energy saving trust

The benefits and considerations of heat pumps, PV, and batteries – an integrated system

Green Heat Installer Engagement Programme

13 September 2023

Presenters

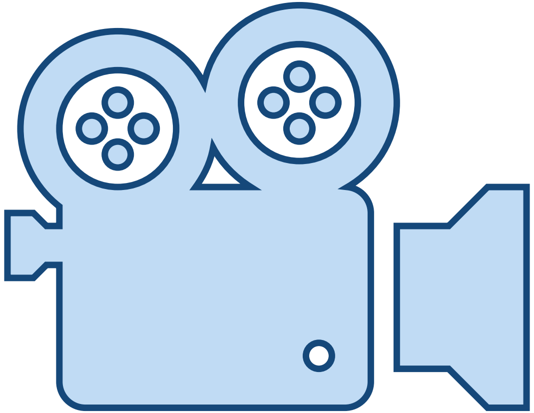
Pilar Rodriguez	Programme Manager, Green Heat Installer Engagement Programme, **Energy Saving Trust**	Presenter, Q&A Panel
Ben Whittle	Senior Low Carbon Consultant, **Energy Saving Trust**	Presenter, Q&A Panel
Torin Clarke	Scottish Home Renewables, **Energy Saving Trust**	Presenter, Q&A Panel
David Stutchfield	Green Homes Network Member	Presenter, Q&A Panel

Questions

Type questions into the **Questions** pane of the control panel

You can send in your questions at any time during the presentation. These will be collected and addressed during the Q&A session at the end of the presentations.

Recording



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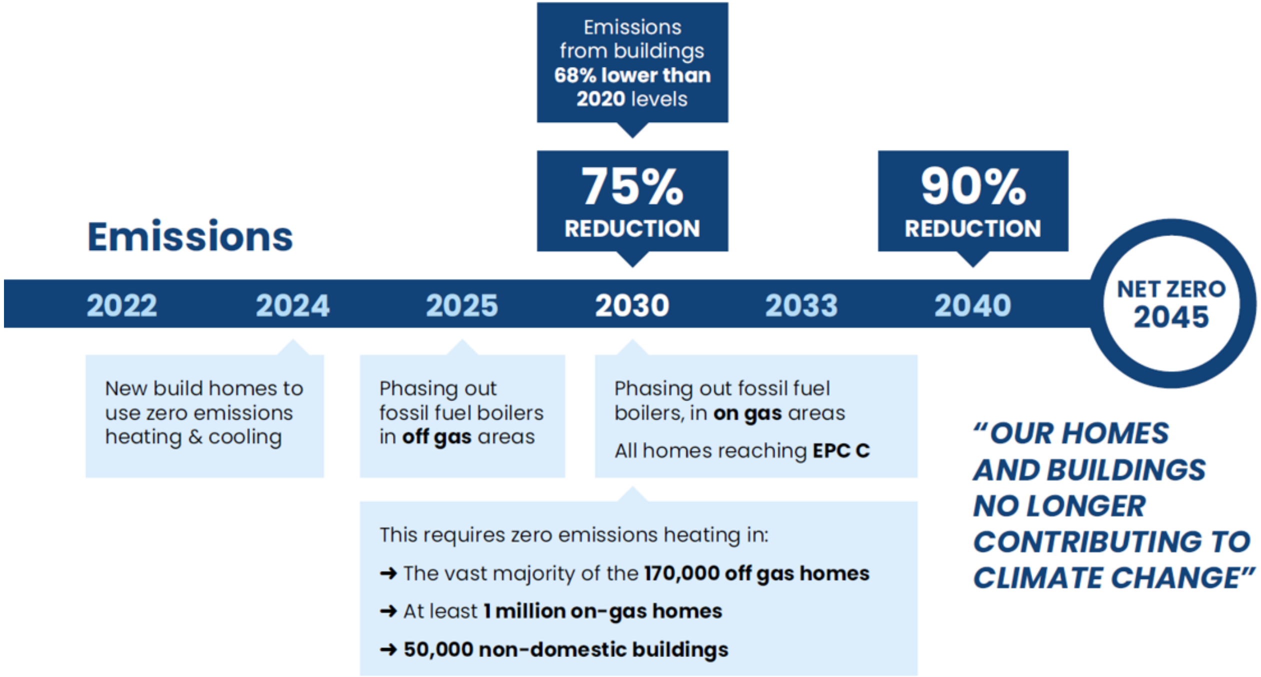
Integrated Systems

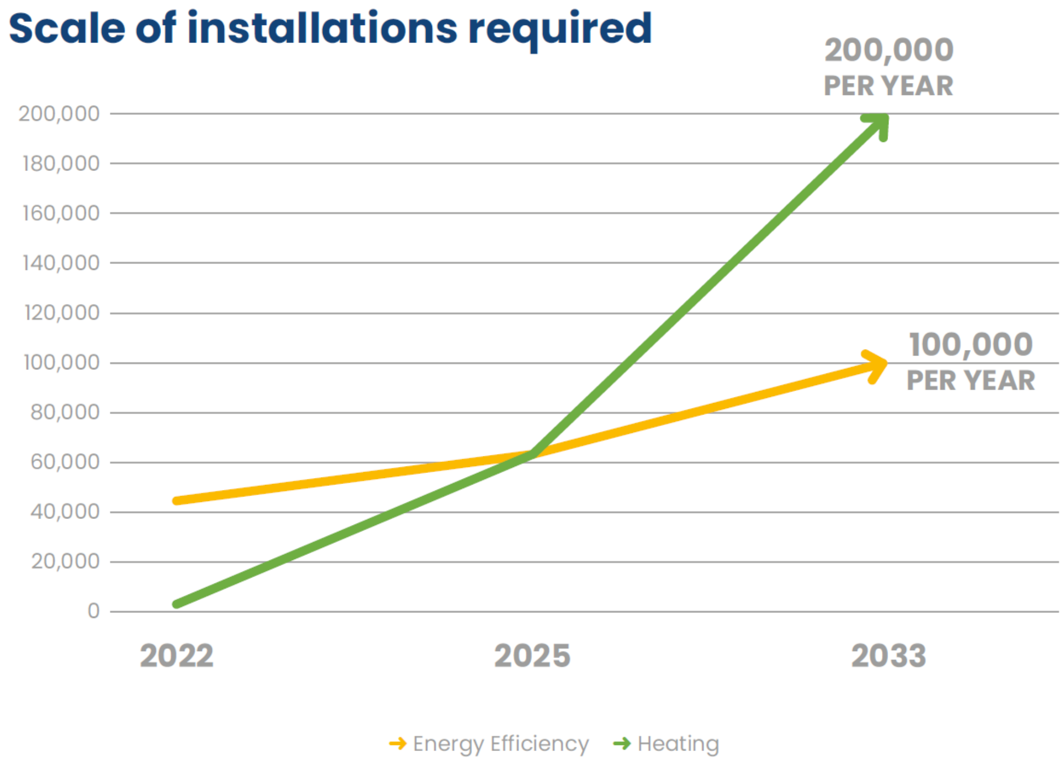
Role in decarbonising our homes

Pilar Rodriguez

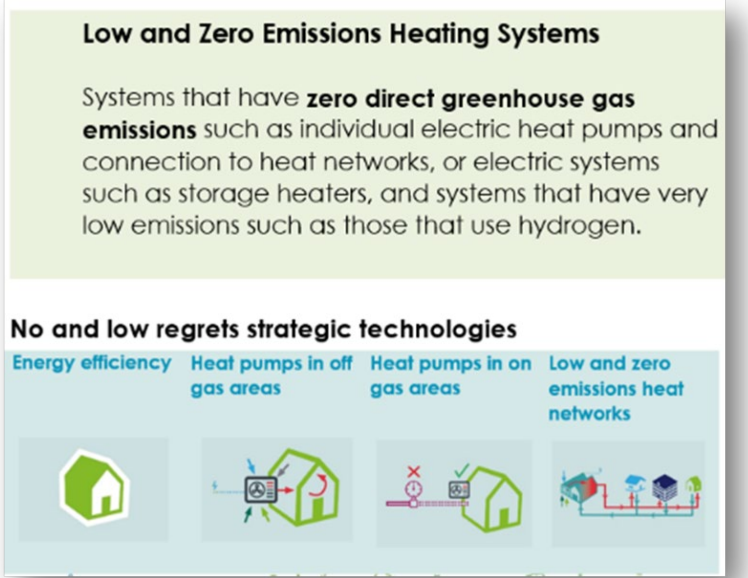
Scottish Government Heat in Buildings Strategy



Domestic energy efficiency installations



How are we going to get there



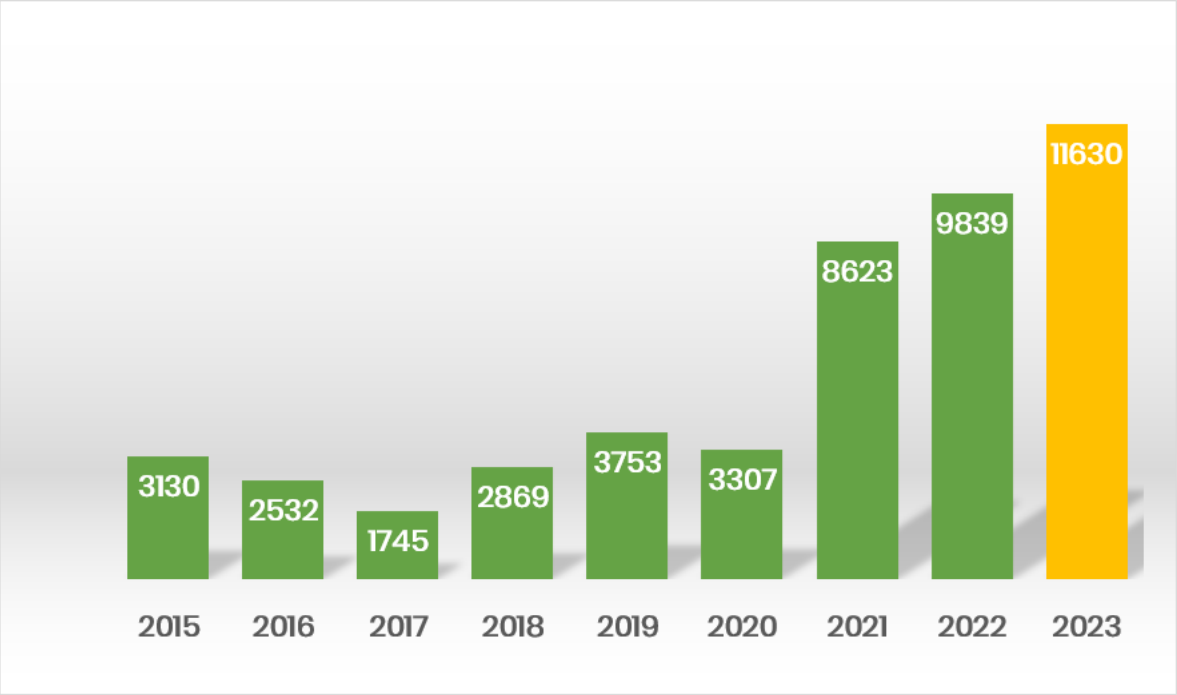
Electrification of heat and secondary technologies

Technologies that work well in conjunction with zero emissions heating systems:

- e.g. solar thermal, solar PV, and battery storage

Solar thermal can supplement the hot water supply and PV can contribute to electrical demand

Rooftop PV installations in Scotland



- **2015:** Major cut to FIT for small-scale installations
- **2019:** End of FIT scheme
- **2020:** Pandemic lockdown
- **2021:** Energy price crisis begins
- **2022:** Gas prices further up due to Russia's invasion of Ukraine

Source: mcscertified.com/low-carbon-landscapes

Green Heat Installer Engagement Programme – useful links

- Website: energysavingtrust.org.uk/green-installer
- Email updates and quarterly newsletter subscription – bit.ly/2PSatkL
- LinkedIn group: linkedin.com/groups/5139242
- Email: GreenInstallerScotland@est.org.uk

Thank you

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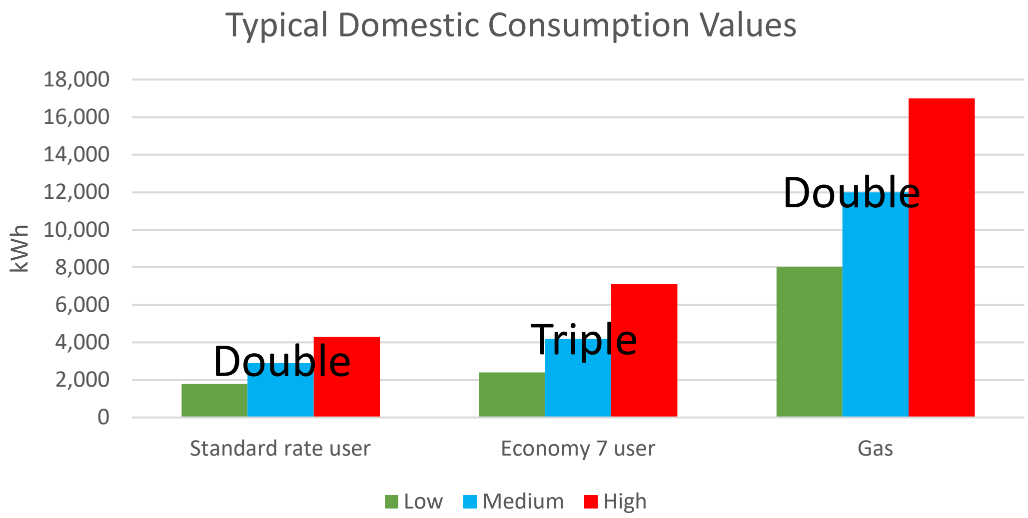
Modelling Solar PV heat pumps and batteries

What do we mean by a “typical” house
What do we mean by “typical” energy use?
What are the ranges we might expect?

