

ORIGIN: Findhorn, Damanhur, Tamera

Orchestration of Renewable Integrated Generation in Neighbourhoods



(tuohy@esru.strath.ac.uk)

<http://origin-concept.eu/>

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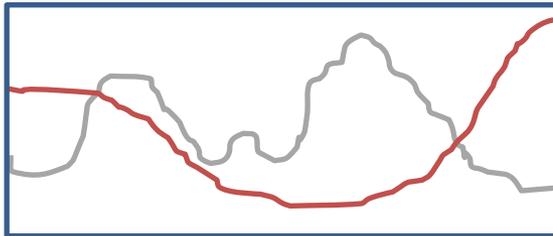
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ORIGIN: Orchestration of Renewable Integrated Generation in Neighbourhoods



Now



The renewable supply to demand miss-match is a problem



Current renewables use grid for import and export – better to shape demand to use more renewables locally



ORIGIN: Orchestration of Renewable Integrated Generation in Neighbourhoods



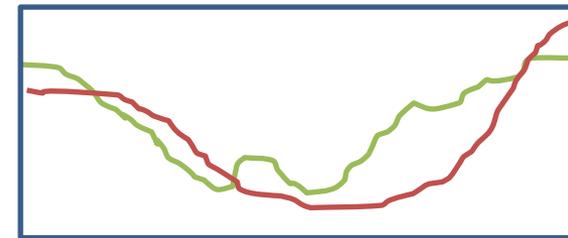
Now



ORIGIN goal: + 20% Local Renewable Use



ORIGIN will orchestrate demand to match local supplies through:

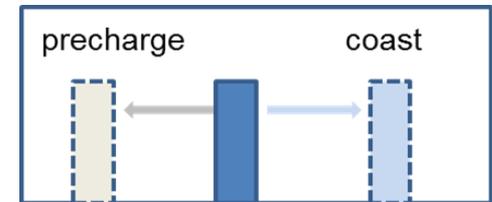


1. **People controlled loads** to be influenced by information and tariffs (PCLs).
2. **Electrical controllable loads**: Pumps, EV charging, Batteries, Appliances (ECLs).
3. **Thermostatic controllable loads**: Space and Water heating or cooling (TCLs).

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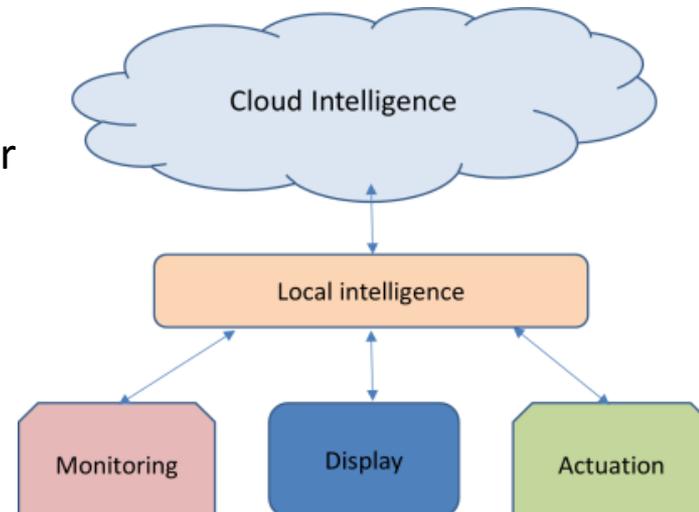
MECHANISMS:

1. **DSM:** based on ability to 'coast' (delay) inputs or 'precharge' (advance) inputs.
2. **MINIMISE:** reduce energy use through avoidance of unnecessary loads using 'coast' function.

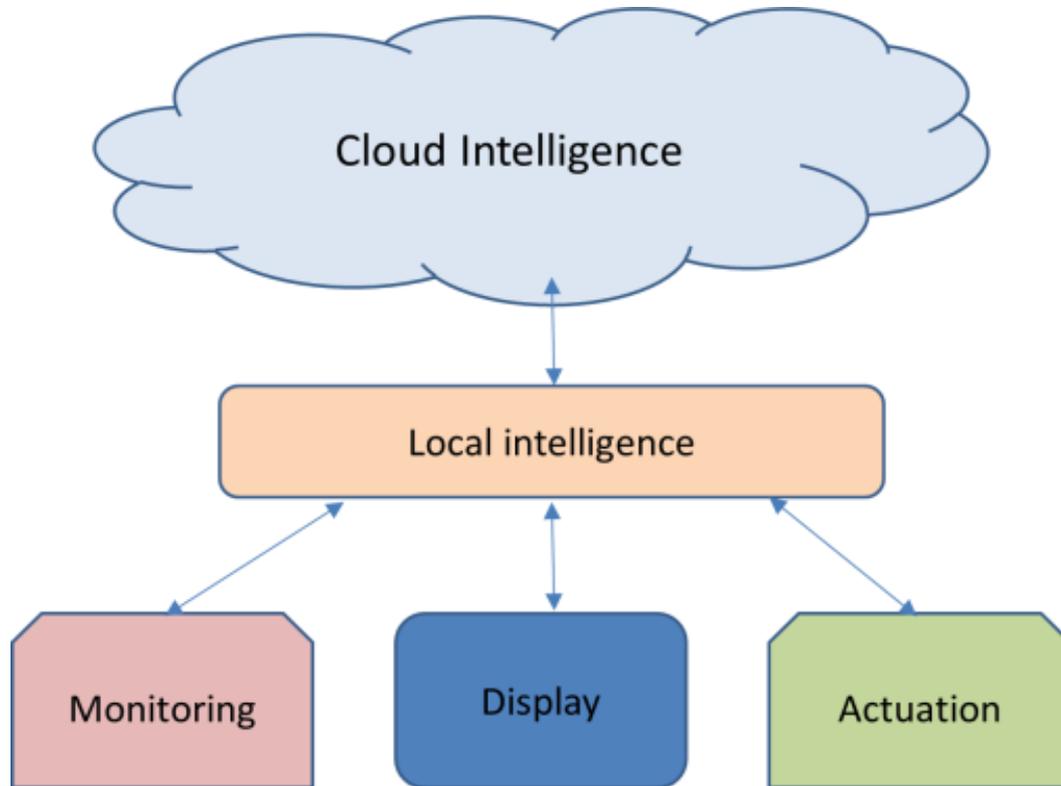


METHODS:

1. **Information** flow to inform individuals so they can alter their behaviour and operation of systems. (PCLs)
2. **Automated actuation:** remote control (ECLs, TCLs).



