USING QUALITATIVE DATA TO EXPLORE KNOWLEDGE TRANSFER SCENARIOS IN AGENT-BASED MODELS: THE CASE OF NEAR ZERO-ENERGY BUILDINGS

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Extended abstract

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1 Background

The EU (European Union) has developed the “Europe 2020” growth strategy, in which climate change and energy sustainability play a crucial role as one of the five main targets (European Commission, 2013). The EU has stated in “Europe 2020” the following ambition targets for climate change and energy sustainability: 1)GHG (Greenhouse gas) emissions 20% lower in 2020 than 1990; 2) 20% of energy from renewables; and 3) 20% increase in energy efficiency. From these EU targets, the GHG emissions 20% lower in 2020 than 1990 and 14% of energy from renewables in 2020 have both become a policy measure in the Netherlands (Verhagen, 2012). Reduction of the Dutch CO2-emissions can be reached by reducing the primary (fossil fuel) energy use of buildings. In particular the primary energy use for spatial heating as this was 660 PJ in 2006 (for both utility and dwellings), which is 20% of the total primary energy consumption in the Netherlands (Duijve, 2012). The Dutch government has set stringent energy standards for new buildings in order to achieve the 2020 goals (Ministerie van BZK, 2011). Although the importance of energy-neutral housing is recognized by government, in practice the con-

adfa, p. 1, 2011.

struction of near zero energy buildings (*nZEB´*s) has not become a reality (Faber and Hope, 2013). This discrepancy between expressed aspirations and practices might be explained by the process of creating innovative solutions to construct *nZEB's*. Until recently, the dominated innovation model in Dutch building sector showed a process focusing primarily in the technological developments by scientists, followed by a cost-benefit adoption by construction companies. However, the traditional manner for promoting innovation has become increasingly replaced by network based initiatives such as "covenants", which embrace a systemic approach to innovation processes.

Relevant frameworks for a system analysis can be found in literature on innovation systems. The concept 'innovation systems' has gained prominence in policymaking since the 1990s as it provides a qualitative explanation for the sources of innovation and economic growth that also covers the role of policies and other institutions (Romer, 1993). Different innovation system concepts have been scrutinized in the literature, including national systems of innovation (Freeman, 1987; Lundvall, 1992a; Nelson, 1992), regional innovation systems (Asheim and Coenen, 2005; Cooke et al., 1997), sectoral systems of innovation and production (Breschi and Malerba, 1997; Malerba, 2002) and technological systems (Hekkert et al., 2007). In this paper, we approach the subject through innovation systems perspective in general, and particularly through sectoral innovation system viewpoint where the level of analysis moves from the holistic cultural, policy and institutional context of a the Netherlands to a sector, to analyze the *nZEB* system and the actors as well as their interactions within the Dutch construction sector. A sectoral innovation system (SIS) can be deined as "a set of new and existing products with specific functions and the set of actors for the creation, production and sale of these products "(Malerba, 2002). Klein-Woolthuis et al. (2005), summarize failures or barriers –as we called them- into four basic categories: 1) Infrastructural (i.e. physical infrastructure); 2) Institutional (i.e. norms); 3) Interaction (i.e. relations in networks); and 4) Capability (i.e. lack of non-physical resources). This classification allows identifying causes that hinder innovation. The main criticism is that it lacks focus on the innovation processes (Bergek et al., 2008). In our study, we first try to get insights into the main barriers that impede the construction of *nZEB*'s and to be able to model them. A second step –in the near future- would be to look at the key processes that influence the development, diffusion and implementation of nZEB's.

1.1 *nZEB*'s System

According to Malerba (2002), the basic components of a sectoral innovation system are: 1) Product; 2) Actors; 3) Knowledge processes; and 4) Interactions (including competition and complementarities between actors/technologies). So as a starting point a depiction of the main actors and interactions within the nZEB sector is shown in table 1. There are four main phases in the project of developing new buildings. The planning phase starts when an initiative is taken normally by a Property Developer. A project management is appointed to coordinate the project. Then, a drafting of the contract by both parties follows. Afterwards -during the design phase- specifications are developed. Finally, the design is communicated to the contractor(s), here the realization phase takes place. Once the building is constructed the project manager and the property developer inspect it. The last phase is the delivery phase, where the building is sold (or rented). House owners provide feedback on the delivered property by means of energy consumption and –sometimes- by demanding for buildings with an specific energy performance. We consider that knowledge and money flow along the different phases of the system.