How much impact does solar have?
How much impact does a heat pump have?
How much can batteries help?
How much can smart tariffs help?

Typical domestic Consumption Values (electricity and gas)



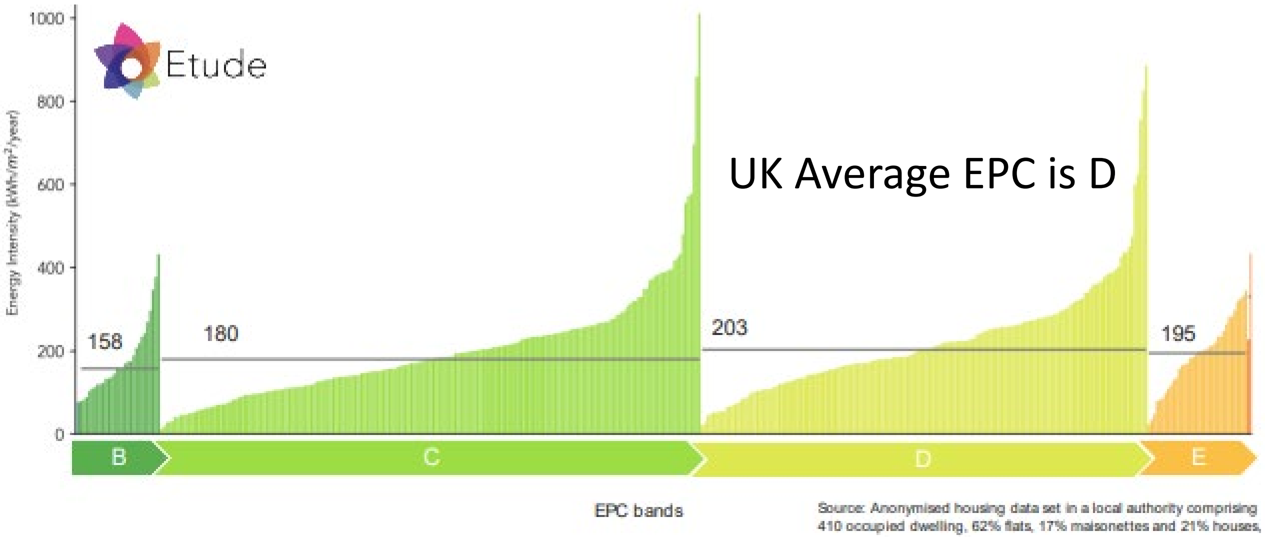
	kWh	**Current TDCVs**	**Revised TDCVs**
Gas	Low	8,000	8,000
	Medium	12,000	12,000
	High	17,000	17,000
Electricity: Profile Class 1	Low	1,900	1,800
	Medium	3,100	2,900
	High	4,600	4,300
Electricity: Profile Class 2	Low	2,500	2,400
	Medium	4,200	4,200
	High	7,100	7,100

	2017 consumption split (GB)	**2019 consumption split (GB)**
Peak (day time usage)	58%	59%
Off-peak (night time usage)	42%	41%

Actual energy use depends on a lot of factors and can cover huge ranges depending on heating system type and efficiency etc

EPC bands don't help…
this chart is total energy use per sqm by EPC band (in 410 houses analysed).

EPC scores combine many metrics and aren't a straightforward representation of actual energy use



What we have learnt so far:

There is no such thing as a typical house
… or typical energy use

Housing Archetypes

How do we go about modelling renewables?

HelioScope

Created with PV*SOL premium 2019 (R10)
Valentin Software GmbH

OpenSolar

PVsyst
PHOTOVOLTAIC SOFTWARE

PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM
European Commission

How do we go about modelling integrated systems?

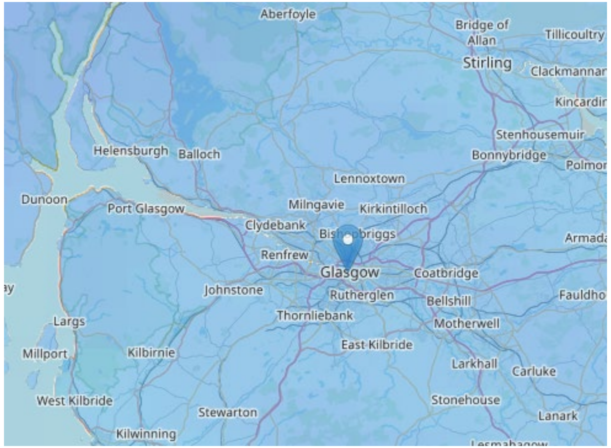
1. Choose a location > get solar and climate information
2. Select system size > get amount of energy produced

3. Create a “grid” of electricity use and generation

4. Sum all the positive and negative amounts
5. Result > an energy system balance
   > an idea of running costs

1. Choose location > get climate information

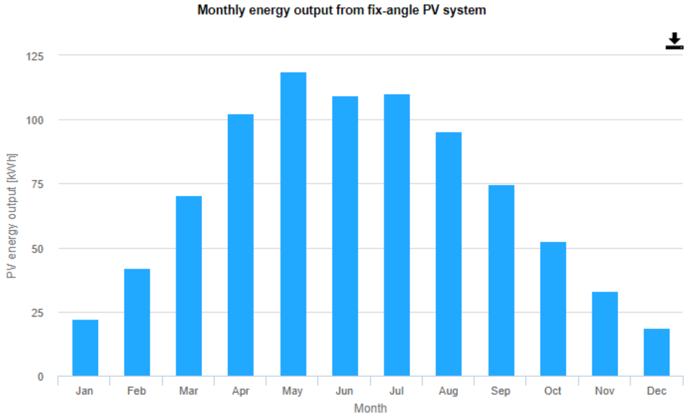
PV-GIS is free, but only monthly data - Not very helpful for detailed models



Summary

Provided inputs:	
Location [Lat/Lon]:	55.853,-4.248
Horizon:	Calculated
Database used:	PVGIS-SARAH2
PV technology:	Crystalline silicon
PV installed [kWp]:	1
System loss [%]:	14

Simulation outputs:	
Slope angle [°]:	35
Azimuth angle [°]:	0
Yearly PV energy production [kWh]:	850.46
Yearly in-plane irradiation [kWh/m^2]:	1052.11
Year-to-year variability [kWh]:	27.56
Changes in output due to:	
Angle of incidence [%]:	-3.32
Spectral effects [%]:	1.75
Temperature and low irradiance [%]:	-4.45
Total loss [%]:	-19.17

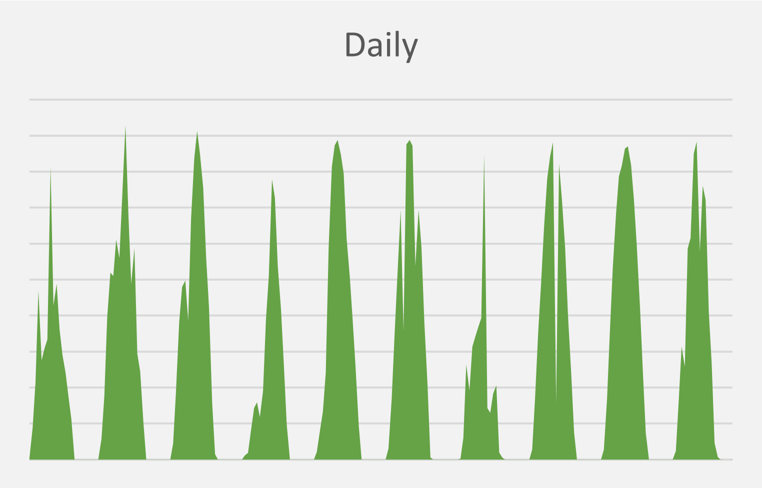


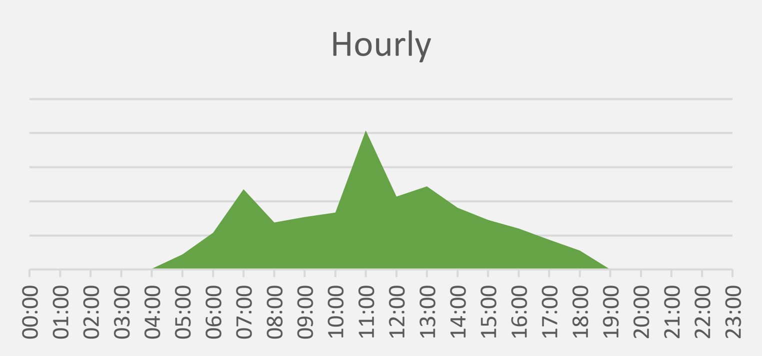
Paid for software –

Hourly,30min or even 5 minute results of typical solar insolation levels anywhere in the world using “TMY” models (Typical Meteorological Year).

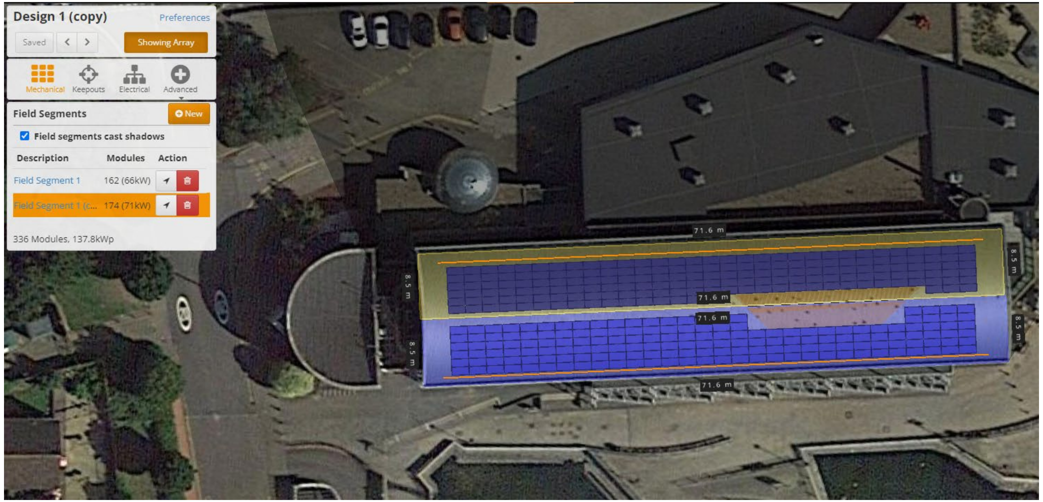
An average of conditions across multi year ranges

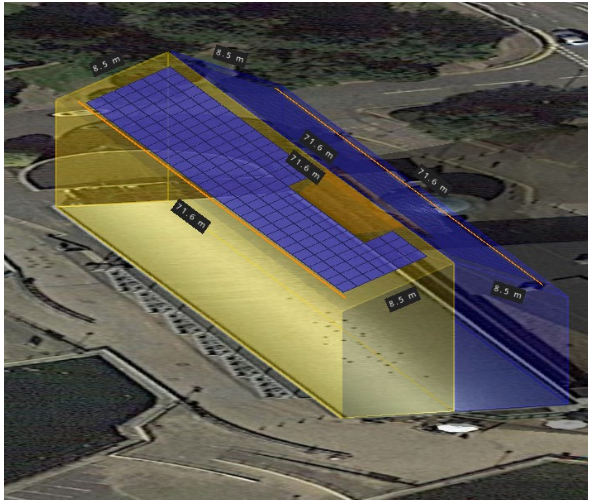
Much more useful!





2. Select system size > get solar output





Areas are defined using aerial photography

Distances can be measured accurately to within about +/- 25cm

HelioScope

Creating the “Grid” of consumption and generation

1. Choose a location > get solar and climate information
2. Select system size > get amount of energy produced

3. Create a “grid” of electricity use and generation

4. Sum all the positive and negative amounts
5. Result > an energy system balance

Negative amounts
Lights, Fridge, cooking
Electric vehicle
Heat pump
Etc

Positive amounts
Generation:
Solar panels (wind, hydro?)

