The development of a new network for eco-sustainability: the Loccioni's "Leaf Community" project

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Abstract
This work-in-progress presents our preliminary findings from an ongoing study of the "Leaf House" project, initiated by Loccioni Group, an Italian mid-sized firm. "Leaf House" is part of a bigger project called "Leaf Community", aiming to create the first ecologically sustainable integrated community in Italy. The idea was proposed by Loccioni, in collaboration with Enel and Whirlpool, who created together with a network of other companies this community in the Marche region of Italy. In the Leaf Community it is possible to live in a zero carbon emission house (the Leaf House) and move with electrical or hydrogen cars and work in eco-compatible buildings. With its six apartments, the Leaf House is a technologically innovative building that relies on environment-friendly solutions: it integrates for instance innovative solutions for an efficient production and use of light and energy. The aim of this paper is to analyze, in a dynamic context like the new technologies applied to eco-sustainability, the origin and the development of the Leaf House network. Loccioni Group has engaged and mobilized a network of other actors in order to carry out the project so to involve and combine several technical and organizational resources. It is therefore interesting to investigate the interactions between the actors in this network, including the conflicts that emerged among them and how these conflicts were handled by the various actors. Other key questions are: How could a smaller firm such as Loccioni convince larger actors such as Enel or Whirlpool to participate? What were the motivations and expected gains of the various actors in relation to the creation and distribution of a key value such as eco-sustainability? How does this restricted project network relate from a technical and an organizational point of view to the broader network that embeds the various actors? From a theoretical perspective, in order to answer these questions we rely on the ARA model (Håkansson & Snehota, 1995), but we focus on the resource layer and apply the 4-Resources model (Håkansson & Waluszewski, 2002) in order to further analyze how different resources have been combined and activated within the network of the Leaf House project.

1. Introduction

Eco-sustainability and the environment have recently become key issues for businesses as a response among others to the pressure of consumers and other stakeholders such as public agencies (Porter & van der Linde, 1995). The previous resistance to these pressures was motivated by increased costs to match tougher environmental standards, but this resistance increasingly leaves place to the conviction that technical innovations can allow matching simultaneously cost and "green" targets, while satisfying a now clearly identifiable consumer need for green solutions (Ibid, Stone & Wakefield, 2000). The development of eco-sustainable solutions accordingly stretches from devising and designing environmentally friendly products and services (Maxwell & van der Vorst, 2002) to conceiving "green" supply chains involved in the production and distribution of these products (van Hoek, 1999; Vachon, 2007). No matter the specific type of environment-friendly solution at hand, it appears difficult to achieve a fully "green footprint" by a single company working in isolation. In fact, developing "green" products is complex and often requires combining technologies from several actors (see Håkansson & Waluszewski, 2002a, 2002b). Moreover, the environmental impact of a product does start from its raw materials (including from where and how these are transported), it includes its production and transportation processes, all the way to final users (including their using context), and concludes with the eventual disposal of the product (cf. Bevilacqua, Ciarapica & Giacchetta, 2007). Considering these two points, it is highly relevant to view the creation of eco-sustainable solutions from an industrial network, interactive perspective (see Håkansson & Snehota, 1995, Ford et al, 2003).

The "Leaf House" is one of such eco-sustainable solutions: it is a technologically innovative building that relies on environment-friendly solutions for an efficient production and use of light and energy. Loccioni Group, an Italian medium size firm, is the promoter of the "Leaf House", which is part of a bigger project called "Leaf Community", aiming to create the first ecologically sustainable integrated community in Italy, allowing living in a zero carbon emission house, moving with electrical or hydrogen cars and working in eco-compatible buildings. This case is particularly interesting from the viewpoint of eco-sustainable technologies because of several reasons: the project embraces not a single product or technology, but several technologies that needed to be integrated into a complex building (and even a whole extended community); moreover, these technologies where all more or less already available on the market and simply needed to be tied together into a functioning whole. However, this was not a technically trivial task because obtaining a truly zero-CO2-emission house required advanced solutions for producing, monitoring and controlling energy and for optimizing the management of energy sources so to match the energy and comfort needs of individual users. For instance, all single hardware pieces needed to be connected with sensors capable to interface with ICT solutions handling several software languages.

Loccioni proposed the idea of the Leaf House to a set of partners who accepted to join their technical and commercial competences to solve the various technical problems. Thus, during the project a network was formed that promoted cooperation among several suppliers in order to improve existing solutions and occasionally develop new ones that were both technically and economically more viable. An important motivator was using the building and infrastructure of Leaf as a location to conduct tests for new energy saving solutions open to all partners. The aim of this paper is to report our preliminary findings on an ongoing study on this network. More precisely we aim to analyze, in a dynamic context like new technologies for eco-sustainability, the origin and the development of the Leaf House network. Loccioni Group has engaged and mobilized a network of other actors in order to carry out the project so to involve and combine several technical and organizational resources (Håkansson & Waluszewski, 2002b). It is therefore interesting to investigate the interactions between the actors in this network, including the conflicts that emerged among them and how these conflicts were handled by the various actors. Other key questions are: What were the motivations and expected gains of the various actors in relation to the creation and distribution of a key value such as eco-sustainability? How does this restricted project network relate from a technical and an organizational point of view to the broader network that embeds the various actors? The rest of the paper is arranged as follows: the next section presents our

theoretical perspective and key concepts, then we present and discuss in separate sections the case material.

2. Theoretical frame: networks and resource interactions

We analyze the technical solutions and the industrial network emerging from the Leaf House project by focussing on the *resource layer* and apply a "resource interaction" (4Rs) model relying on a classification into four types of resources, two physical ones, products and facilities, and two organizational ones, business units and relationships (Wedin 2001; Håkansson & Waluszewski, 2002a, 2002b; Baraldi, 2003). We employ this model in order to further analyze how different resources have been combined and activated within this network in order to create environmentally friendly solutions. Within the frame of this model, eco-sustainability can be viewed as an important *feature* of the physical resources facilities and products, namely as the degree to which they in turn save key natural resources such as water, air, woods/forests. In other words, eco-sustainability is a value that is created when specific products and facilities cause as little as possible negative impact on natural resources. However, embedding such a positive value in a specific resource (e.g., a car, or a piece of furniture) requires that several resources get combined (Baraldi & Strömsten, 2006) in ways that are not only technically functional but that have minimal environmental impact. For instance, IKEA's table Lack present positive ecological features because it saves natural wood, as it is mostly empty inside, and because its lightness and flat packages reduce the pollution in its transportation (Ibid; Baraldi, 2006).

