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Energy Intangibility and Ecological Concerns: What Strategies for Energy Suppliers in the Residential Market?

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Abstract

A physical intangibility affects renewable energies (an electron or a molecule, green or not are similar and their circulation is indistinguishable in common distribution networks). These energies also have a high mental intangibility (difficulties in mentally representing the effects of a green energy consumption). Intangibility poses a strategic problem for energy suppliers that is little debated: perceived risks exist for the consumers who wish to control their commitment against global warming and to be in line with his environmental values. This article sets out four strategies available according to the effort of suppliers to meet two key expectations of the individual consumers: tangibility and environmental concern. Some solutions to remove the physical, financial and organizational barriers to tangibility are discussed. The article concludes with the limitations of these solutions and a call to resolve the issue of intangibility under the pressure of growing public concern for global warming.

Keywords: Energy intangibility, Individual energy consumer, Environmental concerns, Business Model, Value propositions

1. Introduction

Among all the problems related to globalization, global warming appears to be a perfect illustration of this term. The risk of climate change does not spare any part of the planet. Similarly, no individual can feel immune from this major risk that requires an immediate and collective response to limit CO2 emissions (Intergovernmental Panel on Climate Change 2018; Paris Agreement 2016) signed by 197 states even though the decarbonization targets remain insufficient (Watson et al., 2019). The need for answers to this risk has never been greater: 83% of consumers surveyed around the world say they are sensitive to climate issues (Boston Consulting Group, 2021).

This requires a credible climate transition in an increasingly short period of time with clear guidance for energy consumers to ensure they tackle the climate crisis at the source. The solutions to be invented for the energy transition directly challenge the energy sector and its offer making process especially in the individual customers' market. In this sense, the whole energy sector has to face a strategic stake when the issue of creating an attractive offer proposition to individuals disrupts the traditional strategic approach.

This paper investigates the drivers of renewable energy adoption by consumers in the residential market and their strategic consequences for energy producers. Among the possible behavioral barriers or drivers of adoption, this research presents the intangibility of energy as a barrier to end-user adoption of renewable energy and the providers' effort to make it tangible as a powerful driver. This theme is largely unexplored because literature mainly examines the intangibility issues in terms of firm resources including energy resource (Jancenelle, 2021; Shirodkar & Mohr, 2015; Franco & Haase, 2013; Wolff & Reed, 2000). It opposes tangible resources (financial and physical resources), which include property-based assets (Das & Teng, 2000), to intangible resources, generally grouped as organizational, human, or technological in nature (Wolff & Reed, 2000; Hofer & Schendel, 1978).

Similarly, recent literature such as a dictionary (Fouquet, 2016) and a study of 185 academic articles (Fell, 2017) on energy services do not include the intangibility of energy as a characteristic of these services. This literature does emphasize that the use of renewable energies is a consumer demand and could play an important role in decarbonization in the short term (Rilling & Herbes, 2022). However, the intangibility of energy is not presented as a possible obstacle to decarbonization.

Consequently, this article uses the concept of energy intangibility to only designate the indistinguishable physical character of the renewable and the non-renewable in their electrochemical composition (an electron or a molecule, green or not, are similar) and in their circulation (in common distribution networks). It also refers to its mental intangibility (difficulties in mentally representing the current impact of renewable energy consumption).

In this particular sense, intangibility can be defined globally as the difficulty in mentally representing the exact nature of the object or the process represented (Laroche, Bergeron, & Goutaland, 2003; Mittal, 2002; Catsaras, 1995; Shostack, 1977). The path followed by this research on adoption of renewable energy is to explore the different ways for energy providers to tackle the energy intangibility issue. Due to the definition of energy intangibility, this article addresses issues of imperfect information, perceived risk, credibility, and trust already used with other intentions in the literature.

The concept of intangibility developed in service theory (Ding & Tat Keh, 2017; Moeller, 2010; Lovelock & Gummesson, 2004; Zeithaml et al., 1985) refers to the difficulties of the customers to ensure the conformity of the offer to their demand as well as to the specificities of the promised use (impact on the environment and climate). These difficulties are presented by this literature at the origin of perceived risks that all service strategies propose to reduce by tangibilization actions. Intangibility is known to lead to consumer mistrust, especially in this transition stage where energy suppliers can only make promises of decarbonization without providing concrete evidence of its reality.

This research seeks to take stock of the opportunities offered to energy suppliers to struggle against energy intangibility. This search for tangibility solutions is a real challenge to accelerate the transition while customers want to play in complete autonomy an increasingly conscious and citizen role in the energy transition. Tangibilization can be a real lever to accelerate the energy transition of end consumers.

The following points are developed in this paper: first, the striking elements that characterize the grid energy market among individuals, occupants of private dwellings, and the evolution of their expectations in the environmental emergency are analyzed. The green energy intangibility in its physical and its mental dimensions are discussed to conclude that this intangibility can strongly hinder the confidence of individual consumers in decision-making conducive to the climate transition and the willingness to pay for the solutions proposed by green energy suppliers. Next, the focus is on presenting the cause and effect chain that could disturb the existing value chain ranging from the demand for green supply that arises out of private individuals to its impact on the energy supply and its greenhouse gases emissions. This chain leads to the design of a new problematic business model that creates new values for all stakeholders. This new business model reveals specific risks and negative externalities. The last part of this paper seeks to master those risks to underpin the strategic interest of green energy tangibility as a driving topic allowing energy providers to meet individual consumers' energy market expectations.

2. Analytical and Strategic Approach

First, our analytic approach consists of highlighting and discussing a little-explored problem: the importance of the difficulty for the individual consumer on the residential market to mentally imagine, coming from the distribution network, the renewable or non-renewable nature of the energy (gas, electricity) he uses and the direct effects in the short and medium term of their use. This article deals with the difficulty for the individual consumers on the residential market to mentally imagine, coming from the distribution network, the renewable or non-renewable nature of the energy (gas, electricity) they use and the direct effects in the short and medium term of their use.

Second, our strategic approach then seeks to identify four strategies that can be adopted by energy suppliers to make energy more tangible for individual customers. The focus is on the strategic option best placed to meet these two expectations. The characteristics of this so-called “tangible green offer” option are exposed and the limits to its generalization to the entire energy market for households are discussed. The article underlines the strategic importance of providing solutions accessible to all individuals to the problem of energy intangibility as a source of competitive advantages for energy suppliers.

