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# Business Models for Active Buildings

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**Abstract:** Active Buildings that allow users to adjust their demands on the grid to the needs of the energy system could greatly assist the transition to net zero, but will not be widely adopted unless the businesses involved can make money from doing so. We describe the construction, flexibility and information supply chains of activities needed to make these buildings work. Drawing on the results of an expert workshop, we set out four possible business models deserving further investigation. Developers may find it profitable to build or upgrade energy-efficient buildings with the monitoring and control equipment needed to adjust demand and energy storage as required, selling them soon after completion. Aggregators monitor the state of the building and communicate with the energy system to adjust the building's demand while maintaining comfort levels, in return for suitable payments. Energy service companies may sell energy-as-a-service and own the equipment instead of a consumer who wishes to minimize their upfront costs, and the idea of an active, energy-efficient, building may be attractive to the tenants of the new group of all-inclusive rental companies, and hence to those companies. Our discussion shows that each is an evolution of an existing (successful) business model, but that further work will be needed to evaluate their profitability when applied to Active Buildings.

**Keywords:** active buildings; business models; residential smart grid; residential flexibility supply

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## 1. Introduction

Most scenarios for a decarbonized energy system in the UK imply a high level of electrification for heating and transport, and a high share of wind and solar generation. The Net Zero recommendation for 2050 from the Committee on Climate Change [1] includes the extensive use of heat pumps in buildings, and the complete electrification of cars and vans. All three net zero Future Energy Scenarios from National Grid [2] feature more than 100 GW of wind power and over 50 GW of solar PV in 2050.

The output from this amount of variable renewable generation will fluctuate dramatically, overturning the previous paradigm in which controllable generators adjust their output to match variations in electricity demand. Strbac et al. [3] show that effective methods of demand response, in which loads adjust to more closely match the supply of renewable power, can significantly reduce the cost of the power system, without necessarily affecting the user's comfort or convenience. The Consumer Transformation scenario from National Grid [2] foresees eight million homes with heat pumps, over three million of which have thermal storage that enables the heat pump to run more flexibly. Three-quarters of electric vehicle (EV) owners will reduce their costs through smart charging that is timed to coincide with the grid's ability to supply; one-quarter will provide vehicle-to-grid (V2G) services, using their vehicle batteries for electricity storage on behalf of the system.

Active Buildings (ABs) [4] are needed to facilitate this kind of behaviour.

*An Active Building optimizes its habitable environment for the occupant based on their needs, comfort and convenience while also automatically adjusting its energy generation, storage and consumption responses according to the instantaneous demands of the wider energy network.*

Active Buildings (both residential and other buildings, such as schools and businesses) will be highly insulated and may have on-site renewable generation, thermal or electrical storage. They will be equipped with the control and communications systems needed to ensure that the building's energy exchanges with the wider system match that system's needs and ability to supply. If generation is low relative to demand, the building can draw on stored energy to defer its use of electricity; when generation is high, this storage can be replenished.

The Active Buildings Centre is working to overcome some of the technical challenges involved in this [4], and to provide demonstrator projects to prove what can be accomplished. However, the widespread adoption of Active Buildings depends on their financial viability. Developers must be willing to design these features into the building and (preferably) to install the relevant equipment. Building owner-occupiers must believe it is in their interests to use these systems as designed. Energy companies must find it profitable to signal for and accept the many (usually small) adjustments coming from Active Buildings around the country, rather than relying on their tested strategy of turning conventional generators up and down.

This viability depends on finding suitable business models. A business model is a description of how a service is provided to people who will value it, and how the service provider can recover its costs and a return sufficient to justify the effort involved.

This paper sets out several candidate business models and invites comments on them. The candidate business models discussed were developed through a full-day workshop held in November 2019, attended by key stakeholders from the Active Building supply chain. These included regulated network operators, developers, innovators and local authorities. A range of hypothetical scenarios and market opportunities were presented and feedback gathered from attendees, to understand both their needs and how they would respond in these situations. This feedback helped to validate the maturity of the supply chain and also the feasibility of the business models.

For this paper, we selected four models that spanned the most important choices faced by companies involved in Active Buildings. In terms of operating the Active Building, should its demand response be organized by an asset-light Aggregator, or by an Energy Service Company that also installs and owns the equipment needed, and sells energy to the occupiers? In terms of building it, should the developer sell the building at once, or own it long-term and rent to tenants? For this case, we decided to investigate the innovative model of "all-inclusive" residential rentals, where the owner provides utility (and other) services to tenants at a cost that is bundled into their rents. These are based on models developed at the workshop, but some models that overlapped (for example "renter plus aggregator" and "renter plus energy service company") were split into their component parts.

Some of these business models may require access to data that are not currently available, or changes to regulatory or other rules. At this stage in the evolution of the sector, we believe that it is worth considering these models; if they prove promising on all other criteria, then that promise suggests that the data should be made available, or the rules changed. The next stage of this research will be to model potential costs and revenues for the most promising business models under a range of scenarios.

The next section sets out the ways in which an Active Building can reduce the costs of the energy system by using self-generation and storage, and adjusting the timing of electrical loads (but not necessarily the consumption of energy services). Section 3 describes the supply chains of activities needed to make these buildings work, in terms of construction, operation and information flows. In Section 4, we propose four business models for the construction and operation of Active Buildings, showing what different kinds of companies would have to do to make them work. These models are discussed in Section 5, while Section 6 offers a brief conclusion.

