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# Towards Modelling the research in Green IT with Agents

Christina Herzog<sup>1</sup>, Jean-Marc Pierson<sup>1</sup>, Laurent Lefèvre<sup>2</sup>

## Abstract

Technology transfer between academia and industry has for long been an important factor for the development of our society. Different organisations mean also different priorities, different points of view and difficulties in working together. Having the same definitions, getting to know the different players, their aims will support the technology and knowledge transfer in order to develop new Green IT technologies. After analyzing the various positions of the different possible participants in projects, their different aims but also their common points, this article analyses how to build bridges for a common understanding of innovative projects in the field of Green IT and proposes a start of modelling the relationships with MultiAgent Systems.

## 1. Introduction

During the last decades IT is becoming an increasing role in our society. The research has for long been more related to reliability, performance and quality of service than to the ecological impact. Since alarming studies were conducted researchers, governments, funding organisations and companies started research activities in the direction of Green IT. Based on different existing definitions [19, 20], and motivations (social, economic, environmental, etc.) a definition of Green IT is stated, which is for now the basis for this work *“Green IT is the environmental and resource saving effort in the IT. The reason for using Green IT may arise from economically or ecologically interests. Actions can affect on the whole lifecycle of information technology - meaning from the construction via utilisation through to disposal.”*[6].

In [6][11], we analyzed the relationships between academia and industry for innovation in the field of Green IT. We focused mainly of the structural and behavioural differences of the two actors, as well as the different possible interactions they can set through research and development projects. Each agent (companies, researchers, etc.) is having a different access, a different pace and different aims which are making it difficult to have a permanent and an efficient exchange of results.

In this perspective, this article will outline the important findings on the definitions about technology transfers to give common understanding, and will determine the different points of view contextualizing the purpose to the Green IT field. Based on these particular studies, we will elaborate on building multi-agent systems to model the inter-relationships.

## 2. Technology transfer and mission orientated research

The definition of technology, which is used as the base in this article, covers the knowledge of the application of scientific knowledge. Scientific knowledge in the perspective of this work encompasses both empirical and theoretical knowledge; it means all directed processes and methods, including their practical usage and also material artefacts like products, prototypes and software. Technology is the special knowl-

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edge, know-how, in the sense of instructional knowledge and skills. Occasionally knowledge is divided into know-how, know-why, know-what, and know-who, but simplifying all these definitions are summed up under the definition of know-how [10]. In the economical context knowledge is seen as one factor of production respectively as a resource with an important impact on the technical progress (e.g. the virtuous circle in the Green IT that we analyzed previously in [6]) and the long-term development of companies. The difference to other production factors is that technology can hardly be measured quantitatively compared to raw materials or capital. The evaluation of the technology potential is therefore very difficult. In that sense, it is difficult to mathematically model with equations the potential for technology acceptance by the society, as it was outlined by Kiesling et al. in [12] in the case of innovation diffusion from the work of Bass et al [13] and followers. Technology can lose importance in case of exclusive usage and/or when new knowledge is creating new technology, reducing the value of the previous technology. The particularity of Green IT is the pace of development of new ideas and technologies. These are going on very quickly since there are many opportunities where Green IT can be included (Hardware, Software, Cloud Computing, etc.), speeding up the emergence of new technologies and their disappearance. The challenge is to be able to model this pace. Former mathematical models (following the works of [13]) and the associated Gaussian shaped maturity models may have difficulties to model this pace. Changing the perspective from the generation of technologies towards its usage leads to another useful consideration. The usage of technology suggests linking the term technology to the interaction between scientific/technical perception and the society. This is of particular importance in the field of Green IT because a general awareness about technical possibilities is missing together with a comprehensive study of the user acceptance level for greener solutions at the price of potentially degraded quality of services.

This section does not lodge claim of a complete classification of interactions of parties in all sorts of technology transfers. This is not feasible as classifications can be done with different parameters (vertical, horizontal, product-oriented, procedure-oriented, infrastructure-oriented transfer, etc.) [1, 2, 3]. To examine each interaction in an isolated way has only a limited value for the global point of view. Therefore we decided to focus on two kinds of transfers to reach a profound understanding of the potential interaction of parties. Indeed nonpointed [4, 5] and focused transfers are/will be the most profitable ways of technology transfer in Green IT. Reader may refer to [11] for detailed analyses of these transfers in Green IT.

To sum-up the key findings, we can outline the following: in non-pointed research, the diffusion of knowledge is passive, and feedback may or may not happen between the provider of technology and its receivers. As examples, large set of white papers, recommendations, leaflets made by industry, groups of interest or more rarely researchers are freely available online in the Green IT, in particular for datacenter construction and operation: EU Code of Conduct for Datacenter (EU CoC), The Green Grid white papers (53 white papers as of today), to name a few.

