OPDC
OLD OAK AND
PARK ROYAL
DEVELOPMENT
CORPORATION

Circular and Sharing Economy Study

LOCAL PLAN SUPPORTING STUDY

2017

MAYOR OF LONDON

9. Circular and Sharing Economy Study

Document Title	Circular and Sharing Economy Study
Lead Author	Arup Associates
Purpose of the Study	• To develop the understanding and planned approach to adoption of circular and sharing economy (CSE) principles as they apply to the development of Old Oak and regeneration proposals for Park Royal.
Key outputs	• To define CSE as it applies to OPDC • To establish CSE principles and values to help guide design, procurement, construction and operation of the development • To review the flow of resources in and out of OPDC in construction and once occupied • To explore opportunities to apply CSE to development at OPDC • To provide case studies to support opportunities • To set out an enabling framework to support implementation
Key recommendations	• To develop initiatives that will promote CSE in construction and operational phases of the project wide scale buy in from developers and businesses is required. OPDC should establish a team to work to secure support. • Target key sectors including food, logistics, clean technology, the sharing economy and smart technology. • Adopt CSE approaches to design of infrastructure development including for example in looking at clean and low carbon sources of energy, water and waste and infrastructure that supports reuse of those resources • Adopt innovation in CSE in building design for example in design for disassembly and adaptation. • Work with West London Business and Park royal Business Groups to promote circular economy. • Embed CSE objectives into procurement policy • Embed CSE requirements into policy as far as possible • Work with the GLA, LWARB and Central Government to promote CE • Establish clear objectives and targets for CSE on projects especially on development that is either funded or is developed on public land • Look at ways to capture and include the value (economic, social and environmental) that CE delivers over the long term in assessing development. • Support investment in business and innovation in the CSE in the OPDC area especially in Park Royal
Relations to other studies	Interfaces with the Utilities Study, Waste Apportionment Study and Waste Management Strategy
Relevant Local Plan Policies and Chapters	• Strategic Policy SP2 (Good Growth) and SP10 (Integrated Delivery) • Environment and Utility Policies EU6 (Waste), EU7 (Circular and Sharing Economy) and EU8 (Sustainable Materials)

OPDC & LWARB

Circular and Sharing Economy Scoping Study for Old Oak and Park Royal

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Issue 2 | 20 April 2017

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Abbreviations

Abbreviation	Meaning
AD	Anaerobic Digestion
ALCO	Association of London Cleansing Officers
Arup	Ove Arup & Partners Ltd
BBiA	Bio-Based and Biodegradable Association
BIM	Building Information Modelling
C&I	Commercial and Industrial
CCHP	Combined Cooling, Heat and Power
CDEW	Construction, Demolition and Excavation waste
CECC	Circular Economy in the "Chambers of Commerce"
CET	Circular Economy Team
CHP	Combined Heat and Power
CPP	Critical Peak Pricing
DBEIS	Department for Business, Energy & Industrial Strategy
DCLG	Department for Communities and Local Government
Defra	Department for Environment, Food & Rural Affairs
DLC	Direct Load Control
DMC	Domestic Material consumption
DNO	Distribution Network Operator
DSR	Demand Side Response
EA	Environment Agency
ELV	End of Life Vehicle
ESCo	Energy Service Company
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse Gas
GLA	Greater London Authority
HVAC	Heating, Ventilation and Air Conditioning
IDNO	Independent Distribution Network Operator
IDO	Infrastructure Delivery Plan
KTN	Knowledge Transfer Network
LCCI	London Chambers of Commerce and Industry
LROG	London Recycling Officers Group
LWARB	London Waste and Recycling Board

Abbreviation	Meaning
MEF	Managed Ecosystem Fermentation
MSOA	Middle Super Output Area
MSW	Municipal Solid Waste
NISP	National Industrial Symbiosis Programme
OECD	Organisation for Economic Co-operation and Development
OPDC	Old Oak and Park Royal Development Corporation
PBP	Price-Based Programs
PHA	Polyhydroxyalkanoates
PV	Photovoltaic
R&D	Research and Development
RDF	Refuse Derived Fuel
RTP	Real Time Pricing
SMART	Specific, Measurable, Assignable, Realistic, Time-related
SME	Small and Medium-sized Enterprises
SPD	Supplementary Planning Document
SuDS	Sustainable Drainage Systems
TOU	Time of Use
UN	United Nations
VFM	Value-for-Money
WCA	Waste Collection Authority
WDA	Waste Disposal Authority
WEEE	Waste Electrical and Electronic Equipment
WRAP	Waste & Resources Action Programme

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Important notice and disclaimer

This research report and resource flow model (the "Model") was prepared by Ove Arup & Partners Ltd (Arup) for the London Waste and Recycling Board (LWARB) and the Old Oak and Park Royal Development Corporation (OPDC) in connection with Arup's technical advisory and consultancy services in respect of the Circular Economy Scoping Study at Old Oak and Park Royal assignment and its contents are strictly confidential.

This report and the model has been developed using data and assumptions from a variety of sources. Arup has not sought to establish the reliability of those sources or verified the information so provided.

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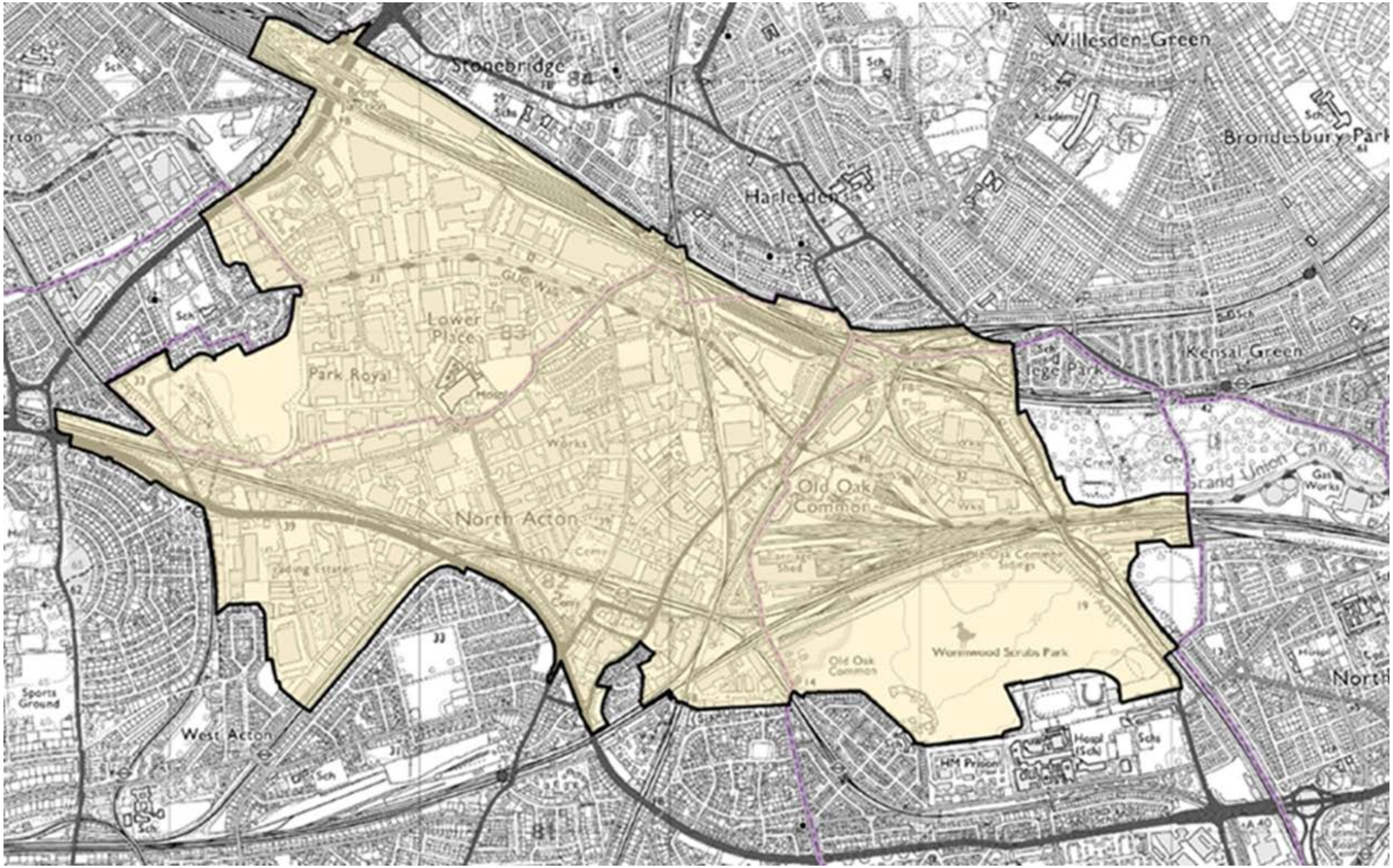

Figure 1: Map of Old Oak and Park Royal Development Corporation, 2015 (Source: OPDC)

1 The circular economy

What is the circular economy?

The circular economy model aims to decouple economic growth from resource consumption. It is restorative and regenerative by design, and aims to keep materials, products and components in repetitive technical and biological loops, maintaining them at their highest utility and value at all times. For organisations working in and around the built environment this will mean a considerable structural change to the way the sector plans, designs, procures, constructs and operates.

Designing out waste and thinking about the way in which materials can be disassembled and reused at the end of their useful life starts with design of buildings and infrastructure that is flexible and adaptable. This means reusing rather than demolishing where possible, designing products and components so that they can easily be disassembled, and using parts that lend themselves to up-cycling or recycling. To design out waste and support product and material reuse and recycling, new business models are needed.

A circular economy actually represents the creation of a more efficient, higher performance economy and built environment. The transition towards a circular economy supports the development of more resilient, healthier and more sustainable cities.

The circular economy also compliments the emerging shifts towards a 'sharing economy', enabled by the emergence of smart cities. The sharing economy promotes more efficient forms of access to services rather than ownership of products, with potentially minimised resource use and cost accordingly.

The Old Oak and Park Royal regeneration project is expected to create 25,500 new homes and 65,000 jobs. A circular economy approach to this process has the potential to create significant cost savings and revenues, to support environmental protection, reduce resource use and waste, and contribute to creating healthy and successful business and residential communities.

For example, by refurbishing buildings that are set for demolition, approximately 21,775 tonnes/annum of demolition waste could be saved each year for 32 years. Similarly, compost generated by the organic waste available from Old Oak and Park Royal could be used to grow at least 21% of the fresh green vegetables requirements of households in the area. Where more intensive urban farming methods are used, this could increase significantly.

At Old Oak and Park Royal, the following processes would facilitate the shift towards a circular economy:

1. **Design**: re-evaluate how buildings and infrastructure are designed to increase their useful life, for example, by creating more adaptable and flexible structures, designing for disassembly, and considering how core elements (façades, structure, glazing, M&E equipment etc) could be reused at the end of their service life.

2. **Services**: rethink services especially energy, water, and waste from a circular perspective. Use low carbon resources, and renewable materials and energy, maximise their utility through conservation and demand-side interventions, and design systems to promote circularity, for example, waste to energy systems, easy waste separation, reuse of waste materials, and take back schemes.

3. **Mobility**: rethink the movement of people and things, taking connectivity into account. Design out the need for vehicles, promote cycling and walling first, design in infrastructure for car sharing and low emission vehicles; support public transport as the transport of choice.

4. **Reuse**: design for reuse of resources, materials and components. For example, reuse water through sustainable urban drainage systems (SuDS) and low carbon local water treatment. Design internal fit-outs from standardised components that can be swapped out, resold and reused.

5. **Biological processes**: promote nutrient harvesting from the biological cycle (e.g. food and garden waste) for production of local food on roofs for example by communities. Extract and reuse biological nutrients via anaerobic digestion and composting.

6. **Engage communities**: design and operate the Old Oak and Park Royal site to encourage local people to adopt circular and sharing economy approaches. Promote healthy lifestyles by implementing walking or cycling infrastructure. Promote, invest in and support local renewable energy generation as a clean, healthy and cost effective approach.

Maximising benefits of the circular economy

To maximise the benefits that a circular economy can bring, one needs to understand the complex relationships between the built environment, mobility, public and green spaces, energy, water and material flows. We also need to address the many layers of human activity that run 'on top' of such things, including retail, education, manufacturing, housing, healthcare, leisure and so on. The circular economy demands that we employ new approaches at every stage of these lifecycles.

The circular economy operates at various scales, from the individual component or asset level – or that of individuals – up to the neighbourhood, district and city scale, via various forms of community. The Old Oak and

Park Royal area has the development scale and density to take advantage of opportunities at each of these levels. It also presents a rare opportunity to forge a new approach, building individual opportunities in energy, water, materials and waste into more complex, integrated and cross-cutting services and business models. This would allow for the emergence, at a 'system-of-systems' level, for a measured, documented and communicated model for the circular economy at scale.

On the Old Oak and Park Royal area, buildings, infrastructure, spaces and services shall be designed to be adaptable and flexible for different lifespans and changing uses, rather than one fixed end use. Flexibility shall be designed in from the start, allowing components to be swapped out, repaired, replaced and eventually reused. Stakeholders shall collaborate on digital platforms, sharing and exchanging data and learning, making informed, incentivised and ultimately intuitive decisions that reinforce the principles above. And new organisational, regulatory and commercial mechanisms and incentives will ensure the Old Oak and Park Royal Development Corporation's (OPDC's) values are upheld whilst being iterated and communicated. The final result will be an exemplary world class neighbourhood underpinned by new business models, as well as new cultures of collaboration, innovation and community engagement.

2 Circular economy principles

2.1 Guiding principles for the circular economy

The eight circular economy guiding principles stated below have been formulated for the Old Oak and Park Royal development area to create a higher performance environment aimed at increasing value for the benefit of all involved. In following these principles, OPDC and its partners should be able to develop a strategy that maximises the benefits of the circular economy.

1. Valuable: The circular economy creates new value

Aligning competing commercial, strategic and community interests to create multiple gains across multiple stakeholders through good 'place-making', creating viable and deliverable developments and outcomes. Creating economic and social benefits by including revenue streams and cost savings from new business models, improved asset utilisation, skill development, and employment creation. Managing risks associated with material scarcity and supply volatility.

2. Accessible: The circular economy forges new business and procurement models

Creating new relationships between buyers and sellers based on access and experience rather than ownership and consumption. Challenging the existing 'take, make, use, dispose' model in procurement and supply chains by adopting servitisation and performance based models. These substitute ownership for access and service, reducing costs, extending the service life, building cradle-to-cradle circular supply chains to recover resources, and making smart choices convenient and rewarding.

3. Shared: The circular economy forges shared ownership, use and activities

Adopting a collaborative approach to gain mutual shared benefits from the development. The provision of community ownership models, and district wide plug-in utility, infrastructure and social systems such as off-grid and micro-grid local energy supply, storage and demand management solutions; shared 'mobility as a service' transport options; shared spaces and amenities; self- and custom-build, and modular construction systems at community scale; and skill-sharing and resource-sharing services.

4. Systemic: The circular economy enables an innovative system-of-systems

Digital technologies help to match supply to demand virtually, optimising material flows and making it easier to share and exchange goods and services, including across systems, such as between electric mobility provision and energy storage. Digital services also facilitate real-time maintenance tasks that formerly required physical interventions. Sensors, broadly defined, can optimise operation and use of resources. Digital services facilitate collaboration, engagement and sharing between people.

5. Resilient: The circular economy builds system reliability, flexibility and integration

Providing a framework and building blocks for a resilient system able to withstand, respond to and adapt more readily to acute shocks and chronic stresses. Digital systems enable predictive maintenance and early warning systems, as well as building social resilience through local ownership.

6. Optimised: Eliminate waste through optimisation, capture and reuse of materials and products

Consider the full lifecycle of materials, products and components and select those that are durable, repairable, recyclable, upgradeable and closed-loop. Design out waste, design for disassembly, deconstruction and flexibility. Use low-impact construction materials and approaches including digital tools such as Building Information Modelling (BIM), standardised components, off-site manufacturing, and materials passport to allow those materials to be easily repurposed at their end of service life.

Create reverse cycles through consolidation of deliveries, automated waste collection systems and smart sensor technology to reduce the leakage of materials out of the system. Intensify land-use and optimise assets using real-time algorithmic and predictive approaches to infrastructure analysis, provision and operation, such as ride-sharing, autonomous mobility, or peak-shaving of energy flows.

7. Social: The circular economy is built around active, collaborative engagement

User-focused design and community-led development ensure that people are at the heart of the development process, and that services are effectively co-created, tightly bound to their needs and desires, and those of the overall development. Social values including health, wellbeing and liveability are promoted and negative externalities minimised. Collaboration, sharing, and co-creation via open source components and well-crafted digital services help to optimise asset utilisation and maintenance, and strengthen trust and community values between users.

8. Renewable: The circular economy enables affordable and secure forms of renewable energy

Development proposals should take an integrated approach to the provision of energy and utility systems and infrastructure. This will reduce energy consumption, supply affordable, clean energy, capture waste for reuse as energy, and minimise carbon emissions. Capture and reuse of water and waste should be treated in the same way. Local ownership of distributed and decentralised forms of these systems unlocks better asset utilisation, demand management and local resilience.

2.2 Applying the principles in Old Oak and Park Royal

Carrying forward the guiding principles and ambitions of the circular economy, the evidence base which underpins options for circular economy are established. A resource flows analysis was undertaken to understand and assess the main opportunities to minimise waste and create circular flows of materials in Old Oak and Park Royal. This analysis is presented in Section 3. Taking the lessons from the resource flows analysis, 10 themes for organising circular economy initiatives are presented in Section 4.

The evidence base (resource flows) and 10 themes provide the basis for developing promising circular economy initiatives for Old Oak and Park Royal, which have been presented within four circular economy scenarios for the Old Oak and Park Royal development area (see **Figure 2**). These scenarios are described in Section 5 of this report, and the specific case studies for projects to deliver the four scenarios are investigated in detail in Section 6.

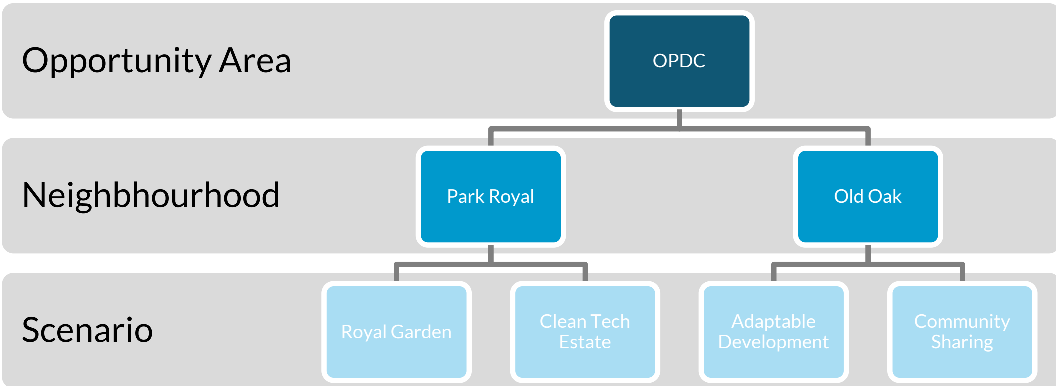

Figure 2: Overview of circular economy application areas

3 Resource flows in Old Oak and Park Royal

3.1 Overview

A high level resource flow model has been developed for the Old Oak and Park Royal area to understand the resource inputs and outputs without any circular economy interventions. The flows focus on three main resources:

- **Materials** – covers the raw material feedstock (input) and solid waste generation (output).
- **Energy** – covers energy demand (input) and surplus energy (output).
- **Water** – covers water demand (input) and wastewater generation (output).

The resource inputs and outputs have been estimated for the first year that the development is fully operational (i.e. 2050) to get a better understanding of the maximum opportunity. The exception for this is Construction, Demolition and Excavation Waste (CDEW) – a solid waste generation output - as the majority of it would be generated from the construction of the Old Oak and Park Royal development itself together with any construction waste contractors based in the development area. Therefore, CDEW has been estimated for an average year during the construction period of the Old Oak and Park Royal development.

The key data sets and assumptions used to develop the resource flow model are provided in the relevant sections below. The full data sets and assumptions used are provided in **Appendix A**.

The material, energy and water flows have then been examined to identify specific resource streams that should be targeted by circular economy initiatives to facilitate the transition to a circular economy. This will help to understand the opportunity ahead and the enabling framework required to facilitate the implementation of the initiatives. The assumptions used to analyse some of the proposed initiatives is provided in **Appendix B**.

For the purposes of the resource flow analysis, this information has been assumed to supersede the numbers published in the Draft Local Plan.

Why undertake resource flows analysis?

In order to meet many of the key principles of the circular economy, the project requires an understanding of the quantum and flow of resources in Old Oak and Park Royal. In particular, the following principles require an understanding of resource flows to identify opportunities for circularity, resource efficiency and sharing:

Systemic – the circular economy enables an innovative system-of-systems approach.

Optimised – eliminate waste through optimisation, capture and reuse of materials and products.

Renewable – the circular economy enables affordable and secure forms of renewables.

Shared – the circular economy forges shared ownership, use and activities.

3.2 Material flows

3.2.1 Raw material inputs

Raw material inputs have been represented by Domestic Material Consumption (DMC), which measures the total amount of materials used by an economy and is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. The DMC indicator was developed by Eurostat and is used by the European Union (EU), the Organisation for Economic Co-operation and Development (OECD) and the United Nations (UN). The DMC provides an assessment of the absolute level of the use of resources including biomass, metal ores, non-metallic minerals and fossil energy materials.

Biomass refers to organic materials that can be used in food supply, other products and energy generation. Biomass can include crops, crop residues, wood and animal products. Metal ores refer to mineral aggregates containing either ferrous or non-ferrous metals. Non-metallic minerals refer to essential raw materials for modern society and include marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate), chalk and dolomite, limestone and gypsum, slate, chemical and fertiliser minerals, salt, clays and kaolin, sand and gravel, and excavated earthen materials. Fossil fuel materials refers to coal, natural gas and oil, used to generate energy[1] and materials.

[1] There is some double counting associated with the portion of fossil fuel materials use to generate energy and the energy demand supplied by fossil fuels.

Table 1 sets out the DMC values used in the resource flow model.

Table 1: UK DMC in 2015[2]

Material category	DMC (tonnes/capita/annum)
Biomass	2.76
Metal ores	0.23
Non-metallic minerals	3.50
Fossil fuel materials	2.38

3.2.2 Solid waste outputs

Household waste

A household waste generation rate of 0.303 tonnes/capita/annum has been used to forecast the quantities of household waste that would be generated.[3] The waste generation rate used represents the average household waste generation rate of the London Borough of Brent, the London Borough of Ealing and the London Borough of Hammersmith & Fulham, during the period 2011 and 2036.

The composition of household waste that would be generated has been modelled based on the national compositional estimates for local authority collected waste and recycling in England in 2010/11.[4] **Figure 3** provides the household waste composition used. It has been assumed that the household waste composition would remain the same over the development period.

[2] Eurostat (2016). *Material Flow Accounts and Resource Productivity: Tables and Figures*. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Material_flow_accounts_and_resource_productivity (Accessed 11 October 2016).
[3] Greater London Authority and SLR Consulting (2014). *Waste Arisings Model: Further Alterations to the London Plan*.
[4] Resource Futures (2013). *Defra EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11 - Household Waste Composition*. Available at: http://randd.defra.gov.uk/Document.aspx?Document=11715_EV0801ReportFINALSENT05-12-13.pdf (Accessed 11 October 2016).

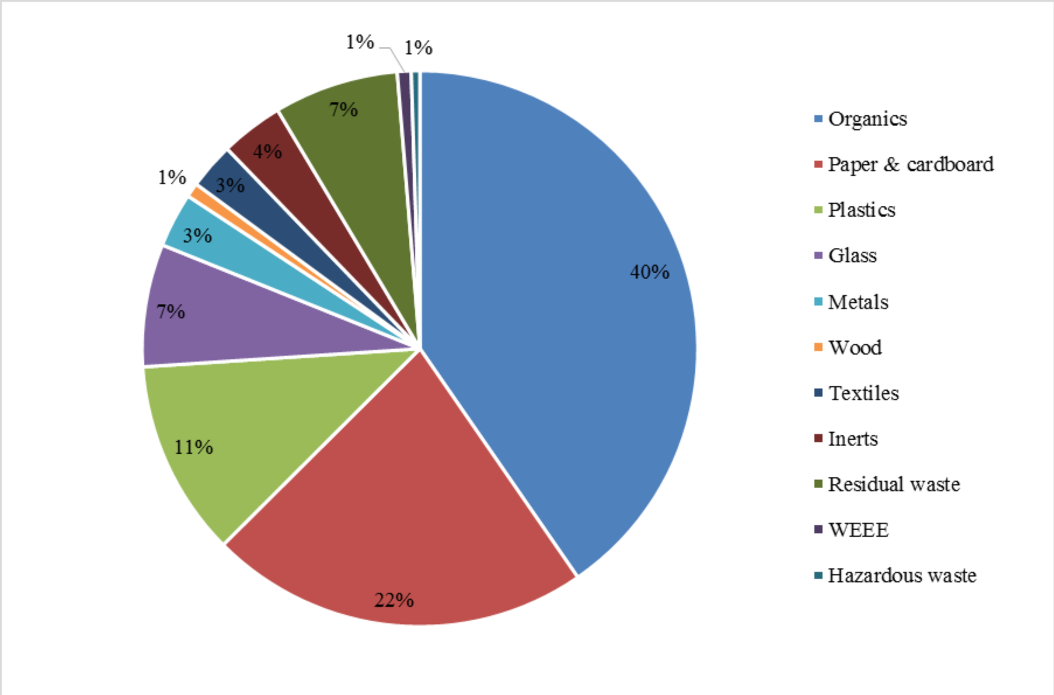

Figure 3: Household waste composition

Commercial and industrial waste

A Commercial and Industrial (C&I) waste generation rate of 0.906 tonnes/ employee/annum has been used to forecast the quantities of waste that would be generated by businesses, institutions and industry.[5] The waste generation rate used represents the average C&I waste generation rate in London during the period 2016 and 2036.

The composition of C&I waste that would be generated has been modelled based on the average C&I waste generated in the London Borough of Brent, the London Borough of Ealing and the London Borough of Hammersmith & Fulham in 2009.[6] **Figure 4** provides the C&I waste composition used. It has been assumed that the C&I waste composition would remain the same over the development period.

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[5] Greater London Authority and SLR Consulting (2014). *Waste Arisings Model: Further Alterations to the London Plan.*

[6] Defra (2009). *Defra Survey of Commercial and Industrial Waste Arisings - Report Tables.* Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/400578/ env20-ci-data-tables.xls (Accessed 11 October 2016).

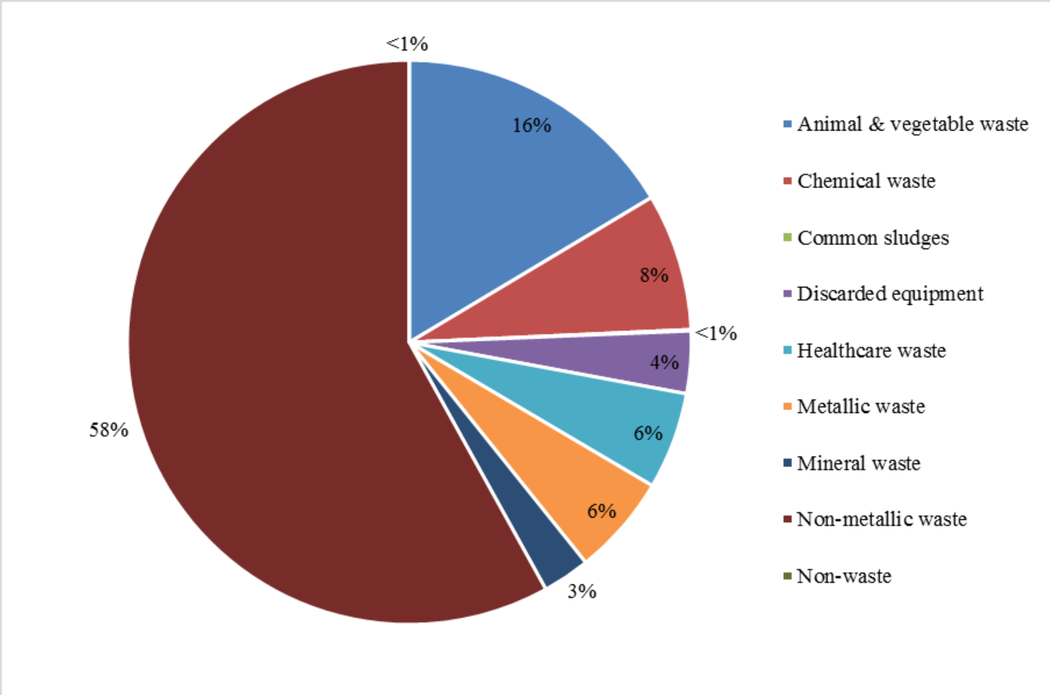

Figure 4: C&I waste composition

According to the Department for Environment, Food and Rural Affairs (Defra)[7], the various C&I waste streams can be defined as:

- Animal and vegetable waste – food, manure, and other animal and vegetable wastes;
- Chemical waste – solvents, acids/alkalis, used oil, catalysts, wastes from chemical preparation, residues and sludges;
- Common sludges – sludges (common) and dredging wastes;
- Discarded equipment – end of life vehicles (ELVs), batteries, and waste electrical and electronic equipment (WEEE);
- Healthcare waste – healthcare wastes;
- Metallic waste – metallic wastes;
- Mineral waste – combustion residues, contaminated soils, solidified mineral wastes and other mineral wastes;
- Non-metallic waste – glass, paper and cardboard, rubber, plastic, wood and textiles; and
- Non-waste – blast furnace slag and virgin timber i.e. materials that, at the time of publishing the document, were recently declassified as wastes.

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[7] Department for Environment, Food & Rural Affairs (2010). *Survey of Commercial and Industrial Waste Arisings 2010 – Interim Results*. Available at: http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/news/files/2010/11/1011stats.pdf (Accessed 27 October 2016).

They were chosen to be recorded by Defra for comparability with previous C&I waste composition surveys.

Construction, demolition and excavation waste

Construction, demolition and excavation waste would be generated by construction activities. This is distinctly separate to CDEW generated by waste management facilities in the Old Oak and Park Royal area that process CDEW – see Powerday example in **Section 3.2.4**.

Excavation waste resource flows have not been quantified due to the unavailability of information at such early stages of the project that this resource flow model has been developed.

The demolition waste that would be generated in the Old Oak and Park Royal area is based on the volume and type of building that would be demolished. **Table 2** provides the demolition waste generations rates used in the resource flow model.

Table 2: Demolition waste generation rates[8]

Type of building	Demolition waste generation rate (tonnes/m^3)
Steel frame	0.47
Structural concrete	0.48
Masonry	0.54

The construction waste that would be generated in the Old Oak and Park Royal area is based on floor area of the new residential, office, retail and leisure developments that would be built over the development period. **Table 3** provides the construction waste generations rates used in the resource flow model.

Table 3: Construction waste generation rates[9]

Development type	Construction waste generation rate (tonnes/m^2)
Residential	0.168
Office	0.238
Retail	0.275
Leisure	0.216

[8] Waste & Resources Action Programme (2016). *Net Waste Tool - Demolition Bill of Quantities Estimator*. Available at: http://nwtool.wrap.org.uk/ToolHome.aspx (Accessed 11 October 2016).
[9] BRE (2012). *Waste Benchmark Data*. Available at: http://www.smartwaste.co.uk/filelibrary/benchmarks%20data/Waste_Benchmarks_for_new_build_projects_by_project_type_31_May_2012.pdf (Accessed 11 October 2016).

To annualise the construction waste quantities, it has been assumed that construction and demolition activities would take place equally each year between 2017 and 2049 (i.e. a 32 year timeframe).[10]

3.2.3 Materials flow model

Figure 5 illustrates the quantity and composition of materials that would flow in and out of the Old Oak and Park Royal area.

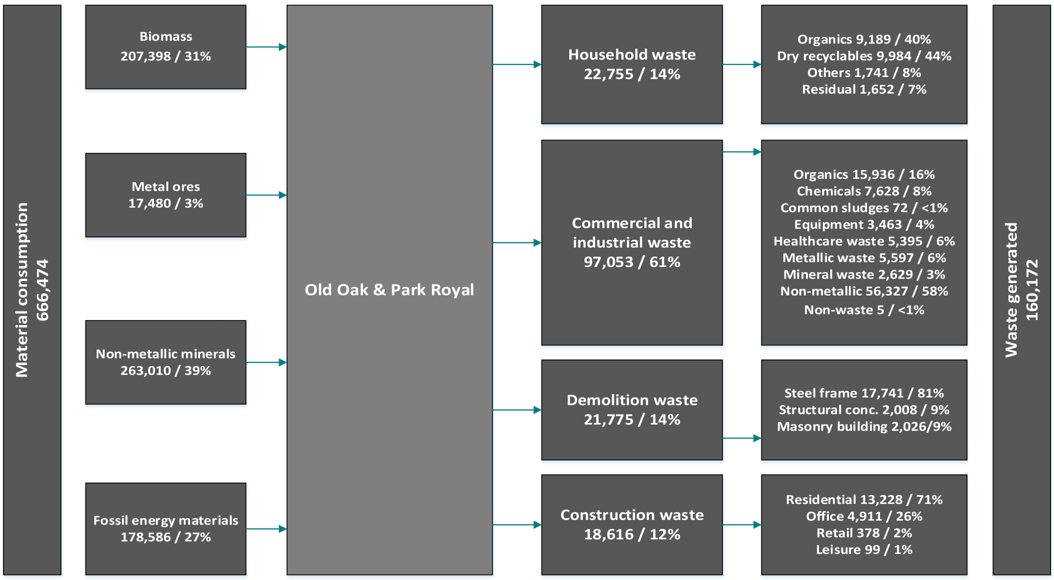

Figure 5: Materials flows in Old Oak and Park Royal in tonnes/annum

The total quantity of materials flowing into the Old Oak and Park Royal area has been estimated as 666,474 tonnes/annum. The majority of the materials used would be non-metallic minerals (39%). There would be similar proportion of biomass (31%) and fossil energy materials (27%) used. It should be noted that there is some double counting associated with the portion of fossil fuel materials use to generate energy in the materials flow model and the energy demand supplied by fossil fuels in the energy flow model. Metal ores used would represent a significantly lower proportion (3%) of the materials used compared to all other material types. The total quantity of waste generated has been estimated as 160,200 tonnes/ annum. C&I waste would account for more than half (61%) of the waste generated each year. Household waste and demolition waste would account for the same quantity of waste generated each year (14%). Construction waste would account for a slightly lower quantity of waste generation each year (12%) compared to household waste and demolition waste. It should be noted that the quantities of demolition waste and construction waste will in fact vary each year depending on the planned construction activities for that

[10] The construction period has been assumed as 2017 to 2049 since the OPDC Phasing Trajectory (version 5) has forecast that residential units will be available each year from 2018 to 2049.

year but in the absence of this information, the quantities have been assumed to be the same each year of the construction period.

Excavated material including contaminated soil have been excluded from the resource flow model as there is currently a lack for reliable information given the early stage of the development.

3.2.4 Powerday plc

Waste management facilities in Old Oak and Park Royal would have their own separate material flows as they receive waste, which can be generated both in and out of the development area, process it and transport it off-site for further treatment or disposal. The Powerday materials recovery facility located south of Willesden Junction station is the only known waste management facility to remain as part of the new development.[11]

Figure 6 illustrates the quantity and composition of materials that would flow in and out of the Powerday facility. This is based on information in the OPDC Waste Strategy[12] and waste returns provided by Powerday to the Environment Agency (EA) in 2014[13].

The total quantity of waste received at the Powerday facility is approximately 346,322 tonnes/annum. The facility predominantly receives CDEW (57%) with the remaining represented by household and C&I waste (43%).

The total quantity of waste removed from the site is approximately 328,475 tonnes/annum. The outputs of the facility have been grouped into seven main types. The majority of materials leaving the site are a mix of bricks, concrete, gypsum, soils and stones, tiles and ceramics (47%). Refuse derived fuel (RDF) leaving the site accounts for almost half of that (22%). Other distinct material streams leaving the site include wood (9%) and metals (3%).

[11] It was recommended in the OPDC Waste Strategy (Draft for Regulation 18 Consultation, 4 February 2016) that Powerday should be safeguarded to meet the London Borough of Hammersmith and Fulham's waste apportionment. The site was also present in the Old Oak and Park Royal masterplan when this report was published.
[12] Old Oak and Park Royal Development Corporation (2016). *Waste Strategy, Draft for Regulation 18 Consultation, 4 February 2016*. Available at: https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/get-involved-op-5 (Accessed 11 October 2016).
[13] Environment Agency (2015). *Waste Data Interrogator 2014*. Available at: https://data.gov.uk/dataset/waste-data-interrogator-2014 (Accessed 11 October 2016).

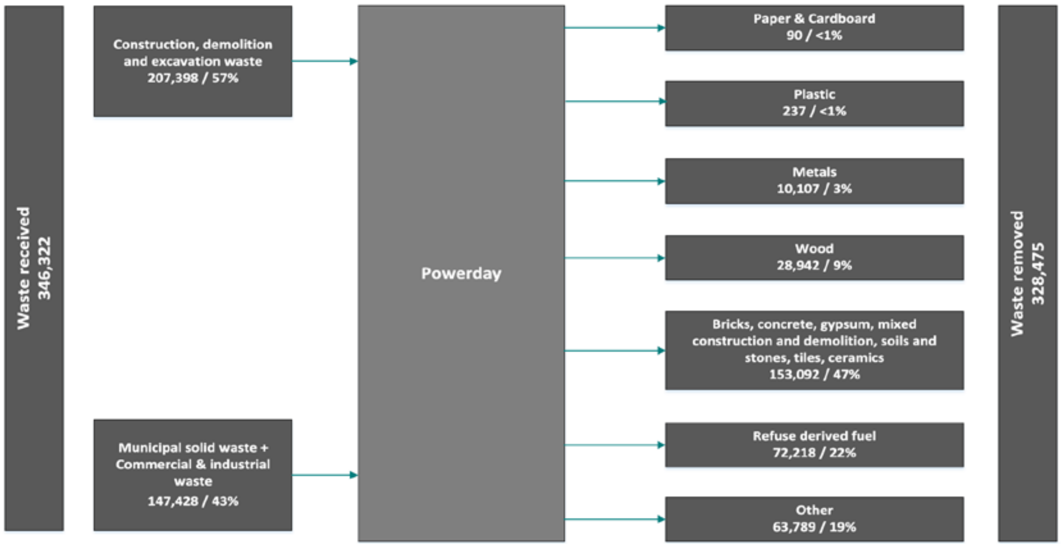

Figure 6: Material flows at the Powerday facility in tonnes/annum

3.3 Energy flows

3.3.1 Energy demand

The energy flows at Old Oak and Park Royal can generally be broken down into three energy vectors: electricity, heat and fuel. The resource flow model focusses on the electricity and heating demands from the buildings that would be on-site. The demand for each vector will vary depending on the land use type. The land use schedule used to calculate the energy demand for each land use has been based on the OPDC Phasing Trajectory (version 5).

Residential energy demands are based on Standard Assessment Procedure (SAP) results for a typical development modelled to meet different energy standards. Residential energy demand benchmarks have been reduced over time to reflect stricter building regulations. **Table 4** shows how the residential energy demands are expected to change over time.

Table 4: Residential energy demands

Energy standard	Development period energy standard applied	Electricity demand (kWh/household/ annum)	Heat demand (kWh/household/ annum)
Code for Sustainable Homes 4	2018	3,670	3,460
Code for Sustainable Homes 5	2019-2023	3,260	3,120
Near zero carbon	2024-2050	2,700	3,110

Table 5 provides the energy demands for non-residential land uses used in the resource flows model. Less significant reductions in non-residential energy demands are expected and have therefore been kept constant over the development period. It should be noted that cooling demand requirements are incorporated in the electricity demand as most buildings (if not naturally ventilated) use electricity powered chillers.

Table 5: Non-residential energy demands[14]

Land use	Electricity demand (kWh/m^2)	Heat demand (kWh/m^2)
Commercial[15]	95	102
Retail[16]	165	0
Leisure[17]	95	281
Industrial[18]	120	286

3.3.2 Secondary heat

Secondary heat sources include waste heat arisings as a by-product of commercial and industrial activities and heat that exists naturally within the environment (air, ground, water). There are a wide variety of these sources each with different characteristics in terms of temperature and availability.

The secondary heat available in the Old Oak and Park Royal area is based on Greater London Authority data for each geographical Middle Super Output Area (MSOA) in 2013[19]. The three main MSOAs found within the red line boundary of the Old Oak and Park Royal development are Brent 027, Ealing 015 and Hammersmith and Fulham 001. **Table 6** provides a summary of the secondary heat available in each of the identified MSOAs by source.

Table 6: Secondary heat available in MSOA Brent 027, Ealing 015 and Hammersmith and Fulham 001 in 2013

Secondary heat source	Heat available (MWh/annum)		
	Brent 027	Ealing 015	Hammersmith & Fulham 001
Open loop ground source abstraction	551	147	141

[14] Non-residential energy demands are generally harder to estimate because of the large variation in use types. Commercial, retail and leisure energy demands are based on CIBSE (2008). Energy Benchmarks - TM46:2008. The industrial energy demand is based on CIBSE Guide F (2012). Energy Efficiency in Buildings.
[15] Modelled as 'General office'.
[16] Modelled as 'General retail'.
[17] Modelled as 'Dry sports and leisure facility'.
[18] Modelled as 'Manufacturing – light'.
[19] Greater London Authority (2013). *London's Zero Carbon Energy Resource – Secondary Heat*. Available at: https://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat (Accessed 12 October 2016).

Secondary heat source	Heat available (MWh/annum)		
	Brent 027	Ealing 015	Hammersmith & Fulham 001
Closed loop ground source abstraction	15,492	4,061	3,996
Air source heat pumps	176,250	0	0
Building heat rejection – Office	4,590	532	3,841
Building heat rejection – Retail	10,000	5,661	5,698
Building heat rejection – Gyms	0	280	0
Industrial sources Part B[20] processes	0	499	1,058
Commercial building non-HVAC source – Supermarkets	0	1,854	0
Commercial building non-HVAC sources – Data centres	167,905	27,781	0
National grid infrastructure	0	29,200	0
UK Power Networks infrastructure	2,948	0	0
Sewer heat mining	2,273	3,353	3,113
TOTAL	**380,009**	**73,368**	**17,847**

3.3.3 Energy flow model

Figure 7 illustrates the electricity, heating and cooling demand in Old Oak and Park Royal from different land uses as well the secondary heat available from various sources in the area.

The total energy demand has been estimated as 341,952 MWh/annum. Heating represents just over half of the energy demand (53%) with the electricity demand representing the remainder (47%). Residential and commercial land uses dominate electricity and heating demands.

[20] Part B processes are those that have the potential to cause air pollution and include activities such as vehicle respraying, petrol stations, waste oil burners, cement works, dry cleaners, printing, roadstone coating, mobile crushing and surface cleaning.

