HEAT

Sustainable Energy Futures, Annual Conference 2016

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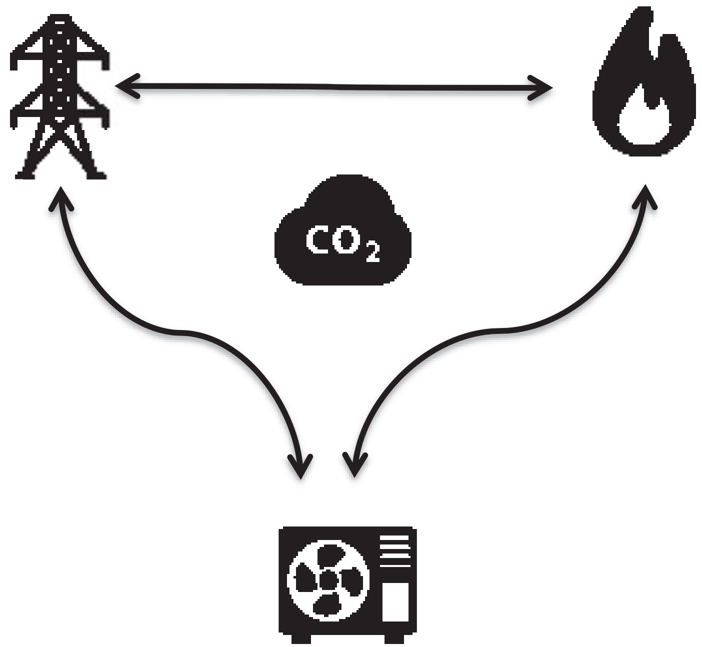
Group 7

Poster No: 09-14

Introduction

Non-residential applications

Residential applications



Industrial applications

Simulating Heat and Electricity Demand in Urban Areas

Panagiotis LADAS

Supervisors:
Dr. Koen H. van Dam
Gonzalo Bustos-Turu, PhD
Dr. Salvador Acha

Aim & Research Motivation

Background

- 54% of the world's population currently lives in urban areas
- Cities account for around 75% of global energy demand

Challenge: Understanding of the dynamics behind the energy demand in urban areas

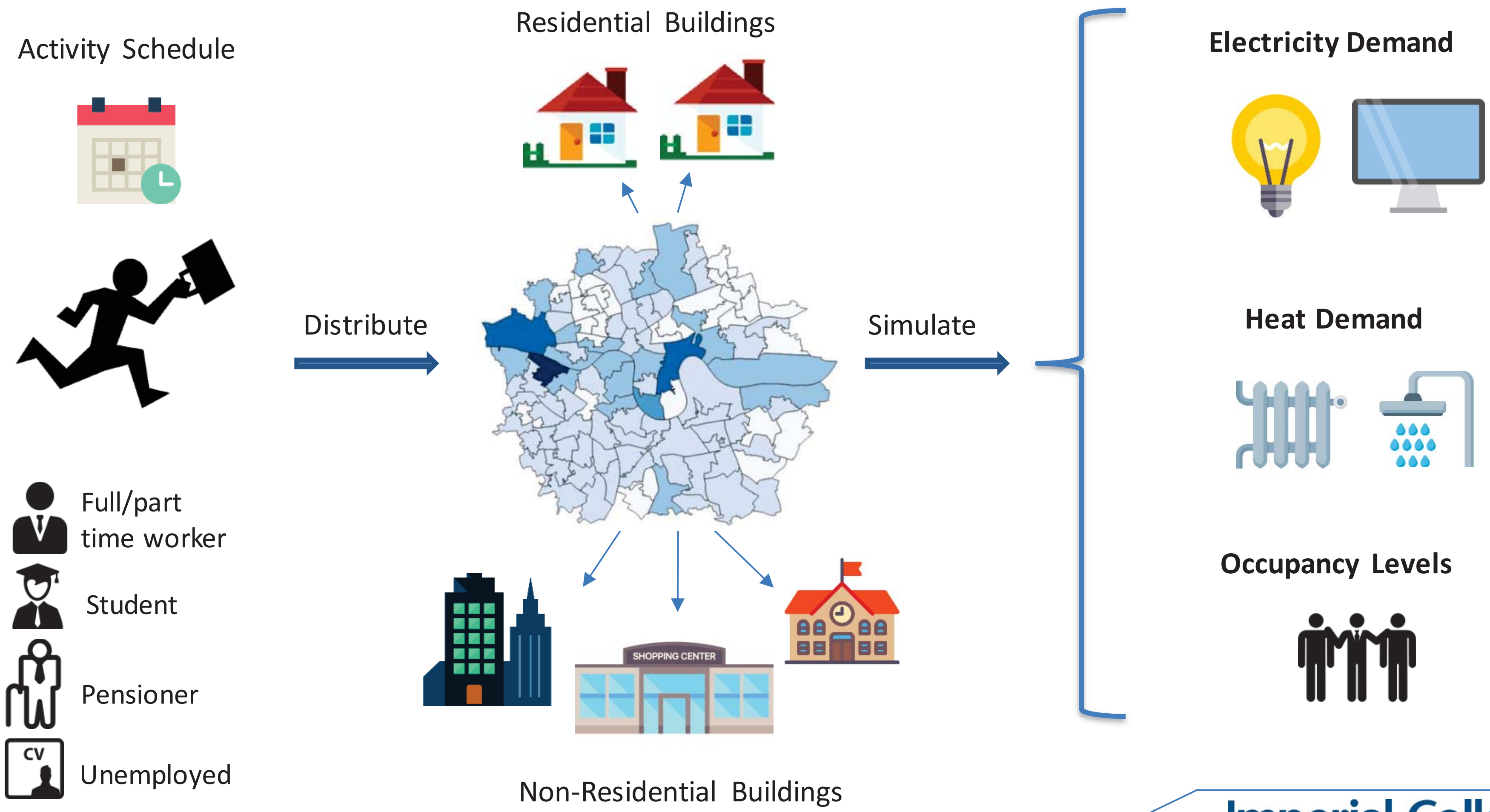
City of London

Aim: Simulate the spatial and temporal energy loads in

- Residential buildings
- Non-residential buildings

Methodology

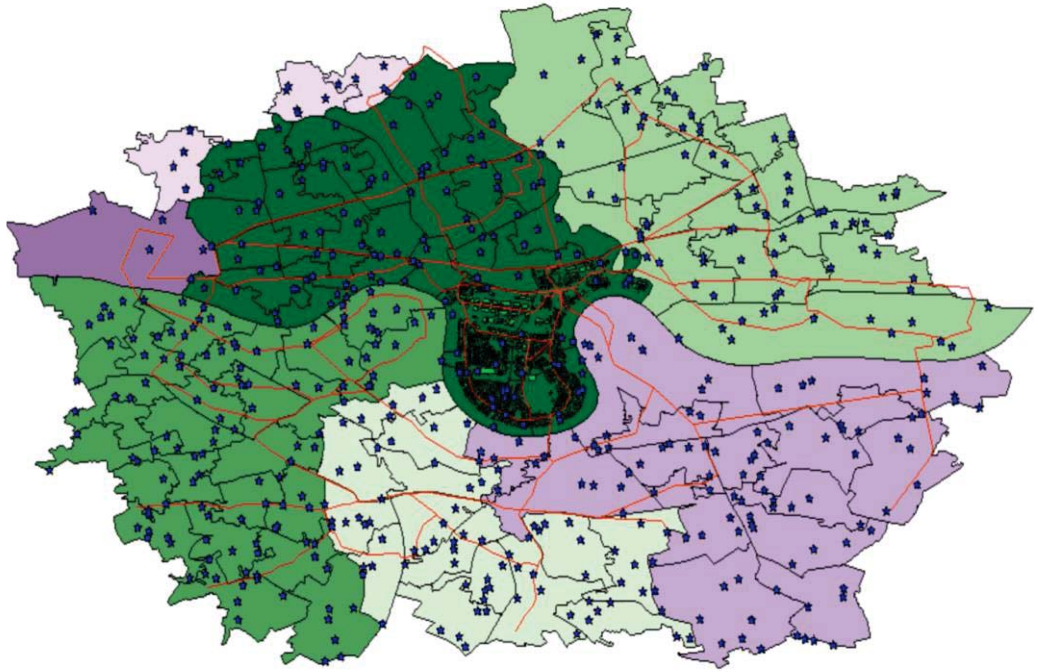
Agent-Based Model (ABM) following a **bottom-up approach**



Case Study

Isle of Dogs area (East London)

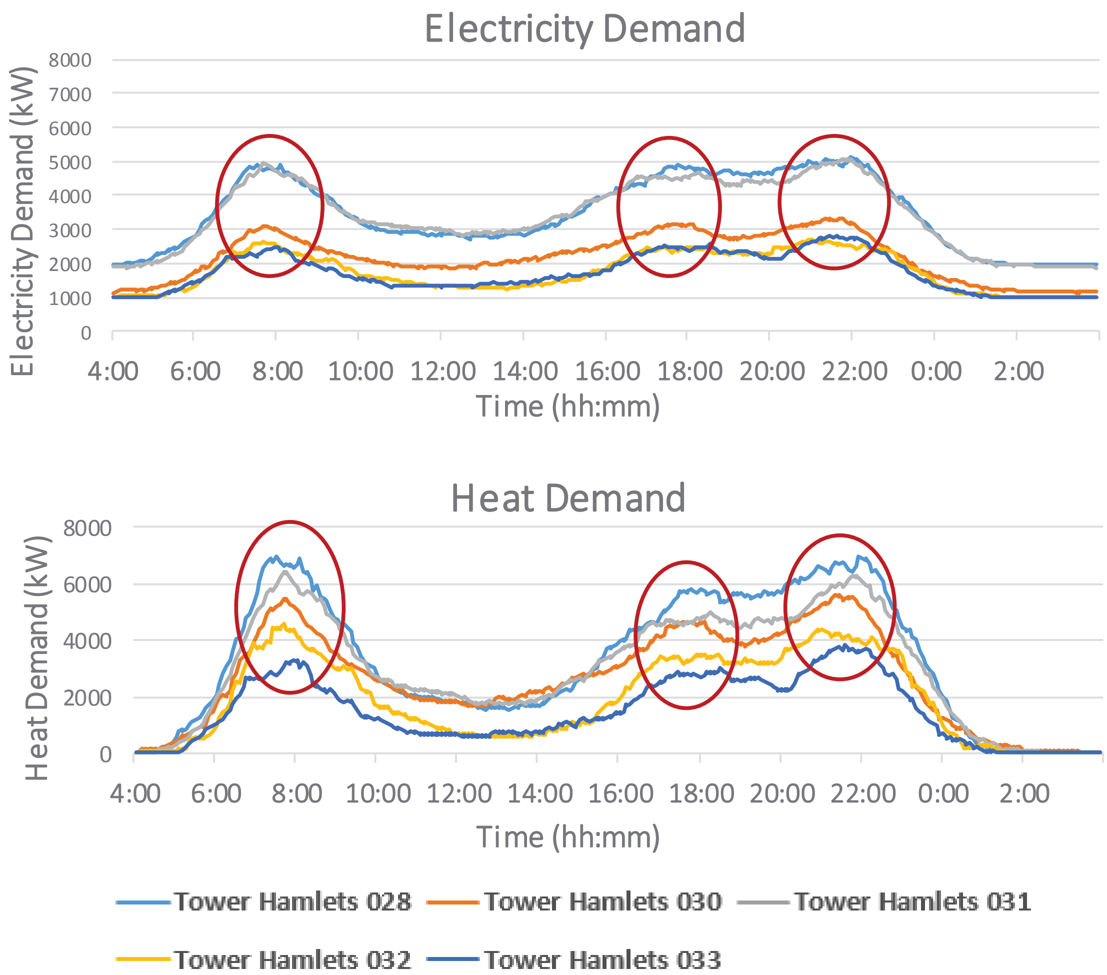
- London Borough of Tower Hamlets
- 42,000 residents
- 93,000 people work in the area



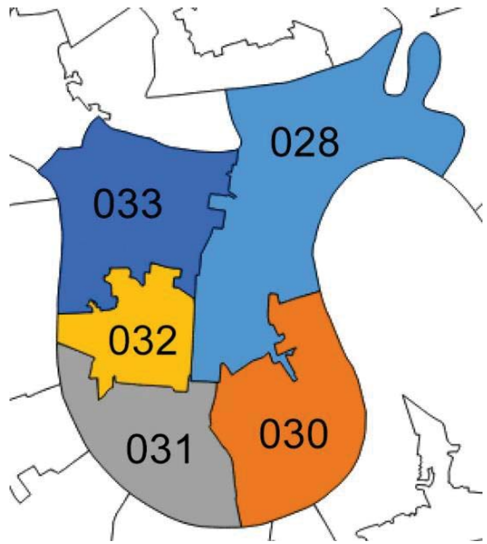
Simulation of the greater area of London from SmartCity Model

Results: Daily Profiles
Residential Buildings

Winter - Weekday



Tower Hamlets

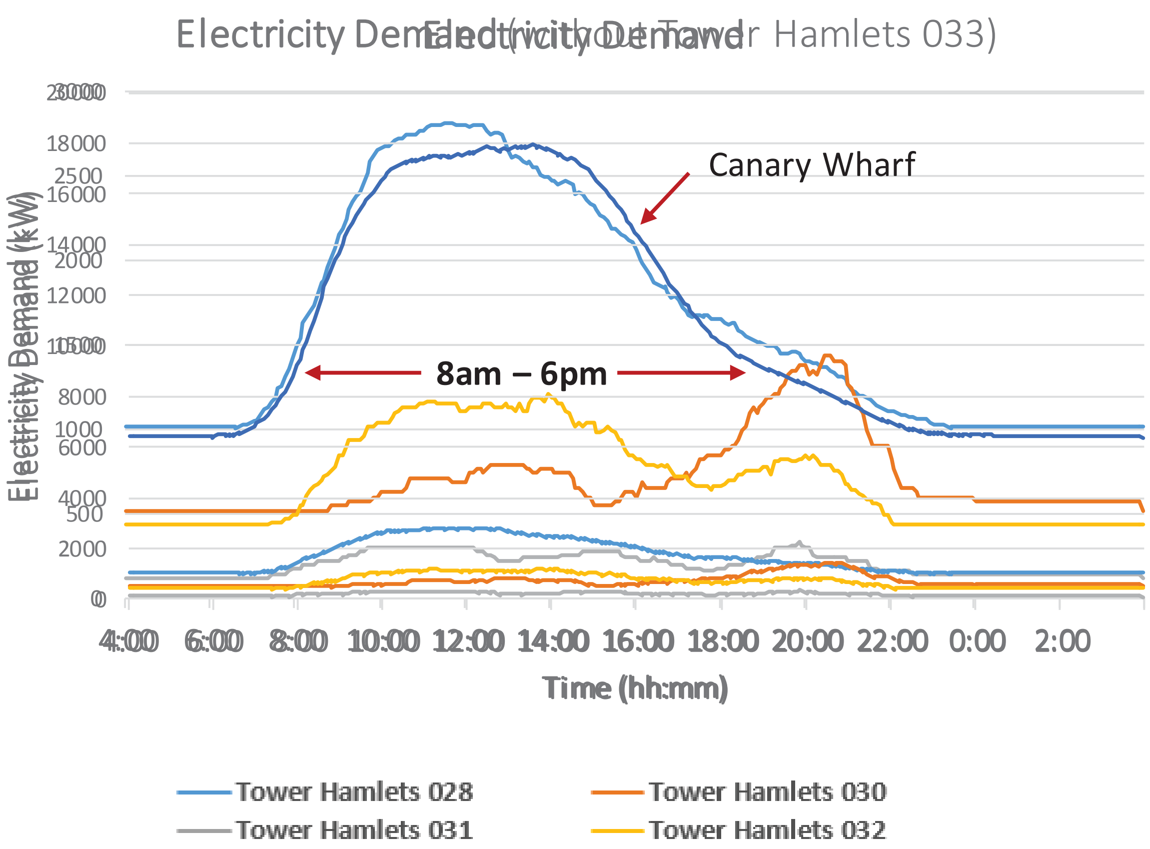


Peak Demand

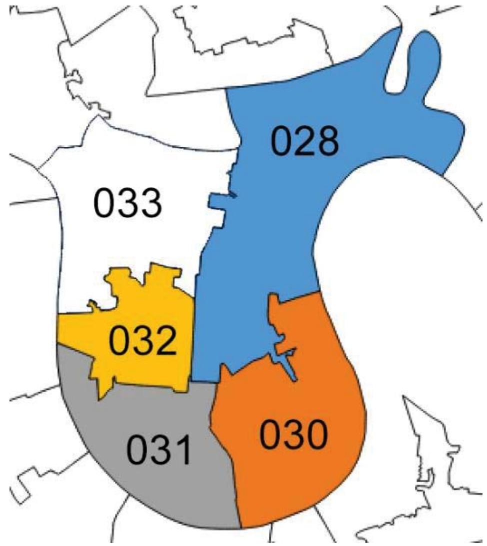
- **7-8am**: wake-up
- **5-6pm**: back from work/school
- **10pm**: all agents at residences

