Actors for innovation in Green IT

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Abstract

Green IT is a mandatory process required for energy consumption reduction and sustainable development. Many actors are involved in the development and adoption of Green IT. They range from single persons to research groups, companies, governments and countries. This chapter identifies actors for innovation in the field of Green IT, explores and defines them. Their interactions are detailed and their influence on the Green IT landscape is pointed out. A definition for Green IT is given as a common understanding to form a basis for all further investigations done on this sector. Then we detail the different actors of innovation in Green IT and outline their relationships to understand the keys for better development and adoption of Green IT.

Keywords: Green IT, Standardization, Innovation

1. Introduction

Green IT is a mandatory process required for energy consumption reduction and sustainable development. Green IT is a factor of innovation which can be considered as a large potential impacting contributor in terms of employment and societal improvements.

This domain is explored by a large set of academic and industrial research groups through the world. To be more impactive, it requires formalized links and support from several bodies (funding agencies, standardization bodies, technology Transfer Offices…). It is crucial to understand the interactions between these entities in order to improve Green IT adoption and advancements. This chapter proposes to define the set of actors involved in innovation in Green IT : standardization bodies, influential groups, funding agencies, universities and academic research institutes, companies, technology transfer offices, business angels.

We will explore involved actors through a standardized canvas which consists in defining the actors, giving some illustrative examples, analyzing the leverages for Green IT development and focusing on their potential for boosting or slowing down the Green IT development. This canvas will be also used for analyzing the links between selected actors in given scenarios.

While describing actors and their links in a formal model is fundamental, we have also investigated the implementation of such a model in a multi-agent system. We will briefly introduce this aspect so as to explain how the consideration of this chapter can be eventually

concretized in a simulator.

The organisation of this chapter is the following: It will quickly revisit the definition of Green IT in section 2. The formalized actors developing innovation in Green IT will be considered in section 3 and in section 4 actors supporting Green IT advances will be described. Section 5 will carefully select and analyze some scenario in order to illustrate links and interactions between subsets of actors. The section 6 will present models for innovation and quickly describe our methodology for implementing a simulator of the complex system while section 7 will conclude this chapter.

2. Green IT

In the scientific and public press, in the scientific community and in general discussions a large number of definitions of Green IT are existing. These definitions are taking several aspects into account like optimizing cooling, optimizing server placement in data-centres, shutting down unused devices from screens to complete servers, etc. They are more or less general. Some definitions also deal with economical aspects while others are mainly focusing on energy management. In that sense, sustainability and Green IT are often used interchangeably.

In our future work, we take the definition given by L. Hilty [1]. Talking about not only the use phase, but also the production and the end of life, Green IT must join in every phase. Green IT helps to decrease the ecological damages, which we all have to pay. Unfortunately the real costs for production and the "costs" for our environment are often not taken into account while we still will have to pay for them: hardware producing and recycling, with the societal aspects of people living in these areas where raw materials came from or are dismantled. Murugesan defines Green Computing in [2] the field of green computing as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems - such as monitors, printers, storage devices, and networking and communication systems - efficiently and effectively with minimal or no impact on the environment". Many such slightly different definitions of Green IT are existing due to the youth of this research field. The energy consumption awareness, the influence of hardware production on the environment, the recycling of IT equipment, etc. have become an important public topic only during the last years. Before, these issues were less discussed in IT and not at all in IT research.

Based on various definitions and motivations for Green IT a basis for this work is stated: "Green IT is the environmental and resource saving effort in the IT. The reason for using Green IT may arise from economically, socially or ecologically interests. Actions can affect on the whole lifecycle of information technology - meaning from the construction via utilisation through to disposal".

Green IT has to be seen as a movement towards sustainability. It can't be understood as a static notion. Following the definition in [13], Sustainability is at the confluence of its three constituents parts: ecological, economical and societal aspects. We argue that Green IT is 100% sustainable only in the best cases, but a lot of cases exist in which Green IT is less sustainable. Let's illustrate this statement with the example of servers hardware: continuing the usage of old equipment leads to higher energy consumption (for a company keeping old servers, given a certain performance), but at the same time disposing equipment too often may lead to a bad image as energy waste is nowadays considered to be a public issue. Both effects may lead Green IT away from sustainability. Buying new equipment will lead to a movement towards the area of sustainability (for the usage phase) but the costs for production have to be taken into account like the ones for recycling the old ones. It is known that when taking all environmental costs into account, the gain in carbon emission due to the replacement of old

hardware by new ones is not interesting in many cases (see for instance the comprehensive study [14] for notebooks where the authors conclude that a replacement can only be justified after 33 to 89 years). In general the movement towards sustainability will be less important than if costs for production, recycling, transport, storage, etc. are not taken into account. It has to be calculated for each action what the consolidated gain for Green IT is.

