

HOW DO WE
MANAGE OUR
(NATURAL)
RESOURCES?
LINKING
KNOWLEDGE WITH
SUSTAINABLE
CHANGE

SOFTWARE WITH A SUSTAINABILITY INTENT

@patricia_lago



LOOKING FURTHER



WHAT IS SOFTWARE WITH A SUSTAINABILITY INTENT?

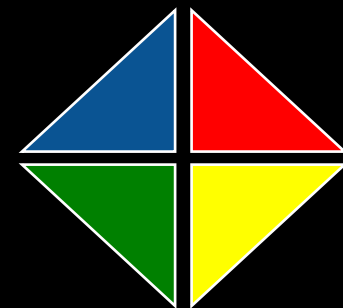
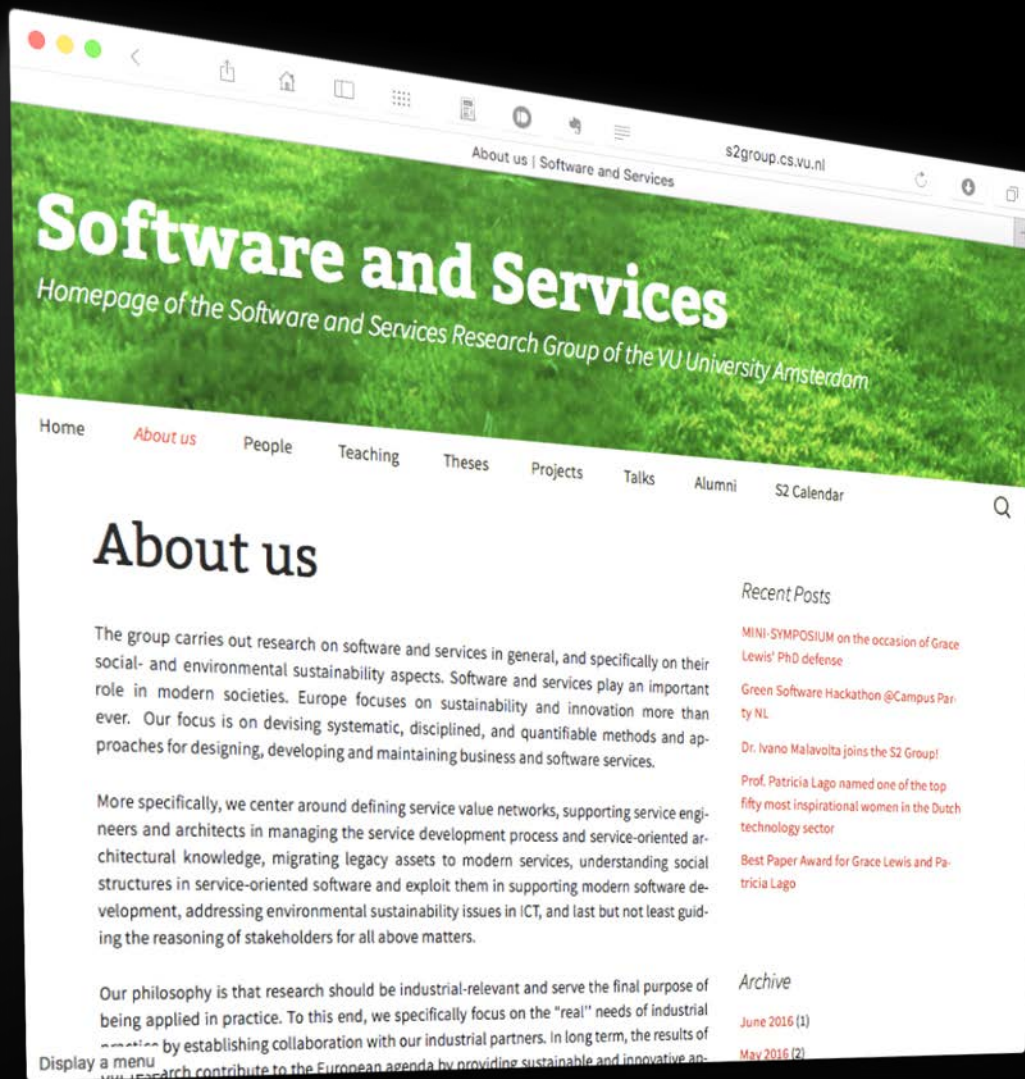
WHAT CHALLENGES DOES IT BRING?





Research and Education

Research in Engineering Smart and Sustainable Software: this is what we do...



THE SOFTWARE LAB

Education: CS Master – Track Software Engineering and Green IT

HOW GREEN IS OUR DIGITAL SOCIETY?

Software-intensive systems support most if not all aspects of modern society. Processing power, data storage, network speed, and energy have become increasingly more powerful and less expensive. However, the energy necessary to keep them on and available is becoming scarce, and is a major global problem that all major nations aim at tackling aggressively. The time has come to build energy-aware software.

PROGRAMME

This extended Master's track allows you to choose either to specialize in energy-aware software engineering, or address the general software engineering competencies while still creating awareness of the implications of software-intensive systems to the environment. The programme provides both current professionals and future generations with the appropriate skills to build an

energy-aware digital society. It provides opportunities for inter-disciplinary assignments and projects addressing societal, business, technical and social aspects of energy-efficient and sustainable software systems. Selected industrial partners will offer innovative case studies and challenging projects.

SELECTED COURSES

Service oriented design: it includes an industry-sponsored project in energy-aware software services (already active since three years, no change).
Software metrics: provides the background on defining and applying software metrics to assess quality requirements of software in general, and energy efficiency and other sustainability-related qualities in the particular case of energy-aware software.
Green Lab: will let students experiment with engineering energy-aware software-intensive systems, measuring, estimating, monitoring their energy consumption, and learning the energy impact of different software engineering practices and design decisions.

