

# PV-Battery-LED systems in offices

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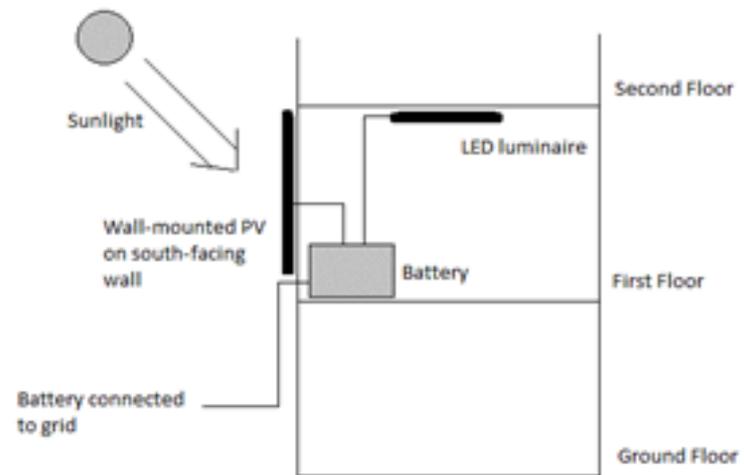
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# Introduction and Background

- Lighting uses up 20% of energy in buildings.
- Traditional light sources (e.g. Filament, Fluorescent) convert little energy into light of sufficient quality, and/or produce too much heat and toxic waste.
- With solid-state Light Emitting Diode (LED) lighting, there is scope to half the lighting energy use. Being DC, it can be combined with Photovoltaics (PV) to produce quite an efficient system, avoiding intermediate-level losses (e.g. due to inverters).
- Both technologies have matured significantly during the last decade, and their uptake in building design has started to increase. Battery technology is not far off either.
- In this study we shall demonstrate that under certain conditions, the PV requirement can be quite modest, and the battery sizing can fall within the capability of current devices.

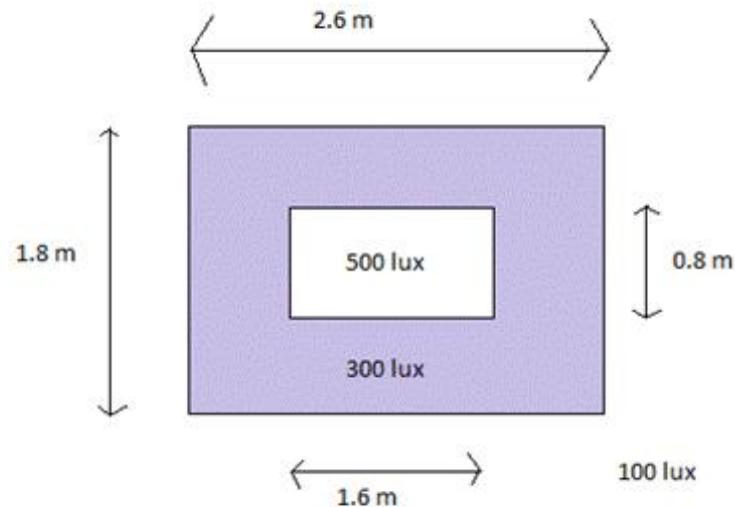
# The PV-LED system

- Wall-mounted PV power generation was predicted for a single room in a multi-level office building, and used to power the interior lighting. MPPT assumed to be in operation.
- Solar data location: Bristol
- Room depth of 6m
- Wall area of 21 m<sup>2</sup>
- Ceiling height of 3m
- Window area of 4 m<sup>2</sup>
- Most of the electricity is used at different times to those during generation, and so a suitably chosen battery is required to store the energy.



# Multi-level Lumen Method

- Office lighting traditionally required a uniform room illuminance of 300 lux. However, the modern requirements are a desk illuminance of 500 lux, the immediate surroundings of 300 lux, and background level of 100 lux.



# Assumptions

- Using this Three-level **Lumen method**, we can decompose lighting requirements into Background and Task components.
- The Task component is determined by occupancy levels (which can be of a quite transient and random nature); whereas the background component was considered as being always switched on during office hours (8am to 6pm weekdays).
- A crystalline silicon PV efficiency of 15%, and a warm-white LED efficacy of 60 lumens/Watt (at least as bright as a fluorescent bulb) was assumed. Present battery cost is 40p per Wh (Lithium-Ion).
- Assume an LED lifetime of 25 years, and capital cost of £10 per 1000 lumens. The existing Fluorescent luminaires have efficacy of 60 lm/W, lifetime of 5 years, and capital cost of £2 per 1000 lumens.

