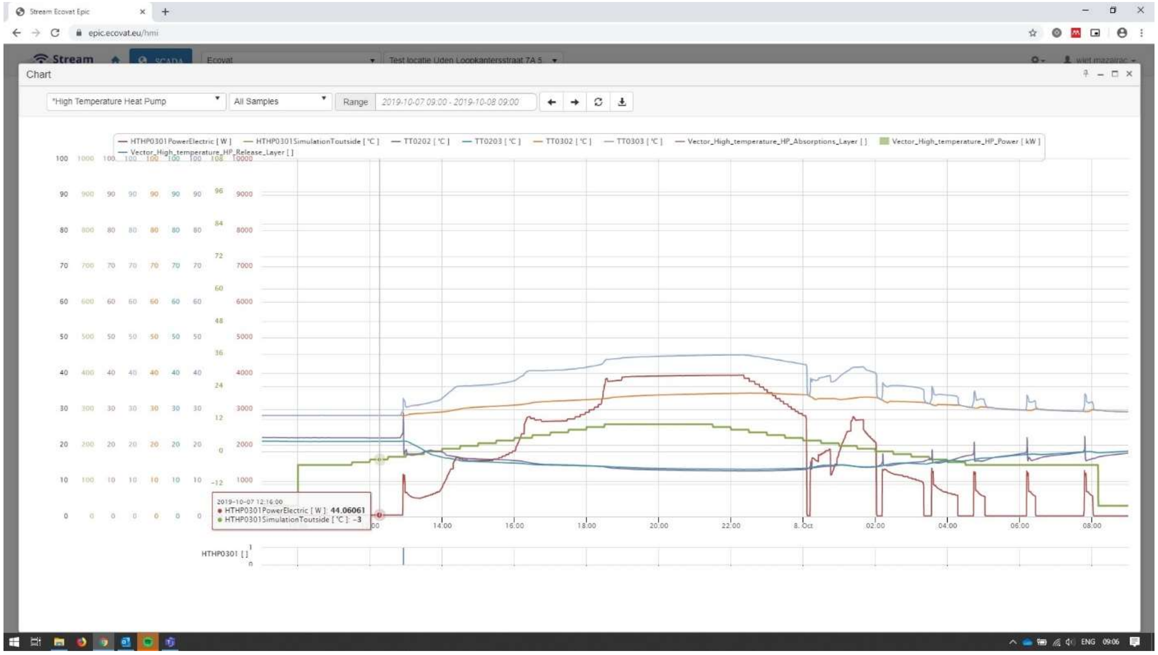

Figure 18: Test with tag "2019_10_08_01_wwhp_manual_pump_speed_heating"

Result

At the start of the test the heat pump only reacts after a long period of time (3 hours). No relation can be observed between the control signal and the power consumption of the heat pump, other than the heat pump increasing its power when the simulated outdoor temperature increases. This result cannot be used to control a heat pump with the outdoor temperature sensor.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

7.2.7 Test with tag “2019_10_11_01_wwhp_interval_2hr_1c_complete”

Goal

To observe a clear relation between the simulated outdoor temperature and the power electric power consumed by the heat pump.

Method

In order to observe a clear relation the duration of the time steps were increased from 1 hour to 2 hours. The assumption is that 2 hours would be plenty of time for the heat pump to stabilize after the control signal changes.

Test

- 20h00: Heat is stabilized. Test start by settings the value of the simulated outdoor temperature at -1 degrees Celsius.
- 20h19: The heat pump reacts and starts ramping up.
- 8/10 20h00 – 10/10 06h00: The simulated outdoor temperature increases 1 degree Celsius every 2 hours.
- 8/10 20h00 – 9/10 23h00: The heat pumps increases it electrical power consumption to meet the requested supply temperature. The increase in supply temperature and consumed electric power is somewhat linear.
- 10/10 10h00 – 12/10 04h00: The simulated outdoor temperature steps down by 1 degree Celsius every 2 hours.
- 10/10 20h00 – 12/10 02h00: The supply temperature and the amount of electric power consumed decreases during this period. Many dips can be observed, both in the supply temperature as in the amount of consumed electric power. The dips are followed by peaks. Both the dips and the peaks are probably a result over overshooting and overcompensation.