## 2. What Can an Active Building Do?

An Active Building can be equipped with technical facilities that enable comfortable living without the occupants being burdened by control tasks [5]. In addition, the residents communicate their preferences and reveal private information about their lifestyle. In a highly insulated building, a control system controls the heating [6], charging of electric vehicles [7], hot water supply, electrical storage [8] and other electrical devices on the basis of these data. The high level of insulation in the building requires a ventilation system with a heat exchanger to maintain the indoor air quality.

A related concept is the Active House [9,10], which also relies on good design and high levels of insulation to provide a healthy indoor environment with high levels of comfort, very low energy consumption and low environmental impact over the building's entire life cycle. It therefore goes well beyond the energy consumption focus of the EU's Nearly Zero Energy Building target [11]. The standard covers lighting levels and acoustic properties, and emphasizes the use of sustainable materials, as well as self- or local generation of renewable energy. Active Buildings, as defined here, will also be highly insulated, but go beyond the Active House concept to include controls and ICT to adjust the building's energy exchanges with the wider energy system in response to the changing needs of the grid.

As the control of the Active Building is delegated from the resident to the control system, an opportunity is created to operate the inherent thermal and electrical storage without loss of comfort. This margin—flexibility—will be a valuable commodity in future energy systems and can therefore be sold. Coordinating the use of flexibility in several Active Buildings can increase the value even further—as noted, without impairing the comfort of use.

In particular, we expect that Active Buildings will be able to do the following things that will be valued by the energy system, in that they reduce the cost of providing a reliable supply of energy services to users [12]. Not every building will perform every function, but the following list and Figure 1 describe the main possibilities:

1. Change the timing of heat loads by small amounts, accepting minor variations in temperature that the building's occupants are unlikely to notice;
2. Change the timing of heat loads by larger intervals, charging or drawing on thermal storage so that user comfort is not affected;
3. Change the timing of EV charging loads, while still ensuring that the vehicle is adequately charged by the time that its user has specified [13];
4. Provide V2G response services from EVs, supplying electricity back to the grid when required, while always maintaining the user's specified minimum level of charge, and reaching the desired state of charge at any time specified by the user;
5. Store electricity in order to reduce the load on the grid when this is desirable [14];
6. Store electricity in order to sell it back to the grid when it is more valuable;
7. Provide accurate predictions of the building's fluctuating loads (whether or not these are managed in the ways described above);
8. Reduce the need for network capacity by doing some or all of the above.

Because an Active Building optimizes its exchanges with the energy system (and particularly the electricity system), existing generating capacity can be used more efficiently, so that less power comes from the highest-cost sources. In a longer-term perspective, less capacity is needed, in generation and in the networks; the Active Building only draws power when it is available and can be transported, and may export power to the local network or directly to its neighbours when this helps the system. Peer-to-peer trading would require a change to regulation, as customers are currently limited to having a single supplier (retailer), but we would not want to rule out such changes in the longer term.

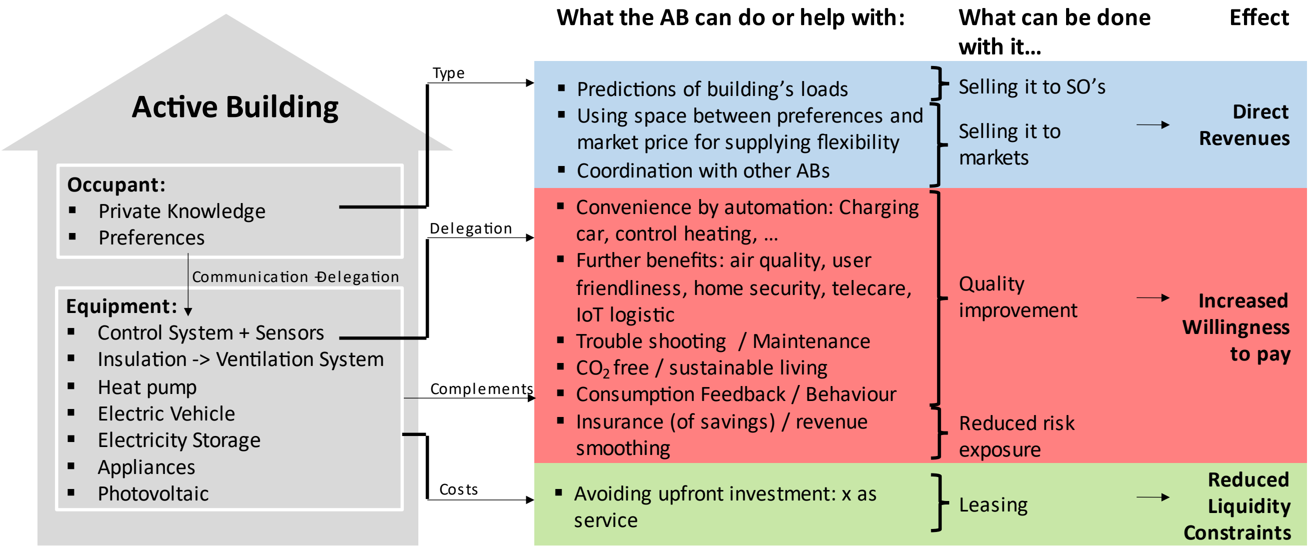


**Figure 1.** Active Buildings: what they can do or help with and what can be done with it.

We do not consider the use of electricity storage with the specific aim of maximizing self-consumption of renewable power generated by the building [8]. This service may well be valued by the building's occupants; it may also be encouraged by electricity tariffs that recover the (largely fixed) costs of the grid through charges per unit of electricity sold that are greater than the marginal cost of power (which has been the case (in most hours) in the UK). An Active Building, as we define it, stores energy and draws it down when this is helpful to the grid; if this increases self-consumption, that is a bonus. It should not be the point of the exercise.

