Towards Ecological Workflow Patterns as an Instrument to Optimize Business Processes with Respect to Ecological Goals

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Abstract

With this paper, we introduce the concept of Ecological Workflow Patterns (EWP) in the domain of Green Business Process Management (Green BPM). The optimization of processes with respect to ecological goals often faces difficulties in adapting to the revised process. Also the consequences of changes to the process are often not predictable which makes necessary the application of simulation measures [1]. We identified ecological weaknesses of processes from existing literature and from process models and applied the concept of patterns to formalize the weaknesses. As a result, we created four initial EWPs from control-flow, operational and data perspective that serve as a blueprint for the development of eco-sustainable processes at design time or for the optimization of existing processes. The results of this paper represent the starting point for future efforts to extract more EWPs and to conceptualize the representation of the patterns.

1. Introduction

A research area that gained momentum for practice and research during the recent years is the field of Green Business Process Management (Green BPM). Green BPM aims at the design and optimization of IT-related processes with regard to ecological objectives such as the resource consumption of business processes. The sustainability of processes refers to the consumption of electric energy, the emission of pollutants or the resource consumption that is caused by the execution of a process. In the field of Green BPM, techniques were proposed to measure such variables, for example by determining the energy consumption of business processes with software or hardware sensors [2-4]. The emergence of ways to measure the resource consumption opened the doors for sophisticated methods such as simulation to be applied for the optimization of processes towards ecological goals [1]. However, many small and medium-sized enterprises (SMEs) do not have available the knowledge or the personnel resources to apply such techniques. That makes necessary the development of methods to optimize existing processes that are easier to apply.

In software-engineering the concept of design patterns is used to synthesize existing knowledge and good practice regarding the development of software artefacts into “easy to understand” guidelines that can be applied even by SMEs. Patterns in software-engineering are commonly used in order to represent knowledge about the design of complex software artefacts [5]. With the use of patterns, software-engineers can benefit from proven and mature practices that have been condensed to patterns to approach a certain problem in software-engineering.

The technique of pattern creation has since been adapted to a number of different areas in IS research. In Business Process Management (BPM) for example, workflow patterns are used to represent the workflow in process models [6-8]. From a control flow perspective, workflow patterns represent a small unit of a business process in terms of a certain control sequence, split or join. Workflow patterns describe a set of elements of a process at type layer without any relation to specific process instances. Hence they have a rather generic character.

Because the concept of patterns allows describing a variety of different characteristics of business processes, it can be used to create process patterns that capture characteristics beyond the process flow, including information on ecological attributes of processes. These patterns can be referred to as Ecological Workflow Patterns (EWP). The EWPs serve as a reference when it comes to the design of robust, eco-friendly business processes during the initial stage of creating new processes. EWPs can furthermore be used to optimize existing processes in terms of ecological parameters such as the consumption of energy or raw materials. As a result, EWPs are an effective
tool to support the strive for eco-efficiency, eco-equality and eco-effectiveness, that are three major steps towards environmental sustainability [9, 10]. Eco-efficiency stands for the reduction of resources consumed by a certain process over time by raising the efficiency of a process. This can be accomplished through substitution of a wasteful process element with an energy-friendly substitute that is formalized as an EWP. Eco-equality means to preserve the finite resources for future generations and is supported by EWPs through the reduction of resource consumption so that resources eventually will last longer. And finally, eco-effectiveness addresses the search for ways to ultimately end environmentally harmful activities [9], which also can be addressed using patterns of new IS technology or paradigms as a substitute for established process elements.

The objective of this paper is to introduce the concept of Ecological Workflow Patterns as a tool for decision-support in the domain of Green BPM. With the application of EWPs, eco-friendly processes can be designed from scratch without the necessity of applying sophisticated optimization methods for process improvement, e.g. business process simulation [1].

The concept of EWPs will be elaborated using existing literature from the field of pattern research (e.g. design and workflow patterns). Further we analyzed existing process models and conducted an empirical evaluation to identify the role of IS in terms of energy savings. The results of this case study is later on used to develop and showcase the concept as well as four specific EWPs. We rely on the energy consumption of processes for two reasons: first, to make sure the impact that comes with the application of EWPs can easily be understood. Second, because the energy consumption involved in business processes is a common and domain neutral figure in the area of Green IS and can be measured with existing methods.