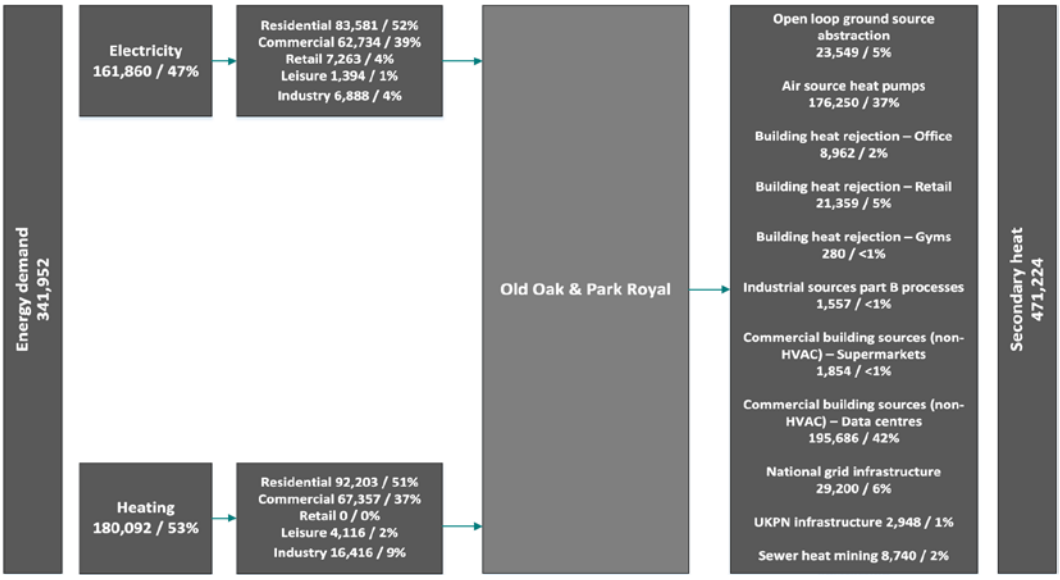

Figure 7: Energy flows in Old Oak and Park Royal in MWh/annum

The total quantity of secondary heat that would be available is approximately 471,224 MWh/annum. The greatest secondary heat sources are non-HVAC related heat sources from data centres (42%) and air sources (37%). Smaller sources include national grid infrastructure (6%), hypothetical open loop ground source abstraction (5%) and building heat rejected by retail units (5%). A much smaller proportion of secondary heat is available from building heat rejected by office units (2%), sewer heat (2%), and UK Power Networks infrastructure (1%). Building heat rejected by gyms, Part B industrial processes and non-HVAC related heat sources from supermarkets all contribute a very small proportion (<1%).

3.4 Water flows

3.4.1 Water inflow

The two predominant inflows to the urban cycle include the centralised water supply, which is imported from outside the area boundary, and the natural hydrological flows in the form of precipitation. The centralised water supply can be potable water and non-potable water as described below:

- Potable water – high quality water supplied for uses within the home including water used for drinking and use in the kitchen and bathroom except for use in toilet flushing; and
- Non-potable water – water that is used for low-contact uses including irrigation and toilet flushing. In general, this water is not required to be of the same quality as that used for potable uses.

The water demand has been modelled based on the water balance models in the OPDC Integrated Water Management Strategy[21].

3.4.2 Water outflow

The centralised water supply would be discharged through the wastewater system as blackwater or greywater as described below:

- Blackwater – wastewater generated from toilets, kitchen and laundry use that requires disposal through the drainage system. Blackwater has a higher concentration of contaminants than grey water.
- Grey water – wastewater generated from use in hand basins, baths and showers that requires disposal through the drainage system.

Precipitation would be lost from the system through roof water, stormwater, evapotranspiration and infiltration as described below:

- Roof water – the quantity of rainwater which falls directly on rooftops. This has been split from stormwater due to the differing water quality characteristics. Within the current system, roof water would leave the area through the drainage system.
- Stormwater – runoff from the urban environment generated during rainfall events. This consists predominately of runoff from impervious areas. Within the current system, roof water would leave the area through the drainage system.
- Evapotranspiration – water which is returned to the atmosphere through the processes of evaporation and transpiration of vegetation, on permeable surfaces.
- Infiltration - the proportion of rainwater which infiltrates through the soil, entering the groundwater table.

As with the water demand, the wastewater has been modelled based on the water balance models in the OPDC Integrated Water Management Strategy[22]. However, estimates for evapotranspiration and infiltration were not used to complete the water mass balance due to the lower relative confidence and importance of these values to the water management.

[21] Old Oak and Park Royal Development Corporation (2016). *Integrated Water Management Strategy, Draft for Regulation 18 Consultation, 4 February 2016*. Available at: https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/get-involved-op-5 (Accessed 11 October 2016).
[22] Old Oak and Park Royal Development Corporation (2016). *Integrated Water Management Strategy, Draft for Regulation 18 Consultation, 4 February 2016*. Available at: https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/get-involved-op-5 (Accessed 11 October 2016).

3.4.3 Water flow model

Figure 8 illustrates the water flows anticipated from the Old Oak and Park Royal area. The total volume of water flowing into the area would be approximately 7,849 million litres/annum. Just over half of this would be precipitation (53%). There would be a greater potable water demand (36%) than non-potable water demand (11%).

The total volume of water flowing out of the area would be approximately 6,477 million litres/annum. There would be a greater outflow of black water and grey water (57%) compared to stormwater and roof water (44%).

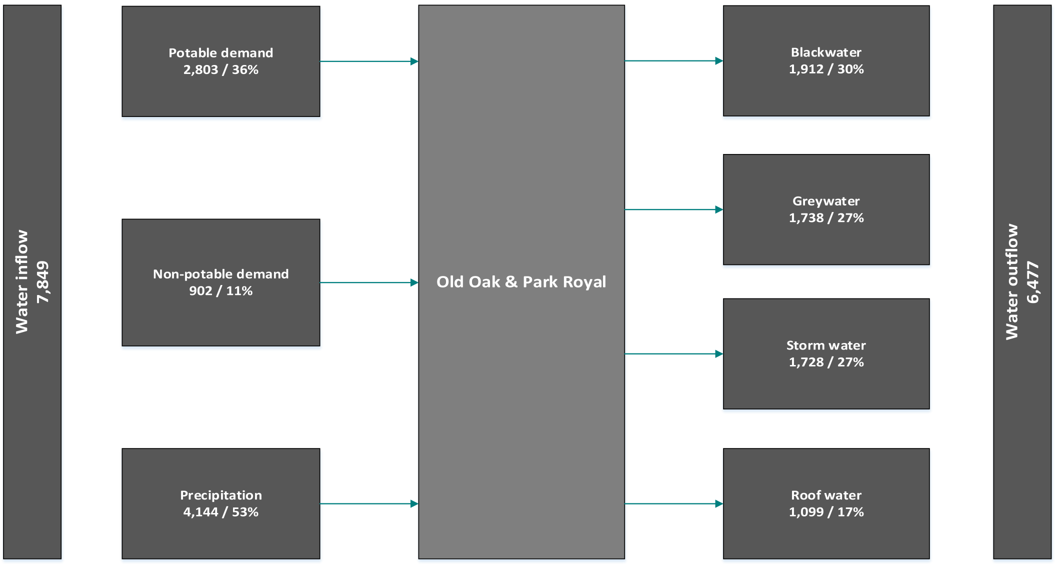

Figure 8: Water flows in Old Oak and Park Royal in million litres/annum

3.5 The opportunity ahead

3.5.1 Organic waste treatment

Out of all waste materials generated by households, organic waste would be the single greatest resource generated at 9,189 tonnes/annum. On top of this, it is estimated that C&I sources would generate 15,936 tonnes/annum of organic waste. Therefore, approximately 25,125 tonnes/annum of organic waste would be available for processing into new useful materials and products such as animal feed, compost and proteins, or for use in energy generation.

Organic waste that is processed into compost can be used to grow fruit and vegetables using urban farming techniques, which can then be distributed back into Old Oak and Park Royal. A portion of the fruit and vegetables will become food waste, which can be captured again and used to produce compost, thereby facilitating a closed loop approach.

It is estimated that by using aerobic composting technology, approximately 12,562 tonnes/annum of compost could be produced, which could be used in rooftop farming initiatives. The use of this compost in a classic raised bed farming method would be able to generate approximately 149 tonnes/annum of lettuce heads. This could contribute 21% of fresh green vegetables required by households in Old Oak and Park Royal, who would require a total of 706 tonnes/annum[23], resulting in a 21% reduction in the import of fresh green vegetables into the area for households.[24]

Organic waste can also be converted into energy via anaerobic digestion. Anaerobic digestion is the decomposition of organic material in the absence of oxygen, which generates biogas and a digestate. The resulting biogas can be used in combined heat and power (CHP) plant to generate heat and electricity or in combined cooling, heat and power (CCHP) plants to produce cooling, heat and electricity. This renewable form of energy can be used to meet the energy demands of Old Oak and Park Royal. Alternatively, the biogas can be cleaned and converted into biofuel or upgraded to biomethane for injection into the gas grid.

The digestate from the anaerobic digestion process can be used to produce organic fertiliser, which can be used to grow fruit and vegetables as described above. The digestate can also be dried and compressed into biomass pellets for use in energy generation. There are other emerging options to use the digestate, which include:

- Producing polyhydroxyalkanoate (PHA) that is a precursor for a range of bioplastics;
- Extracting phosphorous; and
- For conversion into a biocoal using the hydrothermal carbonisation process that can then be used in energy generation.[25]

It is estimated that by using anaerobic digestion (thermophilic process) and CHP plant, approximately 6,028 MWh/annum of electricity and 3,015 MWh/annum of heat could be generated. This represents 4% and 2% of the total electricity and heat demand of Old Oak and Park Royal, respectively. The digestate by-product from the process could be converted into 6,030 tonnes/annum of organic fertiliser, which could be used in rooftop farming initiatives. The use of this organic fertiliser in a classic raised bed farming method would be able to generate approximately 72 tonnes/annum of

[23] Department for Environment, Food & Rural Affairs (2015). *Family Food 2014*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485982/familyfood-2014report-17dec15.pdf (Accessed 14 October 2016).
[24] The contribution of the rooftop farming to food manufacturers in the Park Royal Industrial Estate cannot currently be quantified in the absence of demand data.
[25] Waste & Resources Action Programme (2015). *Optimising the Value of Digestate and Digestion Systems*. Available at: http://www.wrap.org.uk/sites/files/wrap/Optimising%20the%20value%20of%20digestate%20and%20digestion%20systems_0.pdf (Accessed 14 October 2016).

lettuce heads. This could contribute 10% of fresh green vegetables required by households in Old Oak and Park Royal, who would require a total of 706 tonnes/annum[26], resulting in a 10% reduction in the import of fresh green vegetables into the area.[27]

Although the opportunity with anaerobic digestion seems small, in reality, the quantity of organic waste available for anaerobic digestion may be much higher and would be able to produce more electricity and heat for Old Oak and Park Royal. This is because the resource flow model currently uses average C&I waste compositions of the three London boroughs that Old Oak and Park Royal resides in, as the best available data, to estimate organic waste. This may not be truly representative of C&I waste generated in Old Oak and Park Royal as approximately 5% of the 2,150 workplaces in the Park Royal Industrial Estate are food manufacturing businesses who cover about 11% of the 2,314,305m^2 of industrial area.[28] The larger food manufacturing businesses in the Park Royal Industrial Estate include:

- McVities – snack food manufacturer specialising in biscuits and cakes;
- SeeWoo – oriental food wholesaler;
- Charlie Bingham's – manufacturer of fresh prepared foods;
- Bakkavor – manufacturer or fresh prepared foods; and
- Greencore – manufacturer of convenience foods.

The waste generated by these businesses is likely to have a much higher organic waste composition than what has been used in the resource flow model. There are also non-food manufacturing businesses in the area that are likely to have a higher organic waste composition than what has been used in the resource flow model. This includes Central Middlesex Hospital where food waste is generated from preparation in the catering kitchens as well as food leftovers from staff and patients, and Asda where food waste is generated from unsold food and produce that has passed its sell by date or has gone off.

There may also be opportunities to accept organic waste generated outside Old Oak and Park Royal, increasing the organic waste available for anaerobic digestion even further. For example, there are some companies based in Park Royal Industrial Estate that supply food to Heathrow Airport

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[26] Department for Environment, Food & Rural Affairs (2015). *Family Food 2014*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485982/familyfood-2014report-17dec15.pdf; (Accessed 14 October 2016).
[27] The contribution of the rooftop farming to food manufacturers in the Park Royal Industrial Estate cannot currently be quantified in the absence of demand data.
[28] Greater London Authority (2014). *The Park Royal Atlas: An Employment Study of London's Largest Industrial Area*. Available at: https://www.london.gov.uk/sites/default/files/Park%20Royal%20Atlas%20Screen%20Version%201.1_0.pdf (Accessed 12 October 2016).

that could implement a reverse logistics system to bring back food waste generated at the airport to Old Oak and Park Royal for anaerobic digestion.

With this in mind, an opportunity presents itself to capture the value in organic waste for use in producing new materials and products or for use in energy generation.

3.5.2 Non-metallic materials processing

There would be 97,053 tonnes/annum of C&I waste generated. The largest proportion of the waste would be non-metallic waste, representing 56,327 tonnes/annum (58%). Non-metallic waste covers a range of materials including glass, paper and cardboard, rubber, plastic, wood and textiles. In the absence of the exact composition of non-metallic waste that is likely to be generated, a number of potential circular economy options are presented below for each material.

Glass

- Reuse glass panels – glass panels that are carefully extracted as is from their original setting can be reused, where applicable.
- Fine aggregate replacement – the use of crushed glass as a fine aggregate replacement in concrete.

Paper and cardboard

- Recycling – source segregated paper and cardboard, a practice that should be supported through ongoing behaviour awareness programmes, can be recycled into new paper and cardboard products. Businesses who generate paper and cardboard waste should actively procure and use unwaxed materials to facilitate their subsequent recycling.
- Energy recovery – contaminated paper and cardboard waste can be sent for energy recovery in a range of thermal treatment plants.

Rubber

- Retreading tyres – where worn tyres are buffed away and a new tread is bonded to the tyre body using heat and pressure. Only certain worn tyres can be retreaded so they need to be inspected on a case-by-case basis before being retreaded.
- Replacement aggregate – use of tyre-derived rubber materials (i.e. size-reduced rubber fraction of used tyres) in road infrastructure, as roadbed stabiliser, slope stabiliser, drainage fill, culverts, drainage channels, bridge abutments and as an additive for rubberised asphalt.
- Energy recovery – tyre pyrolysis involves the thermochemical degradation of tyres in the absence of oxygen. The resulting products include syngas, char and a liquid residue referred to as pyrolysis oil. The

syngas can undergo combustion in CHP plant to generate heat and electricity. The char can be used as a solid fuel, in the production of activated carbon or as a soil additive. The pyrolysis oil can be used as a fuel or refined further into various fractions of oil.

Plastic

- Recycling – source segregated plastic, a practice that should be supported through ongoing behaviour awareness programmes, can be recycled into new plastic materials. This may include new uses of recycled plastic in filament materials for 3D printing and carpet manufacture.
- Plastic composites – low grade, mixed plastics can be processed into plastic composite materials that can be used in products such as indoor and outdoor furniture, delivery tubs, shower boards, kerbs and scaffolding board. An example of a process that produces plastic composites is powder impression moulding.
- Energy recovery – contaminated plastic waste can be sent for energy recovery in a range of thermal treatment plants.

Wood

- Reuse wood panels: wooden panels that are carefully extracted from their original setting can be reused, where applicable.
- MycoBoard™ – use of wood chips in the production of MycoBoard™, a mycelium-engineered wood. Mycelium is a natural glue, which is formaldehyde-free, safe, and healthy and produces panels that are strong, machinable and fire-resistant. MycoBoard™ can be used in the fabrication of structural and non-structural furniture, architectural panels, door cores and cabinetry.[29] These would all be required by the Old Oak and Park Royal development but could also be sold on the general market.
- Energy recovery – shredding wood into wood chips to produce a biomass fuel for use in energy generation in biomass plants.

Textiles

- Clothes donations – unrequired clothing can be distributed through a local network of charity shops.
- Textile recycling – clothes and textiles that cannot be worn or used again can be sold for other uses such as for padding and stuffing in furniture, insulation and loudspeaker cones, or for industrial wipes for trades such as engineering and printing. Some textile fibres can be reclaimed and mixed with new fibres to re-weave into new clothes and blankets.

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[29] Ecovative (2016). *Myco Board*. Available at: http://www.ecovativedesign.com/myco-board (Accessed 14 October 2016).

- Façade panels – structural façade panels have been successfully designed and built using high performance biocomposites. These materials are made of natural textile fibres and biopolymers obtained from fast growing plants. Biocomposites can be separated from the technical components and recycled in the biological cycle thus creating a low impact circular economy solution for building façades.

3.5.3 Industrial symbiosis

One aspect of the circular economy is industrial symbiosis, which can be defined as the exchange of materials or waste streams between companies, so that one company's waste becomes another company's raw material. Exchanges can be made with solid, liquid and gaseous raw materials as well as surplus electricity, heat and water. The benefits of industrial symbiosis include:

- Maximising use of materials by keeping materials or waste streams in use;
- Reduced depletion of primary resource reserves;
- Resilience against increasing volatile market prices of resources;
- Using waste to generate renewable energy for use on-site, sale to developments nearby or sale back to the grid; and
- Reduction in waste management costs.

It is estimated that C&I waste would represent 61% (97,053 tonnes) of the total solid waste generated each year in Old Oak and Park Royal. With 2,150 workplaces in the Park Royal Industrial Estate alone and additional businesses becoming operational as a result of the Old Oak and Park Royal development, there could be opportunities for industrial symbiosis.

This could be facilitated by the use of an online sharing economy platform similar to the National Industrial Symbiosis Programme (NISP), which essentially matched unwanted resources by one business with resource requirements of another business in England from 2005-2013.[30] A similar sharing economy platform, called Share Peterborough, has been created by Peterborough Council. The purpose of this business-to-business platform is to enable local organisations to maximise the use of resources by exchanging goods and services that are underused or no longer needed, to

[30] NISP was funded by Defra and managed by International Synergies Limited. The following benefits were achieved from the programme: i) Economic benefits - £1.03 billion of cost savings to business and £0.99 billion of additional sales to business; ii) Environmental benefits - 47 million tonnes of landfill diversion and 42 million tonnes of carbon dioxide savings; and iii) Social benefits - over 10,000 jobs created and a Benefit Cost Ratio of a minimum 30:1. Reference: URS (2014). *Industrial Symbiosis, 13th August 2014*. Available at: https://oldsite.iema.net/system/files/urs_presentation_slides.pdf (Accessed 19 October 2016).

promote local organisations and to build a collaborative business community in the city.[31]

3.5.4 Local use of Powerday output materials

Currently, Powerday export the wood chips they produced to two biomass CHP facilities in the UK (i.e. Ridham Docks and Slough). The majority of the RDF they produce gets exported to Germany and Sweden for use in waste to energy plants. Although, they are set to send a portion of it to a new waste gasification plant in Hoddesdon in Hertfordshire, in the near future.

With a significant increase in energy demand in the area as a result of the Old Oak and Park Royal development, an opportunity presents itself to generate local renewable energy using biomass and/or RDF instead of sending it for use off-site. This has the added benefit of reducing carbon emissions associated with the transport of the biomass and RDF.

The total electricity demand by the Old Oak and Park Royal development is estimated to be 161,860 MWh/annum and the total heating demand 180,092 MWh/annum. By using the 28,942 tonnes/annum of biomass produced at the Powerday site for on-site energy generation and distribution, approximately 32,881 MWh/annum of electricity and 65,239 MWh/annum of heat would be generated. This means that approximately 20% of the total electricity demand and 36% of the total heat demand could be met. By using the 72,218 tonnes/annum of RDF produced at the Powerday site for on-site energy generation and distribution, approximately 96,050 MWh/annum of electricity and 190,574 MWh/annum of heat would be generated. This means that approximately 59% of the total electricity demand and 106% of the total heat demand could be met.

Both processes would generate bottom ash. It is estimated that energy generation from biomass would generate approximate 868 tonnes/annum of bottom ash, which could be used as a fertiliser or soil conditioner or second grade aggregate and would be used off-site. It is estimated that energy generation from biomass would generate approximate 18,054 tonnes/annum of bottom ash, which can be processed into secondary aggregate for use in road construction as sub base material, in noise barriers, as a capping layer on landfill sites and in some countries as aggregate for asphalt or concrete. By selling bottom ash as a product, landfill diversion is maximised and additional revenue generating streams for the energy generation plants are created.

Bottom ash also has a relatively high ferrous and nonferrous metal composition. These can be recovered to facilitate closed loop metal cycles to reduce the depletion of primary metal ore resources.

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[31] Peterborough DNA (2016). *What We've Done So Far*. Available at: http://www.peterboroughdna.com/demonstrators/ (Accessed 19 October 2016).

Table 7 provides a summary of the electricity and heat that could be generated using the biomass and RDF generated at the Powerday facility. It is calculated that, together, the energy generated from biomass and RDF would be able to meet 95% of the total electricity demand and 112% of the total heat demand of Old Oak and Park Royal.

Table 7: Summary of electricity and heat generation potential from biomass and RDF generated at the Powerday facility

Energy feedstock	Electricity generation (MWh/annum)	Heat generation (MWh/annum)
Biomass	32,881	65,239
RDF	96,050	190,574
TOTAL	**128,930**	**255,814**
% of total demand at Old Oak and Park Royal	80%	142%

However, it should be noted that the majority of the materials used to produce the biomass and RDF at the Powerday facility do not currently originate from within the Old Oak and Park Royal area; for true circularity in Old Oak and Park Royal area, the materials used to generate energy should be sourced from within the area. In the context of RDF, approximately 16% (11,790 tonnes/annum[32]) of the 72,218 RDF could be met by household waste with the remaining 84% (60,428 tonnes/annum) coming from C&I waste.

The idea of an energy centre at the Powerday facility has already been explored by the company, although they have yet to submit a planning application.

3.5.5 Sustainable construction

The annual average construction, demolition and excavation waste generation in the London Borough of Brent, the London Borough of Ealing and the London Borough of Hammersmith & Fulham, during the period 2016 and 2036, would be approximately 797,719 tonnes/annum.[33] Therefore, the annual construction and demolition waste generated by Old Oak and Park Royal as estimated in the resource flow model (40,392 tonnes/annum), would represent 5% of all arisings.

The use of material resource efficiency measures and the reduction of waste can significantly contribute to reducing the environmental impacts of construction. The five principles of designing out waste set out by the Waste

[32] 11,790 tonnes/annum comes from the sum of organic waste and plastic waste estimated to be generated by households in Old Oak and Park Royal.
[33] Greater London Authority and SLR Consulting (2014). *Waste Arisings Model: Further Alterations to the London Plan.*

& Resources Action Programme (WRAP)[34] provide a comprehensive list of measures to think about implementing:

1. **Design for reuse and recovery** - use of existing materials, structures or components that can be reused/recycled onsite, incorporating site-won materials into design elements, use of materials and components with a recycled content, use of locally available materials and components of sufficient quality and reasonable costs.
2. **Design for off-site construction** – off-site manufacture or prefabrication of design elements, offsite assembly of design elements and use of assembly operations onsite over construction operations.
3. **Design for materials optimisation** – site layout optimisation techniques, consideration of the position and levels of built structures, optimising pile dimensions for specific buildings, simplification of various aspects (e.g. design, building form, structural systems, building services, construction sequence/methodology, layout etc), lightweight structures, reduction of material use, specific construction methods that maximise opportunities for materials optimisation, using standard dimensions for design elements, repetition and co-ordination of design across the design elements to reduce variables, avoid/minimise excess cutting and jointing of materials that generate waste, use of standardised materials and components to encourage reuse of off-cuts.
4. **Design for waste efficient procurement** – project specifications that been select elements/components/materials and construction processes that reduce waste or have reduced wastage rates, incorporation of key performance indicators and targets in the procurement specification handbook, optimisation of construction methods and logistics practices, use of supplier take-back schemes.
5. **Design for deconstruction and flexibility** – considering which design elements may require flexibility/adaptability for future uses, potential 'over-specification' at front-end to accommodate increase in future provision (e.g. services), maintained requirements that do not create an excessive amount of waste, incorporating components and materials that can be recovered for reuse or recycling at end-of-life, specifying building elements/components/ materials for easy disassembly, understanding current material and component attributes that would facilitate future reuse, use of BIM to record which and how elements/ components/materials have been designed for disassembly.

The benefits that can be achieved through designing out waste measures include:

[34] Waste & Resources Action Programme (undated). *Designing out Waste: A Design Team Guide for Buildings*. Available at: http://www.modular.org/marketing/documents/DesigningoutWaste.pdf (Accessed 26 October 2016).

- Cost savings associated with waste prevention and reuse of existing materials;
- Wider resource efficiency (e.g. energy, water, transport, sustainable procurement, labour productivity and carbon savings);
- Cost and programme efficiencies; and
- Opportunities for use of innovative construction processes and materials.

3.5.6 Retaining existing buildings

Demolition waste is estimated to account for 14% of the total solid waste generated each year in Old Oak and Park Royal. As previously identified, this is the same quantity of household waste that would be generated each year.

Reuse is at the heart of the circular economy, therefore, an opportunity presents itself to reduce demolition waste by refurbishing the buildings instead of demolishing them. Part demolition of buildings could also be explored if retaining the entire building is not possible.

3.5.7 District heating and cooling networks

District heating and cooling networks can provide heating and cooling for whole communities and even cities. These network increase resilience by helping cities cope with fuel price shocks and manage heating and electricity demand more accurately.

District heating and cooling networks represent an affordable, efficient, low carbon, resilient solution to the comfort and hot water needs of domestic and non-domestic buildings in densely populated areas. The cost and energy efficiency benefits of such networks also make them a potential tool for cities to tackle social challenges such as energy poverty.

These systems consist of a distribution network carrying heated or cooled water from the generation source to the end users thereby avoiding the need for individual systems. As a result, these networks can facilitate deployment of a larger amount of renewable heat than by individual stakeholders. The networks are flexible in that they can be deployed at the building or community level for the short term with multiple networks eventually becoming interconnected in the long term.

Energy sources for heating and cooling networks include conventional options such as local power stations and smaller scale CHP engines, but also natural sources such as water bodies and geothermal resources, urban infrastructure sources such as underground train ventilation shafts, wastewater in sewer pipes and electricity substations, and rejected heat from a cooled space such as a data centre i.e. secondary heat sources (see **Section 3.5.9**).

An opportunity presents itself to implement district heating and cooling systems, especially those using secondary heat sources as a low carbon option, to help meet the heating demand in Old Oak and Park Royal, which currently represents 43% (180,092 MWh/annum) of the total energy demand. District heating networks can also help meet the Greater London Authority (GLA) targets to reduce carbon dioxide emissions for new developments.[35]

A district heating system in Old Oak has already been explored in the OPDC Old Oak Decentralised Energy report[36] where it has been recommended for implementation. Opportunities to connect to the nearby decentralised energy developments proposed at White City and Wembley are also recommended in the report.

3.5.8 Renewable energy generation

The "energy trilemma" encapsulates three distinct objectives for future energy systems while also recognising the tension between these objectives:

1. Maintaining a reliable and secure energy supply;
2. Ensuring long-term affordability of the energy system; and
3. Drastically reducing greenhouse gas (GHG) emissions associated with energy generation and supply.

Cities can help solve this trilemma by adapting their energy delivery services to become more flexible, responsive and decentralised. These adaptations will enable a greater share of energy to be supplied by renewable and low carbon sources.

Renewables will be deployed at both the national grid scale in the form of large-scale biomass, wind, solar, hydro and tidal plants based outside the city to replace traditional centralised power stations, and at the distribution or building scale in the form of micro renewables and low carbon heat sources such as heat pumps, biomass CHP, waste CHP and solar thermal

[35] "For planning applications received by the Mayor on or after 1st October 2016 the regulated carbon dioxide emissions reduction target for domestic development is zero carbon and 35 per cent beyond Part L 2013 of the Building Regulations for non-domestic development" as stated in the following document: Greater London Authority (2016). *Energy Planning: Greater London Authority Guidance on Preparing Energy Assessment, March 2016*. Available at: https://www.london.gov.uk/sites/default/files/gla_energy_planning_guidance_-_march_2016_for_web.pdf (Accessed 13 October 2016).

[36] Old Oak and Park Royal Development Corporation (2016). *Old Oak Decentralised Energy, Draft for Regulation 18 Consultation, 4 February 2016*. Available at: https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/get-involved-op-5 (Accessed 11 October 2016).

within the city. Both will help cities meet their growing energy demand while reducing GHG emissions.

Focussing on renewable energy generation on the distribution and building scale in Old Oak and Park Royal, there are a number of technology options that could be used. Anaerobic digestion and energy generation from wood chips and RDF have already been explored in **Section 3.5.1** and **Section 3.5.4**.

Another option is the use of solar photovoltaic (PV) systems that could be mounted on the roof or integrated into the façade of a building. The energy generated would be able to be used to meet the building's own energy demand or, in certain situations, be fed back into the national grid. **Table 8** provides an estimate of the area of solar PV modules required to meet the electricity demands for different land uses.

Table 8: Estimated area of PV modules required to meet different land use electricity demands

Land use	Area (m^2)	Area (hectares)
Residential	560,438	56.0
Commercial	420,653	42.1
Retail	48,701	4.9
Leisure	9,347	0.9
Industry	46,186	4.6
TOTAL	**1,085,325**	**108.5**

It is unlikely that the total electricity demand at Old Oak and Park Royal would be able to be met by solar PV due to the large area of PV modules required. However, a portion of the total electricity demand could be met by solar PV to help meet GLA targets to reduce carbon dioxide emissions for new developments.[37]

3.5.9 Secondary heat sources

The carbon intensity of most secondary heat sources is lower than that of heat supplied via large centralised gas boilers, providing a case for its implementation in a transition to a more low carbon economy.

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[37] "For planning applications received by the Mayor on or after 1st October 2016 the regulated carbon dioxide emissions reduction target for domestic development is zero carbon and 35 per cent beyond Part L 2013 of the Building Regulations for non-domestic development" as stated in the following document: Greater London Authority (2015). *Energy Planning: Greater London Authority Guidance on Preparing Energy Assessment, March 2016*. Available at: https://www.london.gov.uk/sites/default/files/gla_energy_planning_guidance_-_march_2016_for_web.pdf (Accessed 13 October 2016).

Cities making the transition to energy self-sufficiency and a low carbon economy will need to adapt infrastructure, buildings and consumers to make use of both primary and secondary sources of energy to deliver lower energy costs, resilience and environmental sustainability.

Secondary heat sources include waste heat arising as a by-product of industrial and commercial activities, including London's infrastructure, and heat that exists naturally within the environment (air, ground, water). There are a wide variety of these sources within London, each with different characteristics in terms of temperature and availability. There are also differing practical considerations to be taken into account related to the heat recovery infrastructure required that can be installed at a site.

For most secondary heat sources, their temperature is too low for direct use in a heat network. It is therefore necessary to 'upgrade' them to a useful temperature using heat pumps powered by electricity. The efficiency with which they do this depends largely on the difference in temperature between the heat at source and the heat as supplied. The greater that difference, the more electricity is required and the less efficient is the heat pump. However, some industrial sources produce waste heat at above 70°C and can be fed directly into heat networks without the need for heat pumps.

Table 9 provides an estimate of the electricity requirements to convert secondary heat in three main MSOAs found within the red line boundary of the Old Oak and Park Royal at various temperatures to a usable temperature of 70˚C, referred to as the delivered heat.

Table 9: Electricity requirements to convert secondary heat available at various temperatures to usable heat that is delivered at 70˚C

Source	Available heat (MWh/annum)	Electricity requirement to upgrade to 70˚C (MWh/annum)	Delivered heat (MWh/annum)
Ground (open loop)	839	210	1,049
Ground (closed loop)	23,549	11,862	35,411
Air	176,250	140,515	316,764
Building heat rejection – Office	8,962	2,663	11,625
Building heat rejection – Retail	21,359	6,346	27,706
Building heat rejection – Gyms	280	83	363
Industrial sources part B processes	1,557	427	1,984
Supermarkets (non-HVAC)	1,854	496	2,350

Source	Available heat (MWh/annum)	Electricity requirement to upgrade to 70˚C (MWh/annum)	Delivered heat (MWh/annum)
Data centres (non-HVAC)	195,686	41,025	236,711
National grid infrastructure	29,200	4,399	33,599
UK Power Networks infrastructure	2,948	444	3,392
Sewer heat mining	8,740	3,910	12,650
TOTAL	**471,224**	**212,380**	**683,604**

The resource flow model indicates that Old Oak and Park Royal would require 180,092 MWh/annum of heat. It is estimated that secondary heat would be able to generate 683,604 MWh/annum, which represents almost 380% of the total heat demand of Old Oak and Park Royal. Therefore, in reality, a much lower amount of electricity would be required to upgrade the available heat to 70˚C to meet the heat demand of Old Oak and Park Royal.

It should be noted that a district heating network using secondary heat may be difficult to implement in retained areas of Park Royal, however, an opportunity still presents itself for Old Oak.

3.5.10 Water management measure

There will be a significant increase in water demand as a result of the Old Oak and Park Royal development. A number of water management measures that can be put in place to reduce potable water demand, non-potable water demand and the discharge of wastewater and surface water into drainage infrastructure. Some measures are more applicable to certain development typologies (new development verses retained development) than others and would need to be selected for implementation appropriately. Examples of water management measures are provided below, all of which have varying degrees of demand and discharge reduction potential:

- Demand management using smart water systems – these systems seek to reduce the overall water demand. It involves combining data from sensors on water quality, pressure and flow rate, with asset data and statistical analysis to gain an insight into asset conditions and systems performance. This allows leaks to be fixed as soon as possible and maintenance or replacement requirements to be easily identified and addressed. Another part of smart water systems are smart water meters that are connected to a wireless network with readings taken remotely that enables customers to monitor their real-time water usage, giving them control over the amount of water they use.

- Green roofs – where the roof a building is partially of fully covered in a planted soil layer to facilitate rainfall attenuation and therefore reduced discharge into the drainage system.
- Sustainable drainage systems (SuDS) – a strategic sequence of techniques used to manage surface water during storm events including storing and reusing surface water at source to reduce the water entering watercourses, the removal of pollutants to improve the quality of water entering watercourses and the delayed discharge of surface water into watercourses.
- Roof water recycling – rainwater can be collected from the roof of buildings and stored for reuse locally. Different treatment requirements are required for different end uses (potable or non-potable), although these are often less rigorous than for other types of water such as storm water and grey water due to the reduced exposure to contaminants.
- Grey water recycling – grey water is collected and stored using separate plumbing to the standard sewage system. The grey water requires treatment in the form of filtration, biological treatment and disinfection due to the contaminants and pathogens present in it before being redistributed for non-potable use.
- Wastewater recycling – wastewater including both black water and grey water is collected and undergoes advanced treatment (e.g. microfiltration, reverse osmosis, advanced oxidation etc.) due to the high concentration of contaminants that can present risks to human health, before being redistributed for non-potable use.

4 Opportunities

4.1 Overview

The detailed resource flows analysis of **Section 3** provides a rich evidence base for understanding the opportunities for circular economy at Old Oak and Park Royal. But, those opportunities are numerous and wide-ranging. A long-list of circular economy initiatives are presented in **Table 10**.

In order to provide structure to these initiatives, they have been arranged by 10 themes: food, water, energy, environment, materials, construction, mobility, logistics, space and community. These themes provide a comprehensive means for organising the circular economy initiatives into sectors through which resource flow can be managed.

Each circular economy initiative in the table includes a brief description and links to relevant research or existing projects in that area. Each of the initiatives is considered applicable and feasible to the Old Oak and Park Royal area; the links provide additional information and context on how such strategies are already being applied. More comprehensive case studies are included in **Section 6**. These provide additional details on the suitability, benefits and enablers of initiatives directly relevant to Old Oak and Park Royal.

4.2 Themes

The themes selected represent the main sectors or focus areas covered by the initiatives and activities proposed in the scenarios and case studies. The applicability of these themes to the Old Oak and Park Royal site is briefly described below.

Food

Localised food production systems such as vertical and rooftop farming, hydroponics, aeroponics and aquaponics, fuelled by local and shared energy and resources. Food sharing, distribution and a neighbourhood food market reduce waste and increase access to high quality, locally grown food.

Water

Sustainable water systems maximise the local water resource. Systems and services include rainwater collection and recycling, green walls, roofs, and bio-façades, sustainable drainage systems and green infrastructure, and smart water demand management, including behaviour change programmes.

Energy

Renewable and low carbon energy sources are prioritised, including rooftop PV, heat pumps, anaerobic digestion, biomass and district heating and cooling networks. Local energy generation, community-owned assets, micro- and nano-grids including battery storage, and smart demand management techniques, including behaviour change programmes, increase energy security, lower costs, reduce environmental impacts and increase local resilience.

Environment

Techniques to improve local air quality, reduce GHG emissions, reduce waste and enhance biodiversity are prioritised, including ongoing measurement, via sensors and digital services. Behaviour change campaigns incentivize smart choices. Green infrastructure, sustainable transport, construction and waste techniques and environmentally engaged communities help to create a healthy, liveable environment. Biological resources are extracted and reused via anaerobic digestion, composting or bio-refining.

Materials

Low impact and renewable materials are selected. Waste becomes a resource for making new materials and components, and to generate energy. Demolition waste is reused where possible. Materials are tracked and recycled using materials passports and databases.

Construction

Low impact construction techniques helps to reduce waste and increase reuse, as well as minimize associated logistics footprints. Modular and bespoke pre-fabrication, on- and off-site, cut waste and costs, and increase engagement and access, as well as innovation. New building technologies are encouraged through on-going engagement activities. Emerging fabrication technologies and lightweight construction techniques allow for more agile development models where structures can be easily and effectively upgraded over time.

Mobility

Mobility services are planned and delivered to maximise asset utilisation, reduce environmental impacts, increase access, and promote healthy lifestyles. Pedestrians and cycling routes are prioritised. Ride-sharing and shared mobility services using electric and autonomous vehicles is implemented and prioritised, supported by a backbone of fixed mass transit connections. Sensor networks, predictive analytics and well-designed user-facing digital services streamline performance and user experience, increasing utilisation.

Logistics

Consolidated and automated waste systems, and reverse logistics minimise waste and maximise reuse. Waste streams are captured locally to produce new sources of energy and resources and minimise transport outside the district. Robotics and autonomous technologies enable new opportunities around on-demand last-mile logistics, including drones and ground robotics.

Space

Space is designed for flexibility, interoperability, minimal material use and waste generation, disassembly and reuse. Shared spaces forms a more important component, due to possibilities of increased utilisation and contemporary ownership models. Space use is maximised through well-designed digital sharing and leasing services. The provision of service performance including for whole assets, facades, energy systems, materials and internal fittings is guaranteed by external providers.

Community

Digital platforms help forge and connect communities enabling new models of sharing and cooperation. Community-led design and ownership of assets (e.g. energy, waste, mobility, and shared space) helps to build equitable and engaged diverse communities. Skills and resources are created, exchanged and shared via digital services. Sustainable behaviour is promoted via economic and other incentives, for example, revenues for local energy generation or electric vehicle (EV) storage access.

