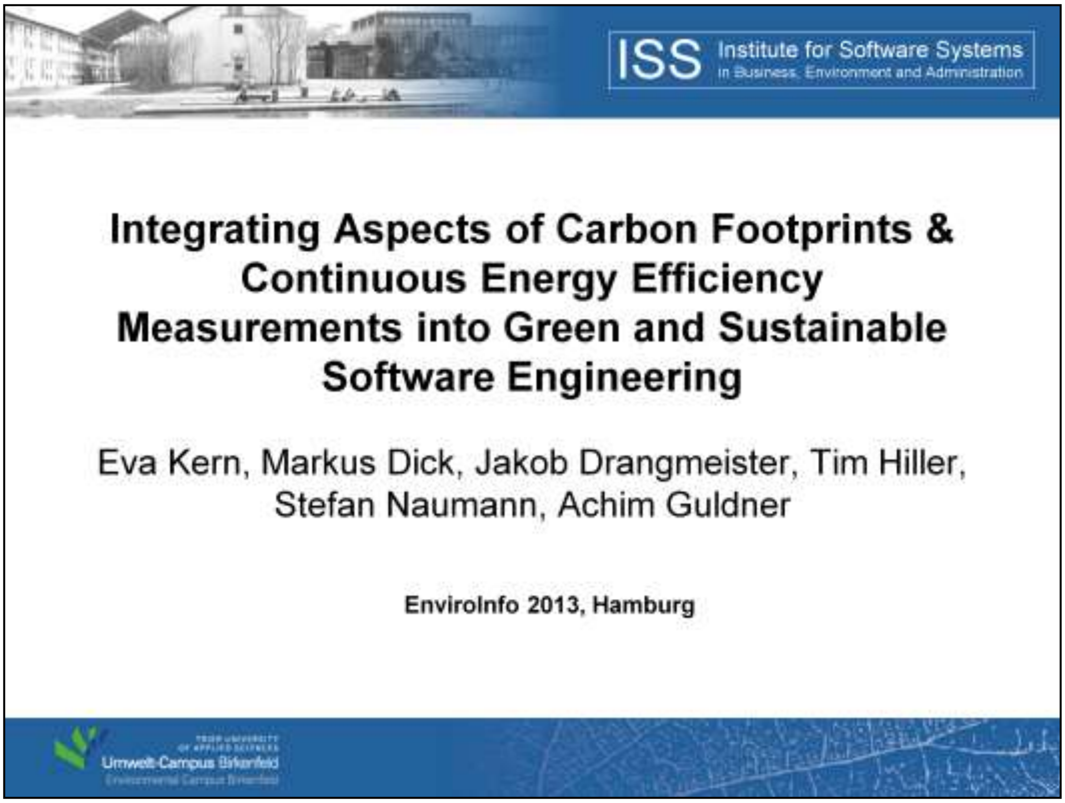

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Integrating Aspects of Carbon Footprints & Continuous Energy Efficiency Measurements into Green and Sustainable Software Engineering

Eva Kern, Markus Dick, Jakob Drangmeister, Tim Hiller, Stefan Naumann, Achim Guldner

EnviroInfo 2013, Hamburg

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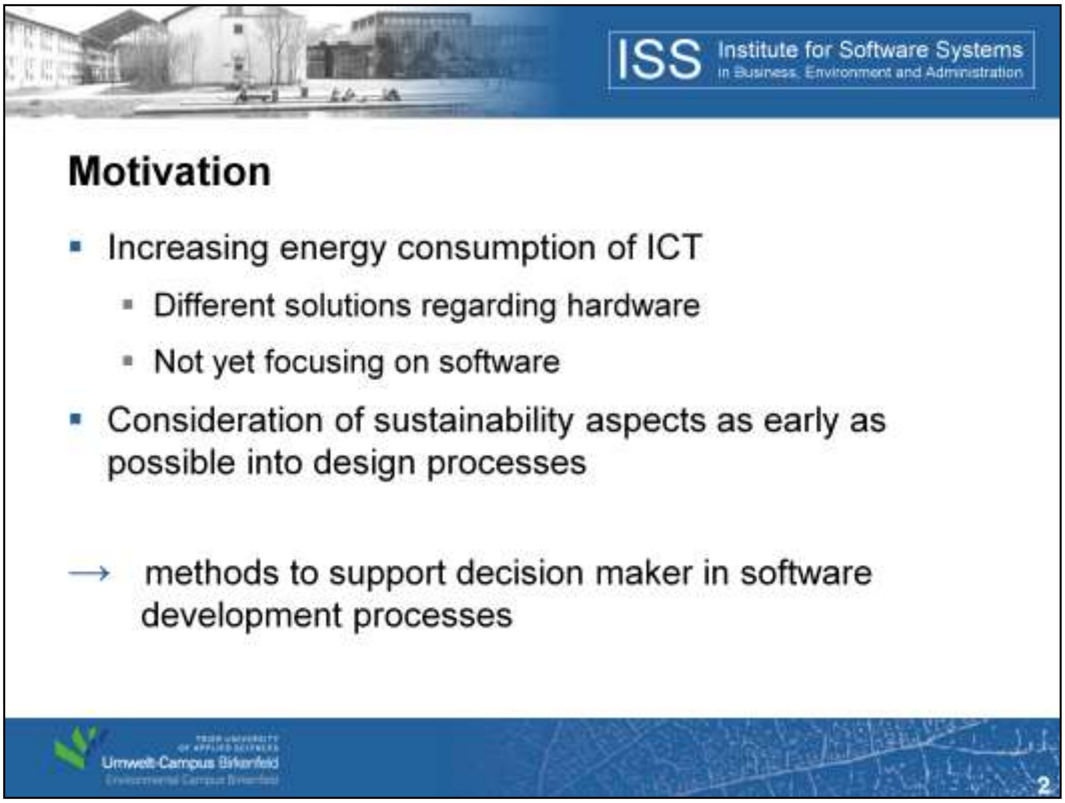
The Blog on http://sustainablesoftware.blogspot.de is about software and software engineering that supports and adheres to Sustainable Development in the spirit of the UN’s wide spread definition of a development that “meets the needs of the present without compromising the ability of future generations to meet their own needs.”



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Motivation

- Increasing energy consumption of ICT
  - Different solutions regarding hardware
  - Not yet focusing on software
- Consideration of sustainability aspects as early as possible into design processes