MASTER'S TRACK IN
SOFTWARE ENGINEERING AND GREEN IT
2 YEARS
ENROLL BEFORE APRIL 1ST / JUNE 1ST (NL
STUDENTS)

MORE INFORMATION

More info about the Green-IT track in the two years Master in Computer Science can be found at: www.vu.nl/computerscience

Questions about the research or courses:
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"IT SOLUTIONS ARE NOWADAYS MOSTLY EASY TO MIND, BUT THE GREEN ONES ARE HARD TO GET. THINKING GREEN OPENS THE CREATIVE MIND!"

Sarah Laktit, student

MASTER'S TRACK IN
COMPUTER SCIENCE

SOFTWARE
ENGINEERING
AND GREEN IT

WWW.VU.NL/COMPUTERSCIENCE

VU UNIVERSITY
AMSTERDAM

LOOKING FURTHER

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Municipality

Citizens

Transportation providers

Workers

Companies

Universities

Students

Hello Zürich.



“Software is eating the world”. Marc Andreessen, 2011



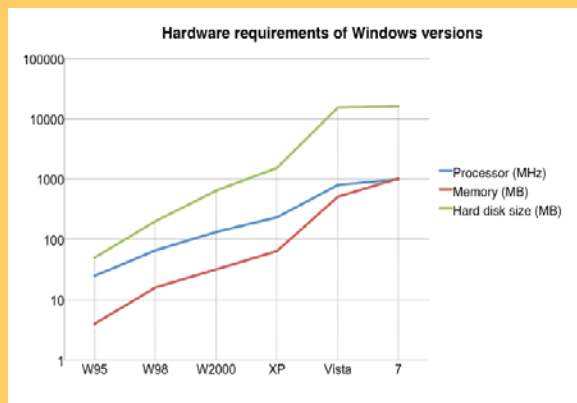
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“Software is eating the world”. Marc Andreessen, 2011

The software industry and *unsustainability*



Hardware optimizations are negated by **software inefficiencies** [cf. Wirth' Law]



Steve Jobs unveils the iPhone (2007)
Photo: Wikimedia Commons



Potential 87% energy savings with cloud migration of legacy software [Berkeley Labs]

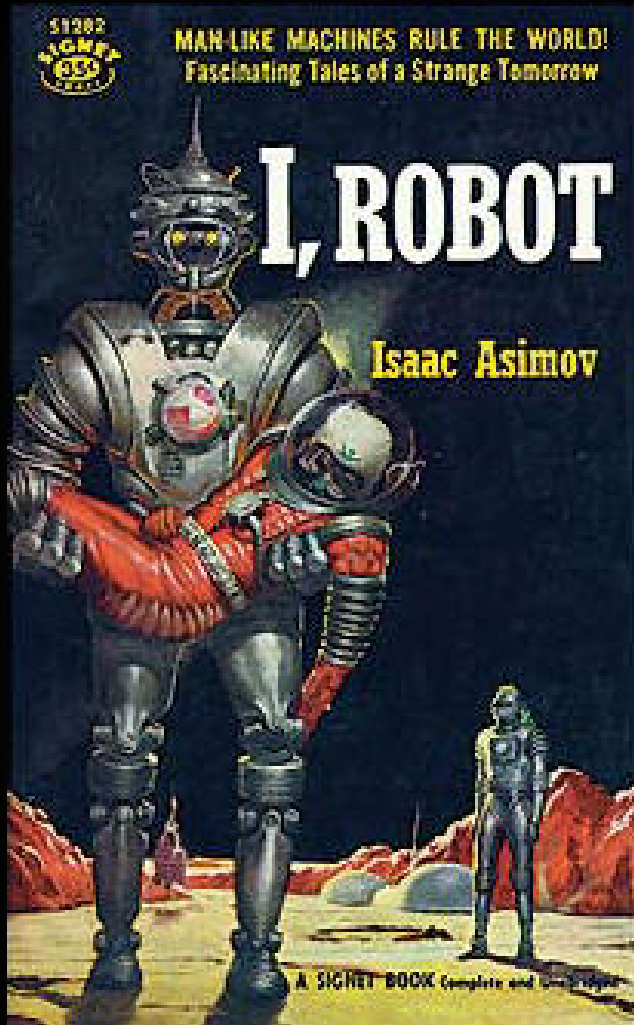


9.7 Billions connected things by 2020 [Gartner]
Image: 盧柏宇, Wikimedia Commons

Software intent:

“the fundamental laws that capture a software system’s intended behavior”

[Huisman et al, Software that meets its intent, 2016]



