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A Categorization of Green Practices used by Dutch Data Centers

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Abstract

Data centers represent today's major energy consumers. This is especially true in the Netherlands, informally called "the data center country" for Amsterdam includes 33% of the data centers of the whole European Union. To address this problem, the Dutch Government initiated the MJA (Meerjarenafspraken, or in English *multiannual agreements*), a nationwide initiative intended to improve energy efficiency of ICT products, services and processes. Major energy consumers, like data centers, actively participate in the MJA initiative to lower and optimize their energy consumption. To this end, the MJA members have documented the green ICT practices developed so far. The resulting documentation consists of an excel sheet of 83 consolidated practices. As a way to formalize, classify and share green practices, in our previous work we have proposed a green strategy model and have mapped the MJA practices accordingly. In this way we made explicit the fundamental knowledge elements of a green practice, namely the MJA green goals, green practices, and practice's effects. In this work, we take a further step into the content of the codified practices, by: i) *classifying the practices based on the concerns they address*, ii) *looking into the goals that data centers intend to achieve in relation to the concerns that practices address*, iii) *classifying the practices based on the role that IT plays*, and iv) *distinguishing practices that are software-related from non-software related ones*. In this way, we provide a picture of how data centers currently address the problem of reducing their energy footprint, possibly offering inspiration to both researchers (in progressing in their research further from what already exists), and practitioners (in reusing practices and learning what knowledge elements are important for informed decision making).

Keywords: Green ICT, green practices, data centers, energy efficiency, sustainability

1. Introduction

The environmental impacts and problems caused by IT are gaining more and more importance [1] [2] [3] [4]. A greater amount of energy is used and required to run server applications, to store data, to maintain data centers, to keep services up and running, etc.

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Practices, strategies and design solutions have been proposed to reduce the amount of energy consumption for the IT (e.g., [5, 6]). However, they are typically kept in-house, hence hindering knowledge transfer and cross-fertilization. This lack of sharing poses an important obstruction to progressing toward more sustainable and energy efficient ICT solutions.

In order to address this problem, in our previous work [7] we introduced an approach and a model used to codify green practices. This model formalizes the crucial knowledge to be transferred in reusable best practices, as well as information about its environmental impact and the economic effects (like necessary investments and possible gains). The model is shown in Figure 1: A green goal *is realized by* a number of green practices, and a green practice can achieve a number of green goals. Each green practice has a description to explain what the green practice means. A green practice *leads to* at least one environmental effect, which *causes* at least one economic impact. A green practice *belongs to* one category and it *has* a role that IT plays.

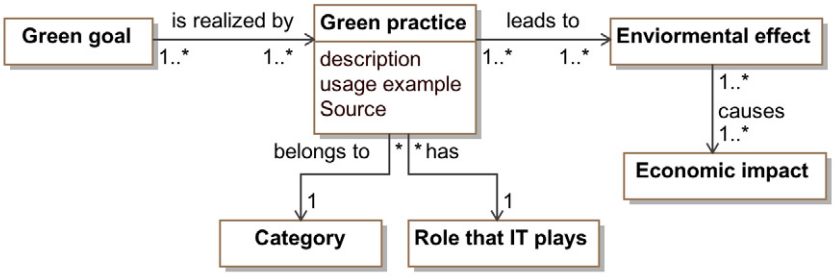

Fig. 1: The Green Practice Model

In this work, we carried out an industrial study on the green ICT practices of Dutch data centers. We gathered them and formalized the related knowledge by using our model. We then analyzed all practices to elicit the major types of practices (i.e. categorize them) for making them available in a more usable manner. More specifically, we classified the practices (i) *based on the concerns they address*, ii) *by looking into the goals that data centers intend to achieve in relation to the concerns that practices address*, iii) *based on the role that IT plays*, and iv) *by distinguishing practices that are software-related from non-software related ones*.