→ methods to support decision maker in software development processes

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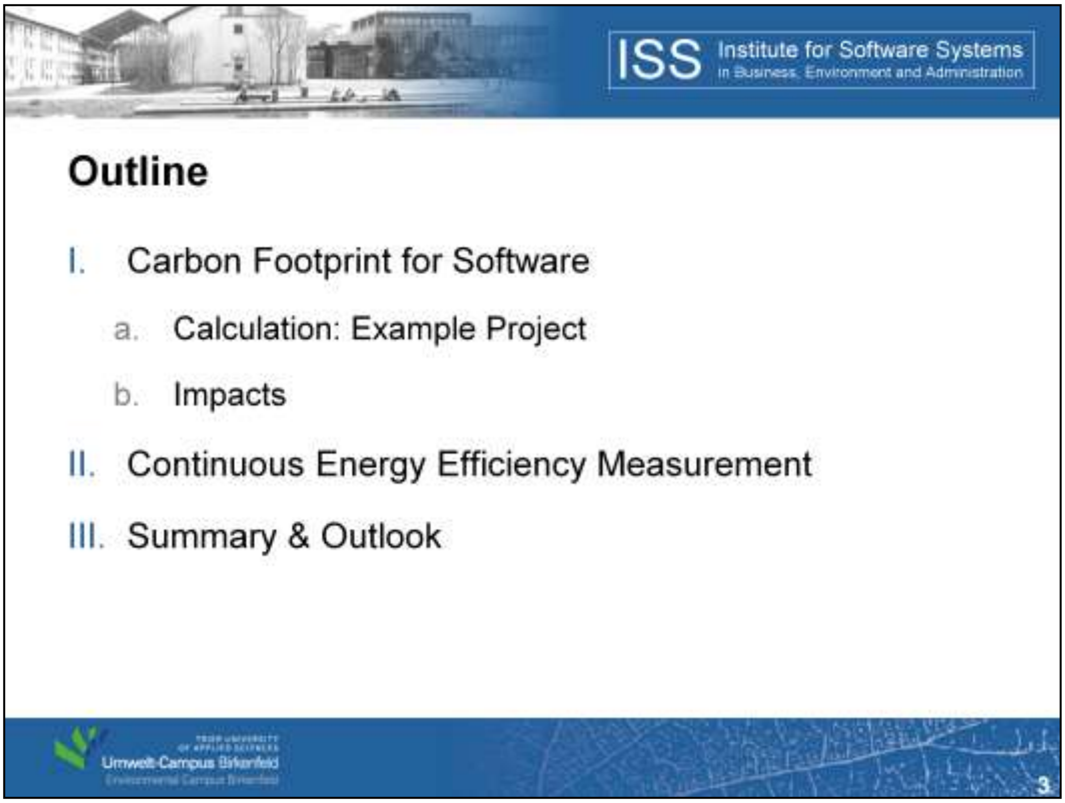
First of all the increasing energy consumption of ICT is our motivation to deal with green it aspects in general. Since there are different solutions regarding hardware, the energy consumption of software shifts into focus only slowly. Indeed, software is the ultimate cause of hardware requirements and its energy consumption.

Hence, one should consider sustainability aspects as early as possible during the software design process.

Today, I will present two methods to support decision makers in the software development process.



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Outline

I. Carbon Footprint for Software
   a. Calculation: Example Project
   b. Impacts
II. Continuous Energy Efficiency Measurement
III. Summary & Outlook

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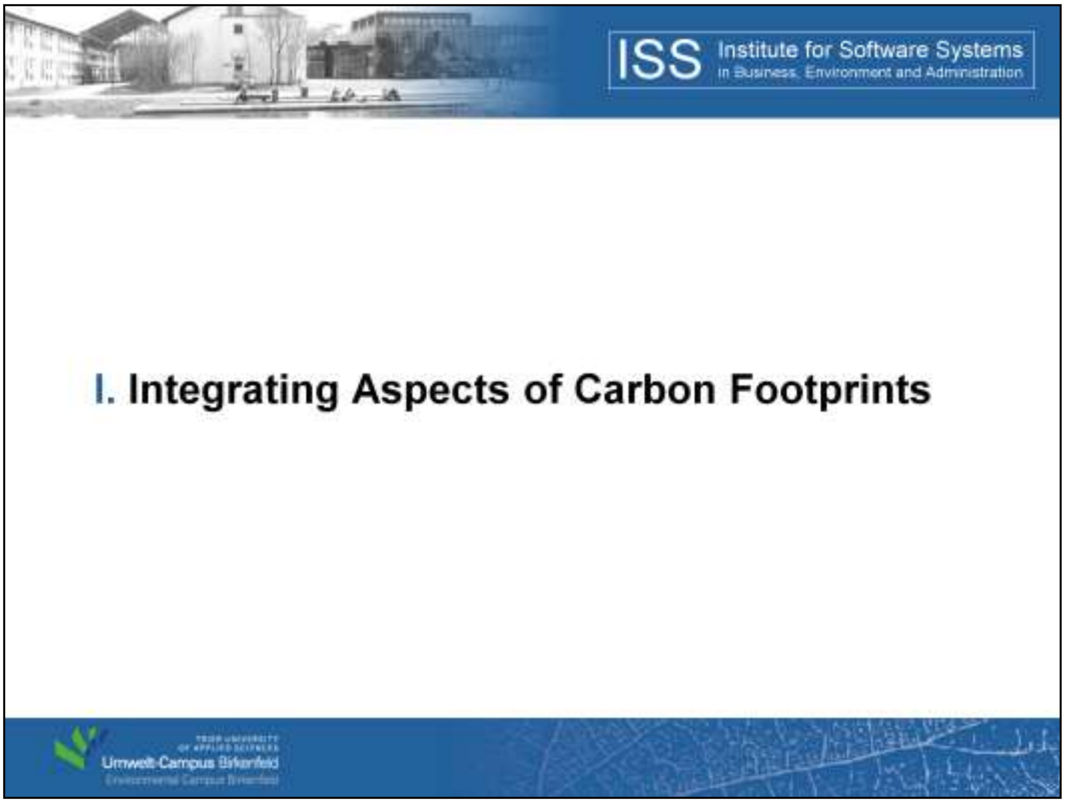
To do so, I will present an approach of calculating the carbon footprint of a software product, focussing on the development process.
That means, I will introduce a calculation method by showing an exemplary project and will go into some impacts afterwards.

Additionally, I will describe a method of continuous energy efficiency measurement and will give a summary as well as a short outlook in the end.



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I. Integrating Aspects of Carbon Footprints

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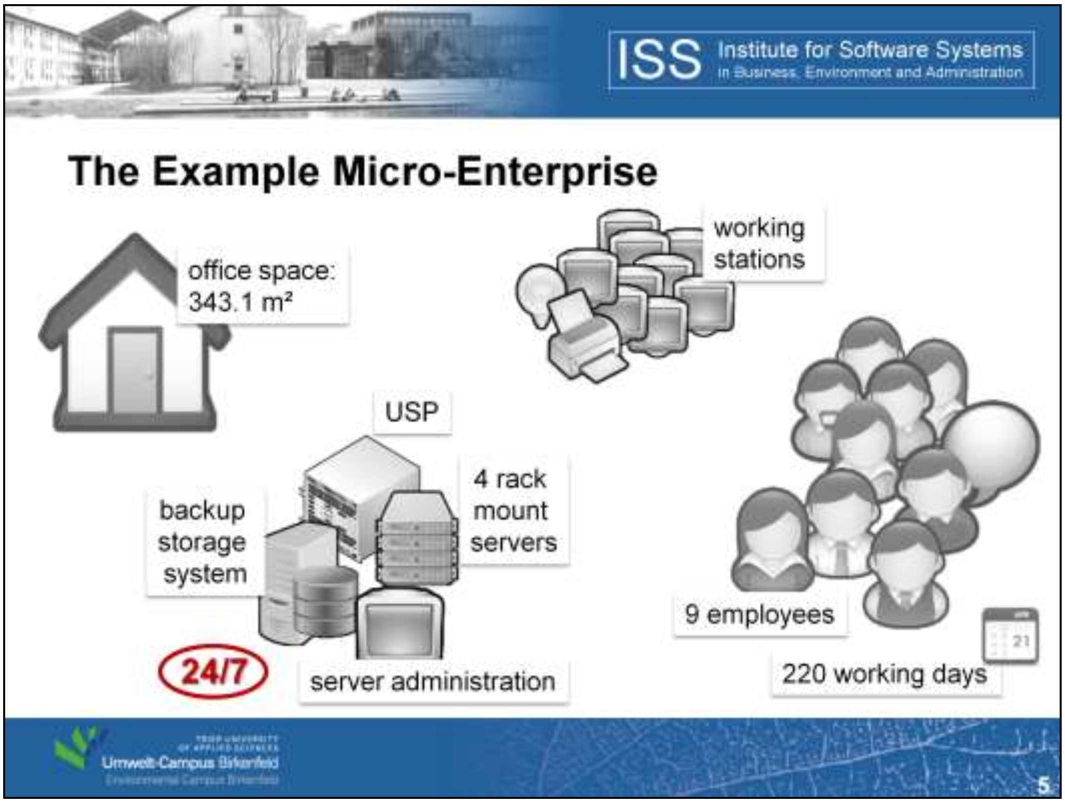
The first part of my presentation is the carbon footprint calculation for software products…



