Advancing Business Process Technology for Humanity: Opportunities and Challenges of Green BPM for Sustainable Business Activities

Constantin Houy, Markus Reiter, Peter Fettke, Peter Loos, Konstantin Hoesch-Klohe, and Aditya Ghose

Abstract The sustainability of organizations' business activities is currently an intensely discussed issue which is gaining increasing importance. The research field of Green Information Systems (Green IS) is concerned with designing and investigating innovative methods and techniques supporting a better sustainability of business activities based on information systems (IS). According to the IEEE tagline *Advancing Technology for Humanity,* IS can contribute to a more sustainable business world and thus to a betterment of humanity. In our contribution, we argue that techniques and methods from the field of Business Process Management (BPM) can considerably support the preservation of the environment while performing business activities and thus contribute to a betterment of human living conditions. Organizational as well as technological opportunities and challenges of Green BPM are investigated and demonstrated by means of exemplary application scenarios from different organizational contexts. In order to delineate the technological potential of Green BPM, a semi-automated approach for process sustainability improvement is presented by means of a further application scenario.

C. Houy (✉) • M. Reiter • P. Fettke • P. Loos
Institute for Information Systems (IWi), German Research Center for Artificial Intelligence (DFKI) GmbH and Saarland University, Saarbrücken, Germany
e-mail: constantin.houy@iwi.dfki.de; markus.reiter@iwi.dfki.de; peter.fettke@iwi.dfki.de; peter.loos@iwi.dfki.de

K. Hoesch-Klohe • A. Ghose
Computer Science and Software Engineering, University of Wollongong, Wollongong, Australia
e-mail: Hoesch-Klohe@uow.edu.au; aditya@uow.edu.au

J. vom Brocke et al. (eds.), *Green Business Process Management*,
DOI 10.1007/978-3-642-27488-6_5,

1 Introduction

The sustainability of business activities is currently an intensely discussed topic in research and practice. Taking resource scarceness, increasing pollution and the debate on global warming into consideration, more and more organizations recognize the upcoming need to improve the sustainability of their business activities. The matter gains increasing importance in the business context and drives organizations to put more effort into enhancing resource efficiency and reducing the production of waste materials in the context of their business activities.

Besides enterprises' growing interest in the topic, sustainability related issues gain more and more importance in the context of the Information Systems (IS) research discipline as IS offer considerable potential for the improvement of business activities' sustainability. In this context, the current research field of Green IS investigates sustainability issues from several different perspectives (Watson, Boudreau, & Chen, 2010). Not only the sustainability of technological components of IS are addressed, which is the focus of Green IT research, but also topics like business processes, people and culture. Recently, first research agendas for Green IS have been developed and the relevance and potential of innovative IS research results for sustainability enhancement and the preservation of the natural environment have been stressed (Melville, 2010). This idea has also been formulated on a general level in the IEEE tagline *Advancing Technology for Humanity* which accentuates the potential of technological change for the betterment of humanity including environment protection (IEEE, 2010).

In the following, we argue that and investigate how the methods and techniques of Business Process Management (BPM) can support the sustainability of business activities referring to this tagline. BPM has become one of the most intensively discussed topics in the IS discipline. Besides the growing maturity of BPM concepts, methods and techniques, the field of research has gained tremendous importance in research as well as in organizational practice (Fettke, 2009). It provides adequate techniques for the design, execution, controlling as well as the analysis of business processes in order to improve value creation within single organizations as well as in inter-organizational value networks (van der Aalst, ter Hofstede, & Weske, 2003). In order to improve the sustainability of business activities, the techniques and tools of BPM have to be adapted to dedicated requirements (Pernici, Ardagna, & Cappiello, 2008). In this article these techniques and tools are summarized under the term "Green BPM" as an intersection of approaches and ideas from the fields of BPM and Green IS, as is shown in Fig. 1.

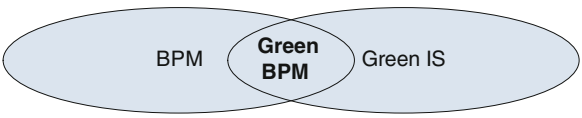

Fig. 1 Green BPM as the intersection of approaches and ideas from BPM and Green IS

First approaches and scientific publications on the topic of Green BPM already exist, e.g. (Ghose, Hoesch-Klohe, Hinsche, & Le, 2009; Hoesch-Klohe, Ghose, & Lê, 2010). Furthermore, a dedicated workshop on the topic was conducted at the 8th International Conference on Business Process Management (BPM 2010) in Hoboken, NJ (*1st International Workshop on Business Process Management and Sustainability, SusBPM 2010*) which focused on the investigation of the potential of BPM concerning business sustainability, e.g. (Houy, Reiter, Fettke, & Loos, 2011). However, the discussions on Green BPM methods are still in the early stages and so far only a few approaches exist. The contribution of our paper is a deeper going assessment and demonstration of both organizational and technological opportunities and challenges of Green BPM for the improvement of the sustainability of business activities. The paper is based on conceptual considerations and the investigation of several different Green BPM application scenarios.

The article is structured as follows: in the second section, underlying concepts and the idea of Green BPM are briefly introduced. The third section presents the potential of Green BPM by means of two exemplary application scenarios from different organizational contexts. Furthermore, an approach for semi-automated process sustainability improvement, the Abnoba framework, is presented and illustrated by a further application scenario. Thereafter, opportunities and challenges of Green BPM are derived from the findings before the article is summarized and concluded.

