ESL-IC-14-09-02

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Orchestration of Renewable Integrated Generation in Neighbourhoods

Development of a detailed simulation model to support evaluation of water load shifting across a range of use patterns

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ORIGIN concept

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Orchestrate energy demand to better match renewable generation

Maximise economic revenues from renewable generation

Reduce CO_2 emissions

Work with each community to develop appropriate demand response architecture and systems

Demand

Heating/cooling

Appliances

Storage systems

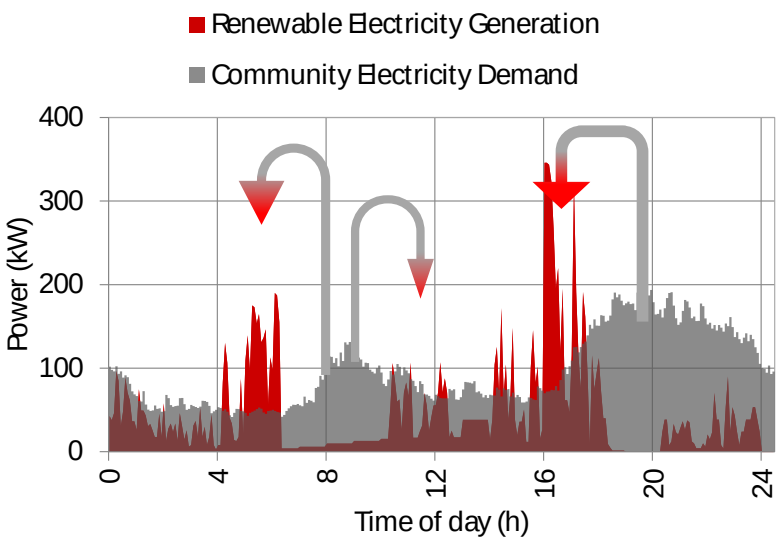
Demand Forecast

Supply Forecast

Load Actuation

Occupant Information

Shift demand to better match renewable supply



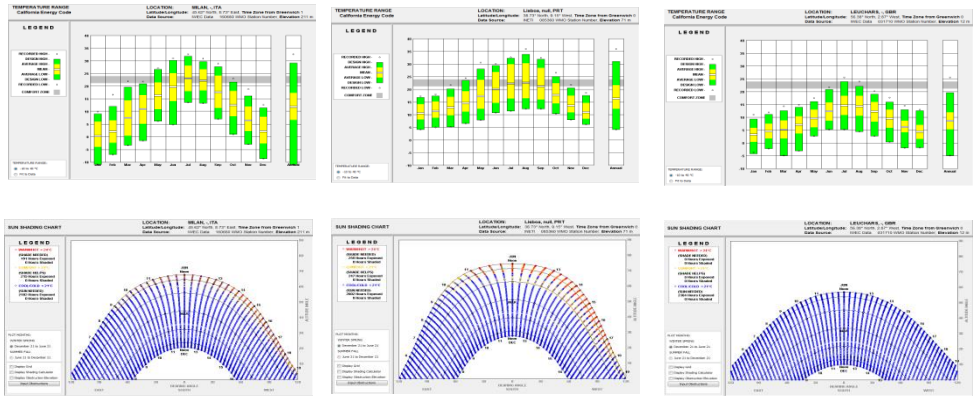
Supply

Solar

Wind

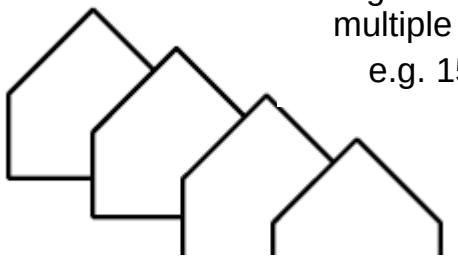
Biomass

This project has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 314742.

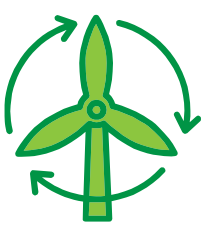


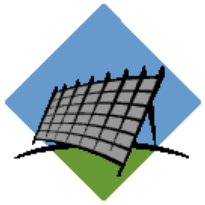
Damanhur Tamera Findhorn

Neighbourhood has multiple integrated renewable and low carbon generation technologies e.g. Wind, PV, Solar thermal, bio-mass, heat pumps etc.

