

National Symposium Software Engineering Research
The Netherlands #sensym2014



Software with Energy



Patricia Lago
Software and Services research group
M: p.lago@vu.nl
T: @patricia_lago



Faculty of
Sciences



Software and Services

Contents

- Why energy efficiency is a software engineering problem
- Emerging results
- The challenges ahead

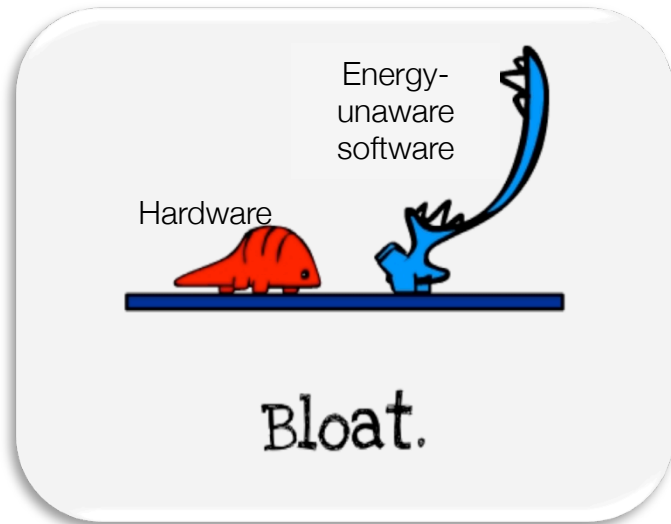
Contents

- Why energy efficiency is a software engineering problem
- Emerging results
- The challenges ahead

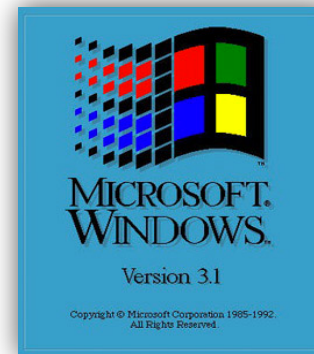
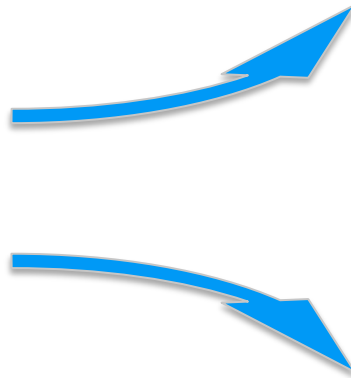
Software and Energy



Software is energy-inefficient



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



Software is energy-inefficient



[The energy efficiency *potential* of cloud-based software: A US case study. Tech. rep., Berkeley, California, 2013]

A green label for software, too...



Contents

- Why energy efficiency is a software engineering problem
- **Emerging results**
- The challenges ahead

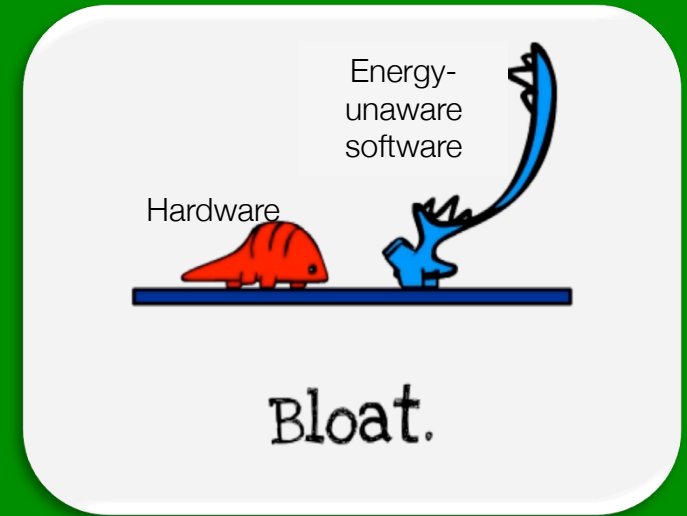
Know – Measure – Scan



[The energy efficiency *potential* of cloud-based software: A US case study. TR Berkeley, California, 2013]



Labels tell how much energy we will *consume* with that product, and influence our *behaviour*.