2.1 Some Relevant Aspects of the Individual Consumers' Energy Market

As a particular category of players in the energy market, the use of grid energies (gas and electricity) by individuals (residential customers) as homeowners or occupants is a significant issue for the success of the transition. In Europe, Eurostat data shows that grid energies consumed by households represent a significant share of the total energy consumption, that has stabilized after a growth in the 1990 decade.

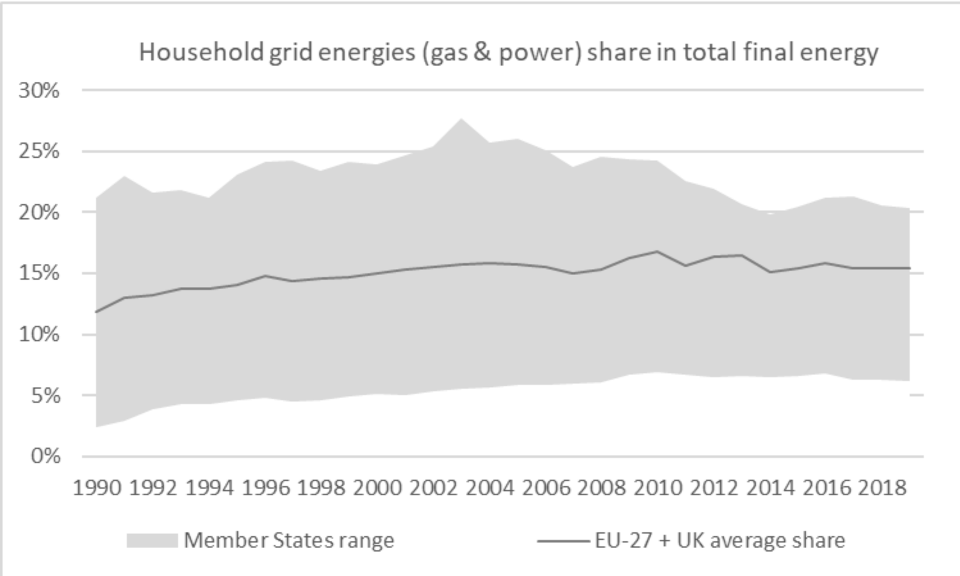

Figure 1. Household gas and power share in EU 27 + UK total final energy share

More significantly for the impact on the climate, greenhouse gas emissions from this sector are important, but their exact level is information that is difficult to grasp for the European citizen. For electricity, Eurostat does not directly provide greenhouse gases emissions of electricity: such a dataset is accessible through the European Environment Agency.

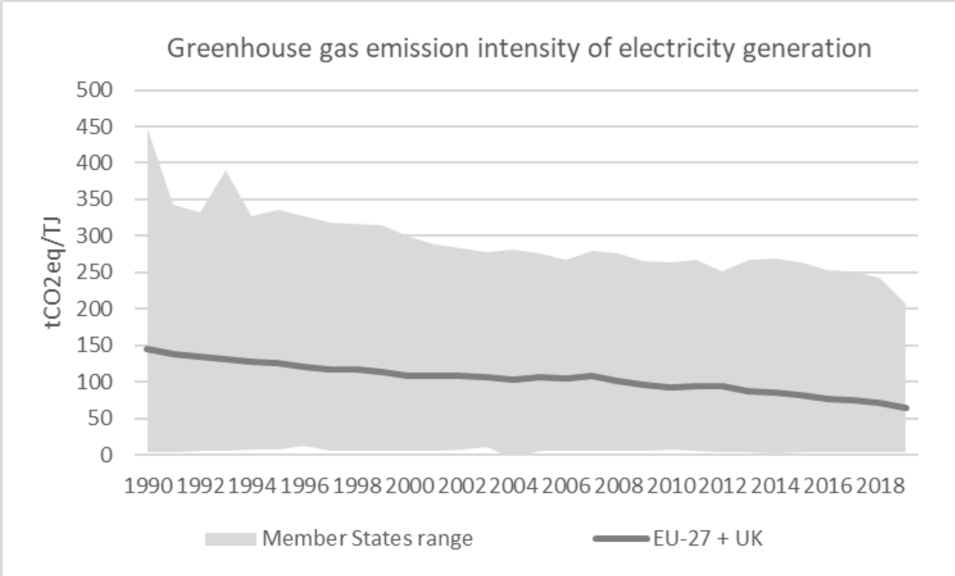

Figure 2. Greenhouse gas emission intensity of electricity generation in EU 27 + UK

The significant decrease observed and the measured values depend on the production park and its evolution for each country. For instance, Sweden's production mix is nearly only made of hydropower and nuclear power plant, while Estonia has been largely reliant on brown coal or peat.

The relevance of this carbon impact data to act against global warming depends heavily on the evaluation methods. Gagnon and Cole (2022) underline how an unadapted choice of metrics can lead consumers to erroneous conclusions. When consumers seek to assess whether to switch from a gas heating system to an electric heating system, they should be able to use the average carbon intensity of each system to make an informed choice provided that the production fleets concerned are homogeneous. With the generally diverse production fleets observed in Europe, very different factories operate simultaneously at every hour of the day and a rule must be defined to allocate carbon intensity to each use. Gagnon and Cole (2022) have identified a new metric, the long-run marginal emission rates (LRMER), that could outperform the average emission rates (AER) and the short-run marginal emission rates (SRMER). Difference between these metrics could be very significant, with an example given where emissions computed with SRMER were twice as high as emissions computed with LRMER. This demonstrates the importance and the difficulty for an end-user to choose the right metric.

The scope taken into account to measure emissions is an additional source of uncertainty and intangibility. Are they only related to the operation of the appliances used in the premises of households (they would then be very close to zero for electrical appliances)? Should we also take into account the emissions linked to the production of energy? Stephan and Stephan (2016), in the context of improving energy efficiency of transportation for individuals, demonstrated the need for assessments with a broad scope, namely life cycle analysis.

For natural gas, the same questions are relevant. Beyond the emissions occurring at the boiler, extraction and transport emissions are significant. These emissions are significantly varying depending on the source of the gas: US shale gas brought by ships in liquefied form does not have the same footprint as natural gas extracted from a Norwegian field. Even taking into account only Norwegian gas, Shaton, Hervik, and Hjelle (2019) demonstrated that the environmental footprint of Norwegian gas imported by pipe outperforms Norwegian gas imported by a Liquefied Natural Gas (LNG) chain.