THE THREE LAWS OF ROBOTICS



1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Isaac Asimov

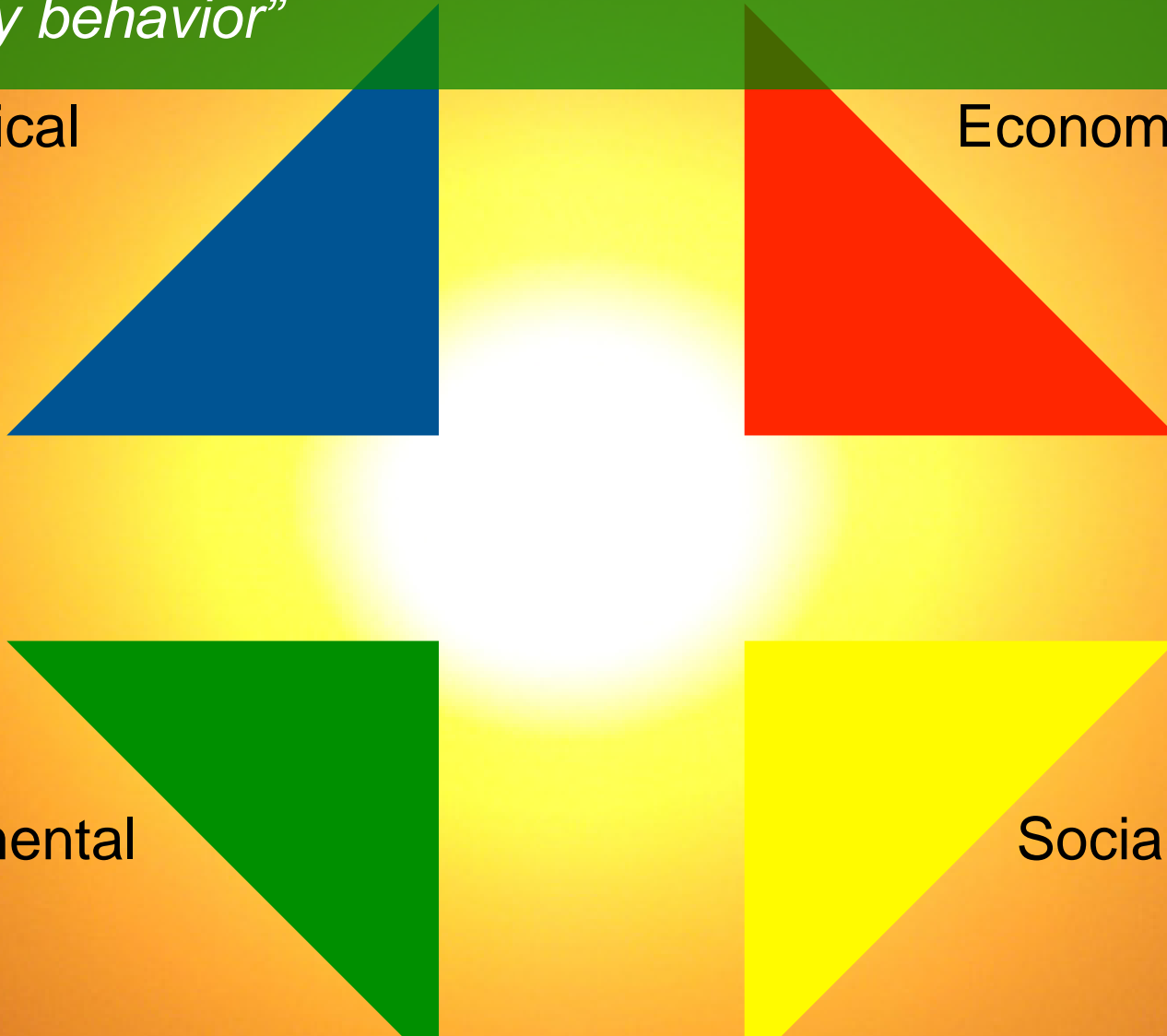
Software with a sustainability intent: *intended sustainability behavior*

Technical

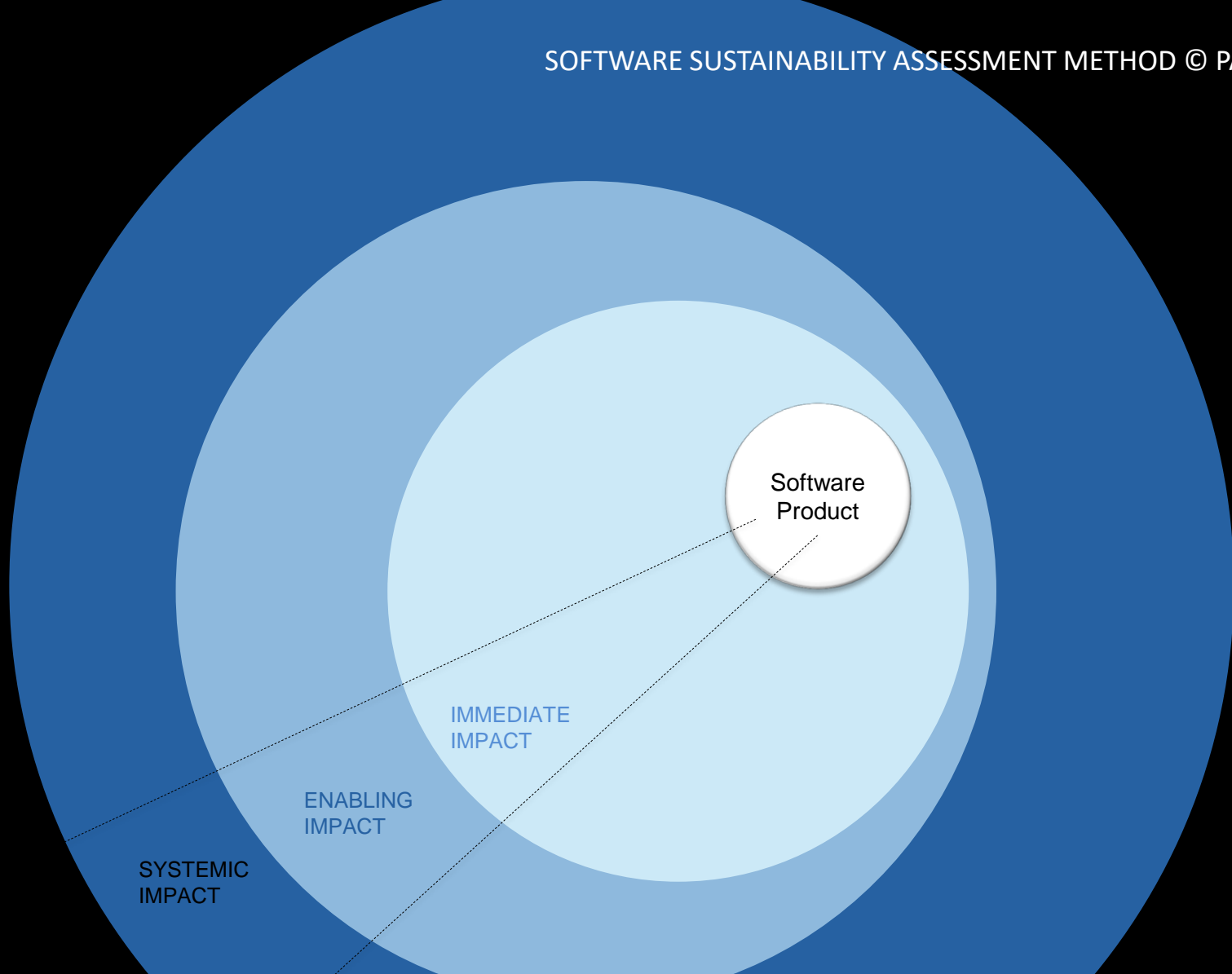
Economic

Environmental

Social



Source: P. Lago et al. "Framing Sustainability as a Software Quality Property", ACM Communications, 2015.