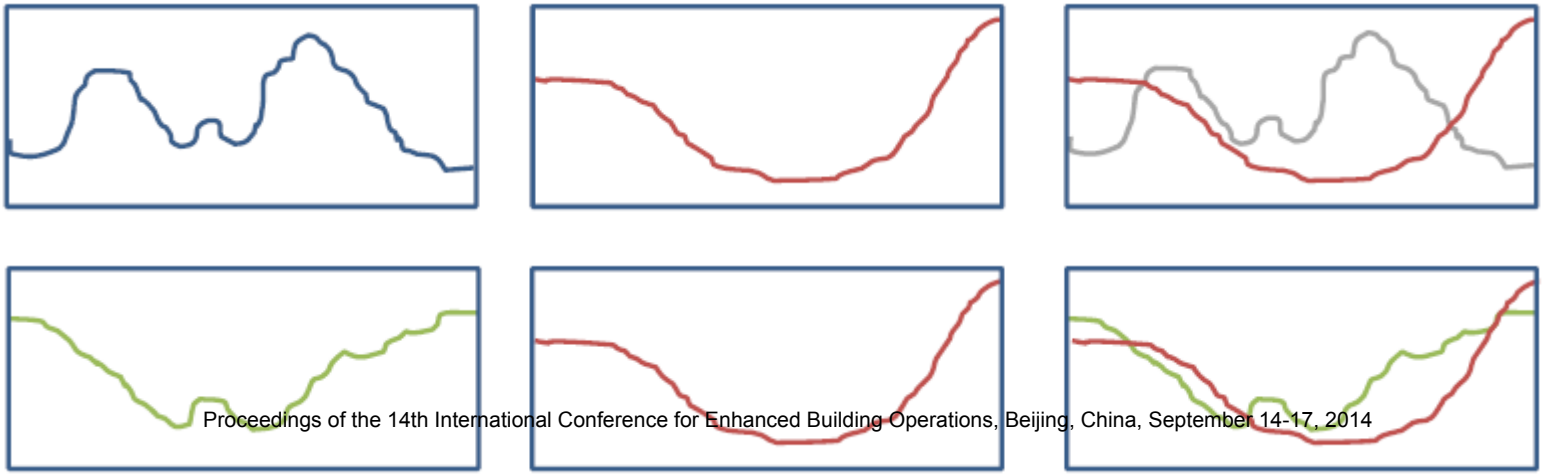


Neighbourhood has multiple buildings e.g. 15 - 500

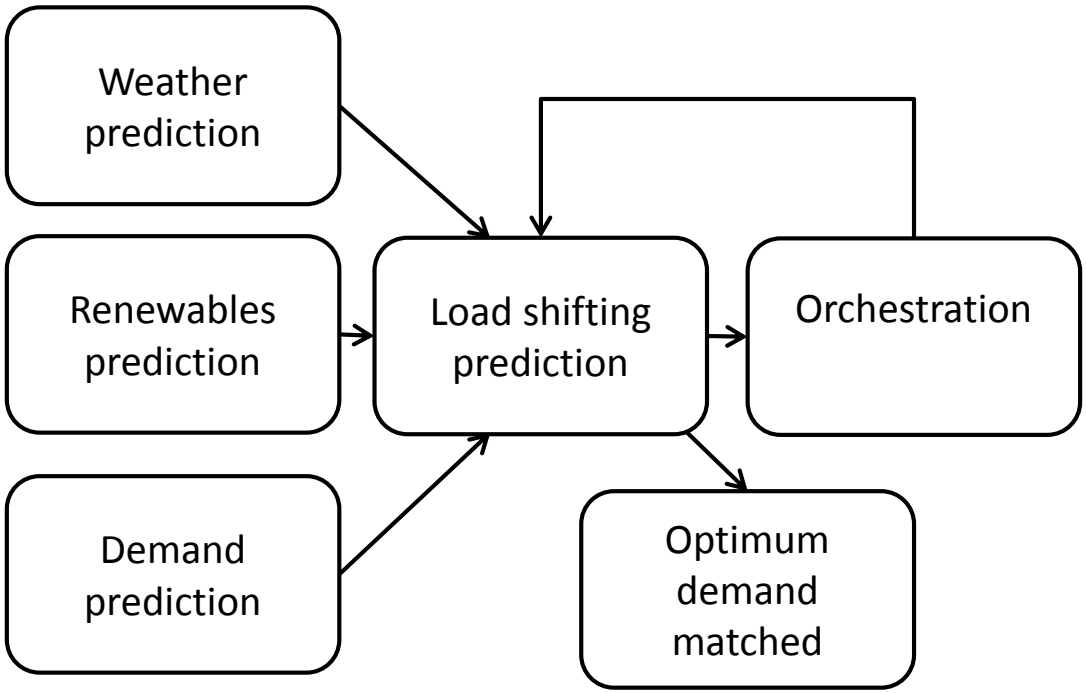




Demand profile Renewables Match



ORIGIN overview



Weather:
Based on monitored conditions

Renewables:
Wind
Solar thermal
Bio-mass

Loads available for shifting:

Hot water tank
Space heating
Plug loads
Refrigeration
Laundry

Load shifting (Orchestration) function:
input power, efficiency function
pre-charge energy and time, coasting energy and time

