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The Role of Economic Rent in Sustainable Dwelling

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Abstract

The research sets out from the observation that contemporary dwelling faces a dual challenge: while the housing question has been on the agenda of the architectural discipline since its inception the material composition of buildings and cities will have to fundamentally change to comply with ecological exigencies and increasingly specific environmental targets. The architectural discourse and practice usually address both problems with technical solutions: better houses for less money using less resources. The underlying paradigm is that of efficiency, i.e. doing the same thing better, within the framework of the existing narratives and institutions. At the same time it is increasingly accepted that architecture "depends" and is socially embedded. Against this backdrop, this thesis aims to build a conceptual bridge between the discourses in architecture and economics by shedding light on the influence of economic institutions on the shape and prospects of sustainable dwelling. To this end dwelling is discussed in the context of the discourse of economics and reframed in economic terminology. A preliminary finding is that dwelling is closely connected to the concept of economic rent. A review of incidences of various forms of economic rent in the process of dwelling identifies the ownership paradox as a central problem. The focus turns to the institutions that govern rent and produce the economic exigencies under which both the architect and the dweller use resources. The observed dynamics are then discussed in the context of two projects that critically engage with sustainable dwelling. A central finding is that the institutions that govern and allocate rents, notably property, play key roles in determining the feasibility and viability of sustainable dwelling proposals. This implies that sustainable dwelling cannot be achieved with efficiency but requires political decisions about the allocation of social privileges. In practical terms, while the most direct way to provide sustainable buildings and cities would be to give dwellers a direct incentive to dwell sustainably it is concluded that well documented and communicated pilot projects, such as the discussed case studies, play an important narrative role as "small scale versions of the future". Moreover, it is observed that looking at dwelling through the lens of resources has important touch points with vernacular architecture. It is proposed that bottom-up engagement with the institutions that govern the resources involved in dwelling could be understood as a modern vernacular.

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Introduction

Contemporary dwelling is structurally unsustainable. Housing crises have been on the agenda of the architectural discipline since its inception[1] while the material composition of buildings will have to fundamentally change to comply with ecological exigencies and increasingly specific environmental targets. The architectural discourse and practice usually address both problems with technical solutions: better houses for less money using less resources. The underlying paradigm is that of efficiency, i.e. doing the same thing better, within the framework of the existing narratives and institutions.

At the same time, though, it is increasingly accepted that architecture “depends”. Architecture forms part of a social landscape and operates within an ecosystem. The work of the architect in providing spatial settings for human dwelling has to be understood and considered in this context. Against this backdrop, this thesis aims to build a conceptual bridge between the discourses in architecture and economics. Specifically, the question to be investigated is: ‘What does economics tell us about the shape and prospects of sustainable dwelling?’ The hope is that by answering this question new light could be shed on current discussions in the architectural discipline about sustainable dwelling. In particular, the findings could be insightful for assessing the feasibility, viability and impact of proposals both at the planning level and when designing concrete solutions.

The thesis in structured in four parts. The first chapter discusses dwelling in the context of the discourse of economics and reframes the problem in economic terminology. The second chapter details the incidences of various forms of economic rent in the process of dwelling. The third chapter discusses the institutions that govern rent and the resulting dynamics under which both the architect and the dweller operate. In the fourth chapter, the findings are discussed in the context of two projects that critically engage with sustainable dwelling.

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[1] See e.g. Davidovici, I. in: Bates et al (2012).

1. Architecture Depends

Dwelling and Prosperity

In the architectural discipline the view is gaining currency that architecture is a social process that "depends" on dynamics in the wider political economy (Till, 2009; de Graaf 2015). Buildings, and spaces more generally, can be understood as "signifiers of underlying social, political and economic systems" (Schneider, 2018: 5). This dependence on external processes and dynamics threatens to undermine the discipline's ethical remits and what should arguably be a central objective of architecture: to facilitate decent human dwelling in both a functional and an existential sense. The architect risks being reduced to serving as a "professional service provider" (Pallasmaa, 2019) supplying the imagery and narrative that allow powerful economic actors to monetise dwelling. As a consequence, an architecture that aspires to more than pragmatically accepting this condition, a socially engaged architecture, needs to "look a the mechanisms and means of production" (Schneider, 2018: 12; Goodbun et al, 2014: 12) and engage with institutional design (Brenner, 2015). This thesis aims to contribute to this theoretical setting.

Taking this set of arguments into economics reveals that the architect's conundrum forms part of a wider problem. As much as decent dwelling appears to be largely incidental to property and construction, in the overall economy prosperity seems to be a side effect of the primary objective of GDP growth. Both economic incentives and the public discourse push for "property and construction led GDP growth" in the hope that it might also yield some "decent dwelling in prosperity". While there is a correlation between GDP and prosperity it only holds up to a certain level of welfare, after which GDP growth becomes an end in itself. Neither does GDP growth per se eradicate poverty (Jackson, 2017: 48). Importantly, both construction and GDP growth rely on material throughput (Jackson, 2017: 84). On a finite planet exponential growth of material throughput is physically impossible and over time carries an immense ecological cost.

In the context of his work on the foundations of an economy beyond growth, economist Tim Jackson proposes looking at the economy in terms "services" to separate economic value from material flows (Jackson, 2017: 142). In a simple example, if the required service is a warm dwelling, this could be achieved either through burning energy sources or through insulation, or arguably by dwelling in a warmer place to begin with. This view has close parallels with the conceptualisation of architecture not as an object but as complex, systemic process.[2] In any case, dwelling as an unavoidable human activity cannot be dematerialised – everyone has to dwell in a physical place with at least minimal qualities that facilitate

[2] See e.g. Goodbun et al, 2014: 51; Awan et al, 2011; Till, 2009: 146

human life. As ecological economist Herman Daly remarked growing the economy while decoupling it from material throughput would ultimately require humans to subsist as "pure spirits" (Daly, 1977: 119, in: Jackson, 2017: 164). That this angelic existence is incompatible with human dwelling is vividly depicted in Wim Wenders 1987 film Wings of Desire.

As a general starting point dwelling could be considered the systemic process in which humans exist on Earth, while a broadly accepted definition of a sustainable practice is one that integrates economic and ecological viability with social justice.[3] In this light it seems relatively clear what "sustainable dwelling" would imply in general terms. There are also many concrete local initiatives aimed at realising it, though often in protected private realms and against the dynamics of prevailing institutional incentives. These include alternative dwelling in cooperatives such as Miethäuser-Syndikat, initiatives at an urban and territorial scale such as Totnes Transition Town, design practices engaged in reorganising the material environment such as Rotor, or couchsurfing as a spatial practice reinventing the use of existing spaces. While there are ample examples, anecdotal evidence suggests that many initiatives contributing to sustainable dwelling encounter practical limits where their economic dynamics operate "in opposition to the institutional and social structures that dominate society" (Jackson, 2017: 129-130). Under the prevailing conditions these initiatives risk remaining patron-sponsored good intentions or being co-opted by the very institutions and actors they intended to question (Schneider, 2018: 3; Brenner, 2015). Hence, what remains unclear is how the two scales, the local initiative and the overall vision, could be connected with a social, cultural and institutional framework that would allow sustainable practices to become the norm.

In the terminology of sociologist Ferdinand Tönnies (1887) sustainable dwelling appears to be operable at a private community level if the community in question is insulated from countervailing dynamics operating at the society level. Communities are neither static and fixed in size nor exclusive and they may overlap. But as anthropologist Robin Dunbar (2010) showed communities do have a maximum size due to humans' limited ability to maintain a large number of meaningful relationships.[4] Moreover, as Elinor Ostrom has shown communities play an important role in the organisation of local common resources (Ostrom, 1990). In this light the "systems of settings" that constitutes dwelling (Rapoport, 1979) may be considered a common good that given its social and physical specificity lends itself to community organisation. However, in a complex society communities will ultimately have to

[3] Based on the 1987 Brundtland Report. Arguably in a long term intertemporal view ecological viability is a necessary condition for both economic viability and social justice. It is not, however, a sufficient condition that economic viability and social justice will actually be realised.
[4] Dunbar puts this number at 150 relationships, although the scope of the community increases or decreases depending on the need in question: support, sympathy, traditions, etc.

engage with one another through abstract institutions with universal criteria (e.g. laws, markets) to negotiate access to resources at the society level. A fundamental question in this respect would be which community would have the right to dwell in which place to begin with.

The complexity of the problem of sustainable dwelling reflects the problem of sustainability in the wider political economy. Bernd Klauer et al propose as a methodology for dealing with the inherent complexity of sustainability the conceptual framework of "stocks". The idea is to map the stocks of the existing situation: specifically material resources, immaterial institutions, and their interaction. Rather than aiming for a distant ideal the methodology resolves to identify opportunities for the right intervention at the right time (*kairos*) (Klauer et al, 2017: 122). This thesis takes stock of the political economy of dwelling. The political economy in this context is understood as an ecosystem composed of an aggregate of practices (Gibson-Graham, 2006, in: Schneider, 2018: 7). The objective is hence to have a closer look at dwelling identifying and mapping its stocks of physical and social resources and the institutions that govern them.

Dwelling in Economic Terminology

In the terminology of economics dwelling is composed of two qualitatively distinct processes. First, dwelling implies the continuous presence of the dweller in a concrete place. This place will have certain qualities that facilitate the dweller's survival on a purely physiological level (e.g. proximity to sources of food or a community) and respond to higher needs (e.g. social status, religious significance). Second, the dweller will likely adapt the local environment of the place to enhance its habitability (e.g. by cutting down a tree to erect a shelter[5]).

1. The site: It is a well-known fact in the architectural discourse that places are unique.[6] In economic terms places on a finite planet are absolutely scarce. If e.g. Alice[7] has the exclusive right to dwell in a place with beneficial solar irradiation and close to a common source of food, she is deemed to be internalising an economic rent corresponding to her exclusive use of the beneficial solar irradiation, and a location rent for her valuable proximity to the common food sources. Sites play a significant role in complex societies. As the division of labour increases higher value added activities concentrate in cities to benefit from innovation density (Florida, 2010). Economic participation requires dwelling close to these activity centres. In a major city such as Munich 79% of the economic cost of dwelling

[5] Or to make a fire; see Reyner Banham's 1965 critique that architecture should extend its view beyond spatial enclosures to include other acts of rendering spaces habitable.
[6] The concept of genius loci popularised by Christian Norberg-Schulz (1979).
[7] Alice could be an individual or a community, in any case a private actor.

correspond to location rents, not buildings (Vogel, 2019: 11). In the UK, 51% of all national assets correspond to land (ONS, 2019).

2. The shelter: The dweller will also adapt the site to enhance its habitability. Following the simple example Alice could cut down a tree to erect a shelter. In economic terms she applies Labour to an object found in nature (the tree) to create a Capital stock (the shelter). Assuming that Alice's Labour is fully compensated (she is self-taught and self-sustained) the only remaining input is the tree. If this tree is the only one locally available in a generation that is suitable for building a shelter, other dwellers will have to forgo erecting a shelter during this period. Alice is internalising a rent derived from using the tree. If, in addition, cutting down the tree would lead to irrecuperable soil erosion the tree would be a non-renewable resource and its use would not constitute a sustainable dwelling practice.[8] In the same vein, if erecting the shelter required burning a non-renewable energy resource Alice would derive a rent from using it and equally the dwelling practice would not be sustainable.

Taken together it is evident that in economic terms dwelling is a process that is intimately tied to economic rents (location, materials and energy). In fact, dwelling arguably implies an internalisation of rent per se given that it involves the continuous exclusive presence in a concrete place on a finite planet with a limited number of places. The predictability needed for decent dwelling and a dweller's increasing association with a specific place (location and material and social surroundings) over time effectively mandate that a dweller enjoys an internalisation of rent at a predictable future economic and psychological cost.

Economic Rent

Concept and Terminology

While there are several types of economic rent, they have the same fundamental characteristics. The most important one is that rent constitutes privileged access to unearned value. As such rents are a zero-sum game: privilege cannot be shared without ceasing to be a privilege. 19th century classical economics recognised two principal sources of economic rent: on the one hand the use of nature, production factor Land. Given that natural resources are unproduced they do not have an original owner.[9] Consequently any rent from natural resources is a political decision to confer a privilege. On the other hand rents can also be derived directly from social institutions, e.g. monopolies and patents. In

[8] The practice would not constitute strong sustainability. It is deemed to constitute weak sustainability if the shelter is more valuable than the ecological degradation.

[9] The Lockean proviso that property of natural resources is justified "at least where there is enough, and as good, left in common for others" arguably cannot be complied with on a finite planet.

both cases the rents are attributable to the society that controls the territory in question and has the legal authority to enforce property rights.[10] The social practices that constitute this society may in turn assign the privilege to internalise these rents to its members.

Economic rent has close relationships with other socio-economic institutions and concepts, notably externalities, monopoly and property. Given that natural resources are by definition subtractable (Ostrom, 1990), i.e. use by one person prevents the use by another person, the rent derived from using a natural asset corresponds to an externality imposed on others.[11] In other words, if Alice uses a tree to build a shelter, the negative side effect is that Bob cannot use the same tree to build his shelter. If there are other trees, they may be less suitable, or located further away. The welfare loss incurred by Bob as a result of Alice's action corresponds to the rent that Alice obtains from using the tree. In a similar vein, Eric Posner and Glen Weyl argue that private property per se corresponds to a monopoly over the object in question in the sense that private property is a social privilege that grants the owner a monopoly over the object in question, allowing her to internalise monopoly rents, unearned income that it should therefore be taxed (Posner & Weyl, 2018). Posner & Weyl are not explicit on which basis private property is unearned. But the fact that they exempt "personal effects" and "family heirlooms" from their argument points to the view that all other goods either don't have an original owner (nature) or are socially produced. The concept of property as a source of monopoly rents in this way builds a conceptual bridge over the nature-society divide.

Posner & Weyl's argument has implications for the role of economic rent in dwelling: arguably the increasing association of a dweller with a material setting and his mental investment in it creates a "personal effect". According to Posner & Weyl this would produce an exemption from private property tax, i.e. society grants the dweller the privilege to internalise the resulting monopoly rent based on her continued presence on the site.[12] Yet at the same time the dweller's continued presence on the site creates an externality for other dwellers who may wish to dwell on the same site, especially if they have contributed to the site's value through collective investment in the vicinity.[13] To put it simply, if everyone left the area the isolated site would be practically worthless to the dweller. Hence the dweller's personal investment can hardly be considered in isolation. It depends on the social

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[10] For exclusionary goods, such as land use, this society would be tied to control of the land (e.g. a nation state). For non-exclusionary goods, such as the right to emit CO_2, this society would be global. There are parallels with the discourse in political science about which society has the right to which land and its resources in the first place. See Moore (2015; 2019).

[11] This is following the definition of externality offered by Mankiw (2014: 196).

[12] The acquisition of dwelling rights through squatting follows this logic.

[13] The collective investment is tied to the place, again implying that the Lockean proviso cannot hold because of the specificity and physical limitation of the place where the investment was made.

production of the spatial context. Specifically, the question would be how to weigh the personal investment of the dweller against the collective investment that makes the site valuable to the dweller in the first place. In a delimited community this problem may be resolved through specific local practices. In a complex society enabling and protecting the dweller's continued presence on the site would require negotiation by means of abstract principles and institutions.

Another important aspect is the time dimension. In both architecture and economics orthodox schools of thought display a distinct neglect of time. In architecture this neglect is encapsulated in Karsten Harries' description of the architect's "terror of time", the moment when a "finished" object is subjected to social processes (Harries, 1982, in Till, 2009: 79). Mainstream economic modelling in turn omits fundamental consequences of time, such as its irreversibility which prevents goods from being generally substitutable (MINE, 2019). In contrast, in the dynamic consideration of architecture as the social processes facilitating dwelling proposed by both socially engaged architecture and ecological economics the time dimension plays a central role. A dynamic view of economic rent relates the three dimensions of sustainability: the prohibition of unsustainable building practices with negative externalities for future generations (e.g. CO2 emissions from concrete or heavy imports) would mean that less resources are available for use today (e.g. only the timber from nearby forests). Under complete ecological sustainability and thus intertemporal justice the availability of natural resources would be limited to the products that can be derived from nearby land today. This dynamic determined the growth of cities until the proliferation of fossil energy (Smil, 2018: 352). In economic terms, if resource rents could no longer be brought forward from the future they would have to be substituted with resource rents available today. This implies that pursuing ecological viability puts pressure on distributive issues today. Sustainable practice expressed through economic rents derived from natural resources creates a direct link between intertemporal justice through sustainability and contemporary social justice. In this light unsustainable practices in excess of Earth's regenerative capacity could be considered an intertemporal enclosure of natural resources mirroring the enclosures of common land. Economic rents as a metric hence aggregates the three dimensions of sustainability: unjustified rents derived from private ownership of natural resources hinder economic efficiency and foster injustice both intratemporal and intertemporal.

