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Abstract. Information and communication technology has experienced a vast development and increased usage over the past few years. This development again yields to increasing energy consumption. In this paper we provide a research agenda that picks up this serious development and suggests first approaches how holistic energy efficiency could be introduced in enterprises without neglecting a company's performance and competitiveness. We propose *green Business Process Reengineering* as one opportunity to make further development more sustainable with respect to the resources of our environment.

Keywords: Green BPR, Cloud Computing, Energy Efficiency, Green IT

1 Introduction

Energy-efficiency in information and communication technology (ICT) has become an important issue over the last years. The highly increasing usage of ICT calls for intelligent energy-efficient technologies to handle and decrease the worldwide energy consumption. According to Amazon's estimations [1] the expenses for energy-related costs amounts to 42% of the total amount spend for cost and operating of servers (based on a three year amortization schedule). Even more critical is the fact that current data centers spend about 60% to 70% of their total expenses just for cooling their ICT equipment [2]. As more and more business processes in enterprises are supported by corresponding IT, energy efficiency of the IT infrastructure and whole business processes becomes an important target to cut costs and to improve the green image of an enterprise. Due to this dramatically increasing consumption of energy a few approaches have emerged targeting the optimization of energy consumption of hardware as well as data centers as a whole. Different vendors introduced techniques to throttle down their CPUs or turn off hardware parts that are idling, for instance [3]. The collection of all techniques, methods, and technologies aiming at an energy-efficient resource usage within modern ICT is summarized under the term *Green IT*.

The main problem within this development is that the currently proposed technologies are only designed for their particular and isolated scope but, however, do not provide a holistic view on a companies' complete ICT. As companies mostly consist of inter-operating processes formed as networks of inter-organizational partners, changes in a single processes may have impact on different parts of the network and thus a couple of other processes. Therefore, a holistic perspective

focusing on all aspects of reducing energy consumption, i.e., people, processes, and infrastructures is needed. In this paper we propose to use the Business Process Reengineering (BPR) methodology to tackle the gap of missing interconnection between existing stand-alone solutions and the holistic reduction of energy consumption in modern ICT. We call this approach *green Business Process Reengineering* (gBPR). In order to show how gBPR can be realized within enterprises in a holistic way, we provide a first taxonomy containing information on which parameters to measure the 'greenness' of a business process. We then show how gBPR can be realized and how it influences an organizations' business processes, IT infrastructure, and organizational structure.

The remainder of this paper is structured as follows: Section 2 summarizes the state of the art concerning Green IT and BPR and identifies the missing gaps. Section 3 proposes the vision of combining Green IT and BPR and discusses the chances and risks that may occur as well as some areas that need further research. Section 4 summarizes the proposed vision and proposes additional topics for future research.

2 Background and Related Work

Green IT in general focuses on a growing sustainability in modern ICT [4]. It characterizes the efficient use of environmental and computing resources with the primary objective to account for the 'triple bottom line': *people*, *planet*, and *profit* [5]. Considering the nature of modern ICT systems that rely on people, networks and hardware, the elements of Green IT may focus on a broad range of items such as customer satisfaction, management and organizational restructuring, regulatory compliance, virtualization of servers, energy use, or thin clients [6]. This comprehensive understanding of Green IT is again one of the most important issues for future development. Therefore, in order to achieve an energy-efficient and sustainable growth in future ICT it is necessary to consider the following aspects: (1) organizational structures and customer demands (*people*), (2) reducing green house gas emissions in processes, software, hardware, and infrastructure (*planet*), and (3) ensure the competitiveness of an enterprise (*profit*). This needs to be incorporated in a combined and holistic manner. However, there is no such holistic approach available so far. There already exist several approaches to reduce power consumption in hardware [7], networks [8], and data centers [9]. Green IT, however, consists of more than optimizing the energy consumption based on technical progress. From a companies' point of view it is also important to involve the people that form a companies' organization, people that are obliged to use ICT systems and the customers that need to be satisfied. However, while optimizing the energy-efficiency it is also important to keep a company competitive.