2 Sustainability Through Green BPM

Green IS initiatives generally focus on designing, building and operating sustainable IS in order to improve the sustainability of organizations. In our contribution the term organizational sustainability is understood according to the common definition. It is defined as an organization's ability to realize profits, to regard social needs and to sustain the environment at the same time (Wikström, 2010) in order to consider the needs of future generations (World Commission on Environment and Development, 1987). In our article, special attention is paid to the environmental and economic dimension of sustainability which can be improved by applying BPM methods and techniques. A better sustainability can be supported by higher efficiency of resource consumption; e.g. of IT infrastructures, or a lower level of fuel consumption of a transport medium in a business process. Furthermore, sustainability can be improved by a reduction of waste materials, greenhouse gases or noise produced by a business activity.

Business Process Management represents an approach which supports organizations in sustaining their competitive advantage (Hung, 2006). It comprises methods, techniques and tools for the design, enactment, control and analysis of business processes in order to facilitate an optimized value creation (van der Aalst et al., 2003). Today BPM is commonly understood as a continuous improvement process throughout the life cycle of business processes (Scheer & Brabänder, 2010) which comprises several phases visualized in Fig. 2 (Houy, Fettke, & Loos, 2010).

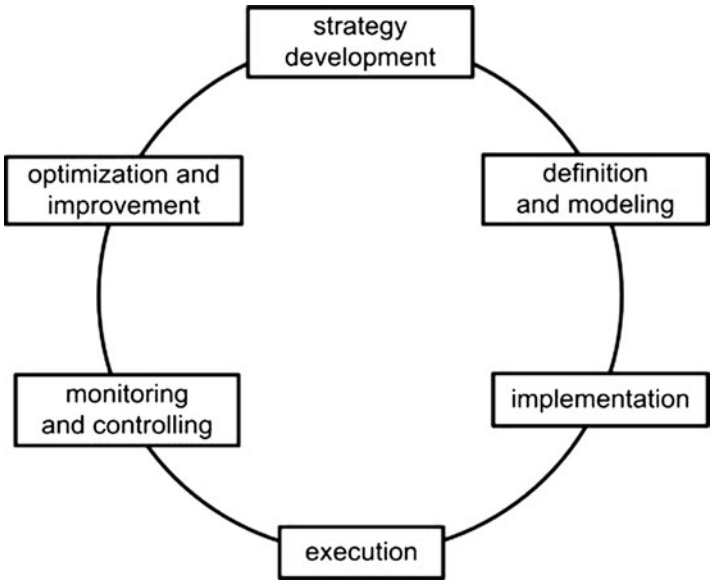

Fig. 2 BPM life cycle for continuous process improvement (Houy et al., 2010)

In this article the BPM life cycle will serve as a reference framework for the description of opportunities and challenges of Green BPM.

Green BPM is supposed to provide techniques for the design, execution, controlling as well as the analysis of sustainable processes in many different application areas. Common BPM techniques and tools can support the sustainability of dedicated Green IT initiatives like IT Service Management (ITSM) to a certain extent; e.g. by simplifying IT service processes. However, most common BPM techniques and tools are designed to support the efficiency of business processes focusing on costs and time. As already mentioned, these methods and techniques have to be adapted and extended in order to fully support sustainability initiatives concerning business processes.

The discussions on Green BPM techniques for modeling, implementing, executing and monitoring sustainable business processes are still in their early stages and so far only a few approaches exist. Ghose et al. (2009) have presented an approach for modeling and controlling the carbon dioxide (CO_2) emission in business processes. This approach aims at a process-based measurement of the carbon footprint of business activities. In recent publications, the understanding of Green BPM has been widened and the potential of Green BPM for improving the production of waste materials and the consumption of other, partly limited resources like water or fossil fuels, has also been considered (Hoesch-Klohe et al., 2010; Houy et al., 2011).

In Green BPM every business activity in a process model can be annotated with an adequate ratio representing the consumption of resources and the production of waste materials. Model annotation is possible for different modeling methods, like

Event-driven Process Chains (EPC) or the Business Process Modeling Notation (BPMN), which will also be demonstrated in our contribution. By accumulating the annotated values, the total consumption of needed resources or the total production of waste materials in a process can be measured and controlled. This method facilitates an optimized organization of activities in a process and the controlling of the ecological impact of its execution. In order to investigate the organizational as well as technological opportunities of Green BPM, the two following sections present exemplary application scenarios as well as a semi-automated approach for process sustainability improvement.

3 Application Scenarios for Green BPM

At first, the *organizational* opportunities of Green BPM are delineated by means of two application scenarios. The first scenario is concerned with sustainable process management for typical IT services. The second scenario broadens the perspective and deals with business processes in general.

3.1 Sustainable IT Service Management Processes

IT services, like web or application services, are mainly produced in data centers. The concept of *Cloud Computing* represents one of the latest developments in the IT service provision context. The concept covers the provision of services based on IT resources which are distributed among several production sites, allowing for a dynamic adaption of capacities. Cloud computing intensifies the concentration of IT service production into data centers. Thus, data centers can be regarded as the hot spots of IT-related energy consumption. In order to produce IT services in a professional way, the application of management best practices and standards is obligatory. The corresponding ITSM standards refer to the principles of BPM. Most steps and procedures applied in ITSM are based on defined process models. Furthermore, both concepts are based on "Plan, Do, Check, Act" lifecycle approaches including strategy formulation, execution, controlling and continuous improvement. Moreover, ITSM standards include descriptions of the service offering portfolio, guidelines for successful service operations and the definition of service quality, typically described as Service Level Agreements (SLAs) which are commonly monitored and reported.

An established best practice supporting these services is the comprehensive IT infrastructure library (ITIL) framework which is widely accepted and applied in professional IT service organizations. ITIL describes standardized processes in the context of Service Delivery, e.g. Service Level Management or Capacity Management, as well as processes for Service Support, Incident Management or Change Management. However, the ITIL framework does not have a special focus on the

sustainability of ITSM processes. In this context, Green BPM can provide an approach for closing this gap and complementing the ITIL framework by sustainability concepts.