	9am	10am	11am	12am
Mon	1	2	2.5	2.75
Tues	0.8	1.6	1.9	2.2
Weds	1.2	1.3	1.9	2.5
Thurs	1.5	2	3	3.5

Solar (Positive)

	9am	10am	11am	12am
Mon	0.5	0.6	0.5	0.4
Tues	0.5	0.6	0.5	0.4
Weds	0.5	0.6	0.5	0.4
Thurs	0.5	0.6	0.5	0.4

General electricity use (Negative)

	9am	10am	11am	12am
Mon	0	0	2	2.5
Tues	0	2	0	2.5
Weds	0	0	2	2.5
Thurs	0	2	0	2.5

Heat pump (Negative)

Balance

	9am	10am	11am	12am
Mon	0.5	1.4	0	-0.15
Tues	0.3	-1	1.4	-0.7
Weds	0.7	0.7	-0.6	-0.4
Thurs	1	-0.6	2.5	0.6

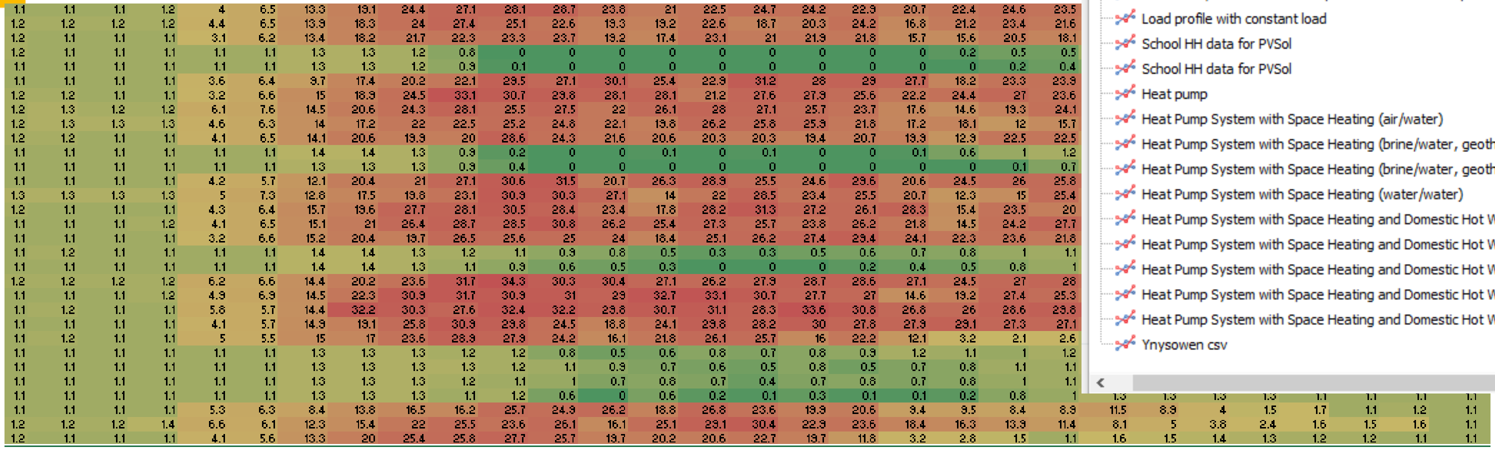
The “grid” of energy consumption

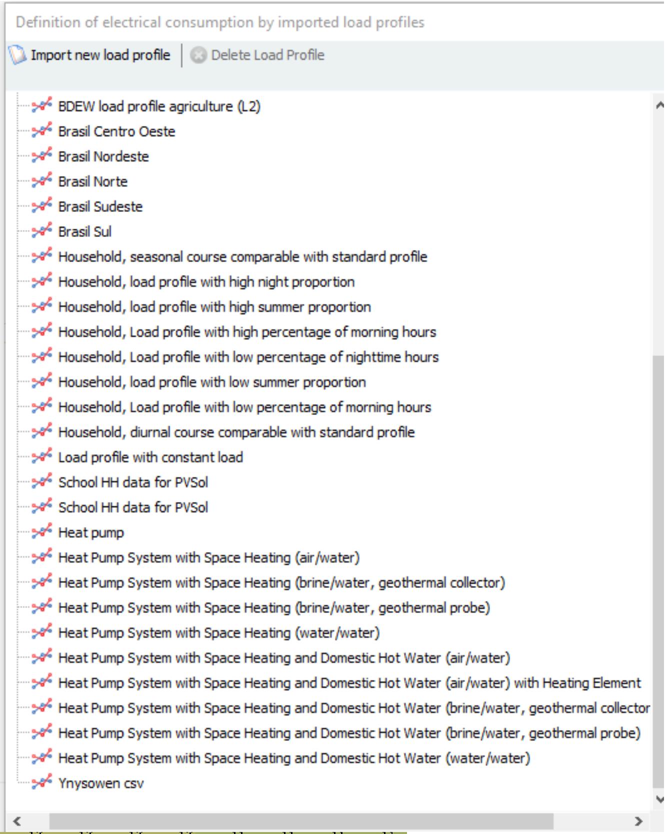
The shapes we are looking at for a day can be put together in a grid for the whole year

1.1	1.1	1.1	1.2	4	6.5	13.3	19.1	24.4	27.1	28.1	28.7	23.8	21	22.5	24.7	24.2	22.9	20.7	22.4	24.6	23.5	22.2	20.4	13.8	5.7	1.8	1.6	1.5	1.4	
1.2	1.2	1.2	1.2	4.4	6.5	13.9	18.3	24	27.4	25.1	22.6	19.3	19.2	22.6	18.7	20.3	24.2	16.8	21.2	23.4	21.6	20.2	15.8	11.4	5.4	3.1	1.9	1.8	1.2	
1.2	1.1	1.1	1.1	3.1	6.2	13.4	18.2	21.7	22.3	23.3	23.7	19.2	17.4	23.1	21	21.9	21.8	15.7	15.6	20.5	18.1	15.7	13.5	9	2.3	1.7	1.6	1.4	1.3	
1.2	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.2	0.8	0	0	0	0	0	0	0	0	0	0.2	0.5	0.5	1.1	1.2	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.2	0.9	0.1	0	0	0	0	0	0	0	0	0	0.2	0.4	0.7	1.3	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	3.6	6.4	9.7	17.4	20.2	22.1	29.5	27.1	30.1	25.4	22.9	31.2	28	29	27.7	18.2	23.3	23.9	22.8	19.9	15.4	6.5	1.8	1.6	1.8	1.6	
1.2	1.2	1.1	1.1	3.2	6.6	15	18.3	24.5	32.1	30.7	28.8	28.1	32.1	21.2	27.6	27.9	25.6	22.2	24.4	27	23.6	32.6	17.4	11.2	4.4	2	1.5	1.8	1.2	
1.2	1.3	1.2	1.2	6.1	7.6	14.5	20.6	24.3	28.1	25.5	27.5	22	26.1	28	27.1	25.7	23.7	17.6	14.6	19.3	24.1	21.9	22.2	14.1	6	1.7	1.6	1.6	1.6	
1.2	1.3	1.3	1.3	4.6	6.3	14	17.2	22	22.5	25.2	24.8	22.1	19.8	26.2	25.8	25.9	21.8	17.2	18.1	12	15.7	19.8	19.5	19.1	11.7	1.3	1.8	1.1	1.1	
1.2	1.2	1.1	1.1	4.1	6.5	14.1	20.6	19.9	20	28.6	24.3	21.6	20.6	20.3	20.3	19.4	20.7	19.9	12.9	22.5	22.5	12.6	11.1	9.2	2.1	1.3	1.7	1.2	1.2	
1.1	1.1	1.1	1.1	1.1	1.1	1.4	1.4	1.3	0.9	0.2	0	0	0.1	0	0.1	0	0	0.1	0.6	1	1.2	1.3	1.4	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	0.9	0.4	0	0	0	0	0	0	0	0	0	0.1	0.7	1.2	1.3	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	4.2	5.7	12.1	20.4	21	27.1	30.6	31.5	20.7	26.3	28.9	25.5	24.6	29.6	20.6	24.5	26	25.8	24.5	20.1	16.1	6.8	1.9	1.7	1.3	1.3	
1.3	1.3	1.3	1.3	5	7.3	12.8	17.5	19.8	23.1	30.9	30.3	27.1	14	22	28.5	23.4	25.5	20.7	12.3	15	25.4	18.4	15.9	20.1	7.4	2	1.7	1.7	1.9	Week days
1.2	1.1	1.1	1.1	4.3	6.4	15.7	19.6	27.7	28.1	30.5	28.4	23.4	17.8	28.2	31.3	27.2	26.1	28.3	15.4	23.5	20	19.8	21.6	12.7	7.8	1.9	1.8	1.3	1.3	
1.1	1.1	1.1	1.2	4.1	6.5	15.1	21	26.4	28.7	28.5	30.8	26.2	25.4	27.3	25.7	23.8	26.2	21.8	14.5	24.2	27.7	25.6	23	14.9	4.3	1.8	1.6	1.1	1.1	
1.1	1.1	1.1	1.1	3.2	6.6	15.2	20.4	19.7	26.5	25.6	25	24	18.4	25.1	26.2	27.4	29.4	24.1	22.3	23.6	21.8	19.3	20.3	9.5	2.6	1.6	2.2	1.2	1.2	
1.1	1.2	1.1	1.1	1.1	1.1	1.4	1.4	1.3	1.2	1.1	0.9	0.8	0.5	0.3	0.3	0.5	0.6	0.7	0.8	1	1.1	1.2	1.4	1.4	1.3	1.1	1.1	1.1	1.2	Weekend
1.1	1.1	1.1	1.1	1.1	1.1	1.4	1.4	1.3	1.1	0.9	0.6	0.5	0.3	0	0	0	0.2	0.4	0.5	0.8	1	1.3	1.4	1.4	1.3	1.1	1.1	1.1	1.1	
1.2	1.2	1.2	1.2	6.2	6.6	14.4	20.2	23.6	31.7	34.3	30.3	30.4	27.1	26.2	27.9	28.7	28.6	27.1	24.5	27	28	23.8	16.3	19.7	6.3	2	1.7	1.9	1.7	
1.1	1.1	1.1	1.2	4.9	6.9	14.5	22.3	30.9	31.7	30.9	31	29	32.7	33.1	30.7	27.7	27	14.6	19.2	27.4	25.3	19.7	22.5	18	5.6	1.3	1.7	1.1	1.1	
1.1	1.2	1.1	1.1	5.8	5.7	14.4	32.2	30.3	27.6	32.4	32.2	29.8	30.7	31.1	28.3	33.6	30.8	26.8	26	28.6	29.8	29.3	30.8	20.4	12.2	2.8	3.1	2.8	2.4	
1.1	1.1	1.1	1.1	4.1	5.7	14.9	19.1	25.8	30.9	29.8	24.5	18.8	24.1	29.8	28.2	30	27.8	27.9	29.1	27.3	27.1	23	17	11.7	4.6	2	1.6	1.5	1.4	
1.1	1.2	1.1	1.1	5	5.5	15	17	23.6	28.9	27.9	24.2	16.1	21.8	26.1	25.7	16	22.2	12.1	3.2	2.1	2.6	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	1.2	1.2	0.8	0.5	0.6	0.8	0.7	0.8	0.9	1.2	1.1	1	1.2	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	1.3	1.2	1.1	0.9	0.7	0.6	0.5	0.8	0.5	0.7	0.8	1.1	1.1	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1	Christmas
1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	1.2	1.1	1	0.7	0.8	0.7	0.4	0.7	0.8	0.7	0.8	1	1.1	1.2	1.3	1.3	1.3	1.1	1.2	1.1	1.1	
1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	1.1	1.2	0.6	0	0.6	0.2	0.1	0.3	0.1	0.1	0.2	0.8	1	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1	
1.1	1.1	1.1	1.1	5.3	6.3	8.4	13.8	16.5	16.2	25.7	24.9	26.2	18.8	26.8	23.6	19.9	20.6	9.4	9.5	8.4	8.9	11.5	8.9	4	1.5	1.7	1.1	1.2	1.1	
1.2	1.2	1.2	1.4	6.6	6.1	12.3	15.4	22	25.5	23.6	26.1	16.1	25.1	29.1	30.4	22.9	23.6	18.4	16.3	13.9	11.4	8.1	5	3.8	2.4	1.6	1.5	1.6	1.1	
1.2	1.1	1.1	1.1	4.1	5.6	13.3	20	25.4	25.8	27.7	25.7	19.7	20.2	20.6	22.7	19.7	11.8	3.2	2.8	1.5	1.1	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.1	

The “grid” of energy use

Electrical usage profiles may come from a predefined library, or actual metered usage

