Retrofit Performance: The Bank Nook Case Study

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The Retrofit Challenge

The majority of UK buildings are more than 50 years old. Many are:-

- poorly insulated and
- Inefficiently heated

80% of existing buildings will still be in use in 2050

Need to treat 1 million homes per year to achieve 2030 energy target

Green Deal

In UK Green Deal take up is about 1,000

German 2013 report - 3 million homes treated

- 74% average carbon reduction
- 1.5% Interest rate (7% in UK)
- Subsidised insulation

Meeting the Challenge

Over 400,000 retrofit solutions per property. There is a need to optimise (Prof Lubo Jankovic)

The following slides show how Bank Nook, built in 1750, has been treated, with performance outcomes.

Notice South Facing Conservatory on next slide

Bank Nook

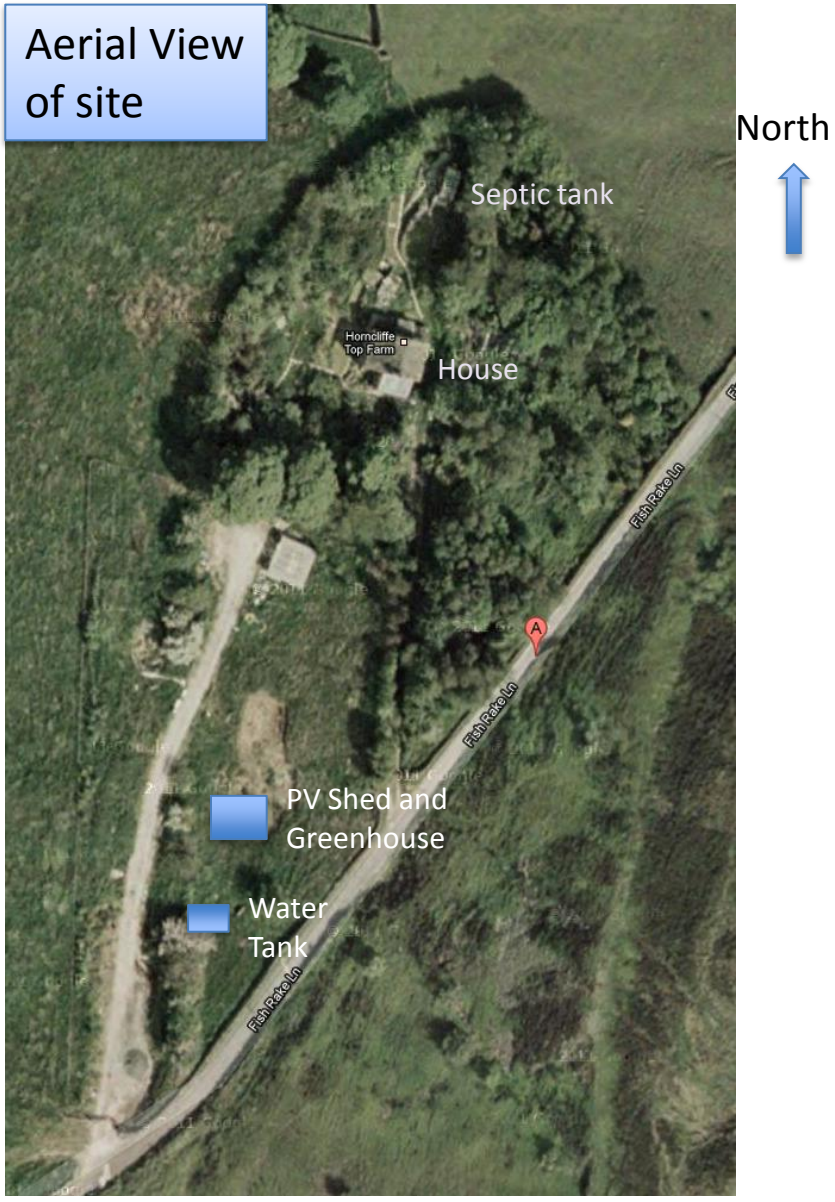
Site:
16 miles north of Manchester
250 metres above sea level
Steeply sloped & very exposed
High humidity

Buildings:
House built in 1750.
External walls are 550 mm thick
Watershot masonry

Water tank about 1850
Adapted for Bank Nook 1977

Septic tank 1993

Photo Voltaic Array, Shed & Greenhouse 2011



Bank Nook features

- Insulation has been installed, 1977- 1995, and 2012-2014.
- Conservatory built on south side in 1996 for solar gain, fire wood storage, and growing plants.
- Highly insulated extension built on North side 2009-10 by AECB passive house contractor.
- North wall of original house now 28 ton thermal store. See next slide.

Bank Nook Heating

Most of the heating for Bank Nook is supplied by an Air Source Heat Pump installed on the West elevation. See next slides

Heat Pump Physics 1

Heat Pumps make use of the ground, water, or air, as a source of heat

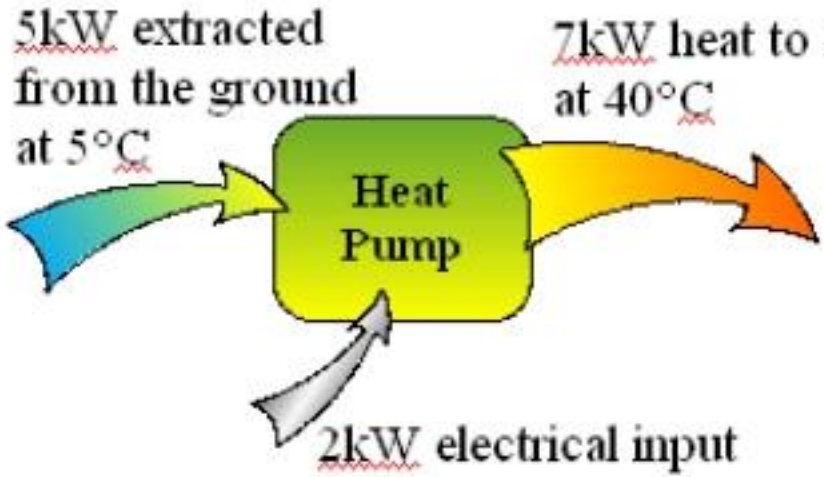
Heat Pumps have the same components and work on the same principals as a refrigerator.