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The Example Micro-Enterprise

office space: 343.1 m²

working stations

USP

4 rack mount servers

backup storage system

9 employees

24/7

server administration

220 working days

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To get an impression of how a carbon footprint calculation can look like, we choose an example micro-enterprise with 9 employees:

These are:

- 1 general manager
- 1 accountance
- 1 person for sale
- 1 costumer support
- 5 software developers

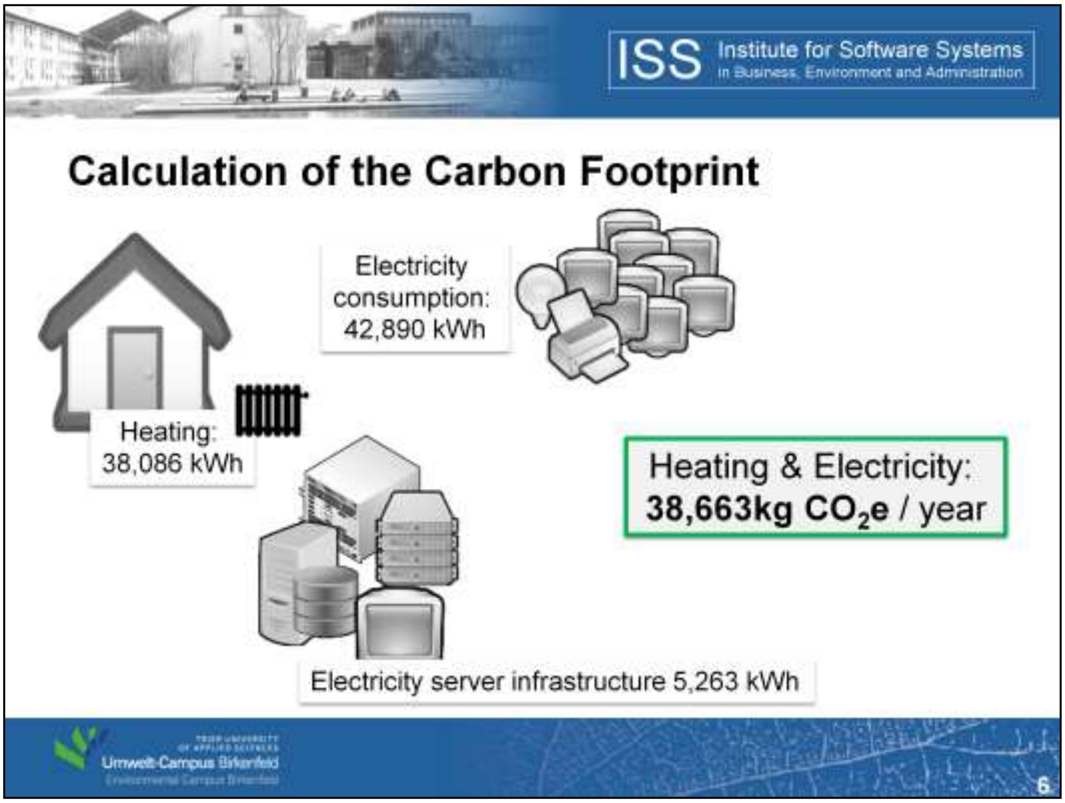
As an average we assume 220 working days per year (including holidays, illness and so on).

All of them need working station, that consumes energy. Furthermore we need

- a backup storage system
- Four rack mount servers
- Another working station for the server administration and
- a UPS

We do not include the energy consumption of the network here.

The office space comes to about 343 square meters.



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Calculation of the Carbon Footprint

Electricity consumption: 42,890 kWh

Heating: 38,086 kWh

Heating & Electricity: **38,663kg CO_2e** / year

Electricity server infrastructure 5,263 kWh

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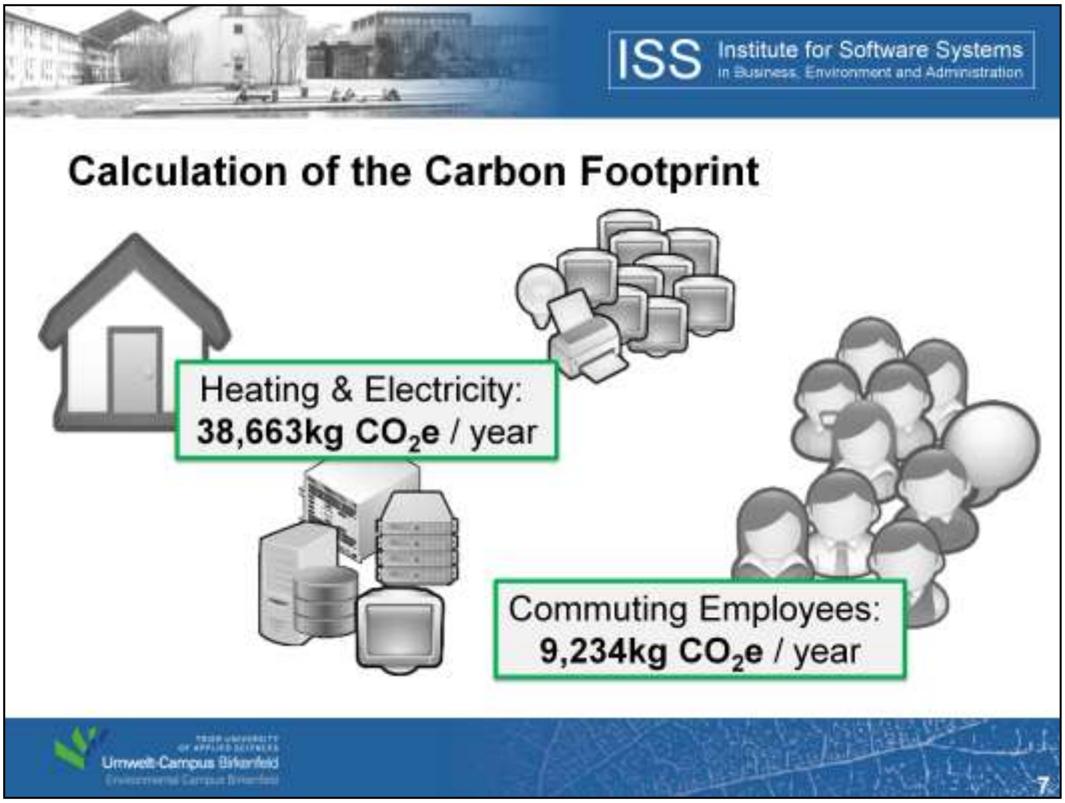
Based on average numbers for heating and electricity consumption we come to an energy consumption of about 86.000 kWh per year.
This includes heating, the electricity for the server infrastructure and the additional consumption for the workstations, lighting, and so on.