ORIGIN: Orchestration of Renewable Integrated Generation in Neighbourhoods



Hardware and Software and User Interfaces

Monitoring: Community Energy Characteristics - 120 buildings

Weather, Demand , Generation Prediction Algorithms

Models capturing community energy characteristics and load shift opportunities

Orchestration Algorithms driving displays and remote controls

ORIGIN: Orchestration of Renewable Integrated Generation in Findhorn

Focus buildings and Systems



Whins

- 25 dwellings
- Passivhaus ~
- MVHR
- Solar Thermal
- 200 litre store
- Heat Pump, PV



Centini

- 14 dwellings
- 2007 regs
- Solar Thermal
- 500 litre store
- Electric off peak
(space and water)



Soillse

- 6 dwellings
- 2010 regs
- Solar Thermal
- 200 litre store
- Biomass district heat
(space and water)

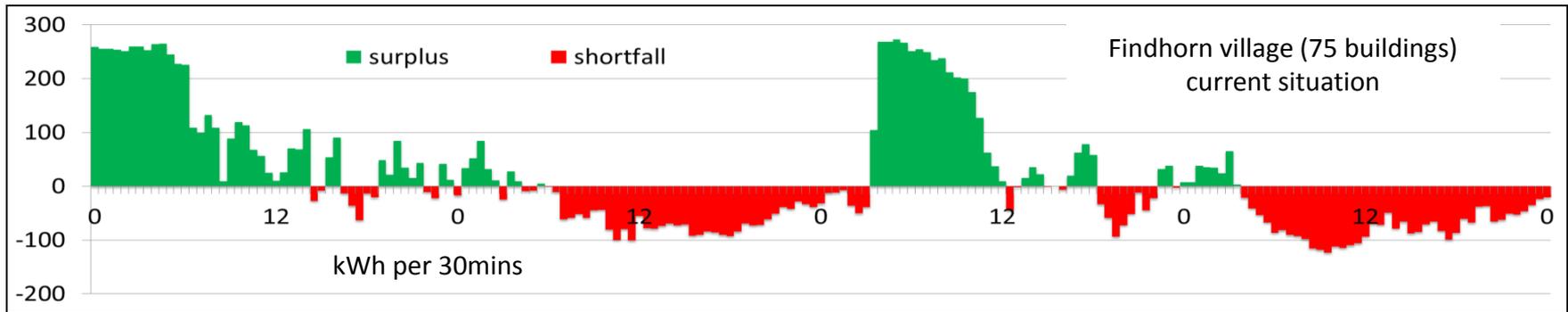


EV

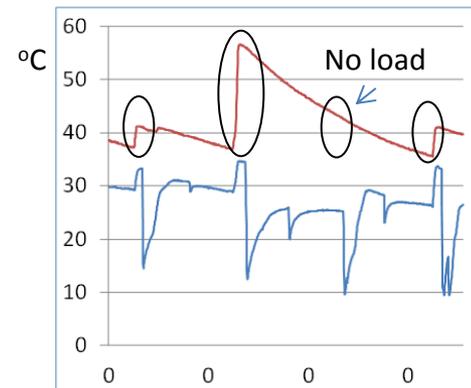
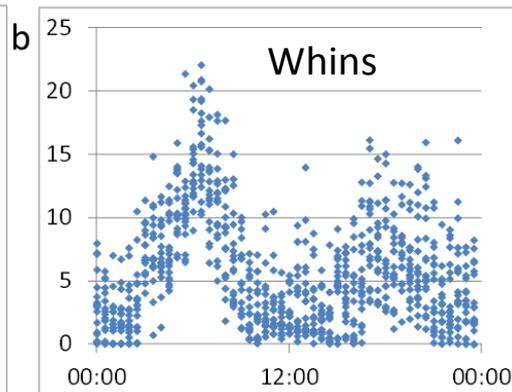
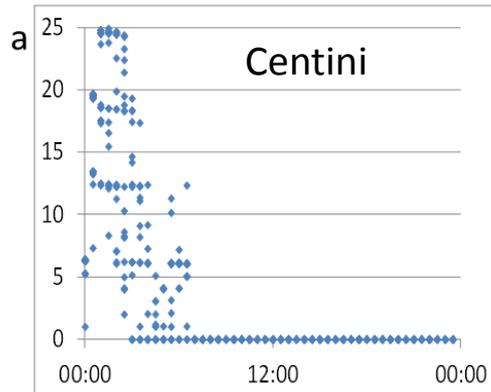
- Twizy (6.1kWh)
- Leaf (22kWh)
- c.f. Tesla (60-85kWh)



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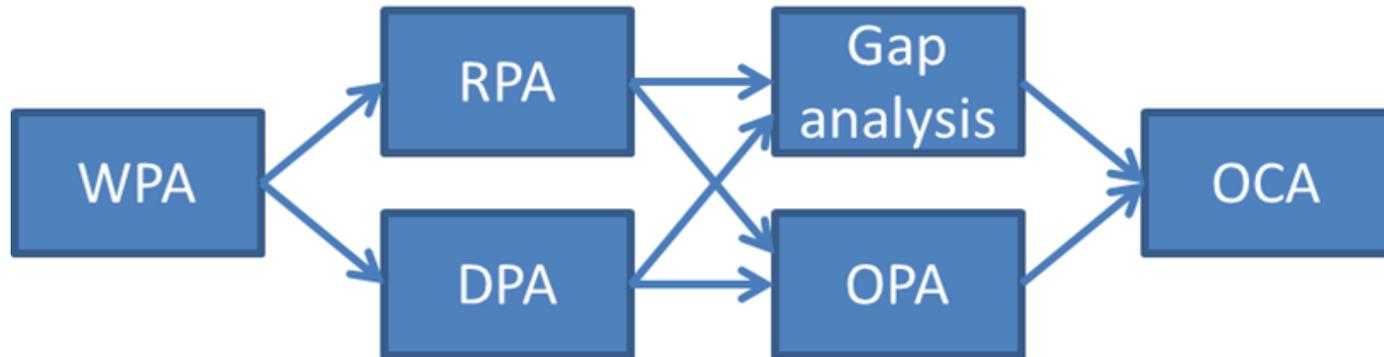
600 kWh
space and
water heat
electric load
in 2 focus
dwelling
types (39
dwellings)



