Software Engineering for Sustainability

Lecture 9

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Slides used from lecture by Birgit Penzenstadler and Karlskrona Manifesto team

Sustainability - what is that?

sustainability

NOUN

1 The ability to be maintained at a certain rate or level.

'*the sustainability of economic growth*'

'*the long-term sustainability of the project*'

+ More example sentences

1.1 Avoidance of the depletion of natural resources in order to maintain an ecological balance.

'*the pursuit of global environmental sustainability*'

'*the ecological sustainability of the planet*'

+ More example sentences

https://en.oxforddictionaries.com/definition/us/sustainability

Why ICT and sustainability?

Prof. Lorenz Hilty

How can we harness ICT for the benefit of sustainability? Two things are essential:

1. To stop the growth of ICT's own footprint

2. To find ways to apply ICT as an enabler in order to reduce the footprint of production and consumption by society

How are the UN Goals related to ICT?

17 PARTNERSHIPS FOR THE GOALS

Goal 17.6. Enhance … access to science, technology and innovation and enhance knowledge sharing … and through a global technology facilitation mechanism

8 DECENT WORK AND ECONOMIC GROWTH

8.6: "..By 2020, substantially reduce the proportion of youth not in employment, education or training."

8.7: "… by Increase Aid for Trade support for developing countries, …, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries"

4 QUALITY EDUCATION

Goal 4.4: "…By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship"

Definitions: Sustainable use & sustainable development

Sustainable use of a system S with regard to a function F and a time horizon T [Hilty 2015]
→ "use S in a way that does not compromise its ability to fulfil F for a period of T"

Sustainable development is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [UN 1987]
→ acknowledging the concept of changing stakeholder requirements

Scoping for ICT systems

- What?
  System purpose. Or mission behind?
- For whom?
  Stakeholders. Are some beyond reach?
- For how long?
  Long-term. A decade? A generation? Three?
- At what cost?
  ROI, *and* environmental and
  social impact.

Tainter, Joseph A. "Social complexity and sustainability."
Ecological complexity 3.2 (2006): 91-103.

Joseph Tainter, Utah State Univ.
https://www.archaeological.org/lecturer/josephtainter

Old hope for solution

- **Reduce – reuse – recycle**
- What is the problem with recycling?
- Most of it is down-cycling
- Ideally cradle to cradle cycles
  (see book in references)

" Our whole economy is based on

Planned Obsolescence...

We make good products, we induce people to buy them, and then next year we deliberately introduce something that will make those products old fashioned, out of date, obsolete.

We do this for the soundest reason... to Make Money! "