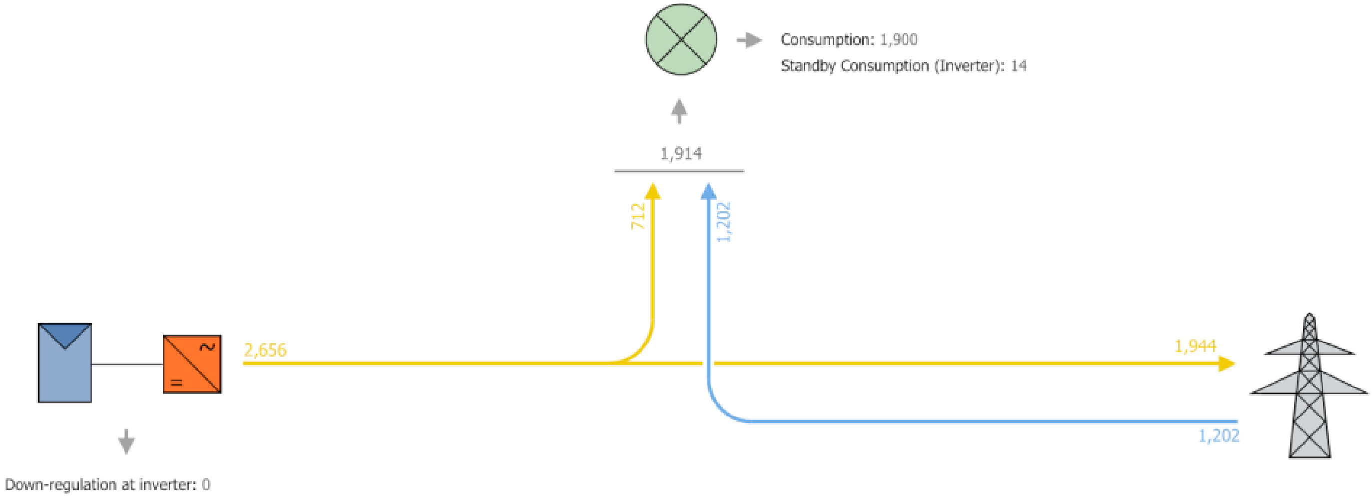




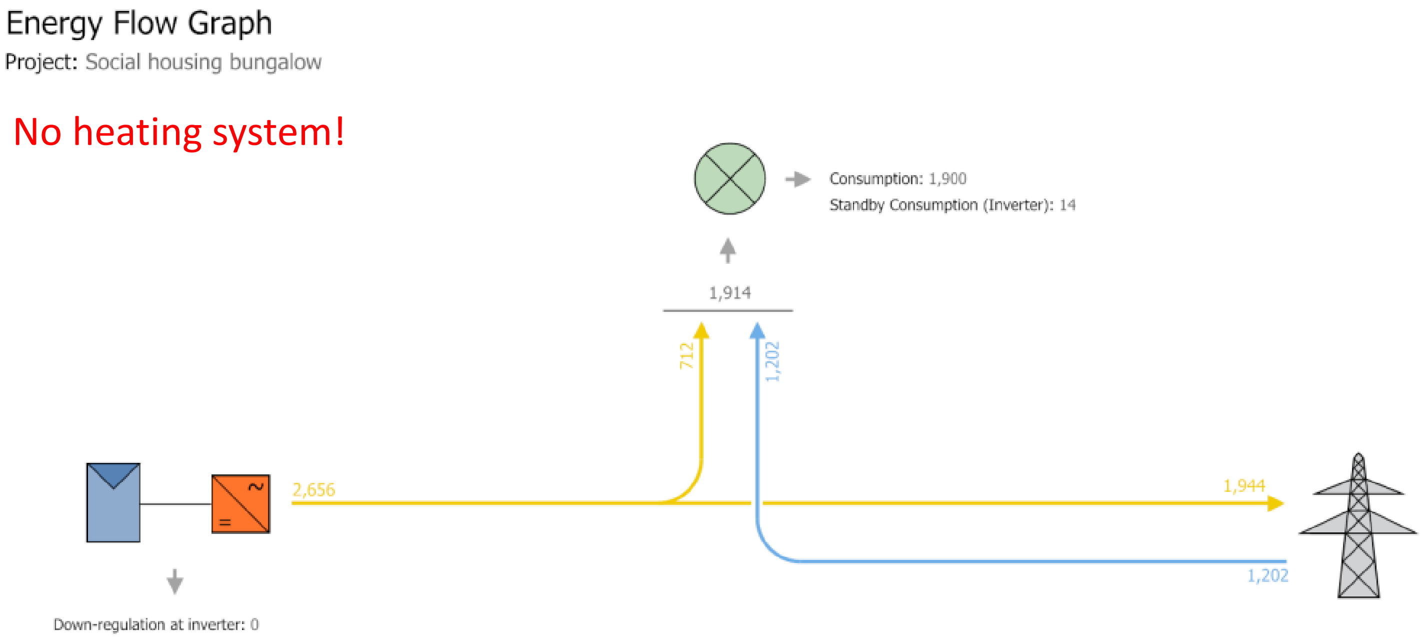
Results

Energy Flow Graph

Project: Social housing bungalow



Results



No heating system!

Self-consumption of solar	= 712 / 2656	= 27%
Solar fraction electricity use*	= 712 / 1914	= 37%

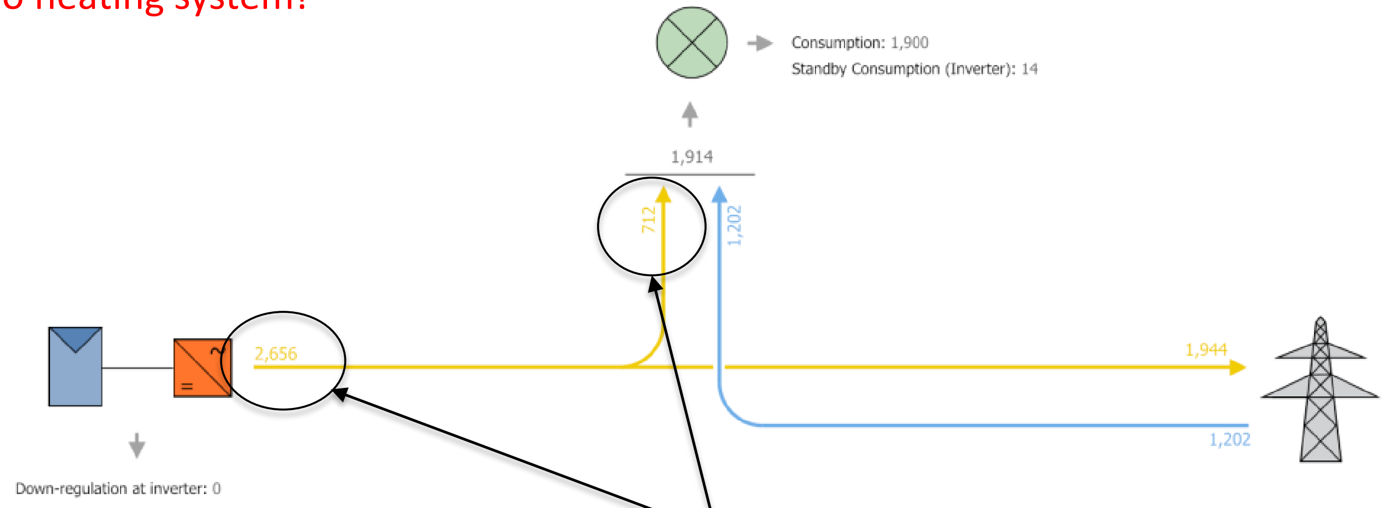
*solar fraction = % of overall electricity use delivered by the solar system

Results

Energy Flow Graph

Project: Social housing bungalow

No heating system!



Self-consumption of solar = 712 / 2656 = 27%

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Results

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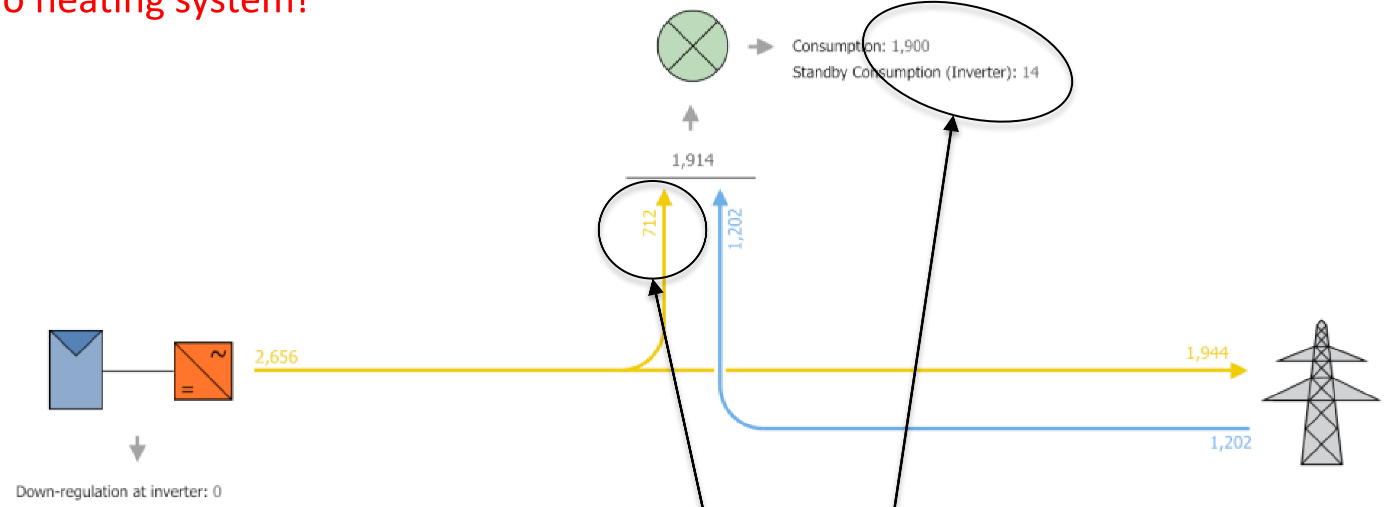
No heating system!



Solar fraction electricity use* = 712 / 1914 = 37%

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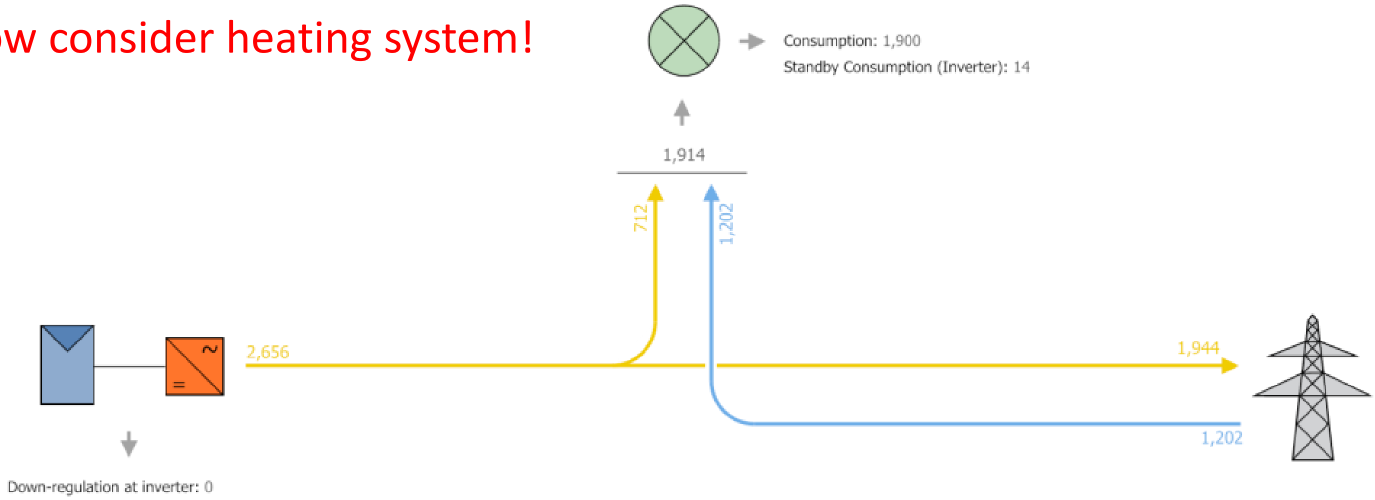
Energy Flow Graph

Project: Social housing bungalow

Results

Now consider heating system!