In the following, the actors for innovation in Green IT are considered, following the above definition. In some cases, actors may push more in the ecological dimensions, some others in economical dimensions, some in societal dimensions. It is idealistic (and not reasonable) to state that one actor is only driving in one direction, hence every actor will have a mix of interests for Green IT, from these three dimensions. These different interests may boost innovation differently.

3. Actors developing innovation in Green IT

As in any other technical or scientific field, many actors are involved in the development and adoption of Green IT. These actors are diverse by nature, by interest and motivation and by means of changing the field. They span from single persons (e.g. an activist, a researcher, a consultant), research groups in academia (research institutes, universities, academic research networks), companies (developing technologies, advising companies), groups of companies (influential and lobbying groups), governments (through public incentives, laws), groups of governments (e.g European Union).

All the actors interact in a kind of microcosm building and feeding each other, influencing and moving forward towards Green IT, at least towards their own view on Green IT. Before going through their links in section 4, we will oversee here some actors of innovation. The following actors may boost or slow down the development of innovation in Green IT depending on different factors.

Formally, in this section we will detail some of the actors involved in the development of innovation in Green IT. The methodology we pursue is the following: For each actor, we first define it, give some examples and we name the action leverages this actor can have in developing Green IT. We try to outline the boost this actor is giving to the field, or, conversely, the slow down it may provoke.

In [4] we studied the similarities and difference between academia and industry related to 13 dimensions grouped in 3 categories: the process of research and innovation; the criteria of success and the dissemination aspects; the organization. This section can therefore be seen as an extension of this preliminary work as well as its modelling.

We will explore involved actors through a standardized framework which consists in defining the actor (a), giving some example (b), analyzing the leverages for Green IT development (c) and focusing on the potential boosting or slowing down features (d).

3.1 Standardization bodies

a - Definition: This section does not aim at giving a full global view on the Green IT standardization initiatives, but rather tries to outline the role and links between and among the standardization bodies [5][6]. It is based on a study on the standardization bodies in the field of datacentre energy efficiency [3], complemented with newer development in standardization efforts.

Standardization bodies can be categorized in two categories: a) international formal

standardization bodies (and their regional, national counterparts); b) influential groups and professional bodies. The section will describe category a) in more detail. Category b) is described in the following section.

On Figure 1, one can see that the first providers of materials and tools that may make their way to actual standards are industry alliances, academic researchers, or both in collaborative projects. Some of the proposed ideas may be presented in one or several standardisation bodies to eventually become standards. These standards can in turn be used by governments (national, federal or European levels) as regulations in laws that must (and can) be enforced. Governments can use directly the materials as regulations, recommendations or labels. While the process for formal standardisation take a long time since a consensus have to be achieved between all members (especially states), the direct link with governments is sometimes more efficient. Finally, it must be noted that some metrics, tools, and methods provided by industry and academia are used directly by final users and may become de facto standards. In the centre of the Figure is the certification authority whose role is to certify that the measurements, claimed by suppliers of technologies actually follow the standards, the labels or the recommendations.

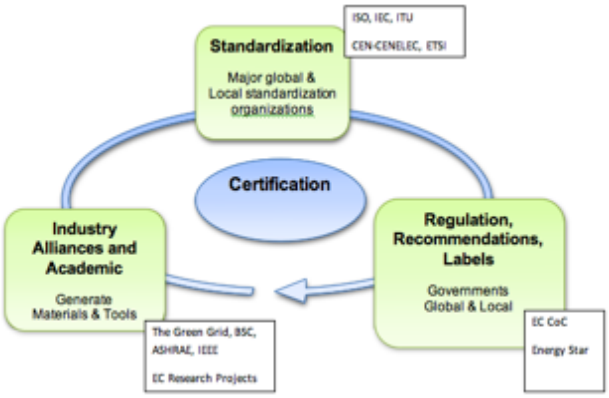


Fig 1: Standardization stakeholders

b - Examples of standardization bodies: The ISO (International Standardization Organization), the IEC (International Electrotechnical Commission), the IEEE-SA (Institute of Electrical and Electronics Engineers Standards Association) and the UN ITU (United Nations International Telecommunication Union) are three important bodies in the Green IT landscape.

c - Leverages for Green IT development: All three standardization bodies have activities in Green IT in general and in datacenter energy efficiency in particular. Their action lies in the development of standards, some of them individually, some of them in joint groups. The standards stand from the design, the production, the operation, to the recycling of IT services and materials. Some standards maybe used directly by stakeholders or by States for regulation.