Interesting opportunities become obvious when Green BPM methods are used in the context of incident management. Incidents are usually defined as unplanned interruptions of IT services or as a reduction of IT service quality which require immediate reaction. According to our idea, this definition can be extended taking sustainability considerations into account. Thereby, incidents would not only be triggered if a deviation in terms of continuity and quality in service production can be stated. An incident should also be triggered if significant deviations in terms of a system's resource and energy consumption occur. If a system consumes too much energy after a reconfiguration, an incident can be triggered and the corresponding incident management process should be started.

An essential part of the extension of the incident management concept lies in the definition of *Green Service Level Agreements (gSLAs)*. It is necessary to introduce new indicators which define thresholds for energy consumption per transaction, total energy consumption or peak energy consumption within a certain period (e.g. *"service may not consume more than 10 kWh per 10,000 transactions."*). These new key indicators should be regarded as a precondition to operate an application system in a sustainable fashion. Nevertheless, they are an extension and may not replace, but complement traditional SLAs (Fig. 3).

Overall, defining Green Incidents and Green SLAs is an appropriate measure to implement the idea of sustainable IT operations into the concept of IT Service Management. It creates awareness for resource efficiency and supports management decisions in data centers. Nevertheless, resource efficiency and classical constraints such as reaction time, availability and downtime need to be balanced carefully.

Another example can be taken from capacity management which covers the planning and provision of physical capacities necessary for service delivery. Based on sales forecasts (e.g. *"100,000 online shop users next year"*), the process of capacity management defines the required physical hardware, as well as space and energy-related facilities in a data center. In this context, it is necessary to precisely forecast the required capacities. If the forecast is too low, additional capacities need to be installed on short notice. If the forecast is too high, overcapacities are installed, resulting in unnecessary capital expenditures and inefficiencies in

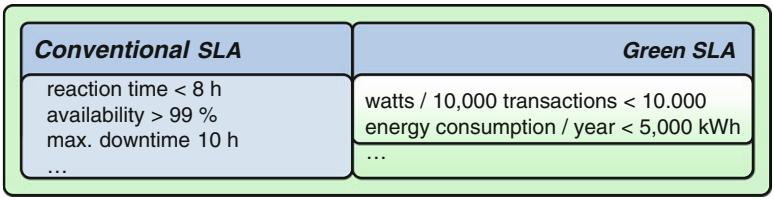

Fig. 3 Extension of the SLA concept by sustainability indicators

the use of resources. Furthermore, capacity management should drive the procurement of energy efficient equipment and support decision makers in avoiding the creation of overcapacities. It needs to create awareness for the effects of business decisions on necessary resources and should incorporate incentive mechanisms which reward the avoidance of capacity extensions (if this can be aligned with business objectives). In the future, *Green Business Capacity Management* can be established as a means to control the demand for IT capacity, taking both business objectives and sustainability considerations into account.

Additionally, the implementation quality of the IT service management processes themselves may have different levels depending on the company implementing them. In some cases, an individual company may have implemented ITSM processes in a very resource-intensive way, using physical meetings with high travel efforts or printing all process-relevant documents on paper. Although this is a general fault in process design, a careful examination of IT service process implementations with regard to such common mistakes should be considered. Thus, the resource efficiency and sustainability of ITSM processes can be further improved.

3.2 Sustainable Business Processes

Not only can the sustainability of ITSM processes be improved by using appropriate ratios. This approach can also be applied in order to enhance the sustainability of business processes in general. For every activity in a business process, relevant values concerning the consumption of resources or the production of waste materials can be considered. Figure 4 shows a typical sales process represented by an EPC (Scheer, 1994). In this process model, different activities are annotated with exemplary values of resource consumption. The sustainability can be optimized by planning and improving the process in a way that these values are reduced. Although, the controlling of actual values is only possible to a certain extent, processes can be designed in a more sustainable way taking these values into consideration.

It can be assumed that the application of this approach has the largest effects in inter-organizational business processes, especially in supply chain management (SCM) scenarios as SCM processes often come with a high resources consumption mainly related to the transportation of goods (Piotrowicz & Cuthbertson, 2009). Thereby, a better alignment of inter-organizational supply chain processes based on production forecasts and process sustainability analyses can significantly improve the emission of CO_2 produced during the transportation of goods. However, the individual situation of every partner in the supply chain has to be considered and the coordination of the different individual interests of each partner appears to be problematic. Therefore, adequate solutions are needed in order to be able to align these needs and to improve the sustainability of the whole supply chain.

Regarding the common BPM life cycle, the cooperating business partners can appoint a corporate sustainability *strategy* as a basis for their Green BPM initiative.