After this introduction we give an overview of the research area of Green BPM and of process and workflow patterns in section 2. In section 3 the concept of Ecological Workflow Patterns will be introduced and three different perspectives of EWPs will be presented. As a result of this typology, in section 4 we introduce to the methods that are necessary to extract EWPs at the three different perspectives. In section 5, we perform a case study where we demonstrate the application of one extraction method and where we highlight the energy saving capabilities that emerge with the application of EWPs. After that, the strengths and weaknesses of the approach are discussed in section 6. The paper closes with a short summary and an outlook on future work in section 7.

2. Theoretical foundations

2.1 Green Business Process Management

Green Business Process Management can be described as defining, implementing, executing and improving business processes in corporations with the aim to support environmental objectives [11]. Environmental objectives reach from the reduction of energy or raw material consumption through the increase of efficiency over the optimization of the resource demand, the replacement of seldom or ecologically harmful materials right up to the reduction of emissions and other pollutants.

Green BPM can be understood as a derivate or differentiation of the concept of “Green IT”. Green IT is a research area that is concerned with the resolution of ecological problems of IT (“Green-for-IT”) and through IT (“IT-for-Green”) [12]. This includes the optimization of the operation of data centers or the development of software for collecting, processing and the preparation of ecological key figures as decision support at management level. To unfold the effect of Green IT to corporate processes, the methods and concepts of Green IT need to be considered within the corporate strategy at management level. For that reason, Green BPM emerged in the recent past [12].

Contrary to Green IT, Green BPM integrates the ideas related to Green IT with widely-accepted management principles rather than focusing on the environmental lifecycle of technological devices [13]. Green BPM for example addresses the extension of conventional process models with emission annotations [14], the calculation of carbon dioxide emission of business processes [15] or establishing software products that collect, process, and report environmental data for management support [16]. In order to create a holistic Green BPM approach, methods must be provided that support the entire lifecycle of processes in terms of the ecological objective (e.g. energy consumption or CO2 emission) (Figure 1).

![Figure 1. Green BPM lifecycle based on [17]](image-url)
In order to be able to evaluate the resource consumption of business processes, techniques have been proposed to measure the energy consumption of processes. This can be either done by measuring the voltage at different points on the mainboard of a personal computer [2] or by using software tools that are able to determine the resource utilization of a personal computer in combination with an energy meter [3] or based on the drain of a laptop battery [4]. The latter two approaches use software that serve as software-based energy sensors to capture consumption data. To improve existing software processes towards ecological goals, the application of business process simulation was proposed recently [1].

2.2 Process- and workflow patterns

The concept of patterns gained momentum with the publication of design patterns by Gamma et al. [18]. It has since been adopted by a variety of other areas such as Business Process Management (BPM).

Coplien denotes the organizational side of process patterns and describes process patterns as a “solution to a problem”, that can be used “to solve organizational and process problems” [19]. Ambler names task process patterns, stage, process patterns and phase process patterns [20] while he also refers to the organizational side of software-engineering.

Some authors point out the analogy between reference models and process patterns [5]. While the process of creating reference models is distinguished from creating process patterns, both concepts represent a configurable (set of) process model(s) and can be applied in order to improve business processes similarly. During this alteration, single tasks or a set of tasks (constructs) of a process are substituted by more efficient alternative tasks/constructs in order to enhance the economic performance of a process. Variables that are typically affected by such alterations are the cycle-time or the quality of the output factor.

In process-aware information systems however, a number of different kinds of patterns can be identified. Van der Aalst et al. distinguish between the control-flow-, data-, resource- and exception handling perspective and refer to the process view that is represented and supported by information systems (Figure 2). The authors call these types of patterns “workflow patterns” [8]. In the control-flow perspective, the process flow is described along with elements for execution control in terms of connectors to split, join or parallelism of the process flow. In the data perspective, the necessary business and processing data is modeled while on the operational perspective, the required information systems to execute the process are modeled [8].

Figure 2. Three perspectives of Ecological Workflow Patterns

3. The concept of Ecological Workflow Patterns

3.1 Theoretical background

Workflow patterns serve as decision support for the optimization of business processes towards economic goals [21]. But the concept of patterns can also be used to support decisions on the design of processes with respect to ecological goals. In the following, the concept of patterns will be used to generate a new type of pattern, the so called Ecological Workflow Pattern which addresses the ecological performance of a process. That is for example the consumption of resources, electric energy or the emission of pollutants during the execution of the process.