However, one can stretch the analysis of how really green a product or a facility is by considering its *interfaces* (Baraldi, 2003: 17-18) with as many resources as possible in the network stretching from raw materials through production to consumption, final use and disposal. In this context, a product may display different degrees of greenness in different moments of its lifecycle, as it is unlikely that the interfaces between the product and all these other resources have been taken care so carefully to reduce their environmental impact. It can be that focussing on greenness in a certain interface (e.g., between the product and a certain machinery) clashes so much with stronger economic logics and investments that it needs to be put aside. It typically takes an active choice made by the producers and the users of a resource to prioritize the green feature. Users are very important in this regard as they evaluate the importance of the green feature in relation to other features such as costs or performance and they can exert pressures on producers to increase a resource's greenness. Powerful and skilled users are even more important in the case of environmentally friendly technologies that have not yet been perfected or gained widespread diffusion: these users can act as *lead users* (von Hippel, 1986) and come with suggestions to improve the technology at hand, as IKEA did for totally chlorine-free paper in the 1990s (Håkansson & Waluszewski, 2002b: 94-6).

Achieving ecologically sustainable solutions often requires creating closer connections between previously separated networks, as shown by Andersson & Sweet (2002) in the case of retailing and recycling networks as food retailers in Sweden were seeking to reduce the environmental impact of their waste. The roles of the actors involved in the new "environmentally sustainable recycling of waste" network needed to change to accommodate the new way of performing activities and a higher degree of technical interdependencies (Ibid: 474). The need to bring together previously separated actors and resources in new network configurations holds even more if we are dealing with innovative buildings, like the Leaf House. A construction project is not only complex per se but it also create a complex set of integrate solutions that will be in use for several years, thereby affecting users and the environment for an extended lifecycle. However, the one-time nature of building projects makes it difficult for most suppliers to adapt to each other in terms of routines and technical solutions (Dubois & Gadde, 2000). In the Swedish context, this problem arises from construction companies' purchasing strategy that focus too much on *single-project* short-term efficiency, which impedes exploiting supplier-to-supplier and project-to-project long-term positive effects for both efficiency and technical development. It takes in fact a lot of energy and special initiatives creating long-term supplier relationships if one wants to attain technological innovation in

specific construction projects (Holmen, Pedersen & Torvatn, 2005). But Holmen, Pedersen & Jansen (2007) stress that a main constructor's initiative, such as the creation of a restricted supply network among selected suppliers, can have positive consequences in terms of mutual adaptations leading to robust technical solutions. Thus, it seems that the initiative of some key actor, be it a construction company or a main contractor, is important to induce other actors to combine their resources to devise project-specific solutions, as well as to identify replicable and economically feasible ones. It is therefore important that this actor is aware of the structure of the network that is being formed, of the content of the various network relationships, and of the match or mismatch between the goals of the other actors involved (Baraldi, 2008: 103-4). In the Leaf House case it is interesting to analyze the above issues, including how the main contractor Loccioni viewed and interacted with the network involved in this project.

A note on methodology:
This is a still ongoing study for which we made about 10 interviews (see among our Sources), which includes interviews at three of Loccioni's main partners in the Leaf House project. Moreover, one of the authors of this paper has been directly engaged in the Leaf House project and worked for a total of three years at Loccioni. Next to these direct horal sources and observations, data was collected in the form of numerous internal reports, brochures and specialized publications such as Home Energy Magazine featuring the Leaf House (e.g., Ceppa, 2009). We collected data with the explicit task to identify the key resources involved in the network that emerged around the Leaf House. Moreover, our interviews dealt with such issues as the goals that induced the various actors to participate in the Leaf House project and potential conflicts among them.

3. Introducing the Leaf Community Project

The Leaf House project is part of a bigger project called Leaf Community, aiming to create a zero-emission neighbourhood in the Marche region of central Italy. Loccioni started at the end of 2007 a collaboration with Federico Butera, a professor in Environmental Engineering at Politecnico di Milano and an expert in ecologically sustainable buildings. Loccioni assumed that existing technologies as well as investments in research and development would enable to create a territory where the impact of man on nature would be minimal. The original idea was to create a community where it would be possible to live in a zero-carbon-emission house, to move with electrical or hydrogen cars and to work in eco-compatible buildings (see figure 1). The most important element of the project would be accordingly the "Leaf House", a building where energy is produced entirely by renewable sources without CO2 emissions.

INSERT FIGURE 1 ABOUT HERE

The Leaf Community was officially launched in the end June of 2008, when the Leaf House was inaugurated, after 8 months of work. The house is composed of six apartments including first of all a laboratory for new clean energy technologies (see figure 2 &3). At the moment 8 people live in the Leaf House, both males and females around 30 years old. These are employees of the Loccioni Group that accepted to live in the house for free while testing all its parts and structures. According to these people the house is very comfortable, but sometimes there were technical problems such as in the air flow from the ventilation system. Loccioni continuously analyzes the behaviour of the people who live inside the building in order to understand for instance the patterns of energy consumption associated with different lifestyles at different hours of the day or days or the week. Loccioni expects to use this knowledge in order to develop and offer on the market customizable technological solutions for building automation and energy consumption control.

INSERT FIGURE 2 & 3 ABOUT HERE

3.1 Inside the LEAF House

The Leaf House is the first house in Italy boasting to produce zero CO2 emissions. One of the main principles behind the design and construction of this house was the idea that “the cleanest energy is the one you save!” Moreover, both energy saving and CO2 emissions reduction were attained with a design that followed the idea and the philosophy of old rural buildings which needed to be energy efficient because they did not have constant and rich energy sources. The Leaf House, with its six flats, is designed and constructed so that it requires a very limited amount of energy to ensure thermal comfort, both in the winter and the summer.

Integrated geothermal heat pumps and photovoltaic and solar panel system provide to the Leaf House more energy than it needs. 100-meter deep vertical pipes extract energy from the earth, but can be used in the summer also for cooling the house as the soil underneath is very wet. Moreover, the whole south-facing roof is covered with 150m2 of integrate photovoltaic panels, so that the Leaf House, like a real leaf, can receive from the sun the energy it needs. According to Clara Ceppa, of the Department of Architectural and Industrial Design of Turin Polytechnic University, the Leaf House’s solar-thermal system will provide 26,500 kWh per year of electricity, eliminating about 18 metric tons per year of CO2 emissions, and 10,200 kWh per year of heat energy, eliminating about 2.5 metric tons per year of CO2. A special technical solution has been installed by Loccioni and ENEL in order to have energy available also at night, when solar energy cannot be produced. The solution relies on storing the solar energy which is not immediately consumed: this energy in excess is stored thanks to an hydrogen production and storage system provided by ENEL (see figure 4). During the day, the photovoltaic panels produce energy to meet the direct needs in the house, but also to power a hydrogen generator (which simply separates water into hydrogen and oxygen). In cloudy days or at night a fuel cell reconverts the hydrogen into electricity for direct use in the house.