For instance, ADEME (2018) estimated that the sole operation of liquefaction is adding 8,5% to the greenhouse gas content of natural gas. Shall a consumer from Emden, who will physically consume mostly Norwegian gas, consider a different emission intensity than a consumer from Barcelona, who will mostly be delivered regasified LNG?

As the 2019 average EU27 + UK 63,9 tCO2eq/TJ emissions intensity of electricity (as computed by European Environment Agency), is practically the same as the 63,1 tCO2eq/TJ lifecycle carbon footprint of natural gas (as computed by ADEME, France), these questions of greenhouse gas content of each energy do not facilitate decisions for the individual customer.

This difficulty for the individual consumers to have access to the actual impacts of their energy consumption is increasingly important. It illustrates the problem of the perceived intangibility of energy consumption. In a context of varied and complex energy choices, this intangibility is an obstacle to reasoned commitment. Decisions must be made in a context of environmental disruption requiring highly responsive and responsible choices. Individual consumers choose whether to purchase “green” or conventionally sourced power from their energy providers. With green offers, electricity comes to the customer through the grid, but the supplier commits to producing or purchasing all or some of the customer’s consumption capacity from environmentally friendly power plants (e.g., no CO2 emissions).

If a consumer’s choice is green electricity, it reaches them via an undifferentiated distribution network. In this case, only the supplier’s commitment to produce or purchase from CO2-free power plants counts. The customer’s bill can sometimes indicate the quantity of CO2 “saved”. Energy suppliers that currently maintain polluting power generators may have difficulty proposing such offers, because they either must buy green power from their competitors or build a low-emission generation park — a huge investment that also entails significant regulatory and market risks. For consumers, a difficulty in mentally representing the physical nature (carbon or not) of the energy consumed does exist. The same is true for the nature of the energy present in distribution networks and its actual greenhouse effects. Consumers are thus led to fight against global warming on the basis of beliefs, of trust without convincing control over the facts, where the perception of intangibility in all its forms dominates.

2.2 Intangibility and Consumer’s Environmental Concerns

The intangibility dimension reflects the very structure of energy offers. Drawing on service theory, Bateson (1979) distinguishes physical intangibility, in which customers cannot directly observe the offering, from mental intangibility, which happens when customers are not aware of all aspects of the offer and have difficulty visualizing all its effects (Lovelock & Gummesson, 2004; Mittal, 1999). Provisions of energy service are highly intangible, on both levels.

The current research suggests that the commercial success of renewable energy also depends on customers' trust in suppliers (Van Prooijen, 2019; De Vries et al., 2015; Wiser, Porter, & Grace, 2004), especially because this purchase is intangible in its search qualities (physical and controllable characteristics), its experiential (unobservable production and distribution practices) and its credence (liability of operators' commitments) (Lovelock & Gummesson, 2004; Zeithaml, 1981). This situation can generate a higher level of perceived risks generated by a lack of materiality (Felix & Sempels, 2009). Intangibility as a bi-dimensional concept comprising a physical dimension specific to the degree of materiality of the offer and a mental dimension tied to the degree of difficulty in understanding the offer and its values in use requires consumers' trust without evidence. In this context, energy consumers overall still feel confused and powerless as to what to do and unable to take green ads from energy suppliers at face value. In addition, consumers think they have a much lower role in causing climate change than large companies, deemed responsible for climate change at 78% (Boston Consulting Group, 2021). According to this survey concerning companies, customers believe that: «there is room for innovation but also for more information on how changing their behavior will address climate change».

When using renewable energy, customers' experience is, at best, limited to reading about the quantity of saved CO2 on a bill. This scenario demands substantial trust, because consumers have no simple means to check that their electricity really comes from a low emissions plant. Moreover, electrons running through distribution networks are totally undifferentiated, so some of them likely come from higher emission plants fueling the overall electricity network. Finally, if only a few individual consumers buy green power from an already largely decarbonized offer, it will have no consequences for the energy mix. Such strong intangibility suggests the need to stimulate renewable energy markets by releasing information about the composition of the renewable power that customers receive (Paladino & Pandit, 2012). Intangibility, as a key dimension of the energy market, thus conditions the suppliers' strategies to gain competitive advantages and establish positions in energy markets. It makes it possible to revisit the process of creating values in energy offer for individual consumers.

In addition to energy intangibility, a second dimension linked to environmental concerns is shaping the energy offer available to residential consumers. The overall consensus suggests primarily a social benefit for customers who perceive that their choices help mitigate climate change (Çelikler & Aksan, 2016; Timmons, Harris, & Roach, 2014; Pearson & Foxon, 2012).

This second dimension is strongly related to the first one. Green energy intangibility may become a real issue for customers as their environmental concerns rise. Such concerns increase the need to differentiate the offers that contain environmentally friendly promises from those which do not have environmental commitment, or just a combination of both. This way of segmenting offers is common (Committee on Climate Change, 2010). Offers without environmental reference are generally provided by high-carbon incumbents; the others reflect diversification, range management or market specialization. With greater accessibility of low carbon technologies, suppliers have gradually responded to changing customer expectations, which go hand in hand with economic, technological and societal changes.

The issue of gaining competitive advantages for suppliers is a pivotal issue, as Pearson and Foxon (2012) argue. In the short term, the debate on the real benefits of providing individuals with information about the nature of distributed energy is now largely outdated. However, this information remains subject to the key issue of the consumers' trust in the energy suppliers' communication. The rise of consumer environmental concerns is bringing forth "proof" strategies. Increasingly, they can provide suppliers with competitive advantages by proposing ways to ensure the tangibility of environmental friendly offers and build customers confidence.

The financial dimension is of course a key dimension regarding the competitiveness of more environmentally friendly offers. One's willingness to pay is linked to energy concerns (Knapp et al., 2020), but remains a key aspect (Conte & Jacobsen, 2016), even if Pearson and Foxon (2012) argue that low carbon externalities are not "fully traded and priced in markets," though in some cases prices might be imposed "through a carbon tax or a tradable permit scheme." Motz (2021) references significant literature regarding green offers structured around consumers' willingness to pay. Beyond the financial dimension of the offer itself, financial incentives such as tax deduction are also very important drivers of consumers' behaviour. However, this financial dimension is by nature not suited to tangibilize the green content of green offers, and is therefore not considered to segment offers in this paper.