Ecological Workflow Patterns can help to create ecology-aware business processes during the initial design stage or optimize existing processes through process revision. In order to change the characteristics of processes, the elements of a process need to be analyzed together with the process models’ components. By doing so, the components can be evaluated at several levels on whether or not they meet the requirements of a hypothetical best approach to a certain process component. The Ecological Workflow Patterns can address different kinds of issues. After the patterns are formalized in a structured way, they can also be implemented in BPM suites such as ARIS or ADONIS to support process design at an initial stage. After this introduction we are going to present three different areas that can be optimized using EWPs.
3.2 A typology of Ecological Workflow Patterns

Similar to the workflow patterns of Van der Aalst et al. [7, 8] that can be used to model process components of three perspectives, a multi-dimensional approach is necessary to assess the ecological performance of processes.

Control-flow perspective

In the control flow perspective of traditional workflow patterns, the flow is controlled through the use of connectors to split, join, sequence or parallelize the flow. In addition, loops can lead to further iterations of process constructs (single tasks or consecutive paths). While with workflow patterns the cycle-time or number of total construct iterations is relevant to assess the economic performance of a process, an assessment of ecological values is necessary to understand the process performance when creating EWPs. Figure 3 shows a basic example of the impact that the control-flow can have on the magnitude of the observed ecological indicator in the form of the energy consumptions in Watt seconds (Ws).

![Figure 3. Impact of the control-flow on the energy consumption](image)

After a customer placed an order and his/her information was received, a sales assistant checks if the customer provided an e-mail address with the order. If the address is not available, the invoice needs to be printed and sent by mail. If the customer provided the address, the invoice can be sent via e-mail. Due to the huge amount of energy needed for the fuser unit, process C (520 Ws) consumes a lot more energy compared to process D (150 Ws). In a verbal form, this Ecological Workflow Pattern would suggest that designers of processes need to create processes that utilize e-mail instead of traditional print techniques.

Operational perspective

In process modeling, the annotation of tasks with supporting information systems is a common practice. The graphical representation of supporting IS components in Event-Driven Process Chains (EPC, see figure 4), is usually a rectangle with two vertical margins that is connected to a related function. In BPMN, IS components such as Customer Relationship Management (CRM) applications are modeled as an exclusive lane with the affected tasks assigned to that lane. The annotation of process models with direct information on the consumption of resources in the form of energy or raw materials has been subject to research as well [14].

In the past, software-artefacts and hardware-based solutions were developed to measure the energy consumption of information systems [2, 4]. The importance of the applications’ energy consumption is highlighted both by current research as well as by recent software failures that strongly affected the user experience in a negative way by causing a battery drain on mobile computers [22, 23].

With the ability to track the energy consumption of applications and considering that for many standard applications a certain number of alternatives are available (pdf reader, browser), applying a best-of-breed approach can help to identify the best application in terms of energy consumption.

In the case of consumption of raw materials or the emittance of pollutants, a similar approach can be taken if mechanisms are available to track the consumption or emittance. These best-of-breed applications can be used as a pattern when designing new processes or revising existing ones.

Data perspective

In information societies, many business processes rely on the processing of information. With the execution of processes, information entities are created, read from, manipulated and deleted. The information entities can either be physically available or stored in a database. In some cases, however, the information entities are subject to a transition of their state when paper-based information is digitalized through optical character recognition or when information stored in a database is printed. If this transition procedure is reversed again, this might be an indicator for a weakness based on the data perspective of the process.

In figure 4, the sales department receives an order from a customer. For quality reasons, the person preparing the order for shipment is asked to tick every position and sign with his/her name to make sure every position is packed in the parcel. For reasons of documentation and compliance the document must be scanned with image or text recognition before the
shipment takes place. The scan must be saved in the document management system of the company.

The example addresses the issue of media disruption that is often used in the domain of BPM to highlight weaknesses in processes. The example is normally used as motivation to reason for optimization measures at organizational level (e.g. the reduction of unnecessary tasks to reduce staff costs). In our scenario however, we argue to eliminate this kind of weakness to reduce the waste of energy or other raw materials as an attempt to bring up a new view on this standard example.

In this example, the unnecessary resource consumption in terms of energy and paper is obvious. The process of printing the document, ticking and retrieval consumes a hypothetical amount of 740 Ws per execution, not to mention the time the retrieval would take. At least the process of retrieval could be replaced by a procedure where the document is processed digitally and where annotations replace the physical tag to save energy.