Ability
to coast
using
storage

Orchestration methodology

Orchestration is through the **ORIGIN** algorithm



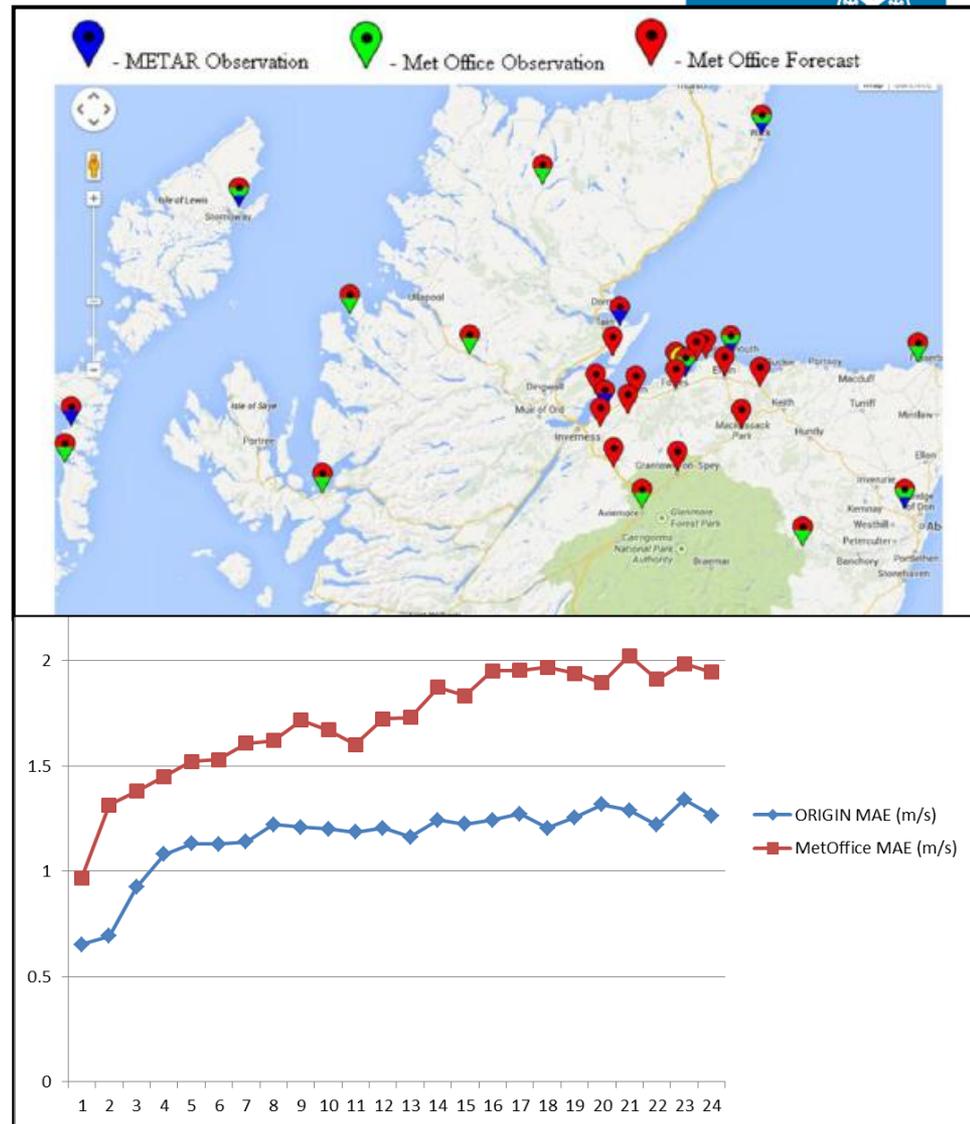
The **ORIGIN** algorithm is in component parts:

- A weather prediction algorithm (WPA)
- Renewable generation prediction algorithm (RPA)
- Demand prediction algorithm (DPA)
- Gap analysis
- Opportunity for load shift prediction algorithm (OPA)
- Orchestration and control algorithm (OCA)

ORIGIN Advanced Weather Prediction



- Takes forecast and observation data for many surrounding sites.
- Predicts next 48 hours local weather using neural networks and regression models.
- Improves on Met Office forecasts.
- Graph is wind speed at Findhorn
 - Vertical axis is m/s error.
 - Horizontal axis is 'hours ahead'.
- Similar methods used for generation and demand prediction plus gap analysis.

