# Community Energy Systems and the UK's National Energy System – the Role of CHPV

Mike Perry
Building Technology Group
20 January 2016

Part of the BRE Trust

## Those in the know think that the world of energy is changing …

– **Steve Holliday, former CEO National Grid; 11 Sep 15:**

‘This [energy] industry is going through a tremendous transformation. We used to have a pretty good idea of what future needs would be. We would build assets that would last decades and that would be sure to cover those needs. That world has ended.’ **…**

‘The world is clearly moving towards much more distributed electricity production and towards micro-grids. The *pace* of that development is uncertain. That depends on political decisions, regulatory incentives, consumer preferences, technological developments. But the direction is clear.

# Government energy policies incorporate 'Distributed Energy'

– Distributed Energy included in number of UK policy documents, including:

  - Planning our electric future - A White Paper for secure, affordable and low carbon electricity, (DECC, July 2011)

  - The Future of Heating – Meeting the challenge, (DECC, March 2013)

– CHP (Combined Heat & Power) technologies are major subset of both future UK electricity generation capacity, and of locally based heating networks

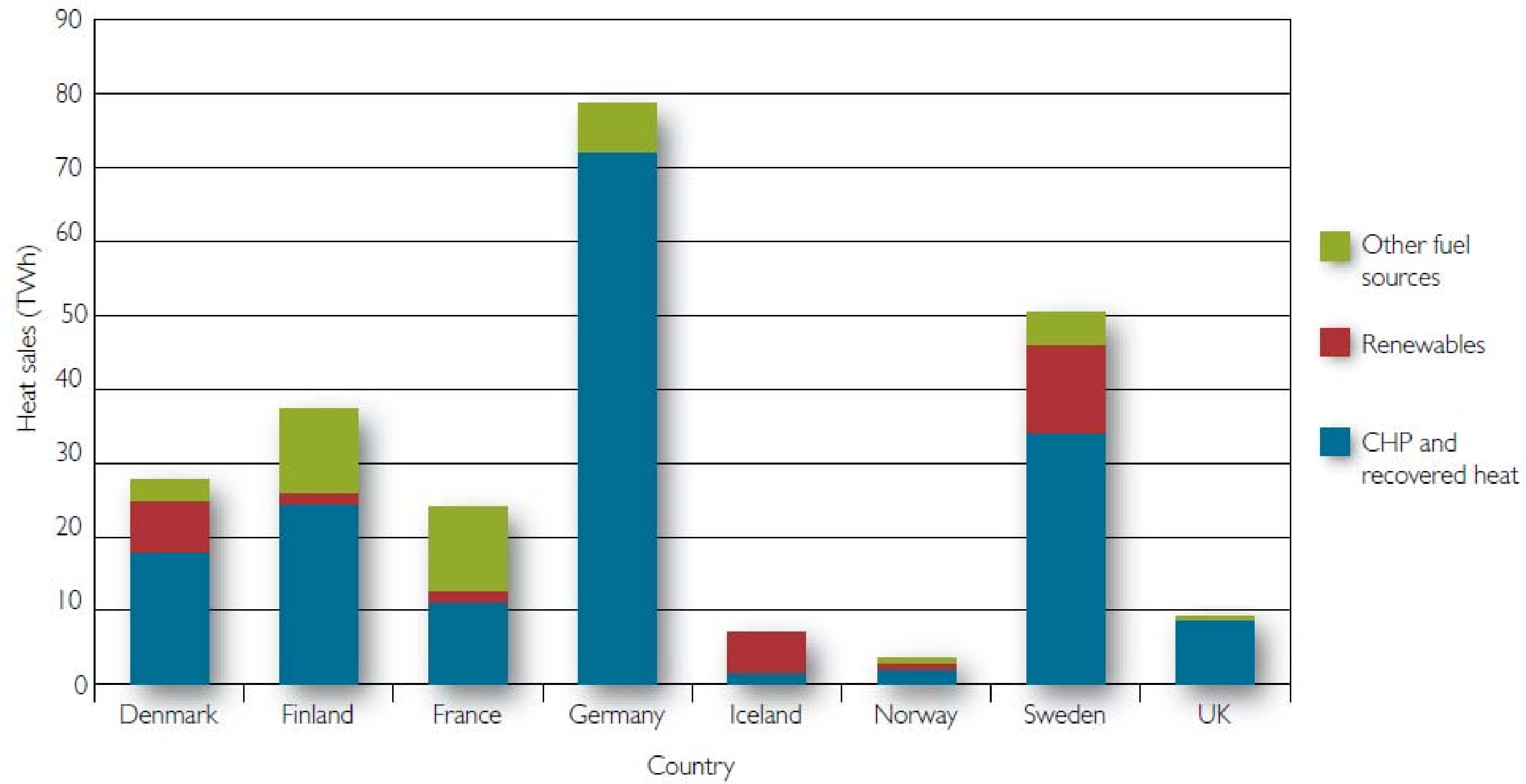
## Application of CHP

- CHP plant produce both electricity and heat as by-product
- Dual generating capacity gives CHP plant greater efficiency than centralised power plant;
- Typical operating efficiencies:
  - CHP plant c.70%
  - Power stations in range c.30%-40%
- CHP capacity: <1MW to c.100 MW, often installed as local energy generating facility, eg hospitals
- CHP plant provide electricity and, because of proximity to the point of use, heat through a local heat distribution network of pipes.
- Reduce carbon emissions, making much greater utilisation of the source of fuel, in many instances gas

## UK energy policy documents acknowledge CHP can help:

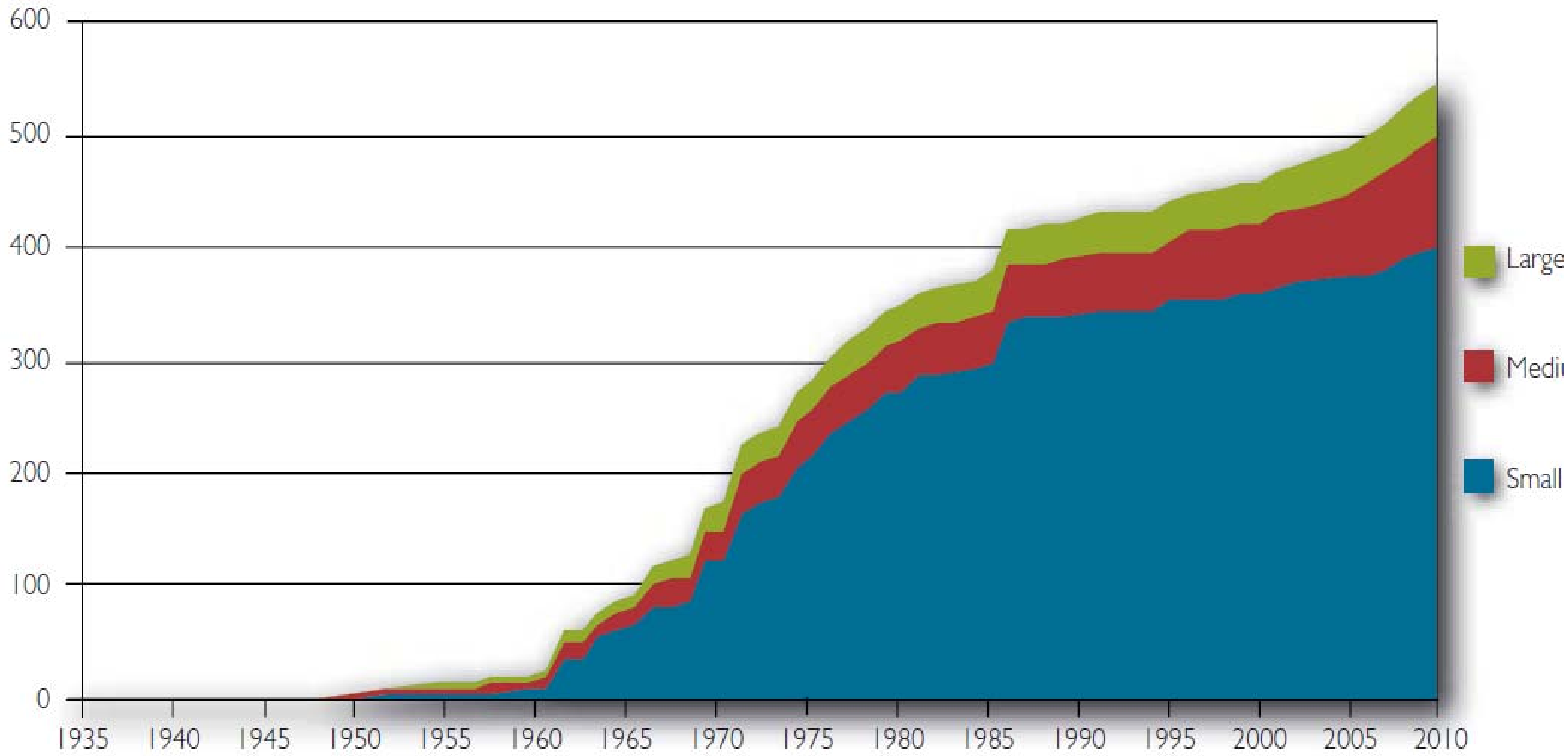
- Increase resilience of the national energy supply;
- Increase security of national energy supply;
- Achieve the UK’s obligatory carbon emissions targets, including decarbonising both electricity and heat;
- Meeting the increasing demand for electricity and heat;
- Ensure affordability of energy supply for all end users, particularly those from low income groups.

# Despite benefits UK has some way to go …




Source: UK figures from DECC heat network model. Figures from other European countries © Euroheat & Power – District Heating and Cooling Country by Country Survey 2011

# … but strong potential to grow UK market, objective of energy policies in this area




Growth in UK heat networks since 1935; source: (4), (DECC, March 2013)

## Typical of CHP (heating network) project categories include …

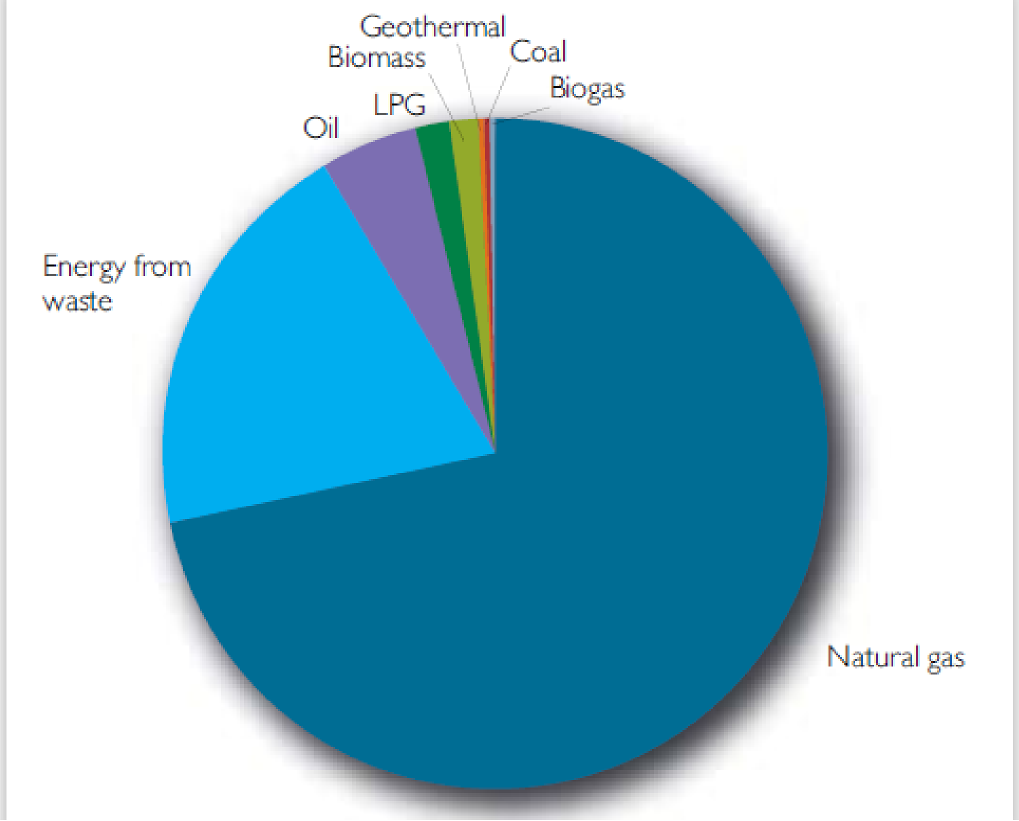
– Local Authority led schemes with connection to schools, leisure centres, other public buildings and social housing

– Private sector developments on new housing schemes, which can include blocks of flats or commercial developments

– Standalone campus networks serving hospital sites or universities

– Significant numbers of individual social housing blocks dating from 1960s and 1970s

# Future growth in CHP market likely to be based on natural gas




Fuel types supplying heat networks in the UK; source, (DECC, March 2013) bre

# Drivers for change – Electricity Market Reform

- Security of supply is threatened by closure of existing plant
  - Up to c.2021 UK will close c.25%, 20 GW of existing generation capacity; closure of older, more polluting generating plants
- The UK must decarbonise electricity generation
  - Urgent action to transform the UK permanently to low-carbon economy; must meet obligatory ‘carbon targets’ – 15% renewable energy by 2020 and 80% carbon reduction by 2050.
- Demand for electricity is set to increase
  - Overall demand for electricity could double by 2050 in response to the electrification of transport, heat and other carbon intensive sectors.
- Electricity prices may rise
  - External & internal factors, eg increased wholesale costs, carbon pricing and environmental policies, point to higher electricity bills in future

bre

# Barriers to market for CHP based energy centres

– Electricity White Paper: lays down measures for electricity market reform, including reducing barriers to entry for small generators, including CHP electricity generation
  - Current state of the electricity market in the UK is a major barrier (‘gap’) holding back innovation
  - Government targeting electricity market reform, encouraging entry of technology and market innovations, and supporting reduction in barriers to market entry by new and small market entrants

– The 2011 White Paper assesses Good Quality fossil fuel CHP to be a highly efficient process, can deliver significant reductions in carbon emissions compared to the separate methods of generating heat and power via a boiler and a power station

# Market barriers CHP projects, 1

– Heating Strategy identifies a primary barrier to market for CHP is sourcing finance for projects:

- Obtaining capital funding – long payback periods
- High upfront cost  and uncertainty of return
- Aggravated by uncertainties in the:
  - Availability and longevity of the heat loads prices obtainable for the heat and electricity produced
  - Cost of the fuel supply
- Market novelty and industry uncertainty about regulation in the area also increase investment risk

## Sensitivity to financial parameters

– Key barrier upfront investment needed and return (discount rate) required by investors

– Analysis by Poyry demonstrated the impact of discount rates and upfront capital costs on investment in heat networks; in summary:

- At a discount rate of 10% it is economic for only 0.3% heat demand to be delivered by heat networks
- Lowering discount rate to 3.5% make it economic for 5.8%-13.9% of heat demand to be delivered through heat networks.

# Market barriers CHP projects, 2

– Lack of Standardised Commercial Models
  - Lack of standardised commercial arrangements for funding construction and operation of heat networks is barrier to market uptake.

– Consumer Challenges
  - DECC study of consumer attitudes to heat technologies reported significant ‘barrier costs’ persuading homeowners in existing properties to join a heat network – higher than micro-CHP, lower than RETs

– Local Authority Challenges
  - Obtaining funding for technical and commercial development work;
  - Procuring advice on how projects should be structured commercially;
  - Obtaining capital funding;
  - Lack of standard contract mechanisms and legal advice

## Combined operation of CHP & Renewable Energy Technologies – the CHPV Project

- Advantages of CHP plant can be enhanced, operating installations in combination with renewable energy technologies (RET)
- CHPV concept combines the use of CHP plant with PV arrays:
  - Automatically blending seasonal benefits of low carbon CHP electricity in cold months with zero carbon electricity from PV in warmer months
- The addition of PV arrays can occur across a range of scales
- Sizing of CHP plant is a core issue in development of a proposed CHP installation
- Sizing directly affects capital budget (capex) and operational budget (opex) – once the plant is installed & commissioned
- Reductions in CHP power capacity will benefit capex and opex
- A balanced CHP &PV capacity enables balanced, flexible operation over annual cycle.

## Primary objectives of CHPV project

- CHPV project is developing a validated system design tool for localised energy, CHPV powered for clusters of commercial buildings
- Creating & accurate calibrated modelling environment for clusters of commercial buildings.
- Application of the tool to three case study sites, including:
  - MediaCityUK, Salford
  - Copperas Hill, Liverpool
  - Greenbank, University of Liverpool
- The application of the CHPV design tool will inform technical and commercial assessment of proposed CHPV projects
- The model outputs will provide answers and insights into many of the key issues acting as barriers to market

Thank you for your attention

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# InnovateUK Combined Heat & Photovoltaics (CHPV) Project 101998

## CHPV Workshop
## Venue: BRE Garston
## 20-JAN-16


University of Liverpool

Dr John Counsell

# Combined Heat & Photovoltaics (CHPV)

- 2 year EPSRC and InnovateUK funded R&D project

- Project:

Integration and control of CHP, DC + PV systems with energy storage in clusters of non-domestic buildings

- Partners:

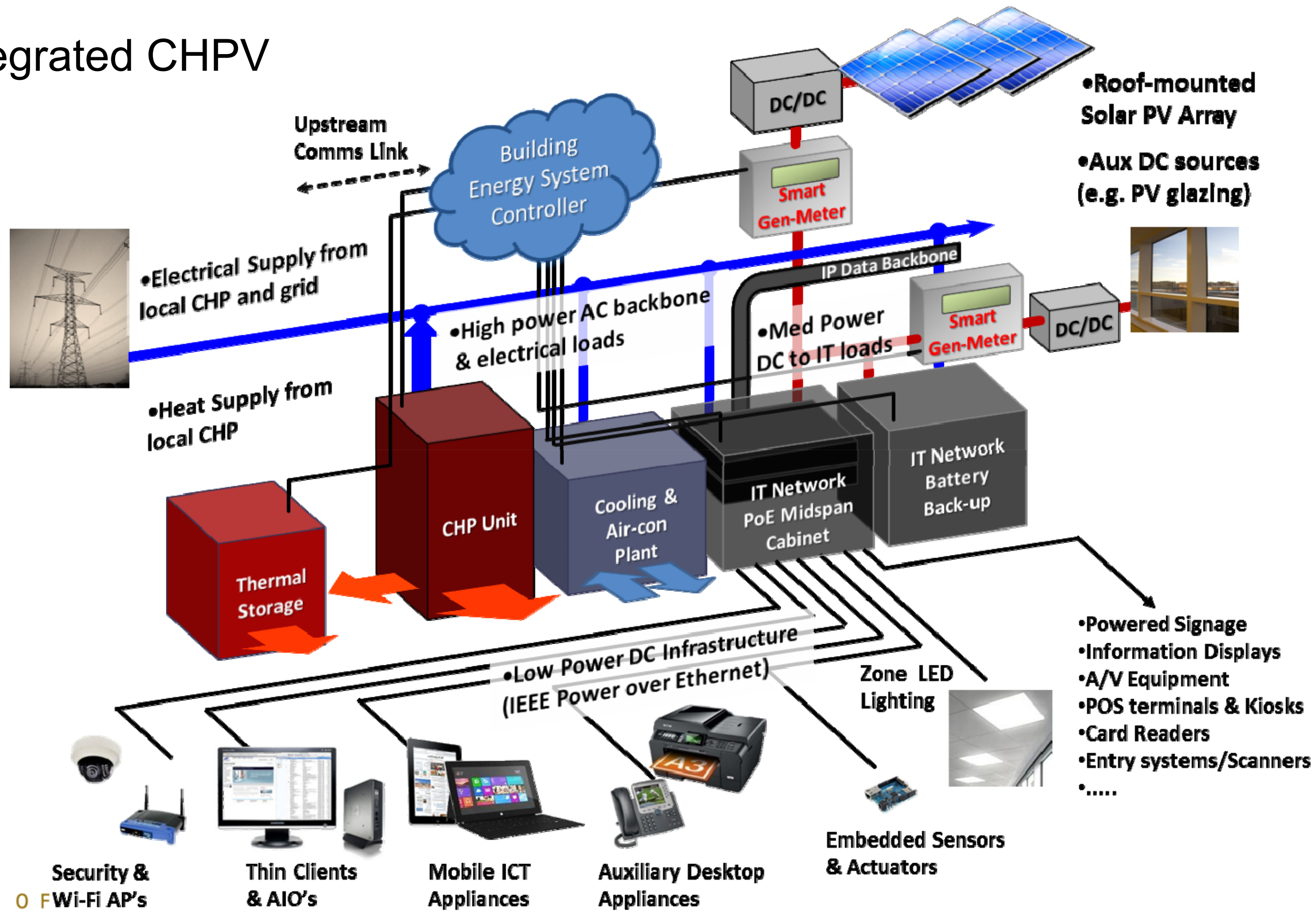
Peel Utilities, Ove Arup, Building Research Establishment (BRE), and University of Liverpool

- Research & Development:

System Modelling and dynamic simulation to research and test multi-channel feedback actuated CHPV control. Development of CHPV design tool

# InnovateUK & EPSRC Local Energy Systems Combined Heat & Photovoltaics (CHPV)

Building Integrated CHPV
+smart DC

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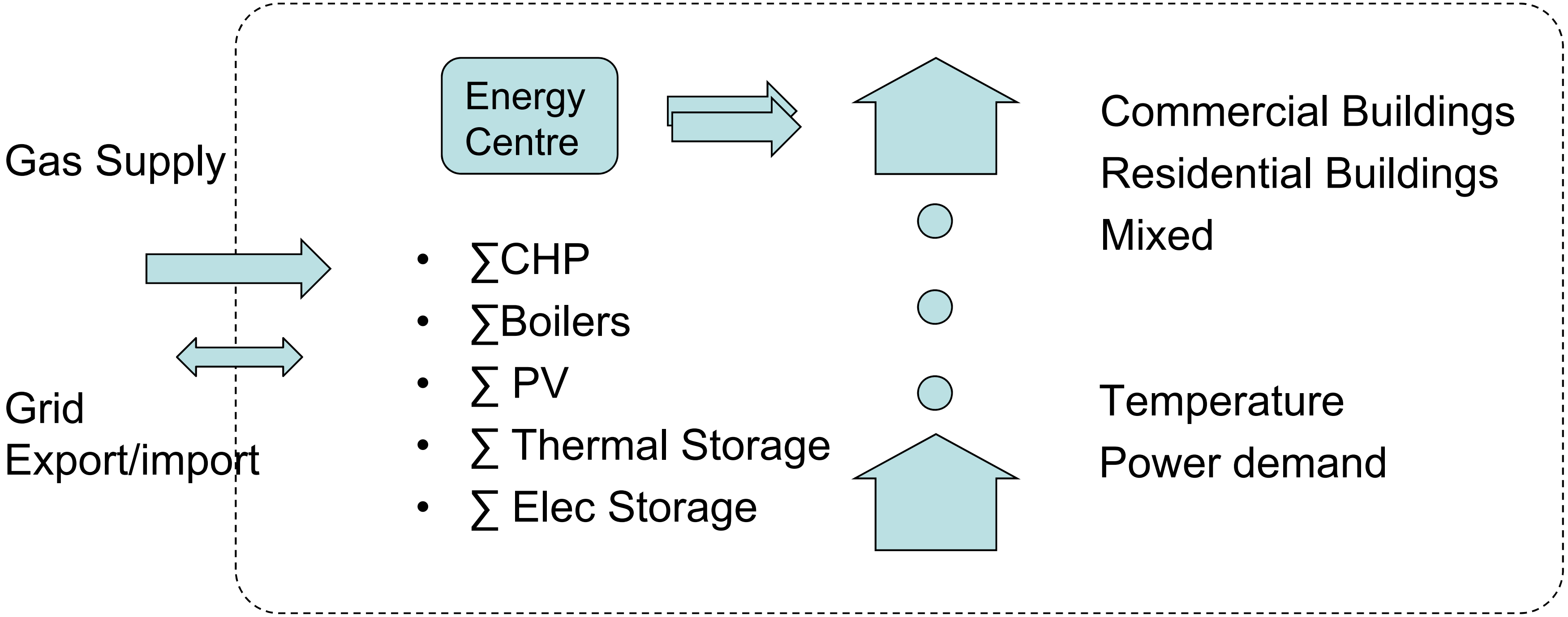
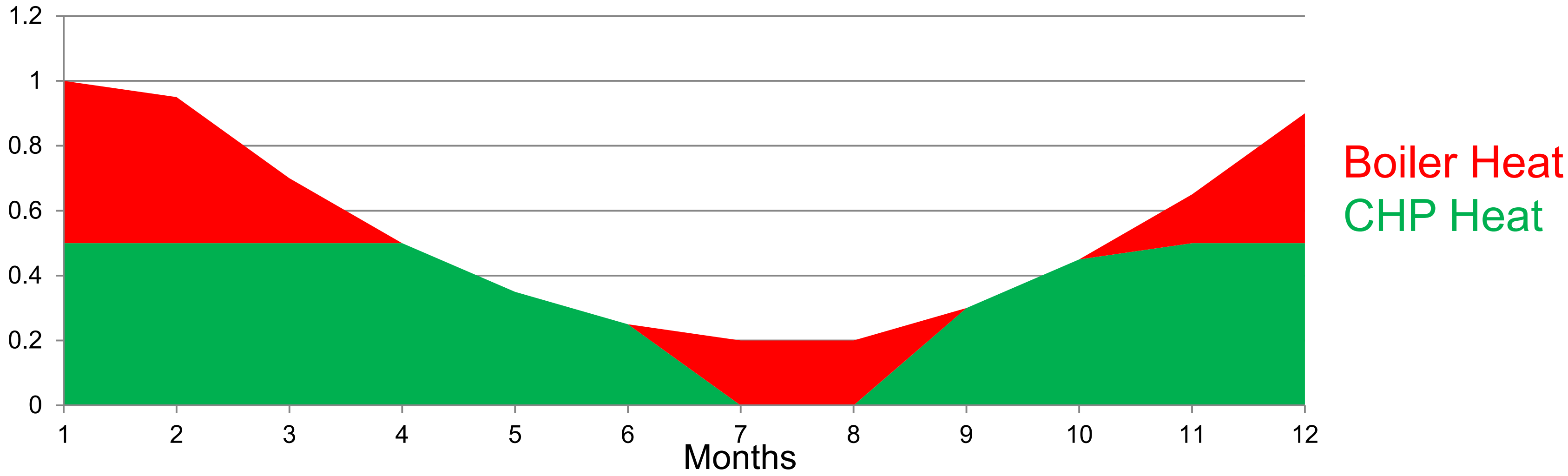
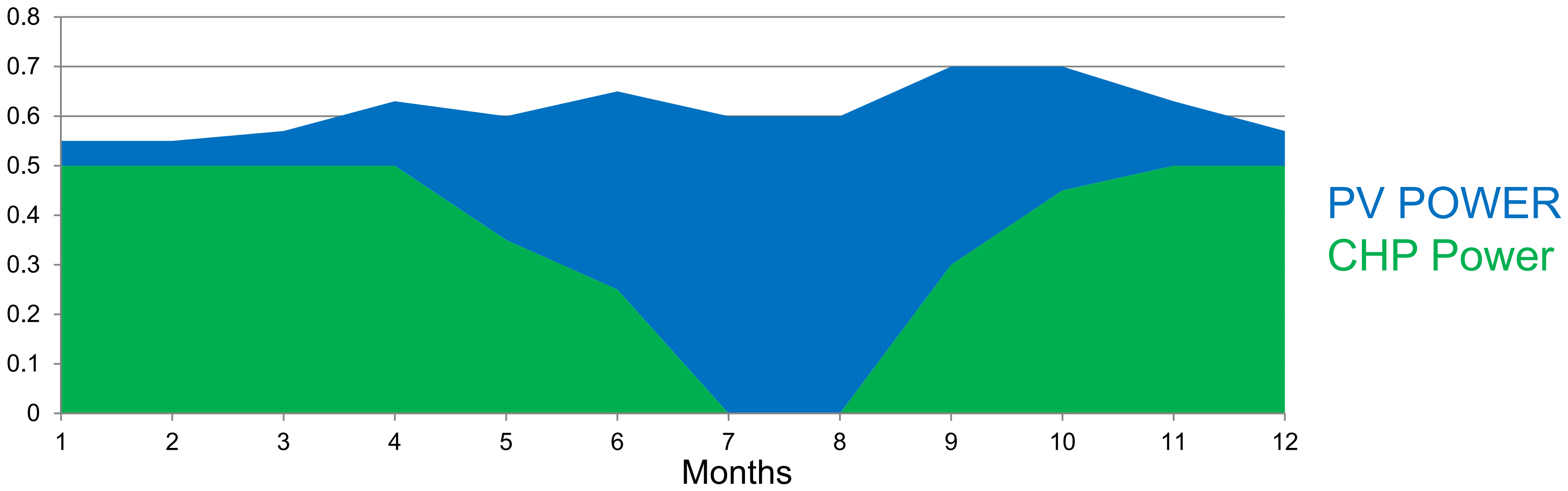
# Combined Heat & Photovoltaics (CHPV)

A DYNAMIC and STEADY energy supply and demand matching problem



# Combined Heat & Photovoltaics (CHPV)

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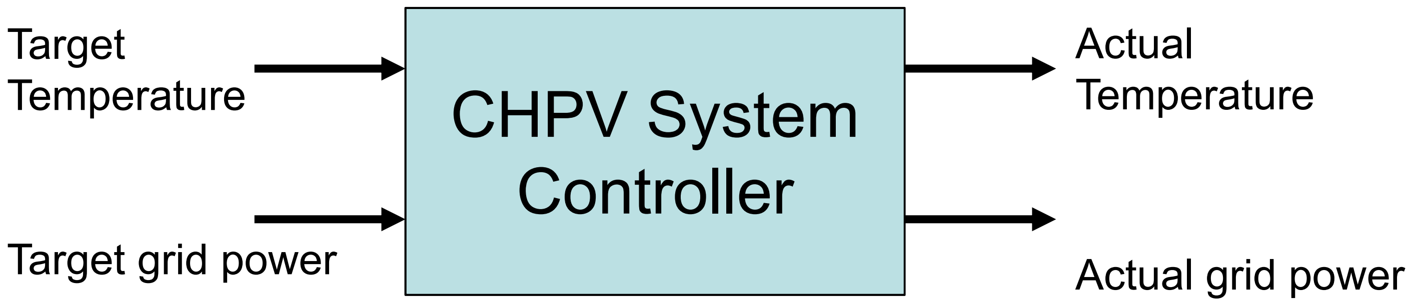
# Seasonally PV and CHP are well matched Dynamic Control Needed to Optimise

- Multi-vector (heat and electricity) closed loop control using feedback




- MIMO Design using Robust Inverse Dynamics Estimation (RIDE)
- Matlab/Simulink CHPV models – 1min timestep for 1yr

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# Energy Management Strategy

1. To try to island the power system, no import or export of power generated.

2. To minimise the amount of supplementary gas boiler use to consequently minimise CO2 emissions.

3. To minimise electricity demand to enable summer demand to be met by PV and increase the heat demand in the heating season.