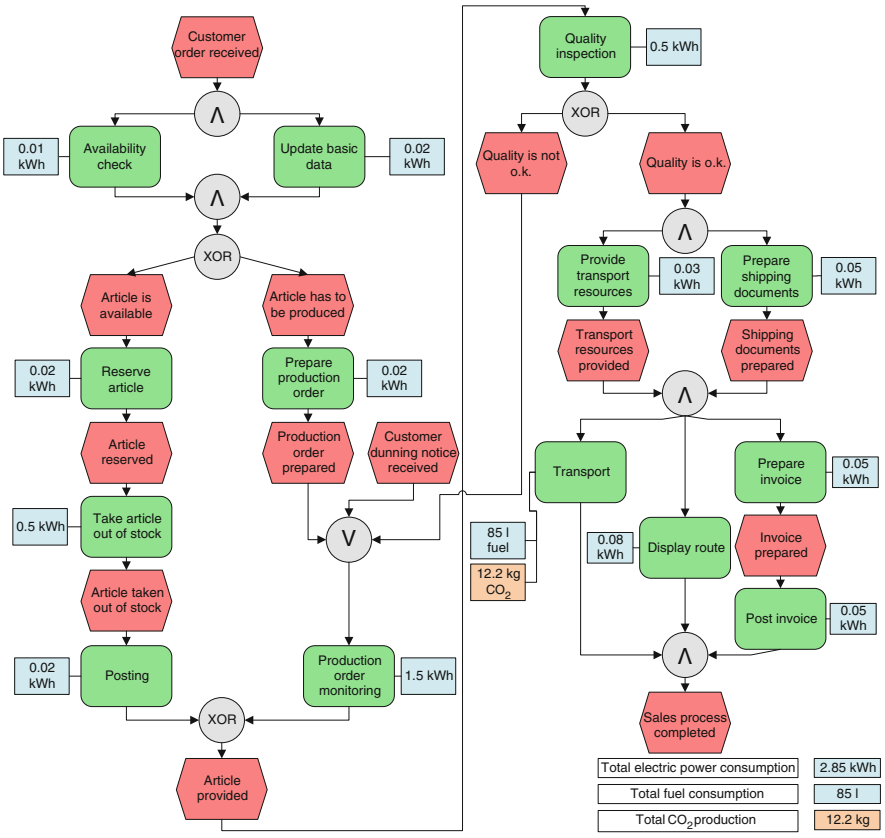

Fig. 4 Sales process (EPC) annotated with relevant sustainability ratios, based on Scheer (1994)

If every partner in the supply chain is interested in improving the process sustainability, sustainability ratios can be appointed as target values which should be achieved during the execution of the whole process. Based on that, the business processes can be *modeled* using ratios for the consumption of resources and the production of waste materials of each process step. The accumulation of these values represents the total effects of a whole process as shown in Fig. 4. The partners could for instance stipulate that the execution of a certain transport process should not consume more than a certain amount of fuel in total. The modeled processes are then *executed* and *controlled* comparing the planned ratios with the actual values provided by a monitoring system. In the improvement phase of the BPM life cycle, the process models could then be enhanced on the basis of monitoring values. Furthermore, different process design alternatives could be derived from executed model instances and then combined in a more sustainable way, which will be demonstrated in the next section. Thus, an optimization of the process's resource and cost efficiency can be achieved.

Based on these considerations, Green BPM could contribute to a more resource efficient supply chain management enhancing environmental performance by minimizing waste; this does not only effect the corporate image, but also the competitive advantages based on cost savings (Rao & Holt, 2005). However, appropriate techniques, tools and also organizational concepts are needed in order to coordinate Green BPM initiatives in inter-organizational contexts. Expanding the presented organizational possibilities, the next section presents exemplary technological opportunities. The Abnoba framework for semi-automated business process sustainability improvement is presented and further illustrated by means of application example.

4 An Approach for Environmentally Aware Process Improvement

Environmentally aware business process re-design/improvement has been identified as one of the key aspects of Green BPM. In an environmentally aware process improvement exercise, we seek to identify process design alternatives with the same desired functional properties, but with a more favorable environmental impact.

In practice, an environmental aware process improvement exercise poses various challenges. (1) To be able to discriminate between a set of process designs, we must be able to order them according to their environmental performance. Therefore, how can we assess the environmental performance of a process during design time? (2) Committing to a process, re-design can have a fatal impact on the organization, if the design is not aligned with the operational functional objectives. Therefore, does a suggested business process design have the desired functional outcomes, as required by a correlated operational objective? This question can be further extended by asking: is the process (re-)design compliant with given regulations; and can it be provisioned by the resource context of the organization? Overall, how can we ensure that the process (re-)design is "fitting" into the enterprise context? (3) Finding process improvements is a challenging task due to the need of the human analyst to explore a fast space of potentially applicable process designs and ensure a fit with the existing enterprise structure. The complexity of such an exercise might on the one hand result in *overlooked process designs* (with many desired environmental properties) and on the other hand result in *overlooked design mistakes*. Both cases can threaten the efficiency of organizations operations.

In this section, we provide a summary of the Abnoba framework for Green BPM (Ghose et al., 2009; Hoesch-Klohe & Ghose, 2010a, 2010b; Hoesch-Klohe et al., 2010) which seeks to provide methodological and tool supported decision support machinery to assist the process analyst in an environmentally aware process improvement exercise and the described challenges. The following elaboration focuses on the latter two challenges, viz. how we ensure that a process (re-)design

fits into the organizational context (we emphasize the alignment with the operational objectives) and how we can support the analyst in identifying process re-design candidates. A detailed exploration on how to assess the environmental performance of a process design is omitted. However, we point the interested reader to the work of Recker, Rosemann, and Roohi Gohar (2011) who analyze various top-down, bottom-up and mixed approaches for assessing the environmental performance of a process design. In addition, Hoesch-Klohe et al. (2010) suggest deriving the environmental performance of a process design by correlating it with resource models. Each activity of the process design is annotated with the resources it requires, how it intends to use the resource and with which intensity. Based on this information and the information given by the resource models, the environmental performance of an activity can be dynamically derived during design time.

