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In Business, Environment and Administration

A Model and Selected Instances of Green and Sustainable Software

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Motivation

- Power consumption of data centres in the world increased from 58 TW h in 2000 to 123 TW h in 2005
- Reducing the consumption of energy and natural resources caused by ICT is necessary
- Efforts exist in the field of computer hardware
- Lack of efforts in the field of computer software
- Up to now it is not clear what sustainable software is

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2

The power consumption of data centres in the world increased from 58 TW h in 2000 up to 123 TW h in 2005 and is still increasing

Hence, reducing the consumption of energy and natural resources caused by ICT is necessary

Where manifold efforts exist in the field of computer hardware (that is: Green-IT), there is a lack of models, descriptions, or realizations in the field of computer software.

Especially, there are hardly any systematic methods available that try to integrate sustainability aspects in software product design and development.

Up to now it is not clear what the term sustainable software means or what sustainable software is.



Outline

- I. Definition of "Sustainable Software"
- II. A Model for Sustainable Software Engineering
- III. Selected Instances of the Model
- IV. Summary & Outlook



I. Definition of “Sustainable Software”





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A Definition of “Sustainable Software”

“**Sustainable Software** is software

- whose direct and indirect negative impacts on economy, society, human beings, and environment
- that result from development, deployment, and usage of the software are minimal and/or
- which has a positive effect on sustainable development”

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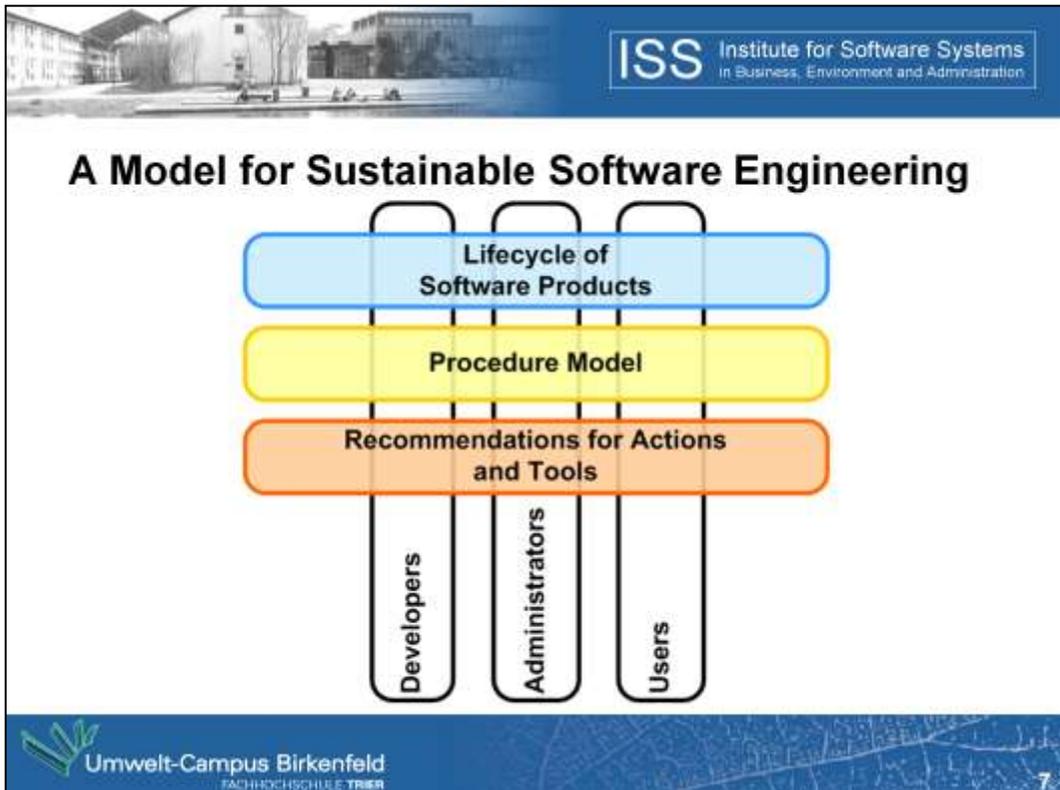
5

In this definition, direct impacts comprise energy and resource demand that is necessary to produce, use and dispose of the software product. Indirect impacts are effects that result from using the software product on other processes and long term systemic effects.