The energy providers' effort to tangibilize the green nature of energy and the different degrees of consumers' environmental concern can be crossed, as shown in the framework in Figure 3. This helps energy suppliers to formulate four possible strategic options to meet the energy expectations of all individual consumers and to choose their long-term development goals.

2.3 A Strategic Approach with a Four Offers Framework

The resulting quartiles provide an overview of offers in the energy sector. The environmental concern axis determines whether the offer lacks any environmental pledge or promises some or total environmental responsibility. In literature related to this axis, Fuller (1999) and Baumann and Rex (2007) propose a segmentation of consumer profiles, depending on their level of environmental concern and requirement. The tangibility axis instead ranges from strong intangibility, linked to a lack of identification of the source of energy, to stronger tangibility, enabled by specific installations in customers' homes.

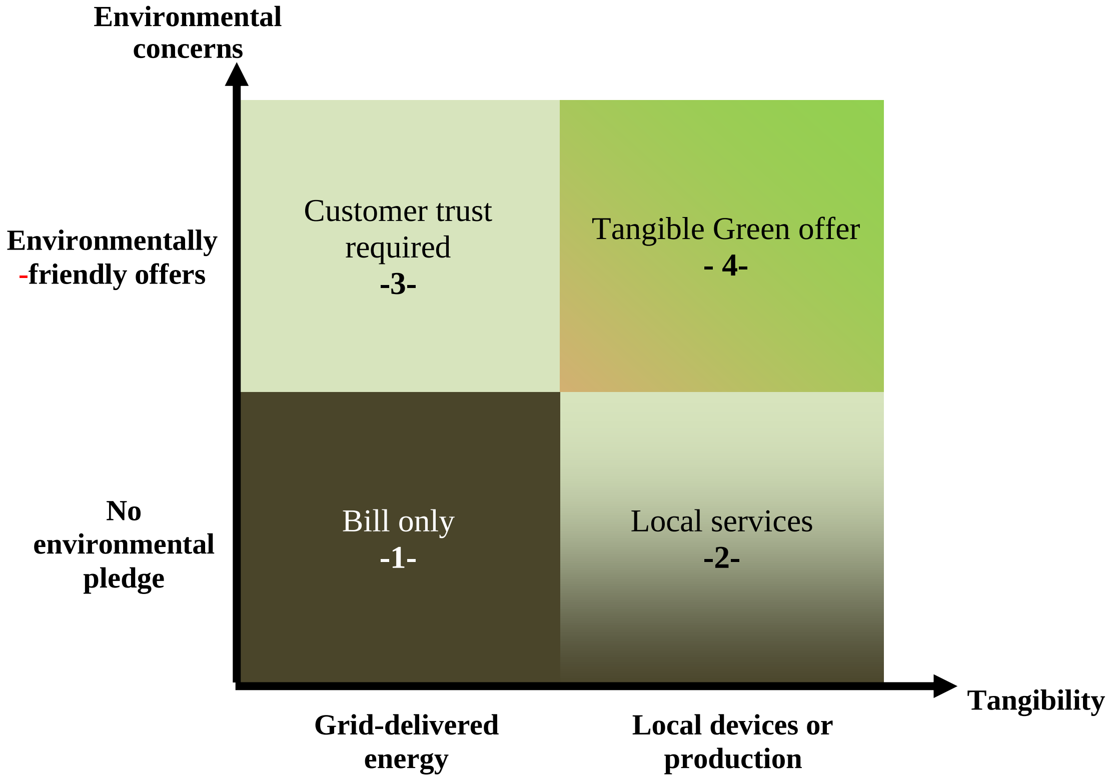

Figure 3. Energy offers framework

This framework reveals four offer types:

1. Bill only: When energy suppliers do not propose environmental offer, they cannot address customers' willingness to pay for environmental added value. In energy markets, these suppliers are often limited to energy supply. The distribution may get conducted by other agents. Therefore, customer relationships involve only the financial transaction of billing and payment for a certain quantity of energy. For these customers, offers are physically indistinguishable and their risk of commoditization increases.

2. Customer trust required: This quartile represents offers based on a pledge by the green energy suppliers. Customers have no means to make the origin of their green energy tangible; they must trust the supplier's pledge. As an attribute, green energy cannot be experienced by the customer, which may generate doubt or distrust and thereby reduce the attractiveness of the offer or diminish the chances of creating customer loyalty.

3. Local services: Finally, in this quartile, producers have no environmentally friendly proposition but offer a wide range of local services to enhance customers' comfort (e.g., connected devices, detailed information, remote controls) or efficiency (e.g., intelligent management of consumption). These enhancements might have environmental dimensions, such as reducing consumption or scheduling it strategically when fewer polluting plants run. We thus note a continuum between this quartile and the trust green offer quartile. Without reference to green production, these offers cannot fully address homeowners' willingness to pay for environmental added value.

4. Tangible Green Offer: Producers propose environmentally friendly offers using solutions that demand investments in specific technologies. They give offers environmental added value (e.g., solar panels, biomass, boilers) and they embed technologies, locally capable of providing these offers with obvious tangibility.

In accordance with this framework, we can outline four main customers' expectations. For those who are unwilling to pay for green energy, bill only (quartile 1) offers are likely most attractive, as are local service (quartile 2) offers, which focus on savings. If customers have an environmentally focused willingness to pay, the upper (quartile 3) can be differentiated by a main characteristic: customer confidence. Additionally, the tangible green offer (quartile 4) can be differentiated by three main characteristics: their financial ability to invest, the long-term vision of their housing conditions (excluding home renting or next move), and some local technical constraints.

Arising from this framework, the strongest tangibility of renewable energy largely depends on whether a customer accepts a "tangible green offer", quartile -4-, which requires investing in new local devices and accepting to be exposed to specific risks and externalities. Such a decision, ensuring a real tangibility of green energy opens up fresh opportunities for customers and energy providers. First, it brings customers an effective response to one of their main expectations: to be an unquestionable actor of the energy transition. Second, following this possible energy market trend for private customers, it urges energy providers to develop as a competitive advantage a new business model able to rein in specific risks and negative externalities that might occur from this "tangible green offer" and are not fully addressed in an attractive energy offer proposition. This business model could inevitably prevail in the more or less near future if energy providers do not create the private and institutional service ecosystem (Vargo & Lusch, 2017; Akaka & Vargo, 2015) capable of making the renewable nature of energy more tangible for individuals.