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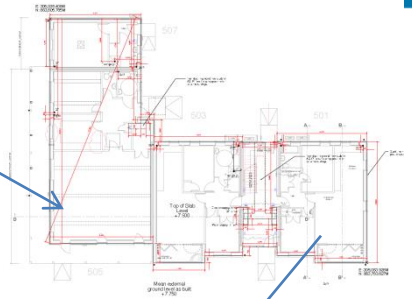
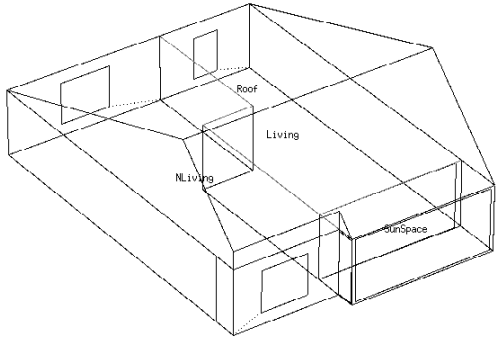
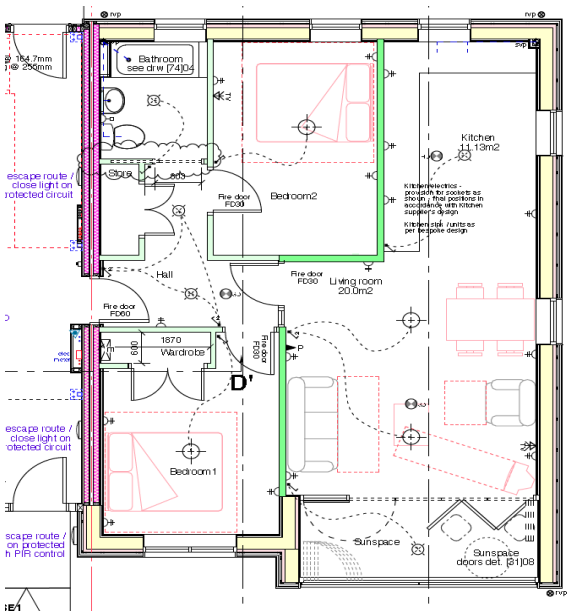
DHW demand / supply matching