With the focused transfer it is possible that a precise solution is transferred target-oriented to the recipient. In this situation the partners are in an equal position. Mainly the constructor modifies and develops the technology according to the needs of the user. The developer has an active role as he supports the user in the implementation and in the gainful use. The interactive relation between the partners is resulting in a lot of work but also boosts the success of this technology. Similarly, a focused transfer can deliver results openly in the same way as a nonpointed transfer does, through open source software for instance. A crucial observation level is to know if the technology constructor sends implicit or explicit information to selected users (e.g. meaning a defined and limited circle of potential users, who he has already a relation with).

### **3. Analyzes of links in Green IT**

In [11] we proposed a thorough analysis of keys to contracted research. We will summarize here the main outputs of this research in line with a modelling in terms of multiagent systems.

For innovation oriented companies the academic research represents a fundamental resource of external produced technologies. The more the industry is oriented towards novelties on the market and leadership in technology, the more the cooperation with public research institutes is interesting for it. Academic institutes could be considered as the best partners as they have a wide experience in cutting-edge-research but also because their interest is not only focused on one product. They have no business interests, but an interest in independent and fair research - they are impartial! Despite this high synergetic potential academic researcher and industry operate in unconnected systems. In reality there exist a variety of options for arrangements in the cooperation, like patents, licenses, specific consulting.

### **3.1 Critics on the model**

Before moving on to the contextualization to Green IT, it appears necessary to discuss one hypothesis mentioned hereby: Researchers are impartial, and act for common welfare. This idealistic view is naïve especially in a fierce competition for faculty positions and lack of government funding. These ambiguous motivations will have to be included in any model.

### **3.2 Duties and responsibilities**

Companies are interested in having a green label on their products or that in their name “Green” is appearing. There are many different aspects making IT to Green IT. It starts with the production over the usage, the energy consumption, the cooling towards the recycling. The individual funding enterprises can get from the State, from individual programs are quite high, therefore they are interested in getting the “green label” [20, 21] even if it is only “green washing”. The Industry is more aware of this hype because they see the new market for business and for extending their field of activity than researchers who are more interested in long-term research, in a contribution to the welfare of the society. For instance a solution can be tight to a specific server (typically by a vendor industry) or general enough to encompass a variety of servers and datacenters at various scale.

### **3.3 Approach**

For the industry it is important that a perfect solution (e.g. Datacenter Infrastructure Management-DCIM software ready to use) is presented/proposed. Solutions, which are not costly, working immediately and non high-maintenance products are definitely the ideal outcome. Even if with more investments e.g. measuring the load of servers, or thinking about different methods of cooling the companies could achieve better greener solutions they keep in mind the profit and the management is setting the their priorities. Conversely the Green IT researchers prefer general approaches as their view is broader-they see also the welfare of the society and the interest to improve research-maybe in also other disciplines.

A very known topic concerns Server Virtualization. Server virtualization decreases the number of needed actual servers to handle users’ requests to services. This saves a large amount of energy. But the system has to be developed, to be studied and to be proved before large investments are made. Measurements are needed, different solutions challenged against synthetic and real workloads. Only universities had the opportunity to invest time and to create a platform to do so in early ages of server virtualization. With additional exchange with industry about their demands the result were achieved more quickly and more precisely: Indeed using real trace workloads is the key for researchers to prove their results. Unfortunately these workload traces are often kept secret and not shared by company without contracted research and non-disclosure agreement (NDA).

### **3.4 Criteria of efficiency**

Green IT must give more value, in terms of money to the company (e.g. stock options must go up, more possibilities for getting new contracts). Green IT is only interesting if there are tax advantages, if it helps to save money immediately and directly-companies often forget the impact of electricity consumption and the costs for electricity; as costs for energy are starting to make a point of discussion (not like costs for stuff) Green IT has to provide clear numbers how much costs can be saved in using Green IT.

For researchers the only criteria of efficiency is the scientific reputation, i.e. the number of published papers (and not research results). There are few conferences dedicated not only to technical Green ICT including other overlapping research topics like management or business process, where researchers can confront their ideas with industry players. Conversely industry forums are not regularly inviting researchers talks. It is mandatory to publish paper for researchers in well established conference or journals, and to reach at the same time a large community interested in energy saving. This criteria in the field of efficiency shows totally divergent points of view, and may result in difficulties in the transfer of technology and building up a long lasting cooperation.

### **3.5 Freedom of Action**

The research institutes are opened concerning new approaches, new ideas. The researchers are free in their decision which research to bring forward and where to put the focus but they have limits through resources like stuff, funding. Many open public calls, where Green IT is present, are limited to iterative research even if Green IT would allow breakthrough research. This effect may lead to difficulties between researchers and the management as the company sold a certain result to one of the clients and is not able to change the contract, even if the solution proposed by researchers having better results in saving energy.