First approaches towards Green-IT mostly concentrate on a single specific element that depends on the objective that has to be optimized. They can fundamentally be distinguished between infrastructure and process optimization. Liu et al. [10], for instance, take the energy consumption of physical servers to derive a cost function for the optimal positioning of virtual machines within data centers. Hence, they directly concatenate energy-efficiency with costs which mostly drives companies' efforts in

Green IT. Berl et al. [3] aim at the reduction of green house gases with respect to energy-efficient infrastructures. For their proposed energy-efficient cloud computing infrastructure this aspect is also reduced to the power consumption in computing, storage and communication. A wider perspective is proposed by Ghose et al. [11] through annotating tasks of business processes with their carbon dioxide equivalent (CO2-e). This enables the optimization of the process structure regarding CO_2 emissions. Thus, the approach by Ghose et al. [11] is a first step to apply business process reengineering (BPR) methods to optimize business processes regarding their CO_2 emissions. This is in line with traditional BPR that has been long used to improve the efficiency of a companies' core business processes by fundamentally and radically redesigning them [12]. These radical changes enable companies to enhance their productivity and competitiveness by adapting state-of-the-art organizational structures and business processes that satisfy customer demands [13]. When thinking about Green IT we are faced with a very similar situation. However, as we showed in this chapter, current approaches towards Green IT do not combine BPR methods with infrastructure reorganization. Consequently, the vision we outline in the following aims at combining these two aspects.

3 A Framework for Green Business Process Reengineering

The previous sections highlighted the need for developing a comprehensive approach to support an energy-efficient ICT that involves the whole ecosystem of a company. Business Process Reengineering is based on such a holistic improvement approach and therefore provides a good starting point for considering energy consumption within and across complete enterprises. To make the effects of 'greenifying' modern ICT visible and measurable, it is important to define criteria that allow measure the differences between both approaches. We refer to such criteria as *Key Ecological Indicators* (KEI) as they are in fact special Key Performance Indicators (KPIs). Due to the holistic point of view KEIs may comprise various elements such as energy consumption, regulatory compliance, carbon footprint, the location of hardware, water consumption, sustainability, or recycling, for instance. It is important not to reduce this KEI only to a process level but to consider them across entire ICT systems. To illustrate our proposed framework we use a running example describing the company *Deal inc.* that buys goods from various manufactures and sells them to customers worldwide. Today, *Deal inc.* manages their shipment services (i.e., printing, packaging, shipping etc.) using an application running in their own datacenter.

3.1 Optimizing Business Processes

With respect to Green IT, the process optimization definition of BPR needs to be extended as changes in business process are faced to influence both KEI and KPI depending on the companies' attitude towards Green IT. The main challenge for novel approaches is to obtain processes that are functionally equivalent or at most similar to the former ones but maximize KEIs (i.e., are 'greener') when executing them. Therefore, new process models need to be derived by optimization algorithms. These

Optimization algorithms must take into account not to worsen existing KPIs on process level (or only worsen them to a degree that is acceptable by the enterprise). Several process optimization techniques known from BPR are possible including: (i) Dynamic binding of services implementing a process activity, based on their KEIs (ii) optimization of control flow and data-flow (i.e. introduce or remove parallelization) to optimize the KEIs of the whole process (iii) addition, removal or modification of (groups of) activities. In future work we will extend the work of [11] to identify suitable optimization techniques. In our running example, *Deal inc.* may decide to outsource their postal service by using ePost that is provided by Deutsche Post AG. This supports *Deal inc.* to digitally send their mail to ePost service which routes the mail electronically near the recipients' location, preventing the pick-up of the mail by a truck and thus decreasing emissions. This is an example of optimization technique (i) and (iii) as different services are bound and additional activities must be added or existing ones must be changed.