	PLANNING		DESIGN		REALIZATION		nZEB DELIVERY	
	Initia-tive	Pre-Design	Architectural Design	Execution Design	Manufacture	Assembly	Adver-tisemen t	Use
Property Developer (Public body: Housing Corporations, Private)	■						■	
Project Management		■	■					
Building Company		■	■	■	■	■		
Contractors			■	■	■	■		
User (Home Owner/Tenant)								■
Knowledge Institutions			■		■			
National Government	■		■		■	■	■	
Financial Institutions		■					■	

Table 1. Actors involved in the different phases of near-zero energy buildings construction

Institutions also affect the system. The national government dictates laws and provides guidance on the planning process, construction standards, financial schemas (i.e. subsidies, mortgages) and procurement aspects. Government influences knowledge institutions through grant programs and development policies. Government also provides information to potential homeowners. Knowledge institutions develop and disseminate technology and knowledge of sustainability. Last, Financial institutions provide loans to property developers and to potential home owners.

The core concern is how to foster the construction of *nZEB*'s that enable energy consumption reductions, amid a landscape of a decentralized set of purposeful interacting actors. The intricacy of the dynamics and interaction of heterogeneous participant in the adoption of better practices has called for a computational approach to study such problems (Squazzoni, 2008). Computational approaches have used to understand different implications of adoption scenarios (e.g., Schilperoord et al., 2008).

1.2 ABM for near Zero Energy Buildings

The growth of agent based modeling (ABM) coincides with how the views and thinking about urban systems has changed (Crooks, 2012). Rather than adopting a reductionist view of systems, whereby the modeler makes the assumption that cities operate from the top-down and results are filtered to the individual components of the system (see Torrens, 2004), people are now adopting a reassembly approach to the system (O'Sullivan, 2004). This change follows the realization that, planning and public policy do not always work in a top-down manner; aggregate conditions develop from the bottom-up, from the interaction of a large number of elements at a local scale. Thus there is a move towards individualistic, bottom-up explanations of urban form and behavior which links to what we know about complex systems. Such an approach is given by ABM.

Our objective here is to explore scenarios than might assure the diffusion of better business practices that allow leading to an eventual energy reduction. The situation depicted here might be considered as a diffusion problem. Yet, our approach differs from other diffusion-related works in at least two aspects: (i) diffusion models emphasize the positive externality effect of adoption, which is commonly represented by a probability function that depends on the current number of adopters (cf. Delre et al., 2007). Other works (e.g., Schwarz and Ernst, 2007) use well-known psychological frameworks to inspect susceptibility to innovation adoption. Our work deals with agents that confront –different- barriers to impulse the construction of *nZEB*'s define certain qualitative courses of action (Bharwani, 2004); (ii) our work aims at a systems design approach, and not merely to study the determinants of specific consumption patterns (cf. Azar and Menassa, 2011). That way, the use of an AB model is expected to bring courses of action that help sustainable consumption practices to be adopted.

2 Data Collection

In this study, interviews were conducted to explore the possible barriers that hinder the development of energy neutral buildings. These findings allowed making a first attempt in the modeling of different scenarios that promote the construction of *nZEB*'s. The selected interviewees were: two project developers, two housing associations, a consultant and three civil servants at a municipality level. These specific actors were chosen for their central position in the building system. The participants have been involved in both successful and unsuccessful projects. In addition, all actors were involved at least in the planning phase, which it is a significant phase of the energy-neutral initiatives. The consultant interviewed is specialized in sustainable housing.

Semi-structured interviews were used to allow actors to make an elaborated explanation of their opinions. All interviews were transcribed and analyzed using thematic analysis according to Bryman (2008). Among each response key ideas were identified. These ideas were merged into core themes. These core themes correspond to the failures discussed by Woolthuis et al. (see 1). The analysis was based on a matrix. This matrix related the thoughts from the different interviewees with the key ideas behind these thoughts. It appears that the infrastructure and the capability needed to implement *nZEB*'s are already there. The main barriers relate to Institutions and Interactions. Table 2 exemplifies how the matrix was built.