3. Outcomes of Analysis and Strategic Approach: A "Tangible Green Offer" Business Model to Explore a Strategic Opportunity

"Bill only" offers still dominate most suppliers' portfolios and consumers of green energy have long been limited to a well-segmented portion of the population (Rowlands, Parker, & Scott, 2003). Yet green power offers and distributed green production are both increasing quickly and studies show that consumers are becoming more willing to pay for environmentally friendly offers (Pleeging et al., 2021; Ul-Mulk & Reynaud, 2018). The generation of green electricity is anticipated to increase 2.7 times between 2010 and 2035 (Ellabban, Abu-Rub, & Blaabjerg, 2014). Awan (2011) warns that main energy suppliers and providers cannot afford to stay away from the green market. Assuming a long-term, continued trend toward more environmental awareness among customers, and even a growing environmentally focused willingness to pay, is anticipating that customer satisfaction will increasingly require offers from the two upper quartiles in our framework -3-4-. Confirming this assumption is difficult: it is always risky to extend historically observed trends over time.

Renewable energy consumption depends on multiple parameters, including economic growth (Ntanos et al., 2018; Apergis & Payne, 2010) which is, of course, tricky to predict in the long run.

Most major energy suppliers and providers have entered the upper quartiles, at least to enhance their image. Nevertheless, it remains difficult to know if they really target a significant share of their turnover or of their margins from such offers. This question of whether green offers are central to their business model is common in prior literature, which describes proactive versus reactive strategies (Vaccaro, 2009), also known as defensive versus assertive approaches (McDaniel & Rylander, 1993) even though a simply reactive strategy can aim to attract large shares of customers through environmentally friendly offers.

The “Customer trust required” quartile is limited by intangibility and thus cannot be a general solution; however, it remains the only choice for customers who cannot invest locally. It also might be attractive for confident customers.

The “tangible green offer” quartile is a promising offer segment for customers whose characteristics do not prevent them from accepting such offers. This type of energy supply is the only offer likely to fully meet the consumers’ need for energy tangibility. No other energy supply favouring the physical tangibility of the offer as well as its mental tangibility (Bateson, 1979) or traceability is currently available at the sole initiative of energy suppliers. “Tangible green offers” are expected to thrive on new or updated generation technologies. In addition, some large suppliers are also expected to increasingly extend such offers, which have at least three potential competitive advantages.

3.1 A “Tangible Green Offer” Business Model: Competitive Advantages

First, these offers can take advantage of the company’s image, which should reassure customers who need to invest heavily in a project that determines their quality of life (i.e. the level of comfort in their home) while offering only long-term returns.

Second, if energy suppliers design devices to be installed on their customers’ premises, they can better take into account their full energy needs, including the additional one to be supplied by the grid. For example, the profitability of a solar panel depends on several parameters such as the purchase price of the energy produced injected into the grid, as well as the period, the price of electricity to be supplied by the grid, and finally the financing of the investment (Bertsch, Geldermann, & Lühn, 2017; Kordas et al., 2013; Colmenar-Santos et al., 2012). A supplier can optimize these parameters by offering a complete solution for customers, as well as various technical solutions for energy that is not produced locally. This is also the case for a gas company integrating a gas boiler to pass peak periods of demand and adjust the renewable energy supply accordingly. Likewise, a power supplier could adapt the load curve of residual energy demand (after accounting for local energy production) that best fits its energy supply. This business opportunity makes the creation of values to the customer more complex both in the co-production relationship and, more generally, in the way of rendering the energy service. It also promises real ex-ante synergies, in the sense that utilities might be better able to anticipate peak periods and define the relative competitiveness of centralized and distributed energy.

Third, we note the potential for ex post synergies (after installation). For example, a dual-energy heating system could function using either biomass pellets or at least partly on power. The supplier can optimize heating costs for its customers by switching from biomass pellets to wind power when, for example, the wind blows and this energy is very cheap. These synergies could also result from access to local customers' production data. Key customer data (mainly meter reading) is generally available to energy suppliers (possibly requiring previous authorization from the customer), but more detailed data could prove useful for local energy production. Across vast numbers of customers, this data would help the suppliers better forecast demand and thereby reduce production costs. Such ex-post synergies require elaborate real-time data management on a large number of retail customers, which is not the norm in Europe. Legal regulations regarding the ownership of customer data are important determinants of these synergies.

3.2 A Business Model Through New Value Proposition

In this business model, the customer is not just a consumer. To optimize the cost of energy this customer must not only choose a supplier but also be able to significantly change its relationship with this supplier. The traditional categories of value creation in services, such as creation, co-production (Vargo, Akaka, & Vaughan, 2017; Vargo & Lusch, 2016, 2008; Galvagno & Dalli, 2014), facilitation or even transfer of value to customers no longer adequately describe the energy supply and its attractiveness to the consumer. The values themselves concentrated mainly in the classic model on the value in use is diversifying to leave a greater place and role to potential values and values in exchange (Vargo, 2008; Moeller, 2010, 2008).

Indeed, in the model, customers can take on the role of producer when they put on the market surplus production made with their own facilities. This situation upsets our view of the co-production of values emphasizing in service science the fact that the customers can also be involved in a service-for-service exchange (Vargo & Lusch, 2004) and use their resources for another actors' benefit in interaction with other service systems. As resources prior integrator, these customers combine their resources as material, intellectual, nominal goods or assets, emotional with these beneficiaries, describing numerous ways of co-creating sustainable values through systems of exchange (Moeller, 2008).

Similarly, the implementation of means of production in the customer's property requires technical collaboration and cooperation without which the choice of technology adapted to the individual case is impossible. In this context, a significant part of the values proposed to the customer will be values in exchange (communication, coordination and consultation). These values in exchange will be even more crucial as the customer will expect the supplier to constantly update the technological means allowing them to maintain a high level of energy optimization and financial amortization of their installation.

The implementation by the energy suppliers of an offer proposition that contains concrete expressions of these values is expected. This offer proposition has to be suited to the new modes of combining resources between suppliers and customers in the energy service related to the "tangible green offer" quartile.