4. To move to an electrically led CHP control system rather than a base load heat led system.  This does bring engine maintenance and efficiency challenges, as well as control and power quality challenges.

5. Use of LVDC (refer IET Code of Practice) to assist with electrical storage to improve power quality.

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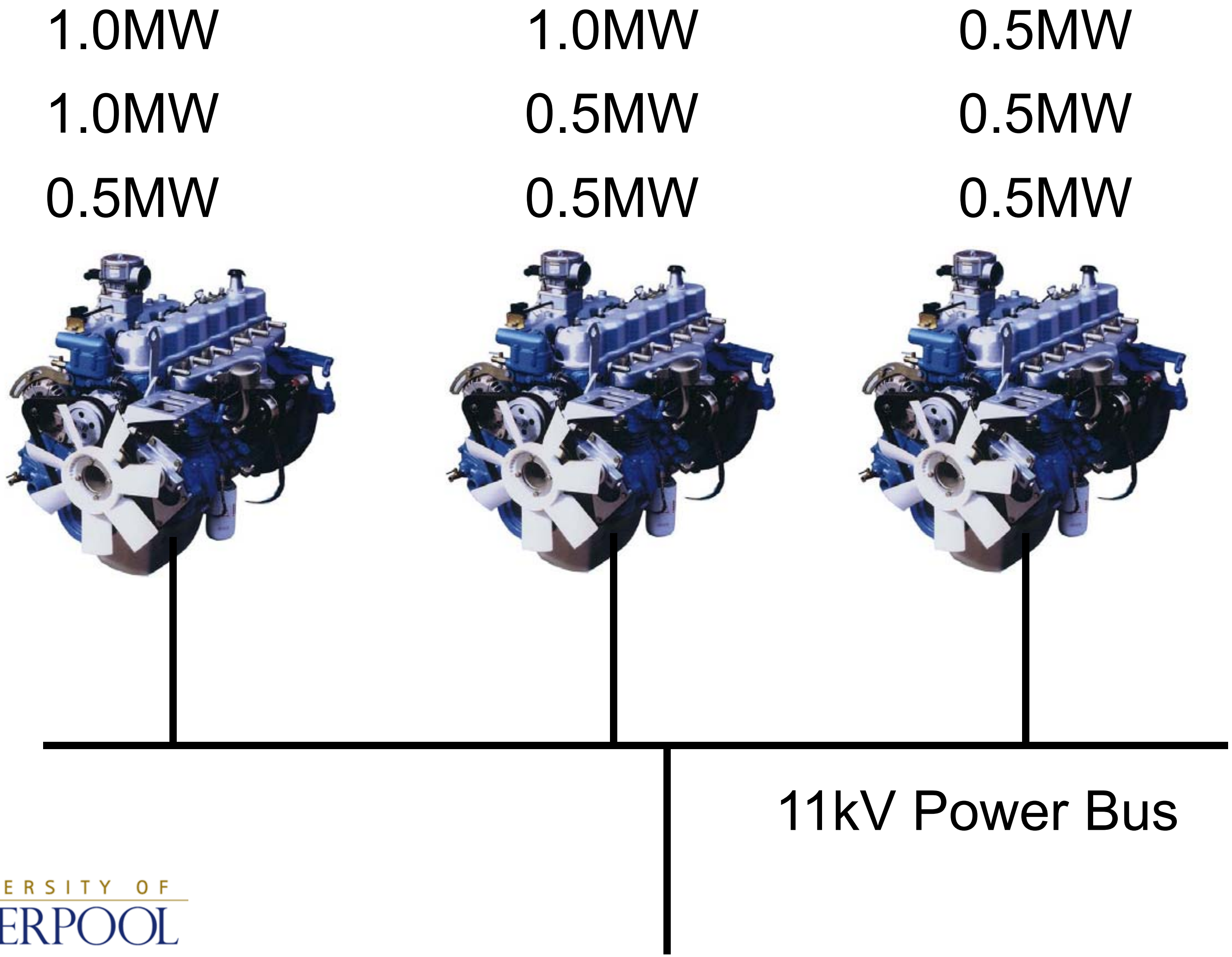
# Resilience Challenge

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# CHPV Summary

1. To minimise gas consumption and reduce carbon emissions
2. An electrically led system designed to utilise electricity demand reduction and demand side renewable power generation (e.g. PV)
3. Aiming to work with the grid or island at a community/local level.
4. Use of LVDC (refer IET Code of Practice) to assist with electrical storage to improve power quality.
5. Explore viability of absorption cooling in a Tri-gen PV mix.

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# Scoping the Market Potential for CHPV

Steve Pimlott

# CHPV findings

CHP-based LES are highly varied in scale and typology

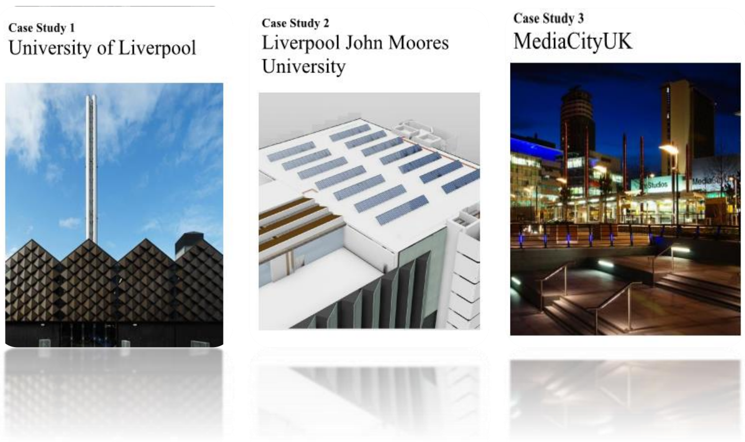
Good system modelling & design alleviates lack of diversity of demand

Modelling process speed and interoperability of model are unique selling points

Controllable energy storage improves active CHP operational efficiency

# Project aims

Developing and validating CHPV LES design tool

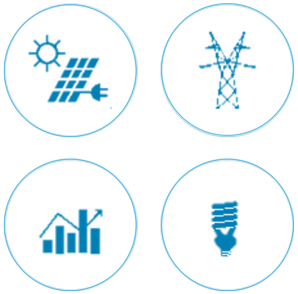



LES architecture suite for suppliers, consumers and prosumers

Exploring a regulatory framework for CHPV LES


Technologies

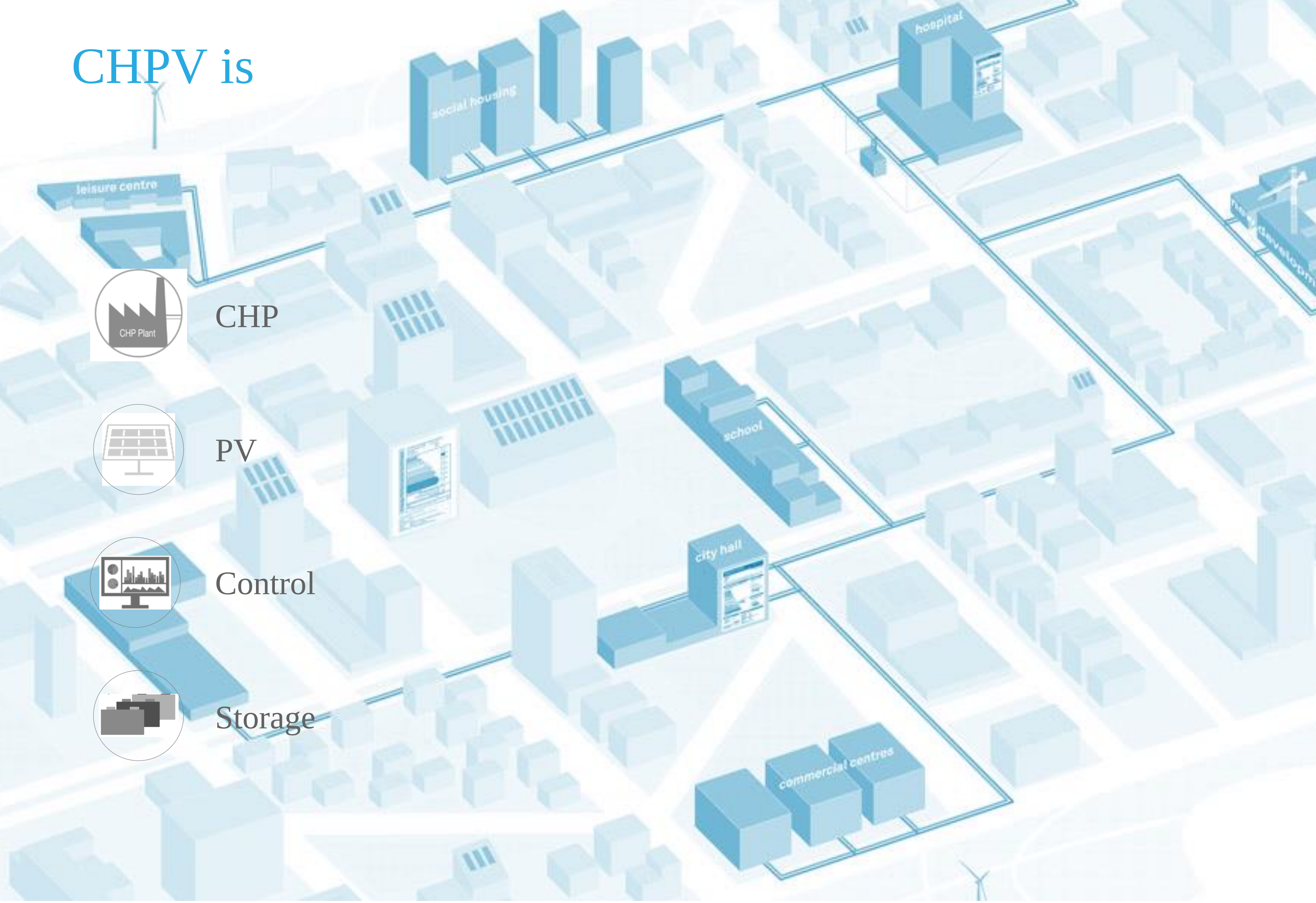
Typologies



Market and
Regulation

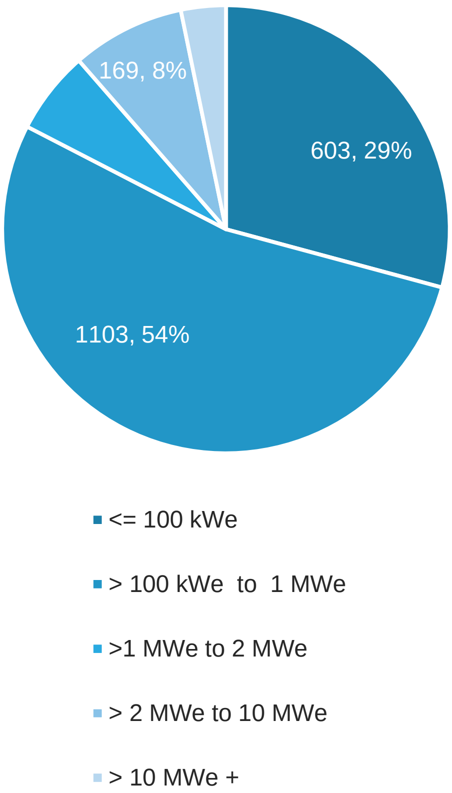
# Technologies

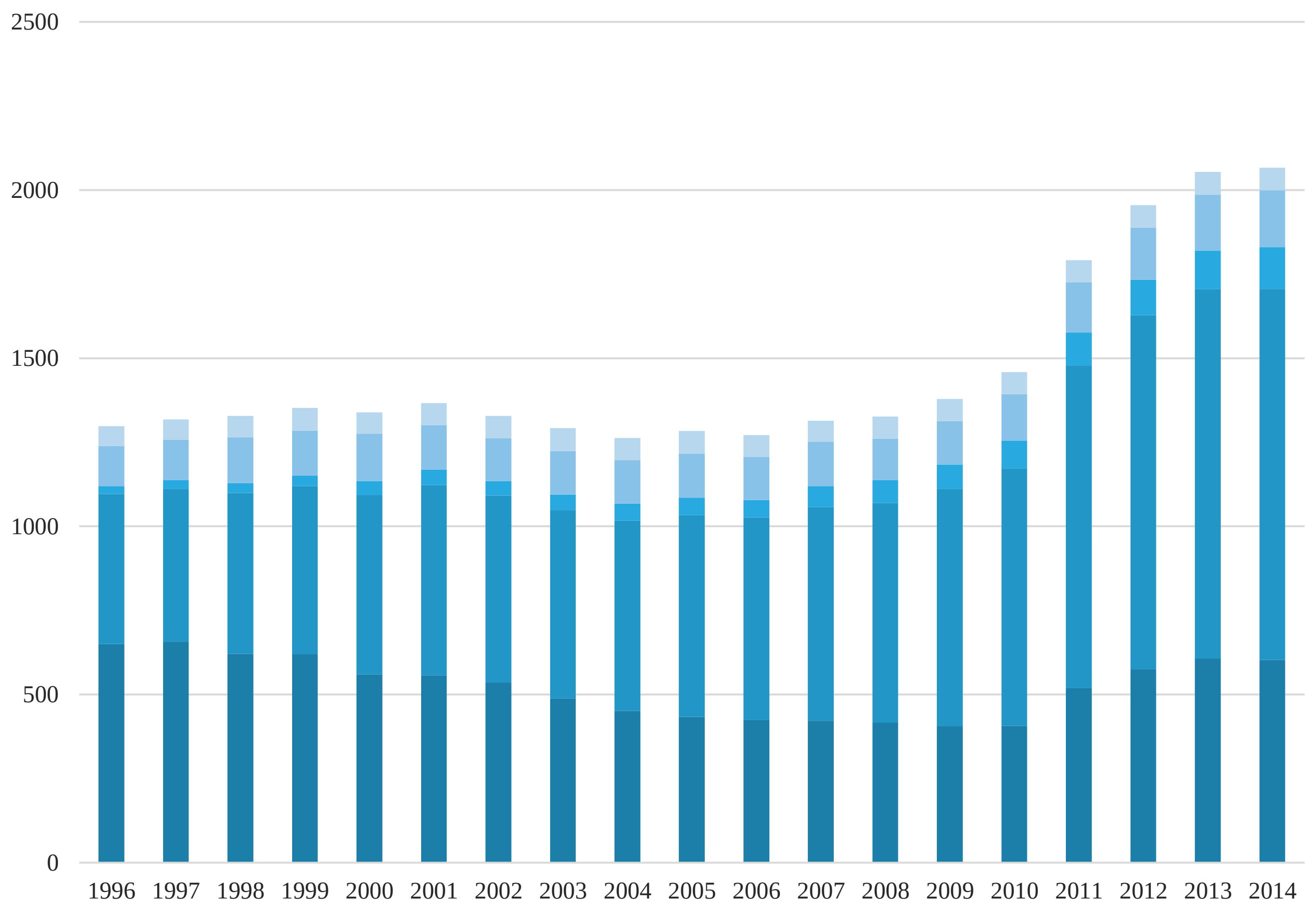
# CHPV is



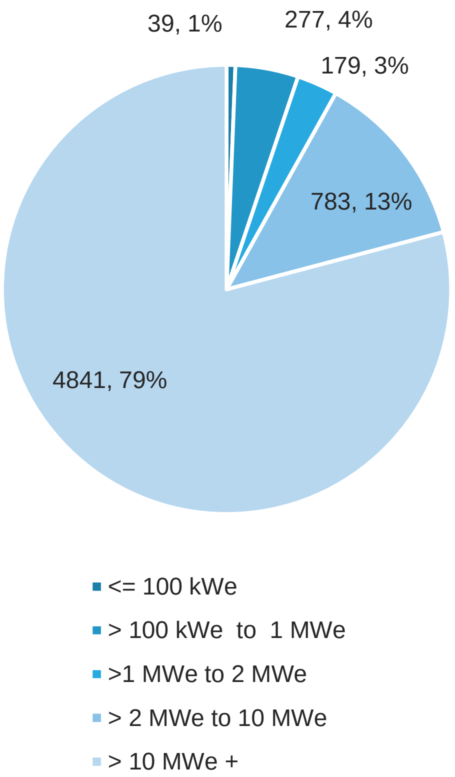

- CHP
- PV
- Control
- Storage

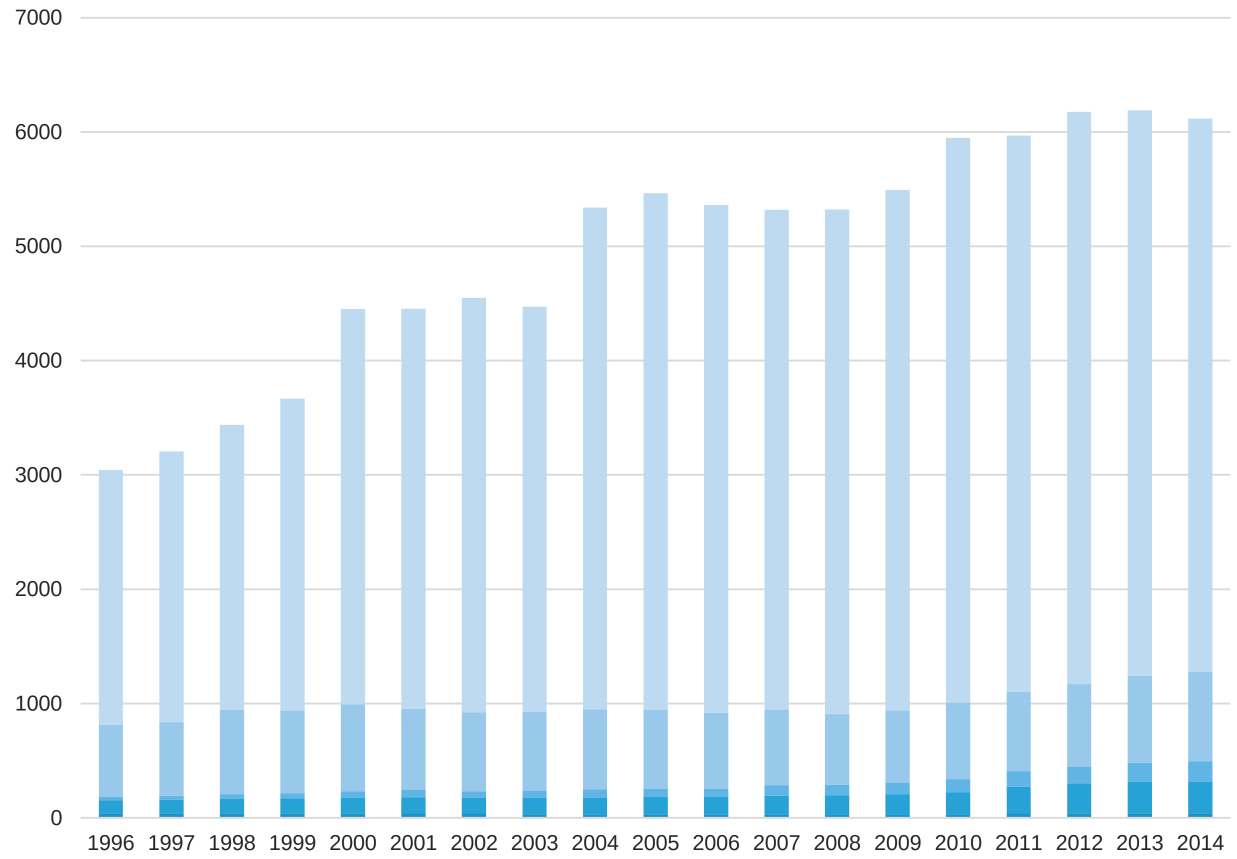
# UK CHP installations



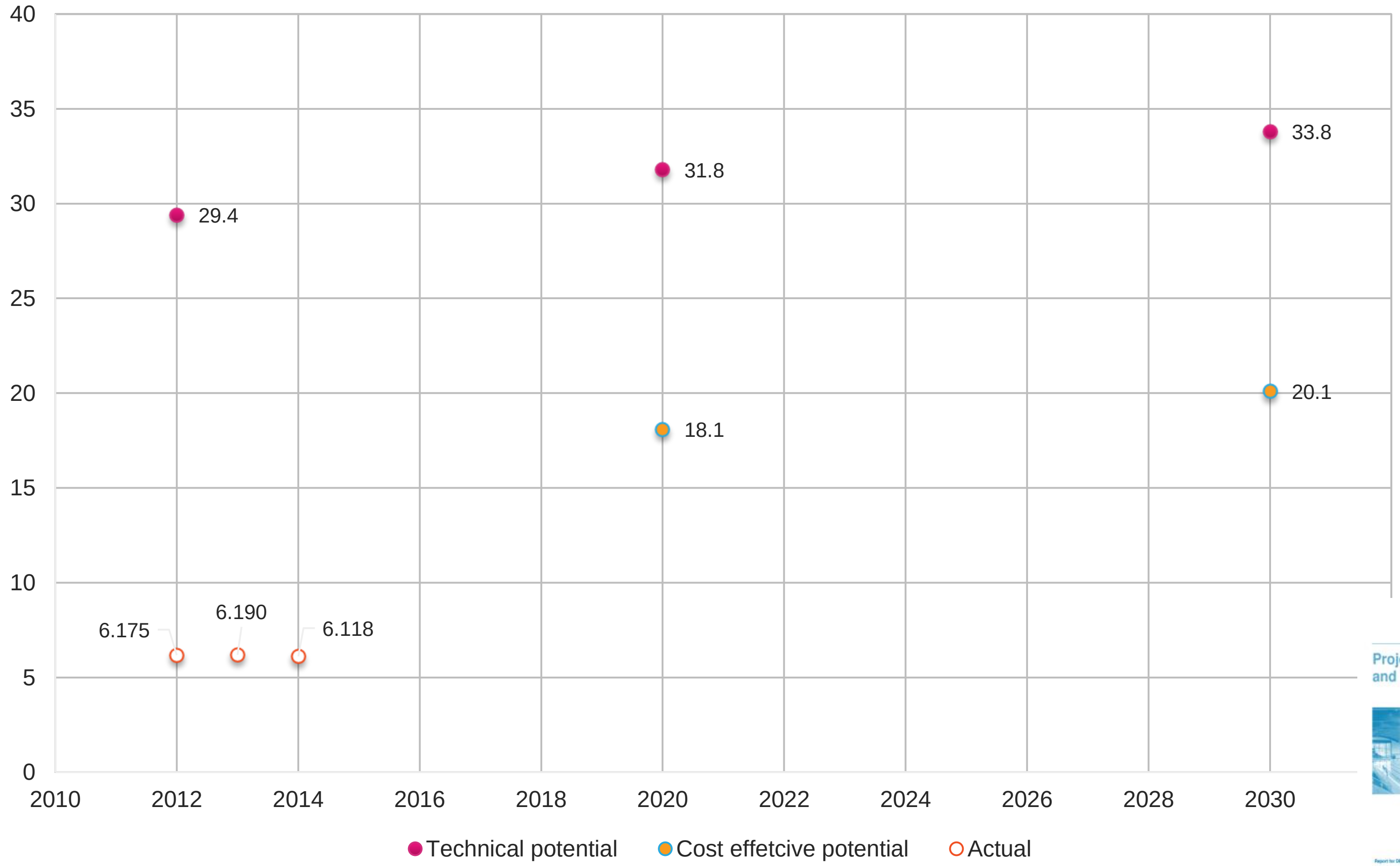



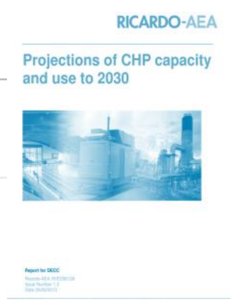
# UK CHP Capacity



# UK CHP Projections



# Global CHP market

## Cogeneration installations to exceed $40bn

Increased adoption of microCHP systems

Growing clean efficient power generation

Growth driven by natural gas price reduction

Source: Global Industry Analysts, Inc. A Worldwide Business Strategy & Market Intelligence Source