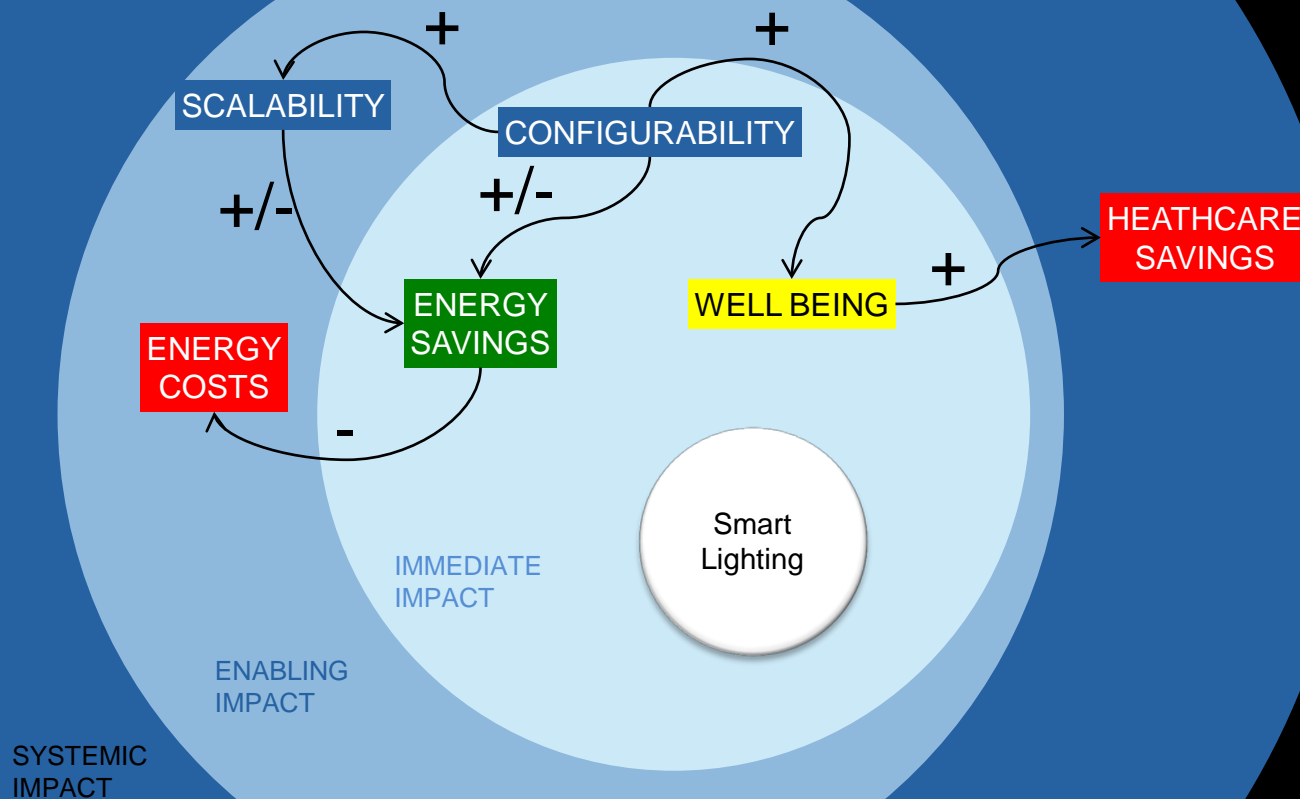
Software with a sustainability intent:
A multi-dimensional problem over *time*

TECHNICAL

SOCIAL

ENVIRONMENTAL

ECONOMIC



Sustainable software:
Cost-effective, socio-technical savvy, energy-aware, reliable, ...