In addition to this use of flexibility that is valued indirectly through the energy system, residents of the Active Building could benefit from the user-friendliness of the control system through the improved air quality. This requires the high level of insulation in the building, through the automatic charging of the electric vehicle, through the use of sensors to improve maintenance, through knowing that they are contributing to $CO_2$-free living and also through the building's improved feedback options. These complements of lower and more flexible energy demand can also contribute to an increase in the willingness to pay for Active Buildings, but some of them may come at the price of data security.

## 3. Value Proposition of Active Buildings

In the previous section, we have described the services of Active Buildings. The most important ones from our perspective are (Figure 2) (1) the provision of convenient and sustainable living space, with (2) the possibility to gain revenues from selling flexibility, and (3) information. There are further amenities that may prove valuable for an occupant, such as home security applications and assisted living. However, we focus on the previous three and describe the supply chains (activities) involved in providing these services. This will enable us, in the next section, to assign the supply chains to organizations or firms, each with their own business model.

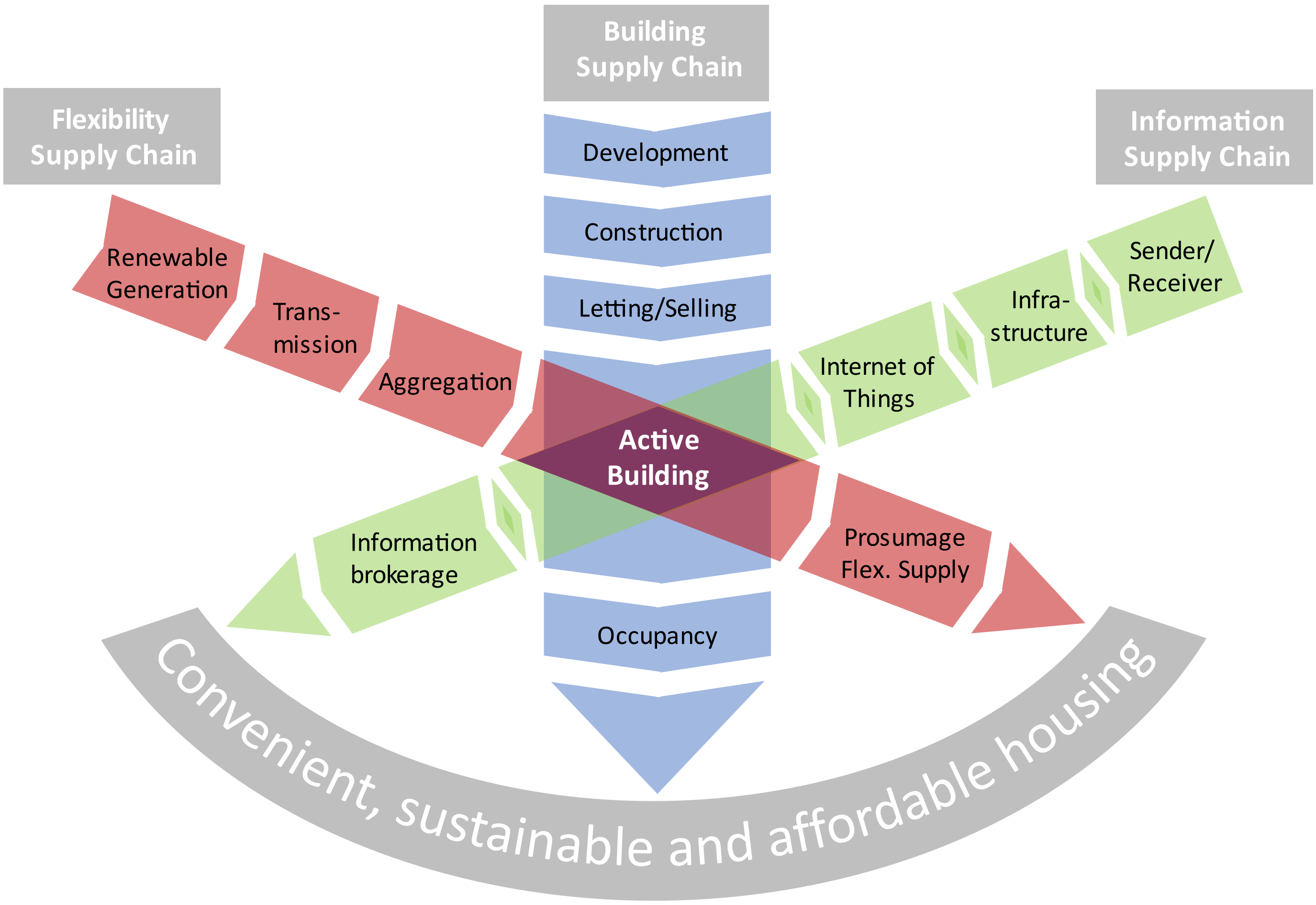


**Figure 2.** Value chains involving Active Buildings.

*3.1. The Building Supply Chain*

Most building projects in the UK are led by a developer rather than by the ultimate occupant, and this developer contracts with many different organizations to deliver the completed building. Creating a cost-effective Active Building (as compared to its conventional counterpart) differs from the construction of a conventional building in the high degree of insulation. This in return requires a ventilation system to ensure air quality. Furthermore, hardware for energy generation and storage, together with communications and control equipment, have to be purchased and installed. The developer will also pay a connection charge to the local distribution system operator, and may carry out some or all of the work involved in connecting the building to the local energy system and the communication network.