II. A Model for Sustainable Software Engineering





Our model comprises

- a lifecycle model for software products
- a procedure model
- and recommendations for actions and tools

These are all provided for several roles, like Developers, Administrators, and Users.

Of course, there may be further and more specialized roles.

In principle we have two views in this model:

- the product view, which is given by the lifecycle model
- the organizational view, which is given by the procedure model

Both are accompanied by recommendations and tools, which support involved people in applying the procedure model and considering the whole lifecycle of a software product.

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Life Cycle Model for Software Products

Product Definition → Development → Distribution → Acquisition → Usage → Deactivation → Disposal

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8

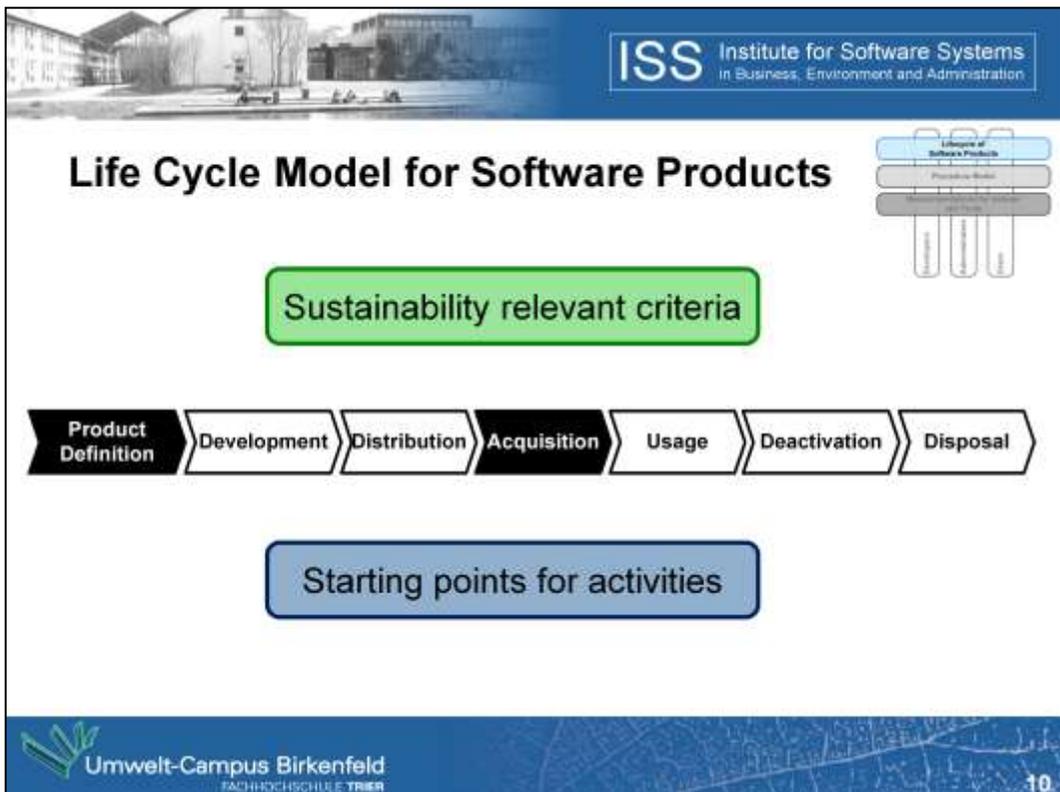
If you look at the phases of our lifecycle model, you will recognize, that it is more a product lifecycle in the sense of Life Cycle Thinking than an ordinary software lifecycle, because these are usually focusing on development phases and activities.

This model fits mainly to standard software products. For custom software products the phase “Acquisition” may follow directly after the phase “Product Definition”.

