ARTICLE IN PRESS

Energy Policy xxx (xxxx) xxx

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Conceptualising domestic energy service business models: A typology and policy recommendations

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ARTICLE INFO

Keywords:
Energy services
Business models
Residential
Energy performance contract
Energy as a service

ABSTRACT

Energy service business models (ESBMs) are potentially critical to reducing household energy demand and mitigating climate change. These models are predicated on a shift from the 'throughput' sale of energy commodities, towards providing 'useful' or 'final' energy services. However, the conceptual delineation of these models and their different variants remains opaque in the literature. In this paper, we seek to clarify this issue through the identification of a typology of ESBMs. Through a series of 53 interviews and 7 stakeholder workshops we explore contemporary domestic ESBM examples in Europe. We find that while more basic energy supply contracts are commonplace, models which deliver energy saving performance or final energy services are rarer. We subsequently identify barriers to the adoption of these business models, before proposing 13 policy recommendations. We conclude that the 'energy throughput orthodoxy' which has governed liberalised energy markets will need to be challenged for these models to have a significant future impact.

1. Introduction

Buildings, and especially homes, are the largest single consumer of energy and producer of greenhouse gas (CO_2e) emissions in most advanced economies (IEA, 2020a). In nations with cold and temperate climates, the bulk of this energy demand and CO_2e emissions result from space heating and hot water consumption (CCC, 2019a), while in hotter climates this demand may be cooling led (IEA, 2018). Electricity systems across Europe are decarbonising (European Environment Agency, 2021); heat systems are electrifying; and electric vehicles (EV) are being adopted at an exponential rate (IEA, 2019). These factors – including the requirement for home EV charging – means decarbonising homes is a key objective to meet ambitious climate targets.

In the European Union (EU), the Energy Performance in Buildings Directive (EPBD) requires that emissions from European homes be drastically reduced by 2030, and near eliminated by 2050 (EC, 2018). This challenge means new homes must meet near zero energy building standards (NZEB), existing homes must be retrofitted to increase energy efficiency, heating systems must transition to low/zero carbon sources, and renewable 'prosumers' with solar photovoltaics (PV) and batteries (Parag and Sovacool, 2016) must become commonplace.

New homes are ostensibly the easiest place to make progress. The limited penetration of NZEBs, however, results from the lack of a strong regulatory environment for new homes. In the UK, for example, plans for a 2016 mandatory Zero Carbon Homes standard were scrapped – in part due to resistance from the construction industry (Heffernan et al., 2015). At the same time, new homes are plagued by a 'performance gap' of energy efficiency measures, where modelled energy demand is not matched by measured performance (Mcelroy and Rosenow, 2018).

Further, most savings must be found in existing homes, since 80% of the UK's homes in 2050 are expected to be those already standing (Federation of Master Builders, 2013). Therefore, energy efficiency, low carbon heat and microgeneration measures must be 'retrofitted' to millions of existing homes in the coming decades. Thus far in Europe, savings have been achieved through incremental measures, such as fluorescent lightbulbs, loft insulation and efficient boilers (Rosenow et al., 2016). Yet, it is increasingly recognised that this approach will be insufficient to meet climate change targets (CCC, 2018; IPCC, 2014). Instead, increasing emphasis is on 'whole-house retrofits' involving multiple, integrated measures (STBA, 2016). Progress in retrofitting the EU's existing housing stock, however, has consistently and substantially underperformed – with emissions from buildings actually increasing in the UK in 2017-18 (CCC, 2018). Since that time emissions from homes have remained essentially flat in the UK (CCC, 2020) with a number of

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https://doi.org/10.1016/j.enpol.2021.112704
Received 4 June 2021; Received in revised form 20 September 2021; Accepted 2 November 2021

Please cite this article as: Donal Brown, *Energy Policy*, https://doi.org/10.1016/j.enpol.2021.112704

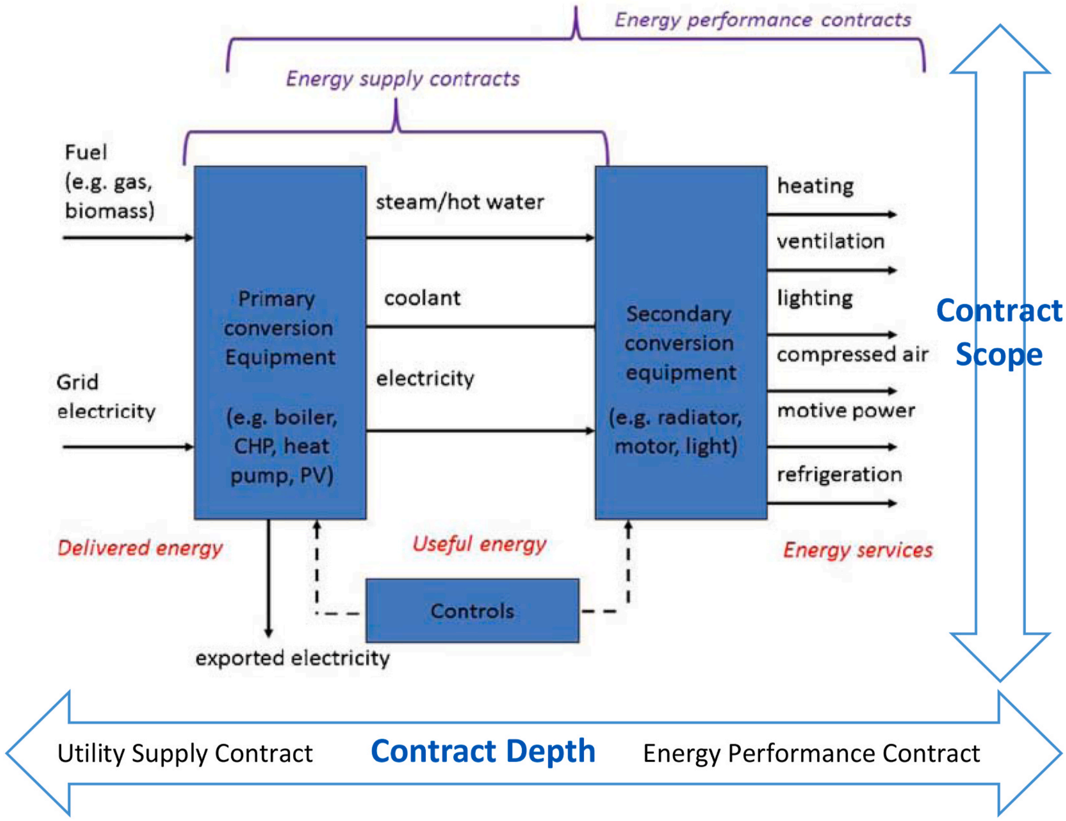


Fig. 1. Energy service contracts: scope and depth. Adapted from Nolden and Sorrell (2016).

high-profile policy failures in recent years (BEIS, 2021).

These issues have led researchers and practitioners to propose fundamental changes to the systems that provision domestic energy services, including the underlying business models operating in liberalised energy markets (Hall and Roelich, 2016). One concept to receive both commercial and academic attention is moving the business model of energy provision away from *energy supply* and towards *energy services* (Bertoldi and Boza-Kiss, 2017; Hannon et al., 2013; Vine, 2005). Under these energy service business models (ESBMs), instead of paying a utility company for units of energy (kWh), customers pay for the provision of services (e.g., indoor thermal comfort, illumination, sanitation) – shifting the responsibility for efficiency from households onto energy service companies (ESCOs). Despite this attention, confusion remains as to what exactly is meant by 'energy service business models', with empirical examples in the domestic sphere becoming prevalent only recently (Labanca et al., 2014). In this paper we seek to clarify these issues by addressing the following questions:

1. How are domestic ESBMs conceptualised in terms of their scope and depth?
2. How might ESBMs incentivise the decarbonisation of housing more effectively than the traditional utility model?
3. What policy framework would be conducive to domestic ESBMs?

We address these questions through a review of previous literature (Section 2) and primary data collected via 53 interviews and 7 stakeholder workshops, as outlined in our methodology (Section 3). Based on previous literature and our data, we then develop a typology of ESBMs and explore emerging residential examples in Section 4, before discussing their potential for the key decarbonisation challenges in the residential sector in Section 5. We conclude in Section 6 by providing 13 policy recommendations to promote the increased adoption of ESBMs in the UK and EU member states.

2. ESBMs – theory and practice

2.1. ESBMs: conceptual foundations

Business models describe the nature of value delivered to customers, how organisations and networks create value and the means of capturing revenues from that value (Hellström et al., 2015; Teece, 2018). Whilst the energy studies field focusses primarily on technologies, there is growing recognition of the integral role of accompanying business models, particularly for the radical, ground-breaking or 'systemic' innovations that characterise energy transitions (Gordijn and Akkermans, 2007).

In the traditional 'throughput' business model, a utility or fuel provider sells an energy commodity – i.e. coal, oil or natural gas – to the end user in its raw form (Hall and Roelich, 2016). Here, the commodity is sold at a price based on its energy content or volume. Under these models, the supplier takes no responsibility for the financing, operation and maintenance (O&M) of the energy conversion hardware and is economically dis-incentivised from reducing the end user's energy consumption (Hannon and Bolton, 2015). This remains the dominant business model for domestic energy supply in most countries.

Instead, ESBMs provide 'useful' energy services like hot water, coolant, or the 'final' energy derived – such as illumination, or room temperatures. These models shift the responsibility for the performance of equipment or a building into long-term contracts between an ESCO and the household or business (Nolden and Sorrell, 2016). Solar-as-a-service models, for example, help households to become prosumers without the upfront cost. Here, the ESCO leases PV panels and takes responsibility for finance, installation and maintenance: offering a solar tariff and dealing with export agreements (Overholm, 2015). Heat-as-a-service (HaaS) models sign-up consumers to a comfort agreement and can operate with district heat network or by installing heat pumps, often with ESCOs owning or leasing the infrastructure

(Hannon and Bolton, 2015). These models may also offer energy performance contracts based on measured and verified energy savings, further incentivising efficiency in building fabric, lighting and appliances (Sorrell, 2007).

Sorrell (2007) and Steinberger et al. (2009) seminal works on the economics of energy service contracts, and the potential of an energy performance-based economy, provide a theoretical foundation for the study of these business models. Steinberger et al. (2009) argue that a transition to a sustainable energy system must also involve a transition from business models that rely upon increasing 'throughput' sales of energy, towards a 'performance-based energy economy' -where profits are decoupled from energy consumption – leading to absolute reductions in demand. Sorrell (2007) outlines how the economic viability of ESBMs is closely related to their associated transaction costs. Consequently, such contracts are only viable when the *transaction costs* of implementing and negotiating an energy service contract can be outweighed by the energy *production cost* savings of efficiency measures and outsourcing to an ESCO. "Transaction costs, in turn, will be determined by the complexity of the energy service, the 'specificity' of the investments made by the contractor, the competitiveness of the energy services market and the relevant legal, financial and regulatory rules" (Sorrell, 2007, p. 507).

Sorrell (2007) also defines energy service contracts both by their *scope* – i.e. the number of energy streams covered by the contract (e.g. electricity, heating, cooling, hot water, lighting, etc.) and by their *depth* – the extent to which the ESCO has control over final conversion equipment. As shown in Fig. 1, shallower utility supply contracts involve the delivery of raw energy commodities whilst deeper performance contracts provide final energy services – incentivising ESCOs to seek maximum efficiency from secondary conversion equipment.