INSERT FIGURE 4 ABOUT HERE

Moreover, important energy savings are obtained because the house is thermally insulated and very efficient in keeping the requested temperature. For instance, walls are built with several layers of isolating materials such as expanded polystyrene. Moreover radiant floors constantly distributes heat, air is mechanically shifted between rooms where warmer/colder conditions are needed, and lighting systems and all home appliances are energy-efficient (see figure 5 and 6). A radiant floor is much more energy efficient than a traditional radiator system, as water needs to be warmed at only 28℃ in the radiant floor, as opposed to 60℃ in a wall radiator. Even water is saved in the Leaf House through a collection system which uses rainwater for toilets and the irrigation system.

INSERT FIGURE 5 & 6 ABOUT HERE

In order to monitor and control all the aforementioned equipment the Leaf House is provided with over 1,000 sensors. Based on sophisticated IT solutions, these sensors and meters are integrated and allow remote assistance and maintenance of the installed equipment. The information and measurements delivered by these IT systems allow the people leaving in the Leaf House to learn more about their own consumption habits in order to improve their energy efficiency. The same information is useful also for the Loccioni Group and the other suppliers of technical solutions in their quest for improving these solutions: the Leaf House works thus as a clean energy laboratory, a place to be analyzed but also visited by those who are interested in solutions for energy problems.

3.2 The Loccioni Group and the environment

The Loccioni Group was founded in 1968, nearby Ancona, in central Italy. The firm operates as a system integrator of monitoring and quality control technologies. The group sold in 2008 for Euro45 millions and employed 300 people. Loccioni targets various industrial customer segments with solutions to improve the efficiency and efficacy of industrial processes and their products' performance through test and quality control. Loccioni has installed its systems in over 40 countries, from the South America to the Far East. The company has now two manufacturing plants, but as a result of the Leaf Community project, they will soon have a new plant built in order to achieve zero-carbon emissions.

Since the beginning of 1990s Loccioni focussed on producing tailor-made solutions to face environmental issues such as saving natural resources at their customers' sites. For example Loccioni Group produced emissions analysis systems for incineration plants, mercury analyzers, and water treatment plant management systems. The aim of these activities was to support customers in their environmental problems. Afterwards, Loccioni started to invest in order to study the connection between technology and nature: the main goal was to find a solution satisfying the growing needs of comfort, offered via technology, but also respecting the environmental respect. More explicitly, Loccioni created a division dedicated to the energy business, which aimed to offer customers such advantages as energy saving, via better plants and equipment management, as well as reduction of greenhouses gases emissions.

3.3 Loccioni's supplier network for the Leaf House Project

Behind the Leaf House project there is a large network of suppliers and partners, including about 80 actors in all (see the Appendix). Loccioni managed to engage them because most of them were customers and suppliers of Loccioni since the beginning of the 1990s. After their acceptance to take part in this project, it became Loccioni's task to see that the technical solutions provided by the various actors could be integrated in the actual building. Among the 80 partners listed in the Appendix about 45 had only a minor contribution, both in economic and technical terms, as they provided for instance wholly standard solutions with limited financial impact. Instead 35 suppliers can be considered as more active and important. Loccioni classifies them into the following categories, based on their technical and economical role and contribution to the project:

1) MAIN PLAYERS: these are two actors, ENEL and Whirlpool. Loccioni involve these two long-term customers of theirs because they represent the two ends of the energy equation, as ENEL produces and distributes energy, while Whirlpool strongly influences the use of energy by the home appliances it markets.
2) TECHNOLOGICAL PARTNERS: this group includes the 9 actors who supplied backbone solutions ranging from ICT to controllers and from lighting to automation and solar panels. These companies are Alvarion, Beckhoff, Cisco, iGuzzini, National Instruments, Rittal, Schuco, Siemens, and Viessmann.
3) ENERGY SAVING PARTNERS: these actors provided solutions enabling to save energy such as insulating materials, wooden or high-conduction floors and water management systems. These 14 partners are Alpac, Bramati, Centro dell'Isolante, Centro Legno, Edil Loroni, Garofoli, Internorm, Leca, Lecablock, Rehau, Roccheggiani, Rototec, Silvelox, and Simonetti.
4) ENERGY PRODUCTION PARTNERS: these actors delivered solutions such as pumps, geothermal heat wells and solar panels. These six actors are Belimo, Galazzini Geotermia, Grundfos, SMA, Solar Spot, and Termoidraulica Agostinelli.
5) TECHNOLOGY INTEGRATION PARTNERS: this group of partners enabled to integrate the various solutions with such products as special wirings, controller and sensors and ICT. These 8 actors are Bticino, Eco-Control, Edildecor, Wimax, EndressHauser, Item, Trafag, and Wavemax.

Another important partner for the project was professor Federico Butera (Polytechnic University of Milan), who acted as a consultant and worked with the Loccioni's R&D team in devising the Leaf House since the first drafts in the beginning of the 2007. The Ancona store of IKEA also played a

role as it provided furniture for free to the house, as a way to increase its visibility as an actor promoting eco-sustainability. But the leading role in the whole project was taken by Loccioni, who was not only the inspirer but also the general contractor. This meant that Loccioni was in charge of guaranteeing that the "zero emission" target was reached in the Leaf House, both in terms of single components and the whole building. Moreover Loccioni conceived and developed one of the critical technological components of the Leaf House, namely the building automation system. This is a new solution which enables the measurement of several parameters inside the Leaf House: the integration of this system with the other technological components in the Leaf House was a key endeavour.

In identifying the actors to be invited to join the Leaf House project, Loccioni started from its existing customers and suppliers: basically it chose actors first of all from its business network. For example, the main players ENEL and Whirlpool are two historical customers of Loccioni; Grundfos and National Instruments have for several years supplied many of Loccioni's product areas. Only a handful of actors participating in the project are new acquaintances for Loccioni, such as Centro Legno and Rehau. In fact, Loccioni meant to prioritize its existing partners by giving them the opportunity to participate in a high-profile eco-sustainability project. Whenever an existing partner had the necessary technical competence this was privileged. However, not all the necessary competences were available at existing partners, so Loccioni explicitly asked the existing partners for help in finding them. Thus, several new partners with the right technical and commercial skills were found thanks to the indications of existing ones. In order to broaden the perspective on the Leaf House Project, the next three sections present how other actors view this project. We start from the other two main players next to Loccioni, ENEL and Whirlpool, and then we move to one of the major technological partners, Beckhoff, which stood for a key system for the Leaf House, namely the one for building automation. We conclude the empirical part of the paper with a preliminary assessment of the project.