Table 10: Long-list of circular economy initiatives

Theme	Initiative	Overview	Related links
Food	Rooftop farming	An urban farming method that sees the growth of fruit and vegetables on rooftops using classic raised beds or more advanced systems like hydroponics, aeroponics and aquaponics. This helps to meet local fruit and vegetable demands with local produce.	http://www.skygreens.com/ http://www.ecowatch.com/worlds-largest-vegetable-factory-revolutionizes-indoor-farming-1882004257.html
	Rooftop greenhouses	An urban farming method that uses redundant rooftop space for housing greenhouses. The greenhouse can reduce heat loss from the building beneath it while the fruit and vegetables growing gain from the heat transfer.	http://www.rooftopgreenhouse.co.uk/index.html http://gothamgreens.com/our-farms/
	Community dining	Communal spaces where residents can share food, cook and eat together.	https://www.ft.com/content/637dda40-07b0-11e6-9b51-0fb5e65703ce
	Local food market	A place to sell locally grown produce from rooftop and other urban farming activities to the community. Produce is grown and consumed within the district, minimising incoming food miles and cost, whilst cultivating local skills and involvement.	https://www.sustainweb.org/localactiononfood/growing_food/ https://www.bigbarn.co.uk/
	Commercial food distribution	The distribution of local grown product from rooftop and other urban farming activities to local businesses e.g. cafes, restaurants, food manufacturers etc. Helps reduce waste and poverty.	http://www.ayrshirefoodnetwork.co.uk/ http://www.thefelixproject.org/
	Urban community gardens	Putting land into community use to grow affordable, fresh, organic food, and support others to do so.	https://www.cfgn.org.uk/ http://growingcommunities.org/food-growing/volunteering/ https://www.organiclea.org.uk/about/
Water	Green roofs	Roofs of buildings that are partially or fully covered in a planted soil layer to facilitate rainfall attenuation and therefore reduced discharge into the drainage system. Green roofs can also increase biodiversity.	http://www.bauder.co.uk/ http://greeninfrastructureconsultancy.com/

Theme	Initiative	Overview	Related links
	Roof water recycling	Collection, treatment, storage and distribution of rainwater collected from the roof of buildings for potable or non-potable reuse locally depending on treatment used.\	https://www.theguardian.com/lifeandstyle/2014/jul/22/rainwater-harvesting-using-the-weather-to-pay-your-bills
	Grey water recycling	Collection, treatment, storage and distribution of grey water for non-potable use using separate plumbing to the standard sewage system. Treatment includes filtration, biological treatment and disinfection.	http://www.anglianwater.co.uk/environment/how-you-can-help/using-water-wisely/greywater-reuse.aspx https://www.theguardian.com/lifeandstyle/2014/jul/21/greywater-systems-can-they-really-reduce-your-bills
	Smart water systems	Reducing water demand by combining data from sensors with water infrastructure asset data and statistical analysis to address inefficiencies in the systems performance and using smart water meters to enable customers to monitor their real-time water usage.	https://www.navigantresearch.com/research/smart-water-networks https://assets.publishing.service.gov.uk/media/57a08ab9e5274a31e000073c/SmartWaterSystems_FinalReport-Main_Reduced__April2011.pdf
Energy	Anaerobic digestion	The decomposition of organic material in the absence of oxygen, which generates biogas and a digestate. Biogas can be used as a renewable energy or fuel source and the digestate as an organic fertiliser or potentially for bioplastics production, phosphate extraction and biocoal production.	http://www.wrap.org.uk/category/subject/anaerobic-digestion http://www.nestle.co.uk/media/pressreleases/decc-minister-opened-ad-plant-fawdon
	Energy generation from RDF	Energy generation using conventional thermal treatment or alternative thermal treatment technologies with RDF as feedstock.	http://www.syngas-products.com/operating-assets/1-avonmouth-bristol/
	Energy generation from biomass	Energy generation using conventional thermal treatment or alternative thermal treatment technologies with biomass as feedstock.	https://www.mvv-energie.de/en/uiu/uiu_mvv_environment/ridham_dock/about_our_plant/aboutourplant.jsp
	Secondary heat use	Use of low carbon waste heat that often requires upgrading to a high enough temperature using a heat pump before being used.	https://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat http://www2.nationalgrid.com/Responsibility/Connecting-for-tomorrow/Preserving-for-the-future/case-studies/Waste-Heat-Recovery/

Theme	Initiative	Overview	Related links
	District heating and cooling networks	Low carbon distribution network carrying heated or cooled water from generation sources that could include local power station, smaller scale CHP, renewables and secondary heat.	http://www.queenelizabetholympicpark.co.uk/the-park/attractions/around-the-park/energy-centre http://www.cibse.org/getmedia/843f2dbd-55eb-4c6c-b219-88fe9eb83949/DH_Manual_for_London_February_2013_v1-0.pdf.aspx
	Solar PV	An electrical installation using a semiconductor that converts solar energy into a renewable form of electricity.	http://www.trinasolar.com/uk https://corporate.marksandspencer.com/media/press-releases/2015/mands-starts-generating-renewable-energy-from-uk%E2%80%99s-largest-roof-mounted-solar-array
	Battery storage	Battery storage helps mitigate grid infrastructure constraints by providing reserve capacity in the event of system failure and assists the seamless integration of renewable energy by allowing renewable energy to be generated when it is most efficient, and stored until there is demand for it.	http://www.r-e-a.net/renewable-technologies/storage https://www.climatecouncil.org.au/uploads/ebdfcdf89a6ce85c4c19a5f6a78989d7.pdf
	Distributed energy storage	Facilitates renewable energy penetration, helps to stabilise the grid and increases resilience. Battery storage technology is advancing rapidly while prices are coming down.	https://cleantechnica.com/2016/05/12/market-opportunity-energy-storage-uk/ http://www.renewableenergyworld.com/articles/print/volume-16/issue-4/storage/the-case-for-distributed-energy-storage.html
	Demand side response (DSR)	DSR can help provide great savings for consumers by reducing or shifting electricity usage during peak times in response to time-based rates or other forms of financial incentives.	http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Presentations/Low+Carbon+London+-+Time-of-Use+Trials.pdf
	Microgrids	Microgrids incorporate energy generation, storage and demand management systems so that supply and demand are matched in a safe, effective and reliable way. The 'smartness' of microgrids means that these are compatible with renewable energy generation.	http://publications.arup.com/publications/f/five_minute_guide_microgrids http://www.britishgas.co.uk/business/blog/microgrids-do-we-need-them/
Environment	Green walls (or Living walls)	Walls of buildings that are partially or fully covered with greenery in a growth medium, which increases biodiversity,	http://www.treebox.co.uk/ http://www.biotecture.uk.com/

Theme	Initiative	Overview	Related links
		reduces the urban heat island effect, lower emissions and reduce building' energy use and associated costs.	
	Urban green spaces	Creating green spaces in dense urban areas helps to reduce the urban heat island effect, increases public amenity and lowers emissions. Planting street trees also contributes to reducing particulate matter in the immediate vicinity and improving air quality.	https://www.woodlandtrust.org.uk/mediafile/100083924/Urban-air-quality-report-v4-single-pages.pdf http://leaf.leeds.ac.uk/wp-content/uploads/2015/10/LEAF_benefits_of_urban_green_space_2015_upd.pdf
	Sustainable Drainage Systems	The management of surface water during storm events to reduce, improve the quality of and delay surface water entering watercourses. Well-designed SuDs also increase biodiversity and provide public green spaces.	http://www.susdrain.org/ http://www.bgs.ac.uk/suds/
	Permeable pavements	Provide allow stormwater to filter through, "catch basins" to capture water and funnel it into the ground. High-albedo pavements also reflect sunlight to reduce the heat island effect.	http://www.arup.com/cities_alive/rethinking_green_infrastructure http://www.susdrain.org/delivering-suds/using-suds/suds-components/source-control/pervious-surfaces/pervious-surfaces-overview.html
Materials	Waste capture	The collection and transfer of waste materials to appropriate reuse, repair, remanufacturing, recycling and treatment facilities. This could be through the use of refuse collection vehicles, automated waste collection systems, robotic collection systems etc.	http://www.veolia.co.uk/our-services/what-we-do/recycling-and-waste-services/local-authorities/refuse-collection http://www.envacgroup.com/
	Centralised resource and energy centre	A centralised resource centre can provide an improved solution for the diversion of waste from landfill by minimising the use of materials, energy, land and labour and by simplifying logistics in comparison to geographically separate facilities.	http://www.veolia.co.uk/london/facilities/facilities/integrated-waste-management-facility https://www.cranfield.ac.uk/centres/bioenergy-and-resource-management-centre
	Materials reuse	Material reuse can range from bulky waste and electronic equipment from households to off-cuts from construction activities. Reuse centres that may have basic repair and processing operations can facilitate this initiative.	http://www.londonreuse.org/

Theme	Initiative	Overview	Related links
	Organic fertiliser production	The decomposition of organic material into organic fertiliser via composting or use of digestate as an organic fertiliser as a substitute to manufactured fertilisers.	http://www.londonwaste.co.uk/community/compost/
	Bioplastics production	The bacteria in sewage sludge from wastewater treatment plants can be used to produce bioplastics. The process removes the volatile fatty acids from sewage sludge, which are mixed with bacteria to digest them and convert them to biopolymers, which can then be refined into biodegradable bioplastics. The use of digestate instead of sewage sludge as feedstock in the production of bioplastics is currently being explored.	http://www.veolia.com/sites/g/files/dvc181/f/assets/documents/2014/04/chroniques_scientifiques_n17-en.pdf http://www.wrap.org.uk/sites/files/wrap/Optimising%20the%20value%20of%20digestate%20and%20digestion%20systems_0.pdf
	Phosphate extraction	Phosphate extraction from wastewater (and potentially digestate) in the form of struvite or other novel ways can help to maximise phosphate recovery to ultimately help advance phosphorous to material circularity.	http://www.lenntech.com/phosphorous-removal.htm http://wwtonline.co.uk/features/project-focus-phosphate-and-energy-recovery-at-stoke-bardolph-wwtw#.WAjRevkrJaR
	RDF production	RDF is an umbrella term for prepared fuel derived from untreated MSW, C&I waste and CDEW. It has a higher energy content than normal waste materials and can be used as feedstock for renewable energy generation.	http://www.powerday.co.uk/news/powerday-secures-uk-rdf-outlet-with-ferrybridge-multifuel-energy-limited/bp120/ https://www.biffa.co.uk/about-us/operational-infrastructure/refuse-derived-fuel/
	Biomass fuel production	Biomass fuels can be derived from waste materials including food waste and wood waste. It can be used as feedstock for renewable energy generation.	http://www.powerday.co.uk/news/powerday-partners-with-mvv-environment-at-ridham-docks/bp119/ http://www.bioregional.com/wp-content/uploads/2015/05/BiomassforLondon_Dec08.pdf
	Mycelium biomaterials	Mycelium (mushroom roots) can be used as a natural glue for agricultural and wood wastes to produce biodegradable packaging products.	http://www.ecovativedesign.com/ http://www.telegraph.co.uk/news/earth/businessandecology/recycling/12172439/Ikea-plans-mushroom-based-packaging-as-eco-friendly-replacement-for-polystyrene.html
	Sustainable construction materials	Using non-toxic, recycled and recyclable materials that do not have an adverse impact on the environment or deplete natural resources.	http://www.designingbuildings.co.uk/wiki/Sustainable_materials

Theme	Initiative	Overview	Related links
	Circular procurement	Local authorities may use procurement mechanisms to catalyse the introduction of circular economy goods and services including leasing of façades and materials.	https://www.ellenmacarthurfoundation.org/case-studies/denmark-public-procurement-as-a-circular-economy-enabler https://ec.europa.eu/environment/efe/themes/economics-strategy-and-information/green-public-procurement-drives-circular-economy_en
Fabrication	Design for flexibility	Designing buildings to be adapted for different uses in the future. Helps to maximise assets' utility.	http://www.carltd.com/services/Design-for-flexibility-and-adaptation
	Modular design	Designing building and structures in modules to allow component modules to be added, removed or replaced as required.	http://www.arup.com/news/2013_02_february/4_feb_new_report_predicts_the_future_of_buildings_in_2050
	Off-site prefab construction	The practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.	http://www.designingbuildings.co.uk/wiki/Off-site_prefabrication_of_buildings:_A_guide_to_connection_choices http://www.offsitehub.co.uk/projects
	Lightweight construction	The use of less construction materials to conserve natural resources. Less material means less embodied energy in the building.	http://www.metsec.com/steel-framing/case-studies/ http://www.lytag.com/case-studies
	Modular construction	The use of factory-produced pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building.	http://www.arup.com/news/2016_06_june/3_june_modular_micro_apartments_to_solve_student_housing_issues_in_berlin http://www.dezeen.com/2012/12/18/worlds-tallest-modular-building-breaks-ground-in-new-york/
	Façade leasing	Leasing model based on performance based contracts that facilitates the rate and depth of energy renovations in buildings. Façades are designed to be removed from buildings and reused.	http://www.frener-reifer.com/services/ http://www.onderzoek.bk.tudelft.nl/index.php?id=133063&L=1
	Building information modelling (BIM)	To track building material and component attributes to facilitate future maintenance, reuse and recycling.	http://www.arup.com/services/building_modelling http://www.bimtaskgroup.org/

Theme	Initiative	Overview	Related links
	Additive manufacturing (3D Printing)	Additive manufacturing, or also known as 3D printing, refers to a process by which digital 3D design data is used to build up successive layers of material to form an object or even a building. This process is avoiding the generation of waste which is associated with the conventional sub-tractive manufacturing method of removing material to form an object.	http://www.arup.com/news/2014_06_june/05_june_construction_steelwork_makes_3d_printing_premiere https://www.theguardian.com/cities/2015/feb/26/3d-printed-cities-future-housing-architecture
Mobility	Pedestrianisation	Pedestrian routes are prioritised. Routes are designed to be safe, and attractive to promote walking.	http://publications.arup.com/publications/c/cities_alive_towards_a_walking_world https://www.theguardian.com/cities/pedestrianisation
	Cycle routes	Cycle routes are prioritised. Safe cycle lanes are designed to facilitate low carbon transport and promote healthy lifestyles.	http://www.makingspaceforcycling.org/ http://www.sustrans.org.uk/policy-evidence/related-academic-research/economic-benefits-active-travel
	Bike sharing scheme	Initiated across the district, subsidised by a corporate partner and connected to other transport modes by a central hub.	https://ecf.com/what-we-do/urban-mobility/bike-share-schemes-bss https://tfl.gov.uk/modes/cycling/santander-cycles
	Car sharing scheme	Car sharing schemes make greater use of a smaller number of vehicles, reducing negative impacts such as traffic congestion and pollution.	https://liftshare.com/uk https://www.zipcar.co.uk/
	Strategic zoning of vehicle access	Creating vehicle free zones through the strategic re-routing of vehicles across road networks.	https://www.london.gov.uk/sites/default/files/leaving-a-transport-legacy.pdf
	Autonomous vehicles	Self-driving vehicles that are capable of sensing the environment around it and navigating without human input.	http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17SAVs_acrossAustin.pdf
Logistics	Canal transportation	Transportation by canal involves placing filled containers on a barge or container ship. It is a highly efficient mode of waste transport e.g. a single 300 tonne barge can take up to 15 waste	https://canalrivertrust.org.uk/business-and-trade/freight http://www.wrwa.gov.uk/waste-authority/waste-transfer-stations.aspx

Theme	Initiative	Overview	Related links
		transfer trucks off the road thereby significantly reducing congestion on roads.	
	Rail transportation	Transportation by rail uses containers mounted on flatbed wagons. The environmental benefits of rail transport over road transport include lower air emissions at source, greater fuel efficiency and reduced road congestion.	http://www.freightonrail.org.uk/CaseStudyWasteByRail.htm http://www.sita.co.uk/downloads/KnowsleyRLTSInformationLeaflet.pdf
	Drone logistics	Unmanned aerial vehicles that are capable sensing the environment around it and navigating without human input for use in the movement of goods.	http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/DHL_TrendReport_UAV.pdf http://www.eft.com/logistics/use-drones-logistics
	Consolidation centres	A facility where materials and deliveries going into or out of an area are combined to reduce the vehicles on the road.	http://content.tfl.gov.uk/directory-london-construction-consolidation-centres.pdf http://www.wrap.org.uk/sites/files/wrap/CCC%20combined.pdf
	Reverse logistics	A closed loop approach that uses remanufacturing, refurbishment, repair, reuse or recycling to recover and process materials and products after the point of consumption.	http://www.edie.net/news/7/DHL-launches-reverse-logistics-model-to-support-circular-economy/
	Autonomous road logistics	Self-driving municipal bots undertaking tasks from waste collection to street maintenance.	http://museum.governmentsummit.org/2015/ https://medium.com/butwhatwasthequestion/the-street-as-platform-2050-98bbb81016f4#.z8fuzpe6w
Space	Building retrofit	Refurbishing of existing building stock to improve efficiency and functionality.	http://www.ukgbc.org/resources/key-topics/new-build-and-retrofit/retrofit-domestic-buildings http://www.arup.com/services/building_retrofit
	Temporary housing	Modular, prefabricated and demountable structures built on land waiting to be developed.	http://www.designingbuildings.co.uk/wiki/Lewisham_Ladywell_Temporary_Housing http://inhabitat.com/tag/temporary-housing/
	Development above railway	Integrated commercial and residential development built directly above and around mayor rail infrastructure sites.	http://www.crossrail.co.uk/route/property-developments-and-urban-realm/property-developments/

Theme	Initiative	Overview	Related links
	Meanwhile uses	Using vacant buildings and spaces for temporary, socially beneficial purposes.	http://www.designingbuildings.co.uk/wiki/Meanwhile_use_of_buildings http://www.meanwhilespace.com/media/media/downloads/Benefits_Landlords.pdf
	Flexible spaces	Flexible design approaches create easily adaptable buildings and spaces with multiple potential uses that evolve over time.	http://whitecollarfactory.com/space http://www.merthyr.gov.uk/media/1219/spg-4-sustainable-design-chapter-12.pdf
	Shared spaces	Live-work and co-living developments provide a combination of serviced private and shared amenity spaces. Digital platforms can facilitate the space as a service business model to intensify the use of space.	https://www.urbanspaces.co.uk/live-work http://www.dezeen.com/2016/07/08/six-best-co-living-developments-around-the-world/
	Sensor network	Space and asset performance monitoring and analysis systems to enhance efficiency and facilitate real time and predictive maintenance and repair.	http://www.powercastco.com/applications/wireless-sensor-networks/
	Cluster development	The development of sites in proximity of each other to create a geographic concentration of interconnected businesses and innovation ecosystems.	http://www.londonsdc.org/documents/LSDC_BetterFuture_March2016_FINAL.pdf
Community	Shared tools platform	Neighbourhood sharing platforms allow people to lend and borrow underutilised household items such as power tools and surplus food.	https://www.peerby.com/dashboard https://olioex.com/
	Shared skills platform	Skills sharing platform allow people to get free help from neighbours with domestic tasks such as bicycle repairs or gardening, often in exchange for other tasks.	https://www.streetbank.com/splash?locale=en-GB http://npoconnect.org/content/free-peer-skill-sharing-platform-0
	Community planning platform	A platform that allows community members to submit design proposals for automatic assessment against planning policy and to facilitate a transparent consultation process.	http://brickstarter.org/an-introduction-to-brickstarter/ http://www.sketchup.com/3Dfor/urban-planning
	Community owned energy infrastructure	Enables communities to produce, store and locally distribute their own energy. Shared ownership give communities more control over type of generation and cost of energy.	https://transitionnetwork.org/tools/building/community-renewable-energy-companies

Theme	Initiative	Overview	Related links
			https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275163/20140126Community_Energy_Strategy.pdf http://www.thamesweyenergy.co.uk/about-thameswey/who-we-are/
	Community led development	Allows local people to oversee the design and construction of their own homes and communities to a particular specification.	http://www.designcouncil.org.uk/what-we-do/community-led-design-development http://buiksloterham.nl/engine/download/blob/gebiedsplatform/69870/2015/28/CircularBuiksloterham_ENG_FullReport_05_03_2015.pdf?app=gebiedsplatform&class=9096&id=63&field=69870&
	Circular economy credit system	A system in which credits are allocated for services with circular economy value. This creates a marketplace where a token currency can be spent.	http://www.coindesk.com/the-theory-of-a-blockchain-circular-economy-and-the-future-of-work/ http://startupmanagement.org/2016/08/02/the-theory-of-a-blockchain-circular-economy-and-the-future-of-work/
	Shared industrial resources platform	An industrial sharing economy platform, which essentially matches unwanted resources by one business with resource requirements of another business.	https://oldsite.iema.net/system/files/urs_presentation_slides.pdf http://www.peterboroughdna.com/demonstrators/ https://www.globechain.com/
	Circular hubs	Circular hubs are designed to attract and provide space for the incubation and development of a range of businesses including clean-tech organisations, academic institutions, live-work spaces, manufacturing facilities and workshop spaces.	http://nomadcapitalist.com/2016/08/15/best-co-working-spaces-europe/ http://cleantech-innovationcenter.de/en/?X-SS-WNB=C15A587B7BAF2377FCEE364004B17A7D

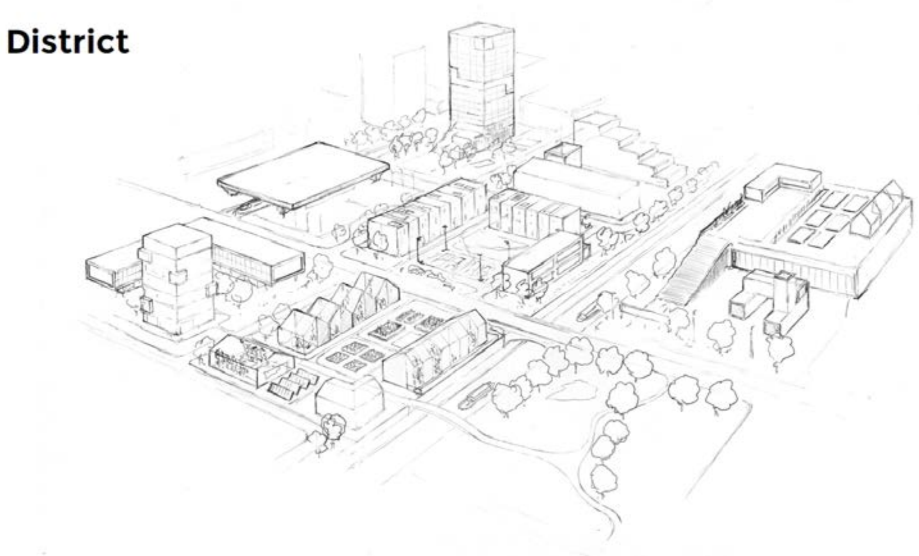
4.3 Applying the themes

The themes provide and organised long-list of circular economy initiatives and opportunities. However, to illustrate the potential for some of the most promising initiatives, four scenarios have been developed which demonstrate circular economy cycles in Old Oak and Park Royal. These scenarios are presented in detail in **Section 5**.

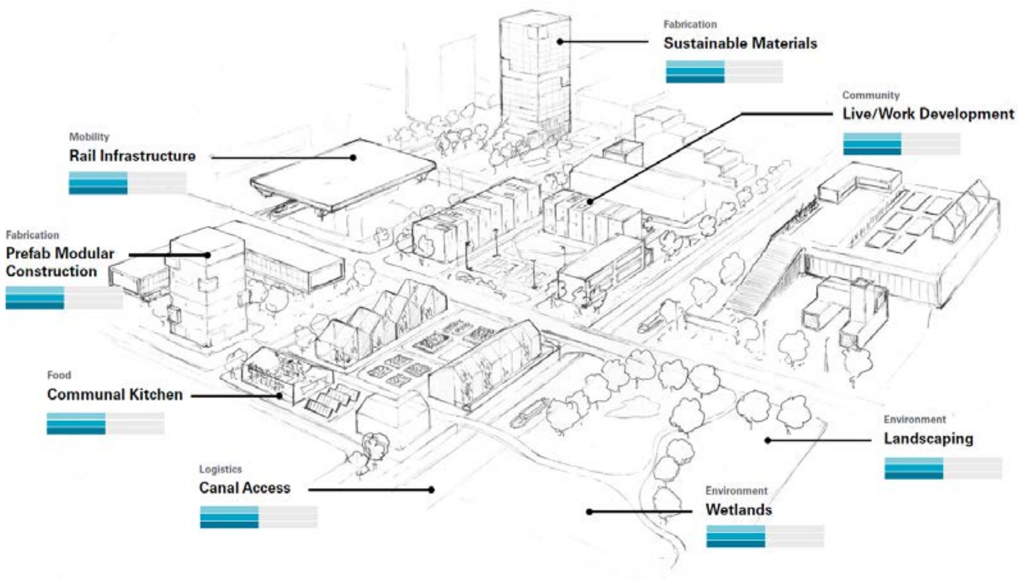
5 Old Oak and Park Royal scenarios

In **Section 2,** eight principles for the circular economy have been defined. To support a circular economy which is systemic, optimised renewable and shared, a resource flows analysis was conducted which highlights the flows of materials, energy and water and opportunities for demand reduction, reuse and optimisation. This baseline informs the production of circular economy initiatives, which are organised into themes to facilitate the formulation of scenarios.

The following section presents four scenarios for the circular economy – two in Old Oak and two in Park Royal. They represent some of the most promising opportunities for circular economy cycles for their respective areas, and build on the evidence base of both proven and emerging circular economy initiatives. The scenarios are represented through an illustrative district, as seen below.



The circular economy initiatives within each scenario are graphically depicted.



Scenarios

We have developed a series of scenarios, as a way of **mapping out systems and circular initiatives**, grounded in their physical context.

Park Royal	Sites	Old Oak
Industrial Post-Industrial	**Site Typologies**	Mixed-Use High-Rise Commercial Residential
Utilise existing industrial processes Industry symbiosis Site intensification Improve working environment Introduce emerging sectors New business-lead communities	**Opportunities**	Build new communities Smarter use of space and resources Design in self-sufficiency from day one New sharing models Build 'just enough'

Park Royal Scenarios

1

The Royal Garden

A zero waste urban garden fuelled by biological nutrients, green infrastructure, local energy and advanced logistics.

2

Clean Tech Estate

A post-industrial development supports new circular-focused businesses and technological innovation.

Old Oak Scenarios

3

Adaptable Development

High-rise tower developments are designed with circular built-in, from sustainable construction to flexible and smart space usage.

4

Sharing Community

Digital platforms and lightweight technologies enable communities to build, operate and share their neighbourhood spaces and resources.

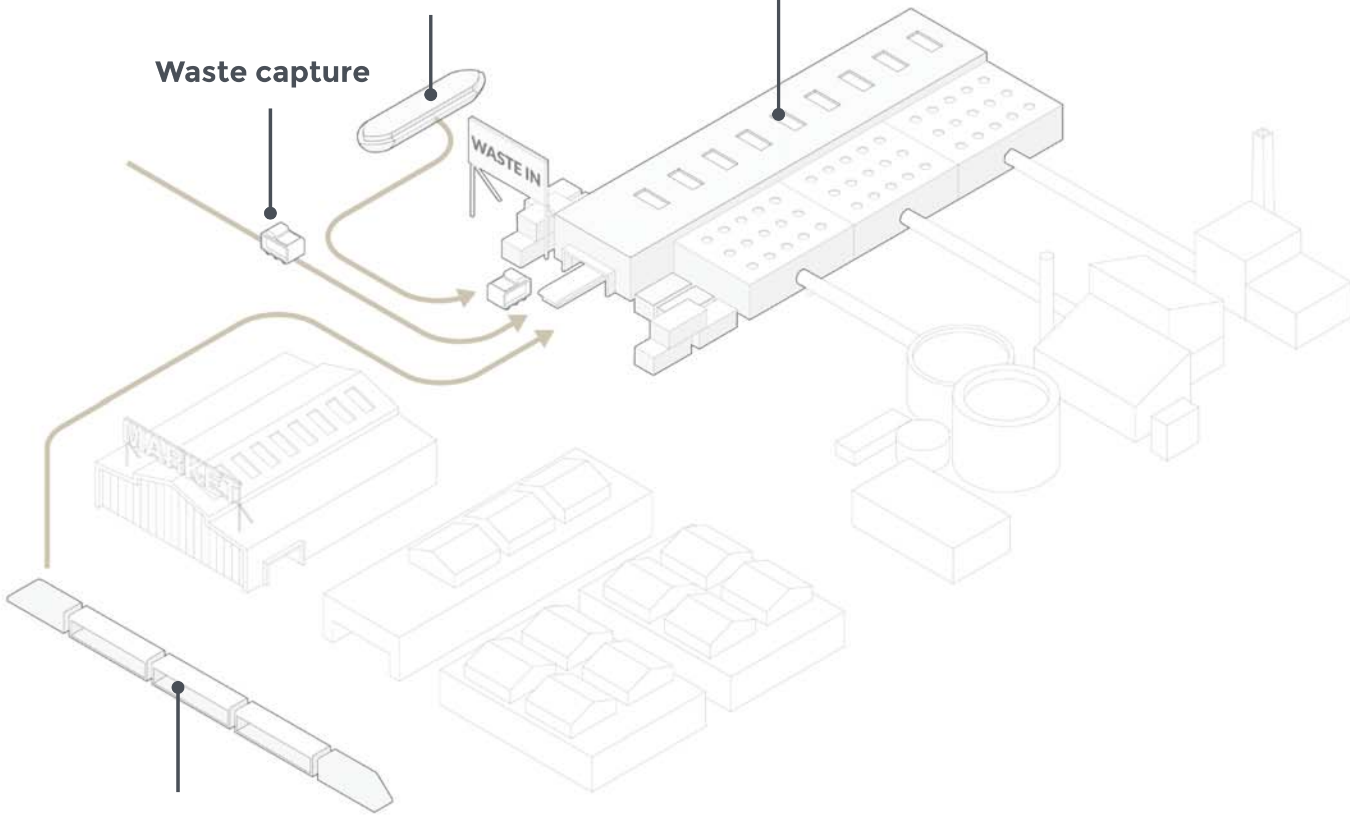
1

Royal Garden

A zero waste urban garden fuelled by biological nutrients, green infrastructure, local energy and advanced logistics.

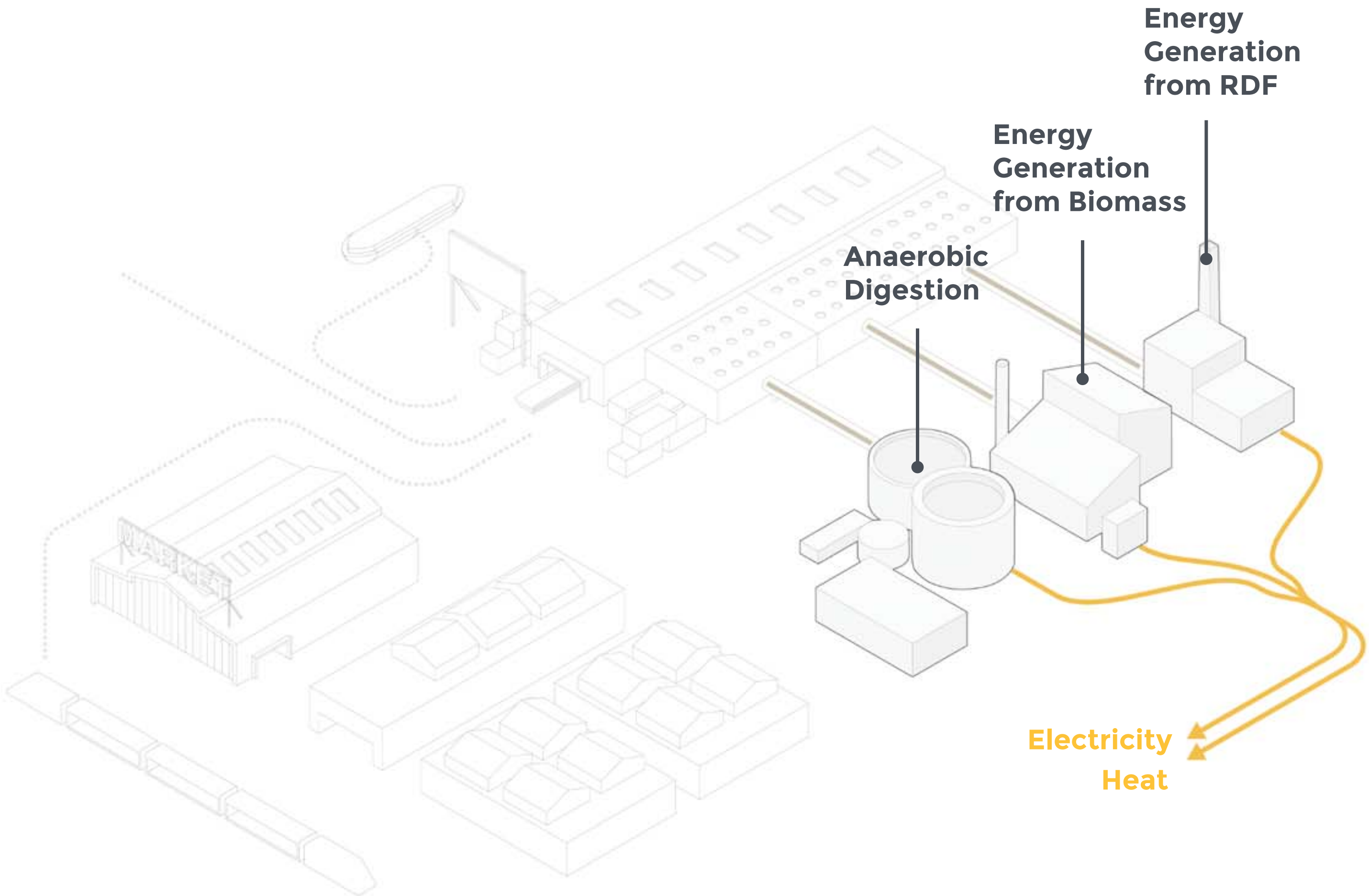
1

Existing waste streams are captured locally and regionally and transported to a centralised resource and energy centre.



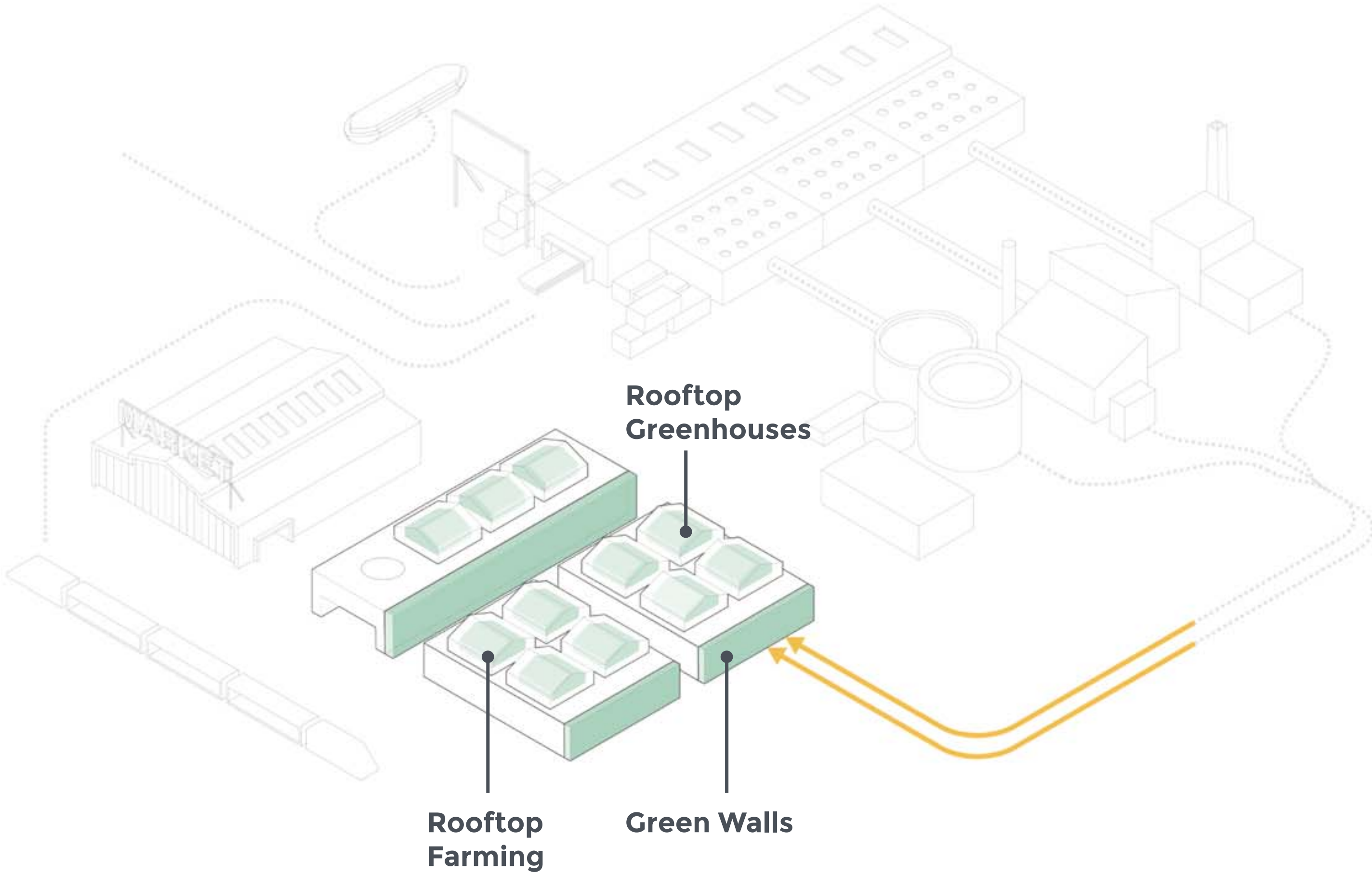
2

Separated waste streams are processed to create new sources of energy and useful resources.



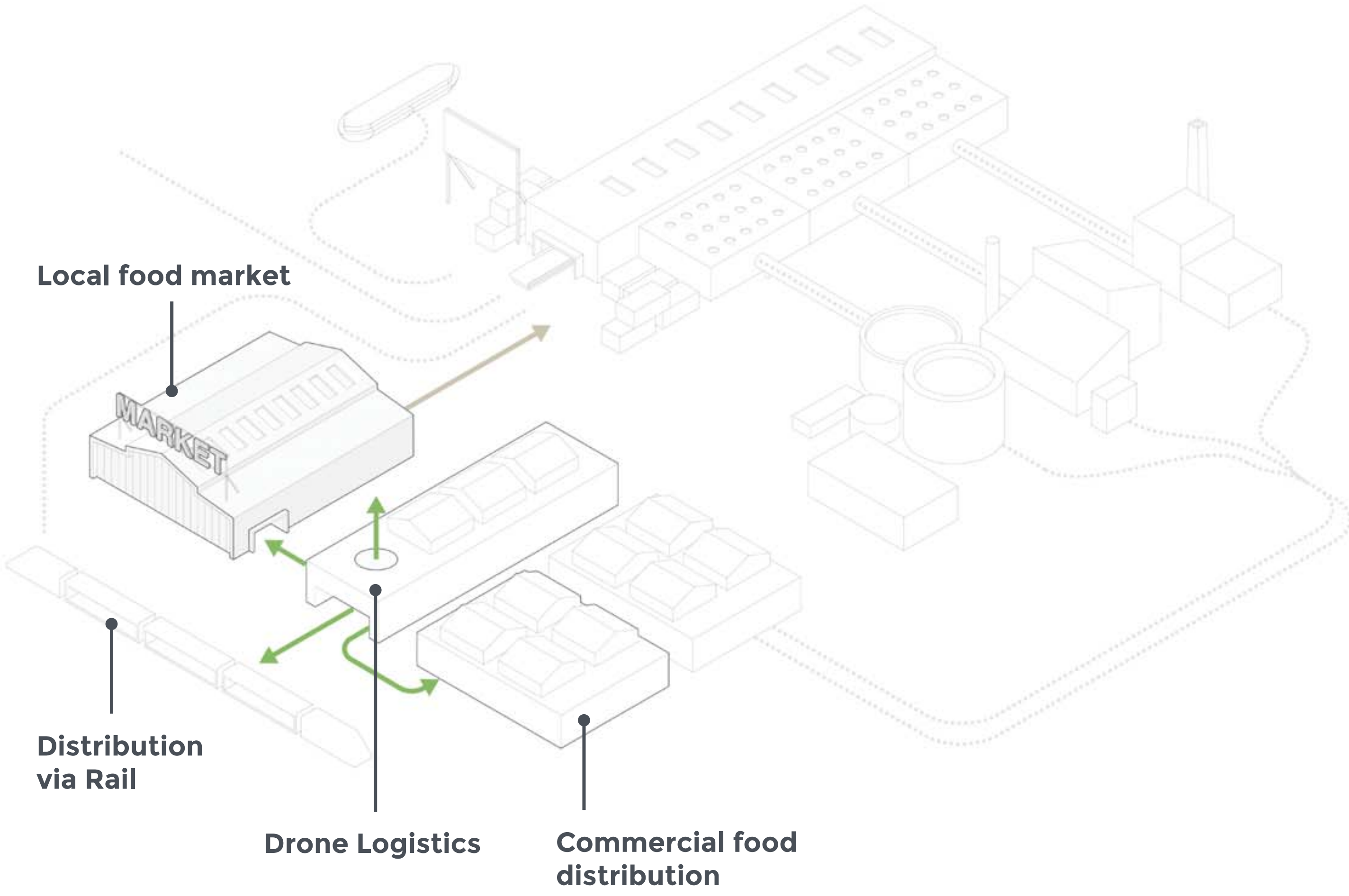
3

A network of urban farming initiatives across Park Royal, fuelled by local energy and resources and generating new food production streams.



4

Logistics networks distribute produce locally and regionally, through new and existing infrastructures.



2

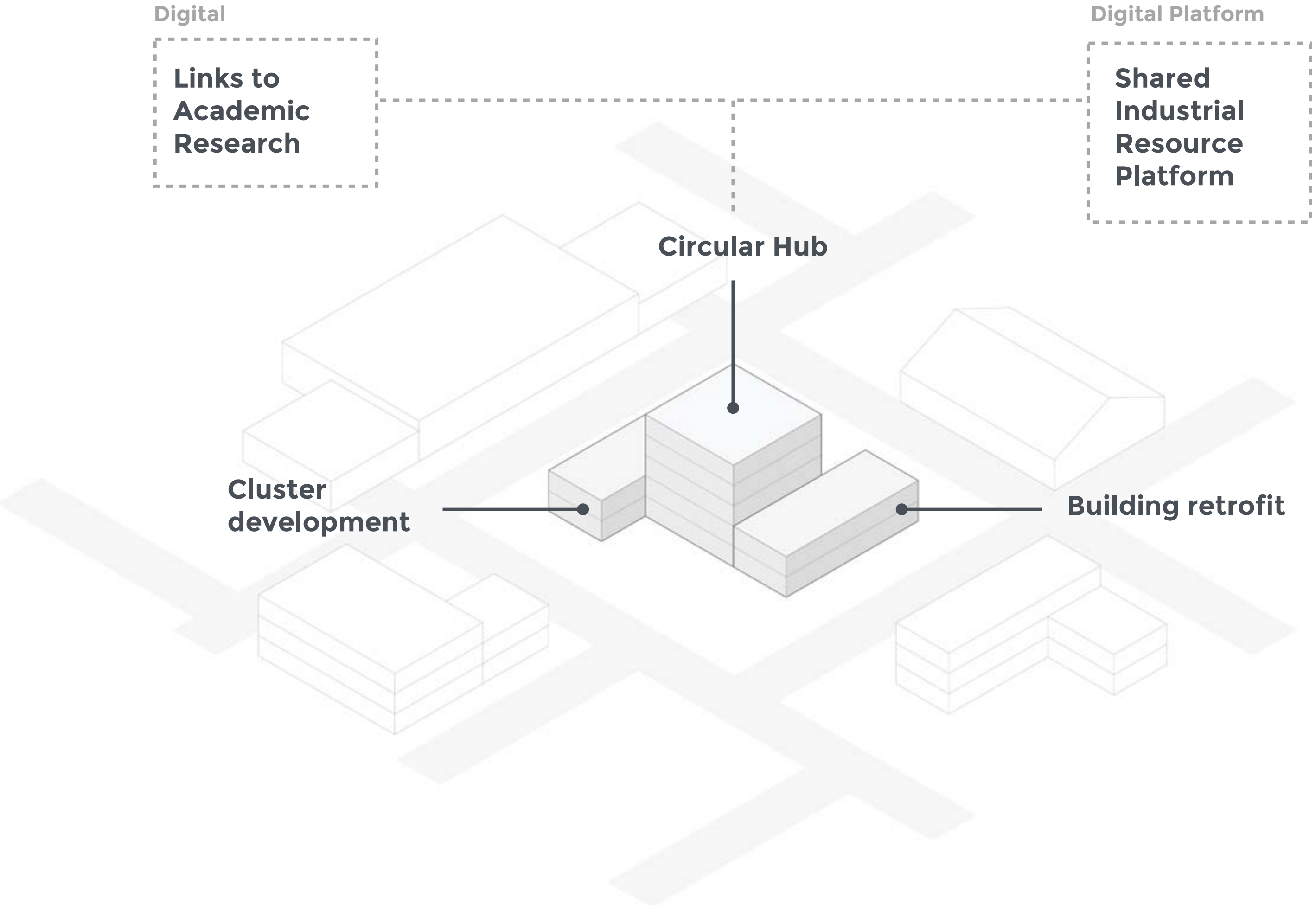
Clean Tech Estate

A cluster development supports new circular-focused businesses and technological innovation, providing clean energy back to the area.

Clean Tech Estate

1

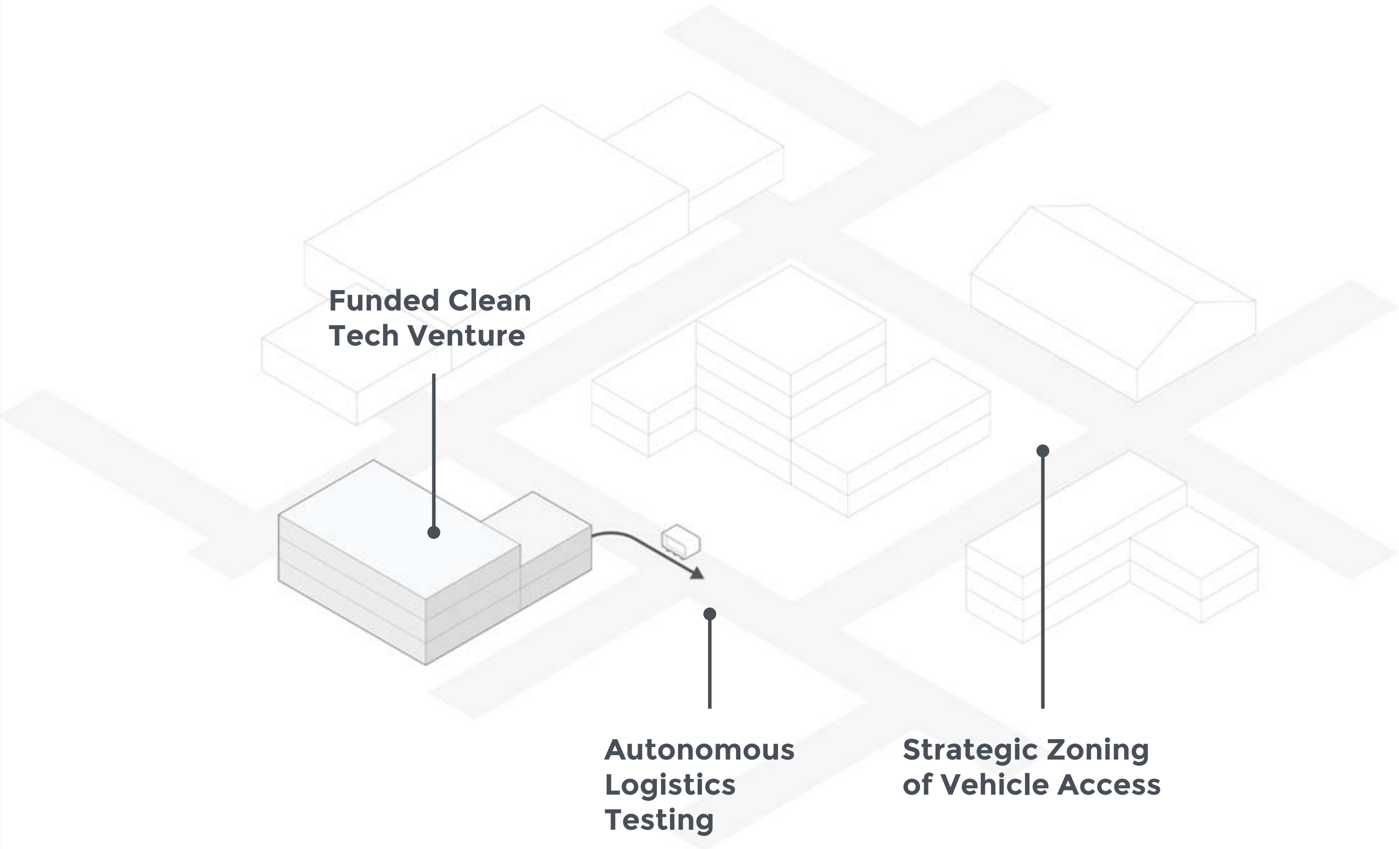
A local incubator is located within a cluster development, providing a nexus between research from nearby imperial White City campus, and new business ventures that require support and funding.