The difference is a refrigerator is designed to extract heat from an object to cool it down.

A Heat Pump works in reverse, extracting heat from a source outside the house and pumping it into the house.

Heat Pump Physics 2

Example



Heat extracted + electrical input = Useful heat output

Efficiency (COP) = 7kW divided by 2kW = 3.5

Diagram from John Cantor, author of "Heat pumps for the home" ISBN 978 184797 292 7 Pub. Crowood 2011

Heat Pump types

- **Ground Source**: Need extensive underground pipes or boreholes to collect heat. Can be expensive. Normal COP 3 to 4
- **Water Source**: Good if stream or lake is available. Normal COP 3 to 4
- **Air Source**: Extract heat from atmosphere. Inefficient when outside temperature is at or below zero. Normal COP 2 to 3.5

Heat Pumps in Retrofit

- Require detailed analysis and design to produce an effective specification.
- Installation requires skill.
- Efficient operation requires careful planning.

Bank Nook Water Source

- Installed 1996 designed and built by John Cantor (AECB). 750 Watt compressor, 3kW output. Coefficient of Performance (COP) 4

- Spring water, 9 degrees at source, supplies energy to internal water system at 35 to 40 degrees for under floor heating and radiators.

- Flow of spring water decreased. By 2009 the Heat Pump could not operate.

Bank Nook Air Source

- 5kW output Ecodan ASHP installed 2010. Bank Nook is a test site for Mitsubishi Ecodan Heat Pumps. Mitsubishi data facilitates ongoing optimisation of Ecodan.
- Under floor heating upgraded to 60% of floor area of house. Operating temperature 35 degrees.
- Feb 2011 system tuned. September 2011 latest controller installed.

Heat Pump with Biomass

- In cold periods, when Air Source Heat Pumps become inefficient, a wood burning stove provides additional heat and hot water.

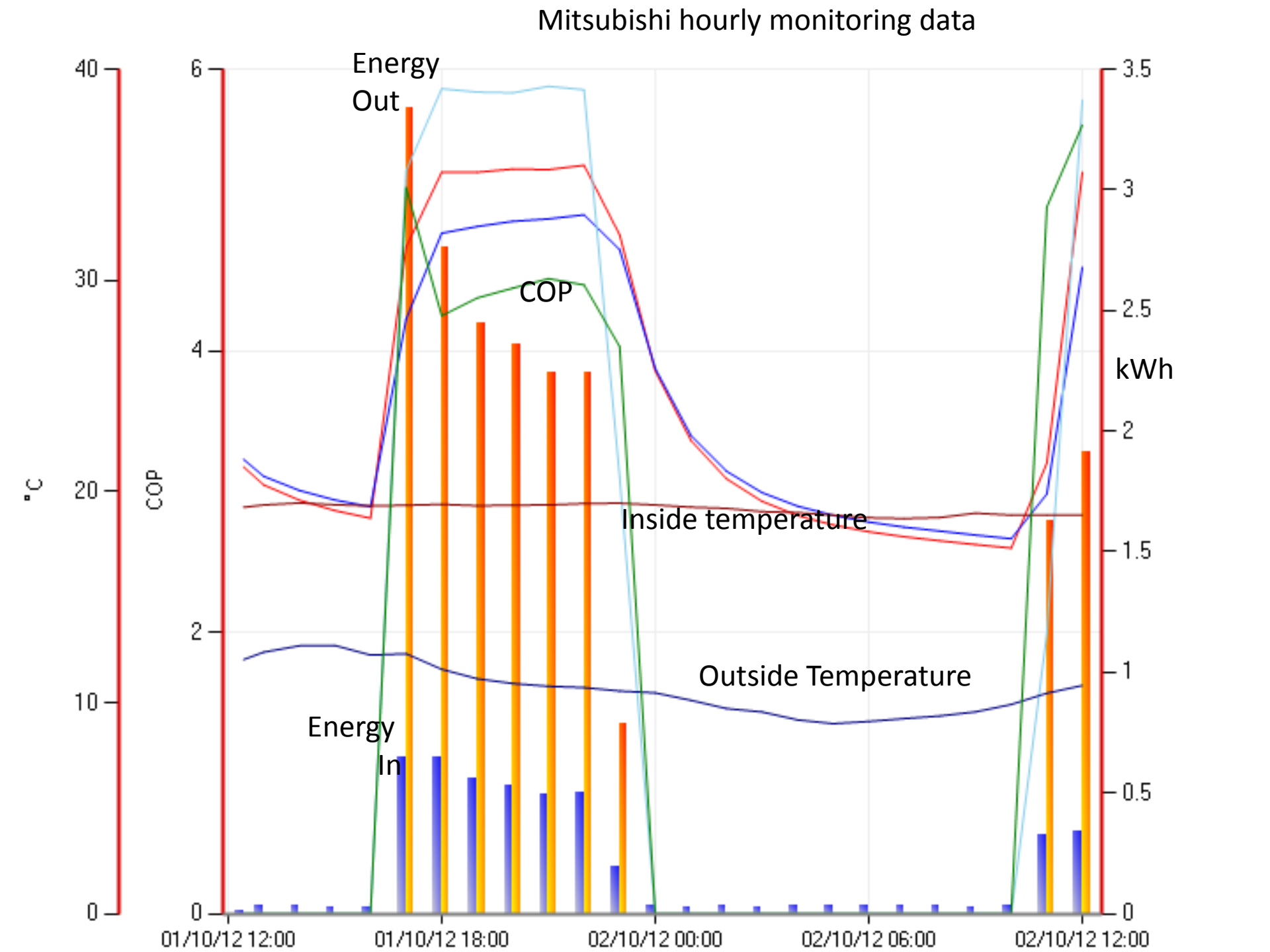
- The Bank Nook stove consumes 1 ton of wood per year, coppiced from 2,000 trees around the house, planted 1977-79.