3.2 Optimizing Process Infrastructures

Another possibility to reduce the energy consumption of ICT systems is to optimize the underlying infrastructure. Introducing Cloud computing techniques, for instance, is one commonly referenced optimization that enables enterprises to decrease their carbon footprint by providing increased server utilization and provisioning of resources on demand [10,14]. This results in energy savings on both, customers and providers side. While improving server utilization increases the efficiency of data centers, cloud infrastructures also enable various opportunities to save energy on consumers' side. Think, for instance, about management tools that smartly coordinate the selective operation of computing resources. Constrained on given Quality of Services (QoS) such tools may queue upcoming requests and only deploy a particular computing resource at a specific time period of each day or when a defined threshold of requests is reached. Note, that this also requires a close association to the underlying business processes which purport their individual QoS. Due to the switching of computational power from local sites into cloud infrastructures thin clients also provide suitable opportunities in reducing energy consumption.

Let us recall the *Deal inc.* example. The CIO of *Deal inc.* may decide to switch computing resources from their own datacenter to a cloud provider. This allows the company to deploy exactly the amount of resources they actually need. They no longer need to provide a high amount of computing resources that most of the time sit idle to cover peaks of order requests, for instance.

3.3 Green Business Process Reengineering

We have shown that existing technologies are able to support Green IT and provide already today a wide range of opportunities for energy-efficient computing. However, through focusing only on particular areas of concern, the full potential for the optimization of KEIs is not used. Companies need to consider energy efficiency like any other aspects they use to improve their business processes on a holistic base. We

therefore propose to use gBPR as a methodology to comprise the stand-alone approaches for fundamentally and comprehensively redesign a company's processes, infrastructure and organization towards an energy-efficient ecosystem. This includes redesigning processes in a way so that they can make use of optimized infrastructure, such as Clouds. As a result, the new approach gBPR comprises means to enable enterprises to (1) sustainable redesign their business processes based on global KEIs, (2) integrate BPR and infrastructure optimization techniques (3) consider the trade-off between KEIs and KPIs, (4) avoid organizational inefficiencies through integrating the 'human factor', and (5) optimize the energy consumption beyond the companies' boundary by taking externally sourced services into account.

Taking our example, *Deal inc.* now wants to use gBPR to lower their carbon footprint even more. First, they decide to restructure their shipping process. The shipper picks up the charge only once instead of three times a day. This will reduce, e.g., the KEI "CO_2 *emission*" of the shipping about two-thirds but also ensures next day delivery provided by the shipper (KPI). Secondly, they decrease the communication with the shipper to a once per day basis as the charge is picked up only once a day. Through the new Cloud infrastructure of *Deal inc.*, the company is now able to start up the necessary computing resources to process the shipping paperwork once a day and shut them down after the communication with the shipping company is completed. Through the combination of process restructuring and using a more elastic infrastructure, *Deal inc.* can now further optimize their overall KEIs.

3.5 Chances and Risks

The need for energy-aware computing is beyond all questions and our proposed approach has shown how current technologies can be utilized to realize such energy-aware environments. However, when performing gBPR there are also several risks that need to be taken into account. First, we need to consider that due to the globalization of economies, companies are always forced to act in a profitable way concerning specific quality of services demanded by customers. Therefore, we need a new systematic approach handling the trade-off between a company's traditional KPIs such as 'throughput', 'availability' or 'costs' and the objectives of Green IT. Second, switching proprietary IT into cloud infrastructures influences the organizational structure of a company. Similar to traditional BPR the 'human factor' needs to be integrated within the migration process [15] to avoid organizational inefficiencies [16]. This also includes the serious aspect of losing business through moving to the cloud. Third, the increasing amount of data volume occurred from new infrastructures needs to be tackled. Novel approaches are needed to transfer data in more intelligent ways by providing the advantages from a more decentralized computation paradigm, for instance.

4 Conclusion

We have provided an overview that illustrates various aspects for future research in the emerging area of energy-awareness in modern enterprises. We pointed out the

crucial demand for a holistic optimization viewpoint and how individual existing methods and technologies are important parts in reducing carbon emission. To strengthen the coherence between the various existing individual approaches we proposed a methodology that supports for a holistic energy-aware approach within and across enterprises, named *green Business Process Reengineering*. Future work will capture the development of first patterns on how green business process reengineering is able to be applied to enterprises.

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