2.2. ESBMs: empirical examples

Historically, ESBMs have been restricted to large public and industrial sites due to high transaction costs. A 2014/15 UK survey showed that the majority exist in the public sector, usually at larger sites (such as hospitals and universities), often involving a combined heat and power (CHP) unit and the provision of heating, hot water and electricity (Nolden and Sorrell, 2016). More recently, however, residential examples have emerged. RENESCO in Latvia, Lithuania and Estonia, ICF habitat in France, and Bristol Energy in the UK have each trialled 'pay for performance' models in the provision of thermal comfort in homes (Brown, 2018). Further, the Energiesprong initiative has deep-retrofitted several thousand homes in the Netherlands, bundling rooftop solar with multiple energy services into 30 year net-zero energy performance contracts with social housing providers (Brown et al., 2019b). In the UK, Smartklub and OVO energies' aggregator platform, Kaluza, are also trialling sophisticated electricity market participation from rooftop solar systems, grid connected batteries, heat pumps and smart home devices in a move to valorise their flexibility potential (Brown et al., 2019a; Wang, 2018).

Several factors contribute to the growing viability of these business models. Firstly, intermediaries (Kivimaa et al., 2019) are helping to reduce transaction costs, through standardised contracts and procurement frameworks (Nolden et al., 2016). Secondly, the profusion of smart appliances, monitoring and machine learning (Wang, 2018) is helping ESCOs to reduce the costs of implementing and maintaining such contracts (Mcelroy and Rosenow, 2018). Equally, as electricity markets are decentralised, 'prosumer business models' open up new revenue streams from the production and self-consumption of renewable energy, allowing ESCOs to 'stack' revenues to improve their underlying business case (Brown et al., 2019a). These developments present a prescient moment to study the potential contribution of these business models to the decarbonisation of residential buildings.

2.3. ESBMs: academic studies to date

Fell (2017, p. 137) defines energy services as "those functions performed using energy which are means to obtain or facilitate desired end services or states", highlighting the distinction between *sources of energy* (i.e. natural gas), *energy consuming practices* (i.e. showering), *end services or states* (i.e. being clean), and the *energy service* of providing hot water itself. Consequently, ESBMs can be described as:

The provision of useful or final energy services and/or guaranteed savings, how organisations and networks provide these services and the means of capturing revenues from them.

Literature on ESCOs, energy services, and energy performance contracts has grown significantly since the early 2000s. Early work by Sorrell (2005) and Bertoldi et al. (2006) emphasises their potential for a low carbon economy. The notion of a third-party ESCO providing information, finance, installation, plus O&M of energy systems under a long-term contract (Bertoldi et al., 2006) – where users pay for energy services rather than units of fuel (Steinberger et al., 2009) – is now central for scholars studying low carbon energy transitions (Knoeri et al., 2016; Roelich et al., 2015). Indeed, moving from an energy economy based on increasing throughput sales, towards one based on provision of energy services is today explicitly recognised by multinational bodies including the International Energy Agency (IEA, 2018) and EU Commission (Boza-Kiss and Bertoldi, 2017).

While much of this literature has been conceptual, studies have sought to map the size and nature of the ESCO market (Bertoldi and Boza-Kiss, 2017; Irrek et al., 2013; Kindström and Ottosson, 2016; Marino et al., 2011; Navigant, 2015; Nolden and Sorrell, 2016; Panev et al., 2014). Boza-Kiss and Bertoldi (2017) estimated the EU ESCO market at €2.4 billion in 2015, forecasted to grow to €2.8 billion by 2024 with a 1.7% annual growth rate (Boza-Kiss and Bertoldi, 2017). Yet, this still represents a tiny fraction of the EU's overall gas and electricity market (IEA, 2020b).

These studies reveal that ESCO markets remain dominated by large contracts in the public and industrial sectors. There is increasing interest, however, in energy service models in the domestic sphere (Labanca et al., 2014; Morris-Marsham and Firth, 2017; Winther and Gurigard, 2017), a sector constituting roughly 2/3 of heat demand in most advanced economies with temperate climates (IEA, 2018). Recent work describes how different energy service models can enable decentralised electricity systems (Brown et al., 2019a; Hall and Roelich, 2016), whole house retrofits (Brown, 2018; Brown et al., 2019b) and reduce the energy performance gap for new build housing (Mcelroy and Rosenow, 2018; Winther and Gurigard, 2017).

A review of the existing literature, however, suggests that the conceptual delineation of these models remains opaque at best and at worst convoluted. Although many papers describe 'ESCO models' (Hannon et al., 2013), this catch-all term conceals significant variability in their nature and purpose. Likewise, the term *energy supply contract* is used interchangeably with the current utility business model (Morris-Marsham and Firth, 2017), based on the delivery of primary energy commodities. Further, the notion of the *energy performance contract* is commonly used in finance circles to describe where both financing and energy saving guarantees are outsourced to a third party (Lee et al., 2015; SUSI Partners, 2017), often without the provision of energy services (Fell, 2017). Thus, ESBMs may simply relate to guaranteed energy savings, include the financing of energy savings measures and may further include the upstream utility supply (Kim et al., 2012).

We seek to unpack this complexity, developing a typology of ESBMs, before introducing some emerging examples in the European residential sphere. We subsequently discuss policy options for the expansion of these business models in the context of the existing throughput-based domestic energy market.

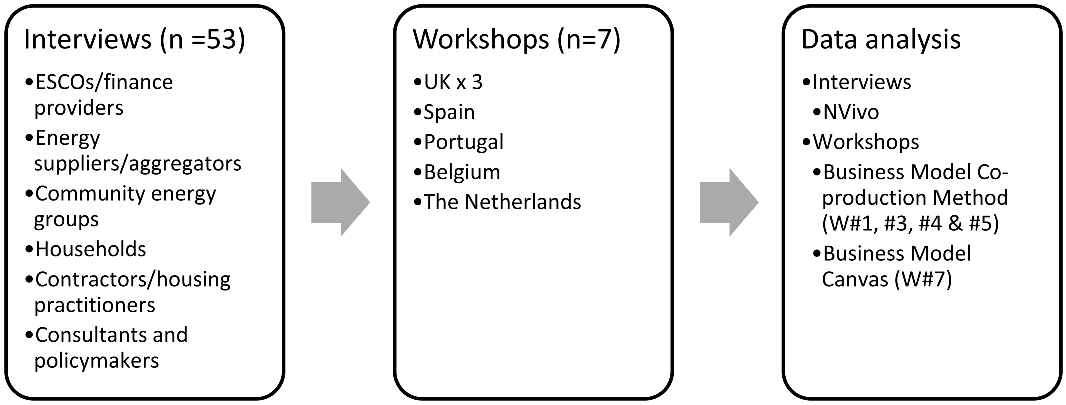


Fig. 2. Data collection and analysis methodology.

3. Methodology

This research adopted a cross-sectional research design of contemporary domestic energy services business models in Europe, using a mix of qualitative methods. This involved synthesis of multiple data sets, across several research projects. The aim of the research was to map the diversity of domestic ESBMs and identify core features that can aid their categorisation, resulting in the typology described in Section 4. Subsequently, we evaluated the potential of these business models to deliver residential energy demand reduction and climate change mitigation, leading to policy recommendations for their increased adoption. The paper draws on 53 interviews and 7 workshops across the UK and EU, conducted between 2016 and 2021.

3.1. Data collection

Interviews were conducted in three phases. Phase 1 (2016–2018) focussed on retrofit business and financing models, phase 2 on prosumer business models (2018–2019), and phase 3 (2020–2021) on households, designers and building management practitioners with experience of ESBMs. This included interviews with n = 12 ESCOs/finance providers, n = 6 energy suppliers/aggregators, n = 3 community energy groups, n = 14 households, n = 10 contractors/housing practitioners, and n = 11 consultants and policymakers. Interview data from phases 1 (I#1–17) and phase 2 (I#18–28) was used to understand and better characterise ESBMs and their applicability to different market segments. Phase 3 was divided into n = 5 case study buildings. Questions were focussed on the users' perceptions of their existing heat and electricity business model, and then alternatives, including those that provide final energy services. This included two Finnish apartment blocks which previously ran on Helsinki's district heating system, and which had converted to a ground source heat pump (GSHP) (I#29–38). UK household interviews (I#38–53) were focussed on a social housing estate in London, connected to an ageing district heating system which was due to be replaced with a low carbon alternative. Greek interviews were focussed on two apartment blocks with communal heating; one which included solar thermal hot water (I#39–42), and another which was oil and electric heated only (I#43–44).

Interviews were mostly semi-structured, following a set interview protocol, but with some flexibility to pursue relevant lines of enquiry. Interviews were either face-to-face or held online and were subsequently recorded and transcribed. Interviewees were given an information sheet and consent form, with the chance to stay anonymous, but some consented to be named. Further details can be found in Appendix A.

Throughout 2019, seven stakeholder workshops were conducted in the UK (x3), Spain, Portugal, Belgium and the Netherlands. The events brought together local government, community energy organisations, businesses, citizens, academia and non-governmental organisations (NGOs). Four workshops (W#1, #3, #4 & #5) were focused on identifying and characterising decentralised energy business models in each host country, with many examples of ESBMs providing services beyond the basic utility supply model. Three further workshops (W#2, #6 & #7) were held in the city of Bristol (UK), where an energy service offer was being developed at the time of research. The first workshop (W#2) focussed on the challenges of developing decentralised energy systems as direct subsidies are removed. The second (W#6) focussed on financing decentralised energy systems. The third (W#7), delivered jointly with Bristol Energy Company, focussed on the challenges of developing domestic ESBMs. This workshop involved a plenary session with three speakers – Bristol Energy Company, Energiesprong UK and Smartklub from the Nottingham Trent Basin project. Details of these workshops are also found in Appendix A.

3.2. Data analysis

Interviews were analysed with the NVIVo 12 qualitative analysis software, using common themes to code the data and structure the analysis. Each interview has a unique signifier (I#X), which is referred to in Section 4.

During workshops W#1, #3, #4 & #5 we adopted a 'Business Model Co-production Method' (Hall et al., 2020), with participants producing diagrams of ESBMs that were at, or close to, market in their host country. This method captures the flows of energy, payments, services, and system interactions by creating component diagrams showing how each business model works. By creating such diagrams, a typology of different business model 'archetypes' emerged. We next compared how each archetype addressed different problems faced by the energy system. An example of these component diagrams is shown in Appendix B.

In W#7, participants were asked to complete a 'Business Model Canvas' (Osterwalder and Pigneur, 2010) outlining the potential features of ESBMs for three key sectors: new build housing, low carbon heat and whole house retrofit. The Business Model Canvas provides a template for developing and documenting business models using nine building blocks. Subsequently, participants were asked to focus on specific opportunities and challenges for ESBMs in their respective sector. Respondents reflected on the challenges and opportunities of these business models from the perspectives of five key actor groups. The three completed business model canvases from W#7 are shown in Appendix C.

The data collection and analysis methodology is summarised in Fig. 2.

4. Residential ESBMs in Europe

Our analysis identified a typology of six ESBMs: *energy supply contracts* (ESC); *energy service financing* (ESF); *energy performance contracts*

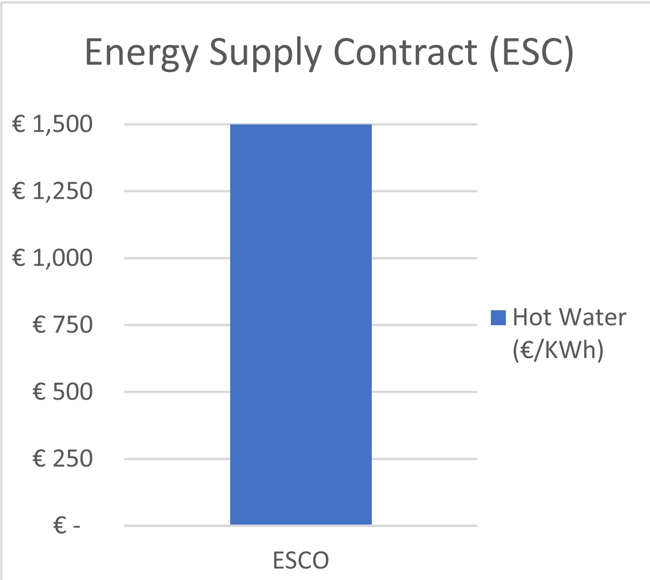


Fig. 3. Payment breakdown of Energy Supply Contract (ESC).

