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PV for heating and hot water: Does this make sense?

Context: PV and heating economics since 2011 to date

- Cost of modules fallen ~25%
- Imported grid electricity costs risen ~30%
- Generation FiT tariffs highest rates fallen ~65%
- Export tariff increased ~50%
- Deeming (Export:Generation) remains @ 50%
- Gas/oil prices increased ~36%
- Electricity Savings: Total FiT ratio increased 15% > 30%
- Hence savings and ‘deeming’ have become more important.

The consequence of deeming? – DHW immersion heater controls

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Example DHW immersion heater controls

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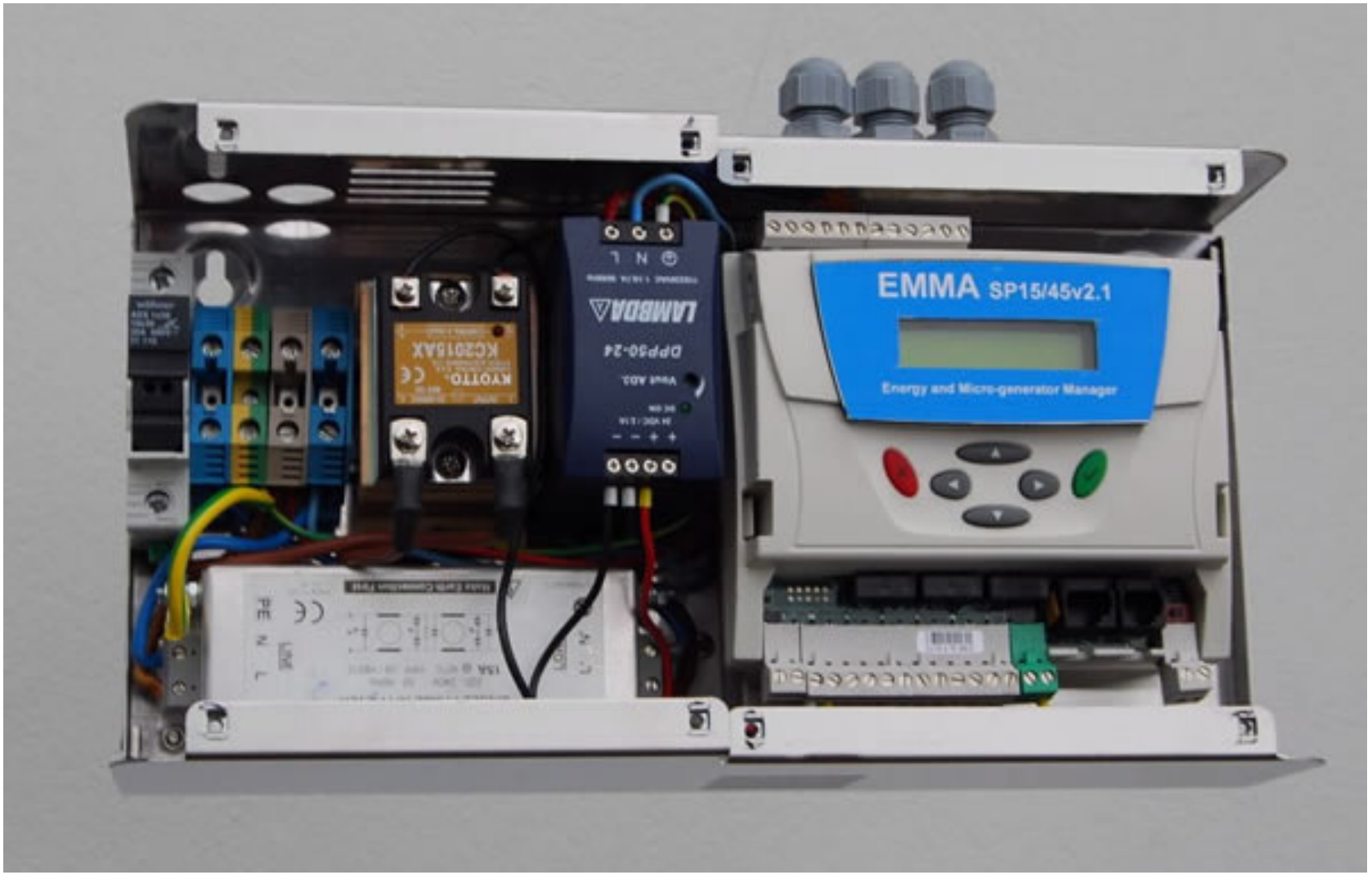
Example multi-use relay controls



Example remote switch

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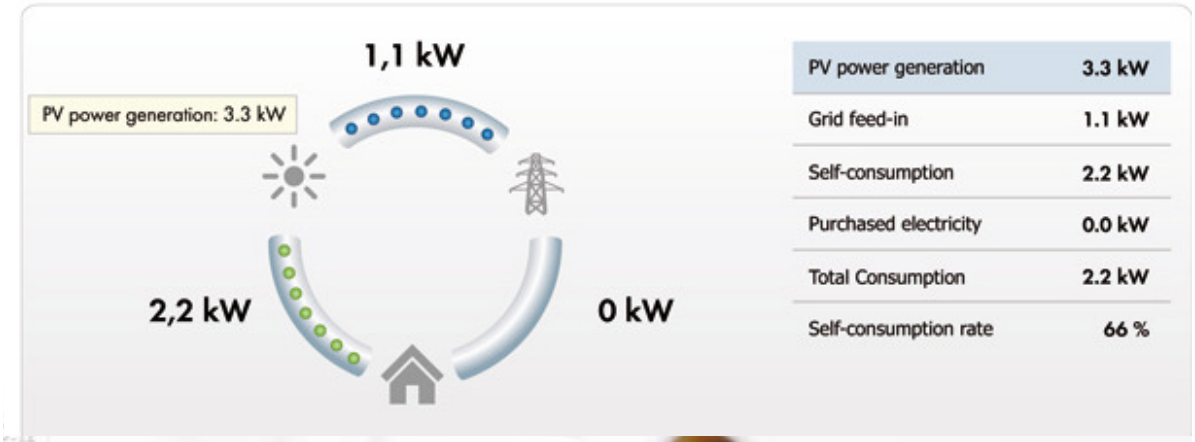
Current status



PV power generation	3.3 kW
Grid feed-in	1.1 kW
Self-consumption	2.2 kW
Purchased electricity	0.0 kW
Total Consumption	2.2 kW
Self-consumption rate	66 %