— Brooks Stevens, Industrial Designer. 1958

Brought to you by the Post-Landfill Action Network

New hopes for solution

- Decoupling
- Substitution
- Dematerialization

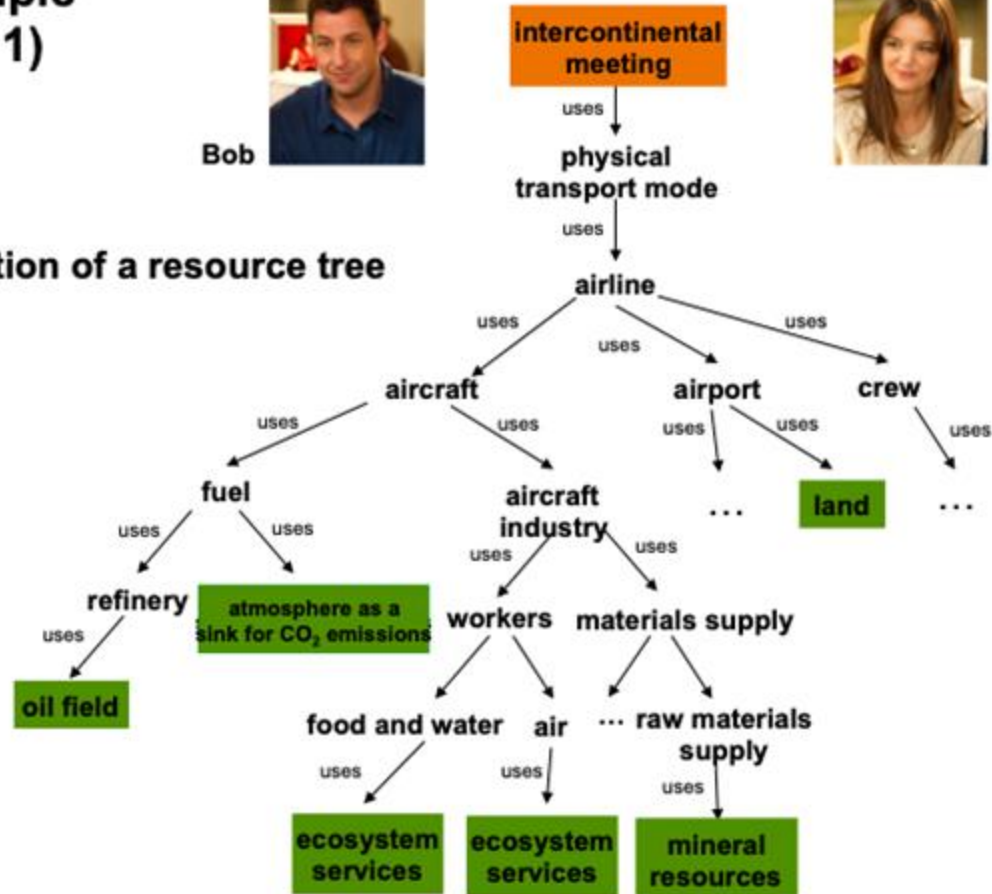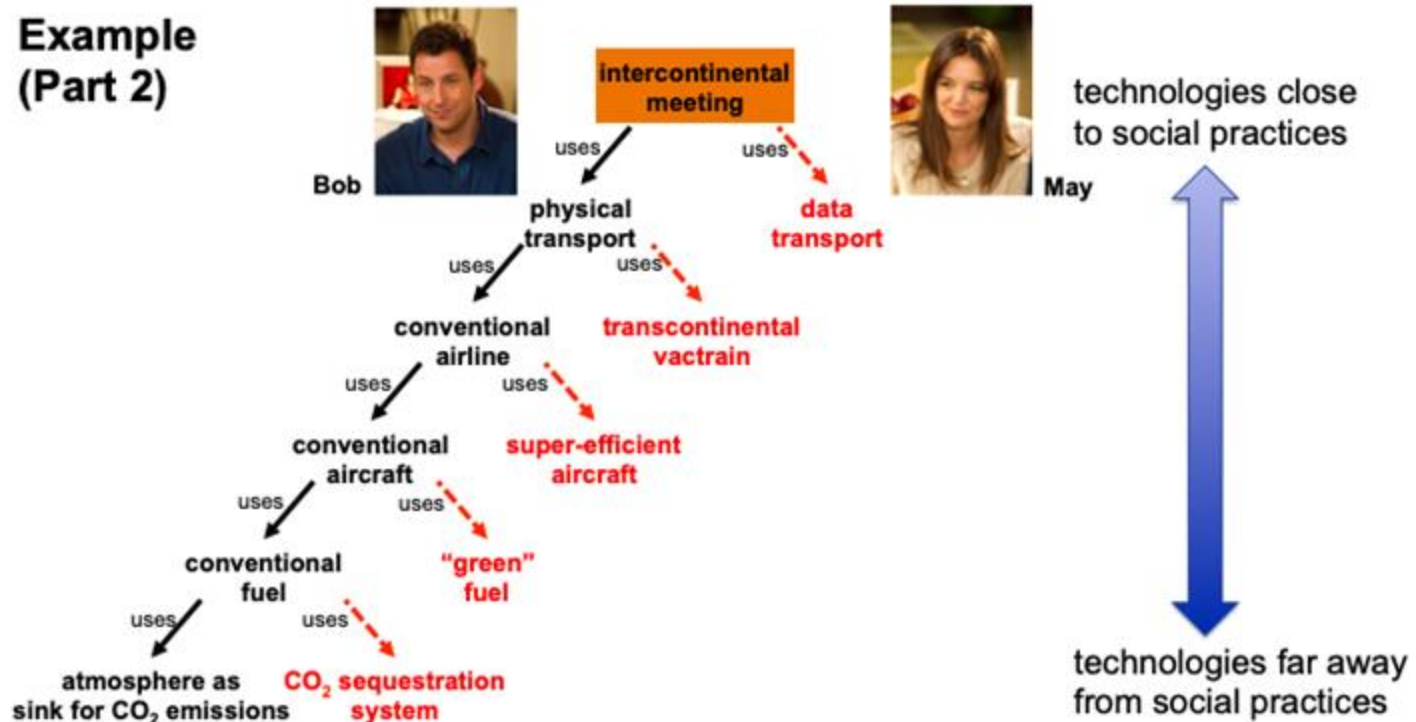Arm-folding exercise

Example (Part 1)

Tiny portion of a resource tree

Bob

May

intercontinental meeting
↓ uses
physical transport mode
↓ uses
airline
uses → aircraft ← uses
uses → airport ← uses
uses → crew → uses

aircraft
uses → fuel
uses → aircraft industry

fuel
uses → refinery
uses → atmosphere as a sink for CO₂ emissions

airport
uses → ...
uses → land

crew
uses → ...

aircraft industry
uses → workers
uses → materials supply

refinery
uses → oil field

workers
→ food and water
→ air

materials supply
→ ... → raw materials supply

food and water
uses → ecosystem services

air
uses → ecosystem services

raw materials supply
uses → mineral resources

Example (Part 2)

Bob

intercontinental meeting

technologies close to social practices

May

uses → physical transport
uses ⤳ **data transport**

uses → conventional airline
uses ⤳ **transcontinental vactrain**

uses → conventional aircraft
uses ⤳ **super-efficient aircraft**

uses → conventional fuel
uses ⤳ **"green" fuel**

uses → atmosphere as sink for CO_2 emissions
uses ⤳ **CO_2 sequestration system**

technologies far away from social practices

A branch of the resource tree with potential technology substitutions
Resource trees can be changed by technological substitution at any level