In this way, we provide a picture of how data centers currently address the problem of reducing their energy footprint, possibly offering inspiration to both researchers (in progressing in their research further from what already exists), and practitioners (in reusing practices and learning what knowledge elements are important for informed decision making). The identified categories also bring light to the expertise already available in data centers, hence suggesting the areas leaving space to further research.

The rest of the paper is organized as follows: Section 2 presents the results of this study (including all categorizations with the related observations). Section 3 includes our conclusions.

2. Categorizing green practices used by Dutch Data Centers

Our previous work [7] has started with a spreadsheet provided by members of the MJA [8], a voluntary agreement in the Netherlands between the Dutch Government, corporations and institutions and intended to improve the energy efficiency of products, services and processes. From this spreadsheet we identified 83 green practices meant to lower and optimize the energy consumption needed to run a data center; we then mapped the identified green practices into our green practice model in order to systematically document green goals, green practices, environmental effects, economic impact and their correlation.

In this work, we take a further step to look into the content of the codified practices in order to gain an insight into the green initiatives and solutions of Dutch data centers. The following describes each step of our study along with the results of that step and our observations.

2.1. Categorization based on concerns

First of all, we classify the practices based on the concerns they address. Green practices propose energy efficiency solutions ranging from reducing the energy consumption of servers to optimizing cooling within data centers. By studying the concerns addressed by the green practices, we gain an overview of which components (e.g. hardware, cooling facilities, organizational policies) of data centers have been drew attention to.

2.1.1. Results

The MJA green practices mainly focus on the following nine concerns. The number of practices addressing each concern is presented in Table 1.

Management This category includes all the practices that refer to the management and maintenance of data centers in terms of data storage, network, software, hardware and non-functional requirements such as availability and reliability. E.g., "log measurement data every hour".

Cooling The practices in the cooling category propose energy efficient solutions to provide cooling and reuse the heat produced by data centers. E.g., "run parallel redundant cooling only when there is additional cooling capacity left due to redundancy reasons or temporary under load".

Design This category includes the practices that have an impact on the decision to be taken during the design of data centers. E.g., "Make sure that heat-producing equipment that does not necessarily need to be on the data floor is placed somewhere else".

Organization This category contains all practices that can have impact on the organizational policies of data centers. E.g., "When providing insight of energy costs of an ICT service, include the energy costs in the total cost of the ICT services due to users".

Purchasing The practices in this category give insight on how and what to purchase when new equipment is needed in data centers. E.g., "use of SPEC (Standard Performance Evaluation Corporation) benchmarks" when deciding to purchase new equipment.

ICT This category includes practices that provide ICT solutions in terms of software technique and architectural solution to be applied in data centers. E.g., 'through virtualization, client workstations can use thin client devices, which consume considerably less energy than traditional 'fat client' PCs".

Emergency power supply This category contains practices to provide emergency power supply efficiency. As example you can refer to action 19 previously presented.

Humidification This category contains practices that control efficiently the humidification in data centers. E.g., "modern IT equipment is usually guaranteed to operate between 20% and 80% relative humidity; setting the same ranges for the cold air in the data center virtually makes the regulation of humidity redundant".

Lighting This category includes practices to get the light right and the right lights in data centers. E.g., "High frequency fluorescent lamps, energy saving lamps and LED lamps are all good choices for energy efficient lighting. It is important above all to produce not too much light and to turn off the lights when not needed".

Table 1: Categorization of MJA green practices based on concerns

Concerns	Number of practices
Management	20
Cooling	20
Design	17
Organization	11
Purchasing	5
ICT	5
Emergency power supply	3
Humidification	1
Lighting	1
Total	**83**

2.1.2. Observations

Management, cooling, and design are the most numerous categories of green practices. From Table 1 we can see that they contain 20, 20 and 17 green practices respectively, which is in total about 65% of all the green practices listed in the MJA spreadsheet. This suggests that experts consider most important (and have more expertise on) how to save energy by closely monitoring and managing energy consumption, by properly designing a data center, and by applying energy saving techniques for cooling and heating.