In total, the heating and electricity of our example micro-enterprise produce about 39.000 kg of CO2 equivalents per year.

Hence, we did not include the commuting so far…



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Calculation of the Carbon Footprint

Heating & Electricity:
38,663kg CO_2e / year

Commuting Employees:
9,234kg CO_2e / year

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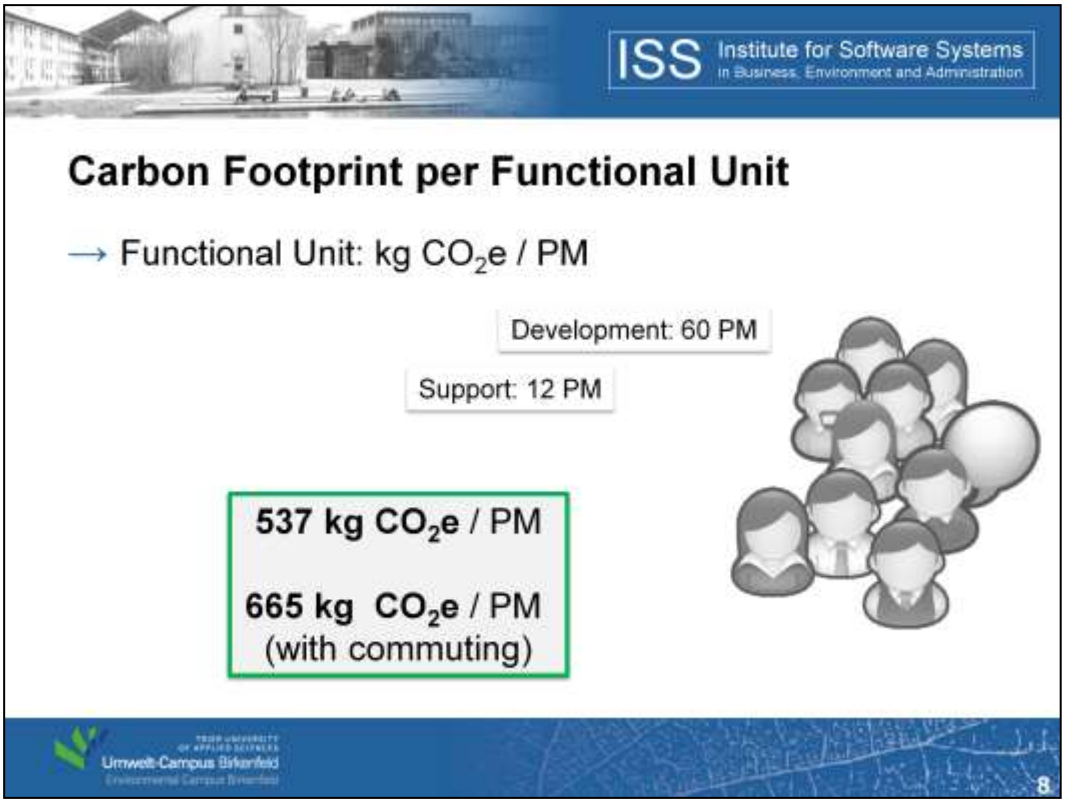
If we include the carbon dioxid emissions of the commuting employees the carbon footprint increases by about 9.000 CO2 equivalences per year.

The example is especially designed to answer the question whether or not the impact of commuting employees should be considered in carbon footprints of software.

Standards like the PAS 2050 or the GHG Protocol require that those emissions are not considered.

Before I will go into detail of how we calculated the commuting lets calculate the carbon footprint per functional unit.



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Carbon Footprint per Functional Unit

→ Functional Unit: kg CO_2e / PM

Development: 60 PM

Support: 12 PM

537 kg CO_2e / PM

665 kg CO_2e / PM (with commuting)

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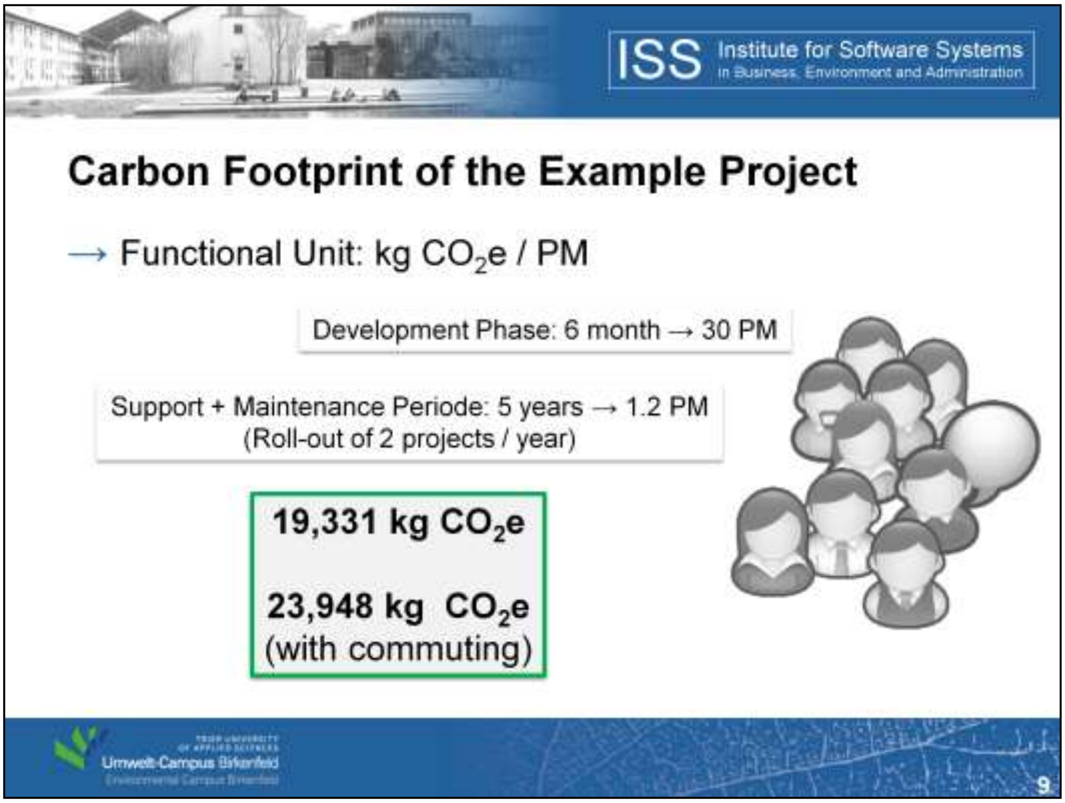
As a functional unit, we set person month (PM).
Apart from that you can choose for example lines of codes, number of modules or files.

We dicided to take person month since it is not linked to personal preferences like for example number of modules or files can be. Lines of codes depends on the style of programming, hence is also a personal leaning of the developer.
Person month does not have this dependence. Indeed, I know that this choice is a big point of discussion.

Assuming that the development comes up with sixty pm and the support with twelf, we come to 537 kg CO2 emissions per person month without commuting and 665 kg including the emissions of commuting employees.

