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Newcastle University

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Session 5b : Energy Storage, Integration and Control in Whole Energy Systems

Newcastle University

Techno-Economic-Environmental Evaluation of Integration of Geothermal Storage in Multi-Vector Energy Networks For Meeting Heat Demand

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Outline

- Introduction
- Research question
- Algorithm of Techno-Economic-Environmental (TEE) evaluation framework
- Test system
- Results
- Key findings

Introduction

- Decarbonisation of heat demand is a priority to meet the UK government 'Net Zero' target.
- Geothermal resources offer huge potential for both energy storage and supply and can play a critical role in decarbonising heat demand as well as offering the continuity of supply that can be difficult to achieve with other low carbon energy sources.
- A framework developed to evaluate the Techno-Economic-Environmental (TEE) performance of different options including geothermal storage for meeting the heat demand of a region.
- The framework provides the basis to make an informed decision to support the most cost-effective and least carbon intensive one.
- The framework can be used to design different components of the heat supplying system.
- It is possible to implement a layer of control and management over the framework.
- Business models can be developed to deploy most suitable scenario for supplying heat to the region.

Research question

How to evaluate different options including geothermal storage for meeting the heat demand in terms of Techno-Economic-Environmental (TEE) parameters in integrated multi-vector energy networks?

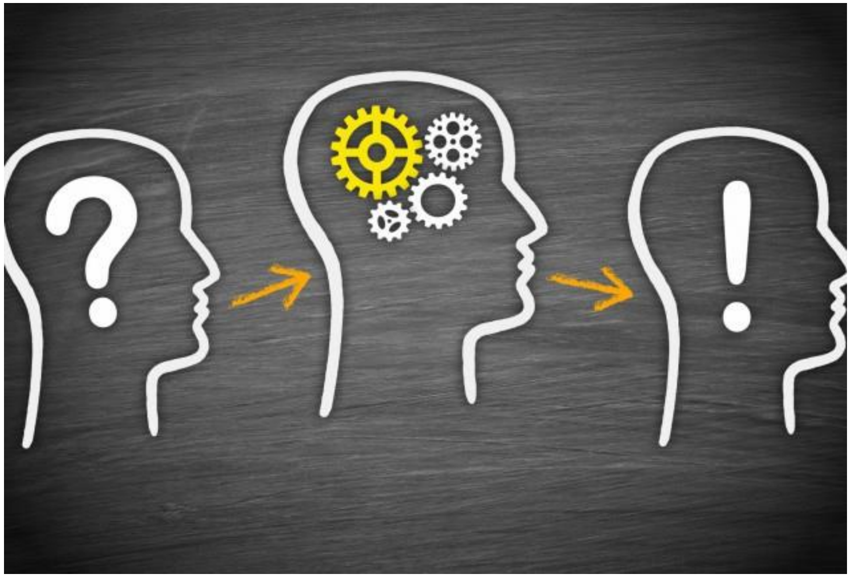

Image taken from 'British school of coaching': http://www.britishschoolofcoaching.com/what-makes-a-good-research-topic-and-what-makes-a-good-research-question/