What to do?
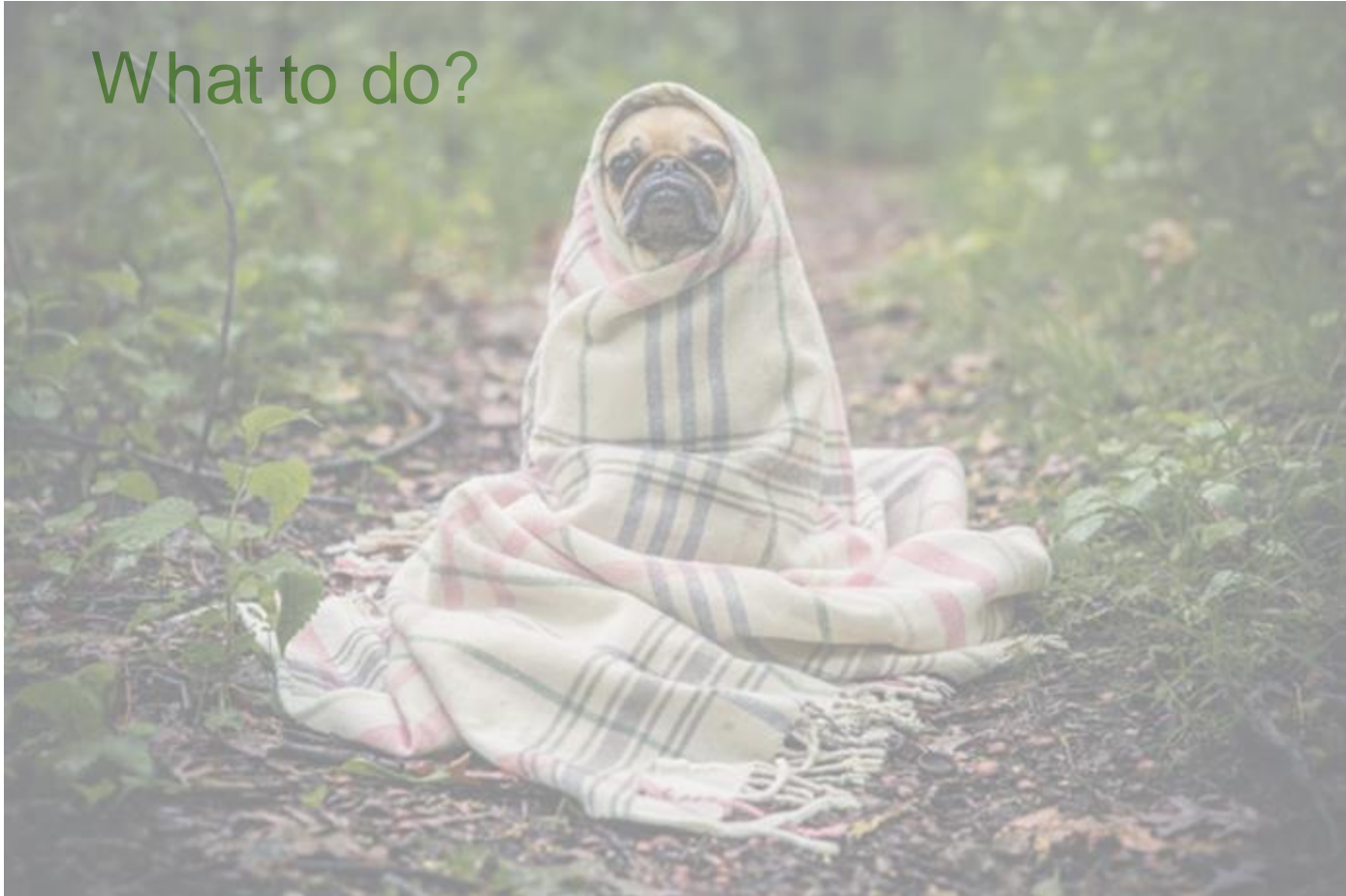
Abstract—Integrating novel software systems in our society, economy, and environment can have far-reaching effects. As a result, software systems should be designed in such a way as to maintain or improve the sustainability of the socio-technical system of their destination. However, a paradigm shift is required to raise awareness of software professionals on the potential sustainability effects of software systems. While Requirements Engineering is considered the key to driving this change, requirements engineers lack the knowledge, experience and methodological support for doing so. This paper presents a question-based framework for raising awareness of the potential effects of software systems on sustainability, as the first step towards enabling the required paradigm shift. A feasibility study of the framework was carried out with two groups of computer science students. The results of the study indicate that the framework helps enable discussions about potential effects that software systems could have on sustainability.