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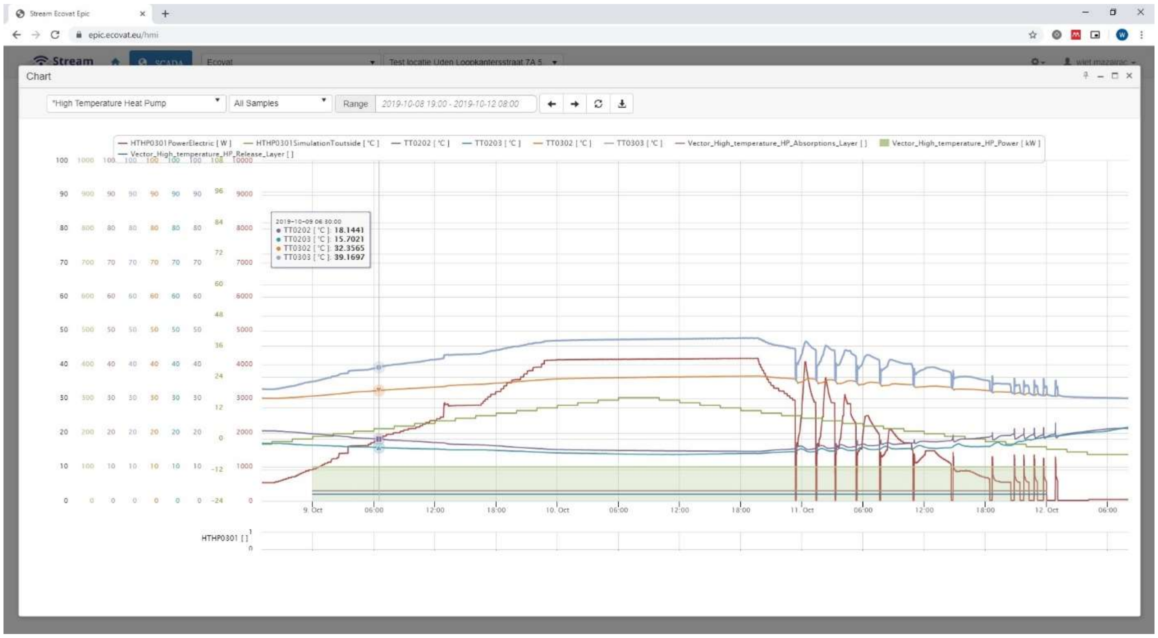

Figure 19: Test with tag "2019_10_11_01_wwhp_interval_2hr_1c_complete"

Result

A clear relation between the control signal and the electric power consumption of the heat pump is not observed. However, the power consumption increases when the control signal goes up. Also, many peaks and dips are observed when the control signal steps down. In order to obtain better results the length of the steps of the control function should be increased.

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7.2.8 Test with tag "2019_10_21_01_wwhp_long_interval_1c_incomplete"

Goal

To observe a clear relation between the simulated outdoor temperature and the power electric power consumed by the heat pump.

Method

In the previous test the step function overwriting the value of the outdoor temperature sensor had a fixed horizontal (time) length. This did not enable the heat pump to stabilize. In this test the duration of the steps is determined on the fly by manually increasing the value with which the outdoor temperature sensor is overwritten. The value will be updated once the heat pump is stabilized.

Test

- 12/10 8h38: Test starts by setting the simulated outdoor temperature at -5 [°C]. The electric power consumed by the heat pump remains almost 0.
- 12/10 16h19: Simulated outdoor temperature is increased to -4 [°C].
- 12/10 19h15: Heat pump turns on.
- 12/10 19h15 – 13/10 15h00: During this period the simulated outdoor temperature is increased after stabilization of the heat pump. During this period the heat pump does not stabilize, i.e. electric power consumption is never constant. Instead the electric power consumption of the heat pump resembles a square wave, however it is not perfectly square. The high period of the square wave starts with a peak with a magnitude of 1,2 [kW] after which it ramps down to 0,5 [kW].
- Idem: During this period the simulated outdoor temperature is increased several times and therefore the heat pump consumes more electric energy. Instead of increasing the power, in this stage the duty cycle of the square wave is increased. The duty cycle increases from ±0,25 to ±0,50 to ±0,75.
- 13/10 15h00: After increasing the simulated outdoor temperature to -1 [°C]. The duty cycles increases to 1, i.e. power consumption becomes continuous.
- 14/10 0h00 – 15/10 0h00: Simulated outdoor temperature is increased after heat pump stabilization. Heat pump starts ramping up within 30 minutes.
- 15/10 06h00 – 16/10 18h00: Electric power consumption is not continuous, instead a square wave can be observed.
- 16/10 18h00 – 18/10 12h00: The simulated outdoor temperature is increases each time after stabilization of the heat pump occurs. A dip and peak can be observed around 16/10 04h00. The reason for this is unknown.
- 18/10 10h00 – 18/10 23h00: After increasing the control signal (simulated outdoor temperature) erratic behaviour of the heat pump is observed. The heat pump oscilates between zero and full power. After increasing the

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simulated outdoor temperature again, at 18/10 23h00, this behaviour disappears.

- 19/10 0h00 – 21/10 08h00: The simulated outdoor temperature is increased each time after stabilization of the heat pump. The heat pumps reacts by starting to ramp up within half an hour.