For instance, ISO 14064-1 is used for reporting on greenhouse gases and makes use of the GHG Protocol, while ISO 14101 addresses the environmental impact of an organisation in general. Within IEC, Task Committee 111 is interested in environmental standardisation for electrical and electronic products and systems. UN ITU-T Study Group 5 is evaluating the ICT effects on climate change, publishing guidelines for using ICTs in an eco-friendly way. It is also responsible for studying design methodologies to reduce environmental effects. ITU-T L.1200 specifies the Direct Current interfaces while ITU-T L.1300 describes best practices to reduce negative impact of data centres on climate.

Joint Technical Committees (JTC) are established between ISO and IEC in specific areas. JTC 1/SC 39 is the joint sub-committee on “Sustainability for and by Information Technology”. The framework for describing metrics for energy efficiency is on the move and must be considered when developing new metrics for their standardisation: standards 30134-1 (General Requirements and Definitions) and 30134-2 (PUE).

At regional level, concerning European standardisation activities on Data Centres, the Network is done by ETSI (European Telecommunication Standard Institute), the Power infrastructure by CENELEC (European Committee for Electrotechnical Standardisation), the IT management by CEN, the cooling by ASHRAE (not EU specific) and the monitoring by CEN/CENELEC. The need for having joint and coordinated groups is obvious with so many different actors involved. The establishment of the Coordination Group on Green Data Centers (CEN-CENELEC-ETSI) helps to harmonize initiatives.

d - Boosting or Slowing down: Without doubt, the role of standardization is globally, and on the long term, boosting the adoption of a technology and its spreading in the society. However, in the context of Green IT, and IT in general, the duration of the standardization process is often not compatible with the pace of innovation. One such example is the TCP/IP protocol stack never standardized but de-facto standards. In Green IT, the same applies with the PUE that is still under development in standardization bodies while already widely adopted (sometimes misused) in industry.

3.2 Influential groups

a - Definition: complementary to standardization bodies, some influential groups propose to enforce and influence development of Green IT by addressing this issue at various levels. Some are country-based, others are interaction on a global level. Some are purely industrial, academic or a mix of both. Some of these groups can be activated by governments. Some of these groups can also propose and defend some standards.

b - Examples: The Green Grid is a non-profit organisation, open industry consortium of IT suppliers, end-users, policy-makers, technology providers and utility companies. The aim is to unite global industry efforts, to create sets of metrics and to develop educational tools. There is a strong link with the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), The Chartered Institute for IT (BCS) and the China Communications Standards Association (CCSA).

The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) is an organisation within the IEEE developing global standards in a broad range of industries. IEEE-SA promotes its own standards for electronic products. In the Green IT, it addresses desktop personal computers, laptops and personal monitors. The standard covers environmental aspects of a product including the life circle.

The GreenTouch initiative is devoted to explore energy efficiency in networks. THe main goal of this large academic and industrial consortium is to support an reduction of a 1000 factor for 2015. This group explores all levels of technology and innovation associated to networks: wired and optical, wireless, routing and switching, services...

c - Leverages for Green IT development: the influential groups can have a big impact in promoting and developing Green IT. By supporting collaborations and direct links between diversified partners, they enforce the promotion and dissemination of innovation.

d - Boosting or Slowing down: like standardization bodies, influential groups have a big

potential of boosting Green IT development. But contrary to these bodies, with some disruptive supported approaches (like in GreenTouch), they bypass limitations due to long processes.

3.3 Universities / Academic institutes :

a - Definition: universities and academic institutes include the groups involved through academic research in the development of Green IT. These groups can be financially supported through a mix of international, European, national, regional or private funding. The innovation in Green IT can come from permanent or temporary contributors: professors and assistant professors, researchers, postdoc, phd, graduate and undergraduate students, engineers...

b - Examples: these actors include purely university research groups or groups coming from research institute.

c - Leverages for Green IT development: academic researchers can have an excellent research overview due to their permanent exchange with other academic research institutions. This overview allows them to connect various research ideas and to be up to date with new developments in the research. Due to the participation in conferences, the collaboration in journals and other activities together with researchers from other universities a worldwide network of linked researchers is existing. This community is interacting on special issues of a well defined research. This specification leads to a very high level of scientific exchange producing new ideas with the possibility to prove easily if it makes sense to continue in this direction, if this direction can be considered unusefull or if this idea is already investigated - if yes, what are the existing but not already published results.

d - Boosting or Slowing down: with some “freedom” in exploring new and disruptive fields, this actor can be a major contributor in boosting innovation in Green IT. But researchers may miss an industrial link as they are not forced to head for industrial cooperations. This missing link may lead to the fact that the research work and results do not meet the industrial market.