Clean Tech Estate

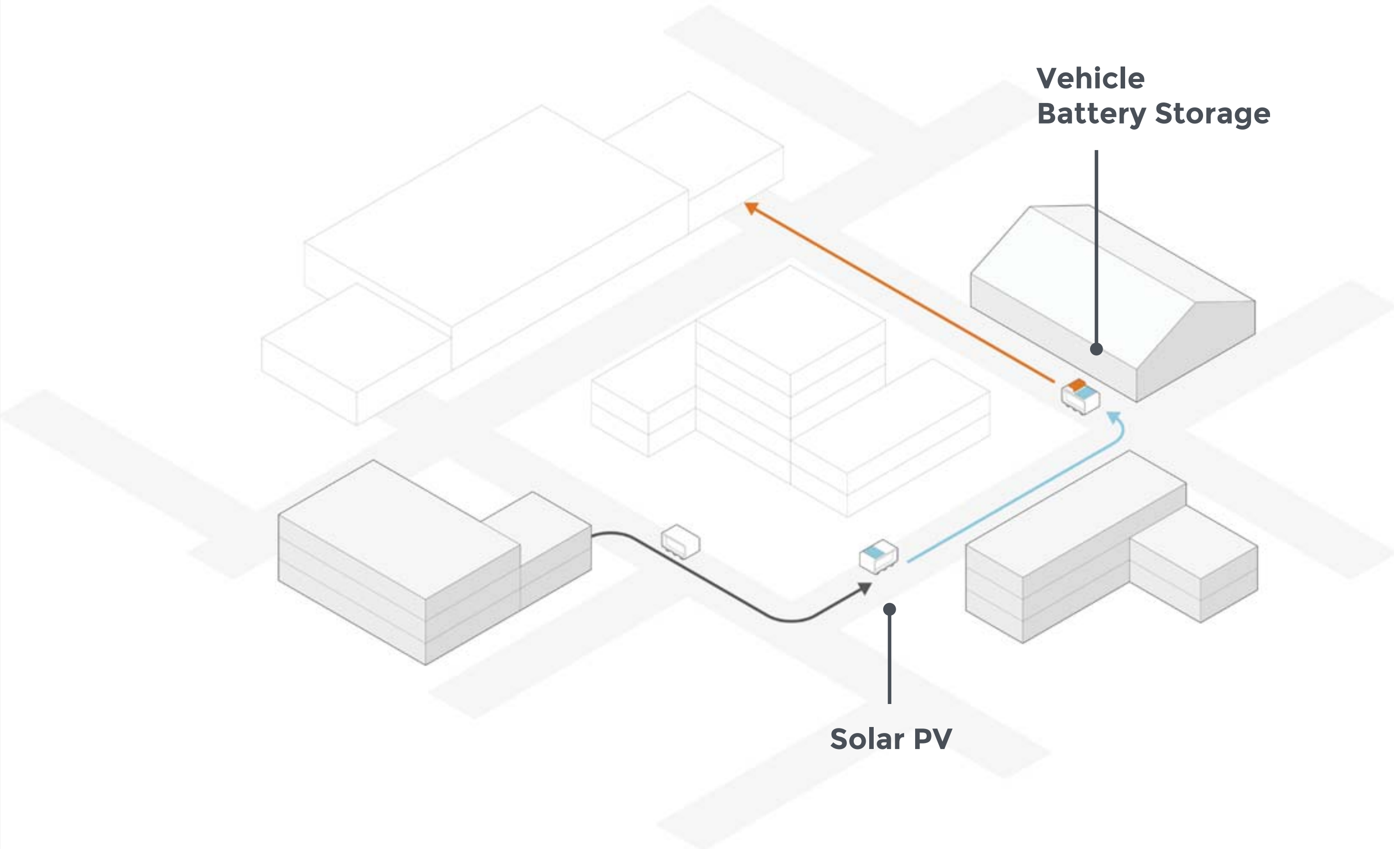
2

The area is demarcated as a car-free zone - providing a testing ground for low carbon clean tech initiatives such as autonomous logistics testing.



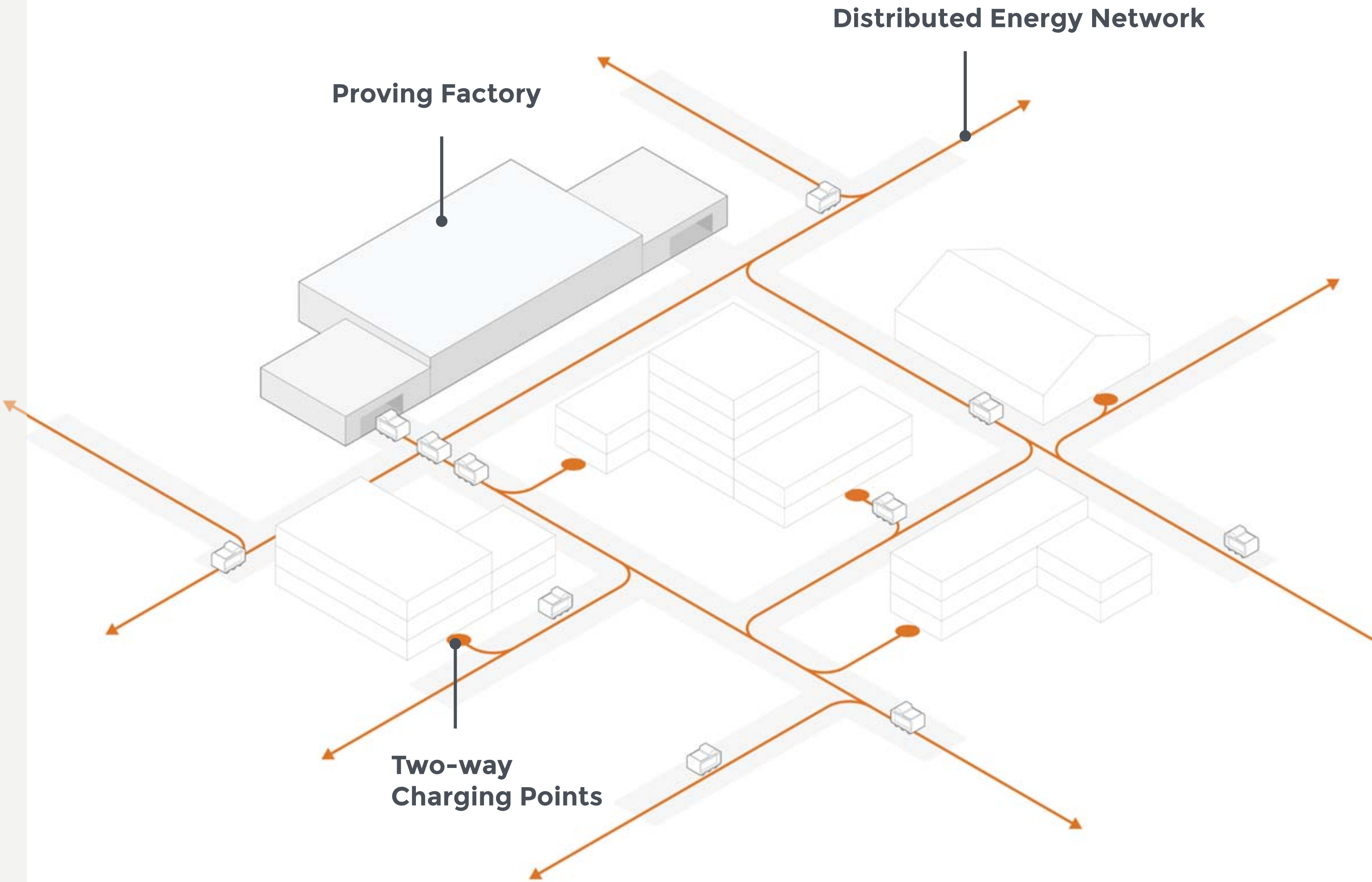
3

The clustered development supports combinatorial innovation, promoting the development and combination of a number of clean tech initiatives.



4

A 'proving factory' turns prototypes in urban pilot schemes. For example, a solar-powered autonomous vehicle with battery storage creates a platform for renewable distributed energy - providing free energy to local businesses.



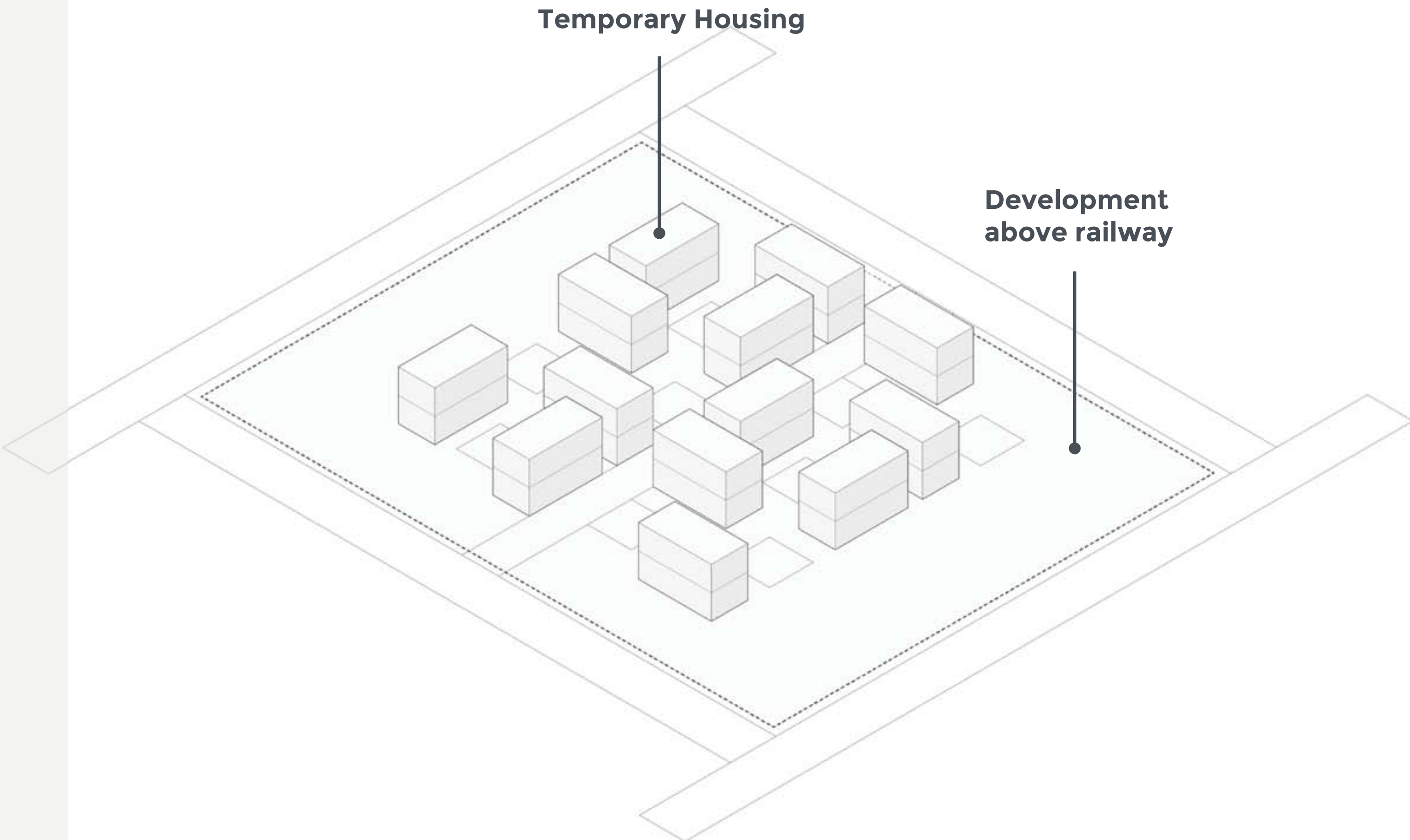
3

Adaptable Development

Adaptable developments are designed with circular built-in, from sustainable construction to flexible and smart space usage.

1

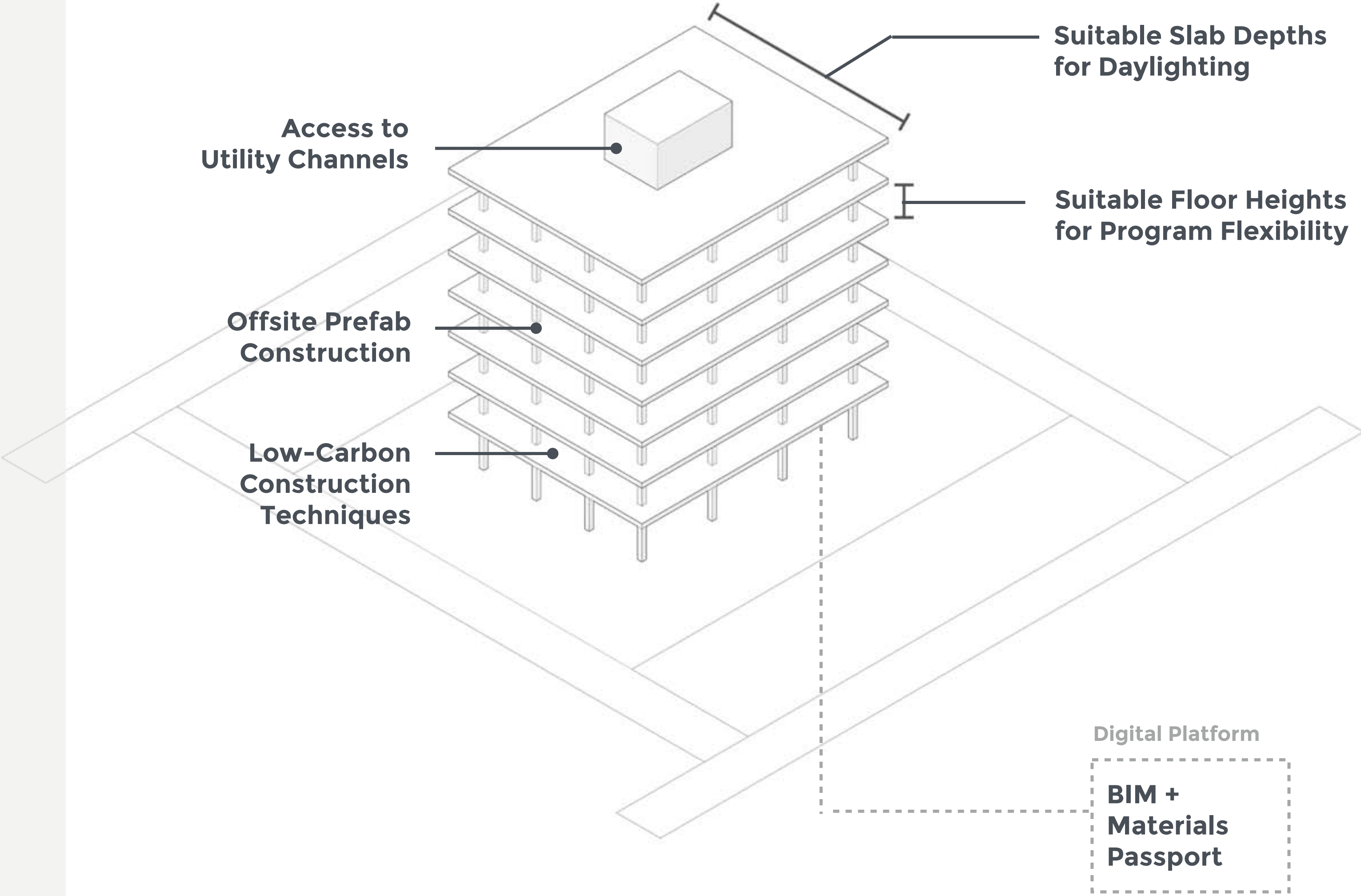
Meantime uses are found for uninhabited sites earmarked for development, publicly activating the site as soon as possible with temporary uses.



Adaptable Development

2

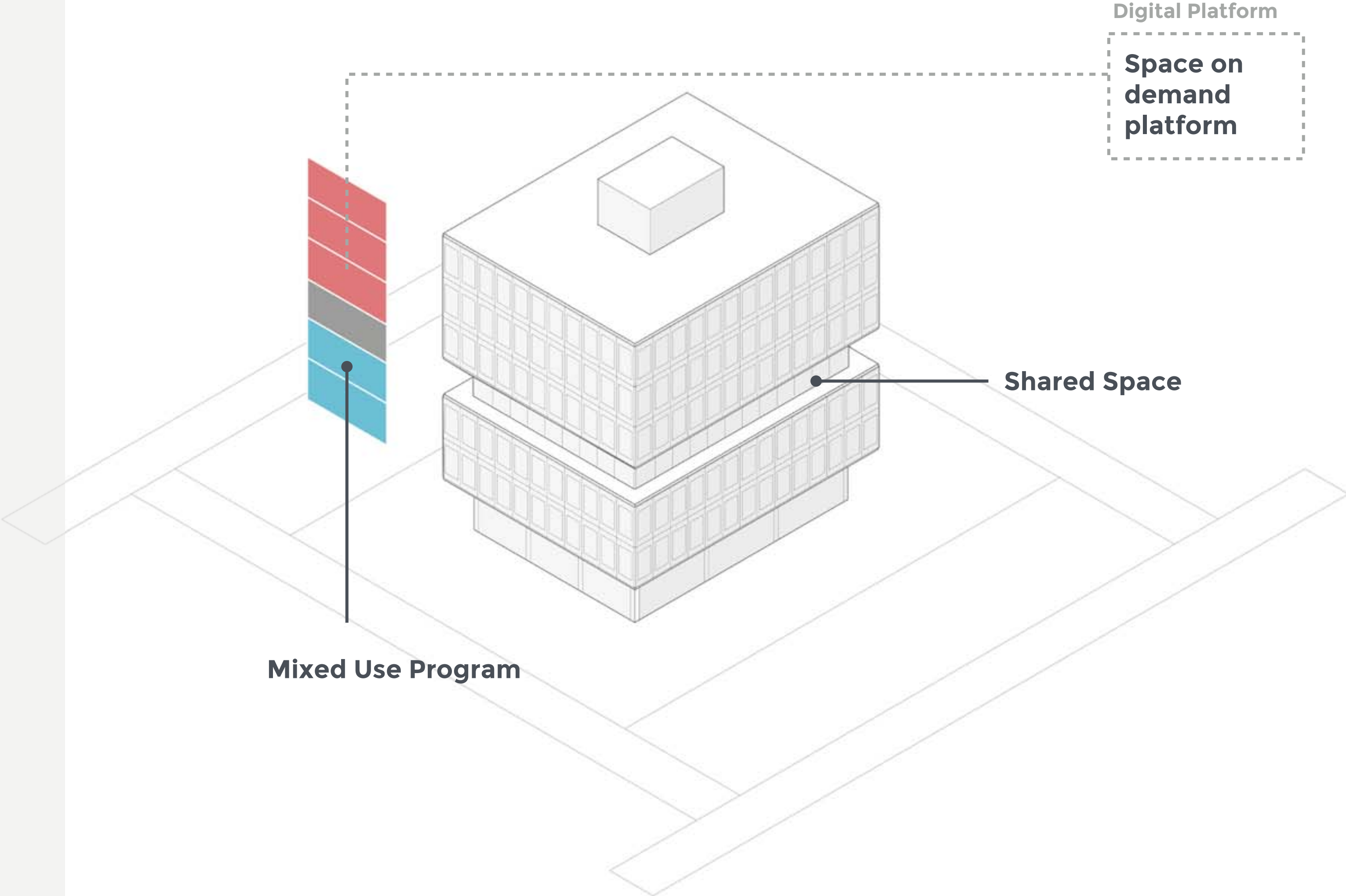
Construction of high-rise developments makes use of cradle-to-cradle materials, innovative fabrication techniques, building in flexible spaces and services from day one.



Adaptable Development

3

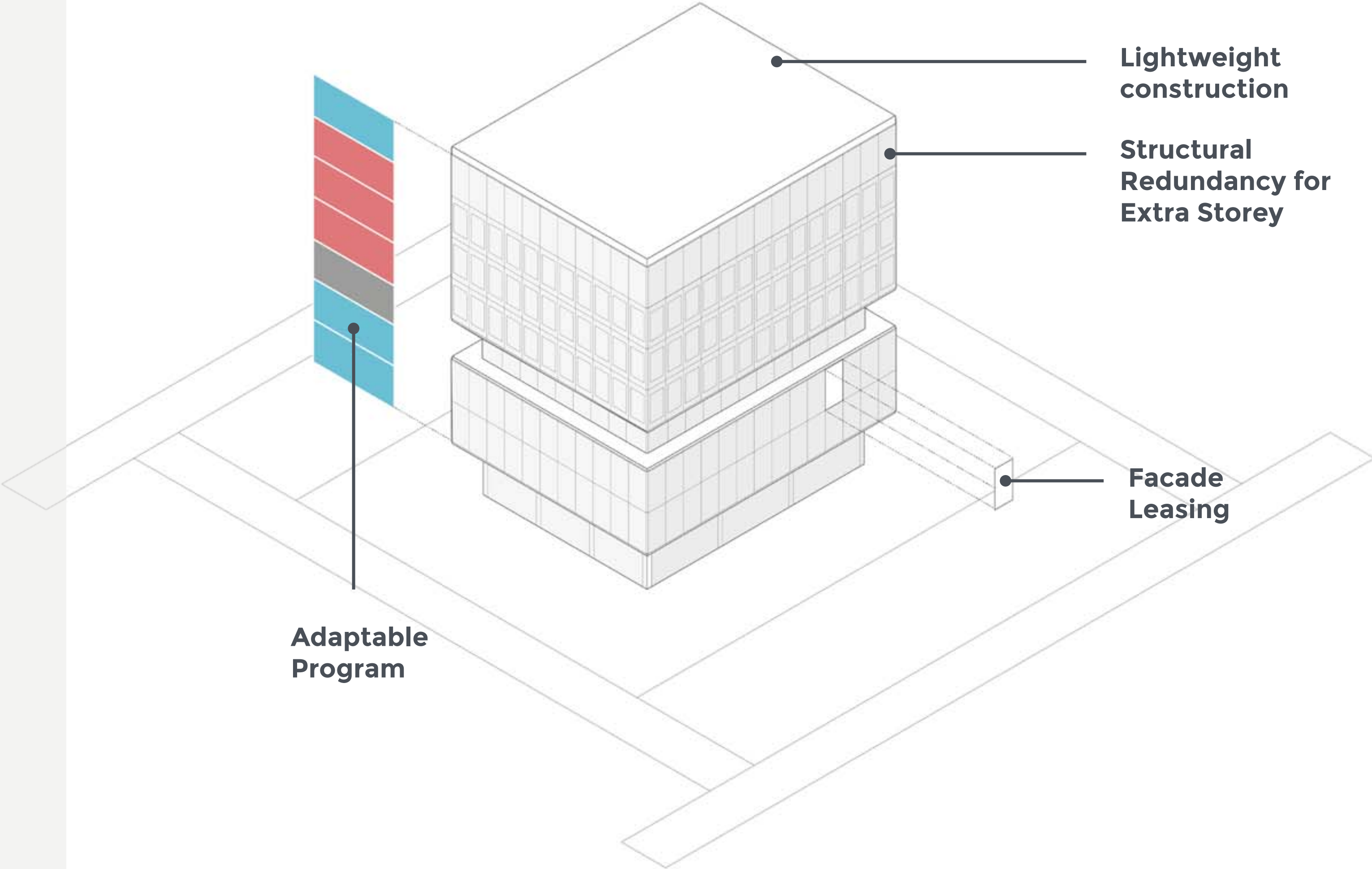
A variety of mixed-use, shared and public spaces are provided throughout the building. Space-as-a-service platforms allow users to access space when needed, intensifying the use of the building.



Adaptable Development

4

The building is designed to be adaptable over time, through physical changes such as facade-leasing, parasitic additions through lightweight fabrication, and new technologies that improve logistics and maintenance around the site.



4

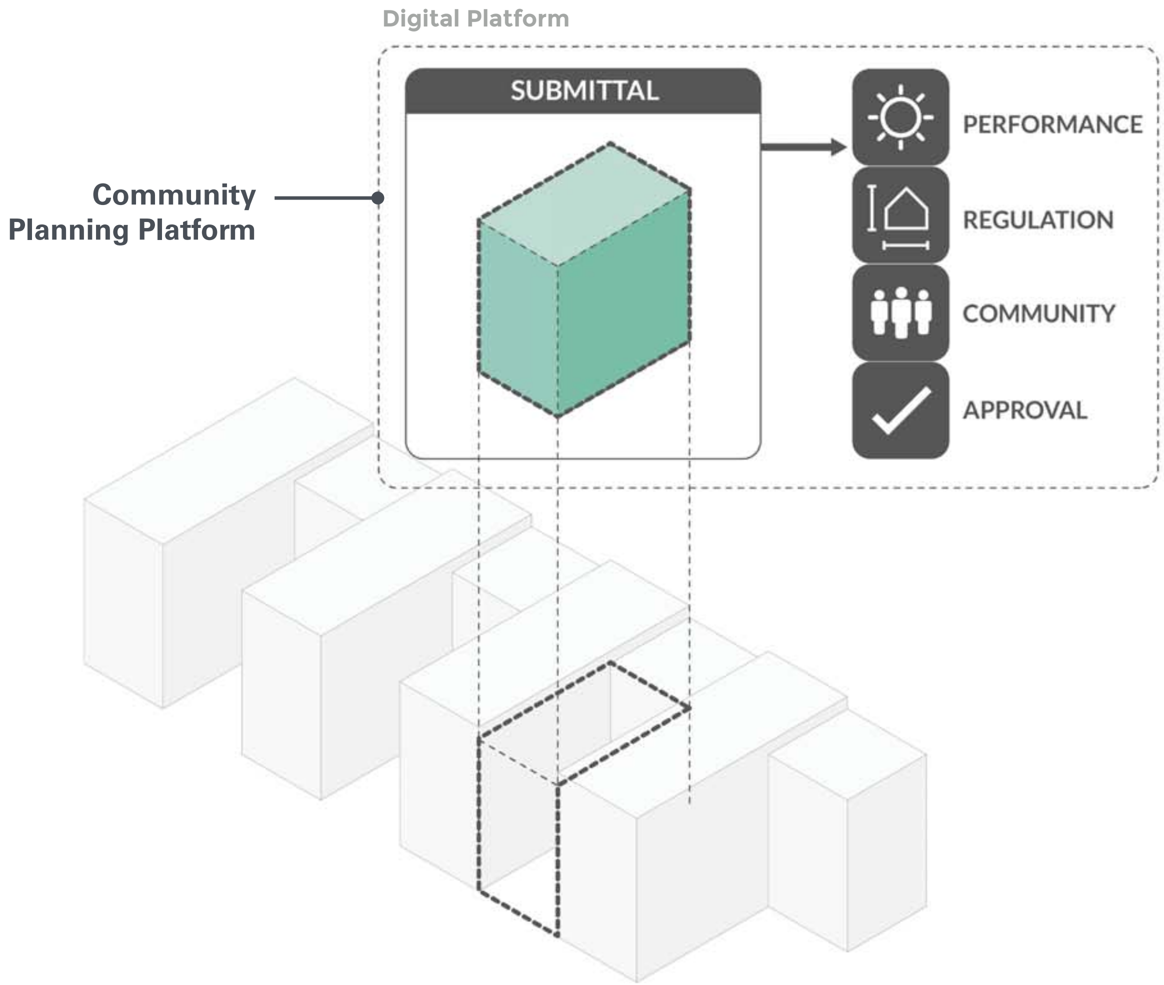
Sharing Community

Digital platforms and lightweight technologies enable communities to build, operate and share their neighbourhood spaces and resources.

Sharing Community

1

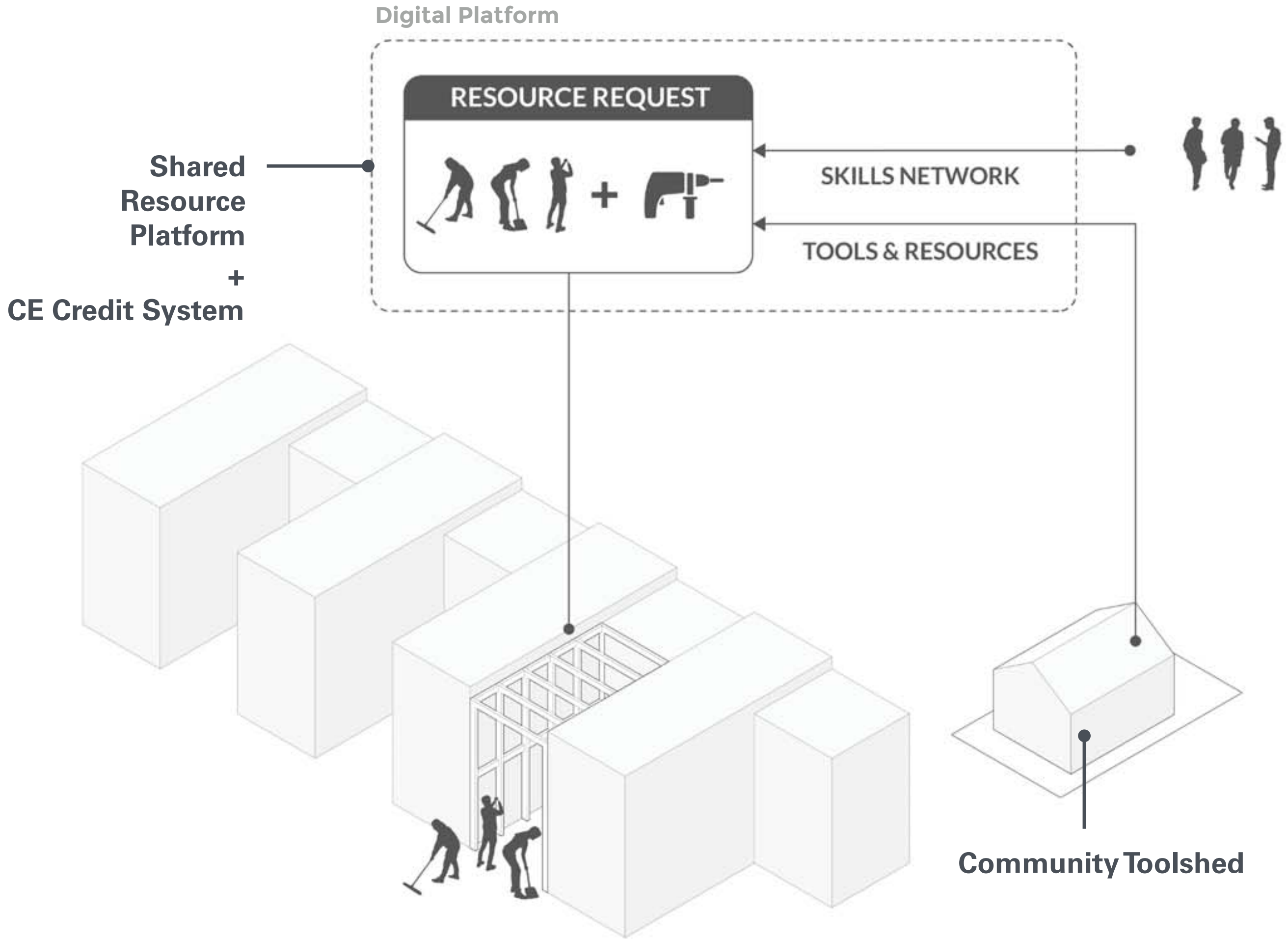
Digital platforms support local decision making around planning, promoting a more accessible and engaged discussion and transparent negotiation.



Sharing Community

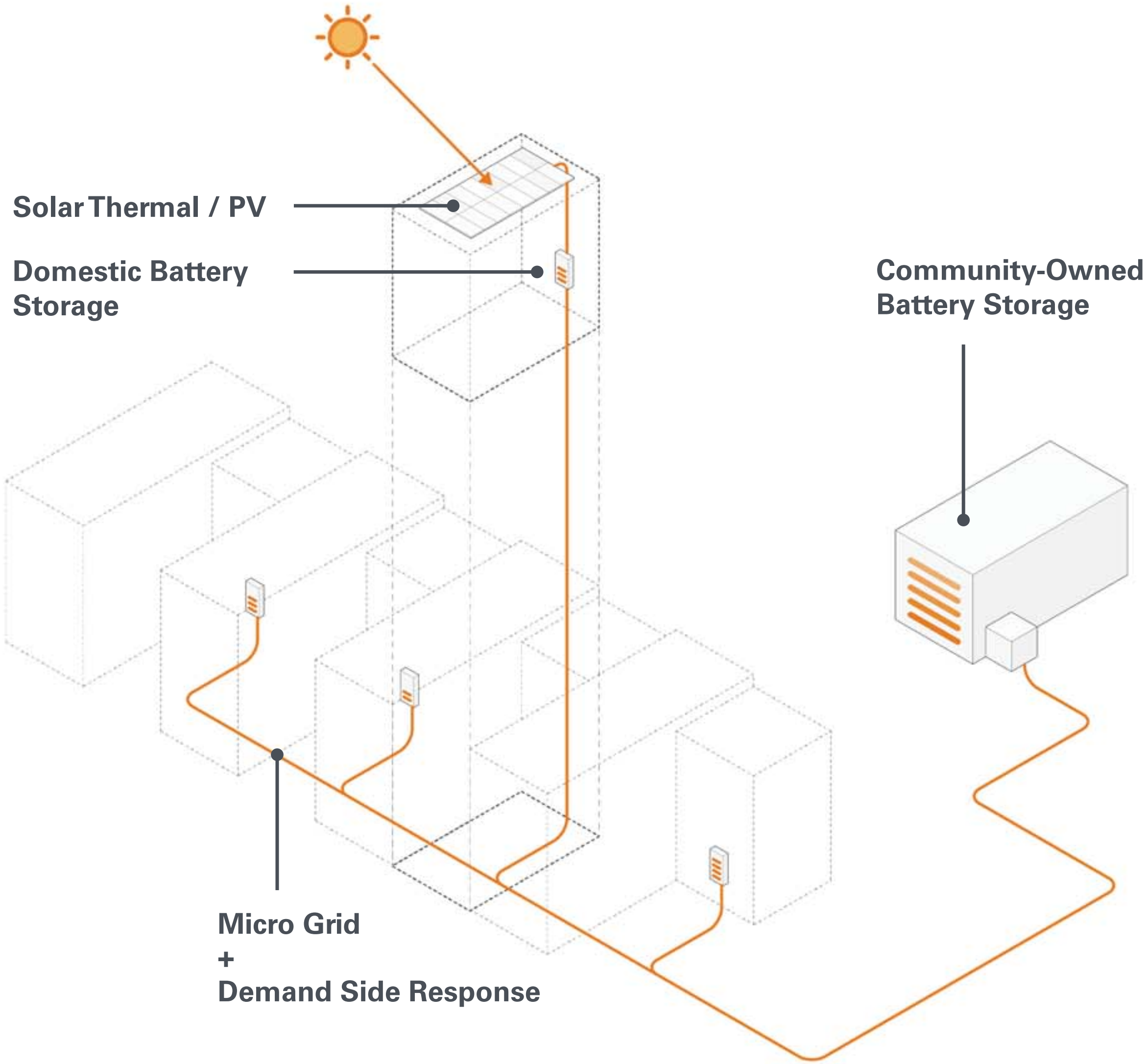
2

Citizens are able to easily access and share local resources, skills and tools, easing access to one-time-use items and specialist knowledge, whilst reducing local resource consumption as a whole. This is supported by a credits system that encourages participation and exchange.



3

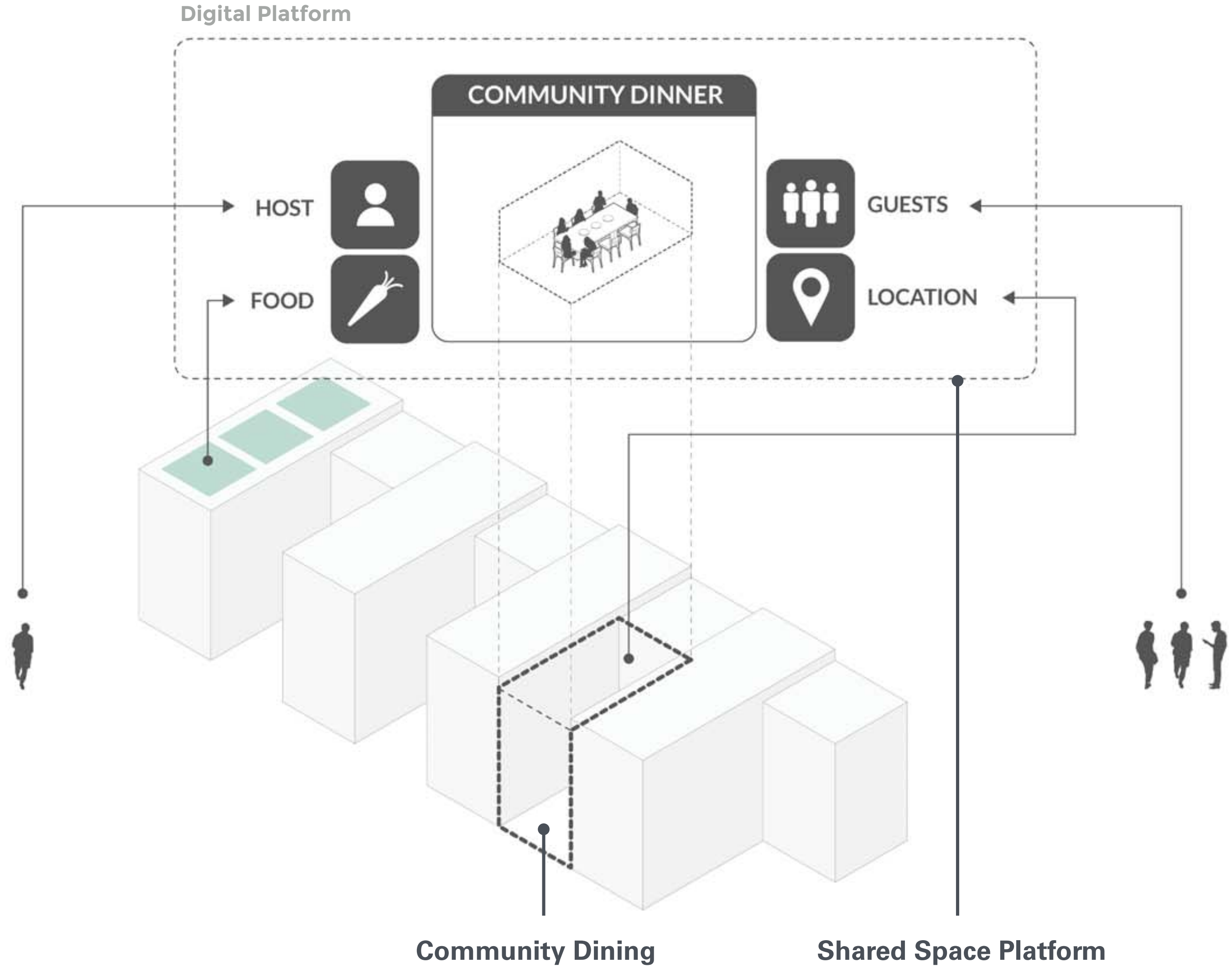
Community-owned infrastructure enables neighbourhoods to produce, store and locally distribute their own energy and resources, encouraging sustainable energy production and reducing reliance on the national grid.



Sharing Community

4

Space-on-demand services, combined with shared resources, enables the community to utilise individual assets for communal benefit.



6 Case studies

6.1 Overview

This section provides details of 10 circular economy case studies relevant and viable for implementation at the Old Oak and Park Royal site. The initiatives cover a range of opportunities, from waste capture and reuse to circular design solutions and community-led development. Each case study describes the suitability of an initiative, enablers for its implementation, benefits, examples and relevant stakeholders and suppliers. The 'lenses' give a quick indication of the relative benefits and costs of an initiative in economic, resource and social terms. This enables rapid comparison and illustrates the values that may be achieved from a given initiative. For example, an initiative may have a high capital cost but also have significant potential to bring increases in resource efficiency and social improvement.

6.2 Anaerobic digestion

6.2.1 Summary of initiative

Anaerobic digestion (AD) involves the decomposition of organic material, in the absence of oxygen, which generates biogas (predominantly a mixture of carbon dioxide and methane) and a digestate (an organic fertiliser). A variety of organic wastes can be processed using AD.

The biogas can be used in CHP plants to generate heat and electricity or in CCHP plants to produce cooling, heat and electricity. A portion of the heat and electricity is usually used to operate the AD process itself with the remainder exported to the grid or directly to a development in close proximity. Alternatively, the biogas can be cleaned to natural gas quality (>95% methane) and used as a vehicle fuel or injected into a gas distribution network.

The digestate is rich in nutrients like nitrogen and phosphorus and can be used as organic fertiliser or soil conditioner. A recent publication by WRAP on optimising the value of digestate has also described potential options for using the digestate in the production of biocoal, bioplastics and as feedstock for phosphorous extraction.[38] However, these options are still under development.

[38] Waste & Resources Action Programme (2015). *Optimising the Value of Digestate and Digestion Systems – Final Report*. Available at: http://www.aquaenviro.co.uk/wp-content/uploads/2015/10/Optimising-the-value-of-digestate-and-digestion-systems-WRAP-Final-Report.pdf (26 October 2016).