The fact that economic rents describe a distributional effect was a fundamental tenet of 19th century classical economics. But with the rise of neoclassical economics unearned rents became conflated with earned profits and rent considered a temporary imperfection in otherwise competitive markets. Recent work by Josh Ryan-Collins et al illustrates how Land as a factor of production that generates rent disappeared from the economics discourse with the rise of neoclassical economics, with far-reaching, little discussed implications (Ryan-Collins et al, 2017: chapter 3). The neglect of rent has radiated on discourses beyond neoclassical economics including heterodox schools of economic thought and the public and political discourse. In architecture, economic rent featured prominently in 19th century urban proposals, such as Ebenezer Howard's garden cities. Building on the ideas of Henry George (1879), Howard called for the development of new cities on common land. The garden cities' entire revenue derived from rents (1898: 11). But with the Russian Revolution (1917) majority opinion arguably lost appetite for such social experiments. The discourse has since centred on the idea that the problem of the commons in society could effectively be transcended with fossil-fuelled economic growth and sufficient capital investment (think Constant Nieuwenhuys' New Babylon, 1956-74) to guarantee continuous compliance with the Lockean proviso that there will be "enough and as good left".

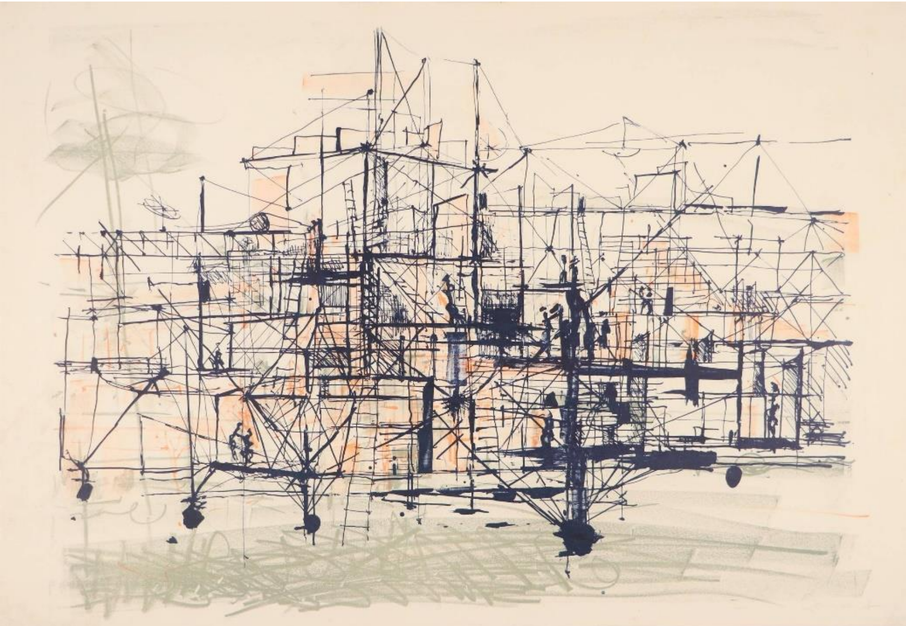

Figure 1: Constant Nieuwenhuys: New Babylon. Transcending scarcity through growth
Source: MutualArt (2020). https://www.mutualart.com/Artwork/New-Babylon/C20B674D46C95E29

In the aftermath of the 2008 financial crisis and the growing visibility of the ecological consequences of exponential growth on a finite planet, economic rent has found renewed academic interest. Josh Ryan-Collins et al's work on the economics of land and Mariana Mazzucato's research on value generation in the economy highlight that the public and academic discourses continue to regularly conflate earned income (wages and profits) and unearned income (rent), leading to important deficiencies in both economic efficiency and social justice, and arguably ecological sustainability. Aside from the political motivations for this development discussed by Ryan-Collins et al, another factor, touching both economics and architecture, may be that economic rent is a constant reminder of human dependence on Earth and as such does not chime with the modern ambition to unshackle humanity from its physical limitations through growth and technological progress.

To summarise, it is little understood that the construction of a steel and concrete building on a privately owned plot of land has significant distributional effects and hence political implications. However, bearing this in mind it comes as no surprise that the housing problem cannot be resolved with the construction of ever more of the best designed houses, as much as poverty cannot be eliminated through technological progress and economic growth alone. Poverty is relative: people suffer from poverty when they become "excluded from ordinary living patterns, customs and activities" (Townsend, 1979, in Jackson, 2017: 48). This situation has not qualitatively changed since Henry George observed the pervasiveness of poverty in the booming economy of 19th century America.[14] Scarcity, whether physical or designed, cannot be solved with efficiency but requires political decisions about the allocation of social privileges (Goodbun et al, 2014: 60). Not acknowledging this gravely complicates efforts to solve the underlying issues. In the words of Bruno Latour, dwelling is not a matter of fact but of concern (Latour, 2014, in: Goodbun et al, 2014: 18). The problem is not that rents are internalised in the process of dwelling – it is inherent to the very nature of dwelling. The important question to ask is who internalises which rents based on which privilege.

Types of Economic Rents

Schwerhoff et al (2020: 402) summarise the literature on economic rents. They identify seven types of economic rents.

[14] In his seminal work Progress and Poverty (1879) Henry George describes the decisive role of rents derived from private land ownership in the perpetuation of poverty.

Type	Description	Example
Market power	A supplier can limit supply due to size. In the extreme case this results in a monopoly. The supplier can dictate a price that exceeds her costs, resulting in a monopoly rent.	The power of large supermarket groups over small farmers
Investment rents	A supplier can asks a higher price because of superior technology, practices, knowledge, or reputation that cannot be replicated. The return in excess of cost is an investment rent.	A patented technology, a professional network, a brand
Inframarginal rents	A supplier has lower costs per unit than the market price, e.g. due to market power or superior technology, resulting in monopoly rents and/or investment rents.	A large supermarket can make a profit at a price at which a small shop cannot compete
Natural monopolies	A market is more efficiently supplied by a single provider, usually due to high fixed costs. The return in excess of cost is both an investment rent and a monopoly rent.	Public infrastructure, e.g. a water utility
Political rents	The government colludes with a supplier to limit supply and privatise the resulting monopoly rents.	Corruption in public tendering
Scarcity rents from bounded supply	Supply is absolutely limited. The more demand the more scarcity rent is yielded by the supplier independent from her costs.	A plot of land on Passeig de Gràcia
Regulation rents	The government levies taxes or quotas on a good with negative externalities. The market price increases beyond the supply costs. The government collects a regulation rent.	Taxes on pollutants, e.g. petrol, CO_2

Table 1: Economic rents based on Schwerhoff et al (2020)

Scarcity

The table below condenses the types of rents identified by Schwertoff et al and links them with the concept of scarcity. In neoclassical economics and in the architectural discourse[15] scarcity defines the relative scarcity of a good in relation to other goods. However, as discussed, neoclassical economics assumes the possibility of full substitutability of goods and disregards irreversibility, both of which conflict with the physical reality of the economy over time. To address this limitation, ecological economist Herman Daly expanded on the concept by distinguishing relative from absolute scarcity (Daly, 1977; in MINE, 2019a). While relative scarcity refers to a lack of supply in the market, absolute scarcity exists if a good cannot be substituted neither on the demand nor on the supply side. Most obviously this condition would apply to goods that are not man-made but found in nature. The two columns

[15] See e.g. Goodbun et al (2012, 2014), Till (2014).

distinguish whether a rent materialises in a laissez-faire market or through government intervention.

	Laissez-faire market	Government intervention
Relative scarcity	Investment rents Monopoly rents	Regulation rents, e.g. patents
Absolute scarcity	Scarcity rents	Regulation rents, e.g. CO2 emission quotas

Table 2: Classification of economic rents

The table indicates the proximity of the concept of relative scarcity to efficiency, competitive markets and neoclassical economics. Here, the concept of economic rent is centred on market imperfections. These imperfections can have both positive or negative connotation. For example a dominant supplier of a medicine could limit supply to increase the market price to yield a price in excess of what would be the price in a competitive market, a monopoly rent, thus reducing social welfare. On the other hand a pharmaceutical laboratory could engage in the same practice in order to recuperate the investment it made into research to develop the medicine. If this research could be replicated easily by other suppliers, the laboratory would have little incentive to assume the risk involved in developing the medicine. In response the government would increase social welfare by granting the laboratory a patent, i.e. a government-sanctioned monopoly allowing the laboratory to recuperate its investment. The resulting rent in this case would constitute both an investment rent and a monopoly rent, as well as a regulation rent as the patent acts like a tax aimed at attributing the positive externality of the research back to the laboratory. Absolute scarcity on the other hand is related to natural resources. Absolute scarcity can exist in otherwise competitive markets, e.g. the supply of plots of land on a prestigious street is absolutely limited, implying that owners of these plots can ask more than they could ask if new suppliers could add more plots to the street. Scarcity rents can also result from government intervention. The government may decide to cap CO2 emissions at a certain level, thus creating absolute scarcity, unless substitutes can be found. If the government renounces its right (or obligation) to levy the regulation required for a sustainable resource use, the regulation rent is effectively internalised by those using it as they don’t have to pay the full cost that would be applicable if the resource was used in a sustainable way.

An important consequence of the above discussion is that economic rent always has a social dimension. This is particularly obvious in the case of relative scarcity: the concepts of monopoly and investment rents and government regulation to increase social welfare all directly imply a social component. But also absolute physical scarcity takes on a social dimension as soon as more than one actor is involved. The unsubstitutability of an absolutely scarce resource implies the internalisation of the scarcity rent by one actor has direct negative externalities for another actor who cannot substitute it. The social dimension of economic rent requires the identification of the author of the value in question to be able to assess the type of rent involved and its desirability.

2. Economic Rent in Dwelling

In what follows the resources and processes involved in dwelling are identified and matched with the types of economic rent described above. As discussed, dwelling has two principal dimensions: the occupation of a site for an extended period of time, and the manipulation of the site to increase its habitability.

The Site

A central input in dwelling is the site. At the outset a site is natural product. In the context of agriculture in a temperate climate a south-oriented site with less slope and fertile soil will be more valuable for dwelling than a north-oriented site with more slope and infertile soil. The scarcity rent resulting from the natural properties of the soil was first extensively described by David Ricardo in 1809 and is therefore regularly referred to as 'Ricardian rent'. However, in all but exceptional situations a site's value is also inextricability linked to the degree that it is connected to collective investments, such as infrastructure, common sources of food and economic participation and places of worship and entertainment. A site that is located closer to a centre of economic or cultural exchange will be more valuable than a site located further away. The resulting rent, a location rent, was first extensively described by Johann Heinrich von Thünen in 1826 in the context of land uses in agriculture. Perishable and heavy crops require short distances to their points of use, the infrastructure required for growing them further away would be too costly given the utility than can be derived from their use.

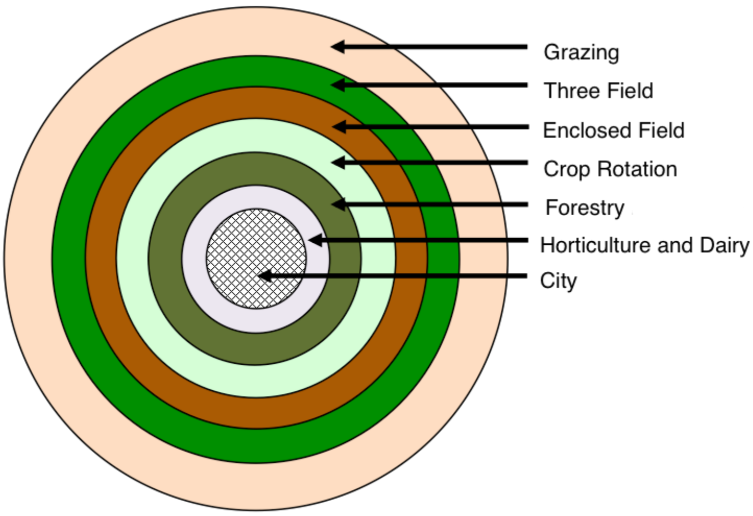

Figure 2: Von Thünen model
Source: Penn State, College of Earth and Mineral Sciences (2020)

Finally, it is also regularly collectively decided which type use is permitted on a given site, including whether it can be used for agriculture or what type building can be erected for which type of activity. Finally, the occupation of a site may imply social prestige, such as an office at a prestigious address.

Value	Type of rent
The site’s natural properties (Ricardian rent)	Scarcity rent
The site’s proximity to collective investment (location rent)	Investment rent
The right to realise permitted uses on the site	Regulation rent

Table 3: Economic rents in sites

<u>The Shelter</u>

A dweller will make physical interventions on the site to increase its habitability. Typically this involves the erection of a shelter to retain heat and expel precipitation, and/or forms of active climatisation through burning fuel. As such, in general terms, erecting a shelter requires access to natural resources. Natural resources involved in dwelling can be categorised in four groups: land, energy, materials, and water (Doan et al, 2017: 245). In the context of this research water will be subsumed into materials given that its characteristics and dynamics largely correspond to those of other materials.

The Calculation Problem

The resource intensity of buildings is regularly assessed by environmental certifications. However, these certifications tend to measure relative improvements on the environmental performance of contemporary conventional construction. To achieve this objective, certifications tend to focus on technological solutions to enhance efficiency. For example a high rating in the LEED Water Efficiency category requires devices such as low flow plumbing fixtures, advanced water metering, cooling towers, and evaporative condensers (USGBC, 2020). The resource intensity and life cycles of these devices in turn are not taken into account. As such environmental building certifications do not provide information on the actual resource intensity of a building. “Green” buildings operate in the same conceptual framework as conventional buildings: they do the same thing more efficiently. They do not address the underlying problem that buildings are resource intensive in the first place. It is also unclear whether a top-rated “green” built environment would actually be ecologically sustainable on a global scale (Brownell, 2017).

To address this shortcoming Bastianoni et al (2006) have proposed analysing the resource intensity of buildings through the application of ecological footprint analysis (2006). The ecological footprint (EF) measures the degree to which human activities draw on natural resources. A sustainable resource use would currently imply a use of 1.6 gha (global hectares) per capita (GFN, 2020). Solís-Guzmán et al (2013) of the ARDITEC research group at the University of Sevilla conclude from a study of a common residential typology in Andalusia that a predominant element of the EF in construction is the CO_2 emitted by fossil energy. In a follow-up paper González-Vallejo et al (2015) extend the methodology to ninety-two common building types in Spain. They find that a 4-floor multi-family residential buildings have the lowest EF per square metre, combining less impact in both mobility and construction. They confirm that the EF is dominated by direct energy consumption and the energetic impact of construction materials. The group has since proposed incorporating the EF in the economic budgeting process that forms part of any significant construction process (Freire-Guerrero, 2019). This has the advantage that both economic cost and ecological footprint could be calculated in the same process.

Condensing a building's EF in a single indicator is an important step towards being able to identify and communicate the resource intensity of the built environment. However, the methodology continues to rely on double book-keeping of economic and ecological accounts. The disconnect between both accounts means that the ecological account relies on extensive data inputs to be meaningful. For example, the use of one ton of steel has a very different EF depending on its production process: a ton of steel produced in China on average results in 2,148 kg CO_2/t whereas the same steel produced in Mexico only emits 1,080 kg CO_2 / t. This is because China predominantly uses coal to fuel its furnaces whereas Mexico uses electric arc furnaces (EAFs). The CO_2 emissions from EAFs in turn depend on the CO_2 emissions intensity of the electricity used at the EAF at the time of production (Hasanbeigi et al, 2016). The correct processing of this information for every input in the building process is extremely cumbersome and prone to errors due to faulty or lack of information. This problem represents a form of the economic calculation problem first proposed by Ludwig von Mises as a critique of economic planning as a substitute for market-based allocation of resources. The underlying idea is that a market primarily serves as a device for exchanging information about preferences. The advantage of a market system is that the price mechanism directly links the exchange of information with the allocation of resources. Purchasers share information about their preferences with vendors by accepting a transaction at a certain price (Posner & Weyl, 2018). In other resource allocation mechanisms this link is broken. That means that market participants have little incentive to share complex information, such as the carbon intensity of the electricity consumed at the steel furnace at the time of production of the steel.

In a broader perspective, a further limitation of analysing a building's EF is that the building is analysed as an object in isolation from its social context. This approach disregards considerations such as whether the construction of a building is necessary in the first place or if the spatial needs could not have been resolved by other means. Even when the building comfortably fits into the sustainable EF of its users, it continues to have an ecological impact that competes for resources with other activities in the economy. It would hardly be sustainable to provide incentives to construct buildings if these are not needed to begin with. In this sense the EF approach remains married to the idea that the objective of sustainable architecture is to optimise the efficiency of the construction process rather than addressing the wider issue of the resource intensity of dwelling.

The concept of economic rent addresses the two problems of meeasuring resource use and the systemic nature of dwelling. First, economic rent priced in a market simultaneously provides information about economic cost and resource intensity. The economic incentive to reduce costs is aligned with the ecological objective to reduce resource consumption. Market participants provide information about the resource intensity of an input directly through the price mechanism. The economic and ecological accounts are cleared in a single transaction. If CO2 emissions have a regulated cost the supplier of steel produced in a furnace fuelled by coal will need to ask a higher price than the supplier of steel produced in an EAF fuelled with solar energy. There would be no need to separately transmit information about the production process to the user. In fact, there would not even be a need to reduce the analysis of resource intensity to a single metric such as the EF. The constituent parts of the EF could be addressed specifically where the problem occurs.