3.3 Specific Risk and Negative Externalities of the "Tangible Green Offer" Business Model

3.3.1 Obsolescence Risks

Obsolescence usually means wear or energy performance installations that become unfavorable to the market standard for similar equipment. To this can be added new externalities that were unforeseen or seemed non-critical at the time of installation and can suddenly call into question the relevance of a particular energy solution. Owen (2006) highlights the significant difficulties in estimating externalities related to existing and mature energy solutions. These externalities can render some technologies obsolete by unforeseen events.

One of the most striking examples is first generation biomass. New externalities have been associated with first-generation biomass. Competition with subsistence crops was not a predictable concern for energy suppliers when this technology was first introduced, but it rapidly became a major threat, leading to a much shorter lifespan for this technology than initially envisaged.

Gas may become another example. A dozen years ago, gas was a relatively expensive form of energy. U.S. suppliers expected to rely more on imported, more expensive and liquefied natural gas to supply their customers. As a result, gas was no longer a preferred retail option. In the "tangible green offer" quartile, the backup energy needed for any distributed energy generation solution would probably come from electric power. However, notably with the massive development of the shale gas industry, gas prices were expected to remain low (Wood, 2016). Gas boilers thus became the most affordable backup solution, and electric heating systems were increasingly becoming economically obsolete. Now, with the development of renewable electricity and electric heat pumps, and current tensions on the global gas price, the tide may be reversing.

Shale gas industry has also created new risks, such as the threat of major water pollution from hydraulic fracturing. Tan and al. (2022) underline that perceived risks associated with shale gas span a wide array of subjects. This could trigger a radical overhaul of consumer opinion on shale gas. Gas might come to be seen as environmentally unacceptable; specific measures to mitigate this risk, such as specific taxation to finance prevention plans, could directly affect retail consumers. Gas-based heating could therefore suffer from an early environmental and economic obsolescence: a gas retailer selling gas solutions prior to the arrival of shale gas could not reasonably have expected such potential pollution problems in the United States, because it could have expected the gas to be extracted from far off-shore fields such as Qatar or Australia.

3.3.2 Negative Externalities

For instance, solar panels have experienced three new externalities:

- Mining externalities: the extraction of rare earth elements needed for solar panels in

China has created local pollution issues, and thus a paradox for a technology that seeks to replace fossil fuels. Moreover, the world's dependence on China for rare earth elements unexpectedly became a major issue when China unofficially banned exports to Japan in 2010. Prior to these events, the importance of rare earth elements in solar panels was far less prominent. Now, with geopolitical tensions, and a still overwhelming domination of China in rare earth production, this question can hit the news anytime, and impact public perceptions. Charalampides et al. (2015) discussed the issue for Europe, Lee and Dacass (2022) proposed strategies for mitigating these effects in the United States.

- Economic and social externalities: China has been accused, at least in popular media, of heavily subsidizing this sector and imposing overly stringent working conditions in its plants. The sudden arrival of massive quantities of low-priced panels has resulted in the near collapse of the U.S. and European solar panel industries. Utilities that installed Chinese solar panels just before the global fiscal crisis were particularly sensitive to such externalities, because beyond the risk of increased customs tariff, they faced a substantial image problem. Including social indicators in analyses of the validity of an energy technology has become more common, in response to this and similar events (Gallego Carrera & Mack 2010).
- Externalities related to electricity generation: the profitability of a solar panel depends on two energy prices: the feed-in price and the regular retail price (Bertsch et al., 2017; Colmenar-Santos et al., 2012). Both prices are defined according to various externalities, often quantified by regulatory processes, and are therefore subject to unpredictable variations over the life of any solar panel.

New energy technologies, such as distributed power storage, can represent an unforeseen externality. If distributed power storage becomes competitive, it will completely change the dimensioning of distributed power production (Colmenar-Santos et al., 2012), making existing installations less suited. However, predicting the emergence of such technologies is extremely difficult because of purely technical issues, but also in relation to institutional barriers (Grünewald et al., 2012).

New technologies and urban energy system transitions are emerging with increasing rapidity (Pasichnyi, 2020; Rutter & Keirstead, 2012; Bulkeley, 2010). For nearly any technology, new externalities could appear virtually any time, creating unpredictable obsolescence. This risk is not specific to the energy sector, but it is particularly important for energy production, which requires installations on customers' premises of devices that need to be amortized over 20 years or more. Therefore, the high risk of unpredictable obsolescence of installed devices is an unavoidable part of customers' decisions.

It is the case when predictions on the economic and ecological value of any new solution are difficult to make. In this climate of technological uncertainty, a customer may need to replace an installed solution before its scheduled expiration even though changing it may be costly and upset the economic and ecological balance of the project as well. Likewise, negative externalities can be brought about by green technologies as first generation biomass or voltaic panels as further developed later. These issues pose market barriers to renewable energies that Owen (2006) lists under the umbrella term "buyer's risk," which implies the difficulties of forecasting over an extended time-period. These risks in the energy market for individual consumers are an important part of making green energy tangible. For consumers, the risks of obsolescence and negative externalities are associated with the financial and material risks of the investments necessary to implement this tangible green offer. They considerably limit the possibilities of generalizing such a response to the needs of consumers to participate in an informed and safe manner in the fight against global warming.

4. Discussion: Is "Tangible Green Offer" an Overall Solution to Energy Intangibility Issues?

Several solutions could contribute to making the "tangible green offer" a generalizable response, attractive and accessible for individual consumers.

4.1 Developing Renewable Energy Market by Servicization

The intangibility of the provision of energy service has appeared as a possible obstacle to individual consumers' commitment in sustainable energy. Both providers and utilities need to help consumers better mentally represent the concrete elements that make up the "tangible green offer" scenario. This scenario includes a "before", with a proposal for an offer attractive enough to enable the consumer to accept it and a "during" presenting how the offer proposal can be applied. Suppliers will have to provide the details of everything that can be done so that the "tangible green offer" be implemented at the customer's home. Finally, the scenario proposes an "after" that allows customers to have an anticipated and sufficiently stable view of the profits at they will be able to draw from their equipment efforts and, when appropriate, from, in turn, their position of surplus energy seller.