Furthermore…



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Carbon Footprint of the Example Project

→ Functional Unit: kg CO_2e / PM

Development Phase: 6 month → 30 PM

Support + Maintenance Periode: 5 years → 1.2 PM
(Roll-out of 2 projects / year)

19,331 kg CO_2e

23,948 kg CO_2e
(with commuting)

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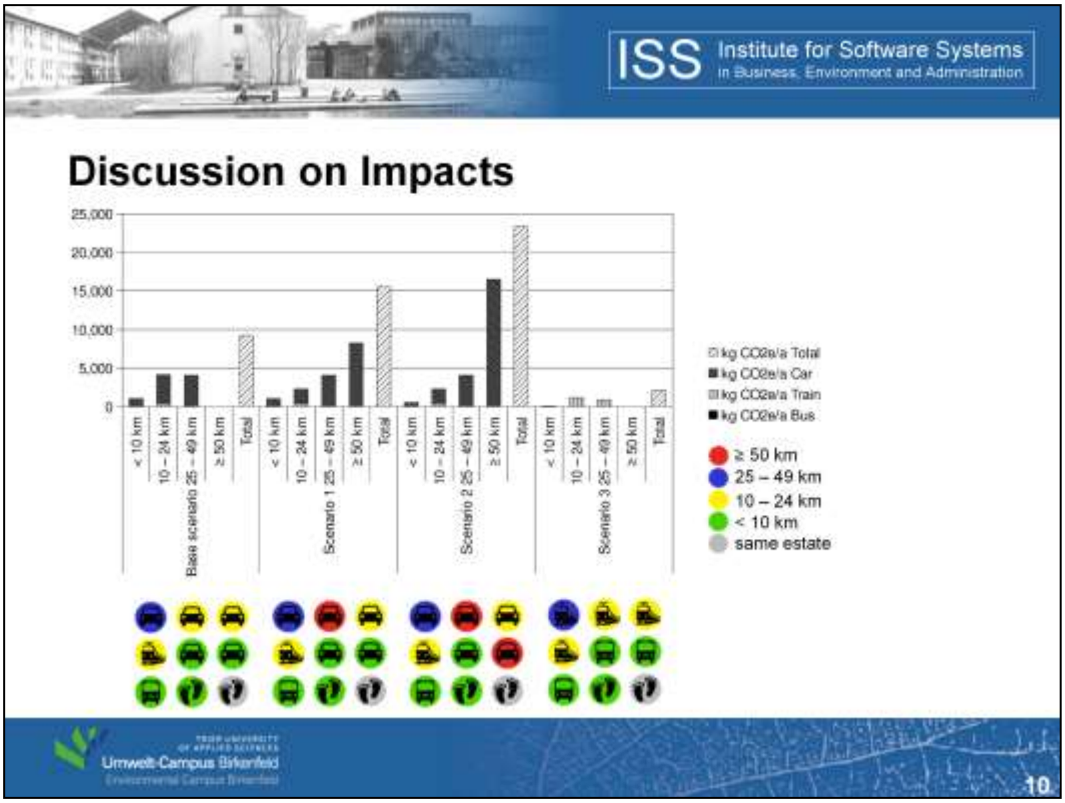
If we assume additionally, that the development phase of the example project takes 6 months and we have a support and maintenance period of 5 years, we come to the following numbers.

Here, we calculate with a roll-out of two projects each year, that‘s why we come up with 1.2 pm (with a fixed support and mainentance periode of five years.)

Thus, the total emissions of the example project are approximately 24.000 kg CO2e with emissions from commuting.

Indeed, there are different impacts we need to deal with…



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Discussion on Impacts

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At first we had a look on are the emissions of commuting.

Overall, considering emissions from commuting increases the carbon footprint of the project (incl. support) by ~ 24%

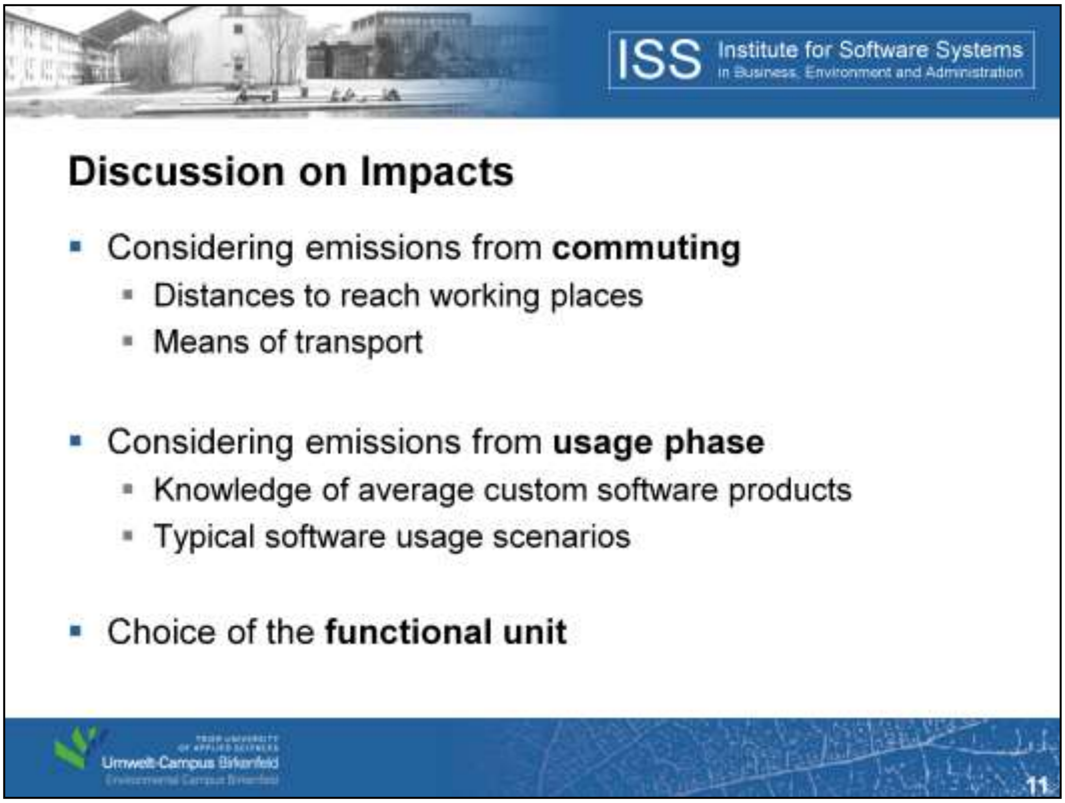
This basic scenario looks like following:

- we have one employee going 25-49km by car, …
- 3 persons have to go 10 to 24km to reach the office, 2 of them are going by car, one takes the train.
- 1 person is living in the same estate, so going by foot
- The other ones have a distance less than 10km, they are going by car (for two of them), bus or by foot.

If we compare this with three further scenarios we have different contributions of commuting to the annual carbon footprint as you can see here.
The best scenario regarding the carbon footprint is when the employees use bus and train, means public transport systems.
So, as you can see here, the commuting is a potential to reduce emissions and to change working and living conditions. That‘s why we had a look onto the impacts of including commuting to our CF calculations.