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

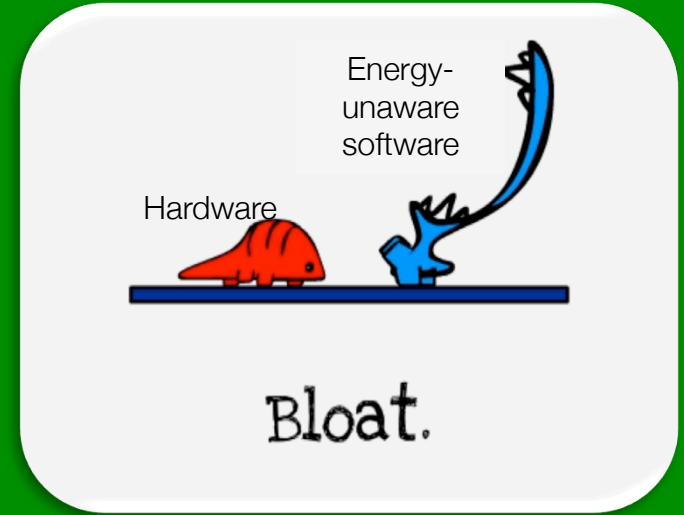
Know – Measure – Scan



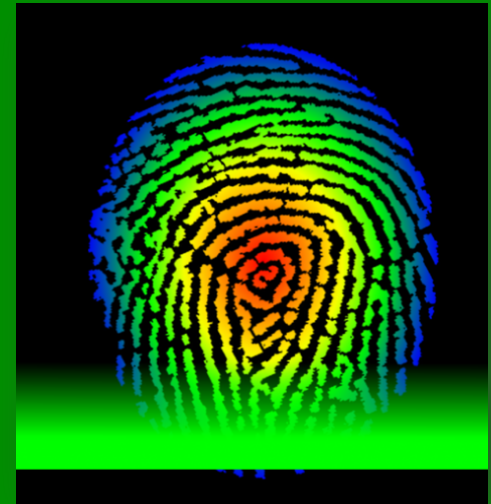
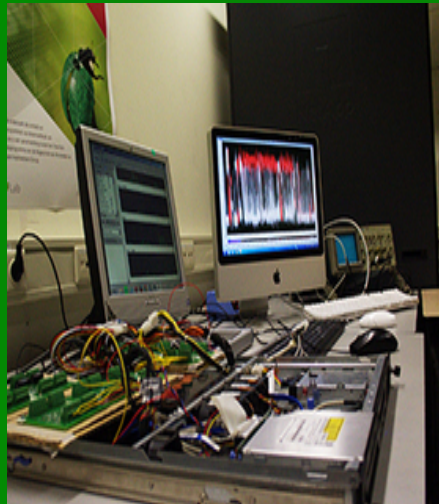
[The energy efficiency *potential* of cloud-based software: A US case study. TR Berkeley, California, 2013]



Labels tell how much energy we will **consume** with that product, and influence our **behaviour**.



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

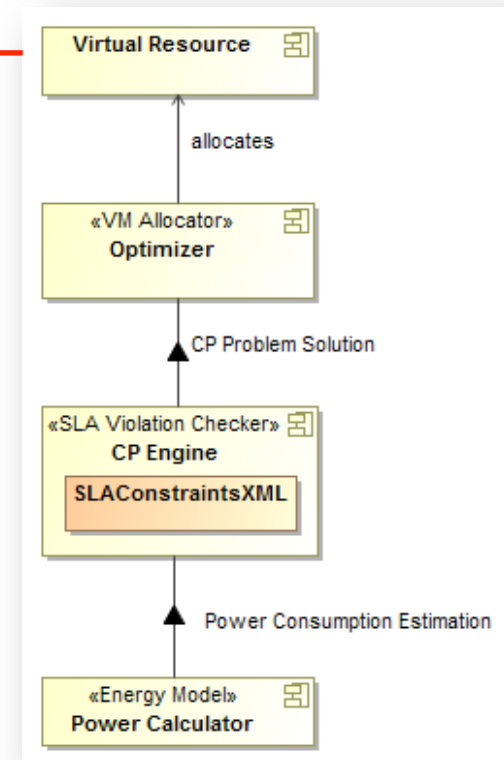
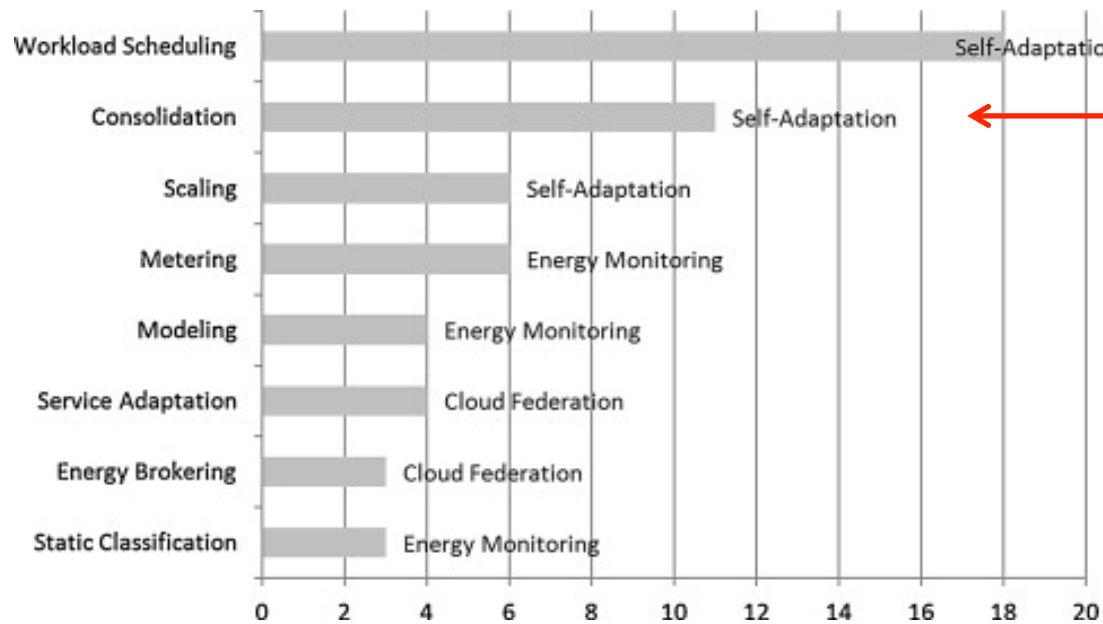