Aside from technical difficulties, the labor-intensive construction requires highly skilled and well-trained workers that are currently unavailable for a rollout of Active Buildings in significant numbers [15]. While it is possible to retrofit buildings to a high standard [11,16], this skills shortage is especially relevant if it comes to the activation of the large number of existing buildings in the stock and may significantly delay the rollout of retrofitted Active Buildings.

While currently, most UK residents live in their own property, high housing prices have already started to force—especially young—residents to rent. It is well understood that limited access to capital markets already forces people to discount heavily and therefore discard investments in energy efficiency. A further significant rise in upfront investment costs can be expected to burden buyers of Active Buildings. Therefore, it appears natural to consider build-to-rent concepts for Active Buildings. Commercial Active Building suppliers use their credit ratings to mitigate liquidity constraints and therefore offer desirable contracts to finance the Active Building equipment as well. Furthermore, while the passthrough of energy efficiency investment to house prices and rents may be perceived to be lower than 100%, this can be mitigated via a contract with a commercial building owner, while [17] shows that highly efficient buildings may have a price premium *greater* than the value of energy savings while such buildings are scarce.

The installed equipment operates in a highly interactive manner with sensors, control hardware and information technology involved. The complexity of this system can be expected to be maintenance-intensive. Furthermore, the calibration of software and its updates can be expected to become necessary for convenience. Since a system failure will be highly inconvenient for the occupants, to ensure reliability of the system, continuous supervision of the operation parameters and proactive interventions would be crucial for the successful rollout of Active Buildings. The provision of these services should not be neglected either, within the design phase of the Active Buildings or during their operation—even if the residents own the building, including the equipment.

### 3.2. The Flexibility Supply Chain

Once the building is occupied, the most important interactions will be with the distribution system operator (a regulated local monopoly), the company selling energy to the customer (who may be a traditional supplier selling energy alone, or an energy services company (ESCo) providing energy services from an optimized combination of energy and the equipment to use it), and perhaps a company that optimizes the flow of energy to the building and its ability to act flexibly within the energy system. At this stage, we are deliberately open about the identity and role of this optimizer; the point of this paper is to discuss a variety of possible business models.

The integration of the Active Building into the energy system, and particularly the electricity system, is shown in more detail in Figure 3. The top section (red lines) represents flows of power over the physical system, from generators and the wholesale electricity market through transmission and distribution to the building itself.

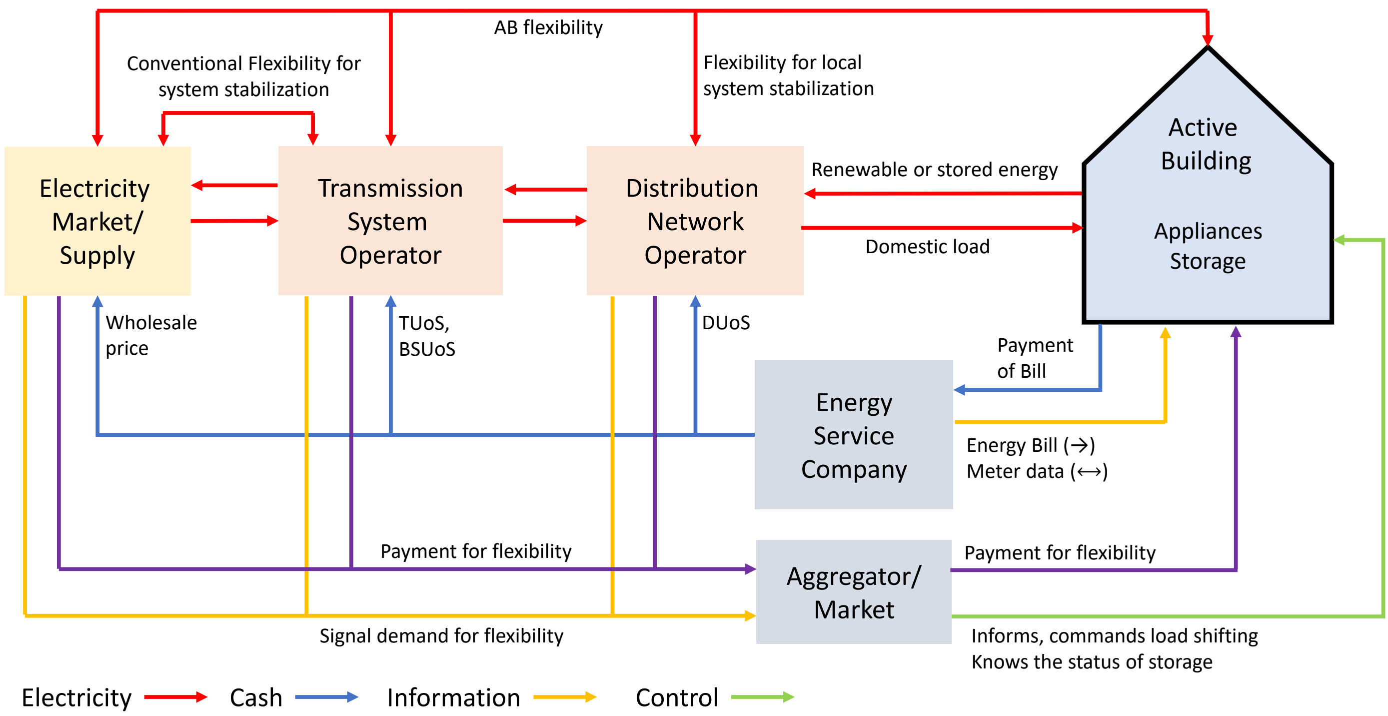


**Figure 3.** System flows involving Active Buildings.

In the middle of the diagram, the blue lines denote the traditional flow of money from the customer to their energy service company (or supplier following some other business model), and onwards to network operators and the wholesale market. The flow of metering and billing information between this company and the building is also indicated, in yellow. The yellow lines in the bottom left quadrant specify how information about the need for flexibility (generally changes in output) moves between system operators, generators and the wider market. The companies providing this flexibility receive payments marked in purple. The bottom right quadrant highlights the distinguishing feature of an Active Building; it can receive information on the need for flexibility (in green), can respond to this information, and will receive payments (or bill reductions) for providing useful services to the system.