Algorithm of Techno-Economic-Environmental (TEE) evaluation framework

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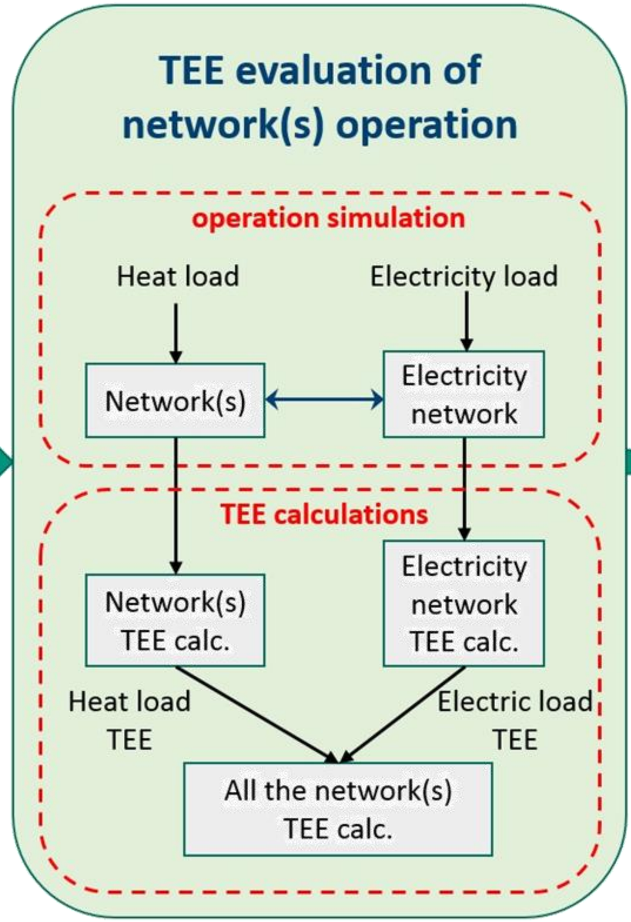
Input

* Energy networks:
  Topology

* Load profiles:
  Heat
  Electricity

* Coupling components:
  Efficiency
  Connections

* Generations (Geo, wind, PV):
  Profile



Output

Technical parameter of meeting the heat and electricity loads (separate&total)

Economic parameter of meeting the heat and electricity loads (separate&total)

Environmental parameter of meeting the heat and electricity loads (separate&total)

Test system: Findhorn

- Consumption of the different user types (domestic/non-domestic) have been aggregated and considered as a lumped load.
- It is assumed the district heating network has the same topology as the electricity network, i.e. the heat source is just next to the electricity network substation (slack bus).
- The geothermal pump, the heat source electric heater, the CHP in different scenarios are all at the heat source/slack bus.
- The gas boiler and heat pump in the scenarios are at the nodes corresponding to the zones.
- Data for the week in winter (w/c 23.2.2015) used.

Unit parameters assumed for economic and environmental analysis

Unit parameter	Gas network	Electricity network
Operational costs (£/MWh) *	9.42	28.06
Emissions (kg.CO2.eq/MWh)	232.00 **	270.00

*: Estimated network costs per domestic customer (GB average), ofgem, 2019. https://www.ofgem.gov.uk/data-portal/estimated-network-costs-domestic-customer-gb-average
**: Houses of Parliament: Parliamentary office of science & technology, 2017. 'Decarbonising the Gas Network'. http://researchbriefings.files.parliament.uk/documents/POST-PN-0565/POST-PN-0565.pdf

Scenarios and Cases

Scenarios for meeting the heat demand

Scenario 1: all electric

Scenario 2: all gas

Scenario 3: gas and electric heat pumps

Scenario 4a: high temperature geothermal & DHN *

Scenario 4b: low temperature geothermal & DHN

Scenario 5: high temperature geothermal, CHP & DHN

Scenario 6: CHP & DHN

* DHN: District Heating Network

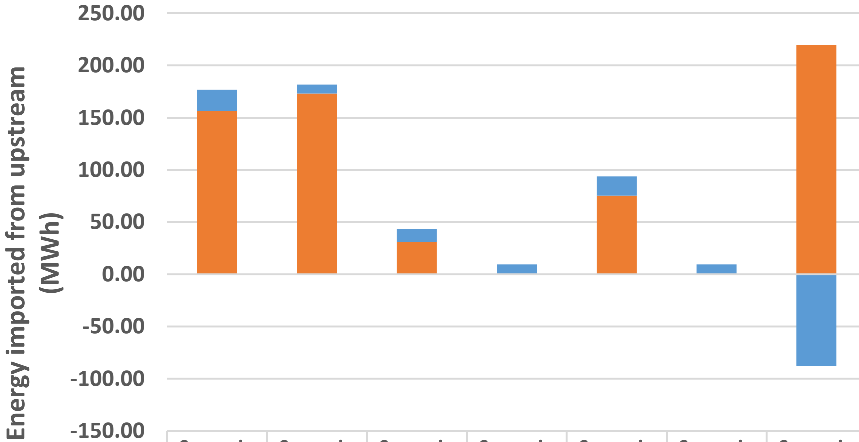
All the scenarios were simulated in all the Cases for loads and generation levels.