Results: Daily Profiles
Non-Residential Buildings

Winter - Weekday



Tower Hamlets



<u>Peak Demand</u>

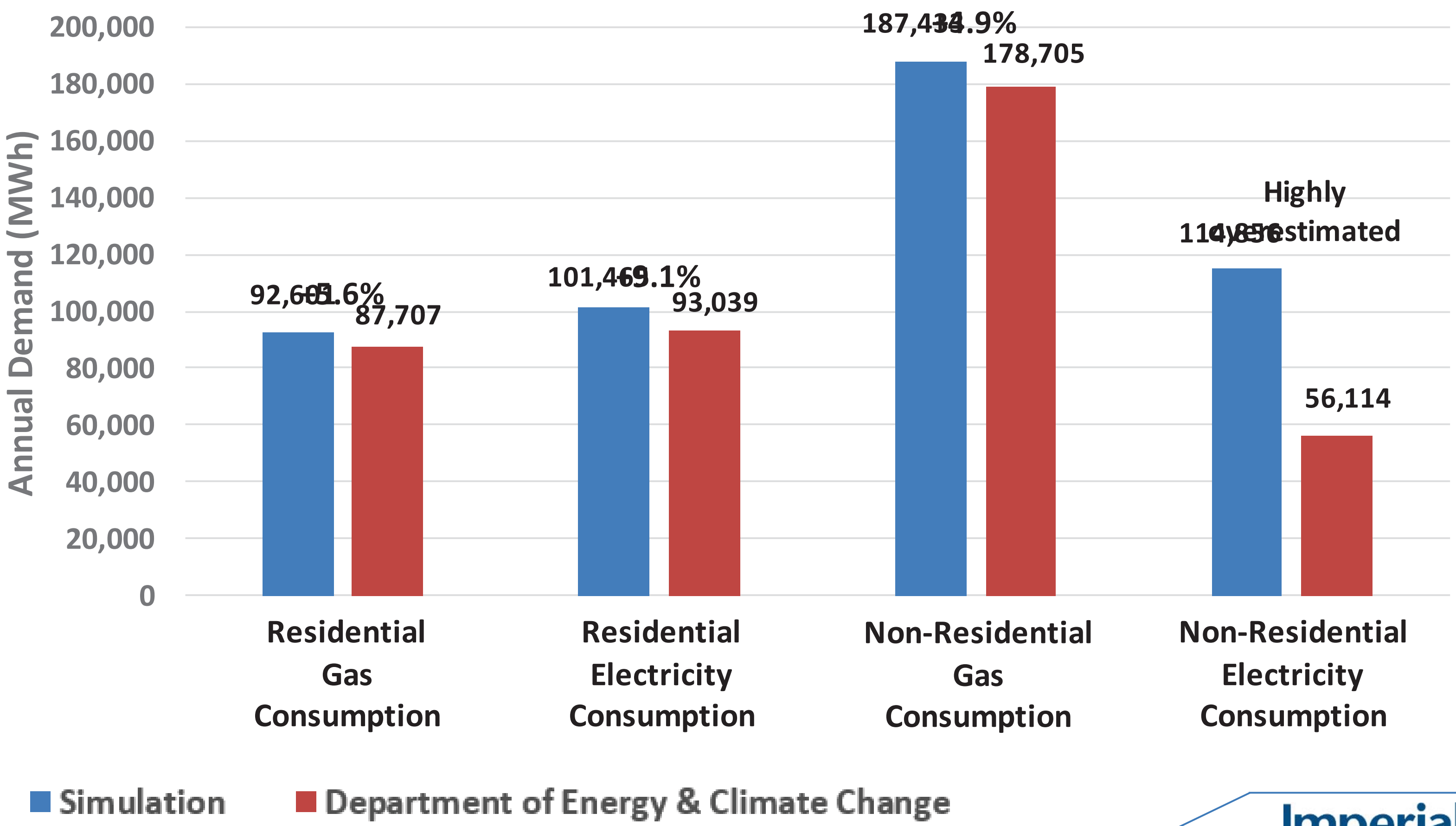
8am-6pm: working hours

- Schools
- Offices
- Commercial Stores

Results: Annual Demand

Validation

Annual Demand VS DECC data



Conclusions

Process

- Reproduces trends of real demand
- Test different scenarios
- Re-usable

Non-Residential Demand

- Lack of adequate data
- Calibration of the results

Computational Tool

- Decision support tool for key stakeholders
- Incorporates end-user behaviour

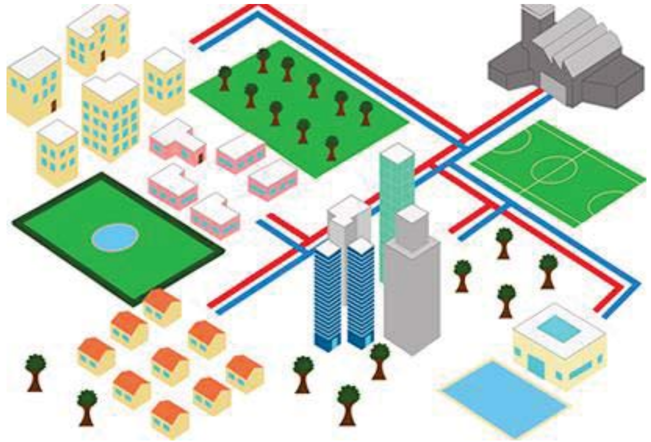
Agent-Based Modelling of Residential Heat Demand in a District Heating Network

Maria BRIOLA

Supervisors:
Dr. Koen H. van Dam
Dr. Christoph Mazur

Scope of the thesis

District Heating Networks (DHN)



- Heat for an area is produced centrally
- Heat is distributed through pipes

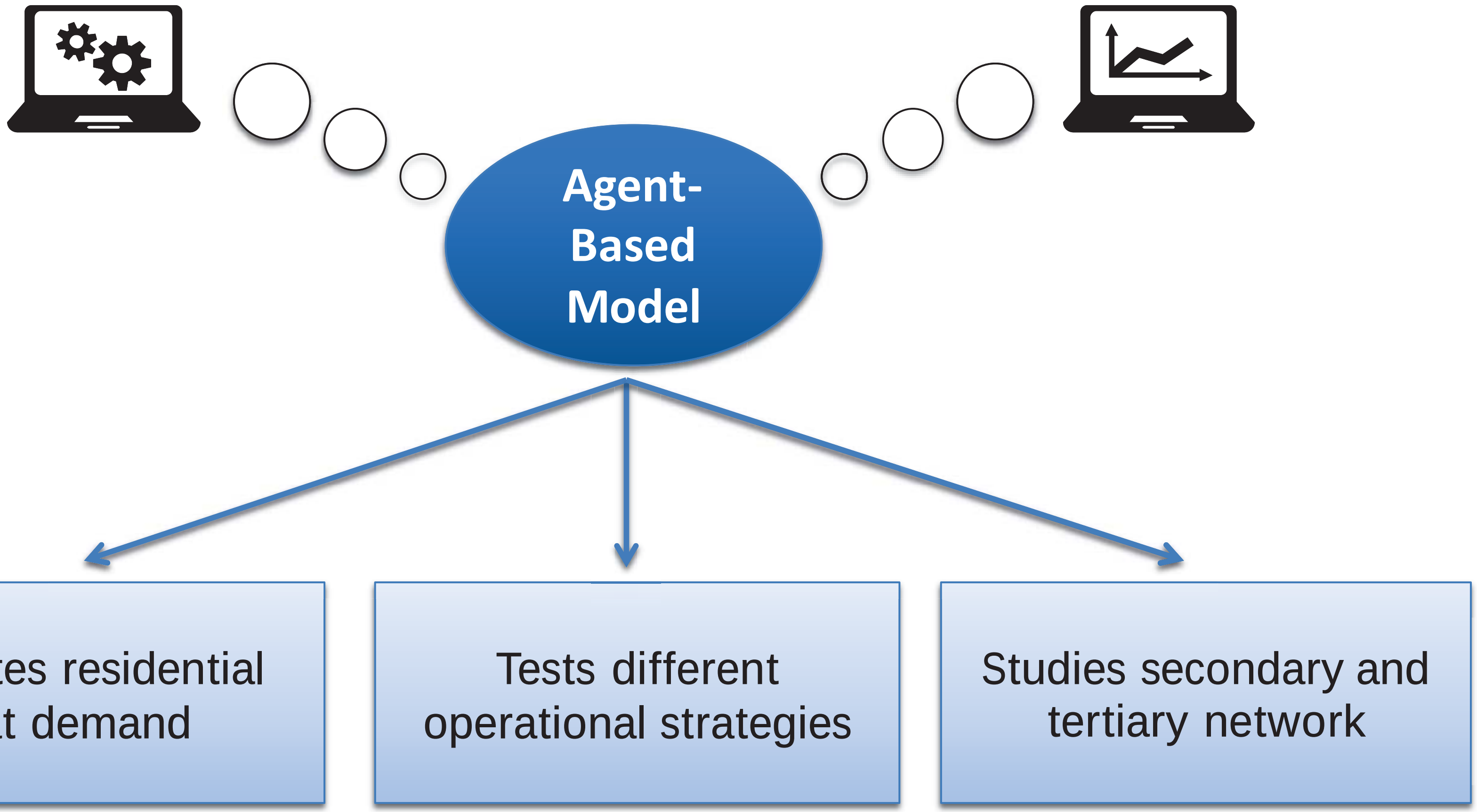
Challenges of DHN

- Demand side barriers
- Residents' mistakes when using thermostats
- Faults in secondary consumer systems

Aim

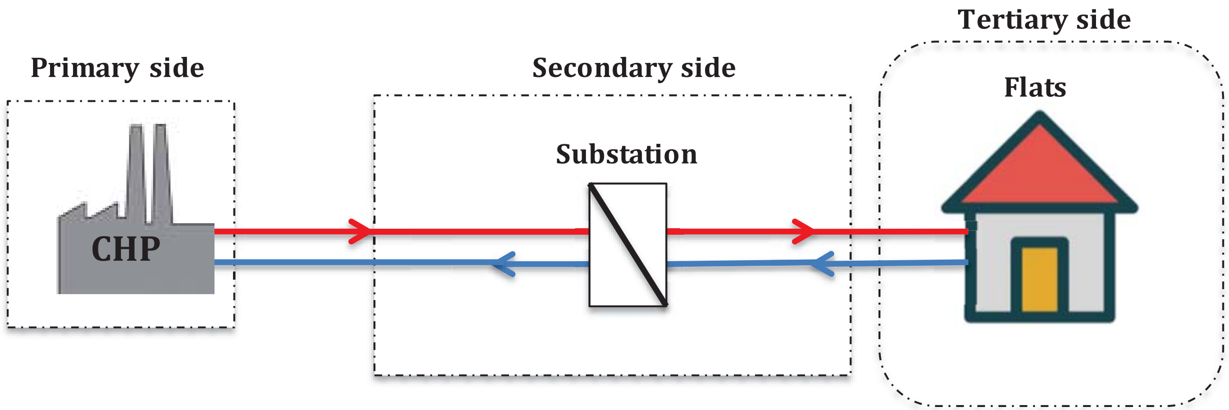
Investigate different strategies that could be applied to achieve optimal operation and maximum efficiency of DHNs.

Methodology



Layout of the DHN

Layout of the DH block examined in this model



Tertiary or demand side of DHN

- Under-floor space heating

- Domestic Hot Water system

Case study

Queen Elizabeth Olympic Park

East Village (residential area)

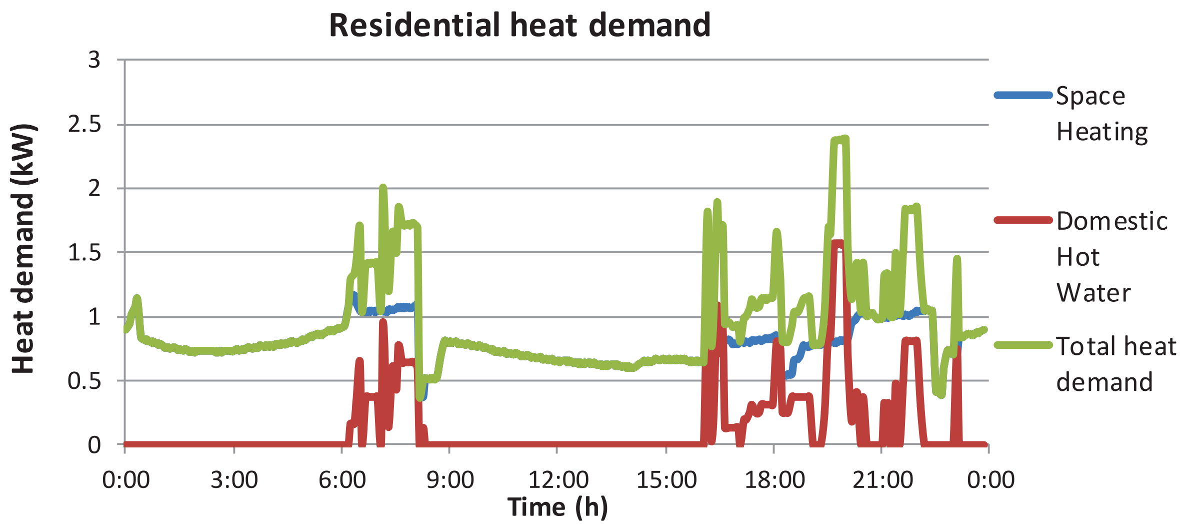
Problem with the DHN

- High return temperatures
- High heat losses

Solution

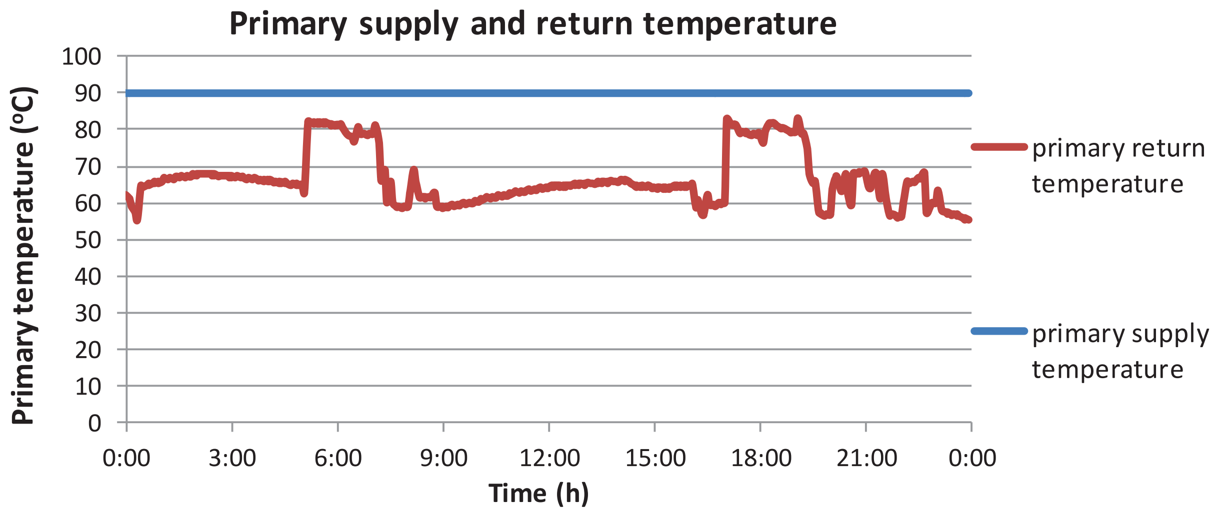
- Apply the ABM
- Test three scenarios
  - Scenario 1: Tank resizing scenario
  - Scenario 2: DSM scenario (improved and ideal case)
  - Scenario 3: Alteration of boosting periods scenario