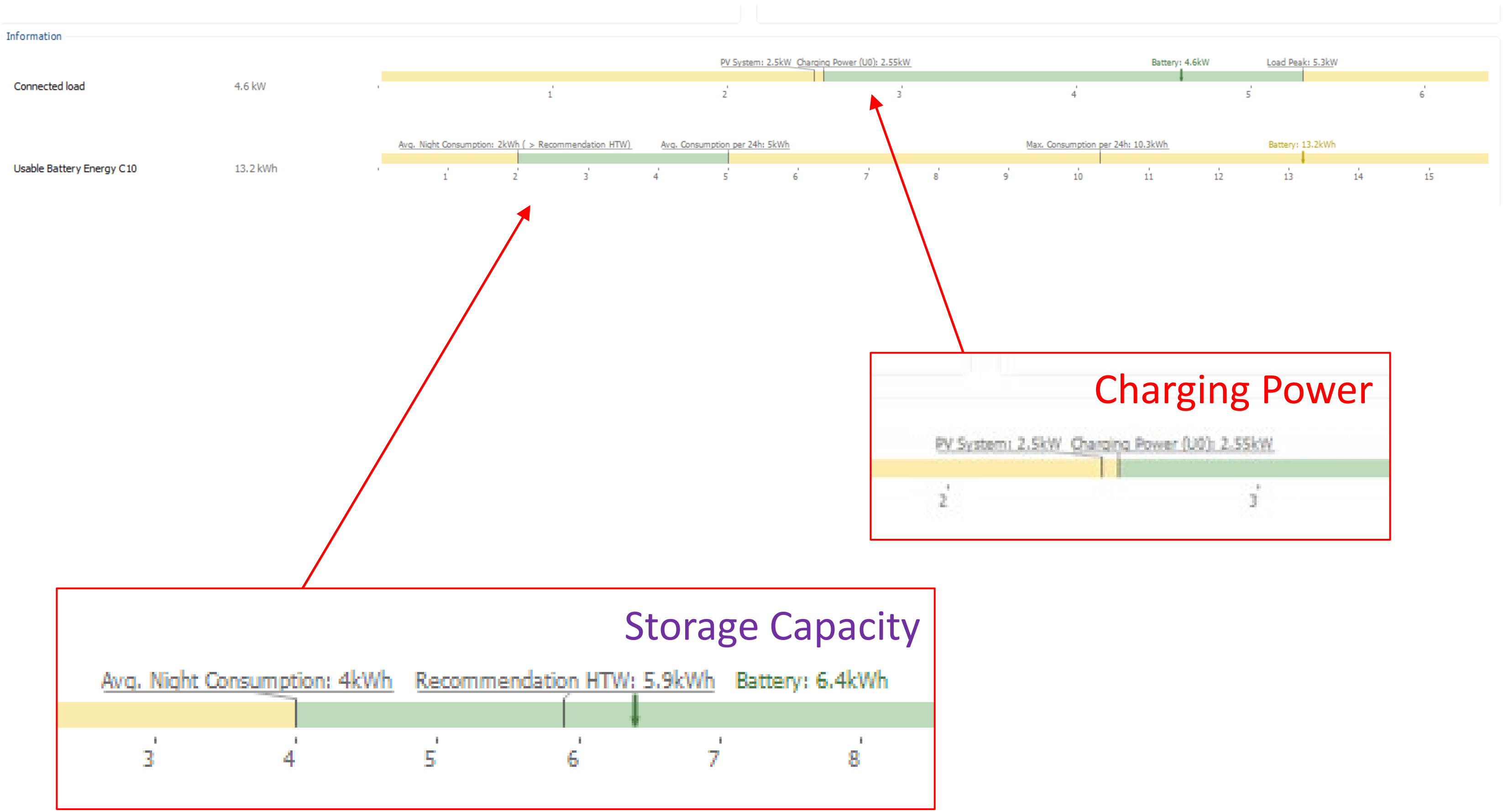
Self-consumption of solar = 712 / 2656 = 27%

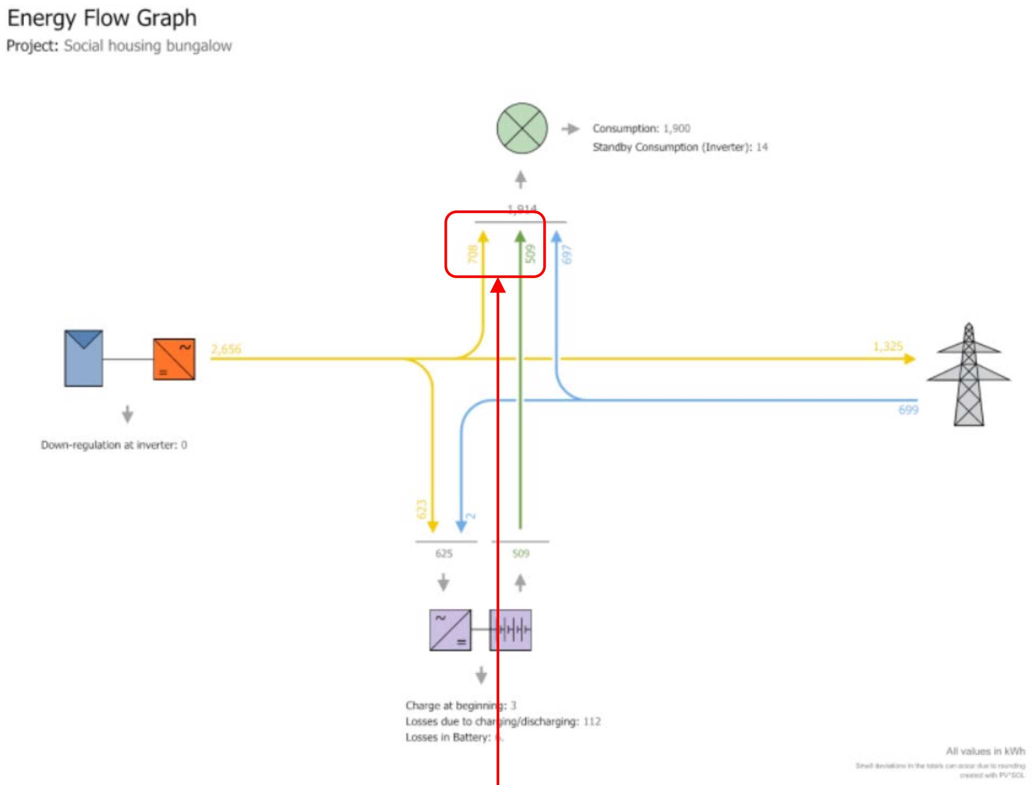
Solar fraction electricity* = 712 / 1914 = 37%

Solar fraction total house energy = 712 / [1914+ 12,000] = 5%

Electricity + Gas TDCV

Now add a battery





Model results

3kW PV
2.6kW charge
5.9kWh batt
No heat pump

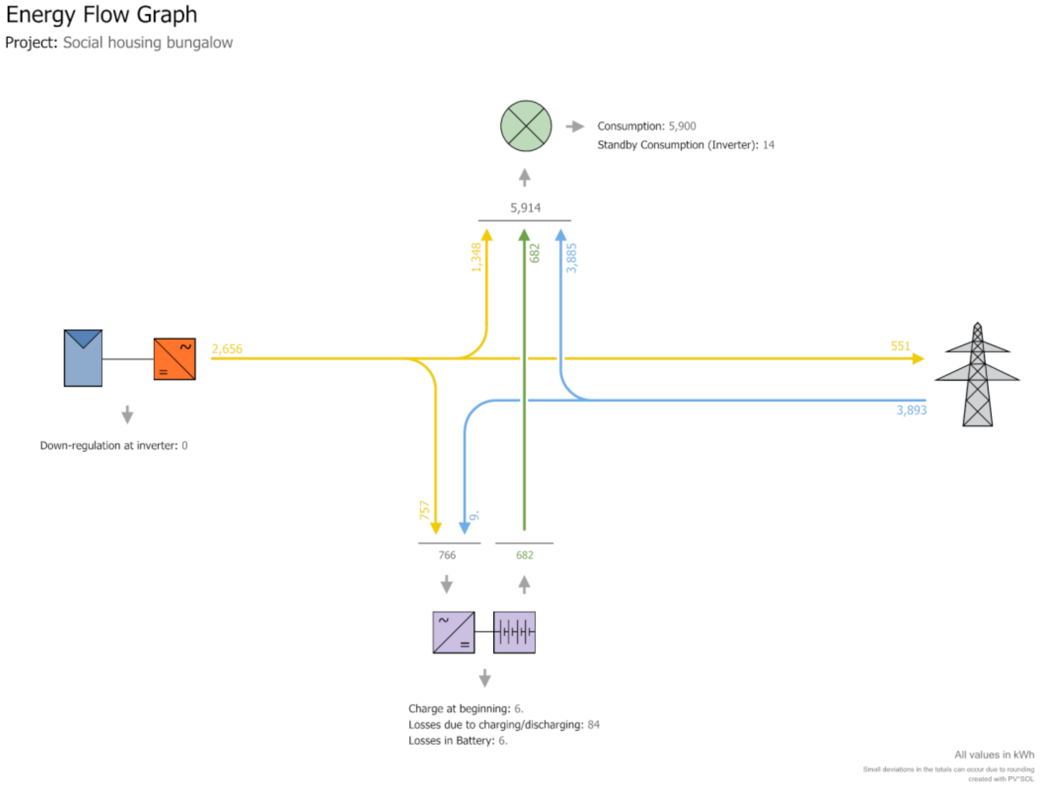
Self-consumption of solar = 45% previously (27%)

Solar fraction electricity* = 63% previously (37%)

Solar fraction total house energy = (708+509) / (12,000 + 1914) = 9% previously (5%)

Heat + Electricity

*solar fraction = % of overall electricity use delivered by the solar system



Model results

3kW PV
3.5kW charge
9kWh batt
Heat pump

Self-consumption of solar = 76% (previously 27% then 45%)
Solar fraction (now total energy)* = 35% (previously 5% then 9%)

How do we go about modelling renewables?

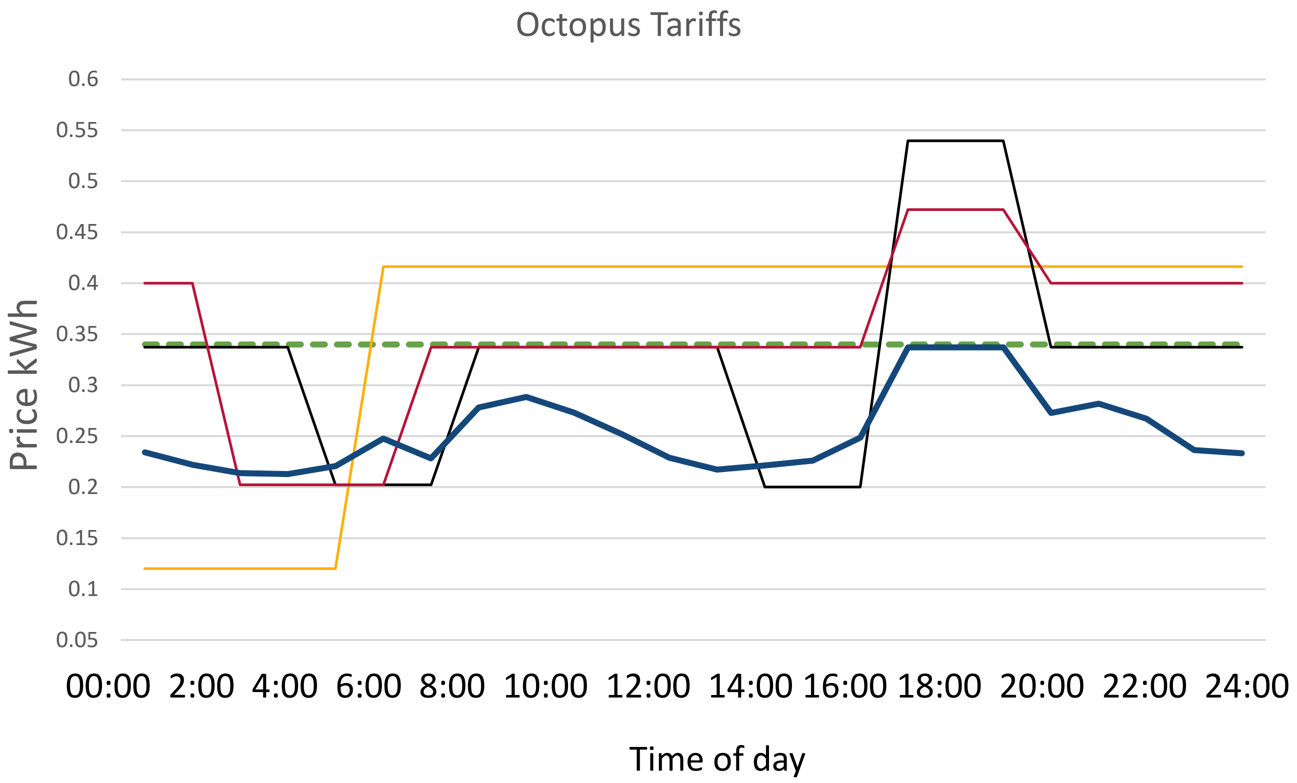
1. Choose a location > get solar and climate information
2. Select system size > get amount of energy produced