# Drivers for co-generation

Higher efficiency in power generation and reduced emissions

Policy makers aware of the benefits of CHP during outages

Growing supply chain

Expansion of existing plant and replacement of obsolete systems

Governments and utility support to use CHP to operate critical infrastructure

New industrial zones

Source: Global Industry Analysts, Inc. A Worldwide Business Strategy & Market Intelligence Source

# UK solar PV capacity

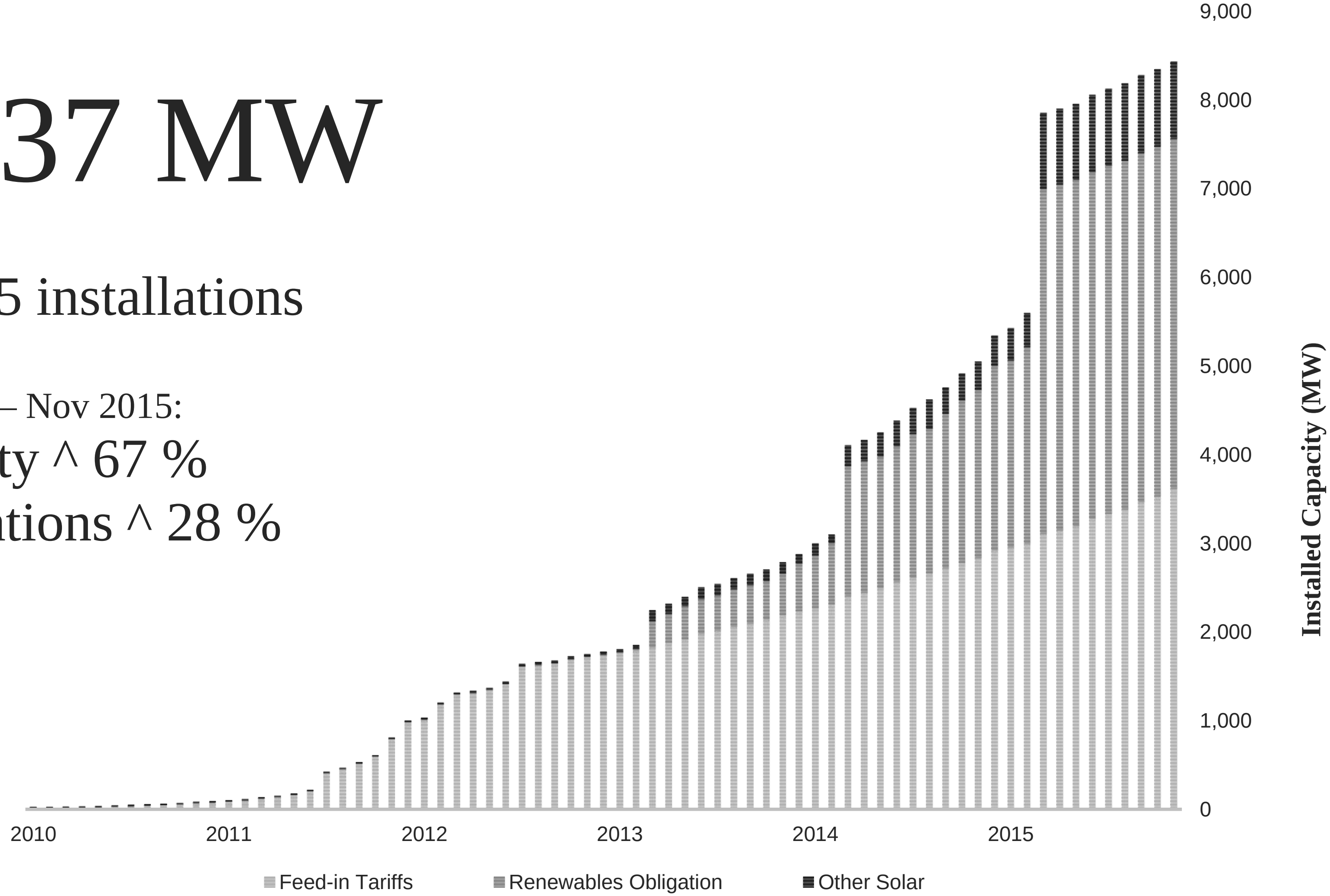
# 8,437 MW

## 815,505 installations

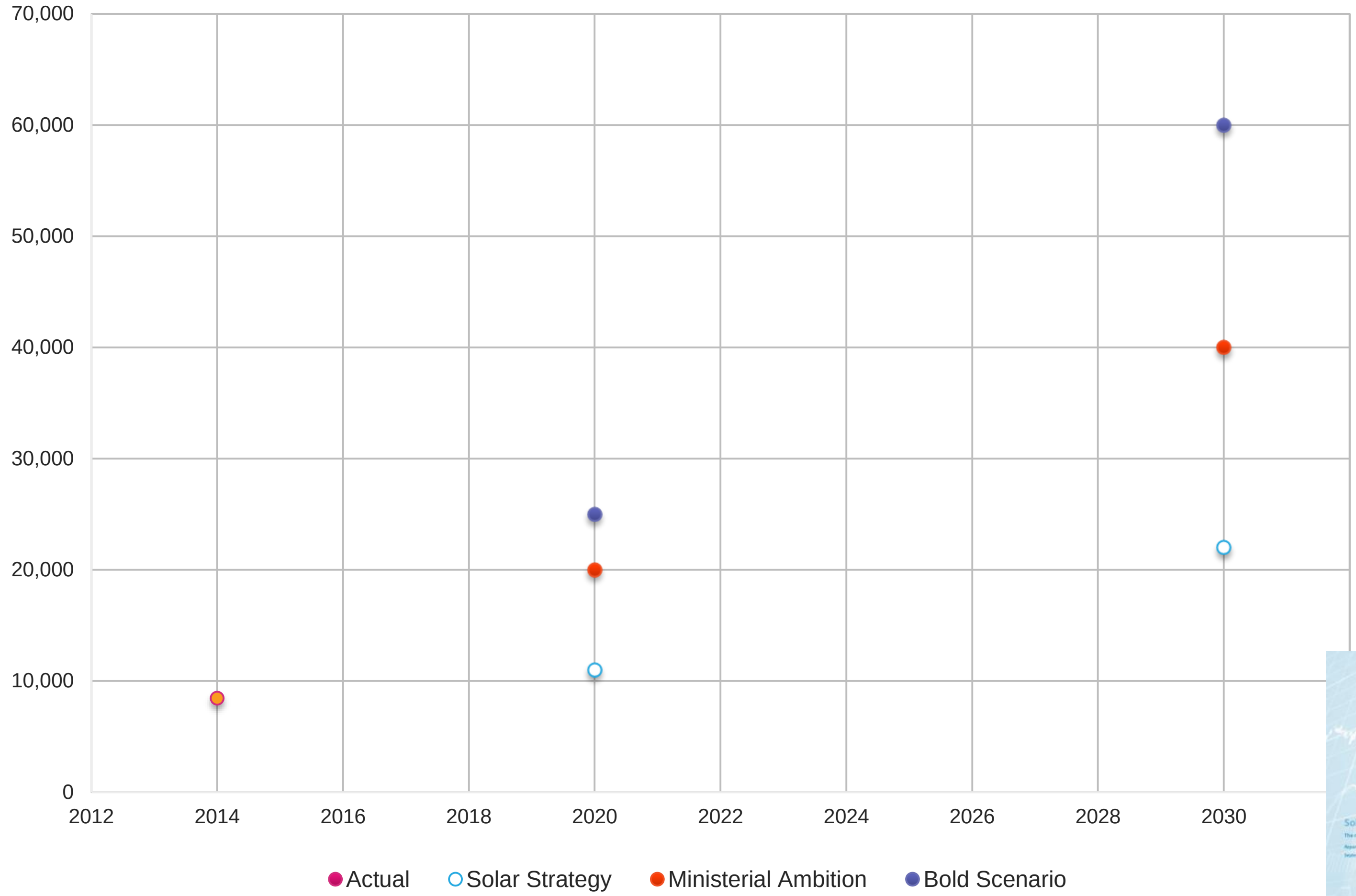
Nov 2014 – Nov 2015:

Capacity ^ 67 %

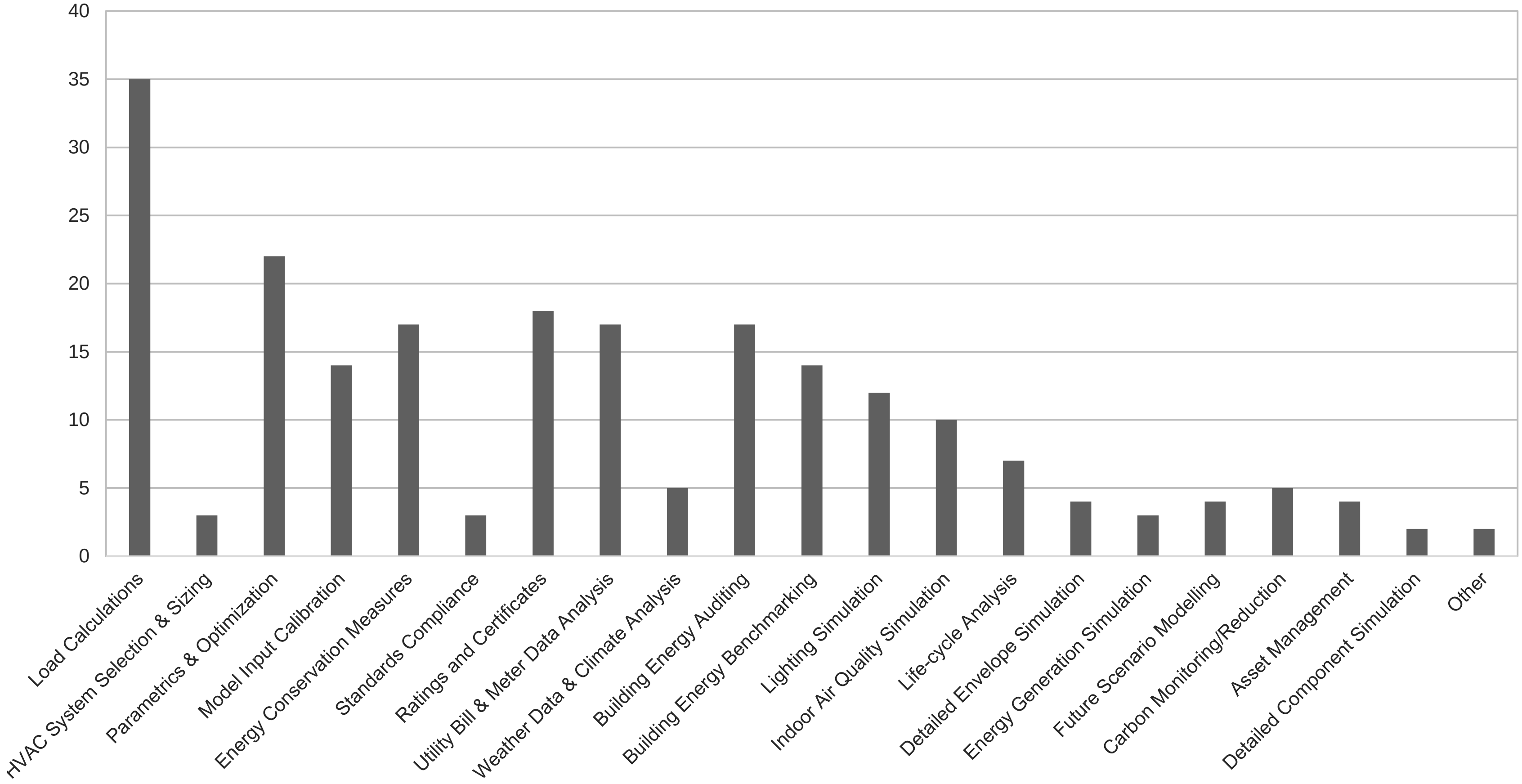
Installations ^ 28 %



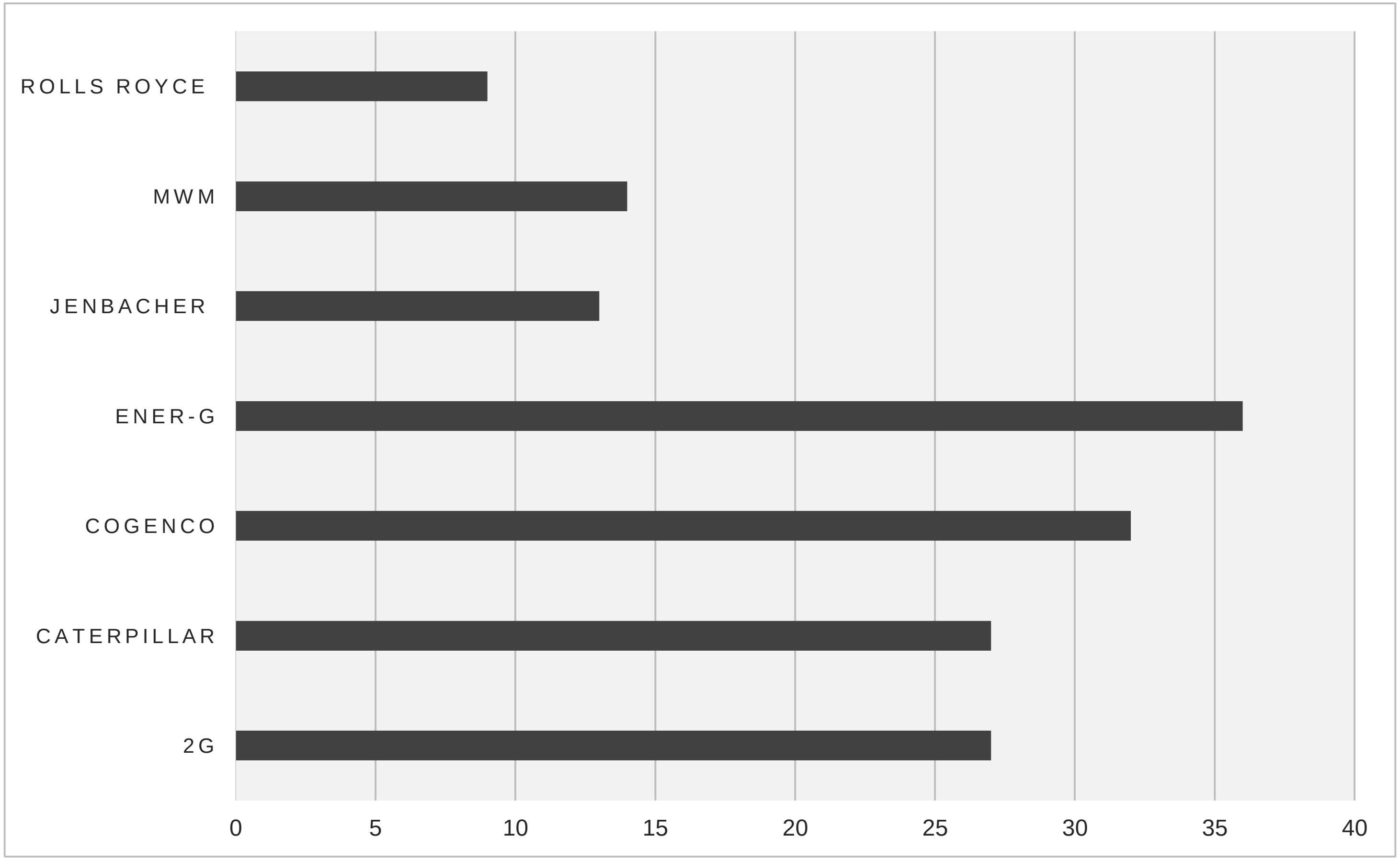
# UK Solar PV Projections




# Established energy software packages

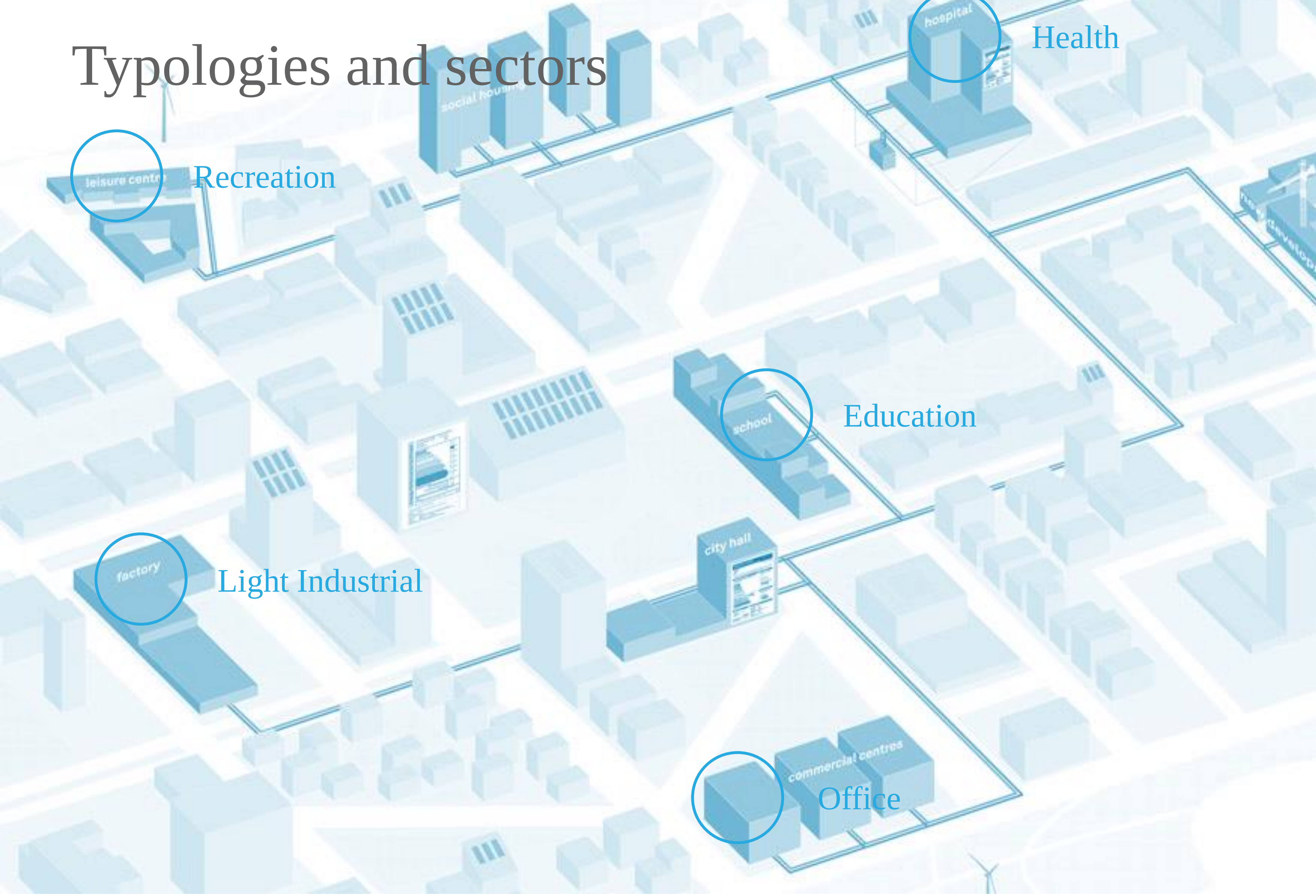


# Manufacturers

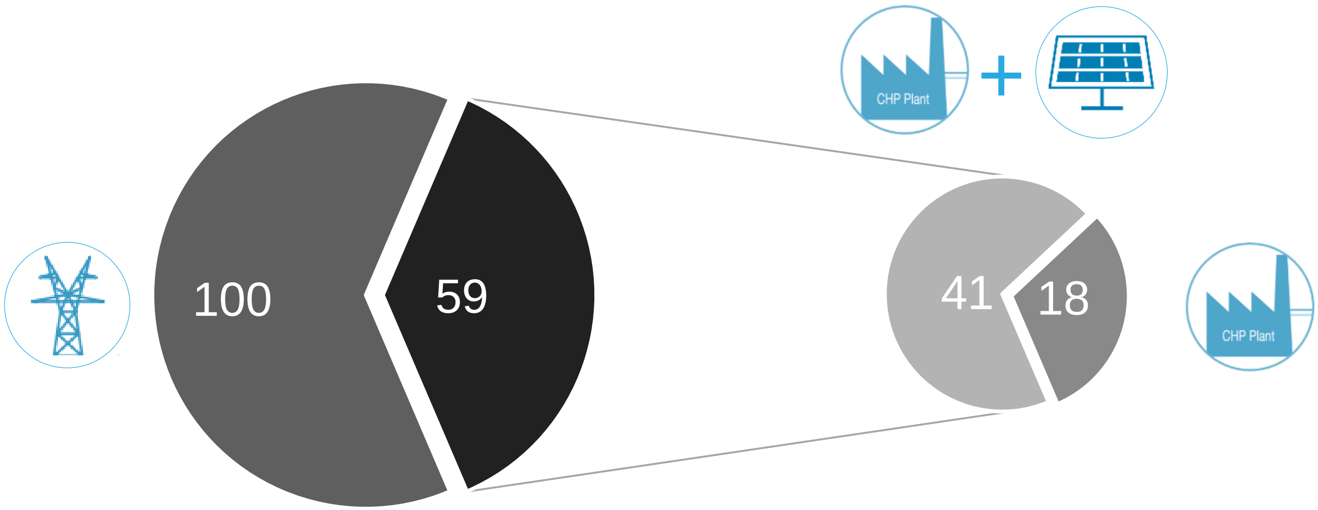


# Typologies

# Typologies and sectors



# UK higher education energy systems




Grid supply

CHP

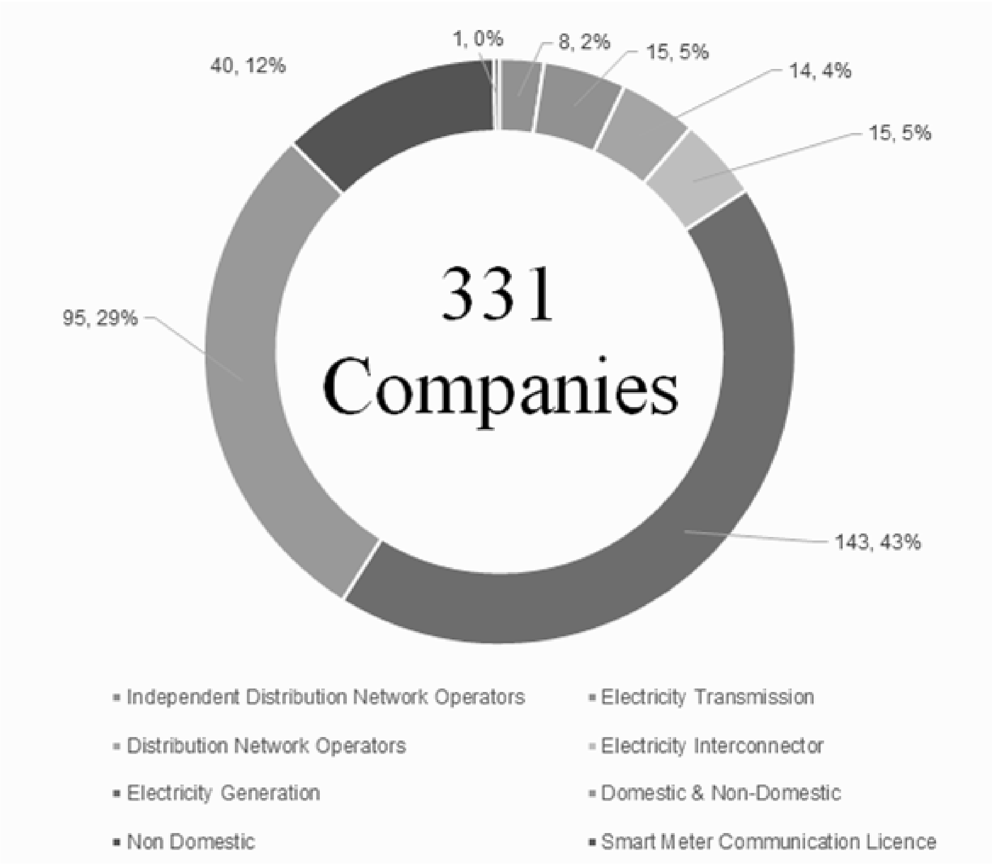
PV

# Markets & regulation

# Benefits and customers

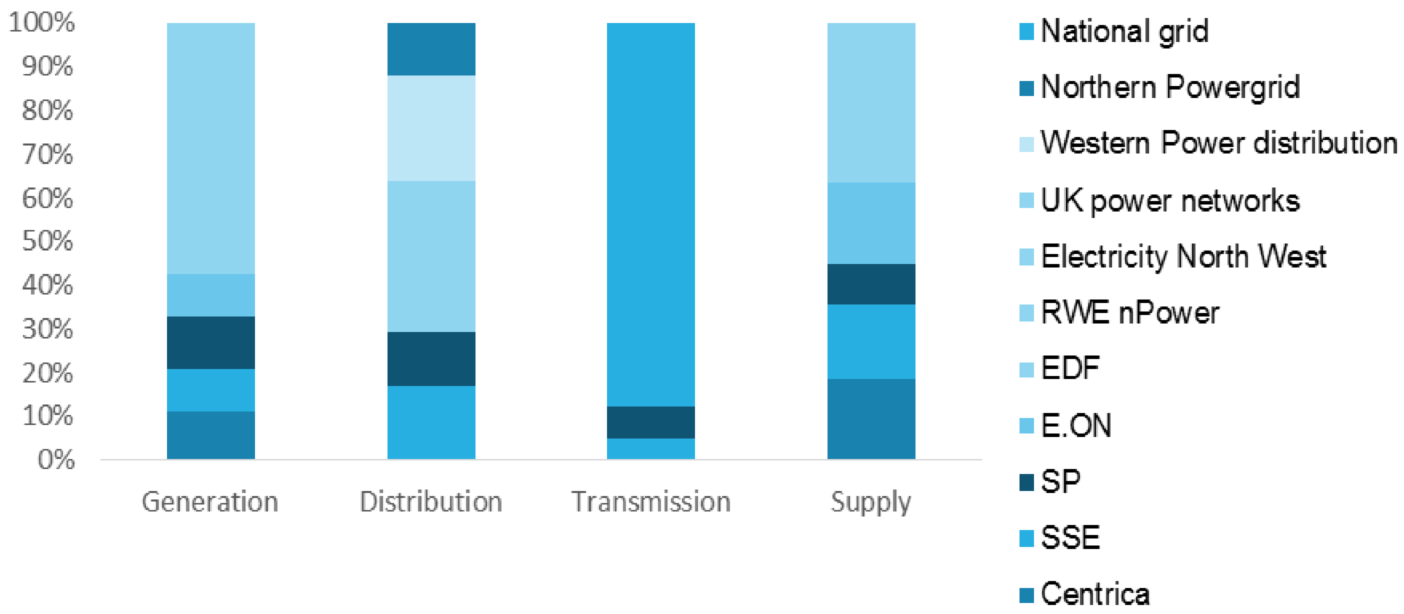
| Beneficiary/customer | Value proposition | How would that value be |
|---|---|---|
| Suppliers & Systems integrators | Increased power &  heat sales | Market share |
| Facilities Managers & operators | Higher efficiency operation of capital plant | Aggregator trading mechanisms |
| End-users | Low carbon energy at competitive cost | Customer supply mechanisms |
| DNOs | Local generation at capacity at peak times | Decreased generation & supply costs & carbon impact |