![Figure 4. Energy consumption due to state transition of data](image)

### 4. Extraction methods for Ecological Workflow Patterns

To identify relevant instantiations of EWPs at the three perspectives control-flow, operational and data, a set of different methods must be applied. Due to page limitations, the process of extraction will be explained argumentatively for the three perspectives. In addition, the process to extract EWPs on the operational perspective will be shown in detail in section 5.

At the control-flow perspective, the process flow and responsible control elements of process models need to be assessed and occurring weaknesses have to be identified. The occurrence of certain control elements or structural patterns within the process model can have a negative impact on the resource consumption. For example, cycles normally lead to multiple iterations over a certain process element or consecutive path. Hence, the resources consumed at the particular tasks will also multiply.

To identify relevant Ecological Workflow Patterns, the basic rules of economic process modeling can be applied very similar. Van der Aalst et al. provided a set of structural workflow patterns that can be reviewed in order to identify workflow patterns that have a negative impact on the resource consumption [7, 8]. In addition to this deductive approach, EWPs shall be identified with an inductive approach. A large number of (reference) models are publicly available at various sources. Due to the large number of models to review, the reviewing process needs to be automated with one of the available approaches from the field of process mining [24]. After identifying such weakness patterns, these should be mapped to the instantiation of the Energy Workflow Patterns.

In the case of data perspective, a similar approach can be taken. With a deductive analysis of a large number of (reference) process models, weaknesses such as the state transition of information from figure 4 can be found analytically. But not only can the processing of data be responsible for a consumption of resources. The storage of data also consumes resources (energy, raw materials) and can be separated into passive and active. Paper or magnetic tape for example is passive storage media. Once the information is stored on the paper or tape, except from energy to read/write from or to tape, no further demand for energy or raw materials will occur to retain the information. On the other side, there are active storage media that continue to consume energy or other resources for as long as the information is stored, e.g. Network Attached Storage or file-server. To be able to extract EWPs, the energy consumption to store the data to active and passive devices and the energy consumption to maintain the storage of active storage devices must be measured with hardware- or software-based sensor systems [3, 4].

In the focus of the operational perspective are the information systems that support the process execution. These are software applications and the necessary hardware devices to run the software. The consumption of resources and energy is driven by these information systems in the first place at the operational perspective. In terms of hardware, in the research area of Green IT were concepts developed to reduce the energy consumption of hardware devices through energy-saving measures. For example, the use of highly energy-efficient processors can help to reduce the overall energy consumption of the device involved in a process task. At the same time, the concept of Green BPM proposed methods to reduce the energy consumption of software with energy-efficient approaches to software-engineering (GPU
utilization instead of CPU, efficient multitasking or algorithms). Today’s computer hardware is highly standardized and became a commodity, granting no more strategic advantage. Software however can still be subject to a strategic advantage of one company over another, especially when software is customized to the needs of the company [25]. One advantage that can be drawn is the ability to gain energy-savings when optimizing the corporate software landscape. Energy Workflow Patterns can provide information and best-practice approaches on what software to use for meeting a certain requirement towards information systems support of business processes.

In order to gain this kind of information, an analysis of software applications with regard to their energy consumption profile is necessary. Many of today’s information systems used in a corporate environment are based on cloud computing or local host-ed server/client-architecture and utilize web-technologies. In this scenario for example, the energy consumption can be reduced by choosing an energy-friendly browser. For other use-cases, a number of alternative software applications are available as well. For example, a company focusing on processing pictures or video clips for the validation of user accounts can use a wide range of different applications to play videos, such as VLC media player, Windows Media Player or any other proprietary solution. All of these applications have their own energy consumption profile as will be shown in section 5.

To measure the energy demand of software-applications, several approaches were developed in the past for the hardware [2] and software-environment of a desktop or mobile computer [3, 4].

5. Case study: Extraction of Ecological Workflow Patterns

5.1 The evaluation environment

In this chapter, the extraction of Ecological Workflow Patterns from the organizational perspective will be presented. To demonstrate the extraction, a process model based on a proof of identity proceeding is performed (Figure 5, unimportant events omitted).

The process is executed when the customer of a credit institution applies for a bank account. In order to verify the identification of the customer, a video chat with an operator will be started where the customer is asked to hold his/her personal ID into the camera. If the information of the personal ID card corresponds with the face of the customer and the data provided with the online-registration for the bank account, the operator initiates the process to activate the account. While for the visual proof of identity a video player is used, the operator uses a browser to start the process of creating the bank account using the corporate CRM software.