Cases for loads and generation levels

	Load w.r.t. Case A	RES generation w.r.t. Case A
Case A: Base case	--	--
Case B: Peak load	120 %	100 %
Case C: High renewables	120 %	140 %
Case D: Low renewables	120 %	60 %

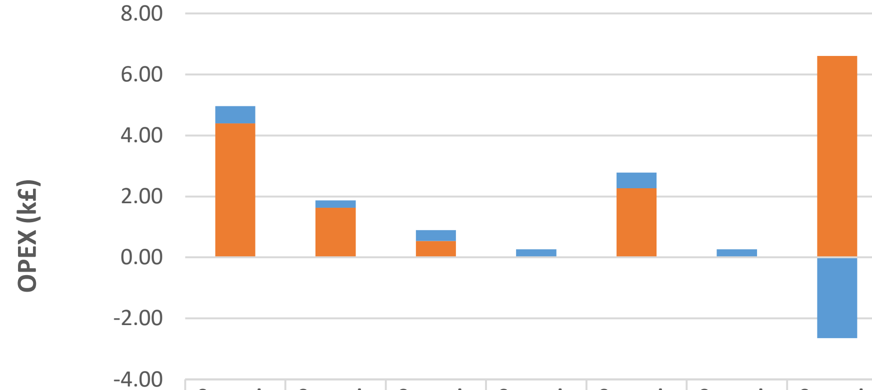
Results – TEE parameters for Case A

Technical parameter *



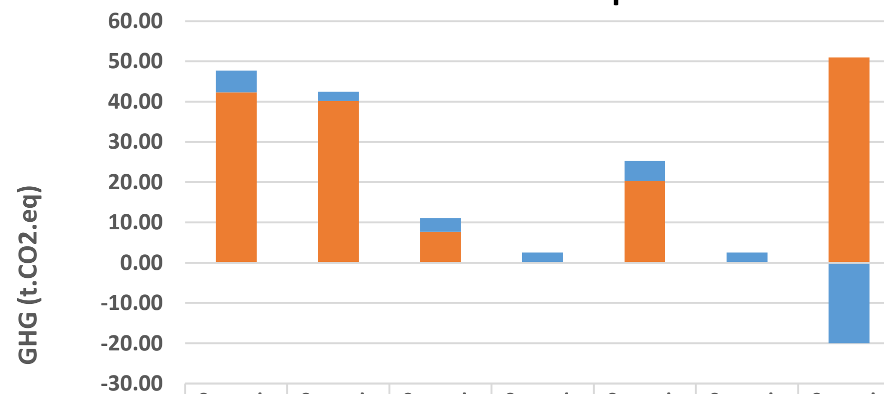
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	20.07	8.58	12.34	8.91	18.31	8.91	-87.51
Heat demand	156.75	173.06	30.91	0.50	75.44	0.50	219.65

Economic parameter *



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	0.56	0.24	0.35	0.25	0.51	0.25	-2.65
Heat demand	4.40	1.63	0.54	0.02	2.27	0.01	6.61

Environmental parameter *



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	5.42	2.32	3.33	2.41	4.94	2.41	-19.98
Heat demand	42.32	40.15	7.69	0.13	20.37	0.13	50.96

Scenario 1: all electric
Scenario 2: all gas
Scenario 3: gas and electric heat pumps
Scenario 4a: high temperature geothermal & DHN
Scenario 4b: low temperature geothermal & DHN
Scenario 5: high temperature geothermal, CHP & DHN
Scenario 6: CHP & DHN

*: Results correspond to one week of operation of the network(s).