The development of potential values by all forms of communication generated by the business model is clearly the consequence of the transition from the simple sale of a commodity (energy) with a classic transfer of ownership to the sale of usage or result oriented service that places the "tangible green offer" business model in a process of servicization (Vuidel & Pasquelin, 2017). For suppliers, it is all the more true that their profit will depend less and less on the quantity of goods sold than on their ability to create economic value from co-production. In France, for example, the POPE law (2005) obliges energy suppliers to actively promote efficiency and energy savings to their customers. Suppliers and public policies must learn all the lessons from this servicization (Wüstenhagen & Menichetti, 2012) to create potential values and values in exchange that can develop an environmental consciousness and the attractiveness of this "tangible green offer" model.

In order for the "tangible green offer" business model to better assert its transition to servicization and the economy of functionality, it is a result-oriented service that it will have to develop as the most appropriate; a result-oriented service capable giving "more emphasis on the task of supporting customer during use" (Moeller, 2008).

This results-based service offering can be designed as a contract focused on energy efficiency monitoring. The part of the contract reserved for this efficiency leads producers to abandon their traditional pricing policy. The cost of a supply is no longer expressed by a one-unit volume price. A long-term economic calculation is attached to efficiency that can call into question the equipment if it decreases. The business model thus tends to promote a Pull-type business organization unlike the Push-type of the classic business model. In this Pull organization, it is not the measures that facilitate access to the offer that make it attractive, but the personalized expression of an energy system cost for a long-term optimized efficiency. This change in organization and commercial communication places the "tangible green offer" business model in an approach to assess the effects of the offer on customer performance. In this servicisized business model, this customer performance can become by contract a result to reach defined as a service rate agreed by the producer and the client.

4.2 Developing Renewable Energy Market by Servicization, Rethinking the Role of Stakeholders as Resources Prior Integrators

The concept of value co-creation, introduced by Vargo and Lusch (2006), supported by home automation or home transformation into a means of collecting renewable energy, communicating objects and all the Web 2 or 3.0 as an intelligent system of decentralized distribution of energy, is working as an internet. It gives access to how companies' agility and local initiatives lead to new uses of energy production and provision.

Even after the energy supply service is rendered, the long-term supplier-customer relationship cycle can be a source of co-creation and innovation, by maintaining the producer-client interface through information technology and smart meters. It is based on producers' knowledge of customers' energy-saving proficiency and their good practices. In the "tangible green offer" model, the role of "Prior integrator" (Moeller, 2008) in combining the resources that lead to value in use provision, can switch from producers to customers, when these are customers' know-how and good practices that initiate the resources combination. This role of "prior integrator" suggests potential values that contribute to the attractiveness of the "tangible green offer" to prospects.

This long-term supplier-customer relationship cycle depends first of all on the managerial and organizational capacity of energy suppliers to act as "prior integrators". They must therefore have, from the co-design stage with the client, localized data, provided in particular by decentralized networks. This data allow them to intervene directly, for example, on the housing stock by targeting the potential of these buildings to produce energy. They must create and organize a new network to combine their resources with other players, including local players (equipment producers, installers, urban renewal specialists, building owners, investors.).

Secondly, producers will need to bring together all the legal and managerial skills to ensure a true "node of contracts" that closely involves customers and stakeholders as installer, equipment manufacturer, energy manager, thermicians, investors who did not participate in the classic business model in the value chain. All this data will need to be shared with relevant stakeholders to start the producer-client cycle. In this sense, the proposed business model assumes that energy suppliers know how to move from a market dominated by mass demand to one hinging on supply, much more focused on energy behaviors and customers' performance. The conditions are then met for the customers of the "tangible green offer" to ensure their role as co-designer, co-producer, facilitator (Grönroos, 2013, 2008, 2006) and co-creator of the value in use.

Thirdly, the "tangible green offer" model leads suppliers to move from a simple lobbying strategy towards public authorities (Pearson & Foxon, 2012) to one inspired by the concept of the "common goods". Such a position can be particularly beneficial for suppliers if they are able to influence the societal judgment on usefulness. It drives policy-makers to make the legal and fiscal framework in which returns on investment are valued evolve. Local authorities, developers, network operators are all targets to strengthen the readability of the market, strengthen quality standards (certifications, brand, label) to change regulations and tax provisions hindering the development of investment in energy transition.

4.3 Reducing Customer Risks

High client risks are present in the "tangible green offer". Advice, assistance in financing plans, help to design and implement the technical projects and facilities management can reduce the client risks. This adaptation to customers can result in savings, for instance. It gives companies a competitive advantage as a source of customer loyalty. The value propositions in this business model are essentially focused on potential values, values in exchange and in use. They deeply change the energy supplier's business. As an energy producer and distributor, it becomes a profitable guarantor of the customers' interests and the financial viability of their contribution to tackle the climate crisis and lower energy costs. This specific role strongly upsets organization of skills and the success factors of all energy companies making it all the more difficult to implement this business model and all the more limited to just a few competitors.

To reduce a big part of the customers' risks, the entire lifecycle of the customer relationship is to be reviewed to lower economic and business costs. This reviewing process is deemed necessary when an energy device has to be changed before the end of the amortization period. This risk of obsolescence arising earlier than initially expected might be shared by the customer during the initial offer presentation. This could foster a trust relationship mitigate the risk of a potential future obsolescence for the energy customer.

A multi-technology strategy can help to mitigate obsolescence risks through the use of solutions combining several technologies, such as for instance PV panels, solar boilers, biomass boilers, biogas… This strategy would replicate a portfolio approach that is recommended for larger energy producers in literature (Ahmadi et al., 2021; Wüstenhagen & Menichetti, 2012; Bhattacharya & Kojima, 2012).

An "agile conception" may also be implemented by energy suppliers, when designing the solution to be installed. This "agile conception" will integrate, from the start, an optimization of the removal or an upgrade of the device.

Despite the interest of these different solutions, they are quite unable to propose a general response and make "tangible green offer" attractive and accessible to a mass market of individual consumers. Consumers and suppliers must overcome significant obstacles for this solution to spread throughout the residential market.

For consumers, many obstacles exist: the financial weight of the necessary investments, the conditions both land (owning a home and planning to occupy it in the long term) and psychological (motivation to install equipment in one's home and manage it, apprehension of new risks including the risks of technological obsolescence), relationships with suppliers which may include high switch costs, depreciation calculation according to the nature of the assets, mobility, difficulty in establishing and guaranteeing contracts for the sale of housing temperature results, choice of renewable energies subject to hazards requiring the use of complementary energies, sources of dependence on supplier networks.

