Breakout Group #2

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Sustainability in the context of software engineering can be investigated along five dimensions, which can be freely combined with each other.

- The first dimension is related to the *software engineering process*,
- the second to the *design of algorithms* (i.e., green software engineering),
- the third to the *management of machines by software* (i.e., cyber-physical systems),
- the fourth to the *modeling and simulation of technological developments* by software (e.g., roads, buildings, etc), and
- the fifth to the *modeling and analysis of needs and goals* of individuals and communities impacted by technological development with the help of software (i.e., analyzing the social aspect of a development and raising human awareness).

While the first two dimensions fall into the category of sustainability **in** software engineering, the last three dimensions fall into the category of sustainability **by** software engineering.

Research or development activities may focus on one or many of these dimensions to varying degrees. A commonality among the five dimensions is the common goal to optimize systems or processes based on a set of criteria and possibly enact automatically changes to the system or process - in essence, a control and optimization problem needs to be solved.

The difference between these five dimensions is which criteria are used for the optimization problem. For the first dimension, metrics related to the software development process are used to assess resource consumption as well as cost and analyze whether the process is sustainable for a community. For the second dimension, software language constructs are analyzed in terms of their impact on resource consumption – typically power usage - to make programs more efficient while using less resources and therefore make programs more sustainable. For the third dimension, cyber-physical systems that are controlled by software are considered instead of software programs. Hence, metrics about the resource usage and cost indicators of non-software entities are employed as criteria for this dimension, and then analyzed by software. For the fourth dimension, models of systems that are not influenced by software are created (e.g., the construction of a bridge), metrics are collected that can be fed into these models, and software is then used to analyze these systems in terms of their impact on sustainability. The fifth dimension goes even one step

further and intends to model and measure the impact of technological developments on social aspects. Developments may either be software-related or not, but software is used to model and analyze social impact.

Each of these dimensions serves as a meta-scenario, from which concrete scenarios and applications for sustainable systems can be derived. For example, a system that controls heating and lighting in buildings represents the third dimension, and the development of a bridge and its impact on transit behavior can be considered for the fourth dimension.

Enabling technologies for applications in these dimensions include:

- techniques for self-adaptive and context-aware systems to reason about criteria at run-time and enact changes,
- domain-specific languages to better express models used to describe criteria and complex systems,
- support for the composition of heterogeneous model types including stochastic, continuous, discrete, probabilistic, and social[1] models
- business intelligence tools for the collection of measurements to assess criteria
- big data techniques to help assess impact of developments on communities/user populations, derive more accurate social models, discover correlations and causation, and understand combinations of multiple models possibly in the presence of uncertainty,
- modularization techniques to separate the core components from the sustainability concerns, and
- software/system design workbenches to help with sustainability issues that are challenging to fully automate, including design notations/languages for sustainability.

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1 We define social models as models built from statistical information about a community collected through means such as a census and other models that try to understand the needs and goals of a community.