Knowledge: design, develop, reuse



- Software determines hardware behaviour
 - We treat EE as a software quality attribute
1. Study the influence of software architectures on EE by means of *architectural tactics*
 2. Capture developers' knowledge in SE guidelines (aka software practices)
 3. Share best practices for reuse

Knowledge: **design**, develop, reuse: Green Architectural Tactics for the Cloud



[Procaccianti et al., Green Architectural Tactics for the Cloud
IEEE/IFIP WICSA, 2014]

[Procaccianti et al., A Systematic Literature Review on Energy Efficiency
in Cloud Software Architectures, Sustainable Computing: Informatics
and Systems, Elsevier, 2014]

Knowledge: design, **develop**, reuse: EE of Software Engineering Practices



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 ←

[Gude & Lago, Best Practices for Energy-Efficient Software, wiki.cs.vu.nl/green_software]

[Procaccianti et al., Empirical Evaluation of Best Practices for Energy-Efficient Software Development, IEEE Trans. Software Engineering, under submission, 2014]



Knowledge: design, develop, reuse: *Share best practices*



GreenICT practices

VU UNIVERSITY AMSTERDAM SURF NET

Home Browse Library Calculator Contact Search for Green Practices... Sign in

Home / Green Practices

Green Practices

10 practices per page Search: software

Name	Category	Role of IT	Proposed By
Avoid software-induced replacement.	Management	Greening by IT	Taken from literature
Deploy software that can manage other software applications.	Design	Greening of IT	MJA
Eliminate the dependency between software applications and dedicated hardware.	Organization	Greening of IT	MJA
Purchase software applications that are equipped with energy management functionality and are also energy efficient at run time.	Design	Greening of IT	MJA
Purchase software applications that exactly fit the required functionality.	Design	Greening of IT	MJA
Structure and classify current and future software applications.	Organization	Greening of IT	MJA
Use power management software.	ICT	Greening by IT	Taken from literature
Use software to manage the package flow.	ICT	Greening by IT	Taken from literature
Use software to turn off PC automatically during the night.	ICT	Greening by IT	Taken from literature

Showing 1 to 9 of 9 practices

<http://greenpractice.few.vu.nl>

GreenICT practices

VU UNIVERSITY AMSTERDAM SURF NET

Home Browse Library Calculator Contact Search for Green Practices... Sign in

Home / Calculator

A web-based calculator for value business of green ICT practices

Manage models Process models

Before				After			
Expenses	Quantity	Cost	Total	Expenses	Quantity	Cost	Total
Maintenance (Investment)	50	50	€ 2.500	Server (Expense)	1	4000	€ 4.000
Server (Investment)	1	2000	€ 2.000	Thin client (Expense)	50	400	€ 20.000
Electricity (Investment)	180	0.5	€ 90	Maintenance (Expense)	50	25	€ 1.250
Electricity (Investment)	2000	0.5	€ 1.000	Electricity (Expense)	288	0.5	€ 144
Fat client (Investment)	50	600	€ 30.000	desktopvirtualizationssoftware (Expense)	1	400	€ 400
Total Electricity Consumption (per month)	2.180 KWh		€ 1.090	Electricity (Expense)	160	0.5	€ 80
Investment (one time cost)		€ 35.590		Total Electricity Consumption (per month)	448 KWh		€ 224
Expenses (per month)	€ 0			Investment (one time cost)	€ 0		
				Expenses (per month)	€ 25.874		