### **3.6 Organizational differences**

What is clearly an advantage of the researchers is that they have existing cooperation with other research units in their university, while industry partner often have only one major experience or one major activity. Let's take the example of cooling in server rooms. It may appear that a company is able to build energy efficient servers but doesn't have the experience in modelling the airflow in a data center, which is another expertise. It belongs to another industry player for small companies, another department in large groups, can be simply taken from recommendations or best practices developed in the past, or develop with the help of academic partners. Researchers do have workshops on a large field of research where they exchange with each other, where they learn from other as well. Academics are linked to other fields of research and they are not in concurrence if they are in different research fields.

## **4 Towards multiagent systems**

Following the current trend in modelling the distributed interactions with multiagent systems, in particular in the field of innovation diffusion [12], we propose in this section a first step for modelling the technological transfer between researchers and industry and its impact for society.

In this initial modelling, we consider 4 kinds of agents: Green IT researcher, IT researcher, general researcher, society.

The technology developed and used by Green IT researcher has to fill the gap to IT researchers, researchers and the society. The valuation and the development of the links between these agents has to be different to model the difference in Green IT acceptance and usage. For instance, an IT researcher might

be more influenced by Green IT researchers on their usage of IT equipments than a researcher in another field. However IT researchers have a stronger influence in general on the society (since they represent older links with society) than Green IT researchers (who are less numerous and less seen). This means that the indirect influence of Green IT researchers towards society benefit from their direct influence towards IT researchers. The model will help to figure out how to increase the direct link.

For non-pointed research, given the passive diffusion of information, each agent influences regularly the adoption of Green IT technologies, knowingly or unknowingly. This means that the valuation of the interactions must be dynamic and reactive to possible feedback. For focused research, the Green IT researchers will influence directly and more strongly (higher valuation) only researchers (other Green IT, IT and general) through contracts. In that scheme the impact on society will only be indirect. It can be noted that the direct link between the IT researcher and the society is directly influenced by its link with the Green IT researchers. Also, focused research may produce freely available results as for instance open source software, that may influence directly the society, creating a loose link between Green IT researchers and the society. This link strengthens indirectly the link between IT researchers and Green IT researchers (through Word of Mouth dissemination or facing the fact that such solutions exist).

Another important aspect is the network topology between the agents. As stated before, the research may or may not be spread out towards a selected number of early adopters. The impact of the topology of the links between the agents has been shown [13] in a number of previous works as very influential on the final spread of the product. Small world and scale-free topologies are the most common ways of interactions used by the existing studies.

It is obvious that the interests of industry and the rest of the society are different. One could argue to separate the "society" agent between industry and others related agents. For industry, as it was noted in 3.2, the interests in Green IT is also influenced by the society itself (the Green labelling). Conversely the society is increasing its green interests after actions of the industry. Taking into account the different interests between industry and researchers this may lead to a loose link between them, as for example in their approach (see 3.3). This involves that links between agents are not only based on contracted research but also on looser links, for instance social links. Nevertheless it might be the case that the needs in certain areas may strengthen the cooperation, for instance when the law has to be enforced or incentives through funding is available to the benefits of both agents. As such the criteria of efficiency (see 3.4) is creating generally loose links between agents. This criteria of efficiency is also advocating for the need to consider Green IT researchers and industry players as different selfish agents that will evolve independently while trying to push other agents in their direction directly (see for instance part 3.1). The criteria of freedom of action (see 3.5) is showing the volatility of the research by Green IT researchers, i.e. they could easily move in and out one research topic without notice. In terms of multiagent systems, the related agents can disappear (or appear) at a faster pace than industry players.

From 3.6, we outline that the granularity at which we model the different agents is important. For instance an university partner is a collaboration can be split between administrative and research agents. For an industry agent, the different IT groups can be split also to different agents who influence each other.

It must be understood that this work represents only the first ideas towards a more complete modelling of interactions in the field of Green IT.

## 5 Conclusion

Green IT is a rather young research area and therefore there are still a lot of topics to explore. Energy saving, protection of resources, recycling, limited possibility in the utilization of technology are catchwords which are accompanying our society. Green IT has been recently embraced in different manners by academic researchers and industrial leaders. This should happen in a strong exchange with researchers of different fields but also in including companies, even if they are not at the first sight in the IT field. It is nec-

essary to enforce the cooperation between academia and industry to advance in the Green IT for our society. Pointing out some different objectives, we are convinced that there will be a better understanding between the partners, but also that there will be a change in the cooperation and in the transfer of knowledge due to the better understanding between industry and researchers but also there will be a change in the different funding systems.

The multiagent systems modelling appears to give the appropriate framework in order to better understand the links. Beyond what is presented in this paper, we still have to analyse a number of links, e.g. the importance of TTO (Technology Transfer Office) and the funding schemes, probably adding new kind of agents in the system. Also, the explicit objectives of this modelling system has to be described, and the actual influence rules (in terms of deterministic mathematics, probability, etc,...) has to be developed. Multiagent systems will help the decision makers about strategies about their involvement in Green IT. This will constitute our main future work.

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