Although generally speaking lighting consumes a lot of energy, too, it is (intuitively) less critical for data centers as compared to office buildings. This might be the reason why only one practice addresses lighting. Of course, should practices be adopted in a domain different from data centers (like for instance energy-efficient buildings) lighting might before much more relevant and attract the development of more green practices.

2.2. Categorization based on goals in relation to concerns

We specifically look into the goals that data centers intend to achieve in relation to the concerns addressed by the related practice. Each data center has its own environmental goals when adopting a green practice. Some data centers' motivation for achieving environmental goals is driven by governmental regulations. As a consequence, these data centers often have quite generic goals such as *reducing Co2 emissions* or *improve energy efficiency*. Other data centers that do realize the importance of greening their business often setup more specific environmental goals such as *green product disposal* or *improving energy management*. By analyzing what type of green goals are achieved by what type of green practices, we gain an overview of the importance of different environmental goals and different solutions to achieve these goals.

2.2.1. Results

Table 2 shows the number of practices addressing the five major goals elicited in the participating data centers (by column) in relation to the concerns they address (by row).

2.2.2. Observations

The columns of Table 2 highlight that data centers are targeting two main goals, corresponding to the majority of green practices. The most frequent goal is *Energy management and good housekeeping*, directly followed by goal *Save energy in buildings and facilities*. This result confirms that the main focus in green ICT in the data center domain is related to cooling. This is further put into evidence by looking at the categorization of practices based on the concerns (corresponding to the rows in the Table), where most green practices are in category *Cooling* and *Design* - the latter ensuring optimal organization of the equipment for it to operate appropriately, but also consume less energy.

2.3. Categorization based on relation to software

We distinguish practices that are software-related from non-software related ones. Software consumes energy as well (through hardware) and it can be greener either by being more efficient itself (i.e. using less resources) or by making its supported process more sustainable (i.e. decreasing Co2 emissions). While so

Table 2: Categorization of practices based on their goals and concerns

Concerns	Energy management and good housekeeping	Save energy in buildings and facilities	Improvement of data center's external energy efficiency	Green product disposal	Optimize the use of appliances
Management	20	0	0	0	0
Cooling	2	17	0	0	1
Design	11	4	1	1	0
Organization	9	0	0	0	2
Purchasing	4	1	0	0	0
ICT	0	0	0	0	5
Emergency power supply	0	3	0	0	0
Humidification	0	1	0	0	0
Lighting	0	1	0	0	0
Total	**46**	**27**	**1**	**1**	**8**

far most of the green IT efforts have been focused on hardware, it is interesting to know how much effort has been put on software solutions by Dutch data centers.

We consider a practice to be related to software if the description of the green practice mentions application deployment, reorganization of software or data management and so on. For instance a practice says "if redundant applications are needed, they need to be virtualized". We consider it related to software because, first it proposes how to obtain redundancy of applications, and secondly because virtualization applications are needed to implement this practice.

2.3.1. Results

Table 3 presents the number of practices identified for each category and the number of practices that are referred to software.

Table 3: Categorization of practices based on their relation to software

Concern	Number of software-related practices	Number of non-software-related practices
Management	7	13
Cooling	0	20
Design	5	12
Organization	1	10
Purchasing	0	5
ICT	4	1
Emergency power supply	0	3
Humidification	0	1
Lighting	0	1
Total	**17**	**66**

2.3.2. Observations

Table 3 also shows that only 17 practices are referred to software, which is slightly more than 20% of all the practices identified, and they are only concerning management, design, organization and ICT. In our opinion, having more green software practices can have advantages for hosting service providers and for their customers. For example, green practices for developing green software in data centers could be investigated and proposed to the customers of the data centers themselves. The customers can be stimulated

to implement such practices, for instance, by offering them with discounts on hosting fees. Therefore economic benefits could be obtained by who requests a hosting service, by means of discounts, by the hosting service provider, and by saving energy in data centers.