The diagram illustrates the Life Cycle Model for Software Products. At the top left is a photograph of a university building. The top right features the logo for ISS (Institute for Software Systems) with the text "Institute for Software Systems in Business, Environment and Administration". The main title is "Life Cycle Model for Software Products". Below the title is a green rounded rectangle labeled "Sustainability relevant criteria". To the right of this is a vertical stack of three boxes: "Library of Software Products", "Productivity Model", and "Sustainability Model". Below these is a horizontal flowchart with seven stages: "Product Definition", "Development", "Distribution", "Acquisition", "Usage", "Deactivation", and "Disposal". The bottom of the slide features the logo for Umwelt-Campus Birkenfeld, Fachhochschule Trier, and a small number "9" in the bottom right corner.

The model has two objectives:

Its first objective is to assign criteria to the life cycle phases that lead to/result in sustainability relevant effects.



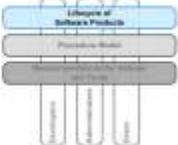
Its second objective is to provide starting points for activities that allow an assessment of the sustainability relevant effects that result from the software product over its whole life cycle. Hopefully, these activities lead to more sustainable software products.



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Life Cycle Model for Software Products

- ...
- Transportation for daily way to work
- Working conditions (offshore workers)
- Business trips
- Energy for ICT
- Office lighting
- Office HVAC

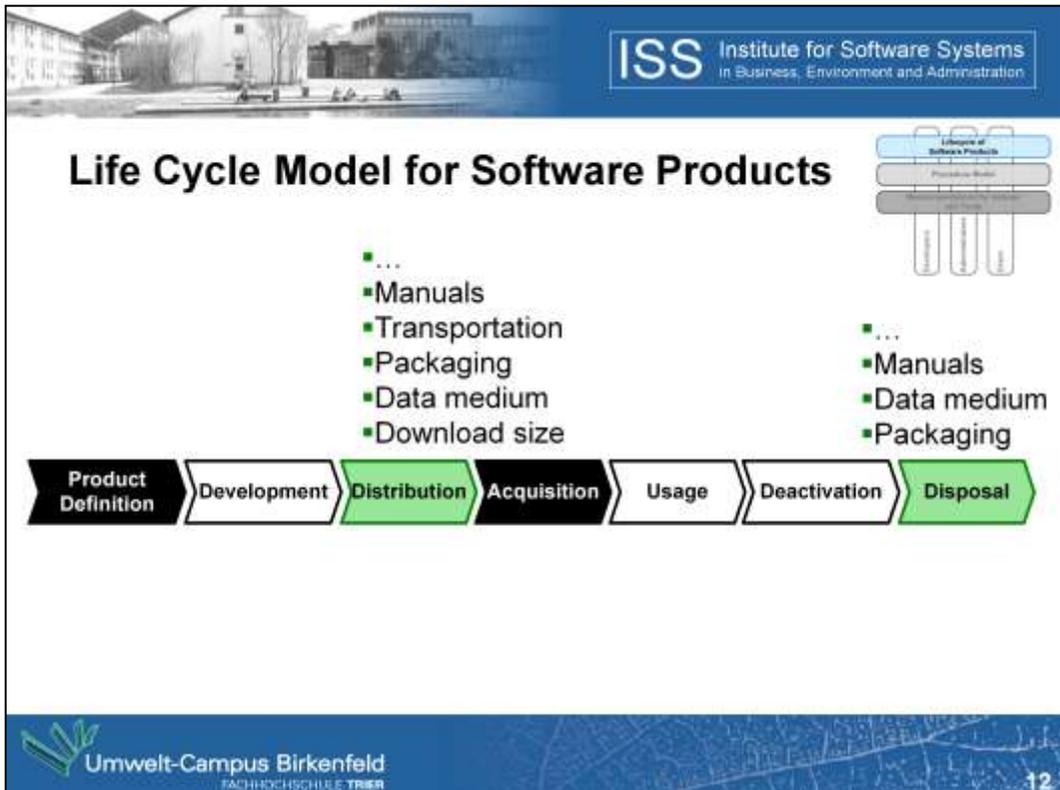
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11

Now, let's have a look at some example criteria. Please, note that these examples are far from complete.