3.4 Companies

a - Definition: A company can be defined as an “artificial person”, invisible, intangible, created by or under law, with a discrete legal entity, perpetual succession and a common seal. It is an association of individuals (natural, legal persons or a mixture of both). Company members share a common purpose, organizing their resources and skills to achieve a well defined goal.

b - Examples: In this actors set we find many different companies, from small SME to large groups. Their potential influences are related to their size and importance in the field, until they develop a product adopted widely. Besides the large historic companies like IBM, some new comers investigate especially the Green IT field (to differentiate their business value) and may become the next generation giant (or be brought by them).

c - Leverages for Green IT development: There is a always a customer-company relationship existing meaning that the company is close to changes in the society, the first one getting to know new trends, hypes and interests. Companies may react quickly on these changes as a new hype means also a new market for them, hence new business/money to make. A company may also create new hypes in proposing new technologies. In this relationship there is also the impact for developing innovations in Green IT. The society discussing about “being green and greener”, the companies proposing greener products with an additional feature creating a new hype, forcing the competitors to follow this direction and moreover inspiring research institutions and funding agencies to take new directions.

d - Boosting or Slowing down: On one hand companies may boost the innovation for green IT but on the other hand they also have the possibility to brake green IT and innovations in general. Companies are in general interested in making money, doing business and to stay on the market. If an innovation would decrease their turnover or favor another brand a company may protect an innovation with the aim not to bring it on the market.

In [4] the different approaches are presented and some are investigated more deeply to show the differences between academia and industry.

4. Actors supporting innovation for Green IT

4.1 Funding agencies

a - Definition: These might be an individual or an organization providing the mechanism in which financial assets are accumulated for the purpose of paying accrued pension benefits. Innovations in the Green IT are influenced by funding organisations and their open calls as deciding the topics of open calls funding agencies drive academia in the direction of a certain research.

b - Examples: The European Framework Program 7 and the new Horizon 2020, or the French National Agency for Research, the German FWF (Fonds zur Förderung der wissenschaftlichen Forschung), fall in this category. Countries may have dedicated agencies for Green aspects, like the US EPA for instance.

c - Leverages for Green IT development: Before starting an open call experts are invited to give their ideas about new interesting research. And already these experts are deciding the direction of the research for the upcoming years as these calls are in general fixed for minimum one year with a specific deadline to respect. By money incentive, their impact on Green IT development is direct (for the actors benefiting from the grants) and indirect (since these actors will have a societal and economical impact on their own).

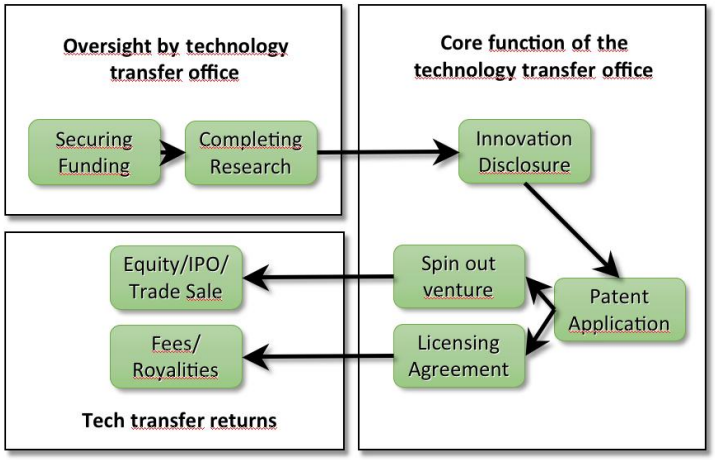
d - Boosting or Slowing down: These facts create already a difficulty as new research ideas, social movements and upcoming trends cannot be taken into account immediately. Additionally there is the high administrative workload creating difficulties to organisations applying for fundings. Looking for partners to have a consortium according to the rules of the funding organisation takes time and not always is the consortium formed by the necessity of the workpackages but more because partners are needed to respect the rules of the funding organization. Energy and money is wasted because rules for open calls are too strict, organisations are wasting time due to too much administrative requirements instead of using this time for new research. But their advantage is that they group research ideas and that their research funds are rather large. Funding agencies grant the fundamental research as other actors implicated in the innovation process are interested in new research and breakthroughs.