3. Create a “grid” of electricity use and generation
4. Sum all the positive and negative amounts

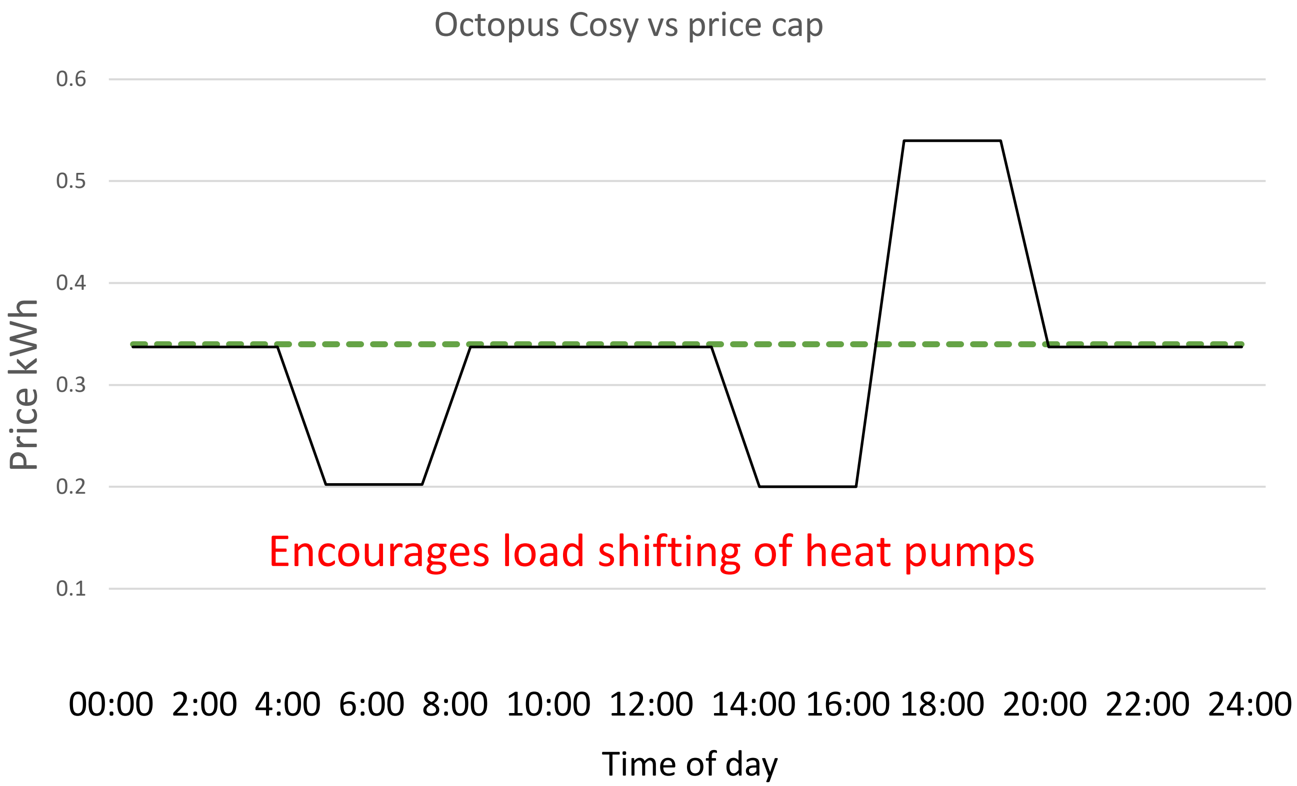
5. Result > an energy system balance
   > an idea of running costs