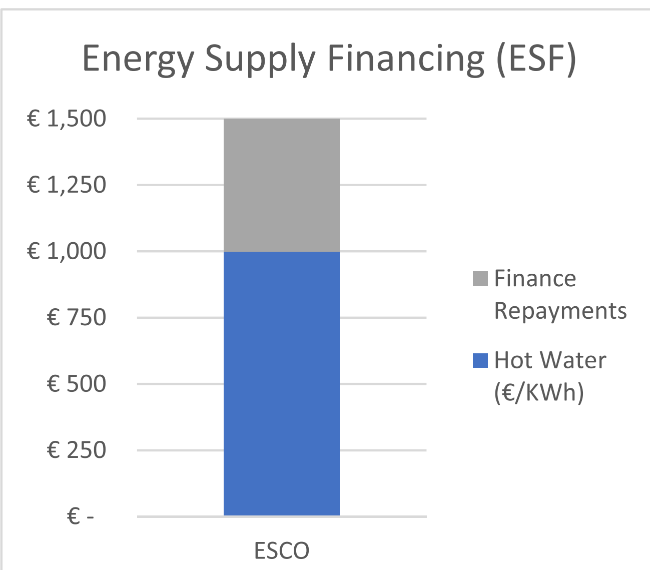


Fig. 4. Payment breakdown of Energy Supply Financing (ESF).

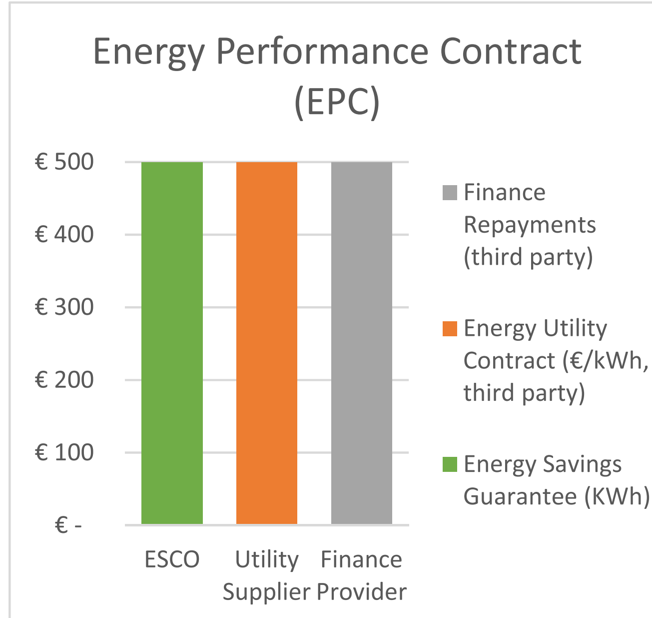


Fig. 5. Payment breakdown of Energy Perfromance Contract (EPC).

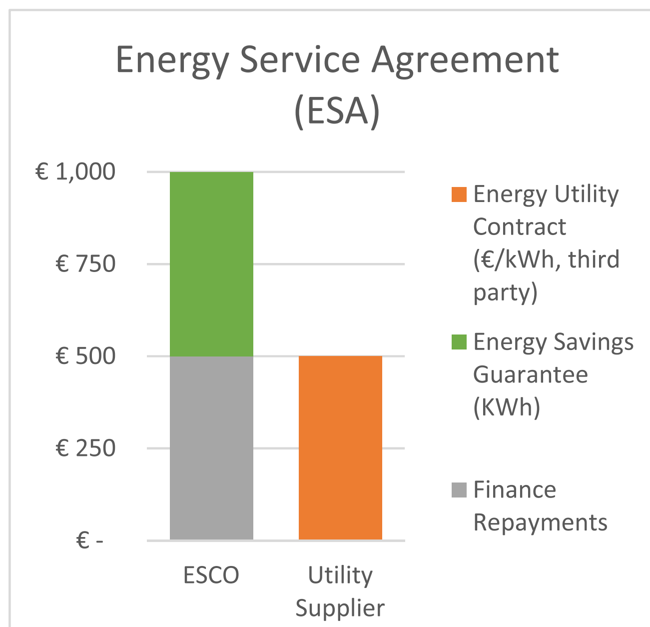


Fig. 6. Payment breakdown of Energy Service Agreement (ESA).

(EPC); *energy services agreements* (ESA); *energy as a service* (EaaS); and *managed energy services agreements* (MESA). In the following section we explore these models using illustrated empirical examples to show a simplified breakdown of the payment structure of a typical household bill for each (Figs. 3-8). For simplicity we have focussed on the single energy service of space heating. We have used commonly understood definitions where possible, building on the work of Black (2020), who describes a range of 'heat as a service' models, Brown, (2018), who identifies six energy efficiency business model archetypes, and Kim et al. (2012) who explore alternative financing mechanisms for energy efficiency. This literature and definitions are combined with our empirical data to elaborate the typology in the following section.

4.1. Energy supply contract (ESC)

Under an ESC, instead of supplying primary energy, an ESCO provides a useful energy supply, such as hot water, directly to users (Nolden et al., 2016). The most common example of these business models is in district heating systems, where ESCOs deliver hot water for space heating and sanitation. Users either pay a fixed price or are metered volumetrically for their hot water usage (kWh), as shown in Fig. 3. These business models incentivise ESCOs to deliver this 'useful energy' as efficiently as possible, shifting responsibility for primary conversion efficiency from users to the ESCO. As these models do not cover the secondary conversion equipment, they do not incentivise ESCOs to seek demand reductions or building fabric improvements. By taking control of primary conversion equipment, these models do enable ESCOs to access additional sources of revenue from the flexibility of decentralised energy systems, such as batteries, heat pumps and CHP generators.

Domestic ESCs were found to be commonplace and are the typical business model for district heat networks, which are particularly

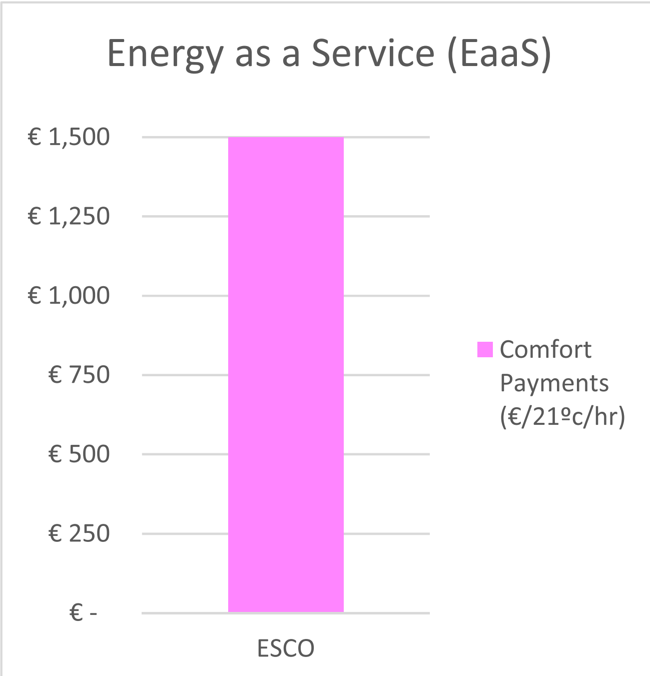


Fig. 7. Payment breakdown of Energy as a Service (EaaS).

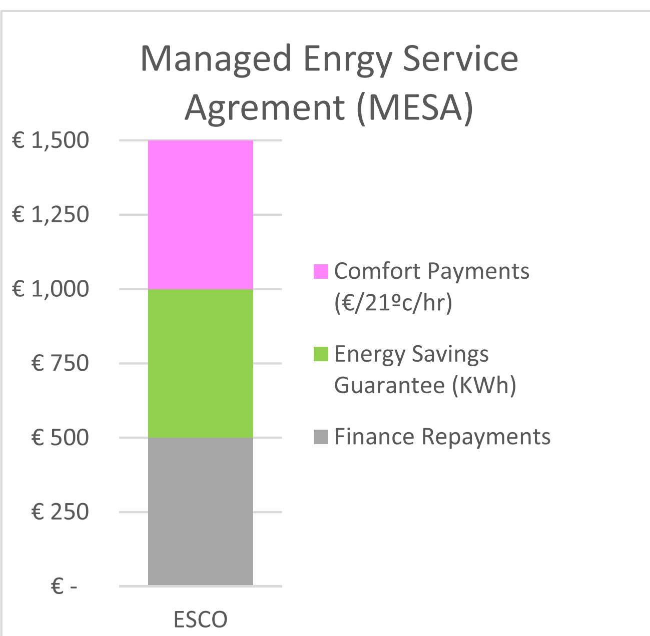


Fig. 8. Payment breakdown of Managed Energy Service Agreement (MESA).

common in northern European countries. Several of our household and building manager case studies - in the UK (London) (I#47, 48, 52,53), Finland (Helsinki) (I#29–38) and Greece (Athens) (I#39–44) – paid a single charge based on the size of their apartment. In Finland, heating is commonly paid as part of a monthly building service charge, which is set annually based on the overall heating usage of the apartment block. Several building designers we interviewed (I#37, 49–51) commented that ageing district heating systems are locking in high carbon heat provision from coal fired power stations and other fossil fuel sources, with the high sunk costs of these networks a barrier to change. Indeed, even in more modern district heat systems, energy planners had built systems around natural gas CHP systems, only to find that their carbon emissions compared unfavourably to grid electricity.

There are also increasing examples of these models being used for district heating provision from low carbon sources, such as GSHP (I#29–37), usually serving new housing developments (I#20, I#21). In the UK, private developers have tended to avoid installing district heat systems themselves as they disfavour ongoing contracts, where high up font cost might be recovered through service payments. That said, community-owned and financed examples, such as Smartklub (I#19) and BHESCo (I#3) in the UK, are looking to buck this trend.

District heating systems usually require centralised governance and planning, necessitating the involvement of a municipal ESCO or city authority, such as Helsinki in Finland (I#37) or Bristol City Council in the UK (I#28). In the UK, these models serve only 446,517 domestic customers, or <0.2% of homes (ADE, 2020), compared to 63% in Denmark and 93% in Iceland (Euroheat, 2015). Our interview and workshop data suggest that the differing municipal energy, planning, governance, and funding regimes in large part explains this difference; with Nordic countries having a strong tradition of municipal energy provision compared to the UK.

An alternative is ESCs from systems located within or close to the building. Here the ESCO has responsibility for the installation, and O&M of primary conversion systems such as boilers, CHP units or heat pumps within the client's premises (such as our Finnish GSHP examples I#29–37). Residents pay a service charge that covers both the useful energy supply and the O&M costs, with the ESCO ensuring efficient operation. In the Greek examples, residents felt the flat rate for heating based on the size of their apartment (I#39–44) was unfair and penalised them for the energy profligacy of their neighbours. These models are also seen as an important route to the adoption of low carbon heat systems, particularly for multi-family buildings, where the ESCO is incentivised to deliver useful energy at lowest cost. For example, several UK municipal housing providers we interviewed (I#17, I#28) were considering setting up their own ESCOs to replace individual fossil fuel boilers with highly efficient GHSPs, with residents paying for hot water instead of kWh's of natural gas.