- First scenario: one car driver switched from 10-24km to >=50

- Second scenario: one more car driver from <10 km to >= 50km
- Third scenario: care usage eliminated by shifting employees to train or rather bus (for less than 10km)



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Discussion on Impacts

- Considering emissions from **commuting**
  - Distances to reach working places
  - Means of transport
- Considering emissions from **usage phase**
  - Knowledge of average custom software products
  - Typical software usage scenarios
- Choice of the **functional unit**

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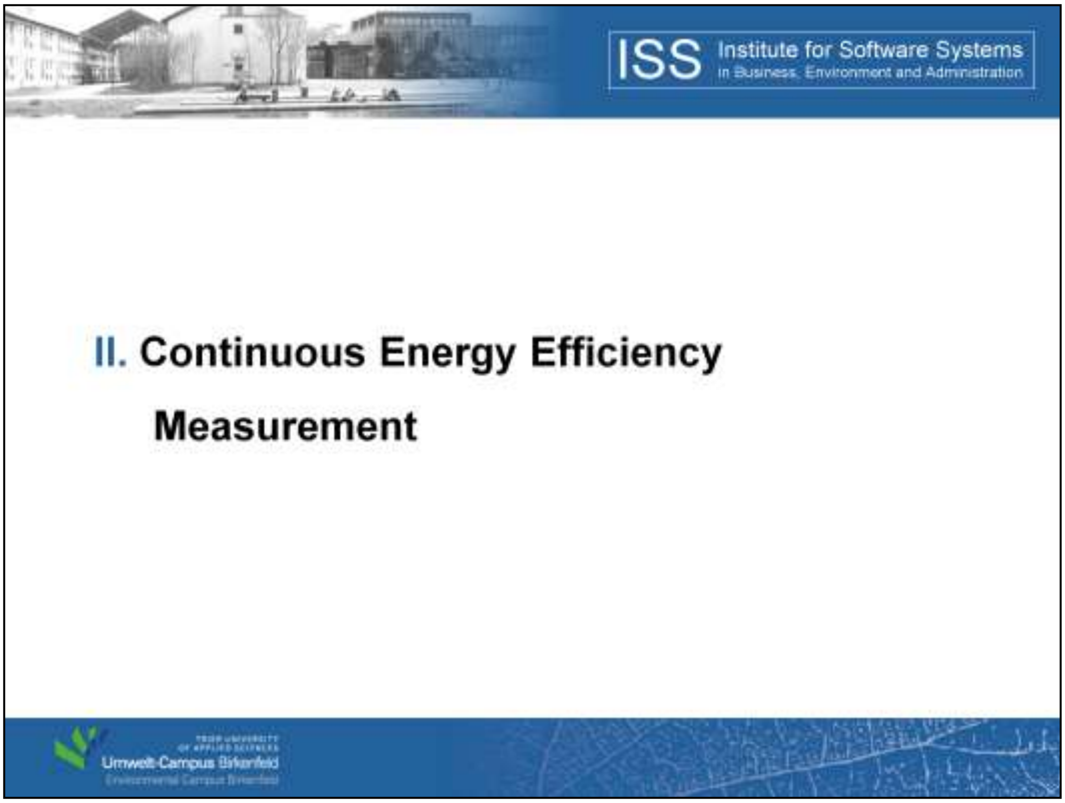
Apart from the distances to reach the working place and the means of transport of the employees, the emissions of the usage phase of a software product are also of high importance.

However, we decided to not consider the usage phase in our example because we lack basic knowledge about average custom software products developed in micro-enterprises.

Furthermore, as a mentioned already, the functional unit is a discussion point in this context.

In spite of our concerns, we give an impression of the dimension of the carbon footprintof the five-year usage phase compared to the carbon footprint of the example project.
As a scale, we provide two oversimplified carbon footprints of working station and server usage, where the number of computers increases in increments of ten.



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II. Continuous Energy Efficiency Measurement

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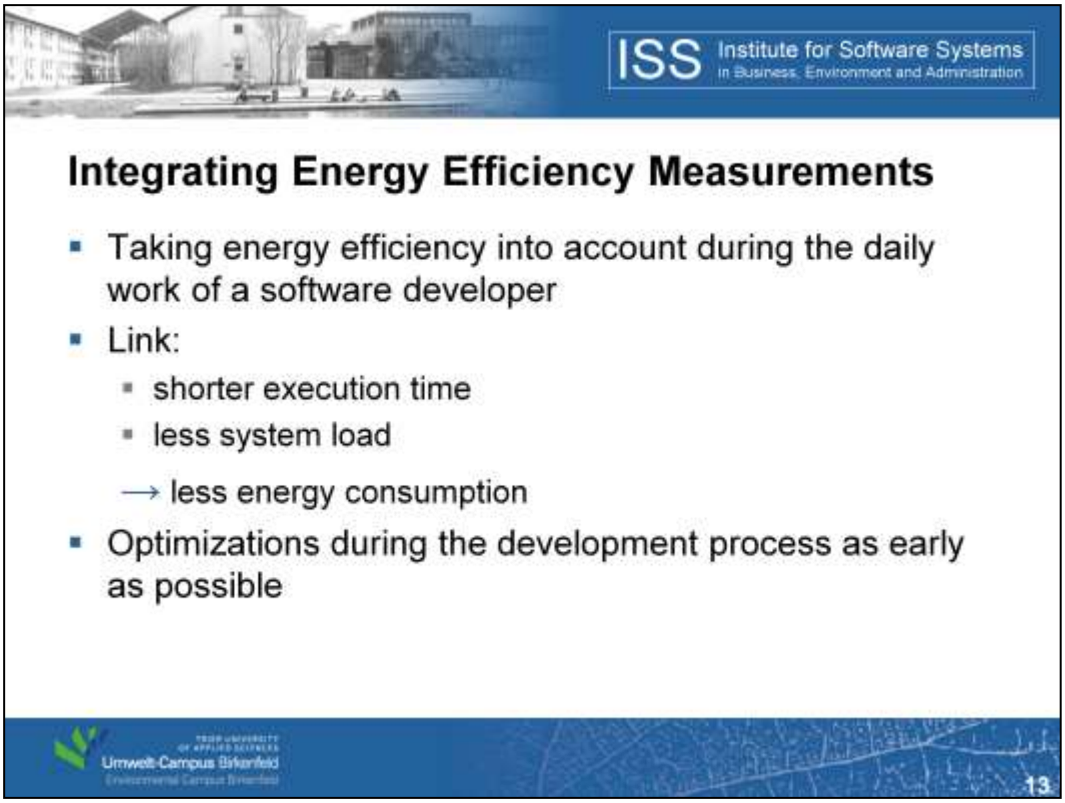
To be able to measure the expected first-order impacts of a software product, developers should be enabled to analyse and rate the energy efficiency with as little efforts as possible. …



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Integrating Energy Efficiency Measurements

- Taking energy efficiency into account during the daily work of a software developer
- Link:
  - shorter execution time
  - less system load

  ⟶ less energy consumption
- Optimizations during the development process as early as possible