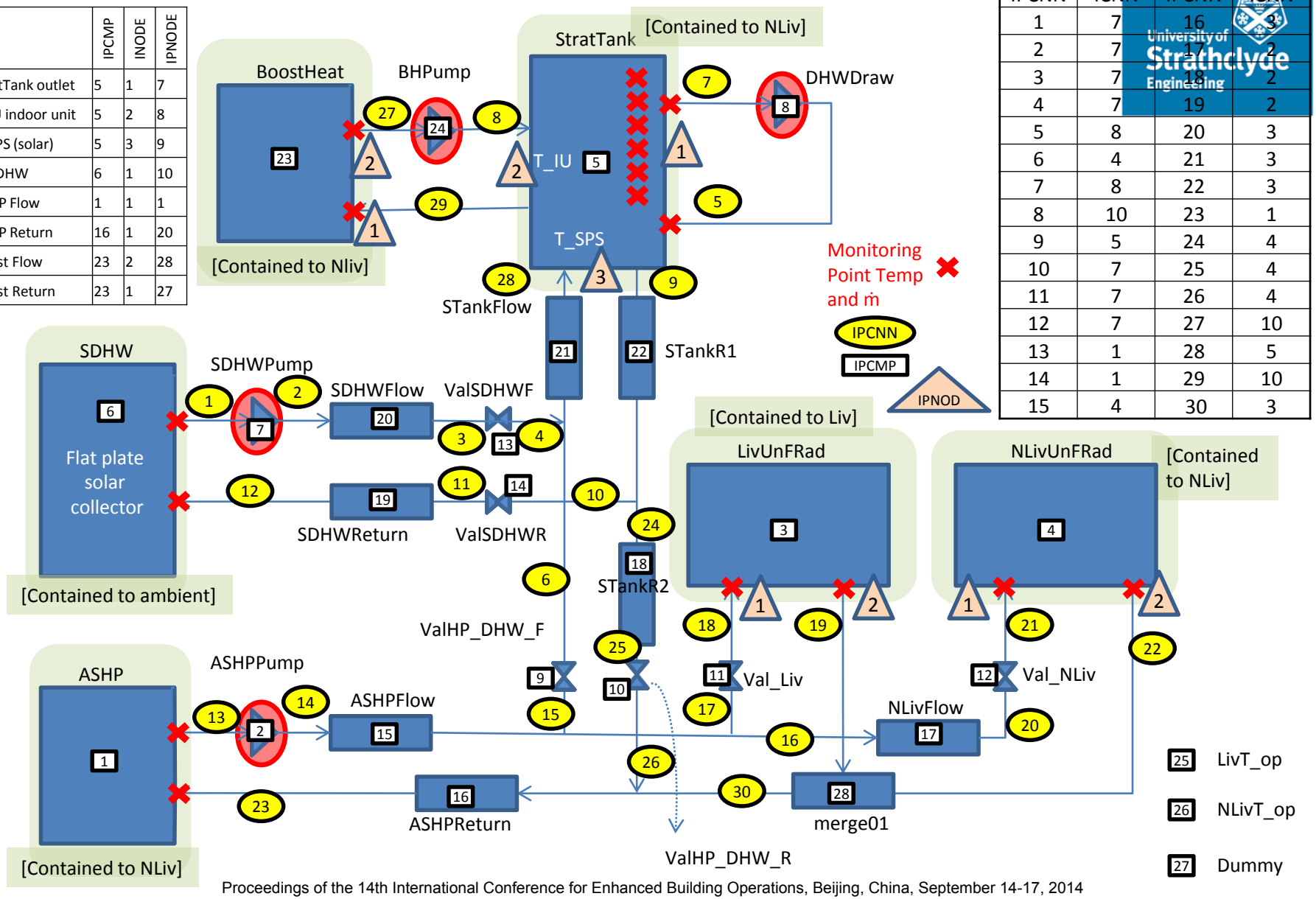


ESP-r coupled building, systems and flow schematic

	IPCMP	INODE	IPNODE
StratTank outlet	5	1	7
T_IU indoor unit	5	2	8
T_SPS (solar)	5	3	9
T_SDHW	6	1	10
ASHP Flow	1	1	1
ASHP Return	16	1	20
Boost Flow	23	2	28
Boost Return	23	1	27

MFN – PLN connection mapping

IPCNN	ICNN	IPCNN	ICNN
1	7	16	3
2	7	17	2
3	7	18	2
4	7	19	2
5	8	20	3
6	4	21	3
7	8	22	3
8	10	23	1
9	5	24	4
10	7	25	4
11	7	26	4
12	7	27	10
13	1	28	5
14	1	29	10
15	4	30	3



Decision flow of heating the domestic water by heat pump or by solar kit

Loop #	Sensor/Normal	Control description	Control law
1	Sensor	ON if T_SDHW > T_SPS + 10	Multi-sensor
2	Sensor	ON if T_IU <= T_ASHPFlow [ON temperature]	Multi-sensor
3	Sensor	ON if T_SPS > T_max	Multi-sensor
4	Sensor (timer)	ON if ASHP timer is ON i.e. 7-9 & 16-23	ON-OFF
5	Sensor	ON if T_IU <= T_BHON	Multi-sensor
6	Sensor (timer)	ON if BH timer is ON i.e. 0-6 & 16-24	ON-OFF
7	Sensor	ON if BH delay time is finished	Multi-sensor
8	Sensor	!S1	Multi-sensor NOT
9	Sensor	!S2	Multi-sensor NOT
10	Sen		
11	Sen		
12	Sen		
13	Sen		
14	Sen		
15	Sen		
16	Nor		
17	Nor		
18	Normal	**Sens:** Top_Liv **Act:** Val_Liv [11]	ON-OFF or P
19	Normal	**Sens:** Top_NLiv **Act:** Val_NLiv [12]	ON-OFF or P
20*	Sensor (DHW by ASHP)	S2 & S4 (no solar priority) !S1 & S2 & S4 (solar priority)	Multi-sensor
21	Sensor	S18 | S19 | S20	Multi-sensor
22	Normal	**Sens:** S21 **Act:** ASHP [1]	ON-OFF or P
	Normal	**Sens:** S21 **Act:** ASHP Pump [2]	ON-OFF
23	Normal	**Sens:** S20 **Act:** ASHP-DHW valves [9&10]	ON-OFF
24*	Sensor (DHW by SDHW)	S1 & !S3 & !S2 (no solar priority) S1 & !S3 (solar priority)	Multi-sensor
25*	Sensor (DHW by SDHW)	S1 & !S3 & S2 & !S4 (no solar priority) ON (solar priority)	Multi-sensor
26	Sensor	S24 & S25	Multi-sensor
	Normal	**Sens:** S26 **Act:** SDHW [6]	ON-OFF
	Normal	**Sens:** S22 **Act:** SDHW Pump [7]	ON-OFF
	Normal	**Sens:** S22 **Act:** SDHW valves [13&14]	ON-OFF
	Normal	**Sens:** DHW Draw Profile Act: DHW Pump [8]	ON-OFF