For example: Alice is looking to erect a shelter for which she is looking to use Timber A or Timber B. If harvesting Timber A is more harmful to the ecosystem than harvesting Timber B, the government would hence cap the supply of Timber A but not the supply of Timber B. This would lead to higher volume prices for Timber A that feed through to the user who will look for other ways of to resolve her spatial needs. She would not have to concern herself with having to simultaneously resolve the competing economic and ecological requirements of her project. Second, economic rent provides an articulation between built and non-built solutions as well as other parts of the political economy: as a consequence of the higher price for Timber A Alice may decide to resolve her spatial needs with a different type of intervention in a different place that requires different natural resources altogether. If all ecological impacts are regulated and her economic budget is the same all solutions available to Alice will have the same EF. The argument made here is that the important aspect in measuring the resource intensity of architecture is not the metric itself, but if and how the metric interacts with the social processes involved in the production of space.

Identifying Resource Uses

The categorisation used by environmental certificates, ecological footprints, etc. provide a helpful indication of the broad categories in which buildings consume resources. Given the extensive documentation available for the Green Building Council's LEED certificate the following analysis follows its principal categories. But other certifications cover the same processes and could just as well have been used (Doan et al, 2017). The EF methodology implies modelling resource flows for which complex relationships have to be converted into specific material inputs.[16] The LEED touches on broader issues, while it does not, however, attempt to explaining their relationships.

In the following table the principal contents of the categories of the LEED certificate (USGBC, 2020) are matched with the resources to which they refer (land, energy, and materials). Subsequently the resources are linked to the categories of economic rent identified earlier.

Category	Pts	Description	Resource
Location & Transportation (LT)	16	Links with existing infrastructure Use of brownfield sites Less private automobile use; walkability	Land Energy
Sustainable Sites (SS)	10	Preservation of the local ecosystem, incl. habitats, pollution, water flows	Land
Energy & Atmosphere (EA)	33	Design to reduce energy needs Passive and natural strategies Local renewable energy production	Energy
Material & Resources (MR)	13	Life-cycle approach to reduce embodied impact reduction: waste hierarchy	Materials Energy
Water Efficiency (WE)	11	Reductions in potable water use: indoor water, irrigation, metering	Materials Energy
Indoor Environmental Quality (EQ)	16	Indoor air quality and thermal, visual, and acoustic comfort: thermal control, natural light and ventilation, contaminants	Energy
Innovation (IN)	6	Strategies not specifically addressed by the LEED certificate	--
Regional Priority (RP)	4	Addressing concrete local environmental issues not specifically addressed by the LEED certificate	--

Table 4: LEED categories and related resources

Land

In the context of building a shelter, the basic considerations brought up by the LEED criteria reflect the earlier discussion of the role of land as a site: any particular piece of land is characterised by its relative location. The LEED criteria distinguish two dimensions: the

[16] See e.g. the methodology flowchart of Solís-Guzmán et al (2013: 241).

social context and access to existing nearby infrastructure (LT category), and the natural context and its embeddedness in local ecosystems (SS category). The LT category mirrors the discussion of the role of land as a site: building a shelter close to existing collective investment (e.g. on a brownfield site close to existing infrastructure) reduces the need for building new infrastructure, which would be more costly both economically and ecologically. The location value of the resource Land directly reflects the value of the nearby collective investment.[17] In the same vein the LT category gives credit for the reduction of Energy and Material intensive means to access the site, giving preference to healthier and more energy efficient walking over the use of private automobiles (Smil, 2017: 187). Consequently, the higher the location value of the land due to proximity to collective investment, the lower the need to rely on energy and materials (public investment, private motorised transport) to access the site. As such, the concept of economic explains the value of land as a function of the resources required for accessing it. The location value of the site corresponds to a combination of the investment rent derived from public infrastructure investment (permitting walkability) and from the public regulation rent derived from the use of common energy and material resources required to access the site (e.g. the resources required for driving there). The modified von Thünen model highlights the intricate relationship of land and energy. The insertion of a navigable river, implying more mobility at the saem energy cost, increases the accessibility nearby adjacent sites.

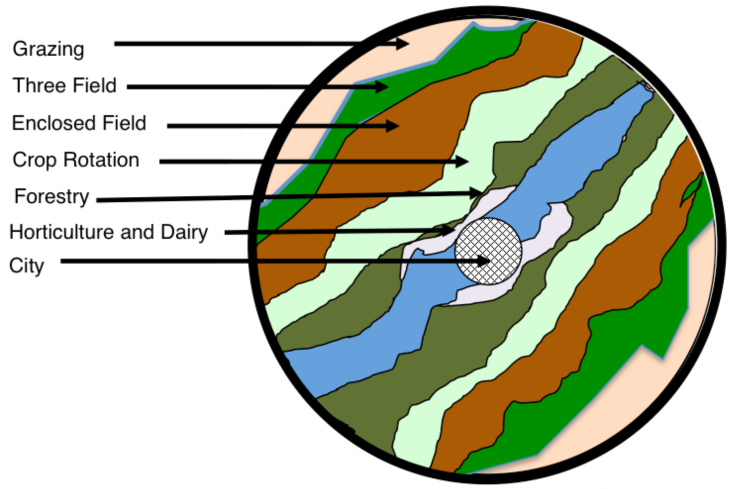

Figure 3: Von Thünen model modified by a navigable river
Source: Penn State, College of Earth and Mineral Sciences (2020)

Moreover, in the SS category, human land use competes with the role of sites in preserving the integrity of local or global ecosystems. A particular site may play an important role as a habitat for other species (e.g. wetlands for migratory birds) or as part of a minimum required

[17] The link is described by the Henry George Theorem first stated by Joseph Stiglitz in 1977.

stock of land to provide global ecosystem services (e.g. bogs as carbon sinks). In a sustainable society the amount of land that could be used for human activities would hence be capped. As a consequence of the reduced supply of land for human use its scarcity value and price would increase. The increase in land value represents a regulation rent.

Land resource use	Type of rent
The land's natural properties (Ricardian rent)	Scarcity rent
The site's proximity to collective investment (location value)	Investment rent
The land's increased value due to limited supply of land for human activities to protect the integrity of ecosystems	Regulation rent

Table 5: Land resource uses and correspondent types of rent

An example is the London Green Belt. Here the regulation rent is partially internalised by private land owners in London whose land's scarcity value has increased as a result of the reduced supply. The same economic logic applies to conservation areas, where the regulation rent derived from protected ensembles and higher scarcity of land is internalised by land owners.

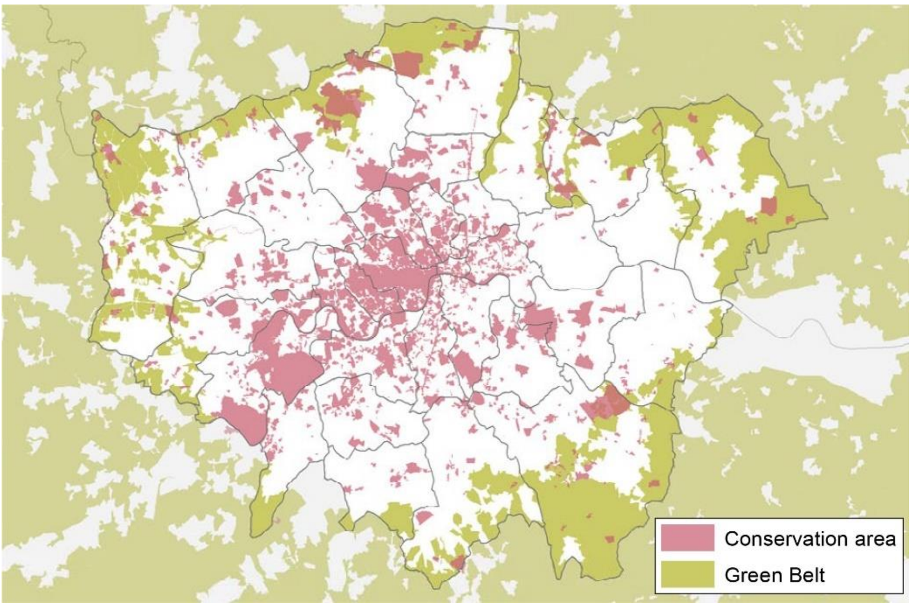

Figure 4: London conservation areas and Green Belt
Source: GLA Economics (2016: 166).

Energy

The resource Energy is pervasive throughout all LEED categories and interacts closely with other resources. The main reason is that energy is required to move or transform matter. In the absence of energy the substitutability of resources is not possible. A dweller would not be able to move from one site to another or substitute a local stone for timber from a nearby wood. Energy is theoretically abundant on Earth as solar irradiation is multiples higher than the energy consumed globally. However, the incidence of solar radiation is disperse at an average flux of 175 W/m2 (Tsao et al, 2006: 11). Capturing and converting it, moreoever, requires implying extensive use of other resources: Land and Materials. In premodern settlements energy needs would be met by renewable biomass in the form of food and fire wood. This implied that a sufficiently large land area around any settlement had to be committed to growing food and fire wood (Smil, 2017: 352; Margalit, 2016: chapter 2).

The same logic holds for solar energy today. Solar panels have to made from finite materials which are obtained through invasive mining, thus in turn consuming energy and land. Land with adequate solar irradiation needs to be committed and transmission losses are avoided by locating the panels sufficiently close to population centres yet consuming more valuable land. Since the Industrial Revolution modern society has been predominantly fuelled by non-renewable fossil fuel. Fossil fuel is past solar energy stored on Earth. The principal advantage of fossil fuel is its power density. Fossil fuel has a power density of 1,000-10,000 W/m2 compared to 0.6 W/m2 for dry wood (Smil, 2017: 13, 352). As such, fossil fuel has permitted human settlements to detach themselves from the carrying capacity of nearby land. However, at the same time the rapid release of fossil fuels has significant side effects. In particular emissions of greenhouse gases, notably CO2, are altering the composition of the atmosphere leading to unforeseen effects, including reducing the habitability of Earth for existing life forms and potentially considerable biodiversity losses.

In sum, the capture and use of solar energy does not in itself cause external effects. However, even the direct capture of solar energy, e.g. by Alice who warms up in the winter sun, draws on another resource, Land, since she will need to occupy a space with adequate solar irradiation located in reasonable proximity. Theoretically, Alice’s action will prevent other dwellers from enjoying the winter sun in the same spot. The issue is more pronounced in the indirect capture of solar energy through biomass, including food and fire wood. As discussed, biomass requires extensive land areas in adequate distance. Moreover, renewable use to avoid depletion means that resource stocks can only be extensively used, further increasing their local scarcity. In addition, the consumption of biomass may have negative effects, e.g. burning excess quantities of fire wood may lead to air pollution that damages the health of dwellers or otherwise affects biodiversity. The use of non-renewable fossil fuel raises a host of additional issues. First, the mining of fossil fuels tends to have a considerable impact on land use and can permanently destroy local ecosystems, e.g. tar sands in North America.[18] Second, as discussed above, the the greenhouse gas emissions

[18] The interplay of Energy and Land resources is portrayed by Klein (2018) in the unlikely alliance of environmentalists and indiginous communities in fighting the mining of tar sand deposits in Canada. The groups aim to protect social and ecological characteristics of the resource Land respectively.

from the combution of fossil fuels has important negative externalities including biodiversity and habitat loss. Third, the consumption of fossil fuels is irreversible and as such represents a negative externality per se on future generations who will not have access to this energy resource. The ise of fossil fuel is particularly pronounced in dwelling. The built environment is responsible for 39% of carbon emissions worldwide, of which 28% are operational emissions and 11% from materials and construction. Transport, als intimately tied to dwelling, accounts for another 22%, resulting in a total of 61% (UNEP, 2017).

The use of the resource Energy has similar implications in all LEED categories. Based on the discussion above, there are two types of strategies related to energy. On the one hand, given that the direct use of renewable energy does not in itself have negative side effects, the same holds for passive energy *capture* strategies where no additional land and materials are used to capture solar energy. To a lesser degree this applies to the local production of renewable energy, which will, however, likely require additional Material inputs. On the other hand, all relevant LEED categories include strategies to reduce the *consumption* of energy, whether renewable or non-renewable as shown in the table below:

Category	Energy consumption reduction strategies
LT	Reduce energy needed for infrastructure by using brownfield sites Reduce motorised transport through walkable design
EA	Reduce operational energy needs through design
MR	Reduce embodied energy through life-cycle approach and waste hierarchy
WE	Less water consumption means less energy for treatment and pumping
EQ	Reduce energy needs through natural lighting and ventilation

Table 6: Energy reduction strategies in relevant LEED categories

Given that solar energy is abundant its consumption does not cause negative externalities and hence economic rents. The economic rent related to renewable energy arises in conjunction with the use of the resources Land and Materials. In cases where the combustion of renewable fuels leads to excessive pollution a negative externality does arise. In this case the government should intervene to cap the consumption of the energy resource at levels at which the resulting pollution can be absorbed by the ecosystem. The value of the capped “right to pollute” corresponds to a regulation rent. Non-renewable Energy resources are depleted over time and the pollution caused by their combustion is not captured in a closed cycle. As such, their consumption causes a negative externality per se. The table below summarises the economic rent implications of Energy resources.

Energy resource use	Type of rent
The consumption of a renewable Energy resource is capped at the level of pollution that can be absorbed by the ecosystem	Regulation rent
The consumption of non-renewable Energy resources and the resulting pollution are irreversible	Scarcity rent

Table 7: Energy resource uses and correspondent types of rent

Materials

Materials includes all resources that are not used as an Energy source or related to the location characteristics of Land. That said, the use of Materials is closely interconnected with both Energy and Land. Specifically, Materials grow or are deposited on Land while Energy is required to transform them or move them where they are needed. As such, even relatively abundant materials may be locally scarce if too much energy would be required to mine, transport or transform them. A distinction can be made between renewable and non-renewable materials. However, the delimitation between both is fluid and depends on how the material is used. For example rain water, timber and recurring sand sediments are practically renewable if their extraction does not have negative side effects that would preclude their renewal, such as soil erosion. On the other hand, metals that corrode in contact with the oxygen of the atmosphere are not renewable, even if they can be reused and recycled for long periods of time. Groundwater deposits have such a low renewal rate that they are considered non-renewable for practical purposes.

Materials are not typically used as found in nature. Instead they have to be manipulated and moved to where they are needed. Both of these interventions require the input of Energy. As discussed earlier, the supply of energy itself in turn requires resource inputs (Materials and Land) and therefore has a cost, which in the case of the external effects of fossil fuel is considerable. As a consequence, materials always experience a certain degree of scarcity. In general, the more Energy is available the less scarce are Materials. If energy is plentiful the cost involved in mining and manufacturing materials is lower and there will be less incentive to reuse existing materials, which may be complicated to dismantle and prepare for reuse. This line of argument is confirmed by Rotor (2020), a Brussels-based design practice, who state that reuse was a predominant material life cycle practice until the early 20th century. Rotor observe that around 1920 the "intrinsic value of construction components became negligible in comparison with the profit that could be made on real-estate operations". The linear material life cycle ending in waste has since been the norm. It is unlikely to be coincidence that the decline of reuse happened around the time that energy per capita consumption had reached unprecedented level, oil started to become ubiquitous in industrialised societies and World War I had led to significant social upheaval that allowed questioning existing practices (see graph below for France as a proxy for Belgium):

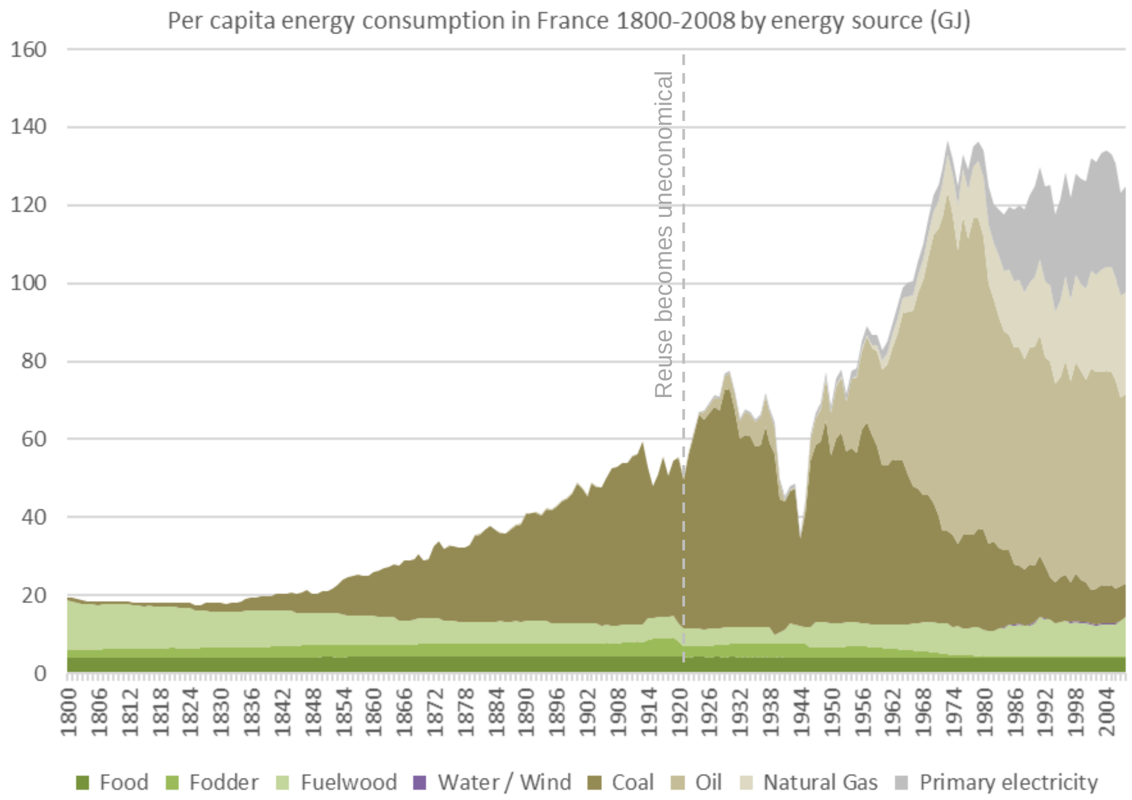

Figure 5: Availability of energy and the demise of reuse
Source: Own elaboration based on CHE (2020) and Rotor (2020).