To measure the energy consumption of the two software applications, we used the software-based energy sensor from [4]. The software is able to determine the actual energy consumption caused by the application while omitting the static energy that the workstation would have caused without running the application. The advantage of this procedure is that a meaningful comparison between applications can be made. The case study was performed on a 15.6” laptop (Intel Core i3, 2.4 GHz, 2 GB RAM, HDD) with a smart meter connected to read the energy consumptions in intervals of one second. The software (browser, video player) were clean installations without any further plug-ins added.

Figure 5. Example process for the extraction of EWP at the operational perspective

5.2 Measurement of the browser energy consumption

The comparison of the browser application included Google Chrome 39, Internet Explorer 10 and Mozilla Firefox 33. We set up a standardized and repeatable scenario that is oriented on the process of figure 5. In the web-based scenario the test person had to choose options from several select input fields, and had to fill out text fields with a predefined text snippet to describe the results of the verification process. The input was predefined to make sure the results would not be biased. It took approximately 11 minutes in total to perform the “confirm application” task. The process step “Open Account Data” was left out from the measurement because of only a couple
of seconds that this process step would take to execute. The results of multiple executions of the process led to very similar results. Therefore, we used the results of a single process execution rather than the mean of a high number of iterations. Table 1 provides the results of the experiment.

<table>
<thead>
<tr>
<th>Browser Software</th>
<th>Seconds to execute process</th>
<th>Energy consumption in Ws</th>
<th>Energy consumption in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Chrome 39**</td>
<td>671</td>
<td>14,867</td>
<td>72.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,067</td>
<td></td>
</tr>
<tr>
<td>Mozilla Firefox 33*</td>
<td>674</td>
<td>16,941</td>
<td>72.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5,641</td>
<td>100% (reference value)</td>
</tr>
<tr>
<td>Internet Explorer 10**</td>
<td>646</td>
<td>14,603</td>
<td>67.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,803</td>
<td></td>
</tr>
<tr>
<td>Internet Explorer 10**</td>
<td>674</td>
<td>-</td>
<td>70.3%</td>
</tr>
</tbody>
</table>

* Originally measured energy consumption and execution time.
** Energy consumption was scaled to the execution time of the reference value (674 seconds) to enhance comparability among the browsers for the reader.

Table 1. Energy consumption of the browser application in direct comparison

The execution of the process with all three browsers took almost the same time. The iteration with the Internet Explorer took only 646 seconds. We scaled the energy consumption of 3,803 Ws at 646 seconds to 674 seconds which is the reference execution time of the Firefox to make the results more comparable. We also scaled the results of Google Chrome for the same reason.

The experiment resulted in some interesting findings. The software that was used to measure the consumption combines the utilization of CPU, RAM, video, network- and disk i/o as well as the brightness of the display to determine the consumption of the browser process at operating system level. First of all, we could not recognize any CPU peaks that would – in theory – cause a higher energy demand on a process execution that takes less time compared to an execution of the same process that takes more time. This indicates a linear coherence between execution time and energy consumption of the application. For the browser process to be executed, the CPU is used as primary resource and the CPU utilization is depending on what web technologies the web site offers (e.g. responsive design, Flash). Besides the CPU utilization, no large amount of data is written to the hard disk nor transferred through the network which results in a low disk and network i/o. The graphic adapter is also utilized only moderately because no sophisticated 3D rendering is necessary. The coherence allows to transfer the results in the form of a EWP to a variety of business processes using a browser as IS-related support function. Because it is the execution time in the first place that affects the energy consumption of the browser which is depending on the process, not on the browser.

The most interesting finding is the variance between the energy consumption across the tested browser software. With 5,641 Ws, Mozilla’s Firefox turned out to be the most inefficient browser when it comes to the energy consumption. Google Chrome outperformed Firefox with 4,067 Ws, which is only 72.1 percent of the energy that Firefox consumed. The most-energy-friendly browser however was the Microsoft Internet Explorer 10 with a consumption of 3,803 respectively 3,967 Ws (scaled) which is only about 67.4 (70.3) percent of the Firefox’ consumption.

5.3 Measurement of the video player energy consumption

We applied the same procedure to the measurement of the video player. This time, the VLC media player was compared to the Windows Media Player which are two of the most used video players available. To include modern internet technologies in the observation, the energy consumption of a video playback was also measured using a HTML 5 video stream (browser).