The role of funding organizations will have to change to become a real booster for innovative research. It does not mean that the traditional role has to disappear but additional roles have to be created.

4.2 Technology Transfer Offices (TTO)

a - Definition: Technology transfer describes the formal way of transferring rights from scientific research to another party. The aim is to use and commercialize innovative research and results. These rights might be intellectual property in form of patents, copyrights or any other form of IP, depending on the product or result of the research. This process involves

invention disclosure, licensing, funded research, also start-up ventures. Milestones payments sponsored research and licensing royalties may appear. Most academic and research institutions have formalized their technology transfer policies meanwhile. Not always these policies fit with the needs of the industry and TTOs have to find the best way to combine the 2 interests. TTOs are the interface between industry and research institution.



b - Examples: In France, the government created a special company status names as SATT, for Technology Transfer. Some universities created within this framework their own TTO, like for instance the TTT in Toulouse, France (Toulouse Technology Transfer). In other places, the initiative is let directly to the actors in order to create such intermediate offices.

c - Leverages for Green IT development: The technology transfer may be cut into 4 phases:

- The TTO has a relationship with the research institution. This relationship might be with one specific researcher, with the faculty or with the whole institution. The TTO monitors the ongoing research. The TTO provides links to commercial partners to fund ongoing research.
- Once the researcher files an invention disclosure with the institution the TTO evaluates the commercial perspectives and possibilities. If there is a potential the TTO will pursue the patent application.
- Once the patent application is filed the TTO will actively pursue commercial partners for licenses agreements or other forms of alliances.
- Fee, royalties emerging from the commercialization will be paid. TTO have the aim to become financially self-sufficient but institution have different aims like societal benefit, the institutions reputation.

d - Boosting or Slowing Down: TTOs are boosting new research as they observe the ongoing research as well as the industry and the market they can give quickly a feedback if the research will be accepted on the market and meets the needs of the industry. But TTOs are interested in financial independency and it might be the case that they only see the financial return and not the innovation for the society. Generally speaking TTOs are in some countries rather new and it has to be observed if they will become an important actor.

4.3 Business Angels

a - Definition: A business angel is an individual providing capital but also knowledge and contact data for a business start-up in a very early stage of their creation. Mainly business angels are successful managers having more experience than the founder of a company.

b - Examples: The World Business Angel Association is an international not for profit organisation with the aim to promote the idea of Business Angels. The aim of this international operating is to stimulate the exchange of knowledge and best practices in angel investing. This not-for-profit organization is based in Brussels and operates worldwide.

c – An obvious leverage of business angels is the money they invest in the Green IT startup. Since Business Angels invest money, they bring in the loop their knowledge of the field and their contacts. The start-up will have to pay back the sum invested. This may happen in exchange of convertible debts or ownership equity.

d - Boosting or Slowing Down: Business Angels have a global view over the industry in their working field. If a start-up needs support at the beginning phase business angels may help. They may provide contacts as well as financial support. Especially in Green IT as a rather young research field business angels are useful as they are experienced managers knowing the markets and potential partners find them more trustable.

But like as all other actors Business Angels have to be convinced about the idea in Green IT. They would decrease their reputation (or at least their credibility in front of the banks) in case the business ideas with the innovation would not work out.

4.4 Governments

a - Definition: At national or international level, governments can certify, regulate or enforce the usage of technologies, based on several factors. These factors can be related to Green IT and sustainability.

b - Examples: The Energy Star program is a widely adopted mean aimed at offering customers the possibility to buy more efficient products than required by law. In US, the Department of Energy is regularly checking the compliance of the products to the Energy Star label, developed by the Environment Protection Agency (www.energystar.gov). The European Union Code of Conduct (EU CoC) is another such inter-state level initiative. Its aim is to inform and foster the improvement of energy efficiency in the planning and operation of data centers. It is also a voluntary initiative to help designing and operating and reporting datacenters power consumptions.

c - Leverages for Green IT development: So far, the above initiatives have no enforcement in laws, and their impacts can be seen as neglectable, while it could help speed the processes. However the choice of governments to promote, even without regulations some standards or technologies have a direct impact on their visibility and attractiveness.

d - Boosting or Slowing down: Indirectly, these initiatives have impacts on Green IT development. Customers tend to choose the most efficient products; companies building energy efficient products promote these labels as marketing keys; datacenter operating under the EU CoC advertize it, display their increase in energy efficiency, and use it as a commercial advantages. The social direct and indirect influence must therefore be encompassed in the study.