4.1 Is a Process Aligned with Operational Objectives?

In this sub-section we summarize how to (automatically) determine and ensure that the outcome of a potential to-be process (given by its process design) can realize correlated objectives. This is done by modeling the objectives of an organization. Objectives can be formulated at different levels of abstraction ranging from strategies to further refined operational objectives. A rich body of knowledge on goal representation, modeling and reasoning can be found in the goal-oriented requirements engineering literature; Yu and Mylopoulos (1995) and van Lamsweerde (2001) provide a good starting point for interested readers. For this elaboration, we assume that there exists a set of operational objectives. To be able to provide automated reasoning support the goals are presented (in natural language and) by a formal language like First-Order Logic. For example, in its simplest form a goal can be formally represented by a single literal α, where α could correspond to the sentence (in natural language) "The package safely arrived at destination". Hence, our goal is to make α true – to have the package at desired destination.

A process design will realize a correlated goal if its (cumulative) effects entail the goal. The cumulative effect of a process design is determined by the immediate effects of each activity of the process design. An immediate effect describes the outcome of executing a given activity in a formal language. For example, given a process design with a single activity with the effect α and β (the activity makes α and β true), this process design realizes a goal that is represented by α (because α is derivable from α and β – in fact α would be derivable from α alone). For process designs with more than one activity, immediate effects are accumulated across a process design using the Process SEER (detailed information in Hinge, Ghose, & Koliadis, 2009). In summary, the machinery allows us to point at any point in the process design and answer the question, what would have happened if the process design were executed up to this point. We omit a description on how to handle multiple paths through the process design and refer the reader to Hinge et al. (2009).

4.2 *Semi-automated Environmentally Aware Process Improvement*

The process improvement machinery of the Abnoba framework (Hoesch-Klohe & Ghose, 2010a) uses a library of best practice process fragments (snippets) to replace fragments of an "as-is design" with (more environmentally friendly) fragments drawn from the library. For each resulting process re-design candidate it is ensured that (1) the functional requirements are met (all correlated goals are realized), (2) the process design can be provisioned by the resource context of the organisation, (3) the process design is compliant with regulatory restrictions, and (4) the process design has a more preferred environmental profile. The majority of the existing process improvement frameworks (Reijers & Mansar, 2005 provide a survey) focus on optimizing the cycle time of a business process, by exploring possibilities for parallelizing activities. However, the resulting process re-designs are not necessarily superior with respect to their environmental performance. Nevertheless, the ability to search for and replace alternative fragments with parts of the as-is design allows for environmentally aware improvement. This approach has many parallels with the adaption of reference models (Fettke & Loos, 2007). Figure 5 provides a conceptual overview over the various steps to be described in more detail below.

- *Given an as-is process design it is disassembled into all its process fragments.* A process fragment is a (sub-)process graph with a single entry and a single exit point. For example, in Fig. 6 the fragment labeled with (1) can be disassembled into the fragments (2), (3), (4), and (5). Splitting a process design into all

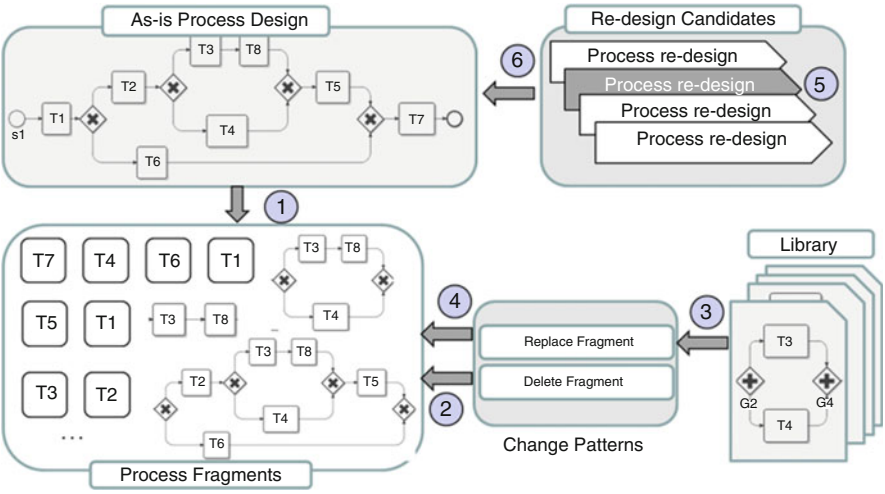

Fig. 5 An overview of the process improvement machinery (Hoesch-Klohe & Ghose, 2010b)

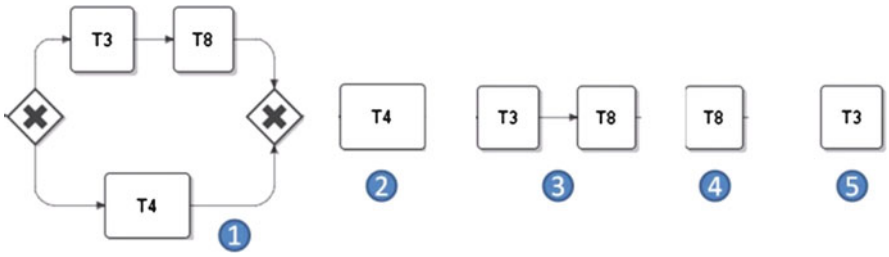

Fig. 6 Process fragment examples

its process fragments allows us to isolate functionality for fragment deletion or replacement with fragments possessing similar functionality (at least the functionality of the fragment to be replaced) in the library.