Finally, while natural products are biodegradable, man-made materials decay much slower or may never decay through biological processes. Early man-made materials, such as glass in early civilizations, were valuable because their production required scarce energy. As such, man-made materials were not wasted and kept in closed life cycles for as long as possible. With the advent of fossil fuel man-made materials became less scarce and new synthetic materials appeared through the large-scale chemical modification of natural materials.[19] The relative ease with which these new materials can be created with abundant energy means that there is no inherent incentive to reuse them. While waste of organic materials largely represents a waste of energy, the disposal of man-made materials and their large-scale introduction into the ecosystem pose a risk to biodiversity and human health.

Arguably even less resource intensive than reusing building materials is to reuse entire buildings. This avoids having to engage in energy intensive construction and dismantling

[19] Fossil fuel also plays an important role as a material. The first mass-produced modern plastic, Bakelite, was created by Belgian-American chemist Leo Baekeland in 1907. Its principal components are phenol (first extracted from coal tars) and formaldehyde (Ventikou, 1999).

processes, which also typically lead to material losses. For buildings to be reused they have to be sufficiently flexible and adaptable (see next chapter). Finally, the most effective material-saving measure would be to abstain from construction in the first place. Daniel Fuhrhop (2020: 23) demonstrates that in the case of Germany new construction would be obsolete if newly built floor space was not absorbed by ever increasing floor space per capita. The table below describes the intervention of energy in the life cycle of materials under various waste hierarchy options. As more energy is available in society through fossil fuel, energy intensive waste hierarchy options (disposal, recycling) become economically more attractive than the re-use of materials and buildings.

Waste hierarchy / Life cycle	Reduce	Reuse		Recycle	Disposal
	The building		The material		
Raw materials extraction	-	-	-	-	X
Manufacturing (+Transport)	-	-	-	X	X
Construction (+Transport)	-	-	X	X	X
Operation + Maintenance	-	X	X	X	X
Dismantling (+Transport)	-	-	X	X	X
Disposal	-	-	-	-	X

X = energy required → more Energy available →

Table 8: Use of energy at life cycle stages under different waste hierarchy options

In sum, while Materials themselves are absolutely scarce, their practical availability also closely interacts with the other two resources Land and Energy. The materials available on a given site depend on the location of the site and the energy available to manipulate them and move them to the site. For example, the value of a brick on a site depends on the scarcity of the raw materials, as well as the energy available to convert the raw materials into the brick and transport them to the site. Man-made materials with low degradability have the potential external effect of pollution at the end of their useful life. Pollution can be avoided by partially or fully closing life cycles. This, however, requires further resource inputs in the form of materials for equipment and the capacity of the land to absorb the emissions and pollutants resulting from Recycling and Recovery processes. The table below shows how this translates into economic rents:

Materials resource use	Type of rent
The availability of renewable Materials is capped at the regenerative capacity of the Land from which they are drawn	Regulation rent
The use of non-renewable Materials is irreversible to the degree that they cannot be recycled	Scarcity rent
The use of non-biodegradable Materials is capped at the capacity of the Land to absorb emissions and pollutants	Regulation rent

Table 9: Materials resource uses and correspondent types of rent

Dwelling in Places

Arguably the raison d'être of architecture is that humans engage with space beyond the satisfaction of purely physiological needs. This view is particular pronounced in the phenomenological approach to architecture. Phenomenology found widespread currency in architectural circles after Martin Heidegger's presentation "Building, Dwelling, Thinking" at Darmstadt in 1951. In his essay Heidegger distinguishes between an abstract-scientific "space" and concrete-meaningful "place". A space only becomes a place through human appropriation, i.e. giving it meaning through action and care, which Heidegger resumes as "dwelling". Hence a place cannot be built but results from the process of dwelling over time during which humans mentally and physically engage with it. In psychology and neuroscience the intimate mental investment in spatial settings is most famously substantiated by the method of loci, an explicit strategy of linking memories with places to improve one's memory of them (Ellard, 2015: 67). Dwelling in a meaningful place gives humans access to more knowledge and less uncertainly, leading to less mental stress.

The argument extends to the social dimension. Dunbar (2010) shows that humans have a limited capacity to maintain a large number meaningful relationships. The people with whom these relationships are maintained equally dwell in places. The entire social community is hence bound by a place. Indeed, in premodern societies the privilege to dwell in certain locations was intimately tied to social status and civil rights. Being expelled from a dwelling place therefore implies losing both the mental and social investment that the dweller had made. Humans will therefore not only carefully consider in which place to dwell but they will resist competing claims to the place that they have become invested with. Posner & Weyl (2018) equally imply that the investment rent resulting by a person's dwelling in place should be protected from competing claims for the same resources. While they argue that property generally has important negative externalities, they exempt "family heirlooms" and "personal effects", i.e. practically anything in which a person may be personally invested. Not unlike in the case patents, societies provide dwellers with institutions to protect her investment, such as tenancy rights, which grant the dweller a monopoly over the resources involved in her mental and social investment. The central role of dwelling in human existence suggests that the concept of property would be closely associated with a person's control over the resources that constitute its dwelling place.

Dwelling process	Type of rent
The dweller becomes mentally and socially invested in his material environment	Investment rent
The dweller has the exclusive right to use the site, and the resources that constitute the shelter	Monopoly rent

Table 10: Dwelling process and corresponding types of rent

<u>Summary</u>

The following table summarises the findings of this chapter, framing them following the classification of economic rents developed in the previous chapter.

	Laissez-faire market	Government intervention
Relative scarcity	Investment rents: The site's proximity to collective investment (location value) The dweller becomes mentally and socially invested in his material environment Monopoly rents: The dweller has the exclusive right to use the site and the resources that constitute the shelter	Regulation rents: The right to realise permitted uses on the site
Absolute scarcity	Scarcity rents: The site's natural properties (Ricardian rent) The consumption of non-renewable Energy resources and the resulting pollution are irreversible The use of non-renewable Materials is irreversible to the degree that they cannot be recycled	Regulation rents: The land's increased value due to limited supply of land for human activities to protect the integrity of ecosystems The consumption of a renewable Energy resource is capped at the level of pollution that can be absorbed by the ecosystem The use of renewable Materials is capped at the regenerative capacity of the Land from which they are drawn The use of non-biodegradable Materials is capped at the capacity of the Land to absorb emissions and pollutants

Table 11: Classification of economic rents in dwelling

The observed economic rents can be condensed into the following topics:

	Laissez-faire market	Government intervention
Relative scarcity	Mental, social and physical **investments** in concrete spatial settings, both personal and collective, require guarantees, usually given in the form of rights, e.g. property rights.	The nature and extend of rights are determined by government regulation, e.g. planning laws, **property rights**, lease terms, taxes. The rights are scarce.
Absolute scarcity	Land and non-renewable Energy and Materials are not man-made and **finite**. Using them has direct intratemporal and intertemporal distributional implications.	The human use of Land and renewable Energy and Materials should be **capped** to maintain the integrity and regenerative capacity of the ecosystem. This increases their scarcity.

Table 12: Classification of topics

The Ownership Paradox

In sum, given that the resources involved in dwelling are not man-made or socially produced, and scarce, using them confers a privilege. At the same time, the mental and social investment involved in dwelling require the guarantee to exclusively use the resources that constitute the specific dwelling environment over an extended period of time. As discussed, this guarantee is usually given by the government in the form of rights, such as tenancy or property rights. Granting these rights, however, results in competing claims over the same resources. Ryan-Collins et al (2017: 29) observe this conflict in their discussion of the economics of housing, and refer to it as the “ownership paradox”: a home is a person’s most private and intimate place, yet its economic value is largely attributable to external factors: the scarcity of natural resources and the social production of space. The analysis shows that the issue is not limited to housing but extends to all resources involved in dwelling and arguably the overall economy. The following chapter looks at how the competing claims on rent in dwelling are negotiated in modern society.

3. The Institutions Governing Rent

Sample Application

Conceptualising dwelling in terms of economic rent allows mapping the identified issues using the same concept. It also permits establishing who accrues these rents based on which social institutions and processes. A simple example of the social processes involved in a typical contemporary dwelling situation illustrates the approach.

#	Social practice	Rent implications
1	Alice purchases a vacant plot of land as an investment	Monopoly rent from property of natural resource Ricardian scarcity rent from use of materials on site
2	The plot is located close to a city implying access to opportunities of economic participation	Location rent resulting from public investment
3	The public authority improves a local road	The location rent increases, a positive externality of the public investment
4	Alice is granted the right to erect a building on the plot by the public authority	Regulation rent
5	Alice commissions an architect to design a building that maximises the site's development potential	The architect assists Alice in extracting the maximum location rent from the site
6	The architect creates visual material to market the building based on lifestyle factors	The architect assists Alice in creating artificial scarcities (monopoly rent) through the intentional reduction of supply
7	The building's spatial distribution is inflexible implying a planned obsolescence	
8	Alice commissions a builder to erect the building with fossil energy fuelled heavy machinery	If the CO_2 emissions and ecological degradation resulting from fossil fuel and concrete extraction, production and consumption are taxed below the price that a sustainable cap-and-auction scheme would yield. The unquantified difference represents a rent internalised by the architect, the builder and Alice
9	The new building is made of concrete	
10	The building is made of concrete because neither the architect nor the builder have experience using more sustainable materials, e.g. timber, implying a higher execution risk for them	The externality arising from the use of concrete could have been avoided either by socialising the private execution risk of using the sustainable resource (e.g. through a training schemes), or by socialising the rent derived from capping CO_2 emissions.

11	Alice rents out the building to Bob	In addition to the exclusive right to use the building (monopoly rent) Bob's contract rent includes the location rent resulting from public investment but internalised by Alice
12	The building decays, preventing Alice from realising the full location rent	A rent-gap[20] evolved
13	Bob organises a street fair in which disadvantaged neighbours can exchange handmade goods circumventing the corporate economy (tactical urbanism)	As a positive externality of this new activity the location value again increases. Alice increases the contract rent to internalise the increased location rent. Bob is required to design new scarcities in the economy to pay the higher rent. The results is GDP growth.

Table 13: Sample application of systemic dynamics

The simple example is far from complete and it captures far from all social practices involved in dwelling. But economic rents flow from all practices that involve natural resources and property both of which feature prominently in dwelling. It is noteworthy that in the example all actors involved in the transactions have an interest that resources are spent to get the building built. The landowner and developer use the building to maximise the location rent that can be extracted from the site. The architect and the builder internalise a rent from using natural resources as inputs far below the price that would result with sustainable resource consumption. To make a living the architect and the builder depend on releasing the natural resource stock (fossil energy, materials) to fuel their activities. Ironically, the process of using up the natural resource stock and converting it into a depreciating capital stock (the building) according to the prevailing narrative "grows" the economy.

Property: Ownership and the Right to Use

Matching the described social practices with the topics identified in the previous chapter highlights two principal issues.

First, with respect to the resource Land, there is a tripartite conflict between the author of land values (nature, society), the owner of land values (the land title holder), and the user of the land values (the tenant) (#1-5 and 11-13 above). The land value represents an investment and regulation rent created by society, as well as a scarcity rent resulting from the finite land controlled by the society in question. However, it accrues at the owner of the land title, whose property represents a monopoly rent (Posner & Weil, 2018). In addition, the holder of the land title may not correspond to the user of land who is actually mentally and

[20] See rent-gap theory developed by geographer Neil Smith (1979)

socially invested on the site. The user equally is invested on the site while she did not, however, generate the land value.

Second, there is a conflict between the author of economic rents derived from Energy and Materials and who effectively owns them (#8-10 above). For example, using a renewable material, such as sand sedimented at the mouth of a river, implies scarcity rents (the resource is absolutely limited), investment rents (by the society who controls the mouth of the river), and regulation rents (limiting extraction at the sustainable level). All three rents are attributable to society, its present and future members. If society grants the right to extract the sand below value and not limiting the extraction to sustainable levels, the resulting conflict is the same as described for Land above. The investment rent attributable to society for controlling and regulating a scarce resource does not correspond to the monopoly rent derived from owning the right to extract the resource below value. In the case of non-renewable resources, such as oil, or metals to the degree that they cannot be recycled, this mismatch is far more significant. Given that the resources will be depleted, the economic rents derived from using them are practically infinite if future members of society are assumed to have the same rights as its present members. The latter is the case e.g. in indigenous populations of North America who assess resource consumption with a view to its impact seven generations into the future (Klein, 2018).

But even if the rights of future members of society are not taken into account, the large scale use of non-renewable energy in particular has important near term negative externalities. The most prominent of these are the CO2 emissions resulting from the combustion of fossil fuel. If society fails to cap CO2 emissions at levels beyond which they cause damage to the ecosystem it renounces the associated regulation rent. The value of the potential rent is instead internalised by those who use it below cost: all current members of modern societies, especially those controlling the value derived from resource intensive economic activities. The economic rent derived from using non-renewable resources, and from renewable resources beyond their rate of renewal, can only be realised in the process of consuming them. There is hence an incentive in the modern economy to create demands and satisfy them with economic activity that involves unlocking the economic rents derived from consuming resources. This dynamic is documented in the example above (#6-7) as well as in the architectural literature.[21] The architect and the builder are dependent on the recurring resource intensive construction of new buildings. An architect who proposes flexible and resource-extensive solutions risks forgoing her share in the economic rents from resource consumption priced below cost and from artificial scarcities resulting from recurring

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[21] See e.g. Goodbun et al (2012; 2014); de Graaf (2015).

interventions in highly specific and quickly obsolete spatial settings (Schneider & Till, 2007: 35).

Both issues described here point to the concept of property as the device that allocates economic rents in society. In particular, conflicts appear to arise from the conceptualisation of property of nature and natural resources as an absolute right to own an object rather than a right to use something that cannot ultimately be owned. Ownership of natural resources is a modern concept. In premodern societies, nature as a divine creation could not be owned. In practice, it would typically be owned by the sovereign as God's representative on Earth.[22] In this light, the concept of property as owning nature implies an emancipation from religious and secular authorities as well as from nature itself. Property conceived as such has close affinities with Enlightenment values, such as the cartesian dualism of the autonomy of the human mind from matter found in nature. These values are echoed the ambition of the architectural discipline to pursue elusive autonomy in process and outcomes (Till, 2009). The discipline's perceived closeness to the centres of power (Schneider, 2018: 7), the owners of nature, consequently does not surprise.

Viewed through the lens of economic rent the scope for private ownership of natural resources is greatly reduced. Instead the monopoly rent derived from property should be matched with the investment rent that is to be protected in order for the investment to be made. A society will only invest into controlling a territory if its fruits benefit its members (or those controlling them); a dweller will only invest into relating with her neighbours if she can be sure to still be around when she might need their help, etc. The concept of economic rent hence suggests that what should be protected through the institution of property in dwelling is not the right to own an object, but the mental, social or physical investment resulting from a process over time. Reframing property rights in such as sense has been suggested in the past, e.g. by politician and lawyer Hans-Jochen Vogel who has proposed splitting the legal institution of property into two separate rights: a own-property, similar to a freehold (*Verfügungseigentum*) to be ultimately held by local authorities, and a use-property, similar to a leasehold (*Nutzungseigentum*) (Vogel, 2019). The monopoly rents implied by each type of property reflect the investments made by society and users respectively. The concept can relatively easily be transposed to other resources, implying that these would be ultimately owned by society, which in turn grants use-property rights guaranteeing the resource's use for an extended period of time. Finally, the management of non-rival goods, e.g. knowledge

[22] In the UK the monarch continues to own the superior interest in all land in England, Wales and Northern Ireland. If a piece of land is deemed ownerless it falls back to the monarch in a process called "escheat".

about construction techniques, could equally be understood in this light.[23] Restricted access to knowledge implies a monopoly rent which would be warranted only if an investment was made. In that case the investment rent would be protected through use-rights (e.g. patents). In the absence thereof, knowledge would be deemed to be free. By the same token it would be a remit of public authorities to extensively publish about the use of resources in society so as to avoid that the rents derived from them are unjustifiably internalised.