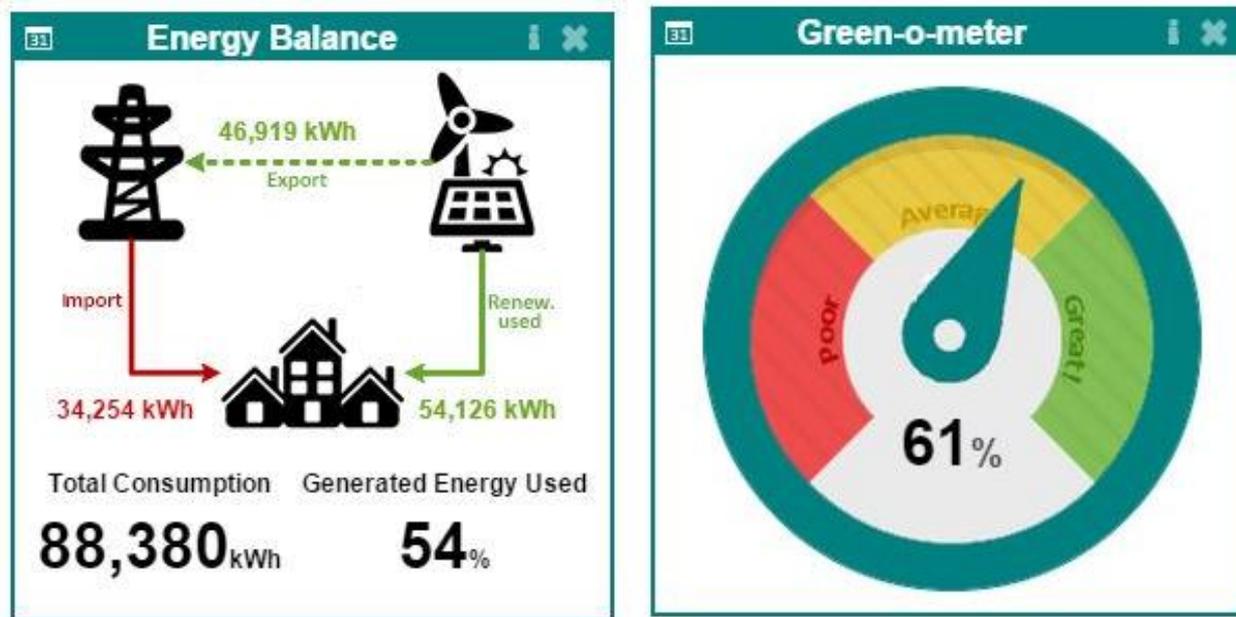


Corne et al, Heriot Watt University, MACS

ORIGIN User Feedback: Web and Phone App

Performance feedback widgets

- community and individual building level
- for yesterday / month / year



Green-o-meter captures % of energy used from local renewable resource

ORIGIN User Feedback: Web and Phone App

Behaviour Stimulus Widgets

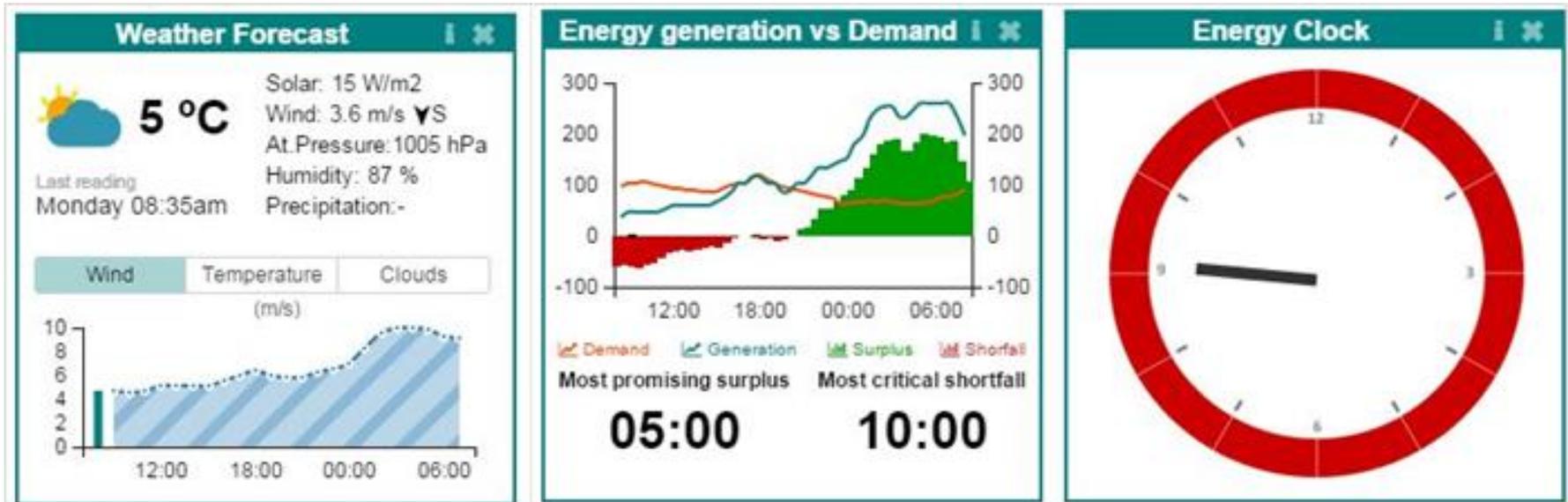
- Real time availability
- Running horse? Blooming plant? Traffic Light?
- Musical prompts? Public Displays? Orbs? Eggs?



ORIGIN User Feedback: Web and Phone App

Behaviour Stimulus Widgets 2

- community level
- forecast local renewable surplus or shortfall next 48 hours

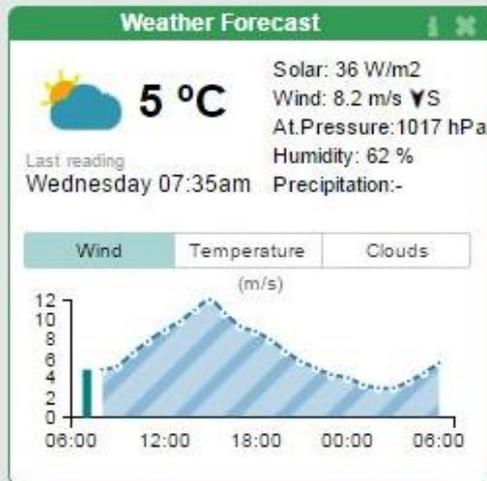
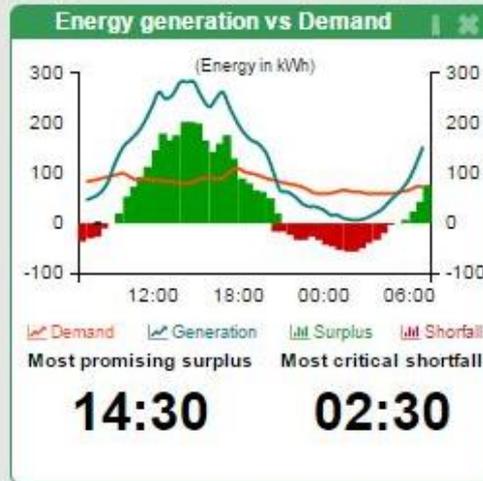
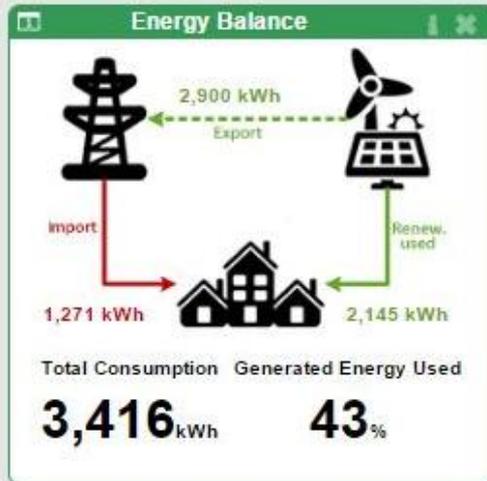