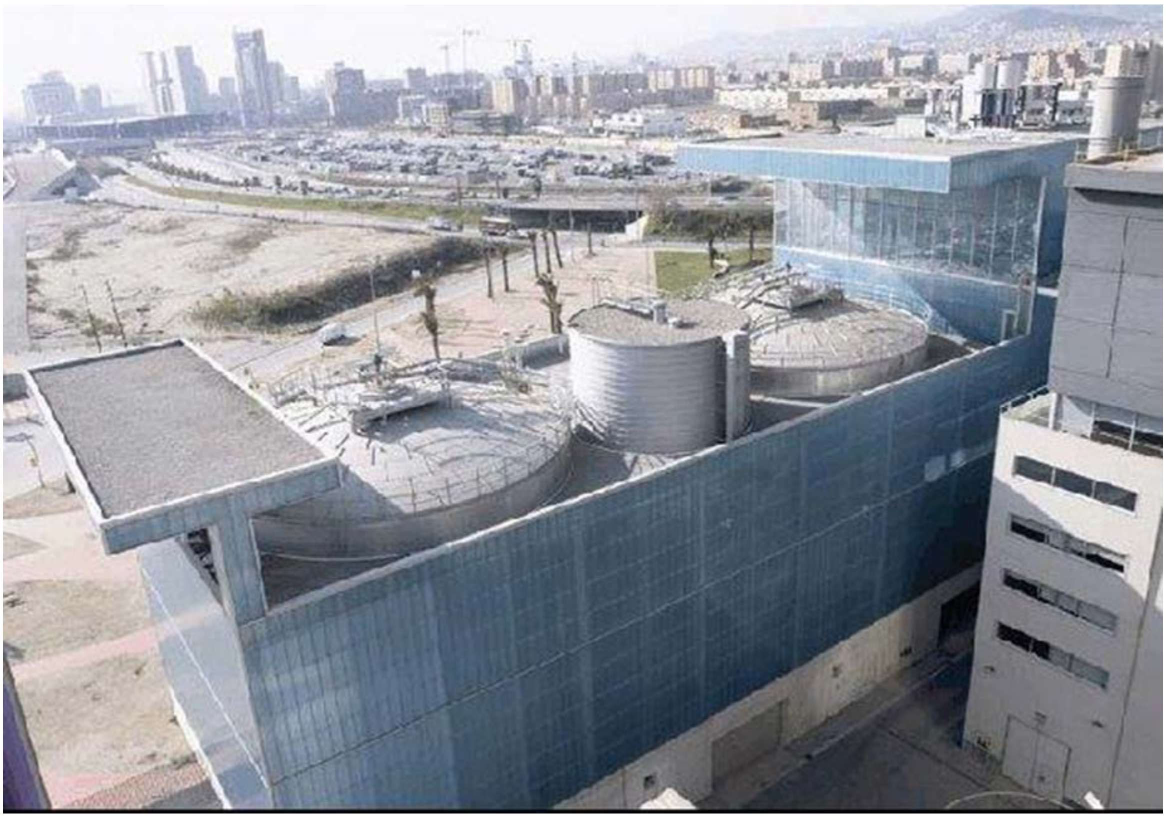
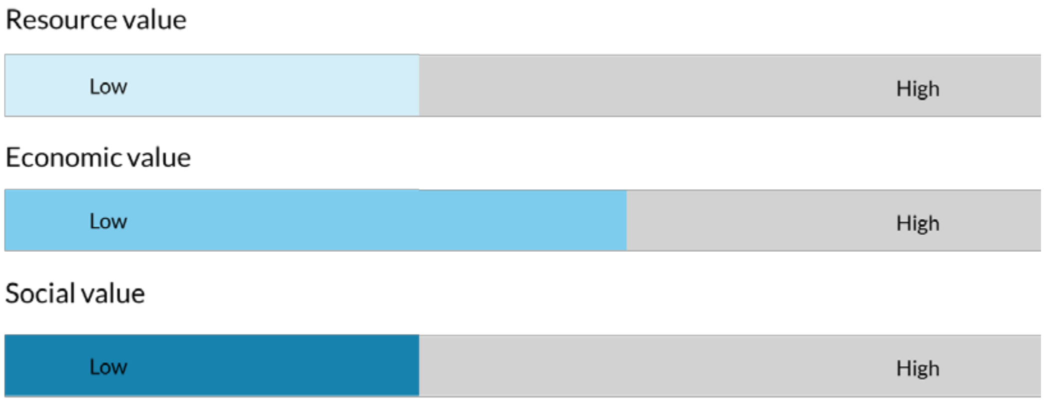


Figure 9: Barcelona Eco Park 3 anaerobic digestion plant, Spain (Source: Ros Roca)

6.2.2 Key facts

- There are two main types of AD technologies: mesophilic and thermophilic;
- A mesophilic system accepts wet organic waste feedstock with a dry solids content of up to 15%. The digestion tank operates in plug flow at temperatures of 20-40˚C for approximately 15-40 days;
- A thermophilic system accepts dry organic waste feedstock with a dry solid content of 15-40%. The digestion tank is a continuous stirred tank reactor at temperatures of 50-60˚C for approximately 12-14 days;
- The resulting biogas yield and composition is dependent on the organic waste feedstock. Biogas yields typically range from 110-170m^3 per tonne of organic waste feedstock; and
- The resulting biogas is composed of approximately 55-70% methane, 30-45% carbon dioxide and approximately 1% nitrogen, with trace elements of hydrogen sulphide.

6.2.3 Lenses



6.2.4 Suitability

- Locations with centralised resources and energy centres;
- Locations adjacent to food and beverage manufacturers, or other suitable feedstock;
- Strategically located away from sensitive receptors such as residential areas, schools and water bodies, as far as reasonably practicable;
- Proximity to an electricity load typically not a constraint. However, depending on the end use of the biogas, it should be located in close proximity to a heat load or a gas network;
- End-market for the digestate must be identified, otherwise it would require drying and further thermal treatment via incineration or landfill disposal;
- Land-take requirements are typically between 0.15m^2/tonne and 0.4m^2/tonne; and
- Investment typically by a private developer or local authority company.

6.2.5 Benefits

Economic

- Converting the handling of waste from an expense to an additional source of revenue.

Social/Environmental

- Can form part of a wider resource and waste management strategy covering organic waste generated from a range of different sources;
- The biogas can be used to generate renewable energy;
- Having a local treatment option reduces the emissions related to the transport of organic waste to treatment or disposal facilities off-site;
- AD offers GHG savings as it reduces methane emissions produced from the anaerobic decomposition of organic waste in landfill;

- There are GHG savings offered by using the digestate as a substitute to manufactured chemical fertilisers, which require energy and non-renewable mined minerals to produce;
- There are further GHG savings by operating the facility under CHP or CCHP mode compared to electricity generation only mode, as additional useful energy in the form of heating and cooling is being extracted from the facility thereby increasing the overall energy efficiency of the facility; and
- Helps local and national government meet diversion of biodegradable waste from landfill targets.

6.2.6 Example

The Riverside AD Facility is located within the Willow Lane Industrial Estate in Mitcham, Surrey, became operational in 2015. The facility is owned and operated by Riverside AD Limited. The facility covers an area of approximately 0.87 hectares and is designed to process up to 77,500 tonnes per annum of a range of food waste including meat, fish, all dairy products, fruit, vegetables, bread cakes, pastries, rice, pasta, beans, tea and coffee. The food waste is pasteurised and pre-processed to remove and packaging at an adjacent thermophilic aerobic treatment facility operated by Riverside Bio Limited. The plastic packaging is washed and sent for reprocessing. The pre-processed food waste is then delivered to the digester via a series of steel pipes. The digestion process takes place as 35˚C for up to 60 days. Biogas drawn from the digester is upgraded to biomethane and injected into the gas grid. Excess biogas is used to generate electricity from a CHP engine (1.2 MW_{th}). The digestate by-product is pumped to a holding tank located at the Riverside Bio Limited facility for separation into solid and liquid fractions and is then despatched off-site using tankers for use in horticulture as a highly valuable fertiliser.[39]

6.2.7 Enablers

- Behavioural change programmes to educate the public on the source segregation of organic waste;
- Showcasing the economic incentive of on-site AD compared to conventional organic waste disposal routes;
- Investment from industry or local authority into AD; and
- Renewables Obligation and Feed-in Tariffs that provide economic incentive to implement AD and associated electricity distribution infrastructure.

6.2.8 Stakeholders

- Local residents;
- Food and beverage manufacturers in the Park Royal Industrial Estate;

[39] Environment Agency (2016). *Notice of Variation and Consolidation with Introductory Note: Riverside AD Limited*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/512661/Variation_Notice.pdf (Accessed 26 October 2016).

- Waste collection and disposal authorities;
- Waste contractors;
- Food manufactures;
- Process suppliers; and
- Investors.

6.2.9 Suppliers

- Bekon Holding AG;
- Biotechnische Abfallverwertungs GmbH & Co KG;
- Hitachi Zosen Inova Kompogas;
- Kompoferm;
- Organic Waste Systems;
- Ros Roca;
- Strabag Umweltanlagen GmbH; and
- Valorga.

6.3 Organic waste to proteins

6.3.1 Summary of initiative

A biorefinery is a facility that uses biological conversion to produce higher value products compared to the biomass it is produced from. Organic wastes are an ideal feedstock for biorefineries due to their carbohydrate, protein and lipid content. Of particular interest at the moment is the use of organic wastes in the production of protein products, namely animal feed, due to the population growth and the increased demand on food supply that comes with it. There are a number of processes that are used in the conversion of organic waste to proteins. The specific process used is usually dependent on the organic waste feedstock.

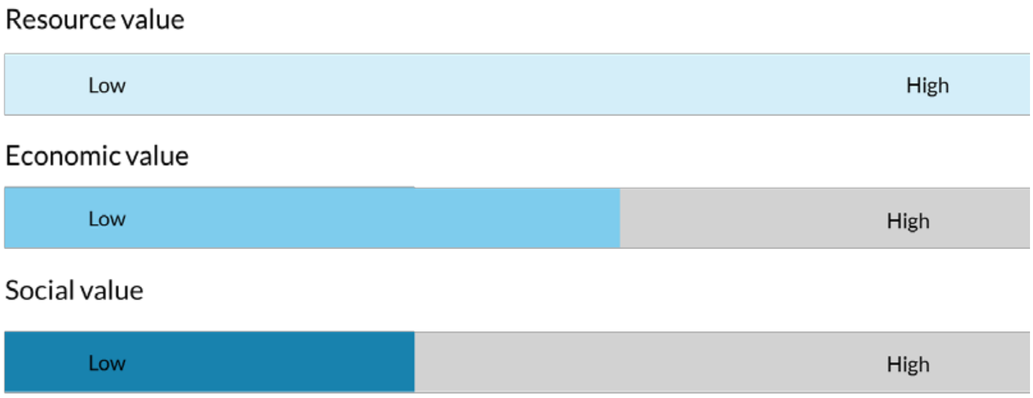
Figure 10: Three Rivers Energy biorefinery in Coshocton, Ohio (Source: US Department of Agriculture via Flickr)

6.3.2 Key facts

- Spent grain from the brewing and distillery industry can be processed into protein products using enzymatic hydrolysis;
- Food waste can be processed into protein products using bacterial fermentation;
- Organic material found in food and beverage manufacturing wastewaters can be processed into protein products using bacteria under controlled conditions;
- The Managed Ecosystem Fermentation (MEF) process involves the fermentation of a range of organic wastes using an ecosystem of microbes found in the digestive tract of ruminant animals. The MEF process actively manages the fermentation process to extract the more valuable long chain molecules unlike anaerobic digestion where the aim is to break up all longer hydrocarbon chains into methane and carbon dioxide[40]; and
- Final processing steps for the aforementioned conversion processes involve protein concentration followed by drying to remove excess water and create a stable, dry and granular product.

[40] Calt, E.A. (2015). *Products Produced from Organic Waste Using Managed Ecosystem Fermentation*. Journal of Sustainable Development; Vol. 8, No. 3; 2015.

6.3.3 Lenses



6.3.4 Suitability

- Locations with centralised resources and energy centres;
- Locations adjacent to food and beverage manufacturer (e.g. Park Royal Industrial Estate) or other suitable feedstocks;
- Land-take requirements would depend on process technology and treatment capacity;
- End markets would need to be identified for the products – the more local, the better; and
- Investment typically by a private developer.

6.3.5 Benefits

Economic

- Up-cycling of nutrients that would otherwise be undervalued or lost;
- Converting the handling of waste from an expense to an additional source of revenue;
- Reduced need for importing animal feed to meet growing demand;
- Supports the development of a new market for protein products; and
- The MEF process is capable of producing several thousand dollars of revenue per ton of organic waste.

Social/Environmental

- The use of waste and by-products as raw materials in the manufacture of new products instead of energy generation and disposal, in line with the waste hierarchy;
- The reduced need for importing animal feed reduces environmental impacts associated with its transport;
- Generation of high quality animal feed of consistent composition that is able to provide better nutrition to animals; and
- The promotion of industrial symbiosis and, therefore, a sharing economy.

6.3.6 Examples

South China Reborn Resources (Zhongshan) Company Ltd, EcoPark, Hong Kong
The site covers an area of 0.85ha at the EcoPark in Hong Kong with a capacity to treat 100 tonnes/day. The company collect food waste from hotels and restaurants for use in their process, which involves bacterial fermentation and drying processes to create protein supplements for fish and animal feed. Approximately 15% of the incoming weight of waste is sold as protein supplement. It is understood that all the product made in Hong Kong is sold within the local market. The company also operates facilities in Mainland China.[41]

Horizon Proteins, Heriot-Watt University Edinburgh campus, UK
Developed by a team at Heriot-Watt University as part of Scotland's 'Making Things Last: A Circular Economy Strategy', the novel patented 'Horizon Proteins' process prepares a concentrated protein product from pot ale – a liquid residue left over from the whisky-making process. The product, which contains about 65-80% protein, is used as salmon feed and hopes to replace traditional proteins used in salmon feeding such as fish meal and soya bean meal.[42]

Nutrinsic, Ohio, USA
The Nutrinsic protein production facility is co-located with MillerCoors at the brewer's water reclamation centre in Trenton, Ohio. The facility has the capacity to produce 5,000 tonnes/annum of its signature protein animal feed known as ProFloc™ from the wastewater comprising water, waste beer, spent grains and yeast.[43]

6.3.7 Enablers

- Process development to increase scale of treatment processes;
- Behavioural change programmes to educate the public on the source segregation of organic waste;
- Showcasing the economic incentive of using a biorefinery compared to conventional organic waste disposal routes; and
- Investment from industry or local authority into biorefineries.

6.3.8 Stakeholders

- Local residents;
- Food and beverage manufacturers in the Park Royal Industrial Estate;

[41] South China Reborn Resources (Zhongshan) Co., Ltd (2016). *Recycling Process of Food Waste for Feed in EcoPark*. Available at: http://www.southchinazs.com/en/news_detail.php?id=9& (Accessed 26 October 2016).
[42] Horizon Proteins (2016). *The Technology*. Available at: http://www.horizonproteins.com/the-technology.html (Accessed 26 October 2016).
[43] Nutrinsic (2014). *ProFloc™: The Future of Animal Nutrition*. Available at: http://nutrinsic.com/wp-content/uploads/2014/10/ProFlocPresentation.11.2014.pdf (Accessed 26 October 2016).

- Local authorities;
- Waste collection authorities;
- Waste contractors;
- Process developers and suppliers; and
- Investor.

6.4 Bio-plastics production

6.4.1 Summary of initiative

The bacteria in sewage sludge from wastewater treatment plants can be used to produce bioplastics. The process removes the volatile fatty acids from sewage sludge, which are mixed with bacteria to digest them and convert them to biopolymers. Polyhydroxyalkanoates (PHA) polymers can then be refined into biodegradable bioplastics that are 100% derived from wastewater.[44]

Bioplastics are already being used in the medical and pharmaceutical industries due to their biodegradability and biocompatibility. Their uses include sutures, patches, stents, tissue regeneration scaffolds, nerve guides, grafts, implants, wound dressings, and other medical products. Further uses include the automotive and packaging industries.

Though the process is capital intensive at the moment and dependant on the oil price by competing with fossil fuel-based plastics, the bioplastics produced also have high value, and the productions costs are likely to reduce as the technology, and scale develops.

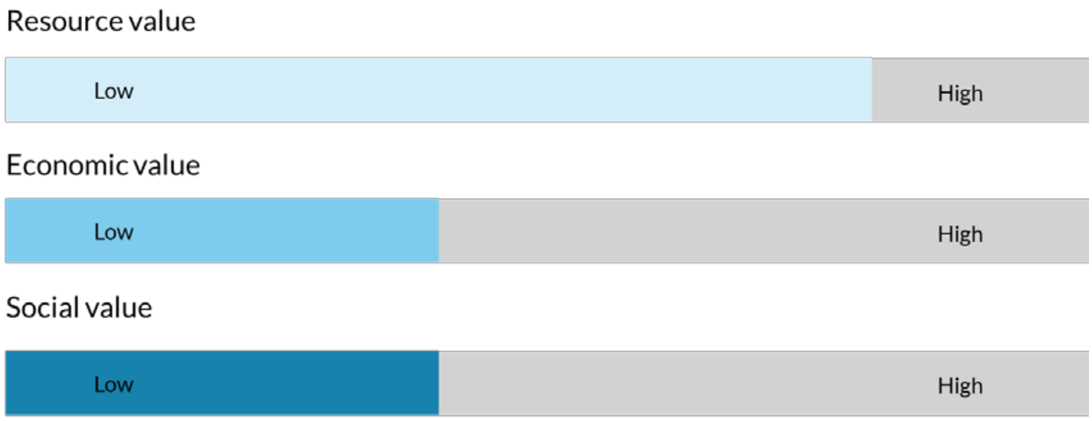
Figure 11: Bioplastic meat tray (Source: Doug Beckers via Flickr)

[44] Circulate News (2015). *A New Way to Make Plastic.* Available at: http://circulatenews.org/2015/09/a-new-way-to-make-plastic/ (Accessed 26 October 2016).

6.4.2 Key facts

- Sewage sludge from wastewater treatment plants can be used to produce bioplastics that can be used to manufacture a range of consumer products and technical equipment;
- Use of digestate from AD as feedstock for bioplastics in research and development;
- The production of bioplastics reduces waste and creates new revenue streams; and
- The economic feasibility of bioplastics remains a challenge as products continue to compete with fossil fuel-based plastics but ongoing market changes are giving a boost to the bioplastics market.

6.4.3 Lenses



6.4.4 Suitability

- Proximity to feedstock to reduce transport costs; and
- End markets would need to be identified for the bioplastics, potentially in Park Royal Industrial Estate as a packaging material.

6.4.5 Benefits

Economic

- Cost savings from reuse of sewage sludge and reduced costs for waste disposal; and
- New revenue stream potential from the sale of bioplastics.

Social/Environmental

- Increased biodegradability;
- Replaces the need for harmful non-biodegradable fossil fuel based plastics and contributes to a shift towards using more sustainable materials and products; and
- Potential for upcycling of sewage and upcycling of digestate.

6.4.6 Example

Environmental services company Veolia, via its subsidiary company Aquiris in Belgium, has successfully completed trials of producing bioplastics from sewage sludge (i.e. upcycle sewage sludge into a product). Veolia discovered that under certain conditions bacteria found in activated sludge from wastewater treatment processes can convert biomass into valuable biopolymers for the plastic and chemical industries. The process can be used to manufacture pens, vehicle bumpers and even farm tarpaulin. This closed loop initiative not only minimises waste, it also creates value for customers and partners.[45]

6.4.7 Enablers

- Incentives for R&D companies and environmental services companies;
- Policy and legislation to tighten environmental targets and promote development of the bioplastics industry;
- Collaboration between waste companies, local authorities and other stakeholders to identify and overcome barriers;
- Higher oil price (>US $80/barrel); and
- Investment.

6.4.8 Stakeholders

- Waste and wastewater treatment and management companies;
- Food and beverage manufacturers;
- Local authorities;
- Central government; and
- Investors.

6.5 Rooftop farming

6.5.1 Summary of initiative

Rooftop farming helps to maximise local resources and the use of valuable space, whilst establishing a healthy local food supply and creating opportunities for community engagement.

Rooftop farming can operate in a closed loop system using rain and wastewater harvested from rooftops and households, energy and heat generated in the local area and by buildings, and waste produced by households and businesses. Growing plants provide cooling and shading to buildings in the summer and thermal insulation in the winter. Food waste from local homes and businesses can be used as compost. And food products may be sold locally at a food market, community kitchen and in

[45] Biovox (2015). *Turning Brussel's Wastewater into Bioplastics*. Available at: http://biovox.be/en/insights/detail/turning-brussels-wastewater-into-bioplastics (Accessed 26 October 2016).

local cafes, minimising food miles and providing fresh produce to the local population. Surplus food can either be sold or distributed for free to those in need via local charities, or a virtual community sharing platform.

Aquaponics, aeroponics and hydroponic growing techniques allow growers to maximise productivity and cultivate a variety of crops throughout the year. Greenhouses also help to raise productivity and facilitate cultivation of a wider range of crops. Larger, flat roof surfaces (e.g. factories, warehouses etc) are most suitable for food growing; successful examples from around the world tend to be at least 2,000m². The economics of urban food growing depend to a large part on contextual issues related to resource availability, the local culture and market, planning regulations and other factors. Capital costs tend to be high and success stories often involve partnerships (e.g. between landowners, supermarkets, growers and investors). The industry is still in its infancy but appears to be growing in response to ongoing food security and pricing issues as well as political and cultural changes in attitudes.

Urban rooftop farming can also bring together communities, increasing outdoor activity, social interaction, health and wellbeing. Growing food and building a temporary food market on land earmarked for future development can further contribute to reducing food miles and negative environmental impacts whilst enhancing place-making and community engagement around food growing, sustainability and healthy living.

There are also opportunities to link food growers and communities with local and regional businesses - including airports - to create a closed loop system in which energy, water, food waste, compost/fertiliser, and food products are cycled in repetitive loops.[46]

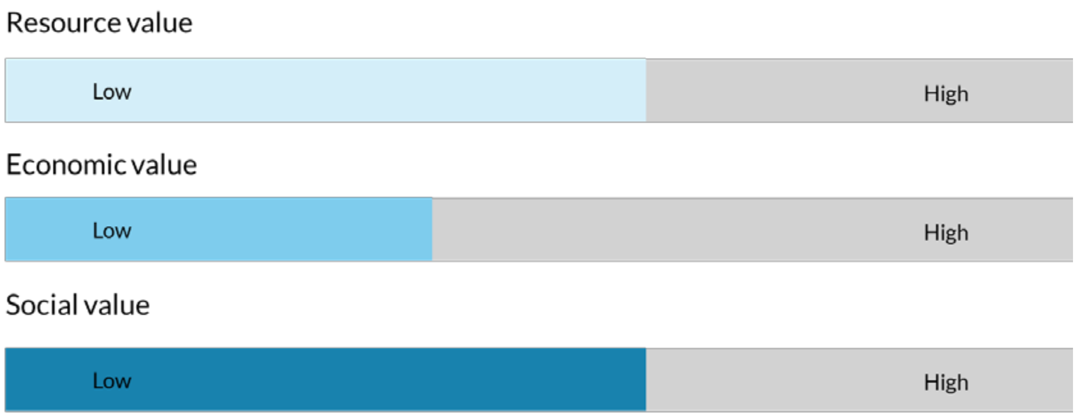
[46] The Guardian (2014). *Next-Gen Urban Farms: 10 Innovative Projects From Around the World*. https://www.theguardian.com/sustainable-business/2014/jul/02/next-gen-urban-farms-10-innovative-projects-from-around-the-world (Accessed 26 October 2016).

Figure 12: Lufa rooftop farm greenhouses, Montreal (Source: Fadi Hage, Macrosize Photography via wikimedia)

6.5.2 Key facts

- Urban farming maximises valuable urban rooftop space and helps create a closed loop between local energy, waste and food resources;
- Rooftop farming promotes sustainability and environmental awareness as well as raising community interactions and wellbeing;
- Large flat spaces are required and regular access, making it only suitable for certain buildings and spaces; and
- Currently, social and environmental benefits outweigh economics though an increasing number of successful cases are starting to illustrate and boost the economic and business case.

6.5.3 Lenses



6.5.4 Suitability

- Areas with sufficient (surface area) and appropriate (flat and structurally sound) roof space for food growing;
- Locations with accessible rooftops, where regular access by growers can be accommodated alongside other business activities e.g. equipment and produce can be transported in lifts without disturbing primary business functions, workers and residents[47];
- A suitable transport system to ensure fresh produce (e.g. highly perishable good like salad) can be moved efficiently between growing facilities, shops/markets, cafes and waste capturing plants. Reverse logistics and autonomous vehicles may be used to minimise food miles and pollution and maximise efficiency;
- Communities with sufficient appetite for produce, i.e. shops and markets where it can be sold; and

[47] Ecologist (2014). *Coming to a Rooftop Near You – The Urban Growing Revolution*. http://www.theecologist.org/green_green_living/2533583/coming_to_a_rooftop_near_you_the_urban_growing_revolution.html (Accessed 26 October 2016).

- Areas with on-site or local sources of low carbon or renewable energy generation.

6.5.5 Benefits

Economic

- Lower overall costs for fresh produce, and discounts for local volunteers;
- Lower food transport costs;
- Revenues generated from sale of products, which is also likely to remain in the local economy;
- Potential for job creation and skills development; and
- High efficiency and yield maximises return on investment.

Social/environmental

- Maximises under-utilized spaces and rooftops;
- Contributes to improving health outcomes from healthy eating of locally grown crops and exercise relates to growing and harvesting;
- Potential to create local closed loop system, integrating and maximising food and other waste, locally generated energy, and water resource streams;
- Reduces food miles and associated environmental impacts including carbon emissions and air pollution;
- Increases social interaction and wellbeing, providing a communal outdoor activity accessible to all;
- Maximises use of local resources – energy, heat, water, food waste;
- Provides cooling and shading, and helps counteract the urban heat island effect;
- Can increase biodiversity;
- Raises awareness about food growing and sustainability, providing educational opportunities for the community and promoting engagement between the public and local businesses; and
- Food growing on temporary land can contribute to high quality place-making and increased resident participation, satisfaction and wellbeing.

6.5.6 Example

Gotham Greens have created a 6,000m^2 greenhouse using hydroponics on the roof of a Whole Foods store in Brooklyn, New York.[48] The commercial scale facility produces over 45,000kg of fresh produce a year, and is supported by 60kW of on-site solar PV panels. High efficiency design features including LED lighting, advanced

[48] Whole Foods Supermarket (2016). *The Greenhouse*. Available at: http://www.wholefoodsmarket.com/service/greenhouse-0 (Accessed 26 October 2016).

glazing, passive ventilation, and thermal curtains further help to reduce electrical and heating demand requirements. Energy use is also reduced via rooftop integration, which helps to insulate the building. Recirculating irrigation systems capture water for reuse, reducing the need for chemical pesticides, insecticides or herbicides.

The advanced hydroponic greenhouse system is highly efficient, using 90% less water than traditional farming methods and achieving 20 times the output per acre. Gotham Greens and Whole Foods operate in partnership with fresh produce from the rooftop farm sold in the supermarket below. Whole Foods also offers educational opportunities for local students and schools to learn about greenhouses, farming and other environmental issues.[49]

6.5.7 Enablers

- Collaboration between growers, land and building owners, and developers to identify and agree space and other requirements;
- Accessible platforms hosting information portals and guidance, a forum for sharing experiences, expertise and volunteering opportunities. Case studies of successful projects may also help to reassure stakeholders curious about the process, and its costs and benefits;
- Local authority advice and support for urban farming, encouraging existing commercial building owners and developers to consider opportunities for food growing. Incentives to host growers on suitable roof spaces could also be explored;
- Workshops and targeted discussions bringing together local and regional stakeholders including businesses and residents to identify opportunities for closed loop services;
- Planning regulation adjustments to facilitate development of roof space;
- Investment via mutually beneficial partnerships;
- Incentives from local authority and development coordinators to promote and de-risk rooftop farming; and
- Advanced food growing technology solutions e.g. hydroponics.

6.5.8 Stakeholders

- OPDC;
- Local authorities;
- Land owners;
- Local business leaders;
- Urban and rooftop food growing specialists;
- Developers;

[49] Gotham Greens (2016). *Our Farms: Gowanus, Brooklyn, NYC*. Available at: http://gothamgreens.com/our-farms/gowanus (Accessed 26 October 2016).

- Investors; and
- Community.

6.6 Battery storage

6.6.1 Summary of initiative

The battery storage market is growing rapidly, creating efficiencies and new opportunities for sustainable urban electricity generation and distribution.[50]

Different energy storage technologies can be installed at various points on the network from the point of generation (e.g. urban power plants such as Energy from Waste facilities), at the neighbourhood level (e.g. substations) and at the point of use (e.g. decentralised storage in domestic buildings and electric vehicles). Batteries are the most common form of electricity storage. Though still expensive at present, the market for lithium-ion – and increasingly sodium-ion – batteries is growing, and prices coming down rapidly thanks to the success of companies such as Tesla and the growth of smart grid applications. Lead-acid batteries are also seeing rapid market growth.[51]

Storage technologies help to accommodate variable renewable energy generation onto the grid, ensuring that supply can match demand when it is needed.[52] This increases a city or district's resilience, adding redundancy and flexibility to the system and reducing the need for additional conventional (gas) generation. It also reduces transmission and distribution losses and their associated costs.

Advanced domestic batteries can be charged from local energy generators, e.g. solar PV and waste to energy, or from the grid outside of peak times, storing and providing energy to homes when they need it. Larger scale battery and grid storage units can also be used to manage commercial users' peak flows and costs, and provide stability to the grid. The integration of smart energy devices means assets such as fridges and lighting can be temporarily turned down or off to help manage energy flows in real time without negatively impacting assets' performance – see energy demand management case study for more details.

The batteries in electric vehicles (EVs) can be used to store energy, helping to regulate and support the electric distribution network when supply is short. Together, plug-in EVs and new battery technologies can also create mobile

[50] Clean Technica (2016). *The Market & Opportunity for Energy Storage in the UK*. Available at: https://cleantechnica.com/2016/05/12/market-opportunity-energy-storage-uk/ (Accessed 26 October 2016).
[51] Tesla (2016). *Sustainable Power your Home or Business*. Available at: https://www.tesla.com/en_GB/energy (Accessed 26 October 2016).
[52] Financial Times (2016). *Battery-Power Investments Energise UK Renewable Sector*. Available at: https://www.ft.com/content/b62b356e-2d10-11e6-bf8d-26294ad519fc (Accessed 26 October 2016).

electricity infrastructure, turning the streets into a platform for renewable energy storage and distribution – see more details in the Clean Tech Estate scenario. After the end of their useful life in EVs, car batteries can also be used for other storage purposes, known as second life uses, for example, in home storage – see Nissan example below.

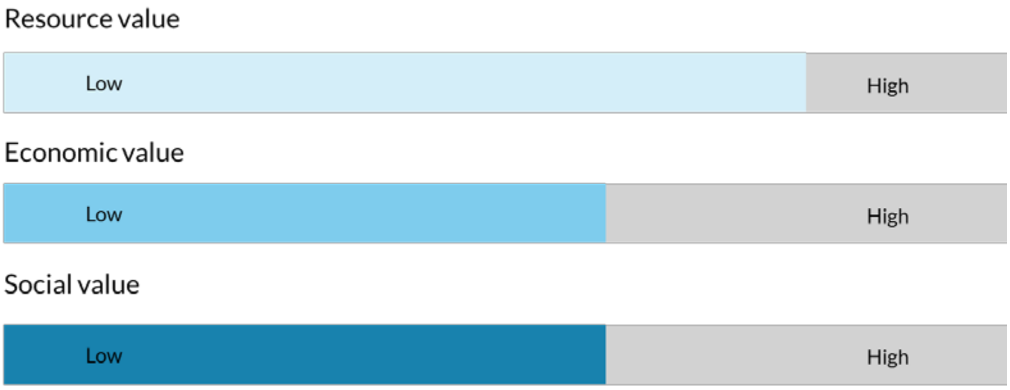
Figure 13: Portland General Electric's Salem Smart Power Centre (Source: Portland General Electric via Flickr)

6.6.2 Key facts

- The battery storage market is expanding rapidly and costs declining for ever more advanced technology solutions[53];
- Battery storage helps commercial and domestic customers to store high quality, low carbon energy, manage power quality, reliability and ever-increasing costs[54]; and
- Electric vehicles are contributing to the battery storage market; batteries are increasingly being used in 'second-life' functions following the end of their use as car batteries, e.g. as domestic storage.

[53] Renewable Energy Association (2015). *Energy Storage in the UK: An Overview*. Available at: http://www.r-e-a.net/upload/rea_uk_energy_storage_report_november_2015_-_final.pdf (Accessed 26 October 2016).
[54] Carbon Brief (2016). *National Grid sees Major Boost for Solar, Electric Vehicles and Batteries*. Available at: https://www.carbonbrief.org/national-grid-sees-major-boost-for-solar-electric-vehicles-and-batteries (Accessed 26 October 2016).

6.6.3 Lenses



6.6.4 Suitability

- Locations where electric vehicle usage is increasing;
- Dense urban areas with a mix of residential and commercial uses; and
- Large energy users with scheduled functions help maximise storage potential.

6.6.5 Benefits

Economic

- Financial savings from avoided need for investment in new gas generation assets;
- Stored surplus electricity can be sold for profit;
- Drives renewable energy technology market and creates jobs;
- Improves transmission and distribution system performance and reduces losses and associated costs;
- Reductions in prices for battery storage is making renewable energy generation more commercially competitive;
- Maximises the use of EV batteries;
- Reduces or defers the need for costly grid infrastructure upgrades; and
- Potential to boost the battery manufacturing market.

Social/Environmental

- Allows renewable energy to be generated when it is most efficient, and stored until there is demand for it;
- Increases grid resilience and energy security by providing reserve capacity in the event of system failure;
- Enables the development of island mode and micro grids;
- Increase system stability and efficiency and maintains quality of supply;
- Reduces emissions from energy generation and increases viability of renewable energy generation; and
- Modular and scalable to meet load requirements – deployable in months rather than in years in the case of conventional (fossil fuel) peaking plants.

6.6.6 Example

Electric car manufacturer Nissan is partnering with National Grid, and power management supplier Eaton and utility Enel to explore 'second-life' uses for the lithium-ion batteries in its EVs. Nissan's vehicle-to-grid (V2G) trial is the first of its kind in the UK; the battery is intended for sale on the European market.[55]

Nissan's home xStorage device consists of 12 batteries taken from Nissan EVs. The system combines Nissan's LEAF batteries with Eaton's uninterruptable power supply (UPS) technology and solar PV to create a stand-alone energy storage and control package. This allows homeowners to draw power from the National Grid when it's cheap or renewable, and store it so that it can be used at peak times at a lower cost. They can also sell electricity back to the grid for a profit. xStorage costs £3,200 and allows homeowners to store 4.2kWh. It is primarily aimed at homeowners with solar panels on their roof.

The company plans to scale up the technology. It claims that if all the vehicles on UK roads were electric, vehicle-to-grid technology could generate a virtual power plant of up to 370 GW – enough to power the UK, Germany and France.

6.6.7 Enablers

- Smart grid development and underpinning technology connecting and communicating between storage facilities and the grid;
- Continuing advances in battery storage technology;
- Policy, regulation or incentives to drive EV and smart grid roll out;
- Contractual agreements to facilitate flow of electricity between battery storage technologies and the grid; and
- Economies of scale to provide increased volume of batteries.

6.6.8 Stakeholders

- OPDC;
- Local authorities;
- Battery technology EV and energy suppliers;
- Aggregators;
- Research institutes;
- Investors; and
- National Grid.

[55] Dezeen (2016). *Nissan Reveals its Answer to Tesla's Powerwall Battery System for the Home.* Available at: http://www.dezeen.com/2016/05/12/vehicle-to-grid-v2g-trial-nissan-battery-system-for-the-home/ (Accessed 26 October 2016).

6.7 Circular hubs

6.7.1 Summary of initiative

Circular hubs are designed to attract and provide space for the incubation and development of a range of businesses including clean tech organisations, academic institutions, live-work spaces, manufacturing facilities and workshop spaces.

Circular hubs seek to maximise the use of space and enhance business opportunities by bringing together like-minded groups on a single, specially designed premises. Clustering facilitates opportunities to incubate and test clean tech and circular economy initiatives, driving experimentation and innovation. It catalyses collaboration, increases opportunities for shared learning and knowledge/skills exchange.[56]

Incentives such as reduced business rates, low cost energy and free ride-sharing services help to attract businesses. On-site restaurants and cafés use food waste from local businesses and food growing ventures (such as rooftop farming), and co-living developments enable businesses leaders and workers to live in affordable, flexible homes on the site. Communal spaces also provide opportunities for networking, socialising and the casual exchange of ideas.

Planning authorities and developers can facilitate the development of circular hubs by providing services that businesses can easily plug-in to, e.g. advanced and accessible digital infrastructure, integrated transport links and fully serviced units, in which access to utilities and other basics is already set up and included as part of an inclusive package.

Smart and digital technologies can also help to maximise the site's efficiency with flexible space rental and leasing opportunities advertised in real time via space sharing platforms and services.

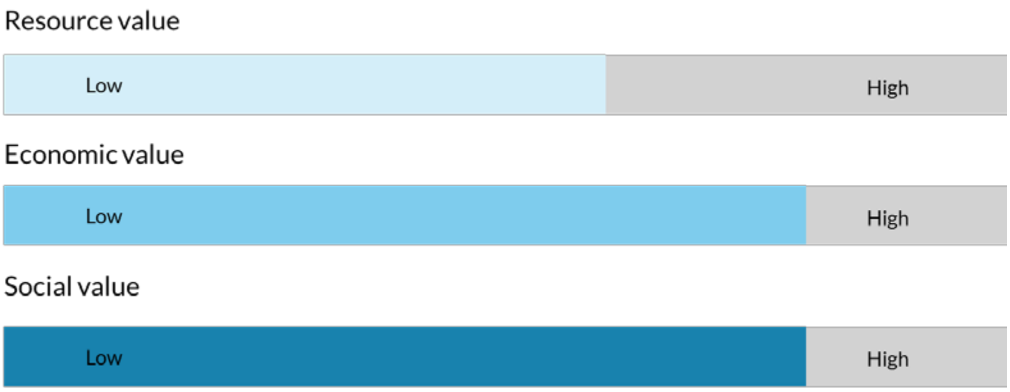
[56] London Sustainable Development Commission (2016). *Better Future: A Route Map to Creating a Cleantech Cluster in London*. Available at: http://www.londonsdc.org/documents/LSDC_BetterFuture_March2016_FINAL.pdf (Accessed 26 October 2016).

Figure 14: CleanTech One, Singapore (Source: KCyamazaki via wikimedia)

6.7.2 Key facts

- Clean tech hubs maximise the utility of space, encourage collaboration and drive innovation;
- Clean tech hubs tend to require a large land area and must be flexibly designed to accommodate different business needs including offices, workshops, homes, factories and research labs and centres and communal spaces;
- Advanced digital infrastructure underpins all activities and must be installed, maintained and managed consistently to the highest level; and
- Sustainability and circular economy should be prioritised from the start of development to ensure they are embedded in all business and recreational activities as the site expands.

6.7.3 Lenses



6.7.4 Suitability

- Major cities with high land values and costs of living;

- Urban areas with a high volume of varied business sectors already in operation;
- Locations well connected to neighbouring cities and regions; and
- Regions with local authorities and developers prepared to experiment with an innovative model of development and provide necessary infrastructure and support.

6.7.5 Benefits

Economic

- Circular hubs contribute to tackling the lack of affordable business premises and affordable homes in major cities;
- Cost savings for business and residential customers from reduced rents and other outgoings e.g. energy and living costs;
- Enhanced business revenue opportunities from co-location of diverse range of organisations;
- Hubs provide attractive investment opportunities; and
- High capital costs but significant economic potential from creation of jobs and boosting of local economy.

Social/Environmental

- Circular hubs maximise building asset utilisation which helps to lower energy and resource use and cut carbon emissions;
- Flexible office space rental (on a daily or monthly basis) is perfect for location independent businesses of all scales and offers the chance to engage with and learn from other professionals whilst increasing business and social networking;
- Provide both a resource and skills sharing platform that promotes industrial symbiosis and helps innovators access the latest technology and market information, rapidly and efficiently;
- Clustering provides opportunities for collaboration, networking, co-creation and knowledge/skills exchange;
- Co-location of businesses, academia and manufacturing provides a test-bed environment to incubate and experiment with innovative technologies and practices such as autonomous vehicle ride-sharing services;
- Encourages public-private cooperation between local authorities, developers and businesses; and
- Enhanced liveability, health and wellbeing in hub areas and surrounding regions.

6.7.6 Example

Berlin's Clean Tech Business Park brings together businesses from clean tech industries including green energy production and storage, energy efficiency, sustainable mobility, circular economy, sustainable water management, resource and material efficiency and green chemistry.[57] The 90 hectare urban industrial space in the Marzahn-Hellersdorf district of Berlin offers a premium location at the heart of Europe's clean tech sector, links to Berlin's world renowned research and development community, and high quality, affordable living options for skilled workers and executives. Berlin is actively promoting the development of future technologies with policies designed to support research and collaboration.[58]

The Agora Collective in Berlin is a co-working space that provides business spaces, workshops, cafes, a garden, and event space across five floors.[59] It is aimed at international and local freelancers, entrepreneurs and clean tech business groups. Art exhibitions are also held at the Agora Collective helping to engage local artists and the public in the project.

6.7.7 Enablers

- Supportive regulatory environment including government/local authority regulations mandating the provision of basic services and guarantee of cut price business rates;
- Incentives for businesses such as affordable rent prices, energy and rapid internet connectivity, use of meeting rooms etc;
- Promotion of the hub format and demonstration of benefits to local businesses; and
- Investment and business partnerships bringing together investors, tech companies and local/city authorities.

6.7.8 Stakeholders

- OPDC;
- Local authorities;
- International and local businesses;
- Local chamber of commerce;
- Entrepreneurs;
- Artists; and
- Local communities and residents.

[57] CleanTech (2016). *CleanTech Business Park Berlin-Marzahn*. Available at: http://cleantechpark.de/en/ (Accessed 26 October 2016).
[58] CleanTech (2016). *CleanTech Innovation Centre*. Available at: http://cleantech-innovationcenter.de/en/ (Accessed 26 October 2016).
[59] Agora Collective (2016). *About Agora*. Available at: http://agoracollective.org/about/the-collective/ (Accessed 26 October 2016).

6.8 Design for flexibility

6.8.1 Summary of initiative

The aim of design for flexibility is to facilitate multiple uses of a building to maximise its utility. Designing for flexibility reduces wasted time, effort and materials traditionally associated with building use transitions and expands the range of possible users of a building. A building designed for flexibility also allows users and owners to tailor it and its spaces to their needs with less cost and supports the return of unneeded materials and components into the supply chain.

Modular design facilitates the effortless customisation and remodelling of a building and its spaces to suit a range of user needs. It offers a far greater range of customisation options and therefore enables the building to meet the user needs precisely to support productivity and occupant health and wellbeing. Effective use and lease models further support smooth and easy use transitions and adaptable building spaces make them well suited for temporary socially beneficial 'meanwhile uses' at times when the building or space would otherwise be vacant.

Modular design enables materials and components to be separated and returned to supply chains when they are no longer needed within the building. Modular design principles can be applied across the range of building 'layers', from its structural core to internal fit out. Early consideration of these principles in the design process enables their deep integration within the building fabric and structure.