5. Links and Interactions

As stated before, the different actors interact. These interactions can be of several kind: between actors of the same group (e.g. between researchers) or between actors from different groups (e.g. researchers and companies). Formally, one should detail and study all the links between all the actors in the section 3 and 4. We determined 8 actors, meaning a potential for

28 links to be explicitly detailed. We argue here that, among all these links, some have higher impact on the development of Green IT than others, or have the potential to have more impact if such links would be established.

Following the formalism used in the previous sections, we detail in this section some of the links by defining them (which actors are involved, what is the nature or the object of the link, which metric could be used to assess this link strength), giving some examples, what are the leverages this link develop for innovation in Green IT, and what is the impact of this link for boosting or slowing down the process.

5.1 Link between Universities

a - Definition: This link is the most common practice for researchers. Research work is done in networks, and this link represent the actual joint research output. It can be assessed by the number of joint publications in Green IT, the number of regular visits, and the number of contracts in which two research groups collaborate. Also, PhD co-supervisions witness a stronger link.

b - Example: The PhD candidate writing this chapter is co-supervised and produced some papers with both research groups. Also the COST (European Cooperation in Science and Technology) Action IC0804 (www.cost804.org), and the new-born IC1305 are examples of such networks in the field of energy efficiency in large scale distributed systems (such as Cloud, HPC, Networks, …) and ultrascale computing (up to exascale).

c - Action means of this link for developing innovation in Green IT: Each research group in universities has some level of freedom to investigate a particular topic, hence Green IT can be one of those. Also, some funding agencies may choose to favor Green IT if they already see some strong collaborations and high level publication results between partners. For instance, the COST office decides which Actions to fund: The presence of the named funded networks clearly put forward the research in Green IT. Not to be forgotten is the intrinsic scientific reputation of each partner (leading to more or less strong commitment to collaborate).

d - Boosting or slowing down factors in Green IT: While research group have the capability to collaborate easily, it certainly boost Green IT research when their choices is in this direction. However, two factors may limit the impact of this link: First is obviously the lack of money to hire staff or students to pursue or support the research, meaning the allocated grants are not in line with the ambition. Second is that a link may lose importance in one of the research group independently of the partner, due to a new policy of the university or better opportunity or growing links in other fields: One can not do everything and interests may change thanks/due to the above mentioned freedom.

5.2 Link between university and company

a - Definition: This link is probably the oldest one existing beside the interaction between universities. It is also one of the most controversial. The role of universities have changed during the last decade. Universities are becoming almost an industrial partner in a collaboration even if differences are still existing as you see in [4]. The link represents the contractual interaction between university and company and the value added to both partners with this (close) cooperation.

b - Example: There are a lot of examples existing but as these contracts are confidential it is impossible to mention some examples. Possible partners of universities in the field of (Green) IT are IBM, Microsoft, but also energy provider as well as big energy consumers or small SME

willing to catch up a new emerging market.

c - Leverages of this link towards Green IT: This link is important for each development in the field of Green IT. Companies are interested in new technologies for being the first one on the market and gaining money. A cooperation with universities is maybe cheaper than having an own research department. Howver many large groups have already their research department, some strongly linked with universities or employing former university staff (PhD; for instance). For universities it is an advantage having links with industries: Industry may finance research in paying for students, or paying for results. In overall it may be a win-win situation.

d - Boosting or slowing down: This link depends probably the most on the contract(s) signed by partners. As the partners have different interests as you see in [4]. These differences are slowing down the impact on Green IT as it takes a long time to define common interests and goals. Also, links may fade after the end of the contract, especially when university staffs are frequently replaced due to limited contract: The knowledge has to be built again almost from scratch, since only few permanent positions are available. This may change in the future as TTOs were created and their impact will be seen in several years. A company may also hide new technologies if these represent a danger for the business. In this case it is not slowing down but stopping the innovation. In a lot of cases the interaction between industry and academia is boosting the innovation in Green IT.