# The players

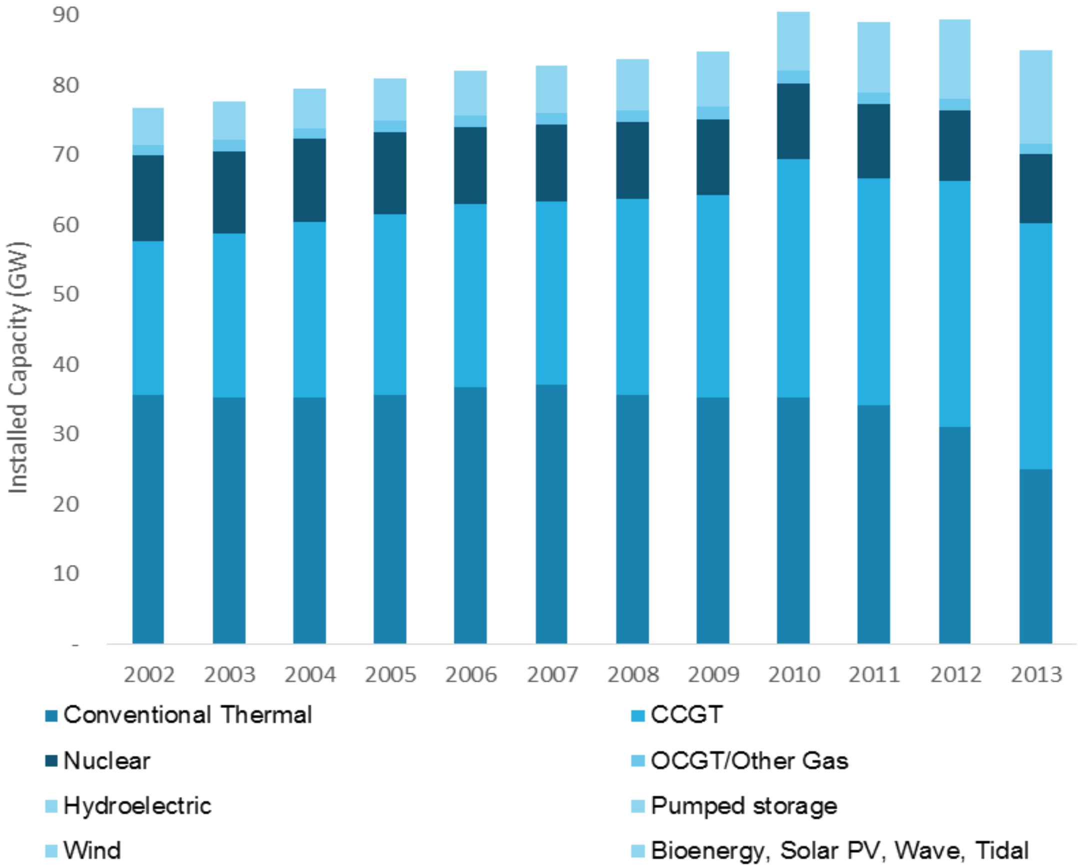


1, 0%
8, 2%
15, 5%
14, 4%
15, 5%
40, 12%
95, 29%
143, 43%
331
Companies
Independent Distribution Network Operators
Electricity Transmission
Distribution Network Operators
Electricity Interconnector
Electricity Generation
Domestic & Non-Domestic
Non Domestic
Smart Meter Communication Licence

# UK Electricity Market Structure

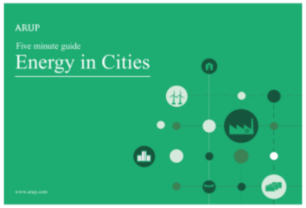
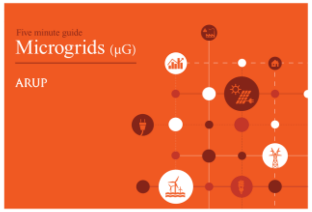
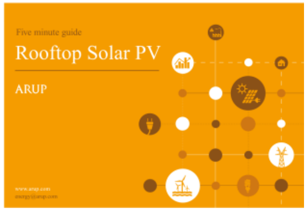
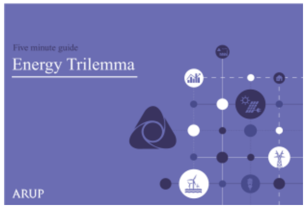


# Installed Capacity for UK Electricity



# Regulatory structural change

# Thank you


Five minute guide
Electricity Storage Technologies
ARUP

ARUP
Five minute guide
Energy in Cities

Five minute guide
Microgrids (μG)
ARUP

Five minute guide
Rooftop Solar PV
ARUP

Five minute guide
Energy Trilemma
ARUP

PEEL
Utilities

# Motivation and Lessons Learnt on Local Energy Systems

Peel Utilities

# Agenda

- Who are Peel Utilities
- Case Study: MediaCityUK
  - Background
  - Challenge
  - Solution
  - What Next?
- Q&A

# Who are Peel Utilities

- The Peel Group is a leading UK real estate, transport and infrastructure investment company
- With prestigious developments such as Liverpool and Wirral Water and MediaCityUK
- Peel Utilities develop and deliver sustainable utility strategies within the Peel Group and 3$^{rd}$ party associates

# MediaCityUK – Background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# MediaCityUK – Background

- The MediaCityUK vision was always to be a leader through its sustainability credentials
- Early masterplans allowed for a small CHP engine in each of the buildings with individual cooling and boiler plant back up

- However centralising this generation equipment offers:
  - Larger lettable space within the buildings
  - Reduced operational and maintenance burden for building owners
  - Increased operational efficiency and run times of centralised plant
  - All of the sustainability credentials of individual plant

PEEL

# MediaCityUK – Background

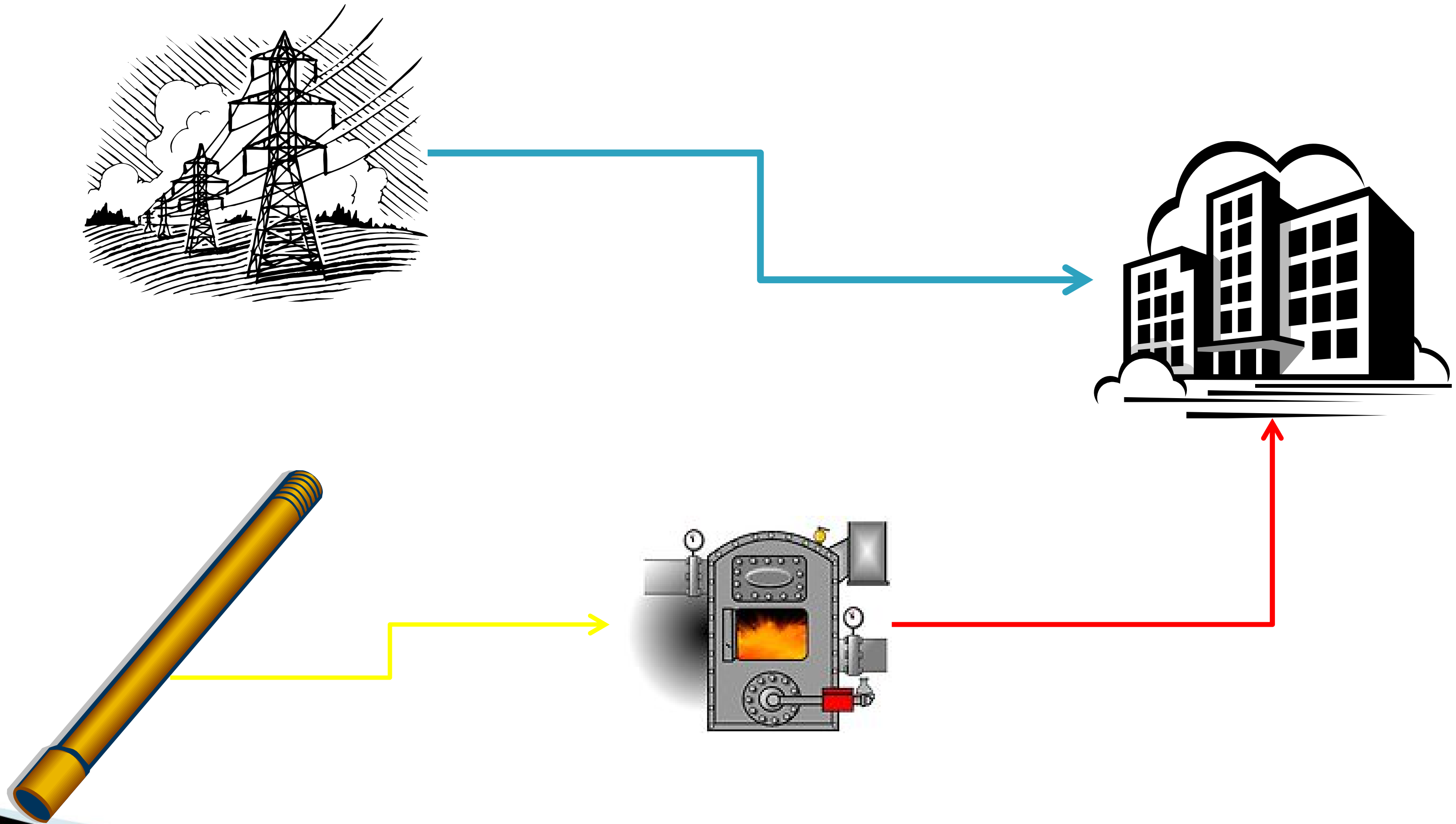
- Served by a tri-gen energy centre, providing electricity, heating and cooling to the occupants

- We installed a 2MW gas fired CHP engine, c2.5km of heat and cooling network as well as c1.5km of electrical infrastructure all backed up by boiler and national grid supplies

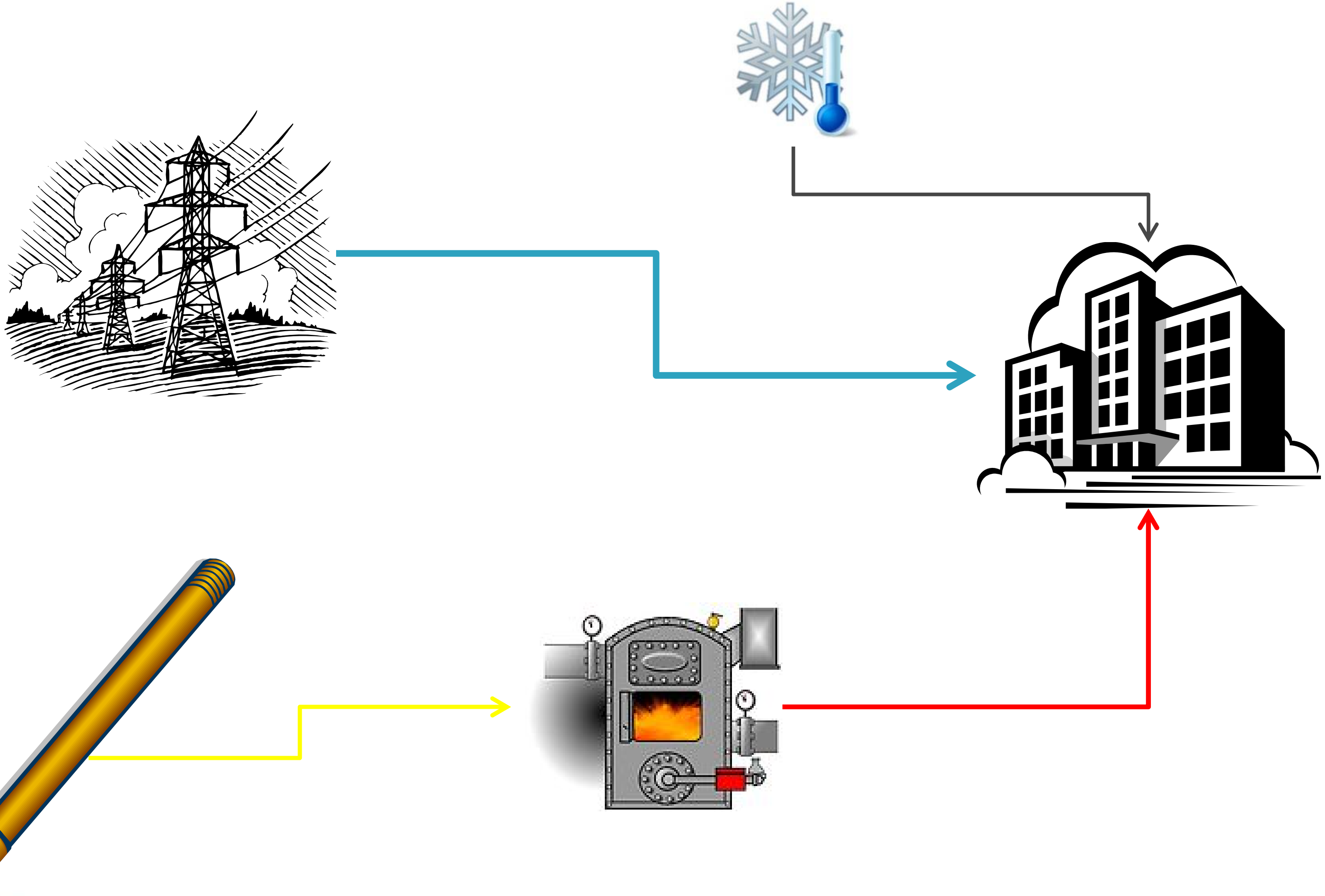
- It was also the worlds first BREEAM Sustainable Community

PEEL

# MediaCityUK – Challenge



# MediaCityUK – Challenge



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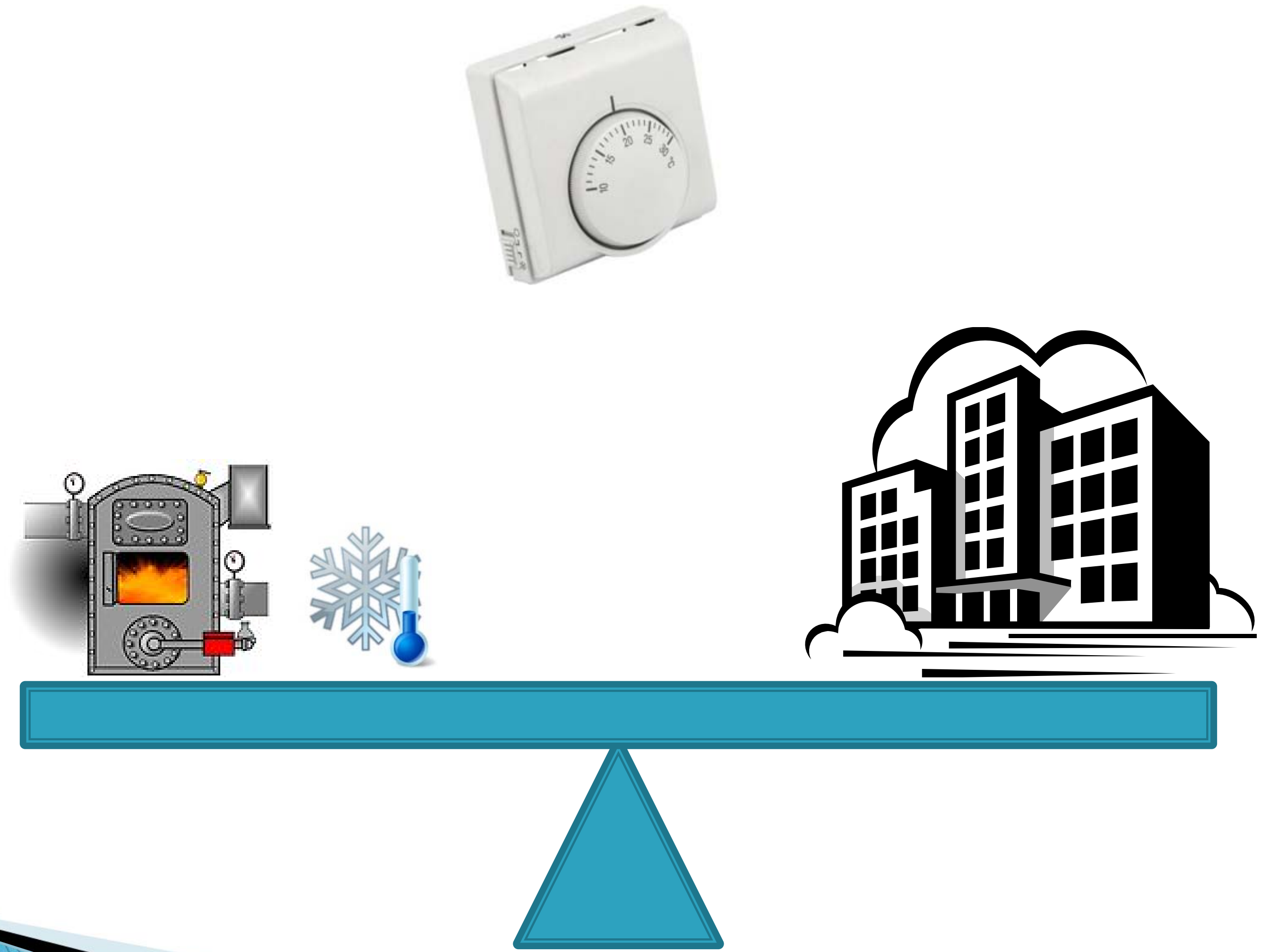

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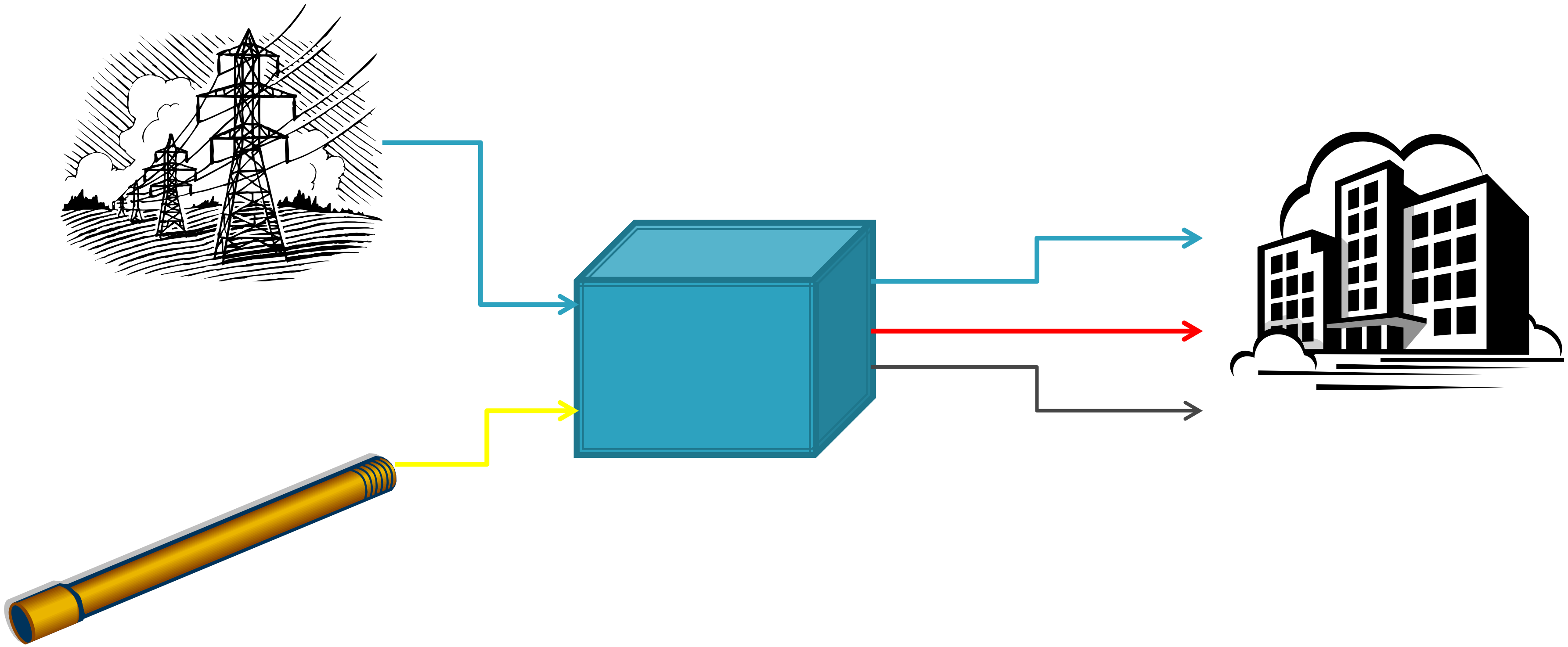

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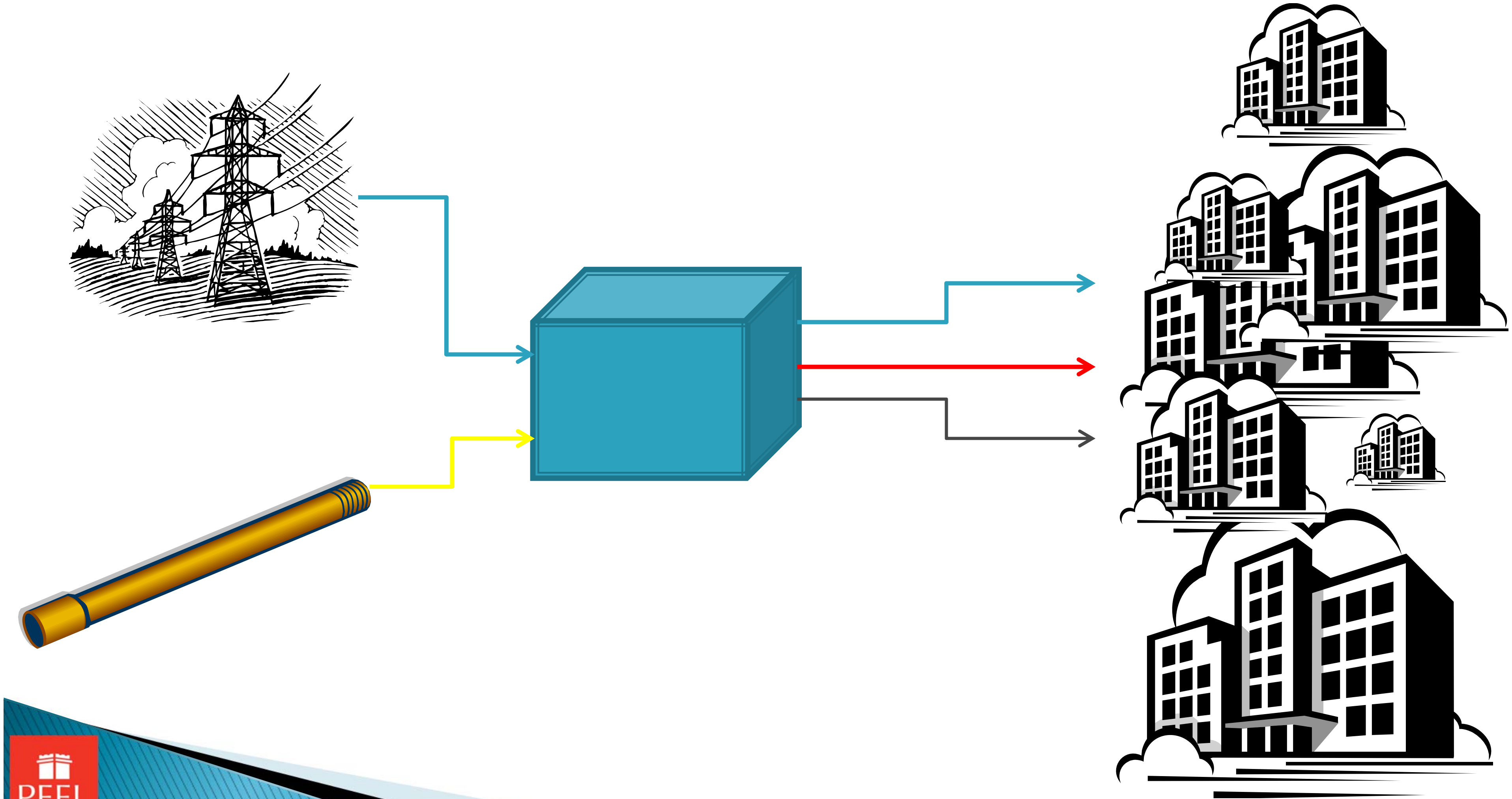