Foundation (1):
5 dimensions of sustainability

Individual

Technical

Economic

Social

Environmental

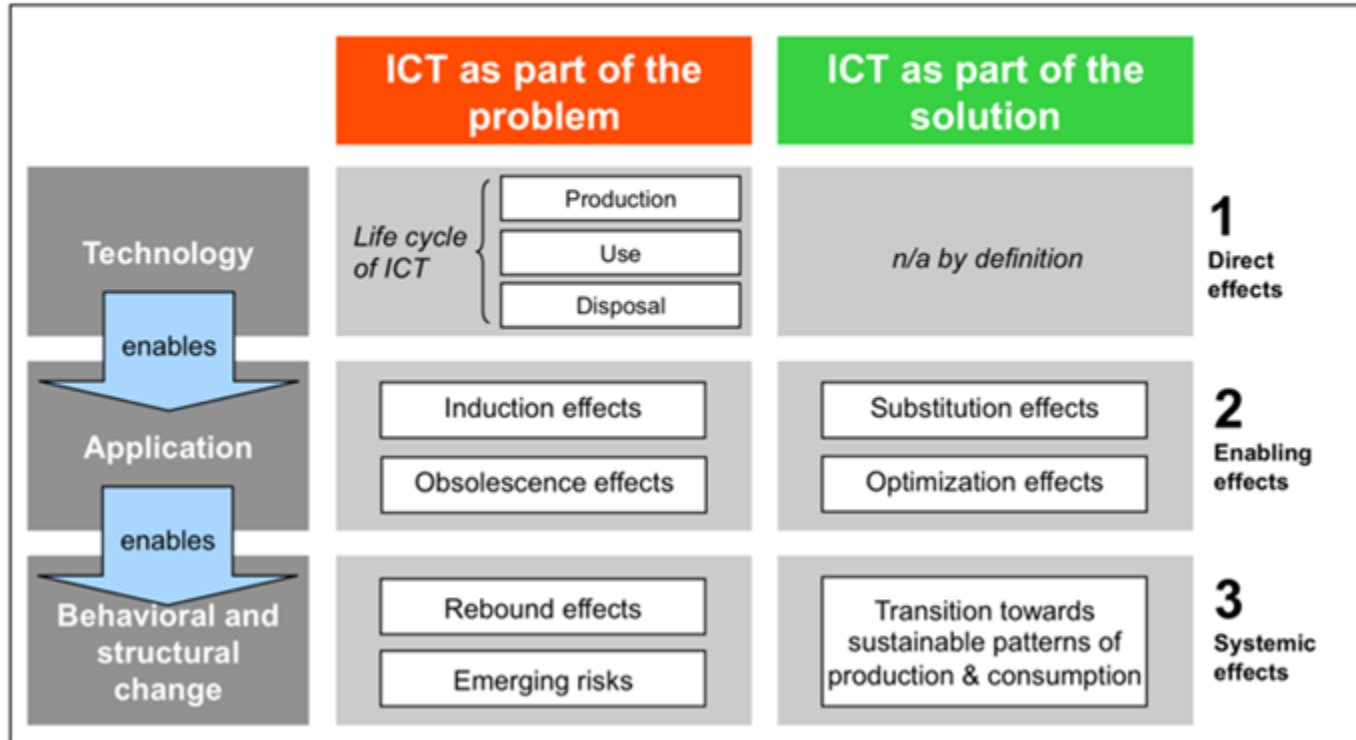Picture: Ahmed Alharti, RE4SuSy 2018

[GIBSE'13] Birgit Penzenstadler, Henning Femmer
A Generic Model for Sustainability with Process- and Product-specific Instances.
1st Intl. Workshop on Green In Software Engineering, Green By Software Engineering (at AOSD'13)
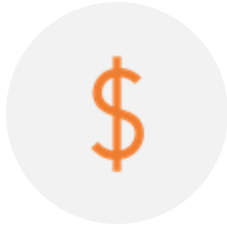
Foundation (2):
LES model – effects of/by ICT

Lorenz Hilty & Bernard Aebischer

	ICT as part of the problem	ICT as part of the solution	
Technology ⬇ enables	*Life cycle of ICT* { Production / Use / Disposal }	*n/a by definition*	**1** Direct effects
Application ⬇ enables	Induction effects / Obsolescence effects	Substitution effects / Optimization effects	**2** Enabling effects
Behavioral and structural change	Rebound effects / Emerging risks	Transition towards sustainable patterns of production & consumption	**3** Systemic effects

Hilty, Lorenz M., and Bernard Aebischer. "ICT for sustainability: An emerging research field." *ICT Innovations for Sustainability*. Springer, Cham, 2015. 3-36.

Motivating Example: Airbnb

NEW YORK: HOMEOWNERS CAN EARN *55%* MORE THAN THE MEDIAN LONG-TERM RENTAL

ESTIMATED: AIRBNB *REMOVED* 7,000 - 13,000 UNITS OF HOUSING IN NY → *INCREASE OF 1.4% IN THE MEDIAN LONG-TERM RENT*
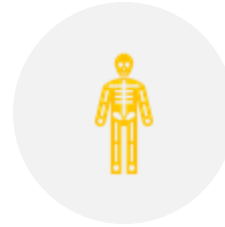
72% OF POPULATION IN NEIGHBOURHOODS AT HIGHEST RISK OF AIRBNB-INDUCED *GENTRIFICATION* ARE NON-WHITE → *INCREASING RACE SEPARATION*

So what has that to do with SE?