Bank Nook Heat Pump performance

The next slide shows performance midday 1st October 1012 to midday 2nd October, 2012

ave outside temp 10.7 c,

COP 4.19


Mitsubishi hourly monitoring data
Energy Out
COP
Inside temperature
Outside Temperature
Energy In
°C
COP
kWh
40
30
20
10
0
6
4
2
0
3.5
3
2.5
2
1.5
1
0.5
0
01/10/12 12:00
01/10/12 18:00
02/10/12 00:00
02/10/12 06:00
02/10/12 12:00

Heating Season May 2013 - May 2014

- COP 3.61 (3.12 in 2012)
- Heat output from system 8,112 kWhrs (10,922 in 2012)
- Energy input 8,112/3.61 = 2,247 kWhrs (3,500 in 2012)
- See next slide for Mitsubishi monthly monitoring data

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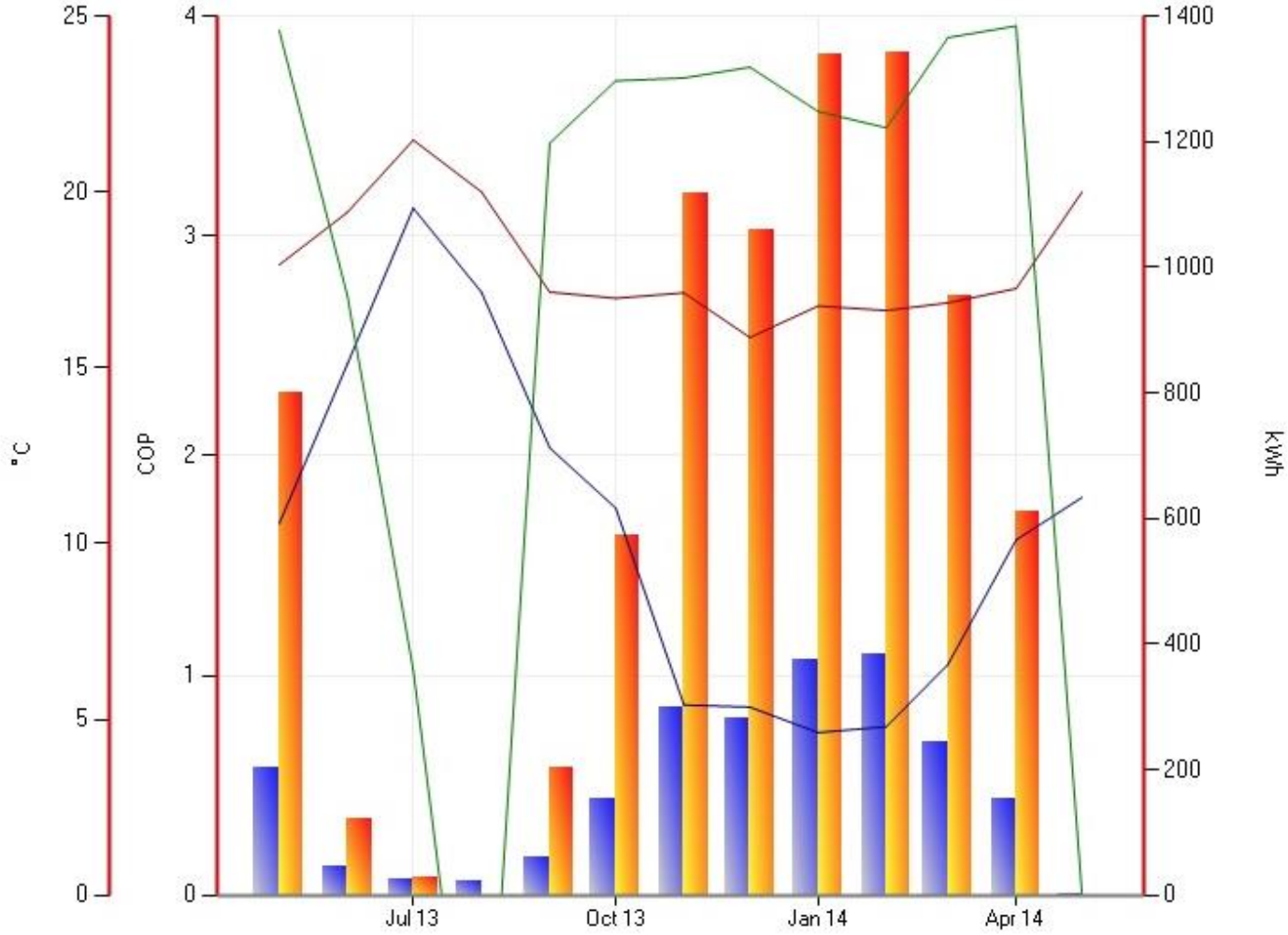
Map | Live Data | Site Details | Historic Data | Compare

3 Bedroom Detached House Rossendale, Lancashire

View the historic performance of the Ecodan system. Add and remove items from the chart using the checkboxes below.