Because these models allow the ESCO to control the operation of the primary conversion equipment, they are also an important way of creating value from flexible assets such as heat pumps or li-ion batteries. Interviews with an energy company (I#22), their independent aggregator arm (I#23) and a community ESCO (I#20), indicated that in future ESCOs will increasingly look to provide grid flexibility services that can be aggregated for electricity network operators and earn revenues from arbitrage – i.e., purchasing electricity at cheaper periods, storing as heat or electricity. The domestic flexibility aggregator commented that the key to unlocking this value is ensuring that end users are not required to control these systems themselves or be directly exposed to time of use pricing (I#23).

4.2. *Energy service financing (ESF)*

In ESF, the ESCO will also act as project developer, financing the primary conversion systems as well as taking responsibility for their O&M (Sorrell, 2005). These options can be attractive to end users as they can upgrade a building's heating/cooling plant at no up-front cost, paying off their cost through energy service payments. For example, in one of the cases in Finland (#29–31) a move from district heating to a GSHP was financed by a loan taken by the apartment block, which households then pay back in their monthly building service charge (with the option to pay back earlier) – meaning little financial risk to the householder. These models tend to suit situations where the building owner has limited access to capital or wishes to take the project off their balance sheet. More common in the commercial and industrial sector, these models require ESCOs to mobilise significant capital. As shown in Fig. 4, financing can provide more efficient primary conversion equipment, such as a new boiler, reducing the cost of the energy supplied (hot water) once finance repayments are complete.

The inclusion of financing, however, can place constraints on the balance sheets of ESCOs with multiple projects (I#2). This has created demand for "third party financing" (Bleyl-Androschin et al., 2009) for projects with proven cashflows, allowing ESCOs to move these projects off their balance sheets, while continuing to receive service payments. These types of projects remain dominated by commercial and industrial buildings, although actors such as the European Regional Development Bank (I#11), Swiss Susi Partners (I#10) and the UK's Green Investment Group are now developing these financial products for larger residential projects.

One specific area where this model is showing potential is through 'solar-as-a service' business models. Here the ESCO installs, maintains and finances a solar PV system, with the end user receiving the useful electricity in the form of a power purchase agreement (PPA) from the solar array (I#18). These models have been prevalent in the USA and may be partnered with a battery to maximise the onsite consumption of power. Tesla are the most high-profile provider, although several smaller actors are also active in this market. In an idealised version, the customer would pay a single electricity bill to an ESCO who would also provide electricity when the system was not generating (see MESA, discussed later). As outlined in several of our workshops (W#1, #3, #4, #5 & #7), however, EU 28-day electricity switching requirements, which would allow the consumer to defect from on bill finance agreements, mean that the ESCO risks being unable to recover the capital investment on the system, and thus the solar-as-a-service payments tend to be disaggregated from the electricity bill.

In the UK, SmartKlub (I#20) are trialling this model in the Trent Basin project, featuring a large PV array, 2.1 MW battery, rooftop solar and GSHP connected to a district heat network. Smartklub have created an ESCO to manage the system, with limited involvement from residents. Residents receive a reliable power and heat supply with the ESCO optimising the system to secure the best revenues and balance between import and export, using the large battery to contract into flexibility markets through an aggregator for additional revenues. Profits from the ESCO are recycled into a community fund, whilst the ESCO itself is designed to pass into community ownership at the end of the trial phase.

4.3. Energy performance contracts (EPC)

Under an EPC, an ESCO provides guarantees for measured and verified performance savings from one or more final energy services such as heating or illumination (Nolden et al., 2016). To ensure that performance is delivered, the ESCO controls secondary conversion equipment such as lighting, heat emitters and controls, and is also incentivised to ensure that the building fabric is efficient (Sorrell, 2005). Because ESCOs are obligated to deliver measured performance, these models create incentives for the maximum efficiency from both primary and secondary conversion equipment. Under a basic EPC, the customer pays the ESCO for measured performance plus O&M. Here the customer secures their own finance and retains a separate energy supply contract with a utility company. In our example (Fig. 5) the user saves €500/year once finance repayments are complete.

EPCs have historically been rarer in the domestic sphere due to the high transaction costs of delivering verified performance savings on individual dwellings. The examples we found have almost exclusively been in social housing, where sufficient scale and standardisation enable these costs to be manageable relative to energy savings. Despite these difficulties, these models promise to exploit the vast fabric energy efficiency potential in the existing housing stock. Proponents argue that these models may also be important in driving household's uptake, who's lack of trust in predicted energy savings has been a barrier to the update of low energy retrofits (I#12–17). Indeed, a UK interviewee (I#52) viewed guarantees on quality and energy saving performance favourably, given their negative experience from previous renovations on their property.

While EPCs in the domestic setting are uncommon, the Financing energy REfurbishment for Social Housing (FRESH) project explored examples in France, United Kingdom, Italy and Bulgaria. While several of these models included financing (dealt with in the following section), some focussed exclusively on delivering guaranteed energy savings. The Energies POSIT'IF project (now called Iles des France Energies) operates an EPC with guaranteed energy savings (average 47%) in the greater Paris region (I#6). The initiative is focussed on multi-family housing and renovates to meet the French energy performance standard "Bâtiment basse consummation" (104 kWh/m2/a). As of 2016, the project delivered €35,581,544 of energy saving investments for the refurbishment of 8 apartment buildings comprising 2127 dwellings (Intelligent Energy Europe, 2020).

Our interviewees and workshop participants described how the technical and economic challenges of implementing EPCs in the domestic sphere remain a major barrier to uptake. These include the performance risk that the measures will not deliver the modelled savings (I#8); the behavioural risk that users will engage in energy profligacy (I#28); the high costs of monitoring and controlling the energy systems in individual homes (I#1); and the risk for the client that the ESCO will cease trading - voiding the performance guarantee (I#1, I#12). Many of the initiatives interviewed were investigating the behavioural and physical characteristics of homes, to mitigate the aforementioned risks (I#1, I#3, I#12–17, I#22–28). Indeed, practitioners described how insurance-backed performance guarantees, low-cost 'smart home' and remote monitoring devices, machine-learning techniques and big data should help to make performance-based business models increasingly viable.

4.4. Energy services agreement (ESA)

Energy service agreements (Fig. 6) are a variant of EPCs that involve integrated financing of energy saving measures, backed by a long-term performance guarantee. These models are viewed as an important way for housing providers to undertake energy saving improvements 'off balance sheet', with the ESCO taking both the financial and performance risk of the project. To date, ESAs have largely been focussed on large commercial and industrial sites, with most examples in the USA, tending to involve private finance providers, focussed on larger projects (>€1m) and on measures with short payback periods. Emerging domestic examples in Europe, however, are focussed on building fabric improvements with longer paybacks through low-cost public financing (I#3, I#4, I#6).

ICF Habitat – a subsidiary of the French state railway SNCF – renovated a 64-unit social housing project in Schiltigheim in the Alsace, France with the ESCO, SPIE (I#4). The 20-year ESA, involving third party financing upstream of the client, achieved an average heat demand reduction of 143 kWh/m2/a (68%) (SPIE, 2013). RENESCO are implementing the ESA model across former Soviet-era multi-family blocks in the Baltic states (I#2), with deep façade renovations of 15 apartment blocks since 2008. RENESCO finance the works from their own balance sheet before selling on the project cashflows, through a forfeiting fund they have developed with the European Bank for Reconstruction and Development (EBRD) called the Latvian Building Energy Efficiency Fund (LABEEF). Thus far, 97% of repayments have been on time with a default rate of 0% during the 6 years of the RENESCO program (CITYnvest, 2020).

Whether the ESCO or the client should finance the EPC is determined by both the cost of capital (interest rates) and the preferred balance sheet treatment. In the ICF habitat example, after adopting an ESA structure with third party private capital on the Schiltigheim project, I#4 described how in future they would self-finance EPC projects due to their access to low-cost debt. By contrast, RENESCO saw the financing provision of an ESA as a crucial feature of their offer, where the client – low-income owner occupiers – cannot easily take on debt to cover the cost of the works. Several Greek household interviewees (I#43–44)

Table 1
Typology of ESBMs.

	SUPPLY	SAVINGS	SERVICES
SELF-FINANCE	**Energy Supply Contract (ESC)** • Useful Energy	**Energy Performance Contract (EPC)** •Guaranteed Savings	**Energy as a Service (EaaS)** •Final Energy Services
ESCO FINANCE	**Energy Supply Financing (ESF)** • Useful Energy • Finance	**Energy Services Agreement (ESA)** •Guaranteed Savings •Finance	**Managed Energy Services Agreement (MESA)** •Final Energy Services •Guaranteed Savings •Finance

viewed integrated finance with suspicion, however, given their lack of trust in the finance sector more broadly. All three European examples of domestic ESAs reverted to some form of public financing in the delivery of their retrofit interventions. This suggests public financial institutions such as development banks or government loan guarantees have an important role in developing the domestic EPC/ESA market.

4.5. Energy as a service (EasS)

EaaS models, bundle the upstream energy supply into a single final service payment. For example, households may pay a comfort charge relating to room temperatures, lighting lumens, or pay for access to certain services such as showering or clothes washing. In our illustrated example (Fig. 7), users would pay for a guaranteed room temperature i. e., 21 °C for a period of 'warm hours' (€/21°c/hr). Bristol Energy in the UK have explored such a 'heat-as-a-service' (HaaS) business model to overcome the dual challenges of high energy bills and climate change (I#28). During their 100 home trial, households were offered either a flat rate HaaS tariff, or a variable tariff based on their consumption of warm hours (Energy Systems Catapult, 2019). Using household energy monitoring, the trial aimed to generate data on building fabric performance, occupant behaviour and heating system operation, for future refinement of the offering.

In the HaaS model trialled by Bristol Energy, the ESCO does not provide any energy saving measures or hardware, but instead operates the existing heating appliance and controls/bears the performance risk of the secondary conversion equipment – i.e., the building fabric of the home. The key challenge identified for Bristol Energy (W#7) was developing a comfort plan that accurately represents the energy demands of the home and can accommodate changes in behaviours and occupancy. Through advanced modelling and remote monitoring, these challenges, and the cost of implementing HaaS contracts are expected to reduce significantly in the coming years.

The promise of HaaS is its potential to improve the value proposition in the electrification of heat –perhaps the single biggest challenge for reducing carbon emissions. When combined with dynamic or time of use tariffs, HaaS models allow ESCOs to arbitrage electricity prices and match periods of high renewable electricity generation and low-cost on the grid with heat demand, with the ESCO controlling an appliance such as a heat pump. Customers pay for preferred room temperatures and can maintain improved levels of comfort through zoned smart thermostats. For now, this potential remains unrealised, with Bristol Energy recently sold to the UK energy giant Centrica. There are no future plans for expansion of the HaaS trial (I#28). Further, I#39 highlighted the subjectivity of 'comfort' and described conflicts with family members relating to preferred room temperatures in the winter and summer months.