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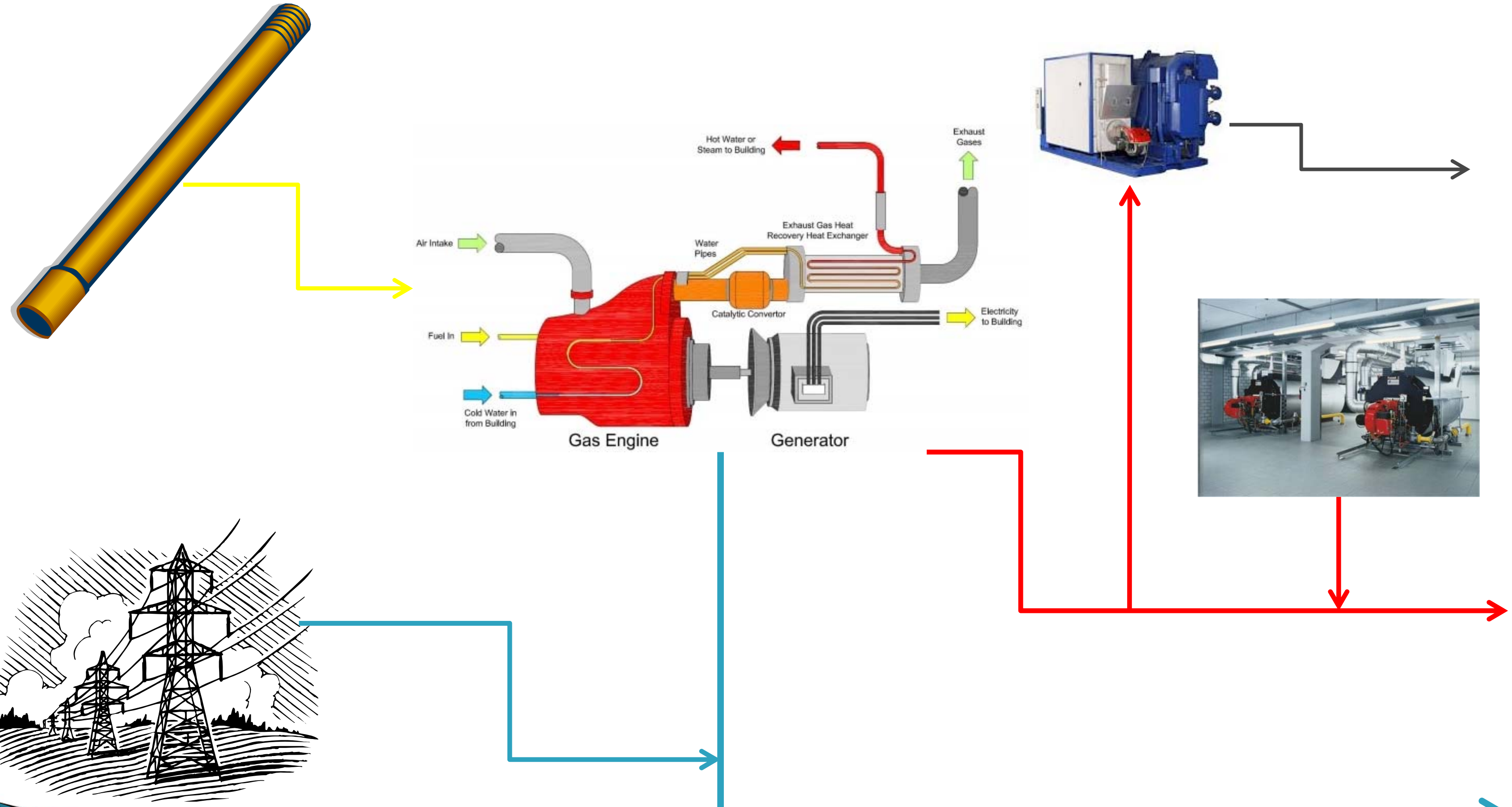

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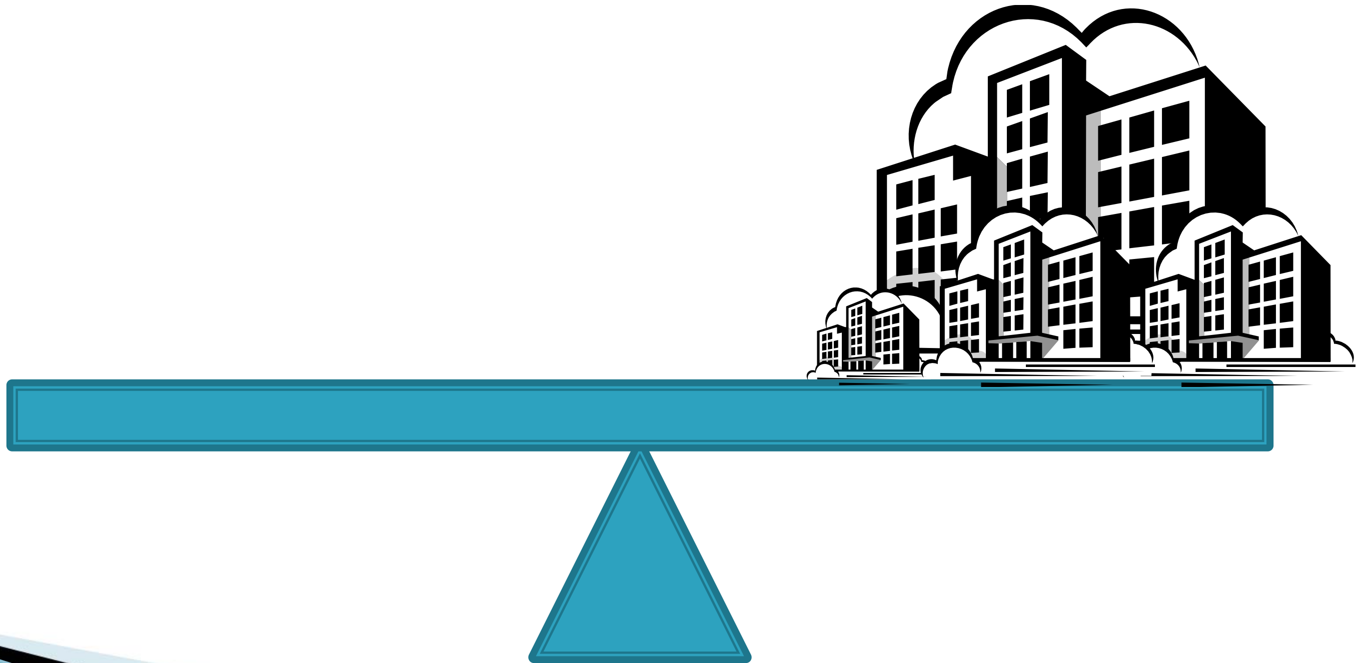
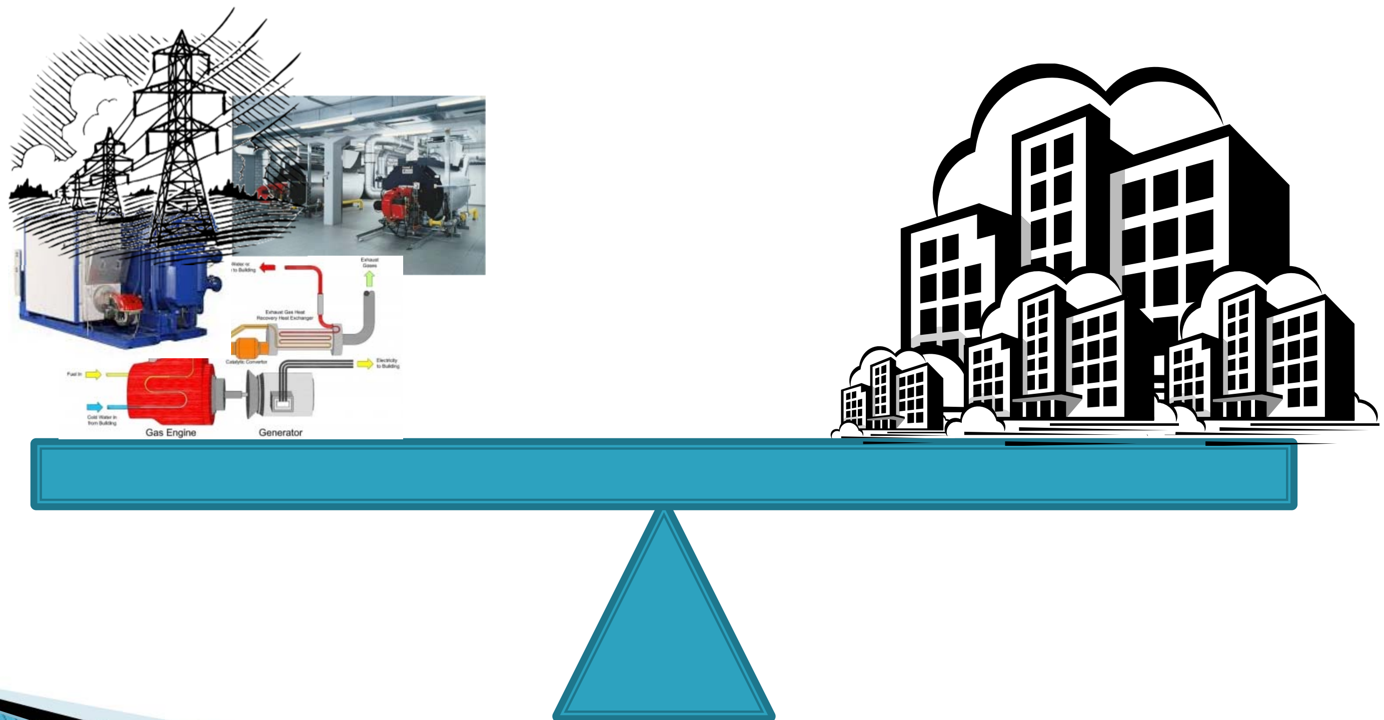


# MediaCityUK – Challenge

Variations:

- Seasonal
  - Summer, Autumn, Winter, Spring
  - Academic year
- Weekly
  - Working week (commercial)
  - Weekend (domestic/retail)
- Daily
  - Half hour peaks and troughs
  - 5/10 min large equipment start up/shut down
- For electricity, cooling, heating and domestic hot water

# MediaCityUK – Challenge



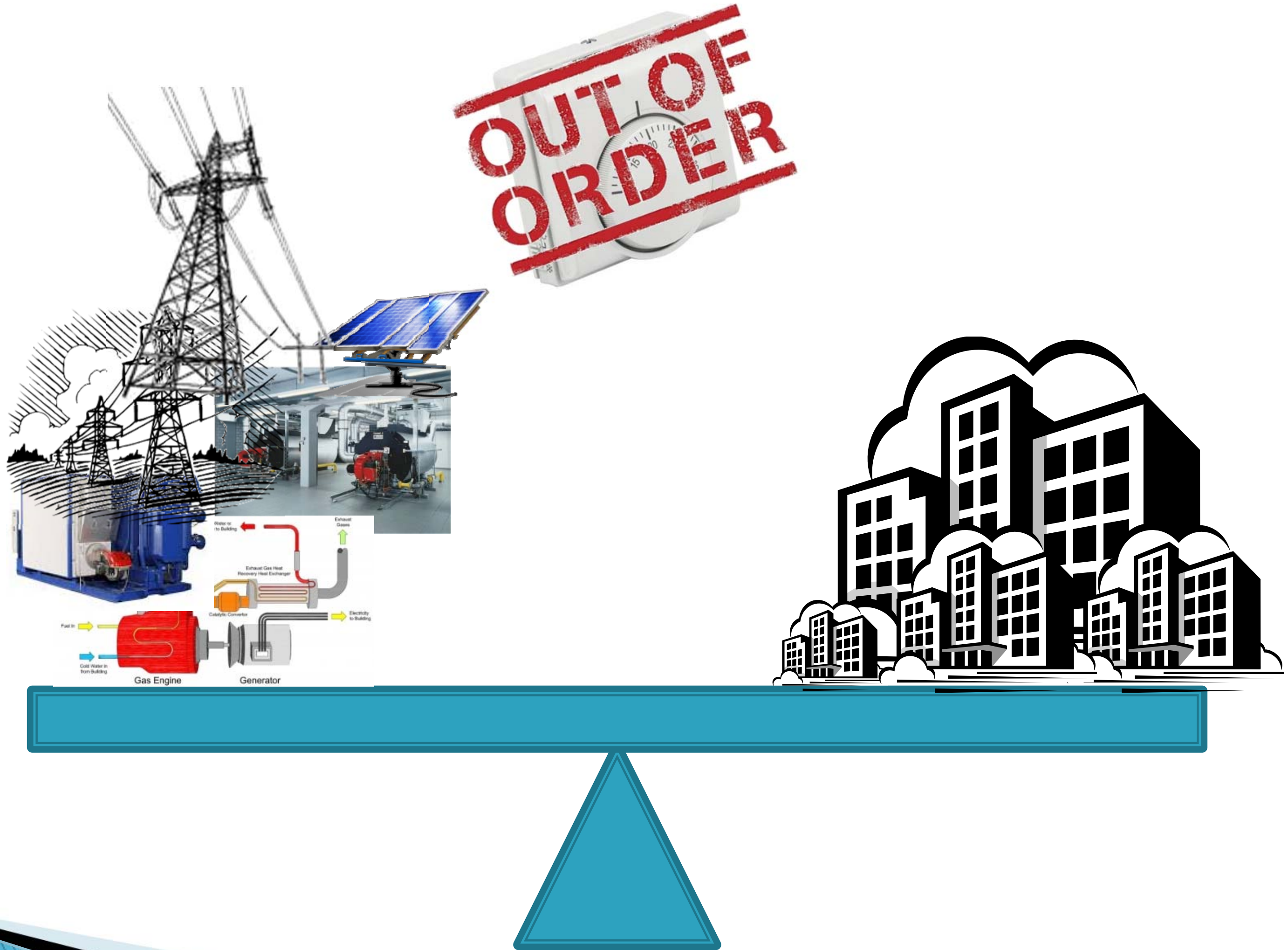
# MediaCityUK – Challenge

Supply challenges:

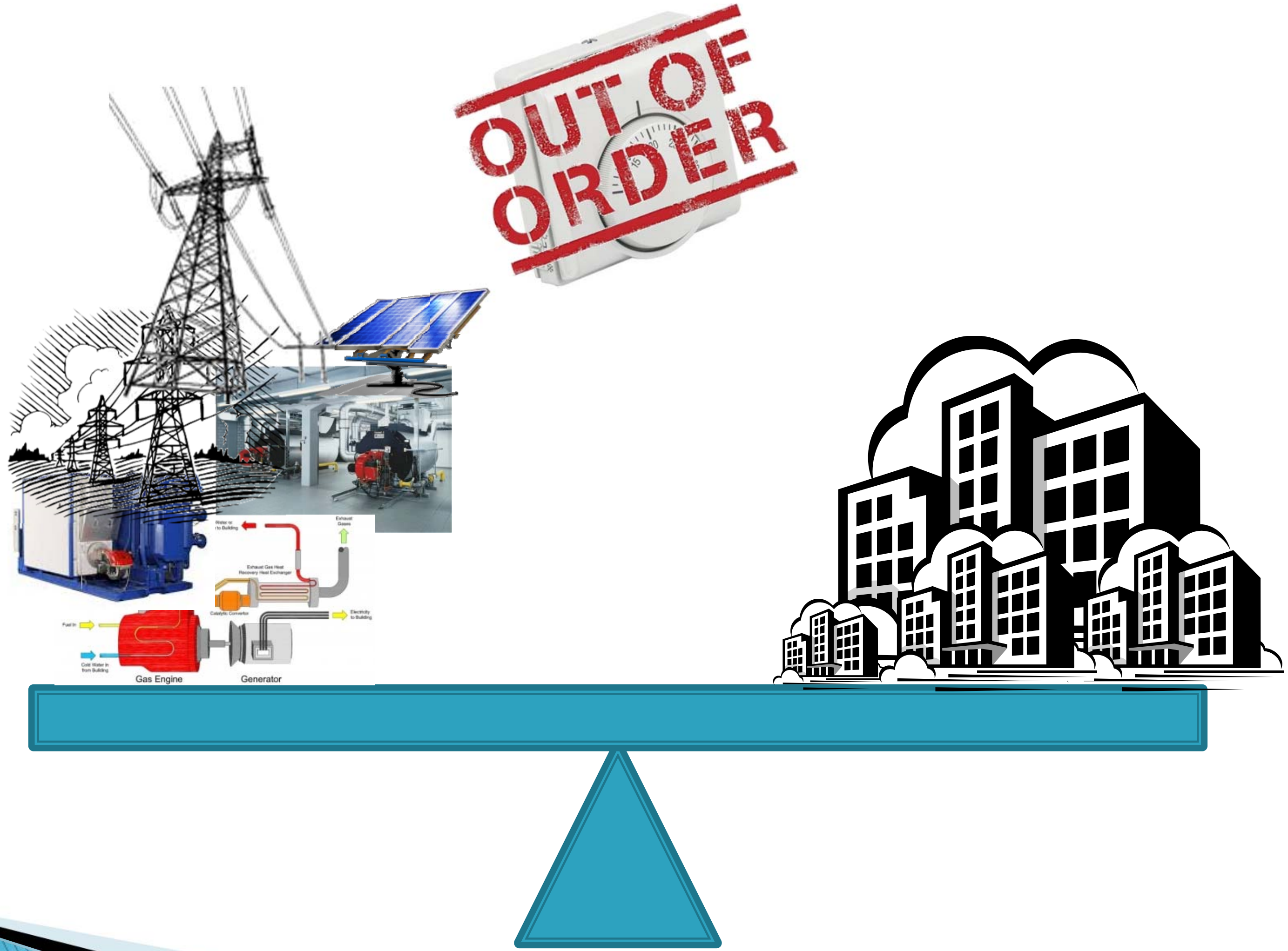
- Commercial
  - Tariffs
  - Fuel cost
  - Carbon taxes
- Operational
  - Security of supply
  - Operations contracts
  - Service Level Agreements
- Sustainability
  - Low carbon commitments

PEEL

# MediaCityUK – Challenge



# MediaCityUK – Challenge



# MediaCityUK – The Solution

- What has been done so far?
  - Improved metering
  - Trial and error tweaks to the system and its control philosophy
  - Improved manual operational models
  - Improved BMS integration

# MediaCityUK – The Solution

The Problem

- There is no one correct operational model, no one centralised control system, no one commercial appraisal which can say what assets to operate and when.

The solution

- Build a better thermostat

# MediaCityUK – The Solution

That system needs to:

- Guarantee a secure supply to customers
- Maximise the use of revenue generating assets
- Maintaining the low carbon credentials of the system

# MediaCityUK – The Solution

That system needs to:

- Be able to gather and collate service data across hundreds of customers
- Needs to recalculate the optimum operational strategy based on live inputs, hence modelling run times need to be minutes not hours
- Juggle the available supply assets with varying efficiency, commercial and sustainable priorities
- Integrate with multiple building BMS systems across varying generations of technology

# MediaCityUK – What Next

- As part of the study we have reviewed today, the Media City model is able to replicate the existing balanced supply scenario and now gives us the opportunity to ask what if questions
  - What if we utilised thermal storage
  - What if we utilised electricity storage
  - What if we invested in further generation

- The KPI outputs from these scenarios can be generated in minutes meaning within a working day meaningful business models can be pulled together rather than taking weeks or months of modelling trailing and analysis.

- Next we need to explore how best to integrate this model with the day to day monitoring and control of the Tri-Gen system in order to maximise security, sustainability and profits

PEEL

# Q&A

Any questions

# BRE CHPV Workshop
# UK Distributed Energy – The Role of CHP&PV (CHPV)
# BRE Garston
# 20th January 2016

Peter Birch

M.Phil.C.Eng.M.C.I.B.S.E.
Engineering Services Manager

Facilities Management Department

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# Introduction

- The Campus – brief description of The University of Liverpool Campus
- Energy and CHP on campus
- Electrical and District heating infrastructure
- New energy Centres
- Greenbank Student Village – CHPV Project model

# Facts and Figures

- Main City Centre campus - 90 Acre site
- A member of The Russell Group of Universities
- 30,000 Students
- 5,000 Staff
- Mix of building stock old and new dating back to 1835
- Victorian Waterhouse design buildings
- 1960’s saw prolific development of campus
- New buildings currently under construction or planned in the next 5 years

# Victoria Building
# The original "redbrick" university building

# Chatham Building

# Harold Cohen Library


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# Sydney Jones Library

# Foundation Building


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# Sports Centre

# Bio Sciences


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# School of Management Building

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# Small Animal Practice


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# Newest Campus Buildings

- Vine Court Halls of Residence - an 850 bed student hall opened in 2012
- Crown Place Halls of Residence a 1239 bed student hall opened in Sept 2014
- Savings to offset this additional energy use will have to be made if the University is to keep in line with it's Carbon Reduction Commitments
- Other new buildings are:

  Ronald Ross Building –adjacent to Bio- Sciences building and is a new medical research facility.
- Central Teaching Laboratories (CTL) linked on to the Lecture Block on the green by Chemistry Department
- All 4 will be relatively large users of energy

# Ronald Ross - Medical Science Facility

# Central Teaching Labs - (CTL)

# Vine Court – ECO Halls of Residences Opened in September 2012

# Crown Place Halls of Residence Opened in September 2014

# Energy Consumption Facts

**The University is a very LARGE USER of ALL utilities:**

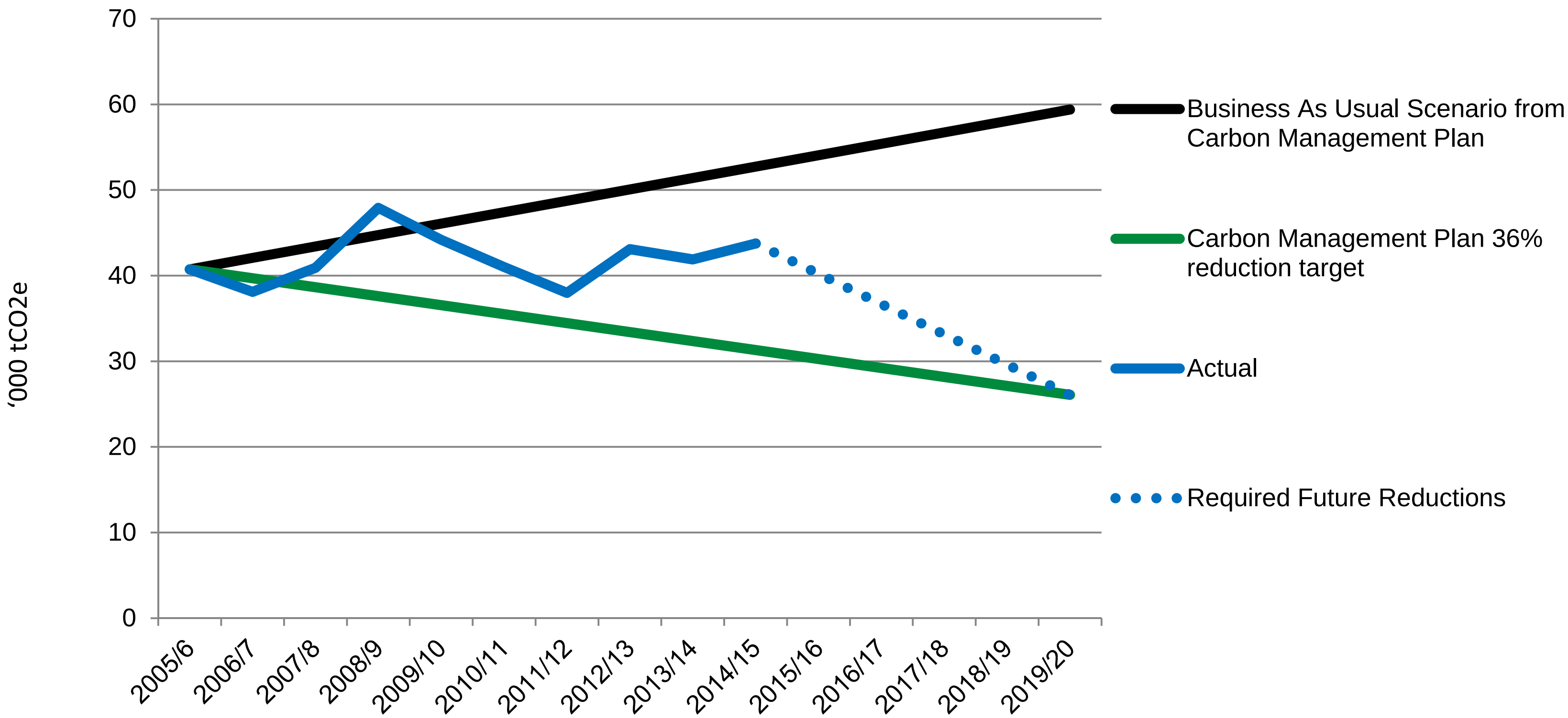
**Electricity Gas and Water**

In a typical year we consume:

64Million kilowatt hours of electricity costing £5.4 Million Pounds
(55 Million kWh on the main campus alone!)
180Million kilowatt hours of Gas costing £2.8 Million Pounds
250 Million litres of water costing £1 Million
Giving a total annual energy bill of around £9.5 MILLION

Our base load electricity consumption is around 5MW - that means that our electricity load on site NEVER DROPS below 5.5 MW – not in the evening/middle of the night/even Christmas and New Year nights! it NEVER DROPS below 5.5MW

# Projected Carbon Emissions Graph

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# Distributing the energy around the campus

High Voltage electricity distribution network –

- 4 off 11kV distribution rings serving 34 substations around the campus
- HV/LV interconnector  circuits

High Temperature Hot Water (HTHW)District Heating system-

- consisting of buried insulated pressurised mains distributing HTHW to plate heat exchangers in plant rooms 5k of buried mains
- Leak detection system and cathodic protection built into pipework

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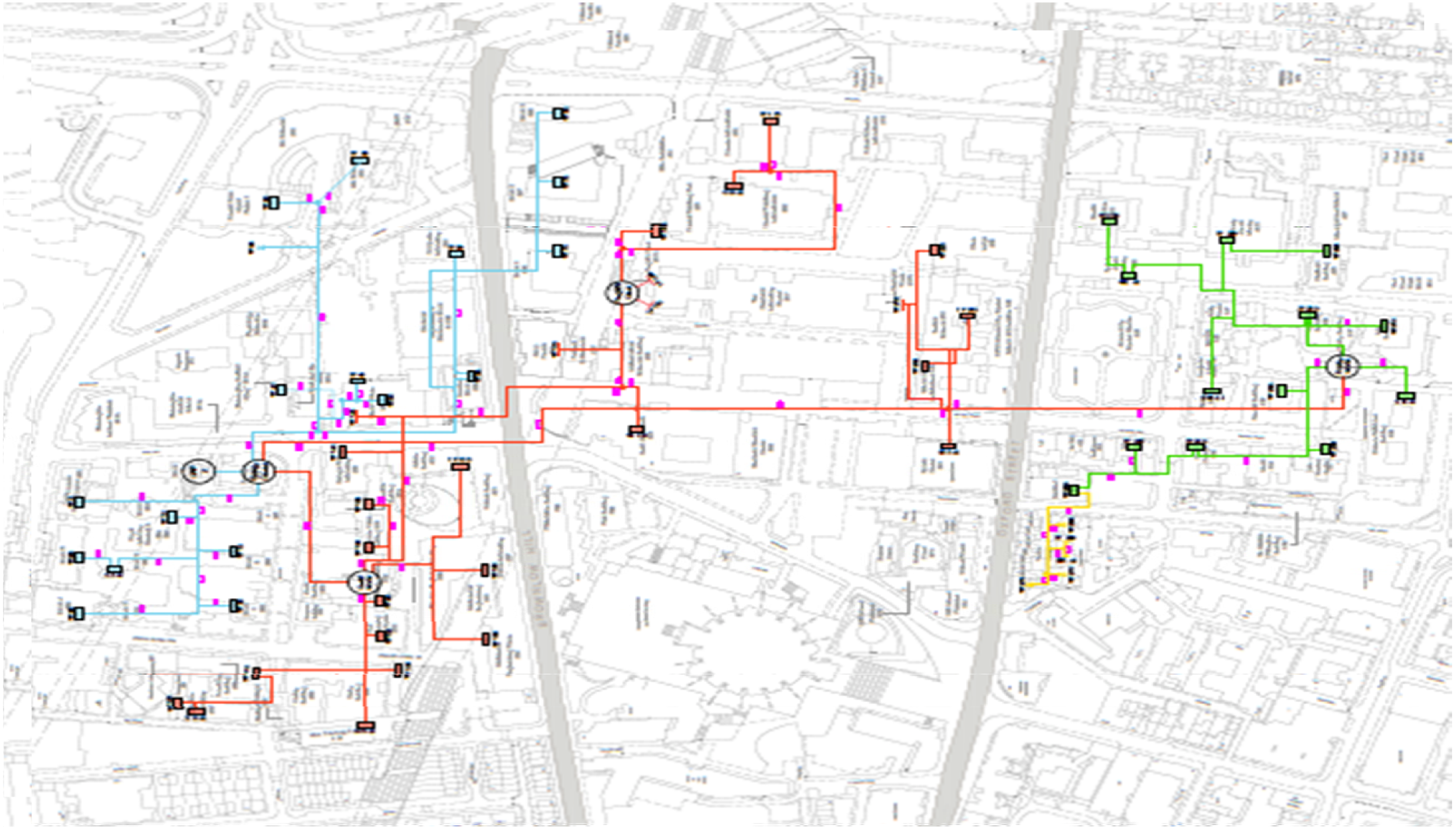
# District Heating Network

- Heat from the energy centre is distributed to building plant rooms via large buried High Temperature Hot Water (HTHW) and Low Temperature Hot Water (LTHW) mains distribution pipework around campus.
- Various zones serve different parts of the campus.
- Each building served from the district heating mains has a plant room with a plate heat exchanger for distribution within that particular building.
- The buried mains are pre-insulated mains and have leak detection monitoring built in

# District Heating Network



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# District heating mains being laid in Bedford St


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# District heating mains being laid in Bedford St.