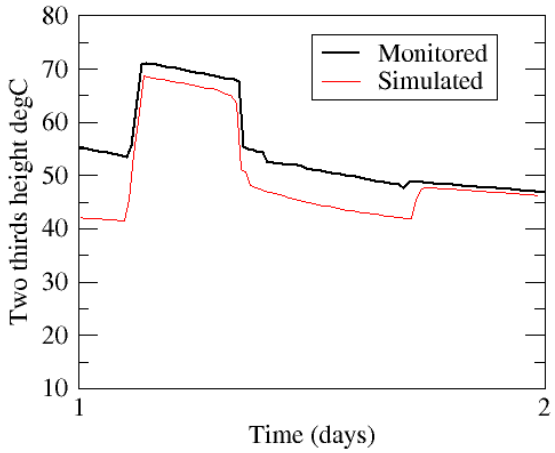
maximur
domestic
tank tem

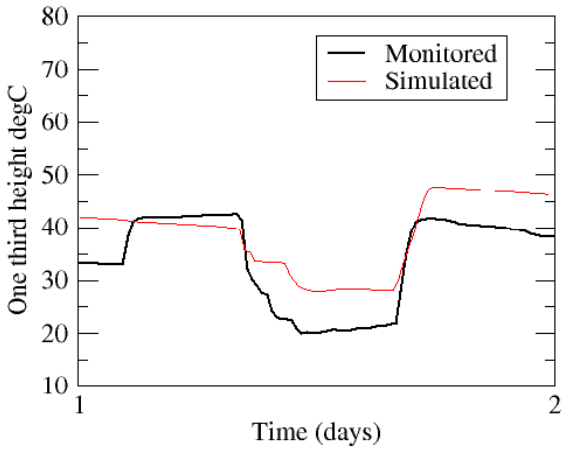
DHW heating by solar kit

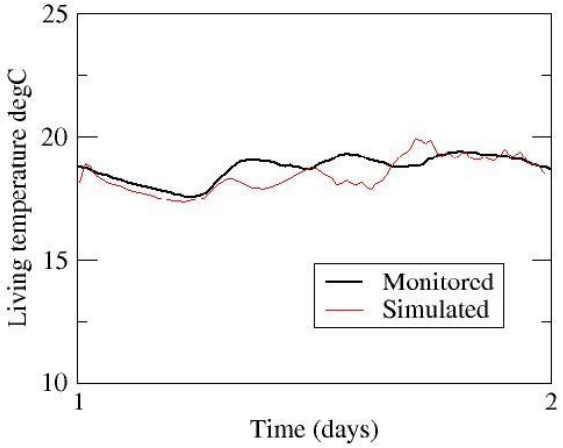
SDHW

* These loops change from solar priority to no solar priority

Model validation







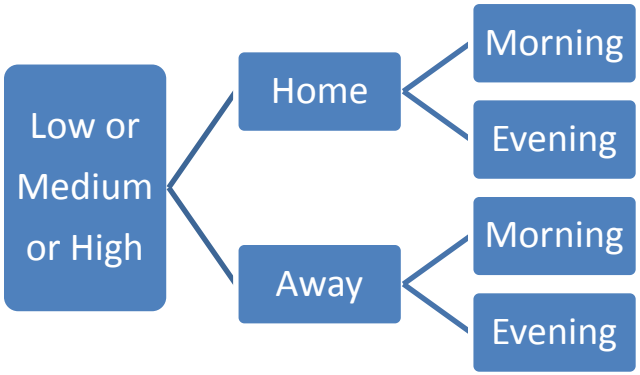
		Mean (°C)	Std Dev (°C)
2/3	Monitored	54.8	8.3
	Simulated	50.0	9.2
1/3	Monitored	34.0	8.6
	Simulated	38.8	7.0
Space	Monitored	18.7	0.5
	Simulated	18.5	0.8

	RMS error	Normalized RMS error	Pearson's correlation coefficient	Spearman's rank correlation coefficient	Inequality coefficient
2/3	0.63	0.01	0.91	0.42	0.06
1/3	0.65	0.02	0.88	0.58	0.09
Space	0.07	0.00	0.61	0.55	0.02

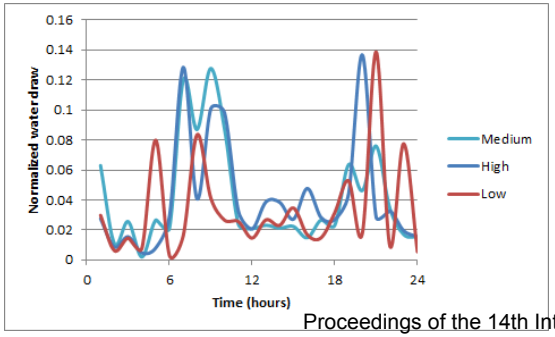
Water draw profiles and heating patterns

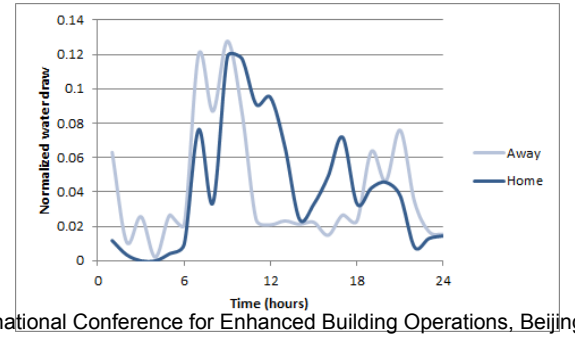
Water draw profiles:
3 use levels x 2 space occupancy levels x 2 time bias = 12 profiles