Mission impossible II (2000), the motion picture

Resource scarce
environment

Smart home



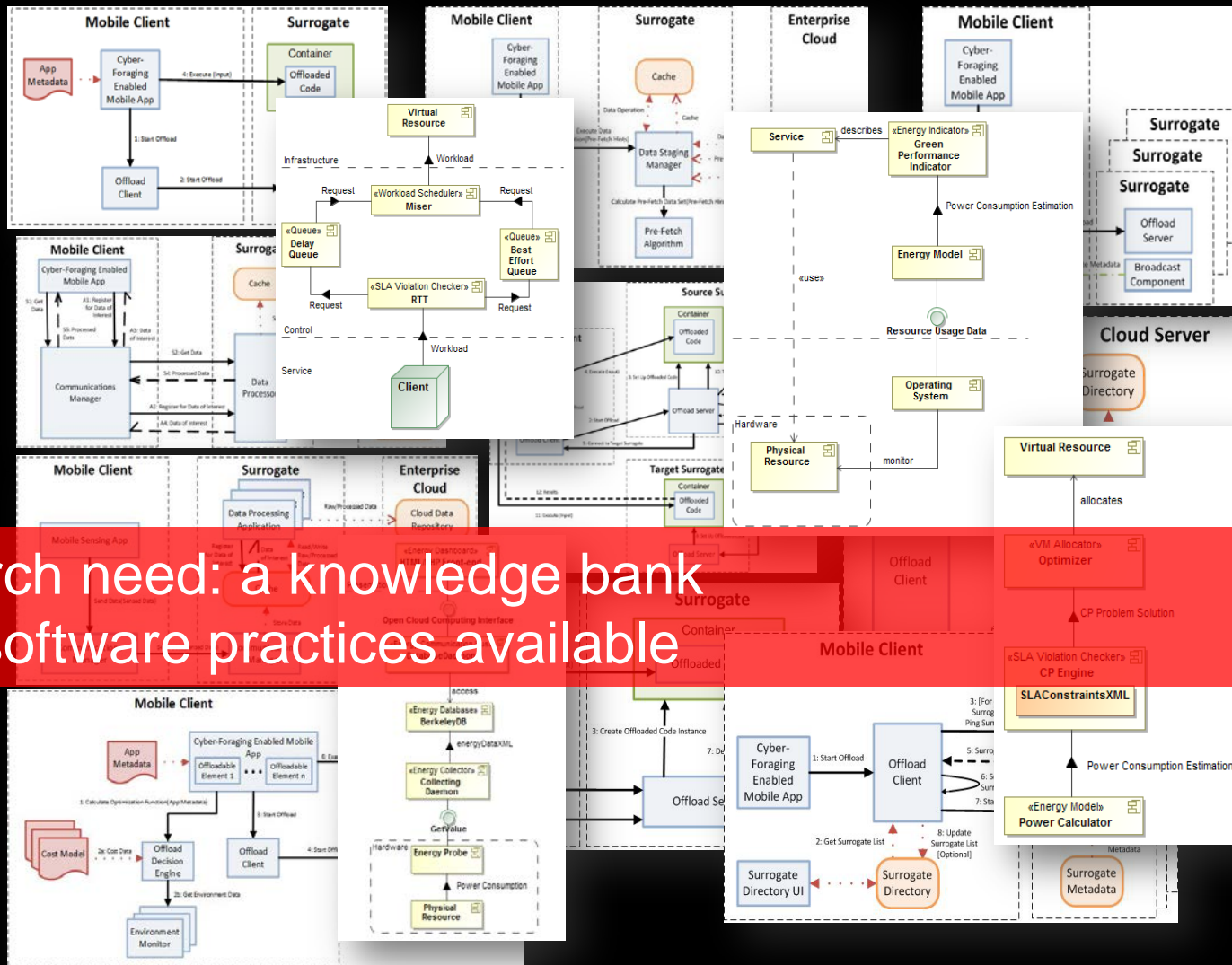
Smart software:
from **Energy**-aware to **Socially**-aware

ID	Practice	Description	Category	Environment	Implementation	Energy Consumption Measures	Energy Impact
1	<i>Use efficient queries</i> 	complex queries can be performed to increase the responsiveness of the application at the expense of energy efficiency. Can be useful to avoid unnecessary "ORDER BY" or to use indexes.	Database	SEFLab	MySQL Server + Wikipedia DB, measure response time during query	System level, resource level incl. usage ratio, software execution measures (response time, number of request/query served)	-25% energy consumption ←
2	<i>Put application to sleep</i> 	in order to save energy the application can be put in sleep mode. An event, a signal, or an interrupt can resume the application.	Coding	SEFLab	Apache WebServer		-8,5% energy consumption ←

[S2 Green Software Wiki, wiki.cs.vu.nl/green_software]

[Procaccianti, Fernandez, Lago, Empirical evaluation of two best practices for energy-efficient software development, Journal of Systems and Software, 117:185-198, 2016]

Energy-efficient software:
By implementation



Research need: a knowledge bank
 Make software practices available

SOURCES: LAGO, LEWIS, ME, PROCACCIANTI (WICSA 2014, ECSA 2015, ECSA 2016)

Energy-efficient software:
 By design

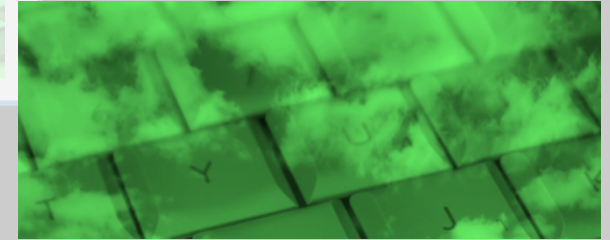
EFFICIENT DATABASE QUERIES
-25% energy consumption