3.4 The perspective of ENEL on the LEAF House Project

ENEL is Italy's main energy producing and distributing company. This former national monopolist was privatized in 1999 along with a process of liberalization of the Italian energy market, even tough ENEL still controls 80% of energy distribution in Italy. As part of a general eco-sustainability trend, in the last few years the company got increasingly interested not only in renewable energy sources, but also in how the energy it produces/distributes is actually utilized depending for instance on consumers' lifestyles and installed equipment. In fact, next to low-emission generation systems, reducing energy dispersion and increasing using efficiency are viewed as pivotal goals to solve current environmental concerns. ENEL considers technology innovation as an important drive in achieving such goals and therefore initiated a series of technical projects under the umbrella of "Environmental Leadership", coordinated by its office for "Innovation & Environment", a small but central business unit manned with 10 senior mangers that aims to pull together all relevant technical competences within the ENEL Group. For these projects, it is particularly important to find technical solutions that enable local energy accumulation (ideally within every house appliance), improve the energy-using efficiency of furnishing and architectural spaces and, with reference to transportation, implement electricity or hydrogen-based vehicles.

Considering the above technology-specific goals, the "Innovation & Environment" office considered as highly relevant to get directly involved in the Leaf project, due to its focus on energy utilization efficiency at the level of final users, namely private homes and local community. In particular, the Leaf House project allowed ENEL to test in a real using context one of its new technical devices, the "electronic meter" aimed to monitor in real time the energy consumption patterns of private homes. Moreover, the Leaf House includes a system for producing, storing and re-using hydrogen generated out of the energy produced in the house's photovoltaic panels: having this type of system installed in the house enabled ENEL to analyse, verify and test in a real life situation one of the key problems related to renewable energy sources, namely the storing and utilization of energy in those hours of the day when solar power is not available. Combined with the constant monitoring

of utilization patterns via the electronic meter, this situation at the Leaf House offered a very interesting testing opportunity for ENEL.

The Leaf project was not the first time ENEL and Loccioni cooperated: they had been involved in several joint projects, including the monitoring of air quality, another area where Loccioni's competence in measuring and controls turned useful for ENEL. However, the Leaf House was the very first project for ENEL covering the issue of zero-emission housing. The choice to join this project and the related network was not problematic for ENEL: they still cannot see any risk with participating, but mostly opportunities. Moreover, they have not stumbled in conflicts with other actors in this network, as all seemed to be interested in pursuing an innovative vision of housing and energy utilization. Even if the test context created is quite advanced from a technological point of view, it still remains enough realistic to provide direct inputs for further development.

3.5 Whirlpool and the LEAF House Project

Whirlpool is a major producer of home appliances. Originated in the USA in 1911, now Whirlpool sells for about $19 billion and employs more than 70,000 employees in over 70 plants and R&D centers around the world. Whirlpool's main products are laundry appliances, refrigerators, cooking appliances, dishwashers and mixers. Whirlpool Europe has 13 plants, of which 6 in Italy, where its headquarters are located, in Comerio. The relationship with Loccioni dates back to 1987, when Loccioni designed an automatic test system for washing machines, installed in their German plant in Schondorf. In 1989 Loccioni designed and delivered a similar system to Whirlpool's plant in Naples. Then the relationship developed constantly, with Loccioni delivering several testing systems for other Whirlpool products such as dish washers and refrigerators. Today Whirlpool is now one of Loccioni's most important customers in the home appliance business.

In the last few years, Whirlpool has showed a growing interest in environmental issues. They were carrying out several research projects on eco-sustainability in order to build zero-emission home appliances and keep their leadership in high performance appliances. Therefore, when Loccioni initiated the LEAF House Project, this seemed as an excellent opportunity to connect with the company's overall sustainability goals, in terms of development of more energy-efficient products. However, one challenge in taking part in this project was the fact that it was necessary to make available for the other partners and for the project new energy-efficient home appliances well before their official market launch: on several occasions product development of these solutions did not take into account the specific needs of the Leaf House Project. Whirlpool supplied every apartment of the Leaf House with a green set of electrical appliances and also created a special loft called ZEOS (zero-emission open space) which is a special laboratory where Whirlpool expects to install and test soon its futuristic concept of Green-Kitchen. Whirlpool views very positively its participation in the project: it did not entail any particular conflicts, but it was instead a forum that provided several contacts with other actors engaged in the area of eco-sustainability, with the possibility of entering into active collaborations for the future.

While with the building of the Leaf House an important step can be said to have been accomplished, namely demonstrating that a totally zero-carbon-emission house is feasible, there are many issues open for the Leaf Community project and for Loccioni's involvement with eco-sustainability. A first issue is how to replicate this so far unique achievement, either in terms of single solutions or of the integrated whole. While reproducing in larger scale single solutions is easier, it may not solve the complex problem of achieving zero-carbon emissions; on the other hand, reproducing the whole integrated solution is certainly very costly and complex per se, including the need to adapt to local contexts, regulations, climate etc. Still, extending a complete solution such as the Leaf House to other location or even countries is highly relevant: for instance, current regulations in the UK require that all newly built houses be zero-carbon emission starting from 2016. The experiences gained and the specific solutions devised for the Leaf House project can therefore turned useful elsewhere. And this was indeed one of the driving forces that induced Loccioni and the other partners to invest and participate in this project.

3.6 Beckhoff's role in the Leaf house project

Beckhoff Automation participated in the Leaf House project via its Italian subsidiary, manned with 17 employees and selling in 2007 for Euro 7 million. This subsidiary belongs to a larger group with about 1,000 employees and Euro 232 million in turnover. Beckhoff develops and markets automation technology solutions including industrial PCs, fieldbus components, automation software and drive technology. Beckhoff had been supplying Loccioni for several years with automation solutions and had been acting as a "consultant" for a number of technical projects. The positive experience of dealing with Beckhoff, their highly innovative products, large portfolio of solutions and high level of customer care were key factors in bringing the two firms together for the Leaf Project. Moreover, Beckhoff had an extensive experience of building automation, including such reference projects as "Home of Today" (Munich), LTU Arena (Dusseldorf) and Holiday Inn (Russia). In accepting to join the Leaf Project Beckhoff aimed to increase their visibility on the market for eco-sustainability.

Beckhoff contributed hardware solutions for the core "framework" for building automation, one of the most complex systems for the Leaf House, developed together with Loccioni's IT manager, Mr. Olivi. For this building automation system managing information was essential because the ambition was that the many sensors placed in the Leaf House could constantly deliver a wealth of data. This various data needed to be tracked and transformed by the "framework" into measures representing different indicators of energy consumption. Business intelligence software would then elaborate in real time the energy consumption trend for every user. The complexity of the Leaf House project was not a major problem because Beckhoff could engage directly for technical calculations their specialized engineers at the German headquarter. From Loccioni's side, the IT team invested a lot in order to develop competences to realize the "framework", especially in terms of business intelligence instruments, object-oriented software applications and design of GUI (graphical users interface). It was also very important to exchange with Beckhoff software prototypes before finalizing the building automation infrastructure: this implied a lot of interactions between the two companies and, even if both actors view the relationship very positively, there were occasionally divergent opinions on software applications and a short delay of one month in putting the "framework" into operations.