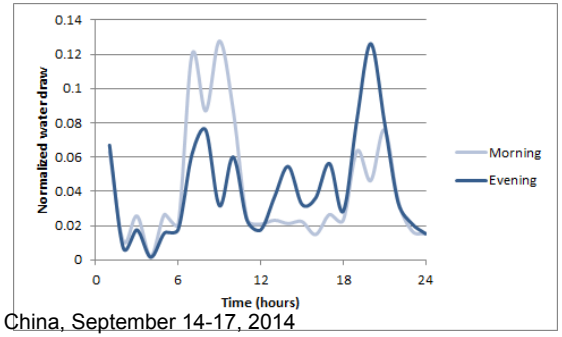
Heating hours:
5 x 2 hour periods



Heating hours
0000-0200
0600-0800
1000-1200
1600-1800
2000-2200







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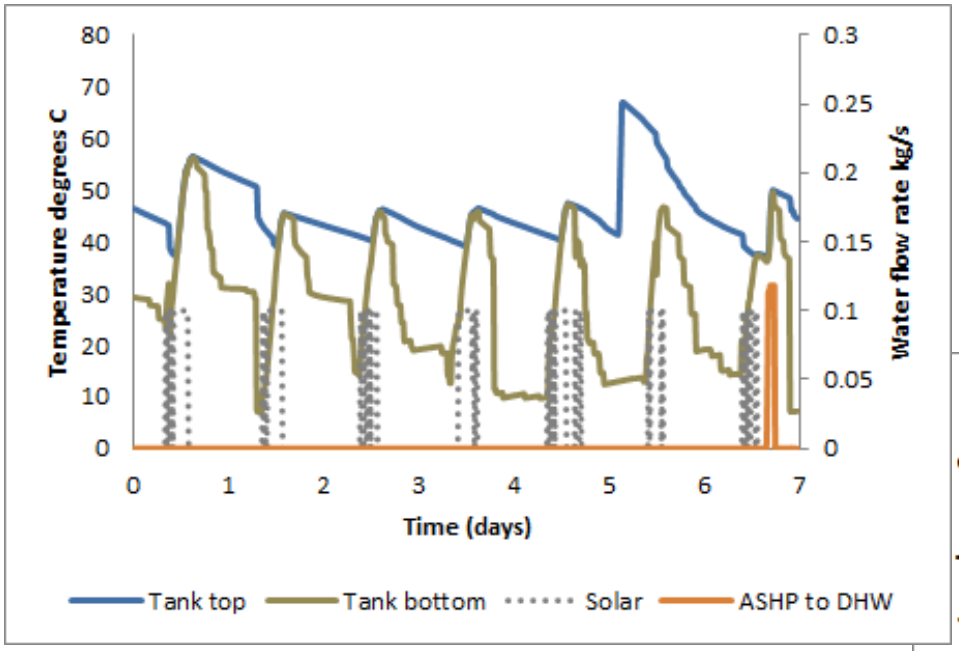
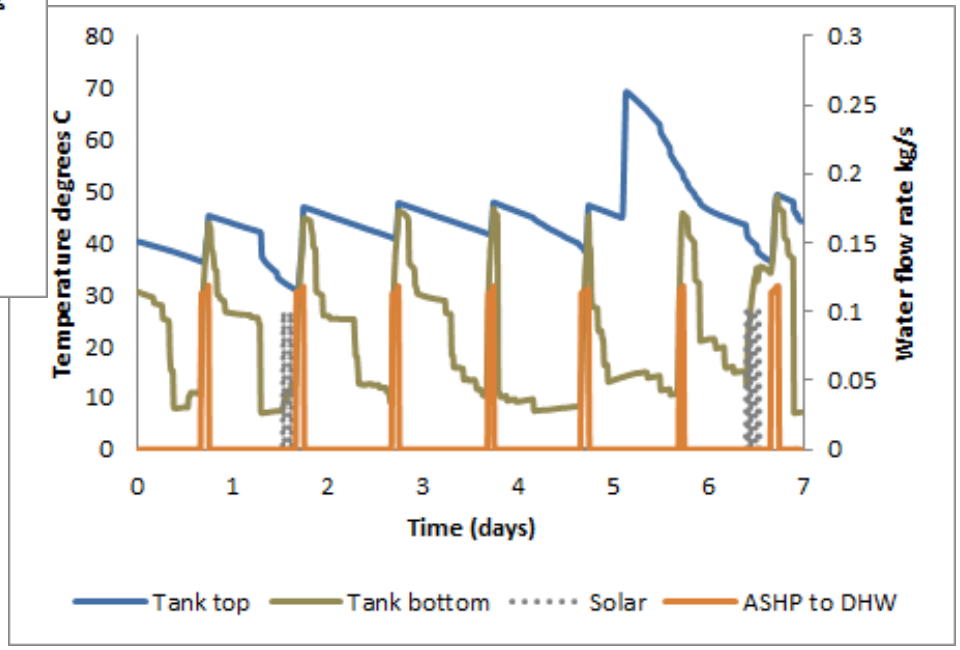
Results