SiS major drivers of change
→ design for sustainability of socio-technical system.

Responsibility of SE: analyse sustainability impacts (across dimensions; extended use time)
→ paradigm shift
→ lessons of tackling wicked problems (sys. thinking)

Tool: Sustainability Awareness Framework

Sustainability Awareness Diagram (SusAD):
Visualisation tool, breaks down graph into the five interrelated dimensions of sustainability.
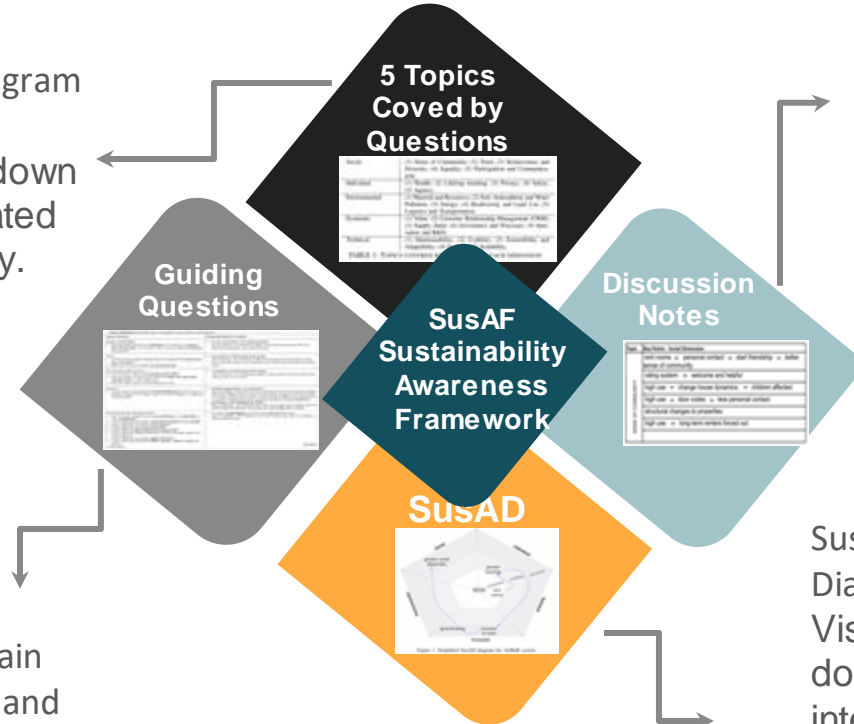
Summary of Discussion Notes:
Identifying chain-of-effects
Reflection on impact of widespread and long-term use.

Guiding Questions:
For each sustainability dimension, questions in plain text, examples, reminders and checkboxes.

Sustainability Awareness Diagram (SusAD):
Visualisation tool, breaks down graph into the five interrelated dimensions of sustainability.

Sustainability Awareness Framework
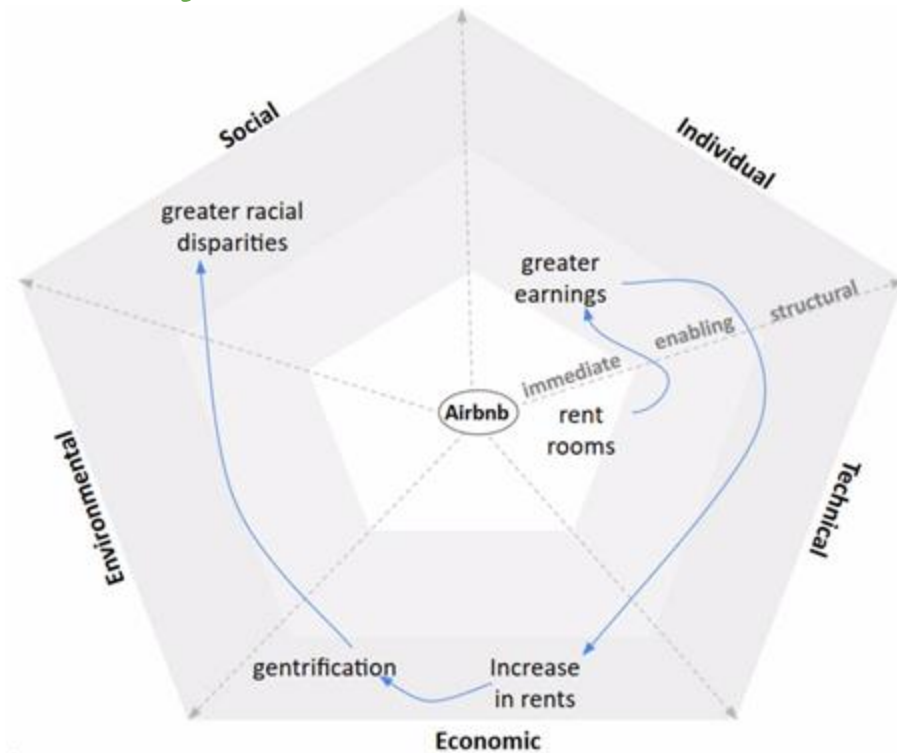
Figure 1. Simplified SusAD diagram for AirBnB system
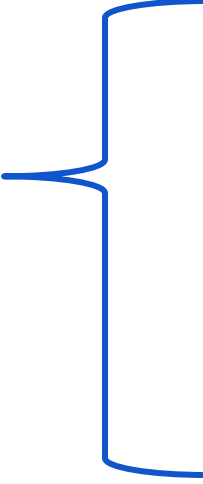
Sustainability Awareness Framework