Economic Context

The issues surrounding the role of economic rent in dwelling tie in with the re-emerging academic discourse about rent in the overall economy. Beth Stratford (2020) argues that as long as there are important elements of rent extraction in the economy the political feasibility of capping resource-intensive growth is limited (Stratford, 2020). This argument supports the hypothesis that economic actors who do not have the privilege of private property over natural resources depend on economic growth fuelled by material throughput. Arguably these economic actors privatise future potential use of nature by bringing its reward forward for current use. These rents allow growing the pie that compensates for other rents that are being extracted in the economy (e.g. location values, monopolies, etc.). Indeed Malte Faber & John Proops (1993) find that ascribing a higher rent to natural resources – the same effect as a public cap-and-auction process – acts as a break on profits the longer time goes by. In response, investors would likely look to rents to boost returns. This trend is visible in cities today where institutional investors exert pressure to unlock location rents that are currently internalised by sitting tenants.[24]

The argument put forward by this thesis works in the reverse sense: as a point of departure serves the economic rent derived from the social processes that provide access to society's natural resources. In a sustainable society natural resource consumption should be capped at ecologically regenerative levels. The rights may then be auctioned as licences and the proceeds distributed to all members of society.[25] Consequently, the consumption of natural resources would no longer offer the possibility to internalise rent to fuel economic activities. Instead the rent resulting from the public auction would accrue at the society level, reflecting the externality that the consumption of the natural resource inflicts on its present and future members. The architect and the builder would be incentivised to reduce the role of material flows in their activities instead of aiding third parties to derive rents from them. The architect

[23] For example, Reusing Posidonia (see case study next chapter) publishes extensively about the materials and techniques employed in this lighthouse project.
[24] See e.g. the documentary Push (2019) by Fredrik Gertten
[25] In economic terms a cap-and-auction process corresponds to a Pigovian tax set at the correct level for the desired degree of consumption (Mankiw, 2009: 18). This would effectively constitute a single tax in the sense of Henry George (1879) but applied to all natural resources, not just land.

as facilitator of dwelling would hence likely propose dwelling practices that do *not* draw on natural resources. Moreover, if the architect was paid a basic income from the public auction proceeds she could reduce her working hours to her desired level, resulting in yet further reductions in resource consumption. In this scenario, the natural resource stock would be steady. Growing the economy would be incidental to prosperity, not vice-versa. The economy may grow if innovation leads to more competition to use the resource stock leading to higher auction prices. But distributing the proceeds to all members of society would likely incentivise some to reduce their economic activity and to instead seek prosperity through other activities, such as gardening or caring for others. The outcome would likely come close to the findings of Tim Jackson and Peter Victor (2018) that a combination of a graduated income tax, a tax on capital and a universal basic income can eliminate inequality as growth declines. However, the proposal is made that a de facto Pigovian tax on the use of natural resources (including land) distributed as a universal basic income could yield the same distributive outcome more efficiently avoiding the deadweight loss incurred by taxes on capital and labour. Moreover, linking the universal basic income to the tax receipts from resource use provides a direct articulation between the intensity of economic activity and the incentive to engage in economic activity, i.e. if no activity takes place, natural resources would be rent-free but no universal basic income is paid[26] thus providing an incentive to engage in economic activity.

Applied to Dwelling

The above description shows that economic rent can serve a useful concept for identifying the dynamics of resource allocation in dwelling. Quantifying specific economic rents would require extensive modelling that would go beyond the scope of this thesis. Nevertheless, the key variables involved in economic rents in dwelling can be identified, matched with available data and parameters, and priced with static assumptions. This would give an indicative idea of the magnitudes and dynamics involved.

Land

While a liquid market does not exist for the resource Land, there are established methodologies for approximating its value. The value of land today does not, however, reflect unsustainable practices in relation to land use and in other parts of the economy. It is regularly argued, e.g. by biologist Ian Boyd, that the integrity of ecosystems requires half of all land to be wild without significant human intervention (Carrington, 2019). Enacting laws to this end would significantly reduce the supply of land available for human use, and increase the value of the land that remains available. The regulation rent implied in the increased

[26] Except for the location rent for the places in which dwelling invariably takes place.

value would be attributable to all members of society. Equally, capping the unsustainable use of energy resources and materials interacts with land values. For example capping permitted CO2 emissions and unsustainable sand extraction would significantly increase the price of concrete as a building material. This would lead to more demand for alternative building materials, such as timber or rammed earth, pushing up the value of land from which these materials can be obtained. Caps on CO2 emissions would also limit the supply of energy available for transporting heavy building materials over long distances, resulting in higher land values of forests near settlements, and of settlements near forests. These dynamics have to be kept in mind when discussing land values that result from resource allocation in the economy today.

Energy

As discussed in the previous chapter, the original source of energy on Earth is solar irradiation. The use of Energy does therefore not in itself have negative side effects. The limitation to using Earth's current solar energy budget ultimately rests in the limited availability of Land and Materials available for capturing the disperse incidence of solar irradiation. However, the consumption of fossil fuel does have important negative externalities, especially climate change due to greenhouse gas emissions, notably CO2. Moreover, given that fossil fuel resources are finite its consumption is not sustainable per se. As a consequence, the price that should ultimately be applied to the consumption of fossil fuel should be sufficiently high to discourage its use entirely. In practice, the government would not auction any CO2 emission rights at all and the price of CO2 emissions from burning fossil fuel would be infinite.

That said, in the medium term it is unlikely that CO2 emissions could be eliminated entirely. This means that the price of carbon emissions depends on the level at which emissions would be capped. As of 2015, annual global CO2[27] emissions amount to approximately 36bn tons, implying per capita emissions of 4.6 tons per year (Our World in Data, 2020). This figure is higher in industrialised countries: the EU's CO2 per capita emissions were 8.6 tons in 2018 (Eurostat, 2020). The price of CO2 emissions allowance in the EU Emissions Trading System (ETS), which covers 45% of the EU's emissions currently hovers around €25 per ton. The ETS is complemented by national carbon taxes on emissions not covered by the ETS which can be as high as €120 per ton in Sweden (implying an average price of €77 per ton CO2). The World Bank High-Level Commission on Carbon Prices concluded in 2017 that global average CO2 prices of €35-70 per ton by 2020 and €45-90 per ton by 2030 would be necessary for the transformational change necessary to reach the targets set for

[27] In the context of this "CO2" stands for "CO2 equivalent (CO2e)", including all greenhouse gases.

2030 by the Paris Agreement (World Bank, 2017). According to UNEP (2019: xviii) reaching the Paris targets would require capping global emissions at 25 bn tons by 2030, implying global per capita emissions of 3 tons per year by 2030. The EU and several countries, moreover, aim to reach zero net emissions by 2050. Again, this would effectively require an infinite price for CO2 emissions from fossil fuel to discourage use entirely.[28] There are emerging technologies to capture emitted carbon at a cost that is estimated to drop to €200 per ton of CO2 by 2025 (Hook, 2019). However, capturing the CO2 emissions of fossil fuels, does not address the depletion of fossil fuels, the negative side effects on the ecosystem of extracting them, the sustainable scarcity of the materials required for the technology, and the potential risks involved in storing large quantities of CO2 on Earth. The cost of emitting CO2 would therefore likely be significantly higher. In the context of this analysis a CO2 emission price of €500 per ton is assumed. This would change incentives to improve carbon intensive processes but it may arguably be insufficient to qualitatively change the economy given the low demand elasticity of fossil fuel, i.e. the difficulty to substitute it entirely.

Materials

The economic rent derived from Materials is equally closely related to the economic rents derived from other resources, Land and Energy. If the government were to restrict the use of both land available for human use and the consumption of fossil fuel, all construction materials would be significantly more costly, even before their own scarcity has been accounted for and regulated. For example, sedimented sand extracted from a riverbed would be scarcer because half of all riverbeds would be protected and because the energy required for extracting it would be more expensive. In addition, the remaining available extraction would have to be capped at the level that allows the resource to renew itself. The same would apply to other renewable resources, such as timber. Non-renewable resources that cannot be recycled would be subjected to regulation following the same principle as non-renewable energy resources, i.e. ultimately their price should be infinite to encourage their use entirely. Renewable materials and non-renewable materials that can be recycled[29] would circulate in the economy and be available for use in construction.

[28] The government would consequently not raise any funds from the tax. The cap-and-auction of zero CO2 emission rights corresponds to a Pigovian tax set at the right level to direct consumption to the desired level thereby eliminating its tax base.

[29] Most non-renewable can only be recycled partially. Each life cycle leads to a material loss. UNEP (2013: 47) estimates that e.g. steel used in construction has a life cycle of 40-70 years and a material recovery rate in recycling of 85% in 2007, potentially increasing to 90% in 2050. Material loss can be avoided by reusing elements instead of recycling the materials from which they are made.

In principle, materials may be understood as mobile derivative of Land. Given that they are scarce by their nature, and their supply further limited through regulation, the rent derived from it should would be attributed to society. The use of a natural resource prevents other users with the same claim to it from using it. The sustainable use of materials would hence attract a rent payable to the government to compensate society for its exclusive use. This logic closely follows the argument proposed by Posner & Weil (2018). However, there are two limitations to its application in practice. First, as in the case of land, dwelling in a specific shelter a dweller will become mentally invested in it. In the terminology of Posner & Weyl, the shelter would over time become a “personal effect” or a “family heirloom” of the dweller, and hence be exempted from compensating society. If, for example, the dwelling is made of a material that over time becomes scarcer, the negative externality of its use increases, implying an increasing cost for the the dweller for compensating society for using the scarce material. Following this, the dweller may ultimately get displaced from her home. The same logic applies to the formal architecture of the dwelling, if its qualities become more sought after, such as in the case of 19th century loft spaces the accumulated history of which cannot be replicated. Mirroring the argument in land, the dweller’s mental investment in the shelter would have to be protected despite the social cost implied in the monopoly rent she obtains from it. This restriction would arguably find less stringent application in the case of commercial buildings. A second limitation is that it is much harder to take stock of all materials circulating in society than it is to take stock of all available land. Assessing the physical composition of a dwelling is complex but it is possible to approximate it. Also, requiring a user to relinquish a building at a self-assessed value, as proposed by Posner & Weyl (2018), would discourage undervaluing the embedded materials. Again, the practical application would be limited to commercial buildings and materials before they are used to conform spatial settings used for dwelling.

In sum, given the complex life cycles of materials and their mutual substitutability, it appears impossible to estimate a concrete value that represents the negative externality that using a building material imposes on society. However, certain qualitative implications can be deduced from the findings up to here. First, due to greater lack of supply, using any material would be significantly costlier than it currently is. There would hence be an incentive to use and reuse materials already in circulation locally. In practice, this implies moving up the waste hierarchy, i.e. reducing the demand for material altogether by satisfying spatial needs without construction, including through flexibility facilitating the reuse existing buildings (see case study La Borda), or integrating ways to reuse existing materials into the building project (see case study Reusing Posidonia). Second, certain materials would likely be significantly more expensive and unlikely to be available for large scale and common use. An obvious example would be concrete, but also certain plastics, and heavy imports of sand and including timber. The ultimate relative costs of using certain materials in a certain place require extensive modelling and would depend on which resources are available locally. The dynamics described here do, however, point to a close relationship between sustainable and vernacular practices.

Summary

The interaction of the resources Land, Energy and Materials can be summarised as follows:

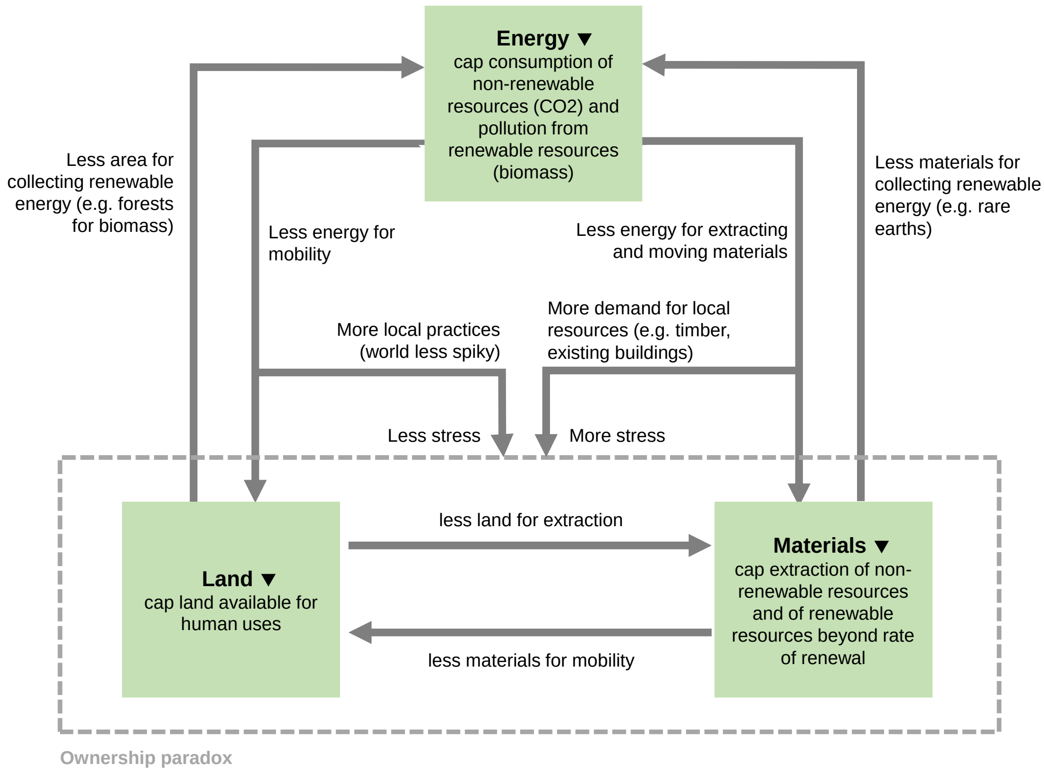

Figure 6: Interaction of Land, Energy and Materials
Source: Own elaboration

For example, if CO2 were priced at a price that leads to acceptable levels of CO2 emissions, this would make the extraction, production and transport of building materials more expensive. As a consequence, there would be more demand for local renewable materials, such as timber, as well as for the reuse of existing materials and buildings. This means that the owners of local forests and buildings, and the land on which these are located, would own more valuable assets. While the public has created the demand for the local materials by capping CO2 emissions, some of the rent accrues at the owners of the local resources. If these owners are mentally or socially invested in these resources, e.g. in the form of a family home, the ownership paradox is accentuated. For example, a daily commuter from Sabadell who cannot travel to Barcelona at a reasonable cost as CO2 emission prices rise may decide to move to Barcelona, increasing land values and the ownership paradox. This logic matches the discourse in economics: capping growth by reducing the material throughput of the economy means that the ownership of existing resources becomes more valuable. Their increased scarcity means that a higher monopoly rent can be derived from their ownership. This process has been visible in the yellow vest protests in France since late 2018. A daily commuter who depends on salaried work at an employment centre, such as Paris, will be worse off by a tax on fossil fuel while an owner of a dwelling in Paris will be better off. The ownership paradox limits the ability of society to capture the regulation rent resulting from the CO_2 emission tax, which partially accrues at the land owner.

But at the same time less available energy and reduced mobility mean that the world becomes less spiky (Florida, 2005), i.e. demand for dwellings becomes more evenly distributed, reducing stress on the ownership paradox. An example would be a second-home owner or a business traveller from London who at higher CO_2 emission prices cannot travel to Barcelona at a reasonable cost and may hence decide to get a second-home or a business partner, respectively, closer to London instead. Both the second-home owner and the business traveller have less need to travel than a commuter who depends on his salary. In economic terms, their demand for spending time in Barcelona has higher elasticity and can be substituted more easily. The same logic was visible in the response to the Coronavirus outbreak in 2020. Many salaried workers on furlough or those working from home prefer dwelling further away from employment centres than their work had previously allowed them to (see e.g. Wall, 2020). The furlough scheme effectively corresponds to a universal basic income. This suggest, that if regulation rents from capping the use of natural resources were distributed to citizens in the form of a dividend, these would be less compelled to take up salaried work or dwell near employment centres. They could instead decide to reduce their work hours or to dwell in locations with lower land values and engage in non-salaried activities. This, in turn, would decrease the pressure on resources and hence the ownership paradox in cities.

Localisation

The dynamics described here lead to localisation and reinforce each other. On the one hand, capping CO_2 emissions from fossil fuel means less available energy with high power density, which implies that society and dwelling would require a energy surplus from current solar energy. This would largely reflect human dwelling forms before the advent of fossil fuel. Throughout most of human history the majority of the population have dwelled dispersed over the territory to extract energy through hunting, gathering, agriculture and forestry. Any surplus would support higher value added activities in the city. With the advent of fossil fuel the countryside no longer serves as a source of energy and has itself become a net consumer of energy.[30] Consequently, most of the population can engage in higher value added activities, leading to urbanisation.

In the absence of fossil fuel society would again be required to live within the energetic budget of current solar gains. Reflecting the disperse incidence of solar radiation this would likely imply more dispersed dwelling forms based on more local resources than is currently the case. At the same time higher value added activities involving complex knowledge (laboratories, cultural institutions) would continue to require agglomerations. The higher value added of these activities would increase location values, generating economic rents attributable to society. Paying the rents out to its members, would allow them to participate in the values generated in the agglomeration without having physically move to the employment centre. More dispersed dwelling would reduce stress on the ownership paradox in cities, where it predominates, and energy consumption through long distance transport of both people and materials.[31] The ambition to localise is reflected in recent high profile initiatives to reconnect with local resources and social processes, such as the '15 minutes-city' plan promoted by Paris mayor Anne Hidalgo.