Spring week



Winter week

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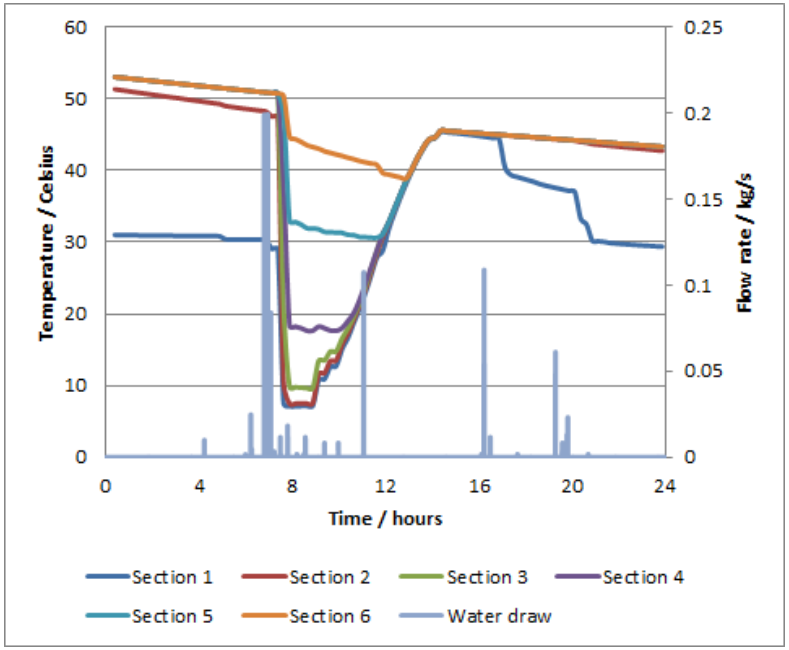
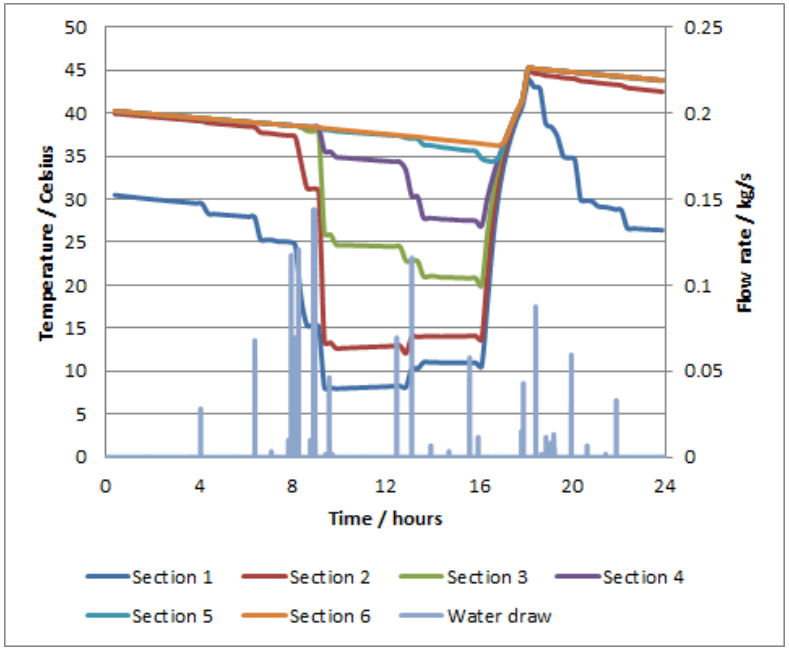
Results