Social	(1) Sense of Community; (2) Trust; (3) Inclusiveness and Diversity; (4) Equality; (5) Participation and Communication;
Individual	(1) Health; (2) Lifelong learning; (3) Privacy; (4) Safety; (5) Agency;
Environmental	(1) Material and Resources; (2) Soil, Atmospheric and Water Pollution; (3) Energy; (4) Biodiversity and Land Use; (5) Logistics and Transportation;
Economic	(1) Value; (2) Customer Relationship Management (CRM); (3) Supply chain; (4) Governance and Processes; (5) Innovation and R&D;
Technical	(1) Maintainability; (2) Usability; (3) Extensibility and Adaptability; (4) Security; (5) Scalability;

TABLE 1. TOPICS COVERED BY QUESTIONS IN EACH DIMENSION

Sustainability Awareness Framework (SusAF)

✓ Guiding questions

- **Individual**: Health, lifelong learning, ...
- **Social**: Sense of community, <u>trust</u>, <u>inclusiveness</u>, ...
- **Environment**: Material & resources, energy, ...
- **Economic**: Value, CRM, supply chain, ...
- **Technical**: Maintainability, usability, security, ...

Trust: "Can the system change the **trust** between **users** and **the businesses that owns the system**."

Inclusiveness and diversity: "Does the system include users **with different background, age groups, education levels,** etc."

SOCIAL DIMENSION (Interviewer copy. Tick questions as you advance in the interview.)

| Specific Questions	Remind participants to consider...
SENSE OF COMMUNITY [ ] Normally people belong to an **organization**, to an **area** or to a **group of like-minded people**. Can the system affect a person's **sense of belonging to** these groups?	[ ] the **user community** and the **local community**. Say, for example: *you mentioned an effect on the sense of community of the user. What about the people in the local community?*
TRUST [ ] Can the system change the **trust** between the **users** and the **business that owns the system**? [ ] What about the trust between the **users themselves**?	[ ] **user groups** and **other groups in the society**. Say, for example: *you mentioned an effect on how people trust the business. What about how other groups in the society that don't interact with the system trust each other?*
INCLUSIVENESS AND DIVERSITY [ ] Can the system impact on **how people perceive others**? [ ] Does the system include uses with different **backgrounds, age groups, education levels**, or other differences? [ ] Does the system caters for these differences? How?	[ ] **user groups** and **other groups in the society**. Say, for example: *you mentioned an effect on the perception of the user. What about other groups on the society?*
EQUALITY [ ] Can the system make people to **be treated differently** from each other? For example, because the system carries out data analytics or influences human decisions.	[ ] **equality of opportunity** [1] and of **outcome** [2]. Say, for example: *you mention how the system gives the same treatment to people[1], what about taking actions to ensure the outcome for each person can be the same[2]? For example, putting in place support, communicating in different ways, giving access to resources, respecting decisions, recognizing, valuing and respecting differences.* [ ] **user groups** or **other groups in the society**. Say, for example: *you mentioned how users are treated by the system. Does the system makes other groups in the society to be treated differently or equally?*
PARTICIPATION AND COMMUNICATION [ ] Can the system change the way people **participate** in an **organization** or other **social groups**? [ ] Does it affect the way people **communicate verbally and non-verbally**? [ ] Does it affect the way people **create networks**? [ ] Does it affect the way people **form bounds**? [ ] Does it affect the **effort** people put in a group work[1]? [ ] Does it affect the **actions** people take to achieve the goals, projects and tasks of a group? [ ] Does it affect the way people **engage with others**? [ ] Does it affect the way people **support, consider, critique** or **argue** with others? [1] social loafing	[ ] the **users**, the **beneficiaries** and other people **affected by the system**. Say, for example: *you mentioned how users change their way to participate or communicate in groups.* **Turn sheet**