OPTIMIZED DATA MANAGEMENT
+70% performance



FLEXIBLE COMPUTATION OFFLOAD
-40% power consumption



SMART USE OF WEB RESOURCES
-8,5% energy consumption



WEBSITE CONTENT DELIVERY
-45% energy consumption

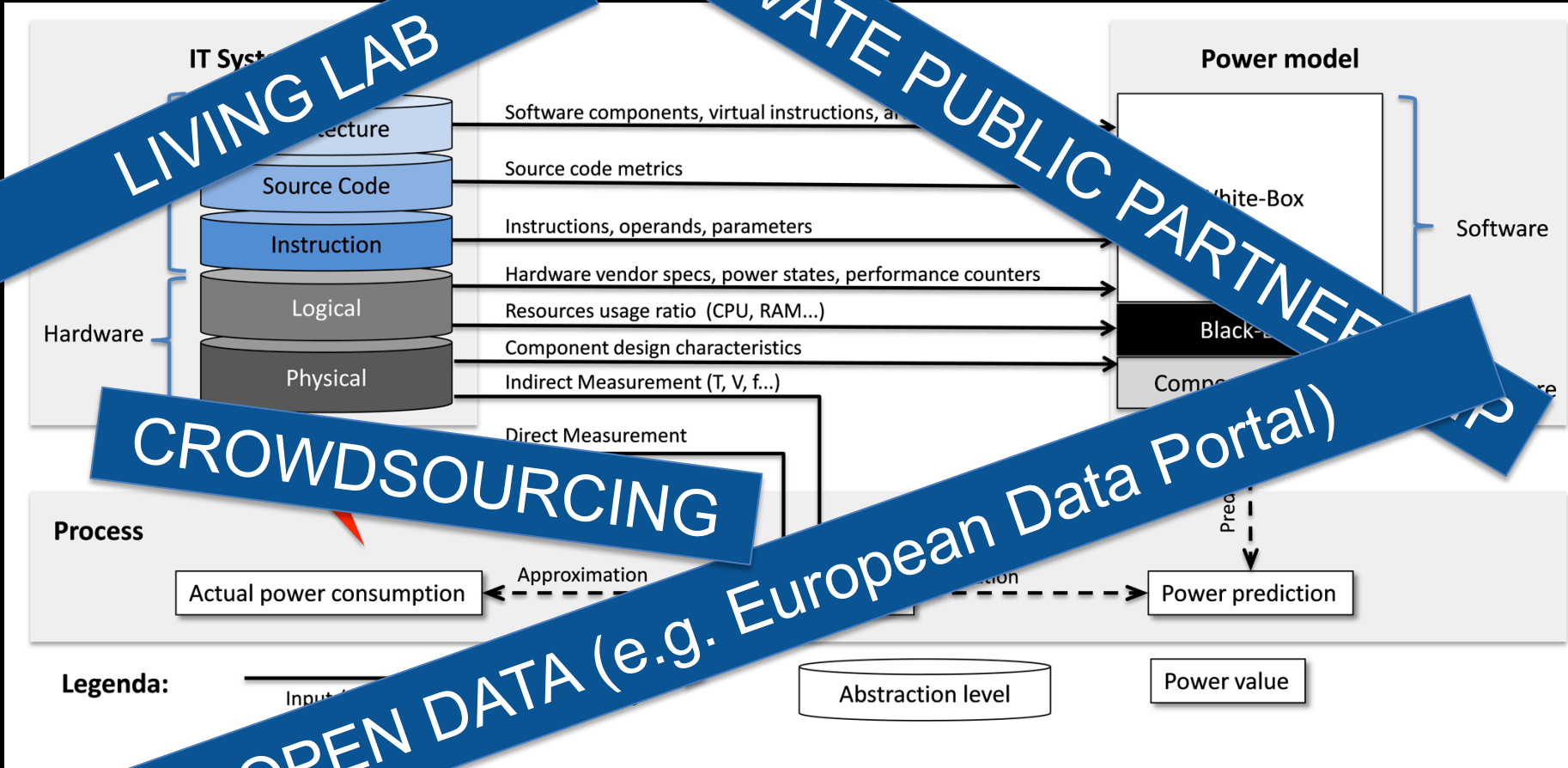


SOFTWARE REFACTORING
-50% energy consumption
-20% power consumption



Some numbers: true or false?





Research need: new empirical methods
 Too many variables, too much “noise”, too little time, ...

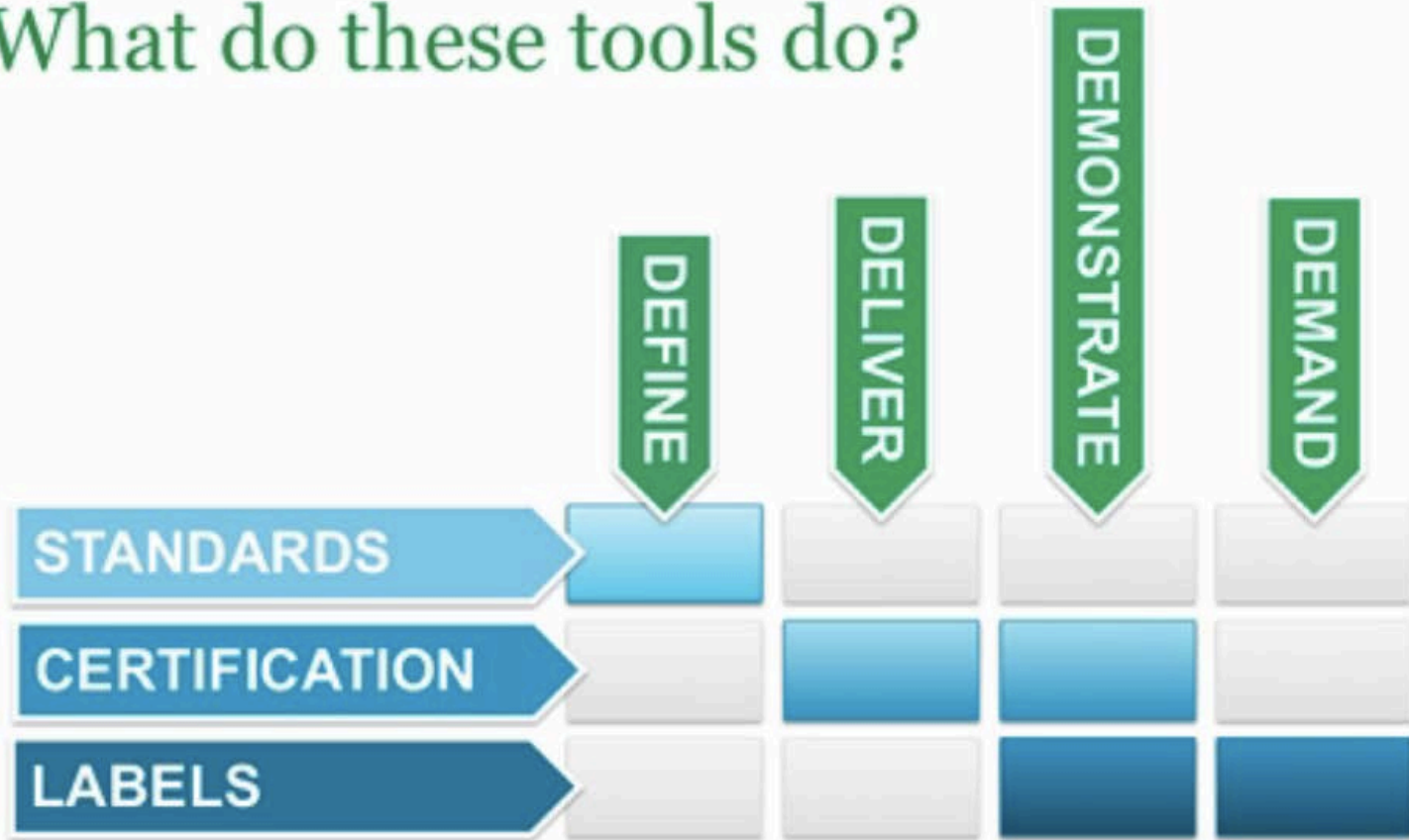


Research need:
A green label for software, too

SIGNED, SEALED... DELIVERED?