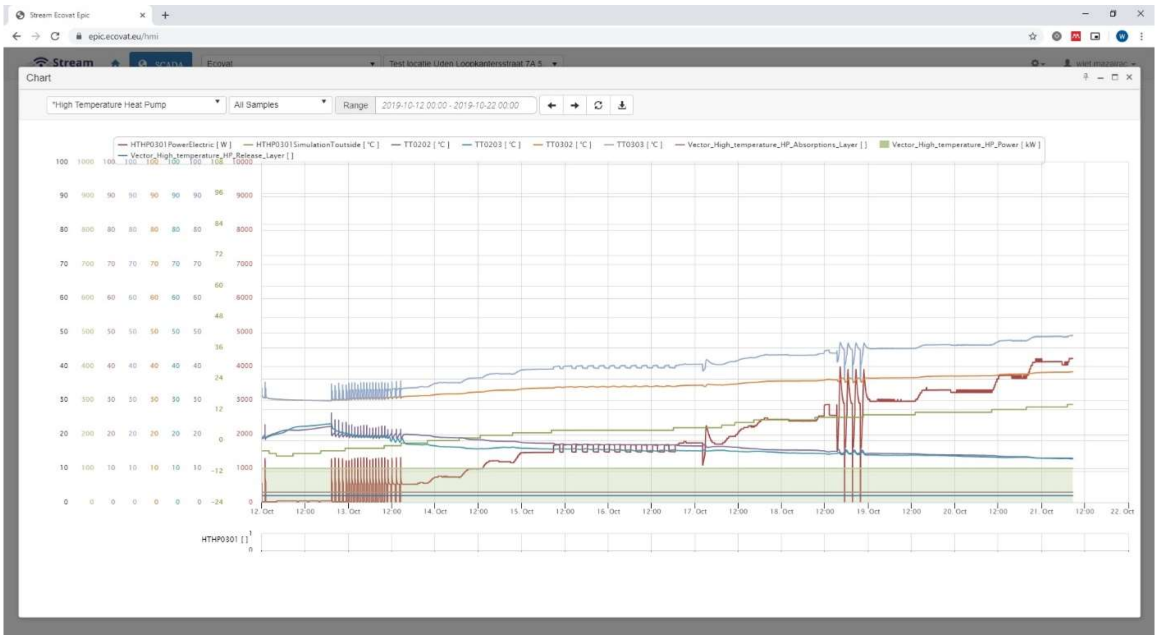

Figure 20: Test with tag "2019_10_21_01_wwhp_long_interval_1c_incomplete"

Result

Electric power consumption of the heat pump responds well to control signals. Heat pump reacts within a reasonable amount of time and the delay between control action and heat pump response seems to be the same throughout the test.

A square wave can be observed when the heat pump is at low power. The duty cycle increases when the required power increases. Halfway during the test another square wave was observed. The reason for this square wave is unknown.

At two thirds of the test oscillating behaviour was observed. The reason for this behaviour is also unknown.

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8 Summary and Outlook

This deliverable gives on overview of the pilot testing and validation activities that were performed by Ecovat at the Ecovat pilot site in Uden in cooperation with mainly VITO.

The first series of tests involved unit testing of the sensors, the actuators, the Ecovat SCADA system (STREAM), and the communication in between them. Due to some last minute changes in hardware design, the lists against Ecovat compared functionality contained hardware that would not be used anymore in future tests.

The second series of tests involved testing of the so called control vectors in which combination of actuators were activated in order to perform a certain task, e.g. charge layer two with the water-water heat pump. During these tests no unexpected events occurred.

In the third series of tests the full-chain integration of and communication between the DSO, the DCM and the Ecovat was tested. Some iterations and SW fixes were required to pass all criteria. E.g. during one of the tests the amount of flexibility available was not communicated correctly, and therefore the DCM was not able to allocate an energy profile to Ecovat. Another problem that Ecovat encountered was related to the database from which Ecovat extracts the most optimal energy profile. This database was slow causing time-outs in communication (up to 30' for one iteration). Changing the database design solved this.

The last series of tests were dedicated to characterizing the heatpumps to create their heat signature model to be used in the indirect control strategy. Two heat pumps were available. After some initial test with the air-water heat pump, it was concluded this heat pump was less suitable because of the dependency on the outdoor temperature which complicates the heat signature model creation. The outdoor temperature caused fluctuation in the amount of electric power consumed. Therefore, these heatpump characterization tests have been focussed on the water-water heat pump.

From the tests to characterize the Heatpump (i.e. create a heat signature model to be used for the indirect control paradigm) it was concluded that with the available heatpumps, it was not possible to create a good enough model to achieve deterministic profile-following control. As was concluded from the experiments done in T2.4, the extent to which indirect control can yield satisfactorily results, is very much depending on the specific heatpump brand and model. And even though excellent support was provided by NIBE to interpret and improve the measurements that were feeding the signature model creation, and advice on heatpump settings, the results that could be obtained by the heatpumps that were installed in the ECOVAT system were inferior to 'the best' model that was achieved in T2.4. The very large behavioural changes that are observed between different heatpump

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brands and models relates to the functionality and behaviour of the heatpump's internal controller, that has not been designed with flexibility in mind. Learnings from the pilot testing activities, as well as T2.4, will be the basis for further engagements with HP manufacturers to improve the fitness for offering flexibility of their internal controller.

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