Summary of discussion in notes

| Topic	Key Points - Social Dimension
SENSE OF COMMUNITY	rent rooms ➤ personal contact ➤ start friendship ➤ better sense of community
	rating system ➤ welcome and helpful
	high use ➤ change house dynamics ➤ children affected
	high use ➤ door codes ➤ less personal contact
	structural changes to properties
	high use ➤ long-term renters forced out
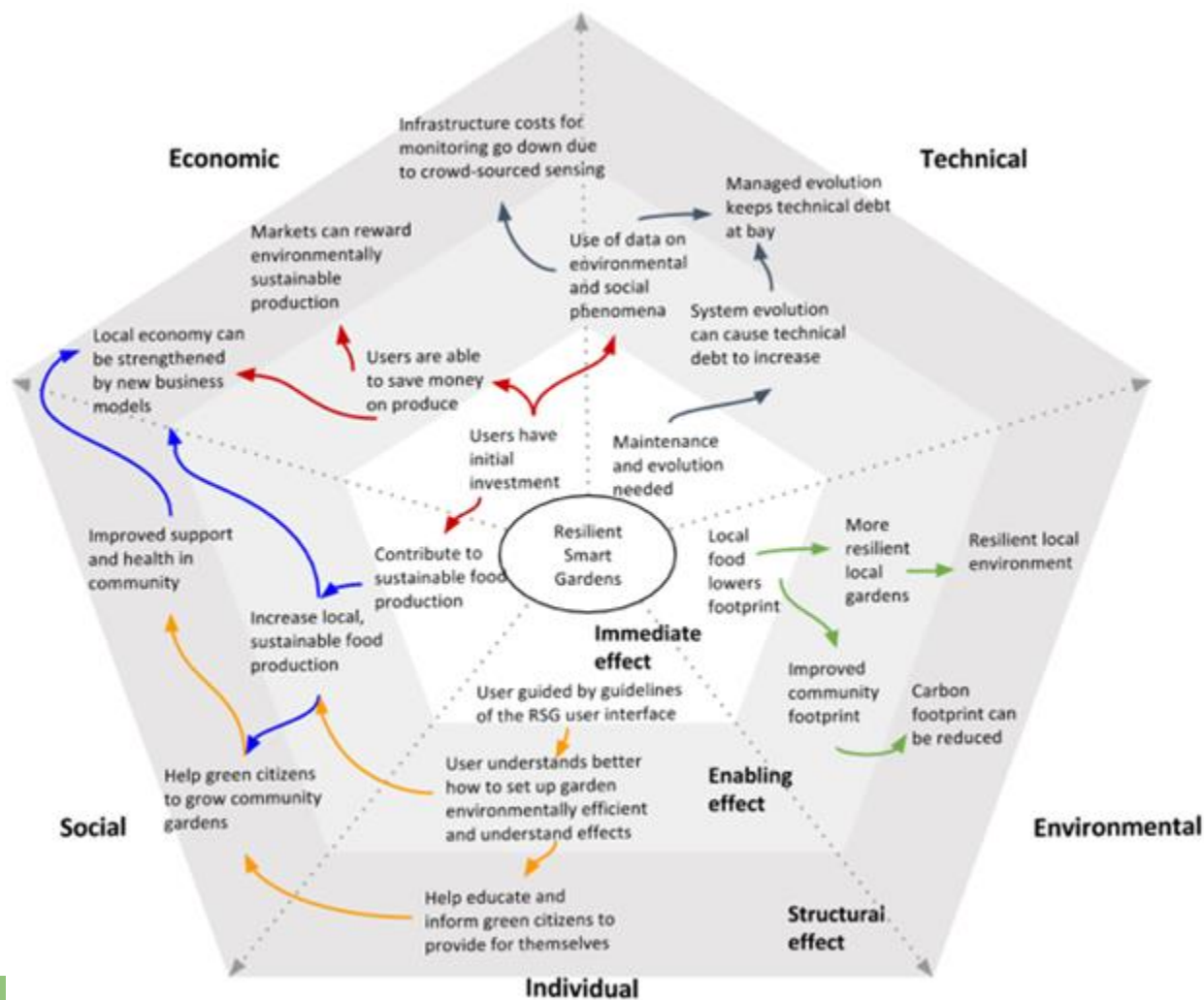
Karlskrona Manifesto on Sustainability Design
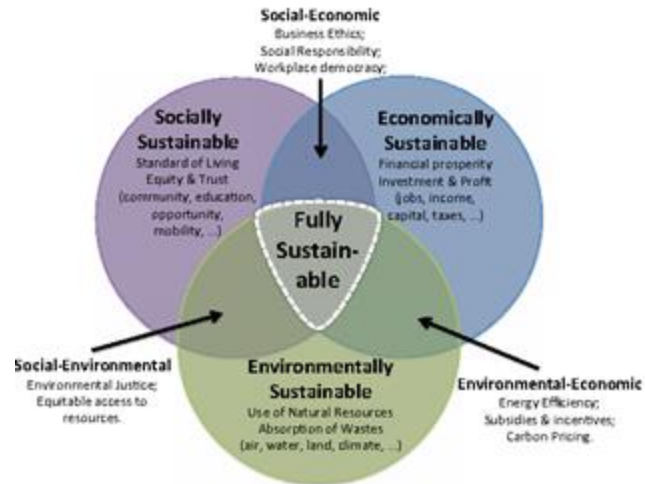
(a) Weak Sustainability (adapted from [18])
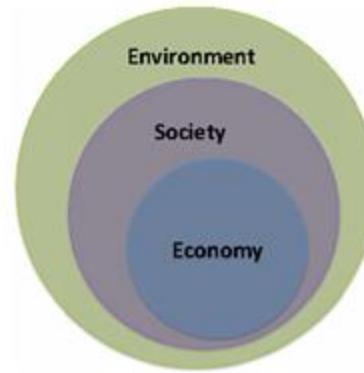
(b) Strong Sustainability
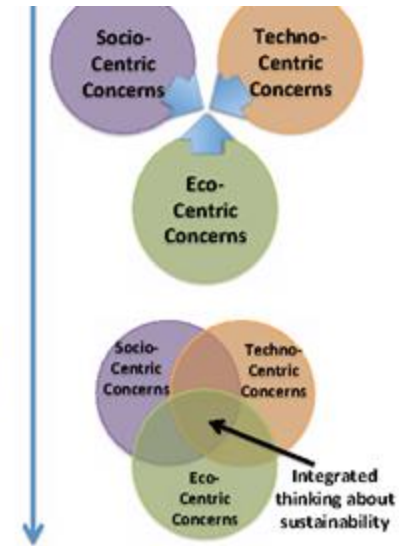
(c) A more pragmatic view for software