ORIGIN User Feedback: Web and Phone App

Behavioural Stimulus 3: Tariffs

dashboard

Yesterday Monthly Since Origin

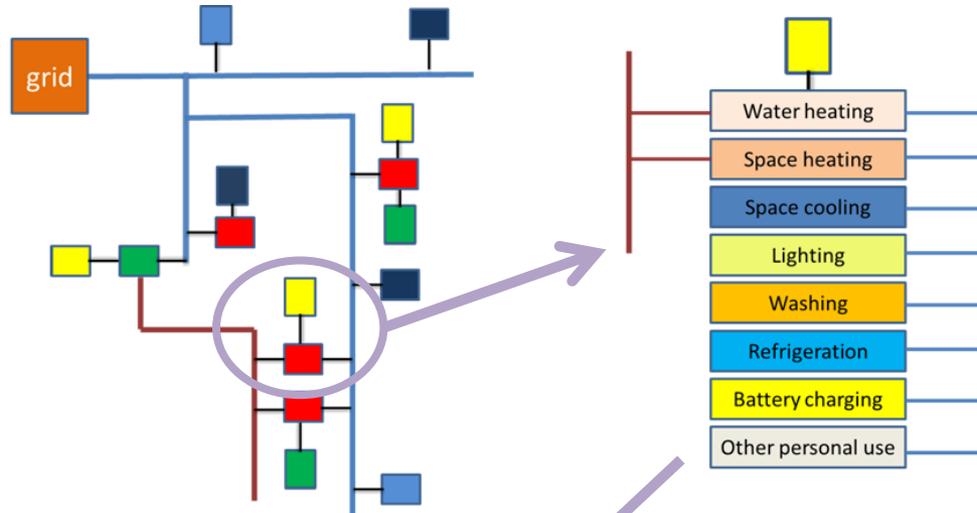


Remote Control Approach

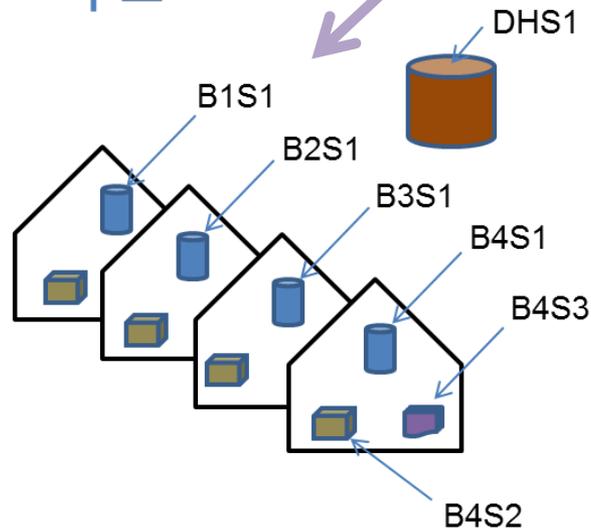
Maps have been constructed identifying load shift opportunities

Key:

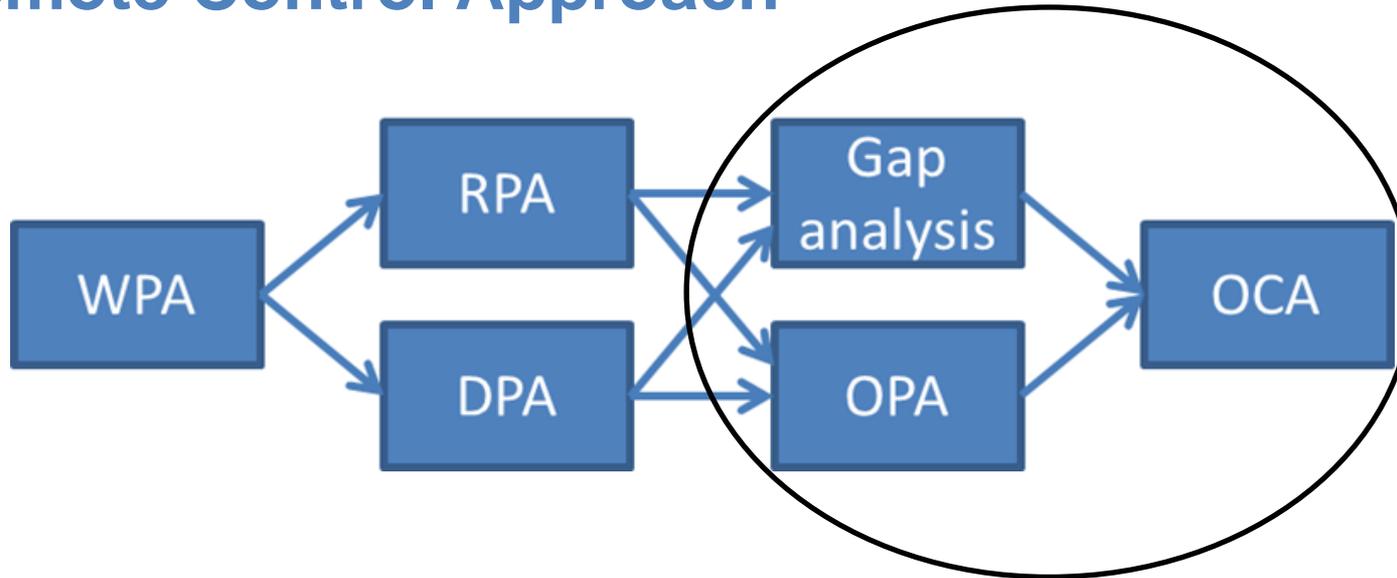
- Electric network —
- DH network —
- Wind Elec Gen ■
- PV Elec Gen ■
- Biomass Thermal ■
- Solar Thermal ■
- Load ■



