



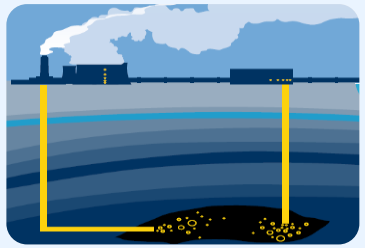



Non-Domestic Archetypes

National Grid ESO

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elementenergy
an ERM Group company

ERM

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Introduction to non domestic consumer archetypes

- These archetypes have been developed to support improved modelling of non domestic consumers in the UK with particular relevance to gas and electricity network modelling.
- This presentation provides supporting information and guidance for using this set of non-domestic consumer archetypes.
  - This includes a discussion of the methodology used, overview of the archetypes and guidance for using the archetypes in any modelling.
- The datasets and features used to describe each archetype can be found in the associated csv files for ease of use.
  - The data provided includes:
    - Building and floorspace per archetype at LSOA level
    - Annual energy demand (electricity and gas) and peak electricity demand per archetype at LSOA level
    - Sector electricity usage profiles
    - Engagement factors for each archetype
    - The split of archetypes in each sector
    - Descriptions and attributes/characteristics of each archetype

Non-domestic archetype methodology overview

- The selected approach draws from CSE's Smart and Fair work in the domestic sector to identify the types of innovations each type of organisation is able to adopt based on its technological and organisational context.
- The analysis of organisations and their capabilities is supported by a literature review which has identified organisational characteristics found to be linked to engagement in the energy system. The core framework is taken from Bull and Janda (2018) and represents how an organisation must have the "**conditions, capacity and concern**" to engage with an innovation.
- Assumptions taken from literature will be tested through stakeholder engagement and clearly outlined to support future archetype updates.
- This approach and the literature identified aims to take a holistic view of non-domestic engagement in the energy system to account for the fact that an organisation may not participate in a new programme or install energy saving measures even if there is a strong financial case for adoption.
- Access to quality data remains a limiting factor in this work, future iterations of archetypes could aim to collect purpose-built datasets.

Bull, Richard, and Kathryn B. Janda. "Beyond Feedback: Introducing the 'Engagement Gap' in Organizational Energy Management." *Building Research & Information* 46, no. 3 (April 3, 2018): 300–315. https://doi.org/10.1080/09613218.2017.1366748.

Non-domestic archetype creation begins with collecting data and formulating assumptions to link consumer characteristics to ability to engage with the energy market

1

Non-Domestic Consumers: Characteristics

- **Conditions** – Technological and local context which limit ability to engage.
- **Capacity** – Organizational ability to meet any non-technical requirements of an innovation.
- **Concern** – Attributes linked to engagement in the energy market or salience of energy issues.

This 3Cs framework is taken from Bull and Janda (2018) and is similar to the Smart and Fair Capabilities Lens but for the non-domestic sector.

Characteristics are mapped to offerings to determine what attributes are needed to engage with each offer. We begin with the organisation as organisational data is the main limiting factor in the analysis.

2

Technologies and Offers: Requirements for Engagement

- **Conditions** – Any technical requirements of innovation or technology (e.g. access to a roof for PV).
- **Capacity** – Organisational hurdles (e.g. specialist energy manager to manage DSR programmes or building ownership).
- **Concern** – Tied to the type of offering and its innovativeness, this captures the fact that not all low-carbon innovations are attractive to all businesses as they may not directly translate to lower energy costs.

This matrix linking requirements and organisational attributes is the “offer-attribute matrix.”

Characteristics of both technologies/offers and consumers are evaluated to estimate ability to engage with each modelled technology by archetype

3

Engagement Analysis

- For each type of organisation, a tool assesses its characteristics and ability to engage with each technology/offer based on the weighting and mapping established before.

	Flexible Sub Loads	Energy Management Ambition	Energy Management Resource
Offer: Demand Response	Yes.	Active.	Specialist energy manager.
Business A	Yes.	Active.	Specialist energy manager.
Business B	No.	Active.	No energy manager.

4

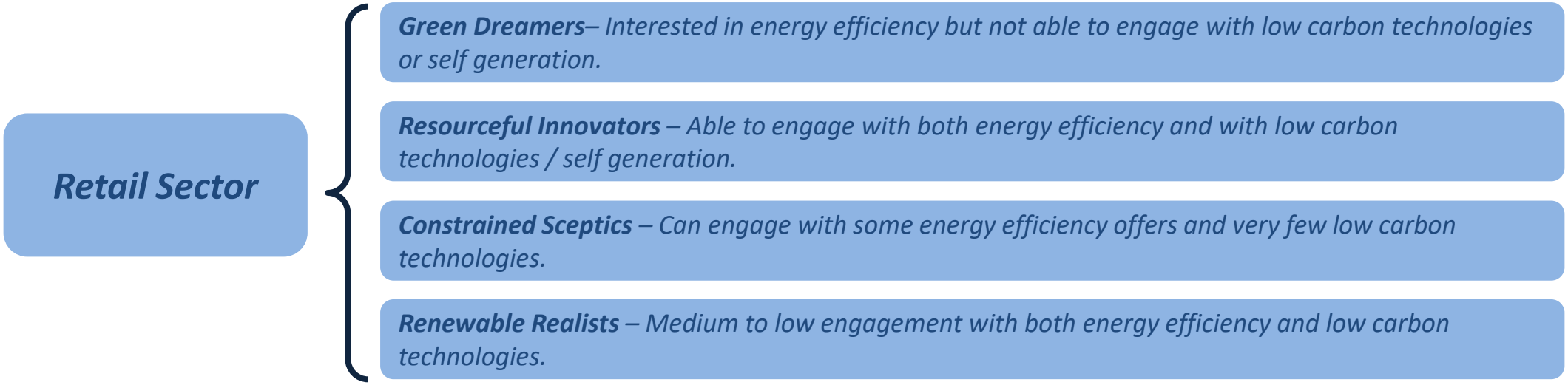
Non-Domestic Consumer Archetypes

- By understanding the number and type of innovations adopted by each type of organisation we can approximate behaviour and adoption of nascent technologies even with limited data.
- Archetypes can then be created from:
  - Segmenting organisations by sector (to best fit with existing modelling).
  - Further grouping organisations by the type and number of offers likely to be adopted within a sector.

- Methodology Overview
- **Archetype Structure**
- Characteristics and Features
- Results
- Using Archetypes in Modelling
- Detailed Methodology and Datasets
- Appendix

Archetype Structure

- To produce a set of archetypes that is both manageable and sufficiently granular we have opted to produce a nested set of archetypes.
- To create the nested archetypes, we first create a large number of organisational archetypes which are then grouped together by sector and their engagement with different types of offers.
- Within each sector we have four archetypes which are consistent across sectors, as illustrated below.



Overview of sector split used in Archetype Creation

Sector	Description	% of National Stock
Community Arts and Leisure	Museums, theatres, libraries and community centres.	2.7 %
Education	All types of school – Nursery to higher education (includes residential higher education).	2.8 %
Emergency Services	Law courts, police stations, prisons, and fire/ambulance stations.	0.1 %
Health	Health centres, hospitals and nursing homes.	3.3 %
Hospitality	Pubs, hotels, restaurants and cafes.	13.3 %
Offices	Private and public sector offices.	26.8 %
Retail	Large and small food and non-food shops. Retail warehouses.	35.2 %
Storage and Warehouses	Cold stores, large distribution warehouses and warehouses.	8.6 %
Light Industrial	Workshops and small factories.	6.6 %
Heavy Industrial	Large industrial sites with high emissions.	0.03 %
Other	Sites which do not fall into existing sectors.	0.6 %

The sectors used here were largely taken from the sector spilt used in BEES as to best fit multiple datasets.
BEES does not include an "other" category, values taken from BEES for this category are averages across all other sectors.

Archetype segmentation from results of modelled engagement

- Results of modelled engagement produced 4 distinct types of behaviour across sectors.
- The split of each sector into the 4 archetypes varies between sectors.

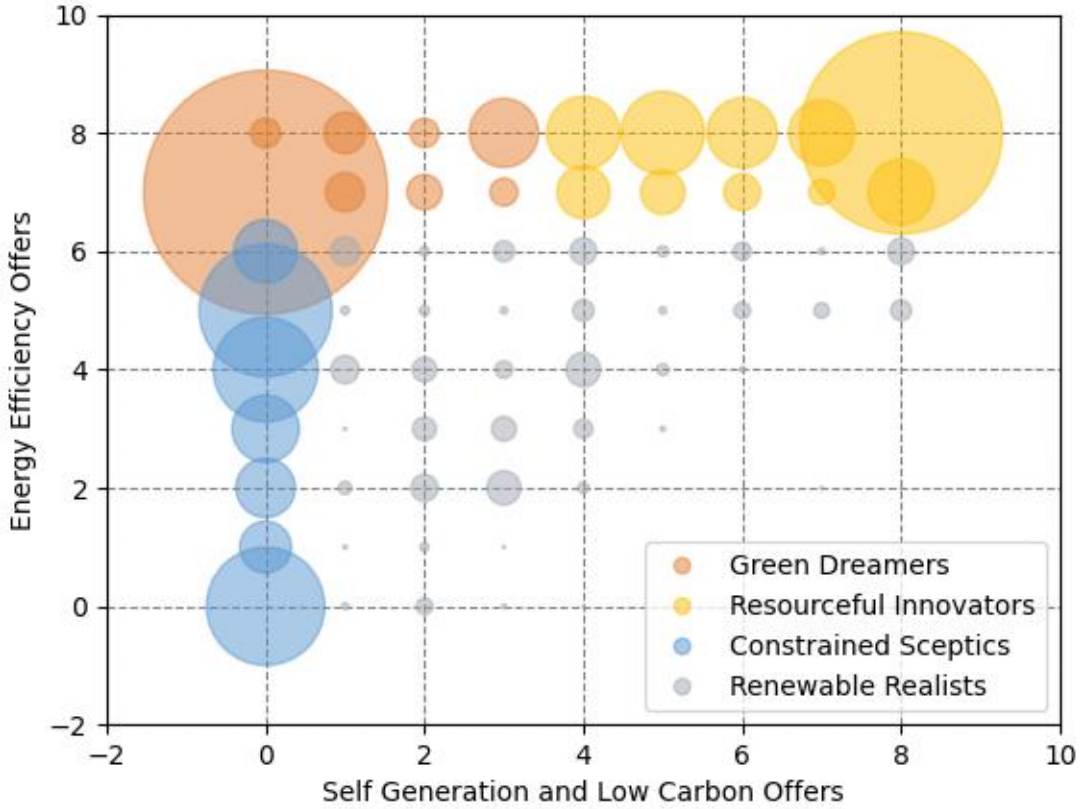
Green Dreamers *– Interested in energy efficiency but not able to engage with low carbon technologies or self generation.*

Resourceful Innovators *– Able to engage with both energy efficiency and with low carbon technologies / self generation.*

Constrained Sceptics *– Can engage with some energy efficiency offers and very few low carbon technologies.*

Renewable Realists *– Medium to low engagement with both energy efficiency and low carbon technologies.*

Engagement across all sectors:
low carbon technologies and energy efficiency



Green Dreamers: 33% of pop.
Resourceful Innovators: 34% of pop.
Constrained Sceptics: 27% of pop.
Renewable Realists: 6% of pop.

The size of each bubble represents the percentage of the population that engages with that number of offers.

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Each archetype is described by a set of features which can be used to model behaviour

Features capture both the modelled engagement of an archetype and their load needs including any projected flexibility.

	Feature/Parameter	Description	Resolution
Engagement	Engagement with Flexibility: High, Medium, Low	A baseline engagement factor to represent level of engagement with flexibility.	Archetype
	Engagement with EE: High, Medium, Low	A baseline engagement factor to represent level of engagement with energy efficiency.	Archetype
	Engagement with LCT: High, Medium, Low	A baseline engagement factor to represent level of engagement with low carbon technologies.	Archetype
	Key policy/financial hurdles to engagement	Key barriers by archetype that may be relevant to the scenario framework.	Archetype
Load	Percentage of peak load which is technically flexible	The total potential flexible peak load for each sector.	Sector
	Annual demand (electricity and gas) per archetype/floorspace	Annual demand of each archetype in an LSOA.	Archetype/LSOA
	Load profiles + peak demand	Electricity load profiles assigned by sector to each archetype, used to calculate peak load.	Sector
Geography	Archetype distribution at LSOA	Distribution of floorspace by archetype at each LSOA.	Archetype/LSOA

These features are explored in the following slides. The varying resolutions are a product of the quality of available data.

Archetype features were designed to match key stakeholder needs and use cases

Stakeholder(s)	Use Case/Modelling	Non Domestic Archetype Features
Electricity Networks and ESO	Electricity demand modelling, core (non-LCT) demand (incl. scenario modelling)	Peak and annual electricity demand, Engagement with EE, Key policy/financial hurdles to engagement
	Technology uptake and flexibility provision (incl. scenario modelling)	Engagement with EE, Engagement with LCT, Engagement with DSR, Key policy/financial hurdles to engagement
	Vulnerability insights	Key policy/financial hurdles to engagement, ND population information (e.g. business size, last time switched suppliers)
Gas Networks	Gas demand modelling (incl. scenario modelling)	Annual gas demand, Engagement with EE, Key policy/financial hurdles to engagement
	Technology uptake (incl. scenario modelling)	Engagement with EE, Engagement with LCT, Key policy/financial hurdles to engagement
	Vulnerability insights	Key policy/financial hurdles to engagement, ND population information (e.g. business size, last time switched suppliers)
Suppliers	Understanding consumers and engagement	Engagement with LCT, Engagement with DSR, Key policy/financial hurdles to engagement, ND population information (e.g. business size, last time switched suppliers)
Policymakers	Energy decarbonisation policy	Key policy/financial hurdles to engagement, ND population information (e.g. business size, last time switched suppliers)

We expect the geographic resolution of archetypes to be useful for all stakeholders. Priority use cases identified in consultation with the expert steering group.

EE: energy efficiency, LCT: low-carbon technology, DSR: demand-side response

Archetype engagement features

Four features are used to describe archetype engagement with different types of decarbonisation changes.

- **Engagement with Energy Efficiency, Low Carbon Technologies and Flexibility**
  - Each metric was determined based on the modelled uptake of offers in that category (as described in the methodology).
  - As engagement with energy efficiency and low carbon technologies are used to define the archetypes, these metrics are consistent across archetypes regardless of sector (e.g. Green Dreamers will have high engagement with energy efficiency regardless of sector).
  - Provided in the associated CSVs and on slides 23-32 with the split of archetypes in each sector.
- **Key barriers to engagement + Archetype descriptions**
  - Using the framework that an organisation needs the “conditions capacity, and concern” to engage with an offer these descriptions reflect the particular aspects of that framework which an archetype is missing, illustrating any barriers likely to hinder an organisation participating in the future energy system.
  - Provided on slide 10 and in the associated CSV output files.

Archetype load and flexibility features

Three archetype features describe the expected load requirements of each archetype in each sector.

- **Annual Energy Demand –**
  - Annual gas and electricity demand is calculated using floorspace by LSOA from EPC and VOA data and the consumption per floorspace values from ND-NEED. Final values are also calibrated to the National DUKES statistics (to split demand from heavy industry) and regional BEIS values.
  - Provided in CSV format at LSOA resolution for each archetype and sector.
- **Load Profiles and Peak Electricity Load –**
  - Load profiles have been sourced from previous Element Energy work for Ofgem and were used to convert the annual demands above into peak demand and are applied based on sector.
  - Note that no peak gas load has been provided for the archetypes. This is due to data constraints and the evolving relationship between annual and peak gas demand. Peak day demand remains a key part of determining demands necessary to plan gas networks.
  - Peak electricity demand is provided in CSV format at LSOA resolution for each archetype and sector. Load profiles are presented in an excel file as well as on slides 23-32.
- **Flexible portion of peak load by sector –**
  - These percentages are calculated using assumptions from previous work for Ofgem and using the sub loads by sector from BEES.
  - These values are listed and explained in more detail on slide 20 and in the output CSV files.

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Archetype breakdown across sectors

Archetypes are consistent between sectors:

- As the same organisational characteristics are used to model engagement with offers across sectors and we have segmented these archetypes based on this modelled uptake, the split of characteristics within these archetypes are the same between sectors.
- The descriptions to the right apply across sectors to each sub archetype.
- Some attributes, such as organisation size, are the same across all archetypes in all sectors.
- While the groupings are consistent, their split within a sector does change.

Some engagement metrics are consistent between sectors:

- As we segment the population based on engagement with energy efficiency and low carbon technologies we see the same spread of engagement with these offers across sectors.
- Engagement with flexibility does vary slightly.

	Energy Efficiency	Low Carbon Technologies
Green Dreamers	High	Low
Resourceful Innovators	High	High
Constrained Sceptics	Low/Medium	Low
Renewable Realists	Medium	Medium

Archetypes (All Sectors)

Green Dreamers : *Description*

- Mostly leased properties, half have an active energy management ambition and most have some sort of energy manager.

Resourceful Innovators: *Description*

- Entirely owner-occupiers, just under half have an active energy management ambition and most have some sort of energy manager.

Constrained Sceptics: *Description*

- Mostly leased properties, lower percentage have high energy spend than the archetypes above. Less than half of these organisations have an energy manger and very few have an active energy management ambition. Mostly smaller businesses.

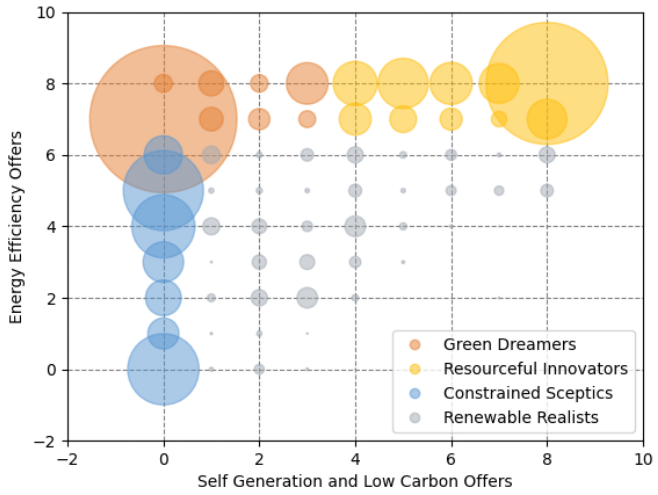
Renewable Realists: *Description*

- As in Resourceful Innovators these organisations are entirely owner-occupiers. Most of these organisations have no energy manger. Very few of these organisations have an active energy management ambition. Mostly smaller businesses.

Characteristics of organisations in each archetype across sectors

+ Impact on…	Attribute	Green Dreamers	Resourceful Innovators	Constrained Sceptics	Renewable Realists
Concern	High gas spend (Over 20%)	49%	53%	35%	35%
Concern	High electricity spend (Over 20%)	59%	57%	23%	17%
Capacity	Is a large business	56%	54%	34%	43%
Conditions	Uses all of a building or multiple buildings	52%	55%	51%	38%
Concern	Has an active energy management ambition	46%	44%	15%	11%
Capacity	Has an energy manager	82%	77%	36%	22%
Capacity	Owns their premises	7%	100%	6%	100%
Concern	Planning to adopt Energy Efficiency	65%	55%	27%	13%

The average percentage of an archetype which has a particular attribute. Chart only contains attributes found to vary between archetypes.