### 3.3. The Information Supply Chain

As already described, the Active Building will be equipped with sensors and control units, and it will be connected to a high-performance information transmission infrastructure (the so-called Internet of Things). These enable the recording of parameters of the building status such as indoor temperature, energy consumption or the preferences of the building occupant. Displaying some of this information will allow the occupant the option of analyzing and changing their own behaviour. In the other direction, information "flows" into the building with control information for electrical devices based on information from outside, such as real-time prices [18].

For example, the temperature data of the building, its environment and information about the preferences of the building occupant are a prerequisite for the convenient operation of the heating system by an Aggregator. Information from electronic calendars can also be used to precisely charge electrically powered vehicles. As previously described, this exchange of information can enable the Active Building to be integrated into the electricity system.

The supply chains for information and flexibility are closely linked in this sense, but not identical, since the exchange of information does not have to be limited to added value in the electricity system. Exchanging information with third parties can also create added value for residents. For example, by analyzing historical data and preferences, conclusions about the temporal profile of the demand for electricity can be improved, which is important for the efficient use of resources. Home security applications and assisted living services are also discussed as important applications in this context, as is pure home automation, remote maintenance and failure analysis of appliances, and simple self-analysis. We have therefore also included the information supply chain separately in Figure 2.

## 4. Candidate Business Models

While the value proposition and its environment have been explained in more detail using supply chains in the previous section, the ownership of the ABs and its equipment has not yet been specified. However, as this is necessary to explore how a company can offer something of value to its customers and capture some of this value for itself, we need to describe business models.

The business model canvas is the most prominent tool [19] for thinking about what a business needs to do and hence whether it can become viable. We will be using it to describe our candidate business models and offer a brief description here. Its nine building blocks were initially proposed by Osterwalder and Pigneur [20].

The central question of the business model canvas is the value proposition: what is the business offering to its customers? Which potential customers should be sold to—which are the customer segments? Given these segments, how should the business interact with them (customer relationships) and how will it tell them about its offering (channels)? The answers to these questions determine the revenue streams.

A viable business is one that has revenues greater than its costs or (for those that are temporarily loss-making) a realistic prospect of reaching this position before exhausting its current cash reserves. What does the cost structure depend upon? What are the key activities that the business will have to undertake to deliver its value proposition?

Which are the key resources to undertake these activities? To what extent can key partners help to provide these? They will include important companies within the supply chain, but also sources of advice or funding.

To create value from Active Buildings, all links of the value chain need to be assigned to economic actors (entities; companies and occupants) with property rights and operational responsibility. Following a workshop with practitioners organized by the Energy Systems Catapult in November 2019, that proposed a range of plausible business models, the current authors have selected and refined four of them. While there are likely to be other ways in which companies can profit from involvement with Active Buildings, we believe that these four business models represent some of the most important ones. As they relate to three different stages in the value chain, we hope that they offer contrasting insights into the activities needed to make Active Buildings work commercially. The business models are:

1. The Aggregator, controlling the building's equipment to provide flexibility to the energy system;
2. The Energy Service Company, providing energy services through the right mix of energy-using equipment and energy supply, and using the Active Building to reduce the cost of doing so;
3. The All-Inclusive Rental Company, providing housing in an Active Building, energy services and other utilities for a single payment;
4. The Build-and-Transfer Developer, creating an Active Building for onward sale and expecting no further relationship with the owner-occupier after that sale.

A major source of the appeal of Active Buildings is their ability to generate income from the sale of flexibility. For this purpose, an Aggregator (business model canvas in Figure 4) is authorized to control the building's equipment and thus to shift loads. This flexibility can reduce the operating and capacity costs of the electricity system (locally and centrally), and hence the amount that has to be paid for it. This may come simply from concentrating purchases at cheaper times (assuming either a fixed time-of-day tariff, or better, a real-time tariff linked to current wholesale prices) or because the Aggregator receives revenues for supplying services to the system. The resulting cost savings should therefore decrease electricity prices and hence bills.

The role of the Aggregator is central to the operation of Active Buildings and so, we consider it first. However, we do not ask whether the Aggregator is an independent contractor or part of a wider energy business, nor whether that energy business is a supplier (selling only energy) or an Energy Service Company (also providing equipment). The tasks involved in providing flexibility will be the same in each case, although the channels by which they are sold to customers will differ. Energy suppliers and standalone Aggregators face different regulations in the British electricity market at the moment, but the government, regulator and wholesale market operator [21–23] are considering options that would improve the standalone Aggregators' access to the market.