info	Control
Y	TCL
Y	TCL
Y	TCL
Y	
Y	ECL
Y	TCL
Y	ECL
Y	

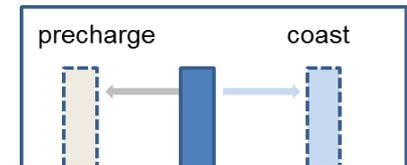


Remote Control Approach



OPA: Each opportunity is quantified at each timestep by the following parameters:

- Load available to be shifted (kW)
- Capacity available for pre-charge (kWh, 'kWhp')
- Period of demand that can be covered by a pre-charge (hours, 'hp')
- Energy in store available for coasting (kWh, 'kWhc')
- Period of demand coverable by coasting (hours, 'hc')
- Cost ratio for precharge or coast (kWh/kWh, 'Cost')

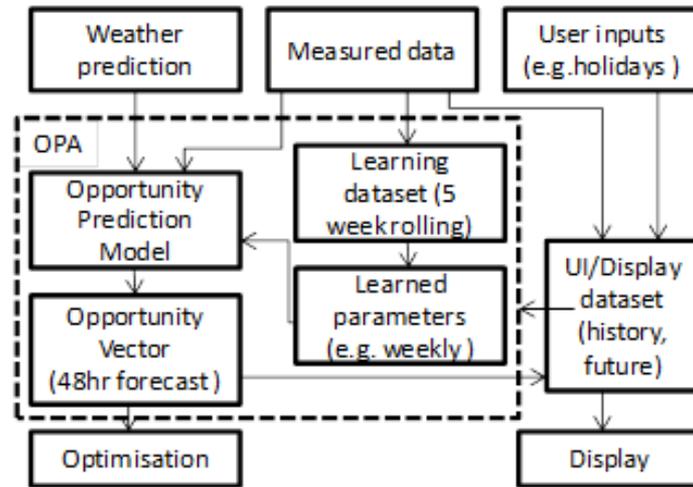
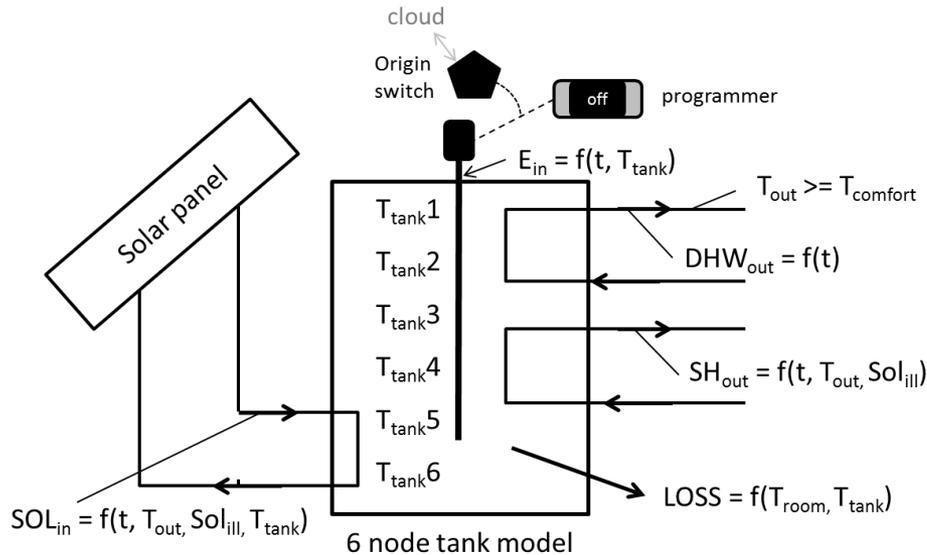
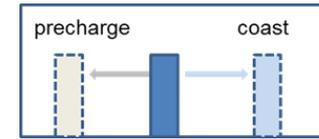


OPA: Each opportunity at each timestep has prediction for future timesteps of form:

- B1S1:[kW, kWhp, hp, CFp, kWhc, hc, Cost]

OCA: Each opportunity is then considered by the orchestration and control algorithm for load shifting, and a subset of the possible loads selected for actuation.

Remote Control Example (TCL): Space and Hot Water Heating



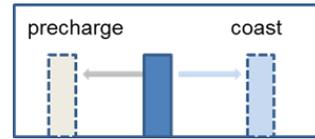
Periodically (e.g. Weekly):

- System and user behaviours learned ($LOSS$, DHW_{out} , SH_{out} , SOL_{in} , E_{in})

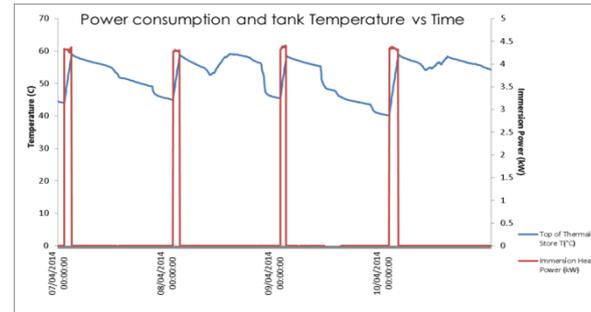
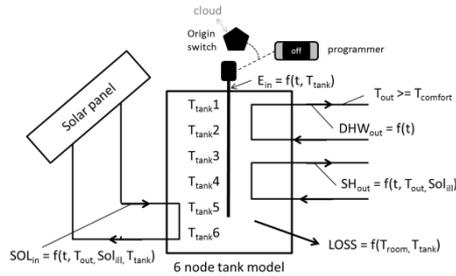
For each timestep:

- Current state established from tank temperatures and simple 6 node tank model.
- Forecast using (i) current state, (ii) model, (iii) weather prediction (iv) learned behaviours.
- Forecast for standard load time and each possible load shift.
- Vectors produced for each possible shift (load times, load, energy cost factors).
- Optimisation algorithm selects best shifts and sends control signals.
- If coast can cover load period then load avoided. (coast ok while $T_{out} > T_{comfort}$). (Will max SOL_{in}).