- [x] Energy In (kWh)
- [ ] Immersion Energy In (kWh)
- [x] Energy Out (kWh)
- [ ] Flow Temperature (°C)
- [ ] Return Temperature (°C)
- [ ] Flow Rate (l/min)
- [x] Inside Temperature (°C)
- [x] Outside Temperature (°C)
- [ ] Humidity (%RH)
- [ ] Cylinder Temp - Top (°C)
- [ ] Cylinder Temp - Middle (°C)
- [ ] Cylinder Temp - Bottom (°C)
- [x] COP (COP)



Average COP 3.61
Total Energy Out 8112kWh
Average Outside Temp 10.3°C
Average Inside Temp 18°C

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Export Data

Group data by Minute

Export

Bank Nook Space Heating: Heat Pump

Bank Nook Heating from Heat Pump requires 2,247 kWh/annum

Floor area of Bank Nook = 110 sq m.

Energy input is

2,247/110 = 20.43 kWh/m2/annum

Space Heating: All sources

- Heat Pump output 8,112 kWhr/an or
  - 8.112 mWhr/an

- From 1 ton of wood in 70% efficient stove approx 2-3 mWhr/an

- Solar gain from conservatory

  1.5? mWhr/an (15 sq metre roof)

- Total is approx 12mWhr/an – typical UK house

Electrical Energy for Heating

Needed for Heat Pump : 2.247 mWh/an

Produced by 2.55 kW PV array : 2 mWh/an

Therefore net input 2.247 – 2 = 0.247 mWh/an

Net input likely to reduce to zero in 2015 as effects of 2014 insulation reduces heat load.

Comfort

- Under floor heating very pleasant
- Stove provides extra warmth on cold evenings
- Stove keeps humidity 40-60% in winter

  High ambient humidity: problems keeping wood dry
- High thermal mass moderates temperature

  Allows Heat pump to be operated intermittently
- Air tightness not strictly applied: avoids MV

Reflections

- Heat Pump is run in the afternoon to match peak input to PV panels,
- Grid input in winter will always be needed.
- Electricity is needed for media and appliances.
- A customised integrated system is effective.

The Bank Nook Vision

If we are to avoid vast areas of land taken up by Wind Turbines and PV panels as we replace generating capacity powered by fossil fuels, dwellings will have to become energy autonomous, at least in heating.

Bank Nook demonstrates how this can be achieved, when supplemented by ecologically rich woodland, which in urban communities could be a resource for all to share and enjoy.

My thanks to the following:

- AECB members
  - John Cantor - Heat Pumps
  - Nick Parsons - Retrofit insulation
  - Peter Wilkinson - Bank Nook Extension

  Also
  - World heat – Heat Pump installation
  - Mitsubishi – Heat Pump monitoring
  - Keith Trippier – Bank Nook joiner etc for 36 years
  - Prof Lubo Jankovic – for successfully applying chaos theory to Retrofit

  Contact me: andyham@gmail.com

Bank Nook 1977

Heat Pump Performance

The next 2 slides illustrate Heat Pump performance at Bank Nook:-

1. Temperature below zero with COP 2.7
2. Minute by minute analysis

The remaining slides show poor and good operation of Heat Pumps in other properties.

Cold Day performance

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Map | Live Data | Site Details | **Historic Data** | Compare Fuel