INTERVIEWEE	KEY IDEAS	BARRIER	PHASE
"The municipality establishes private agreements, but no building permit can be refused if you do not build according to the (...) agreed measures, but built according to the legal requirements"	Municipalities do not make high emphasis on the requirements of energy performance included in the energy performance certification (EPC).	Interaction	Planning and Design
"Builders and contractors have been long accustomed to squeeze subcontractors. They [builders and contractors] always go for the lowest price. A kind of fighting culture prevails in the construction sector"	The choice of a particular contractor is mainly based on price. This, forces contractors to focus on cost reduction with this they prevent the use of more energy efficient systems.	Interaction	Design and Realization
"Today consumers simply cannot buy a house. Not to mention an energy-neutral house, which it costs additional 20,000 euro. "	It is complicated to invest in energy-neutral housing projects in the current housing market.	Institutional	Delivery
"The regulations make it difficult for us to build energy-neutral (...) we wanted to install solar panels on a meadow. We wanted to generate and deliver energy to our tenants. Well, this is not possible according to the government "	Restrictive regulations exist for the installation of certain materials used to build energy-neutral homes	Institutional	Design and Realization

Table 2. Determination of barriers for the construction of *nZEB*'s.

3 Mapping qualitative data to systemic diagrams

Results from collected qualitative data were confronted with the elaboration of a systemic diagram, or a "systemigram" (Boardman and Sauser, 2008). Systemigrams are visual maps of entities and their interactions, inspired by "soft systems methodologies" (e.g. Checkland, 1999). Systemigrams attempt to represent dynamic aspects of complex problems and offer a wide range of multiple representations, from which "money flow" usually is a very insightful one (cf. Boardman and Sauser, 2008). Here, we place in the same diagram "money flow" and "knowledge flow", for the sake of having a unique representational display.

The proposed systemigram can be observed in Fig. 1. Our systemic diagram basically illustrates two types of entities: actors and objects by which actors build their interactions. The state of such objects can also be modified according to the actions of actors.

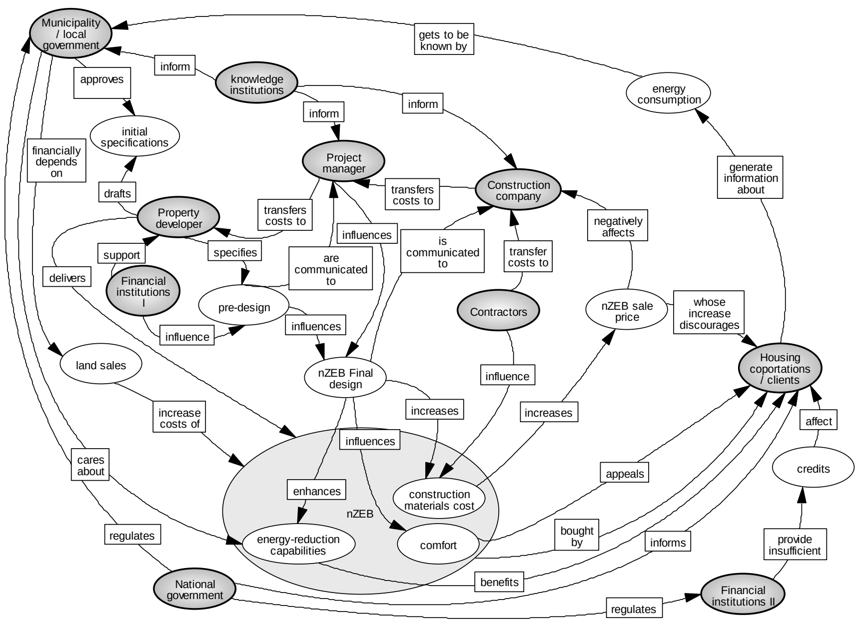

Fig. 1. Actors (dark gray ellipses) and relevant objects of interaction (white ellipses).