# Methodology

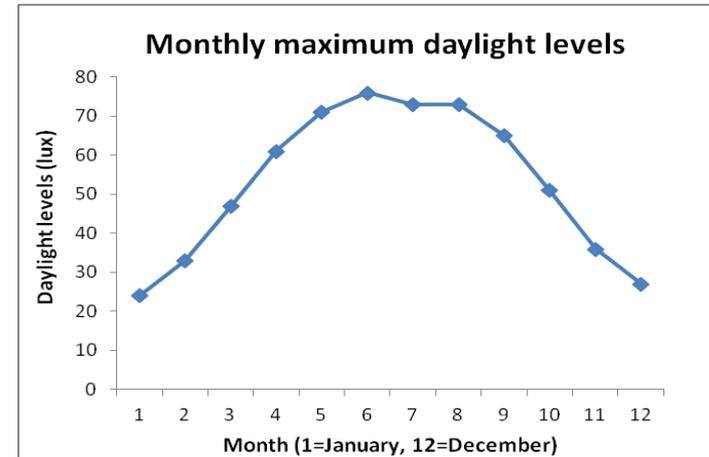
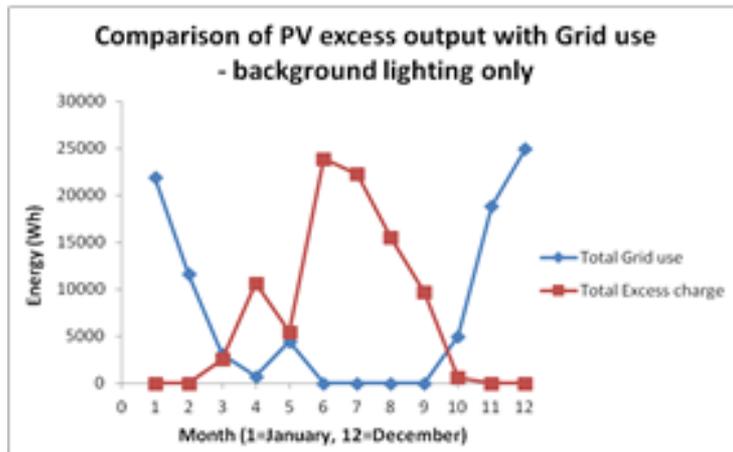
- The daily lighting profile was: Background lighting on weekdays between 8am-6pm, and off at all other times.
- The lighting requirements were calculated using the Multi-level Lumen method, taking into account the contribution from daylighting (Overcast sky assumed).
- The key determinant of the economic viability is the lifetime costs, in particular the **payback period**. Components purchased at intermediate stages during the lifetime must be considered in terms of today's costs using **Net Present Value**.
- Annual hourly solar data was obtained from ECOTECH, and based on this, the whole system was sized at 0.5 kW. Hourly analysis performed using a Spreadsheet developed at WSA.

# Methodology (2)

- In order to size the battery, the daily shortfall (averaged over the whole year) of PV energy was compared to the lighting energy requirements. An extra margin of 50% was allowed for departure from ideal behaviour.
- The hourly **state-of-charge** on the battery was determined by the difference between PV input, and its use by the lighting.
- Taking into account the battery capacity, any **excess** is fed to the grid, and **deficit** is taken from the grid.
- The monthly and annual energy movements to/from grid are evaluated, as is the resulting costs and sales.
- Grid cost of 12p/kWh, FIT of 16p per kWh, export 4.5p/kWh.

# Energy generation and use in lighting

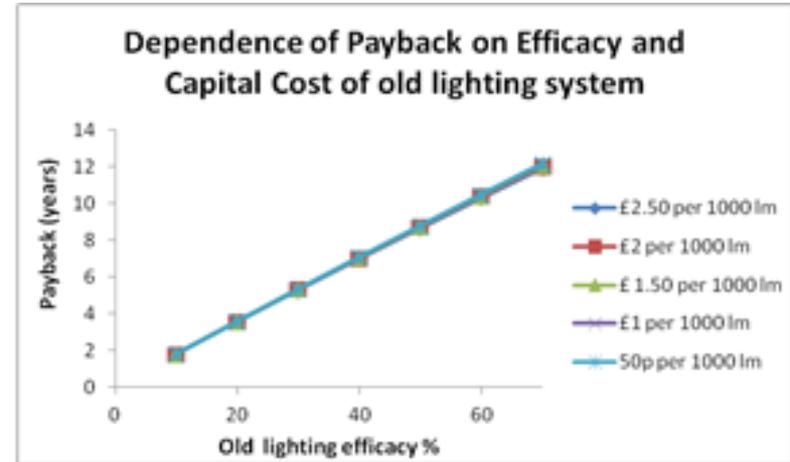
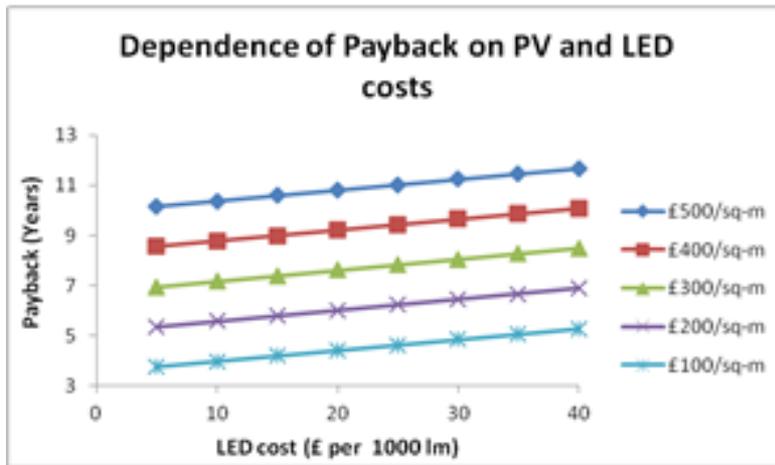
- Left: Annual PV generation versus background lighting requirements
- Right: Monthly daylight levels



- For 6 months PV supplies to grid, and for other 6 months lighting takes from grid. Annual Net Sum = 0 Wh. This determines PV area for background lighting. Additional PV is required for task lighting.
- Daylighting levels vary from 25 lux (winter) to 75 lux (summer).