# District heating mains being laid in Peach St


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# HTHW Plate Heat Exchanger

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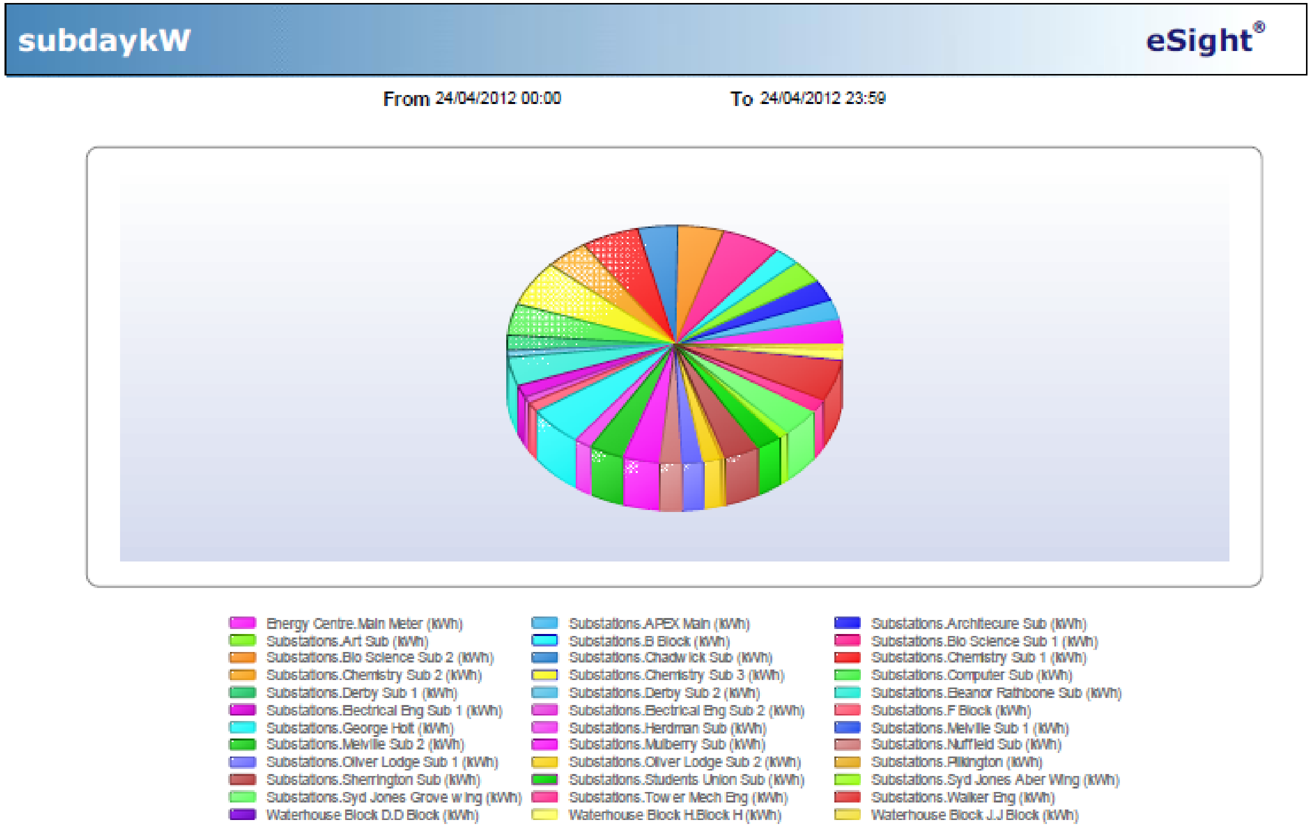
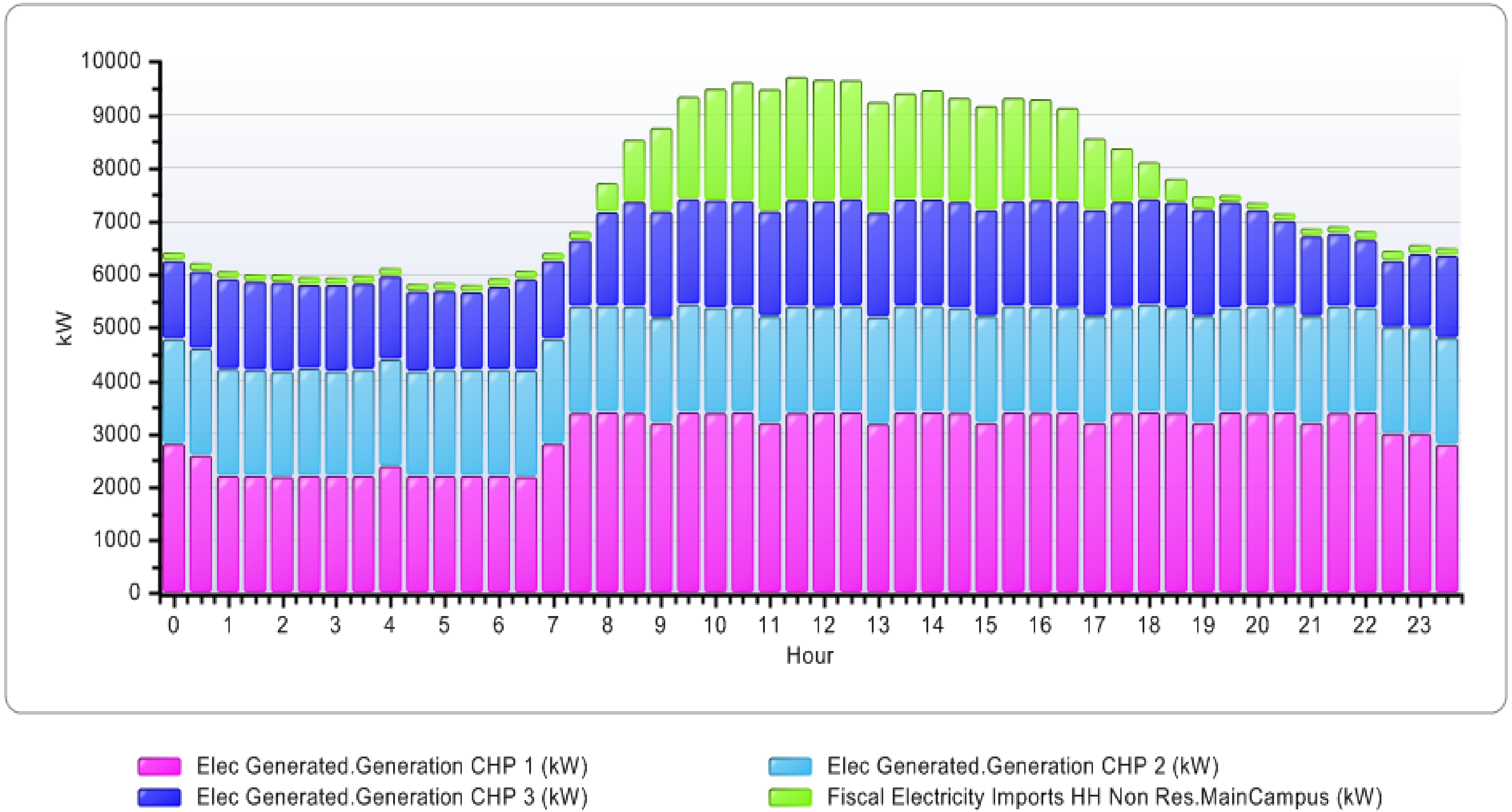
# UNIVERSITY OF LIVERPOOL



# Main Campus electricity profile  Jan 2015

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# Local Collaboration on Energy Issues

- The University is part of several local energy collaboration initiatives such as:
- CHPV Research Project as a partner organisation
- The “Knowledge Quarter” encompassing Liverpool University and Liverpool John Moores University and the Royal Liverpool University Teaching Hospital along with Liverpool Enterprise Partnership (LEP) with a view to sharing energy networks and experiences and expertise
- Smart City/Campus exploring initiatives with Liverpool City Council and our own academics looking at several areas such as combining energy awareness with mobile technology and social networks
- Part of local Universities “support group” meeting with peers form other North WEST Universities to share practices information experiences etc...

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# Energy Centre

# Energy Centre

# CHP Jenbacher CHP Engine

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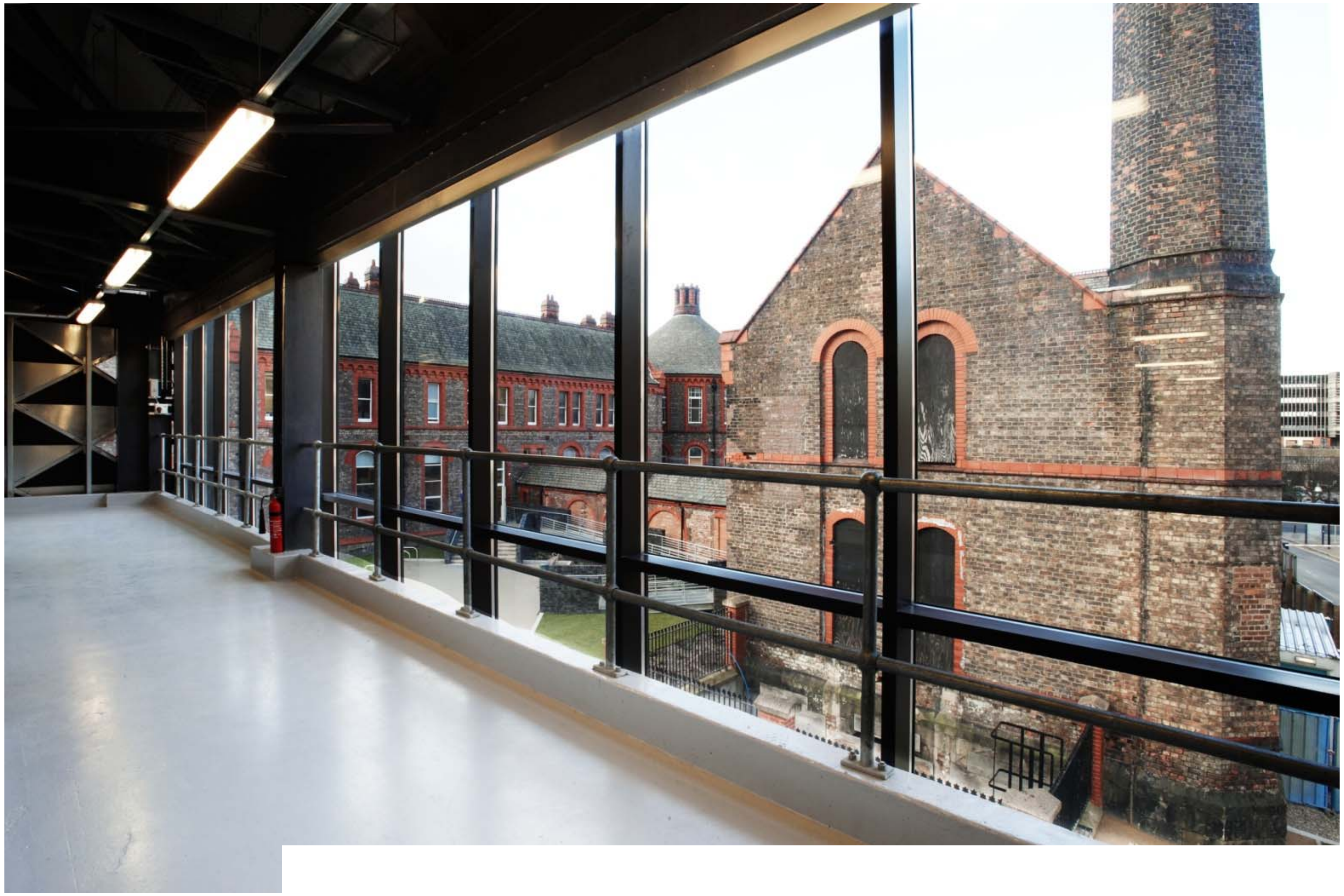

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# Benefits of building NEC

The University will own and operate a state of the art environmentally friendly energy centre capable of supplying the energy requirements of the University for the next 25 years

The NEC will go a long way to helping the University meet its challenging carbon reduction commitments

The NEC will help the University keep energy costs under control in an ever changing utilities market

Students will have direct access to live energy centre data for a variety of academic projects in collaboration with Mechanical Engineering Department

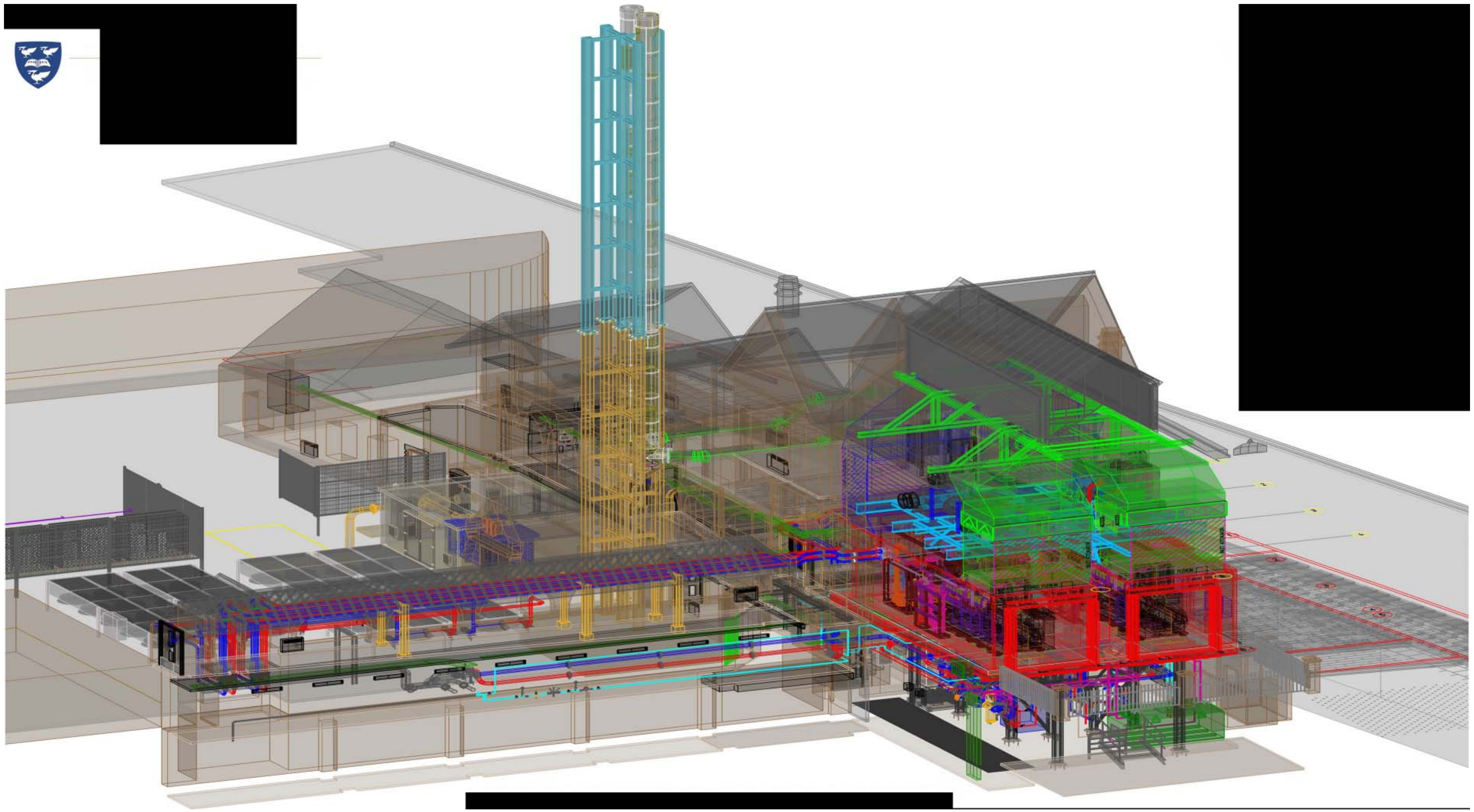
# CHP 2 – Renovated Victorian Boilerhouse funded with SALIX loan

- SALIX loan of £6.2Million (of an £8.5Million scheme)
- CHP installation adjacent to new energy centre (in old Royal Infirmary Victorian former coal fired boilerhouse)
- 2 x 2.0 MWe CHP EDINA engines to run 5000 hours per year and generate an additional 20 + Million kWh of electricity and another 4MW of heating capability.
- Electrical export facility built in
- Helping to further reduce carbon emissions in line with Carbon Management Plan

# CHP 2 – Project Issues - Condition

[redacted]

[redacted]



[redacted]

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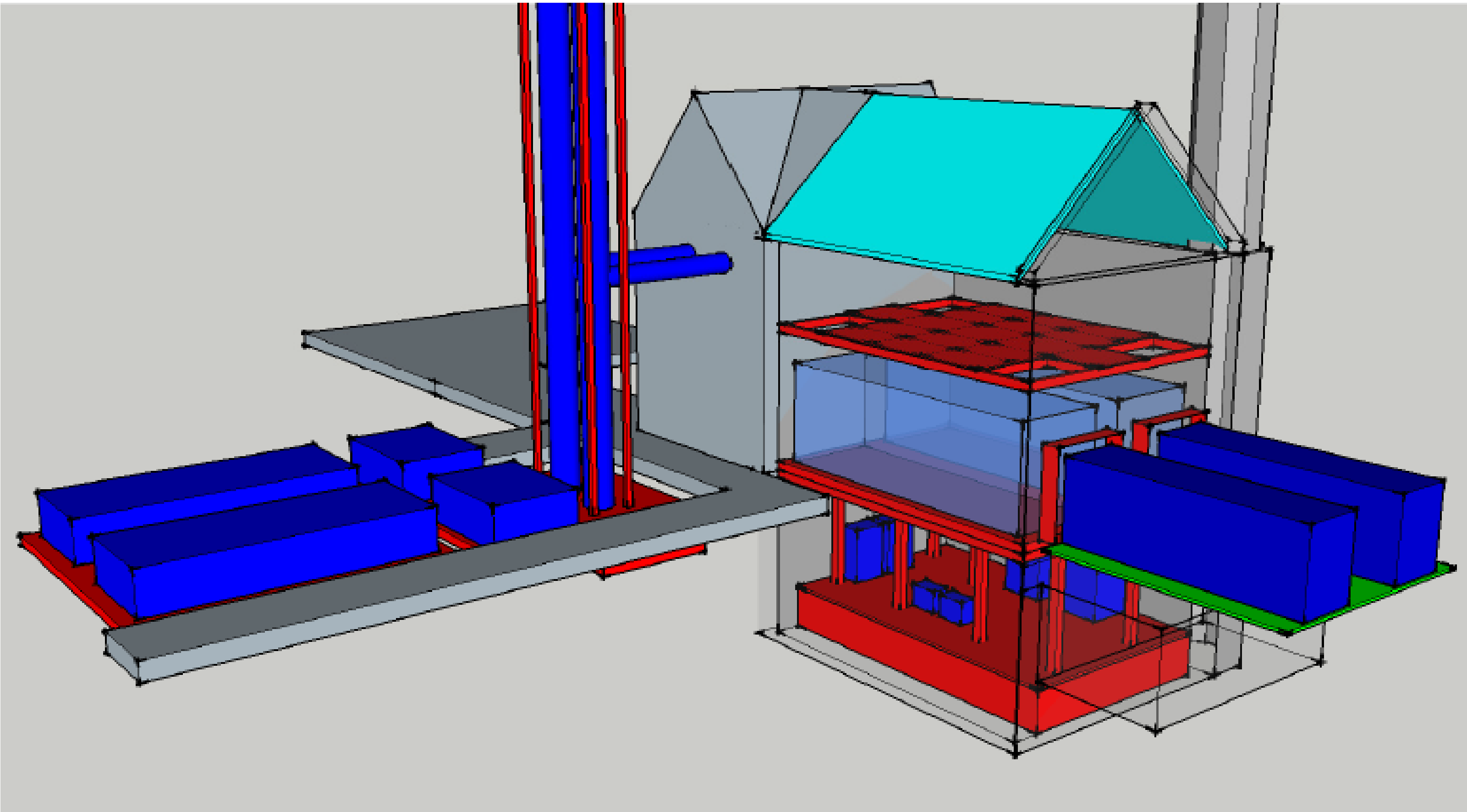
# CHP 2 – Project Issues – access for main plant



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# Chimney re-enforcing

# New Roof Ventilation Chamber


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# CHP Engine Cells - access

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# CHP Engines  being delivered into cell


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# CHP 2 – Project Issues – access for main plant


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# Finished cells

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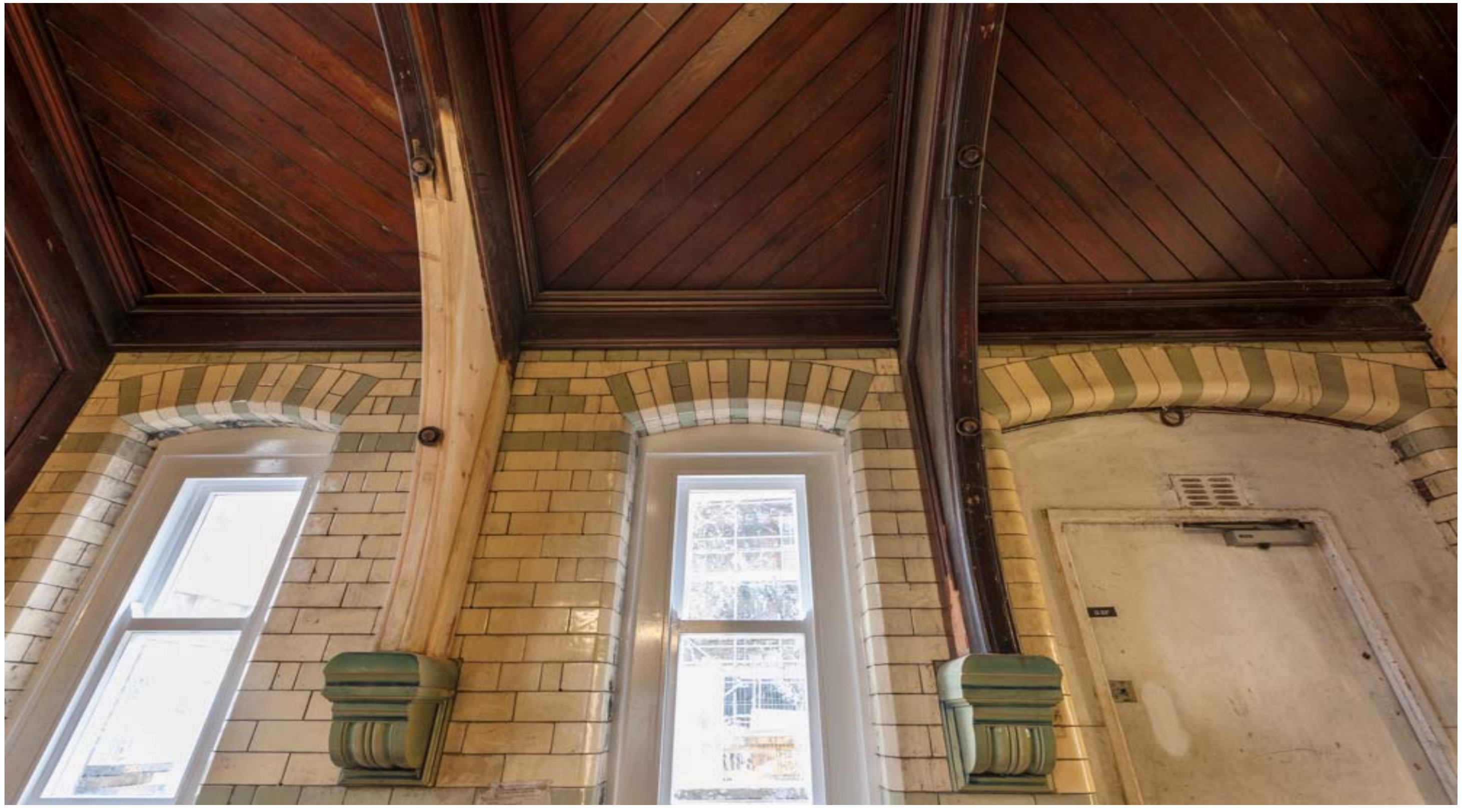
# Restorative joinery work in former chapel



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# Restorative joinery work in former chapel