Digital technology can be utilised to further building adaptability. Digital technology solutions which integrate sensors and cloud computing - smart systems - can provide users real time control of the building environment, through elements including heating, lighting or ventilation. Integration of smart solutions with Intelligent BIM can provide building users a deeper insight into potential use and customisation opportunities.[60]

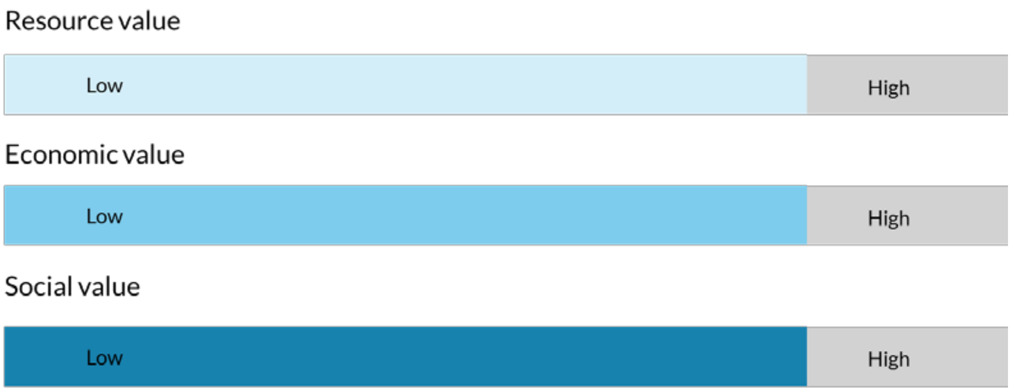
[60] Arup (2016). *Circular Economy in the Built Environment*. Available at: http://publications.arup.com/publications/c/circular_economy_in_the_built_environment (Accessed 26 October 2016).

Figure 15: Arup Circular Building 2016, London (Source: Arup Associates)

6.8.2 Key facts

- Design for flexibility aims to enable multiple, diverse uses of a building in order to maximise its utility;
- Modular design enables customisation of a building in line with new user needs;
- Early consideration modular design principles in the building development process enable flexibility at a deeper level within the building;
- Integration of digital technologies, sensors and cloud computing through design can facilitate real time, personalised control of internal building environments; and
- Implementation of BIM enables better building design and configuration.

6.8.3 Lenses



6.8.4 Suitability

- New buildings and development areas being designed and built from scratch; and
- Building retrofit or renovation projects.

6.8.5 Benefits

Economic

- Reduces cost of use transitions e.g. from commercial uses to residential;
- Optimisation of building and space use opportunities, maximising revenues for the owner/ developer;
- Building environments can be precisely and easily tailored to user needs to support productivity; and
- Materials can be returned to the supply chain, or sold via reuse platforms. This boosts secondary markets for reuse of materials.

Social/Environmental

- Avoided waste from associated use transitions;

- Potential for avoiding construction of new buildings and associated impacts e.g. resource use and emissions; and
- Buildings suitable for beneficial 'meanwhile uses' provide opportunities for place-making and community functions, increasing social interactions and wellbeing amongst local residents.

6.8.6 Example

The Circular Building was developed by Arup, Frener & Reifer, BAM Construction and The Built Environment Trust as a prototype to explore the potential for a completely circular building.[61] The building was showcased in the 2016 London Design Festival and explores how building design can use off-site fabrication, modularity and smart systems to develop a simple building which responds to user needs, minimises energy and water consumption and can be smoothly deconstructed and returned to the supply chain at the highest possible material value.

An integrated NextGen Living Wall helps to enhance the space aesthetics and air quality of the building. These systems are simple to install and maintain and can be easily dismantled and moved without any wasted materials. As each plant is individually potted they can be easily removed and replaced without damage to neighbouring plants, allowing customisation of plant arrangements to suit user tastes. Desso carpet tiles were used in the Circular Building. While these are exceedingly modular and allow for customisation, Desso also offers tiles through a carpet leasing service option. Instead of owning the carpet, customers lease it as a service from Desso, who install, clean maintain and eventually remove and recycle the carpet.

Arup investigated options for use and lease options for kitchen appliances. While some companies, such as Amsterdam-based Bundles, are already offering kitchen appliances as services, the design team was unable to find a UK-based firm offering such a service. This highlights the gaps and opportunities that remain in this area.[62]

A majority of the elements within the Circular Building can be returned into the supply chain but those which are modular by design can be returned at a higher value use. For example, Lindtapers are a clamp type bolt which were used to fix façade elements to the steel structural beams without making holes in the steelwork. These provide flexibility, ease of deconstruction and enable reuse and recycling. Similarly, Fatra water proof membrane sheets were joined in such a way that allows the membranes to be removed and reused.

Lighting within the Circular Building was provided by Track Sopt Lighting which incorporates wireless light fitting controls and sensors through Xicato Bluetooth based LED technology. This opens up the freedom of control of light fittings to individual users working in a space under 'their own' lights. The modules in the light

[61] Arup (2016). *Circular Building 2016*. Available at: http://circularbuilding.arup.com/ (Accessed 26 October 2016).
[62] Arup (2016). *The Circular Building: The Most Advances Reusable Building Yet*. Available at: http://www.arup.com/news/2016_09_september/19_september_the_circular_building_the_most_advanced_reusable_building_yet (Accessed 26 October 2016).

fittings can be updated to cope with developments in technology and the light fittings themselves have been designed such that key components can be removed for servicing, repairs and updates.

Each material in the Circular Building comes with its own QR code containing the information required to allow reuse. Together this information feeds into a Materials Database created using a cloud-based platform from which data has been fed to both the Circular Building website and the BIM model.

6.8.7 Enablers

- Policy to drive consideration of design for flexibility early within building design development;
- Scope within building design for research and investigation into emerging design for flexibility approaches and engagement with suppliers to develop modular, intelligent solutions;
- Technology maturity and declining costs (e.g. BIM models, sensor and control systems and cloud computing);
- Development of products-as-service business models and availability; and
- Education to bring design for flexibility into mainstream practice.

6.8.8 Stakeholders

- OPDC;
- Developers;
- Financiers;
- Architects/designers;
- Building engineers; and
- Potential occupants.

6.9 Community-led development

6.9.1 Summary of initiative

Community-led development – also known as self-build and custom-build development – allows local people to oversee the design and construction of their own homes and communities. Local authorities can facilitate the process by providing land or basic services including access to the public highway and connections for utilities (e.g. electricity, water, and wastewater).

In self-build, a person arranges all elements of the design and construction themselves, while in community-led and custom-build development a person or community works with an architect and specialist developer to manage, adapt and deliver homes to a specific set of criteria. The latter is less hands-on for the client and may involve the developer managing finance on the project. Both approaches enable local residents to specify the quality and functionality of their homes, adapting the size, lay-out and fittings to their budget and needs. People may also choose to collaborate on the design of their community based on shared values such as sustainability. These approaches tends to result in lower costs and can help to create affordable homes and cohesive, intergenerational communities.[63]

Shared services, spaces and assets may be designed-in to maximise space utilisation. Communal spaces such as kitchens and living areas create opportunities for sharing meals and skills and casual social interactions between neighbours. Basic internal fit-outs allow for flexibility of spaces' use. And sustainable practices such as on-site renewable energy generation and modular, pre-fabricated house building 'kits' help lower energy and construction costs and increase local resilience.

Digital design sharing and editing services such as BIM may be used to assist the design process in addition to platforms that facilitate space, asset, and skills rental and sharing.

Figure 16: Malmo, canal housing (Source: La Citta Vita via Flickr)

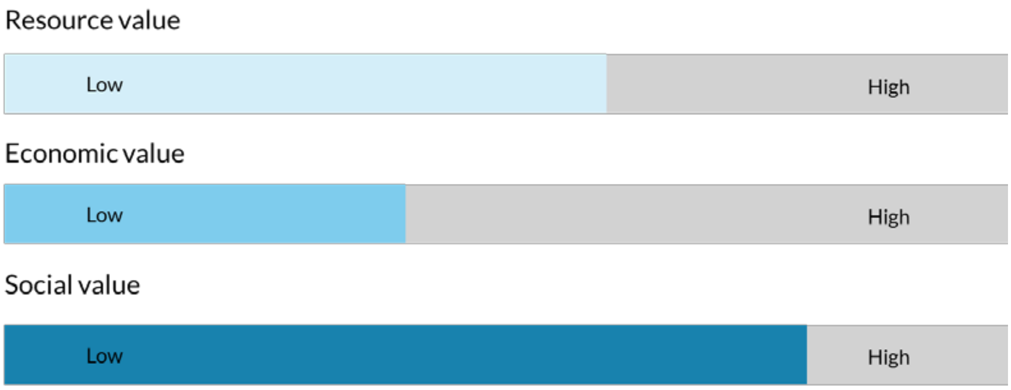
6.9.2 Key facts

- Provides ordinary people choice and flexibility as to how their home is designed and used;
- Tends to be cheaper than buying a house on the open market;
- Can be designed to integrate shared spaces, sustainable elements and boost opportunities for sharing meals, skills and socialising within a community;

[63] Design Council (2016). *Community-Led Design & Development*. Available at: http://www.designcouncil.org.uk/what-we-do/community-led-design-development (Accessed 26 October 2016).

- Modularity and prefabricated construction techniques can lower costs and significantly reduce construction times; and
- A possible solution to the lack of affordable housing in dense urban areas.

6.9.3 Lenses



6.9.4 Suitability

- Groups with a particular shared interest or goal e.g. sustainability or circular economy;
- Individuals seeking more involvement in the building of their homes or influence over design than can be expected in the open market;
- Individuals and groups seeking to build or join a community rather than an individual property;
- Locations where regulations/incentives are in place to facilitate self and custom building e.g. where local authorities have earmarked plots of land especially; and
- May be better suited to denser urban areas with high property prices and land values.

6.9.5 Benefits

Economic

- Cost savings due to low Stamp Duty Land Tax, zero VAT on new build housing and increased control over choice of materials, size and other features (in the UK); and
- Lower overall costs than equivalent homes bought on the open market.

Social/Environmental

- Provides individuals with flexibility and control over design and construction quality, functionality and affordability of homes;
- Asset utilisation is maximised through space sharing. This lowers overall energy and resource use which cuts costs and environmental impacts such as carbon emissions;

- Passive house standards, renewable energy sources and other sustainable approaches contribute to lowering energy costs and environmental impacts and enhancing resilience; and
- Creation of cohesive, supportive communities, increasing residents' social and physical resilience and enhancing the desirability of certain locations. Communities tend to design in communal green spaces which further contribute to liveability, sustainability and community wellbeing.

6.9.6 Examples

The Buiksloterham district of Amsterdam is being designed and built using self-build and circular economy principles.[64] The municipality is working in collaboration with local businesses, community organisations and individuals to create 3,500 new homes and 200,000m^2 of workspace. Sustainability and circularity are at the heart of the scheme, and self-builders' applications will be judged on how proposed developments meet these criteria. The final development area will be zero-waste, emission-free and entirely energy self-sufficient. All products and materials will be recovered for reuse, repair and recycling. And incentives will be put in place to attract businesses to the area, creating a 'living lab' for testing smart, digital and circular technologies and practices.

Amsterdam's city council is supporting the self-build development approach by providing plots to private individuals and groups in attractive locations. The city is also providing urban development guidelines emphasising the need to maximise space use. Local stakeholders will retain responsibility and authority over local decision-making towards agreed targets, increasing buy-in and engagement. And urban sensing and open data infrastructure will be implemented to monitor, manage and communicate the functioning of the community and its systems. An Action Plan will be developed providing a community web portal and guidelines for residents, developers, and other local stakeholders.

Similar self-build and custom-build development projects are underway in Almere near Amsterdam, in Berlin, and in the UK including the Graven Hill Village development project in Oxfordshire, the Cohousing Woodside development project in Muswell Hill, North London as well as Brixton Green South London.[65],[66]

6.9.7 Enablers

- The England Self-build and Custom Housebuilding Act 2015[67];
- Government and local authority support to unlock land, ensure it is affordable and provide services such as access to utilities. Planning regulations may need to

[64] Amsterdam Smart City (2016). *Circular City: Circular Buiksloterham*. Available at: https://amsterdamsmartcity.com/projects/circulair-buiksloterham (Accessed 26 October 2016).
[65] The Self Build Portal (2016). *Almere, Holland*. Available at: http://www.selfbuildportal.org.uk/homeruskwartier-district-almere (Accessed 26 October 2016).
[66] CoHousing Berlin (2016). *About CoHousing Berlin*. Available at: http://www.cohousing-berlin.de/en/about (Accessed 26 October 2016).
[67] UK Parliament (2015). *The Self-Build and Custom Housebuilding Act 2015*. Available at: http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN06998 (Accessed 26 October 2016).

be adjusted to make land easier to buy and develop for private individuals and groups;

- Incentives to encourage groups to choose certain locations, e.g. land cost/rent and tax reductions;
- Alternative financial and legal arrangements (including mortgages) for purchases of land by self-build individuals or groups including to promote and enable shared ownership, and improve access to funding for collective projects;
- Practical support for self-builders, e.g. case studies and examples illustrating successful projects and how they overcame common obstacles;
- On individual projects, a committed project manager (ideally experienced in design/ construction) is desirable but to oversee the coordination of the build; and
- Information and skills sharing platforms and services amongst communities and self-builders.

6.9.8 Stakeholders

- OPDC;
- Local authorities;
- Central government;
- Architects;
- Builders/construction companies;
- Developers;
- Legal advisers;
- Banks and investors; and
- Community groups and individuals.

6.10 Community-owned energy infrastructure

6.10.1 Summary of initiative

Community-owned energy infrastructure enables neighbourhoods to produce, store and locally distribute their own energy, and retain a degree of control over local services and their associated costs.[68] Low and zero carbon solutions such as solar PV, wind, anaerobic digestion and biomass can be used to fuel a distributed energy network.[69] This can help to lower the community's reliance on the grid and increase local resilience to price volatility and grid failures. Neighbourhood storage facilities

[68] Clark, D., Chadwick, M. (2011). *A Rough Guide to Community Energy*. Available at: https://www.bre.co.uk/filelibrary/nsc/Documents%20Library/Not%20for%20Profits/Rough-Guide-to_Community_Energy.pdf (Accessed 26 October 2016).
[69] Woking Borough Council (undated). *Defra Community Energy*. Available at: https://www.woking.gov.uk/environment/climate/Greeninitiatives/sustainablewoking/defra (Accessed 26 October 2016).

further enable communities to balance variable decentralised and renewable energy and manage peak demand – see battery storage case study.

To manage locally produced energy, communities may choose to develop an Energy Service Company (ESCo). Unlike conventional energy suppliers, ESCos provide local businesses and residents with a service – such as heat – rather than equipment – like a boiler. The ESCo retains responsibility for the performance of the service including installation, maintenance, and operation, as well as the upfront costs. The end user effectively leases the energy service (e.g. the provision of heat) at an agreed rate.

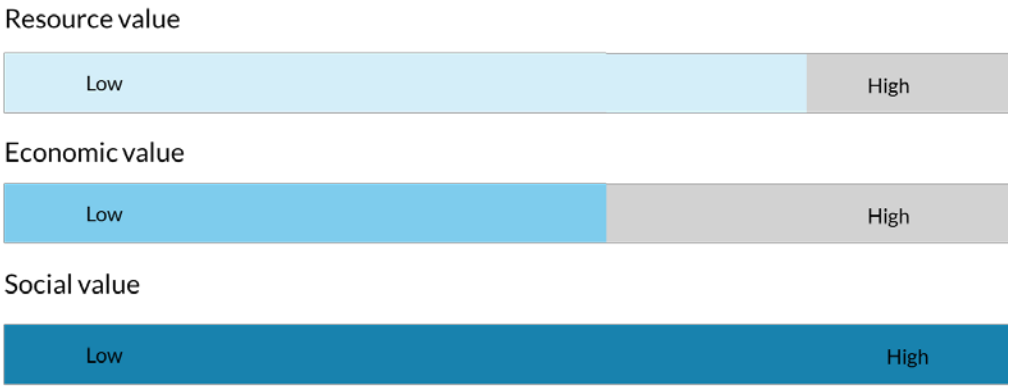
A joint public-private ESCo may be developed between a local authority and a private company (or individuals) to benefit a community. Local authority involvement helps the organisation to access finance and meet local targets (e.g. on fuel poverty or carbon emissions), while the private entity may aim to maximise economic returns, which can be reinvested in local projects that benefit the community.

Figure 17: Moss Community Energy, Salford (Source: 10:10 via Flickr)

6.10.2 Key facts

- An ESCo can be set up to help a community manage locally produced energy; and
- Community energy projects help communities to implement renewable energy, increase resilience and lower energy bills.

6.10.3 Lenses



6.10.4 Suitability

- Dense urban developments;
- Communities looking to implement high cost energy projects but lacking capital funding; and
- Communities committed to specific goals – such as sustainability or improved air quality.

6.10.5 Benefits

Economic

- Communities can earn revenue via a feed in tariff, demand management mechanisms and sale of energy via a community-run ESCo. Profits can be reinvested into community projects;
- Helps communities to implement innovative and low carbon energy projects whilst avoiding upfront costs needed to finance projects and guaranteeing energy performance levels;
- Contributes to increasing local energy security and resilience to power and price shocks;
- Profits can be retained within the local economy and help to lower residents' energy bills; and
- Potential to stimulate local supply chains and create jobs.

Social/Environmental

- Enhances local management of energy generation (e.g. choice of technology) and price setting;
- Maximises local waste streams and minimise landfill through using waste to energy;
- Potential to trial a local smart metering system;
- Integrates renewables and minimise environmental impacts including local emissions and air quality. Contribute to lowering wider regional and national emissions; and

- Promotes engaged communities and social cohesion. Enhance energy consciousness and facilitate behaviour change.

6.10.6 Examples

In 2000, Thameswey Energy Ltd (an ESCo) was set up as a public-private joint venture between Woking Borough Council and a Danish biogas plant developer named Xergi. It uses CHP to supply electricity and heat to local authority buildings, businesses and homes in Woking.[70]

The company receives funding through shareholding capital and loan finance and is owned 90% by Thameswey Energy Ltd and 10% by Woking Borough Council, who bought out Xergi at the end of 2011. To avoid charges for using the grid, Thameswey Energy Ltd established a private electricity network. It was thus able to fund the development of its own infrastructure and assets and provide electricity to low income households at below market rates. This helped the borough meet the targets it set itself around fuel poverty.

Thameswey Energy Ltd invests some of the profits it makes from supplying electricity back into local energy efficiency programmes. It uses its status as a public-private venture to avoid capital controls that would ordinarily be placed on a local authority company. With these savings it has implemented larger scale projects using private finance and funds recycled through the council's efficiency fund.

Thameswey Solar Ltd manages 1,800 kW of PV installations on public, community and residential buildings across the borough.[71] This is enough to power a laptop in every household or equivalent to the entire average annual electricity demand of 460 households in Woking. It is jointly owned and operated by Thameswey Solar Ltd and Total Gas Contracts Ltd. It also takes advantage of the government's feed-in-tariff.[72]

6.10.7 Enablers

- Supportive policy environment including incentives such as tax breaks (e.g. enterprise investment scheme) or feed-in-tariff;
- A strong community leader with the relevant technical and commercial skills and experience and supportive group members to share set-up and operation activities;
- On-site or local renewable energy generation capacity;
- Partnerships between local authorities, investors, and technology providers; and
- Local authority approval and engagement with Independent Distribution Network Operator (IDNOs) and developers.

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[70] Thameswey (2016). *Welcome to the Thamesway Group*. Available at: http://www.thameswey group.co.uk/ (Accessed 26 October 2016).
[71] Thameswey Solar (2016). *About Thameswey's Solar Energy*. Available at: http://www.thameswaysolar.co.uk/about-contact/ (Accessed 26 October 2016).
[72] Thameswey Solar (2015). *Business Plan 2016-18*. Available at: http://cl-assets.public-i.tv/woking/document/5e_Thameswey_Business_Plans_2016_Appendix_4.pdf (Accessed 26 October 2016).

6.10.8 Stakeholders

- OPDC;
- Local authorities;
- Community groups/individuals;
- Banks/investors;
- Energy technology suppliers;
- IDNOs;
- Technology experts; and
- Legal advisers.

6.11 Demand side response

6.11.1 Summary of initiative

Demand side response (DSR) is a rapidly developing technical area and commercial business offering in the power sector. It aims to use electricity more intelligently. DSR can help provide savings for consumers by reducing or shifting electricity usage during peak times in response to time-based rates or other forms of financial incentives.[73] DSR implementation can help more efficient electricity grid operation by altering consumption patterns to reduce congestion in parts of the network thus avoiding component failures as well as allowing more renewables, such as solar PV and wind electricity to feed-in. It also leads to a more economic network operation by avoiding reliance on expensive power plants to generate electricity to meet peak demands, allowing consumption to be reduced. DSR will play a significant role in the transition to smart networks and in the longer term to a transactive energy paradigm, thus allowing consumers to have an active role in the electricity energy markets.

Currently, various available DSR schemes are offered to both commercial and residential consumers namely incentive based and price-based programmes.[74] In incentive DSR programmes, consumers participate voluntarily by allowing the system operators to control certain electric appliances (e.g. HVAC units) directly during the peak or emergency periods. DSR schemes such as direct load control

[73] UK Power Networks & EDF Energy (2011). *Residential Demand Response – The Dynamic Time-of-Use Tariff*. Available at: http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Presentations/Low+Carbon+London+-+Time-of-Use+Trials.pdf (Accessed 26 October 2016).

[74] UK Government (2014). *Smart Meter Roll-Out for the Domestic and Small and Medium Non-Domestic Sectors (GB)*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/276656/smart_meter_roll_out_for_the_domestic_and_small_and_medium_and_non_domestic_sectors.pdf (Accessed 26 October 2016).

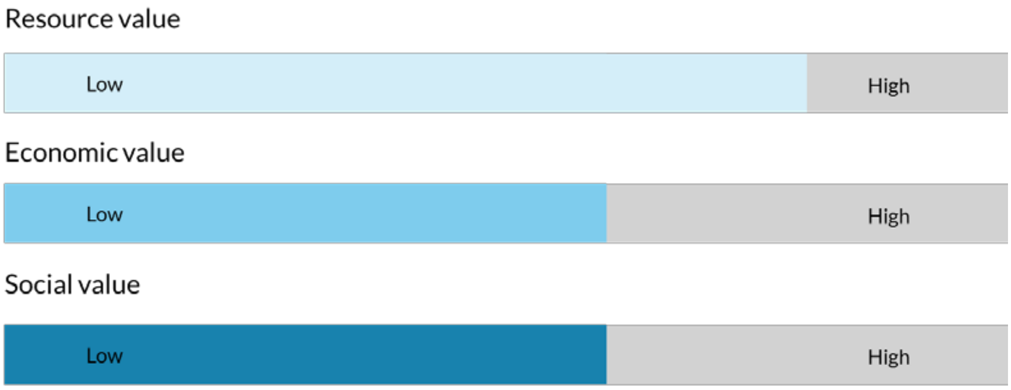
(DLC) and interruptible/curtailable service have been used by utilities for some time. Participants in these programmes are offered incentives in exchange for the reduction of their loads to pre-defined values. Participants who do not respond may also be penalized. Price-based programs (PBP), include three different DSR programmes; these are time of use (TOU), critical peak pricing (CPP), and real time pricing (RTP). In general, these programmes are based on dynamic pricing rates in which the main objective is to flatten the demand curve by offering higher price during peak periods and lower prices during off-peak periods.

Figure 18: Smart domestic energy management (Source: Newtown graffiti via Flickr)

6.11.2 Key facts

- Consumers can make cost savings by joining DSR programmes and volunteering to alter their electricity usage in various ways;
- Consumers should have a minimum monthly energy consumption depending on which DSR programme they enrol in. For example, residential consumers using a TOU programme should have at least an average monthly electricity demand of 100kW;
- Customers can enrol directly with the distribution network operators (DNOs) or via an aggregator; and
- Each DSR customer should submit a load reduction plan detailing specific actions taken to reduce its load down within a certain time duration response (for example from 30 minutes to four hours).

6.11.3 Lenses



6.11.4 Suitability

- DSR programmes are suitable anywhere that uses electricity. DSR is enabled using smart meters, which are designed for easy installation to any asset; and
- DSR has potential applications with the following assets: mining and quarries; foundries and metal processing; IT and telecoms; commercial property; airport and hospitals; manufacturing; commercial refrigeration; universities; and water and wastewater treatment.

6.11.5 Benefits

Economic

- Benefits from relative and absolute reductions in electricity demand;
- Benefits resulting from short run marginal cost savings from using DSR to shift peak demand;
- Benefits in terms of displacing new plant investment from using DSR to shift peak demand;
- Benefits of using DSR in providing reserve for emergencies/unforeseen events;
- Benefits of DSR in providing standby reserve and balancing for wind;
- Benefits in terms of reduced transmission network investment by reducing congestion of the network and avoiding transmission network re-enforcement; and
- Benefits from using DSR to improve distribution network investment efficiency and reduced losses.

Social/Environmental

- Reduction of high levels of pollution (CO_2 and other pollutants) created by plants that generate peak power;
- Helps integrate renewable energy onto the electric grid by providing increased stability and management;
- Reduction in greenhouse gas emissions; and

- Increase of social-welfare, as consumers will have the opportunity to participate on the wholesale energy market.

6.11.6 Examples

UK Power Networks in London engaged a control group of 4,500 households for trials using smart meters and dynamic, fixed tariffs. This aimed to determine which appliances are most frequently used by customers, to measure the impact of DSR on electricity bills and to investigate whether customers were happy to participate in tariff based DSR services. The trial resulted in consumer savings of 4.3% on annual electricity bills. It also found that £2.13 million could be saved by the DNO through deferring reinforcement of grid infrastructure.

DSR participation in the UK market remains small but is growing. Currently DSR accounts for around 2GW or 3% of the load of the maximum winter peak electricity demand of around 58GW. Recent trials in the UK also suggest potential reductions of 8.8% peak load using Time of Use tariffs.

Outside the UK, SA Power Networks in Australia has created a discrete demand management unit within the Demand and Network Management Department. Using around 1,000 volunteer households, trials to date indicate a 19-35% reduction in peak load where direct load control demand management is used. All trials undertaken investigate three key factors – technology, customer acceptance and impact on peak reduction. All trials are also exposed to stringent and independent cost benefit analysis.

6.11.7 Enablers

- The UK government has taken the decision to roll out smart meters to enable DSR programmes. This will lead to a significant increase in the potential for DSR[75];
- Incentives to promote DSR projects through regulatory subsidies;
- Creation of uniform standards and methodologies for measuring the cost-effectiveness of DSR programmes and the associated return on investments; and
- Customer engagement via more accessible educational programmes and policy adjustments.

6.11.8 Stakeholders

- OPDC;
- National government / Department for Business, Energy & Industrial Strategy (DBEIS);
- Local authorities;
- The Energyst
- The Office of Gas and Electricity Markets (Ofgem);

[75] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42740/1485-impact-assessment-smart-metering-implementation-p.pdf

- Energy Managers Association;
- Local businesses;
- Investors;
- Aggregators; and
- DNOs.

6.11.9 Suppliers

- DNOs; and
- Aggregators including Energy Pool, REstore, Open Energi, KiWi Power, Reactive Technologies.

7 Enabling framework

7.1 How to enable the CE principles and overcome barriers: policies, incentives, infrastructure and support

Section 6 provides the first comprehensive options for circular economy programmes in Old Oak and Park Royal. These options represent the most promising opportunities for the area and reflect the opportunities for the districts today and looking forward to the future, from development to operation.

To deliver the circular economy initiatives addressed in this research – among other wider initiatives which may arise with new opportunities and challenges in OPDC – stakeholders must clearly identify the challenges or impediments to achieving success and address them with enabling factors.

7.1.1 Solutions fit for purpose

Some challenges are better met with different enabling tools which the public and private sector can influence, depending on the characteristics of the challenge and the tools at the stakeholders' disposal. In the **Figure 20** below, the Ellen MacArthur Foundation helpfully demonstrate the manner in which various regulatory, economic and other factors are better addressed by different "enablers."

Given the extensive list of opportunities in OPDC, it may prove quite challenging to produce a robust assessment of the matrix above for each initiative. While a deep-dive may prove helpful at a later stage in the work, we have prepared a method, or framework, to address the essential enablers for the ten initiatives from Section 6 of this report which will also build the institutional, financial or policy frameworks to support a much broader range of initiatives over time.

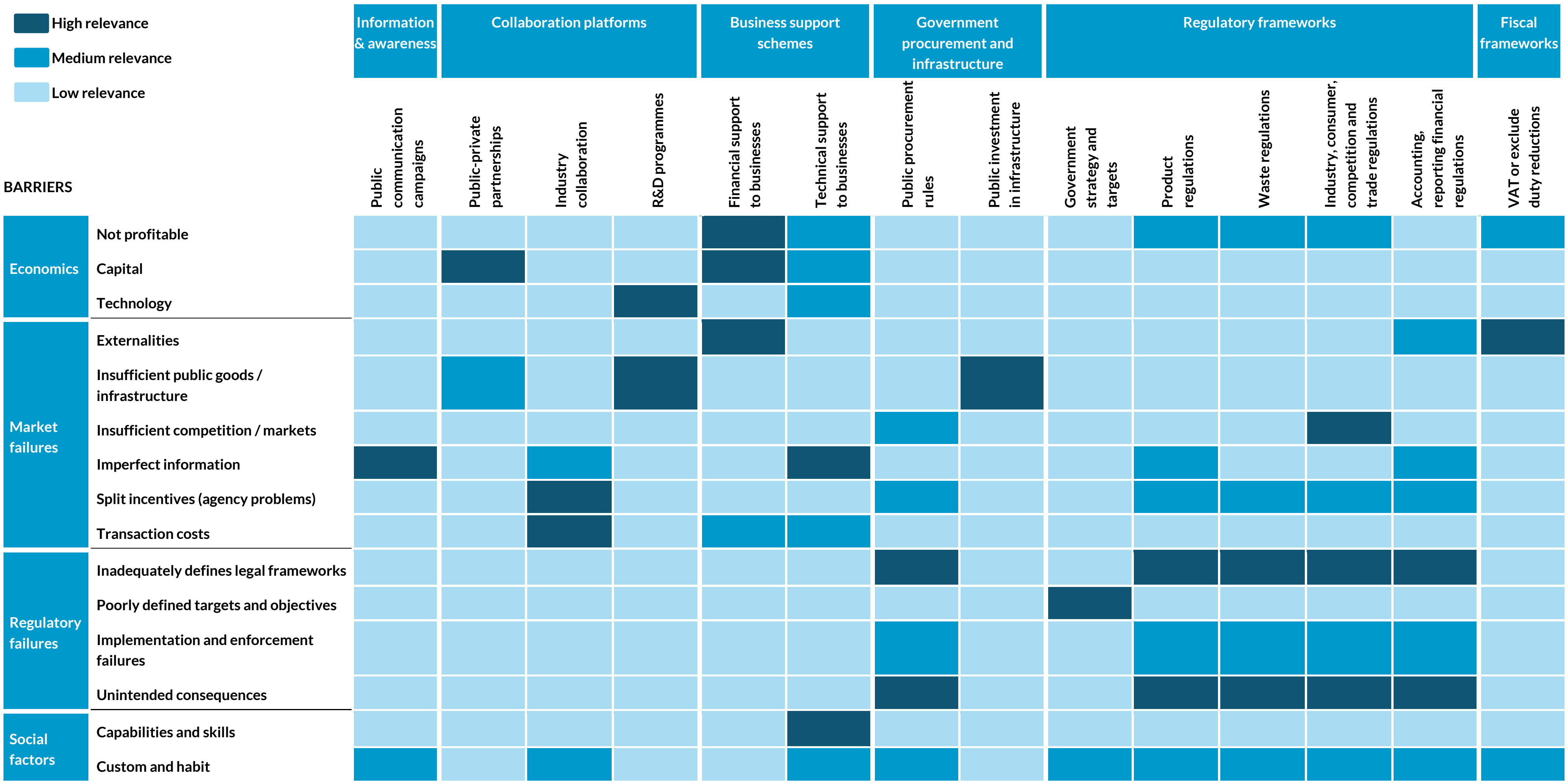


Figure 19: Reproduced Ellen MacArthur Foundation prioritising matrix[76]

[76] Ellen MacArthur Foundation (2015). *Delivering the Circular Economy – A Toolkit for Policymakers.*

7.1.2 Bringing the solutions together

The Ellen MacArthur Foundation highlighted the importance of structuring the enabling factors to support the circular economy in a way that mutually reinforces them and builds efficiencies in the system. For example, the ten initiatives presented in Section 6 identified a wide range of enablers which require some form of education, information and awareness programmes. Creating ten separate programmes would not only prove logistically difficult, it would be financially challenging and not provide a means for sharing resources, knowledge and joining up work. Accordingly, we match enabling factors that share common stakeholders to identify where common and shared resources or efforts can be focused to deliver a range of circular economy measures.

Following on from the Ellen MacArthur Foundation framework, we now outline key enabling factors to overcome the challenges to delivering the ten initiatives outlined in Section 6. These include education, information, awareness and collaboration platforms; public procurement and infrastructure; regulatory or policy frameworks; and fiscal, funding and finance frameworks. In addition, we also identify where market factors, largely outside of local public or private sector influence, could act as enablers to circular economy initiative adoption – both economic and technological.

7.1.3 Education, information, awareness and collaboration platforms

A range of initiatives require the public – residents, businesses and visitors – to change behaviours and be informed and aware of different requirements of living in a more circular economy. For example, the public will need to understand the importance of and rules for segregating waste or the opportunities and rules (or new cultural norms) for community sharing programmes. These can only be effective if they include tailored programmes for education, information, design, "nudging", and rule formation and enforcement.

Oftentimes, the best way to share information, increase awareness or build support for initiatives is through collaboration platforms. Community groups, online platforms and knowledge networks can bring residents, businesses and experts together to help deliver change and support circular economy initiatives.

OPDC Circular Economy Team

For those services which the council controls or influences, the OPDC and three councils should develop a Circular Economy Team (CET). This team should be comprised of communications and community engagement specialists who can liaise with the specific programme and specialist teams within the councils to develop education, information and awareness programmes. The CET should also work with design teams to develop "nudge" programmes. For example, studies have found that matching the shape of recyclables to the shape of the disposal hole in the bin lid can increase recycling rates by 34%.[77] Working the process and project design teams can develop effective nudge principles which do not require much education or

[77] Center for Environmental Policy and Behavior (2013). *Nudging Environmental Behavior*. Available at: http://environmentalpolicy.ucdavis.edu/node/291 (Accessed 26 October 2016).

awareness of the public but generate a series of "nudges" that encourage the desired behaviour.

The CET will work with groups across a range of projects, sometimes engaging with residents and the local community. Other times, they will pull in expertise from the OPDC or three Borough councils to support educational, information and awareness for more technical work – like self-build housing.

Circular Community

Community involvement will be essential for delivering many circular economy measures in Old Oak and Park Royal. They will bring awareness of opportunities for involvement in community programmes, share knowledge and know-how for specific projects, and raise awareness and help enforce community rules.

Effective community groups will require strong community leaders, public spaces to meet and connect with the broad community, and online platforms for collaborating and carrying out their work. And, to be most effective, the community groups should have a single point of contact within the OPDC CET to help implement programmes and provide feedback loops for local government policies, strategies and programmes.

Circular Economy in the "Chamber of Commerce" (CECC)

Many circular economy projects require communication among businesses about new investment opportunities or collaboration to find ways to overcome investment challenges. Using the existing platforms such as the London Chambers of Commerce and Industry (LCCI), the Park Royal Business Group and other local business groups – will make the most of business networks and professional and knowledge networks. Additional support could be leveraged through the London Enterprise Panel's programmes supporting innovation in science and technology and ensuring London's status as a "global hub".

7.1.4 Public procurement and infrastructure

Local and central government play an important role in providing the infrastructure and public services to support a circular economy. Investment in reuse and recycling facilities or mandating the use of recycled content materials in construction projects often bring wider public benefits and can help support emerging sectors and technologies. Evidence from the Centre for Cities demonstrates the local government procurement practices can deliver change for more low-carbon and environmental sustainability programmes while supporting employment and local economic growth.[78]

In Denmark, green public procurement has been shaped at the national and local government levels. The Partnership for Green Public Procurements is a collaboration between regional and local governments with the Ministry of Environment and Food. The partners set criteria such as recyclability, product lifespan and total cost of ownership to integrate green goals into their procurement

[78] Centre for Cities (2014). *Delivering Change: Low Carbon Economy*. Centre for Cities: London.

policies. The cost of administering the Partnership is relatively small, estimated at less than £150,000 per annum across all government.[79]

Often, especially when new technologies and methods are used to implement circular economy projects, there is limited evidence on effectiveness or cost-effectiveness. This is a particular challenge for local government which must demonstrate they are providing value-for-money (VFM). To overcome this challenge, local government should:

- Share information: learn from one another to understand the opportunities, challenges and lessons from circular economy investments.
- Re-think costs and benefits: circularity is particularly challenging to model in public finance terms. Public benefits and cost savings are often realised by individuals or community groups rather than the public purse. Public procurement should take into account the wider economic, environmental and social impacts of projects to support investment in projects that deliver the best VFM for society.
- Develop new value-capture mechanisms: local government must also find ways to make the finances stack up. Cost savings often accrue across a wider range of stakeholders, and often the investor may not have a formal mechanism to capture the financial benefits of circularity. Within existing rules and regulations, and working with experts in the Chartered Institute of Public Finance and Accountancy, local government should work to develop new ways to capture wider benefits to support the investment case.

7.1.5 Regulatory or policy frameworks

Regulation and policy – both national and local – play an integral role in driving change for the circular economy. Regulations and policies can either set the rules of the game, create incentives or set targets to support people and businesses to adapt their behaviour to a prescribed goal. Three strategic enablers are required to deliver the regulatory and policy frameworks to support circular economy in Old Oak and Park Royal: lobbying central government, setting local policies and collaborating across government bodies to set ambitions and targets.

Lobbying central government to adapt national policies

The UK is one of the most centralised countries in the OECD. Central government sets most policies and strategies regarding public policy, and they also largely control the financial resources of local councils.[80]

A range of policies and regulatory challenges have been identified as strategic enablers for the circular economy initiatives in the OPDC area, and most of them are governed by central government departments. Ofgem, the DBEIS, Defra, Department for Communities and Local Government (DCLG) and HM Treasury all set policies which affect the viability of those initiatives, including but not limited to:

[79] Ellen MacArthur Foundation (2016). *Denmark: Public Procurement as a Circular Economy Enabler*. https://www.ellenmacarthurfoundation.org/case-studies/denmark-public-procurement-as-a-circular-economy-enabler (Accessed 10 October 2016).
[80] London Finance Commission.

- Renewables Obligation and Feed-in Tariffs that provide economic incentive to implement sustainable energy infrastructure.
- Policy and legislation to tighten environmental targets and promote development of the bioplastics industry.
- Policy, regulation or incentives to support the uptake of electric vehicles.
- Policy, regulation or incentives to support investment in smart grid technologies and infrastructure.
- Including circular economy within DBEIS' new industrial strategies, including support and incentives for businesses to support circular hubs.
- Planning regulations to support community-led development.
- Support for alternative financial and legal arrangements (including mortgages) for purchases of land by self-build individuals or groups including to promote and enable shared ownership, and improve access to funding for collective projects.
- Business support and incentives for new enterprises which support circular economy projects, like the Enterprise Investment Scheme which offers tax reliefs for investors in those slightly riskier companies.

This list demonstrates that Central Government policies and programmes play an integral role in achieving local circular economy initiatives at OPDC. In order to achieve many local ambitions, the OPDC and GLA will need to engage with Whitehall to support a wider agenda for policy change.

Setting local policies and programmes in OPDC

Local authorities have control over some local policies, in particular planning policy and local transport strategies, which can support circular economy initiatives. The OPDC's work with developers and community groups will shape the planning frameworks and policies that will define the parameters of circularity and feasibility of projects. Examples of local policies and programmes within the remit of the OPDC or GLA include but are not limited to:

- Planning regulation adjustments to facilitate development of certain types of buildings or green infrastructure on buildings.
- Policy to drive consideration of design for flexibility early within building design development.
- Local planning policy and support to encourage community-led development, particularly around land release and assembly.
- Local authority approval and engagement utility companies, including working with IDNOs and developers to coordinate utility investments.

Local policies and programmes will shape the 'rules of the game' for future development in the OPDC area. They can creative incentives and define the parameters across a range of policies and public services which can support the successful implementation of the circular economy.

Collaborating with central and local government to set ambitions and targets

Setting goals and targets gives stakeholders a concrete ambition to work towards. Scotland's Circular Economy Strategy has established a number of goals, including reducing all food waste by 33% by 2025. A range of initiatives and policies have developed from this target, including a programme from Resource Efficient Scotland which is helping small and medium-sized enterprises (SMEs) to prevent food waste and the establishment of the Scottish Household Recycling Charter, which promotes a consistent approach to household recycling, including food.[81]

The OPDC, LWARB and other local and central government stakeholders should work together to set targets for the OPDC area. Targets could include a reduction in waste compared to the London average, increase in local food grown, reduced carbon emissions and establishing platforms for sharing by a certain date. Whatever the ambition or target, they should follow the SMART principles, meaning:

- Specific – target a specific area for improvement;
- Measurable – quantify or at least suggest an indicator of progress;
- Assignable – specify who will do it;
- Realistic – state what results can realistically be achieved, given available resources; and
- Time-related – specify when the result(s) can be achieved.

7.1.6 Fiscal, funding and finance frameworks

Many circular economy opportunities are profitable but are not realised due to financial and non-financial barriers. Challenges may arise around managing project risk, navigating regulations and understanding the true economic and financial costs and benefits. Businesses or residents may require incentives to adapt their behaviour or to overcome other market failures. Accordingly, a range of fiscal, funding and finance frameworks should be implemented to enable circular economy in Old Oak and Park Royal.

Improving methods for assessing circular economy costs and benefits

The circular economy is inherently difficult to assess regarding the costs of benefits of projects, as circularity is difficult to model for traditionally linear financial models. Even more so, business cases must take into account various costs and benefits which may not be taken into account in traditional cost-benefit models. For example, measures resulting in waste reduction reduce the long-term demand for land for waste treatment facilities, which could potentially be used for other purposes. That additional land may bring more economic benefits but may be of limited value (due to its location next to a waste facility); at the same time, the reuse value of materials not sent to landfill may be hard to estimate, especially if it displaces sales of new goods.

OPDC and the GLA will need to work with Government, and HM Treasury in particular, to agree better methods to assessing the costs and benefits of circular economy investments within the existing Green Book framework.

Facilitating investment in business and innovation

New and innovative projects will always carry additional risk because of the unknown factors. Many circular economy measures are new and untested; that risk

[81] Ellen MacArthur Foundation. Scotland: Making things last – a circular economy strategy. https://www.ellenmacarthurfoundation.org/case-studies/scotland-making-things-last-a-circular-economy-strategy. Accessed 10 October, 2016.

can keep prevent investment by increasing the costs of capital to a level such that the project cannot achieve the returns the market demands. However, mechanisms may be put in place that facilitate investment in such circumstances by reducing risk through improving investor information, providing guarantees, and providing co-investment from other parties among others.

When the market is not investing in circular economy projects, the project developers must first seek to understand what market failures may exist – this may be low predicted returns, high risk-reward ratios, or lack of market information. From this point, a range of interventions can be used to meet the specific challenges of the investment. Examples of typical financial and funding tools include:

- Co-funding or seed funding from the public sector to de-risk an investment.
- Developing arm's length companies from government bodies which are willing to take lower financial returns in exchange for greater public benefit.
- Providing market information through marketing and promotions campaigns.
- Government backing of investments (underwriting risk).
- Providing uniform standards and methodologies for measuring programmes' return on investment so they are more easily comparable.

Incentives

Incentives will be required to support the circular economy investments in Old Oak and Park Royal. Incentives often take the form of financial tools to influence decisions and realise pre-determined objectives. For example, to encourage technological innovation benefitting environmental projects, incentives are offered to firms undertaking research and development to reduce their tax liabilities.