This suggests…

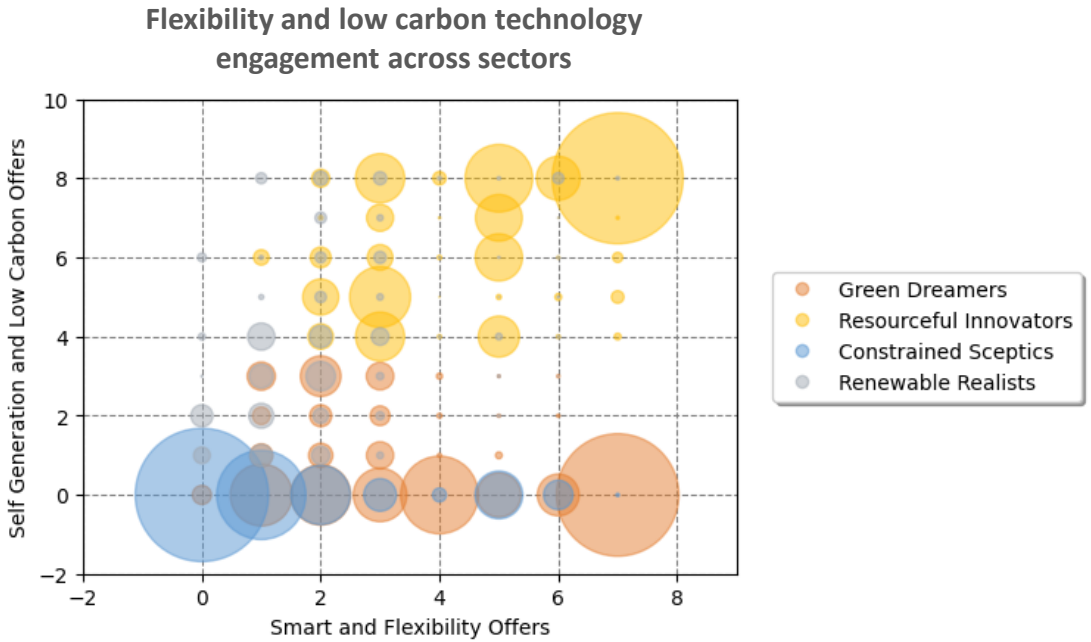
- **Constrained Sceptics** often lack conditions, capacity and concern.
- **Resourceful Innovators** often have all resources necessary to engage.
- **Green Dreamers** may be highly concerned but may lack the capacity and conditions to engage.
- **Renewable Realists** have some capacity to act but may not be sufficiently motivated to engage. This is supported by low engagement in EE, a lower difficultly offer.

Across archetypes and sectors, we see limited engagement with flexibility

Engagement with flexibility by archetype

	Smart Energy	DSR	Aggregators	Variable Tariffs
Green Dreamers	26%	14%	20%	31%
Resourceful Innovators	33%	15%	23%	33%
Constrained Sceptics	5%	3%	4%	19%
Renewable Realists	3%	0%	0%	4%
All	**17%**	**8%**	**12%**	**22%**

This table shows the average proportion of consumers that engage with offers of each category across all sectors.



Who engages with DSR?

Most organisations who engage with flexibility…

- Have a **specialist** energy manager
- Have an **active** energy management ambition
- Are at **least planning to adopt DSR**
- Are **larger businesses**

These organisations are also …

- More likely to have a high energy spend (in the Resourceful Innovators and Constrained Sceptics archetypes)

Percentage of peak demand which is flexible by sector

	Percentage Flexible Peak Demand
Community, arts & leisure	18%
Education	17%
Emergency Services	19%
Health	15%
Hospitality	9%
Industrial	20%
Other	19%
Offices	13%
Retail	20%
Storage	20%

Determining flexible portion of peak load…

- The split of sub loads (as a percentage of annual demand) for each sector were taken from BEES, this annual split was assumed to be the same split at peak (as no more granular data is available).
- Building off previous ND DSR work for Ofgem we estimated the flexible percentage of each sub load. This proportion ranged between 50% flexibility for hot water to 0% flexibility for lab and ICT equipment.
- The sub loads were multiplied by these flexible potentials to get the total assumed flexible load.

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Archetypes by Sector

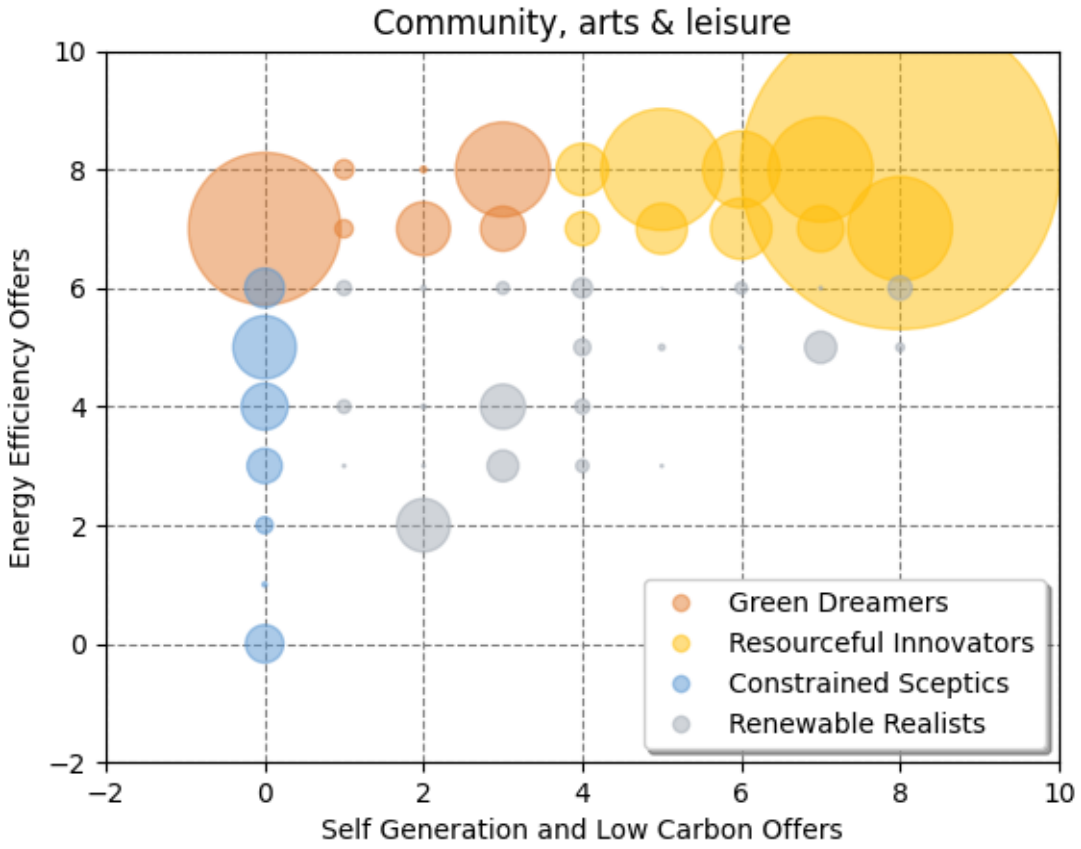
- The following slides present the split of the sub archetypes within each sector as well as the features which vary by sector and/or archetype.
- As these sub archetypes are best defined by their engagement with energy efficiency and low carbon technologies we first present a plot of engagement with these two offer categories to display the spread of each sub-archetype.*

For each archetype we also present:

- The split of the archetypes in the sector.
- Engagement with each offer sub-category scored from low to high.
  - As discussed, engagement with LCTs and EE is the same for each archetype across sectors.
- Load profile used for the sector.
  - This profile has been sourced from previous Element Energy work for Ofgem.

* Additional graphs showing engagement with flexibility plotted against low carbon and energy efficiency engagement can be found in the Appendix.

Community, arts & leisure Sector: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 18% of Sector

Resourceful Innovators: 73% of Sector

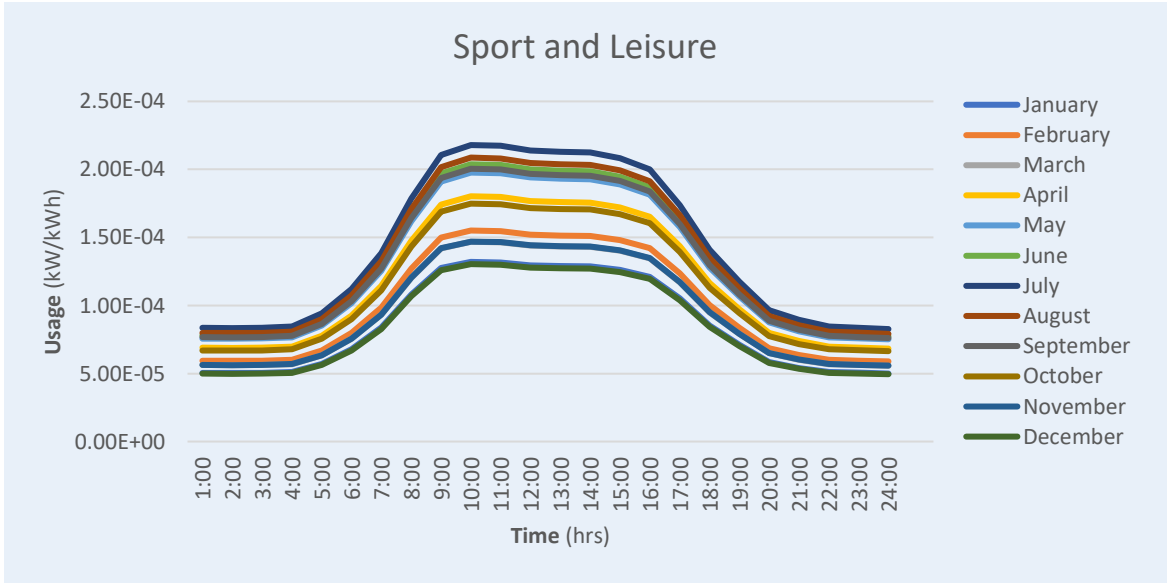
Constrained Sceptics: 5% of Sector

Renewable Realists: 4% of Sector

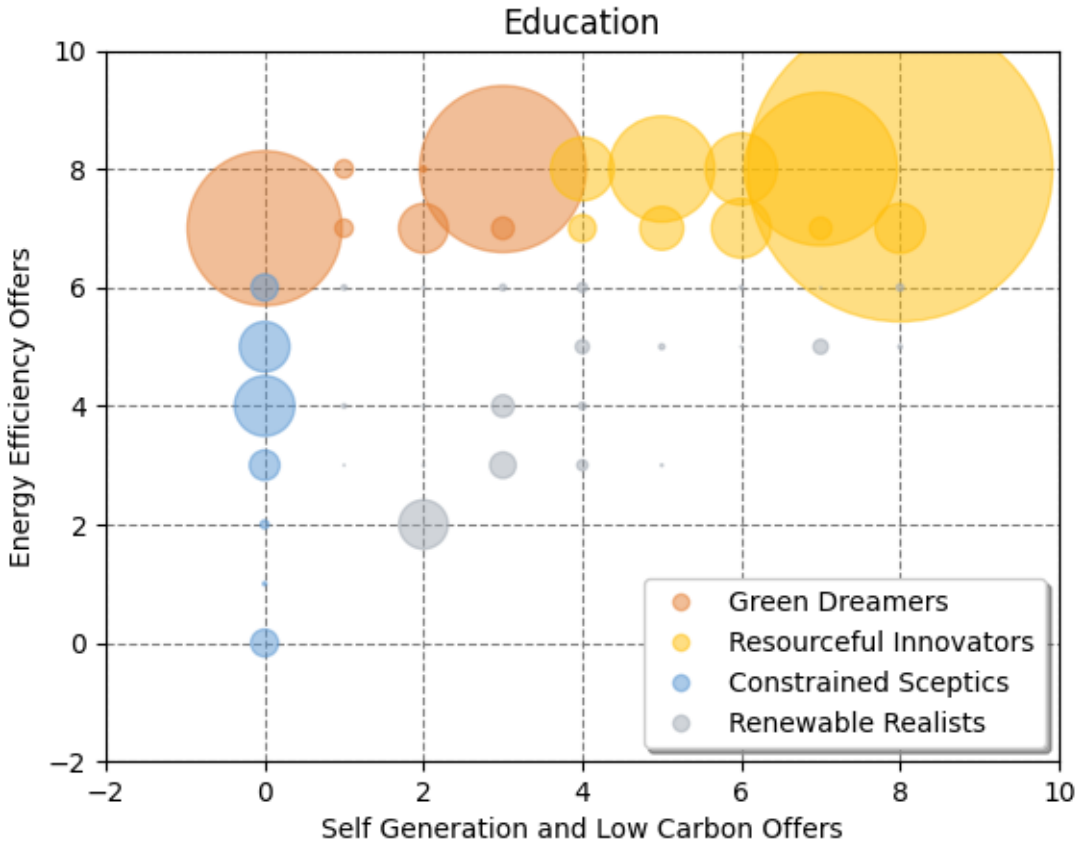
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Low

Normalised load profile



Education Sector: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 26% of Sector

Resourceful Innovators: 68% of Sector

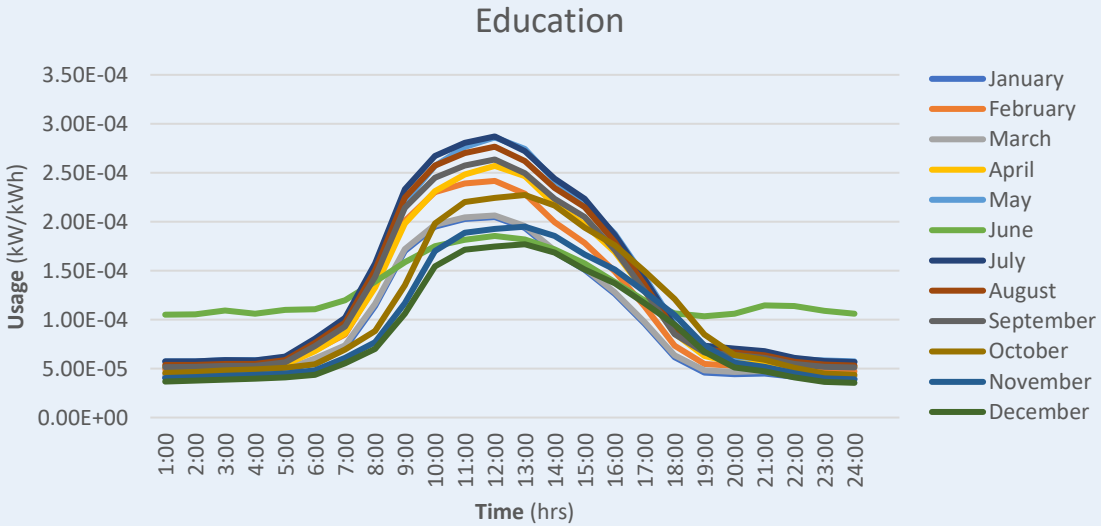
Constrained Sceptics: 4% of Sector

Renewable Realists: 2% of Sector

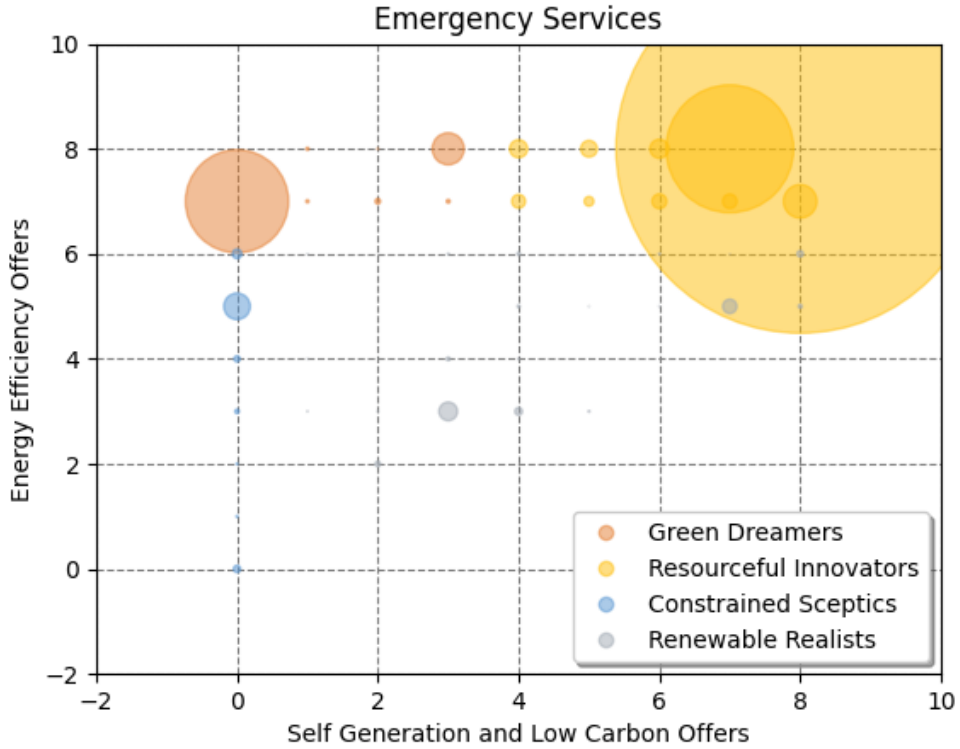
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Low

Normalised load profile



Emergency Services Sector: Sub archetypes and features



Engagement is high in this sector due to the prevalence of both energy managers (94%), high energy management ambition (78%) and high instance of building ownership (93%).

Split of sub groupings in sector

Green Dreamers : 7% of Sector

Resourceful Innovators: 92% of Sector

Constrained Sceptics: 1% of Sector

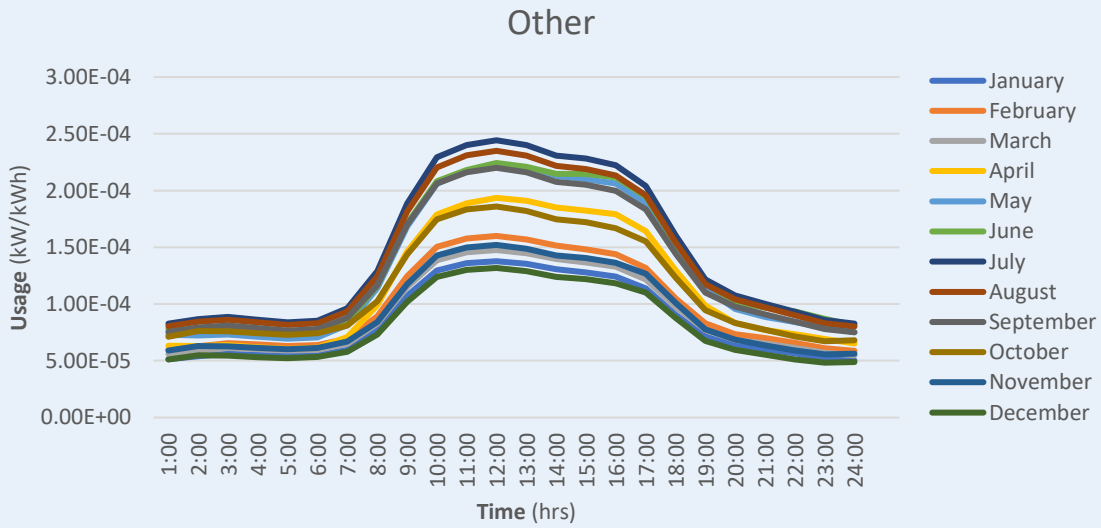
Renewable Realists: 0.4% of Sector

Engagement metrics

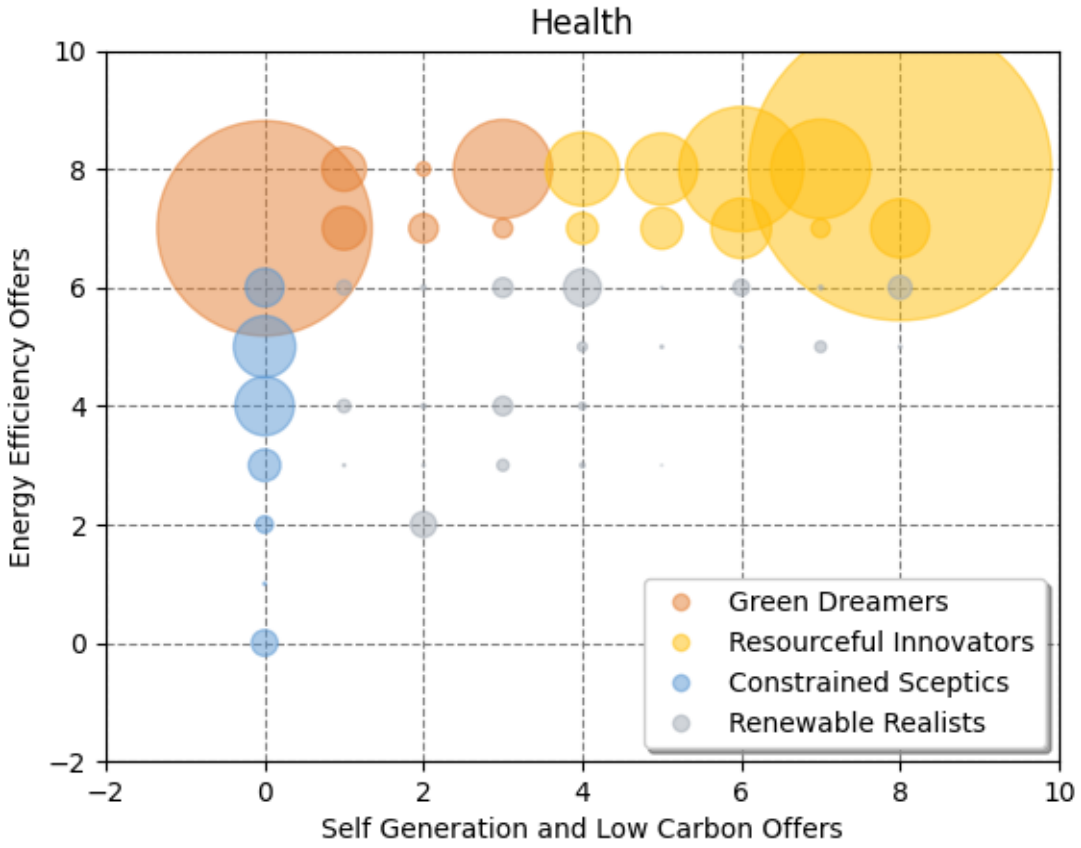
	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	High
Resourceful Innovators	High	High	High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Low

Normalised load profile

Note that the profile used for emergency services is the same as the "other sectors" profile.