For suppliers many obstacles exist as well , the installation of means of production at the customers' premises without transfer of ownership, the need for capital concentration, the mastery of new skills in production and consulting, the long-term sustainability of the model, the arrival of fragmented competition from local energy producers through the multiplication of production sites, energy-producing buildings and the deployment of smart grids to control local supply and demand via the internet of energy.

5. Conclusion and Orientations: A Call for Innovative Solutions for Residential Market

This article highlights three key elements that have received very little attention in the literature. It proposes a definition of energy intangibility revisited on the basis of service theory. Inspired by this definition, it identifies four strategic options (the energy offers framework) based on the concept of intangibility and the degree of consumers' environmental concern. From this framework, a strategic option (the "tangible green offer") is presented as a possible solution to make the producers/distributors offer more tangible to individual consumers. Due to the limits of the "tangible green offer" solution, a call for innovative solutions for residential market is requested.

The strategic contributions of the general service theory draws from services properties are clear (Bowen & Ford, 2002; Edgett & Parkinson, 1993). Intangibility appears in its material and mental forms as an obstacle to the influence of service providers on the market. Applied to the energy service, this represents an issue for energy producers or distributors. Consequently, their tangibilization efforts may contribute to directing end-consumer choices towards renewable energy. The theory thus predicts that by tangibilizing, energy providers deploy means expected by society to accelerate the energy transition and gain competitive advantages.

Energy service tangibilization provides a good example of what Moeller (2008) calls "the customer integration". This integration may appear as a condition of energy tangibilization. It involves the customers' activities in a resource and production perspective in an energy service encounter that could even partially be a source of tangility. It provides a favorable impetus to their environmental engagement which can be motivated both by values perceived as extrinsic towards themselves (Sanchez, Iniesta-Bonillo, & Holbrook, 2009; Holbrook, 1999). The "tangible green offer" is a limited example of the course of action to satisfy these personal expectations, but also as an intrinsic value oriented towards others (Holbrook, 1999) associated with the will to act for the future of one's own and the planet. With sufficient information to become an enlightened and effective actor, the solutions of energy tangibilization should position the end-consumers in the chain of the energy production and distribution, so that they can control the real origin of the renewable energy they buy, while taking into account the inevitability of its natural physical intangibility and the existence of a single distribution network.

These tangibility solutions should remove the radical dependence of end-consumers on energy suppliers created by intangibility. These possible solutions appear to be an important objective of the ecological transition. They are particularly valuable if they escape the constraints of the "tangible green offer". This effort to work on design and implementation on the basis of existing experiences could be led in three different and complementary orientations.

The first orientation could be the analysis of the energy service ecosystems (Kolinjivadi et al., 2019). Indeed, more generally, the search for possible tangible solutions can be facilitated theoretically and practically by designing them within service ecosystems. The solutions require thinking in terms of interconnections and interdependencies of actors (Capra & Luisi, 2014) to extend the quartile of the "tangible green offer" that is currently not very accessible to all consumers. These ecosystem services imply a new conceptualization of the market, described as an ecosystem of services that requires "broker functions" (Ekman, Rondell, & Yang, 2019) to facilitate their "resource integration and their service for service exchange activities" to achieve what Vargo and Lusch (2016) call a "relatively self-contained, self adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange". They require the integration of the resources of several stakeholders and take place in a defined network (Humphreys, 2010). In the case of energy, the list of stakeholders in the ecosystem is long: producers, distributors, states, territorial and local authorities, regulators, appliance manufacturers, individuals, etc. For instance, in the residential market, energy policies involve decisions about regulated tariff on the sale of energy, or carbon tax and pricing that make political institutions key stakeholders, but the scope of stakeholders should be wider. Such an energy service ecosystem denotes an "actors-environmental interaction and energy flow" (Vargo & Lusch, 2016) and could serve as a unit of analysis for the co-production and co-creation of new potential values, values in exchange and in use and their extension into value in social context (Edvardsson, Tronvoll, & Gruber, 2011) favoured by the reduction of energy intangibility.

The second orientation suggests that the solution to fully make renewable energy tangible to consumers must be applicable to all households, unlike the "tangible green offer". This solution could seek to meet at least three objectives for the residential market: maintain an accessible energy price in this highly subsidized market, ensure security of supply, provide the means of information that allows the growing consumer's commitment as citizen in the fight against the climate crisis. The solution would have to resolve a real paradox between consumers' search for sovereignty over their energy choices and the material or mental intangibility that limits the scope and relevance of these choices. In addition, if this solution should allow the residential customer to make decisions with full knowledge and autonomy, it should be as clear and simple as possible.

Finally, a third orientation could be to strengthen the territorial involvement of consumers as citizens. In a context of foreseeable fragmentation of renewable energy production, consumers are all looking toward using short-circuit energy mixes if the territory concerned is able to produce renewable energies ensuring their necessary proliferation (biomass, sun and wind resources are very unevenly distributed over the territories). This territorial anchoring of a possible solution is particularly expected. It can be a source of co-production and co-creation of values and especially in this case of value in social context. From their local environmental concerns, consumers are able to understand how access to energy tangibility and citizen engagement requires arrangements between stakeholders within a constantly evolving service ecosystem to satisfy all the constraints mentioned. These dynamic arrangements are more or less numerous depending on the territory. They can be complex in terms of networks of actors (institutions, firms, individuals) necessary to maintain and develop a service ecosystem. In this ecosystem all stakeholders will be active and critical contributors by co-producing or co-creating values useful for the preservation of the planet. Moreover, it should be stressed that these service eco-systems for energy tangibilization have a peculiarity: the great flexibility of their implementation. They are perfectly compatible with an “experimental” application, territorially limited. Governance and regulation of a reduced-scale energy policy applied to a “pool of experimentation” could assume the institutionalization of tax or regulatory initiatives and thus strengthen in the cycle of potential values, values in exchange and in use, the promotion by evidence of this business model.

Such an experiment would be based on a collaborative and sustainable community of initiatives from all stakeholders (Losardo, 2016; Zamchevska, 2013; Wagner, 2012), including customers, as players in the territory-wide energy transition. New indicators should be tested to assess how best companies can offer these new value propositions which underpin the existence of economic value.

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