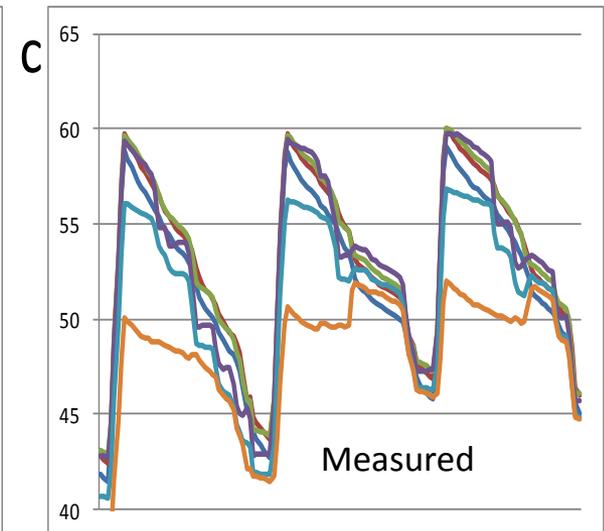
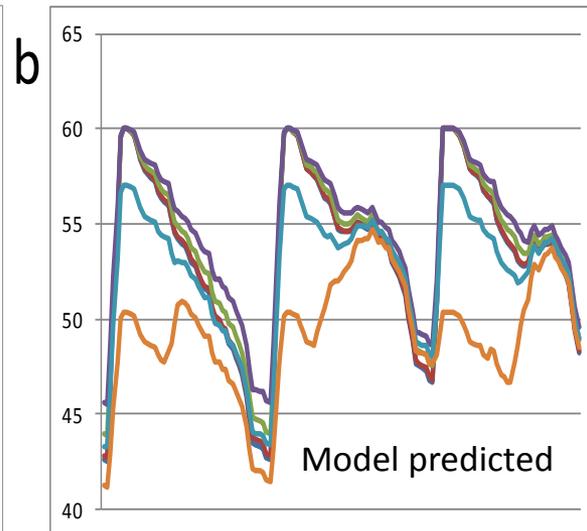
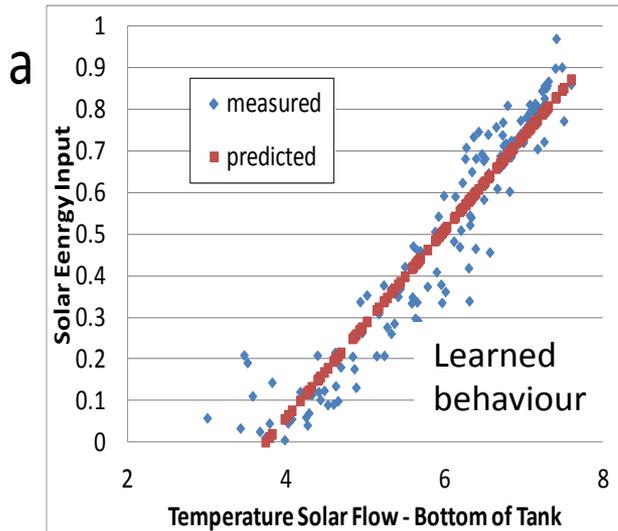
Remote Control Example: Space and Hot Water Heating



Centini System

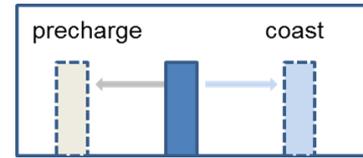


Centini Load



Weather, Model and Learned Behaviour Based Prediction Methods have Auto Correction through re-read of tank temperatures every timestep. Safe default control and user overrides in place for communications outage.