Baseline scenario results



Morning peaks: residents prepare for work

Evening peaks: residents return from work



Average difference between primary supply and return temperature: **25ºC**

Comparison of scenarios

	Change in heat losses	Change in difference between supply and return temperature	Change in fuel consumption	Change in primary return temperature
Scenario 1	-0.7%	+0.96%	-0.07%	-0.32%
Scenario 2 (improved case)	-3.16%	+3.3%	-0.76%	-1.3%
Scenario 2 (ideal case)	-1.8%	+13%	-1.38%	-4.6%
Scenario 3	-12.3%	-	-2.7%	-

- **Scenario 1**: lowest improvement
- **Scenario 2**: lowest return temperatures and higher difference between supply and return temperatures
- **Scenario 3** lowest fuel consumption and heat losses

Conclusions

Case study

- Combination of scenario 2 and 3 could be the best solution

Stakeholders

- Effective collaboration must be achieved

Model

- Could be used as a decision support tool for DHN operators

Modelling and optimisation of a district energy centre

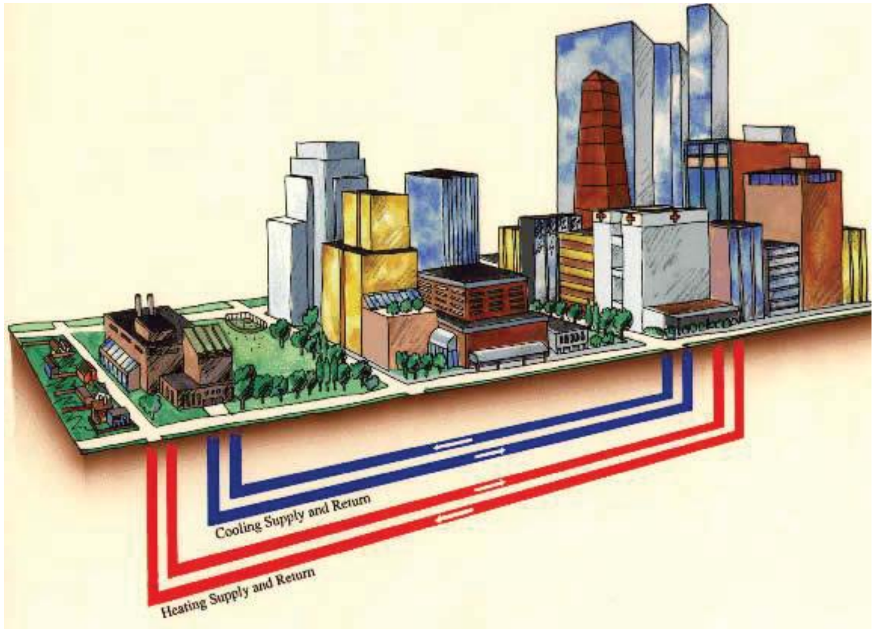
Adrian REGUEIRA-LOPEZ

Supervisors:
Prof. Nilay Shah
Dr. Romain Lambert

Overview

District energy schemes:

- Centralized energy production
- Economies of scale



Energy centers:

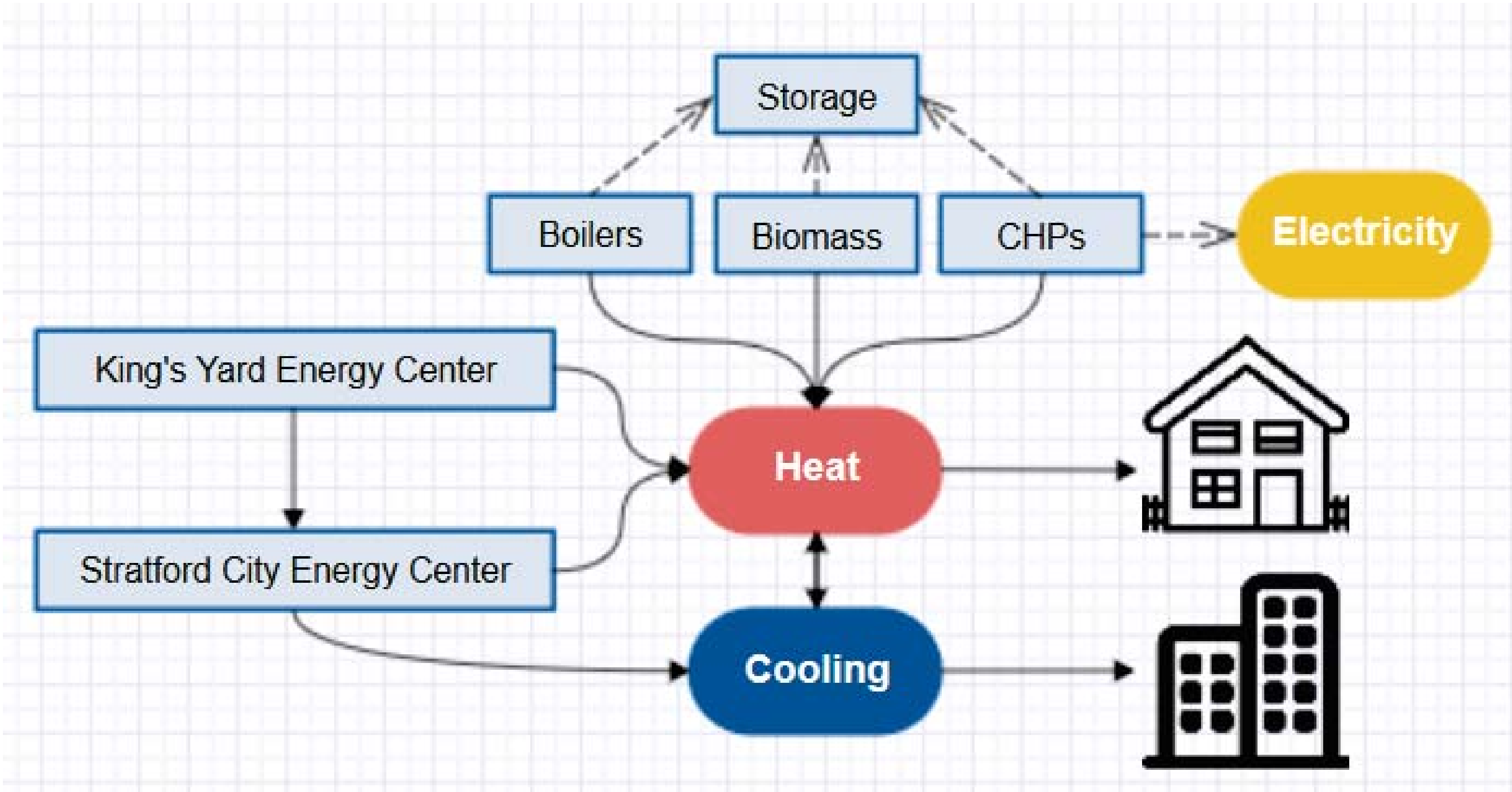
"Big" equipment
+ Several technologies

Efficiency + CO_2 savings

→ **System more complex than a domestic boiler**

Need for an optimisation?

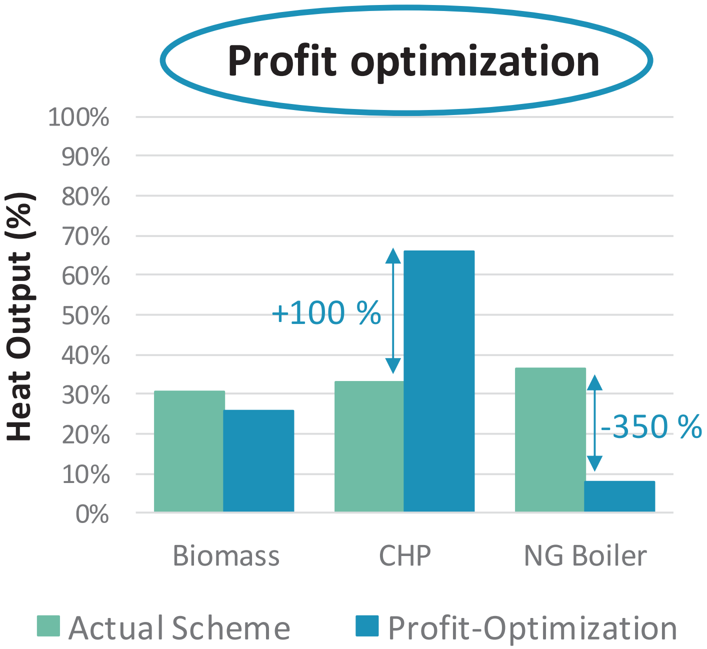
Queen Elizabeth Olympic Park

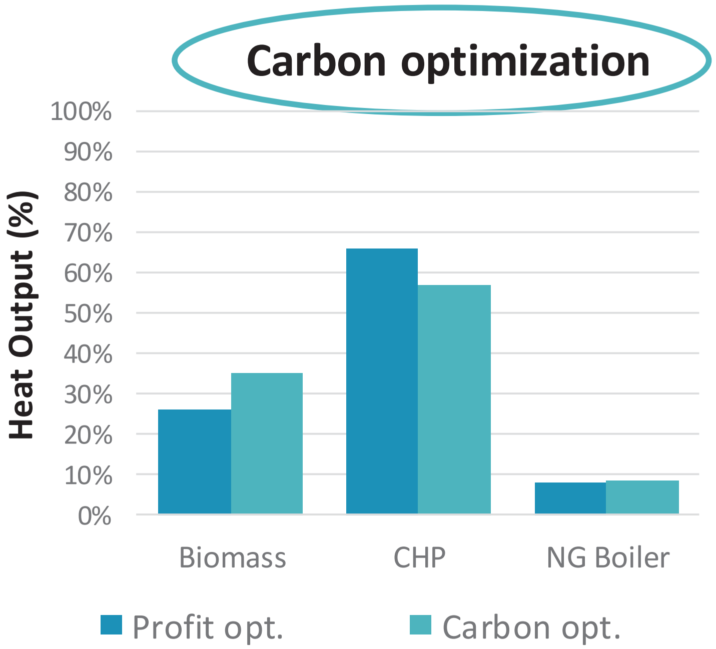


➔ Too many factors to operate "manually" = <u>Model</u>

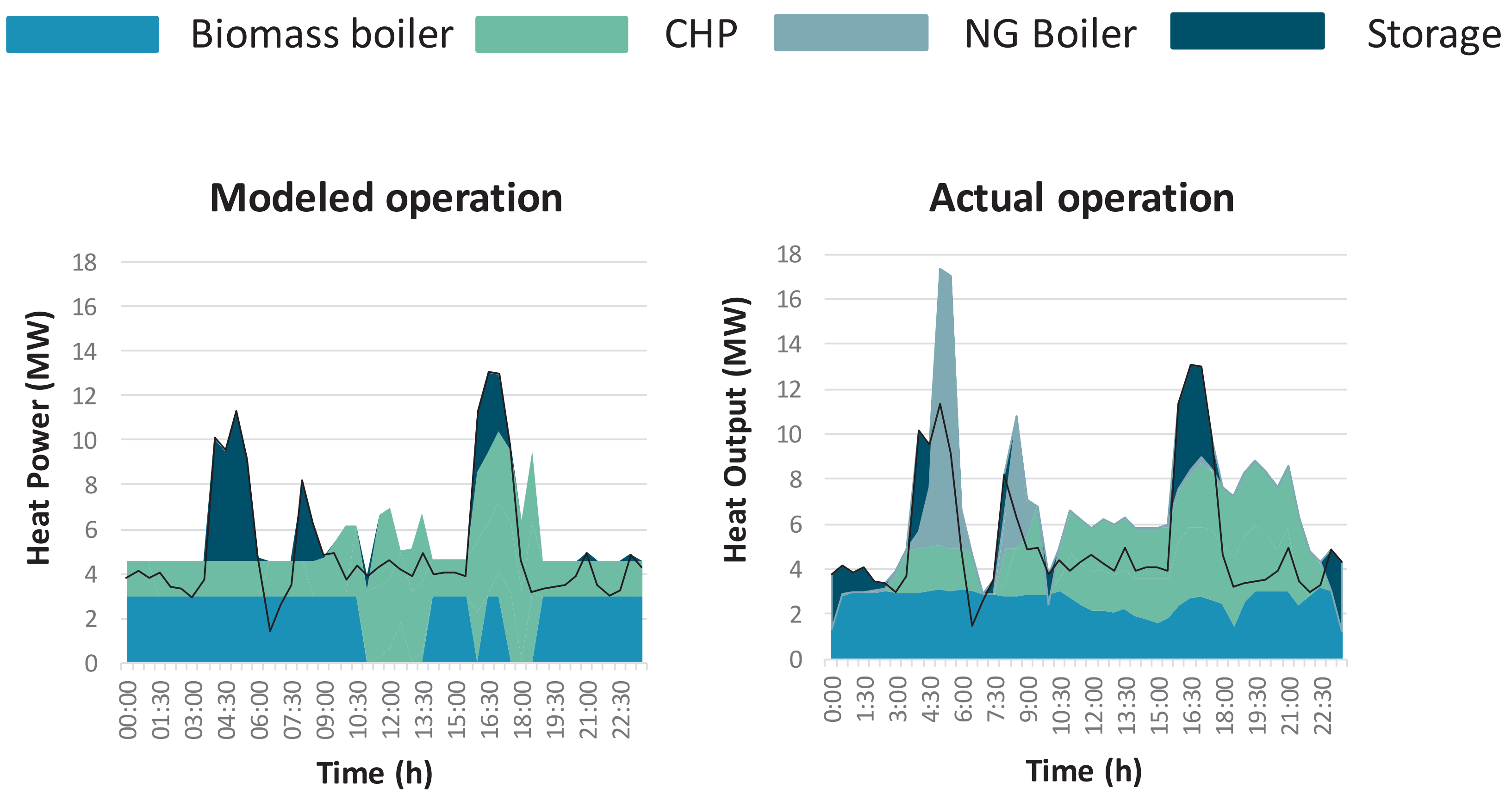
Results: annual

	Heat carbon int. (gCO2/kWh)	CO_2 emissions (tons)	Profit (£)
Profit opt.	90.5	12.7k	5.73m
Carbon opt.	83.3	11.7k	5.36m
Actual scheme	103	-	-





Results: daily profiles



Conclusions

Energy Center Operation

- In order to achieve maximum efficiency in DE schemes, energy centers operation should be based on an optimization model.