Example online apps

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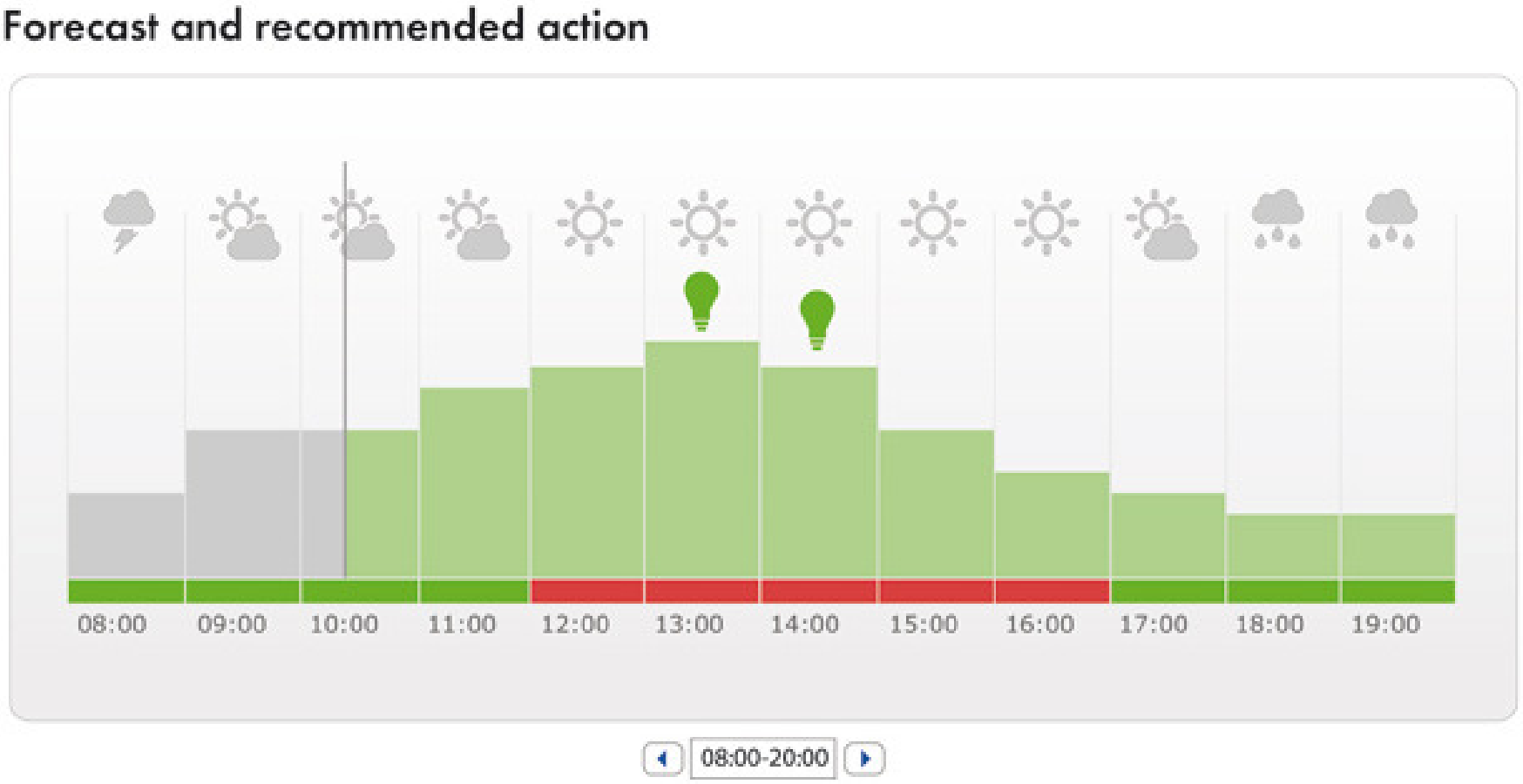
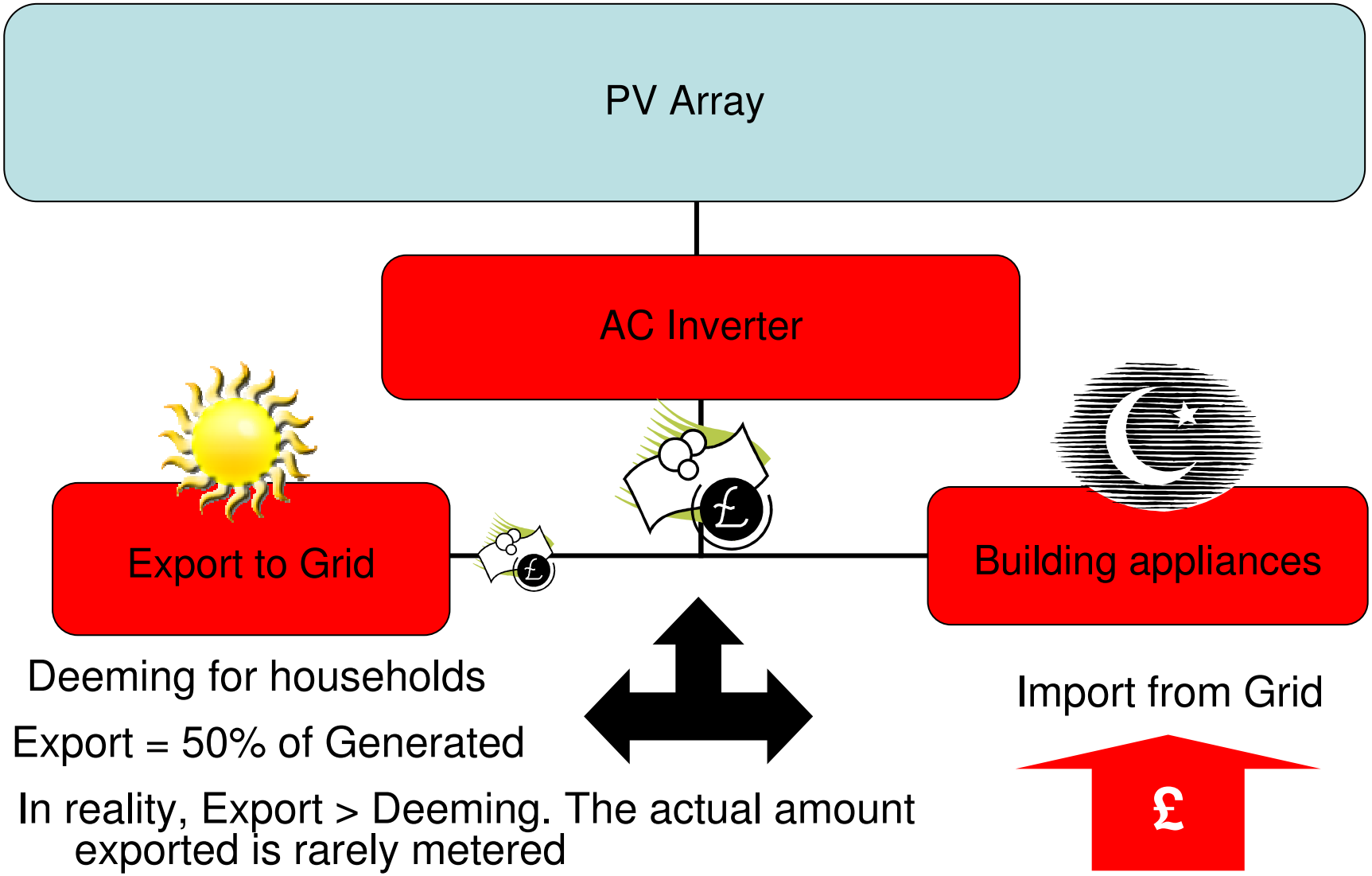


Typical FiT layout



How to increase savings: Reduce export and imports

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1) ‘Instant’ alteration timing of electrical loads

2) Convert to heat – displacing other fuels

3) Storage and re-use as electricity in batteries.

Increase savings:
Reduce export and imports

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>1) Timing<

- Synchronising loads to match generation
- Change lifestyle, use appliances when sun shines
- Weather forecast > Manual/Remote switching
- Simple timers (washing machine) if forecast good
- Individual appliance remote controlled switches
- Generation-sensitive relays (one sensor) adjusted to match appliances; often inside inverters
- Generation: Appliances (two sensor) remote relays
- Generation: Export (two sensor) remote relays
- Export-sensitive proportional relays.

Increase savings:
Reduce export and imports

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>2) Convert and use as heat<

- DHW cylinders, Space & Process heating
- Power of heat loads relative to production
- Switched electrical loads greater than instantaneous generated power will lead to import
- Example 4 kW (DC) array spends most daylight hours <1kW
- Example : Typical DHW immersion is 3kW
- Retrofit 1 kW or 1.5 kW immersion heaters?
- Reduce power/voltage using transformers?
- Issues with DHW reheat time and temperatures
- Regulate resistive loads i.e. PWM vs Burst vs Phase Angle?
- Issues with harmonics, flickering and electrical standards.

Various domestic electrical load profiles

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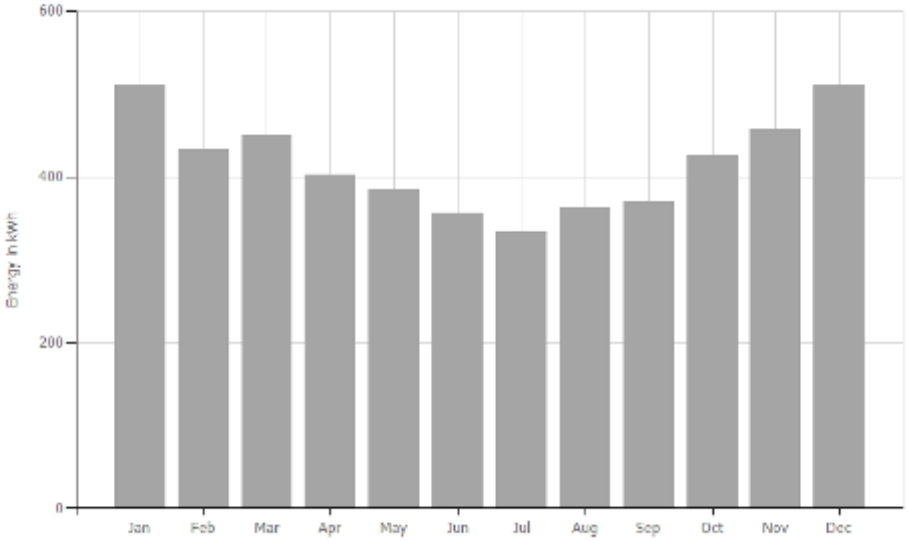