5.3. Link between standardization bodies and influential groups

a - Definition: This link details the relationship existing between standardization bodies and influential groups. The metric for assessing this link can be the ratio of representant from each influential group in one standardization body, in terms of absolute number and percentage. This will help to figure out their respective weight in the decision process and final adoption.

b - Example: One such example are the ISO/IEC Joint Technical Committees. Despite between open to members of the participating countries, there are only a few number of academic researchers in the formed groups, for reasons outlined earlier: Motivations for researchers are linked with their scientific reputation and career, and involvement in such bodies is not a key for these. More specifically, the JTC1/39 group mentioned earlier is strongly linked with the GreenGrid in particular for defining the Power Usage Effectiveness (PUE) first described by the Green Grid in 2007 and definition refreshed in 2012 [9], and now considered for standardization. When looking at the editors and contributors of the reference document from Green Grid, there is only one academic out of 29, and 20 companies represented. Only large IT-related groups are present in the list.

c - Leverages of this link towards Green IT: As explained earlier in 3.1 and 4.4, the impact of standardization and governments can be high. The stronger the link between influential groups and standardization bodies, the fastest the development could be. Indeed, standardization activities suffer from a long process duration that can not be followed by individuals, and only structured groups can actually influence choices.

d - Boosting or slowing down: Mostly driven by company-paid officers, standardization initiatives are therefore encompassing the interest of companies, member states trying to effectively defend their industry. One example comes with the metrics for assessing the efficiency of the datacenters. Each country may participate in the final document for standardization (and eventually vote for it). However, it should be noticed that the groups following this work are small in each country, and basically represent the same interests (sometimes even they are the same people). Other examples also discussed in the JTS1/39 group are the WUE (Water Usage Effectiveness), CUE (Carbon Usage Effectiveness) and the

more controversial GEC (Green Energy Coefficient). This latter promotes the use of green energy (which has also to be defined). Every country, protecting its industry, may behave differently in front of these metrics. For instance, France electrical power source is nuclear. Datacenters located in France benefit from a very good CUE value, but may have a bad GEC value compared to Canada for instance where power comes from mainly from water plants. The choice of which standard may emerge for regulations (for instance in EU directives and laws) is therefore a strategic issue for governments and industries.

5.4 Links between TTO and university

a - Definition: This link is one of the most crucial if universities, hence researcher, research groups, faculties want to commercialize innovations, results, and research. TTO (should) watch the ongoing research carefully in order to see important outcomes immediately. Important outcomes has to be seen under the scope of industrial importance. This link represents the value of a university for the industry.

b - Example: A lot of universities have a TTO now, but maybe they do not have this name as eg the project service office (PSB) at the University of Innsbruck. In France the government created the SATT having the function of the TTOs. As universities are mainly independent now, each may have a different contract with the TTO in charge.

c - Leverages of this link towards Green IT: As TTOs are the interface between universities and industry the influence on Green IT and a new research direction is rather high. TTOs are aware of new hypes in the industry and may therefore influence due the relationship with the university the academic research. TTOs may give advices concerning the direction of the research, meaning it is the duty of the TTOs to discover new hypes on the markets and to encourage universities to enforce the research for the industry.

d - Boosting or slowing down: TTOs and their interaction with universities may boost as well as slow down the innovation. The daily business of TTOs is dealing with contracts, IP, and research therefore TTOs and their relationship with universities is clearly boosting the innovations as administration takes less time, people working for the TTOs are up to date with research, in best cases they were researchers before working for TTOs. A close relationship between TTOs and universities is clearly an advantage for a collaboration with the industry. On the other hand there is a 3rd party joining and what was so far a contract between 2 parties (industry, academia) is now turning into a virtual contract between TTO, industry and university. Even if TTOs represent the university they also have the interest to become financially self funded. Their interest is to gain money in selling results and this may slow down the smooth flow between industry and academia.

6. Models for innovation

We outline in this section first steps for modelling the technological transfer between researchers and industry and its impact for society. Multi-agent systems (MAS) are well suited for modelling the interactions in distributed environments, and aiming at optimizing a cost function, either for each individual, for the community, or both. They have been successfully used in a variety of scenarios, including in Green IT where agents can be software pieces moving among the physical hosts to find greener places, or conversely agents are the hosts trying to minimize their own ecological footprint.
The usage of MAS is not limited to the computer science, and social science [11] uses MAS for instance to model loose and hidden interactions, where non expected behaviour can emerge from a crowd. In this trend, the authors in [10] propose a survey of the usage of multi-agent systems for innovation diffusion. They show that the diffusion of innovations theory is a