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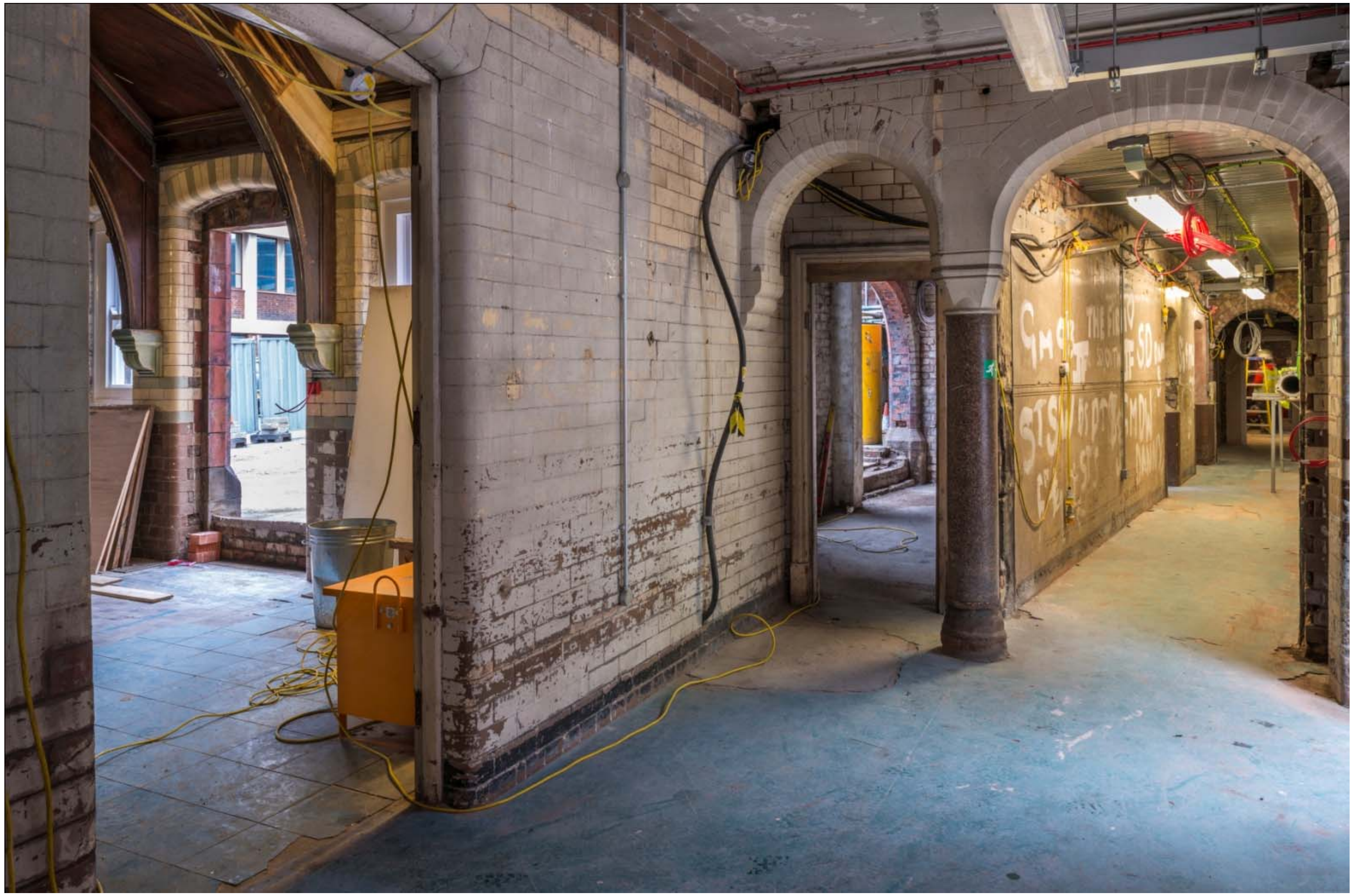
# Example of building interior before re-furb



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# Link Corridor pipework

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# HV Switchroom

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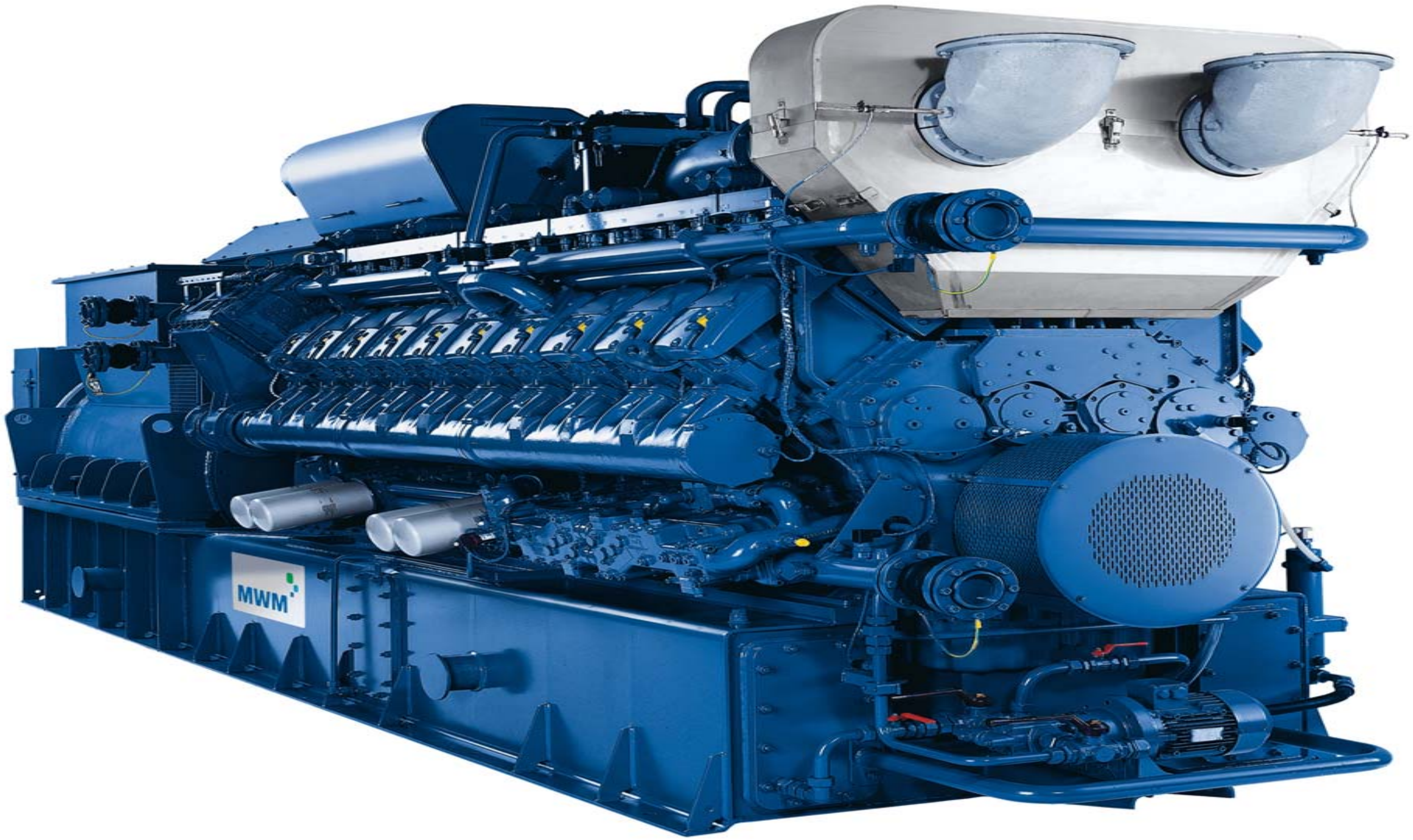
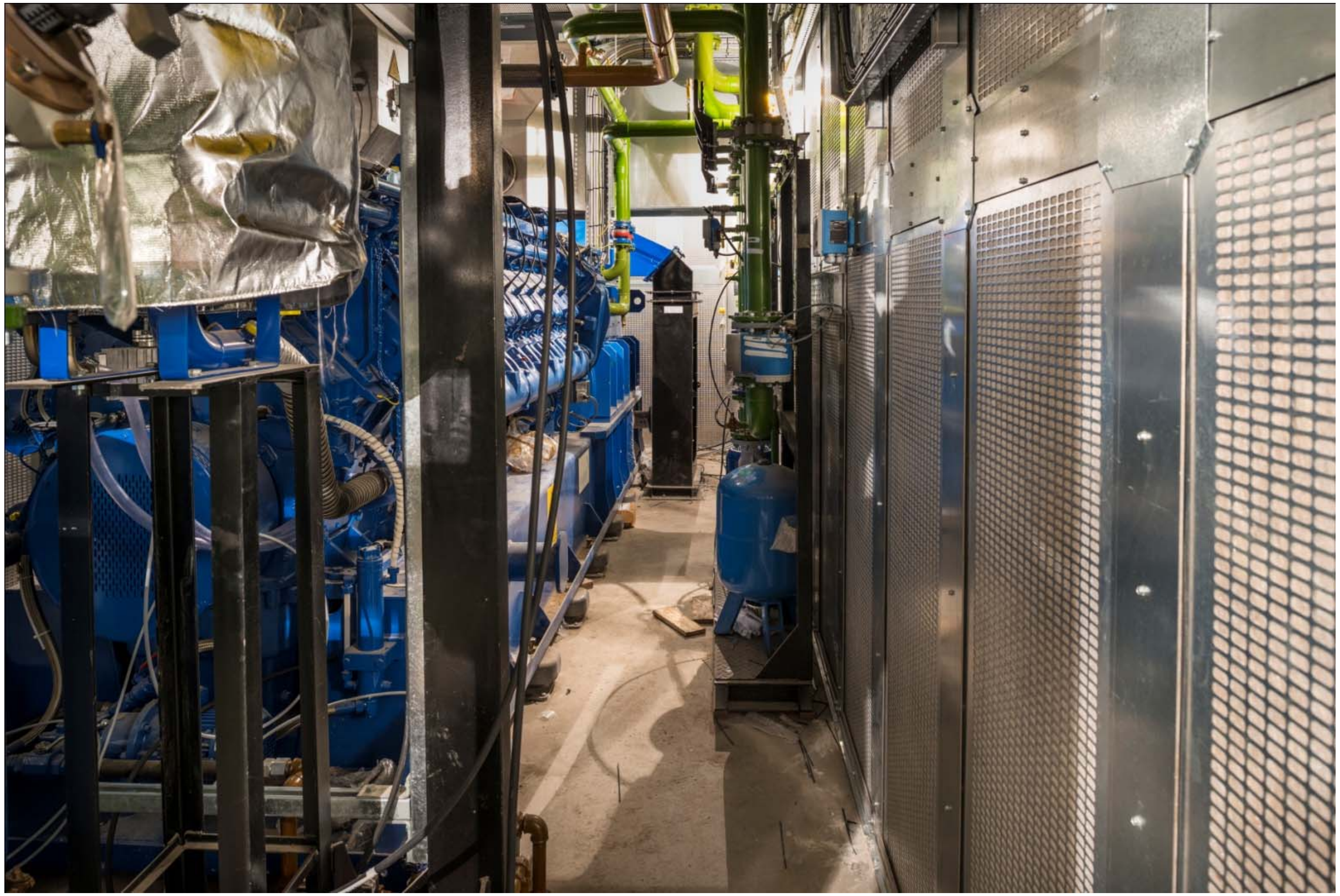
# EDINA CHP ENGINE 2MWe



# Inside Edina Engine Cell



# Main Plantroom and distribution pipework

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# Finished exterior

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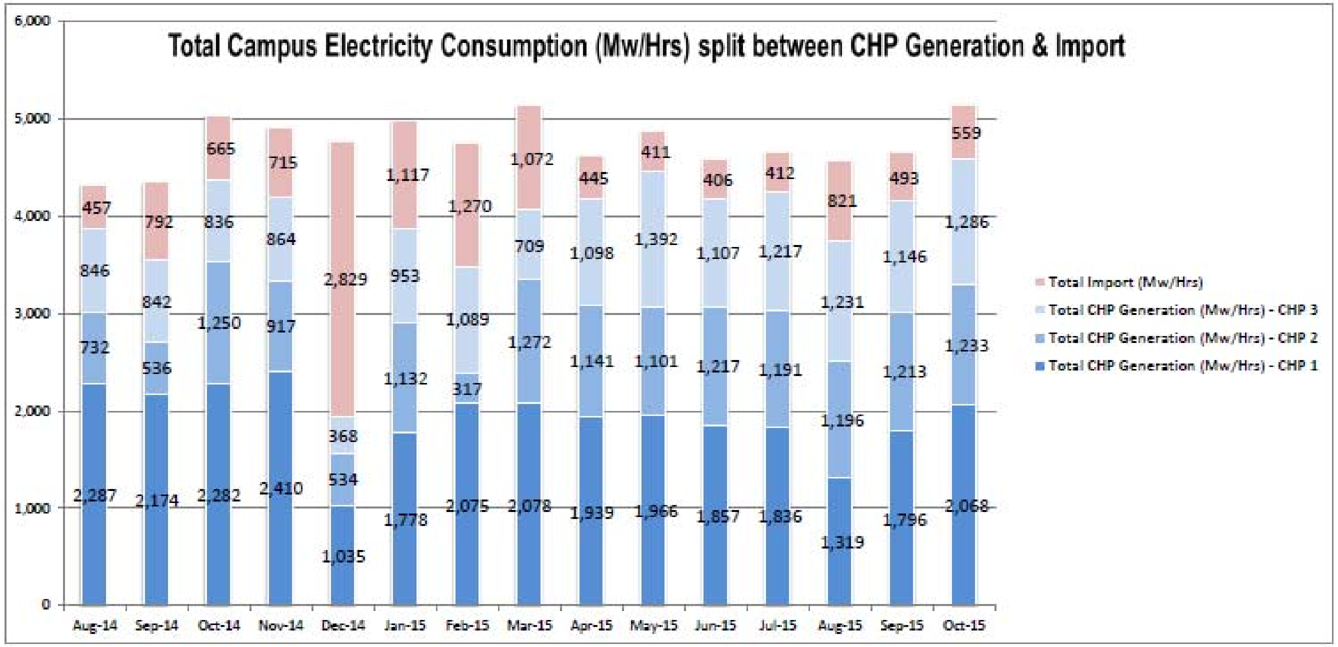
# Operational slide – how has the new CHP2 performed in the first year?

- Both engines have run in excess of 6000 hours each which exceeded our expectations/business case assumptions of 5000 hours
- Total generated electricity in first year of operation from CHP2 is 22.4MkWh
- Site has acted as an exemplar for Heritage restoration and hosted many visits of staff students and outside bodies and institutions.

# Generation and Import in MWhrs

**ULEC**
**15 months to 31 October 2015**

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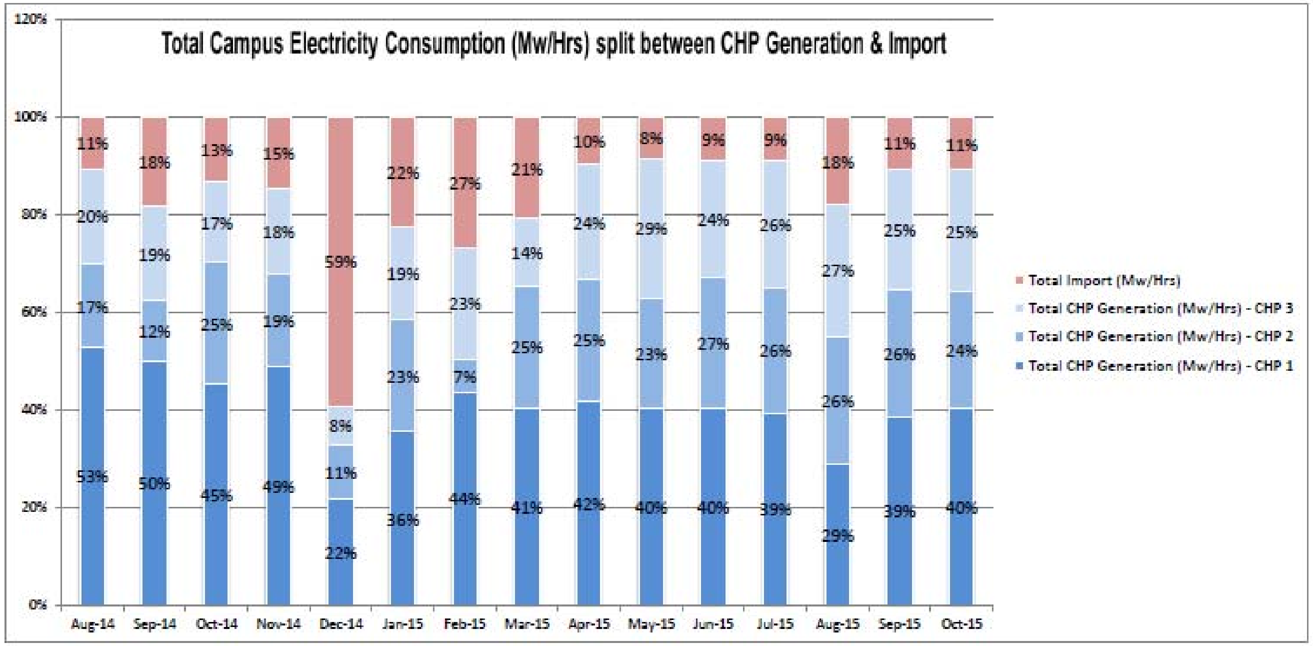
# Generation and Import % split

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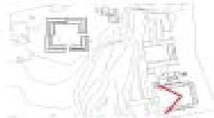
# GREENBANK STUDENT VILLAGE

Perspective Views

04 - View from Derby Old Court towards Sports Block





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# GREENBANK CHP/DH

- New halls of residence campus situated 4 miles from main university campus
- 2 phase building project to be completed by Sept.2019
- £100 Million re-development knocking down old 1960’s halls buildings and building a new 21st Century Student Village
- Re-furbishment of Grade 2 listed Greenbank House.
- 1400 en-suite study bedrooms
- CHP/DH Energy centre and thermal storage facilities
- 2 gas engine CHP sets (1x 220kW +1 x 150kW)

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# GREENBANK SITE PLAN


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# Some existing buildings to be retained and converted to en suite accommodation

Derby Old Court

# STUDENT VILLAGE - IMAGE

University of Liverpool, Greenbank Student Village | Detailed Planning Application | Planning Addendum

February 2015

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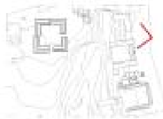
# STUDENT VILLAGE - IMAGE



Perspective Views

02 - View from Greenbank Road between Derby Hall and Rathbone Hall

Proposed Visualisations

Detailed Planning Application - Planning Addendum

Page 2

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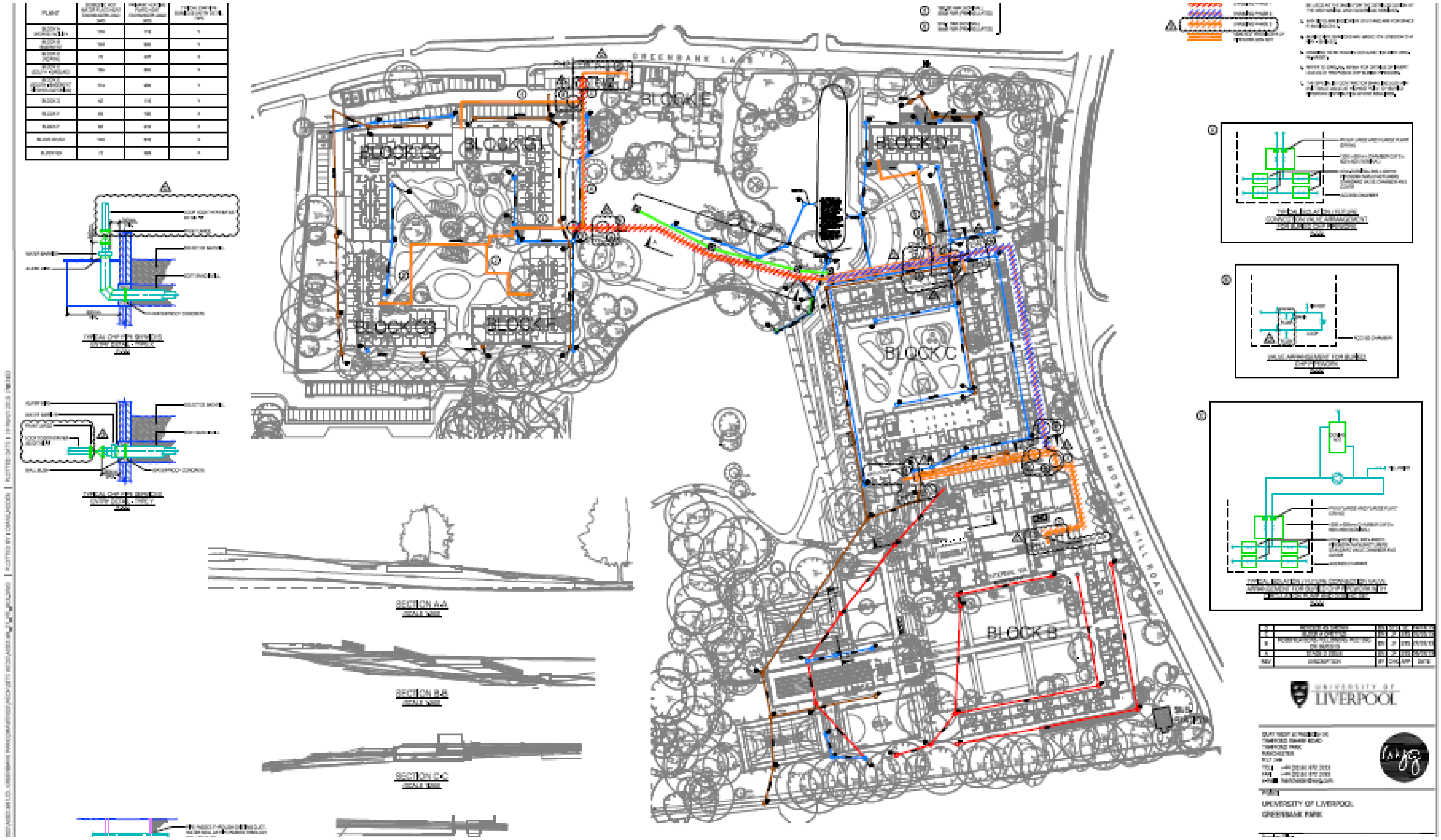
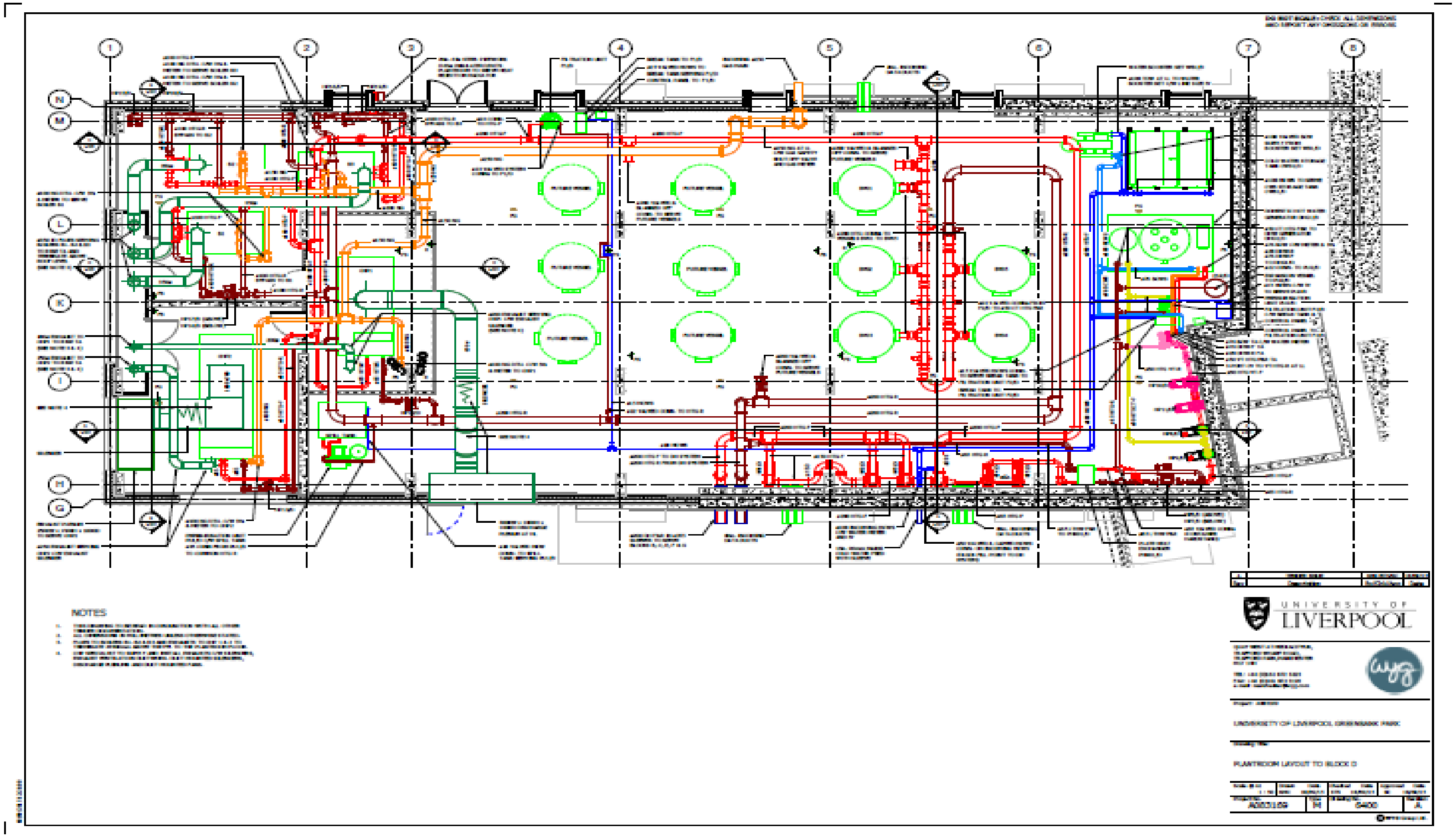
# Site plan showing District Heating mains distribution



# Greenbank Energy Centre plant layout

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# SUMMARY

- Our experience of operating a large CHP plant and District Heating Network for many years has given us a platform to examine further the effects of innovations such as CHPV on the operation of the plant to further maximise potential energy savings by combining these technologies.
- The Greenbank student village project will be an ideal model in which to examine if CHPV technology can be integrated into a design scheme to help bring additional benefits both in terms of operation and energy savings over the life of the scheme.

THANKS FOR LISTENING

ANY QUESTIONS?