While the Aggregator only operates the equipment, its property rights remain with the building owner. Alternatively, the connection between the building and the equipment ownership can be split, such that the equipment is owned by an Energy Service Company (ESCo; Figure 5). The ESCo invests in the equipment and meets consumer demand for energy services (such as heat and light, rather than simply electricity) by buying and delivering energy. The ESCo is likely to also act as the Aggregator, controlling the equipment to offer flexibility services, but we do not see this as an inevitable part of this business model; it might buy aggregation services from a third-party specialist. If the equipment has not yet been installed, the ESCo offers its participation in the design and construction process of an Active Building, and further selects and installs the equipment. The ESCo thereby covers upfront investments and organizes maintenance. The avoidance of upfront investment is especially valuable for liquidity-constrained owner-occupiers. The unified ownership and operation of the equipment may furthermore ease the consideration of equipment degradation during operation.

Similarly to how the ESCo model allows building occupiers to avoid upfront investments in equipment, the "All-Inclusive" Rental (AIR) Business (Figure 6) enables residents with limited liquidity to live in Active Buildings. Therefore, the Active Building is bought from a developer (unless developed by the rental service provider itself) and managed to optimize its cost and performance. Energy will be bought by the AIR Business from a supplier (or perhaps an ESCo) and the equipment operated by an Aggregator (perhaps within the ESCo). These high-quality Active Buildings are rented for a fixed price including all utility costs, which are reduced by the energy cost savings from flexibly operating the equipment. Given that the AIR Business already requires a large amount of capital to own the building, the benefit of using an ESCo comes mainly from its specialized knowledge of what to install, rather than from reducing the upfront cost of the equipment.

The "Build and Transfer" (B&T) Business (Figure 7) develops Active Buildings and installs the equipment. It thereby anticipates the Active Building's ability to generate revenues and makes the necessary design changes in the building fabric. The B&T Business contributes the know-how to design an efficient and convenient building, the skilled personnel for the installation of the equipment and selects the technical components. The future occupier of the Active Building values its capabilities of reducing energy bills while maintaining comfort. This enables the B&T Business to sell the Active Building to an owner-occupier (or perhaps an AIR Business) for a price markup that more than covers the extra costs incurred. The building might also be sold for more conventional renting, but it is less clear that the tenant would operate it as intended, the landlord would be able to capture the value of the building in the rent charged, and hence that a conventional landlord would pay a price that covered the B&T Business's costs.

*Key partnerships*

- Meter and communications infrastructure operator (telecoms; implement best practice)
- Soft- and hardware installation, operation, and maintenance within ABs and central operations (optimal control strategy; to maintain required service levels)
- Financial services—risk mitigation of selling flexibility (e.g., insurance for DNO)

*Key activities*

- Load and opportunity prediction
- Deriving an optimal control strategy (centrally) for flexibility maximizing the revenue potential, considering capacity constraints of the grid, preferences and external conditions (weather, grid utilization, flexibility demand)
- Control of loads, storage and on-site generation (if any)

*Key resources*

- Customer record of loads
- Decision-making algorithm for price, supply, and load analysis and controlling (experience, records)

*Value Proposition*

- Lower electricity costs with no visible change in comfort or convenience (for building occupiers)
- Fewer network constraints requiring investment or other actions (DSO)
- Cheaper balancing, reserve and other ancillary services (ISO)
- Load records, knowledge of preferences and the environment of ABs enable accurate load forecasting
- Reliability and convenience by maintenance and support

*Customer relationship*

- AB occupiers: communication of preferences (including permission to control), data transmission (permission), load controlling (remuneration if owner)
- AB equipment owners: permission to use the equipment; maintenance of equipment (reliability)
- Infrastructure parties: communication of goals for control, remuneration

*Channels*

- Direct consumer marketing
- Alliances with suppliers
- Property agents
- Equipment installers/sellers

*Customer segments*

- AB occupiers
- AB equipment owners:
  - Individual AB owners (households and commercial)
  - Owners of multiple ABs (domestic landlords (including social housing) and larger corporates)
- Energy and infrastructure parties satisfied by Aggregators' load-control effort: ESCo, Distribution system operator, ISO
- Distribution system operators satisfied by load-control effort
- System operators: data/load forecasts

*Cost structure*

- Payments to customers (AB occupiers, infrastructure parties) for net-load-shifting and data usage
- Staff payments
- Software and hardware costs for communication, control, decision and prediction systems
- Payments for non-performance
- Diverse: supply license obligations (if any), customer acquisition and relationship

*Revenue streams*

- Flexibility sales:
  - Network operators pay for constraint management (share of savings)
  - Balancing market sales (local and national) and other ancillary services from ISO
  - Wholesale market sales
- Data sales: record of loads and estimate of future loads

Business Model Canvas from Strategyzer.com

**Figure 4.** The AB-Aggregator.

*Key partnerships*
- Meter and communications infrastructure operator (telecoms; implement best practice)
- Soft- and hardware installation, operation and maintenance within ABs and central operations (optimal control strategy; to maintain required service levels)
- Financial services-risk mitigation of selling flexibility (e.g., insurance for DNO)
- Subcontractors for installation of the AB Equipment

*Key activities*
- Installation and maintenance of the equipment
- Load and opportunity prediction
- Deriving an optimal control strategy (centrally) for flexibility maximizing the revenue potential, considering capacity constraints of the grid, preferences and external conditions (weather, grid utilization, flexibility demand)
- Control of loads, storage and on-site generation (if any)

*Key resources*
- Customer record of loads
- Decision-making algorithm for price, supply and load analysis and controlling (experience, records)

*Value Proposition*
- Lower electricity costs with no visible change in comfort or convenience (for building occupiers)
- Fewer network constraints requiring investment or other actions (DSO)
- Cheaper balancing, reserve and other ancillary services (ISO)
- Load records, knowledge of preferences and the environment of ABs enable accurate load forecasting
- Reliability and convenience by maintenance and support
- No upfront investment for the building owner (?)