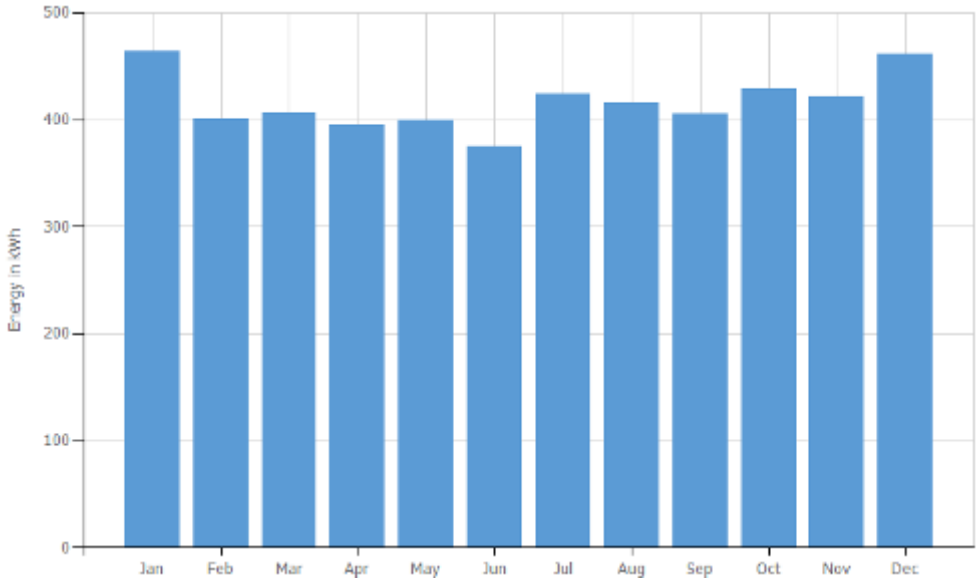

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Histogram: Generated hourly average power for 4 kW array optimum facing - Sheffield

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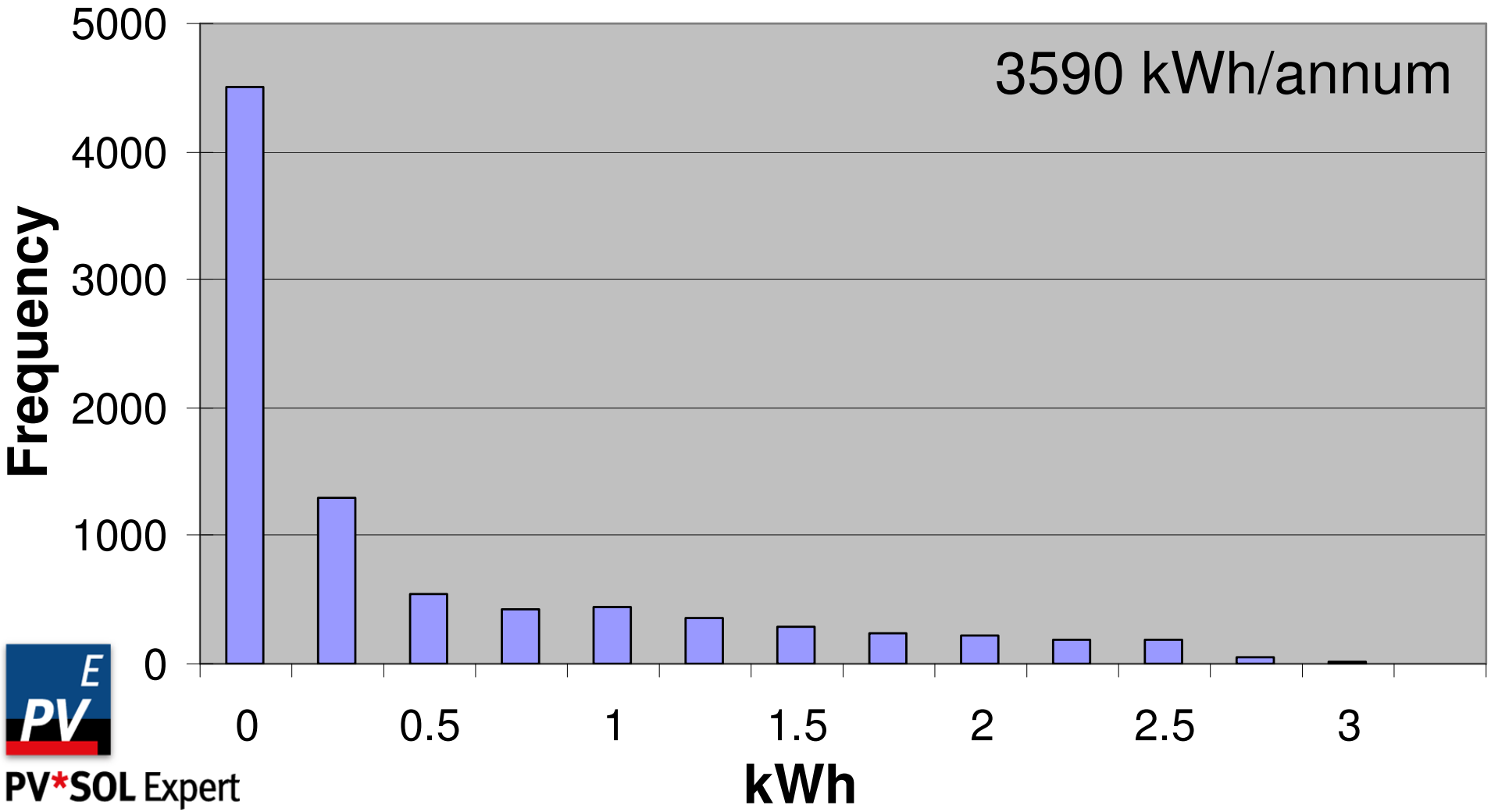

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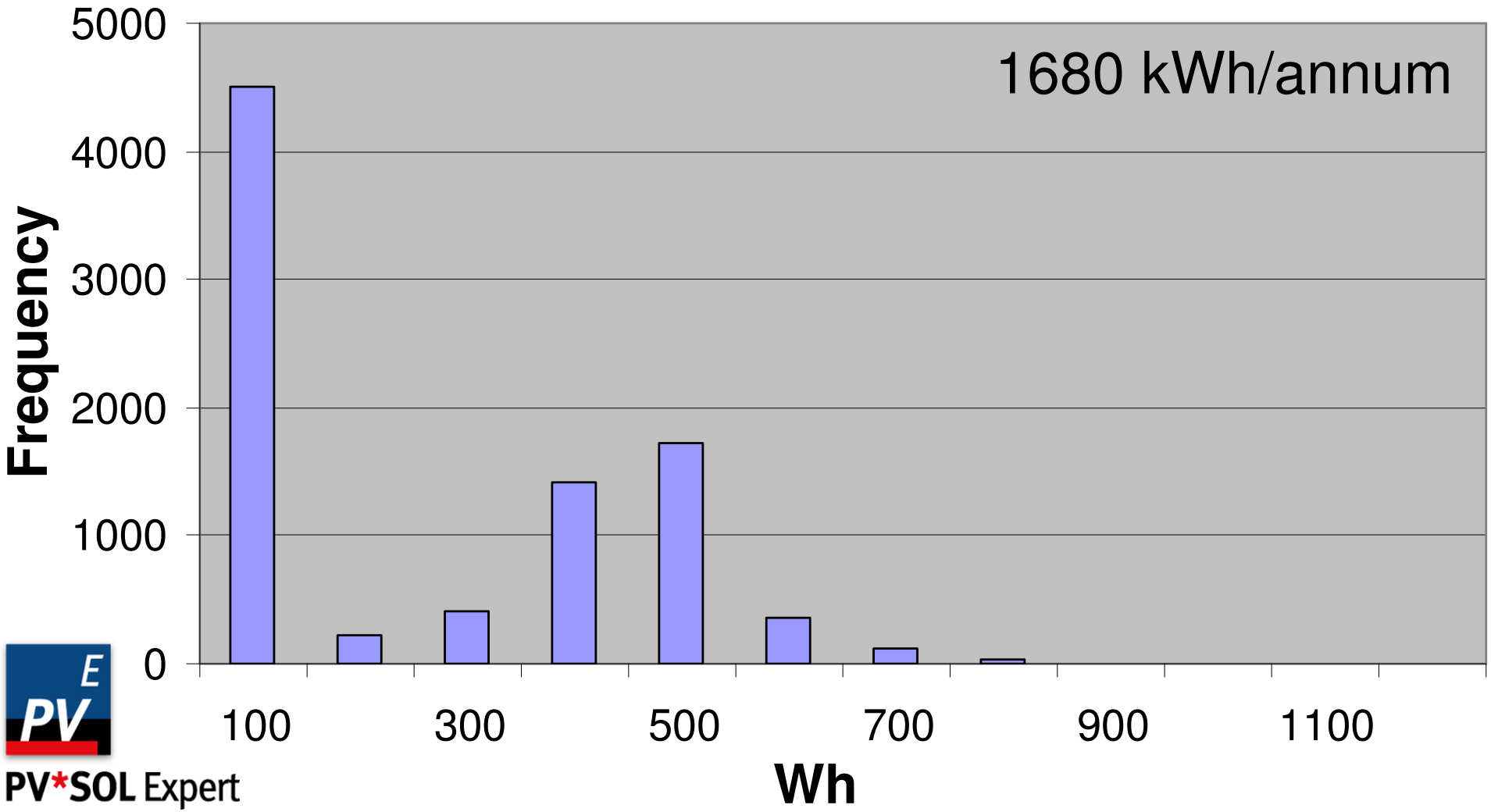
Histogram: Electrical consumption average hourly when array is generating (no electric heating)