Examples of criteria for the development phase are:

- Working conditions
- Business trips
- Energy for IT-Infrastructure
- Office heating and air conditioning



Examples of criteria for the distribution phase are

- Printed manuals
- Packaging
- Data medium
- Download size

These relate directly to criteria for the disposal phase, like

- the disposal of printed manuals
- the data medium, and
- the packaging



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Life Cycle Model for Software Products

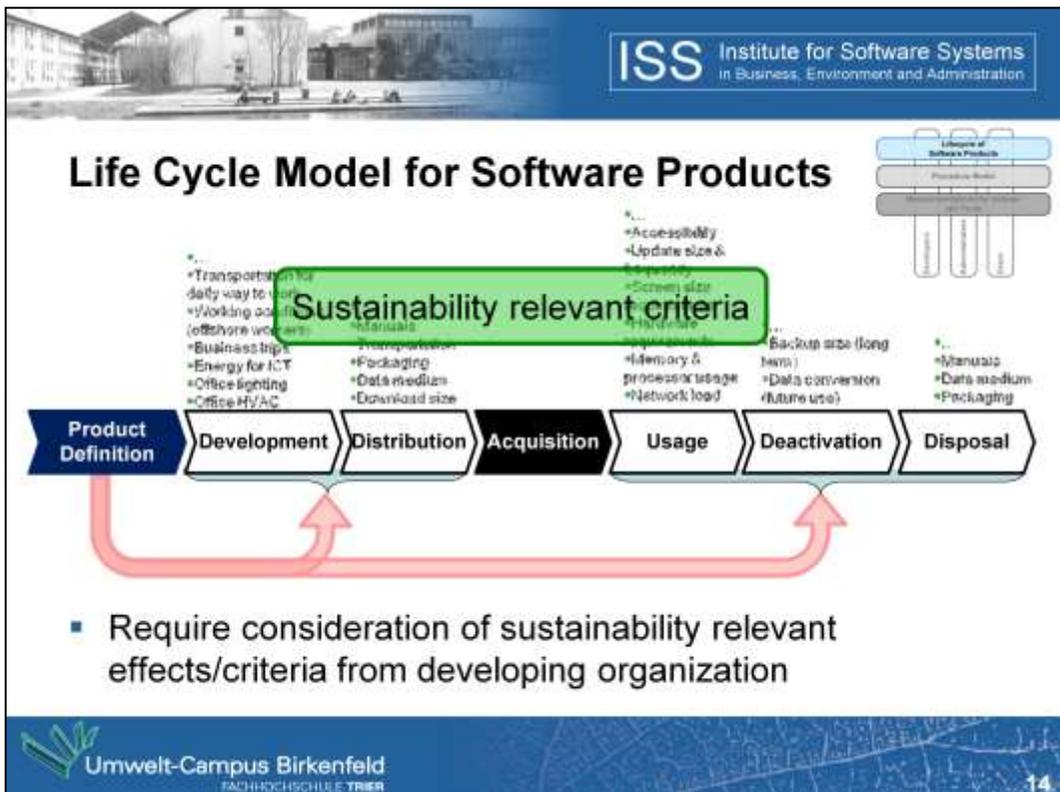
- ...
- Accessibility
- Update size & frequency
- Screen size requirements
- Hardware requirements
- Memory & processor usage
- Network load


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13

Examples of criteria for the usage phase are:

- Accessibility issues
- screen size requirements
- other hardware requirements
- memory and processor use during program execution



There are two preconditions:

1. During the Product Definition phase, consideration of sustainability relevant effects/criteria must be required from the developing organization (e.g. as non-functional software requirements). This forces the developing organization to consider these criteria during development and to apply further activities in order to assess impacts that result from the software product over its whole life cycle.