3 Bedroom Detached House Rossendale, Lancashire

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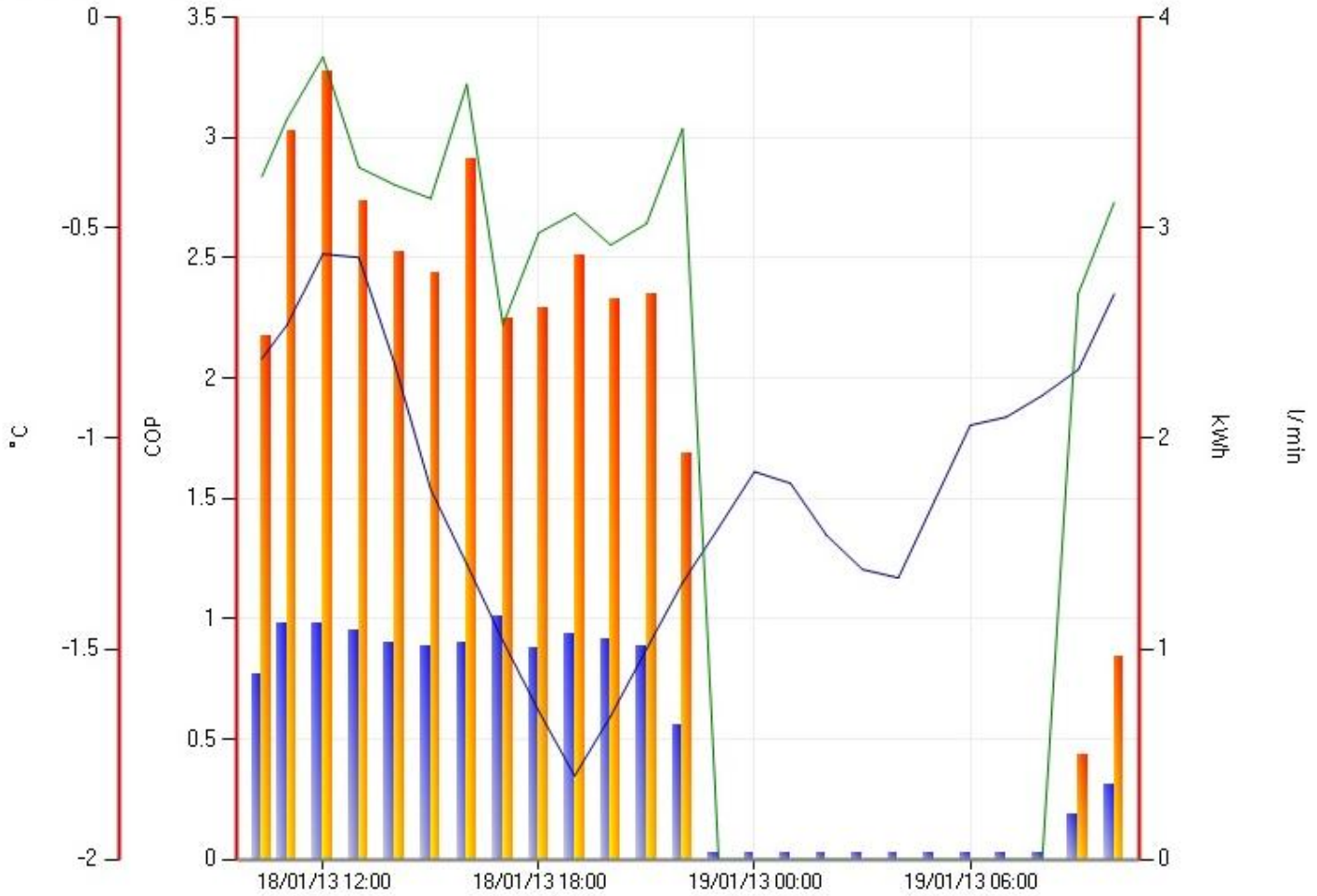
- [x] Outside Temperature (°C)
- [ ] Humidity (%RH)
- [ ] Cylinder Temp - Top (°C)
- [ ] Cylinder Temp - Middle (°C)
- [ ] Cylinder Temp - Bottom (°C)
- [x] COP (COP)

Average COP 2.74
Total Energy Out 39kWh
Average Outside Temp -1.1°C
Average Inside Temp 15.3°C



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Minute by minute data:- Tuning for optimum performance

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Map | Live Data | Site Details | **Historic Data** | Compare Fuels

3 Bedroom Detached House Rossendale, Lancashire

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- [x] Power Out (kW)
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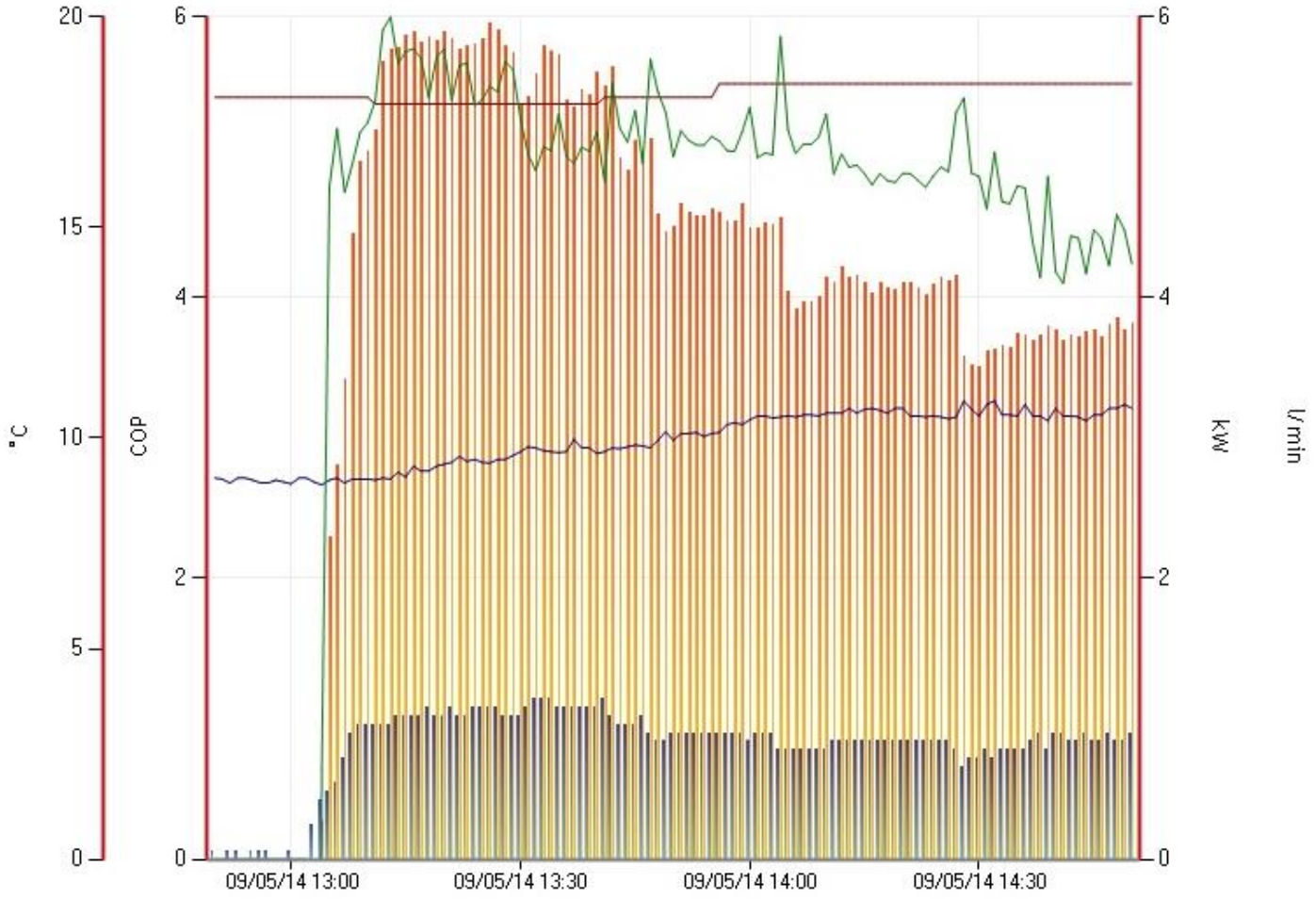
- [x] Inside Temperature (°C)
- [x] Outside Temperature (°C)
- [ ] Humidity (%RH)
- [ ] Cylinder Temp - Top (°C)
- [ ] Cylinder Temp - Middle (°C)
- [ ] Cylinder Temp - Bottom (°C)
- [x] COP (COP)