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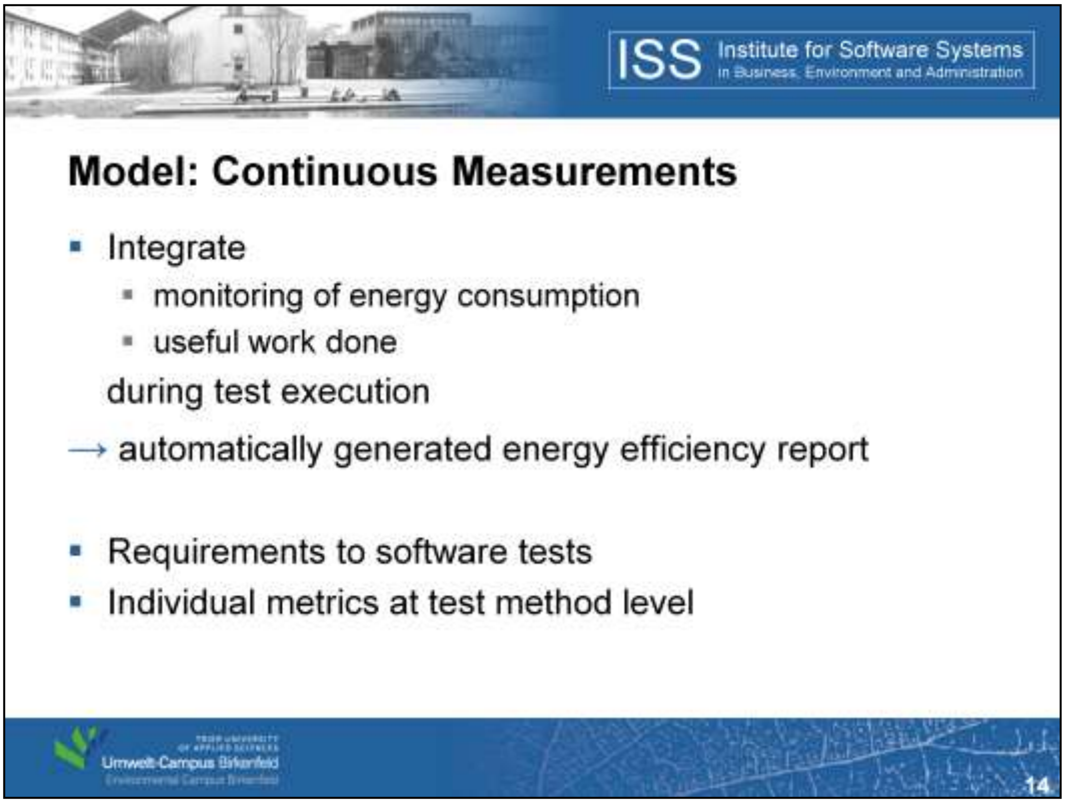
Our aim is to take energy effficiency into account during the daily work of a software developer. As I said before, it is important to integrate such measurements as early as possible.

What is the motivation here?
The energy consumption is liked to the execution time and system load. That means: if we have a shorter execution time and less system load we need less energy.



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Model: Continuous Measurements

- Integrate
  - monitoring of energy consumption
  - useful work done

  during test execution

→ automatically generated energy efficiency report

- Requirements to software tests
- Individual metrics at test method level

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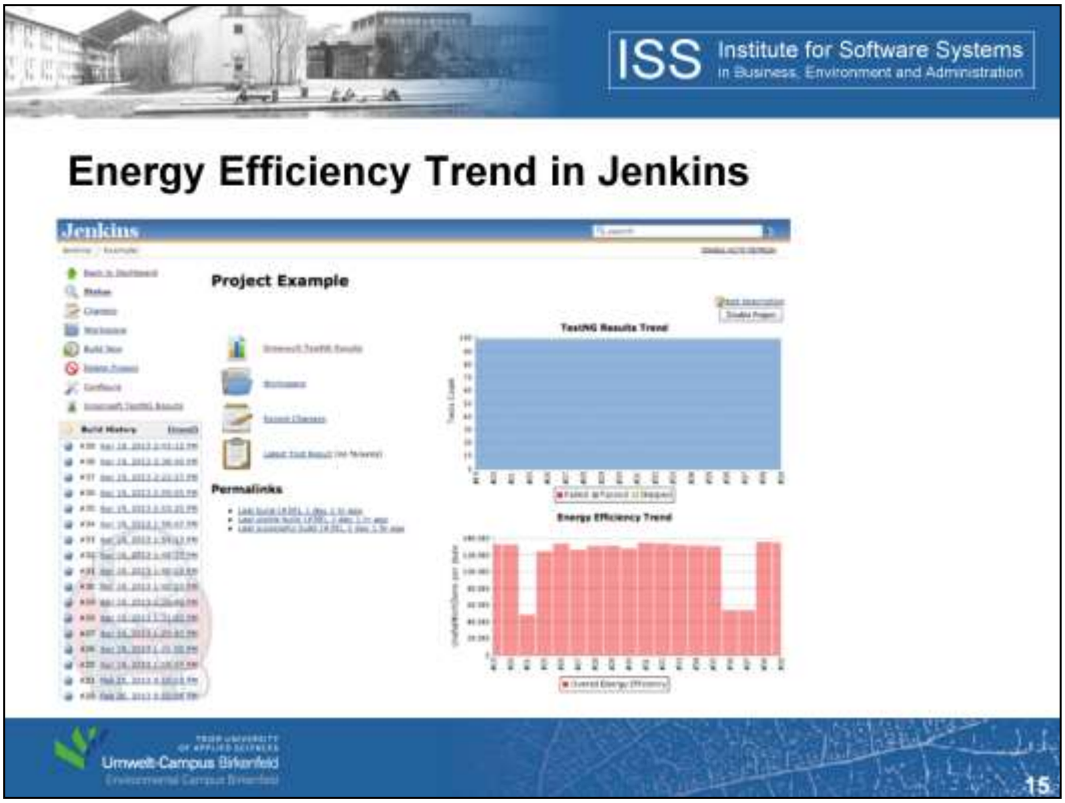
Our approach integrates the monitoring of energy consumption and useful work done during the test execution to be able to automatically generate an energy efficiency report.

To do so
- Requirements to software tests and
- Individual metrics at test method levels are needed.



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Energy Efficiency Trend in Jenkins

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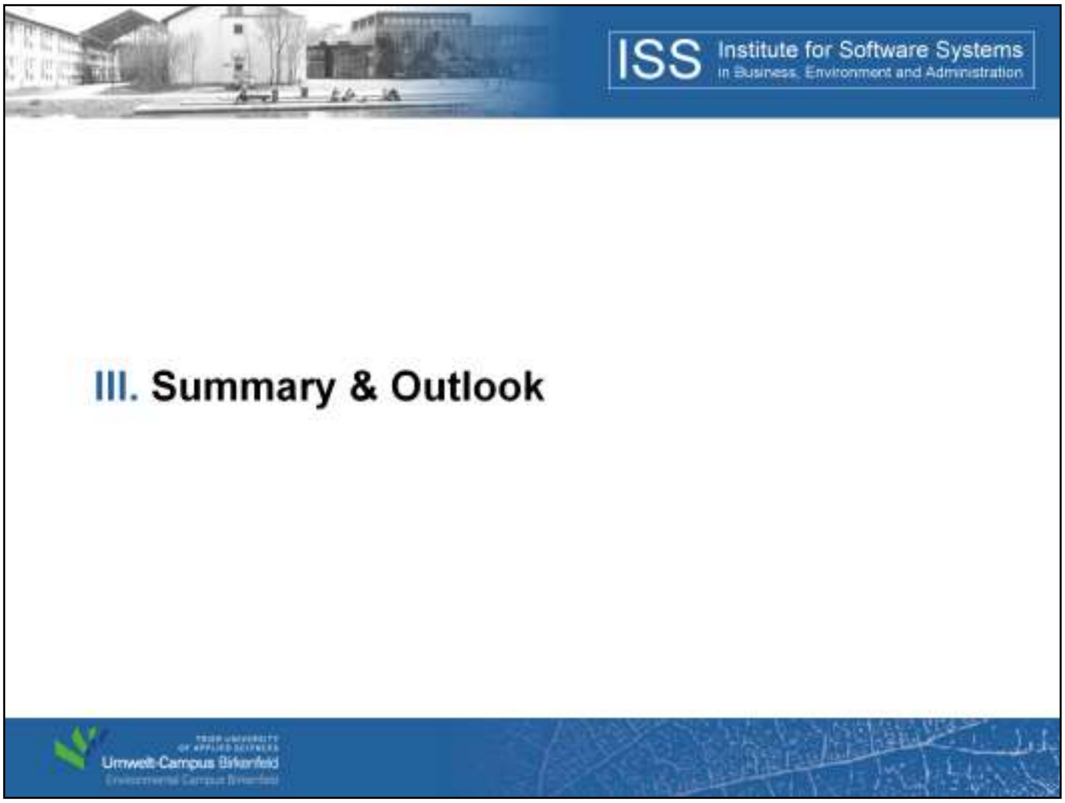
How can it look like?