Model

- Carbon emissions savings and higher profits can be realized through the optimised operation

Operation-support tool

- The proposed model could be used and further developed as an effective decision support tool for the energy centres operation

Modelling and optimisation of a district heating network's marginal extension

Axelle DELANGLE

Supervisors:
Prof. Nilay Shah
Dr. Romain Lambert
Dr. Salvador Acha

Aim & Research Motivation

District heating networks (DHN):

- Well known & mature technologies
- Expansion already considered in several DHNs

➔ **Limited research on DHN expansion**

Main objectives:

- Modelling approach
- Strategy to design & operate the energy centre
- Connection scenario to select

Case study: Barkantine

Existing network:
- 22 buildings connected
- 2.4 km of pipes
- One existing energy centre

Extension considered:
- 31 buildings to connect
- 3.5 km of pipes
- 12 years horizon time

Methodology

Heat demand analysis

- Scenario 1
- Scenario 2

Design of the energy centre

Model key inputs → **Problem statement** → **Constraints** → **Products** → **Model key outputs**

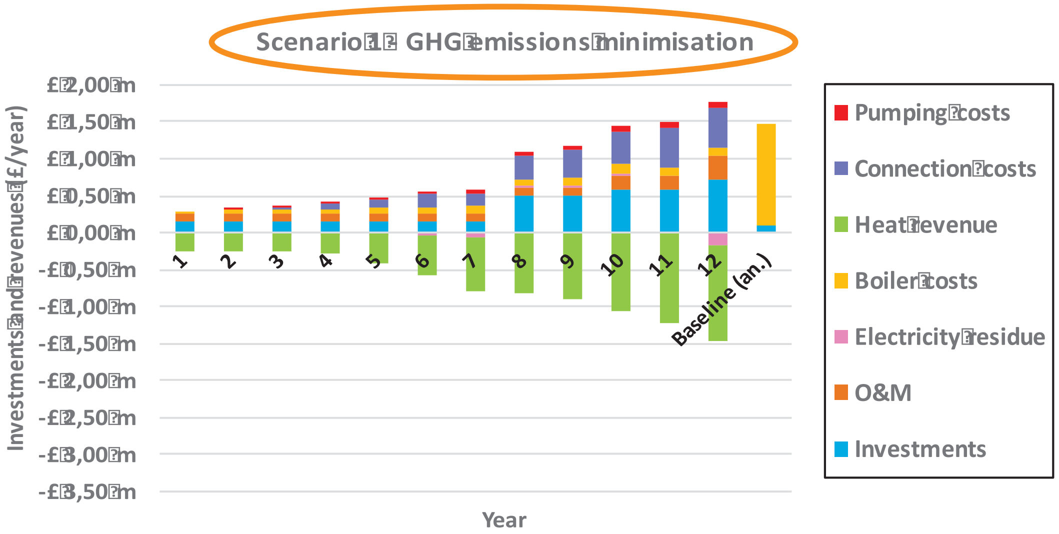
Maximise net present value or minimise GHG emissions under given constraints.

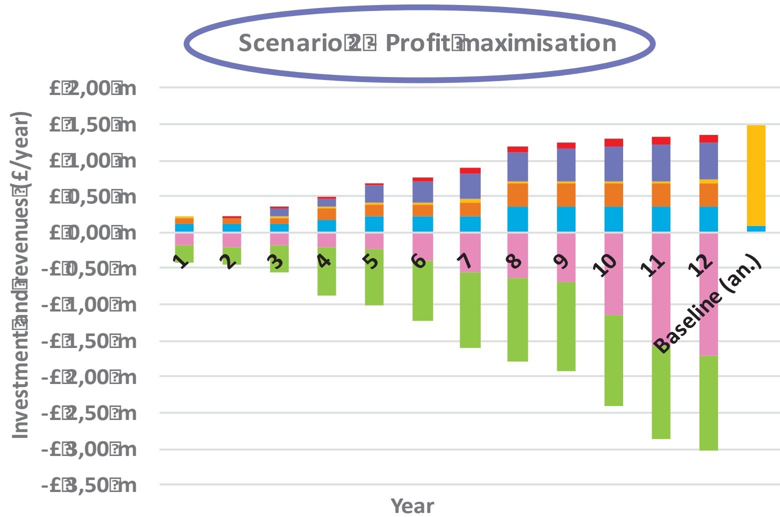
Spatial network extension costs

Main results

Optimisation performed	Objective function	Scenario 1 (slow connections first)	Scenario 2 (quick connections first)
Profit maximisation	Net Present Value (£)	£10,101,800	£13,173,700
GHG emissions minimisation (DUKES)	GHG emissions (t_{CO2eq})	1,670	1,920

Table 1: Design of the energy centre





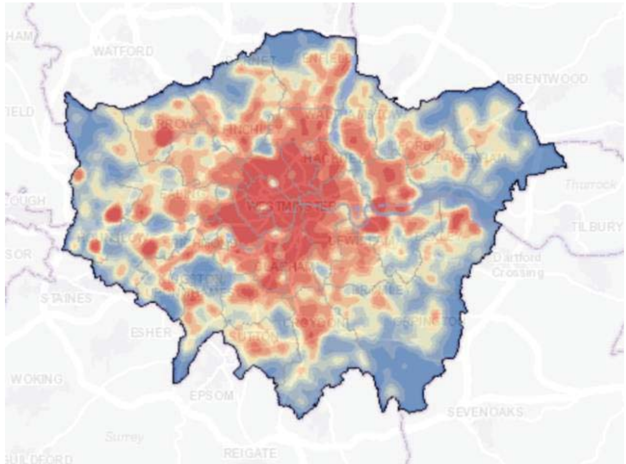
➔ **Not financially viable**

➔ **Financially viable**

Conclusions

DHN expansion:

- Financial & environmental advantages
- Planning strategies are essential
- Using an optimisation approach is crucial



Barkantine case study:

- **Costs** optimisation performed: **Scenario 2.**
  → **Financially viable**
- **GHG emissions** minimisation: **Scenario 1.**
  → **Additional subsidies required**

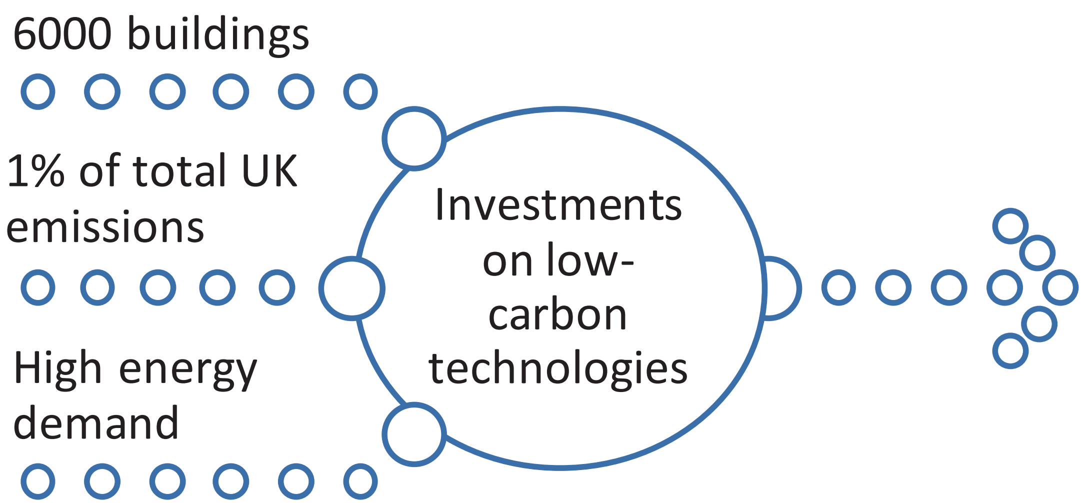
The model developed can be applied to other DHNs.

Modelling and Optimisation of Distributed Energy Resources in Food Retail Buildings: An Investment and Management Approach

Aspasia GEORGAKOPOULOU

Supervisors:
Dr. Salvador Acha
Dr. Christos N. Markides
Prof. Nilay Shah

Research motivation and aim of the project



Combined Heat and Power (CHP)

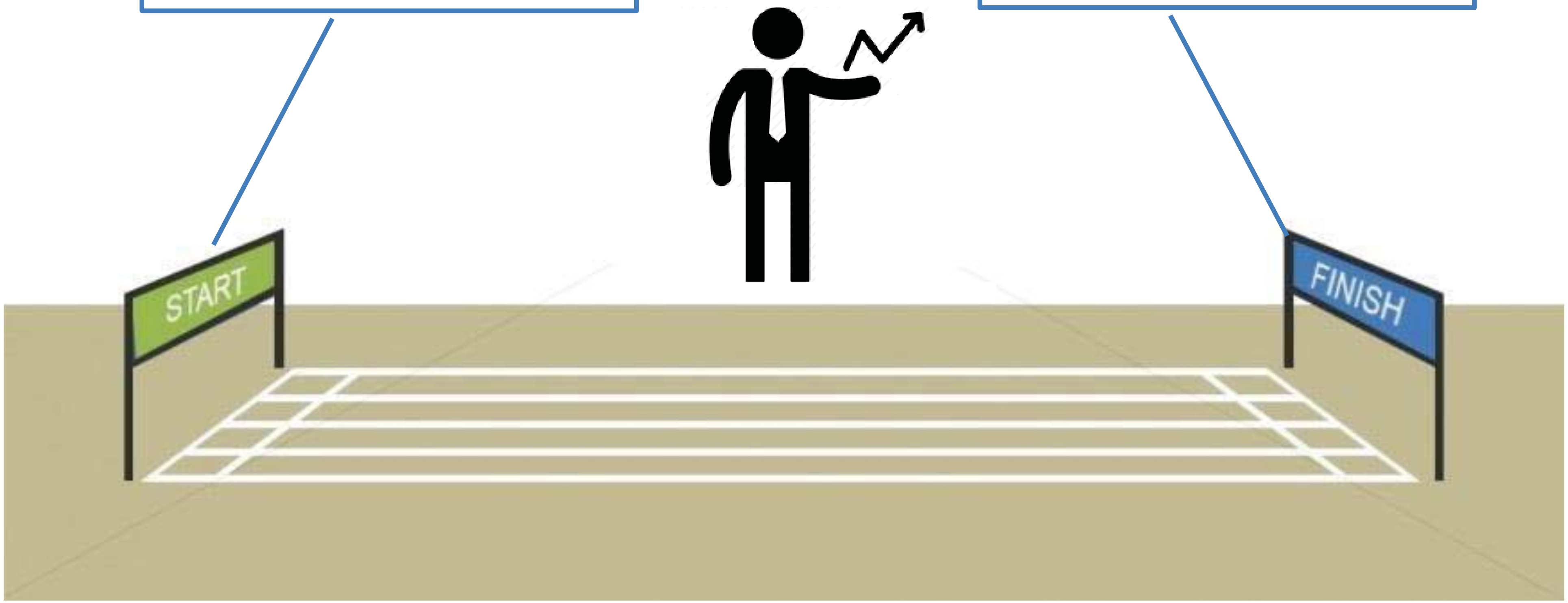
Aim of the project:

"Optimal implementation and operation of gas-fired internal combustion CHP units, when integrated with heat recovery and conversion technologies."

Method:
Optimisation Model

- ✓ *Gas & Electricity prices*
- ✓ *Technology options*
- ✓ *Energy demand*
- ✓ *Fuel employed*

- ✓ *Optimal technology*
- ✓ *Operational strategy*
- ✓ *Total cost*
- ✓ *Total emissions*



Method: Case studies

First case study: Supermarkets
- Single-CHP
- CHP+ORC

Second case study: Distribution Centres
- Single-CHP
- CHP+ORC
- CHP+Absorption chillers (AC)

Business-as-usual scenario

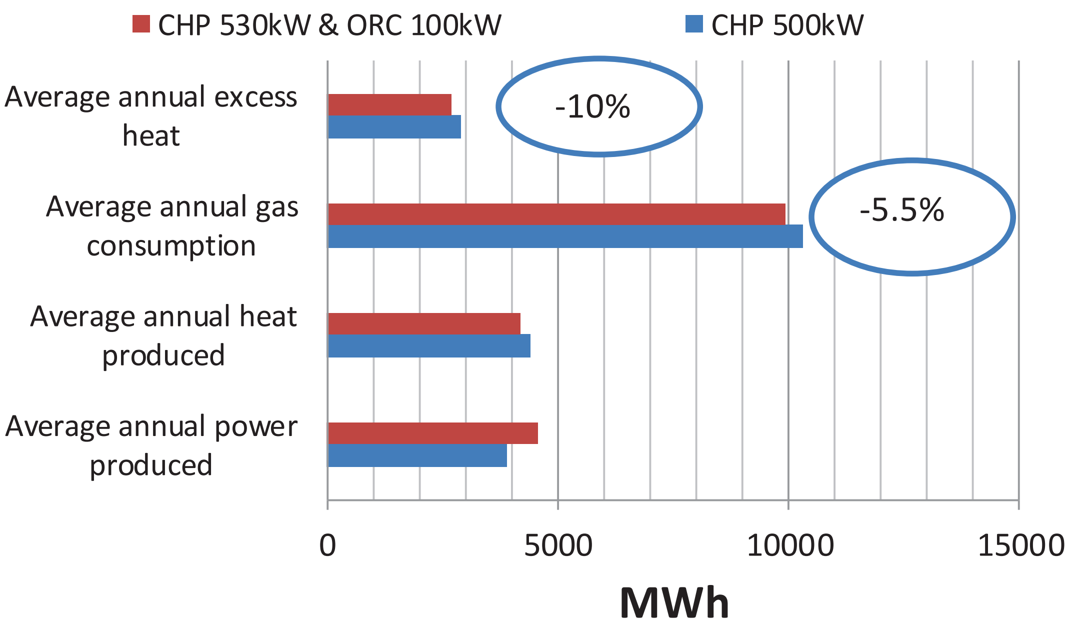
→ Electric demand

→ Heat demand

→ Cooling demand

Results: first case study

CHP 530kW ORC 100kW	Average savings per year (£)	Savings (%)	Average carbon emissions reduction per year (tn CO_2eq)	Reduction (%)
Minimum cost NG vs Baseline	£193,500	32.5%	430	18.8%
Minimum cost BM vs Baseline	£227,400	38.2%	2260	99.3%



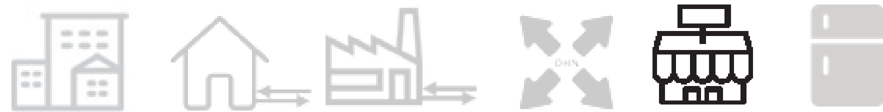
✓ Payback period: 4 years
✓ ROI: 321%

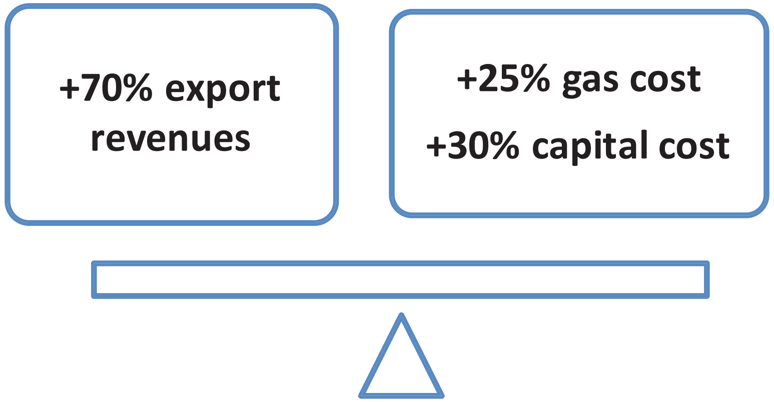
Results: second case study

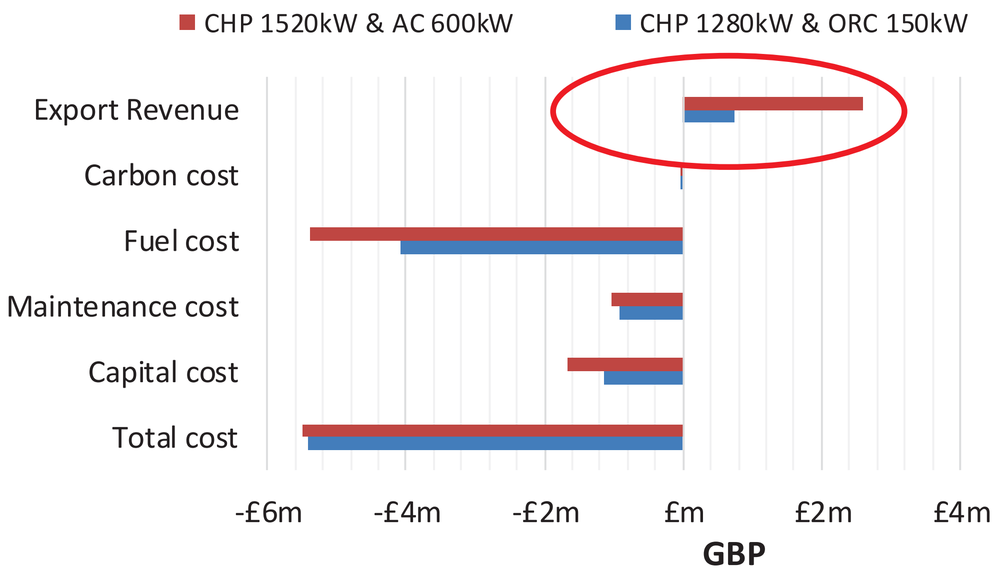
Technology	**CHP 1280kWe & ORC 150kWe**	**CHP 1520kWe & AC 600kWth**
Fuel	**Biomethane**	**Biomethane**
Average annual cost savings	37.8%	37.1%
Average annual carbon savings	99.8%	99.8%
IRR	37.8%	29.3%
ROI	277%	186%
Payback period	4 years	5 years

Total cost for CHP+AC **1.25%** higher than for CHP+ORC

Results: second case study







<u>CHP+ORC Operational strategy:</u>

- No grid-imported electricity;
- **10% of electricity is exported;**
- Electric chiller covering cooling demand
- Boiler not contributing to heat generation;

<u>CHP+AC Operational strategy:</u>

- No grid-imported electricity;
- **40% of electricity is exported;**
- AC covers 40% of cooling demand;
- Boiler provides 15% of heat required.