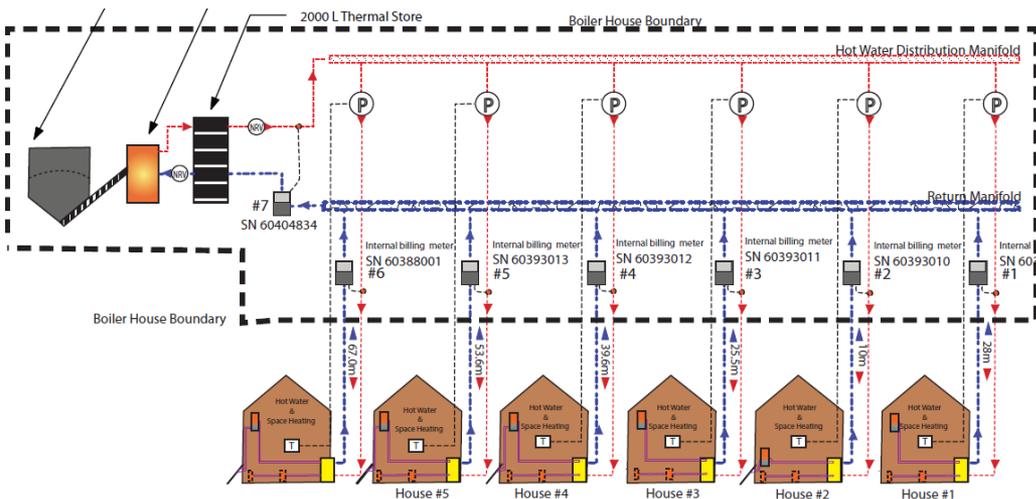
Remote Control - Summary



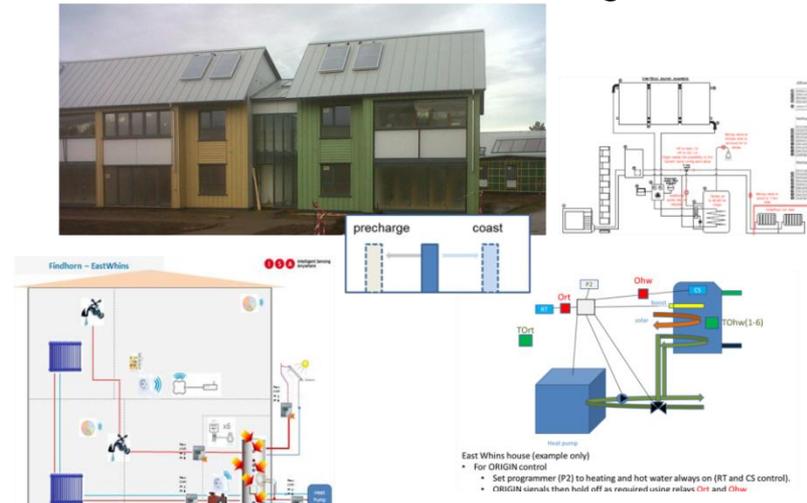
Actuation of switchable loads to match generation

- Heat Loads with electrical (or heat pump) heating are prime candidates.
- District heating and individual building storage tanks provide opportunity.
- Domestic solar systems have larger storage capacity than non-solar.
- Well insulated buildings provide space heating opportunity.
- Monitoring and switching hardware and software in place.
- Cloud based systems monitor thermal state.
- Learning algorithms predict weather, renewable generation and user behaviours.
- Load shift opportunities are quantified and costs associated with shifting.
- Best opportunities are selected and controls actuated via the cloud based system.
- Electric vehicles, appliances, battery storage, water pumping also included.
- Unnecessary loads avoided to maximise renewable inputs.

Orchestration – district level



Orchestration – individual building level



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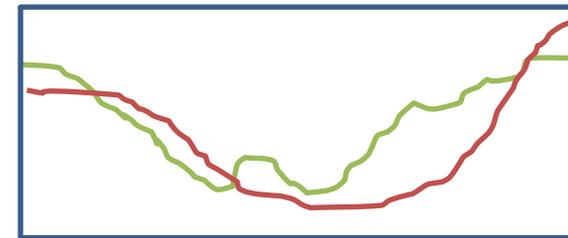
Now



ORIGIN goal: + 20% Local Renewable Use



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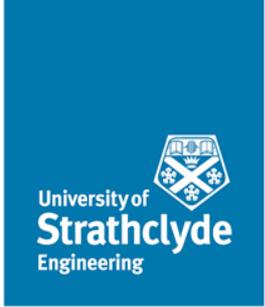
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Complementary technologies to maximise use of renewable generation ?

Future ORIGIN districts, buildings and systems?

ORIGIN: Complementary technologies



Generation:

- PV
- CHP
- Tidal
- Hydro
- Wind

District Systems

- Heat networks / heat pumps / storage
- Electric central and distributed storage
- Water pumping

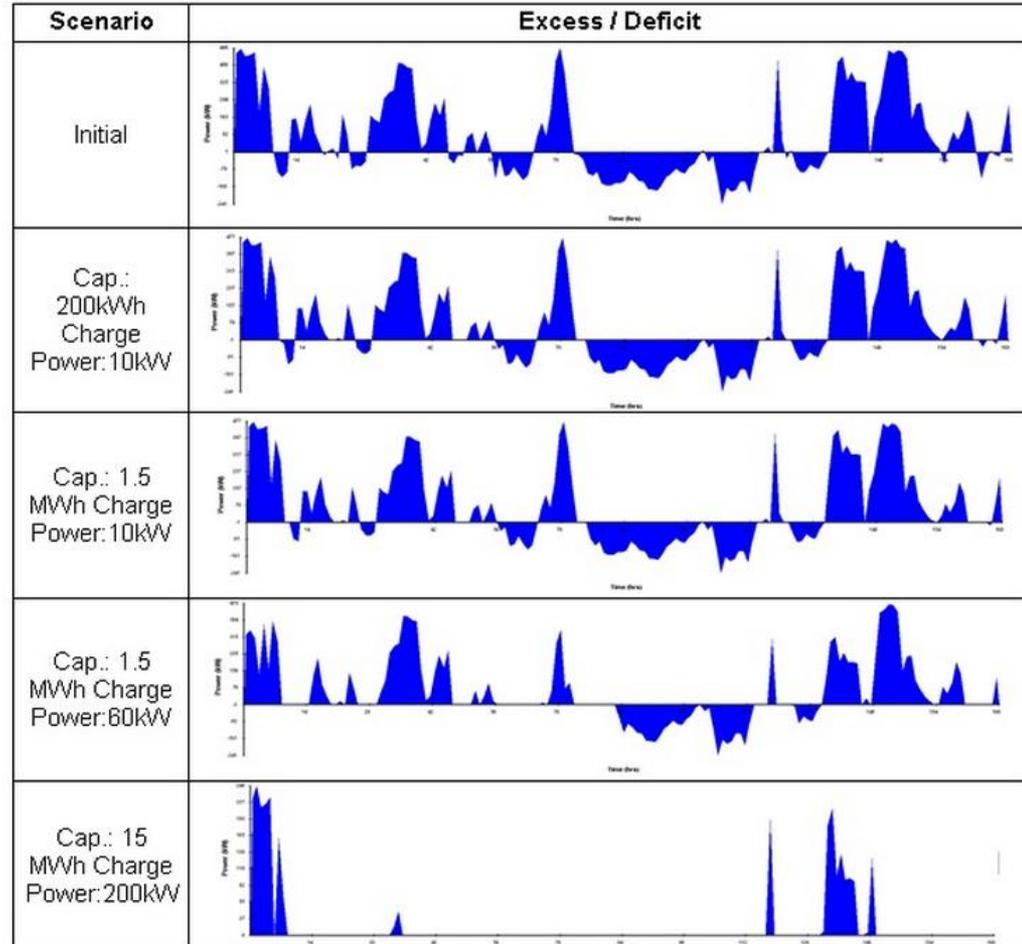
Transport

- EV
- Biofuels

Building and Systems

- Refrigeration
- Hybrid Systems

Elec Storage: Li-ion, CAES, FloBatt, Cryo, Lead Acid..



Effect of the electrical energy storage

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