- *All obsolete fragments are removed from the as-is design.* Process designs evolve over time and hence might include functionality which has become superfluous. We identify obsolete fragments, by checking for each identified process fragment whether it can be deleted from the design, so that the resulting re-design remains to satisfy the correlated goals and is compliant. Note that due to the nature of a process fragment (single entry, single exit point) we can delete (and replace) fragments without impacting the correctness of the process syntax.
- *A capability library is used to search for substitutable fragments.* The capability library constitutes a set of effect-annotated process fragments. The library can be populated with past revisions of a process's design, with fragments from external "best practice" business processes and services (which can be treated as complex activities) derived from a service broker. Given such a library, for each fragment of the as-is process design we search for a substitutable fragment in the library. A process fragment p' is a potential substitute for another process fragment p, if p' has at least the functionality of p (every terminal effect scenario of p is entailed by some terminal effect scenario of p').
- *Replace substitutable fragments.* All substitutable fragments, identified in the previous step, are replaced. Each replacement results in a process re-design candidate. For each candidate it is checked whether it is compliant (a machinery for compliance checking can be found in (Ghose & Koliadis, 2008)), can be provisioned by the resource context and achieves the desired functional outcome. The latter has to be checked because a new fragment drawn from the library can introduce additional functionality, which might cause inconsistencies. All valid process re-designs are added to a list of final process re-design suggestions.
- *Ordered process re-designs according to their environmental impact.* Given the final list of process re-design suggestions, their cumulative environmental impact is determined (Ghose et al., 2009; Hoesch-Klohe & Ghose, 2010b), the list respectively ordered, and finally presented to the analyst.

4.3 Process Sustainability Improvement: An Application Scenario

In the following we provide an application scenario showing a potential usage of the elaborated machinery. An obvious application scenario is a scenario in which a process fragment of the as-is design is replaced by a service, drawn from the library, which has a more preferred environmental profile – the functionality is outsourced to the respective service provider. In this scenario, the library is populated with services (or rather service descriptions). These services could be derived (in an automatic manner) from a service broker. The services in the library are matched against the fragments of the as-is design using their respective post-conditions (this requires the services to be formally represented using either the same ontology or a translator between the applied ontologies). The overall idea of this scenario is that functionality denoted by its process design fragment is outsourced to a service provider who has the means to operate more environmentally friendly.

However, a less obvious application scenario describes the case in which an old design version of a business process is used in the design of a to-be process. We use the BPMN to model an as-is "Handle Job Application" business process in an HR department. The process design is given in Fig. 7.

The business process is triggered by the arrival of a job application. The receipt of the application is confirmed and the strength and the correctness of the application are examined and verified before a decision is made. Finally, the applicant is informed about the outcome of his application. The given as-is *process design can be disassembled* into 23 *possible* process fragments. Due to space constraints we cannot show all these fragments, but Fig. 8 shows one of the 23 fragments.

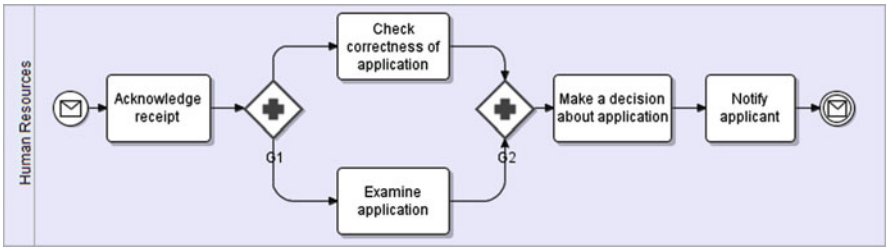

Fig. 7 As-is "Handle Job Application" business process

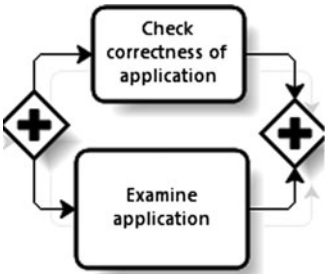

Fig. 8 A fragments from the as-is design

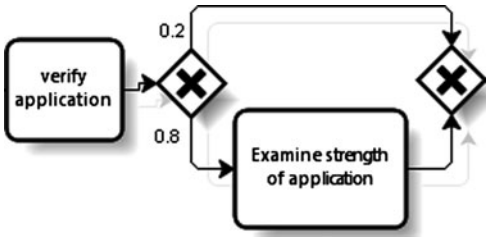

Fig. 9 Fragment from a past version of the "Handle Job Application" process design

Searching through the library reveals the process fragment shown in Fig. 9 which is a fragment from a past revision of the "Handle Job Application". In the fragment shown in Fig. 9 the activity "verify application" is executed before either the activity "examine strength of application" is performed (in the case the verification was positive) or the activity is skipped. Note that such a fragment is not identified based on the labels of the activities, but rather on the effects annotated of both fragments (we omit details for brevity). This fact is denoted by distinctly labeled activities in both fragments.

Note that the fragment shown in Fig. 9 might have been changed to the fragment shown in Fig. 8 to optimize the cycle time of the business process (activities are parallelized). However, new Quality of Service (QoS) requirements, reflecting the recent trend in industry towards more sustainable operations might make the past fragment more applicable (if environmental performance is ordered more important than cycle time).

A process re-design candidate is created by replacing the fragment given in Fig. 8 with the fragment given in Fig. 9. The candidate is then checked for compliance and goal realization. Given this check is successful the candidate is suggested to the analyst as a process re-design. The amount of e.g. carbon dioxide emission saved depends on probability of the positive or negative outcome of the "verify application" – in other words how often the execution of "examine strength of application" can be skipped.

In this section, we highlighted some challenges an analyst might face in an environmentally aware process improvement exercise. Based on the highlighted challenges, we summarized the Abnoba framework for Green BPM. The summary focused on how an automated machinery can be devised for improving a business process design and how it can be checked whether a process re-design fits into the organizational context. The former has been exemplified by an application scenario.

5 Opportunities and Challenges of Green BPM

The application scenarios and the description of the Abnoba framework have demonstrated opportunities and challenges of Green BPM for internal and inter-organizational business processes both from the organizational as well as from the technological side. These opportunities are systematized by means of the BPM life cycle (Fig. 10).

