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Subject: **IBM EcoGrid Direct-Price Agent Implementation Status**

1 Scope

Based on the findings of test runs conducted using the price agent described in (Mueller, Sundstroem, & Gantenbein, 2013) as well as discussions with Oestkraft, Energinet, and with IBM internally, our implementation of the direct-price agent has been updated.

This document describes the updated tactical low-impact approach "v2".

Specifically, we describe how IBM plans to control EcoGrid houses, the way user comfort settings are taken into account, and what additional safety features have been implemented in this version of the price agent. Section 2 provides an overview of constraints with regard to the operation of a heatpump while the utilized heatpump model is introduced in Section 3. The computation of energetic flexibility is discussed in Section 4 followed by a listing of security features in Section 5.

2 Heatpump Operational Constraints

Our approach has been extended to include different constraints on the heatpump's runtime, cf. Section 2, to allow the heatpump to run as efficiently as possible while still providing some minimum amount of flexibility. Additionally, a constraint on a heatpump's maximum total off-time per 24 hours is explicitly incorporated.
Above mentioned constraints depend on the aggressivity level that every user can select individually in the GWR GUI. Table 1 summarizes the constraint settings for different choices of the aggressivity level.

User-set Aggressivity Level	*Min. Off-time*	*Max. Off-time*	*Min. On-time*	*Max. total Off-time per day*
Low	15min	15min	120min	15min
Medium	15min	30min	60min	30min
High	15min	60min	30min	60min

Table 1 Heatpump operational constraints for different user settings.

3 Heatpump Model

The version of the direct-price agent described in this document uses a very simple heatpump model. It is assumed that the heatpump consumes a constant amount of power P_{ON} when in operation, and a constant amount of power P_{OFF} when idle.
The numeric power level values can be identified for every house individually. Table 2 provides a set of typical values.

Heatpump Operation State	*Constant Power Consumption*
ON	4000W
OFF	130W

Table 2 Example of heatpump power levels.

4 Computation of Energetic Flexibility

The constraints on the heatpump operation as described in the previous section are also reflected in the computation of an EcoGrid house's energetic flexibility. Figure 1 provides a visualization of the energetic flexibility for the case when the user-selected aggressivity level is set to *Medium* and under the assumption that the heatpump has been running from midnight until the computation of flexibility at around 6am the same day.

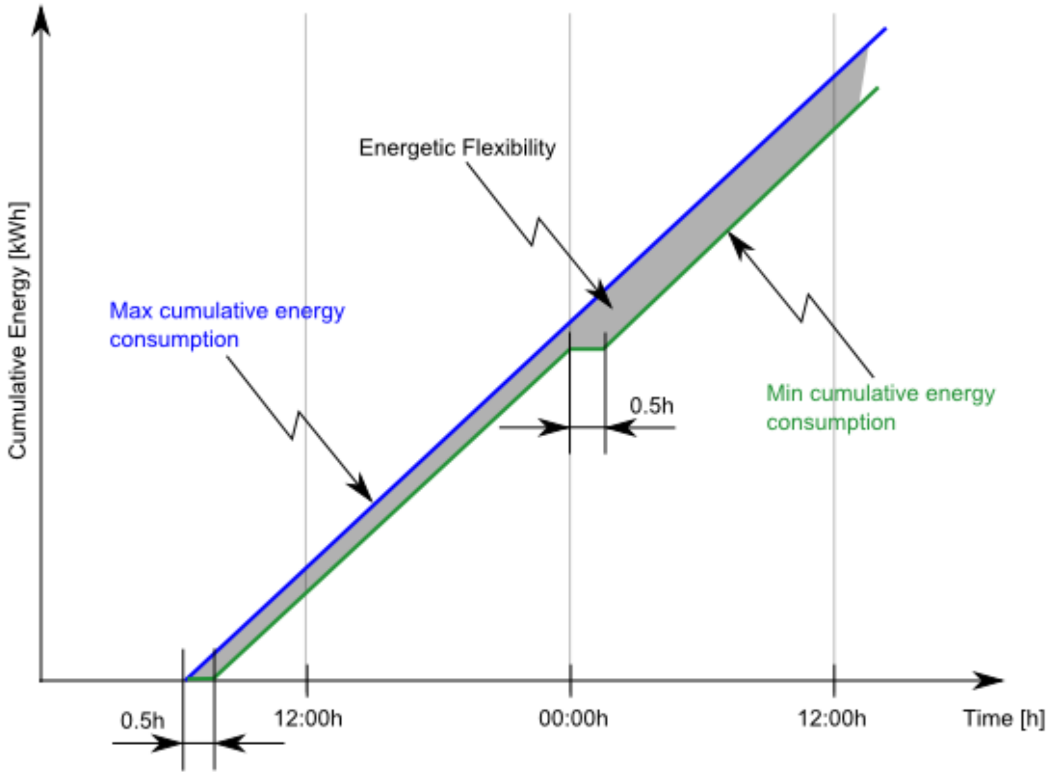

Figure 1 Example of energetic flexibility for the case of medium aggressivity.

In this scenario, the heatpump is allowed to turn off and stay off not longer than 30 minutes. After this off-time period, the heatpump has to be running for the remaining time of the day since the maximum allowed total off-time per day is also 30 minutes. This operation strategy corresponds to the minimum cumulative energy consumption and is shown as a green line in Figure 1.
On the other hand, the maximum cumulative energy consumption is achieved by allowing the heatpump to run all day. This strategy is shown as a blue line in Figure 1.
The grey-shaded area between the minimum and maximum cumulative energy trajectories is what we call the energetic flexibility of the house and serves as a measure of how flexible we are in consuming energy.

5 Energy Procurement-Cost Minimization

Given a price forecast for a certain planning horizon, the energetic flexibility is computed according to Section 2. The goal is to compute a heatpump ON/OFF schedule minimizing the energy procurement costs while at the same time satisfying

i. all the heatpump operational constraints a described in Section 1 and summarized in Table 1 and
ii. the constraints on the cumulative energy consumption as represented by the energetic flexibility discussed in Section 3.

6 Security Features

In addition to the heatpump constraints discussed in Section 1, the following security features are implemented to guarantee participant freedom and an indoor air temperature higher or equal to the user set minimum temperature at all times.

As soon as at least one of the following conditions is true, *any* planned minimum procurement-cost optimization schedule will be pre-empted and the heatpump is unconditionally enabled to operate according to its native parameters.

i. The indoor air temperature as measured by the Greenwave temperature sensor is below the user-set minimum temperature.
ii. The indoor air temperature is below 20oC.
iii. The latest indoor air temperature sample from the Greenwave temperature sensor was received more than 4 hours ago.
iv. The communication between server and GreenWave gateway in house is lost for more than 30 minutes.
v. Oestkraft or the participant operationally bail out the household from automation by unchecking the flag in GreenWave user interface.
vi. The IBM administrative automation state for the household is set to disabled (example as done over Xmas 13/14).

References

[1] Mueller, F., Sundstroem, O., & Gantenbein, D. (2013). *IBM EcoGrid Direct-Price Agent Implementation Status v1.0.* IBM Research Zurich.

[2] Gantenbein, D. (2014). *EcoGrid Task 5.3 Installation and Testing - TnT Taskforce: IBM Price-Agent Response Test-Program description*, Version 1.0, IBM Research Zurich (Consortium internal document).