Health Sector: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 29% of Sector

Resourceful Innovators: 64% of Sector

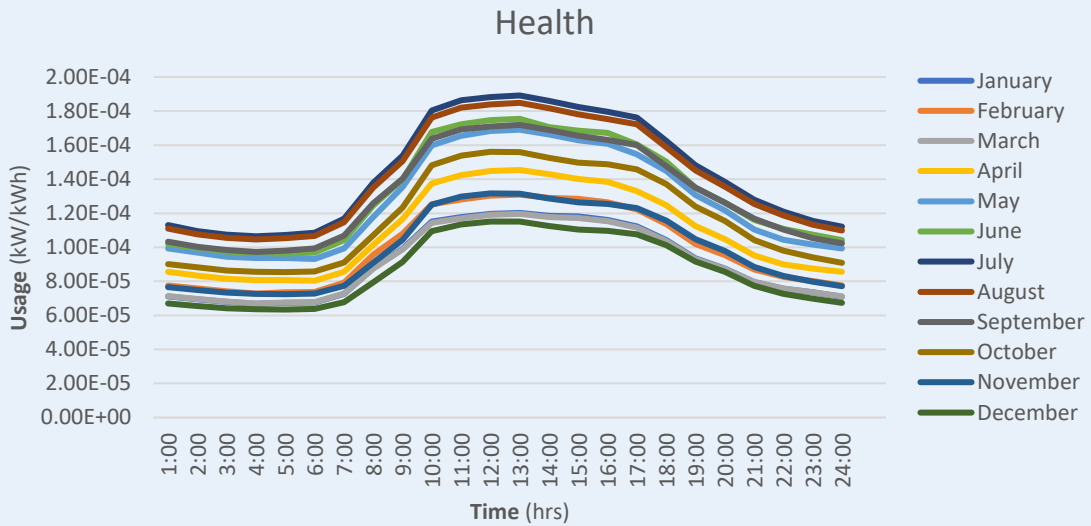
Constrained Sceptics: 5% of Sector

Renewable Realists: 2% of Sector

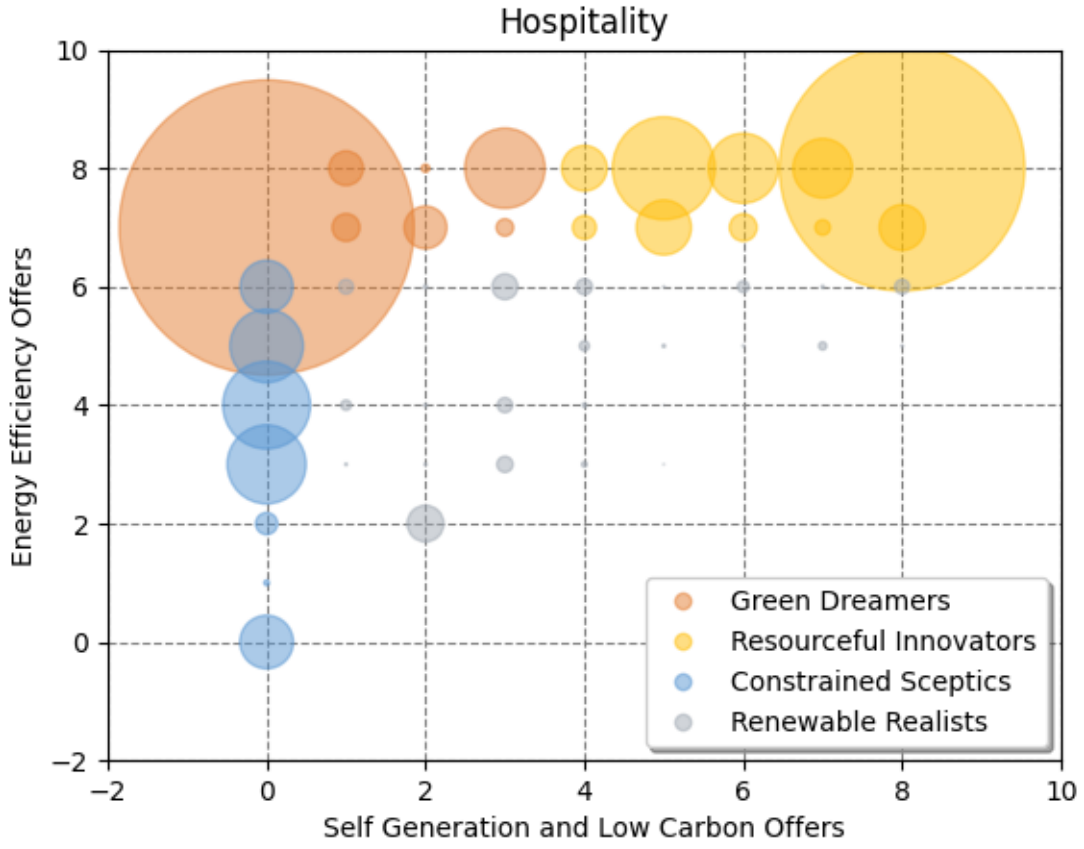
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Low

Normalised load profile



Hospitality Sector: Sub archetypes and features



Split of sub groupings in sector

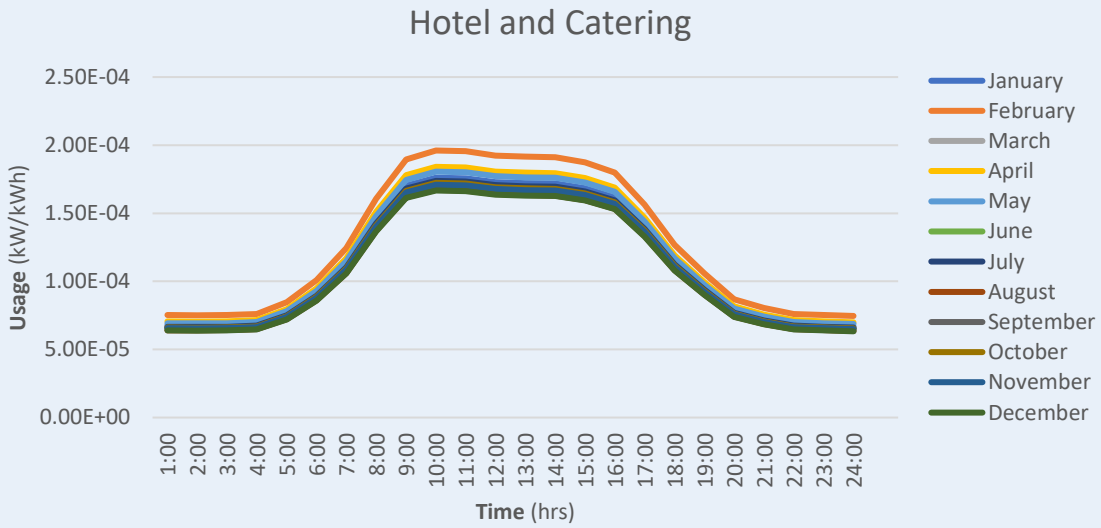
Green Dreamers : 46% of Sector **Resourceful Innovators:** 41% of Sector

Constrained Sceptics: 12% of Sector **Renewable Realists:** 2% of Sector

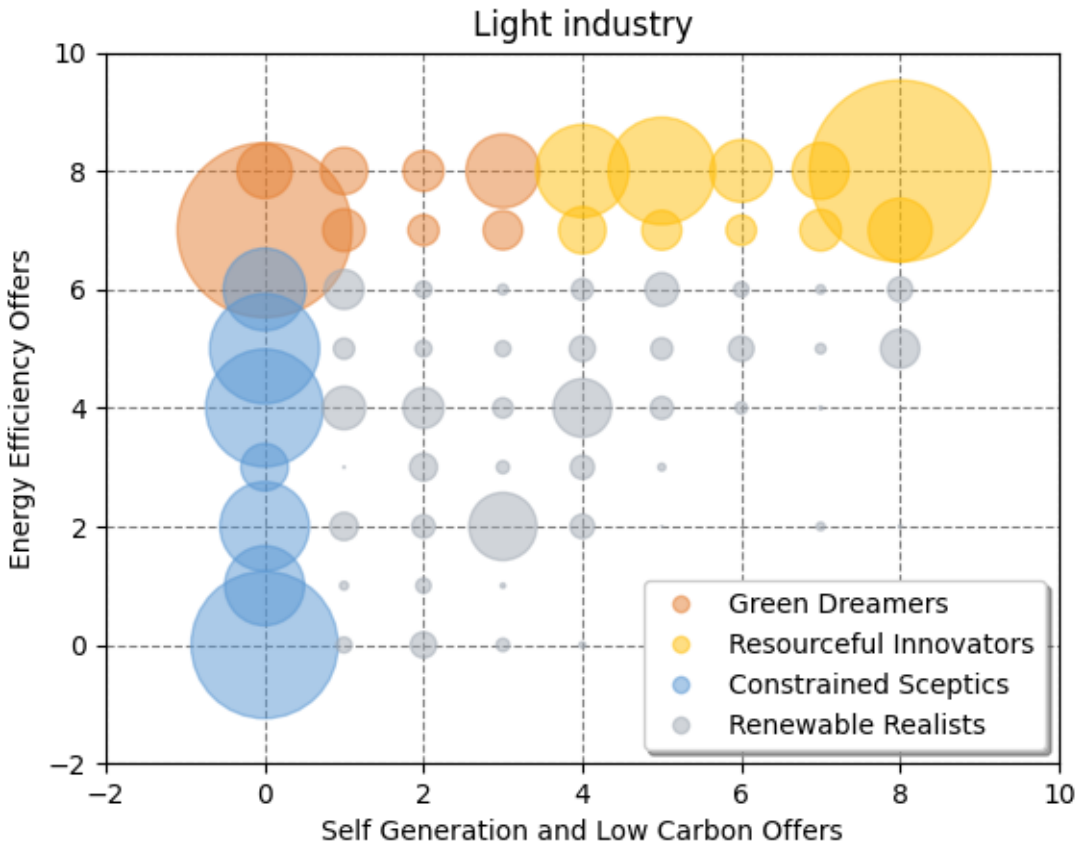
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Low

Normalised load profile



Light Industry Sector: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 22% of Sector

Resourceful Innovators: 33% of Sector

Constrained Sceptics: 33% of Sector

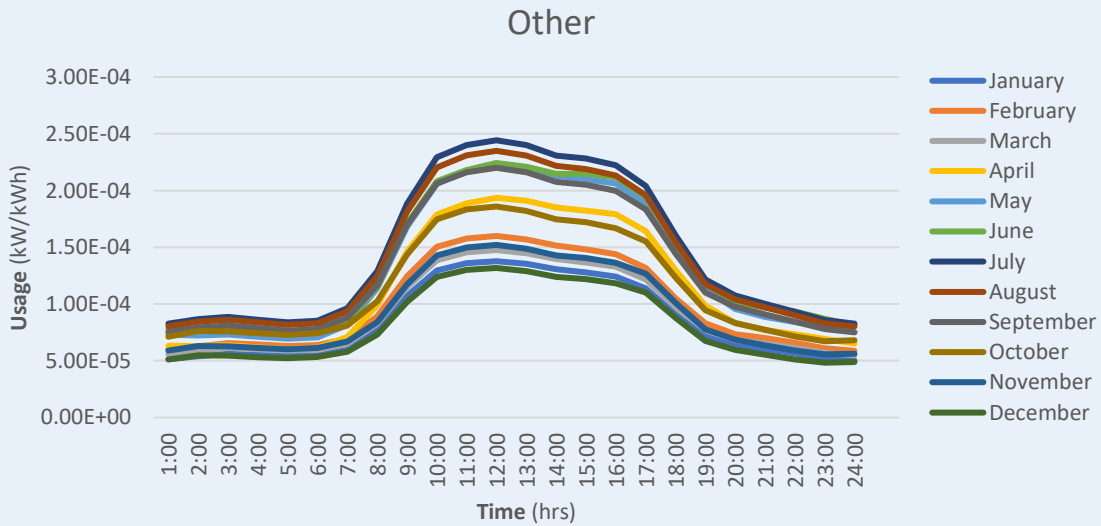
Renewable Realists: 12% of Sector

Engagement metrics

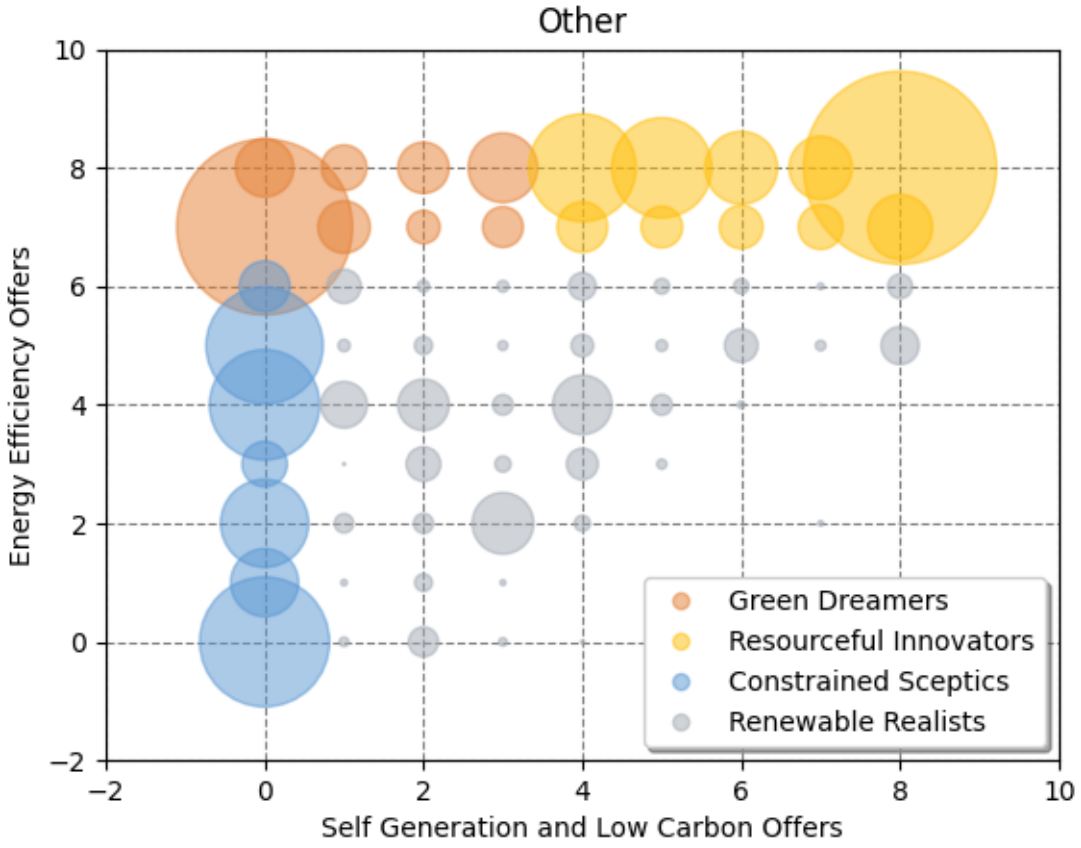
	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Medium/Low

Normalised load profile

Note that the profile used for light industry is the same as the "other sectors" profile.



Other Sectors: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 23% of Sector

Resourceful Innovators: 38% of Sector

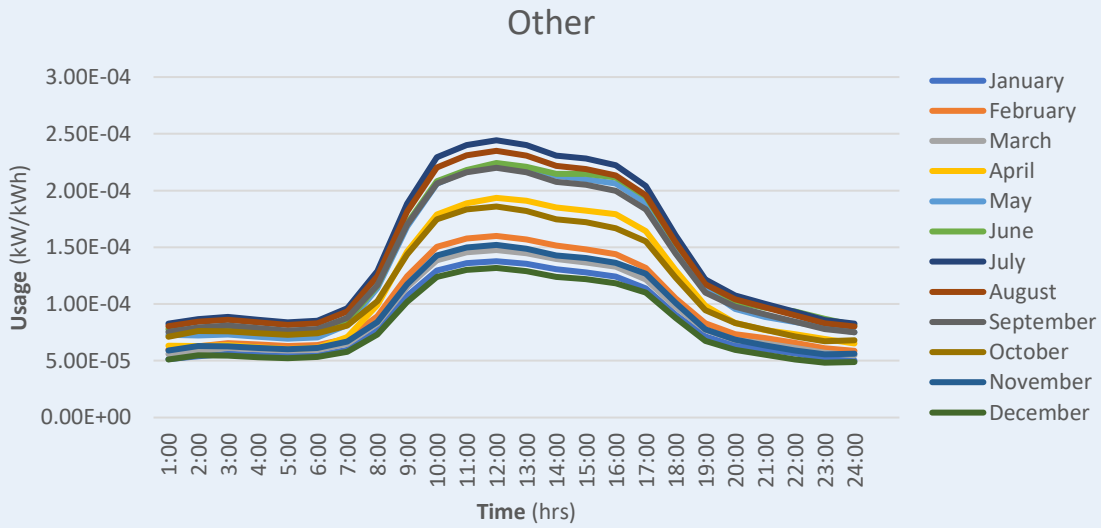
Constrained Sceptics: 28% of Sector

Renewable Realists: 12% of Sector

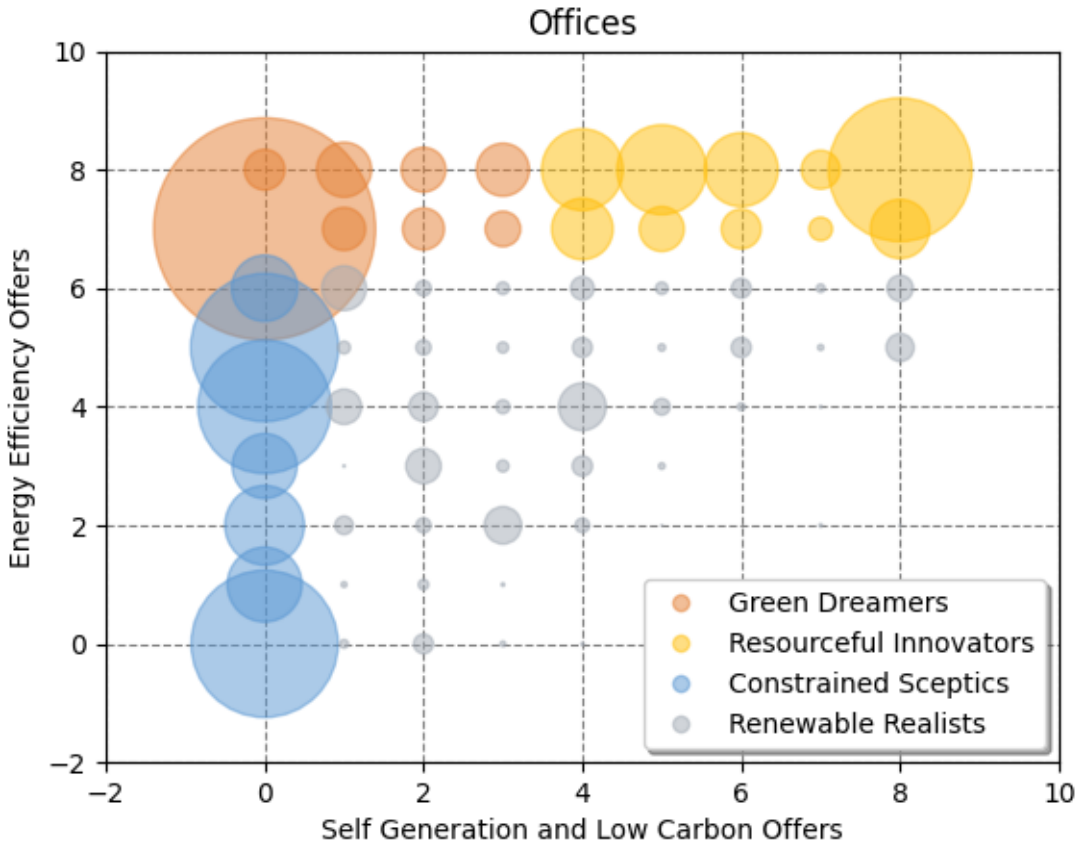
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Medium/Low