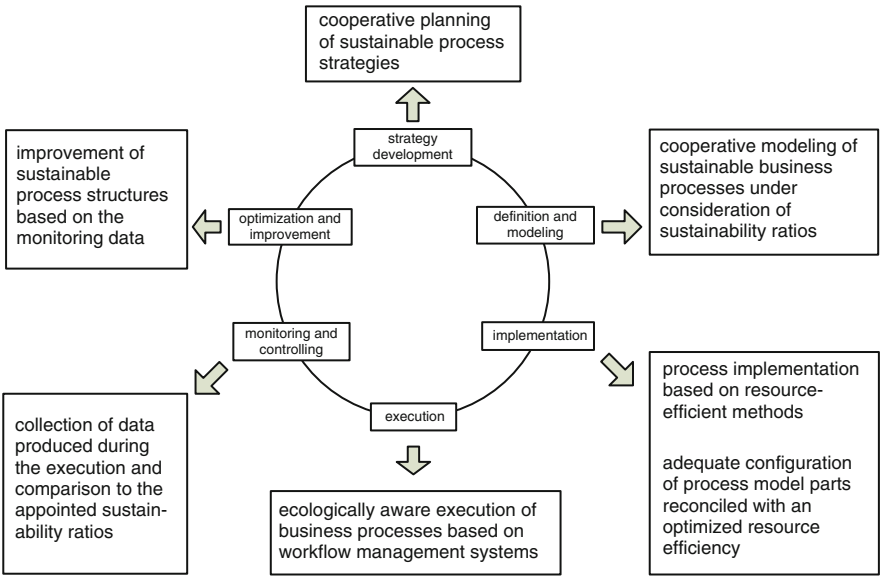

Fig. 10 Potentials and challenges of Green BPM (Based on Houy et al., 2011)

- Strategy development: In the phase of strategy development, a single organization or cooperating partners plan and appoint a sustainable corporate business process strategy. The objectives which should be achieved can be documented in a corporate Sustainability Balanced Scorecard (SBSC) with different sustainability ratios (Schmidt, Erek, Kolbe, & Zarnekow, 2009).
- Definition and modeling: In the phase of process modeling, models are developed considering the actual production of waste materials and the consumption of resources in order to create awareness of the problem. The individual sub-processes of the participating departments can then be defined in a more sustainable and resource efficient way in order to meet appointed ratios.
- Implementation: During the implementation phase, the several sub-processes have to be adequately configured in order to achieve an improvement of resource efficiency. In the context of configuring the sub-processes, the partners in cooperative scenarios should be supported by IT-based communication, e.g. video conferencing which is commonly more efficient than travelling.
- Execution: A more ecologically aware execution of business processes can be facilitated by inter-organizational workflow management systems driving the defined sustainable processes. In this context, electronic documents are often used in order to support the reduction of paper consumption.
- Monitoring and controlling: In this phase, the actual ratios of the process execution are measured for controlling purposes and can then be compared to the appointed sustainability ratios.

- Optimization and improvement: Based on this comparison in the preceding phase, weaker points and problems of process execution can be identified and considered during the improvement. Based on the process execution data, more sustainable process alternatives can be derived and combined, which is also supported by the presented Abnoba framework.

Nevertheless, there are also challenges which have to be faced in order to tap the full potential of Green BPM. In the first place, adequate and measurable sustainability ratios have to be identified and developed as these ratios provide the basis for process implementation, controlling and improvement. In some cases, the actual consumption of resources can only be estimated and is not exactly measurable.

Sustainability has become an important factor for many organizations. However, cost efficiency usually is the more important factor. In many cases, resource efficiency and an environmentally friendly economic activity go along with reduced costs; e.g. in the case of an optimized route for a travelling sales man. In other cases, cost-conscious business activities on globalized markets accompany high ecological costs; e.g. in the case when simple goods are transported far away to different countries in order to save personnel costs for further processing. Moreover, sometimes business processes have to be executed within a certain time limit producing higher ecological costs. In such a scenario further Green BPM tools are needed to support flexible and situational adaption of business process models for single process instances in order to facilitate an agile BPM fitting the needs of different emerging situations. Under certain circumstances, an optimization of time efficiency can be more important for the achievement of a business goal than resource efficiency (Ghose et al., 2009). Green BPM research has to examine whether existing tools can be adapted or new ones have to be developed.

In addition, further experience with the application of sustainability ratios in Green BPM is needed. Based on this experience, adequate green reference process models can be developed in order to document best practices for improving process sustainability in different business domains (Fettke & Loos, 2007).

6 Conclusion and Outlook

Green BPM is of relevance for both research and practice and offers considerable opportunities for the improvement of enterprises' sustainability. Our contribution has illuminated and discussed organizational as well as technological opportunities and challenges of Green BPM. At first, the topic was motivated by the actual debate on global warming and the need for better sustainability of business activities. Then, our understanding of Green BPM was explained and exemplified in the context of two application scenarios. Furthermore, the Abnoba framework as a current approach for semi-automated business process sustainability improvement has been presented. The opportunities and challenges of Green BPM were thereafter demonstrated and discussed based on the BPM life cycle.

The presented considerations as well as the application scenarios show that Green BPM can significantly contribute to more environmentally friendly business operations. It can be assumed that a lot of sustainability potential can be identified and realized in business processes of many different industries. Realizing these opportunities can significantly support more sustainable business activities and contribute to a betterment of humanity.

Future research should further develop concepts for Green BPM; e.g. in the form of green reference process models or procedure models for the implementation of green processes. Furthermore, adequate techniques and tools for the realization of Green BPM potentials in inter-organizational scenarios throughout the whole business process life cycle can considerably contribute to more sustainable business activities.