Average COP 5
Total Energy Out 8kWh
Average Outside Temp 9.9°C
Average Inside Temp 18.2°C



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Pontefract:- On-off cycling lowers efficiency

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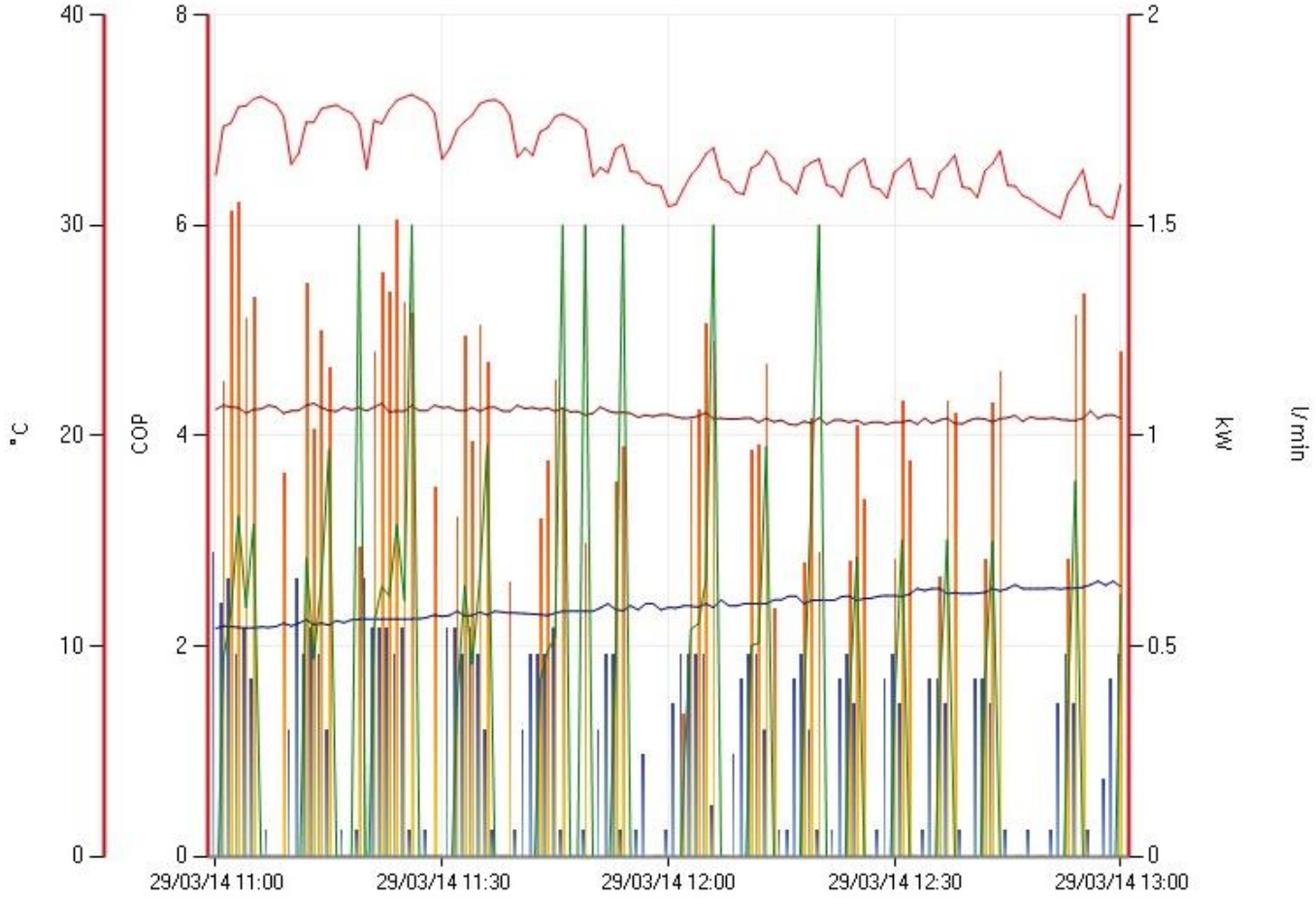
Map | Live Data | Site Details | Historic Data | Compare Fuels

2 Bedroom Flat Pontefract, West Yorkshire

View the historic performance of the Ecodan system. Add and remove items from the chart using the checkboxes below.