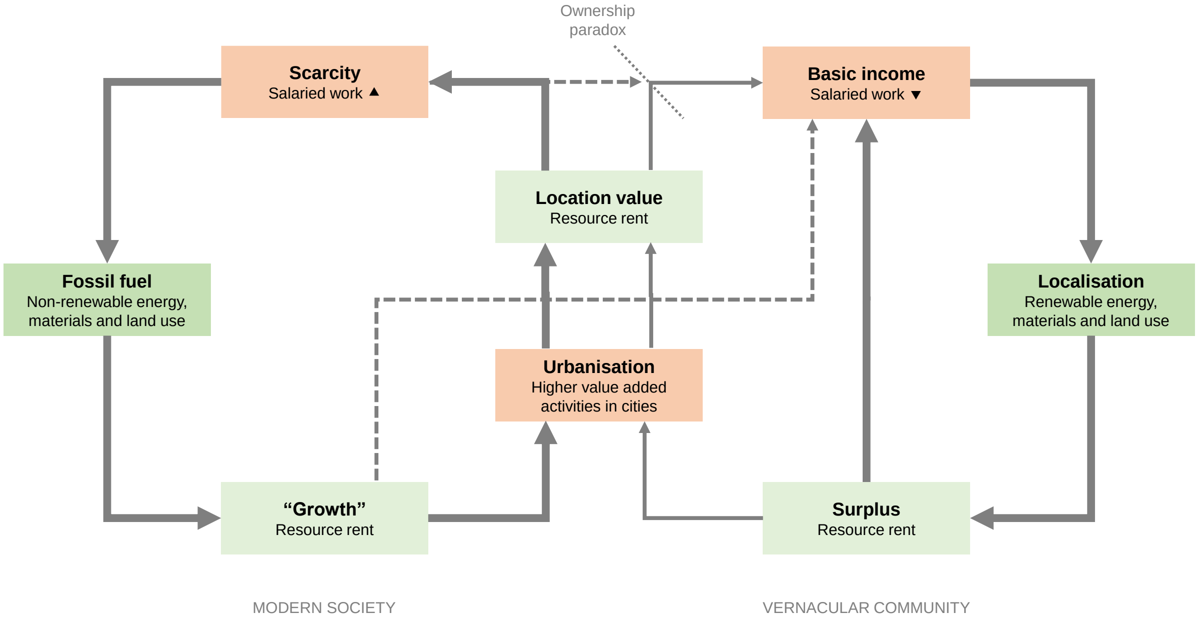

Figure 7: Resources and rents in modern society and vernacular community
Source: Own elaboration

[30] Enric Tello and Luis González Reyes give an account of the situation in the Vallés county of Catalonia where the energy returned on energy invested (EROEI) in agriculture decreased from 1.08 to 0.22 between 1860 and 1999 (COAC, 2019).
[31] Hertweck (2020: 178, 216) describes the same resource strains of the current model in the case of Luxembourg.

4. Case Studies

In what follows, the role of economic rent in dwelling in elaborated in the previous chapter will be analysed in the context of two case studies. The selected case studies critically engage with the identified issues, which means that they are well documented and have worked on solutions to mitigate the resource intensity of dwelling. The availability of potential case studies was restricted by the scope of required data including land leases, material life cycles and operational energy consumption.

Location	Land	New construction	Refurbishment
Countryside	Private		(N/A)[32]
	Public	Life Reusing Posidonia	
Urbanised	Leasehold	La Borda	

Case Study 1: La Borda

Overview

La Borda is a seven-storey cooperative apartment block in the La Bordeta neighbourhood of Barcelona's Sants district. It was developed from 2014 to 2018 in a participatory process assisted by the architecture cooperative Lacol and is operated by a cooperative that was formed for this purpose. The building comprises 28 dwellings of 40, 60 and 75 m2 which share a variety of collective spaces and facilities inside the building. The GFA of the project is 3,071 m2. The cooperative grew out of earlier local initiatives to recuperate the Can Batlló industrial site, on which the building is located, for community use. The plot on which the building stands is owned by the Ajuntament, the municipal government of Barcelona, which granted the cooperative a 75-year leasehold. The lease was the first of its kind in Barcelona. The format has given rise to a municipal scheme ('La covivienda') under which five more municipal plots were tendered to cooperatives in 2017. The project has three principal objectives: First, to develop the concept of collective housing, in which small private apartments are complemented by shared communal spaces. Second, to reduce the building's environmental impact, in particular by harnessing passive energy strategies. And third, to involve the users in the design and construction of the building (Lacol, 2020).

[32] Various projects were surveyed but sufficient data could not be obtained. Assessing the resource inputs in refurbishment projects is more complex than of new build projects.

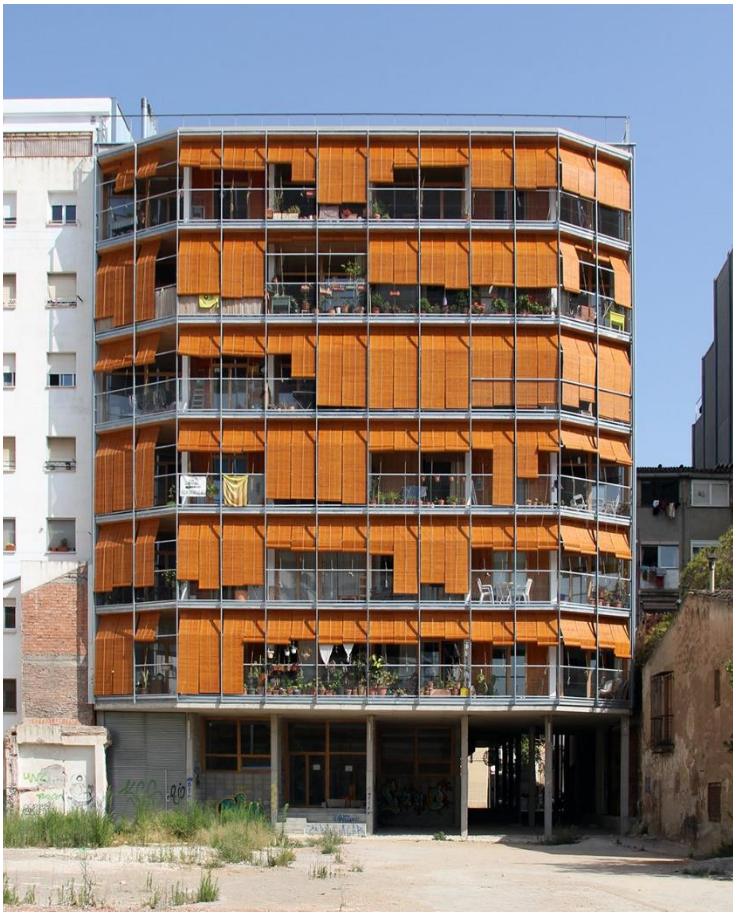

Figure 8: La Borda south façade
Source: Lacol

Land

The 627 m2 site is owned by the Ajuntament, Barcelona's municipal government. Based on local residential rents and the floor area ratio (FAR) of the site the market rental value of the land is approximately €19,000 per month (see Annex). In 2015, the Ajuntament granted the cooperative a 75-year leasehold. The ground rent on the lease is €400 per month, implying a subsidy to the cooperative of €18,600 per month, or €665 per dwelling per month. The site is classified as social housing (HPO, Habitatge amb Protecció Oficial), which means that only members of the cooperative who qualify for social housing in Barcelona are permitted to live on the site. As such, the economics are not fundamentally different from other social housing: public land ownership ensures that society internalises the value of the site that resulted from public investment in the first place. The value is then returned to members of society, specifically to those with less access to resources, i.e. who qualify for social housing. The limitation of this process is that there is regularly more demand than supply for social housing. In the municipality of Barcelona, 36,577 households were on the waiting list for social housing in the city in 2017 (Cañizares, 2018). Because the value of public land is not distributed equally among those with a claim to it the process by which social housing is awarded has highly distributional effects. If the value of the public land was awarded equally to all households with an equal claim to social housing the monthly subsidy per dwelling at La Borda would shrink from €665 to €0.51. The awarding of social housing among those with a claim to it literally constitutes a lottery. The arbitrary allocation of value in social housing is thus not much different to the luck of a private land owner whose property increases in value as a result from nearby public investment.

In a modern society the criteria used for awarding social housing have to be abstract, legally enforceable and relatively broad to avoid discrimination. Dwelling, however, is an activity that takes place in concrete delimited spatial and social settings, i.e. in community. Describing and delimiting a community with abstract criteria would require gathering data on social practices that are not currently formalised, such as whether a citizen has physically spent time in a community or positively contributed to it. Access to local resources would depend on scoring high on relevant criteria.[33] Needless to say such a system would be highly invasive and its applicability questionable in a democratic society. The problem of awarding social housing derives from the aforementioned ownership paradox. Both (eligible) members of society and the local community have competing claims to the land value of the site. The claim of a member of society is based on abstract criteria, such as her citizenship and socio-economic situation, whereas the claim of the local community is based on engagement with the physical and social reality of the site. In a modern society based on abstract rights (civil, social), resources tend to be allocated based on abstract criteria while concrete local considerations are disregarded. This can lead to situations in which e.g. a person who has recently moved to Barcelona from elsewhere is awarded social housing in the La Bordeta neighbourhood in which she has never set foot, while another person with the same socio-economic condition who was born and raised across the street from the site is not. Intuitively, one would think that the local resident has a superior claim to the social value of the site. On the other hand, the site's value originates to a large degree in public investment at the societal level, in the form of public infrastructure, rule of law and economic opportunities beyond the local community.

In the case of La Borda, the Ajuntament, representing society, and the local community have worked together to find a process to resolve the competing claims. Specifically, rather than building and awarding conventional social housing based on abstract criteria, the Adjuntament granted the site on favourable terms to a cooperative that is active in the local community. The dwellings are developed and awarded by the cooperative, however, based on the social housing criteria mandated by the Ajuntament. While the cooperative is open to

[33] An example would be the Social Credit System created by the Chinese Communist Party.

any member of society, engagement in the cooperative requires a certain local interest and social investment by the participant. Being open to society yet specific to the community the cooperative integrates the claims of society and community. It could be understood as a "speed bump" designed to localise the otherwise abstract criteria for allocating resources in modern society. At the same time, while the cooperative, i.e. the local community, is granted privileged access to *using* the site, it remains public property. In the terms of Vogel (2019), the "own-property" (freehold) is matched with the economic value that results from public investment and regulation, while the "use-property" (leasehold) is matched with the mental and social investment of the local community.

At the same time, the cooperative model has certain limitations. First, the allocation criteria problem is not resolved but merely reduced in scope by delegating it to the cooperative level. If the criteria for joining the cooperative and awarding the dwellings are too closely aligned with abstract rights, then the effect of the cooperative is diluted and the same distortions result as those resulting from conventional social housing. If, on the other hand, the criteria are specific to the operation of the cooperative and its membership restricted, the public value would be allocated by non-public criteria. Granting privileged terms to the cooperative would de facto constitute a privatisation. In the case of La Borda, the terms of the leasehold stipulated that future inhabitants had to comply with the requirements of social housing in Barcelona. Beyond this places were made available in an open list on a 'first come, first served' basis. This implies that community insiders were likely advantaged; although arguably that is the objective. An important consideration is that participation in the cooperative was linked to a high degree of mental and social investment because the participants were involved in developing the building and because the cooperative grew out of an earlier imitative to recuperate the Can Batlló industrial site for community use. At the same time, however, the required degree of engagement represents a limitation of the model. Community engagement in formal associations requires an outward personality and disposable time. There may hence be members of the local community who cannot or do not want to participate in the cooperative despite being equally invested locally. In this light, the cooperative may be a somewhat crude measure of who forms part of the local community.

A second limitation is related to the award of the site to the cooperative and the users of the dwellings in particular. Theoretically the leasehold has a duration of 75 years. In practice, however, not extending the lease on similar terms, would have significant distributional consequences and could result in displacing the dwellers, who will have become invested on the site both mentally and socially. However, if the leasehold *is* extended, the benefit of using the site has practically been privatised. The ownership paradox will have ultimately been postponed, not resolved. A related, underlying problem is that users of social housing in Spain are not continuously means-tested, i.e. the socio-economic conditions giving access to social housing do not have to be maintained over time. As such, while users may not be able to liquidate the increased value from public investment at the end of their use period, they can internalise the use value unconditionally. The ownership paradox would continue to be resolved by partially privatising the public value to protect the mental and social investment of the dweller.

Energy

An central objective of the La Borda project is to reduce its environmental impact. An important consideration in this regard was to reduce the overall costs of dwelling and to eliminate the risk of energy poverty, i.e. absence of means to maintain habitable conditions in the dwelling.[34] The primary strategy was to reduce energy demand through passive strategies (Lacol, 2019). The seven storey building is built with pine CLT panels sourced from the Basque Country. The life-cycle emissions from the building are 200 kg CO2 per m2 (La Borda, 2020), representing a 73% reduction on the average new build in Catalonia.[35] The foundation and ground floor are made from concrete. An approximate calculation indicates that the latter likely contributed around 40% of carbon emissions of the building. The project was exempted from a regulatory requirement to build one on-site parking space for each dwelling, which would have involved significantly more extensive concrete structures. The total cost of the building was €840 per m2. At the current rate of €25 per ton CO2 the implied costs of CO2 emissions were €5 per m2. If carbon emissions were capped considerably resulting in a carbon price of €500 per ton CO2 the construction costs would have increased by €95 per m2 to €935 per m2. Around €40 of the increase per m2 would be attributable to the use of concrete for the foundation and the ground floor. The construction cost per m2 of La Borda would be 11% higher, compared to a 35% cost increase for the average new build in Catalonia.

The energy consumption from the operation of the building is 20.3 kWh per m2 per year, representing a 68% reduction compared to legal requirements. 5.9 kWh of this correspond to electricity, sourced from a renewable supplier, and 14.4 kWh correspond to heat and hot water, generated by an on-site biomass boiler. The carbon emissions from operations are 0.65 kg CO2 per m2 per year. At the current carbon price of €25 per ton CO2 this represents a carbon cost of €0.08 per month for the average dwelling at La Borda, compared to €5.81 per month for the average existing dwelling in Catalonia.[36] It is noteworthy that the energy

[34] 56% of La Borda's dwellers were at risk of or subjected to energy poverty in their previous homes (Lacol, 2019a: 23).
[35] Based on data in IBAVI (2018: 117).
[36] Based on area and consumption data by Hernández (2012).

poverty previously experienced by La Borda's inhabitants largely results from the cost of the energy itself, even before a meaningful price was put on CO_2 emissions. At the higher rate of €500 per ton CO_2, the carbon cost of the average dwelling at La Borda would increase to €1.57 per month, compared to €116.25 per month for the average existing dwelling in Catalonia. If the proceeds from the higher CO_2 emission price were to be distributed directly to citizens, the resulting income would amount to €198 per month, even if overall CO_2 emissions were to decrease by a third.

The minimal energy consumption at La Borda would allow its inhabitants to benefit from a basic income. The users of the average existing dwelling in Catalonia on the other hand would expend most of their basic income on the energy costs of their dwelling. Dwellings with high operating energy costs would lose significant value giving owners and occupiers an incentive to improve energy efficiency and hence reduce CO_2 emissions. However, there remains a conflict where owner and occupier are not the same party. If the dwelling is in a scarce location, such as major city, owners would likely have less incentive to provide energy efficiency given that the occupier pays the operating costs. Marmolejo et al (2020) find that energy efficiency labels do not currently have an impact on rental values. This is likely because the owner has more market power resulting from his property (monopoly) of the scarce site. The occupier will likely be more able to substitute other consumption and absorb the energy costs of the dwelling, thus pushing up the demand for energy and CO_2 emissions. There is hence a case for owner-occupancy, in which occupants shape their own dwelling environments taking into account their local knowledge and preferences, such as in the case of La Borda.

Materials

As discussed above, a key objective in developing La Borda was reducing its environmental impact. The building is built with pine CLT panels and insulated with rockwool. The foundation and first floor structure are made of concrete. Throughout the project a particular focus has been the use of recycled or recyclable materials (La Borda, 2020).

As discussed in the previous chapter, the implications of more sustainable practices on Materials are harder to estimate than in the case of Land and Energy as this would imply identifying and modelling the supply and demand of numerous construction materials and relative substitutability. In general, all construction materials would be significantly scarcer and hence more expensive. This would discourage new construction and encourage the reuse of existing buildings and materials. Most importantly, it would increase the scarcity value of all existing buildings and materials in circulation thus increasing the benefit that is derived from using it. The ownership paradox already pronounced in land would become more visible in materials. In general terms, the practices employed at La Borda, the use of timber from sustainable sources and of recycled materials imply that more stringent sustainability practices would have a lesser impact on the project. La Borda's design implies low operating cost both from reduced energy consumption and from a high degree of flexibility which allows reusing the building without costly interventions. As such, it is likely that the materials employed in the project have been put to more effective use than if they had been used for refurbishing existing buildings.