According to Beckhoff, the network around the Leaf House project included high profile and skilled actors, reflecting the need to handle a high complexity task like the Leaf House project. Beckhoff expects that this project will have positive consequences on the eco-sustainability sector, but it is too early now to see a positive feedback from the market on "zero impact" solutions and products.

3.7 A preliminary assessment of the Leaf House Project

The Loccioni Group invested in this project Euro 1.7 million for R&D, purchased materials/equipment and own salaries, and Euro 600.000 for marketing and communication related to the Leaf House initiative. Loccioni stood for by far the largest part of the investments in the project. Whirlpool, ENEL and Ikea were the only other actors that made direct investments, firstly as a contribution to Loccioni's marketing and communications costs and secondly "in kind". For example, ENEL contributed for free its hydrogen system (worth about Euro 18.000), while Whirlpool and Ikea granted respectively their home appliances and furnishings to the house. All other suppliers did not formally invest in the project, except for the time and efforts required to stay and develop their business relationships within the project.

The Leaf Project gave the Loccioni Group the opportunity to act for the first time as general contractor, meaning that they were responsible for the means and methods used in the construction and execution of the project. While some part of the project were contracted to companies belonging to the Loccioni Group (AEA and General Impianti) and the very land were the house was build belonged to the owner of the group, much of the construction and engineering work was contracted to external companies such as Edil Loroni (building) and Trillini Engineering (thermal design). The latter firm as was very important to face and prevent technical problems

during the early phases of project development. The “energy team” within Loccioni was constantly involved in close cooperation with these other subcontractors.

One of the most important advantages Loccioni obtained from this experience was a high visibility in the eco-sustainability context, in terms of communication and marketing strategies. However, from a technical point of view, it is not easy for Loccioni’s managers to forecast the applications of the technical solutions devised for the project “outside” the Leaf House, mostly because the Leaf Project is still a work-in-progress. What appears quite sure is instead that Loccioni does not aim to become a constructing company and is not interested in building any more carbon-neutral houses in the future. A possible future direction could be offering project design competence to potential users such architects involved in similar projects for zero-emission buildings commissioned by their customers. Moreover, the Leaf House technical infrastructure is working well and Loccioni is ready to offer on the market the “framework” solution for building automation developed with Beckhoff for several kind of buildings operated by owners interested in monitoring and reducing energy consumption. More broadly, potential customers for this technology could be system integrators or ICT infrastructure suppliers, but also companies interested in automating for example illumination control or internal logistics activities.

Another advantage of this project for both Loccioni and its partners is having now the Leaf House available as a real-life laboratory where to test and analyze solutions for the future. A key role of the Leaf House would be to verify if the suppliers products are really “zero impact”: for example Whirlpool is quality testing its “green home appliances” in the Leaf House, or Loccioni is carrying out tests of hardware components like photovoltaic systems and pumps. The important value added of this project according to Loccioni’s R&D manager consists in the capacity of Loccioni group to measure the performance of different systems when used together and in the same time. Moreover, thanks to the “framework” developed by Loccioni it is possible to evaluate the functioning of these various systems inside the Leaf House. Then Loccioni can suggest suppliers how to improve the performance of these systems. Therefore, rather than rushing into launching ready new products from the Leaf House experience, Loccioni prefers to focus now on the goal of providing its partners with technical results from the many tests carried out in the Leaf House on their various equipments and components. After that step, it may be possible for the suppliers to have idea about the quality and functioning of their products and decide when and how to market them. For partners like Whirlpool and ENEL it is in fact were useful to receive technical and use-related feedback on the state-of-the-art products they have installed inside the Leaf House.

4. Discussion: resource combinations in the Leaf House project

The network map on figure 7 presents the key resources involved this project. The most important technical resources are, next to the finished building in the centre of the network, the following pivotal components/subsystems: ENEL’s hydrogen plant, the ICT solution by Cisco, Solar Trading’s solar collectors, Whirlpool’s home appliances and, finally, the building automation system jointly developed by Loccioni and Beckhoff. Special combinations and adaptations were necessary for the hydrogen plant, Cisco’s ICT solution, the solar collectors and, especially, for the building automation system which relied on a unique “framework”. Whirlpool’s home appliances are instead standard, but have important interfaces with the rest of the technical resources in two ways: they are directly responsible for consuming the energy produced by the other technical elements and they are constantly monitored by some other technical systems in order to reach the overarching goal of the Leaf House, namely to control and contain energy consumption.

The combinations between the above technical resources was made possible by several connections between the corresponding social resources, that is, the business units and relationships involved in this network. All the key technical resources and interfaces are mirrored by important business relationships connecting the respective supplier/partner to Loccioni. It is important to point that this holds also for technical resource that was delivered as simply standard products to the project, namely Whirlpool’s home appliances. A reason can be here that

contributing to Whirlpool's own product development, on the one side, and measuring energy consumption by "green" home appliances for the whole project, on the other side, required a strong established relationship by the two parties. But it is where specific adaptations or joint development were necessary that strong pre-existing relationships were important the most, as in the example of the "framework" for building automation to which a competent and experienced partner like Beckhoff contributed important knowledge and skills. From a structural point of view, all the resource combinations that happened close to the Leaf House were directly supervised by Loccioni according to a "Loccioni-single external partner" interaction pattern and minimal "partner-partner" interactions. This interaction patterns may depend on two reasons: (1) the fact that very few completely new technical solutions needed to be developed and most elements were already existing, even standards, and simply needed to be integrated in a functioning whole, and (2) Loccioni took the role not only of general contractor but also of system integrator for the project.

These two reasons are important also for understanding an otherwise unusual outcome of innovative construction projects involving network of actors, namely the fact that the whole project unfolded with minimal problems in terms of timing, quality and technical solutions. It is also a bit puzzling the fact that this project was driven and the network was catalysed by a relatively small player, Loccioni which is certainly not a powerful actor, especially in relation to colossi like Whirlpool and ENEL. But Loccioni was able to apply its strategic intent in relation to other actors' interests to participate: it turned out to be rather easy to convince them and no particular conflicts emerged during the project. Does this situation hide something? How could a small actor like Loccioni plan all the necessary ingredients and put them together in a working whole to solve globally relevant environmental issues?