Conclusions

Optimisation model:
Generic tool for selection of technology portfolios in commercial buildings

Waste heat conversion technologies:
- ✓ Reduced gas consumption
- ✓ Increased CAPEX

Fuel employed:
- ✓ Biomethane for full decarbonisation
- ✓ Natural gas CHP+ORC: 19% emissions reduction

CHP coupled with ORC or AC:
- ✓ Comparable benefits
- ✓ Applications in buildings with high cooling demand

Water-Cooled Refrigeration Systems in the Food Retail Industry

Maria-Aliki EFSTRATIADI

Supervisors:
Dr. Christos N. Markides
Dr. Salvador Acha
Prof. Nilay Shah

Aim & Research Motivation

Supermarket refrigeration: **30%-60%** of total energy consumed in the stores

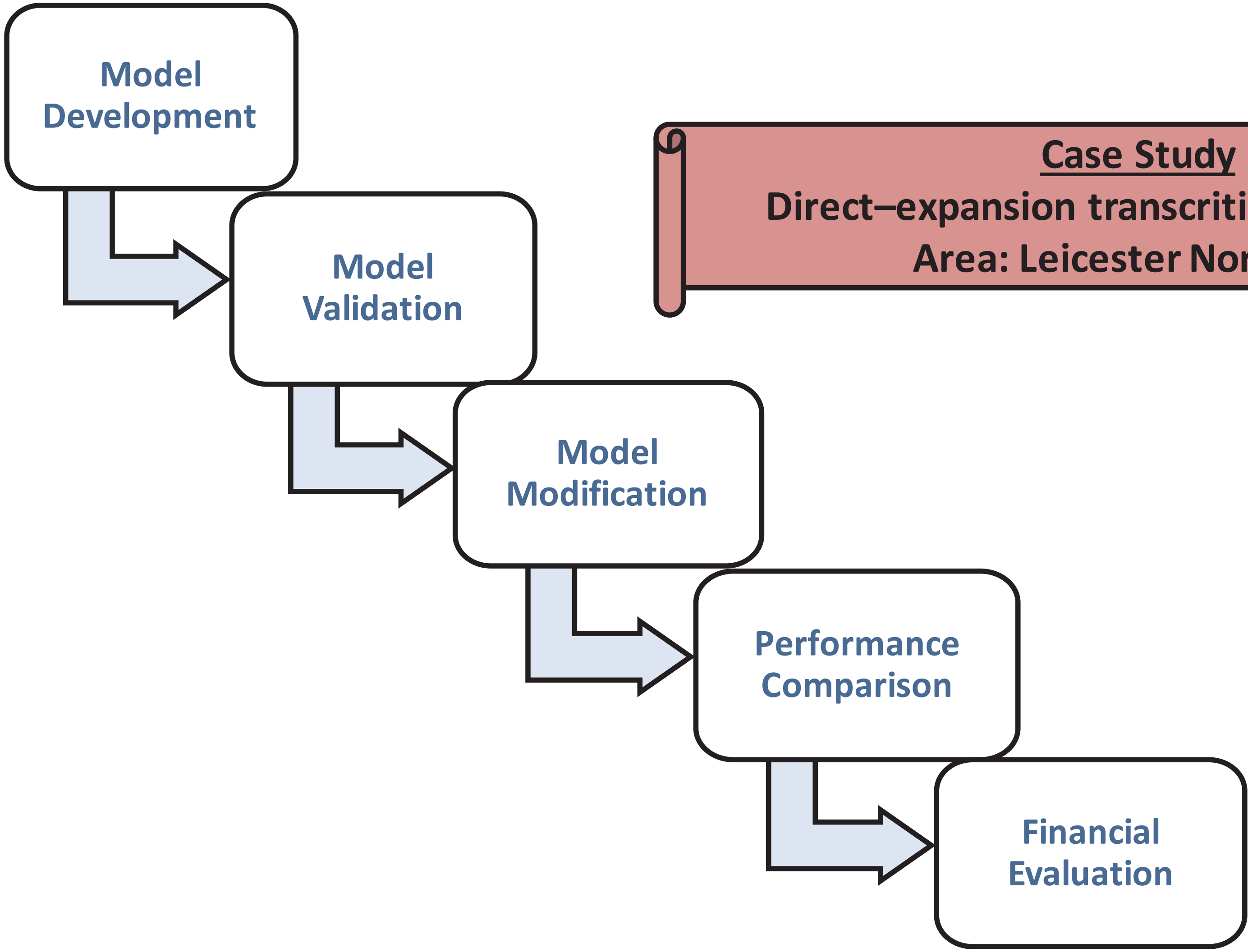
➔ **High amounts of low-grade heat rejected by the air-cooled condensers to the ambient air**

➔ **Current status: Air-cooled condensers situated on the rooftop of the stores**

Typical commercial air-cooled condenser

Could a water-cooled condenser rejecting heat to the soil via an intermediate closed water-circuit address this problem?

Methodology

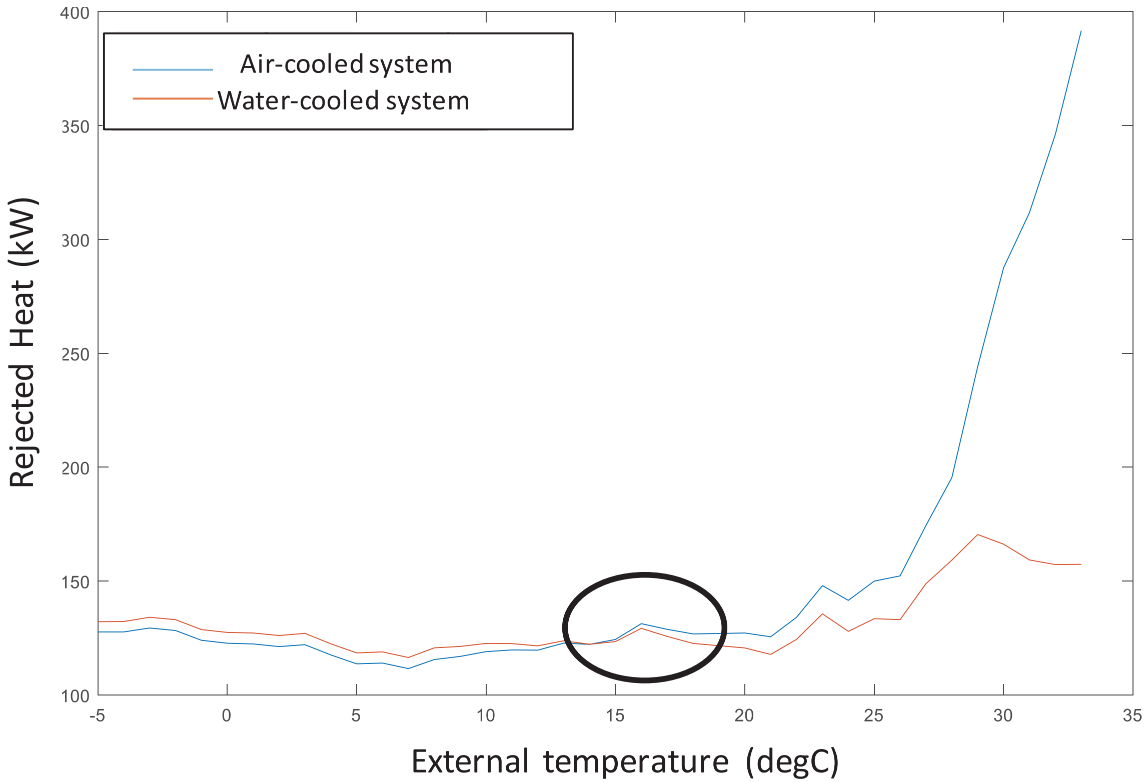


Case Study

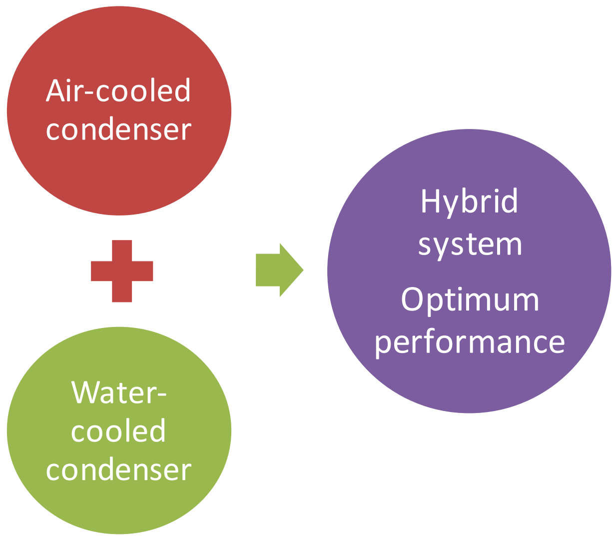
Direct–expansion transcritical CO_2 system

Area: Leicester North, UK

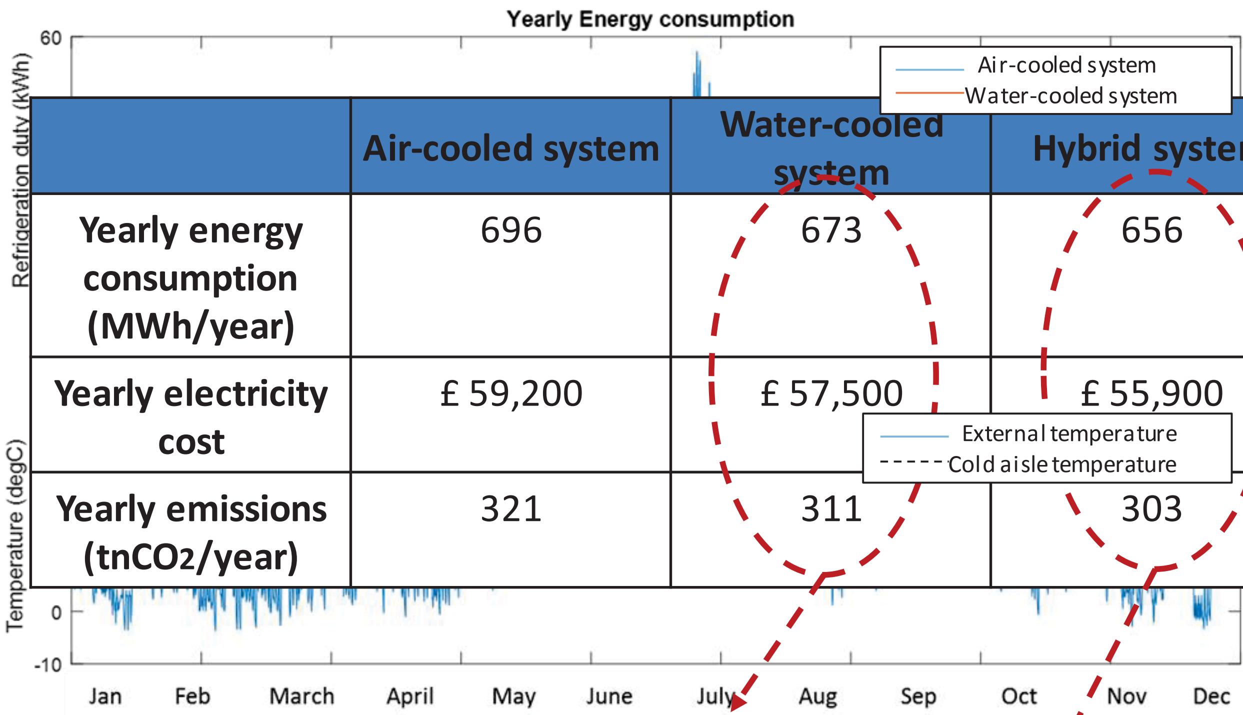
Modelling Results(1/2)



- ✓ **High external temperature**: Up to 5 times less heat rejected by the water-cooled condenser
- ✓ **Low external temperature**: Marginally higher performance of the air-cooled system



Modelling Results (2/2)



	Air-cooled system	Water-cooled system	Hybrid system
Yearly energy consumption (MWh/year)	696	673	656
Yearly electricity cost	£ 59,200	£ 57,500	£ 55,900
Yearly emissions (tnCO2/year)	321	311	303

-3.5%

-5.5%

Marginal energy savings

- **65% of the year** the air-cooled system consumes less energy than the water-cooled system
- **Main reason:** Low average temperature throughout the year

Financial Evaluation

	Retrofit with a Hybrid System	Water-cooled System in a new store	Hybrid system in a new store
CAPEX	**£ 83,000**	**-£ 40,000** relative to BAU	**+£ 7,000** relative to BAU
OPEX relative to BAU	+200%	+150%	+200%
Energy costs per year relative to BAU	-£ 3,500	-£ 1,800	-£ 3,500
Total annual savings relative to BAU	£ 1,800	£ 1,100	£ 1,800
Payback Period	**>10 years**	**Immediate payback**	**4.8 years**

Systems downsized upon design

Conclusions

Air-cooled systems

- Highly dependent on external conditions
- Show higher performance levels in cold ambient conditions

Water-cooled systems

- Less sensitive to external temperature variations
- Systems downsized
- Attractive economics for new stores applications