Key findings

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- The performance of the TEE evaluation framework is verified and can be used for well-informed decision making on design choices of future energy scenarios since it has produced sensible results.
- The most operational cost-effective and least carbon intensive options for heating are, in order:

Increase in:
- **Import from upstream**
- **Operational costs**
- **Carbon emissions**

Technical parameter	Economical parameter	Environmental parameter
High temperature geothermal	High temperature geothermal	High temperature geothermal
Electric heat pumps at zones that follow the load	Electric heat pumps at zones that follow the load	Electric heat pumps at zones that follow the load
Low temperature geothermal boosted by heat pump	Gas network	Low temperature geothermal boosted by heat pump
CHP	Low temperature geothermal boosted by heat pump	CHP
Gas or electricity networks (depending on RES levels: electricity network at higher RES, gas network at lower RES)	CHP	Gas network
	Electricity network	Electricity network

- The higher the renewable levels, the less energy imported from upstream networks, more cost savings for both network operator and customers and cleaner air.
- The TEE framework can actually assist in quantifying the impact of different technology mixes as well as different load and RES levels on comparing different options for meeting the heat demand.

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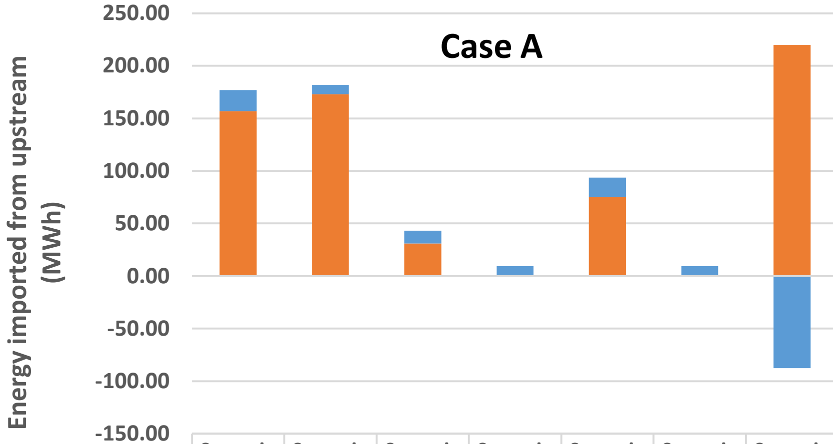
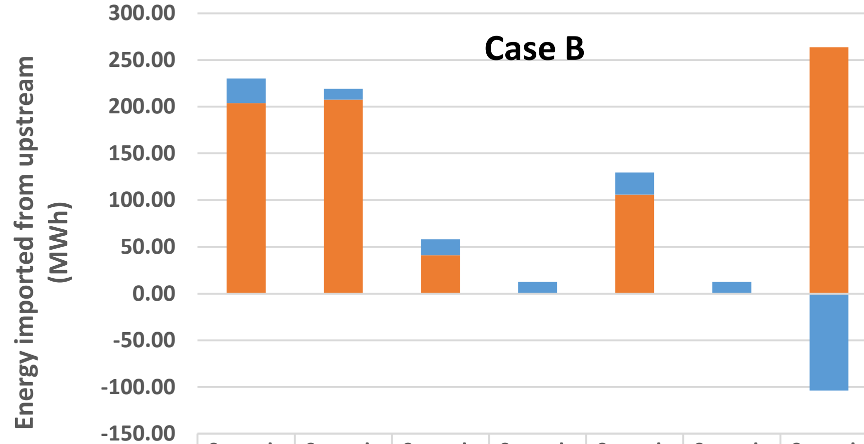
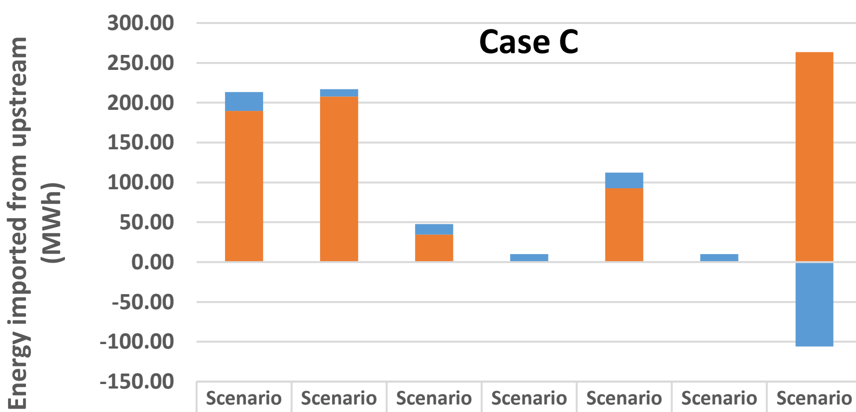
Results – Technical parameter