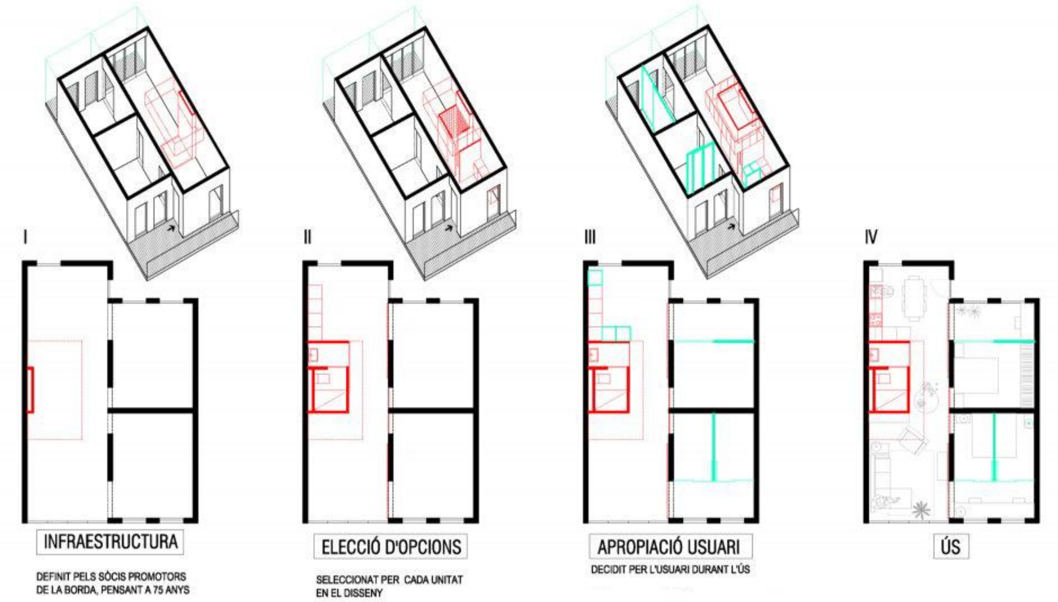

Figure 9: La Borda: less life cycle resource cost through flexibility
Source: Lacol

The project implies a significant reduction in water consumption. Much of this reduction is achieved with efficiencies, e.g. of water-saving fixtures (Lacol, 2019a: 24). Following the Jevons paradox, the economic savings from more efficient water use risks being offset by higher consumption. In the case of La Borda, significant water savings are projected from showering. Presumably this implies that users take the same length showers with more efficient fixtures resulting in less water consumption. At the sight of the lower than expected water bill, users may then take longer showers. The effect would be prevented if the cost of water were to increase as a result from capping unsustainable water supplies.

__Case Study 2: Reusing Posidonia__

Overview

The project comprises seven two-storey terraced buildings with a total 14 social housing rental apartments in Sant Ferran, an inland village on the Balearic island of Formentera. It was developed by the Institut Balear de l'Habitatge (IBAVI) from 2013 and finished in 2018. The GFA of the project is 1,083 m2. All 14 apartment have two bedrooms ranging in size from 53 to 66 m2. The project was partially funded by the European Union's LIFE program supporting environmental, nature conservation and climate action projects. The principal idea of Reusing Posidonia is that humans "don't inhabit a house, but an ecosystem" (IBAVI, 2018: 14). In operational terms, the project aims to work with local resources, both social and natural, and thus re-engage building and dwelling with its immediate environment of which it forms a constituent part. The project is therefore not just about providing social housing but about providing a conceptual reference.

Figure 10: Reusing Posidonia: south façade with private patios
Source: IBAVI. Copyright: José Hevia

Land

The 874 m2 site is publicly owned and forms part of the social housing stock (HPO, Habitatges amb Protecció Oficial) of the Institut Balear de l'Habitatge (IBAVI). Based on local residential rents the market rental value of the site is approximately €9,200 per month, corresponding to €660 per dwelling per month on average (see Annex). The average rent paid by tenants is €400 per month which roughly covers the discounted construction costs of €322 per month.[37] This implies that payment of around 88% of the land rent is waived and internalised by the dweller. The economics are typical for social housing: public land ownership ensures that society internalises the value of the site that resulted from public investment. The value is then returned to the members of society, specifically to those with less access to resources, i.e. who qualify for social housing. The limitation is the same as in

[37] Assuming construction costs of €1,851,431 financed at 3% over 50 years.

the case of La Borda. Broad eligibility criteria mean that there is regularly more demand than supply for social housing. Upon completion the Posidonia project received 202 requests for 14 dwellings (Diario de Ibiza, 2016). Because the value of public land is not distributed equally among those with a claim to it the process by which social housing is awarded has highly distributional effects. If the value of the public land was awarded equally to the applicants, assuming that they have equal valid claims, the monthly subsidy per dwelling would shrink from €582 to €40. Again, the awarding of social housing among those with a claim to it literally constitutes a lottery, implying a significant distributional deficiency.

Unlike in the case of La Borda where the cooperative served as a device for localising the pool of applicants, the dwellings at Sant Ferran are conventional social housing units. As such there could be a risk that applicants who do not have a personal connection to the site could be prioritised over those who do. In the case of Formentera the problem could be mitigated by prioritising applicants with a dwelling record on the island, which forms a delimited municipality of only around 12,000 inhabitants. The problem of means-testing corresponds to the situation at La Borda.

Energy

In contrast to La Borda, which concentrated on energy consumption resulting from the operation of the building, a central objective of Reusing Posidonia is the reduction of CO2 emissions attributable to the materials used during the execution of construction work (IBAVI, 2018: 13). To this end, the project looked to identify and revive vernacular practices and materials. These tend to have significantly lower carbon footprints than industrial solutions, which, in the case of Formentera in particular, involve cost and emission intensive movements of materials, equipment and personnel to the island. The built project resulted in CO2 emissions from materials and construction of 412 kg CO2 per m2. This corresponds to a 63% reduction from 1,128 kg CO2 if the project had been built with conventional materials and processes (IBAVI, 2018: 117). The construction costs were €1,709 per m2, of which €10 per m2 correspond to an implied current carbon emissions price of €25 per ton. If CO2 emission prices were to rise to €500 per ton the construction cost would increase by €196 (11%) per m2 to € 1,905. The cost of an equivalent conventional building would increase by €564 per m2 (45%) from an estimated € 1,200 per m2 to €1,736 per m2. While the specific implications of a higher carbon cost on building practices are difficult to estimate, it is noteworthy that even at an elevated price of €500 per ton conventional building practices would continue to be economically competitive.

Energy consumption during the operation of the building amounts to 20.9 kWh per m2. This is comparable to La Borda and significantly lower than the 64 kWh per m2 implied by current legislation (Lacol, 2020) and the estimated 165 kWh of the existing housing stock in Catalonia (Hernándex, 2012). Primary energy is provided by a biomass boiler and electricity presumably by a renewable provider[38], resulting in relatively low CO2 emissions of 2.77 kg per m2 and an implied cost of €0.35 per month for the average dwelling at a CO2 emissions price of €25 per ton. This compares favourably with the 7.22 kg per m2 (€1.35 per month) consumed by a conventional new build and 31 kg per m2 (€5.81 per month) for the existing housing stock. If carbon emission prices were to rise to €500 per ton CO2, the carbon cost of the average dwelling at Sant Ferran would increase to €6.92 per month, compared to €27.08 per month for a conventional new build and €116.25 for the average existing dwelling in Catalonia. Similar to the case of La Borda, the low energy operating costs of the dwellings at Sant Ferran insulate dwellers from increases in CO2 emission prices.

As in the case with any other project aimed at reducing resource consumption, it should be noted that measurements correspond to prototypes. The actual consumption depends on the behaviour of the user. In general, this implies the risk that the resource efficiencies may be lower than projected because lower absolute costs leave the user with more economic resources to consume more, the Jevons paradox. Indeed, the authors of the Posidonia project point out the risk "of excess energy costs due to inadequate uses such as excessive domestic hot water consumption" (IBAVI, 2018b: 18).

Materials

As discussed in the context of La Borda, the implications of sustainable practices on the availability of building materials are difficult to assess due to the magnitude of materials involved and their potential substitutability. Reusing Posidonia specifically addresses this problem in the context of local resources. A central tenet of the project is that local practices and resources have the potential to greatly reduce the ecological footprint of construction. The problem is that the sustainability of these practices and resources is not usually audited or registered as such because of the complexity involved in this process. This would require e.g. performing a life cycle assessment (LCA) measuring the CO2 emissions and identifying the resources involved in a practice such as using posidonia seaweed for insulation (IBAVI, 2018: 15). The project authors recommend dealing with this problem through public sector-led initiatives to facilitate better access to eco labels and assessment programs to formalise these practices and facilitate their adoption. Given the scope of such efforts, the authors suggest as an immediate measure creating lists of regional materials and practices. Their

[38] IBAVI did not confirm the source of electricity consumed. However, the implied carbon intensity of the electricity consumed at the prototype 175 g CO2 / kWh. That is significantly higher than that of solar energy (30 g aprox) but significantly less than of the electricity grid in the Balearic islands (766 g) which relies heavily on fossil fuel.

adoption could be fostered by requiring their use in public procurement (IBAVI, 2018: 136-139). In addition, knowledge about the materials and processes would be made publicly available and open-source. In this vein, the Posidonia has created a catalogue of regional materials for the Balearic islands, reflecting the materials and practices involved in the project itself. The materials in the catalogue are ordered into four classes C1-C4 with a varying degree of resource intensity ranging from the reuse of local waste to the procurement of non-local optimised products. The table below shows the key materials used in the project and their respective classification:

Class	Description	Examples
C1	Reusable local waste	Dried posidonia, straw, reused doors, etc.
C2	Local eco-friendly products	Marès sandstone, clay (BTC, adobe, etc.), tiles cooked in a biomass kiln, aerial lime, etc.
C3	Non-local eco-friendly products	Wood, hydraulic lime, etc.
C4	Recycled or optimized products, whether local or not	Y-tong, metal profiles with at least 85% recycled steel

Table 14: Summary of the Catalogue of Sustainable Materials of the Balearic Islands

Figure 11: Value chain of posidonia seadweed as local material
Source: IBAVI (2018: 80-81)

The project also aims to reduce water consumption by 60% compared to a conventional dwelling with garden in Formentera. These savings are project to be achieved through efficiencies (taps, plumbing design, greywater) and using rainwater for irrigation. As discussed in the context of La Borda, the Jevons paradox may result in users increasing their consumption beyond the projected level because of the lower cost involved. In this context it is important to note that the water supply in Formentera is currently being exploited at unsustainable levels (Romero, 2018). The absolutely scarcity of sustainable water supply cannot ultimately be resolved with measures aimed at increasing efficiency.

Discussion

Both cases represent leading examples of addressing the challenges of housing provision and sustainability. The two projects have in common that they consider the practice of architecture in its wider social and ecological context. Yet their approaches are quite distinct. At La Borda the focus is on the social dimension of user participation and community while sustainability considerations are handled pragmatically. In the case Reusing Posidonia the focus is on the ecology of dwelling, which implies engaging with local resource and practices, such as the inclusion of unskilled labour with local knowledge. The users of the dwellings, however, were not known until after the project's completion. The respective dynamics likely originate in the genesis and context of each project. La Borda grew out of a local initiative in a urban context with the ambition to force the hand of the public authorities to facilitate their dwelling needs. Reuising Posidonia on the other hand was developed at a public institution, which in turn engaged with a local rural context. Hence, while both projects aim to serve as a reference, the way they go about it is the opposite. La Borda, and Lacol, provide interested groups with a roadmap of how to engage with public institutions to address their dwelling needs. Reusing Posidonia on the other hand proposes a series of measures to be implemented by the public administration to direct actors involved in the provision of dwelling towards more sustainable practices. As shown in the graph below, both projects also address two different aspects of the dynamics of the natural resources involved in dwelling identified in this thesis:

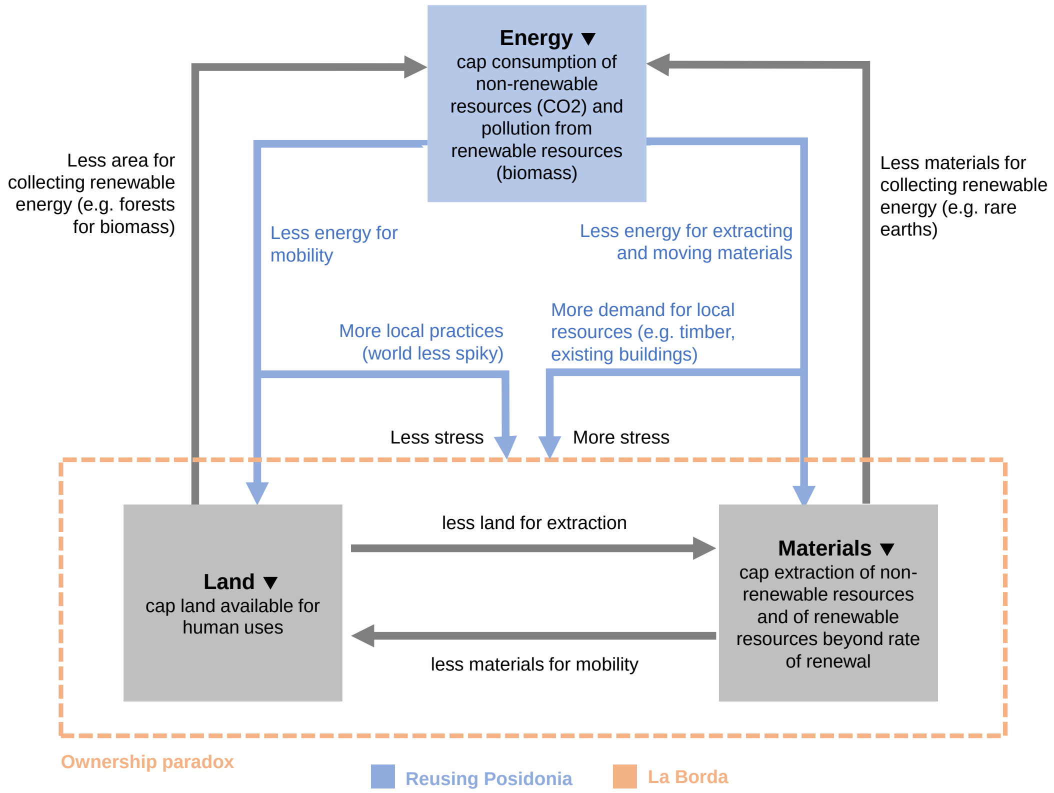

Figure 12: The case studies in the context of Land, Energy and Materials
Source: Own elaboration

A central consideration at La Borda is dealing with the ownership paradox, particularly in relation to Land but also highlighting the ability of owner-occupiers to shape their dwelling environment to reduce operational resource consumption. Cheap energy from fossil fuel leads to the concentration of employment opportunities in major cities, such as Barcelona, where new residents compete with local communities for dwelling resources, in particular land. These dynamics are equally present on the island of Formentera. However, given its relative isolation it is easier to delimit who may be considered local and hence be granted privileged access to dwelling resources, such as the discussed social housing. Formentera is also rural with many disperse settlements which means that resources other than land are a limiting factor, e.g. the unsustainable use of aquifer water and the dependence on fossil fuel for energy. Reusing Posidonia focuses on the interaction of fossil fuel, measured by CO2 emissions, and local resources. As proposed by the project’s authors and shown the graph above, there is an inverse correlation between the availability of cheap energy and the relative value of local resources. If CO_2 emissions are capped, as implied by the self-imposed limits set by the project, local resources and practices become a viable alternative to resource-intensive conventional building practices.

The process at Reusing Posidonia, however, is inverse: it starts from local resources and practices, following the idea that human dwelling forms an integral part of the local ecosystem. The project catalogues, revives and applies traditional techniques and materials, complemented by modern enhancements, to proof that the resulting dwellings are indeed less resource-intensive and would be viable in the absence of fossil fuel. The recommendations of the project then take the same direction: first identifying local practices and then working toward their adoption through education and public procurement policies. As has been argued in this thesis, there is an inherent difficulty in identifying and modelling the complex relations of substitutability between resources and practices. Mandating their use ex ante without taking into account the dynamics of the wider political economy may risk leading to the folkloristic adoption that the authors of the project were trying to avoid (see figure below). That said, Reusing Posidonia is an important case study *because* it suspends the strictures of the political economy to show that local resources are likely to play a more important role in a resource-constraint political economy and that the resulting architecture has an inherent appeal rather than being a trimmed down version of conventional architecture today.

Figure 13: “Complete landscape integration, far from decoration and folklore”
Source: IBAVI, 2018: 135

La Borda on the other hand has more pragmatic approach, primarily responding to the concrete needs of its users in *today’s* political economy, in particular dealing with the risk of displacement and energy poverty. While this entailed efforts to reduce the environmental impact of the project, certain compromises were made, such as the use of a concrete foundation to be able to build higher and sourcing the timber structure from the Basque Country rather than involving a local supplier. Given its location at the built-up centre of a major metropolis, arguably there is less scope for engaging with local resources than there is at Reusing Posidonia. La Borda is also rather more agnostic in formal considerations. The resulting building is designed to facilitate dwelling in a 21st century metropolis and as such bears little resemblance with vernacular typologies found in the region. Nevertheless, the use of passive energy and the flexible structure (Schneider & Till, 2007: 13) are important conceptual touch points with vernacular architecture. The proposition of Amos Rapoport that “people do not live in buildings but they live in systems of settings” (Rapoport, 1979: 114) chimes with both La Borda and Reuising Posidonia, albeit in quite different ways.

A noteworthy observation is that both case studies indicate that conventional building practices could absorb relatively high CO2 emission prices. A CO2 emission price of €500 per ton is much higher than what is currently discussed, yet at first sight it would seem to primarily act as an incentive to reduce the use of fossil fuel rather than trigger qualitative changes.