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Life Cycle Model for Software Products

The diagram illustrates the Life Cycle Model for Software Products, consisting of seven stages: Product Definition, Development, Distribution, Acquisition, Usage, Deactivation, and Disposal. A green box highlights 'Sustainability relevant criteria' across the Development, Distribution, and Usage stages. A small tree diagram on the right shows the hierarchy of software products.

Sustainability relevant criteria:

- Development:**
 - *Transportation for daily way to work
 - *Working conditions (offshore workers)
 - *Business trips
 - *Energy for ICT
 - *Office lighting
 - *Office HVAC
- Distribution:**
 - *Packaging
 - *Data medium
 - *Download size
- Usage:**
 - *Accessibility
 - *Update size & frequency
 - *Screen size
 - *Hardware requirements
 - *Inventory & processor usage
 - *Network load
- Deactivation:**
 - *Backup size (long term)
 - *Data conversion (future use)
- Disposal:**
 - *Manuals
 - *Data medium
 - *Packaging

■ Customers should require information about sustainability relevant issues

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15

- Customers should require information about sustainability relevant issues.

For custom software, this condition is met with the non-functional requirements and with e.g. reports about assessments and applied activities.

For standard software, this may lead to some kind of a seal of quality or eco-label for software products in the future.

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Procedure Model

Sustainability relevant criteria

- Product Definition:**
 - *Transportation for daily way to work
 - *Working conditions (offshore workers)
 - *Business trips
 - *Energy for ICT
 - *Office lighting
 - *Office Hy/AC
- Development:**
 - *Manuals
 - *Preparation
 - *Packaging
 - *Data medium
 - *Download size
- Distribution:**
 - *Accessibility
 - *Update size & frequency
 - *Screen size
 - *Hardware requirements
- Acquisition:**
 - *Inventory & processor usage
 - *Network load
- Usage:**
 - *Backup size (long term)
 - *Data conversion (future use)
- Deactivation:**
 - *Manuals
 - *Data medium
 - *Packaging
- Disposal:**
 - *Manuals
 - *Data medium
 - *Packaging

■ Extend software development processes with reflection meetings and assessment activities

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16

We propose a procedure model that extends arbitrary software development processes with continuous reflection meetings and assessment activities. These are targeting at assessing direct and indirect impacts, –which result from the software development process itself and –which are expected to arise from distribution and future use of the software product

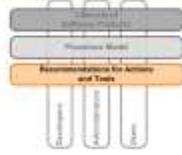
The outcomes of the assessments and reflection meetings should be used to take action towards more sustainable software products.



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Recommendations for Actions & Tools

- Represent the implementable part of the model
- Forming an open knowledge base, containing
 - future developments, trends, and evolving technical expertise
 - recommendations for actions e.g. tips, guidelines, checklists etc. on how to develop, use, provide, and maintain software products in a more sustainable way
 - different technical skill levels and user roles



The diagram shows a central box labeled 'Recommendations for Actions and Tools' connected to three other boxes: 'Requirements', 'Architecture', and 'Design'.

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17

Recommendations for Actions & Tools represent the implementable parts of our model.

In principle they form an open knowledge base, which enables the consideration of future developments, trends, and evolving technical expertise. It contains recommendations for actions (e.g. tips, guidelines, checklists) that provide information on how to develop, use, provide and maintain software products in a more sustainable way. These recommendations can be written for people with different technical skill levels and different user roles within the life cycle of a software product.



III. Selected Instances of the Model



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Recommendations for Action and Tools

The diagram illustrates a structured approach to software development and management. It features three horizontal bars at the top: 'Lifecycle of Software Products' (grey), 'Procedure Model' (grey), and 'Recommendations for Actions and Tools' (orange). Below these bars are three vertical red outlines representing user roles: 'Developers', 'Administrators', and 'Users'. Red lines connect the top bars to the vertical outlines, indicating that the lifecycle and procedure models inform the recommendations for each role.