Normalised load profile



Offices Sector: Sub archetypes and features



Split of sub groupings in sector

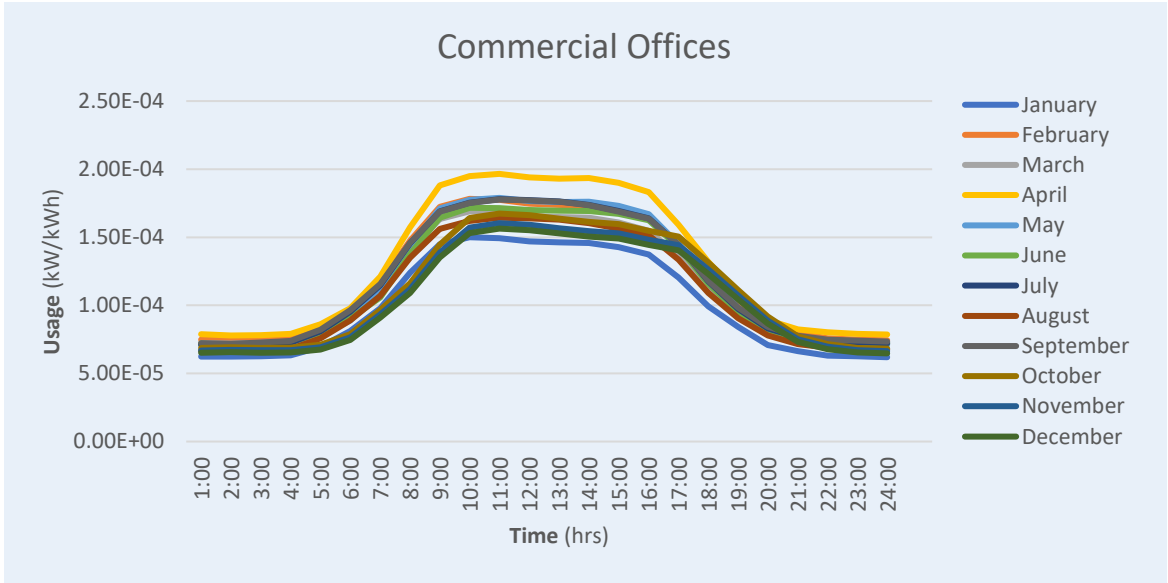
Green Dreamers : 30% of Sector **Resourceful Innovators:** 25% of Sector

Constrained Sceptics: 38% of Sector **Renewable Realists:** 7% of Sector

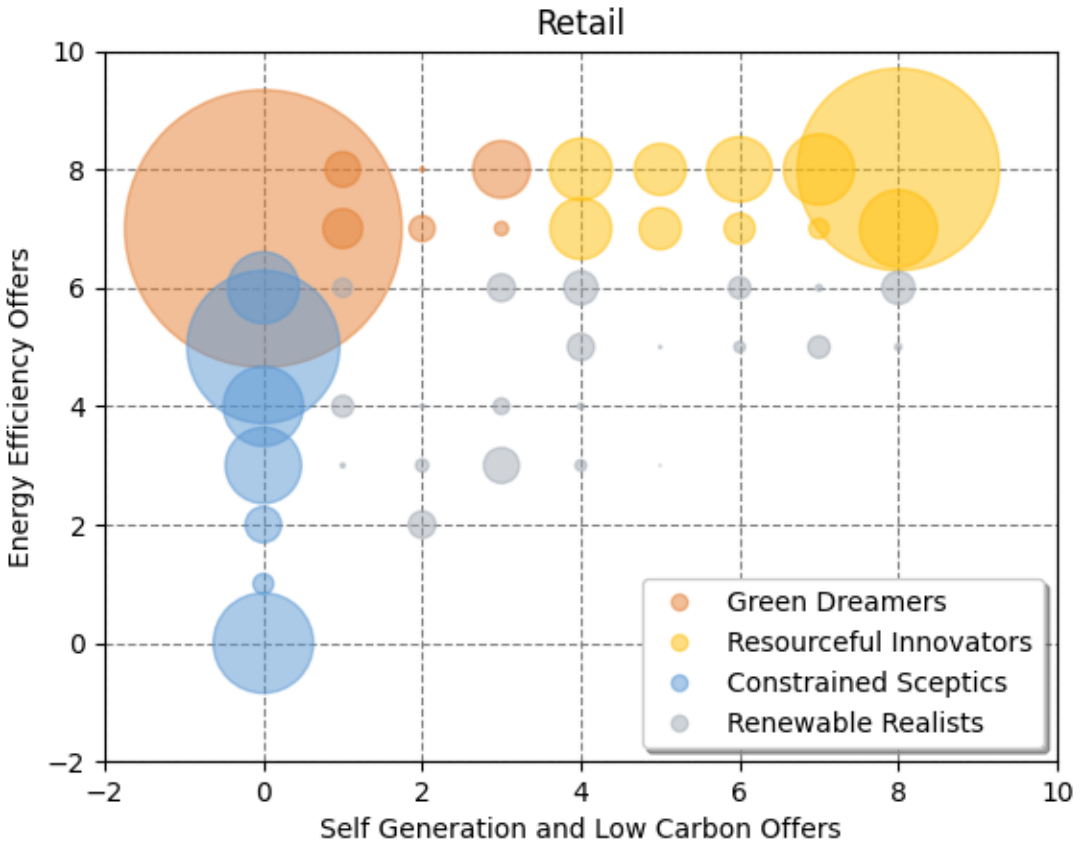
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Medium/Low

Normalised load profile



Retail Sector: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 39% of Sector

Resourceful Innovators: 32% of Sector

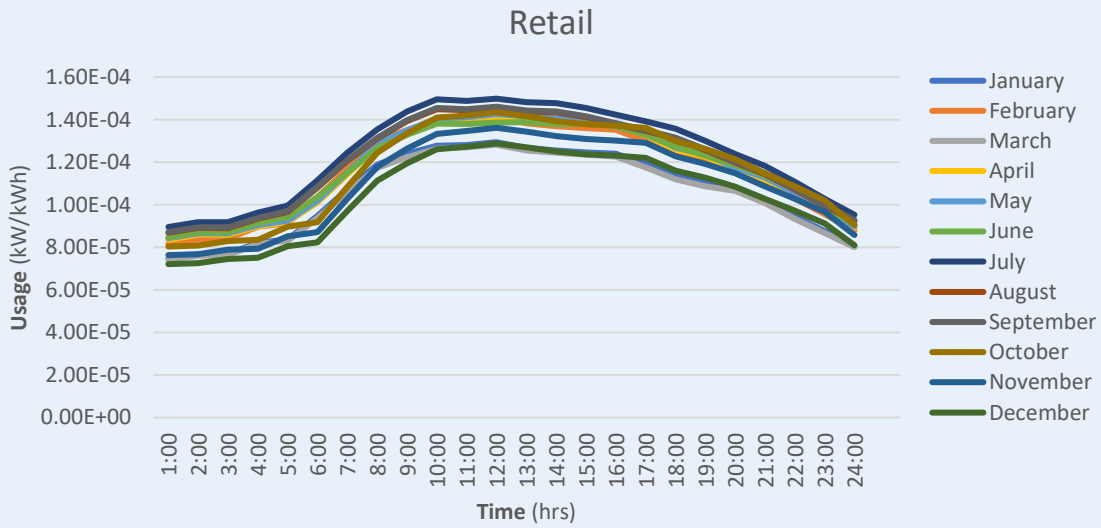
Constrained Sceptics: 24% of Sector

Renewable Realists: 4% of Sector

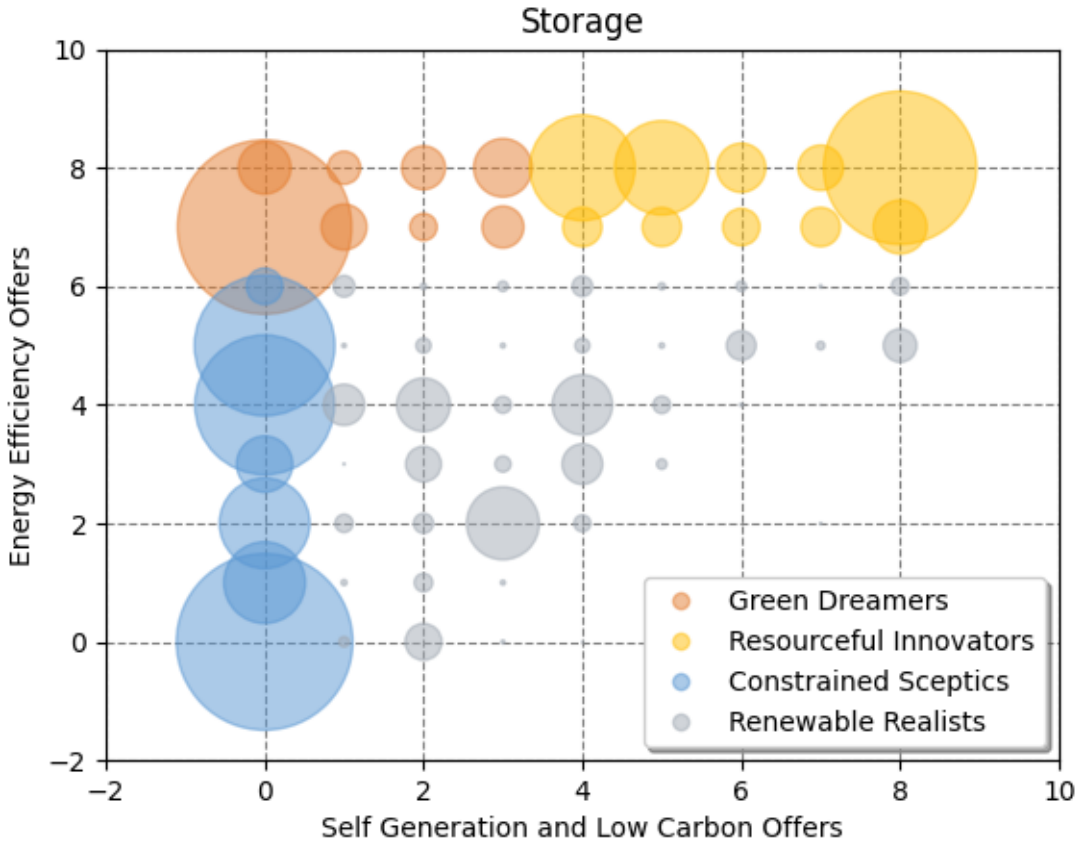
Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Low/Medium
Resourceful Innovators	High	High	Medium
Constrained Sceptics	Low/Medium	Low	Low
Renewable Realists	Medium	Medium	Low/Medium

Normalised load profile



Storage Sector: Sub archetypes and features



Split of sub groupings in sector

Green Dreamers : 21% of Sector

Resourceful Innovators: 26% of Sector

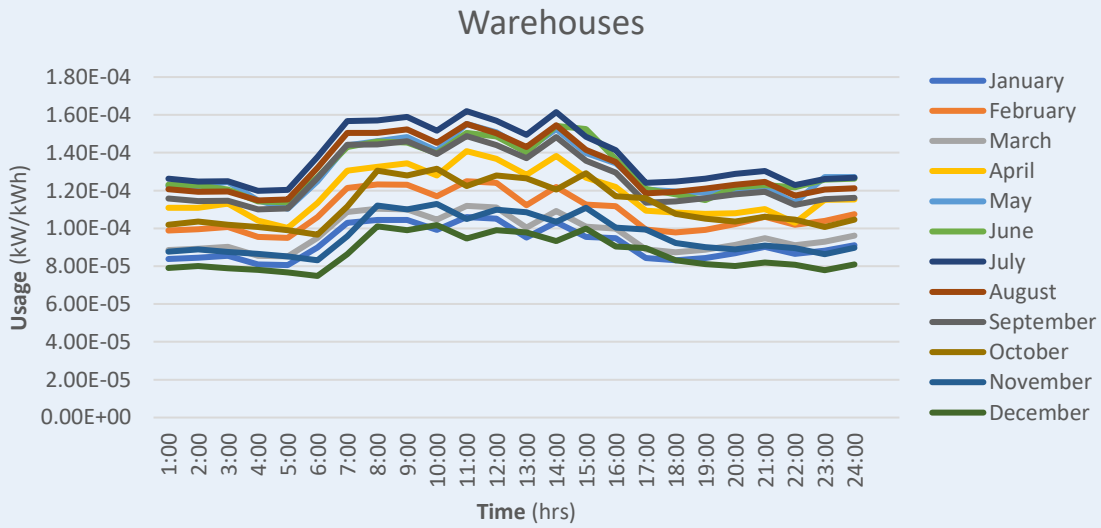
Constrained Sceptics: 42% of Sector

Renewable Realists: 11% of Sector

Engagement metrics

	Energy Efficiency	Low Carbon Technologies	Flexibility
Green Dreamers	High	Low	Medium/High
Resourceful Innovators	High	High	Medium/High
Constrained Sceptics	Low/Medium	Low	Medium/Low
Renewable Realists	Medium	Medium	Medium/Low

Normalised load profile



Heavy Industry: Archetypes

- These sites were handled separately to the data sourced from non-domestic EPCs. Each site and its point location was taken from the NAEI database which contains all industry sites in the UK with emissions over 2.5 ktCO2/year.
- The national demand from industry was calibrated against the DUKES 2021 total demand from industry.
- As this sector is incredibly diverse in terms of their energy needs and decarbonisation options we have segmented the population by industrial-sub sector rather than engagement with particular technologies.
- The decarbonisation options for each sub sector were developed through a detailed analysis of the industrial sector which builds off of the "Industrial Fuel Switching Market Engagement Study" conducted by Element Energy in 2018.

Industrial Sub-Archetypes	Percentage of Sector
Iron and steel	11%
Chemicals	25%
Food and drink	9%
Paper	10%
Cement	5%
Other	39%

- Each sub-sector has particular loads and processes that informs decarbonisation options.
- We expect the constraints of these processes to be more restrictive than any of the organisational characteristics used to model engagement in other sectors with less diverse loads.
- The decarbonisation options for each sector are listed on the next few slides and can be used in scenario modelling to inform modelling decision about how each sector can evolve.

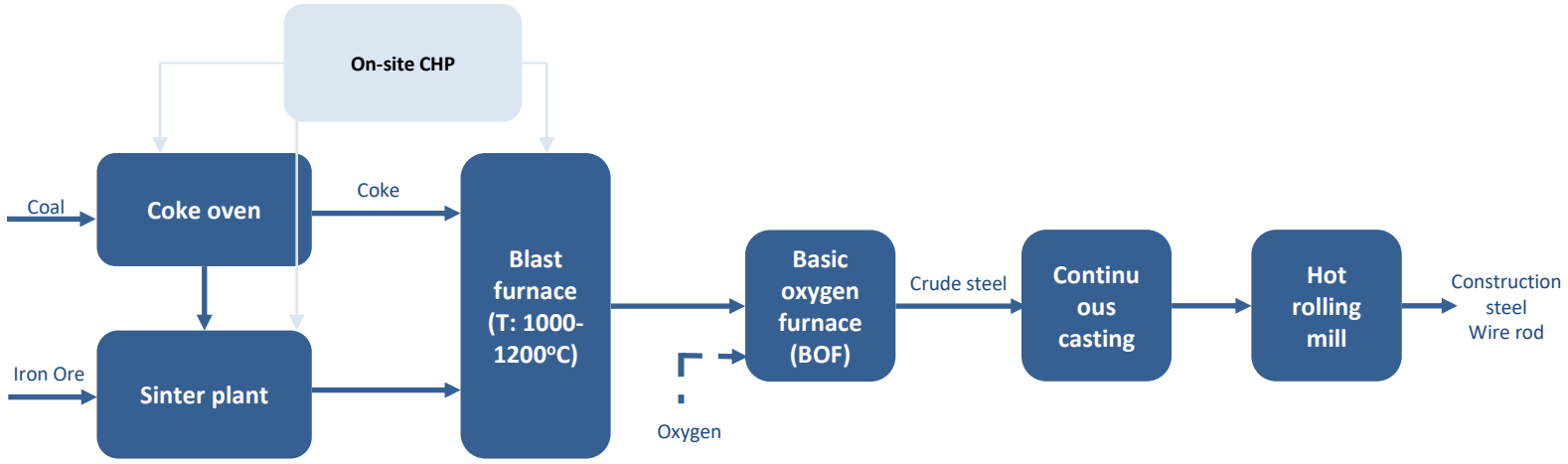
Iron and steel

The iron and steel sub-sector is modelled by 35 sites taken from the NAEI dataset and represents 11% of the industry sites modelled.

Sector summary

Sector	Iron and steel
SIC code	24100
Key uses of energy	Blast furnace, sinter, coke ovens, rolling mill furnaces, oxygen furnaces
Main products	Construction steel, wire rod

Archetypal process diagram for an integrated iron and steel site[1]



Option	Description	TRL	Disruption on existing UK sites	Likely fossil fuel reduction
CCS	Apply carbon capture to sinter plant, coke oven, blast furnace (BF) and basic oxygen furnace (BOF)	7	Low	Medium
H2	A hydrogen powered shaft furnace replaces the blast furnace to produce Direct Reduced Iron (DRI) which can then be fed into an Electric Arc Furnace	5	High	High
Electrification	The Electric Arc Furnace (EAF) route: it is the manufacture of steel from scrap. Alternatively, EAFs can also be charged with direct reduced iron (DRI)	9	Medium	High

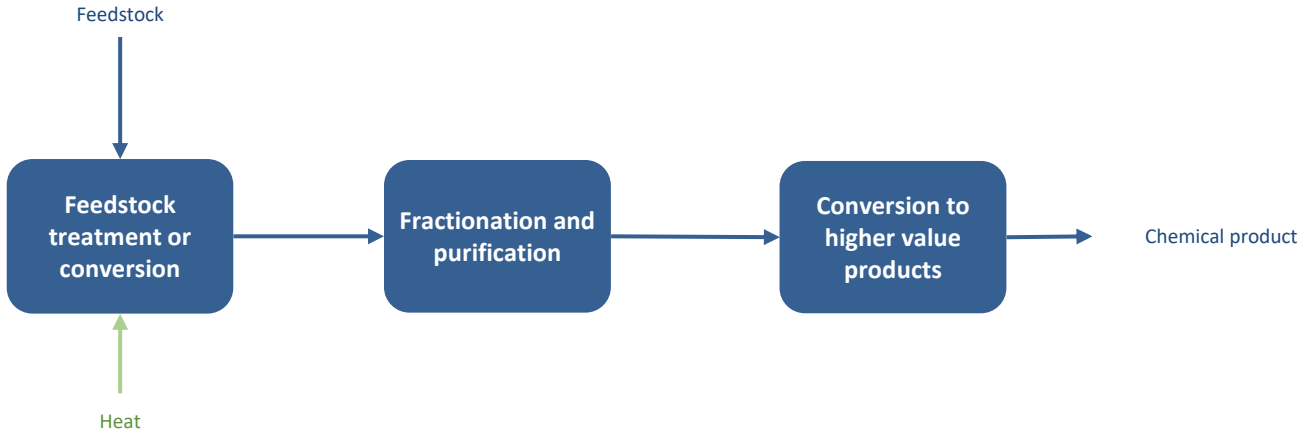
[1]Port Talbot | Tata Steel in Europe (tatasteeleurope.com), **TRL**: "Technology readiness level" which describes the maturity of a given technology. Further guidance available here

Chemicals

The chemicals sub-sector is modelled by 83 sites taken from the NAEI dataset and represents 25% of the industry sites modelled.