In the systemic diagram, actors are in gray, while objects are in blue. The systemic diagram depicts the intricate interdependence of actors` interests and performance. For instance, while the property developer initiates and delivers the final neutral-energy homes, he or she has little monitoring power on subsequent costs transfers to clients. Energy-reduction capabilities are not fully internalized in the money flow dynamics towards consumers' willingness to buy a near zero-energy (*nZEB*) home, and therefore *nZEB* advantages lack of enough appeal to them. On top that, there is a lack of enforcement from governmental authorities, who face a dilemma between fostering construction of *nZEBs* and their own financial viability through land sales. The diagram also reveals other conflictive issues not revealed through interviews: (i) interviewees call for an internalization of energy reduction capabilities on *nZEB* rental prices for home owners (in case the owner rents the property to someone else); however, it can be observed that such internalization would might only work if it is embedded at multiple stages of the *nZEB* production chain (including the financial institutions); also, (ii) knowledge flow and money flow appear to follow different dynamics: For instance, the "systemigram" reveals that de facto some actors that, in principle, are interested *nZE* homes appear to have no clear economic-driven incentives to impulse construction of *nZEB*'s (e.g. property developers), although they have a good degree of knowledge (e.g., they are involved in construction designs, local government requirements and costs).

4 A framework for agent specification (summary)

<u>Environment</u>: We assume a space of *n* x *n* cells, each of which can sustain a nZEB / home.

<u>Municipality's behavior</u>: Receives an income due to sales of land *L*, I_L. Utility function is defined as $U_m(.)$. E_{max} and E_{nZEB} are the default energy consumption and the near-zero energy building consumption, respectively; N_t is the number of nZEBs / homes at time *t*. Then, $U_m(L, E_{nZEB}, N_t) = LI_L + \alpha |E_{\max} - E_{nZEB}| N_t$. Coefficient α is a scale factor. We assume that $E_{max} \geq E_{nZEB}$ and that the benefit from a land sale is much larger than the maximum gain from a *nZEB* energy consumption: $\alpha\, E_{max} \leq I_L$. At every time step *t*, the municipality has to allocate time between attending a permit request from *land sales*, or studying an *nZEB initial specification request*. This is done by assigning a service probability according to a *Q-learning* algorithm. At every time step *t*, the municipality keeps track on two indicators, Q^t_i for each option *i* = {*nZEB*, land} and updates them according to the observed revenue at time *t*-1. For instance,

$$Q^t_{land} = \begin{cases} (1-\alpha)Q^{t-1}_{land} + \delta L, & \text{if land is sold} \\ Q^{t-1}_{land}, & \text{otherwise} \end{cases}$$

Coefficient δ represents an *adoption rate*. Then, the probability of giving priority to a *land sale request* is represented by:

$$P(\text{land}) = \frac{Q_{land}^{t} - \min(Q_{i}^{t})}{\sum_{i} (Q_{i}^{t} - \min(Q_{i}^{t}))}$$

The maximum number of *nZEB* specification requests is *n* x *n*, the size of the environment lattice.

Property developer / project manager: Both property developer and project manager decide on the final *nZEB* design, if any. For practical purposes, we merge these two actors in the same agent. Joint decision on building a *nZEB* home type is linked to different cost options. Therefore, we assume two different cost variables, C_{nZEB} and C_{normal}, to represent cost figures of *nZEB* constructions and normal buildings, respectively. Also, $C_{nZEB} \geq C_{normal}$. The utility function of this agent is defined as $U_{developer} = P_{house} - transCost$, where $P_{house} = \{ P_{nZEB}, P_{normal}\}$ is the price of the house paid by a client ($P_{nZEB} \geq P_{normal}$) and *transCost* is the cost incurred in house manufacturing (also, $transCost_{nZEB} \geq transCost_{normal}$).

Construction company / contractors: Construction companies and contractors transferred their operational costs to project managers and ultimately to developers. In addition, nZEB construction *takes more time* due to the additional training workers need to get in order to build *nZEBs*. Therefore, construction costs are assumed to be higher for *nZEB* constructions. Construction times have an impact on municipality assessment of requests.

House corporations / clients: Clients might be of three types: house corporations, developers and private ones. Clients evaluate buying a house according to *Comfort*, and not energy savings, through their utility function $U_{client}(.)$. Also, clients' preferences indicate that $U_{client}(Comfort_{nZEB}) > U_{client}(Comfort_{normal})$, but a buying decision is restricted to budgetary constraints. Such constraints are not explicitly represented in client's equations, but we rather assume that a price increase lowers the chances of acquiring a nZEB home (recall that $P_{nZEB} \geq P_{normal}$). Therefore, we also consider two important parameters: a marginal rate of substitution between the two goods (house types), and price-quantity elasticities.

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