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19

Now, to some selected instances of our model, which are realized as recommendations for actions and software tools for

- Developers
- Administrators
- Users

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CSS Optimization Hints in IDEs

```

corporate-style.css
105 input[type=text]
106 {
107     color:#000000;
108     background-color:#FFFFFF;
109     border-width:0px;
110 }
111
112

```

Problems: 1 error, 3 warnings, 0 others

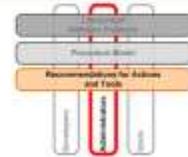
Description	Resource	Path	Line
Errors (1 item)			
Warnings (3 items)			
Optimise colour: Change "#000000" to "#000"	corporate-st...	/StudentAssistan...	lin
Optimise colour: Change "#FFFFFF" to "#FFF"	corporate-st...	/StudentAssistan...	lin
Optimise number: Change "0px" to "0"	corporate-st...	/StudentAssistan...	lin

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20

This screen-shot shows an example of a tool, which is integrated in the eclipse IDE. It analyzes CSS files and gives hints on how these files may be optimized in order to reduce their filesize. The tool can be applied by web developers during the development phase, which leads to a lower download size of the website during the usage phase.

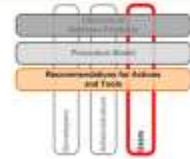
Guideline for HTTP Compression



Example files	File size (KB)	GZIP size (KB)	Savings
index.html	5.45	2.44	55.2%
style.css	2.73	0.68	75.1%
prototype.js	126.00	29.51	76.6%
ida-logo.png	24.80	24.86	-0.2%
ucb-logo.png	9.27	9.28	-0.1%
	168.25	66.70	60.4%

This slide motivates a guideline for HTTP compression. By enabling HTTP compression in web servers, it is possible to reduce network traffic. For this example web site, we achieved overall savings from 50 to 76 per cent for uncompressed file types. This guideline can be applied by administrators during the usage phase when they set up the web server for the website. It affects the download size for all users who view the website during the usage phase.

Visualizing the Power Quality of Websites




Text	Icon
Power Indicator active	pi
Power Indicator inactive	pi
Green Power Class A	Green Power Class A icon
Green Power Class B	Green Power Class B icon
Green Power Class C	Green Power Class C icon
No Green Power	No Green Power icon
Power Quality unknown	Power Quality unknown icon
...searchingsearching ... icon
...for	...for icon

The Power Indicator is an add-on for the Firefox browser. It visualizes, whether a website is hosted with renewable energy or not. It belongs to the usage phase and it is intended to support web users in making informed decisions on which websites they want to or do not want to surf on.



IV. Summary & Outlook





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Summary

- It is not clear whether energy savings through ICT outbalances energy consumption, or not
- It is rational to integrate sustainability aspects not only in hardware products, but also in software products
- We presented a model that comprises
 - Lifecycle model for software products
 - Procedure model
 - Recommendations for actions and tools.
- We presented some selected instances of our model



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24

Summarizing, it is currently not clear whether energy savings through Information and Communication Technology outbalances its energy consumption or not. In either case it is rational to integrate sustainability aspects in software product design and development as it is already common for material products today.

Hence, we presented a model that comprises

- A Life Cycle Thinking inspired Life Cycle of Software Products,
- A Procedure Model, and
- Recommendations for Actions and Tools.

As implementable instances of the model, we presented some examples of these recommendations and tools.



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Outlook

- Detail and broaden our model
 - Criteria for different software scenarios and software types
 - Criteria addressing social and economic dimensions
 - Indirect effects (examples and educational material)
- Develop procedures that integrate sustainability aspects into arbitrary software development processes
- Develop a knowledge base to support sustainable software development, administration, and use



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25

Our next steps are to detail and broaden our model with e.g.

- More criteria for different software scenarios and types of software
- Criteria that addresses the social and economic dimensions of sustainability
- Examples and Educational Material that address indirect effects of software use, because we do not expect software developers to recognize these intuitively.

Two main parts are currently missing: the procedure model and plenty of recommendations and tools. Hence, we plan to develop and evaluate procedures that integrate or help to integrate sustainability aspects into arbitrary software development processes and we plan to develop and operate the already mentioned knowledge base that provides recommendations for actions, which support development, administration, and use of software in a more sustainable way.



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Thank you for your attention!

Feel free to contact us:

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