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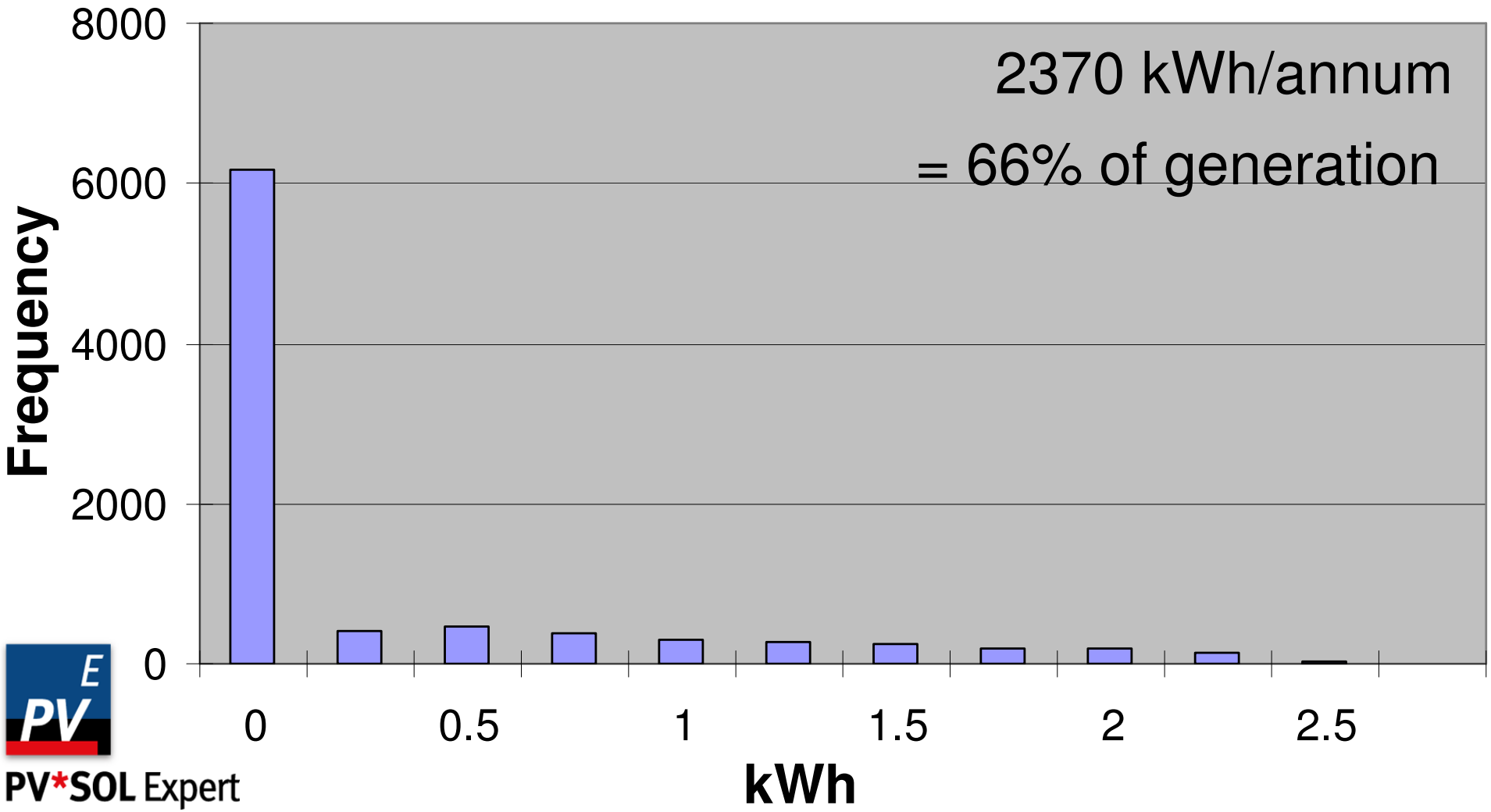
Histogram: Export average hourly



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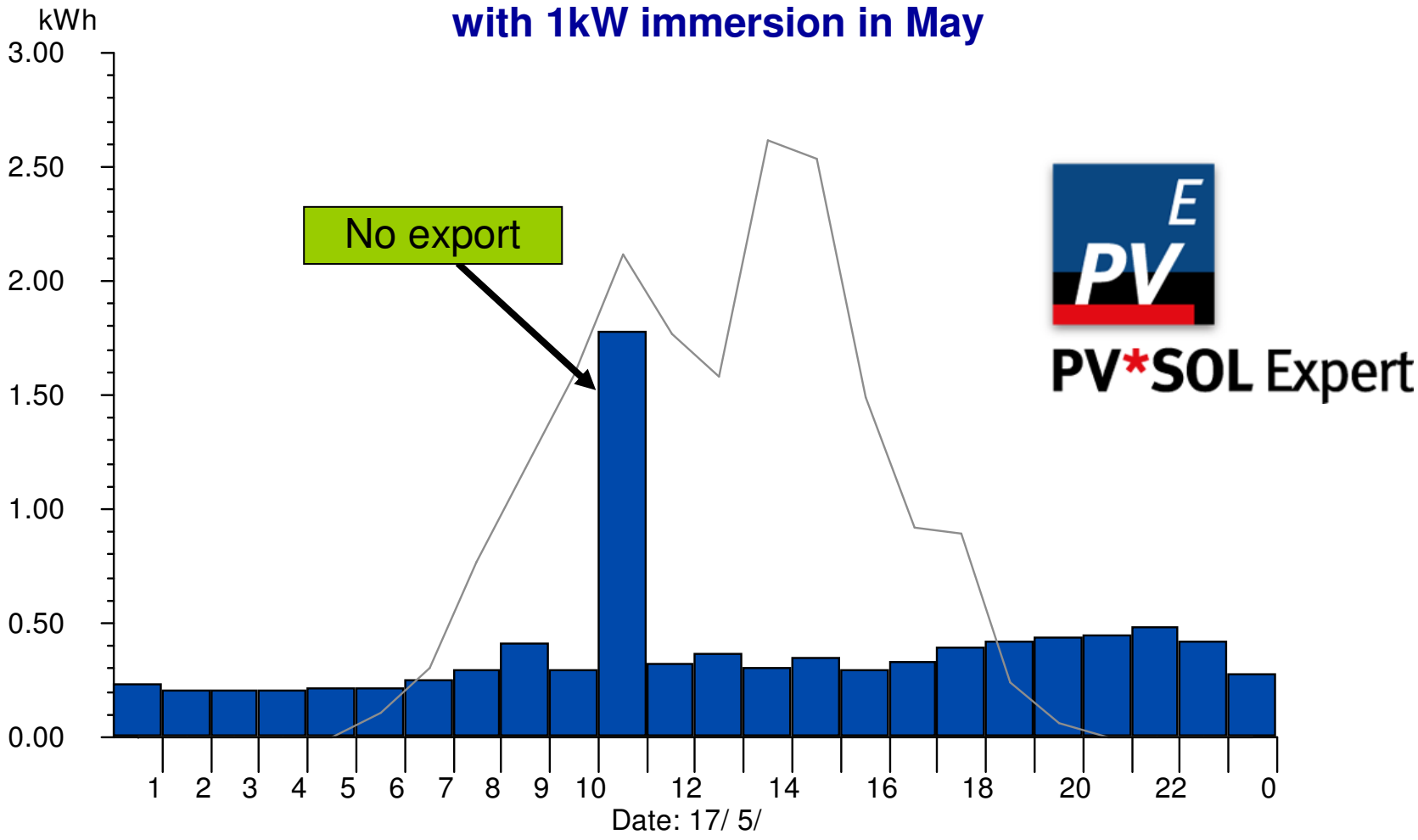
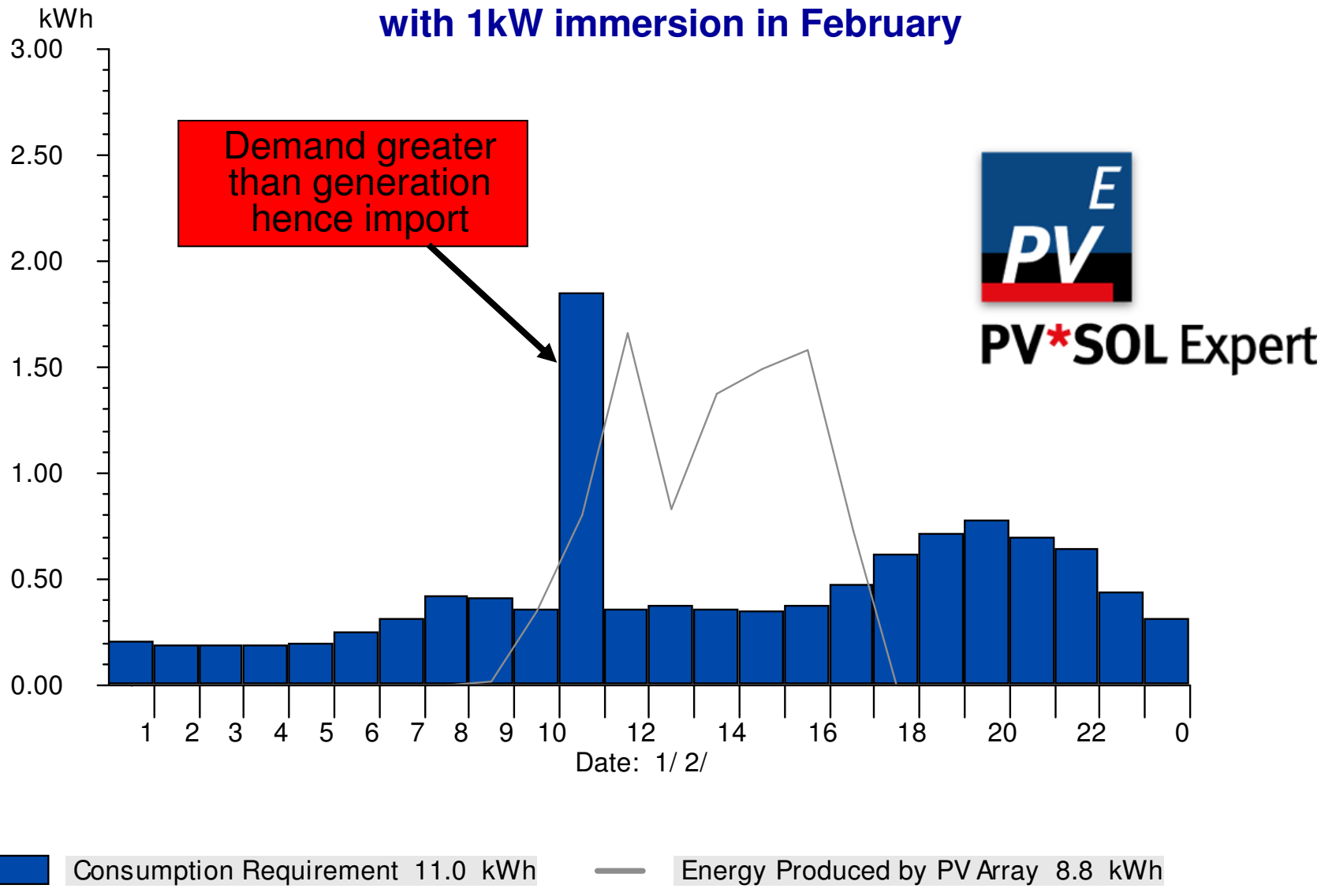
Example Hourly demand profile with 1kW immersion in May