Model: Reliable but Case specific

Needs to be applied in other systems for a general understanding

Acknowledgments

Dr. Salvador Acha

Gonzalo Bustus-Turu, PhD

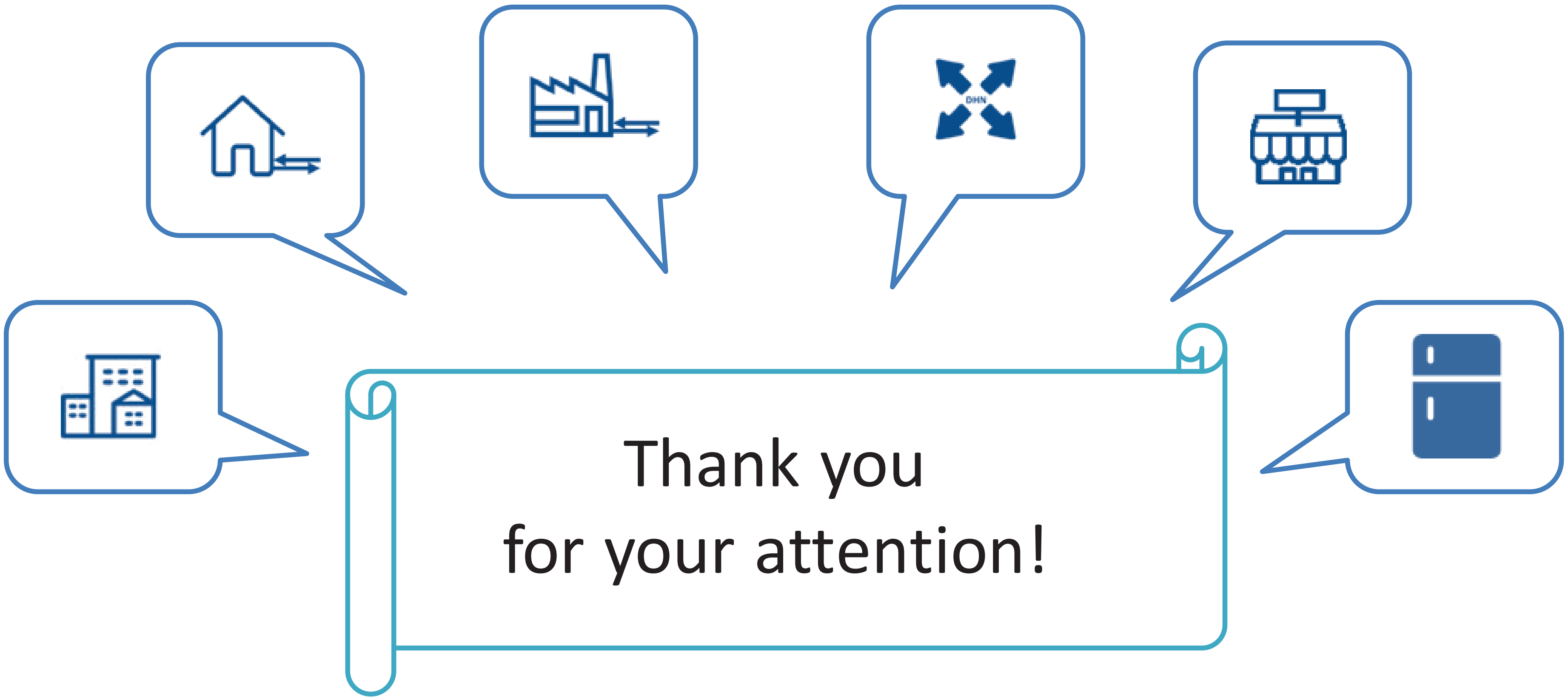
Dr. Romain Lambert

Dr. Christos N. Markides

Dr. Christoph Mazur

Dr. Koen H. van Dam

Prof. Nilay Shah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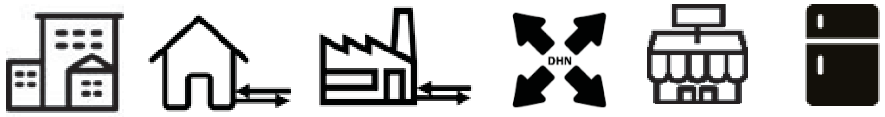
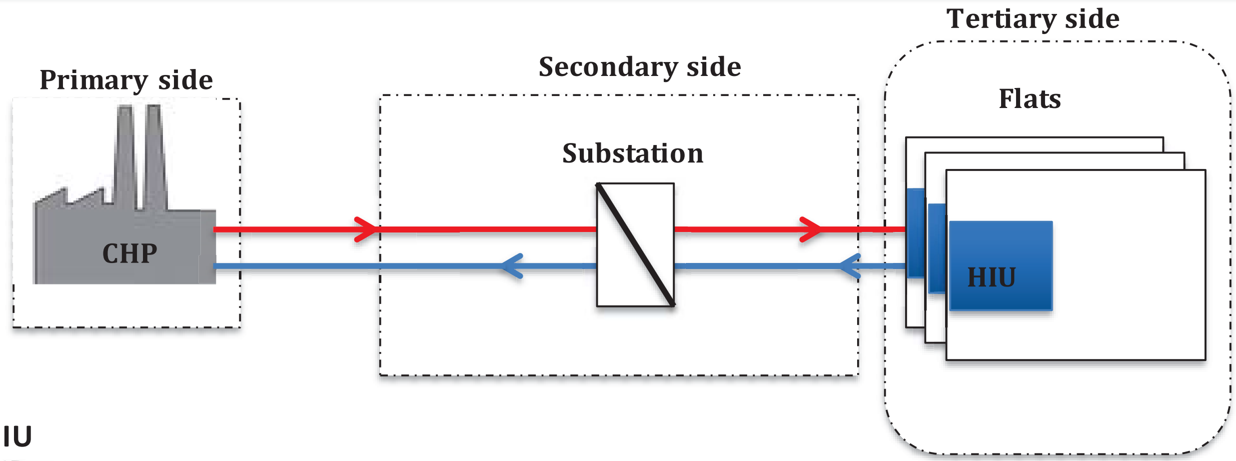
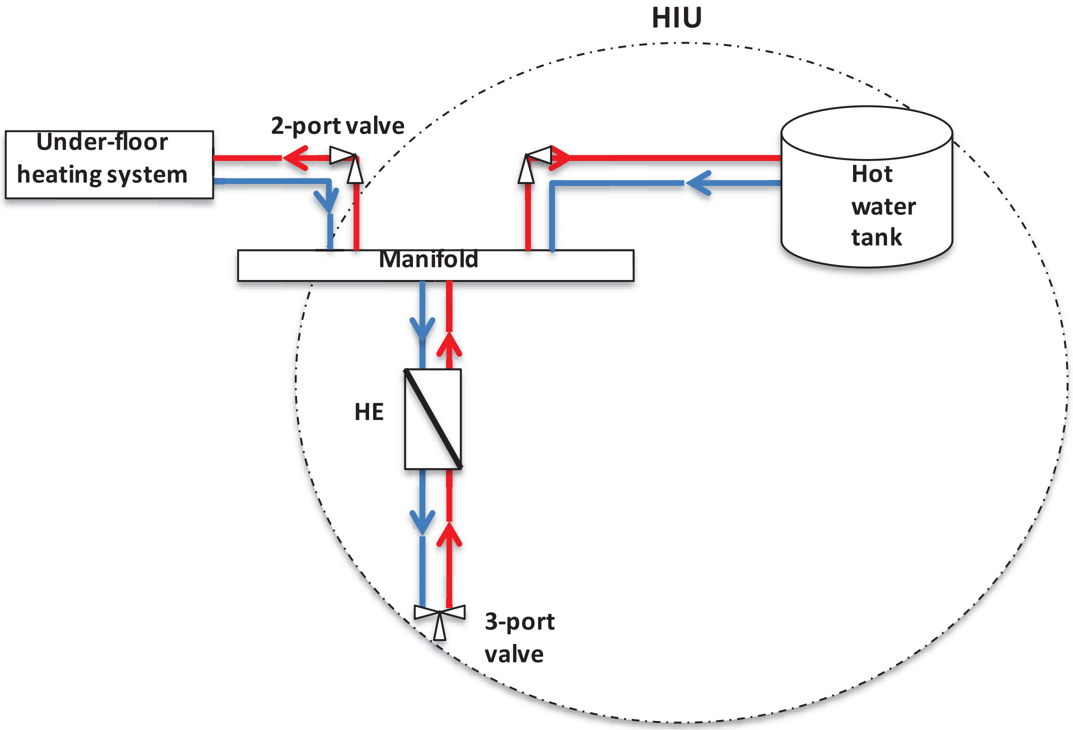


APPENDICES

Layout of the DHN

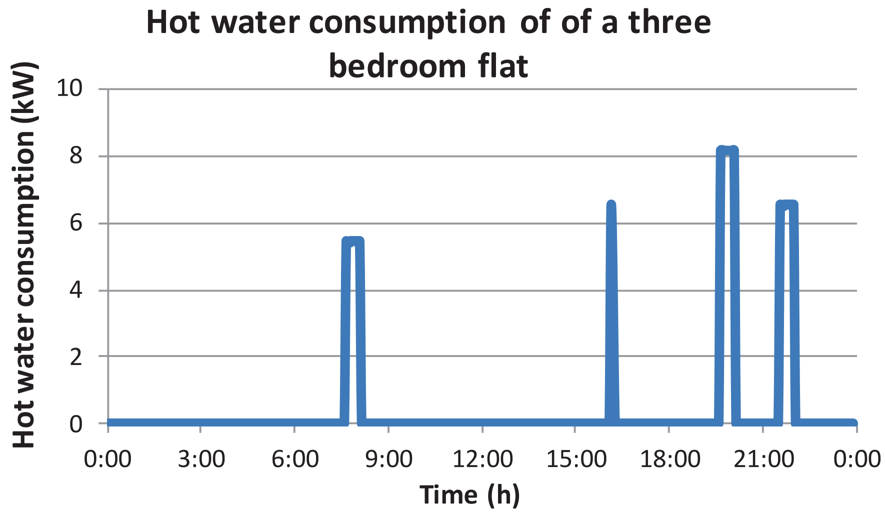
Layout of the DH block examined in this model

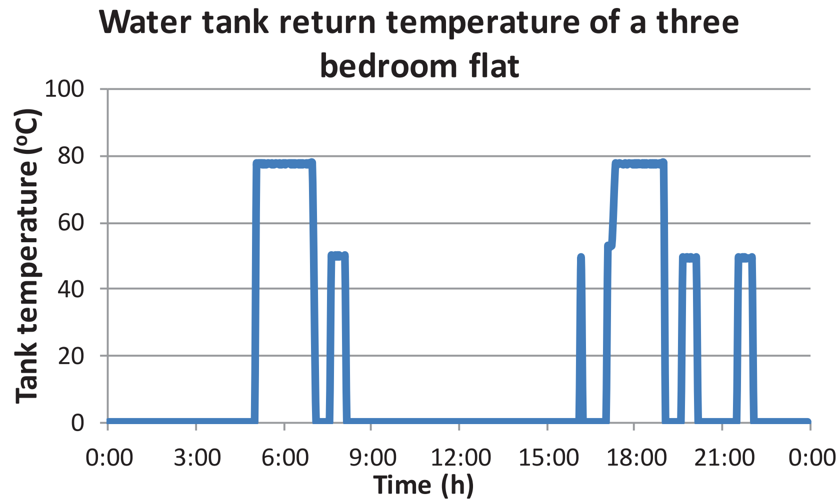


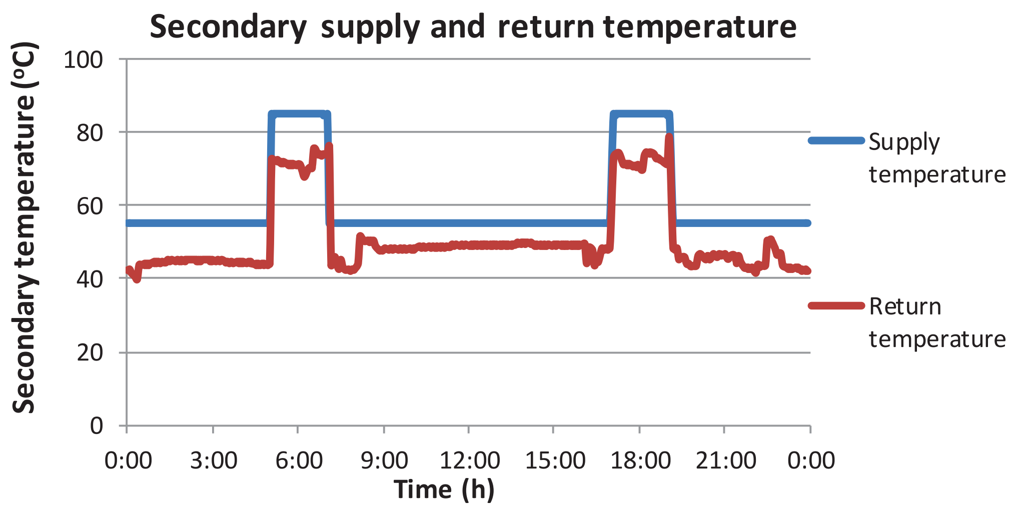


Simplified representation of the tertiary side studied in this model

Baseline scenario results





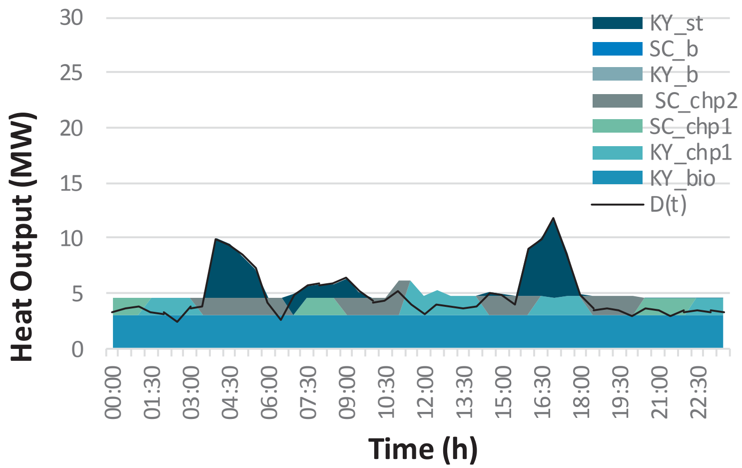


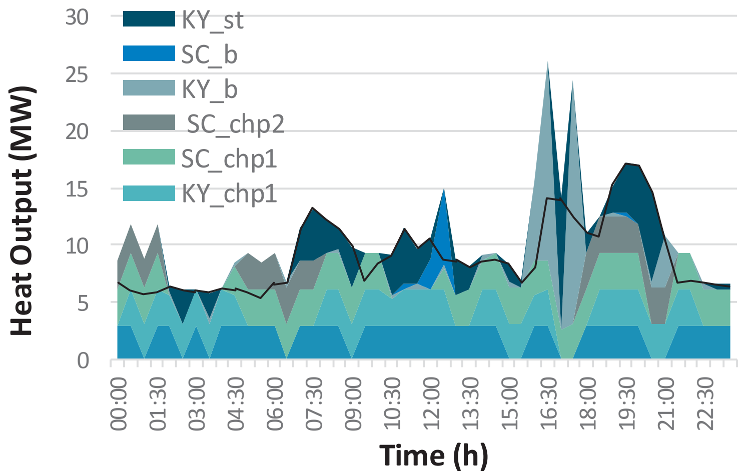
Comparison of scenarios

	Change in heat losses (%)	Fuel consumption change (%)	Change in cost of fuel consumption (%)	Change in carbon emissions (%)	Change in temperature difference between supply and return (%)	Water tank return temperature change (%)	Primary return temperature change (%)	Secondary temperature change (%)
Scenario 1	-0.7	-0.07	0	-0.086	+ 0.96	-1.8 (for non zero values)	-0.32	- 0.16
Scenario 2 (improved case)	-3.16	-0.76	-0.88	-0.76	+ 3.3	No change	-1.3	-0.5
Scenario 2 (ideal case)	-1.8	-1.38	-1.55	-1.38	+ 13	No change	-4.6	-2.4
Scenario 3	-12.3	-2.7	-2.7	-2.7	Not consistent during the day	Negligible	Not consistent during the day	Not consistent during the day