*Customer relationship*
- AB occupiers: communication of preferences (including permission to control), data transmission (permission), load controlling (remuneration if owner)
- Building owners: maintenance of equipment (reliability)
- Infrastructure parties: communication of goals for control, remuneration

*Channels*
- Direct consumer marketing
- Alliances with suppliers
- Property agents
- Equipment installers/sellers
- Cross-selling/adding AB services to existing customers

*Customer segments*
- AB occupiers
- Building owners:
  - Individuals (households and commercial)
  - Owners of multiple buildings (domestic landlords (including social housing) and larger corporates)
- Distribution system operators satisfied by load-control effort
- System operators: data/load forecasts

*Cost structure*
- Energy purchase cost on wholesale market
- Rebates to customers (AB occupiers, infrastructure parties) for net-load-shifting and data usage
- Staff payments
- Soft- and hardware costs for communication, control, decision and prediction systems
- Payments for non-performance
- Purchase of other in-building equipment (insulation, etc.)
- Installation of equipment (incentives to treat equipment carefully)
- Diverse: supply license obligations (if any), customer acquisition and relationship

*Revenue streams*
- Selling energy services
- Flexibility sales:
  - Network operators pay for constraint management (share of savings)
  - Balancing market sales (local and national) and other ancillary services from ISO
  - Wholesale market sales
- Data sales: record of loads and estimate of future loads

Business Model Canvas from Strategyzer.com

**Figure 5.** The AB-Energy Service Company.

<table>
<tr>
<td rowspan="2">Key partnership<br>▪ AB-Build and transfer developers<br>▪ Contractors for maintenance, operation of the building and the equipment<br>▪ Communication infrastructure operators (telecoms)<br>▪ Financial services (liquidity and risk mitigation)<br>▪ Energy service company; metering and billing of services/import/export of energy (contract: communal heating?)<br>▪ Eventually: Aggregator selling flexibility + load information</td>
<td>Key activities<br>▪ Provision, maintenance and operation of an efficient building<br>▪ Provision and maintenance of AB equipment</td>
<td rowspan="2">Value Proposition<br>▪ Living space for rent:<br>– Convenient (ventilation system; energy management system; home security system; eventually: access to EV pool)<br>– Sustainable (= environmentally friendly/low-$CO_2$)<br>– Cheap (revenues from selling flexibility and information)<br>– Low hassle (all-inclusive rent; energy bill; operation of the building)<br>▪ Reducing the impact of liquidity constraints and risk exposure on tenants<br>▪ Improving the passthrough of efficiency investment</td>
<td>Customer relationship<br>▪ Long-term customer relationship with rents including management of building, energy service, operation and maintenance of AB equipment, data supply</td>
<td rowspan="2">Customer segment<br>▪ Occupiers<br>– Aged 24–35<br>– Who want inclusive energy bills<br>– Have environmental conscience<br>– Interested in SMART and service provision</td>
</tr>
<tr>
<td>Key resources<br>▪ Active Building<br>▪ Staff<br>▪ Subcontractors (maintenance)<br>▪ Customer relations team</td>
<td>Channels<br>▪ Direct marketing<br>▪ Estate agents<br>▪ Universities (students)<br>▪ Employers (for their staff)</td>
</tr>
<tr>
<td colspan="3">Cost structure<br>▪ AB price (including equipment)<br>▪ Communication and electricity network usage<br>▪ Maintenance costs<br>▪ Energy costs<br>▪ Marketing and customer relations</td>
<td colspan="2">Revenue streams<br>▪ Rent from occupant<br>▪ Compensation for delivery of flexibility (ESCo)</td>
</tr>
</table>

Business Model Canvas from Strategyzer.com

**Figure 6.** The “All-Inclusive” rental model.

<table>
<tr>
<td rowspan="2">Key partnerships<br>▪ Contractors for construction of the efficient building<br>▪ Equipment manufacturers<br>▪ Communication infrastructure operators<br>▪ Energy service company</td>
<td>Key activities<br>▪ Design and construction of an efficient building with integrated controlling and communication capabilities<br>▪ Development of the know-how: building design, AB equipment integration, savings potential and WTP of customers<br>▪ Training of constructors</td>
<td rowspan="2">Value Proposition<br>▪ Designing, implementing and selling:<br>– Convenient living space (ventilation system; energy management system; home security system)<br>– Sustainable (= environmentally friendly/low-$CO_2$) housing<br>– The potential to achieve revenues from selling flexibility (= cost reduction) and information (load timing, preferences, etc.)</td>
<td>Customer relationship<br>▪ Pure sales transaction<br>▪ Possible interaction during design and build (tailor the building to subsequent owners' wishes)</td>
<td rowspan="2">Customer segments<br>▪ Owner-occupier of an AB<br>▪ Renting company (build to rent or community housing associations)</td>
</tr>
<tr>
<td>Key resources<br>▪ Development land<br>▪ Trained constructors<br>▪ Reliable AB equipment<br>▪ Building design and kit integration know-how<br>▪ Knowledge of the savings potential and the WTP for services</td>
<td>Channels<br>▪ Direct sale<br>▪ Via estate agents</td>
</tr>
<tr>
<td colspan="3">Cost structure<br>▪ Land price, construction and equipment cost</td>
<td colspan="2">Revenue streams<br>▪ Sale of ABs</td>
</tr>
</table>

Business Model Canvas from Strategyzer.com

**Figure 7.** The Build and Transfer model.

## 5. Discussion

Just as Active Buildings could be viewed as an extension of current trends for improved insulation and smart control systems, the four business models presented here are built on concepts that already exist. Developers sell hundreds of thousands of buildings a year but they are not yet selling Active Buildings. There are some all-inclusive rental companies but they are not yet renting units in an Active Building. Energy service companies installing equipment to make their clients' energy consumption more efficient already include some of the control systems that an Active Building would require. Aggregators already sell demand response and other services to the national grid and distribution network operators, generally from large industrial and commercial premises with significant energy demands. The hope for Active Buildings is that greater automation, and economies from learning by doing, would make it possible for smaller buildings to provide these services without incurring excessive transactions costs.