Example Hourly demand profile with 1kW immersion in February



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What's the DHW savings potential?

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- Typical household 2400 kWh @ 50 l/day @ 50C
- Add tank/pipe losses ≈ 20% (+600 kWh)
- Represents all DHW heated from cold ≈12C
- Clothes/dish washer often not from stored DHW
- If nat. gas @ 4.5p/kWh, η:@ 80% = £168-/annum
- If on-peak electric @ 15p/kWh = £450-/annum
- If off-peak electric @ 7p/kWh = £210-/annum
- Offices, leisure centre, hotels, schools, farms?

DHW Load (consumption) profiles: Multiple Occupancy dwellings

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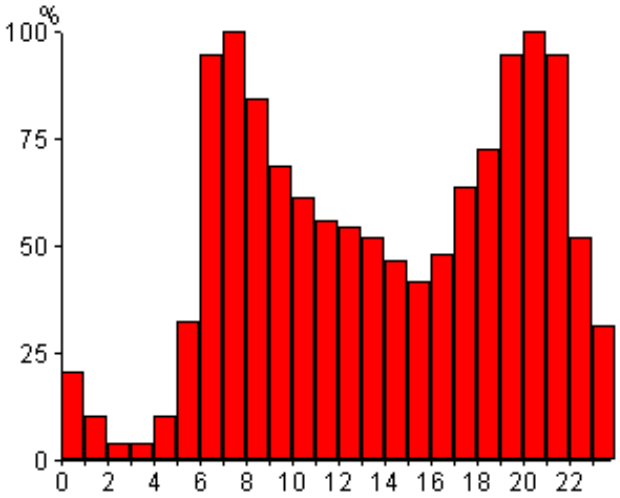
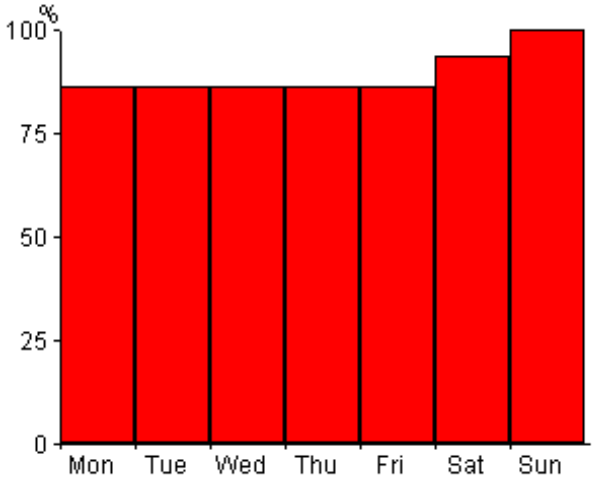
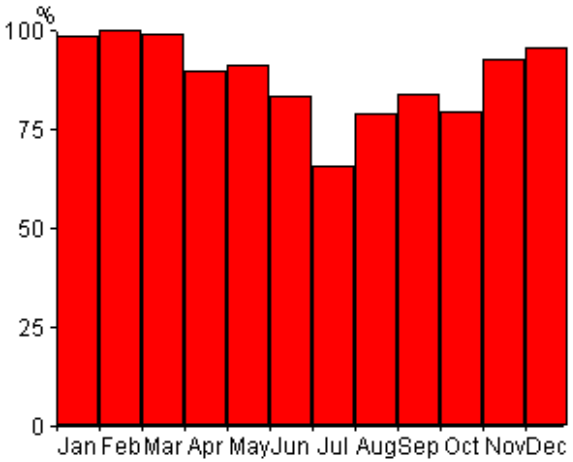


- **Daily**
- **Weekly**
- **Annually**





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Convert and use as heat: Further issues

- Daily summer DHW usage may be low
- Seasonal holidays: weeks no-one using DHW
- Excess export may be low power: i.e. <1kW
- Background appliances (chillers, security) often bring demand close to 100% of generation
- For space heating > Surplus tends to occur on sunny days when space heating least required
- Opportunities: thermal stores, underfloor, storage heaters, drying towel rails.

Convert and use as heat: Household issues

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- Not all premises have DHW tanks/immersion heaters: i.e. combi boilers, electric showers
- Electric DHW: i.e. washing machines, dishwashers
- Size of tanks limits maximum storage
- Immersion heaters don't always heat whole tank
- Immersion thermostat control not always accurate
- Back-up heater not switched off at all
- Back-up heater used in morning leaves residual DHW: i.e. off-peak overnight.