Sector summary

Sector	Chemicals
SIC code	20110-20200
Key uses of energy	Cracking, quenching, compressing, separation, refrigeration
Main products	H_2, ethylene, propylene, BTX, nitric acid, polymers, pharmaceuticals



Option	Description	TRL level	Disruption on existing UK sites	Likely fossil fuel reduction
CCS	Apply carbon capture to the flue gases (and boilers)	9	Low	High
Electrification	Use electricity to generate heat and/or steam	9	Medium	Medium
Bio-based feedstocks	Replace ethane and naphtha with bio-based feedstocks which do not require steam cracking	6	High	Medium

TRL: "Technology readiness level" which describes the maturity of a given technology. Further guidance available here.

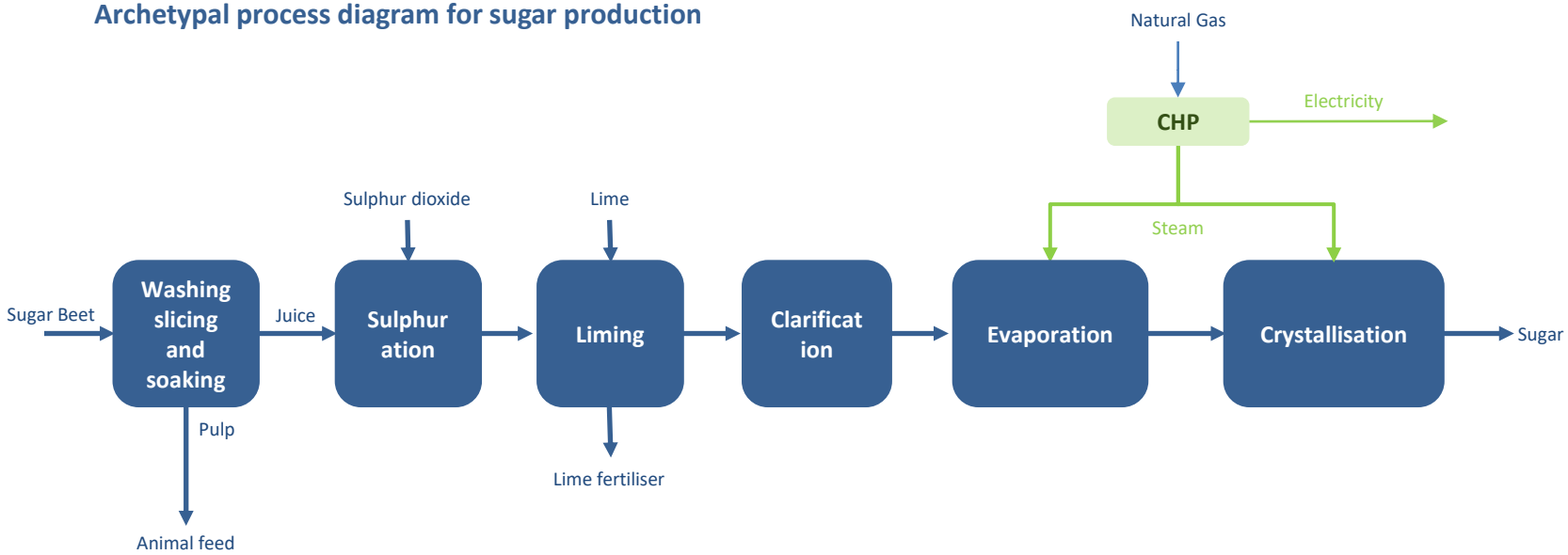
Food & Drink

The food & drink sub-sector is modelled by 31 sites taken from the NAEI dataset and represents 9% of the industry sites modelled.

Sector summary

Sector	Food, drink and tobacco industry
SIC code	10810
Key uses of energy	Combined Heat and Power, heating, cooling
Main products	Sugar, meat, milk, whiskey, beer

Archetypal process diagram for sugar production



Option	Description	TRL level	Disruption on existing UK sites	Likely fossil fuel reduction
Biomass + BECCS	Food waste produced as a by-product could be burnt in a biomass boiler to produce heat and power	9	Low	High
Electrification	Replacement of CHPs with a heat pump to upgrade waste heat	9	Medium	Medium

TRL: "Technology readiness level" which describes the maturity of a given technology. Further guidance available here.

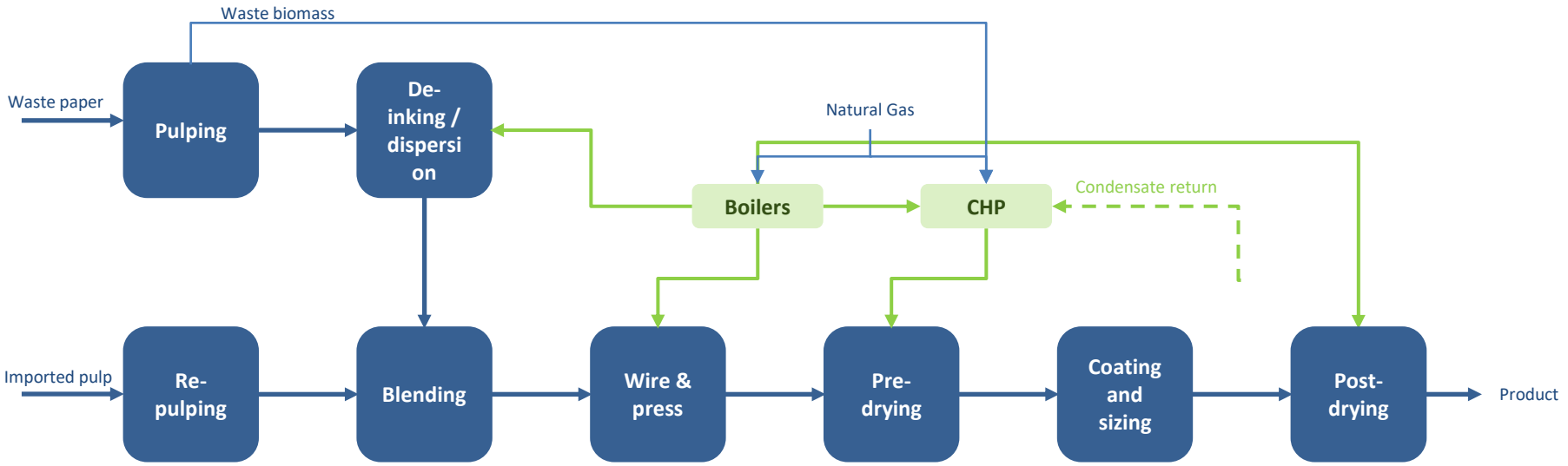
Paper & Pulp

The paper sub-sector is modelled by 34 sites taken from the NAEI dataset and represents 10% of the industry sites modelled.

Sector summary

Sector	Paper & pulp
SIC code	17110-17290
Key uses of energy	Drying pulp and paper
Main products	Paper of various grades

Archetypal process diagram for a paper mill



Option	Description	TRL level	Disruption on existing UK sites	Likely fossil fuel reduction
Biogas (+ CCS)	Organic residues can be combusted in their solid form or fed into anaerobic digesters to produce biogas which can replace natural gas.	9	Low	High
Electrification	Replacement of existing fossil fuel fired boilers with dedicated electric boilers or hybrid boilers.	9	Medium	Medium

TRL: "Technology readiness level" which describes the maturity of a given technology. Further guidance available here.

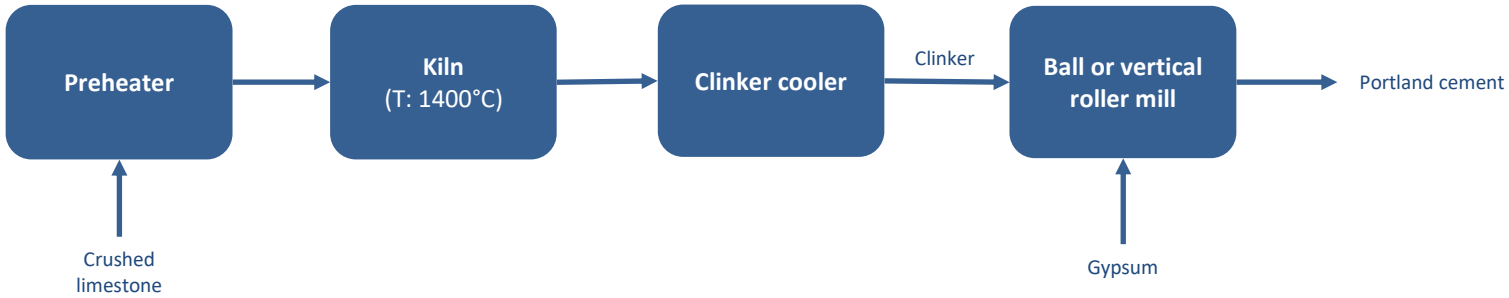
Cement

The cement sub-sector is modelled by 17 sites taken from the NAEI dataset and represents 5% of the industry sites modelled.

Sector summary

Sector	Cement
SIC code	23510
Key uses of energy	Kiln
Main products	Cement for construction

Archetypal process diagram for a cement kiln



Option	Description	TRL level	Disruption on existing UK sites	Likely fossil fuel reduction
CCS	Carbon capture can be applied to abate combustion emissions but it will also enable abatement of process emissions.	9	Low	Medium
Electrification	The kiln is electrified.	8	High	High

TRL: "Technology readiness level" which describes the maturity of a given technology. Further guidance available here.

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Using the archetypes in modelling

As discussed, each archetype is described by a set of features.

- These features represent how the archetypes ***currently*** behave.
- Features can and should be combined to reflect a more diverse set of behaviours.
  - For example, using an archetype's peak demand, flexible percentage of peak load for that sector and the engagement with flexibility you can model the expected flexibility contribution of an archetype.
  - If the peak demand is 100 kW for a group of Green Dreamers in the Retail Sector, and 20% of that peak demand is technically flexible that leaves 20 kW of flexible load. As the archetype has low/medium engagement with flexibility we would not expect full participation (20kW) in flexibility from this archetype.
  - In a more ambitious scenario, the archetype may be willing to flex more of this technically flexible load.
- The framework for engagement used to create the archetypes (3Cs) and the provided archetype descriptions should be used to adjust the behaviour represented by the features for different scenario worlds.

	Feature/Parameter
Engagement	Engagement with Flexibility: High, Medium, Low
	Engagement with EE: High, Medium, Low
	Engagement with LCT: High, Medium, Low
	Key policy/financial hurdles to engagement
Load	Percentage of peak load which is technically flexible
	Annual demand (electricity and gas) per archetype/floorspace
	Load profiles + peak demand
Geography	Archetype distribution at LSOA

System Change: How do archetypes behave over modelled time?

Archetypes and consumer distribution into archetypes are *constant* through time but behaviour/interaction with models changes with time and modelled FES scenario world.

- So, while 38% of the Offices sector will always be “Constrained Sceptics” the entire group is likely to become more engaged as policy reduces the hurdles to uptake.

The behaviour of each archetype is captured by the features presented and the archetype descriptions (below) indicate how that behaviour is likely to change in response to different scenarios:

Green Dreamers:

- Green Dreamers may be highly concerned but may lack the capacity and conditions to engage.
- They are more likely to engage in scenarios where change is driven by system-wide enablers which reduce individual hurdles to engagement.

Resourceful Innovators:

- Resourceful Innovators often have all resources necessary to engage.
- These consumers have the conditions, capacity, and concern needed to engage but their ultimate engagement will depend on the options made available to them in a scenario.

Constrained Sceptics:

- Constrained Sceptics often lack conditions, capacity and concern.
- This group will be the most difficult to mobilise and will be the last to engage across all scenarios.

Renewable Realists:

- Renewable Realists may have the capacity to act but may not be sufficiently motivated to engage.
- These organisations will be engaged in scenarios where policy forces consumers to shift or when it makes low carbon technologies cost-optimal.

Implications of archetype characteristics for scenario modelling

The current and future engagement of an archetype ties back to the framework used to understand organisational behaviour:

- For an organisation to take action they must have the “conditions, capacity and concern” to engage with an innovation.
- A scenario may represent changes to any one of these levers and boost engagement from an archetype.

How each framework element relates to archetype behaviour:

- **Concern**: The low energy spend and energy management ambition in the Constrained Sceptics and Renewable Realists are representative of their low concern – these organisations may not currently spend a lot on energy and are less engaged. Rising energy costs may boost this concern and mandatory decarbonisation targets may also be a reasonable substitute for concern to facilitate action.
- **Capacity**: Support for businesses with fewer resources may boost organisational capacity. Increasing maturity of flexibility and LCTs is also expected to reduce the barriers and resources necessary to engage.
- **Conditions**: As these represent the technical characteristics which limit engagement these are also likely to improve with technological maturity. Decisions in scenarios regarding how particular areas may decarbonise (e.g. a heat network in one area) will impact the conditions for each archetype.

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The first step in archetype creation involves cleaning and linking datasets to produce a large set of “proto-archetypes”

1

Non-Domestic Consumers: Characteristics

Step 1 combines and calibrates datasets to create a set of proto-archetypes (building archetypes) which represent each type of organization and building.

A. Read and process EPC data
Process EPC data in Python.

B. Compile organisation data
Transform data to map to BEES sectors.

C. Aggregate EPC data to LSOA level
Sum and average statistics to produce LSOA level numbers.

D. Process VOA data
Convert VOA data into the right format and account for missing properties.

E. Account for missing floorspace
Use VOA statistics to fill in gaps in EPC records.

F. Calculate and split industry usage
Use the split of DUKES consumption from industry to calculate consumption from industry.

G. Calibrate consumption
Calibrate electricity and gas consumption values using ND-NEED and BEIS statistics.

H. Generate combinations
Create a complete list of all the combinations of variables within a sector.

Output: Set of proto-archetypes and their breakdown at LSOA level.

The second three steps set the requirements for engagement and evaluate offer uptake to nest proto-archetypes into a usable set

2 Technologies and Programmes: Requirements for Engagement

Step 2 determines which attributes a proto-archetype must have to engage with an offer or technology.

A. Engagement assumptions
Literature review and stakeholder engagement used to build and refine assumptions around engagement.

Iterative process

B. Create offer-attribute matrix
Assign weighting of attributes for each offer considered in modelling.

Output: Matrix of key requirements for each offer and their weighting.

3 Technology and Programme Engagement Analysis

Step 3 evaluates the ability of each proto-archetype to engage with an offer.

A. Offer uptake simulation
Evaluate which proto-archetypes engage with each offer.

Iterative process

B. Calibrate results
Use the Ofgem 2022 ND Consumer Survey to adjust expected engagement.

4 Non-Domestic Consumer Archetypes

Step 4 transforms the proto-archetypes into a set of nested archetypes primarily defined by sector.

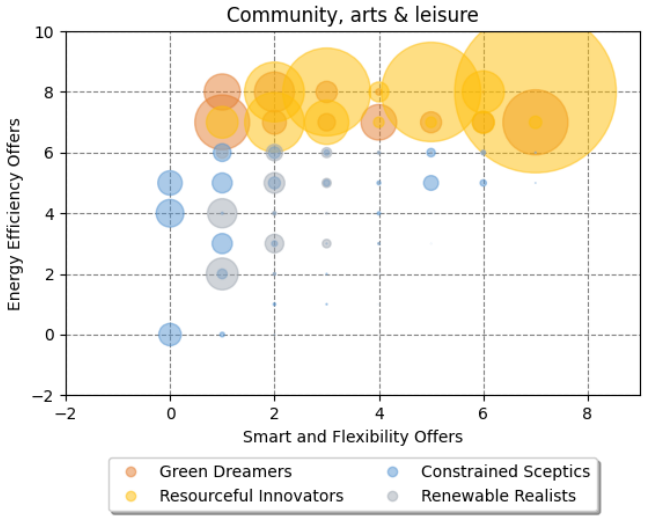
A. Analysis of offer uptake
Examine uptake across sector for initial insights to nest archetypes.

B. Formatting outputs
Create plots showing engagement by archetype.

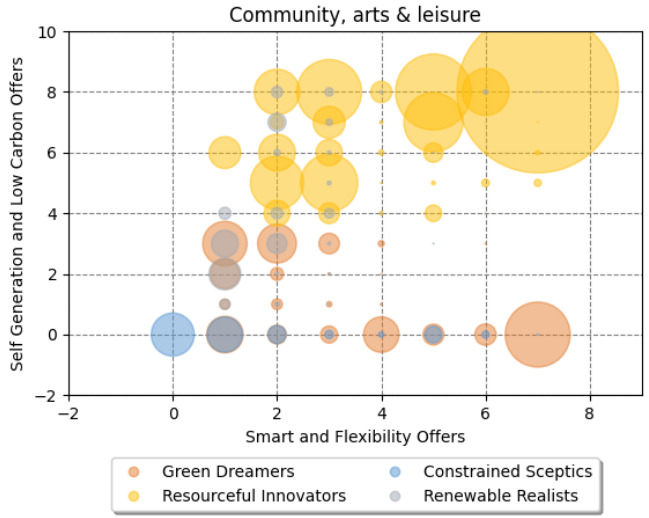
Archetype Segmentation

- To segment the non-domestic population we plotted offer uptake by sector across **three offer categories– engagement with energy efficiency, smart + flexible energy, and low carbon + self generation**.
- The charts below show how the archetypes can be plotted against the three offer categories. The graph to the far right shows engagement with energy efficiency plotted against engagement with self generation + low carbon offers, which was used to create the four archetype segments.
  - Each colour in the charts represents an archetype and the size of the bubble indicates the percentage of the sector that engages with each offer.
- Across all three graphs, the Constrained Sceptics and Renewable Realists have lower engagement (as shown by their concentration on the bottom left of the plots).
- The Resourceful Innovators show consistently high engagement (with high concentration in the top right of the plots).
- The Green Dreamers shift around the graph with mixed engagement with flexibility, low engagement with LCTs and high engagement with energy efficiency.

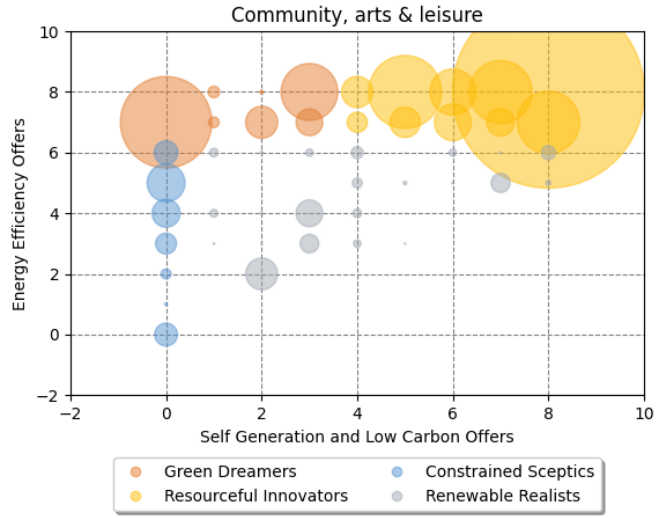
Flexibility vs Energy Efficiency



Flexibility vs Low Carbon Tech.



Low Carbon Tech. vs Energy Efficiency



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Summary of datasets used to describe the non-domestic consumer population

Non Domestic EPC Database 2022

Scope:

- Separate databases for Scotland and England/Wales.
- All properties covered by mandate.

Limitations:

- Does not cover all properties.
- Some fields (floorspace, usage) missing for many properties.
- Entries can be up to 10 years out of date.

ND National Energy Efficiency Data-Framework 2022

Scope:

- Covers metered electricity and gas consumption of non-domestic buildings in England and Wales.
- Data spans from 2012 to 2020 and was last updated in 2022.

Limitations:

- Relies on modelled outputs to account for gaps in collected data.

Building Energy Efficiency Survey 2016

Scope:

- England/Wales only.
- A sample of 3690 telephone surveys and 214 site surveys.

Limitations:

- Does not include Scotland.
- Data is over 5 years old, some load assumptions may not be accurate.

Ofgem ND Consumer Research 2022

Scope:

- Survey of 1,000 non-domestic consumers in the UK.
- Focus on impacts of energy price increases and attitudes towards energy market.

Limitations:

- Data collected during the peak of the energy crisis, some insights may not reflect views as prices fall.

Summary of additional datasets used to calibrate demand and support archetype creation

BEIS MSOA Data — 2021

Scope:

- Annual gas and electricity consumption at MSOA/LA data for non-domestic customers in the UK.
- Includes both HHM and non-HHM usage.

Limitations:

- HHM data is only presented at local authority.
- Usage is not attributed to a particular sector.

VOA Floorspace Data — 2020

Scope:

- Provides data on rateable floorspace at LSOA level in England and Wales.

Limitations:

- Some floorspace is not rateable and is excluded from the dataset including some welfare buildings and places of worship.