Testing our candidate business models is therefore not a case of asking whether (for example) a viable business could ever come from building homes for sale to owner-occupiers—the answer is an obvious "yes". The question has to be whether a business that builds homes for sale would find it profitable to make those homes Active Buildings, rather than continuing to sell traditional buildings with the legal minimum of insulation and no smart controls. That is a matter of comparing the incremental costs the developer would incur with the incremental revenues it might obtain from selling a higher-quality building. Geske and Green [24] carry out these calculations, given that house price premia depend on relative scarcity, and suggest that the premium for a limited number of Active Buildings (up to about one-tenth of the UK housing stock) would outweigh the incremental costs involved, making the business model a profitable one. Similar calculations are needed for the incremental effect of equipping and operating Active Buildings on the other business models described here.

The business models differ in the amounts of capital required and the time for which they must be committed. The Aggregator requires the smallest amount of capital, invested in decision-making, control and communications systems, and is likely to depreciate them over short timescales. Investments in its customers' energy efficiency mean that the energy service company needs more capital, and this is typically longer-lived, even if many investments of this kind have short payback periods. Nonetheless, the energy service company will need a longer-term relationship with its customers than the Aggregator, which might need to match the relatively short life of most electricity (retail) supply contracts.

The developer needs far more working capital than the two "operational" businesses, in order to cover the substantial cost of building a home until it is sold; furthermore, while an individual home might only need 6–12 months for construction (with a lot of variation around this average), a large site is typically developed (and sold) in phases over several years. Even this is short compared to the multi-decade life of a building and the potential commitment of the all-inclusive rental developer (although individual companies are sometimes bought out of their commitments).

While we have focused these examples on the housing sector, the Active Buildings Centre is also working with the Welsh Government and Carmarthenshire County Council to develop a commercial and light industrial estate of Active Buildings at Cross Hands [25]. Many large industrial customers already adjust their consumption in response to price signals and system operators' requests; for energy-intensive industries, however, their "industrial" load often dwarfs the part due to heating or cooling their buildings. Commercial buildings (some already managed by Aggregators) may be more promising than residential ones, in that the load available to be shifted is larger, and hence transaction costs per kWh can be lower. This is especially important in the early stages, when the cost per transaction is relatively high. The provider of serviced offices is perhaps equivalent to the all-inclusive rental developer; another analogy could be an incubator for startup companies.

We believe that these business models are all compatible with the industry's regulatory requirements, not least because they are variations on existing models. The one that might be the most complex, from a regulatory point of view, is the energy service company selling to domestic (household) customers. To recover its investment, the company needs a long-term relationship, whereas regulators have tended to promote consumers' ability to switch between suppliers as part of a competitive market. Rosenow and Eyre [26] have also highlighted the need to make "pay as you save" energy efficiency financially attractive to consumers while also appealing in terms of comfort. The success of a business model does not turn on economic calculations alone.

## 6. Conclusions

We have presented four candidate business models for Active Buildings which help their occupants to respond to the needs of the energy system: The "Build and Transfer" Business develops Active Buildings and installs the equipment required, but does not operate them. Active Buildings purchased or developed by an "all-inclusive" rental company are managed to optimize their cost and performance, including the operation of the equipment by an Aggregator or an Energy Service Company. The former supplies flexibility to the energy system by controlling the Active Building equipment according to occupants' preferences, internal sensor information and external scarcity signals; the latter also invests in that equipment upfront. Both types of company can also sell their services to owner-occupiers of Active Buildings, both domestic and non-domestic.

The next stage in this research is to develop quantified business plans with realistic timetables. What are the likely costs and revenues, in a startup phase and longer-term, and is there a long gap between incurring significant costs and receiving revenues? How much working capital would be required and how much money must be committed to the business for the longer term? What would its staffing look like, and how fast would employees have to be hired and trained? How vulnerable would the business be to an economic downturn, rising (or falling) energy prices or voids between tenants?

Could there be a "valley of death", in which small-scale businesses would struggle to establish themselves, even though a sector in which Active Buildings had become normalized would be a viable—and valuable—part of a net zero economy? If so, there could be a good case for government support, and further research would show whether this would have the greatest impact in the form of (for example) grants towards the initial investment costs or through widely disseminated demonstrator projects, subsidized as necessary to ensure their attractiveness for participants.

These models were initially developed at a workshop involving a range of industry and other stakeholders, and refined by the present authors. They are not intended to be exhaustive; the workshop suggested several other possible ways of making money from Active Buildings. However, they encompass two extreme alternatives for the length of the building developer's relationship with it, and the two leading candidates for managing the interaction between the building and the grid. We thus believe that they are good examples for further research into their commercial viability and any regulatory barriers that would have to be removed before the benefits of Active Buildings can be more widely obtained.

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