Sometimes, local authorities require incentives to overcome market challenges. Because new development brings additional costs to the local area (in the form of public services, like school places, or crowding out, like congestion), local government is incentivised to take on new homes through a New Homes Bonus. For the circular economy, local government may also require incentives to make additional investment in community-led development or urban gardening.

Regardless of the end-user or policy target, there are principles for designing good incentives which should be followed to implement incentives for take up of circular economy projects and principles. These include:

1. Sufficiently large to influence behaviour;
2. Affects decisions at the margin, to influence decision between doing a little more and a little less;
3. No thresholds—no minimum or maximum levels of performance;
4. Incentivise the intended behaviour with minimum unintended consequences;
5. Target the appropriate decision markers;
6. Be easy to understand and transparent; and
7. Be predictable and long-term.

Using these principles for a good incentive can help ensure that incentives are used efficiently and effectively to change behaviours and encourage public goods.

7.2 Detailed enabling initiatives

To provide further detail to the broader initiatives in **Section 7.1**, this section provides a long-list of enabling factors which will support the four circular economy scenarios presented in **Section 5**. These enabling factors cover a wide range of initiatives, policies and programmes for the stakeholders who must work together to shape and deliver a circular economy at Old Oak and Park Royal.

7.2.1 Royal Garden[82,83]

Table 11: Enabling factors for the Royal Garden scenario

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Waste capture	Regulatory frameworks	All households and businesses in Old Oak and Park Royal should be required to segregate their food waste and green waste (i.e. organic waste) to facilitate the collection of uncontaminated organic material. This would help to significantly boost London's recycling rates and improve the efficiency of downstream organic material conversion and treatment processes.	OPDC; waste collection authorities (WCAs); waste disposal authorities (WDAs); Housing associations; Commercial developers	LWARB; WRAP; Local residents; Businesses; Investors; Developers; Waste contractors
	Fiscal framework	The biggest barriers to organic waste collection is financial. WCAs and WDAs should take a 'total budget' approach to balance higher organic waste collection costs with savings from disposal of less residual waste (i.e. organic waste is not landfilled), which can make it economic to fund this initiative. WCAs should offer a financial incentive (i.e. council tax rebate) to developers for installing automated waste collection systems. OPDC and WCAs to seek funding for the retrofit of organic waste collection systems and removal of single stream waste chutes. WCAs to provide incentives/rewards (e.g. Bexley Green Point Scheme) for residents to maximise participation in organic waste collection in high-density housing areas.	OPDC; WCAs; WDAs	Developers; Investors; Local residents

[82] Waste & Resources Action Programme (2016). *Food Waste Recycling Action Plan*. Available at: http://www.wrap.org.uk/content/food-waste-recycling-action-plan (Accessed 30 October 2016).
[83] London Assembly (2015). *Bag it or Bin it? Managing London's Food Waste*. Available at: https://www.london.gov.uk/about-us/london-assembly/london-assembly-publications/bag-it-or-bin-it (Accessed 30 October 2016).

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
	Education, information & collaboration	Develop and maintain educational awareness and behavioural change programmes to educate the public and businesses on the economic and environmental benefits of source segregation of organic waste. OPDC in partnership with the GLA, LWARB and WRAP to develop a clear and consistent London-wide communication strategy to encourage the participation in organic waste collection. OPDC to prepare developer guidance for the storage and collection of organic waste and other recyclables for all building types including high-rise building stock. OPDC and WCAs to learner from successful organic waste collection schemes such as Bexley in London and Milan in Italy. OPDC and WCAs to collect more reliable data regarding the collection of organic waste to plan more effective service provision. Link food manufacturing with LWARB's CE Business Support Programme – Advance London	OPDC; WCAs and WDAs;	LWARB, WRAP; Community groups; Housing associations; Developers; Architects; Local residents; Food and beverage manufacturers in Park Royal; Waste contractors; Social innovation enterprises; Association of London Cleansing Officers (ALCO); London Recycling Officers Group (LROG);
Centralised resource and energy centre	Education, information & collaboration	A centralised energy and resource centre will require the collaboration of developers who design buildings that facilitate the diversion of waste materials to a centralised resource and energy centre, local authorities who are responsible for municipal solid waste collection, commercial waste collection contractors and businesses or business groups to develop the centralised resource and energy centre. This could be set up using an organic material collaboration platform, procured by OPDC. OPDC to provide long-term direction and certainty regarding the organic waste collection and treatment. A business plan should be developed for the new centralised resource and energy centre. And LWARB will need to take a stronger brokerage role between waste industry, local authorities and other businesses to enable the provision of waste treatment infrastructure.	OPDC; LWARB; WCAs and WDAs	Waste contractors; Developers; Business groups; Social innovation enterprises; Food and beverage manufacturers in Park Royal

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Anaerobic digestion/energy generation from RDF/Energy generation from biomass	Regulatory frameworks	Renewables Obligation and Feed-in Tariffs provide economic incentives to implement renewable energy generation and associated electricity distribution infrastructure. The GLA and OPDC should lobby DBEIS and Ofgem to ensure the financial viability of these schemes.	DBEIS; Ofgem	Waste contractors; Investors; Developers
	Fiscal frameworks	OPDC, LWARB, GLA, business and local industry should evaluate the opportunities and business cases for investing in this infrastructure. Devolution of landfill tax to London would allow more investment into organic waste collection and treatment.	Central government; GLA; WDAs; Waste contractors; Investors; Developers	WCAs; Food and beverage manufacturers in the Park Royal; Businesses; Business groups
	Education, information & collaboration	The OPDC, LWARB and the GLA should work together to demonstrate the economic viability of on-site renewable energy generation and distribution compared to using energy from the National Grid. OPDC should commission open design competitions to explore local energy generation and storage possibilities at micro- and nano-grid scale, and incorporating energy sharing software and social systems appropriate to current and future Old Oak and Park Royal communities.	Process suppliers; energy start-ups; social innovation enterprises	Investors; Local authority; Food and beverage manufacturing businesses in Park Royal; Developers
	Technological forces	Innovation will be required to support low emissions treatment processes that are not objected by the local community. OPDC to work with industry partners and academia on innovation process to meet low carbon and clean air ambition including seeking funding sources.	OPDC; Process suppliers	Imperial College West; Knowledge Transfer Network (KTN); Investors
	Public procurement & infrastructure	GLA to use some of its land holdings to aid and enable (or directly provide) new treatment facilities for organic waste. New buildings should be designed with the required drainage infrastructure for green walls.	GLA; OPDC; Developers; Architects	

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Bioeconomy / organic waste to proteins, bioplastics etc	Education, information & collaboration	OPDC to work with Innovate UK and Academia to develop the evidence for further developing the bioeconomy identify and develop the further actions deeded to support this sector Showcasing the economic benefits of using a 'biorefinery' compared to conventional organic waste disposal routes. Set up a practical demonstration project in partnership with Innovate UK and industry partner.	OPDC; LWARB; Innovate UK; Academia	Imperial College West; KTN; Bio-Based and Biodegradable Industries Association (BBiA); Investors
Green walls	Regulatory frameworks	OPDC Planning regulations shall allow for a presumption in favour of the development of rooftop greenhouses and rooftop farming unless it causes due harm to the safety or security of buildings. OPDC should commission open design competitions and planning studies to explore airborne autonomous logistics for rooftops, in order to devise planning guidelines.	OPDC; Local authorities	
Rooftop greenhouses/ Rooftop farming	Education, Information & Collaboration	Pre-development: Investigation into the suitability of existing buildings to house rooftop greenhouses or other rooftop farming activities, including autonomous airborne logistics Pre-development: Collaboration between urban farmers, logistics companies, developers and building owners to identify and agree on roof space for use as well as other requirements. Post development: Accessible platforms hosting information portals and guidance, a forum for sharing experiences, expertise and volunteering opportunities. Procured by OPDC. Platforms could also host case studies of successful projects that could help to reassure stakeholders curious about the process, costs and benefits. OPDC should commission open design competitions and planning studies to explore subterranean urban farming methods.	OPDC; Urban farmers; Developers; Building owners; logistics companies	GLA; Local business leaders; Urban farming specialists; Rooftop farming specialists; Investors; Local community; autonomous logistics start-ups
	Fiscal Frameworks	Investment via mutually beneficial partnerships to develop rooftop greenhouses or other rooftop farming activities.	Urban farmers; Developers; Building owners; Businesses; Occupants; Local community	OPDC; Local authorities; Land owners; Local business leaders ; Urban farming specialists; Rooftop farming specialists
	Fiscal Frameworks	Incentives from local authority and development coordinators to promote and de-risk rooftop greenhouses or other rooftop farming activities (including logistics). These could include business rates	Local authority; developers; property owners/renters;	OPDC; Local authorities; Land owners; Local business leaders ; Urban

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
		discounts (funded through cost savings through circular initiatives), simple planning approval processes, and clear rules and regulations around insurance and liability.	businesses; social innovation enterprises	and rooftop food growing specialists; Developers; Investors ; Community; start-ups
Urban community gardens / Local food market	Education, Information & Collaboration	There shall be a presumption in favour of use for redundant space (either of a business, unoccupied building or public space) to locate local food markets where fruit and vegetables grown on rooftop greenhouses or other local urban farming activities can be sold. In particular, meanwhile spaces shall be allowed to be used for urban farming through the development stage. There shall be a presumption in favour of urban farming (and associated waste recovery) for meanwhile spaces. OPDC to encourage urban community gardens and community dining initiatives.	OPDC; Urban farmers; Local community; developers; housing associations	Local authorities; Businesses; Land owners; Local residents
Commercial food distribution	Education, Information & Collaboration	Link food manufacturing businesses in Park Royal with LWARB's CE Business Support Programme OPDC should commission open design competitions and planning studies to explore food manufacturing technologies linked to local autonomous logistics, in order to future-proof planning guidelines.	OPDC	LWARB; Food and beverage manufacturing businesses in Park Royal; Heathrow City businesses

7.2.2 Clean Tech Cluster

Table 12: Enabling factors for the Clean Tech Estate scenario

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Cluster development	Technological forces	Research and development by private companies and academia to develop clean technologies that can be commercialised. OPDC should work with the new Imperial College West to establish a platform for collaboration, business opportunities and investment between the research and spinoff companies at Imperial College West and the Clean Tech Cluster in Park Royal.	Academia; OPDC; private companies	Entrepreneurs
	Education, Information & Collaboration	The creation of a formal collaboration programme that links research and innovation at the Imperial College innovation campus at White City with Old Oak and Park Royal.	London Sustainable Development Commission; DBEIS	Imperial College London; Businesses; Business Groups; GLA

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
		OPDC should commission a series of collaboration projects concerning circular economy principles and opportunities focused on Old Oak and Park Royal, with Imperial College postgraduate researchers, with outcomes displays in meanwhile spaces at Old Oak and Park Royal and at Imperial College West campus. OPDC to enable a series of maker facilities as a core component of meanwhile space.		
Battery storage	Regulatory Frameworks	Regulation or policy incentives that promote driving electric vehicles (EVs) and facilitate the roll out of smart grids and micro-grids. All new parking spaces should be equipped with EV charging infrastructure, ensuring a presumption in favour of EVs. All developments shall also be required to host smart grid infrastructure for energy storage, battery charging and battery energy supply, as well as supporting connecting infrastructure for autonomous vehicles (AVs). Regulation or policy incentives that enable a Clean Tech Cluster at Old Oak and Park Royal to be a primary testing ground for AV networks. OPDC should commission open design competitions and planning studies to explore the impact of AVs onto planning and urban design guidelines. All housing providers, developers and local authorities will be required to produce fine grain data on mobility systems (including related environmental data points) across Old Oak and Park Royal, such that it can be incorporated into GLA London Datastore (whilst respecting commercial and privacy issues appropriately.)	DBEIS; Ofgem; GLA; OPDC	Imperial College researchers; Local authorities; Developers
	Regulatory Frameworks	Contractual agreements to facilitate flow of electricity between battery storage technologies, community-owned micro-grids and sharing systems, and the National Grid.	Entrepreneurs and start-ups; National Grid; social innovation enterprises	DBEIS; Ofgem; OPDC; Local authorities
	Technological forces	Advances in battery storage technology, EV and AV connectivity infrastructure, software and hardware developed by entrepreneurs and businesses in the market or academia for it to become a viable solution.	Entrepreneurs; Businesses; Academia	

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
	Public Procurement & Infrastructure	All public sector owned or rented buildings within OPDC shall be required to have smart grid development and underpinning technology connecting and communicating between storage facilities and the National Grid.	Entrepreneurs; Local energy company; Social innovation enterprises; Developers	
Overall	Education, Information & Collaboration	Holding a global 'Clean Tech Exhibition' in the Old Oak and Park Royal area to attract business and investment as well as to lure other clean tech companies into the area.	OPDC; London Sustainable Development Commission; Entrepreneurs;	
	Regulatory Frameworks	Supportive regulatory environment that guarantees reduced business rates and mandates the provision of infrastructure (e.g. workshops, physical test spaces and early stage manufacturing centres) with the right services (e.g. energy availability, rapid internet connectivity, meeting rooms etc).	DBEIS; HM Treasury	Developers; Local authorities; Entrepreneurs
	Regulatory Frameworks	Old Oak and Park Royal shall be able to enforce and regulate the necessary infrastructure changes (e.g. strategic zoning) to be used as a test bed for new clean technologies developed in the area.	OPDC; Local authorities	Developers; Land owners; DBEIS
	Fiscal and financial frameworks	The GLA and others shall develop investment proposals to incubate seed invested start-ups through to the growth investment stage. This will bring together investors, academia and clean tech companies. GLA will develop research and innovation agenda to access European and other funding for clean tech-related infrastructure and activities.	GLA; Chamber of Commerce and Industry; Financial institutions; Businesses	Academia; London Sustainable Development Commission; OPDC; Local authorities
	Education, Information & Collaboration	Promotion of the hub format (e.g. by creating information, expertise and resource sharing platforms) and demonstration of benefits to local businesses. OPDC should set up an agile governance entity, comprising local research stakeholders, in order to align clean tech-related existing and future development activities onto Old Oak and Park Royal. A business plan should be also developed for physical infrastructure on the clean tech estate.	Entrepreneurs; Businesses; Business groups; Academia	OPDC; Local authorities

7.2.3 Adaptable Development

Table 13: Enabling factors for the Adaptable Development scenario

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Meanwhile uses	Regulatory Frameworks	OPDC planning regulations shall help unlock land for temporary public uses (e.g. food market and temporary housing) though a streamlined planning process and "presumption in favour of meanwhile use" within certain prescribed uses and terms.	GLA; Local Authority; OPDC; Developers	Central government; Architects; Builders/ construction companies; Developers; Legal advisers; Academia; Banks and investors; and Community groups and individuals
Low impact construction materials and techniques; flexible design	Education, information and collaboration	Collaborative working groups (bringing together innovative designers, tech companies and educators) helping to integrate low impact techniques and design for flexibility concepts into mainstream education and training, subsequently disseminating them into standard practice.	Architects; Designers; Tech companies; Product suppliers	Central government; Architects; Builders/ construction companies; Developers; Legal advisers; Academia; Banks and investors; and Community groups and individuals
Mixed use, shared space and public space	Regulatory Frameworks	Local policy to promote adaptable mixed-use spaces, including planning regulation targets and incentives such as rent/land price reductions upon demonstration of a design's future adaptation and reuse potential, and ultimately performance (evidenced through real-time usage data). Criteria to be developed through collaboration between designers, builders, developers and local planning policy-makers. All housing providers and developers/operators will be required to produce fine grain data on building systems performance (including space utilisation as well as utility systems and related environmental outcomes), across entire lifecycle from pre-construction to end-of-life, across Old Oak and Park Royal, such that it can be incorporated into GLA London Datastore (whilst respecting commercial and privacy issues appropriately.)	OPDC; Industry groups	Central government; Architects; Builders/ Construction companies; Developers; Legal advisers; Academia; Banks and investors; Community groups and individuals

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Adaptable design	Education, information and collaboration	Promotion of cross-industry partnerships to catalyse design for flexibility pilots and collaborative projects (e.g. design competitions). Link projects with local research stakeholders, such as Imperial College, regarding design and construction innovation (including new materials research). LWARB's CE SME Business Support Programme - Advance London may be used to link and support stakeholders.	OPDC; Industry groups	Central government; Architects; Builders/ Construction companies; Developers; Legal advisers; Academia; Banks and investors; Community groups and individuals
Digital platforms	Education, information and collaboration	Collaboration between OPDC, developers and providers of digital solutions (e.g. sensors, BIM, cloud computing) to test and implement real time controls and space-on-demand services. OPDC should facilitate the creation or procurement of a coherent 'space-as-a-service' platform for Old Oak and Park Royal.	OPDC; Local Authorities; Developers; Tech companies; Academia	Central government; Architects; Builders/ construction companies; Developers; Legal advisers; Academia; Banks and investors; and Community groups and individuals.
Space-as-a-service	Fiscal frameworks	Funding and support for development of service-based business model development and testing of digital platforms hosting services. OPDC should set up an agile governance entity, comprising local research stakeholders, in order to align existing and future digital innovation development activities onto Old Oak and Park Royal.	OPDC; Developers; Tech companies	Central government; Architects; Builders/ Construction companies; Developers; Legal advisers; Academia; Banks and investors; Community groups and individuals
Circular procurement	Public procurement and infrastructure	Initiation of circular procurement trial by local authorities and OPDC. Incentives and targets for businesses and developers encouraging implementation of low impact materials use, pay-per-use and buy back services. Analysis of procurement potential including costs and benefits.	Local Planning Authority; OPDC; Local residents	Central government; GLA; LWARB; Architects; Builders/ Construction companies; Developers; Legal advisers; Academia; Banks and investors; Community groups and individuals

7.2.4 Sharing Community

Table 14: Enabling factors for the Sharing Community scenario

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Community-led development	Fiscal Frameworks	Promotion of government Housing Development Fund providing access to loan finance for custom build, small and medium builders, co-housing, and other innovative building methods. Local authorities and OPDC to agree incentives (e.g. tax breaks and land cost reductions) to encourage specialist developers and self-/custom-builders. Creation of policy to enable and encourage land owners to defer settlement on land until co-housing or small-/ medium-sized building entities are formed and construction is ready to commence. OPDC to commission open design competition into co-housing models for high-density development.	OPDC; Developers; Local residents; start-ups; Housing associations; Social innovation enterprises	DCLG; GLA; OPDC; Local Authority; Land owners
Community planning platform	Regulatory frameworks	Design and development of platform for citizen participation in planning and development, including match-funding through partnership with technology providers and oversight of regulatory aspects. OPDC to commission strategic design process to explore planning innovation possible in Old Oak and Park Royal, related to existence of such a platform. All housing providers, developers/operators and local authorities will be required to install open communications infrastructure to enable local platform development and operations. OPDC to mandate interoperable system design and operations.	Local Authority; OPDC; Local residents; Technology providers	DCLG; GLA; Central government; Architects; Builders/ Construction companies; Developers; Legal advisers; Banks and investors; Community groups and individuals
Community-owned Energy Services Company (ESCo)	Fiscal frameworks	Provision of tax breaks and other financial incentives to facilitate creation of community ESCos to oversee community energy projects including renewable energy generation, demand response services, battery storage sharing mechanisms, trust-based local exchange systems, and micro-grids. OPDC shall run open competition for development of digital platform and infrastructure for local energy sharing networks.	Local Authority; OPDC; Local residents; IDNOs; Technology providers; Banks; social innovation enterprises	
Shared resource platform	Education, Information & Collaboration	OPDC should facilitate the creation or procurement of a coherent platform for shared learning, and skills development for Old Oak and Park Royal Creation, to enable access to shared resource repositories (e.g. skill-sharing networks, tool bank).	Local Authority; OPDC; Local residents	

Initiative	Enabler category	Description of enabler	Lead stakeholder	Other stakeholders
Community-owned infrastructure	Education, Information & Collaboration	Initiation of community-expertise groups to facilitate engagement between energy, water, materials, waste, mobility and technology companies, social innovation enterprises, and residents to understand infrastructure priorities, challenges and opportunities for communities in Old Oak and Park Royal.	Local Authority; OPDC; Local residents; social innovation enterprises	
Shared space platform	Education, Information & Collaboration	Education campaigns to promote value of sharing and on-demand services, creating longer term support from residents resulting in lasting behaviour change.	Local Authority; OPDC; Local residents	
Circular economy team (CET)	Education, information and collaboration	Develop a CET comprised of communications and community engagement specialists who can liaise with the specific programme and specialist teams within the councils to develop education, information and awareness programmes raising local involvement and knowledge about circular initiatives, as well as design, develop or procure digital platforms. All housing providers, commercial developer/ operators and local authorities will be required to install open communications infrastructure to enable local platform development and operations. OPDC to mandate interoperable system design and operations, and to be responsible for data on infrastructure systems (including shared infrastructure systems) across Old Oak and Park Royal, to be incorporated into GLA London Datastore (whilst respecting commercial and privacy issues appropriately.)	Local Authority; OPDC; Local residents	GLA; Developers

7.3 Stakeholder engagement

Stakeholder engagement: Regeneris

- A clean tech cluster in Old Oak and Park Royal is recommended by the London Sustainable Development Commission. The development of a major innovation campus by Imperial College at White City and the simultaneous redevelopment of Old Oak and Park Royal brings together Europe's top technical university and Europe's largest urban redevelopment. It has the clear potential to provide a home of global significance for the cleantech sector in London. The development of the Imperial College White City science and innovation campus could be an intellectual and creative seed for a clean tech cluster that spreads out into the neighbouring development.

Input to deliverables

- The idea of one of the scenarios is a 'Clean Tech Estate'.

Next steps

- OPDC to consider inplementation of a 'Clean Tech Estate' cluster based on the findings of the Regeneris report and further discussion with the masterplanning team for Old Oak and Park Royal

Figure 20: Stakeholder engagement – Regeneris

Stakeholder engagement: Lori Hoinkes, Park Royal Business Manager at OPDC

- Food manufactures are a main target sector
- The Park Royal area has maximised its energy demand from the grid. Any additional energy requirements and associated infrastructure have to be funded by the company that require the additional energy
- Suggested to explore anaerobic digestion (especially with food waste and energy demand issues)
- Logistics companies seem to have already optimised their business in terms of optimising vehicle use and storage space, but there may be scope in reducing vehicles on the road and reducing use of corrugated cardboard (maybe some potential to link with food manufactures)
- It will be difficult to implement an initiative with a single company; it is better to identify clusters to implement an initiative for
- Little capacity for companies to expand operations. Future development will be more about intensification of the area
- Growth sectors including clean tech identified by Regeneris will only emerge if they need to be in or in close proximity to London, and if the right infrastructure and workspaces are available for them to use
- Lori Hoinkes is able to help approach specific companies for resource flows as engagement with the Park Royal businesses is part of her team's remit

Input to deliverables

- Anaerobic digestion explored as part of 'The Royal Garden' scenario
- Other decentralised renewable forms of energy are explored as part of the scenarios including refused derived fuel, biomass, solar photovoltaics and secondary heat use
- Intensifcation built into 'The Royal Garden' scenario
- With the help of Lori Hoinkes and Rachel Thevanesan at OPDC, the following companies have been approached to obtain resource flows (materials, waste, water, wastewater, energy, surpluss energy) for their site: Dephna, Charlie Bingham's, See Woo Food & Panalux, McVities, Greencore, Central Middlesex Hospital, Asda, Vale Inco and Bakkavor. Due to delays, the information was not received in time to include in the resource flow model. Dephna, Central Middlesex Hospital and Vale Inco have already expressed interest in being invovled

Next steps

- It is suggested that Lori Hoinkes and Rachel Thevanesan continue obtaining resource flows from the selected companies to help identify industrial symbiosis opportunities
- To build on this, it is suggested to involve the Park Royal User Group to obtain breadth of data and widen scope of the companies involved

Figure 21: Stakeholder engagement – Lori Hoinkes, Park Royal Business Manager at OPDC

Stakeholder engagement: Powerday

- 7.5acre (three hectares) site with road, rail and canal access
- Licensed to process 1.6 million tonnes in total with specific licensed quantities for waste delivered by road, rail and canal
- Currently only uses road for the delivery and removal or waste from site. Currently, no economic incentives to use canal
- Long-term lease with aspirations to stay on current site. Already in talks with HS2 Ltd to provide construction waste management services for them
- Definitely considering the removal of materials during the development period by rail and canal
- Wood chips sent to biomass plants across the country
- Majority of RDF generated on-site gets exported to Germany and Sweden although Powerday will soon be sending it to the new gasification plant in Hoddeson, Hertforshire
- Are considering a ~50,000tpa energy centre on-site using pyrolysis or gasification technologies
- However, they are open to new suggestions and are not 100% set on having an energy centre if another opportunity presents itself. They are open to negotiations of phasing out construction waste treatment during the development period to become a resource hub to service the waste generated by the development (potentially using an automated waste collection system)
- Interested in exploring building on decks above railway lines to create land value as in Canary Wharf

Input to deliverables

- Powerday's openness to changes in their future operations has put them at the heart of 'The Royal Garden' scenario
- The different forms of transport that are currently underutilised are also part of 'The Royal Garden' scenario
- All renewable energy sources that Powerday currently export off-site are considered as part of 'The Royal Garden' scenario
- Building on decks considered as part of the 'High Density Living' scenario

Next steps

- To continue engaging with Powerday mangement sector about OPDC's potential ideas about the Powerday site, and also other companies in the resource management sector (e.g. SUEZ)

Figure 22: Stakeholder engagement – Powerday

Stakeholder engagement: Veolia

- Veolia' operational expertise span across water, waste and energy
- They are beginning to think about resource management from a circular systems and business perspective
- They provided OPDC with a suggested integrated water, waste and energy strategy
- OPDC have been approached by other waste/resource companies but are interested in bringing in a commercial partner like Veolia to support future work looking at the business rational for circularity

Input to deliverables

- Their integrated water, waste and energy strategy is similar to the work that Arup have been commission to do, so there was no input into any deliverables

Next steps

- It is suggested to compare and contrast the work done by Veolia with the work done by Arup to understand the differences in the flows, metrics and technologies that sit behind the respective models
- Veolia are to consider if being a commercial partner to OPDC is something they would be interested in

Figure 23: Stakeholder engagement – Veolia

Stakeholder engagement: Hawkins Brown

- From the initial description of the scenarios, Hawkins Brown have identified two potential areas where the circualr economy inititives could be applied. This includes an area new Willesden Junction and an area near Victoria Street Estate

Input to deliverables

- Overall scenario development for the Old Oak and Park Royal development areas.

Next steps

- Hawkins Brown to consider including circular economy initiatives for Clean Tech and the Royal Garden in Willesfen Junction and Victoria Street Estate.

Figure 24: Stakeholder engagement – Hawkins Brown

8 Action Plan: delivering the circular economy in Old Oak and Park Royal

8.1 Overview

This study has outlined the evidence base and framework for implementing circular economy principles within the OPDC area. In order to take this research forward to the next step of deliverability, OPDC, LWARB and other stakeholders will need to commission further analysis and feasibility studies. These are outlined in the sections below.

8.2 Briefs for future circular economy work and studies

Five key areas have been identified for further developing circular economy policies, programmes and investments in Old Oak and Park Royal. These include:

1. **OPDC Infrastructure Development Plan for the Circular Economy.** The Infrastructure Delivery Plan (IDP) identifies OPDC's infrastructure requirements including social, physical and green infrastructure. The IDP sets out what is needed, where it is needed and when it is needed. It should also provide an update on the delivery of the required infrastructure to date. Each infrastructure type should be accompanied by an Infrastructure Delivery Schedule, which provides further detail on delivery, funding sources, costs and identifies whether there are any funding gaps. The IDP should be updated on an annual basis to support the Local Plan.
2. **Supplementary Planning Document (SPD) for OPDC Circular Economy policies**. It provides a framework which will guide development over the development period, ensuring that regeneration is coordinated, sustainable and embodies the circular economy principles. The SPD well be part of the OPDC framework of planning documents, and it will be a material planning consideration in deciding planning applications in the Opportunity Area.
3. **Individual project feasibility studies and business cases.** Whenever the public sector is considering new policies or investments, they should carry out the appropriate assessments to support making the best decision. According to HM Treasury Green Book, "All new policies, programmes and projects, whether revenue, capital or regulatory, should be subject to comprehensive but proportionate assessment, wherever it is practicable, so as best to promote the public interest." Feasibility studies and the various iterations of business cases should be conducted on activities covered by the Green Book including:
   - Policy and programme development;
   - New or replacement capital projects;
   - Use or disposal of existing assets;
   - Specification of regulations; and
   - Major procurement decisions.

4. **Impact Assessments for Circular Economy Programme: Implementation into Planning Policy.** A range of impact assessments are likely to be required for adopting circular economy principles into OPDC planning policy and for the implementation of major policies, programmes and investments. These impact assessments may include:

   - Equality Impact Assessments;
   - Social Impact Assessments;
   - Environmental Impact Assessments;
   - Health Impact Assessments; and
   - Sustainability Impact Assessments.

   Conducting such assessment can also help improve the strategic and economic cases for certain policies, programmes and investments by taking into account the wider benefits of circular economy projects which may not be properly assessed or valued otherwise.

5. **Baseline studies for long-term evaluation**. Economic, social and environmental baseline studies will be required to conduct a proper evaluation of the impacts of circular economy measures in the OPDC area. This evaluation will give OPDC and government an understanding of the impacts of the circular economy which is informed by a comparison with what would have happened without it; help to shape and inform the way we think about the circular economy in London and the UK; inform the planning of future major infrastructure and regeneration schemes; and contribute to the sparse wider evidence base on the impact of circular economy on economic, social and environmental outcomes.

8.3 Next steps

Research and stakeholder engagement are considered the most pressing and relevant next steps. For each of the four circular economy scenarios, a process of planning and evaluation will help to identify which activities can be initiated immediately and which require further scheduling, engagement and funding.

8.3.1 Scenario planning and further research

- Draft a plan for practically initiating activities under each scenario; include cost estimates, timings and prospective partners for each.
- Evaluate potential changes required to planning and other local regulations to facilitate delivery of circular economy solutions.
- Start to identify barriers and build business cases to support solutions considered challenging to implement.

Examples of planning activities for each scenario:

- Scenario 1 – conduct research into best practice food growing techniques and technologies, for example, most appropriate food crops for rooftops and green spaces taking into account climate, water and energy requirements, transportation capacity and lifespan, costs and materials requirements.

- Scenario 2 – update energy requirement calculations for Park Royal and engage local energy providers to consider possibility of joining local district heat networks in Wembley and White City.
- Scenario 3 – plan meanwhile activities by assessing available space, investigate planning requirements and funding opportunities, identify potential partners.
- Scenario 4 – identify examples of best practice in community-led development and community-owned infrastructure. Assess structural and contractual underpinnings and feasibility for Old Oak and Park Royal.

8.3.2 Stakeholder engagement

- Fulfil existing commitments and plan future engagement opportunities with existing contacts, for example, with Park Royal businesses, Powerday, Middlesex Hospital, Veolia, West London Business etc.
- Identify other/new local stakeholders and initiate early engagement to understand priorities and synergies. For example, initial conversations may be set up with digital technology providers to understand requirements to implement systems, e.g. integrated transport systems and autonomous vehicle roll-out.
- Establish a stakeholder engagement plan to capture all current and future activities and regularly assess outcomes, challenges and further opportunities.
- Engage with local council, OPDC partners, designers and contractors to introduce circular economy principles and encourage them to create their own circular economy plans.
- Conduct workshops to promote circular economy planning and support stakeholders to understand and identify opportunities and increase collaboration.
- Initiate an information sharing service (email or social media platform) to keep stakeholders informed, promote networking and plan ahead.

Appendix A

Resource flow modelling assumptions

Appendix A: Resource flow modelling assumption

Assumption	Value	Units	Comment	Source
Population				
Households				
Existing residential units	2,800	households		OPDC (2016). Draft Local Plan.
Additional residential units	26,804	households	Total housing provision from OPDC 'Design and Technical Study Input' column (26,247 households) plus hotel and student accommodation provided (26,804 households)	OPDC - Phasing Trajectory v5
Total residential units	29,604	households	Calculated value	-
Residential unit density - Brent	2.684	capita/household	Average between 2011 and 2036 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Residential unit density - Ealing	2.642	capita/household	Average between 2011 and 2036 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Residential unit density - Hammersmith & Fulham	2.280	capita/household	Average between 2011 and 2036 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Residential unit density - Average	2.535	capita/household	Calculated average	-
Residential population	75,053	capita	Calculated value	-

Assumption	Value	Units	Comment	Source
Employees				
Existing employee population	36,000	employees		OPDC (2016). Draft Local Plan.
Additional employee population - Old Oak	59,000	employees	3,108 new retail jobs / 56,000 new office jobs	OPDC (2016). Development Capacity Study.
Additional employee population - Park Royal	12,100	employees	300 new retail jobs / 11,800 new industrial jobs	OPDC (2016). Development Capacity Study.
Additional employee population - Total	71,100	employees		OPDC (2016). Development Capacity Study.
Total employee population	107,100	employees	Calculated value	-
Total material consumption				
High level materials				
Biomass consumption	2.76	tonnes/capita/annum	UK Domestic Material Consumption (DMC) 2015	European Commission (2015). Material Flow Accounts and Resource Productivity: Tables and Figures.
Metal ores consumption	0.23	tonnes/capita/annum	UK Domestic Material Consumption (DMC) 2015	European Commission (2015). Material Flow Accounts and Resource Productivity: Tables and Figures.
Non-metallic minerals consumption	3.50	tonnes/capita/annum	UK Domestic Material Consumption (DMC) 2015	European Commission (2015). Material Flow Accounts and Resource Productivity: Tables and Figures.
Fossil energy materials consumptions	2.38	tonnes/capita/annum	Fossil energy materials includes fossil fuel sources used to generate energy and materials. There may be	European Commission (2015). Material Flow Accounts and Resource Productivity: Tables and Figures.

Assumption	Value	Units	Comment	Source
			some double counting with energy demand.	
Household material consumption (specific examples of consumption)				
Fresh green vegetables	0.009	tonnes/capita/annum		Department for Environment, Food & Rural Affairs (2015). Family Food 2014.
Fruit and vegetable consumption	0.113	tonnes/capita/annum		Department for Environment, Food & Rural Affairs (2015). Family Food 2014.
Food consumption	0.308	tonnes/capita/annum	Calculated value (excludes liquids and eggs)	Department for Environment, Food & Rural Affairs (2015). Family Food 2014.
Household waste generation				
Household waste generation rate - Brent	0.301	tonnes/capita/annum	Calculated value	-
Household waste generation rate - Ealing	0.293	tonnes/capita/annum	From 2016-2036	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Household waste generation rate - H&F	0.316	tonnes/capita/annum	From 2016-2036	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Household waste generation rate - Average	0.303	tonnes/capita/annum	Calculated average	-
Organic waste composition	40%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Paper & cardboard waste composition	22%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional

Assumption	Value	Units	Comment	Source
				Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Plastics waste composition	11%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Glass waste composition	7%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Metals waste composition	3%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Wood waste composition	1%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Textiles waste composition	3%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Inerts waste composition	4%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.

Assumption	Value	Units	Comment	Source
Residual waste composition	7%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
WEEE waste composition	1%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Hazardous waste composition	1%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Total waste composition	100%	%		Department for Environment, Food & Rural Affairs (2013). EV0801 National Compositional Estimates for Local Authority Collected Waste and Recycling in England 2010/11.
Commercial and industrial waste generation				
Commercial and industrial waste generation rate	0.969	tonnes/employee/annum	2016 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Commercial and industrial waste generation rate	0.937	tonnes/employee/annum	2021 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Commercial and industrial waste generation rate	0.905	tonnes/employee/annum	2026 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Commercial and industrial waste generation rate	0.875	tonnes/employee/annum	2031 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP

Assumption	Value	Units	Comment	Source
Commercial and industrial waste generation rate	0.845	tonnes/employee/annum	2036 value	GLA & SLR Consulting Final Waste Arisings Model 6 Feb 2014 FALP
Commercial and industrial waste generation rate - average	0.906	tonnes/employee/annum	Calculated average	-
Animal & vegetable waste composition	16%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Chemical waste composition	8%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Common sludges composition	0%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Discarded equipment composition	4%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Healthcare waste composition	6%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Metallic waste composition	6%	%	Average C&I waste generation in LB Brent,	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.

Assumption	Value	Units	Comment	Source
			Ealing and Hammersmith & Fulham	
Mineral waste composition	3%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Non-metallic waste composition	58%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Non-waste composition	0%	%	Average C&I waste generation in LB Brent, Ealing and Hammersmith & Fulham	Department for Environment, Food & Rural Affairs (2010). Survey of Commercial and Industrial Waste Arisings - Report tables 2009.
Construction, demolition and excavation waste generation				
Additional residential units	26,804	households	Total housing provision from 'Design and Technical Study Input' column (26,247 households) plus hotel and student accommodation provided (26,804 households)	OPDC - Phasing Trajectory v5
Residential usable space	94	m^2	In 2014, homes had an average usable floor space of 94 square metres	Department for Communities and Local Government (2016). English Housing Survey Housing Stock Report 2014-15.
Residential development area	2,519,548	m^2	Estimated floor space	-

Assumption	Value	Units	Comment	Source
Office development area	660,360	m^2	Total office floor space provision from 'Design and Technical Study Input' column	OPDC - Phasing Trajectory v5
Retail development area	44,018	m^2	Total retail and leisure floor space provision from 'Design and Technical Study Input' column. OPDC Retail and Leisure Needs study suggests potential retail floor space is 3 times more than potential leisure space	OPDC - Phasing Trajectory v5
Leisure development area	14,673	m^2	Total retail and leisure floor space provision from 'Design and Technical Study Input' column. OPDC Retail and Leisure Needs study suggests potential retail floor space is 3 times more than potential leisure space	OPDC - Phasing Trajectory v5
Industrial development area	57,400	m^2	Represents designated new industrial development areas (i.e. Strategic Industrial Locations), which reflects existing industrial uses rather than replacing non-industrial uses - as described by Peter	OPDC (2016). Draft Local Plan.

Assumption	Value	Units	Comment	Source
			Farnham, OPDC Principal Planning Officer	
Commercial residential construction waste generation rate	0.168	tonnes/m^2		Building Research Establishment (2012). Waste Benchmark Data.
Commercial office construction waste generation rate	0.238	tonnes/m^2		Building Research Establishment (2012). Waste Benchmark Data.
Commercial retail construction waste generation rate	0.275	tonnes/m^2		Building Research Establishment (2012). Waste Benchmark Data.
Commercial leisure construction waste generation rate	0.216	tonnes/m^2		Building Research Establishment (2012). Waste Benchmark Data.
Commercial industrial construction waste generation rate	0.126	tonnes/m^2		Building Research Establishment (2012). Waste Benchmark Data.
Average floor height	3	m	Assumption	-
1A demolition volume (steel frame)	135,632	m^3	Buildings to be demolished: Portal West Business Centre, The Portal, Ramada Encore Hotel and two other buildings	OPDC Demolition Schedule
1B demolition volume (structural concrete)	13,394	m^3	Buildings to be demolished: Newly built, not yet occupied	OPDC Demolition Schedule
2 demolition volume (structural concrete)	120,466	m^3	Buildings to be demolished: Perfume factory and Victoria Industrial Estate	OPDC Demolition Schedule

Assumption	Value	Units	Comment	Source
3 demolition volume (masonry)	2,309	m^3	Buildings to be demolished: Esso station and two other buildings	OPDC Demolition Schedule
4 demolition volume (-)	0	m^3	-	OPDC Demolition Schedule
5 demolition volume (masonry)	112,520	m^3	Buildings to be demolished: Westway Estate and Brunel House	OPDC Demolition Schedule
6 demolition volume (steel frame)	317,818	m^3	Buildings to be demolished: Torpedo Factory, Chandos Park Industrial Estate, Europa Studios, Boden House, Waitrose, Lewis House, HR Owen, Acton Business Centre, Hedley Humpers, Bestway Cstering, Jack Wills, Braitrim House and other buildings	OPDC Demolition Schedule
7 demolition volume (steel frame)	61,208	m^3	Buildings to be demolished: Chandelier Building, Pentacostal City Mission Inc, Willesden Diesel Locomotive Depot and two other buildings	OPDC Demolition Schedule
8 demolition volume (steel frame)	310,264	m^3	Buildings to be demolished: Apex Industrial Estate, Gateway Trading Estate, Hyrthe Road Industrial Estate and Regents House	OPDC Demolition Schedule

Assumption	Value	Units	Comment	Source
9 demolition volume (steel frame)	37,326	m^3		OPDC Demolition Schedule
10 demolition volume (steel frame)	34,737	m^3		OPDC Demolition Schedule
11A demolition volume (steel frame)	13,403	m^3	Buildings to be demolished: Triangle Business Park	OPDC Demolition Schedule
11B demolition volume (masonry)	5,254	m^3		OPDC Demolition Schedule
12 demolition volume (steel frame)	7,887	m^3		OPDC Demolition Schedule
13 demolition volume (steel frame)	28,356	m^3	Buildings to be demolished: Powerday Recycling Centre	OPDC Demolition Schedule
14 demolition volume (steel frame)	20,636	m^3		OPDC Demolition Schedule
15A demolition volume (steel frame)	26,800	m^3	Buildings to be demolished: Railyard	OPDC Demolition Schedule
15B demolition volume (steel frame)	26,800	m^3	Buildings to be demolished: Railyard	OPDC Demolition Schedule
16 demolition volume (steel frame)	97,131	m^3	Buildings to be demolished: Railyard	OPDC Demolition Schedule
17 demolition volume (-)	0	m^3		OPDC Demolition Schedule
18 demolition volume (steel frame)	58,435	m^3		OPDC Demolition Schedule

Assumption	Value	Units	Comment	Source
19 demolition volume (steel frame)	31,462	m^3		OPDC Demolition Schedule
Steel frame demolition waste generation rate	0.470	tonnes/m^3		WRAP Net Waste Tool - Demolition Bill of Quantities Estimator
Structural concrete demolition waste generation rate	0.480	tonnes/m^3		WRAP Net Waste Tool - Demolition Bill of Quantities Estimator
Masonry demolition waste generation rate	0.540	tonnes/m^3		WRAP Net Waste Tool - Demolition Bill of Quantities Estimator
Excavation waste generation rate	0		Scoped out due to early stage of project and therefore unavailable information	-
Development period	32	years	Construction period assumed from 2017 to 2049 seeing as residential units are planned to come online in 2018 with the last residential units planned to come online in 2049	OPDC - Phasing Trajectory v5
Powerday materials received on-site				
Construction waste - 2014	198,894	tonnes/annum	Latest available data that there is associated materials removed from site data for	OPDC (2016). Waste Strategy.
MSW + C&I waste - 2014	147,428	tonnes/annum	Latest available data that there is associated materials removed from site data for	OPDC (2016). Waste Strategy.