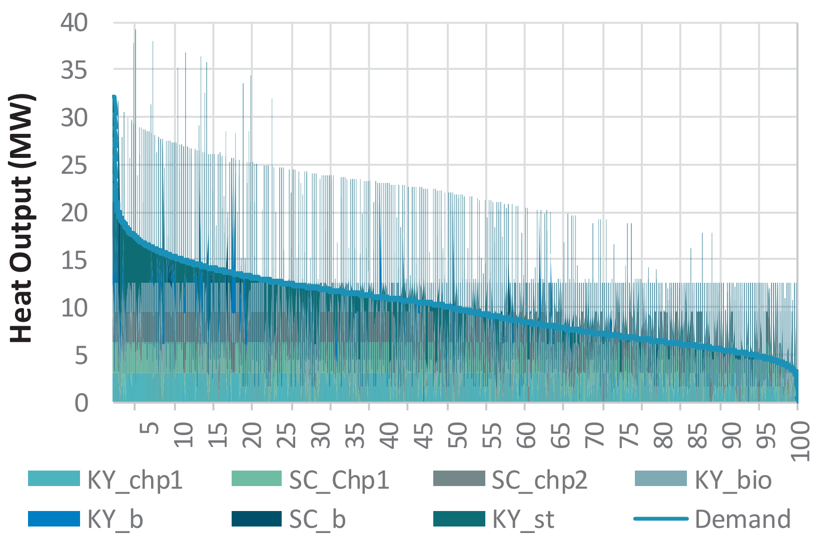
Results: heat

Daily half-hourly profiles

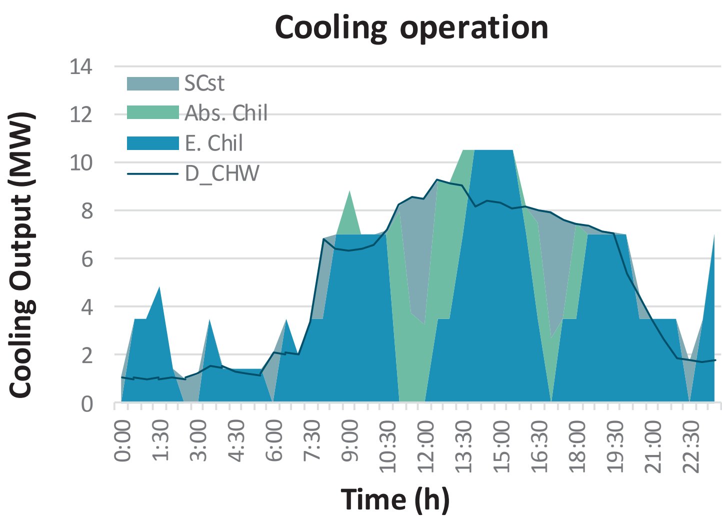


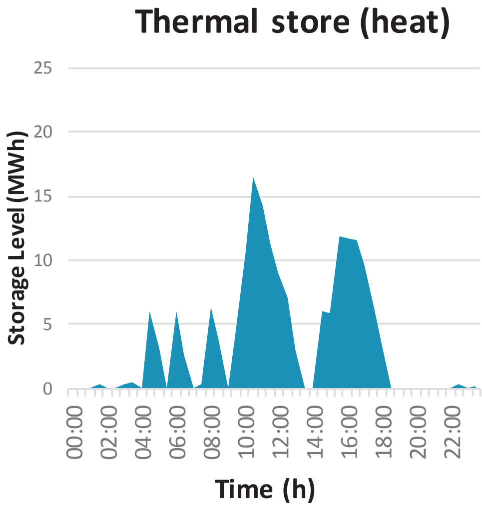


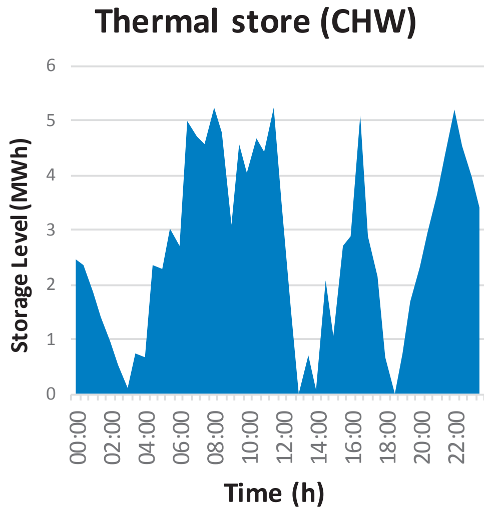
Annual load duration curve

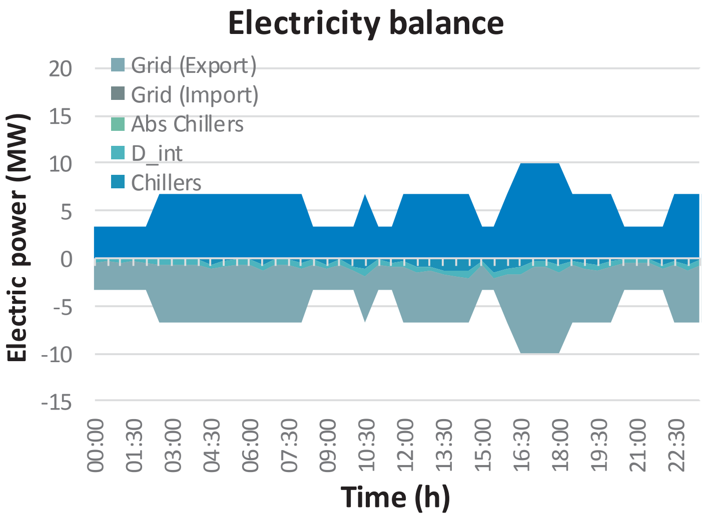


Results: other outputs





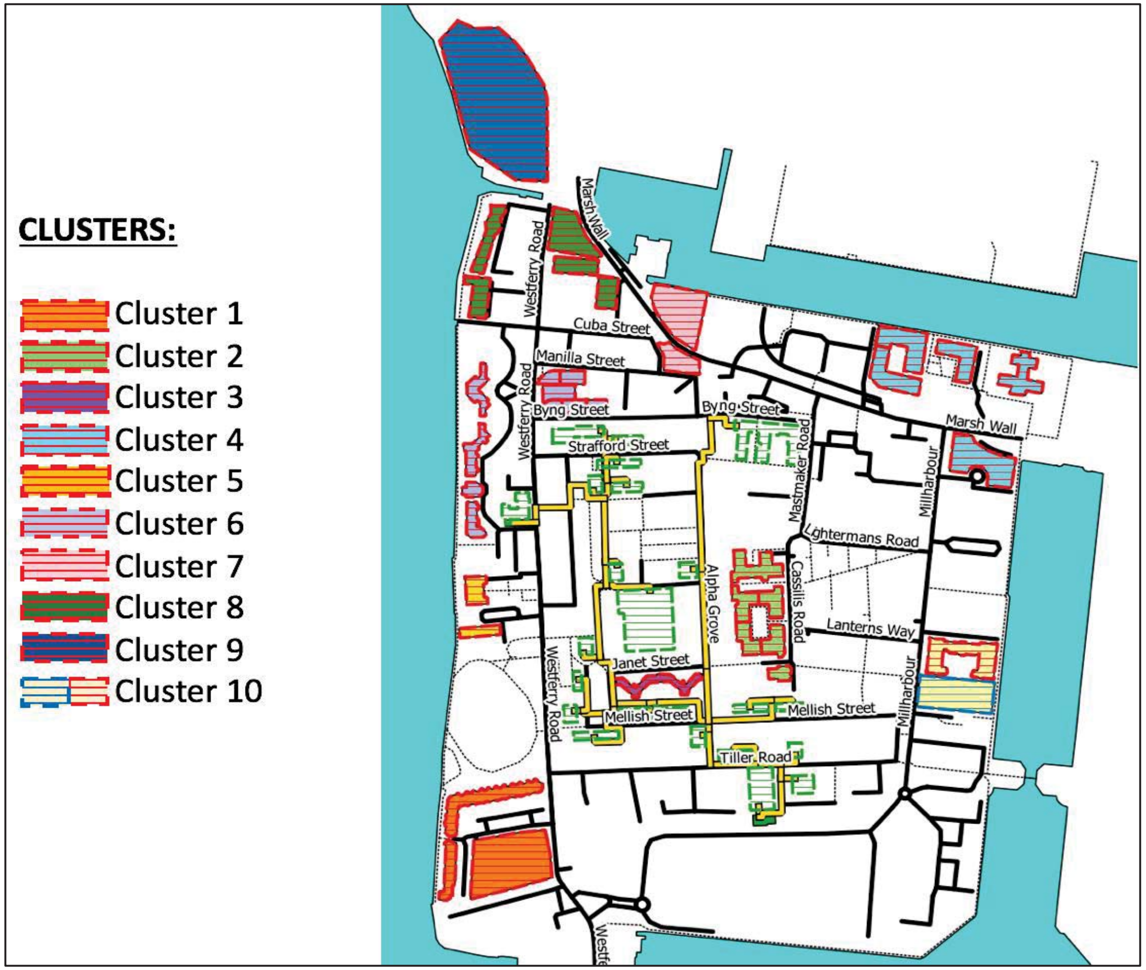




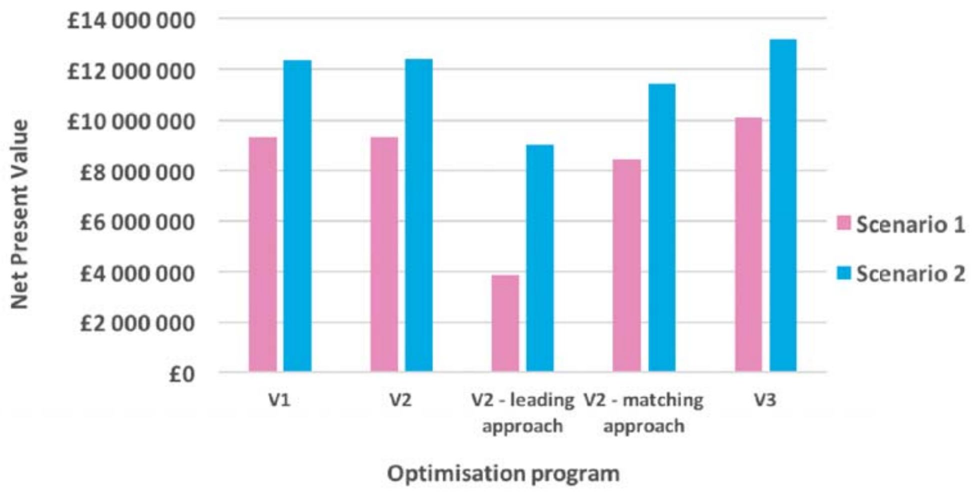
Annual Results

	Heat carbon int. (gCO2/kWh)	CO_2 emissions (tons)	Profit (£)
Profit opt.	90.5	12.7k	5.73m
Carbon opt.	83.3	11.7k	5.36m
Actual scheme	103	-	-

Gathering of loads into clusters

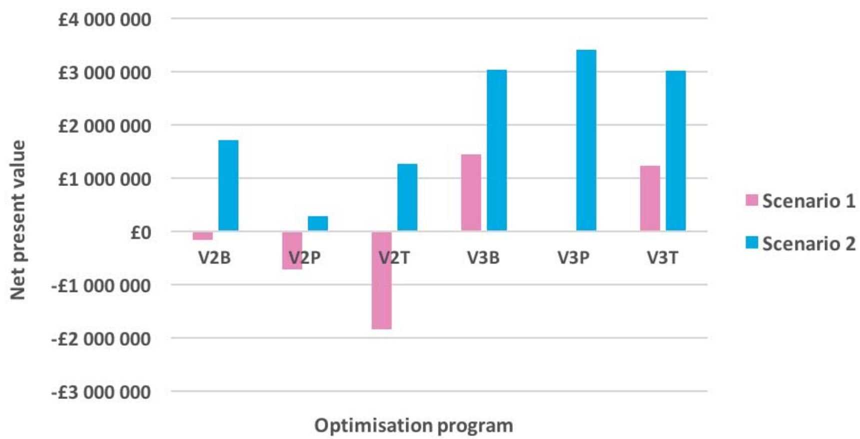


Comparison of the NPV obtained in each model

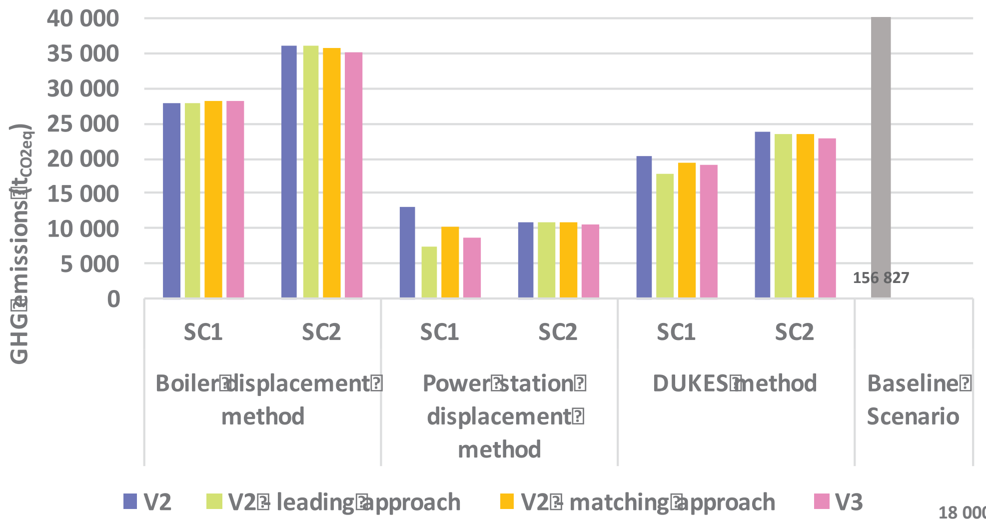


Costs optimisation approaches

GHG emissions minimisation approaches

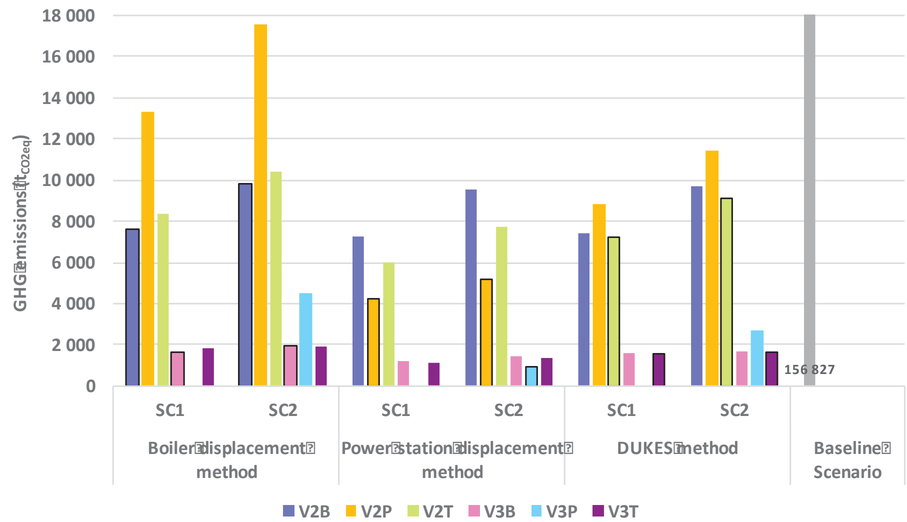


Comparison of the emissions obtained in each model

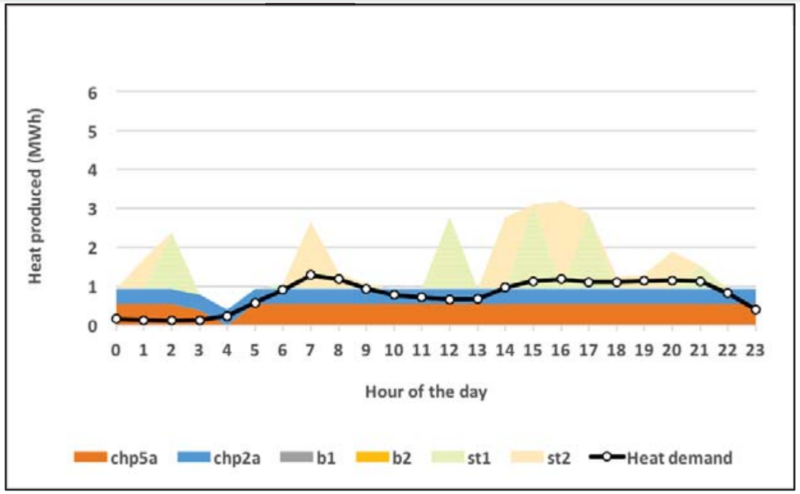


Costs optimisation approaches

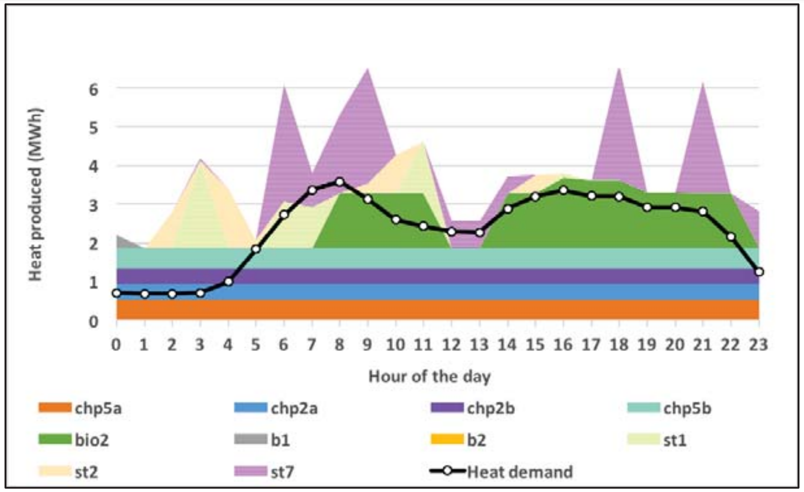
GHG emissions minimisation approaches



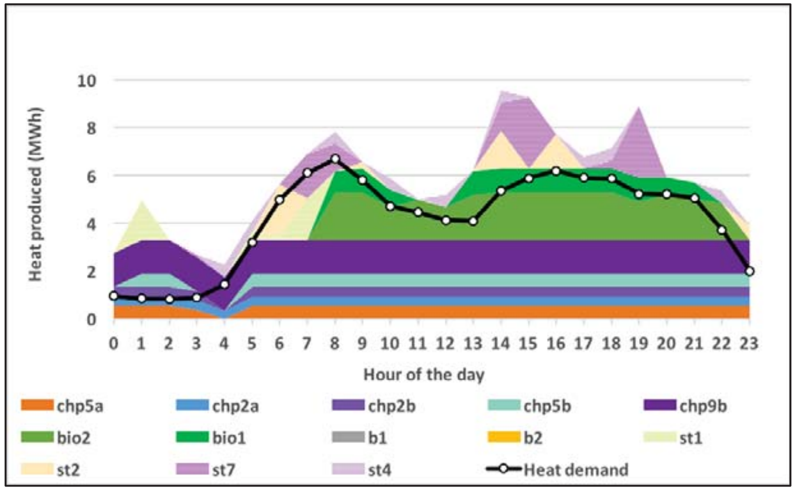
Heat production profiles, costs optimisation model (V3), day 1