contagious process, driven by external influence such as mass media, and internal influence (word-of-mouth). The influence is derived from such influences in terms of mathematics and probability for anyone to adopt a technology. Then aggregate models are derived for communities of potential adopters. Showing the limits of aggregate models, they advocate for individual level models of innovation diffusion. Agent-based models are shown to outperform aggregate models in a number of dimensions. Each agent is an autonomous decision-making entity interacting with others and its environment through a set of rules. Micro-level interactions between entities (the interactions described in Section 4), lead to macro-scale dynamics in an autonomic emergent manner. Thanks to this modelling, the global status of Green IT can be studied and compared for different scenarios of cooperation, funding, influences between the partners.
We argue that it is feasible to model the innovation patterns in Green IT. In [5] we proposed a first step towards such a model. This study encompassed 4 kinds of agents: Green IT researcher, IT researcher, general researcher, and society. Building on the formalism described in sections 3, 4 and 5, we can develop the agent-based model further.

In this section, we will detail some scenarios using some actors and links just defined.
Scenario 1 (Direct Collaboration): A company is contacting an University research group in order to start collaboration. This collaboration will be effective by the signature of the contract between parties, and the TTO acts as an intermediate for determining Intellectual Property right, contract details and the like. The agreement states the amount of money allocated by the company, this is the input of the model. The output of the part in the model can be either a product, a patent, some publications, depending on the agreement.

Scenario 2 (Funded Project): This scenario includes 4 actors. A funding agency is raising a call for proposal in the Green It area. A consortium is formed between one company and two universities. Based on this consortium (quality of the consortium) and the research project proposed, the chances of being funded are determined. When funded, the output of the project will be both some industry-related results or academic-related outputs, the effective output depending on the quality of the groups, the size of the company, the publication history, and other factors.

Scenario 3 (Standardization activity): This scenario involves 4 actors. A research group develops one metric for assessing the energy efficiency of DataCenter. He tries to interact with the appropriate standardization body: This interaction depends on the body and number of academic participating. Then the metric is assessed in the standardization body where influential groups or companies may promote or conversely limit, its diffusion, based on their own interest and roadmaps. Therefore for this scenario are needed the interests of companies participating in influential groups and/or standardization bodies. The output in this scenario can be null or lead towards an effective standard in some time frame, promoted eventually for regulation by a government. The duration of each interaction must therefore also be accounted.

In these scenarios, different parameters are used as input or decisions patterns by the stakeholders. Building a statistical background from previous observed real-life interactions will help to determine the probabilities the actors behave in general. For instance, in Scenario 1, the amount of money can be computed as a mean of previously observed contracts, and the output can be probabilistically determine as a percentage for each possible output (patent, product, publications, …). It is obvious that, when the model set, we can observe the impact of increasing the amount of money in a collaboration (scenario 1), changing the grants allocated or the reputation of the partners (scenario 2), or the number of academic involvement (scenario 3). Also the indirect output of one scenario must also be accounted: For instance when a research

group is getting a new publication, it increases its societal impact (even though all publications may not have a high impact, their consolidated number have on the longer term), its reputation, its future potential success in contracts, and so on. The same applies for every actors that evolve during their lifetime.

To get some realistic input for the data at hand is one main difficulty of the modelling. To build properly the model, it implies a deep knowledge and precise data analysis from various possible sources. We have designed a survey towards the research and industry communities for tackling this difficulty that we circulated in order to retrieve / determine the different input for the models.

We are currently investigating some easy-to-understand metrics in order to assess the impacts of changes towards objective functions. These objective functions encompass a global Green IT innovation impact of each scenario (that can be computed from their outputs, with different weights associated to each output values) that could serve as decision maker help: For instance one could figure out the global impact of increasing a participation in project calls, or the impact of raising funds in funding agencies for Green IT, and so on.

We started to implement the proposed model using the NetLogo framework (version 5) [12], widely used in the Agent-Based Modelling community. Already preliminary experiments with few actors showed us the strength and expressiveness of the associated language to describe properly the actors (agents, links) of the system, and the associated tools to figure out some key metrics and objectives to assess.

7. Conclusion and future works

In this chapter we analysed the actors of innovation in Green IT, from the developments in research and technologies to influential groups down to standardization efforts. While many actors interact with each other, the interplay between them is an important aspect to take into consideration when trying to push forward the Green IT concerns. The future of our work will be to complete the modelling of these actors in terms of agents in a multi-agent systems, each actor being an agent behaving for its own interest and motivation, tight with others by a number of valuable links, and to determine quantitatively the main drivers or influential factors for a greener IT society.

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