Behind Certifications and Beyond Labels

What do these tools do?



What should a green label *mean* for software?



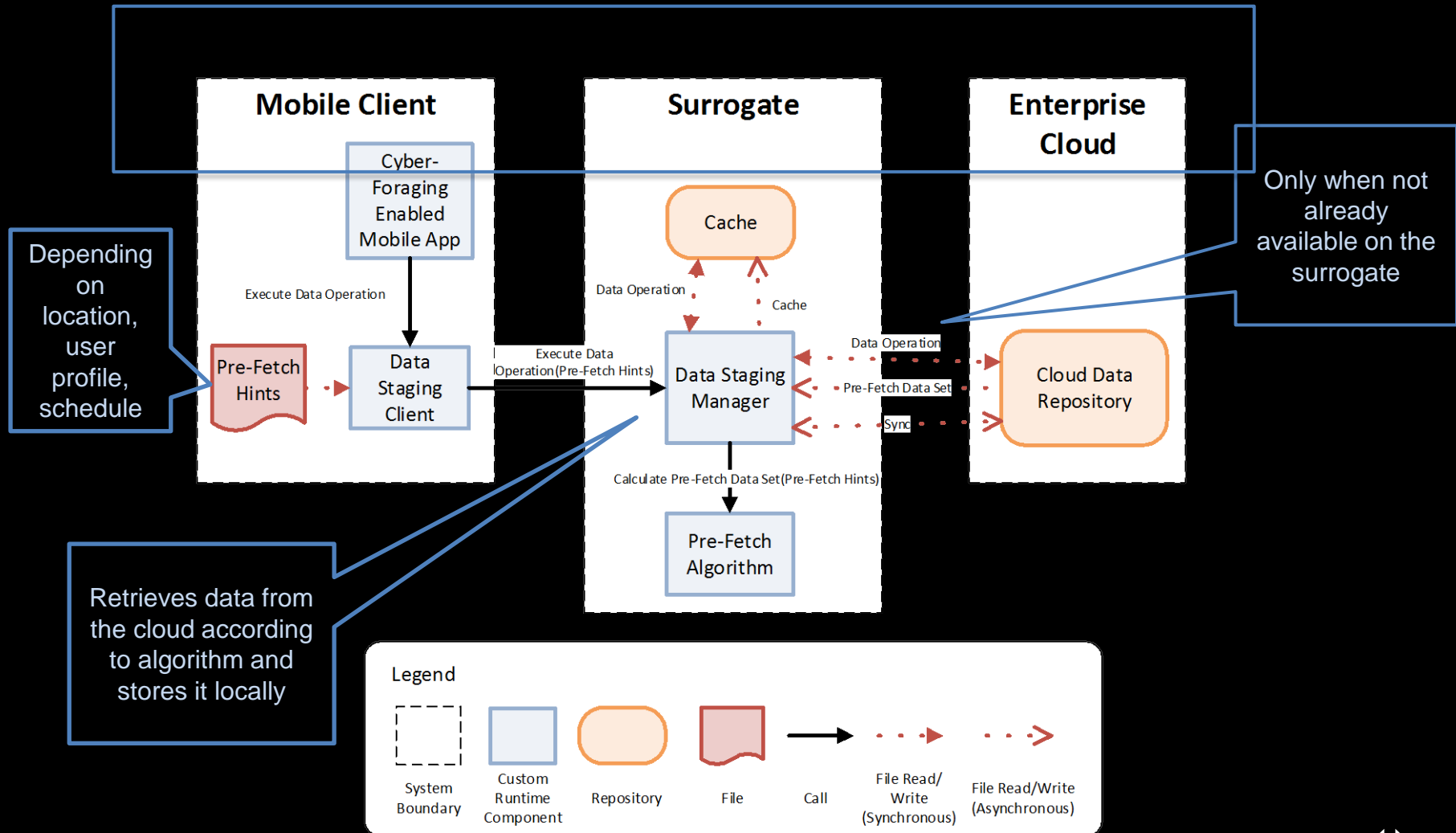
Smart Mobility

Connected Driving

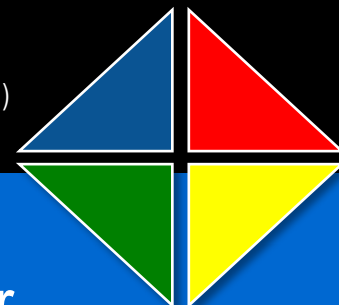


ANWB

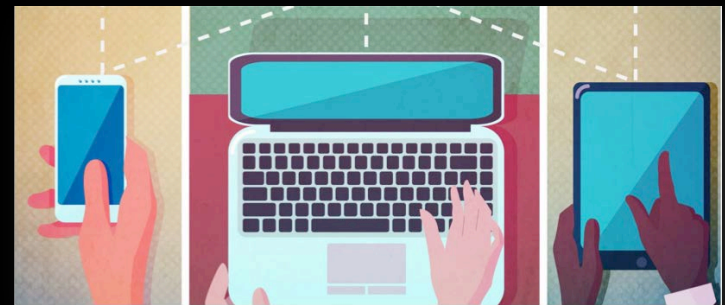
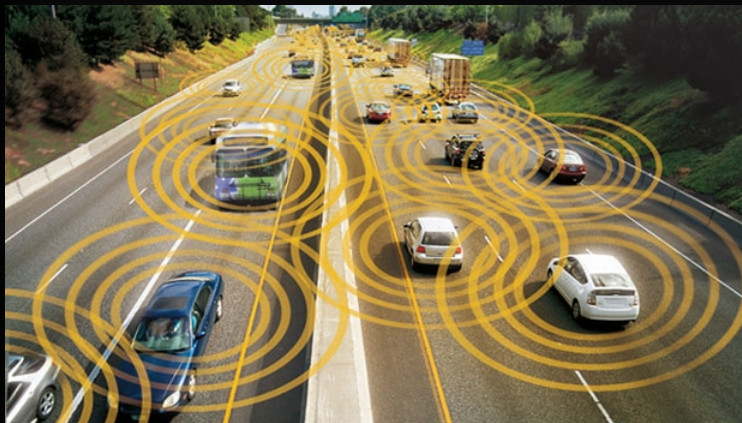
Smart software:
from **Business** innovation to **Technical** breakthrough



G. Lewis & P. Lago, "Characterization of Cyber-Foraging Usage Contexts", In Software Architecture, Springer LNCS (2015)

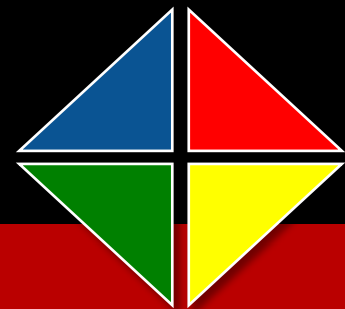


Smart software: Cyber-foraging software tactics make the cloud smarter



Serverless Architectures → Internet Architectures
1-Person Responsibility → Collective process