6. Compare “grid” to different tariffs
7. Consider load shifting

Extracting extra value through time of use tariffs

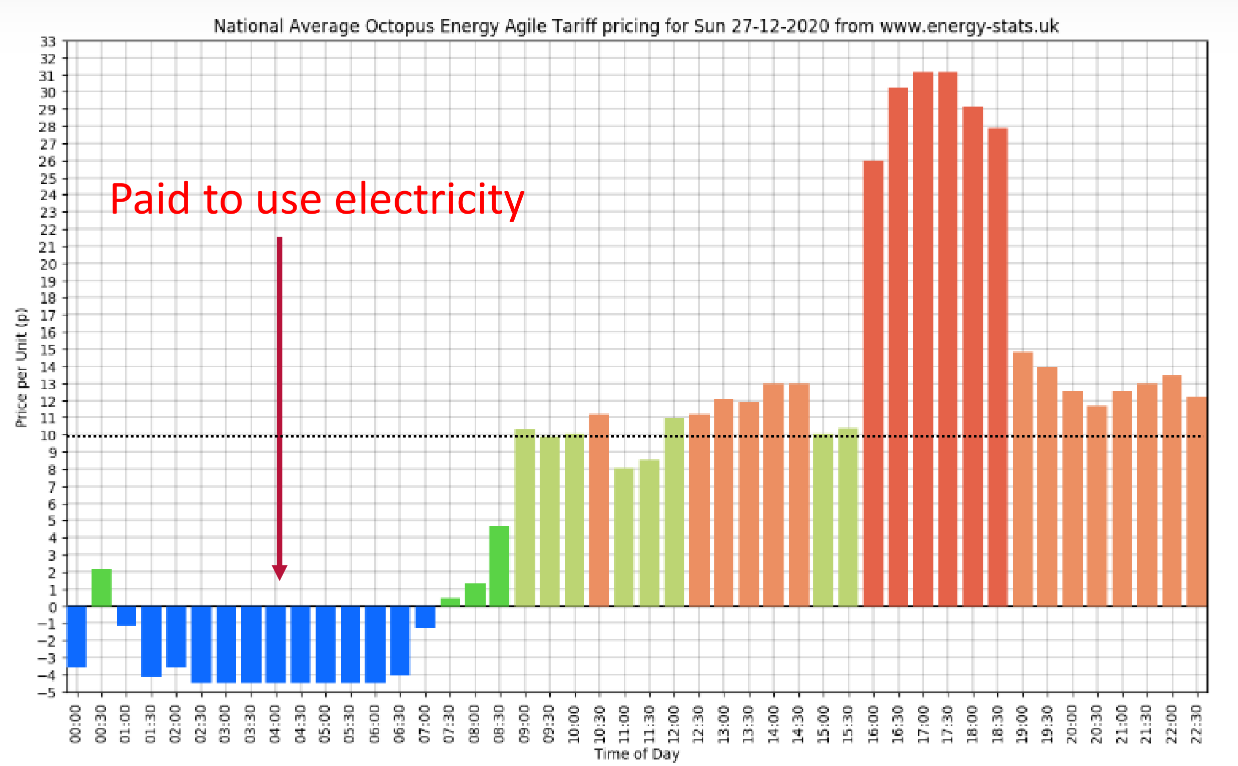


Extracting extra value through time of use tariffs



Extracting extra value through time of use tariffs

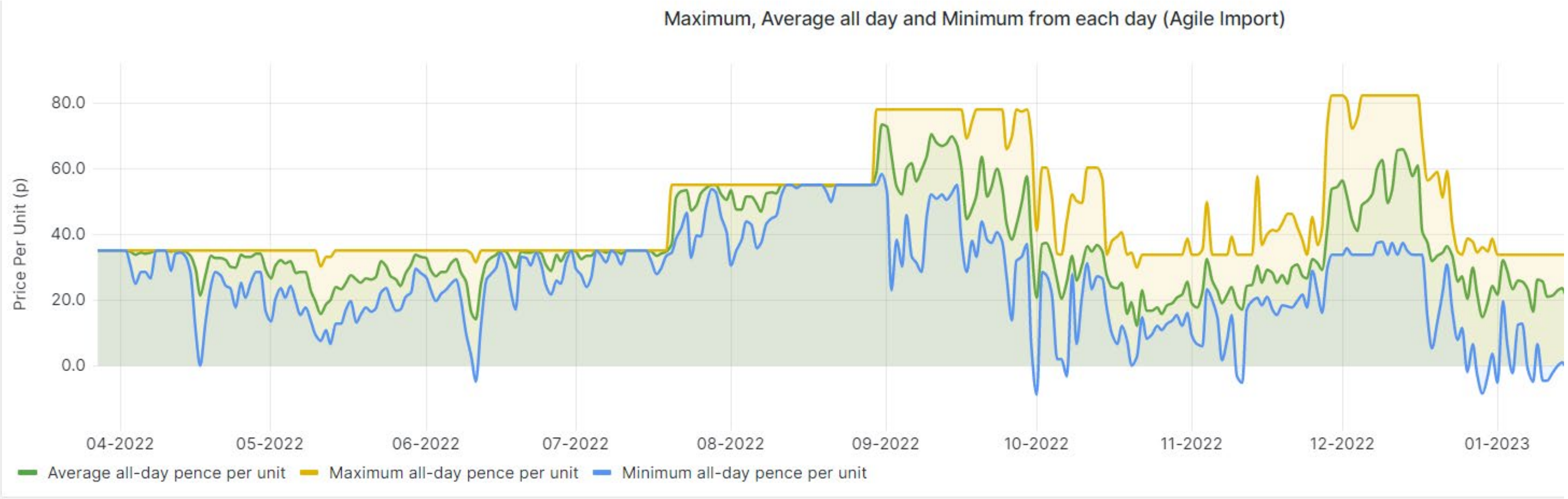
One “good” day of Agile in 2020



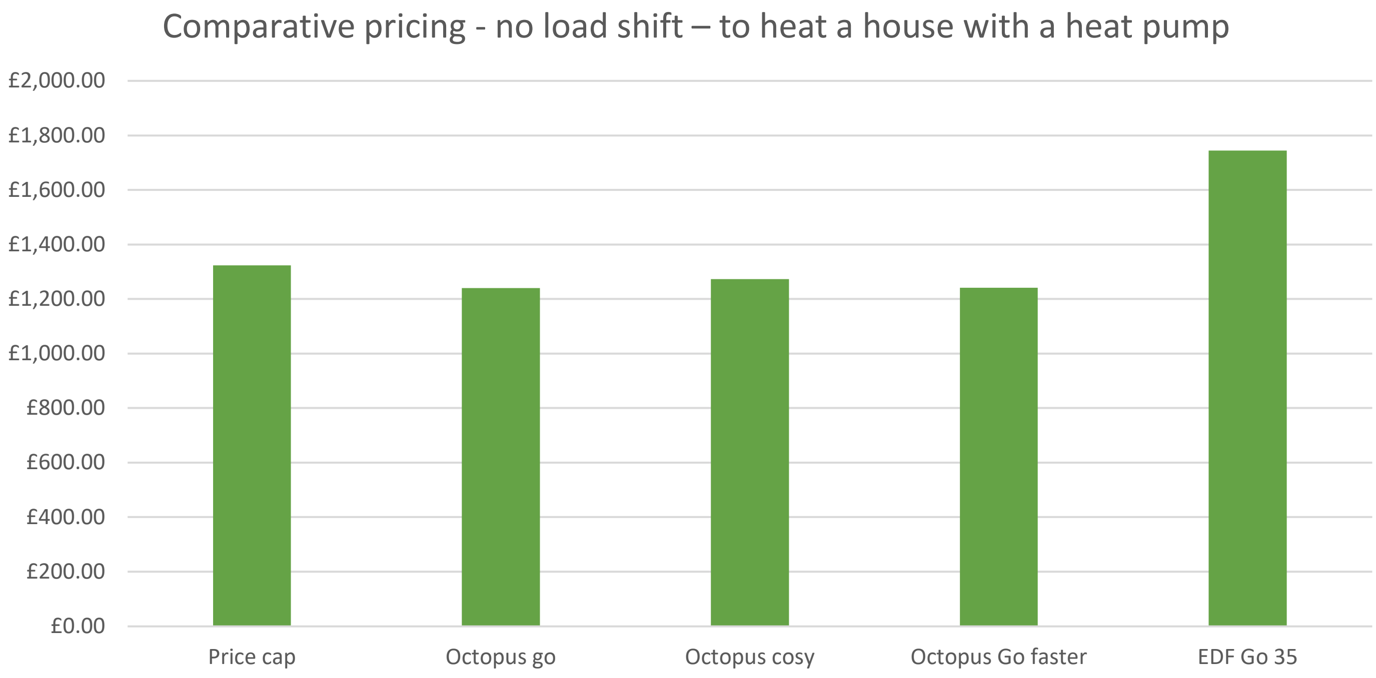
Average about 10p/kWh

How bad it got in 2022

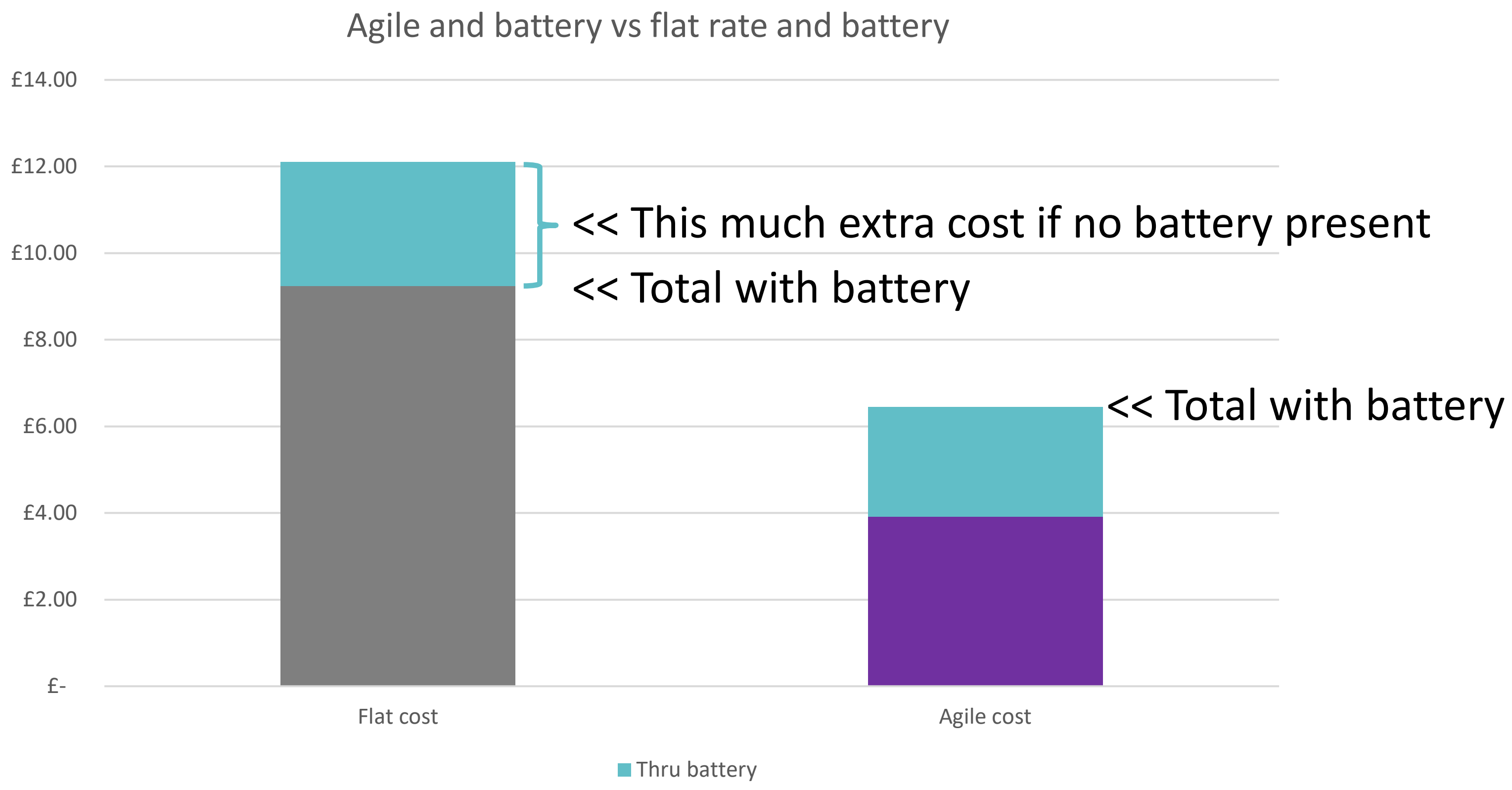
Peaks at 80p/kWh



Extracting extra value through time of use tariffs



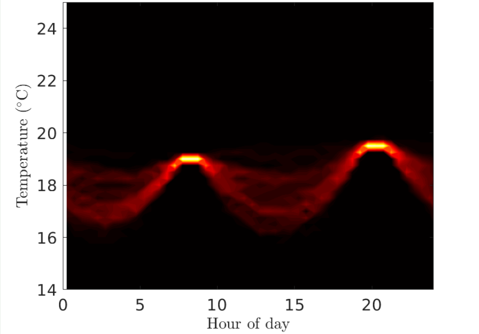
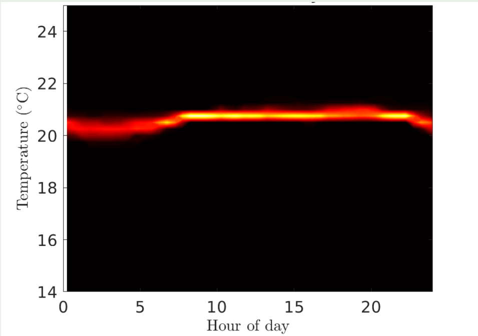
One day in April



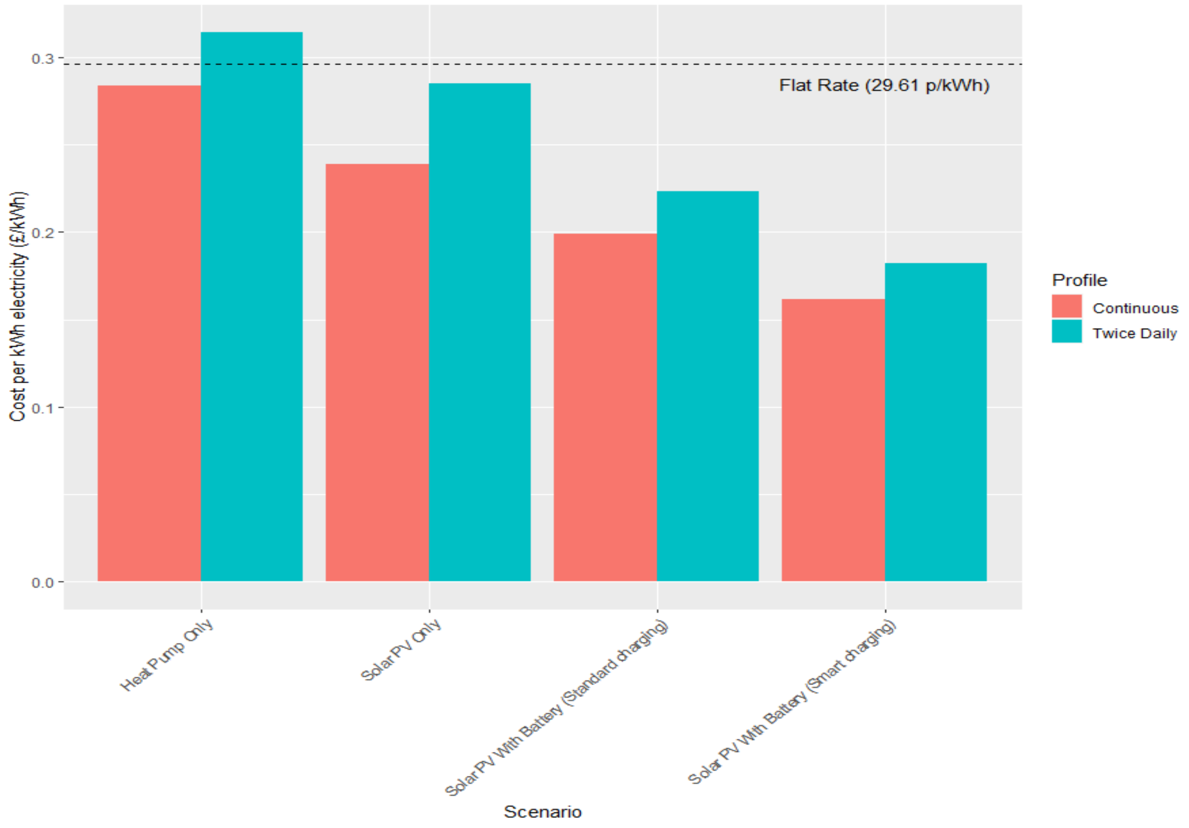
Methodology Slide

- Two EoH properties
- Three months during the winter period (October –December)
- Only considered space heating
- Grouped to half hourly data
- Modelled energy flows with/without solar PV and battery
- Applied different logic to battery charging
    - Standard: battery only charges from PV using excess generation and discharges to home preferentially to importing from grid.
    - Smart: battery charges from grid during low cost times (other times same as standard). Discharges as standard.
- Applied time of use carbon and cost factors to half hourly data

Two different heating patterns same heat pump (different properties)

Profile	Twice Daily	On all day
Electricity consumption	635 kWh	1297 kWh
Heat output	1712 kWh	5311 kWh
SCOP (3 month period)	2.7	4.1
Assumed set point	19.5°C	21°C
Average Int temp	18.1°C	20.5°C
Heating Profile		

Impact on cost & carbon (cosy)



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Green Homes Network

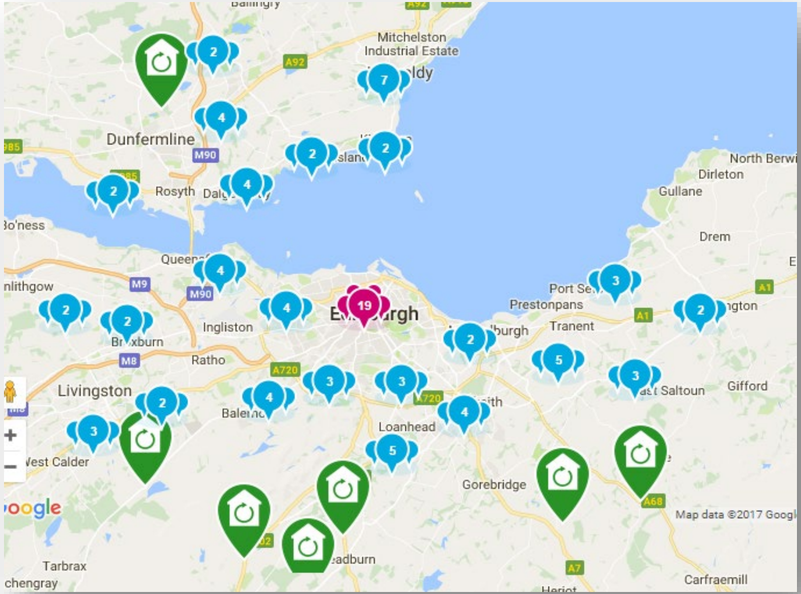
Torin Clarke 13/09/23

Takeaways

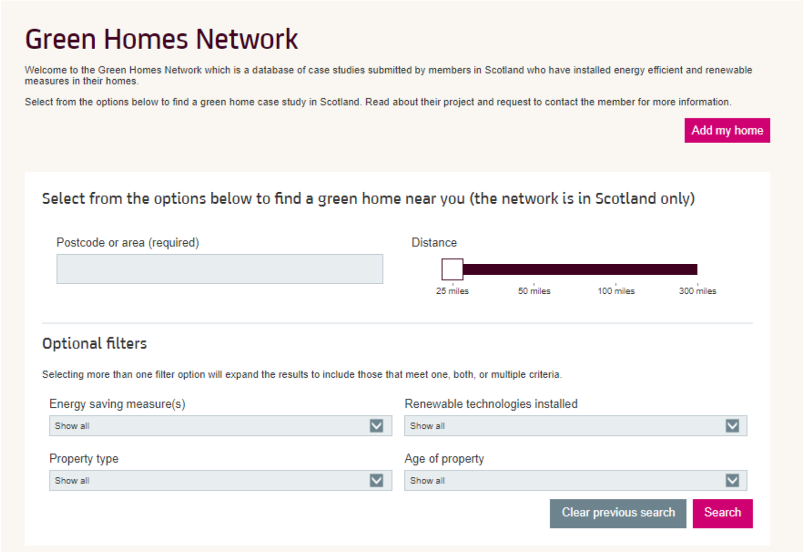
- What is it?
- How do you use it?
- Why should you use it?

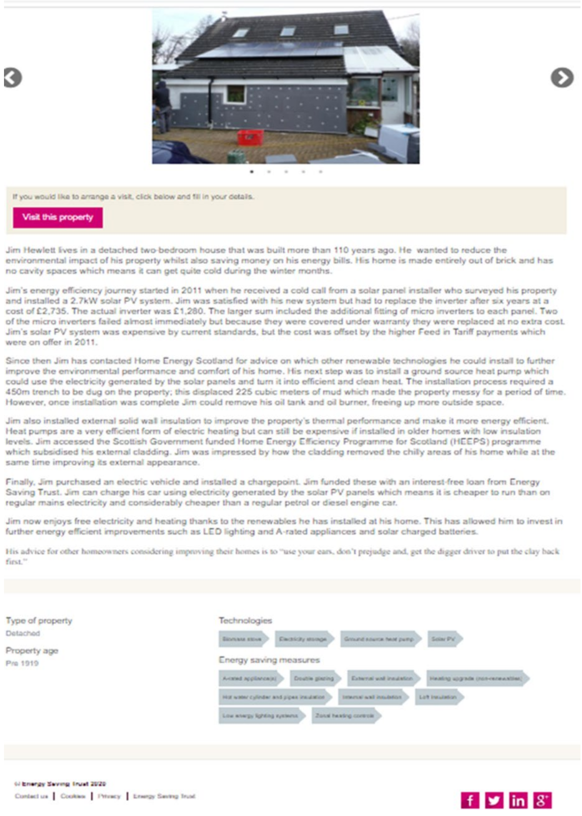
What is the Green Homes Network?

- A network of over 350 households across Scotland which have installed renewables and energy efficiency measures
- Hosted on a free-to-use searchable database, case studies vary from old stone cottages to new builds, and everything in-between
- Case studies provide honest feedback about experiences installing, and living with, different sustainability measures



How do you use the database?