Acknowledgments The research described in this paper was partly supported by a grant from the German Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung, BMBF*), project name: "Process-oriented Web-2.0-based Integrated Telecommunication Service" (*PROWIT*), support code FKZ 01BS0833.

References

Fettke, P. (2009). How conceptual modeling is used. *Communications of the Association for Information Systems (CAIS), 25*(43), 571–592.

Fettke, P., & Loos, P. (Eds.). (2007). *Reference modeling for business systems analysis*. Hershey, PA: Idea.

Ghose, A., Hoesch-Klohe, K., Hinsche, L., & Le, L.-S. (2009). Green business process management: A research agenda. *Australasian Journal of Information Systems, 16*(2), 103–117.

Ghose, A., & Koliadis, G. (2008). *PCTk: A toolkit for managing business process compliance*. Paper presented at the Proceedings of the 2008 international workshop on Juris-informatics (JURISIN-2008), Hokkaido, Japan.

Hinge, K., Ghose, A., & Koliadis, G. (2009). *Process SEER: A tool for semantic effect annotation of business process models*. Paper presented at the Proceedings of the 13th IEEE international EDOC conference (EDOC-2009), Auckland, New Zealand.

Hoesch-Klohe, K., & Ghose, A. (2010a). *Business process improvement in Abnoba*. Paper presented at the Proceedings of the 1st international workshop on services, energy, & ecosystem (SEE 2010), San Francisco, CA, USA.

Hoesch-Klohe, K., & Ghose, A. (2010b). Carbon-aware business process design in Abnoba. In P. P. Maglio (Ed.), *ICSOC 2010* (LNCS, Vol. 6470, pp. 551–556). Berlin, Germany: Springer.

Hoesch-Klohe, K., Ghose, A., & Lê, L.-S. (2010). *Towards green business process management*. Paper presented at the 2010 IEEE international conference on services computing (SCC), Miami, FL.

Houy, C., Fettke, P., & Loos, P. (2010). Empirical research in business process management – Analysis of an emerging field of research. *Business Process Management Journal, 16*(4), 619–661.

Houy, C., Reiter, M., Fettke, P., & Loos, P. (2011). *Towards Green BPM – Sustainability and resource efficiency through business process management*. Paper presented at the business process management workshops 2010, LNBIP 66, Hoboken, NJ, USA.

Hung, R. Y. (2006). Business process management as competitive advantage: A review and empirical study. *Total Quality Management, 17*(1), 21–40.

IEEE. (2010). Tagline: Advancing technology for humanity http://www.ieee.org/about/toolkit/brand/tagline.html, 20.2.2012.

Melville, N. P. (2010). Information systems innovation for environmental sustainability. *MIS Quarterly, 34*(1), 1–21.

Pernici, B., Ardagna, D., & Cappiello, C. (2008). Business process design: Towards service-based green information systems. In A. M. Mazzeo, R. B. Bellini, & G. M. Motta (Eds.), *E-government, ICT professionalism and competencies, service science* (Lecture notes in biomathematics, Vol. 280, pp. 195–203). Berlin, Germany: Springer.

Piotrowicz, W., & Cuthbertson, R. (2009). Sustainability – A new dimension in information systems evaluation. *Journal of Enterprise Information Management, 22*(5), 492–503.

Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance? *International Journal of Operations & Production Management, 25*(9), 898–916.

Recker, J., Rosemann, M., & Roohi Gohar, E. (2011). Measuring the carbon footprint of business processes. In J. Su & M. zur Muehlen (Eds.), *Business process management workshops 2010. LNBIP 66* (pp. 511–520). Berlin: Springer.

Reijers, H. A., & Mansar, S. L. (2005). Best practices in business process redesign: An overview and qualitative evaluation of successful redesign heuristics. *Omega-International Journal of Management Science, 33*(4), 283–306. doi:10.1016/j.omega.2004.04.012.

Scheer, A.-W. (1994). *Business process engineering – Reference models for industrial enterprises* (2nd ed.). Berlin: Springer.

Scheer, A.-W., & Brabänder, E. (2010). The process of business process management. In J. vom Brocke & M. Rosemann (Eds.), *Handbook on business process management 2 – Strategic alignment, governance, people and culture* (pp. 239–265). Berlin: Springer.

Schmidt, N.-H., Erek, K., Kolbe, L. M., & Zarnekow, R. (2009). *Towards a procedural model for sustainable information systems management*. Paper presented at the Proceedings of the 42nd Hawaii international conference on system sciences 2009 (HICSS-42), Big Island, Hawaii.

van der Aalst, W. M. P., ter Hofstede, A. H. M., & Weske, M. (2003). Business process management: A survey. In W. M. P. van der Aalst, A. H. M. ter Hofstede, & M. Weske (Eds.), *BPM 2003* (LNCS, Vol. 2678, pp. 1–12). Berlin: Springer.

van Lamsweerde, A. (2001). *Goal-oriented requirements engineering: A guided tour*. Paper presented at the Proceedings of the 5th IEEE international symposium on requirements engineering, Toronto, ON.

Watson, R. T., Boudreau, M.-C., & Chen, A. J. (2010). Information systems and environmentally sustainable development: Energy informatics and new directions for the IS community. *MIS Quarterly, 34*(1), 23–38.

Wikström, P.-A. (2010). Sustainability and organizational activities – Three approaches. *Sustainable Development, 18*(2), 99–107.

World Commission on Environment and Development. (1987). *Our common future*. Oxford, England: Oxford University Press.

Yu, E. S. K., & Mylopoulos, J. (1995). From ER to 'AR'-modelling strategic actor relationships for business process reengineering. *International Journal of Cooperative Information Systems, 4*(2–3), 125–144.