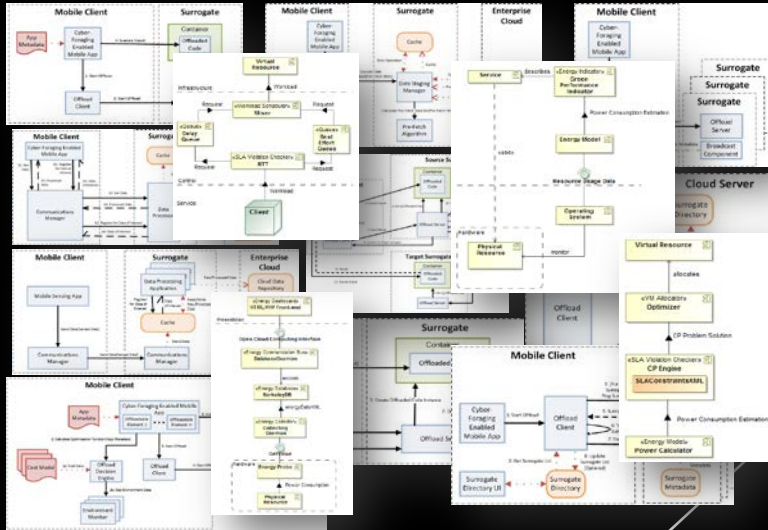
[Hope et al. The Software Architect's Role in the Digital Age, IEEE Software, 33(6), 2016]



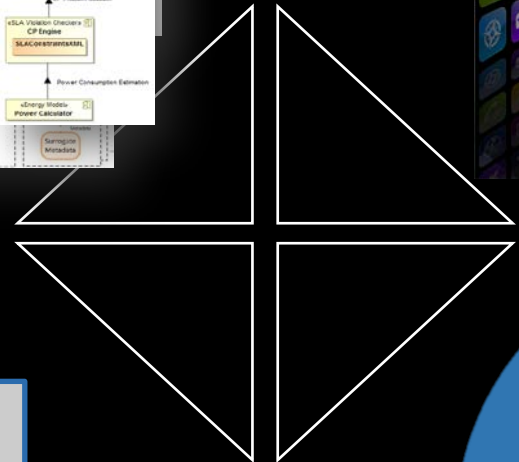
THE SOFTWARE LAB

Research need: new software architecture methods
Change in context, boundaries, intents, practices, ...

KNOWLEDGE BANK

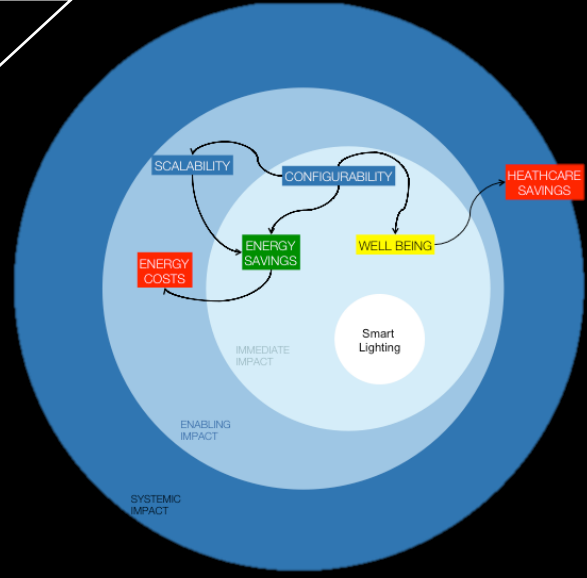


GREEN SOFTWARE LABEL



SOFTWARE REFACTORING
-50% energy consumption
-20% power consumption

NEW EMPIRICAL METHODS



NEW ARCHITECTURE METHODS

Thank you

Credits: slides, ideas and results are a collective effort with my bright and energetic colleagues in the S2 Group @Vrije Universiteit Amsterdam

www.s2group.cs.vu.nl

@patricia_lago

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LOOKING FURTHER