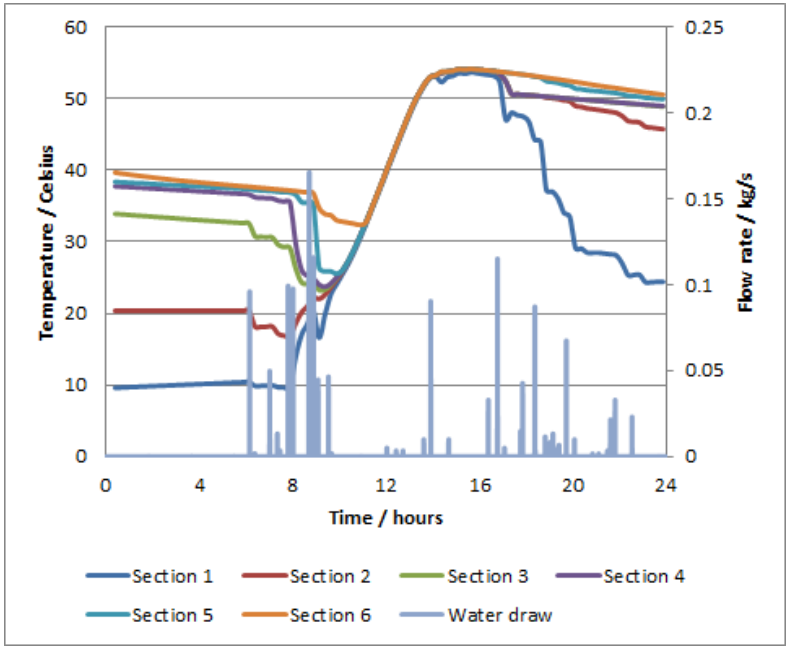


Spring day

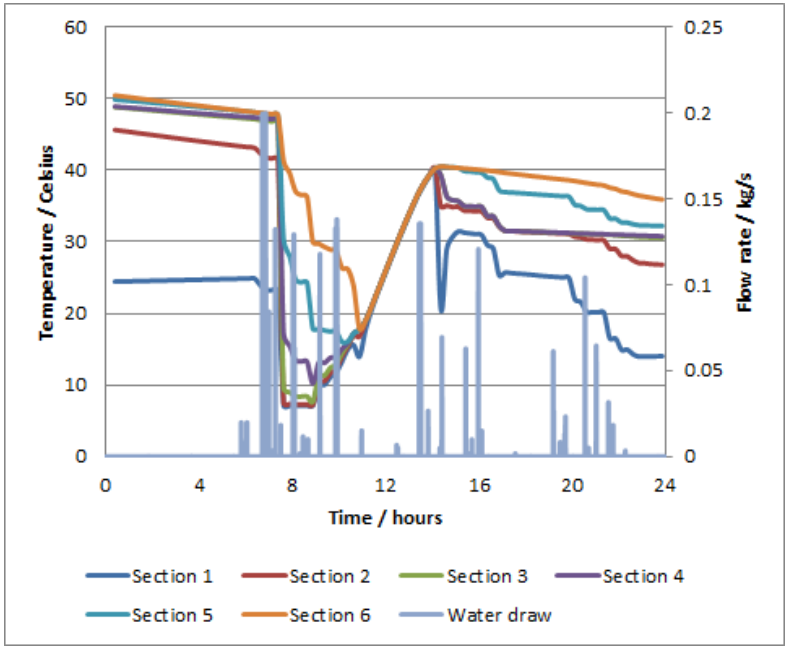


Winter day

Results



Spring day



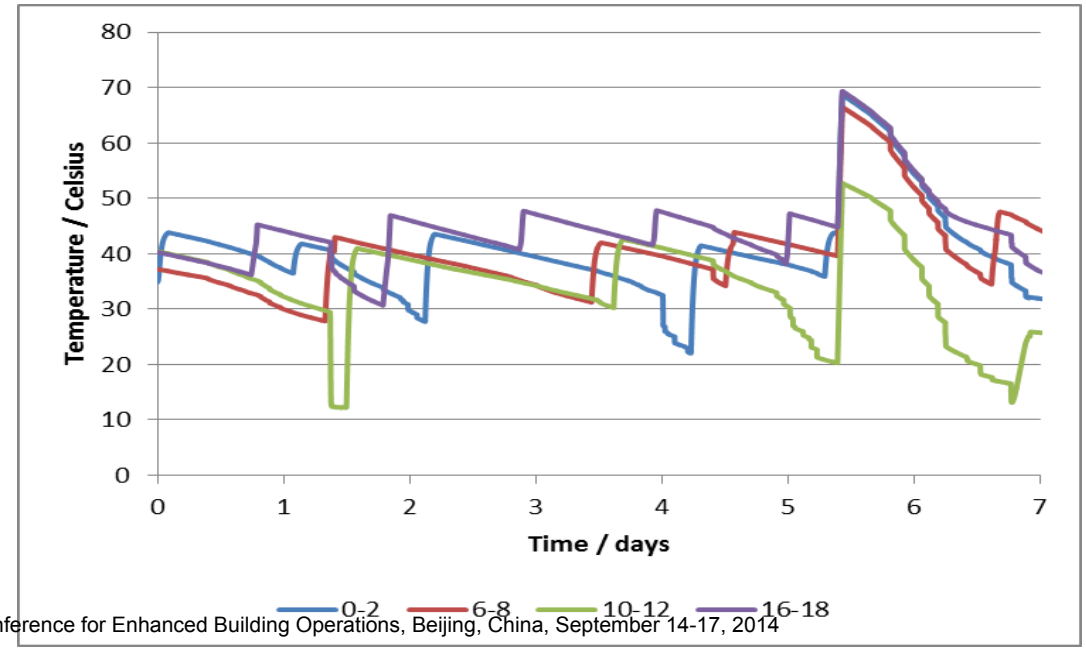
Next Spring day

Results

Heating hours	Heating kWh	Electrical kWh
0000-0200	19.7	6.2
0600-0800	18.5	5.6
1000-1200	18.1	7.0*
1600-1800	18.0	5.8
2000-2200	18.9	5.9

* Immersion heating required

Tank top temperatures



Conclusions & Recommendations

- Many influencing factors
- Detailed DSM exist to adequately describe the problem
- All draw profiles can be supplied by solar energy in summer
- High use profiles require ASHP in spring
- Evening biased profiles utilize more solar energy
- Range of shifting benefits is 10-15% of standard heating energy

- Individual use patterns monitored and behaviour learnt to tailor shifting strategy to individual households
- Demand / supply cost matching is a function of many parameters

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