We can approach these issues by looking at the Leaf House network was "designed". This is a network that seems to include all the "necessary ingredients", that is, the *solution developers* (architects, environmental experts, Loccioni as the integrator), the *producers/distributors* of the key resource, namely energy, (ENEL as producer/distributor of energy and the various manufacturers of the machines/systems that will produce energy from sunlight or earth heat) and the *users* of energy (Whirlpool, as a manufacturer of machines that use energy). But in analyzing this network and its technical solutions, one should not forget that all this works well so far only on a small scale, as a test lab. This is actually not a real *full-scale* production and use of the solutions developed in the Leaf House. But to obtain a stable and truly embedded innovation there will need to be strong interfaces going from development, through full-scale production and use (Håkansson & Waluszewski, 2007: 152-6). In the real life and full scale situation (e.g., producing a whole city with hundreds of houses), the technological resources as combined in the Leaf project will meet many other new pressures next to the "green" one, namely a whole set of cost and large-scale efficiency issues and several investments already made by other actors than those involved in the Leaf House project. It will therefore be much more challenging and difficult for the whole integrated solution of the Leaf House to fit in a broader socio-technical network already burdened by existing heavy investments that the involved actors will not be willing to change (Håkansson & Waluszewski, 2002). As also suggested by our interviewees at Loccioni and the other companies, it is more likely that individual, non-integrated solutions devised for the Leaf House will find place and fit some restricted parts of the larger construction network, in Italy or maybe elsewhere.

5. Conclusions: the value of the Leaf House

This paper provided our preliminary findings from the analysis of the network around the Leaf House project. We reviewed the structure and key resources of this network and stressed the driving role of the general contractor, Loccioni. However, all the other actors we investigated view positively this network and stood to obtain some, although different form of value from participating in the project. While for the smallest actors the gains were related to supply contracts, the largest ones (ENEL and Whirlpool, and partly Ikea) were also ready to commit investments as they saw the project as a window to become updated on a key and growing area such as eco-compatibility.

Image and reputation gains were also important for the major partners, as being associated with a high profile project like this could become part of their communication strategies.

One of our research purposes was to investigate how this restricted project network and its technologies relates with the broader socio-technical network embedding construction solutions (not depicted in figure 7). To address this issue we can discuss the eco-sustainability of the Leaf House project beyond the fact that the house has zero CO2 emissions. In fact, a full scale implementation of zero-emission houses requires to evaluate the eco-sustainability of the production processes of the various single components. Even if we do not aim to provide a definitive answer to these questions, we can approach them with the 4Rs "resource interaction" model by considering the Leaf House first as a *facility* and then as a *product*.

The Leaf House is certainly eco-compatible as a unique facility, because while it is "working" day and night and is utilized by its tenants it produces no pollution and is totally independent from an energy viewpoint. However, the same artefact can be viewed as a complex product that has been not only conceived but also physically assembled by using a set of natural materials, components and subsystems that were transported and required in turn raw materials and manufacturing processes whose ecological impact deserves to be investigated in detail. What would be in fact the ecological gain of zero emission if single components were produced or transported with so great carbon emission or negative ecological impact to nullify the positive effect of the Leaf House as a facility. Thus the next key question is how reproducible is the Leaf House as a product and which costs would it entail to produce it in series, with which ecological impact from the whole construction project? While these issues remain open for further research, what can be stated certainly now is that the Leaf House played and plays an important role as a *testing* facility in a double meaning: firstly, by the simple fact of having been created, it allowed to experiment and prove that it was possible to build a zero-emission house with already existing technologies and, secondly, by being currently utilized for evaluating various environmental friendly components and solutions, it enables to refine and improve them for future large-scale production and launch. This is probably the main value of the Leaf House project for the main actors involved in it.

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-Visit at Loccioni premises, 5-2-2009
-Visit at Loccioni premises, 11-3-2009
-Direct participation to the Leaf House project by one of the paper's authors.

Figure 1: A stylized image over the LEAF Community, with the LEAF House (upper left corner)
(Source: Loccioni's LEAF Community brochure)

Figure 2 & 3: A couple of images of the exteriors of the Leaf House
(Source: Loccioni's brochure)

Figure 4: The hydrogen production & storage system of the Leaf House
(Source: Loccioni's brochure)

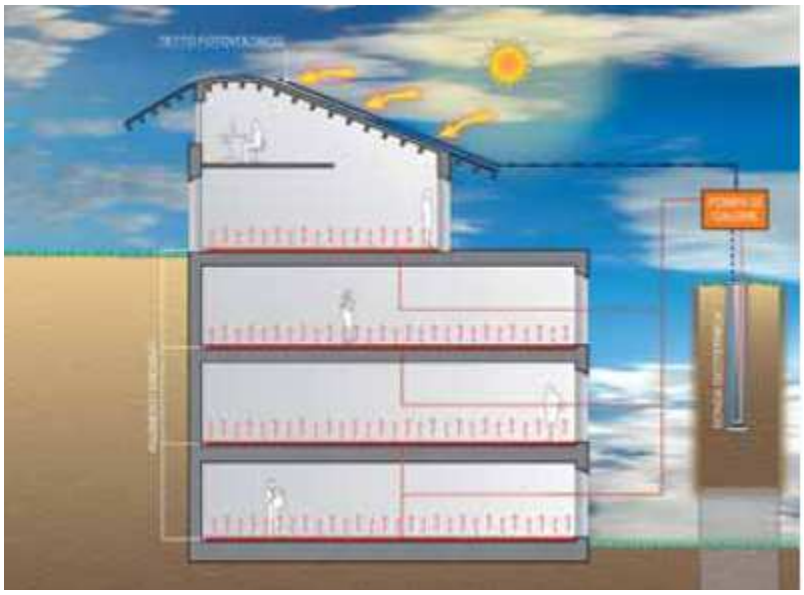

Figure 5 & 6: The thermal distribution system based on the heating/cooling floor
(Source: Loccioni's brochure)