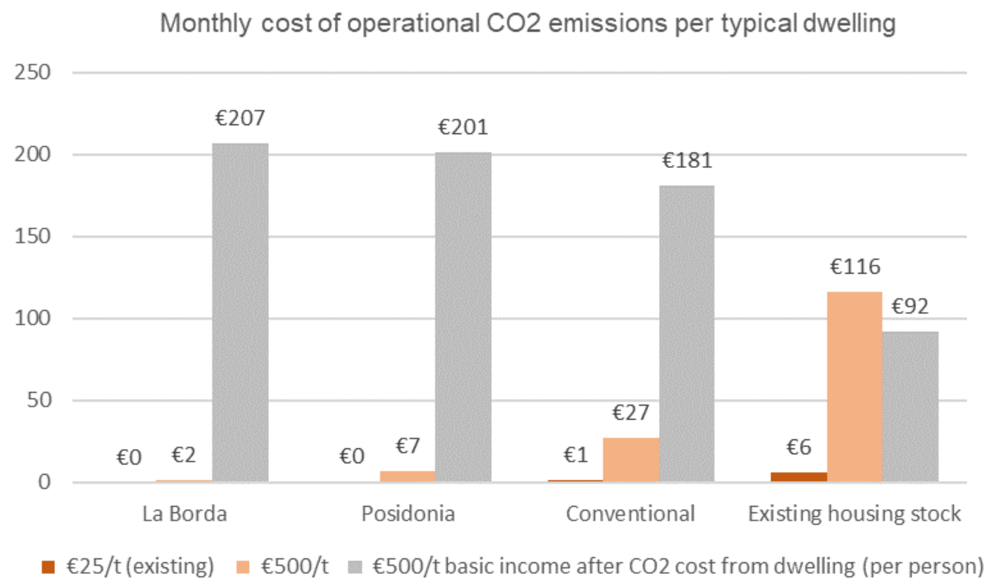

Figure 14: Monthly cost of operational CO2 emissions per typical dwelling
The basic income assumes that CO2 emissions decrease by one third and that proceeds are distributed among all citizens. Typical dwellings: La Borda 58 m2; Posidonia 60 m2; conventional and existing 90 m2
Source: Own elaboration based on case study data; Lacol (2020); Hernández (2012)

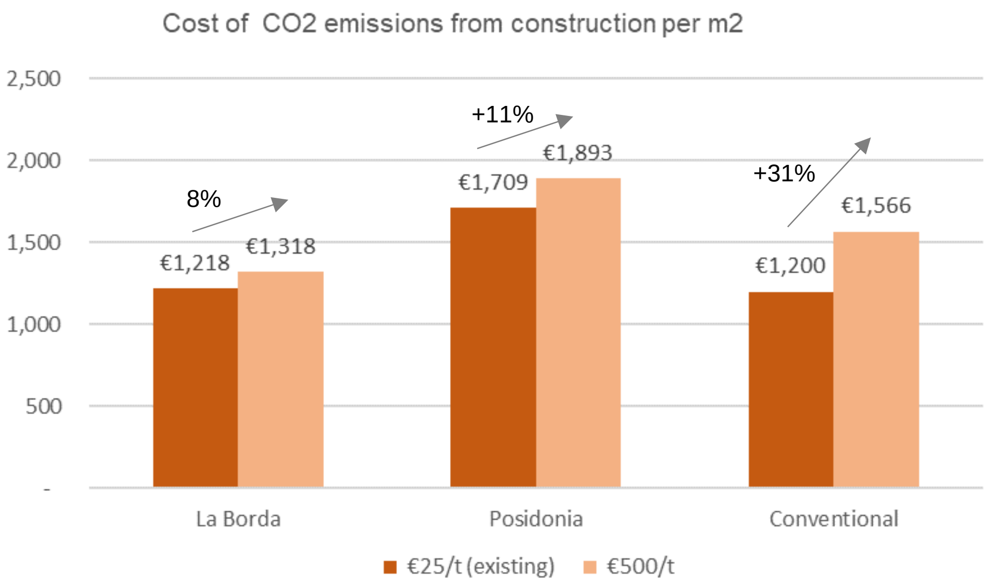

Figure 15: Cost of CO2 emissions from construction per m2
CO2 emissions per m2: La Borda 200 kg; Posidonia 367 kg; conventional 732 kg
Source: Own elaboration based on case study data; IBAVI (2018)

The effect is accentuated by path dependence as lack of experience with new practices means that they carry inherently higher execution risks. Conventional building practices will prevail unless the benefits of new practices are sufficiently high to compensate for the execution risk. Reusing Posidonia proposes addressing this problem by educating the trades about the benefits of the identified practices and by publishing the specifications of the reference project. Equally, as discussed, higher CO_2 emission prices have a reduced effect where the owner and the occupier of a dwelling are not the same party. La Borda addresses this by involving the community of users in the design and operation of the project, whereas at Reusing Posidonia the users were less invested in social processes leading up to the formation of the project.

Finally, it is important to remember that the case studies operate under the conditions of the current political economy, in which e.g. CO_2 emissions are priced far below their costs. But both projects critically engage with this political economy and proactively shape its institutions to make more resources available for localised, community-centred dwelling forms (see figure below). The analysis of this thesis sketches out the repercussions that a sustainable use of resources in society overall would have in the context of both projects. For example, the economy of Formentera heavily relies on tourism based on CO_2-intensive air travel. If air travel was significantly more expensive, and if land could not serve as an investment for second-home owners, there would arguably be less demand for buildings in Formentera. Consequently, the demand for aquifer water could shrink to sustainable levels. Demand for housing may be satisfied by reusing existing buildings and new construction avoided altogether. In the case of La Borda, less need to live near employment centres would lead to less pressure on communities, reducing the ownership paradox. At the same time significantly more expensive concrete could imply a lower rise structure, mirroring the lower demand. The scenarios reinforce the idea underlying both case studies that a more sustainable society would imply more use of local natural resources and social practices.

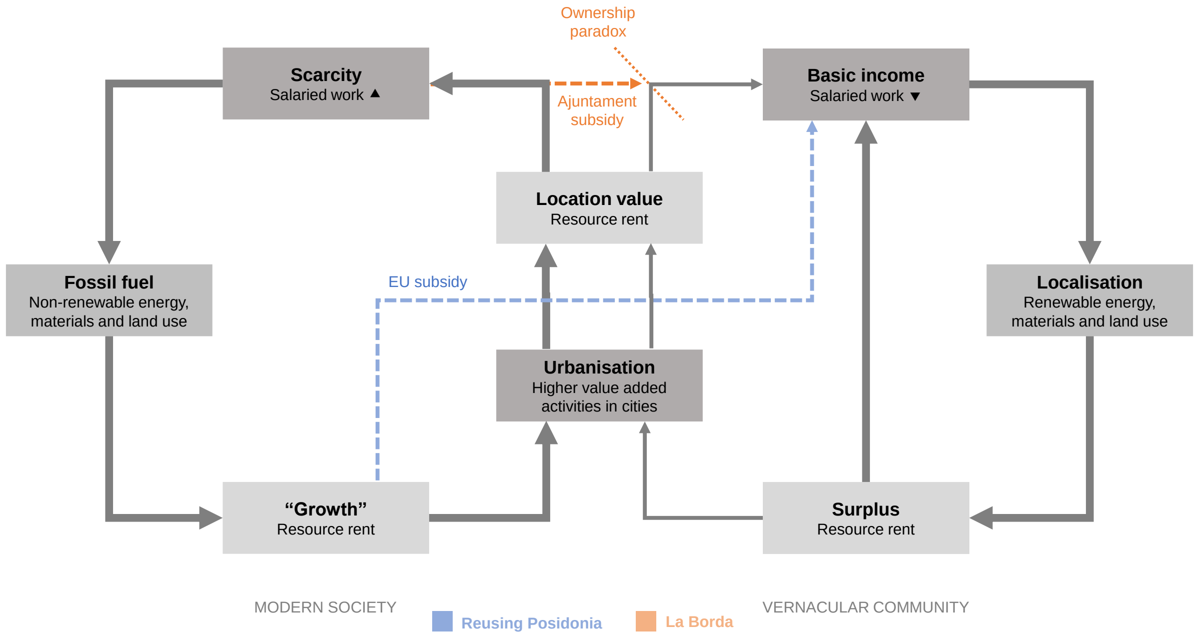

Figure 16: The case studies in the context of resources and rents
Source: Own elaboration

Conclusions

This thesis aimed to investigate what economics tells us about the shape and prospects of sustainable dwelling. A central finding is that dwelling is closely connected to the concept of economic rent. As such, the institutions that govern and allocate rents, notably property, play key roles in determining the feasibility and viability of sustainable dwelling proposals. Economic rent is a zero-sum game and its allocation is socially constructed. Therefore, sustainable dwelling by definition cannot be achieved through the design and construction of more and better houses using less resources. Instead the findings of this thesis suggest that sustainable dwelling proposals should incorporate the institutions that govern economic rent. These institutions can be understood as the “software” of dwelling, the social processes that facilitate access to the material and immaterial stocks involved, the “hardware” (Westbury, 2011, in Goodbun et al, 2014: 41).This includes in particular a discussion about the notion of property in the sense of who can use society’s natural and social resources, and why. In this context, a particular role is played by the ownership paradox. The resources involved in dwelling have two legitimate owners: the dweller and society. Given the magnitude of resources involved in dwelling it is rather startling that the problem is practically absent from both the public and the academic discourse. This lack of understanding, combined with the existential nature of dwelling, may explain the continuing propensity to seek to resolve dwelling through efficiency and growth.

Looking at dwelling through the lens of resources has important touch points with vernacular architecture. Amos Rapoport (1979: 114) finds that vernacular architecture serves as a useful access point for understanding the system of settings that constitutes man-environment relations. A key variable in man-environment relations are the social practices that govern access to natural resources. In premodern communities natural resources were allocated through customs, and knowledge about vernacular building practices transmitted through traditions. In modern society, these social practices are codified in formal institutions that administer abstract rights. At the heart of resource allocation in modern society is the institution of property. In economic terms, property grants the privilege to monopolise the rents obtained from both natural resources and knowledge. But as Gibson-Graham (2006) point out, institutions are not unitarian but themselves constantly reaffirmed through social practices. As such, bottom-up engagement with the institutions that govern the resources involved in dwelling could be understood as a modern vernacular.

There is, indeed, an emerging discourse about the potential of vernacular building to serve as a model for sustainable architecture today. However, this body of work primarily addresses technical and formal aspects. The findings of this thesis suggest that understanding the practices governing the allocation of natural resources and knowledge in vernacular architecture could prove insightful for the provision of sustainable dwelling in modern society. There are, in fact, marked parallels between open source architecture, and vernacular architecture and urbanism. Both are bottom-up practices that involve extensive horizontal sharing of general knowledge about techniques that optimise the use of a common resource stock in concrete local situations (See e.g. Ratti & Claudel, 2016, chapter 2; Goodbun et al, 2014: 64). But whereas vernacular practices are linked to traditional communities, open source architecture leverages the mechanisms and values of modern society, such as communication technologies, transparency and universal rights. In this light, both examined case studies make reference to the vernacular. Reuising Posidonia specifically re-engages traditional practices to show their efficacy for managing natural and social resources. The findings of the project were then digitally shared as open source knowledge. La Borda constitutes a bottom-up process at the centre of a wider effort to gather and share knowledge about cooperative dwelling forms. The initiative led to the creation of a municipal scheme to provide public resources to similar dwelling projects. It is noteworthy that in both projects the architect played a central role in the aggregation, distribution and application of knowledge about resources and techniques.

In practical terms, this thesis proposes that the most direct way to provide sustainable buildings and cities is to give dwellers a direct incentive to dwell sustainably. In the words of behavioural economist Richard Thaler: ‘If you want people to do something, make it easy’. Rather than prescribing or prohibiting certain resourses and techniques, or proving sustainability through complex models, the easiest way would arguably be to disincentivise the unsustainable use of resources to begin with. Rather than imposing architectural knowledge the idea would be to encourage the exercise of architectural intelligence (Till, 2009: 167). A key requisite for this is understanding the institutions that allocate the resources involved in dwelling. A logical starting point would be for resource uses to reflect their social costs. The narrative potential of the concept of economic rent derived from common resources could play a central role in this. Morever, the preference of one resource or practice over another is also driven by other costs, notably cultural and technical path dependence through lack of knowledge. Well documented and communicated pilot projects, such as the presented case studies, play an important role as “small scale versions of the future” (Till, 2009: 193) that create knowledge through precedents, allowing others to build on the experience.

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Annex

Calculations for case studies

		La Borda	Posidonia	Conventional	Existing
General					
Municipality	--	Barcelona	Sant Ferran		
Population	#	1,604,555	11,878		
Cars	#	561,416	6,138		
GFA	m2	2,119	1,083		
NFA	m2	1,624	824		
GFA / NFA		1.30	1.31		
Dwellings	#	28	14		
Dwellings types	m2	40 / 58 / 76	53 - 66		
Average dwelling	m2	58	60	90	90
Construction cost	€	2,580,000	1,851,431		
Construction cost / GFA	€ / m2	1,218	1,709		
Land					
Castastre		ZV=NO&ZR=NO	CC6865N0001LK		
Land ownership	--	leasehold	public		
Owner	--	es La Borda SCCL	IBAVI		
Size plot	m2	627	874		
Rent min	€	450	350		
Rent max	€	700	450		
Rent average (estimated)	€	575	400		
Cars / 1000 pop	#	350	517		
GFA	m2	2,119	1,083		
Construction cost	€	2,580,000	1,851,431		
Cost / m2	€ / m2	1,218	1,709	1,200	1,000
Cost / month	€ / mo	8,113	5,822		
Cost / month / m2	€ / mo / m2	3.83	5.37		
Cost / month / dwelling	€ / mo	222	322		
Use value / m2 / month	€ / mo / m2	12.80	13.85		
Use value / month	€ / mo	27,122	15,003		
Price/rent multiple	years	20.2	20.2		
Use value	€	6,565,504	3,631,903		
Use value / m2	€ / m2	3,099	3,353		
Use value / dwelling / month	€ / mo	742	831		
Land rent / month	€ / mo	19,009	9,182		
Land rent / month / m2	€ / mo	8.97	8.48		
Land rent %	%	70%	61%		
Land value	€	3,985,504	1,780,472		
Land rent collected / month	€ / mo	400	0		
Land rent waived / month	€ / mo	18,609	9,182		
Land rent waived / dwelling	€ / mo	665	656		
Land rent waived / m2	€ / mo / m2	8.78	8.48		
Rent collected	%	2%	0%		
Rent granted	%	98%	100%		
Land rent waived / month full list		0.51		36,577	
Energy					Equivalent
Energy cost LCA	kWh/m2				
CO2 emissions from LCA	kg CO2	423,784	564,085		
CO2 emissions from LCA / m2	kg CO2 / m2	200	412	732	1,128
Reduction vs conventional	%	73%	63%		
Cost of CO2 emissions / m2 (existing)	**€ / m2**	**5**	**9**	**18**	**28**
Cost of CO2 emissions / m2 (higher)	**€ / m2**	**100**	**184**	**366**	**564**
Total increase / m2	€ / m2	8%	10%	29%	54%
lime concrete with renewable energy	kg CO2 / m2		367		
Reduction vs conventional	%		67%		
Energy for electricity	kWh / year	12,474	16,172		
of total	%	29%	72%		
Energy / m2	kWh / year / m2	5.9	14.9	60.0	
Carbon intensity	g CO2 / kWh	30.0	175.5	304.3	
CO2 emissions / m2	kg / year / m2	0.18	2.62	18.26	
Energy sources	--	Som Energia; 30	% electricity will b	Grid	
Energy for heating/hot water	kWh / year	30,540	6,437		
of total	%	71%	28%		
Energy / m2	kWh / year / m2	14.4	5.9		
Carbon intensity	g CO2 / kWh	25.0	25.0		
CO2 emissions / m2	kg / year / m2	0.36	0.15		
Energy sources	--	Biomass boiler	Biomass boiler (		
Energy cost total per m2	kWh / year / m2	20.3	20.9	64.0	165.0
Reduction vs conventional		68%	67%		
CO2 emissions total per m2	kg / year / m2	0.65	2.77	7.22	31.00
CO2 emissions total per dwelling	t / year	0.0	0.2	0.6	2.8
Cost of CO2 emissions / m2	€ / year / m2	0.02	0.07	0.18	0.78
Cost of CO2 emissions / dwelling / month	**€ / month**	**0.08**	**0.35**	**1.35**	**5.81**
Cost of CO2 emissions / m2	€ / year / m2	0.33	1.38	3.61	15.50
Cost of CO2 emissions / dwelling / month	**€ / month**	**1.57**	**6.92**	**27.08**	**116.25**
Materials					
Materials types and sources	m3	CLT (pino radiata	Ytong + posidoni		
Water consumption	l / pers / day	69	88	220	
Reduction vs conventional	%	69%	60%		
Rain water use	--	No	Yes, for plants ar		
Waste production	t		35.2	70.4	
Reduction vs conventional	%		50%		
Recycling rate	%	90%			
Dividend Spain					
CO2 emissions per capita	t / year			7.5	
Population	#			46,937,060	
CO2 emissions	t			352,027,950	
Existing price	€ / t			25	
Dividend / year	€			125	
Dividend / month	€			10.42	
Lower emissions	t / year			5	
Higher price	€ / t			500	
Dividend / year	€			2,500	
Dividend / month	€			208.33	