Assumption	Value	Units	Comment	Source
Total - 2014	**346,322**	**tonnes/annum**	**Calculated value**	
Powerday materials removed from site				
Paper & Cardboard - 2014	90	tonnes/annum	0%	Environment Agency Waste Data Interrogator 2015
Plastic - 2014	237	tonnes/annum	0%	Environment Agency Waste Data Interrogator 2015
Metals - 2014	10,107	tonnes/annum	3%	Environment Agency Waste Data Interrogator 2015
Wood - 2014	28,942	tonnes/annum	9%	Environment Agency Waste Data Interrogator 2015
Bricks, concrete, gypsum, mixed construction and demolition, soils and stones, tiles, ceramics - 2014	153,092	tonnes/annum	47%	Environment Agency Waste Data Interrogator 2015
RDF - 2014	72,218	tonnes/annum	22%	Environment Agency Waste Data Interrogator 2015
Other - 2014	63,789	tonnes/annum	19%	Environment Agency Waste Data Interrogator 2015
Total - 2014	328,475	tonnes/annum	100%	Environment Agency Waste Data Interrogator 2015
Energy demand				
Total residential units	29,604	households		OPDC - Phasing Trajectory v5

Assumption	Value	Units	Comment	Source
Commercial development area	660,360	m^2	Total office floor space provision from 'Design and Technical Study Input' column	OPDC - Phasing Trajectory v5
Retail development area	44,018	m^2	Total retail and leisure floor space provision from 'Design and Technical Study Input' column. OPDC Retail and Leisure Needs study suggests potential retail floor space is 3 times more than potential leisure space	OPDC - Phasing Trajectory v5
Leisure development area	14,673	m^2	Total retail and leisure floor space provision from 'Design and Technical Study Input' column. OPDC Retail and Leisure Needs study suggests potential retail floor space is 3 times more than potential leisure space	OPDC - Phasing Trajectory v5
Industrial development area	57,400	m^2	Represents designated new industrial development areas (i.e. Strategic Industrial Locations), which reflects existing industrial uses rather than replacing non-industrial uses - as described by Peter	OPDC (2016). Draft Local Plan.

Assumption	Value	Units	Comment	Source
			Farnham, OPDC Principal Planning Officer	
Boiler efficiency	85%	%	Standard operational efficiency	-
Residential electricity demand	2,823	kWh/household/annum	Calculated average over development period 2018-2050	Standard Assessment Procedure (SAP) results for typical development modelled at different building codes
Residential heating demand	3,115	kWh/household/annum	Calculated average over development period 2018-2050	Standard Assessment Procedure (SAP) results for typical development modelled at different building codes
Commercial electricity demand	95	kWh/m^2/annum	Modelled on 'General office'. Demand includes lighting, cooling, employee appliances, standard IT, basic tea room	CIBSE (2008). Energy Benchmarks - TM46:2008.
Commercial heating demand	102	kWh/m^2/annum	Calculated by multiplying fossil-thermal typical benchmark (kWh/m^2) with boiler efficiency	CIBSE (2008). Energy Benchmarks - TM46:2008.
Retail electricity demand	165	kWh/m^2/annum	Modelled on 'General retail'. Demand includes lighting, cooling,appliances for small number of employees	CIBSE (2008). Energy Benchmarks - TM46:2008.
Retail heating demand	0	kWh/m^2/annum	Calculated by multiplying fossil-thermal typical benchmark (kWh/m^2) with boiler efficiency	CIBSE (2008). Energy Benchmarks - TM46:2008.

Assumption	Value	Units	Comment	Source
Leisure electricity demand	95	kWh/m^2/annum	Modelled on 'Dry sports and leisure facility'. Demand includes lighting and basic office equipment	CIBSE (2008). Energy Benchmarks - TM46:2008.
Leisure heating demand	281	kWh/m^2/annum	Calculated by multiplying fossil-thermal typical benchmark (kWh/m^2) with boiler efficiency	CIBSE (2008). Energy Benchmarks - TM46:2008.
Industrial electricity demand	120	kWh/m^2/annum	Modelled on 'Manufacturing - light'. Electricity demand assumed to equal 'other uses' of building related energy and all process related energy	CIBSE Guide F (2012). Energy Efficiency in Buildings.
Industrial heating demand	286	kWh/m^2/annum	Modelled on 'Manufacturing - light'. Heat demand assumed to equal 'space heating' of building related energy	CIBSE Guide F (2012). Energy Efficiency in Buildings.
Secondary heat				
Available heat for MSOA: Brent 027 (E02000119)				
Open loop ground source abstraction	551	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Closed loop ground source abstraction	15,492	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
Air source heat pumps	176,250	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Office	4,590	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Retail	10,000	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Gyms	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Industrial sources part B processes	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Supermarkets	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Data centres	167,905	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
National grid infrastructure	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
UKPN infrastructure	2,948	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Sewer heat mining	2,273	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Total	380,009	MWh	Calculate value	-
Available heat for MSOA: Ealing 015 (E02000252)				
Open loop ground source abstraction	147	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
Closed loop ground source abstraction	4,061	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Air source heat pumps	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Office	532	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Retail	5,661	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Gyms	280	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Industrial sources part B processes	499	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Supermarkets	1,854	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Data centres	27,781	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
National grid infrastructure	29,200	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
UKPN infrastructure	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Sewer heat mining	3,353	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Total	73,368	MWh	Calculated value	-

Assumption	Value	Units	Comment	Source
Available heat for MSOA: Hammersmith & Fulham 001 (E02000372)				
Open loop ground source abstraction	141	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Closed loop ground source abstraction	3,996	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Air source heat pumps	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Office	3,841	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Retail	5,698	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Gyms	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Industrial sources part B processes	1,058	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Supermarkets	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Data centres	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
National grid infrastructure	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
UKPN infrastructure	0	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
Sewer heat mining	3,113	MWh	2013 available low grade heat	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Total	17,847	MWh	Calculated value	-
Water inflow				
Potable demand	2,803	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Non-potable demand	902	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Precipitation	4,144	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Water outflow				
Blackwater	1,912	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Greywater	1,738	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Stormwater	1,728	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Roof water	1,099	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Infiltration	-		unknown value	OPDC (2016). Integrated Water Management Strategy.
Evapotranspiration	-		unknown value	OPDC (2016). Integrated Water Management Strategy.

Appendix B

Resource flow model assumptions for circular economy initiatives

Appendix B: Resource flow model assumption for CE initiatives

Assumption	Value	Units	Comment	Source
Aerobic composting of organic waste				
Compost generation from organic waste	50%	%	The aerobic composting process reduces the input organic waste by approximately 50% in mass and 80% in volume	http://www.2cg.ca/pdffiles/2cgOrganicWasteOverview.pdf
Anaerobic digestion				
Solid digestate generation from feedstock	30%	%	About 70% mass reduction	Based on information from Braunschweig Biowaste Plant, Germany
Biogas yield per tonne	140	m^3/tonne	110-170m^3/tonne	Eunomia (2007). Feasability Study Concerning AD in Northern Ireland.
Methane content of biogas	60%	%	Approximately 60% methane and 40% carbon dioxide	-
Calorific value of biogas	40	MJ/m^3	CV methane 40MJ/m^3 (890.61 kJ/mol)	UK National Physical Laboratory
Electricity generation efficiency	30%	%	CHP gas engine 30% efficiency	-
MJ to kWh conversion	0.28	kWh/MJ		-
Parasitic load	15%	%		-
Heat generation	300	kWh/tonne		Based on information from Braunschweig Biowaste Plant, Germany

Assumption	Value	Units	Comment	Source
Process heat requirements (if thermophilic process)	60%	%	About 50-60%	Based on information from Braunschweig Biowaste Plant, Germany
Compost generation from solid digestate	80%	%		Based on information from Braunschweig Biowaste Plant, Germany
Biomass pellet production from solid digestate	31%	%		WRAP (2012). Driving Innovation in AD Optimisation - Uses for Digestate.
Energy generation from refuse derived fuel				
Net calorific value of refuse derived fuel	19	MJ/kg	High quality RDF produced with NCV 19-22 MJ/kg	Based on information from Larnaca MBT Plant, Cyprus, and information provided in WRAP (2012). A Classification Scheme to Define the Quality of Waste Derived Fuels.
Annual plant operational hours	8,000	hours	Minimal down time	-
Electricity generation efficiency	28%	%	Modelled as combustion. CHP gas engine 30% efficiency	-
Parasitic load	10%	%	Calculated using the heat and electricity produced compared with the heat and electricity exported	European Commission (2006). Integrated Pollution Prevention and Control: Reference Document on the Best Available Techniques for Waste Incineration.
Heat generation efficiency	50%	%		-
Bottom ash generation	25%	%	The bottom ash typically represents around 20%-30% of the original waste feed. The average value has been taken.	Defra (2013). Incineration of Municipal Solid Waste.
Energy generation from biomass				
Net calorific value of wood chips	16.23	MJ/kg	Modlled on 'Treated wood - Others'	ECN Phyllis classification

Assumption	Value	Units	Comment	Source
Annual plant operational hours	8,000	hours	Minimal down time	-
Electricity generation efficiency	28%	%	Modelled as combustion. CHP gas engine 30% efficiency.	-
Parasitic load	10%	%	Calculated using the heat and electricity produced compared with the heat and electricity exported	European Commission (2006). Integrated Pollution Prevention and Control: Reference Document on the Best Available Techniques for Waste Incineration.
Heat generation efficiency	50%	%		
Bottom ash generation	3%	%	The bottom ash from the process would represent 1% to 5% of the total throughput. Therefore, an average value has been undertaken.	https://democracy.kent.gov.uk/Published/C00000138/M00002815/AI00012693/$ItemC1RidhamDockRoadIwade.docA.ps.pdf
Food production				
Raised beds on green roofs				
Growing medium required for growing Amaranth	0.18	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Arugula	0.00	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Asparagus	0.40	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Beans (grown on pole)	0.11	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Beets	0.09	m^3	Calculated value - area required for growth multiplied by root depth	-

Assumption	Value	Units	Comment	Source
Growing medium required for growing Broccoli	0.20	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Brussels Sprouts	0.24	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Cabbage	0.24	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Carrots	0.02	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Cauliflower	0.26	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Celery	0.03	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Corn	0.27	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Cucumber	0.28	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Eggplant	0.70	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Kale	0.09	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Lettuce (head)	0.15	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Onions	0.01	m^3	Calculated value - area required for growth multiplied by root depth	-

Assumption	Value	Units	Comment	Source
Growing medium required for growing Peas	0.06	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Peppers	0.15	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Potatoes	0.08	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Radish	0.00	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Spinach	0.12	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Squash	0.53	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Strawberry	0.06	m^3	Calculated value - area required for growth multiplied by root depth	-
Growing medium required for growing Tomatoes	0.64	m^3	Calculated value - area required for growth multiplied by root depth	-
Portion of growing medium that is organic compost	25%	%		http://cssf.usc.edu/History/2012/Projects/J1904.pdf http://forums2.gardenweb.com/discussions/1612021/topsoil-compost-ratio-newbie-question
Number of times organic compost applied	2	applications/ annum		-
Density of organic compost	0.6	tonnes/m^3		http://www.severnwaste.com/composting/greengrow/

Assumption	Value	Units	Comment	Source
				http://open-furrow.soil.ncsu.edu/Documents/DHC/Composting_Basics1.pdf and compost
Mass of lettuce head	0.000539	tonnes/plant	medium iceberg lettuce head	http://calorielab.com/search/?search_input=lettuce
Vertical farming				
Gotham Greens Greenpoint, Brooklyn, NYC greenhouse vegetable growth rate	0.032	tonnes/annum/m^2	Our flagship greenhouse, built in 2011, was the first ever commercial scale greenhouse facility of its kind built in the United States. The rooftop greenhouse, designed, built, owned and operated by Gotham Greens, measures over 15,000 square feet and annually produces over 100,000 pounds of fresh leafy greens. The greenhouse remains one of the most high profile contemporary urban agriculture projects worldwide. Designed and built with sustainability at the forefront, the facilities' electrical demands are offset by 60kW of on-site solar PV panels with high efficiency design features including, LED lighting, advanced glazing, passive ventilation, and thermal curtains, sharply reduce electrical and heating demand. Rooftop integration further reduces energy use while serving to insulate the historic Greenpoint Wood Exchange building,	http://gothamgreens.com/our-farms/greenpoint

Assumption	Value	Units	Comment	Source
			which once housed a bowling alley, below. All produce is grown using recirculating irrigation systems that capture all water for reuse and are free of any harmful chemical pesticides, insecticides or herbicides. The greenhouse employs integrated pest management solutions, including biological controls such as using beneficial insects to prey on harmful pests. 15,000 ft^2 = 1,394m^2 100,000 pounds/annum = 45 tonnes/annum	
Gotham Greens Gowanus, Brooklyn, NYC greenhouse vegetable growth rate	0.049	tonnes/annum/m^2	Gotham Greens' second greenhouse facility was built in 2013 in the Brooklyn neighbourhood of Gowanus, on the roof of Whole Foods Market's first ever Brooklyn store. The rooftop greenhouse, designed, built, owned and operated by Gotham Greens, measures over 20,000 square feet and grows over 200,000 pounds of fresh leafy greens, herbs and tomatoes each year. Perhaps the most ecologically advanced supermarket development in the country, the innovative project also features a 157kW CHP plant and a	http://gothamgreens.com/our-farms/gowanus

Assumption	Value	Units	Comment	Source
			325kW solar PV system located in the parking lot. 20,000 ft^2 = 1,858 m^2 200,000 pounds/annum = 91 tonnes/annum	
Gotham Greens Hollis, Queens, NYC greenhouse vegetable growth rate	0.483	tonnes/annum/m^2	Gotham Greens' third and largest New York City greenhouse facility is located in the Greater Jamaica neighbourhood of Hollis, Queens. Spanning 60,000 square feet, the greenhouse, designed, built and operated by Gotham Greens, was completed in 2015 and grows over 5 million heads of fresh leafy greens each year for the New York City market. The climate controlled greenhouse employs advanced automated greenhouse technologies while demonstrating that urban agriculture can be more than a small scale gardening project but rather a robust food manufacturing business. 60,000 ft^2 = 5,574m^2 Assume lettuce are grown 1 head of lettuce = 539g = 0.000539 tonnes 5,000,000 million heads of lettuce/annum = 2,695 tonnes/annum	http://gothamgreens.com/our-farms/hollis

Assumption	Value	Units	Comment	Source
Gotham Greens Pullman, Chicago greenhouse vegetable growth rate	0.774	tonnes/annum/m^2	Opened in 2015, our largest and most technologically advanced greenhouse built until date, is located in the Pullman neighbourhood of Chicago's south side. Measuring over 75,000 square feet, the greenhouse represents the world's largest and most productive rooftop farm. Our Pullman facility annually grows up to 10 million heads of leafy greens and herbs, year-round, for the finest retailers and restaurants across the greater Chicagoland area. Spanning nearly two acres, the climate controlled greenhouse facility, owned and operated by Gotham Greens, is located on the second floor rooftop of Method Products manufacturing plant. The unique partnership between Gotham Greens and Method Products, leaders in their respective industries — urban farming and eco-friendly cleaning products — is a ground-breaking vision for the 21st century manufacturing facility. Method's factory, designed by William McDonough + Partners, is the world's first LEED-Platinum certified manufacturing plant in its industry. 75,000 ft^2 = 6,968 m^2 Assume lettuce are grown	http://gothamgreens.com/our-farms/pullman

Assumption	Value	Units	Comment	Source
			1 head of lettuce = 539g = 0.000539 tonnes 10,000,000 head of lettuce/annum = 5,390 tonnes/annum	
Sky Greens vertical farming vegetable growth rate	0.321	tonnes/annum/m^2	Half a ton of his Sky Greens bok choy and Chinese cabbages, grown inside 120 slender 30-foot towers, are already finding their way into Singapore's grocery stores. Ng's technology is called "A-Go-Gro," and it looks a lot like a 30-foot tall Ferris wheel for plants. Trays of Chinese vegetables are stacked inside an aluminium A-frame, and a belt rotates them so that the plants receive equal light, good air flow and irrigation. The whole system has a footprint of only about 60 square feet, or the size of an average bathroom. Sky Greens was the world's first commercial vertical farm. Plants are grown on 9m tall, A-shaped troughs, each hosting 38 tiers of troughs. Troughs rotate around the aluminium towers to ensure uniform distribution of sunlight, proper air circulation and irrigation. Each tower is capable of producing 150kg of vegetables each month. $60ft^2 = 5.6m^2$ 150 kg/month = 1.8 tonnes/annum	http://www.npr.org/sections/thesalt/2012/11/06/164428031/sky-high-vegetables-vertical-farming-sprouts-in-singapore http://permaculturenews.org/2014/07/25/vertical-farming-singapores-solution-feed-local-urban-population/ https://www.youtube.com/watch?v=k4SMGhmoAeA

Assumption	Value	Units	Comment	Source
Mirai Corp vertical farming vegetable growth rate	0.847	tonnes/annum/m^2	Mirai Corp, a 25,000 square foot facility, is currently world's largest indoor farm. The facility uses 40% less power, 80% less food waste, and 99% less water than outdoor fields. It is also 100x more productive than outdoor fields, producing 10,000 lettuce heads per day. 25,000 ft^2 = 2,323m^2 1 head of lettuce = 539g = 0.000539 tonnes 10,000 head of lettuce/annum =	http://pioneersettler.com/vertical-farming/ http://thepotomacreporter.com/tech/3246
Solar PV				
Panel size	1.6	m^2	Average value	-
Panel rating	0.255	kW	Average value	-
Panel orientation (variation from south)	0		Average value for London	-
Panel slope	40	degrees	Average value	-
kWp/kWh factor	985	kWp/kWh	Using panel orientation and panel slope assumption in the 'Microgeneration Certification Solar Irradiation Chart from the London Region'. Solar electricity systems are given a rating in kilowatts peak (kWp). This is essentially the rate at which it	-

Assumption	Value	Units	Comment	Source
			generates energy at peak performance for example at noon on a sunny day.	
Shading factor	0.95		Average value	-
Electricity requirements for heat pumps to upgrade secondary heat sources				
Delivered heat at 70 degrees Celsius for MSOA: E02000119 (Brent part of OPDC development)				
Open loop ground source abstraction	689	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Closed loop ground source abstraction	23,296	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Air source heat pumps	316,764	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Office	5,953	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Retail	12,972	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
Building heat rejection - Gyms	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Industrial sources part B processes	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Supermarkets	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Data centres	203,105	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
National grid infrastructure	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
UKPN infrastructure	3,392	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Sewer heat mining	3,290	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Total	569,463	MWh	Calculate value	-
Delivered heat for MSOA: E02000252 (Ealing part of OPDC development)				
Open loop ground source abstraction	184	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
Closed loop ground source abstraction	6,106	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Air source heat pumps	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Office	690	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Retail	7,343	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Gyms	363	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Industrial sources part B processes	636	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Supermarkets	2,350	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Data centres	33,606	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
National grid infrastructure	33,599	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
UKPN infrastructure	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Sewer heat mining	4,854	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Total	89,729	MWh	Calculated value	-
Delivered heat for MSOA: E02000372 (Hammersmith & Fulham part of OPDC development)				
Open loop ground source abstraction	176	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Closed loop ground source abstraction	6,009	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Air source heat pumps	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Office	4,982	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Building heat rejection - Retail	7,391	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat

Assumption	Value	Units	Comment	Source
Building heat rejection - Gyms	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Industrial sources part B processes	1,349	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Supermarkets	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Commercial building sources - Non HVAC - Data centres	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
National grid infrastructure	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
UKPN infrastructure	0	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Sewer heat mining	4,506	MWh	2013 delivered heat at 70 degrees Celsius	http://data.london.gov.uk/dataset/londons-zero-carbon-energy-resource-secondary-heat
Total	24,413	MWh	Calculated value	-
Electricity input requirements for MSOA: E02000119 (Brent part of OPDC development)				
Open loop ground source abstraction	138	MWh	Includes coefficient of performance of heat pump	-

Assumption	Value	Units	Comment	Source
Closed loop ground source abstraction	7,804	MWh	Includes coefficient of performance of heat pump	-
Air source heat pumps	140,515	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Office	1,364	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Retail	2,971	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Gyms	0	MWh	Includes coefficient of performance of heat pump	-
Industrial sources part B processes	0	MWh	Includes coefficient of performance of heat pump	-
Commercial building sources - Non HVAC - Supermarkets	0	MWh	Includes coefficient of performance of heat pump	-
Commercial building sources - Non HVAC - Data centres	35,201	MWh	Includes coefficient of performance of heat pump	-
National grid infrastructure	0	MWh	Includes coefficient of performance of heat pump	-
UKPN infrastructure	444	MWh	Includes coefficient of performance of heat pump	-
Sewer heat mining	1,017	MWh	Includes coefficient of performance of heat pump	-
Total	189,453	MWh		-
Electricity input requirements for MSOA: E02000252 (Ealing part of OPDC development)				

Assumption	Value	Units	Comment	Source
Open loop ground source abstraction	37	MWh	Includes coefficient of performance of heat pump	-
Closed loop ground source abstraction	2,046	MWh	Includes coefficient of performance of heat pump	-
Air source heat pumps	0	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Office	158	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Retail	1,682	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Gyms	83	MWh	Includes coefficient of performance of heat pump	-
Industrial sources part B processes	137	MWh	Includes coefficient of performance of heat pump	-
Commercial building sources - Non HVAC - Supermarkets	496	MWh	Includes coefficient of performance of heat pump	-
Commercial building sources - Non HVAC - Data centres	5,824	MWh	Includes coefficient of performance of heat pump	-
National grid infrastructure	4,399	MWh	Includes coefficient of performance of heat pump	-
UKPN infrastructure	0	MWh	Includes coefficient of performance of heat pump	-
Sewer heat mining	1,500	MWh	Includes coefficient of performance of heat pump	-

Assumption	Value	Units	Comment	Source
Total	16,361	MWh		-
Electricity input requirements for MSOA: E02000372 (Hammersmith & Fulham part of OPDC development)				
Open loop ground source abstraction	35	MWh	Includes coefficient of performance of heat pump	-
Closed loop ground source abstraction	2,013	MWh	Includes coefficient of performance of heat pump	-
Air source heat pumps	0	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Office	1,141	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Retail	1,693	MWh	Includes coefficient of performance of heat pump	-
Building heat rejection - Gyms	0	MWh	Includes coefficient of performance of heat pump	-
Industrial sources part B processes	290	MWh	Includes coefficient of performance of heat pump	-
Commercial building sources - Non HVAC - Supermarkets	0	MWh	Includes coefficient of performance of heat pump	-
Commercial building sources - Non HVAC - Data centres	0	MWh	Includes coefficient of performance of heat pump	-
National grid infrastructure	0	MWh	Includes coefficient of performance of heat pump	-
UKPN infrastructure	0	MWh	Includes coefficient of performance of heat pump	-

Assumption	Value	Units	Comment	Source
Sewer heat mining	1,393	MWh	Includes coefficient of performance of heat pump	-
Total	6,565	MWh	Calculated value	-
Water strategy savings				
Demand management demand reduction				
Park Royal - existing	122	million litres/annum	Up to 27% reduction	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	28	million litres/annum	Up to 11% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	408	million litres/annum	Up to 14% reduction	OPDC (2016). Integrated Water Management Strategy.
Demand management discharge reduction				
Park Royal - existing	122	million litres/annum	Up to 6% reduction	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	28	million litres/annum	Up to 7% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	408	million litres/annum	Up to 11% reduction	OPDC (2016). Integrated Water Management Strategy.
Green roofs demand reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.

Assumption	Value	Units	Comment	Source
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Green roofs discharge reduction				
Park Royal - existing	233	million litres/annum	Up to 10% reduction	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	35	million litres/annum	Up to 9% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	167	million litres/annum	Up to 4% reduction	OPDC (2016). Integrated Water Management Strategy.
Roof water recycling demand reduction				
Park Royal - existing	197	million litres/annum	Up to 42% reduction	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	62	million litres/annum	Up to 27% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	238	million litres/annum	Up to 8% reduction	OPDC (2016). Integrated Water Management Strategy.
Roof water recycling discharge reduction				
Park Royal - existing	197	million litres/annum	Up to 9% reduction	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	63	million litres/annum	Up to 16% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	238	million litres/annum	Up to 6% reduction	OPDC (2016). Integrated Water Management Strategy.

Assumption	Value	Units	Comment	Source
Grey water recycling demand reduction				
Park Royal - existing	0	million litres/annum	Unlikely to be feasible for existing buildings	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	63	million litres/annum	Up to 27% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	642	million litres/annum	Up to 21% reduction	OPDC (2016). Integrated Water Management Strategy.
Grey water recycling discharge reduction				
Park Royal - existing	0	million litres/annum	Unlikely to be feasible for existing buildings	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	63	million litres/annum	Up to 16% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	642	million litres/annum	Up to 17% reduction	OPDC (2016). Integrated Water Management Strategy.
Green source control measures demand reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Green source control measures discharge reduction				

Assumption	Value	Units	Comment	Source
Park Royal - existing	237	million litres/annum	Up to 11% reduction	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	11.5	million litres/annum	Up to 3% reduction	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	24	million litres/annum	Up to 1% reduction	OPDC (2016). Integrated Water Management Strategy.
Below ground storage demand reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Below ground storage discharge reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Strategic SuDS networks demand reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.

Assumption	Value	Units	Comment	Source
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Strategic SuDS networks discharge reduction				
Park Royal - existing	-	million litres/annum	Unknown but there would be a reduced volume of surface water discharge through enhanced evapotranspiration and biological uptake	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	-	million litres/annum	Unknown but there would be a reduced volume of surface water discharge through enhanced evapotranspiration and biological uptake	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	-	million litres/annum	Unknown but there would be a reduced volume of surface water discharge through enhanced evapotranspiration and biological uptake	OPDC (2016). Integrated Water Management Strategy.
Downstream stormwater retention ponds or wetlands demand reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.

Assumption	Value	Units	Comment	Source
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Downstream stormwater retention ponds or wetlands discharge reduction				
Park Royal - existing	-	million litres/annum	Unknown but there would be a reduced volume of surface water discharge through enhanced evapotranspiration.	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	-	million litres/annum	Unknown but there would be a reduced volume of surface water discharge through enhanced evapotranspiration.	OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	-	million litres/annum	Unknown but there would be a reduced volume of surface water discharge through enhanced evapotranspiration.	OPDC (2016). Integrated Water Management Strategy.
Stormwater recycling demand reduction				
Park Royal - existing	0	million litres/annum	Unlikely to be feasible for existing buildings	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build Old Oak Common	681	million litres/annum	Up to 21% reduction	OPDC (2016). Integrated Water Management Strategy.
Stormwater recycling discharge reduction				
Park Royal - existing	0	million litres/annum	Unlikely to be feasible for existing buildings	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build Old Oak Common	681	million litres/annum	Up to 17% reduction	OPDC (2016). Integrated Water Management Strategy.
Wastewater recycling demand reduction				

Assumption	Value	Units	Comment	Source
Park Royal - existing	0	million litres/annum	Unlikely to be feasible for existing buildings	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build Old Oak Common	681	million litres/annum	Up to 21% reduction	OPDC (2016). Integrated Water Management Strategy.
Wastewater recycling discharge reduction				
Park Royal - existing	0	million litres/annum	Unlikely to be feasible for existing buildings	OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build Old Oak Common	681	million litres/annum	Up to 17% reduction	OPDC (2016). Integrated Water Management Strategy.
Expansion of the counters creek flood alleviation scheme demand reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Expansion of the counters creek flood alleviation scheme discharge reduction				
Park Royal - existing	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Park Royal - new build	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.
Old Oak Common	0	million litres/annum		OPDC (2016). Integrated Water Management Strategy.

Assumption	Value	Units	Comment	Source
Car sharing				
A 2014 study supports that car sharing has resulted in reduced car ownership. They found that the average vehicles per household prior to car sharing is 0.47, and the average after car sharing is 0.24. The comparison of the use of walking, cycling and public transport for carshare members compared with non-car share members undertaken by Sioui et al. (2012) is slightly nuanced. They found that 82% of trips undertaken by their study participants (1311 households) were by these modes compared to 53% of trips undertaken by the general population of the same city (as measured by a comprehensive citywide household travel survey). This is possibly related to vehicle ownership in that once a car sharing member is freed from the fixed cost of a vehicle, they are more likely to consider the true cost of alternatives, choosing the	0.24	vehicles/household	49% reduction (from 0.47 vehicles per household)	http://ac.els-cdn.com/S2214140513000054/1-s2.0-S2214140513000054-main.pdf?_tid=b6399a4e-865e-11e6-9e2d-00000aacb35f&acdnat=1475165382_af15e66d9449f353d17755c8d233a390

Assumption	Value	Units	Comment	Source
most appropriate mode on a journey by journey basis.				
Shared autonomous vehicles				
AutoVots (i.e. shared autonomous vehicles) could remove up to 44% of all cars travelling today at peak hours assuming high capacity public transport and 23% reduction if there is not.			Policy insight: 1. Actively managing freed capacity and space is still necessary to lock in benefits. 2. The deployment of self-driving and shared fleets in an urban context will directly compete with the way in which taxi and public transport services are currently organised. Labour issues will be significant but there is no reason why public transport operators or taxi companies for that matter could not an active role in delivering these services. Governance of transport services including concession rules and arrangements will have to adapt. 3. The drastic reduction in the number of cars will significantly impact car manufacturer business models. New service based models will develop under these conditions but it is unclear	http://oecdinsights.org/2015/05/13/the-sharing-economy-how-shared-self-driving-cars-could-change-city-traffic/ http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf https://practicalmotoring.com.au/car-news/autonomous-cars-will-shrink-the-market-study/

Assumption	Value	Units	Comment	Source
			who will manage them and how they will be monetised.	
Smart energy				
Demand side response demand reduction	60-200%	%	Demand side response: A review of previous demand side response trials with a range of different tariffs (e.g. Time of Use, Critical Peak Pricing) found that peak energy demand reductions are 60-200% greater with automation and / or control by other parties (e.g. suppliers, Distribution Network Operators) than without.	Departments of Energy and Climate Change (2015). Towards a Smart Energy System.
Smart meters demand reduction	3-11%	%	The combination of smart meters and real-time displays consistently resulted in energy savings of up to 11%, with an average of 3%.	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321852/Policy_Factsheet_-_Smart_Grid_Final__BCG_.pdf
Smart energy systems demand reduction	27%	%	A smart energy system can reduce energy consumption to 27% (this includes a mixture of renewable energy sources, smart sensors, smart mobility, smart electricity appliances, and vertical farming/façade greening).	https://www.iea.org/media/workshops/2016/smartenergysystemsworkshop/2._Michael_H%C3%9CBNER.pdf

Appendix C

Value lens methodology

C1 Value lenses

C1.1 Resource lens

The resource lens evaluates each proposed circular economy initiative on a scale between one and five based on the increase in resource efficiency from 'business as usual' where the initiative is not implemented. An increase in resource efficiency can come from the direct reduction in the consumption of resources (e.g. the generation of local solar power to reduce the demand from the grid), an initiative that seeks to close the loop on resources so that they do not have to be imported into Old Oak and Park Royal (e.g. the distribution of vegetables grown on rooftop farms to meet local demand) or it can come from optimising the use of a resource (e.g. meanwhile use allowing a building to be used 24 hours a day compared to 10 hours a day). The resources in question can include energy, materials, water and space. The relevant resource for each initiative depends on the initiative's theme.

Table 15 sets out the resource lens scale. A scoring of one represents a negligible increase in resource efficiency while a scoring of five represents a very high increase in resource efficiency. The resource lens scale and the scoring is described further below.

Table 15: Resource lens scale

Score	Description
1	Negligible increase in resource efficiency
2	Low increase in resource efficiency
3	Medium increase in resource efficiency
4	High increase in resource efficiency
5	Very high increase in resource efficiency

Score 1: A negligible increase in resource efficiency represents an initiative with no or extremely little impact to resource efficiency from business as usual. This contradicts the fundamental objective of the circular economy but has been included for completeness. In any case, these initiatives would receive a scoring of one on the resource lens.

Score 2: A low increase in resource efficiency represents a small improvement from business as usual. For example, a high level estimate indicates that 25,125 tonnes/annum of organic waste could be used as feedstock for anaerobic digestion.[84] The digestate by-product from the process could be converted into 6,030 tonnes/annum of organic fertiliser, which could be used in rooftop farming initiatives. The use of this organic

[84] In reality, this could be much higher using real organic waste data from the Park Royal Industrial Estate.

fertiliser in a classic raised bed farming method would be able to generate approximately 72 tonnes/annum of lettuce heads. This could contribute 10% of fresh green vegetables required by households in Old Oak and Park Royal, who would require a total of 706 tonnes/annum[85], resulting in a 10% reduction in the import of fresh green vegetables into the area.[86] Therefore, rooftop farming would receive a scoring of two on the resource lens. It should be noted that more intensive rooftop farming methods such as greenhouses and vertical farms would produce a greater yield of fresh green vegetables for the same farming area and would therefore provide a greater contribution to the fresh green vegetables required by households. As a result, they would receive a higher scoring on the resource lens.

Score 3: A medium increase in resource efficiency represents a moderate improvement from business as usual. For example, grey water recycling initiatives could reduce the potable water demand in new buildings up to 27% in new build areas of Park Royal and up to 21% in Old Oak.[87] Grey water recycling is unlikely to be feasible for existing buildings in Park Royal due to the plumbing requirement for dedicated grey water collection pipework and non-potable redistribution pipework. Therefore, grey water recycling as water management strategy would achieve a scoring of three on the resource lens.

Score 4: A high increase in the resource efficiency represents a substantial improvement from business as usual. For example, it has been found that members of car sharing organisation either surrender a vehicle after joining or defer an otherwise intended vehicle purchase. One specific study found that the average vehicles per household prior to car sharing was 0.47 and the average after car sharing was 0.24.[88] This is an approximate 49% reduction in vehicles driving on the roads of Old Oak and Park Royal. Therefore, car sharing schemes would achieve a scoring of four on the resource lens. Ride sharing using autonomous vehicles has been found to remove up to 44% of all cars travelling today at peak hours[89], which would also achieve a scoring of four on the resource lens.

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[85] Department for Environment, Food & Rural Affairs (2015). *Family Food 2014*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485982/familyfood-2014report-17dec15.pdf (Accessed 14 October 2016).
[86] The contribution of the rooftop farming to food manufacturers in the Park Royal Industrial Estate cannot currently be quantified in the absence of demand data.
[87] Old Oak and Park Royal Development Corporation (2016). *Integrated Water Management Strategy, Draft for Regulation 18 Consultation, 4 February 2016*. Available at: https://www.london.gov.uk/about-us/organisations-we-work/old-oak-and-park-royal-development-corporation-opdc/get-involved-op-5 (Accessed 14 October 2016).
[88] Martin, E., Shaheen, S.A., Lidicker, J. (2010). *Impact of Carsharing on Household Vehicle Holdings Results from North American Shared-Use Vehicle Survey*. Transportation Research Record 2143, 150–158.
[89] International Transport Forum (2015). *Urban Mobility System Upgrade: How Shared Self-Driving Cars Could Change City Traffic*, http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf (Accessed 14 October 2016).

Score 5: A very high increase in resource efficiency represents close to 100% or 100% resource efficiency. For example, secondary heat use via heat pumps in a district heating network for Old Oak and Park Royal would be able to generate almost 380% of the total heating demand (as calculated in Section 3.5.9). Therefore, secondary heat use would achieve a scoring of five on the resource lens.

C1.2 Economic lens

The circular economy initiatives bring both economic benefits and costs which can be borne by different people or organisations. The economic lens take into consideration both the benefits and costs impacts to the wider local economy as a whole.

Economic Benefits

The economic benefits include both value creation and cost reduction.

On the value creation side, direct financial revenue can be generated from the sales of products and services associated with circular economy initiatives, for example locally-produced food or ride-sharing services. Increased flexibility, sharing of spaces and resources, and increased lifecycle may have positive externalities, which increase productivity of an investment or businesses in the area. For example, shared co-working space encourages more interaction and communication, exchanging knowledge and ideas, which can promote innovation and increase productivity.

Economic benefits can also be seen from cost reduction perspective. Direct financial cost savings can be achieved through the use of recycled and reused materials, prolonging the lifecycle of existing resources, or reducing input costs through shared or locally-sourced goods. For example, the modularisation and pre-cast of construction materials could reduce the waste in construction materials and achieve cost savings in construction. Negative externalities can be reduced, especially on environmental externalities, but also on the reduced loss in economic value of time from congestion. For example, clean energy and shared transport could reduce air pollution and congestion, which also save people's time to be devoted to more productive uses.

Economic Costs

There will be costs associated with these initiatives, including direct financial costs and indirect costs, such as negative externalities. Direct financial costs include investing, operating and maintaining the infrastructure, materials and programmes. The true financial costs are the additional costs of initiatives as compared to business of usual. For example, the true financial costs of a roof-top farm would be the difference between the costs of appropriate planting, irrigation and drainage systems compared to the costs of standard roof and drainage systems.

There are also indirect costs from the opportunity cost of the new initiative. For example, if the workers employed for a circular economy project could potentially create higher value elsewhere or the land area used for urban farming achieves lower land value than if it were developed for commercial uses, these represent indirect costs (in the form of opportunity costs). Other indirect costs include negative externalities, or costs borne by people or organisations outside the decision or transaction. Negative externalities can occur when circular economy reduces demand (and thus sales and profits) of goods because residents and businesses are reusing and sharing more of their own resources.

Table 12 sets out the economic lens scale. A scoring of one represents low economic benefits and high economic costs while a score of five represents very high economic benefits and low economic costs. The economic lens scale and the scoring is described further below.

Table 16: Economic lens scale

Score	Description
1	Low economic benefits, high economic costs
2	Low economic benefits, low economic costs
3	Medium economic benefits, medium economic costs
4	High economic benefits, high economic costs
5	Very high economic benefits, low economic costs

Note: When deciding where each initiatives lie on the scale of the lens, we prioritise high economic benefits, high economic costs to low economic benefits, low economic costs, as bigger impact could be delivered.

Score 1: Such projects would be ineffective or have minimal positive impact and are expensive compared to their benefits as well as compared to other options for achieving the same means. An example project could include building a waste landfill with outdated technologies on greenfield land.

Score 2: A project receiving this score achieved limited benefits, but it was also low cost to implement. For example, a system of paper leaflets explaining in vast detail the importance of separating different types of recycling may change the recycling behaviours of a few people, but it will have been at minimal cost to produce and disseminate the information.

Score 3: This type of project will achieve moderate gains, but it will also increase in price compared to other, lower-cost solutions. This type of project would likely use established technologies and have moderate capital investment costs. Developing shared tool shed/workshops for communities may require some additional investment in capital, but the long-term cost saving for space and resources can bring measurable benefits to the community including cost savings on tools and maintenance and repairs costs.

Score 4: These projects achieve high benefits but at high financial costs. These projects may be deemed worthwhile so long as the stakeholders have the resources available and the gains are large and of particular interest. Capital-intensive projects which require substantial infrastructure fall into this category. Many heavy public transport projects can fall into this category.

Score 5: Projects achieving this score have high impact and relatively little cost. Such projects are fairly uncommon. Particular care should be given to ensure that the low financial costs of investment have not accrued as hidden economic, social or environmental costs. Examples of projects have been suggested from using “nudge” principles. In Edinburgh, the use of smaller waste collection bins and larger recycling bins increased household recycling by 85 percent. The cost was minimal, but the effects were very large in comparison.[90]

C1.3 Social lens

The circular economy has the potential to create employment opportunities, cut waste, raise standards of living, improve air quality, and enhance public health and social equality. While social factors are often harder to quantify than economic indicators, social values are essential to the functioning of a city or district, its liveability, and attractiveness to current and prospective residents, businesses and investors. Efforts to understand and quantify the social benefits of specific circular economy initiatives are now underway, though the metrics used to capture them are not always in hard financial terms.

For example, we know that meanwhile space developments provide important resources for business and communities but these values are not readily translatable into revenue generated or saved. Instead there is a growing acknowledgement that the public realm and quality place-making are essential to building vibrant and diverse communities and increasing business success. The social values added by such projects are illustrated by other metrics, such as the desirability of businesses to move to an area, increased investment in an area or improved public health. Social value also tends to not to be measured consistently. Rather it is judged on a case-by-case basis depending on stakeholders’ priorities, for example, whether they are aiming to improve health outcomes or create space for community activities and so on. It is thus more difficult to match initiatives to a position on the social lens than for the other two lenses.

Table 17 sets out the social lens scale. A scoring of one represents a negligible increase in social improvement while a scoring of five represents a

[90] Zero Waste Scotland (2015). *Edinburgh ‘Nudging’ Success in Recycling*. Available at: http://www.zerowastescotland.org.uk/content/edinburgh-%E2%80%98nudging%E2%80%99-success-recycling (Accessed 14 October 2016).

very high increase. The resource lens scale and the scoring is described further below.

Table 17: Social lens scale

Score	Description
1	Negligible increase in social improvement
2	Low increase in social improvement
3	Medium increase in social improvement
4	High increase in social improvement
5	Very high increase in social improvement

Score 1: An initiative that creates a negligible increase in social improvement as compared to a business as usual scenario. Initiatives that are more focused on enhancing the other two areas – resources and economics – but that have little social impact may be included in this score. For example, while anaerobic digestion has strong implications for resource reuse and waste reduction, as well as long-term costs savings, it will bring little or no benefit in the social sense, for example in raising standards of living. Any positive impact may be considered highly indirect or vicarious and therefore a score of one can be assigned to the initiative.

Score 2: A low increase in social improvement from business as usual. Flexible design of buildings, for example, creates multiple uses for assets and maximises their utility. This will bring certain positive social impacts, for example by creating additional job opportunities and boosting the manufacturing industry (e.g. for modular assets). Flexibly designed buildings can also be tailored to users' needs which can support productivity as well as improve the desirability of a certain building or location. The capacity to influence the use of a building or space – for example by choosing to convert office space into recreational uses creates a positive attitude towards built assets and can increase health and wellbeing for building occupants.

Score 3: A medium increase in social improvement from business as usual. Local food growing not only minimises food waste and packaging waste but can also help reduce poverty and facilitate community engagement around food cultivation. Food growing promotes healthy eating and gives people the opportunity to learn new skills and spend time outdoors, activities known to promote healthy lifestyles, increase social cohesion and reduce isolation and obesity. Food growing also contributes to raising awareness about health and consumption patterns which may lead to longer term social improvements, for example in consciousness and behaviour towards food waste and energy use. These changes will eventually create more socially and environmentally conscious places where externalities such as poor air quality are minimised and people enjoy healthier lifestyles.

Score 4: A high increase in social improvement from business as usual. Community-led development, self- and custom-build housing projects have the capacity to create a range of positive social impacts. By involving ordinary people in the design and planning of their homes and community spaces, opportunities for shared learning, skills exchange, collaboration and social engagement are created. When users have influence over the design of their future spaces, they tend to include socially advantageous elements such as green space and green infrastructure. These create multiple benefits including increased biodiversity, reduced heat risk and increased shading, cooling and water retention, improved air quality, community engagement and social cohesion, higher levels of resident satisfaction and wellbeing, and the promotion of physical activity such as cycling and walking. Shared amenity spaces are often designed into homes and businesses (i.e. kitchens and dining areas) further promoting the sharing of produce, cooking and casual social interaction.

Score 5: A very high increase in social improvement from business as usual. Community-owned energy infrastructure provides communities and local residents with the capacity to produce their own energy and increase the control they exert over how their energy is generated and the price they pay for it. Local ownership will necessarily bring people together to decide upon priorities and targets. For example, a community may decide that air quality is extremely important to them and thus choose energy generation sources that produce the least pollutants. Engagement in and influence over this process is socially empowering for members of that community, a trait closely associated with a high level of social wellbeing. Installing, monitoring and maintaining new infrastructure will also create jobs and support the local economy which in turn will create wellbeing and avoid social challenges such as crime, drug abuse and unrest. Recycling of revenue generated from the sale of energy may also be used to initiate socially-oriented activities in the community – such as the creation of recreational spaces and funding of health and educational facilities and programmes.