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A MEMBER OF THE RUSSELL GROUP

# InnovateUK Combined Heat & Photovoltaics (CHPV) Project 101998

CHPV Workshop

Venue: BRE Garston

20-JAN-16

University of Liverpool

Matt Stewart

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# Combined Heat & Photovoltaics (CHPV)

- 2 year EPSRC and InnovateUK funded R&D project

- Project:

Integration and control of CHP, DC + PV systems with energy storage in clusters of non-domestic buildings

- Partners:

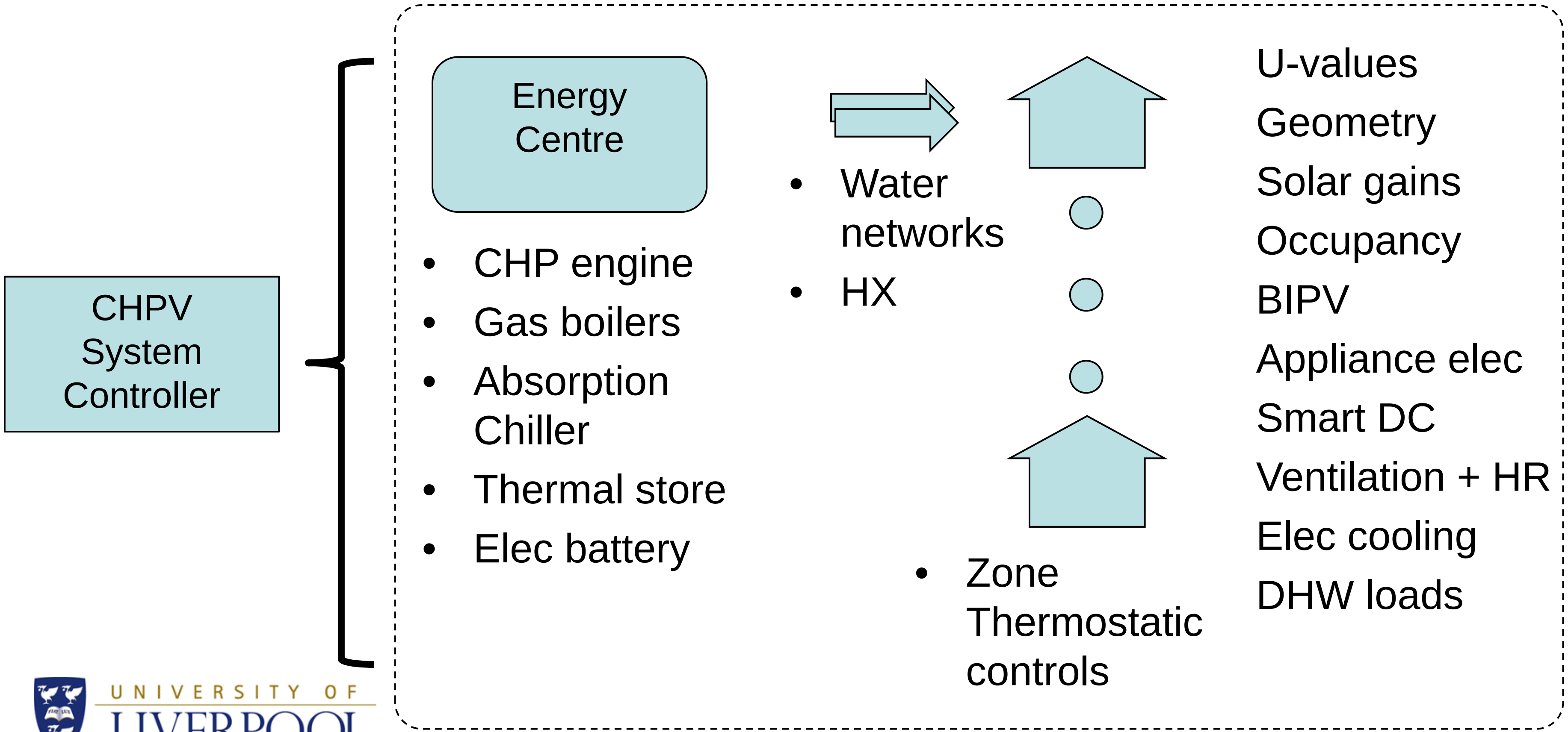
Peel Utilities, Ove Arup, Building Research Establishment (BRE), and University of Liverpool

- Research:

System Modelling and dynamic simulation to research multi-channel feedback actuated CHPV control.

# Combined Heat & Photovoltaics (CHPV)

CHPV Model Structure:

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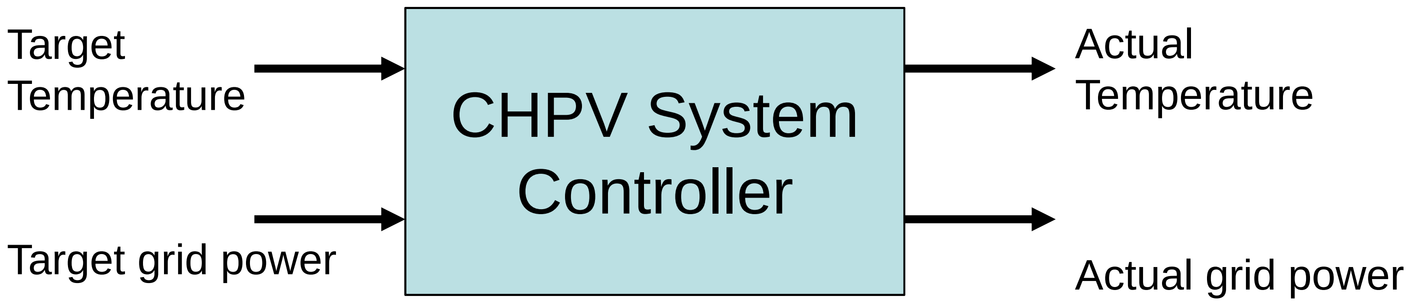
# Combined Heat & Photovoltaics (CHPV)

- Multi-vector (heat and electricity) closed loop control using feedback




- MIMO Design using Robust Inverse Dynamics Estimation (RIDE)

- Matlab/Simulink CHPV models – 1min timestep for 1yr

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# Combined Heat & Photovoltaics (CHPV)

Model Validation:

**Case Study 1: Copperas Hill Building, Liverpool**

**Case Study 2: MediacityUK, Salford**

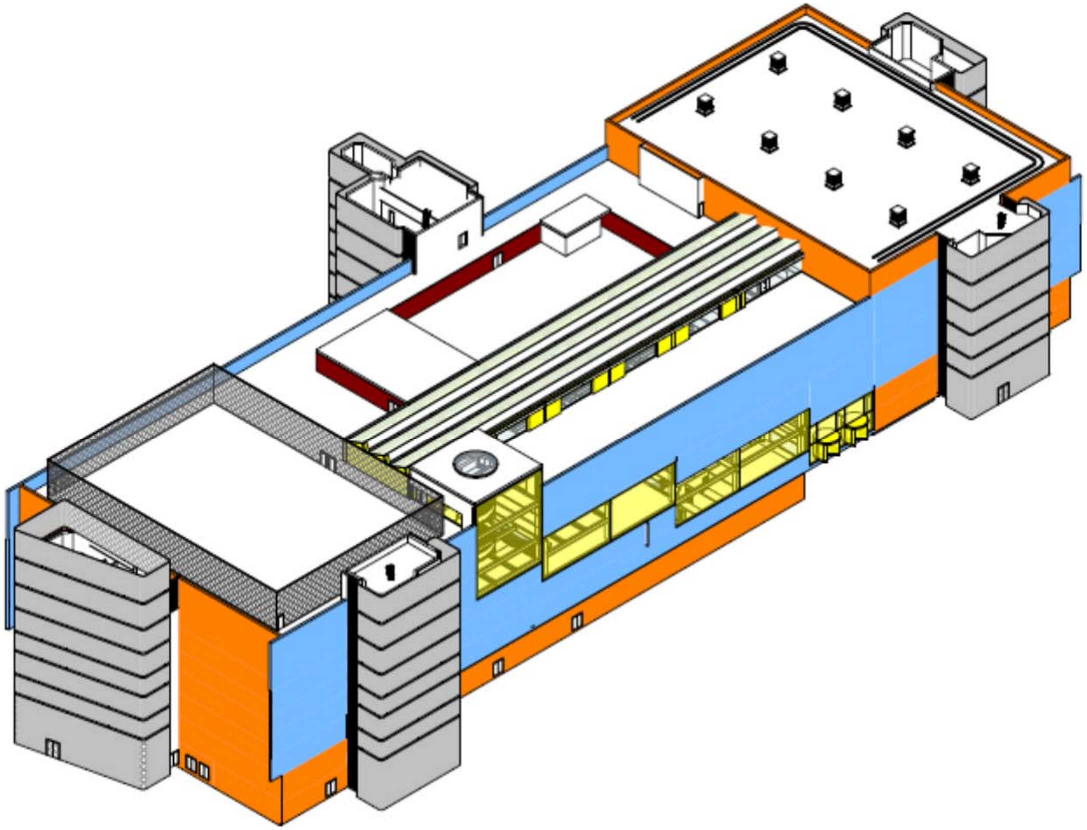
**Case Study 3: Greenbank Student Village, Sefton**

# Combined Heat & Photovoltaics (CHPV)

Model Validation across 3 Project Case Studies:

**Case Study 1: Copperas Hill Building, Liverpool**

- Single university building
- 1 zone, 25,000m2 total
- Integrated CHP
- Roof mounted PV



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# Combined Heat & Photovoltaics (CHPV)

**Case Study 3. Greenbank Student Village, Sefton**

- Staged development ~1,300 Beds, 5 primary buildings
- District heat network
- Active thermal store

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# Combined Heat & Photovoltaics (CHPV)

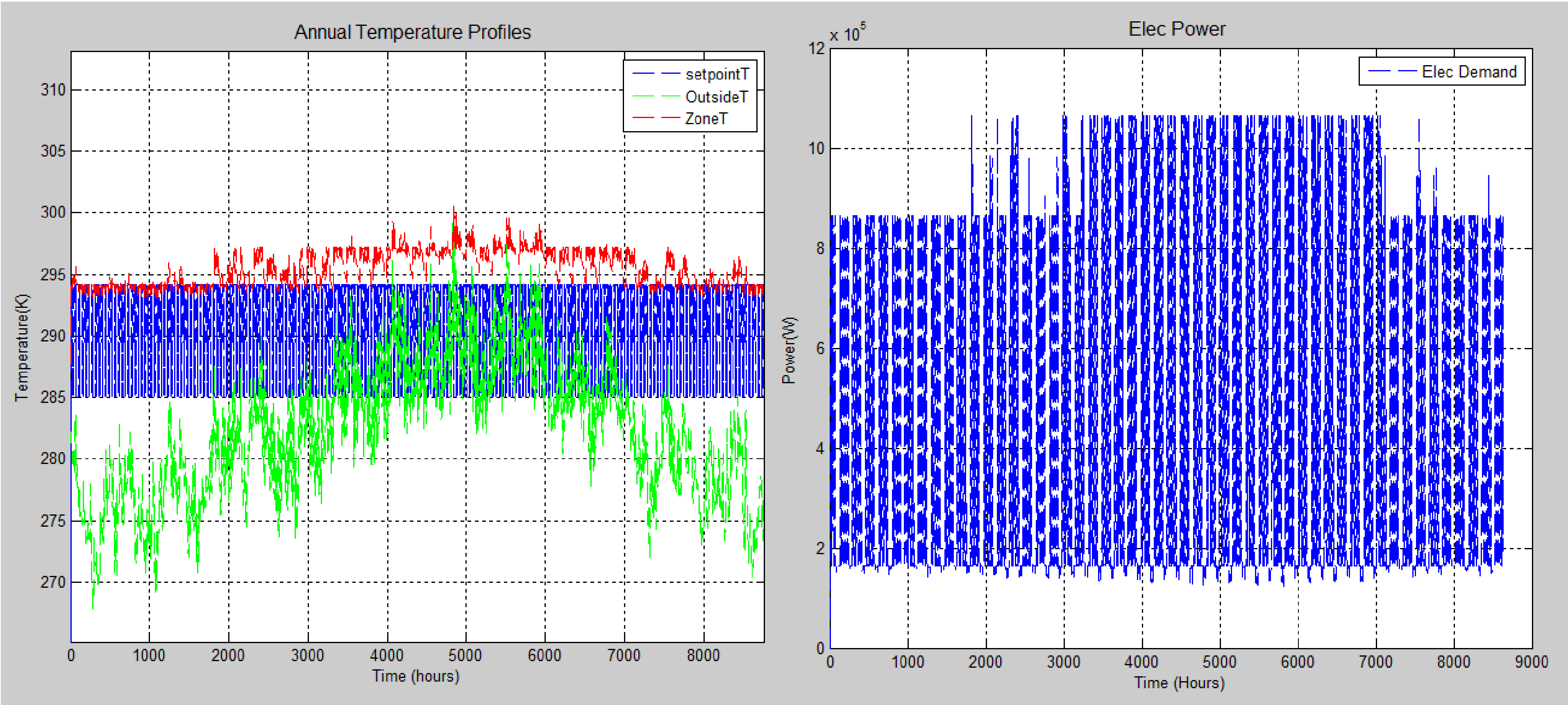
**Case Study 2. MediacityUK, Salford**

- Mixed cluster, 10 zones, CHP / GB  district heat & ABO cooling networks

# Combined Heat & Photovoltaics (CHPV)

Case Study 1: Copperas Hill Building, Liverpool

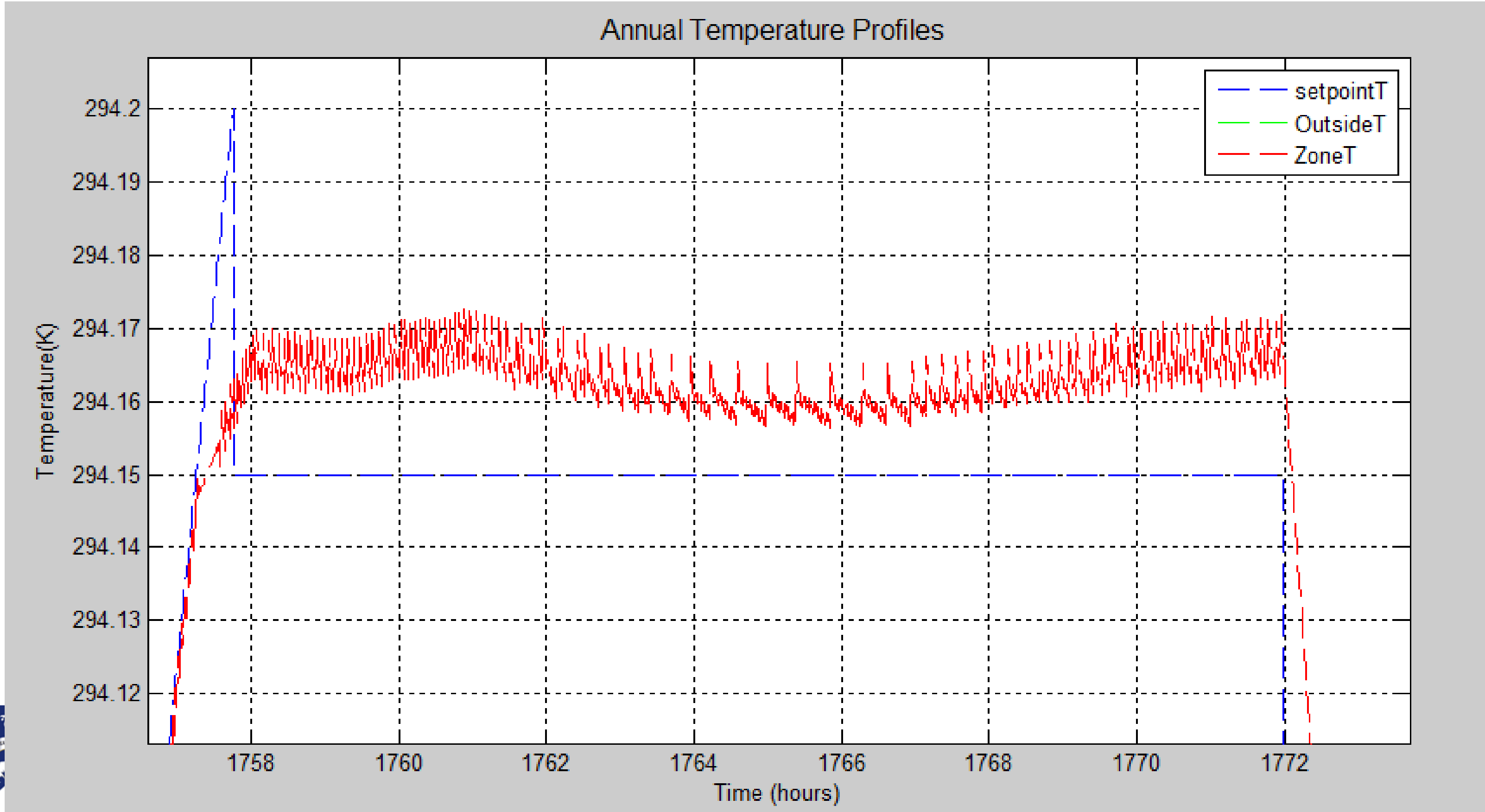
- Example simulated building temperatures @1min over 1 year



# Combined Heat & Photovoltaics (CHPV)

Case Study 1: Copperas Hill Building, Liverpool

- Temperature control detail



# Combined Heat & Photovoltaics (CHPV)

## Modelling Summary

| | Copperas Hill | Greenbank SV | MediacityUK |
|---|---|---|---|
| Building types | University | Residential | Mixed |
| No. Zones | 1 | 5 | 10 |
| Source data | Design | Design | Metered |
| CHP | 132kWe | 370kWe | 2MWe |
| PV | Y | N | N* |
| Heat store | N | Y | Y |
| DHN | 150m | 1500m | 2500m |
| Cooling tech | Electric MVHR | Electric MVHR | ABO + Electric MVHR |
| Elec load | 4,000MWh | 2,770MWh | 20,000MWh |
| Heat load | 1,647MWh | 3,450MWh | 8,000MWh |
| model error | **<5%** | **<3%** | **<10%** |
| Simulation time | 2 min | 3 min | 4 min |

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# Combined Heat & Photovoltaics (CHPV)

Results so far

Modelling and dynamic simulation of CHP+PV supplies, energy storage, building heating and electrical demands with system level control

- CHPV model validated against 2 independent designs & 1 real system

Key conclusions so far

- High variation in CHPV system configurations
- High variation in control

Further work

- Optimized CHPV system design & sizing is critical to decision making processes for clients and designers



Q?

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LIFE CHANGING
World Shaping

A member of the Russell Group

# CHPV System Optimisation

Ameer Al-Khaykan

PhD student University of Liverpool

supervisor : Dr. John Counsell

20 January 2016

BRE (Garston, Watford,UK)

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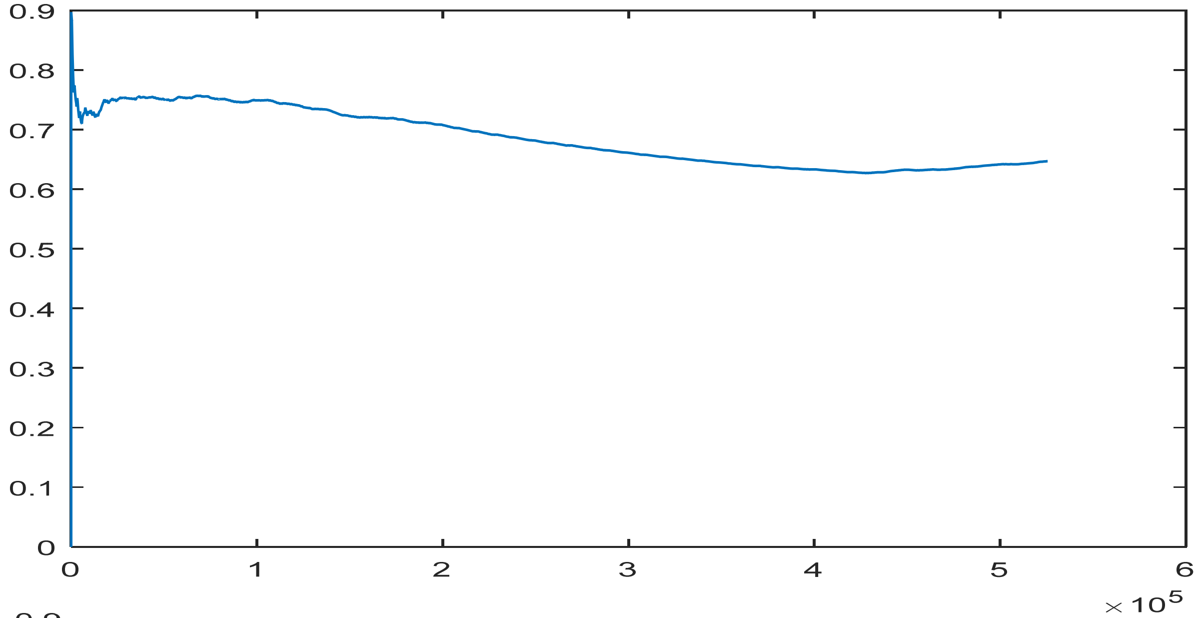
# Optimisation's Goal

- Meet the needs of consumer energy demand
- Minimize the capital cost and running cost of the total energy system
- Increasing the total system's efficiency
- Increase the reliability of the system
- Reducing the $CO_2$ emissions by minimising gas and grid electricity usage

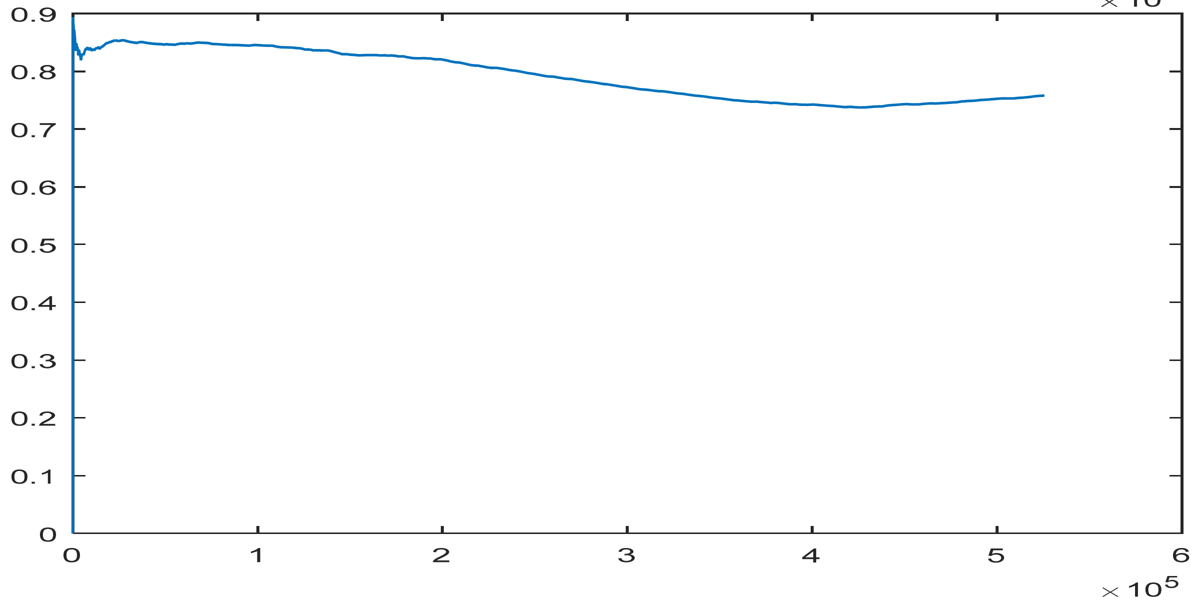
# Key Parameters to optimise

- CHP engine size
- Heat storage size
- Gas Boiler size
- Photovoltaics (PV) area
- Absorption Cooling system size
- Electric Chiller Cooling size

# Example impacts e.g. CHP engine size




CHP size= 13700 W
Co2per year= 2.2*$10^6$ kg




CHP size= 6400 W
Co2per year= 1.68*$10^6$ kg

Same results

# Constraints for Optimisation

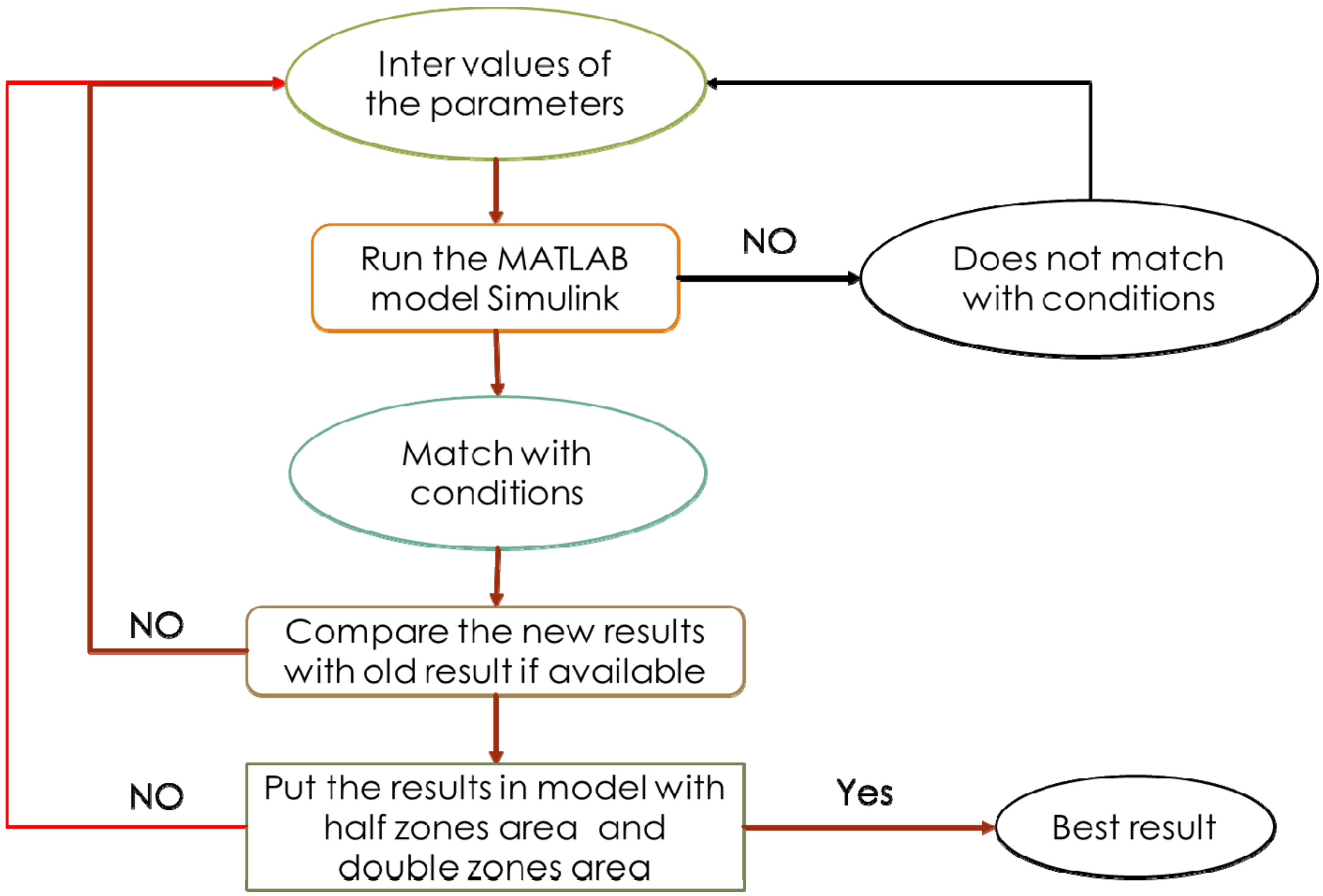
- No electrical export to the National Grid
- Meet the thermal comfort requirements of the buildings (e.g. 21C heating and 24C cooling)
- Meet the electricity demand at all times.
- The hot water network is limited to <100C temp at all times including thermal storage tank.
- Meet the domestic hot water demand at all times

# Strategy of optimisations

I consider four approaches for optimisation:

1. Generators are controlled to meet demand
2. Generators over supply
3. Generators under supply
4. Ignoring constraints

# Optimisation Methodology



# Importance of Accurate Control

- To enable a seamless controller design method to give perfect control to satisfy all constraints regardless of sizing of energy plant/systems.
- The accurate control will allow design metrics such as the size of CHP/m2 for given system topology.

# Initial Study Design Metrics

For the Copperas Hill Project the optimum number for each parameter :

1- CHP Engine size = 0.478 w per m2

2- G.B. size = 0.956 W per m2 (efficiency 90%)

3- heat storage surface area = 101.32 m3

4- P.V. area = 0.104 m2 per m2

## Future work

# J.A.M. Equations

Thank You