4.6. Managed energy services agreement (MESA)

A MESA (Fig. 8) integrates the ESA model for energy saving improvements with the EaaS model for final energy service provision. Savings, financing, and upstream energy supply are bundled into a single performance contract based on final energy services. Because this

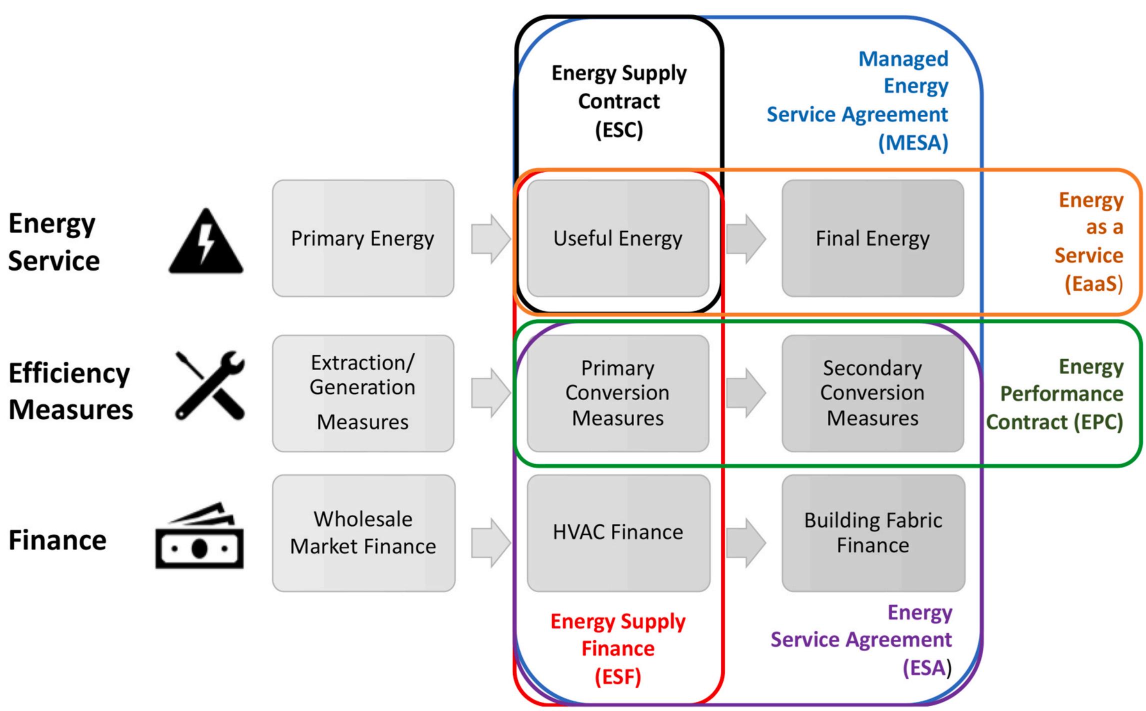


Fig. 9. Typology of ESBMs.

model combines a financed energy savings guarantee, and the value that can be created by optimising both the primary and secondary conversion systems, it has the greatest potential to deliver energy and carbon savings. Because of this complexity, however, MESA models have thus far only been adopted in the industrial and commercial sector, where the high transaction costs can be outweighed by substantial savings. In recent years, the Energiesprong initiative has been seeking to deploy a variant of the MESA model in new build and social housing retrofits in several countries (#1, #12–17).

The Energiesprong model involves a 'net zero energy' retrofit that includes a new exterior façade, renewable microgeneration, and new heating systems and controls. Over a 30-year contract, the ESCO guarantees the performance of the building, energy bills stay constant, and the householder benefits from an improved exterior appearance and internal building health. Savings on the energy bill pay back a large proportion of the investment and PV panels contribute to any residual electricity bill that accrues through the year. Thus far, these models have been tried in higher density and social housing units. As discussed, the high transaction costs of these contracts may be a greater barrier to their adoption in single dwellings and for owner occupiers.

The original MESA model was centred around the Dutch net metering system, where no residual energy bill would be required provided the 'net-zero electricity' objective was delivered. With requirements for 28-day supplier switching, as stipulated in the EU Electricity Market Directives, there is a significant risk that the customer could switch energy supplier away from the ESCO/solution provider, meaning the full cost of the retrofit could not be recovered from a single service charge. In the first UK trial, this was worked around through use of a microgrid, where the PV array and communal GSHP would feed into the homes 'behind the meter', circumventing the switching requirements. Interviews with the Energiesprong Market development team (#1, #12–17) outlined how current market rules prevent a single MESA contract, and the model would instead revert to a simpler EPC, with the customer retaining an individual utility supply contract. Our UK social housing case study (I#49–51) design team were also considering the Energiesprong model for retrofitting part of the estate, although they described contractual difficulties this model presented under current market rules.

Consequently, our typology of ESBMs is shown in Table 1 and Fig. 9 using a synthesis of the multiple data sets described above and published literature. Developing the typology was a cumulative process throughout the study period with the typology and individual model archetypes delineated by developing Sorrell (2007) notions of 'scope' and 'depth'. For business model scope, we articulate three key components: the nature and number of energy service(s) included (e.g., heat, light etc.), the inclusion of energy efficiency measures, and the inclusion of financing within the offer. The depth of the ESBM is a product of whether primary, useful, or final energy services are provisioned. This determines the nature of the energy efficiency measures involved; whether at the point of extraction, primary or secondary conversion, which in turn directs the type of financing required.

These models may be applied to a single energy service such as space heating, with different business models potentially applying across multiple energy services of heat, light, motive power etc. For example, a household may have an ESA for building fabric improvements but retain a conventional utility contract for electricity provision. As we discuss later, the choice of business model has significant implications for the adoption of low carbon energy systems and demand saving measures.

4.7. Barriers for key stakeholders

Workshop (W#1–6) participants were asked to identify stakeholder groups critical for the adoption of ESBMs. These included property owners, developers/contractors, energy suppliers, and market regulators. During the final workshop (W#7), participants were divided into three groups to focus on the barriers for these stakeholders across three

Table 2
Opportunities and challenges for energy service models – workshop stakeholder perspectives.

	Issue	New Build	Low Carbon Heat	Whole House Retrofit
Property owners	Higher purchase price of homes/cost of measures	x	x	x
	Concept is poorly understood with requirements for changed behaviour and expectations	x	x	x
	Customer concerns over ESCO "lock in" to service contracts/comfort plans	x	x	x
	Risk of tenant disruption/ dissatisfaction & space requirements of new equipment		x	x
	Special finance lacking with preferential interest rates or tax breaks		x	x
	Landlords concerns around voids and losses from disruption			x
Developer/ contractors	Significant performance risk of measures	x	x	x
	Lack of local/regional manufacturing capability, supply chain, accreditation, and training		x	x
	Inconsistent demand, uncertainty of pipeline		x	x
	Specialist legal contracts needed – expertise not necessarily available	x	x	x
	No long-term interest for developers in delivering energy performance requiring ESCOs to take on the guarantee	x		
Energy utilities	Reduced energy consumption reduces income for suppliers	x		x
	Domestic ESCOs present radical change of supplier business model -– move away from energy sales to service - move away from vertical integration	x	x	x
	Customer choice and churn hampers long term models	x	x	x
	New metering requirements – smart meters insufficient, requiring big data management, privacy and compatibility	x	x	x
	Regulatory barriers for revenue stacking from domestic flexibility	x	x	x
	Financing dimension currently necessitates separation between ESCO and energy supplier		x	x
Regulator	Regulation needed to assign roles and responsibilities & liabilities to: Developer, ESCO, Management Company & Finance	x	x	x
	Need liquid/competitive market	x	x	x

(*continued on next page*)

Table 2 (*continued*)

Issue	New Build	Low Carbon Heat	Whole House Retrofit
ESCO failure – need accreditation and regulated ESCO of last resort	x	x	x
Network Charging – MESA models may require virtual private networks (VPNs) to be commercially viable	x	x	x
New forms of consumer protection are required	x	x	x
Building Regulations do not currently require performance outcomes	x		x

areas where ESBMs may play an important role: new build housing, low carbon heat, and whole house retrofit. Each group was asked to contemplate the opportunities and challenges of ESBMs from the perspective of these four stakeholder groups, summarised below and in Table 2.

4.7.1. Property owners

Key challenges identified were concerns of higher purchase prices of homes and the costs of low carbon heat and whole house retrofit measures; creating a need for specialist low interest finance, and preferential tax treatment. There were also concerns surrounding insufficient understanding of the energy service concept, requirements for behaviour change, and altered expectations. Issues of disruption for tenants, loss of landlord rental income, ease of access and the space needed for new equipment were also raised. These were viewed as generic to retrofit projects, however, and the offer of guaranteed performance improvements from ESBMs was viewed as a key benefit. Finally, there were concerns surrounding consumer protection for long-term service contracts and the potential to be "locked in" to a poorly performing ESCO.

4.7.2. Developer/contractors

The primary risk of ESBMs identified was the performance of measures and potential losses from underperformance. Relatedly, the skills gap for delivering energy savings measures is pervasive across Europe, with the ongoing energy performance requirements of ESBMs and the lack of accreditation and standards especially challenging. SMEs were viewed as reluctant to innovate and invest in new capacity when demand for these services is inconsistent and uncertain. Housing developers also have little incentive to deliver ongoing performance under current building regulations, with the lack of standardised ESCO contracts and ESBM providers adding uncertainty, cost and complexity.

4.7.3. Energy utilities

Utilities were viewed as threatened by ESBMs, which represent a fundamental challenge to their busines model. Current electricity market regulation was viewed as antithetical to ESBMs, however, with long-term contracts hampered by supplier switching rules. The rollout of smart meters in many European countries was also viewed as a missed opportunity, with a gap between the specification of most meters and the data required for detailed performance monitoring. A further issue is the barriers for distributed energy systems in accessing electricity flexibility markets, which exist to varying degrees in Europe.

4.7.4. Regulators

Many of the previously identified barriers related to the current regulatory regime surrounding energy supply, installer standards and building codes and regulations. Specific areas included: the barriers to offering long-term contracts in electricity supply markets; the lack of specific regulation governing the ESCO market and the accreditation of ESCO contractors; the lack of clear consumer protections and standards for ESCO customers; the absence of performance-based compliance in building regulations for new homes; and electricity wholesale and balancing market designs which currently favour traditional utilities and centralised power generation.

This exercise demonstrated that many of these issues were commonly held between the different sectors, although in general fewer barriers were thought to exist for new build housing and the most for whole house retrofit models – suggesting that ESBMs would be easier to adopt in a new housing context. Workshop W#7 findings are summarised in Table 2 and inform the policy recommendations in Section 6, with crosses representing where challenges were relevant for the sector.

5. Discussion

This paper has developed a novel typology of ESBMs and identified emerging examples in the domestic sphere. While this builds on previous studies (Black, 2020; Brown, 2018; Kim et al., 2012), our typology in Table 1 and Fig. 9 provides future researchers with a novel analytical framework to rationalise their study and characterisation. Our interviews, workshops and review of previous literature (Bertoldi and Boza-Kiss, 2017; Nolden and Sorrell, 2016) identifies that while energy supply contracts for district heating and CHP systems are common, deeper performance contracts and models focussed on the final energy services remain rare in Europe. While our research findings support Sorrell (2007) analysis that the high transaction costs of implementing and enforcing these contracts remain a barrier, we find anecdotal evidence that these costs are reducing through standardised procurement frameworks (Nolden et al., 2016), smart home devices and remote monitoring systems (Brown et al., 2019b; Wang, 2018) and the paring of these data with machine learning algorithms (Amayri et al., 2016). Indeed, future research should aim to quantify the contribution that such developments are having on these transaction costs.