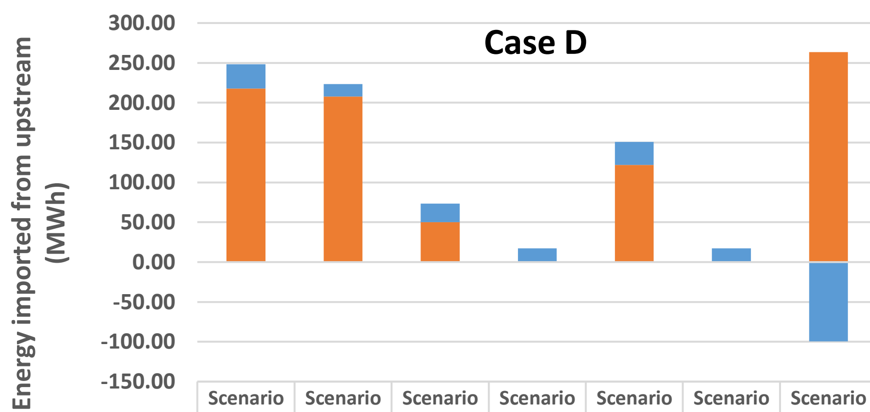
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	20.07	8.58	12.34	8.91	18.31	8.91	-87.51
Heat demand	156.75	173.06	30.91	0.50	75.44	0.50	219.65



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	26.41	11.65	17.16	12.04	23.83	12.04	-103.64
Heat demand	203.64	207.67	40.79	0.57	105.82	0.57	263.50



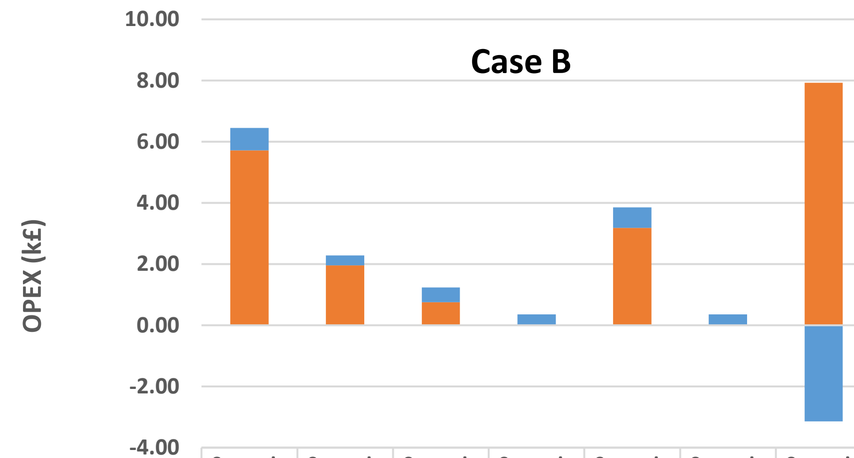
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	23.52	9.45	13.29	9.73	19.99	9.73	-105.83
Heat demand	189.68	207.67	34.58	0.44	92.45	0.44	263.50