Daily average generation @ AC inverter from 4kWp

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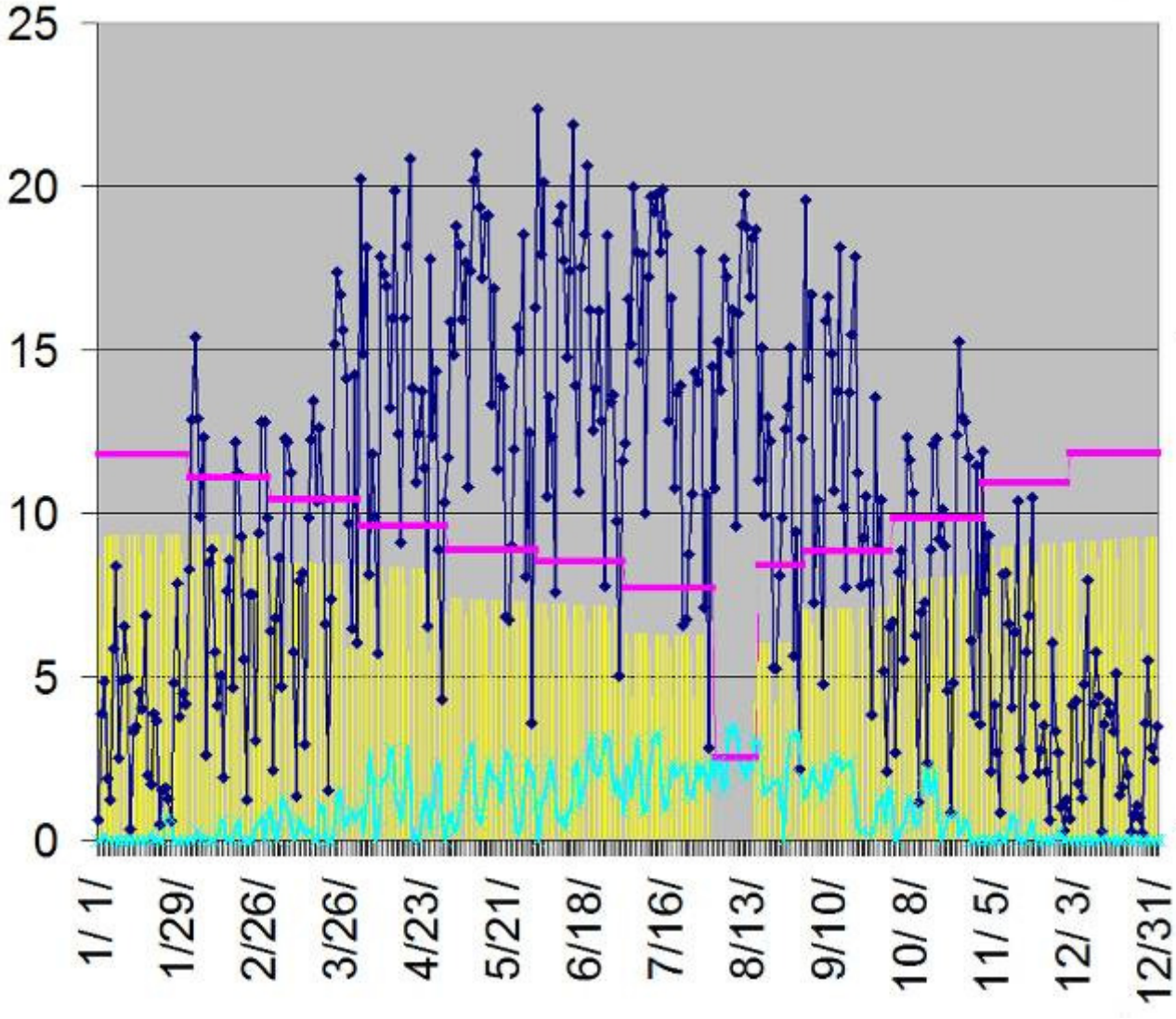

Dishwasher, clothes washer & electric showers not included in DHW tank

- Energy from Inverter kWh
- Electrical Consumption Requirement kWh
- DHW demand kWh
- DHW Tank losses - Solar only kWh

Quantifying the benefits

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- Empirical versus simulation analysis
- Need more monitoring using DHW profiles, tank types, climate types and control strategies
- Expensive and time consuming to set up
- Accuracy of kWh readouts on built-in controls?
- Control standby/parasitic losses?
- Using hourly energy balance analysis software to predict outcomes
- Generation, consumption, export, DHW usage, tank sizes and temperature limits
- Large number of variables mean assumptions have to be made to simplify results.

Assumptions: Example simulation

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- Climate location: Sheffield, no shade, 2+2 household
- 4kWp optimum facing HIT, Single MMP inverter
- Deemed export @ 50%
- Base electrical load profile @ 3500kWh/a
- EST Domestic Profile
- Added PV > PWM 3kW immersion control
- Tank 150 litre with back-up ***normally off until after 4pm*** heating all tank @ 60C
- At least 130 litres DHW at taps @ 50C per day
- Generous DHW tank usage, ***evening only***
- Using bath or mixer shower, no electric shower
- Dishwasher, washing machine (electric only)
- 2 week holiday in summer.

Peak solar days from 4 kWp exceed storage limit of most domestic tanks ~ 8 kWh

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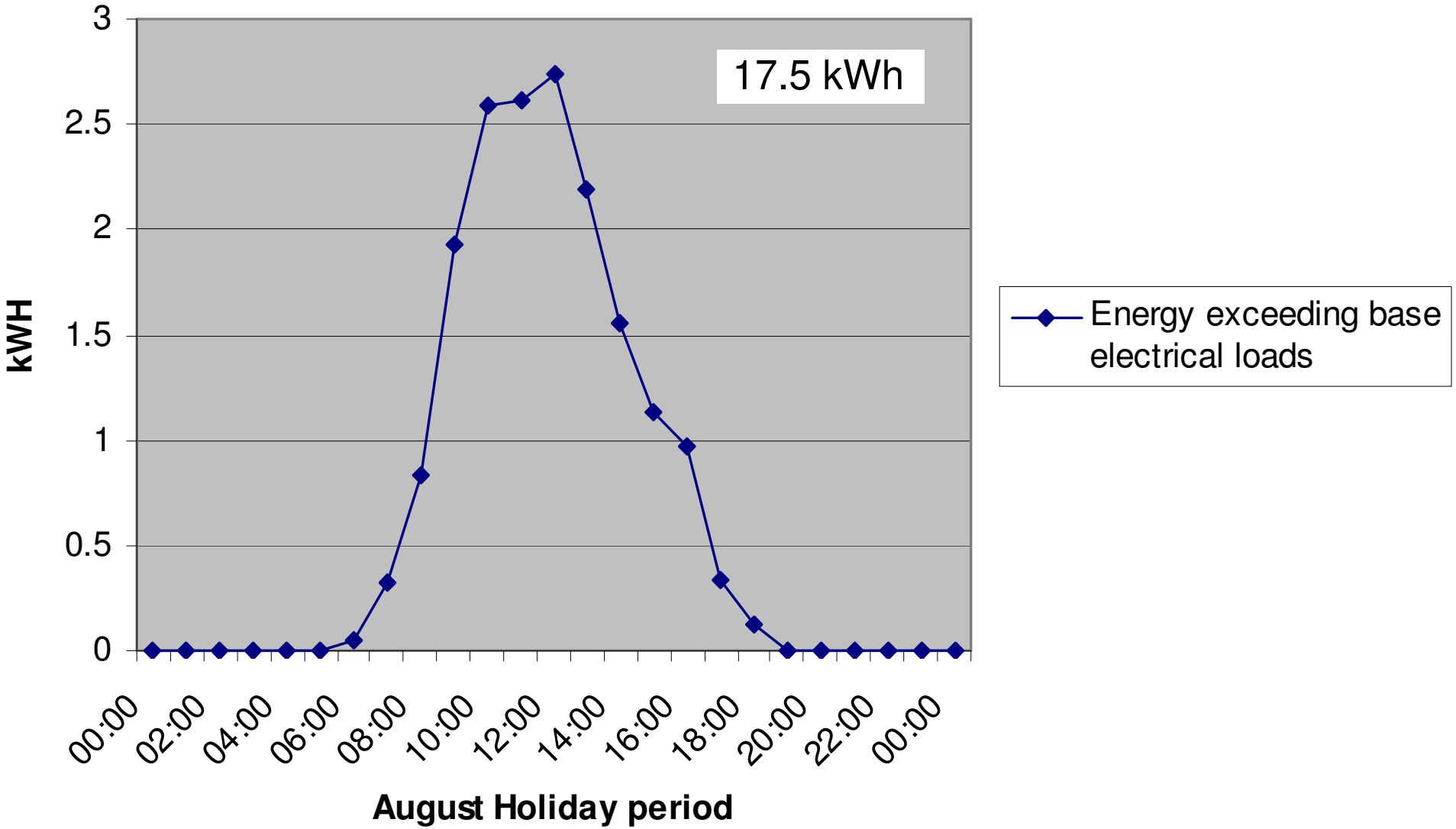