Non-Domestic Load Profiles — 2012

Scope:

- Average load profiles for each sector from EE work for Ofgem.

Limitations:

- The age of these profiles may limit their relevance.
- Users with access to more granular data may want to substitute their own data – as profiles are appended to the archetypes after segmentation this should be an easy substitution.

ONS Postcode to LSOA Mapping — 2022

Scope:

- Dataset linking postcodes to LSOAs.

Limitations:

- Although this dataset is frequently updated there are some postcodes missing from the mapping.

Additional data used to characterise heavy industry users

National Atmospheric Emissions Inventory	2022

Scope:

- All industrial sites with emissions over 2 kilotonnes CO2e annually.
- 330 sites in GB with emissions data.
- Data segmented into five industry sub-sectors.

Limitations:

- Does not cover all industry sites.
- No demand/energy usage information.

Industrial Sub-Sectors
Iron and steel
Chemicals
Food and drink
Paper
Cement
Non-modelled

Treatment of heavy industry data

- Unlike the EPC data used to characterise all other sectors, heavy industry sites are not run through the offer tool.
- We instead characterise these sites based on their sub-sector (and associated process loads) as this is the most significant indicator for how these sites might decarbonise and engage with the energy market.
- This treatment also accounts for the fact that this industry data does not fit well with a number of the other datasets used as it is missing floorspace and demand information.

The variables used to describe organisations in the modelling uses three types of attributes linked together by the sector

Organisation Attribute Variables
Sector
Age of heating boiler
Building structure
Gas spend as a proportion of total costs
Electricity spend as a proportion of total costs
Energy management ambition
Business Size
Switched energy supplier in past 12 months
LCTs: Awareness and plans to use
Energy management resource
Tenure
LSOA/Location-Dependent Variables
Modelled energy usage
Flexible Peak Load
Static Variables
Electric sub load breakdown and suitability
B2B vs B2C (Public Image)
Safety regulations

The sector split comes from the split of property types in EPC data for each LSOA.

These variables are used to determine the bulk of offer uptake.

They largely represent the Capacity and Concern portion of the framework.

The data comes from national surveys and indicates what percentage of a sector has a particular attribute.

Sources: BEES, ND-NEED, Ofgem Consumer Survey

These variables come from EPC records which are aggregated to LSOA.

They represent key Conditions for flexibility offers and other useful stock information.

Source: Non-domestic EPC database

These variables are consistent within each sector and represent all three portions of the framework.

Source: BEES

Modelling considers a wide range of offers sourced from stakeholder engagement and FES

Offer Categories	
Flexibility + Smart Energy	Smart Energy
	Frequency Services
	Reserve Services
	Aggregation and Automation
	Tariffs
Energy Efficiency	
Low Carbon Technologies: *Self Generation + Low Carbon Heating and water*	

These offers cover a broad section of flexibility services considering both contracted services as well as price flexibility.

The technologies considered by these offers largely comes from technologies currently modelled in FES with the exception of energy efficiency offers which are sourced from abatement measures considered by BEES.

We consider 24 offers overall with 8 offers within each category with slightly different attributes required for each offer.

As we have very little financial data, engagement with any of these offers is not dependent on any CAPEX/financial hurdles.

A complete list of modelled offers can be found in the Appendix.

Complete list of modelled offers

Flexibility	Smart Energy	Energy as a Service
		EE and renewables retrofit services
		Smart heat and Energy controls or management systems (Automated devices)
	Demand Response	Frequency Services
		Reserve Services
	Automation and Aggregation	Aggregator Services - Demand
		Aggregator Services - Frequency
	Tariffs	ToU Tariff + variable pricing (electricity)
Energy Efficiency		General energy management practices (these include awareness campaigns and energy management systems)
		LED Lighting and automatic controls
		Hot water efficiency improvements
		Refrigeration efficiency improvements
		Upgrades to small appliance efficiency
		Space heating efficiency improvements
		Building fabric efficiency improvements
		Ventilation efficiency improvements
Low Carbon Technologies: Self Generation and Low Carbon Heating and water		On-site PV
		On-site wind
		Battery
		CHP
		District Heating (user)
		Hydrogen
		Heat Pumps
		Electric Boiler

Modelled Offers:

- 24 offers modelled overall.
- Offers are grouped into the three core groups and engagement with offers in these three groups is used to differentiate sub-archetypes within each sector.

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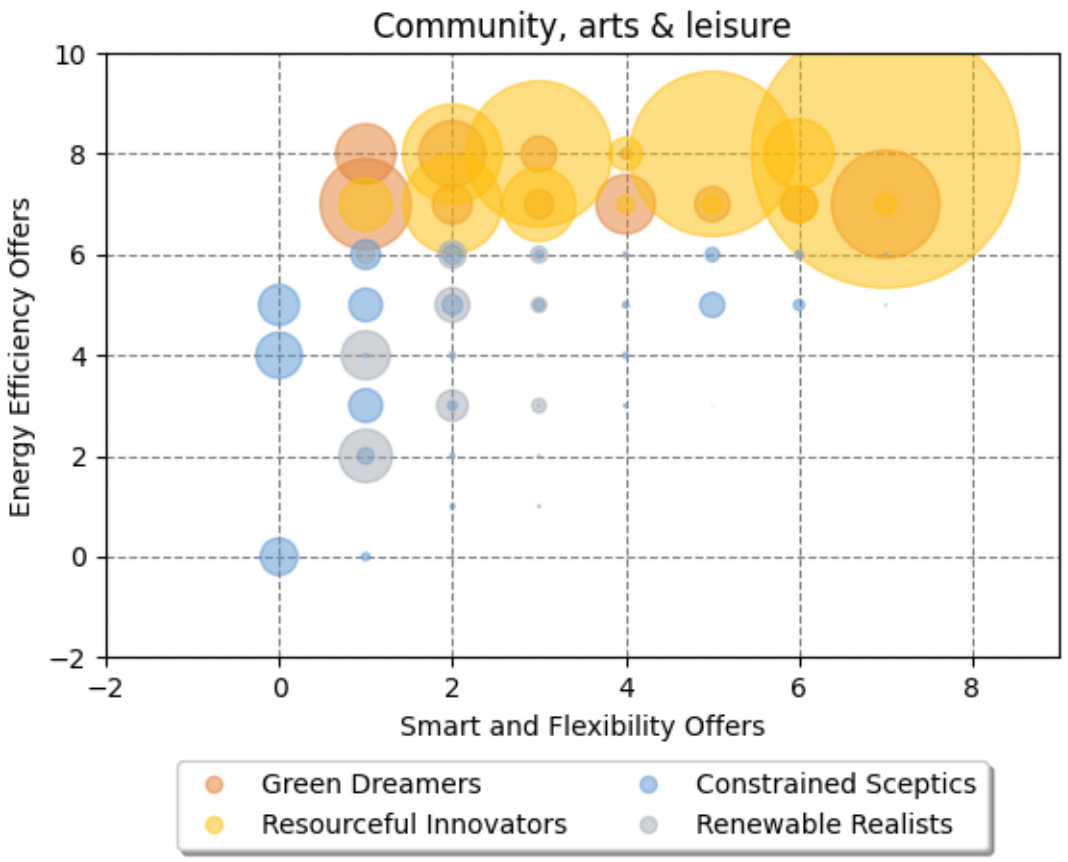
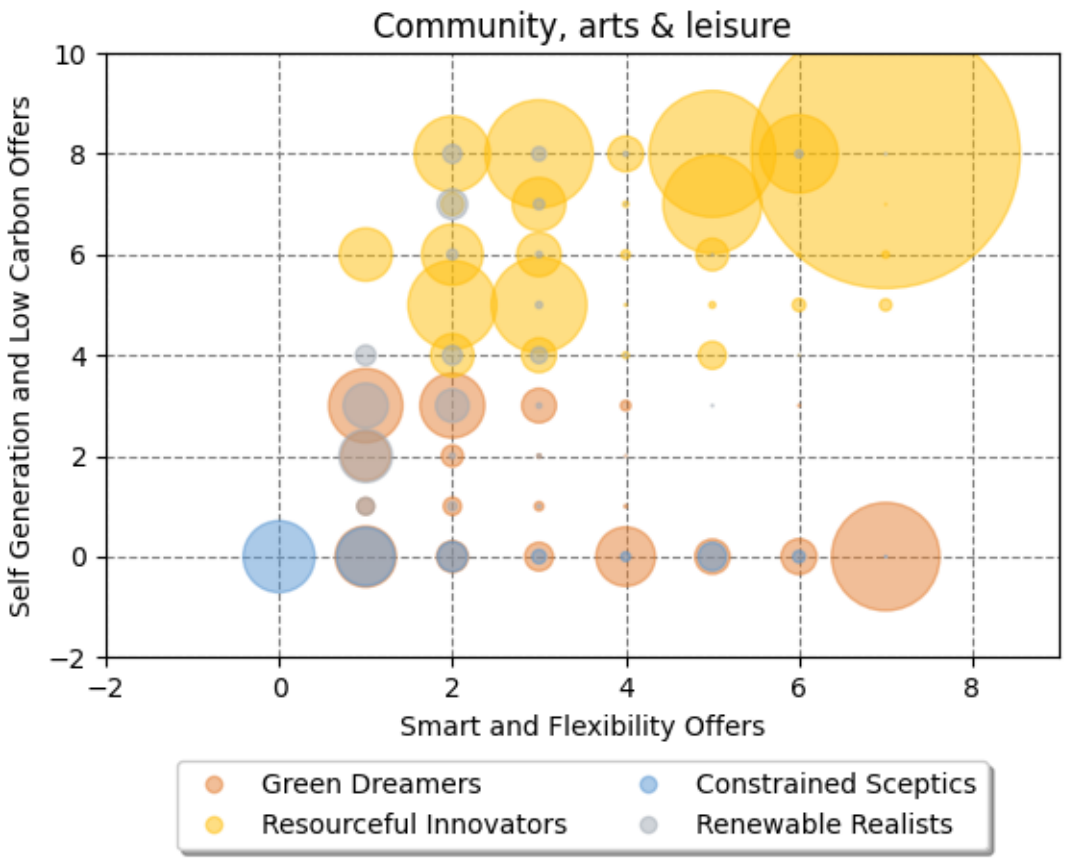
Community, arts & leisure Sector: Additional cluster graphs