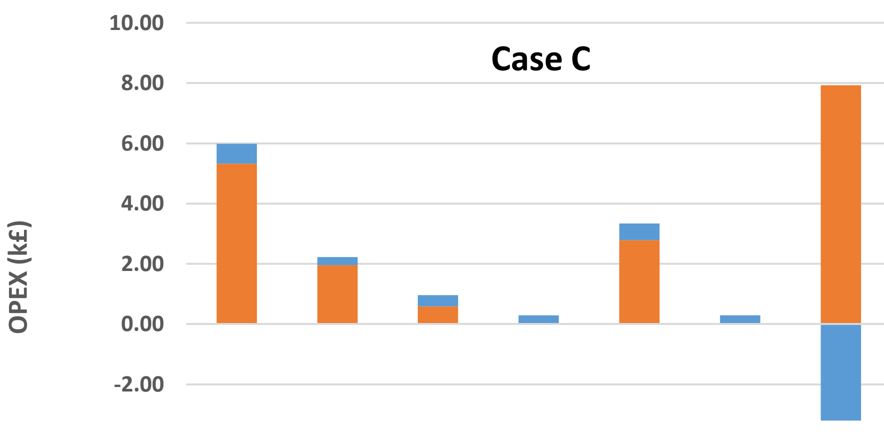
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	30.29	15.68	23.16	16.35	29.13	16.35	-99.61
Heat demand	217.99	207.67	50.22	0.88	121.81	0.88	263.50

Results – Economic parameter

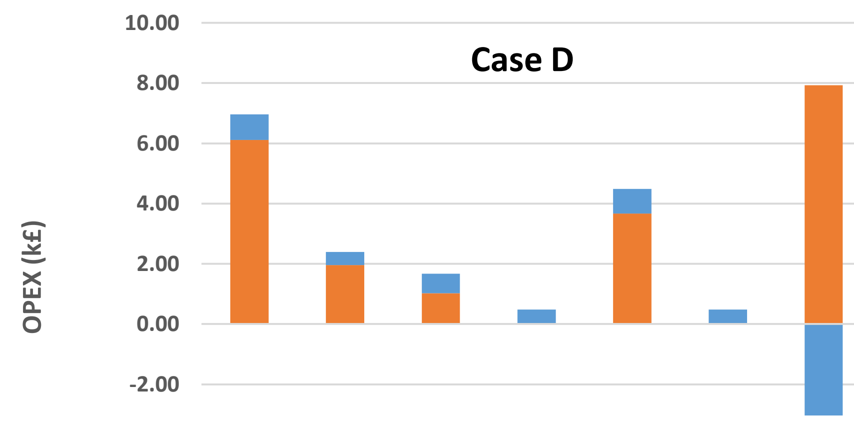
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	0.56	0.24	0.35	0.25	0.51	0.25	-2.65
Heat demand	4.40	1.63	0.54	0.02	2.27	0.01	6.61



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	0.74	0.33	0.48	0.34	0.67	0.34	-3.14
Heat demand	5.71	1.96	0.76	0.02	3.19	0.02	7.93



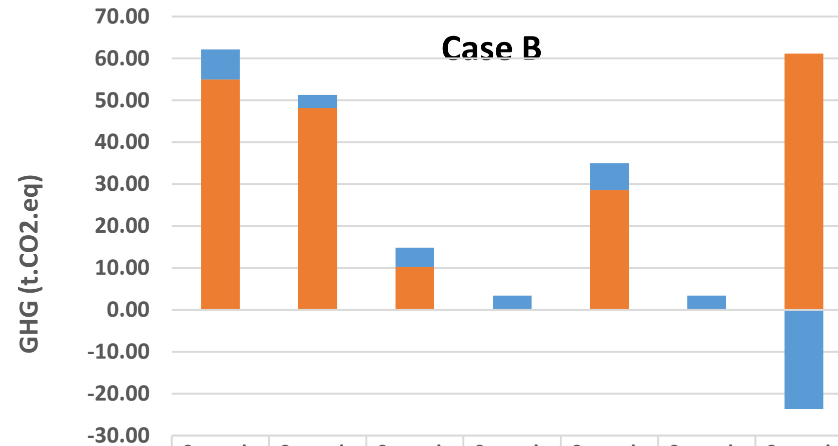
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	0.66	0.27	0.37	0.27	0.56	0.27	-3.20
Heat demand	5.32	1.96	0.58	0.01	2.78	0.01	7.93