- [x] Power In (kW)
- [ ] Immersion Power In (kW)
- [x] Power Out (kW)
- [x] Flow Temperature (°C)
- [ ] Return Temperature (°C)
- [ ] Flow Rate (l/min)
- [x] Inside Temperature (°C)
- [x] Outside Temperature (°C)
- [ ] Humidity (%RH)
- [ ] Cylinder Temp - Top (°C)
- [ ] Cylinder Temp - Middle (°C)
- [ ] Cylinder Temp - Bottom (°C)
- [x] COP (COP)

Average COP 1.13
Total Energy Out 1kWh
Average Outside Temp 11.9°C
Average Inside Temp 21°C



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Pontefract: System works OK in winter

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Map | Live Data | Site Details | **Historic Data** | Compare Fuels

2 Bedroom Flat Pontefract, West Yorkshire

View the historic performance of the Ecodan system. Add and remove items from the chart using the checkboxes below.

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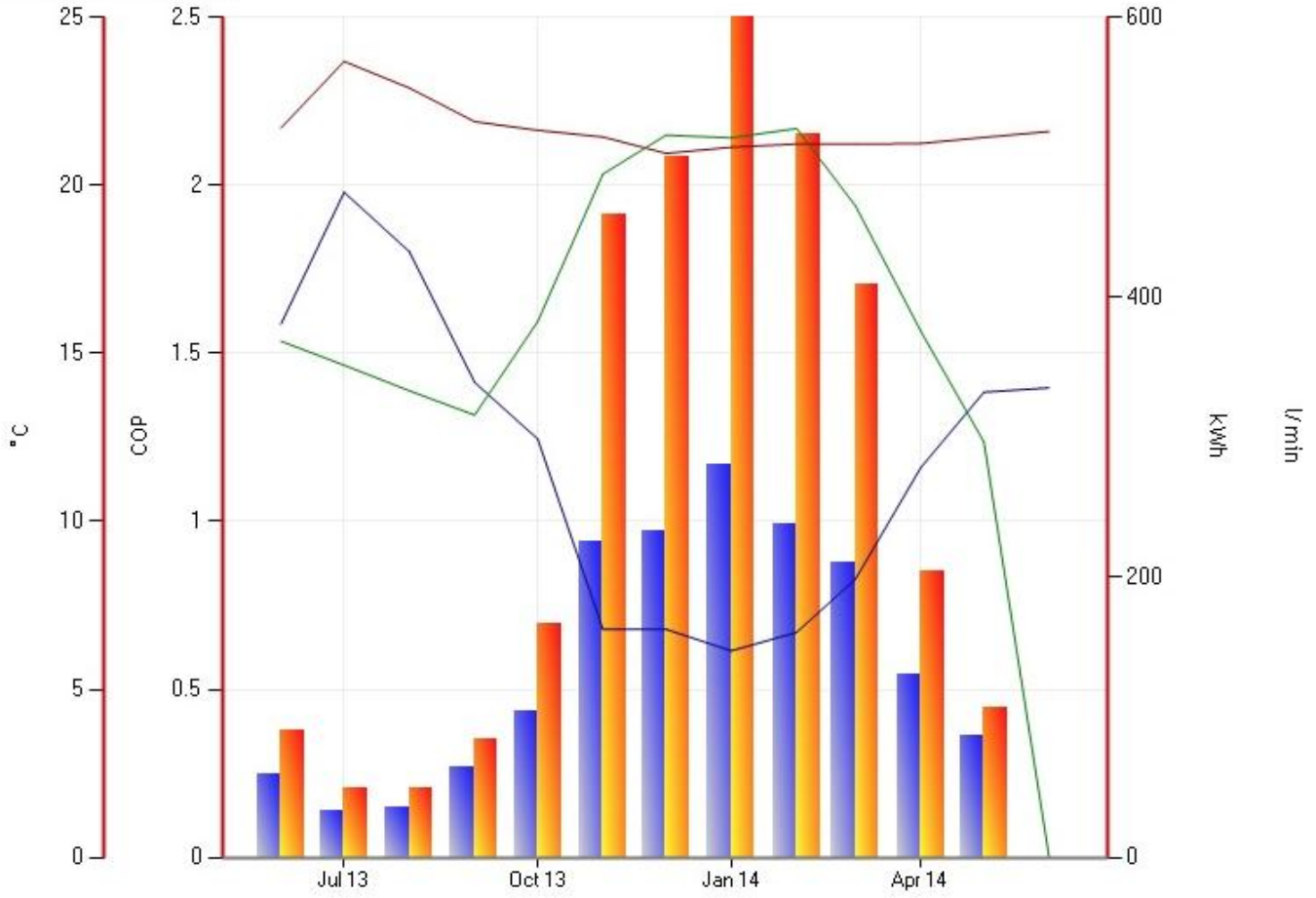
- [ ] Immersion Energy In (kWh)
- [x] Energy Out (kWh)
- [ ] Flow Temperature (°C)
- [ ] Return Temperature (°C)
- [ ] Flow Rate (l/min)
- [x] Inside Temperature (°C)
- [x] Outside Temperature (°C)
- [ ] Humidity (%RH)
- [ ] Cylinder Temp - Top (°C)
- [ ] Cylinder Temp - Middle (°C)
- [ ] Cylinder Temp - Bottom (°C)
- [x] COP (COP)



Average COP 1.9
Total Energy Out 3237kWh
Average Outside Temp 11.9°C
Average Inside Temp 21.7°C

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Export

Effective system (8.5kW) in 3 Bed semi

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Map | Live Data | Site Details | **Historic Data** | Compare Fuels

3 Bedroom Semi Detached House Ferry Hill, County Durham

View the historic performance of the Ecodan system. Add and remove items from the chart using the checkboxes below.