Energy Efficiency and Flexibility

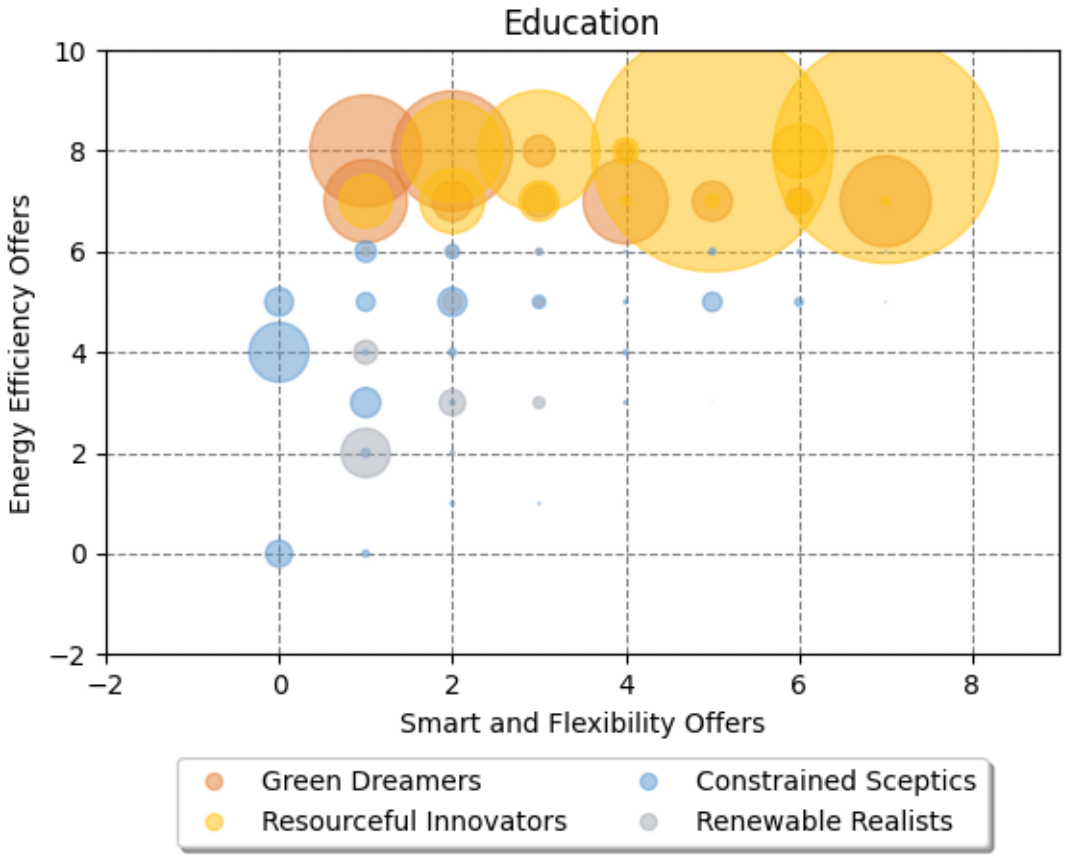


Low Carbon Technologies and Flexibility

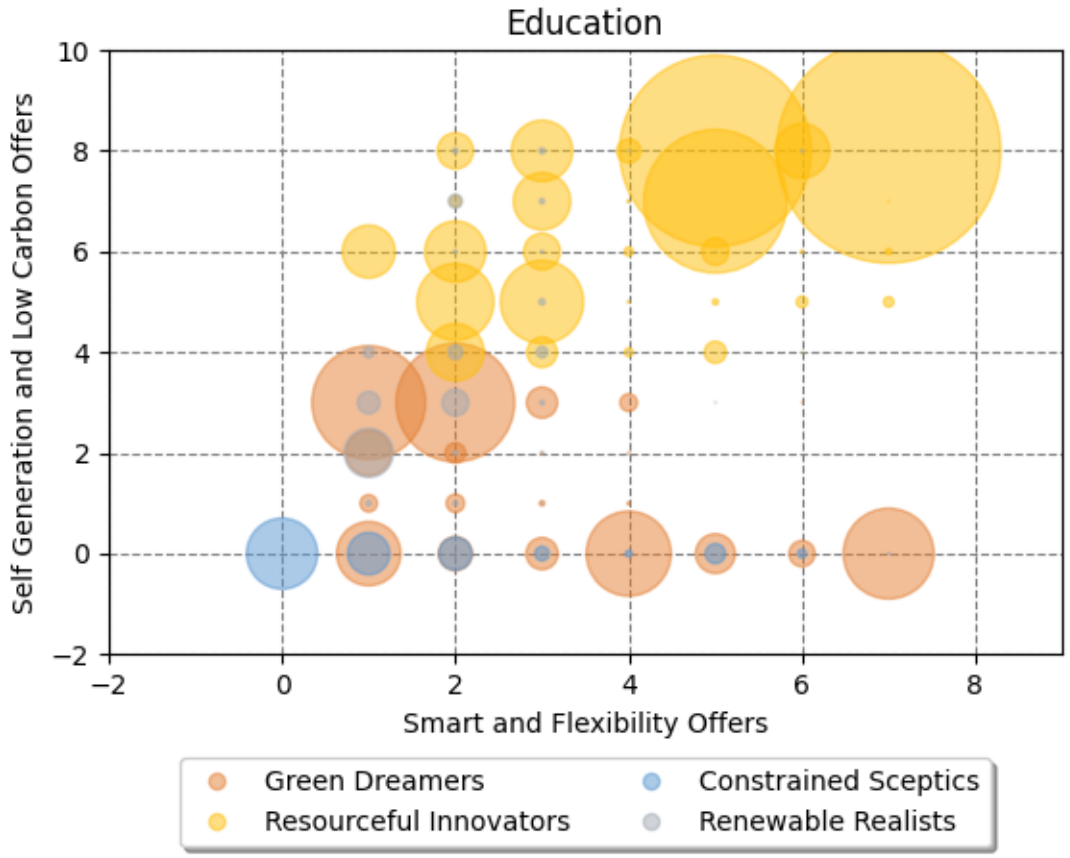


Education Sector: Additional cluster graphs

Energy Efficiency and Flexibility

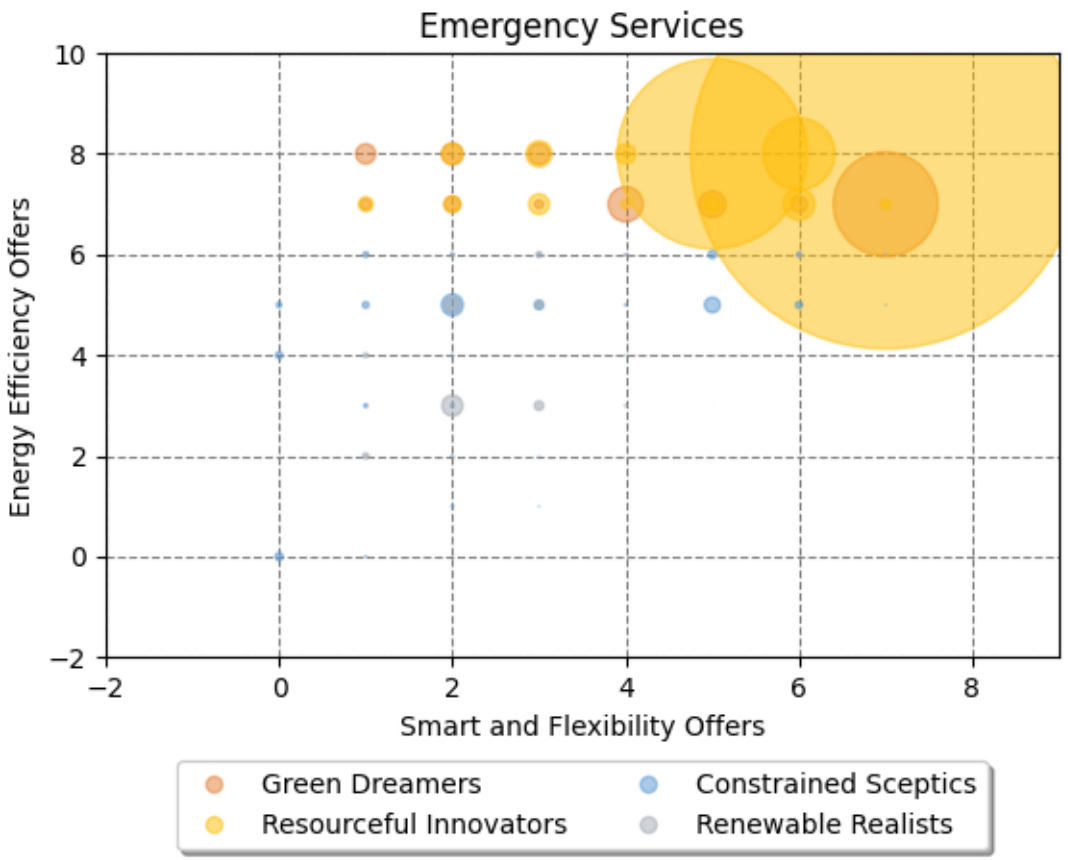


Low Carbon Technologies and Flexibility

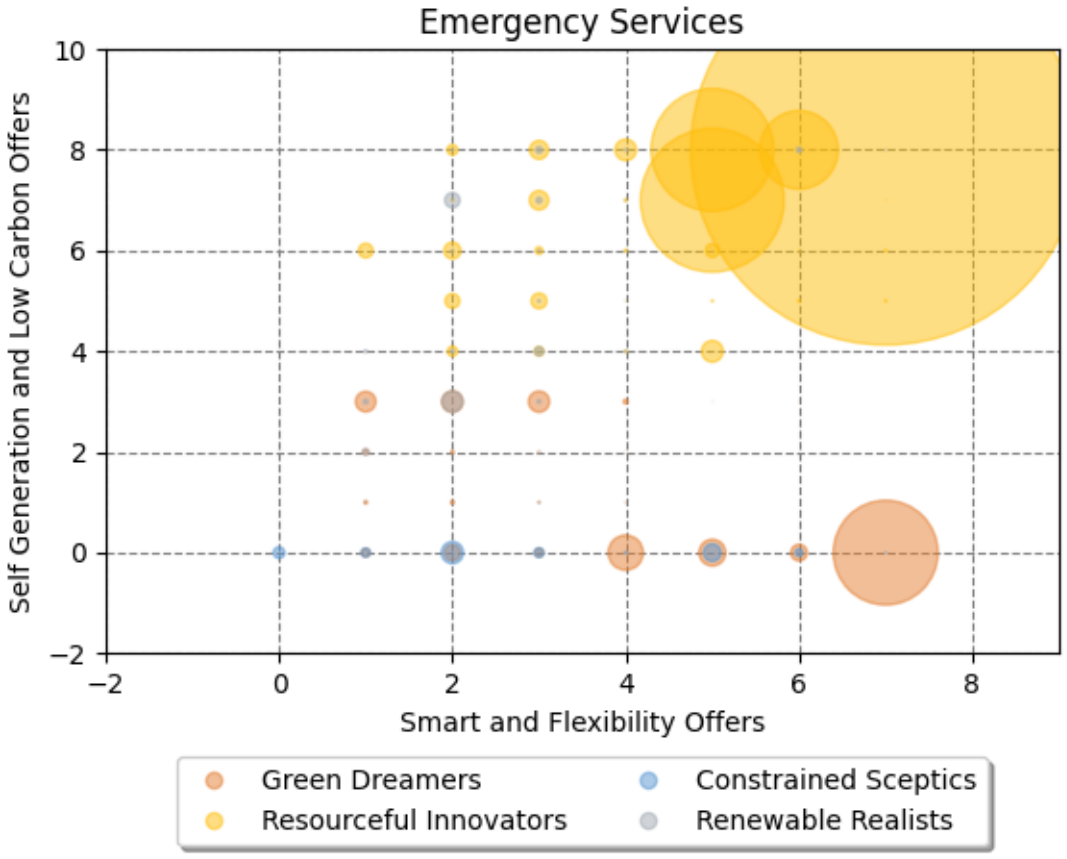


Emergency Services Sector: Additional cluster graphs

Energy Efficiency and Flexibility

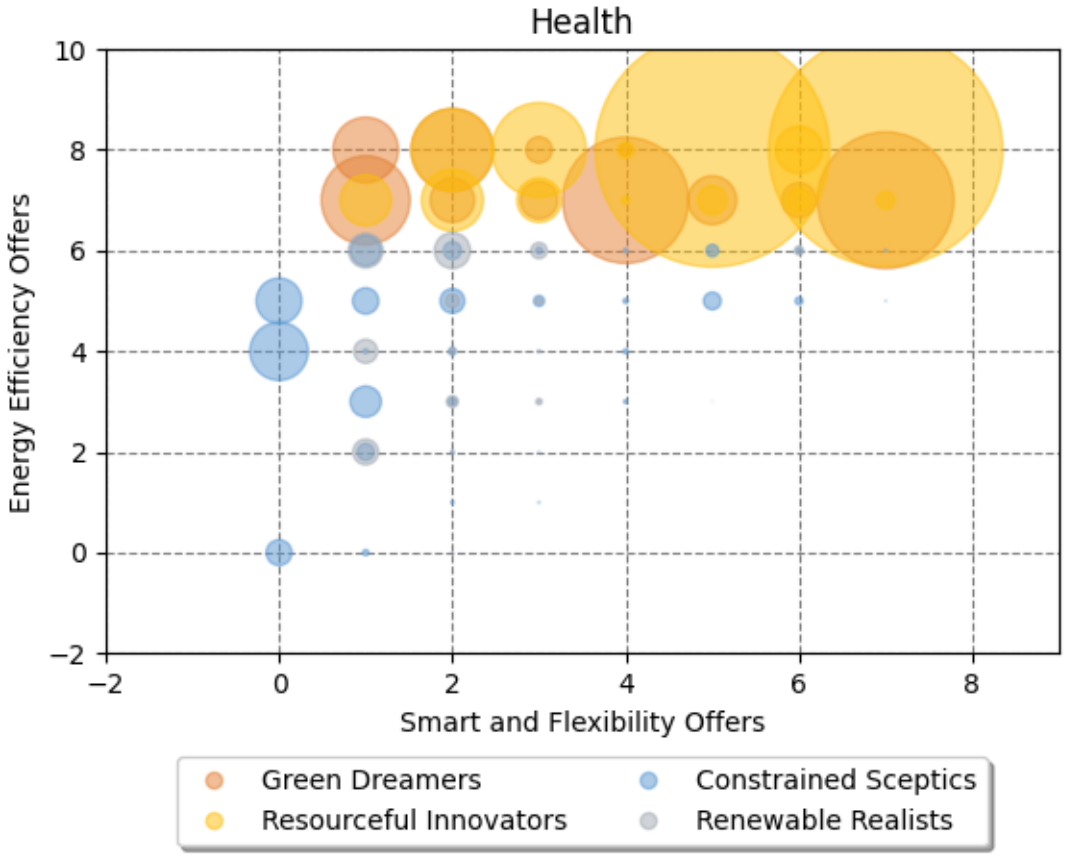


Low Carbon Technologies and Flexibility

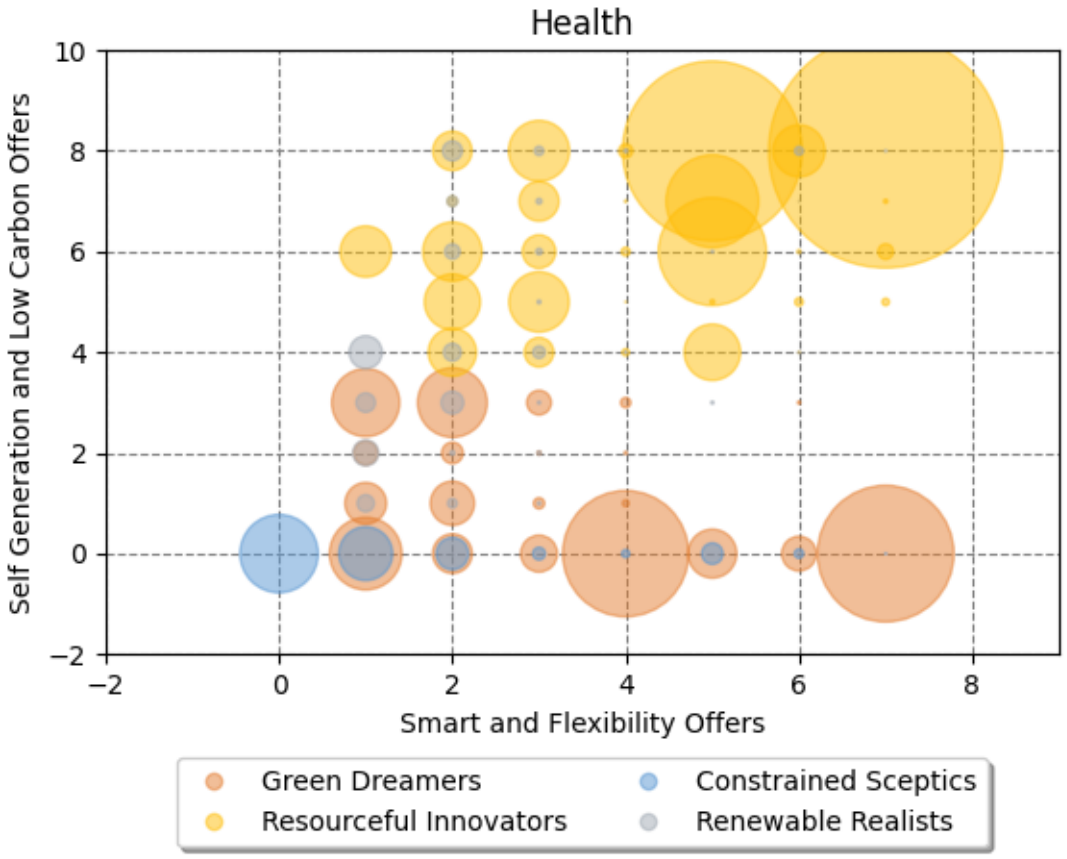


Health Sector: Additional cluster graphs

Energy Efficiency and Flexibility

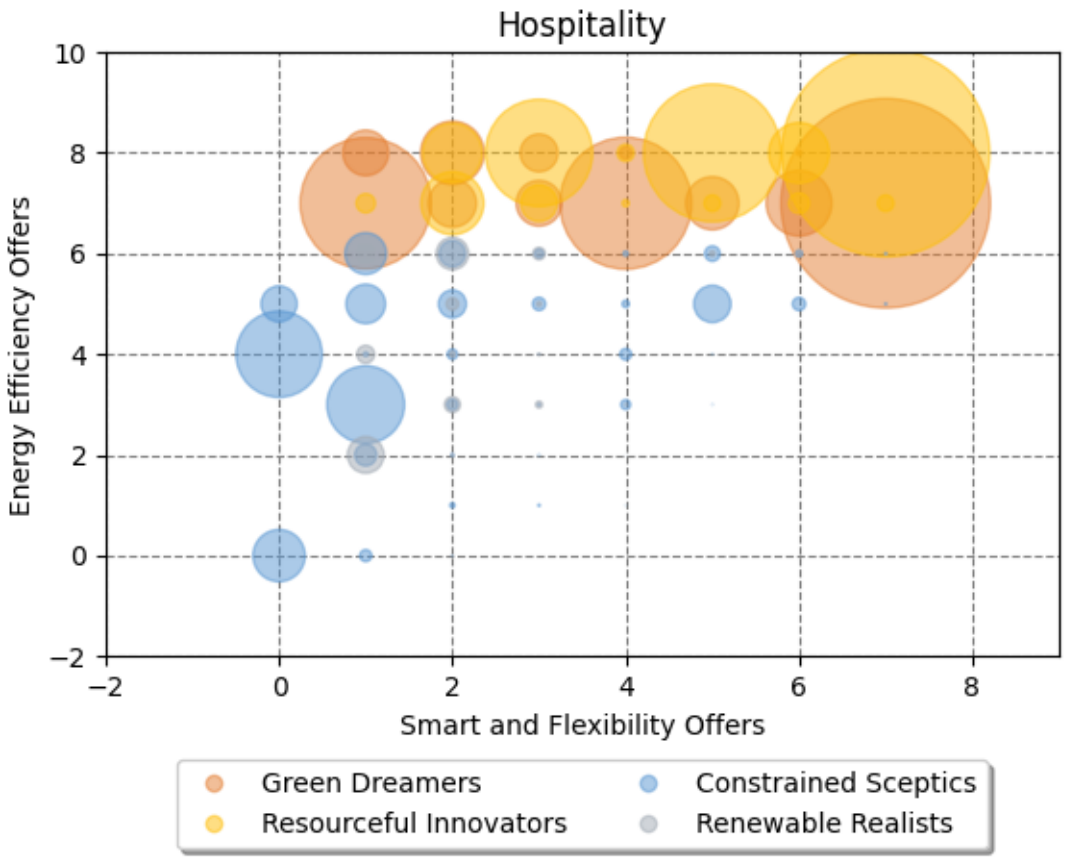


Low Carbon Technologies and Flexibility

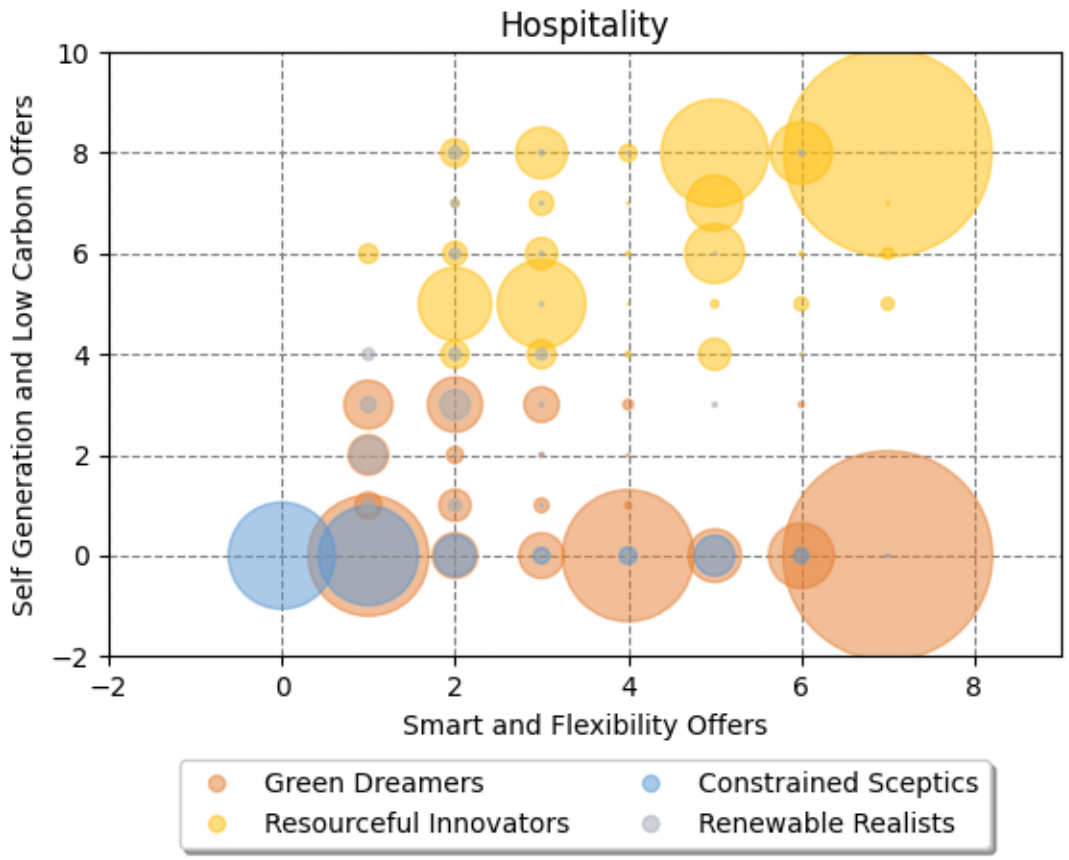


Hospitality Sector: Additional cluster graphs

Energy Efficiency and Flexibility

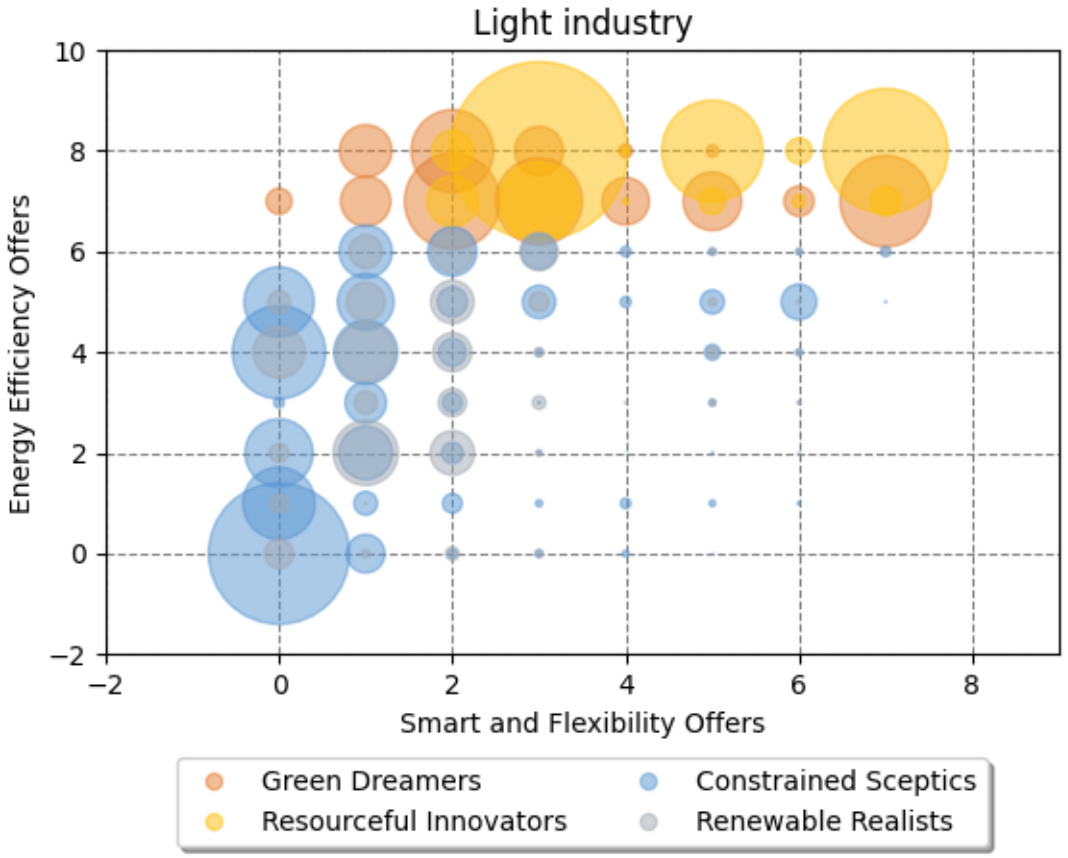


Low Carbon Technologies and Flexibility