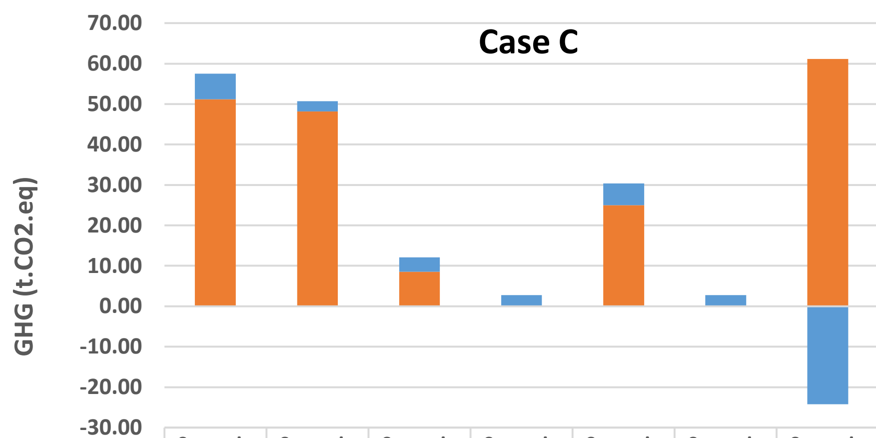
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	0.85	0.44	0.65	0.46	0.82	0.46	-3.03
Heat demand	6.12	1.96	1.02	0.03	3.67	0.02	7.93

Results – Environmental parameter

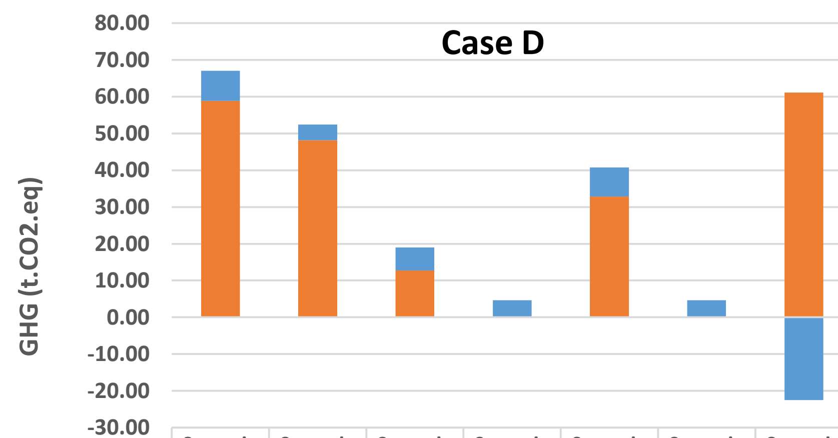
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	5.42	2.32	3.33	2.41	4.94	2.41	-19.98
Heat demand	42.32	40.15	7.69	0.13	20.37	0.13	50.96



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	7.13	3.14	4.63	3.25	6.43	3.25	-23.60
Heat demand	54.98	48.18	10.22	0.15	28.57	0.15	61.13



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	6.35	2.55	3.59	2.63	5.40	2.63	-24.19
Heat demand	51.21	48.18	8.55	0.12	24.96	0.12	61.13



	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b	Scenario 5	Scenario 6
Electricity demand	8.18	4.23	6.25	4.41	7.87	4.41	-22.51
Heat demand	58.86	48.18	12.77	0.24	32.89	0.24	61.13