Tank size affects energy 'lost' to export with 4 kWp array

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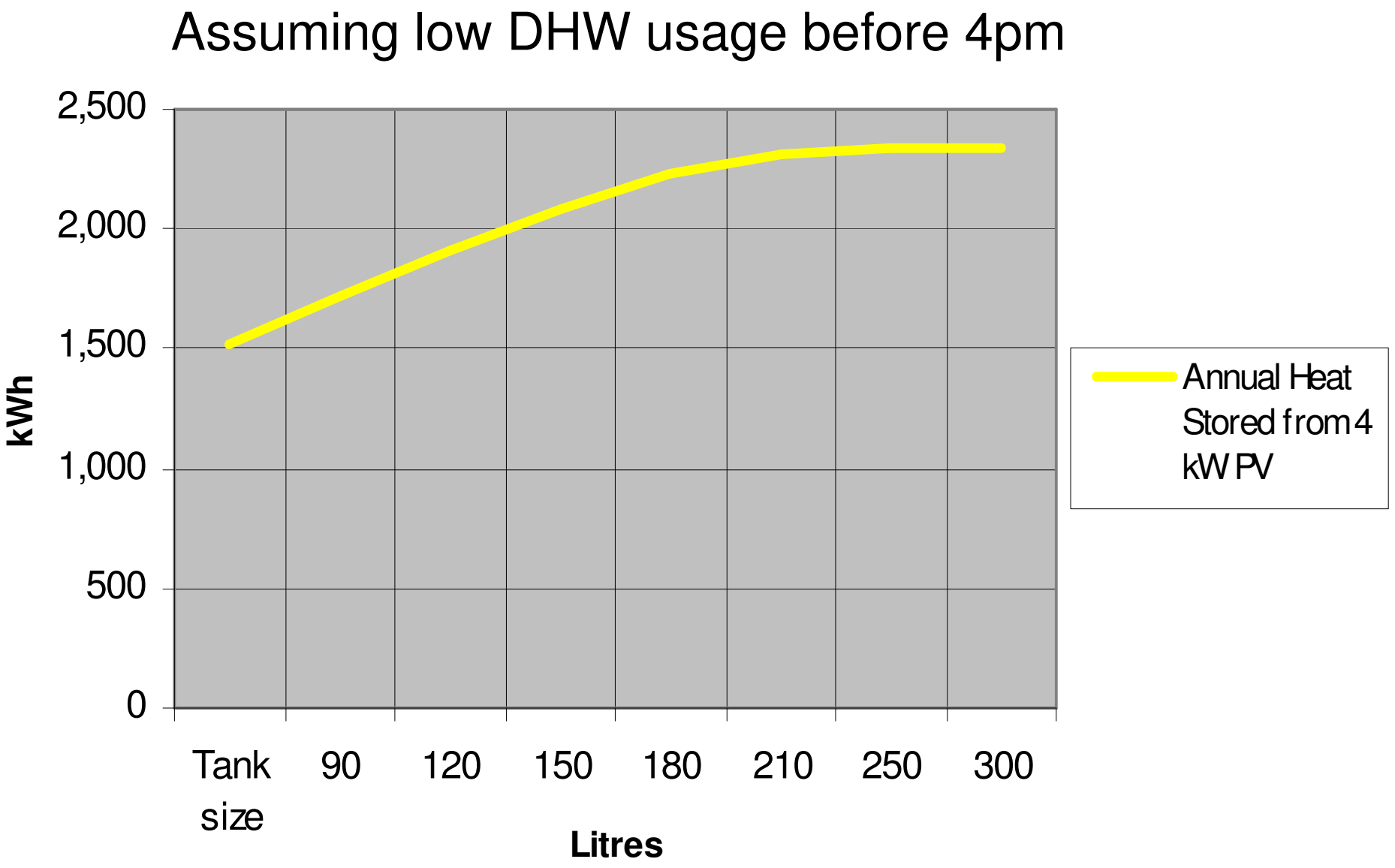

Residual heat left in tank from previous day

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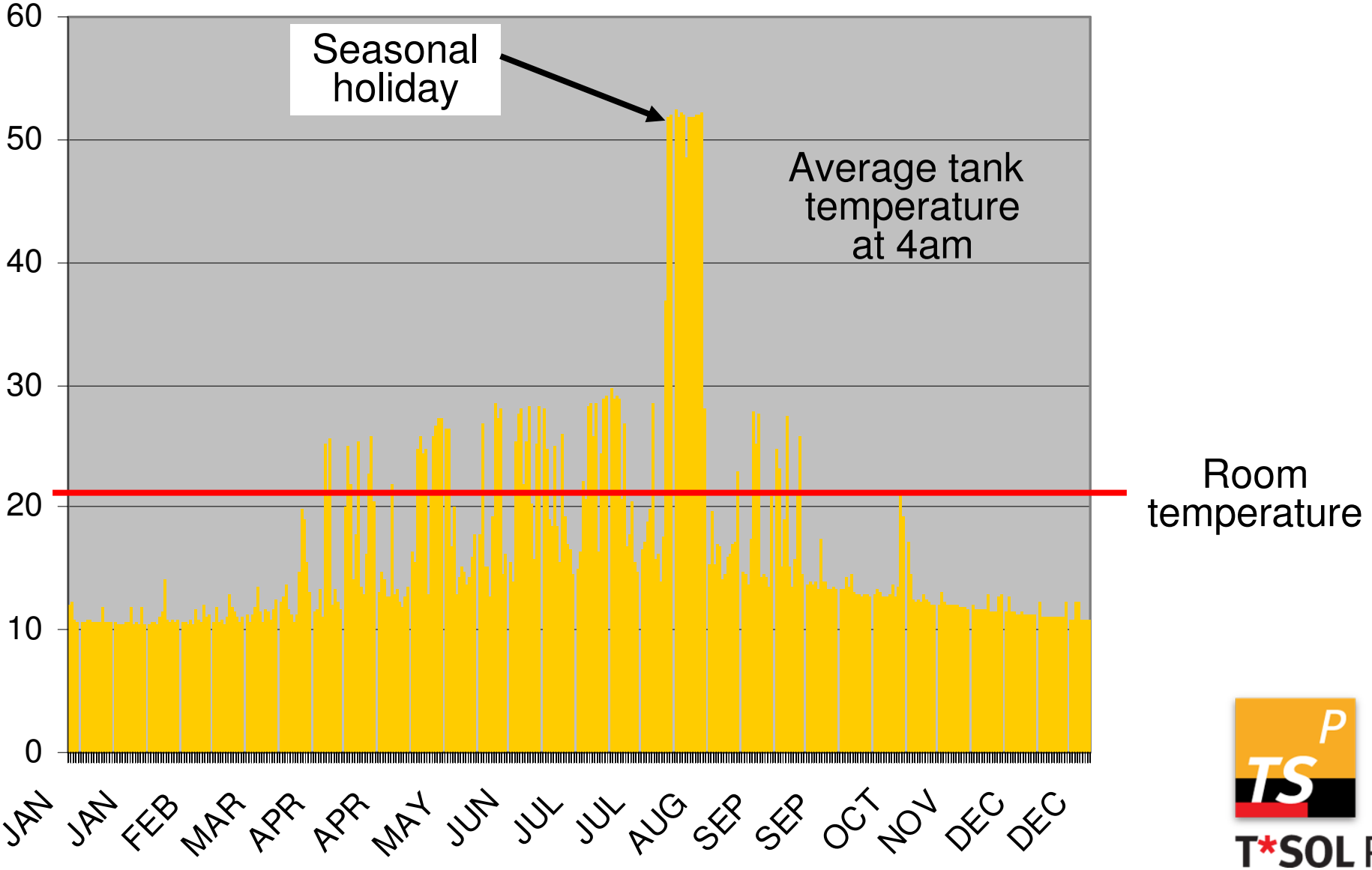

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Best results - Immersion control with 'ideal' DHW regime

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- ~1900 kWh currently exported has potential for extra self-use
- ~1400 kWh potential to DHW: i.e. limits of summer usage
- ~1000 kWh still needed for DHW back-up on dull days
- Tank losses ≈ 300 kWh ~50% from PV
- Solar fraction (of DHW demand and losses) = 58%
- FiT payments remains same due to deeming
- ~1100 kWh still exported: Opportunity for other appliance control and/or batteries?
- Off-peak comparison not feasible with DHW regime

Savings – PWM 3 kW immersion + DHW after 4pm

Back-up natural gas DHW
Before = £168-
After = £56-
Gain £112/a

Back-up peak electric DHW
Before = £450-
After = £150-
Gain £300/a

With morning back-up, 'average' DHW use and 110 litre tank?

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- Backup now on twice a day: i.e. default settings
- ~900 kWh potential to DHW: i.e. limits of summer usage
- ~1500 kWh still needed from back-up on dull days
- Tank losses ≈ 350 kWh ~ 40% from PV
- Solar fraction (of DHW demand and losses) = 38%
- FiT payments remains same due to deeming
- 1600 kWh still exported: Opportunity for other appliance control and/or batteries?