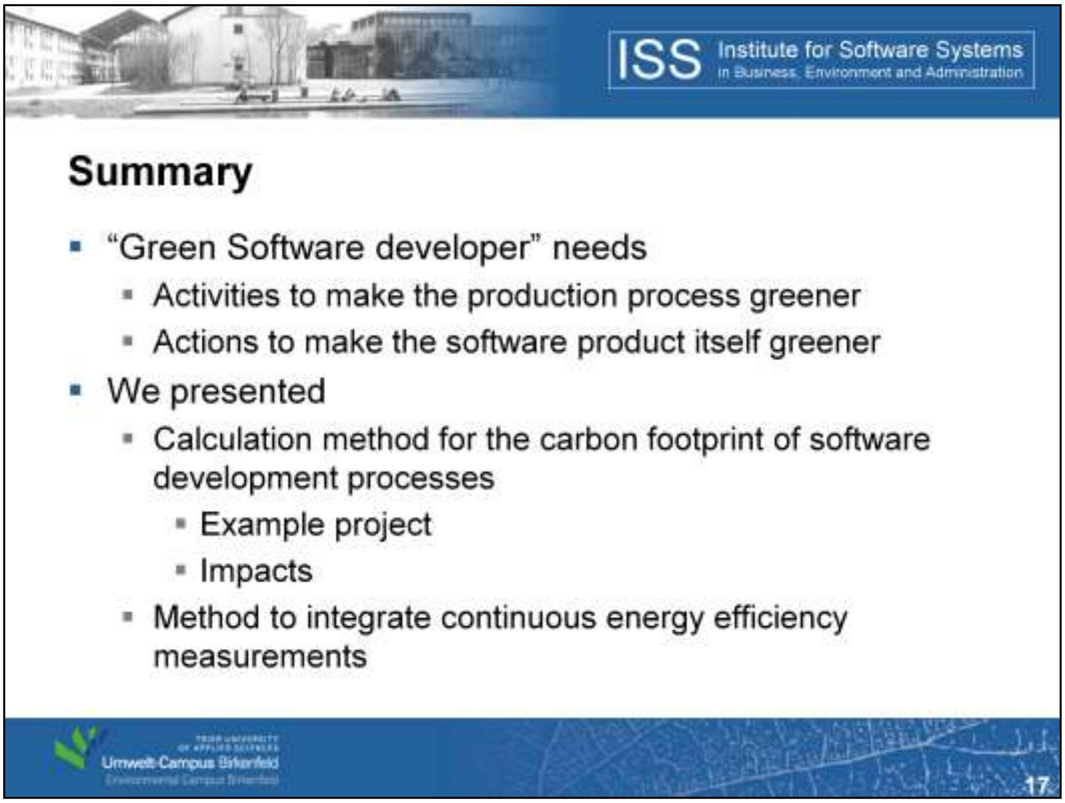
So far we build up a first prototype. We did so by extending the test result report offered by the Jenkins Continuous Integration environment (and the TestNG testing-framework).

This is an example how the developers will get maximized feedback on energy efficiency of their software.

You can see the energy consumption of builds, test classes and test methods
And the rating of ist energy efficiency caused by test execution and measurement results.



III. Summary & Outlook



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Summary

- "Green Software developer" needs
  - Activities to make the production process greener
  - Actions to make the software product itself greener
- We presented
  - Calculation method for the carbon footprint of software development processes
    - Example project
    - Impacts
  - Method to integrate continuous energy efficiency measurements

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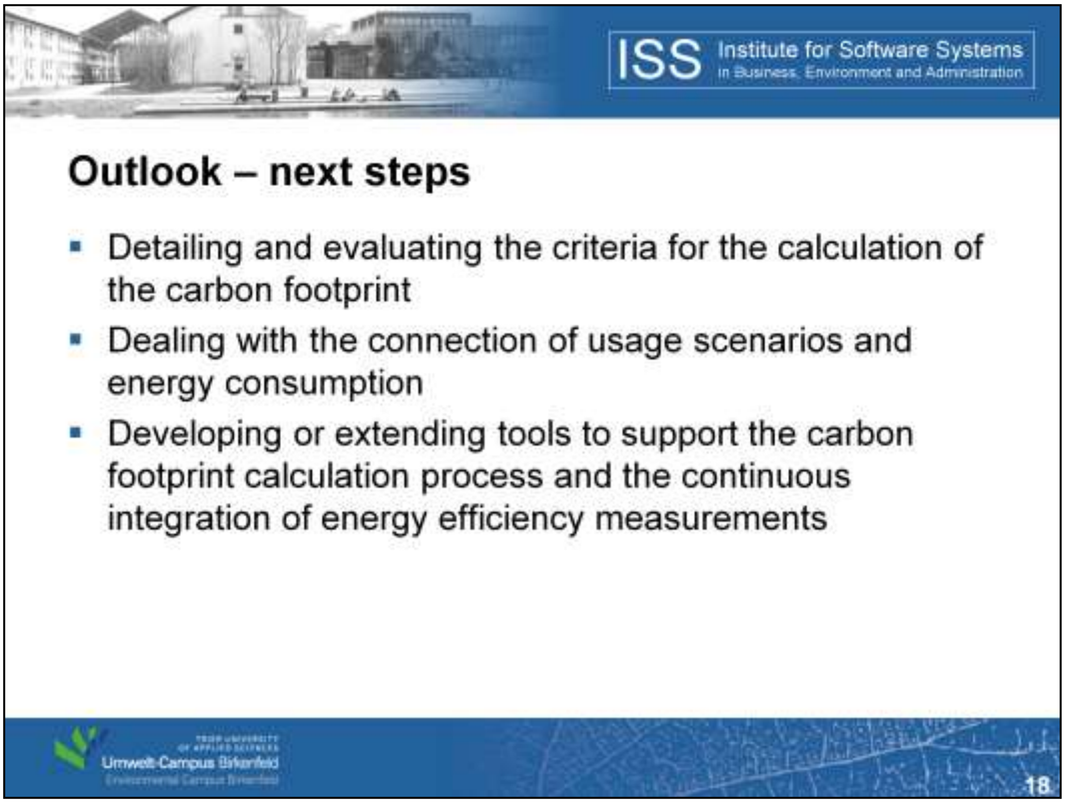
Summerizing,…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Outlook – next steps

- Detailing and evaluating the criteria for the calculation of the carbon footprint
- Dealing with the connection of usage scenarios and energy consumption
- Developing or extending tools to support the carbon footprint calculation process and the continuous integration of energy efficiency measurements

Based on that

- The calculation method needs to be detailed and evaluated
- And one needs to deal with the connection of usage scenarios and the resulting energy consumption
- In general the methods and tools for CF as well as for integrating measurements during the development process need to be further developed.

These are our efforts – so far!

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Thank you for your attention!

Feel free to contact us:

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If you have further ideas or suggestions on how to improve the methods,

feel free to contact us at the Environmental Campus Birkenfeld of the Trier University of Applied Sciences in Germany.