Alongside these technical and financial challenges, we also identified institutional, legal and cultural barriers to the adoption of domestic energy service models. These findings are consistent with the work of Hannon et al. (2013) and Bolton and Hannon (2016) who describe the co-evolutionary relationship between energy systems and the dominant energy supply paradigm. Our research highlights how the rules governing electricity markets, codified under EU directives, are proving a direct impediment to the adoption of these business models, often reifying consumer choice and liquid markets at the expense of long-term efficiency investments (Brand-Correa and Steinberger, 2017). Further, the emphasis on throughput is also present in the housebuilding and construction sectors, with a clear reticence to develop long-term relationships and performance-based compliance (Winther and Gurigard, 2017). Indeed, we find that many of the impediments to an energy service economy go beyond the regulation of energy markets, and relate to issues of municipal governance (Bale et al., 2012; Hannon and Bolton, 2015; Roelich et al., 2018), the nature of national financial institutions (Hall et al., 2016; Mikler and Harrison, 2012) and the increasing financialization of housing provision (Blakeley, 2020).

In the following sections, we discuss these issues in the context of three core areas where energy service models can contribute to decarbonising the European energy system: new build housing; low carbon heat and whole house retrofit.

5.1. New build housing

ESBMs in new build housing would fundamentally alter the dominant housebuilding model. Currently, the majority of European homes are built by large speculative developers (Eurostat, 2020) who take little or no interest once homes are built. This disincentivises investment in energy efficiency and other low carbon measures, as developers seek to reduce capital costs (Heffernan et al., 2015). This lack of accountability for energy performance is also a major driver of the pervasive 'energy performance gap' that plagues modern housebuilding (Gupta and Dantsiou, 2013).

Mcelroy and Rosenow (2018) argue that ESBMs could contractually oblige developers to meet the standards to which homes were designed. Further, by involving an ESCO at an early stage, developers would be compelled by the ESCO to ensure maximum efficiency and carbon reductions through their design, fabric specification, HVAC and onsite renewables. Equally, developers and ESCOs could merge their activities to offer design, build and operate contracts and could offer a single service charge for comfort, appliance use and lighting.

Our review of barriers to adoption indicated that new build housing is perhaps the easiest place to trial ESBMs, providing an opportunity to design buildings that deliver measured performance in practice. This includes the use of rigorous design standards e.g. the Passivhaus approach, proven to deliver realised energy performance outcomes (Mitchell and Natarajan, 2020), the adoption of modern methods of manufacture and offsite construction (Jin et al., 2020), and early stage integration of decentralised energy systems (Bolton and Hannon, 2016). Moreover, as argued by Burman et al. (2014), the energy performance component of national building regulations should increasingly move towards 'performance based compliance', with contractual penalties for underperformance.

5.2. Low carbon heat

ESBMs also have the potential to address the major challenge of heat decarbonisation in homes. Most of Europe's homes are heated using fossil fuels, where households purchase units of fuel (i.e. gas, oil, electricity) taking responsibility for the efficiency and maintenance of the primary conversion equipment themselves (i.e. boilers, heat controls, radiators). The need to decarbonise domestic heating means these high carbon systems must be converted to heat pumps and heat networks in the coming decades. This has presented a problem in many existing homes, where the high cost of infrastructure and equipment combined with different features such as lower flow temperatures and new controls has presented a barrier to uptake (Watson, 2016).

ESC models are already more common in Nordic countries (Euroheat, 2015), often involving heat networks and the delivery of centrally-produced hot water through an ESCO. Although these models will need to make a significant contribution to heat decarbonisation, they tend to be restricted to dense population centres and require the active involvement of municipal authorities (Bale et al., 2012; Hannon and Bolton, 2015). We found evidence of HaaS models emerging where customers adopt a 'comfort tariff', paying for temperature levels in specific rooms in the home. As outlined by Marques et al. (2019), HaaS models may present a solution by providing households with the useful end service – a thermally comfortable home – and bundling the control, optimisation and financing of these higher capital cost but lower operational cost systems upstream into a single service payment.

Our research did identify highly subjective and personalised attitudes to comfort, however, reinforcing the notion that a single room temperature may not be agreed within households (Sovacool et al., 2020). Indeed, following Fell (2017) distinction between sources of energy, energy consuming practices, end services or states and energy services, arguably these HaaS models offer the final energy service of room temperature rather than the subjective end state of being 'thermally comfortable' - suggesting this 'comfort' framing is a misnomer. Further, Shove (2017) argues the prescription of a universal room temperature (e.g., 21°c) may perpetuate a higher level of service expectation and energy consumption, which is reified and reproduced through building performance standards.

As heat pumps become more prevalent, ESCOs may also introduce smart heating control and storage – taking advantage of variations in the daily electricity price – to maximise revenues whilst ensuring the same comfort and service (Brown et al., 2019a; Richter and Pollitt, 2018). Proponents argue these customer-centric 'servitised' heat offerings will reduce barriers to the adoption of low carbon heat (Energy Systems Catapult, 2019; Marques et al., 2019). Our research suggests that improvement in occupant health and wellbeing are seen on an equal footing with energy savings by households (Brown et al., 2019b; Knoeri et al., 2016; Wilson et al., 2015). Consequently, local authorities and not-for-profit housing providers may be key actors in developing HaaS business models due to their greater emphasis on distributional benefits, social value and public health outcomes (Hall and Foxon, 2014; Roelich et al., 2015).

The MESA example is more challenging under existing energy market regulations. The desire to finance a heat pump and recover the costs through energy savings (including the arbitrage of daily electricity price fluctuations) would represent an optimal route to decarbonising heat at no up-front cost to the user. Currently, unless the upstream electricity supply can be protected from the supplier switching rules, these models represent an unpalatable proposition to the ESCO (Littlechild, 2006). Thus, the client would either need to self-finance their own equipment under an EaaS model or, if connected to a heat network, an ESCO would provide an ESC/ESF offering for volumes of hot water.

5.3. Whole house retrofit

Many homes may also require invasive energy efficiency measures, alongside low carbon heat, smart controls electricity microgeneration and batteries. Indeed, the scale of domestic heat consumption necessitates absolute reductions in demand if domestic heat is to be electrified (CCC, 2019b), with many homes not suitable for lower temperature heat pumps, requiring efficiency improvements as a pre-requisite (Barnes and Bhagavathy, 2020). Although some incremental improvements to the European housing stock have been implemented, many of these low hanging fruit have now been exploited (Rosenow et al., 2018). What remains are millions of un-insulated walls, floors and single-glazed windows. This 'whole house retrofit' challenge is therefore among the most beguiling of all decarbonisation goals. Increasingly, policymakers and practitioners are looking to ESBMs as a potential route to overcoming this challenge (Green Alliance, 2019).

ESBMs for retrofit were observed in our case studies in the UK, France and Netherlands. Some models, such as the Energiesprong example, build on the principle of the HaaS, aiming to include building fabric efficiency measures, new HVAC systems and electricity microgeneration in a full MESA offering across multiple energy streams. Again, the challenges of supplier switching and the need to recover the significant capital outlay have meant that energy supply and the financing of measures must be kept as separate line items on the contract between the client and the ESCO. Thus, actors such as Iles des France Energies and RENESCO focussed on measured performance outcomes, leaving the customer to retain their utility supplier contract.

Although performance-based retrofits may appeal to both residents and third-party finance, there remains significant disruption for residents, presenting a major barrier to uptake (Maby and Owen, 2015). Further, the extent to which energy service contracts alone can be a demand driver for deep retrofit remains to be seen. Given the high transaction costs surrounding performance contracting, we expect these models to remain restricted to social housing for the foreseeable future (Brown et al., 2019b). Indeed, the literature on the barriers to deep

Table 3
Policy recomendations.

General
EU legislation surrounding electricity supplier switching is being strengthened in the Clean Energy Package (European Commission, 2019), and switching times are to reduce to as little as 24 h. This legislation currently disincentivises long term service contracts and hampers ESCOs offering these contracts. The EU should review these rules for the provision of electrified heat which would put it on an equal footing with thermal/fossil heat supply contracts. The UK's exit from the EU could also present an opportunity to review this logic.
New regulation is needed to manage the domestic ESCO market and to protect consumers from lock into poorly performing ESCOs. This could include developing a 'supplier of last resort' to take on failed ESCOs' contracts.
National governments should develop a training and skills program for the low carbon housing sector – emphasising measured performance outcomes and a move away from 'fit and forget' construction practices.
Electricity network charges should be made increasingly dynamic and cost reflective and move away from static and volumetric charging. This will incentivise business models which provide energy services to homes, whilst also providing flexibility to electricity system operators.
Access to low-cost capital is critical for the financial viability of energy service models which include finance. As part of Green Stimulus and COVID recovery packages governments and public banks should facilitate low cost, patient investment to ESCOs and grant funding to projects which deliver clear public good outcomes.
New Build Housing
The EU should introduce legislation for performance-based compliance for new buildings, to ensure developers are required to deliver measured energy performance outcomes. Alternatively, developers could be required to meet similar standards through municipal planning policy.
In many European countries, the responsibility for ensuring energy performance and building regulations compliance has been outsourced to the private sector, with the result that much of the industry is now self-regulating. This is creating perverse incentives and a lack of enforcement of regulations. These functions should be brought back under public purview with strict enforcement of energy and environmental standards.
Low Carbon Heat
Domestic heat decarbonisation will require electrification, especially through the adoption of heat pumps. Current EU electricity market regulations mean that customers must have a single electricity supplier. Some national regulators are trailing the potential for multiple suppliers under a single meter point, potentially allowing an ESCO to enter a long-term contract for heat service provision, whilst allowing the customer to switch their main electricity supplier. This should be encouraged across Europe.
The share of policy costs on electricity bills unfairly prejudice electrification – these costs should be shifted into general taxation to level the playing field away from gas and oil.
Whole House Retrofit
In several EU countries Value Added Tax (VAT) is added at full rate to building materials and products which promote energy saving, while household energy supply receives a VAT discount. These fiscal policies should be reviewed considering the imperative to reduce energy consumption.
Minimum energy efficiency standards (MEES) across all housing tenures are likely to be necessary to drive the uptake of whole-house retrofits in Europe.
Performance based retrofit in local authority and social housing could be first step to wider performance contracts becoming mainstream.
In several national contexts the offer of a combined rent and service charge is prohibited. Following the example of the Netherlands, legislators should enable this 'whole cost of living approach' in social housing, to encourage ESMBs for retrofit.

retrofit (Brown et al., 2018; Fylan et al., 2016; Sorrell, 2015) suggests that alongside new business models, the mass uptake of deep retrofits will require public engagement programs, minimum energy performance standards, investment in the skills gap and a range of grant funding and financing packages.

6. Conclusion and policy implications

This paper has sought to clarify the conceptual understanding of ESBMs, introducing a new typology and a review of emerging domestic examples in Europe. We characterise ESBMs as *'The provision of useful or final energy services and/or guaranteed savings, how organisations and networks provide these services and the means of capturing revenues from them'*. Through a novel typology, we differentiate ESBMs by whether they deliver useful energy *supply, performance* or final energy *services* and the inclusion or exclusion of *financing* upstream of the customer. It is hoped that this typology will be useful to scholars and practitioners in the future study and evaluation of ESBMs.

Following our interviews and workshops, we propose 13 policy recommendations for local and national governments in Europe, which could facilitate the increased adoption of domestic ESBMs, shown in Table 3 below.

Domestic ESBMs represent a huge opportunity to decouple the profits of energy supply from ever-increasing throughput sales of energy. These business models may prove instrumental to building homes that deliver the performance outcomes for which they were designed, enable the decarbonisation of domestic heat, and provide a route to delivering energy efficiency measures to millions of homes in the coming decades. Such approaches may be a crucial tool as governments seek to build back better from the COVID-19 pandemic and meet decarbonisation targets. Our study has identified a series of technical, economic, institutional, and cultural barriers that constrain their increased adoption in the domestic sphere. Ultimately, we believe that, for these models to play a significant role, a paradigm shift will be required to alter the throughput energy policy orthodoxy that has governed liberalised energy markets for the past 30 years.