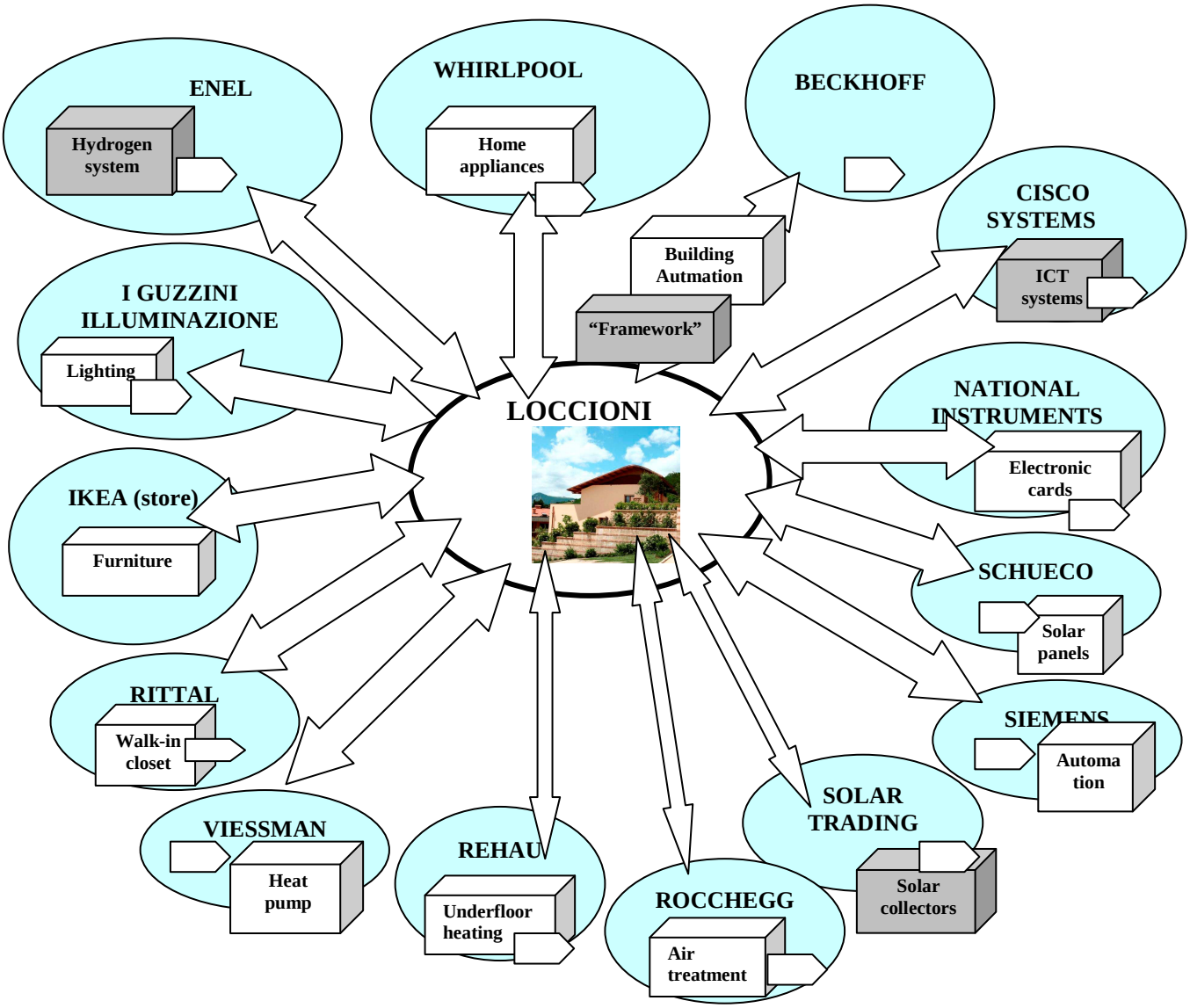

Figure 7: The network of resources involved in the Leaf House project

Appendix A: Loccioni's list of suppliers to the LEAF House project (Source: Loccioni internal)

Supplier	LOCATION	Component or competence supplied	Supplier's role	Previous relation	Strategic import-ance	Supplies adapted solution	Economic impact	Reason to choose supplier
BECKOFF	Nova Milanese (MI)	Home comfort solutions	Tecnhology partner, producer	yes	A		2,30%	Performance
BELIMO SERVOMOTORI SRL	Zanica (BG)	Electric valves	Second level supplier, producer	no	B		0,50%	Performance
BTICINO	Varese	Electric components	Second level supplier, producer	yes	C		0,00%	QUALITY
CENTRO DELL'ISOLANTE 2 SRL	Jesi (AN)	Thermic insulation	Second level supplier, reseller	yes	C		4,50%	QUALITY
CENTROLEGNO SPA	Fano (AN)	Wooden roof	Second level supplier, reseller	no	C		5,50%	QUALITY
CISCO	Vimercate (MI)	ICT	Tecnhology partner, producer	yes	A	X		Performance
ECO-CONTROL	Vimodrone (MI)	Comfort sensors	Second level supplier, producer	yes	A		0,10%	Performance
EDIL LORONI SRL	Mergo (AN)	Building materials	Second level supplier, installer	yes	A	X	14,60%	COMPETENCE
EMISFERA	Reggio Emilia	Wimax	Second level supplier, producer	no	A	X	0,10%	Performance
ENDRESS HAUSER ITALIA SPA	Cernusco s/N -MI	Temperature sensors	Second level supplier, producer	yes	A		0,40%	Performance
ENEL	Roma	Energy distribution	Main player, producer	yes	A	X		COMPETENCE
F.LLI SIMONETTI SPA	Castelfidardo (AN)	Building materials	Second level supplier, installer	yes	C		13,20%	Performance
GAGLIARDINI SRL	Monte Roberto (AN)	Building materials	Second level supplier, installer	yes	C		0,90%	Performance
GALAZZINI GEOTERMIA	Ponti s. Mincio (MN)	Geothermal heat wells	Second level supplier, consultant	no	A	X		COMPETENCE
GAROFOLI	Castelfidardo (AN)	Doors	Second level supplier, producer	no	C		0,60%	QUALITY
GITEK DI GIOIA GIACOMO SAS	Ancona	Alarms	Second level supplier, installer	yes	C		0,50%	QUALITY
GRUNDFOS POMPE ITALIA SRL	Truccazzano (MI)	Electric pumps	Second level supplier, producer	yes	B		0,20%	Performance
I GUZZINI illuminazione	Recanati (MC)	Lighting solutions	Tecnhology partner, producer	yes	C			Performance
IKEA Ancona	Ancona (AN)	Furniture	Unplanned support, reseller	no	C		2,90%	COST
ING. TRILLINI	Morro d'alba (AN)	Thermal engineering	Second level supplier, consultant	yes	A	X	1,40%	COMPETENCE
INTAC srl	Senigallia (AN)	Humidity sensors	Second level supplier, installer	no	A		0,30%	Performance
INTERNORM (f.lli Simonetti)	Gardolo (TN)	Windows & glasses	Second level supplier, producer	no	A			Performance
ITEM SRL	Valbrembo (BG)	Aluminum profiles	Second level supplier, producer	yes	C		0,30%	Performance
LECA	Milano	Dry clay	Second level supplier, producer	no	B		0,09%	Performance
LECABLOCK MARCHE SRL	Monsano (AN)	High-conduction floors	Second level supplier, producer	no	A		0,20%	Performance
NATIONAL INSTRUMENTS	Milano	Controlers & I/O devices	Tecnhology partner, producer	yes	A			Performance
ING. CIMARELLI	Jesi (AN)	Architecture engineering	Second level supplier, consultant	yes	A	X	1,40%	COMPETENCE
REHAU SPA	Cambiago (MI)	Heat emitting underfloor	Second level supplier, producer	no	A		1,50%	Performance
RITTAL	Vignate (MI)	Control cabinets	Tecnhology partner, producer	yes	C		0,10%	Performance
ROCCHEGGIANI SPA	Camerano (AN)	Air treatment unit	Second level supplier, producer	yes	A		1,80%	Performance
ROTOTEC	Lunano (PU)	Water mgmt systems	Second level supplier, producer	no	B		0,30%	Performance
SCHUECO	Sarmeola (PD)	Solar panels	Tecnhology partner, producer	yes	A		4,40%	Performance
SIEMENS	Milano	Automation	Tecnhology partner, producer	yes	A		1,30%	Performance