# Payback Times (background lighting)

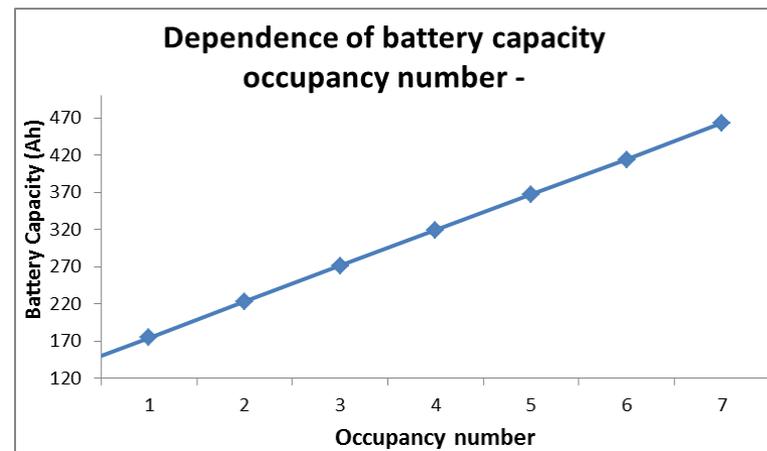
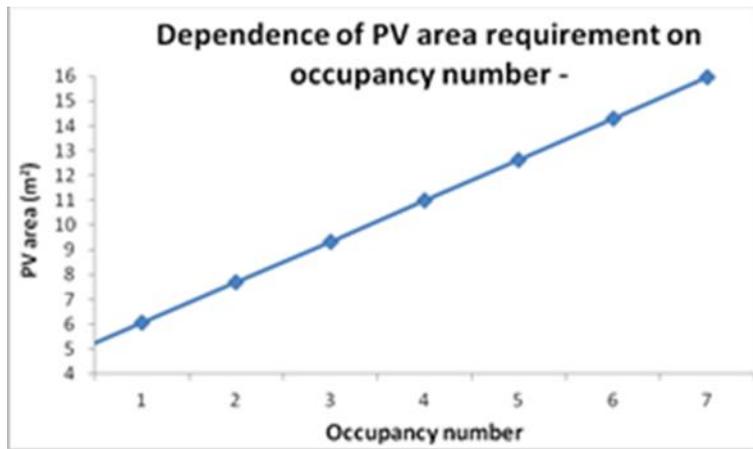
- Left: Comparison of PV and LED capital costs on payback times
- Right: How the old lighting system affects payback times



- PV costs are more dominant than LED costs
- Efficacy of old lighting system (electricity costs) is more important than its capital costs (number of replacement bulbs).

# The effect of Occupancy number

- Left: The effect of occupancy number on PV area requirement
- Right: The corresponding effect on required battery capacity



- Max available wall area filled with PV. 16m<sup>2</sup> → 7 occupants.
- Once there are more than a few occupants, the battery size goes outside the range of current commercial devices.

# Discussion of results

- The battery size for background lighting was calculated to be 125 Ah, which is within the range of some commercial Li-Ion devices. But task lighting requires a much greater battery sizing.
- For the background lighting alone, the Wall-mounted PV is capable of providing enough power for 6 months of the year, and a relatively small area of PV modules are needed (approx 4.5 m<sup>2</sup>). This requirement increases with occupancy level, and the resulting task lighting requirement.
- A systematic survey of the payback time on various parameters was performed, and the most significant ones were found to be PV cost and efficiency, Occupancy number, and cost of the Old Lighting System: 10 years for Fluorescent, 2 years for incandescent. Payback is also currently much more sensitive to PV parameters than those of Battery and LEDs. This will improve with future technologies though.

# Summary and Outlook

- By introducing the Background-Task splitting, one only requires a small PV area to power the background lighting (around 4.5 m<sup>2</sup>), and a small battery size (around 120 Amp hr). *This is now within the range of some commercial batteries.*
- Important not to oversize the system (even moderately), as this significantly increases costs and payback times.
- Increased occupancy levels will cause a major increase in payback time, due to the task lighting being more energy intensive than background lighting. When designing BIPV, a careful early decision must be taken as to precisely what the generated power is used for.
- Ongoing R+D: Further develop the Spreadsheet to include Thermal effects, and apply to other LED-based systems (e.g. Ultraviolet)