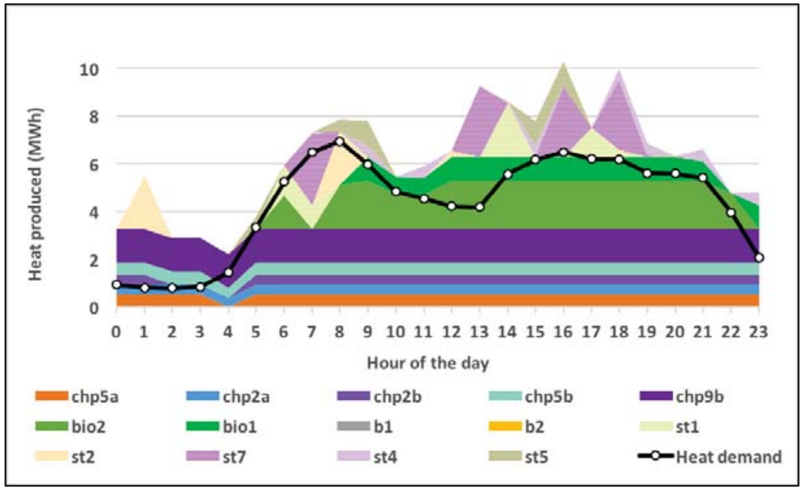
Year 2



Year 5

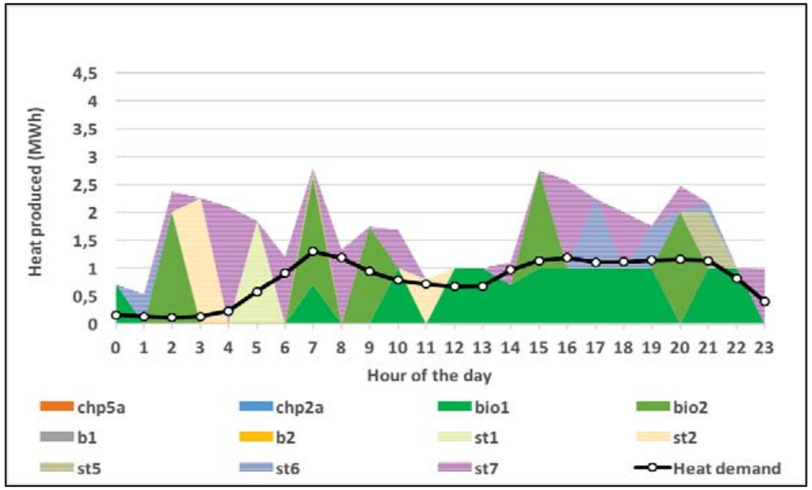


Year 10

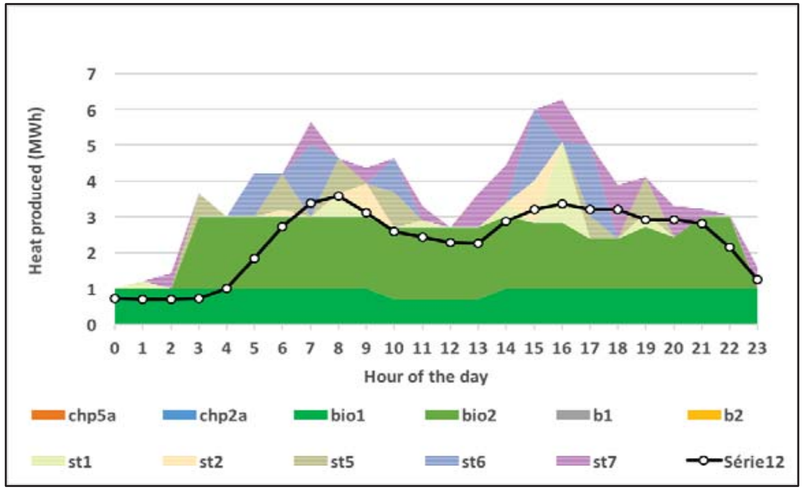


Year 12

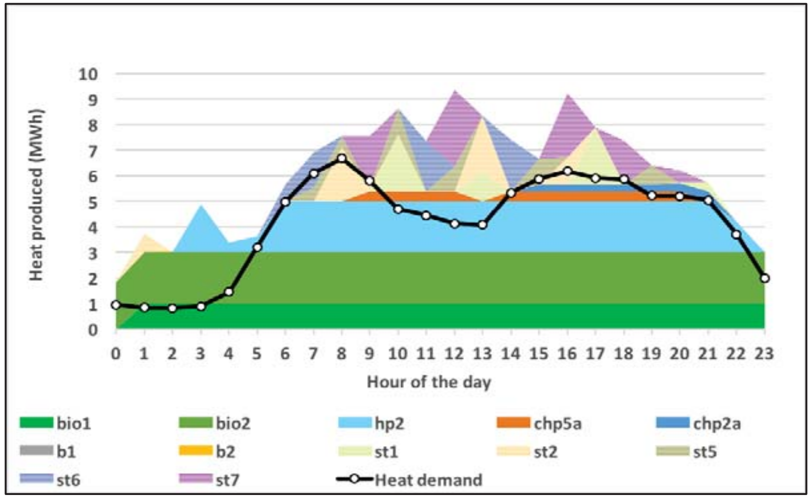
Heat production profiles, emissions minimisation model (V3T), day 1



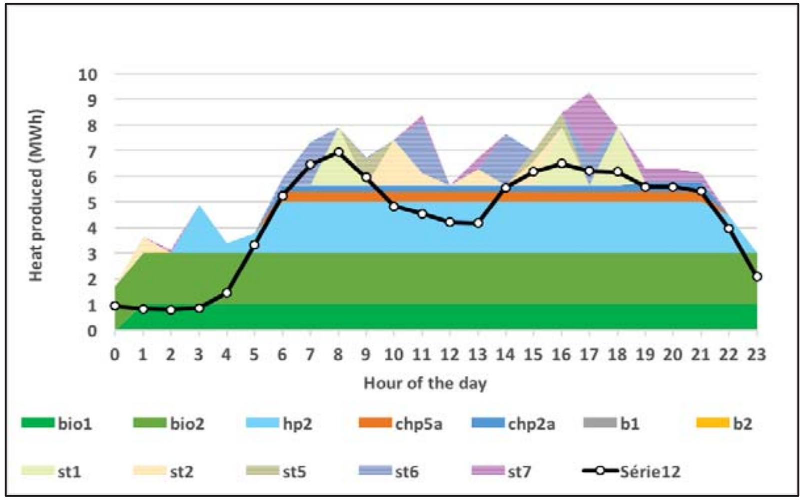
Year 2



Year 5



Year 10

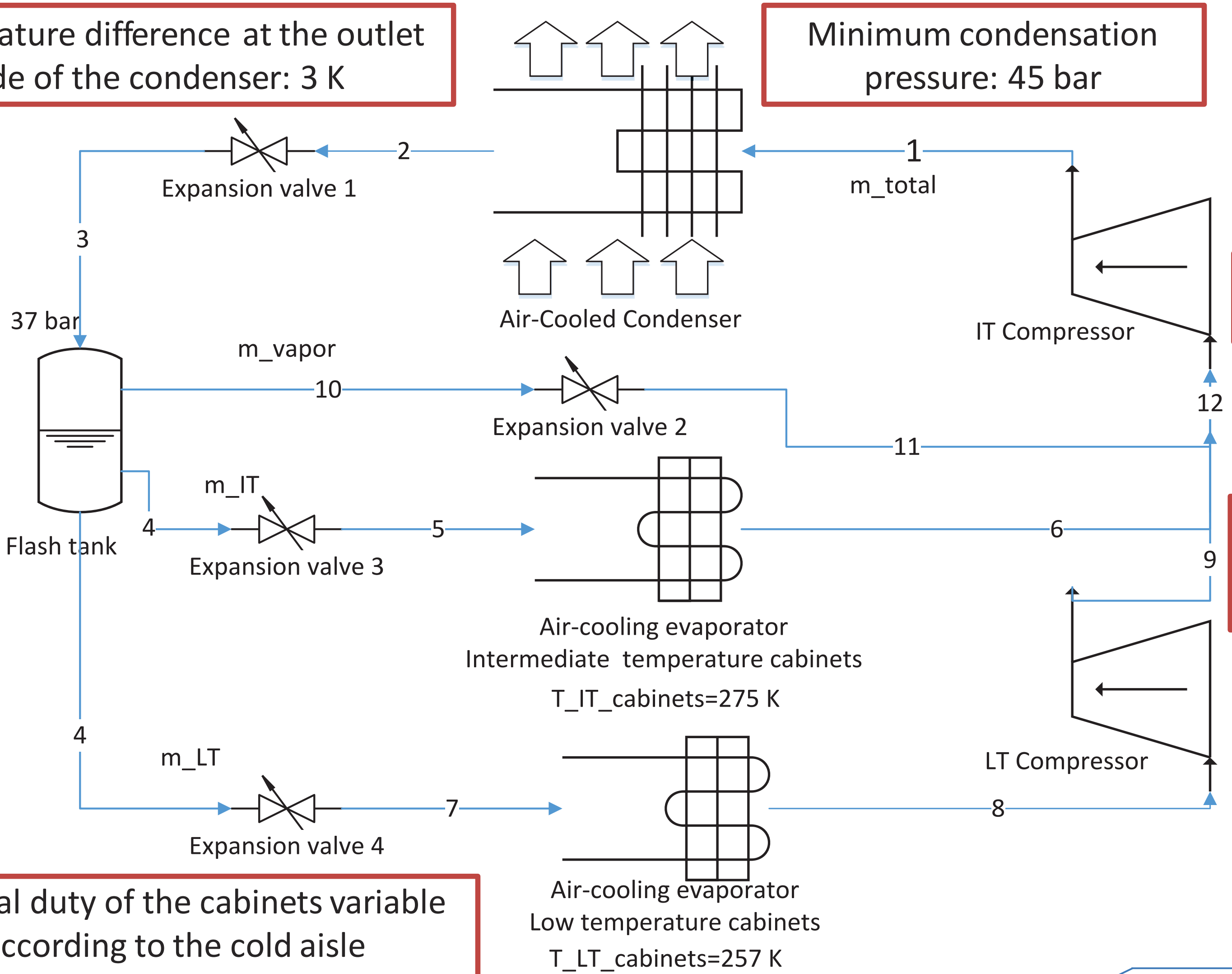


Year 12

Case Study: Leicester North

Temperature difference at the outlet side of the condenser: 3 K

Minimum condensation pressure: 45 bar



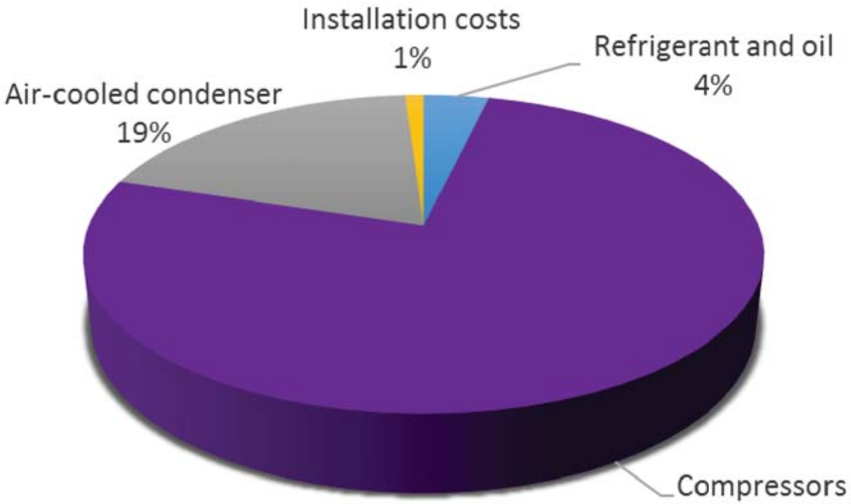
η_{is}=80%

Isenthalpic expansion in the valves

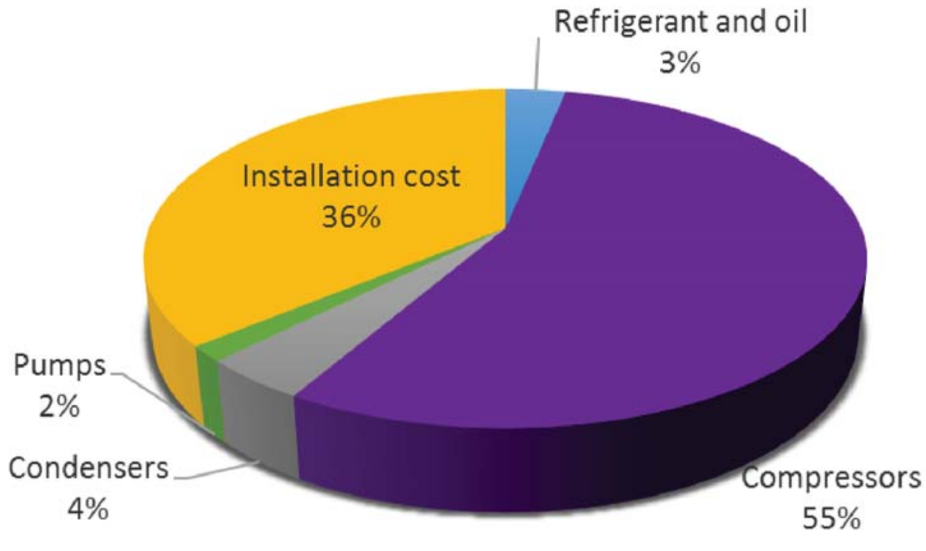
Thermal duty of the cabinets variable according to the cold aisle temperature in the store

CAPEX of air-cooled and water-cooled systems

Air-cooled system
Total cost: £ 193,000



Water-cooled system
Total cost: £ 200,000



Costs of the heat rejection system increase the CAPEX