CRediT authorship contribution statement

Donal Brown: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Stephen Hall:** Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Project administration, Funding acquisition. **Mari Martiskainen:** Methodology, Validation, Formal analysis, Investigation, Writing – review & editing, Project administration, Funding acquisition. **Mark E. Davis:** Investigation, Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

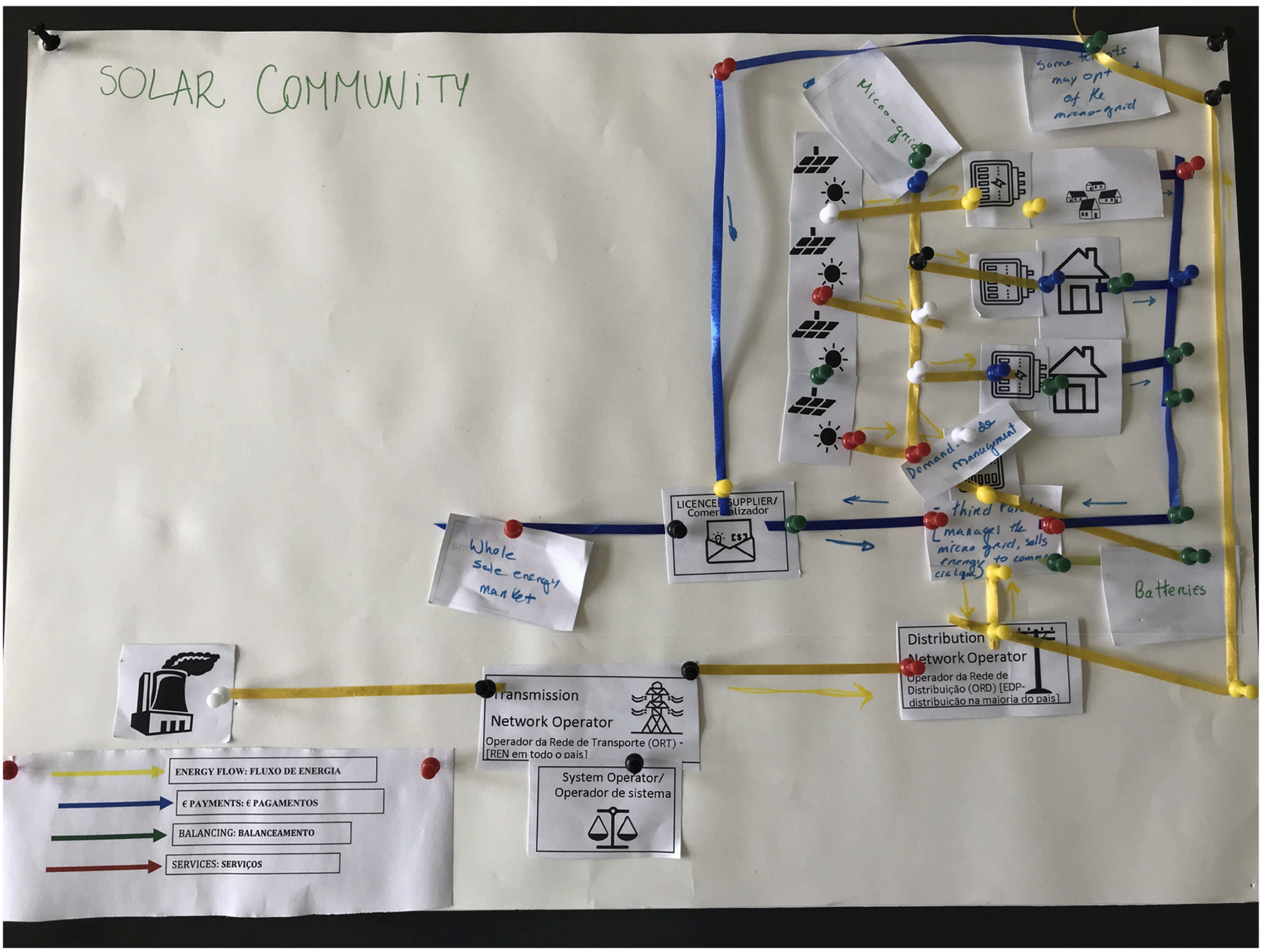
This work was supported by the European Commission Horizon 2020 project: PROSumers in the Energy Union (PROSEU) grant agreement ID 764056. This work was also received funding from the European Union's Horizon 2020 research and innovation programme Solar Biomass Reversible Energy System (SolBio-Rev) under grant agreement No 814945.

Appendix A

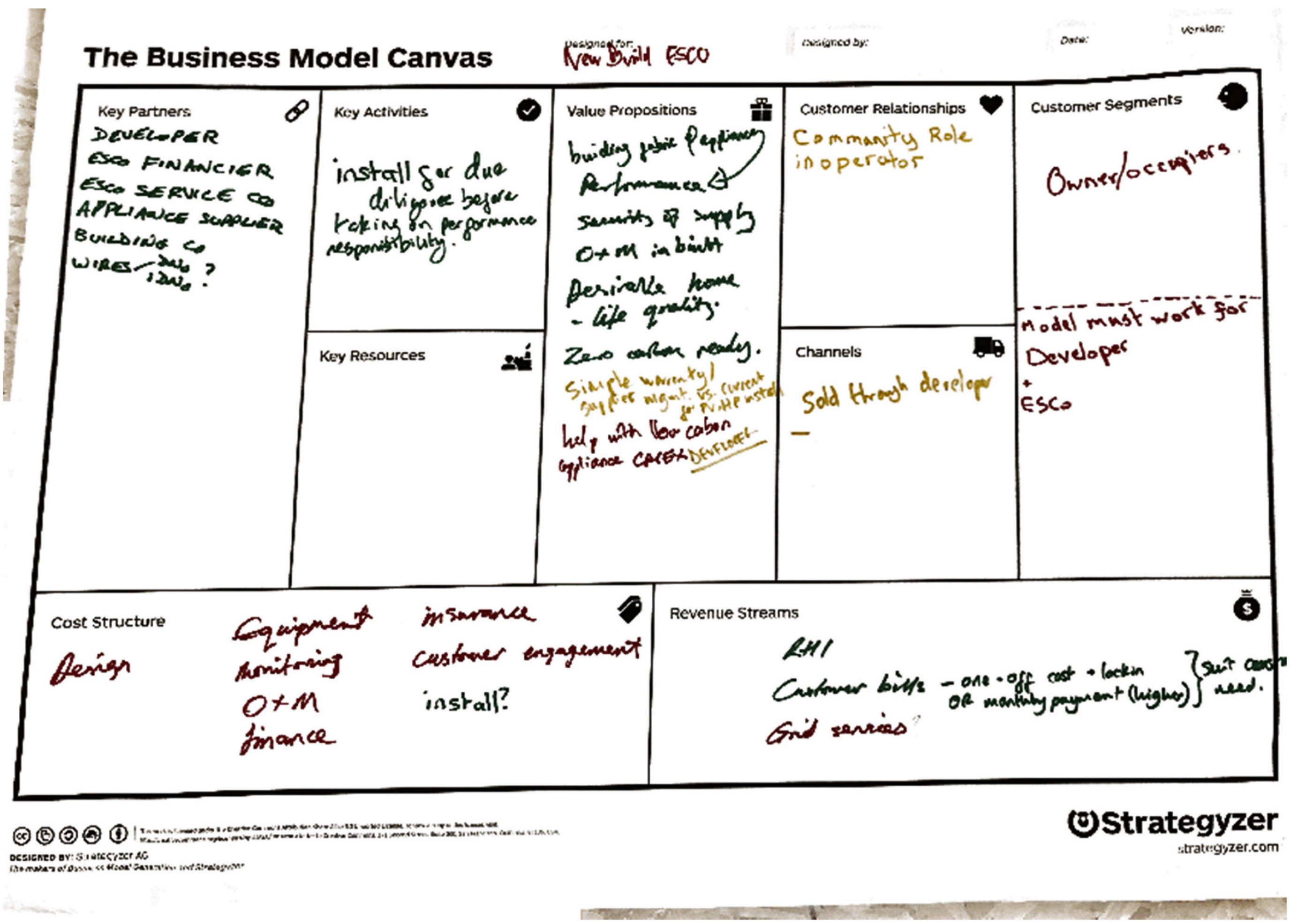
Interview number	Organisation/Actor	Date
#1	Energiesprong – UK, Netherlands	December 12, 2016
#2	RENESCO – Riga, Latvia	February 02, 2017
#3	BHESCO - Brighton, UK	February 13, 2017
#4	ICF Habitat- Paris, France	February 16, 2017
#5	Energy Programs Consortium (USA)	February 17, 2017
#6	Buildings Performance Institute Europe (BPIE), Brussels, Belgium	March 01, 2017
#7	Climate Strategy and Partners (Madrid, Spain)	July 27, 2017
#8	Energy Pro Ltd (London, UK)	August 14, 2017
#9	Joule Assets Europe (Brussells, Belgium)	October 19, 2017
#10	Servizi Energia Ambiente (SEA)	November 22, 2017
#11	Amber Infrastructure (LEEF/MEEF)	November 30, 2017
#12	Energiesprong (Netherlands)	May 15, 2018
#13	Melius Homes (UK)	May 31, 2018
#14	Nottingham City Council (UK)	June 13, 2018
#15	Energiesprong – UK, Netherlands	June 20, 2018
#16	Ministry of the Interior and Kingdom Relations (Netherlands)	June 20, 2018
#17	Nottingham City Homes (UK)	June 29, 2018
#18	Community Energy Company 1 (UK)	(Decemeber, 2018)
#19	Community Energy Company 2 (UK)	(August 2019)
#20	ESCo Intermediary (UK)	(January 2019)
#21	Muncipal ESCO (UK)	(January 2019)
#22	Flexibilty Service Provider 1 (UK)	(February 2019)
#23	Flexibilty Service Provider 2 (UK)	(February 2019)
#24	Local Energy Company (UK)	(December 2018)
#25	Peer-to-peer Consultant (UK)	(February 2019)
#26	Microgrid Developer (UK)	(January 2019)
#27	Trading Platform Provider (UK)	(February 2019)
#28	Municipal Energy Company (UK)	(September 2019)
#29	FIN_Household User_01	November 27, 2020
#30	FIN_Household User_03	December 14, 2020
#31	FIN_Household User_05	January 20, 2021
#32	FIN_Building Manager_02	February 09, 2021
#33	FIN_Building services_02	February 12, 2021
#34	FIN_Household User_02	November 30, 2020
#35	FIN_Household User_04	January 12, 2021
#36	FIN_Household User_06	February 04, 2021
#37	FIN_Building Manager_03	February 25, 2021
#38	FIN_Heating system designer_01	March 26, 2021
#39	Greece_USER1_BG_1	October 24, 2020
#40	Greece_USER2_BG_1	October 24, 2020
#41	Greece_USER3_BG_1	November 06, 2020
#42	Greece_MNGR_BG_1	November 06, 2020
#43	Greece_USER1_BG_2	January 21, 2021
#44	Greece_USER2_BG_2	March 30, 2021
#45	Greece_DSNR_1	April 12, 2021
#46	Greece_DSNR_2	April 13, 2021
#47	UK_MNGR1_BG_1	November 24, 2020
#48	UK_MNGR2_BG_2	December 10, 2020
#49	UK_DSNR_1	January 18, 2021
#50	UK_DSNR_2	January 25, 2021
#51	UK_DSNR_3	January 26, 2021
#52	UK_USER1_BG_2	January 27, 2021
#53	UK_USER2_BG_2	February 01, 2021