A second observation, from a broader perspective, is that data centers (as any business organization) have developed green practices for what they call the *low-hanging fruits*, i.e. optimizing energy consumption in the categories that they *believe* promise highest returns on investments in the short term. Not much has been done so far to make data centers smarter (e.g. by optimizing or automatizing power supply, humidification, multi-tenancy, data migration and management. Trends towards migrating to cloud-based business models show that software-related practices will be soon needed in this area [9]. While higher investments are likely, the economic- and environmental benefits promise to be rewarding.

2.4. Categorization based on the role of IT

According to Gartner estimates, the ICT sector is only responsible for 2% of the total global CO2 emissions. The remaining 98% includes information systems that supports both business process from private sectors (e.g. companies) and society from public sectors (e.g. government), as well as end-user software applications that improve our daily lives. It would be interesting to know to what extent Dutch data centers address energy efficiency by making use of IT resources as compared to considering IT equipment only.

With this objective, we classified the practices based on the role that IT plays. Some practices focus on the optimal use of IT to minimize its environmental impact (i.e. *greening of IT*) whereas others focus on minimizing the environmental impact by using IT resources (i.e. *greening by IT*). The rest of the practices are relevant for data centers to achieve high energy efficiency but are not per se directly related to IT, e.g. encouraging employees to turn off light when leaving office, or using more efficient pumping techniques for cooling.

2.4.1. Results

Table 4 shows the results that we obtained for each category. In this way we can see how many practices refer to IT itself and how many of them are meant to lower the environmental impact of other sectors.

Table 4: Number of green of IT and green by IT practices

category name	Greening of IT	Greening by IT	Not applicable
Management	14	6	0
Cooling	6	2	12
Design	10	1	6
Organization	11	0	0
ICT	4	1	0
Purchasing	4	0	1
Emergency power supply	2	0	1
Humidification	1	0	0
Lighting	0	1	0
Total	**52**	**11**	**20**

2.4.2. Observations

In our opinion the MJA participating organisations should invest more efforts to design and develop green practices that bring benefits to other sectors. This stems for the fact that IT accounts for only the 2% of the carbon footprint worldwide. However, IT can potentially have high impact on all other sectors as well. In Table 4 we noticed that only 20% of practices are “greening by IT” (11 practices) while the others are “greening of IT” (52 practices). The latter are mainly concerning about management, organization, design and cooling. Therefore, in our opinion, data centers should always keep in mind the good impact that IT can have on the rest 98% of carbon footprint impact, and strive to help reducing the energy consumption in other sectors. The recent trend towards environmental sustainability will help to achieve this goal. For

instance, nowadays the sector Transportation & Logistics mostly relies on ICT for its functioning: optimizing transportation services and logistics business processes will make them more environmental sustainable, too, by bringing both economic benefits (in delivering services at lower costs) and environmental benefits (in optimizing the support given by ICT infrastructures and applications).

3. Conclusions

Saving money on energy costs is a fundamental activity when managing data centers. Green practices must be designed, implemented and most importantly shared. Members of the MJA provided us with a list of green practices they currently apply in their business. Unfortunately, practices are hardly disseminated and made available, nor are they clearly describing the actions they prescribe, the environmental effects they have when adopted and their economic effects (e.g. necessary investments and possible gains). We investigated these practices to identify best ways to make them reusable.

While not surprisingly the majority of practices is related to hardware (data centers are mainly concerned about cooling, management and data center design), we could identify a relevant set of practices focusing on management and design that are related to software. Still, the number of software-related green practices is limited indicating a need of practice to grasp opportunities in greenify the software portfolio. Also, we envisage major research opportunities in finding solutions to realize sustainable and energy efficient software/software engineering. In addition, by creating software practices that can be used by companies that want to place their software in third party data centers, one would give indirect advantages and costs reduction for energy consumption, both for the hosting service provider and for the customer.

Our categorization is currently being validated in a larger project offering open access to green practices. Our online open library of green ICT practices can be found at: `http://www.greenpractice.few.vu.nl`. By using categories, one would be facilitated in finding the right know-how and transferring it to the own situation. Experimentation involving multiple organizations (other than data centers) as well as universities is in our ongoing research plans.

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