SILVELOX	Castelnuovo (TN)	External doors	Second level supplier, producer	yes	C		1,90%	QUALITY
SMA ITALIA	Milano	Control systems	Second level supplier, producer	no	C	X		COMPETENCE
SOLAR TRADING	Firenze	Solar tubes	Second level supplier, installer	yes	A	X	0,20%	Performance
TERMOIDRAULICA AGOSTINELLI	Castelfidardo (AN)	Installer	Second level supplier, installer	no	C	X		COMPETENCE
TRAFAG ITALIA SPA	Legnano (MI)	Sensors	Second level supplier, producer	no	A		0,10%	Performance
VIESSMAN	Pescantina (VA)	Heat pumps and heaters	Tecnhology partner, producer	yes	A		1,30%	Performance
VINCENZO BRAMATI	Castelplanio (AN)	Plumbing installations	Second level supplier, installer	yes	C	X	7,50%	COMPETENCE
WAVEMAX by CITY CARRIER	Gubbio (PG)	WIMAX	Second level supplier, installer	no	B	X	0,40%	COMPETENCE
WHIRLPOOL	Comerio (VA)	Home appliances	Main player, producer	yes	C			Performance
IME	Corsico (MI)	Electric materials	Second level supplier, reseller	yes	C		3,30%	QUALITY
SOVERCHIA GIOVANNI	Apiro (AN)	Gates and fixtures	Second level supplier, reseller	no	C		2,50%	QUALITY
EDIL DECOR	Castelplanio (AN)	Inner paintings	Second level supplier, installer	yes	C		2,10%	COMPETENCE
GIACOMONI MAURO	Serra S. Quir. (AN)	Inner finishing	Second level supplier, installer	no	C		2%	QUALITY
GRONDEX	Maiolati Spon. (AN)	Building materials	Second level supplier, reseller	yes	C		2,00%	QUALITY
IL CONTROSOFFITTO	Maiolati Spon.i (AN)	Plastered walls	Second level supplier, producer	yes	C		1,80%	QUALITY
VIVAI UGUCCIONI	Fano (PU)	Gardening	Second level supplier, reseller	yes	C		1,20%	QUALITY
EDIL PAVIMENTI	Castelplanio (AN)	Flooring	Second level supplier, installer	no	C		1,10%	QUALITY
FOR.EL	Castelbellino (AN)	Electric materials	Second level supplier, reseller	yes	C		1,00%	QUALITY
ING. COFANELLI	Jesi (AN)	Water recovery pumps	Second level supplier, consultant	yes	A		0,90%	COMPETENCE
S.A.P.	Monsano (AN)	Cabling	Second level supplier, installer	yes	C		0,70%	COMPETENCE
SPURIO LORENZO	Jesi (AN)	Flooring	Second level supplier, installer	no	C		0,70%	COMPETENCE
A.E.G. FLLI SAGRATI	Belvedere O. (AN)	Cabling	Second level supplier, installer	yes	C		0,60%	COMPETENCE
EDILIZIA ARTIGIANA DI GUIDO		Flooring	Second level supplier, installer	no	C		0,60%	COMPETENCE
BRUNATA	Danimarca	Meters	Second level supplier, producer	no	B		0,50%	Performance
CASAVECCHIA MARMI	Ostra Vetere (AN)	Marble tiles	Second level supplier, producer	no	C		0,50%	COMPETENCE
EDIARTIS	Cingoli (MC)	Pavements	Second level supplier, installer	no	C		0,40%	COMPETENCE
WIRE-CONNECT	Serra S. Quir. (AN)	Wimax cabling	Second level supplier, installer	yes	C		0,40%	Performance
ARTIGIANA PARQUET	Jesi (AN)	Wooden flooring	Second level supplier, installer	no	C		0,30%	Performance
TIBERI FRANCO	Staffolo (AN)	Underfloor installation	Second level supplier, installer	no	C		0,30%	Performance
CARLETTI MAURIZIO	Staffolo (AN)	Underfloor installation	Second level supplier, installer	no	C		0,30%	Performance
CICILIANI MAURO	Staffolo (AN)	Underfloor installation	Second level supplier, installer	no	C		0,30%	Performance
GIGLI STEFANO	Staffolo (AN)	Underfloor installation	Second level supplier, installer	no	C		0,30%	Performance
COOPERATIVA FACCHINI JESI	Jesi (AN)	Cleaners	Second level supplier, installer	yes	C		0,30%	Performance
EDIF		Electric materials	Second level supplier, reseller	yes	C		0,30%	QUALITY
NESSOS		Electric materials	Second level supplier, reseller	yes	C		0,30%	QUALITY
ANIXTER	Peschiera Bor. (MI)	Cabling systems	Second level supplier, reseller	yes	C		0,30%	QUALITY

UBERTINI S.R.L.	Castelplanio (AN)	Various installations	Second level supplier, installer	yes	C		0,30%	COMPETENCE
IMETER	Ancona	Electric materials	Second level supplier, reseller	yes	C		0,20%	QUALITY
MERCANTI FRANCO	Castelplanio (AN)	Metal workings	Second level supplier, reseller	yes	C		0,20%	COMPETENCE
FRANCO SCALE	Senigallia (AN)	Stairs	Second level supplier, reseller	no	C		0,20%	COMPETENCE
ELMAT	Padova	Electric materials	Second level supplier, reseller	yes	C		0,20%	QUALITY
BINI SILVANO	Rosora (AN)	Plastered walls	Second level supplier, installer	no	C		0,10%	QUALITY
RDZ	Ancona	Plumbing materials	Second level supplier, reseller	yes	C		0,10%	QUALITY
BIAGETTI		Copper wirings	Second level supplier, installer	no	C		0,10%	QUALITY
ECO-CONTROL	Vimodrone (MI)	Comfort sensors	Second level supplier, producer	yes	C		0,10%	Performance
PHOENIX		Electric materials	Second level supplier, reseller	yes	C		0,10%	QUALITY
GRAPOSERVICE	S:Maria Del P. (AN)	Graphic consultant	Second level supplier, consultant	no	C		0,10%	QUALITY
SARTI ERMENEGILDO	Castelplanio (AN)	Building materials	Second level supplier, reseller	no	C		0,10%	QUALITY