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- [x] Energy Out (kWh)
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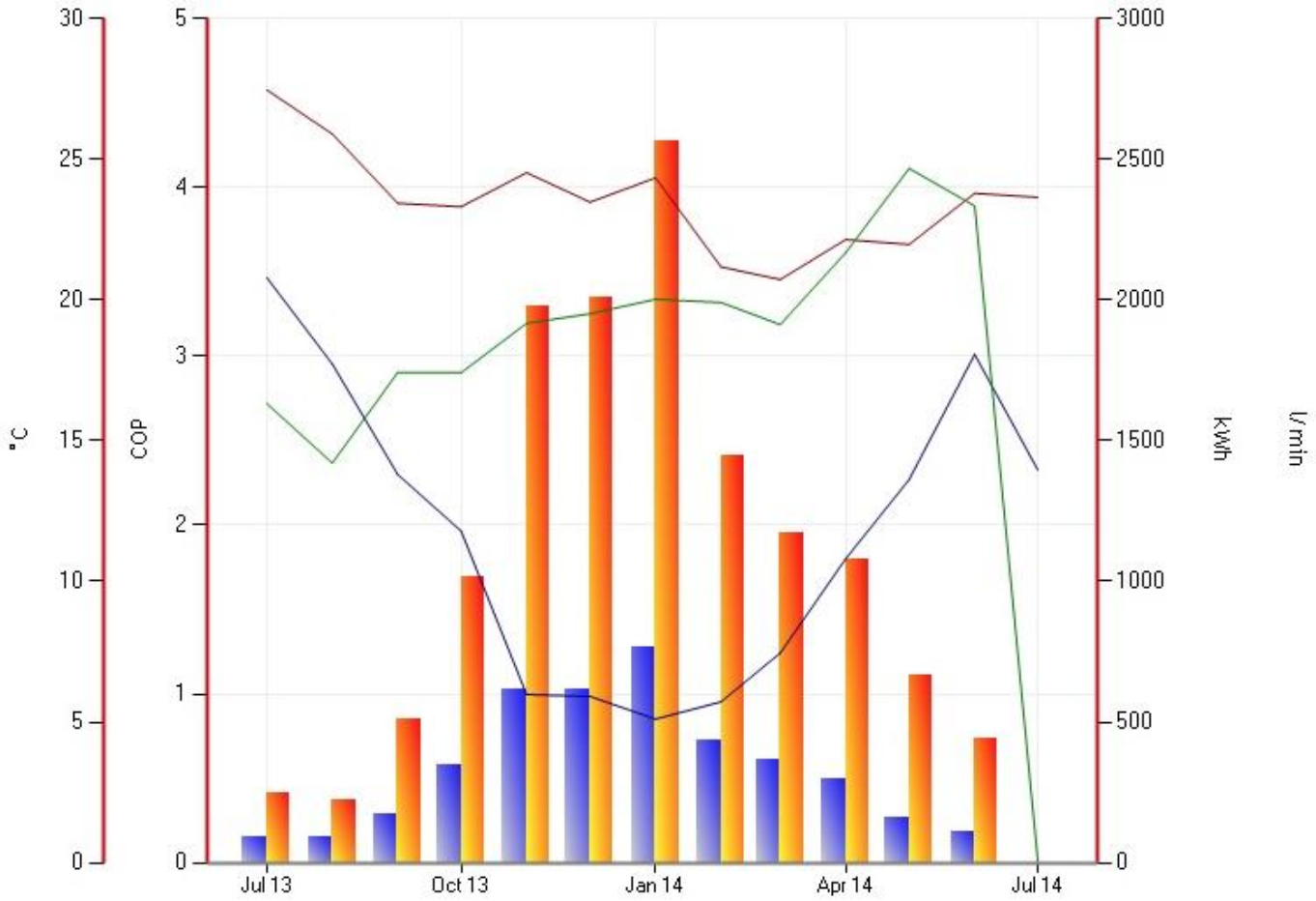
- [ ] Flow Rate (l/min)
- [x] Inside Temperature (°C)
- [x] Outside Temperature (°C)
- [ ] Humidity (%RH)
- [ ] Cylinder Temp - Top (°C)
- [ ] Cylinder Temp - Middle (°C)
- [ ] Cylinder Temp - Bottom (°C)
- [x] COP (COP)

Average COP 3.26
Total Energy Out 13348kWh
Average Outside Temp 11.6°C
Average Inside Temp 23.5°C



Site details for 3 Bed Semi

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Map | Live Data | Site Details | Historic Data | Compare Fuels

3 Bedroom Semi Detached House Ferry Hill, County Durham

3 Bedroom Semi Detached House Ferry Hill, County Durham

Property Details

- Total floorspace of property is 61 sq. metres
- Brick & block insulated external cavity walls
- Peak heat losses of property (kW) = 5.67kW
- Double glazed windows
- 1940's post war house

Heating System Details

- 8.5kW Ecodan
- Design flow temperatures = 45˚C
- Off-gas area
- Previous system: Storage heaters
- M2M Serial number: SN298824

The Integrated Approach

An integrated approach to energy reduction requires a particular perspective.

Perspectives differ, depending on your viewpoint ……..

(aka Kim Kardashian) trying to look like the Octomom?

– Alreadystoppedcaring

HIGH WAY: I think it is just terrible and disgusting how everyone has treated Lance Armstrong, especially after what he achieved winning seven Tour de France races while competing on drugs. When I was on drugs, I couldn't even find my bike.

– Tricky