KARLSKRONA MANIFESTO
FOR SUSTAINABILITY DESIGN

https://www.sustainabilitydesign.org/karlskrona-manifesto/

Introduction   *Version 1.0, May 2015*

As software practitioners and researchers, we are part of the group of people who design the software systems that run our world. Our work has made us increasingly aware of the impact of these systems and the responsibility that comes with our role, at a time when information and communication technologies are shaping the future. We struggle to reconcile our concern for planet Earth and its societies with the work that we do. Through this work we have come to understand that we need to redefine the narrative on sustainability and the role it plays in our profession.

What is sustainability, really? We often define it too narrowly. Sustainability is at its heart a systemic concept and has to be understood on a set of dimensions, including social, individual, environmental, economic, and technical[1].

Sustainability is fundamental to our society. The current state of our world is unsustainable in more ways that we often recognize. Technology is part of the dilemma and part of possible responses. We often talk about the immediate impact of technology, but rarely acknowledge its indirect and systemic effects. These effects play out across all dimensions of sustainability over the short, medium and long term.

Software in particular plays a central role in sustainability. It can push us towards growing consumption of resources, growing inequality in society, and lack of individual self-worth. But it can also create communities and enable thriving of individual freedom, democratic processes, and resource conservation. As designers of software technology,

There is a perception that sustainability is a distinct discipline of research and practice with a few defined connections to software.
Whereas sustainability is a pervasive concern that translates into discipline-specific questions in each area it applies.

There is a perception that sustainability is a problem that can be solved, and that our aim is to find the 'one thing' that will save the world.
Whereas it is a 'wicked problem' - a dilemma to respond to intelligently and learn in the process of doing so; a challenge to be addressed, not a problem to be solved.

There is a perception that there is a tradeoff to be made between present needs and future needs, reinforced by a common definition of sustainable development, and hence that sustainability requires sacrifices in the present for the sake of future generations.
Whereas it is possible to prosper on this planet while simultaneously improving the prospects for prosperity of future generations.

There is a tendency to focus on the immediate impacts of any new technology, in terms of its functionality and how it is used.
Whereas the following orders of effects have to be distinguished: *Direct, first order effects* are the immediate opportunities and effects created by the physical existence of software technology and the processes involved in its design and production. *Indirect, second order effects* are the opportunities and effects arising from the application and usage of software. *Systemic, third order effects*, finally, are the effects and opportunities that are caused by wide-scale use of software systems over time.

There is a tendency to overly discount the future. The far future is discounted so much that it is considered for free (or worthless). Discount rates mean that long-term impacts matter far less than current costs and benefits.
Whereas the consequences of our actions play out over multiple timescales, and the cumulative impacts may be irreversible.

There is a tendency to think that taking small steps towards sustainability is sufficient, appropriate, and acceptable.
Whereas incremental approaches can end up reinforcing existing behaviours and lure us into a false sense of security. However, current society is so far from sustainability that deeper transformative changes are needed.

There is a tendency to treat sustainability as a desirable quality of the

Takeaways and discussion:

SusAF as a Systems Thinking activity: Potentially high cost vs. few guiding questions

Systems vs Software Requirements Engineering: Need to look at wider socio-economic system

Requirements Engineers as leads for Sustainability Engineering: timely consideration helps fostering informed choices

References

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., ... & Venters, C. C. (2015). Requirements: The key to sustainability. *IEEE Software*, *33*(1), 56-65.

Hilty, L. and Aebischer, B. "ICT for Sustainability: An emerging research field", in ICT innovations for sustainability, pp. 3-36 2015, Springer

Hilty, L. "A research agenda for ICT4S" 2014, keynote talk at the ICT4S conference, Stockholm, Sweden http://publicationslist.org/data/lorenz.hilty/ref-235/2014_Hilty_Keynote_ICT4S.pdf

Michael Braungart, William McDonough: "Cradle to Cradle: Remaking the Way We Make Things", 2002, Farrar, Straus & Giroux

Duboc, L, et at Do we really know what we are building?, International Conference on Requirements Engineering, 2019