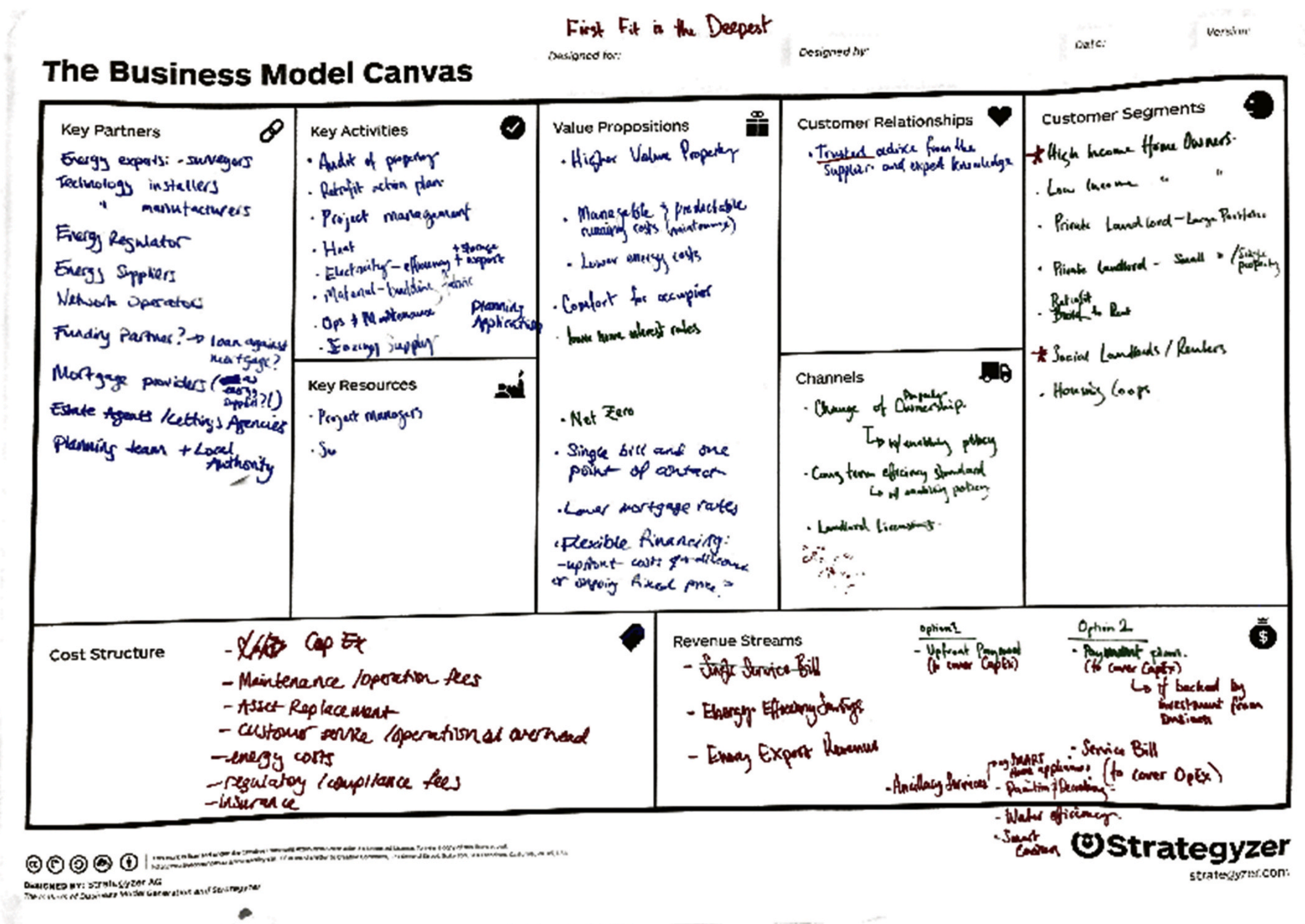
Workshop	Title	Date/location
#1	Prosumer Business Models in Spain	May 27, 2019 EcoUnion, Barcelona, Spain
#2	Decentralized Energy in Bristol: Opportunities and challenges in the post subsidy landscape	June 11, 2019 Engine Shed, Temple Meads Station, Bristol, UK
#3	Prosumer Business Models in the Netherlands	June 18, 2019 Impact Hub, Amsterdam, Netherlands
#4	Prosumer Business Models in Portugal	June 19, 2019 FCUL, Lisbon, Portugal
#5	Prosumer Business Models in Belgium	September 19, 2019 Interluven, Leuven, Belgium
#6	Community Municipal Bonds in Bristol- How can we finance decentralised energy systems?'	November 21, 2019 Engine Shed, Temple Meads Station, Bristol, UK
#7	Energy Service Models: the route to zero carbon homes?'	December 06, 2020 Tony Benn House, Victoria Street, Bristol, UK

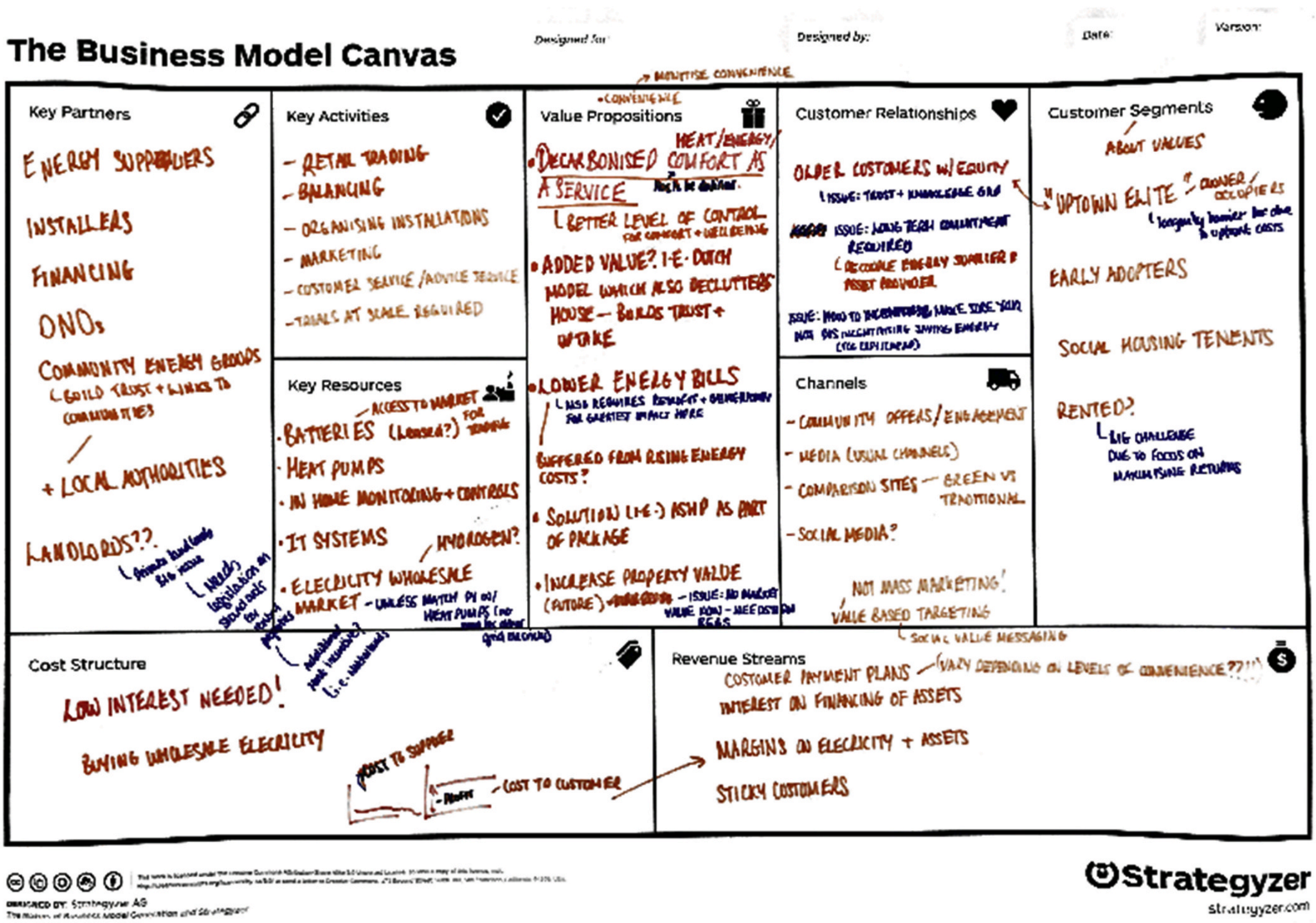
Appendix B


SOLAR COMMUNITY
Micro-grid
Whole sale energy market
Batteries
Transmission Network Operator
Operador da Rede de Transporte (ORT) - [REN em todo o país]
System Operator/ Operador de sistema
Distribution Network Operator
Operador da Rede de Distribuição (ORD) [EDP-distribuição na maioria do país]
ENERGY FLOW: FLUXO DE ENERGIA
€ PAYMENTS: € PAGAMENTOS
BALANCING: BALANCEAMENTO
SERVICES: SERVIÇOS

Appendix C


The Business Model Canvas
Designed for: New Build ESCO
Designed by:
Date:
Version:
Key Partners
DEVELOPER
ESCO FINANCIER
ESCO SERVICE CO
APPLIANCE SUPPLIER
BUILDING CO
Key Activities
install for due diligence before taking on performance responsibility.
Key Resources
Value Propositions
Zero carbon ready.
Customer Relationships
Community Role in operator
Channels
Sold through developer
Customer Segments
Owner/occupiers.
Model must work for Developer
+ ESCo
Cost Structure
Design
Equipment
Monitoring
O+M
finance
insurance
customer engagement
install?
Revenue Streams
RHI
Customer bills – one-off cost + lock-in OR monthly payment (higher)
Grid services?
Strategyzer
strategyzer.com


First Fit is the Deepest
Designed for:
Designed by:
Date:
Version:
The Business Model Canvas
Key Partners
Energy experts: - surveyors
Technology installers
" manufacturers
Energy Regulator
Energy Suppliers
Network Operators
Funding Partners? → loan against mortgage?
Mortgage providers
Estate Agents / Letting Agencies
Planning team + Local Authority
Key Activities
• Audit of property
• Retrofit action plan
• Project management
• Heat
• Electricity – efficiency + storage + export
• Material – building fabric
• Ops + Maintenance
• Energy Supply
Planning Application
Key Resources
• Project Managers
Value Propositions
• Higher Value Property
• Manageable + predictable running costs (maintenance)
• Lower energy costs
• Comfort for occupier
• Net Zero
• Single bill and one point of contact
• Lower mortgage rates
• Flexible financing: - upfront costs or ongoing fixed price
Customer Relationships
• Trusted advice from the supplier and expert knowledge
Channels
• Change of Property Ownership
• Long term efficiency standard
• Landlord licensing
Customer Segments
★ High Income Home Owners
• Low Income
• Private Landlord – Large Portfolio
• Private Landlord – Small
• Build to Rent
★ Social Landlords / Renters
• Housing Coops
Cost Structure
- Cap Ex
- Maintenance / operation fees
- Asset Replacement
- customer service / operational overhead
- energy costs
- regulatory / compliance fees
- insurance
Revenue Streams
Option 1
- Upfront Payment (to cover CapEx)
Option 2
- Payment plans (to cover CapEx)
- Service Bill (to cover OpEx)
- Energy Efficiency Savings
- Energy Export Revenue
- Ancillary Services
- Water efficiency
Strategyzer
strategyzer.com



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