Savings – PWM 3 kW immersion + DHW twice a day

Back-up natural gas
Before = £168-
After = £84-
Gain £84/a

Back-up off-peak electric
Before = £210-
After= £105-
Gain £105/a

Does it make sense?

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- What about ‘smart’/export meter rollout?
- Is CO_2 mitigation better if other grid users can use in daytime?
- Overhead DNO cable losses ~7%?
- How will PV DHW heating affect RHI solar with deeming?
- Displacing energy from more efficient solar thermal?
- Displacing wind, hydro, heat pumps & biomass?
- USA and Germany have brought in restrictions on self-use
- Will MCS/REAL deal with mis-selling: i.e. oblige load analysis
- The wisdom of converting high-grade energy to low-grade
- Is autonomy possible? Is this where government policy is leading?
- The Feed-in Tariff is becoming in name only!

Maximum savings
> Full autonomy ?

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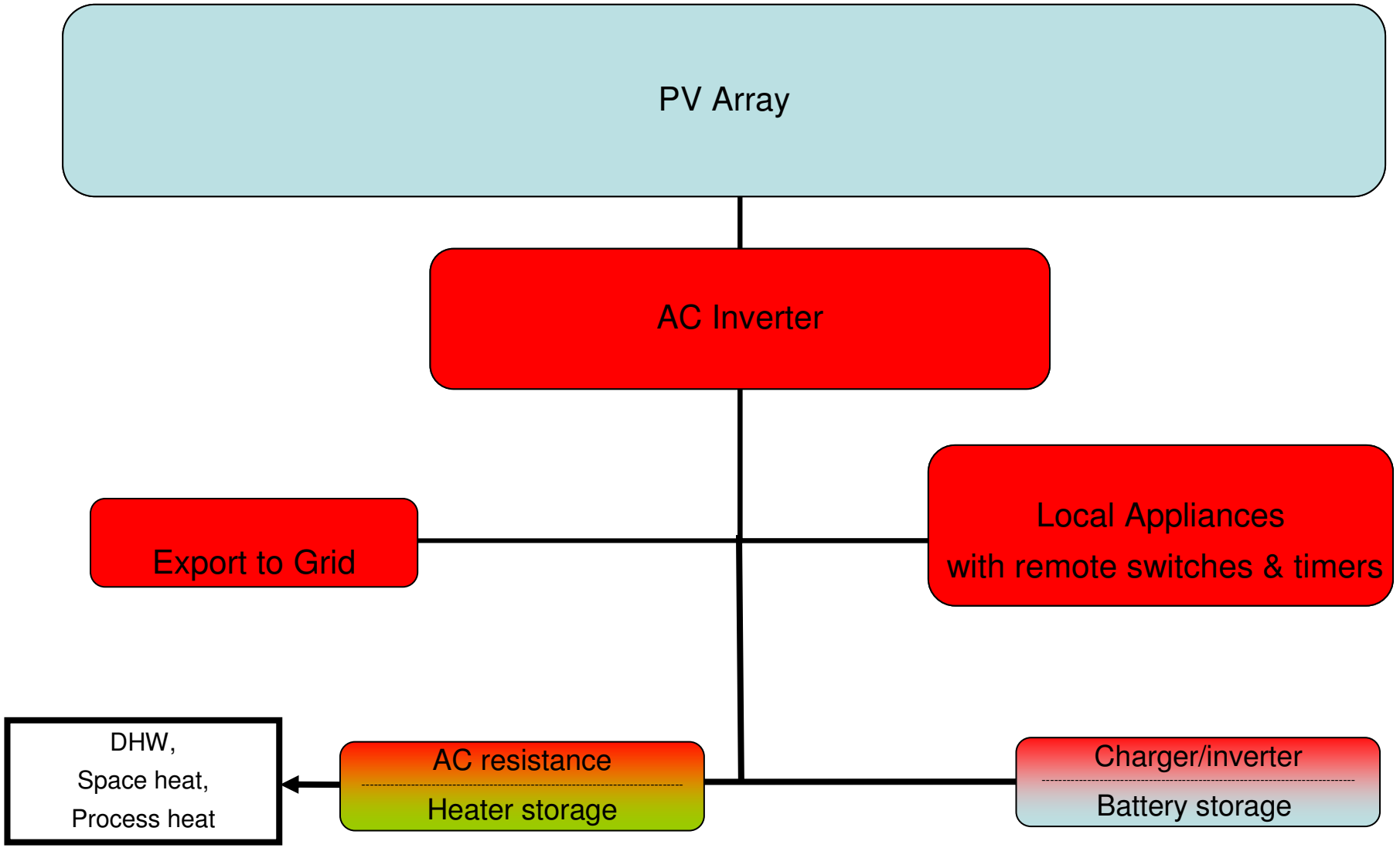
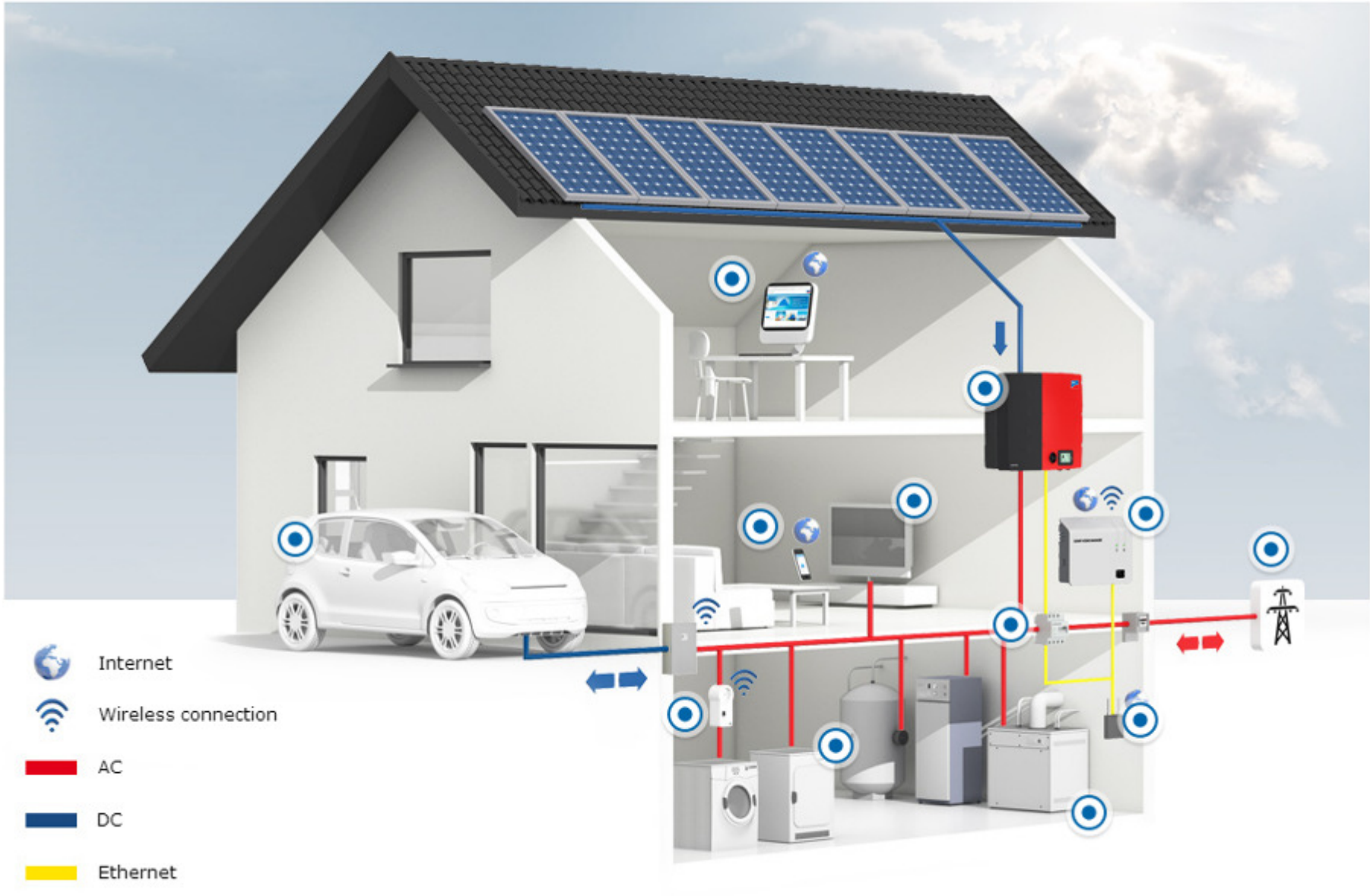


SMA Integrated Storage System

Learn more about this easy storage solution as part of the SMA Smart Home by placing your cursor over the point



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