This time we compared the consumption based on a short video clip with duration of 60 seconds. Table 2 shows the results of the measurement.

<table>
<thead>
<tr>
<th>Browser Software</th>
<th>Energy Consumption per 60 seconds</th>
<th>in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLC media player</td>
<td>782,006</td>
<td>100% (reference value)</td>
</tr>
<tr>
<td>Windows Media Player</td>
<td>736,662</td>
<td>94.2%</td>
</tr>
<tr>
<td>HTML 5 (Firefox)</td>
<td>855,139</td>
<td>109.4%</td>
</tr>
</tbody>
</table>

Table 2. Energy consumption of the video playback

Again the measurement resulted in interesting findings. The playback using VLC player consumed a total of 782,006 Ws for the 60 seconds video. Windows Media Player only took 736,662 Ws to playback the video which is a reduction of 5.8 percent compared to the reference value of the VLC media player. One interesting note is that the playback of the video in an HTML 5 environment using a browser had consumed 9.4 percent more energy compared to the VLC media player and resulted in a total consumption of 855,139 Ws for the 60 seconds clip.
5.4 Building Ecological Workflow Patterns from the empirical results

The results of the empirical measurements and of the conceptual introduction to EWPs can now be synthesized to Ecological Workflow Patterns. In the domain of software-engineering, authors use an exemplary style of describing patterns providing code-examples or a design motif with the involved software components (classes, methods, procedures). To describe the patterns, we followed the description of the workflow patterns by Van der Aalst et al. [8]. The authors use a verbal way to describe a process pattern with the catchwords Description, Synonyms, Examples and Implementation. Because EWPs address the workflow from a descriptive perspective and no code is involved at any point, we preferred this approach and omitted the example but added two more variables: the context gives information on the application environment (e.g. technical details) while the variable resources lists the resources that can be saved by applying the pattern. Also the recipients for the EWPs are business process specialists that do not necessarily have knowledge on the technical implementation of software-artefacts at code-level. However, the description of each pattern must be applicable to a variety of domains. That means “patterns should be formulated generically enough to withstand variations of context and domain” [26].

The first pattern that we introduced as an example in section 3.2 was about the transition of the state of information entities during the execution of the business process. The unnecessary transition consumes resources (paper, ink, toner, energy) that can be avoided by using integrated annotation tools to add annotations to the original document (e.g. a signature).

EWP 1 – data perspective: State transition of information entities.
Description: An information entity undergoes a transition of its state from a digital representation (e.g. database) to a physical representation (e.g. paper) or vice versa. Later in the process the state transition is reversed again. Annotations to the physical representation before the reversal of the state are optional.
Synonyms: none
Resources: Paper, ink, toner, electric energy
Context: none
Implementation: To avoid the state transition and reduce the resource demand during the transition, techniques to digitally edit and process the information entities should be implemented as a substitute to the processes where the transition occurs.

The second pattern refers to the supporting IS components of the process “confirm application” and holds results on the energy demand of the browser applications. Because the pattern functions as a guideline on what applications to use in a certain situation, the application scenario needs to be described. In the case of the “confirm application” task, the browser application was used to enter information regarding the proof of identity to a CRM system. The results of our measurements have to be interpreted accordingly.

EWP 2 – operational perspective: Use of web browser.
Description: In process tasks where a web browser is used to interact with information systems through a web interface, the use of Microsoft Internet Explorer is more advantageous in terms of energy consumption compared to Mozilla Firefox or Google Chrome.
Synonyms: Choice of browser.
Resources: Electric energy.
Context: Simple web application with input elements (text field, select button). No flash or other multimedia content.
Implementation: For new processes, the use of the Internet Explorer shall be considered and dependent software tools shall be tested for compatibility with the Internet Explorer. In existing processes, the substitution of Mozilla Firefox or Google Chrome with Internet Explorer should be evaluated. Compatibility of existing applications with Internet Explorer should be tested as well.

In the third pattern the question of ecological superiority of video players that are occupied during a process is addressed. The exploration method was the same as with the examination of the web browser. Again the context of the situation where the application is used must be described in detail.