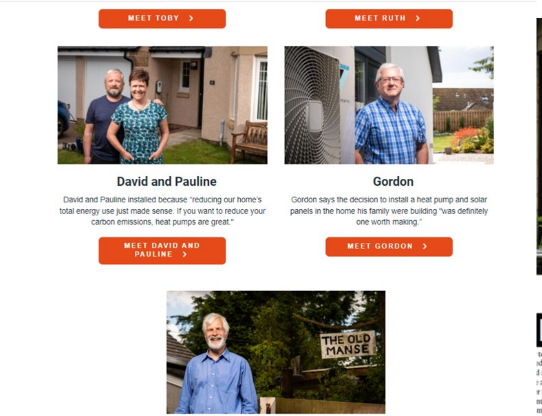


Visit: https://energysavingtrust.org.uk/tool/green-homes-network/

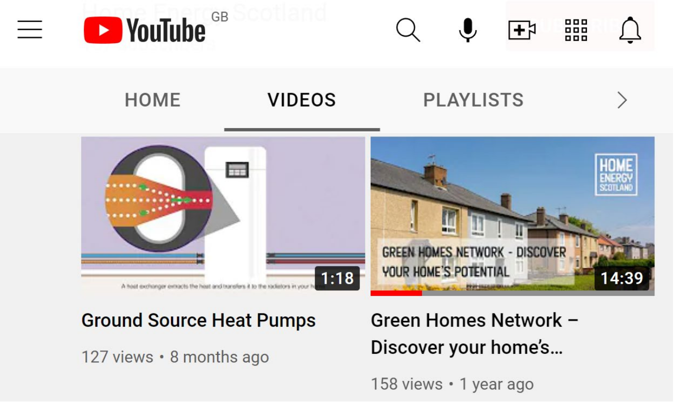
Apply your search criteria, review a case study from the list and complete a simple contact form


Opportunities
straight ahead

Getting the word out



- The network is more popular than ever with thousands of users viewing case studies tens of thousands of times each year
- Members regularly speak to the media, support educational events and even get involved in research studies
- Case studies often mention installers used



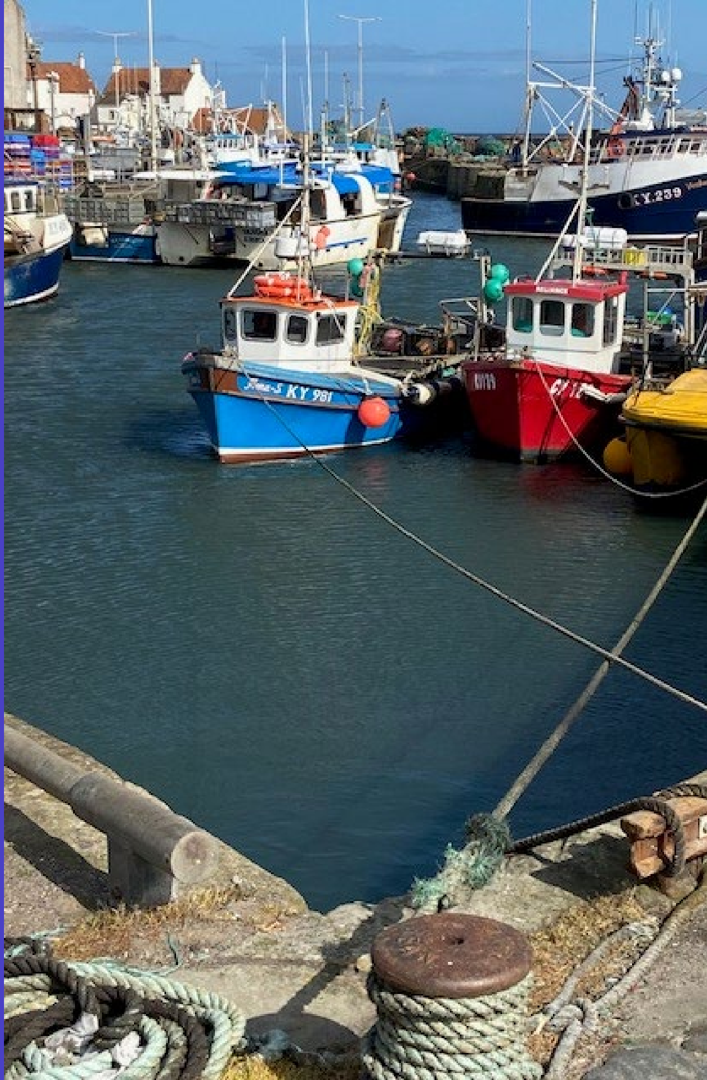
“Great to speak to someone who changed from storage heaters to an air source heat pump. I had a very useful conversation about his experience having it installed. I found out about the savings he is getting and how it operates in real life. It puts my mind at rest that I am making the right decision.”

“The visit on Sunday went very well, thank you for arranging this. The member was extremely knowledgeable and helpful. I was reassured by his experience of installation and heating with the ASHP to date.”

Thank you

Living with integrated heat pump, solar PV, and battery storage systems

David Stutchfield, Pittenweem, Fife



Summary

- 115m2 3 bedroom detached house
- Exposed location beside sea in Fife
- Both retired, but were working from home before
- Upgraded from EPC E to EPC A rating over 15 years
- House annual carbon emissions down from 2.7 to 0.6 tCO_2e
- House is more comfortable to live in

Solar Thermal

- **3m2 AES flat plate panel inst 2007**
- **Supplemented wood stove back boiler (now removed)**
- **Dual coil DHW cylinder replaced when heat pump installed**
- **Provides 67% annual hot water, (95% summer 35% Dec/Jan)**
- **Super insulated box over cylinder reduces losses 10%**

Heat Pump

- **7kW Vaillant AroTherm Plus, installed by BEIS Electrification of Heat project**
- **New heating system, all radiators 3x size with TRVs**
- **Low temperature continuous heating is superb – creates much better living environment than radiators that are too hot to touch and are only on for short periods of time.**
- **App easy to use for day to day changes**

Heat Pump Controls

- Heating set 19C day, 17C after 10pm, 18C at 2am (Cheap tariff)
- Seasonally commissioned by me – most aggressive OA compensation curve set (until house wasn't warm – then backed off) – now max flow temp 38C
- Anti-legionella cycle turned off & DHW set to 50C
- Issue with leaking air vent after a service – replaced and moved

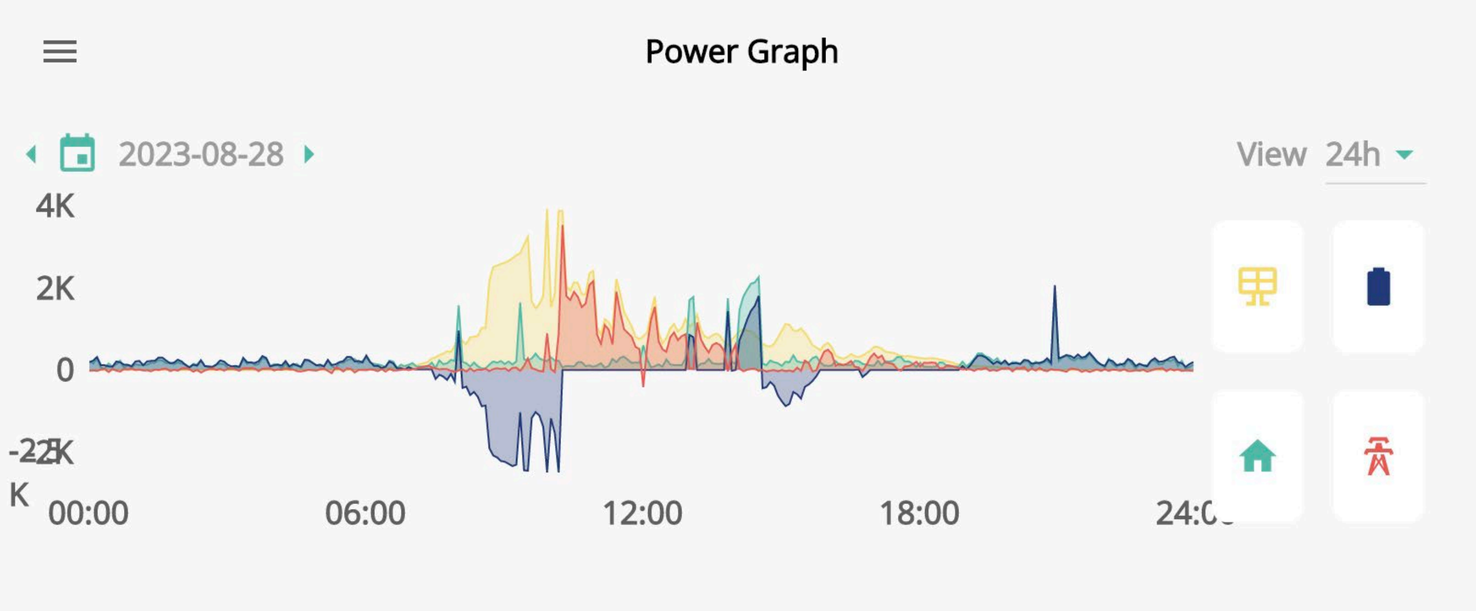
Heat Pump Learning Points

- **Original quote showed annual heat pump electricity consumption expected to be 6,780kWhe for 21,600kWh heat consumption – quite alarming.**
- **Previous system gas boiler consumed annual 9,900kWh gas -do ask about customers previous bills. Last year heat pump actually used 1,900 kWhe delivering 6,900kWh heat.**

- **Very disruptive during installation – team in all rooms at once for 3 days (we sat out in garden each day)**
- **Worried about fan noise, but system operates silently**
- **Installer set very conservative controls – changes I have made give ~20% + savings**
- **Since installation I have installed triple glazing so probably 5kW heat pump would suffice.**

Solar PV/ Battery

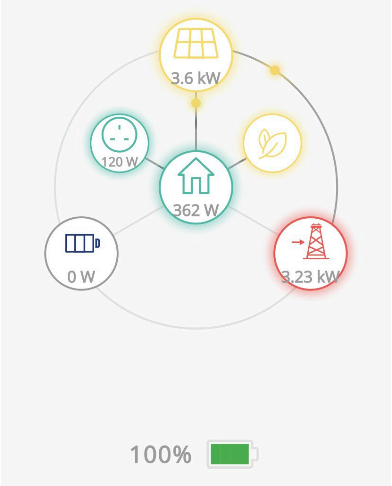
- **4kWp Solar PV (10 panels)**
- **3.6kW hybrid inverter & 8kWh battery installed in combe space**
- **Sized to maximise renewable energy use**
- **Easy to change charging / discharge strategy in App and website**



Solar PV/ Battery Operation

- Initially daily look at graphs / now just content all works.
- Operation changes winter / summer and with tariff
- Now on Octopus Flux – in winter charge both EV and battery fully between 2-5am @17.8p/kWh
- In summer batteries store PV generation, so bills show only export to grid

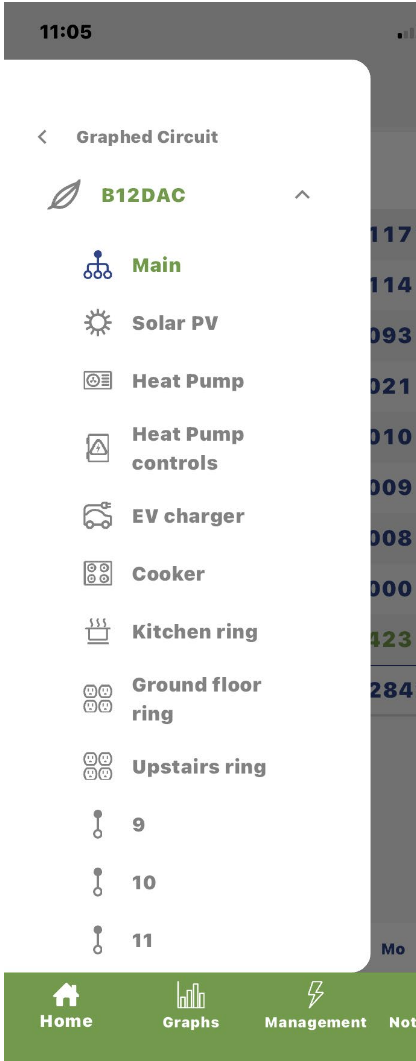
Solar PV/ Battery Learning Points



- When system installed export @ 4.5p/kWh, so ran system to maximise self use of PV, but now getting 18.7p/kWh, so cheaper to charge EV at night than charge off PV during day even in summer.
- Assumed we would get island mode capability – would now insist on external earth during install (retrofit very expensive).
- Would now install 13.5kWh battery and inverter capable of delivering up to 6.5kW & island mode.

General Learning Points

- Started with a well insulated draughtproof house – invested £10k over the years on insulation and £15k on new windows.
- Probably wouldn't install solar thermal – PV generation through a heat pump can efficiently generate hot water.
- Current inverter can only produce 2.5kW from battery – made changes to how we use the kitchen ie a 3kW kettle changed to 1.5kW kettle (takes longer to boil) / don't put the kettle and toaster on simultaneously
- Heat pump pulls 3kW on startup so cannot run 100% from battery.



General Learning Points

- Participated in demand response trial – being paid to not use electricity at peak times in winter (heating setpoint lowered during period to ensure heat pump not operating / ensure battery full before hand)
- Battery 94% efficient in charge / discharge cycle
- Still have gas installed for cooking hob, but will probably change to induction.

David Stutchfield

Pittenweem

Thank you

https://greenhomesnetwork.energysavingtrust.org.uk/CaseStudy.aspx?cid=1677

September 2023

energy saving trust

Q&A

You can ask questions by typing them into the **questions** box of the control panel

Panellists:

Pilar Rodriguez	Programme Manager, Green Heat Installer Engagement Programme, Energy Saving Trust
Ben Whittle	Senior Low Carbon Consultant, Energy Saving Trust
Torin Clarke	Scottish Home Renewables, Energy Saving Trust
David Stutchfield	Green Homes Network Member

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- Email:
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- LinkedIn Group:
https://www.linkedin.com/groups/5139242/

- Email updates and quarterly newsletter subscription:
bit.ly/2PSatkL

- Website:
https://energysavingtrust.org.uk/business/energy-efficiency/green-installer/

Please remember to complete the feedback survey after the webinar has finished

Thank you for attending