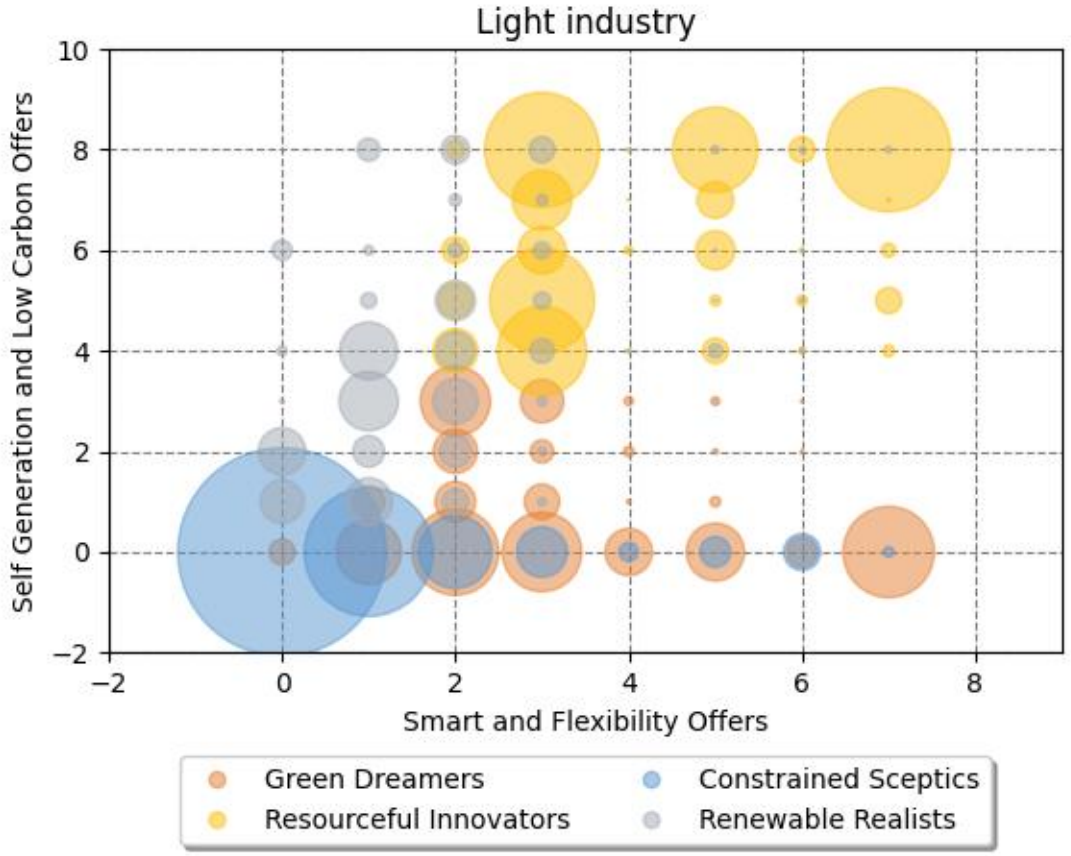


Light Industrial Sector: Additional cluster graphs

Energy Efficiency and Flexibility

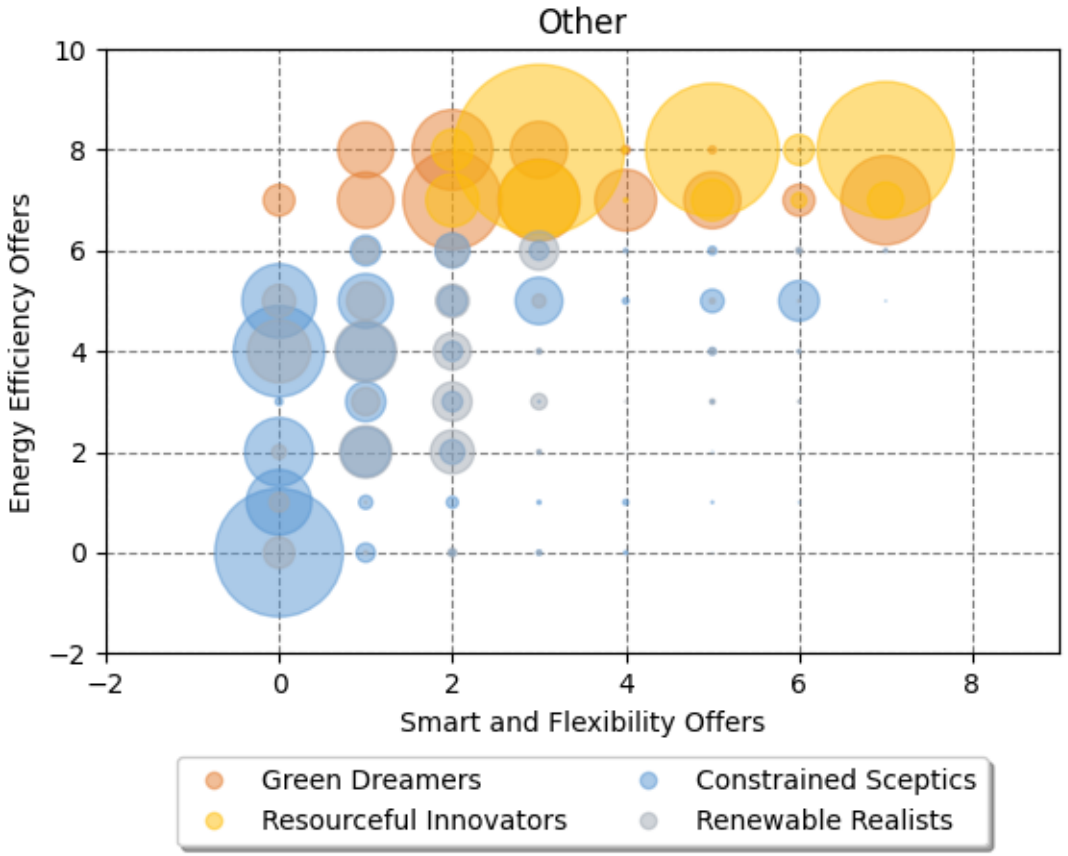


Low Carbon Technologies and Flexibility

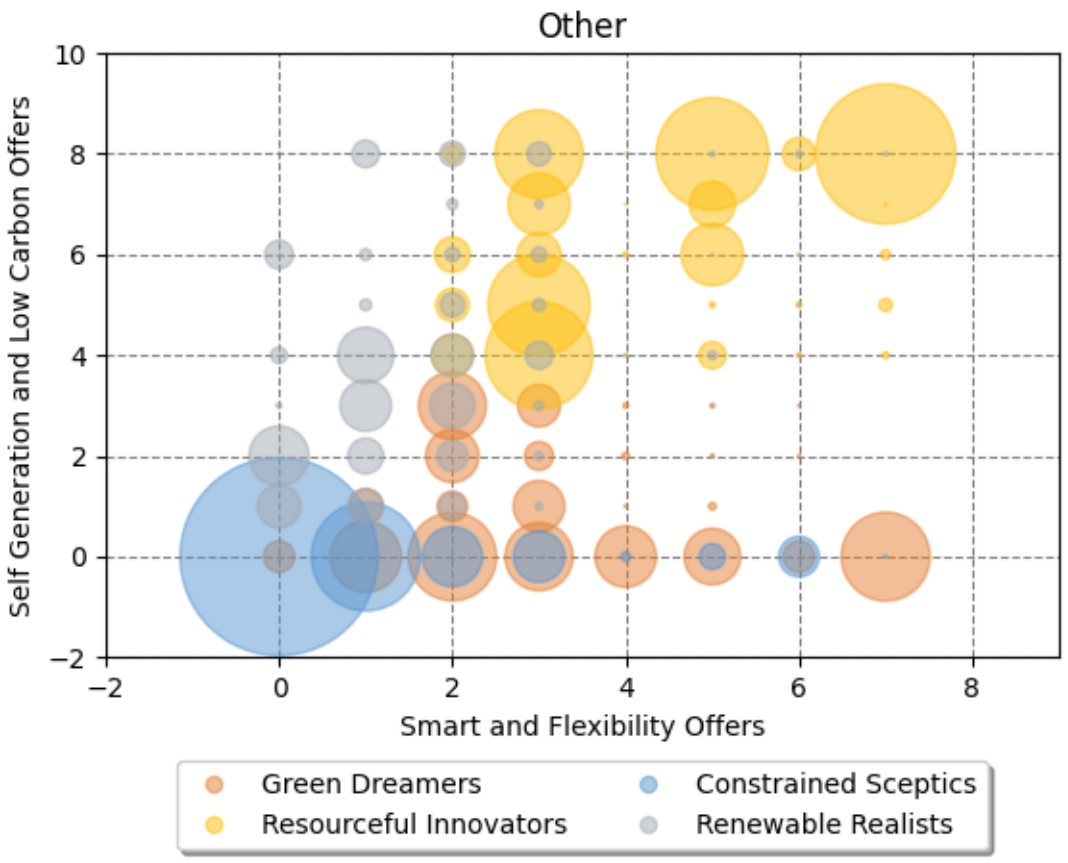


Other Sectors: Additional cluster graphs

Energy Efficiency and Flexibility

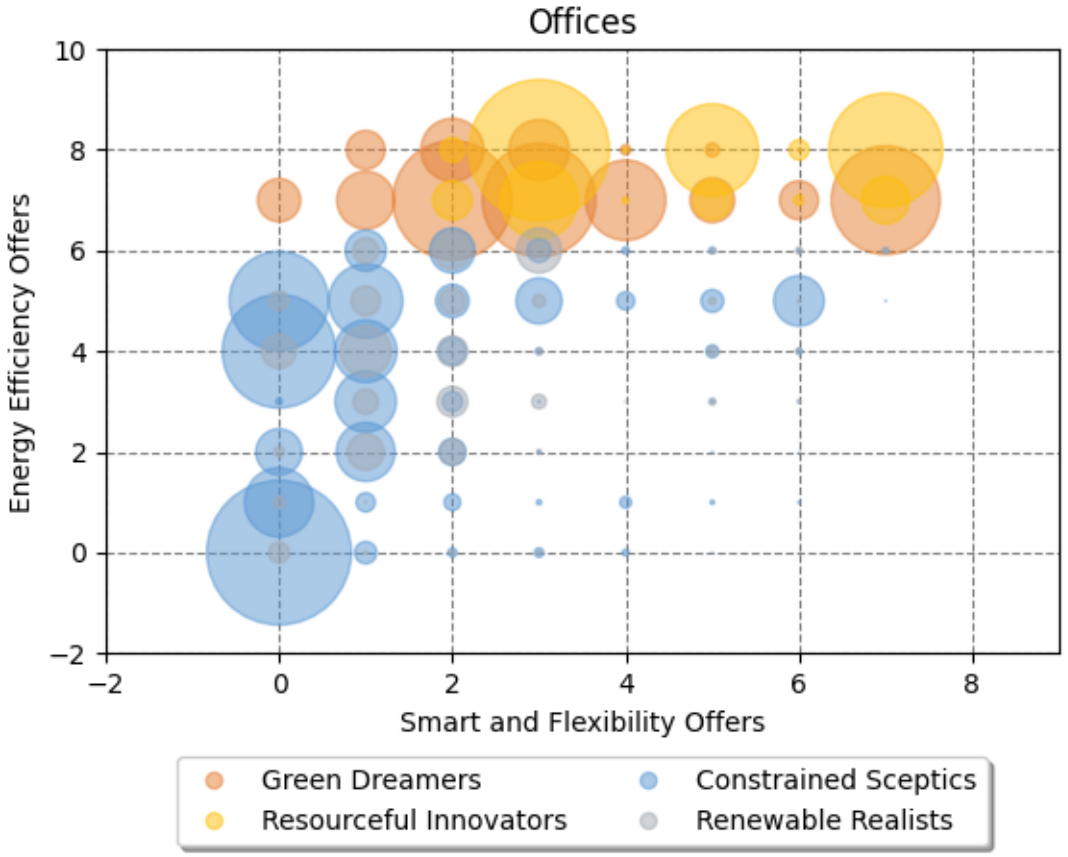


Low Carbon Technologies and Flexibility

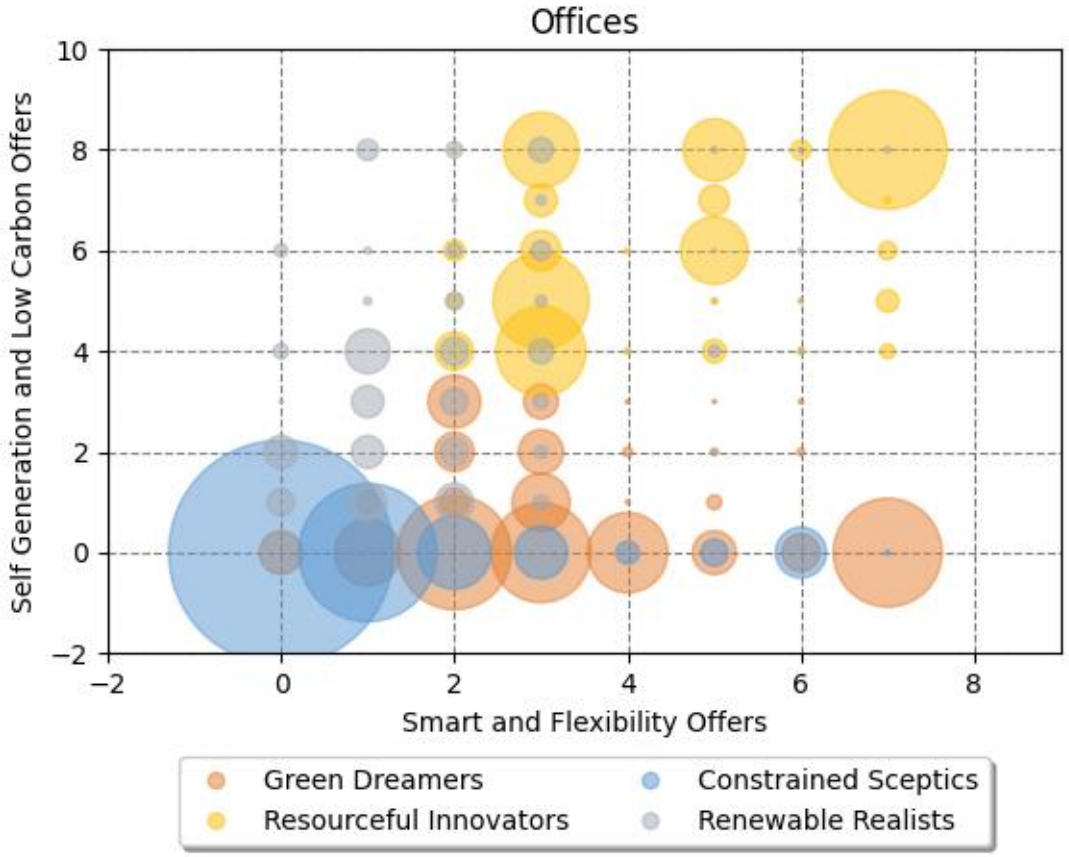


Offices Sector: Additional cluster graphs

Energy Efficiency and Flexibility

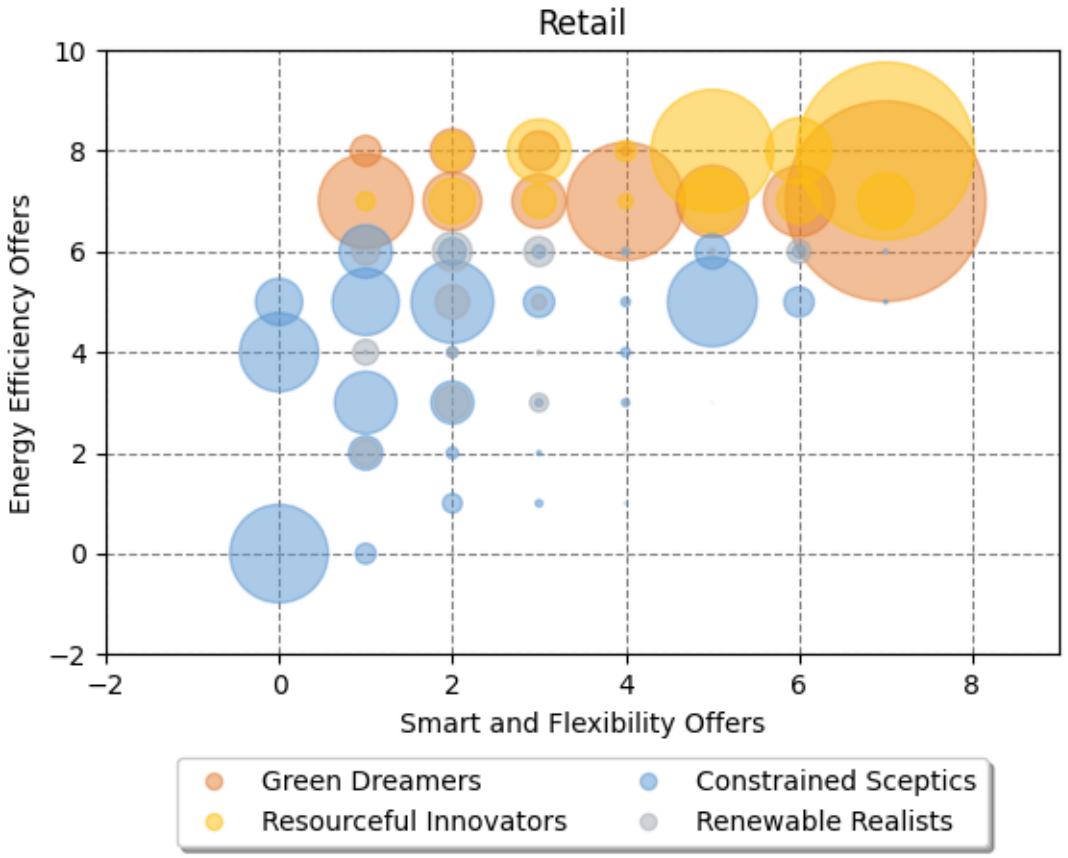


Low Carbon Technologies and Flexibility

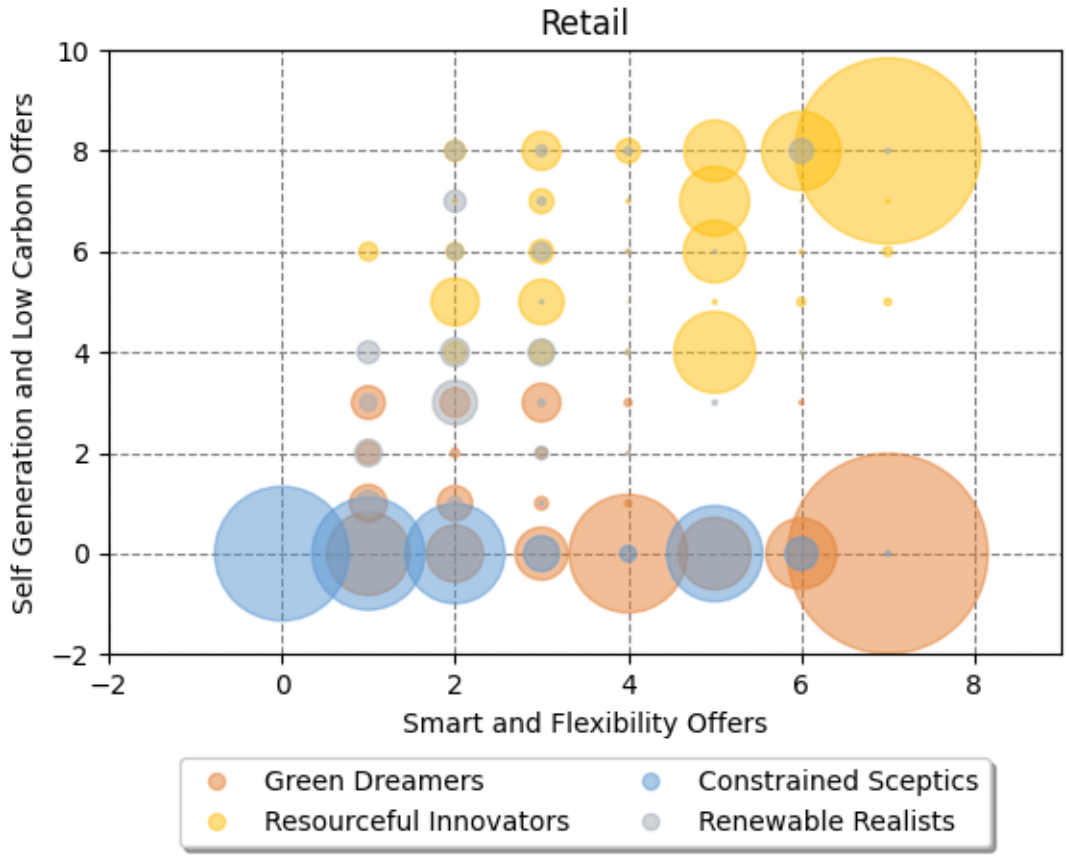


Retail Sector: Additional cluster graphs

Energy Efficiency and Flexibility

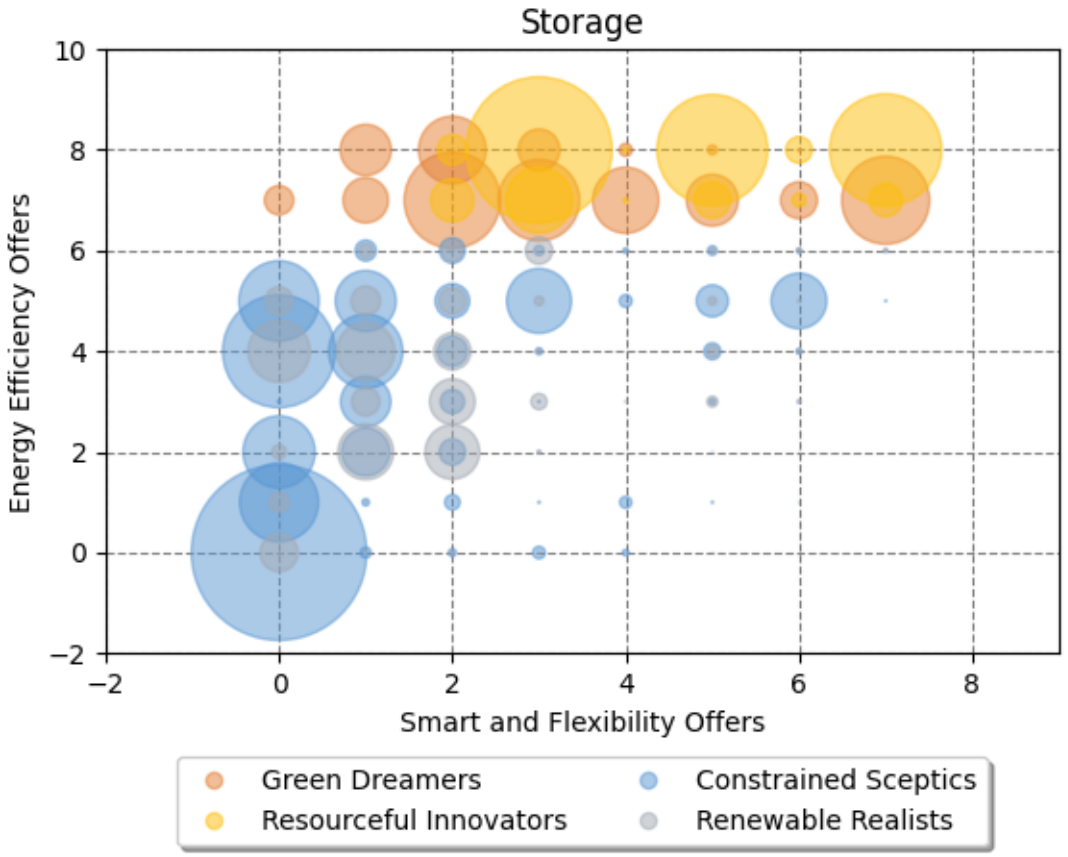


Low Carbon Technologies and Flexibility



Storage Sector: Additional cluster graphs

Energy Efficiency and Flexibility



Low Carbon Technologies and Flexibility