EWP 3 – operational perspective: Use of video player.
Description: In process tasks where a video player is used to play back video streams, the use of Windows Media Player is more advantageous in terms of energy consumption compared to VLC media player or HTML 5 in combination with the web browser Mozilla Firefox.
Synonyms: Choice of video player.
Resources: Electric energy.
Context: Play back of video streams with a resolution of up to 1280x720 pixels.
Implementation: To reduce the energy consumption during the playback of videos, Windows Media Player should be used in processes rather than VLC media...
player or HTML 5 video streaming in combination with Mozilla Firefox.

The last EWP addresses the example from section 3.2 (figure 3) and refers to the control flow perspective:

**EWP 4 – control-flow perspective: Routing of process flow over one out of two processes with different energy profiles.**

**Description:** In processes where a document can either be sent using traditional mail or e-mail and the document is printed using a laser or electro-photographic printer, the document should be sent by e-mail if feasible.

**Synonyms:** Choice of transmission method.

**Resources:** Electric energy, paper, toner.

**Context:** Send documents physically by mail or virtually by e-mail.

**Implementation:** To reduce the energy consumptions caused by the adverse process task, appropriate measures should be taken to route the process-flow over the more advantageous process path.

6. Discussion and Findings

The intention of this paper was to provide an easy-to-apply way to support the design of new and the optimization of existing business processes towards environmental objectives. With the introduction of the concept of Ecological Workflow Patterns we provided decision analytics in terms of Green Business Process Management. With the provided approach, business processes can be easily orchestrated with the goal to create environmental-friendly processes on the three perspectives control-flow, data and operations. But not only does the approach support the creation of new processes. The EWPs can be applied to existing processes as well as a blueprint to find and eliminate weaknesses in such processes.

By using a software-tool that is able to measure the energy consumption of processes at the level of operating system, we found that Microsoft Internet Explorer 10 offers more energy-saving potential compared to the browser applications from Google or Firefox. The energy-saving compared to Mozilla Firefox is substantial with an energy demand of only 70.3 percent compared to the consumption of Mozilla Firefox. The substitution of Google Chrome or Mozilla Firefox with Internet Explorer can lead to the reduction of the energy demand without having to apply extensive optimization measures such as Business Process Simulation.

We could also identify a minor energy saving opportunity for scenarios where the VLC media player is used as the standard way to play back video streams or files. In this case, with the use of Windows Media Player instead of VLC, the energy consumption caused by the video player would decrease by 5.8 percent. Based on these opportunities we created four Ecological Workflow Patterns that can be used as a blueprint to optimize business processes.

However, the presented approach comes with some drawbacks as well. First of all, currently the EWPs are not yet integrated to a BPM / Green BPM suite. The automatic validation of newly created processes or process components under consideration of every EWP could enable to enhance the quality of new process models at design time and is required as the number of EWPs may increase rapidly.

Also the extraction of further EWPs needs to be subject to further research. With this paper we demonstrated the concept on basis of three examples. As explained, the extraction needs different methodologies to be applied in order to gain reasonable results. In the case of the control-flow perspective, the application of process mining technologies can help to extract weaknesses through the processing of large of publicly available and corporate process corpora. With process mining, it is possible to search for a certain configuration in the process that is considered to be a weakness. Such a configuration was shown with the state transition of data from non-physical to physical and back or vice versa. Finally, the results have to be interpreted according to the set-up of our experiment. Future releases of the tested software may alter the results. Configurations that were not subject to our research must be observed more in detail, e.g. flash websites, video resolution etc.

7. Conclusion and future research

As Green BPM becomes a popular issue, methodical support for the optimization of business processes with respect to environmental objectives becomes necessary. We presented a pattern-based optimization approach and the application along with a sample process to demonstrate the applicability of the method.

Our future work in the field of Ecological Workflow Patterns shall focus on the extraction of further patterns. We aim at the development of a structured methodology to identify the patterns semi-automatically by using process mining concepts to enable the analysis of large sets of process models. To prove the relevance of EWPs for practice, an extensive evaluation in a corporate environment has to be conducted. Before the evaluation can be conducted, a fair number of patterns must be available.

After the evaluation, we plan to integrate the final set of patterns to a BPM suite to create a conven-
inent and easy to apply method for decision support in the area of Green BPM. The tool-supported design of ecology-oriented process models can help to significantly reduce the energy consumption of IT-related processes and therefore protect the environment from unnecessary emittance of pollutants or to diminish the consumption of rare materials.

Acknowledgement: The research described in this paper was supported by a grant from the German Ministry for Education and Research (BMBF), project name PRISMA, support code 033RK001B.

8. References