One time savings	Savings per month		
Investment	Electricity in KWh	CO2 emissions	Monthly costs
€ 35.590	866 KWh	0,52 Tons	€ -25.874

Calculate Chart Reset

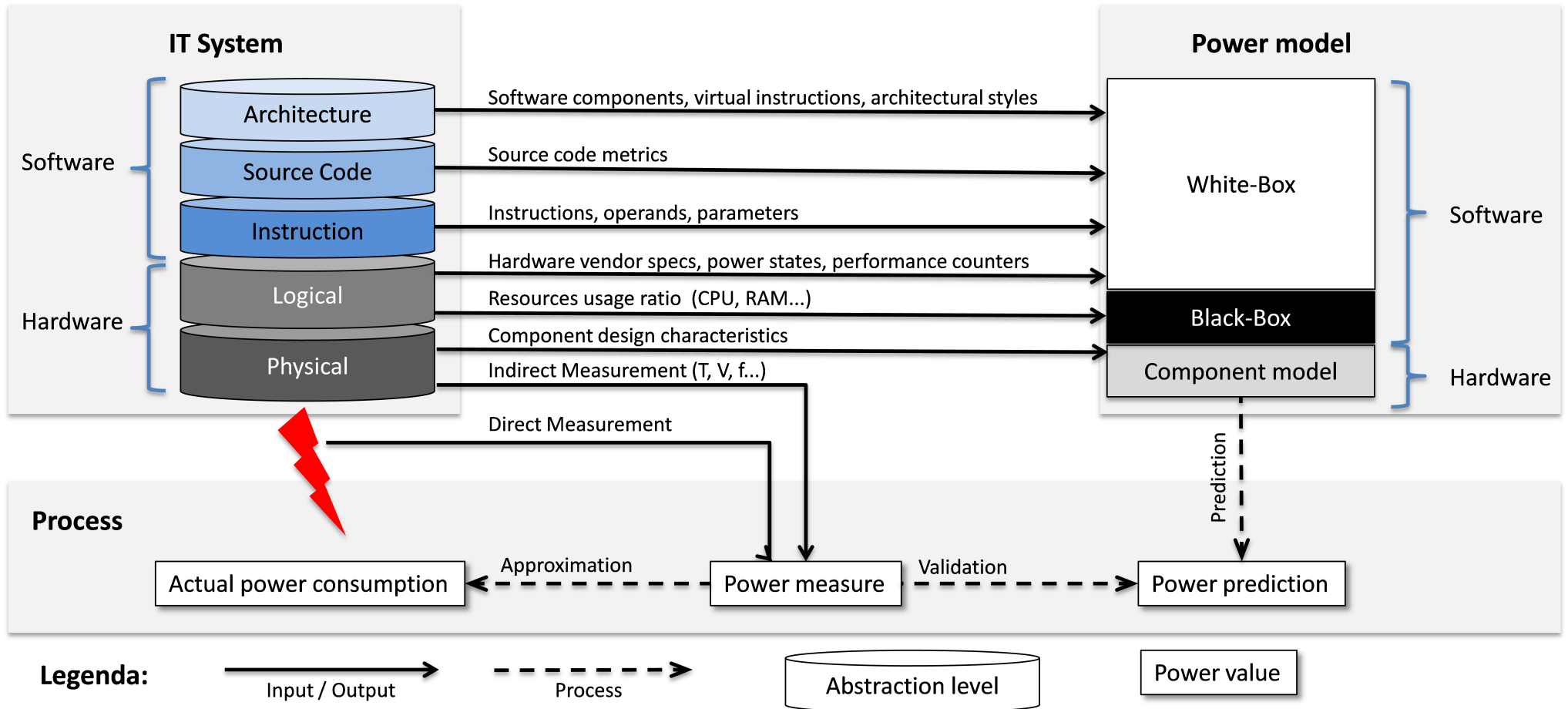
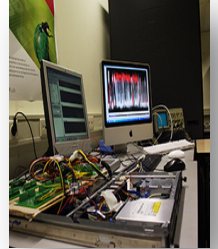
Work in progress

ICT and Sustainability

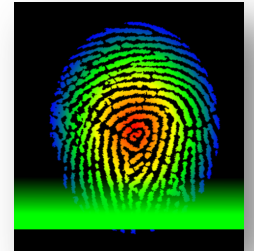


[Gu and Lago, Estimating the economic value of reusable green ICT practices, ICSR, Springer, 2013]

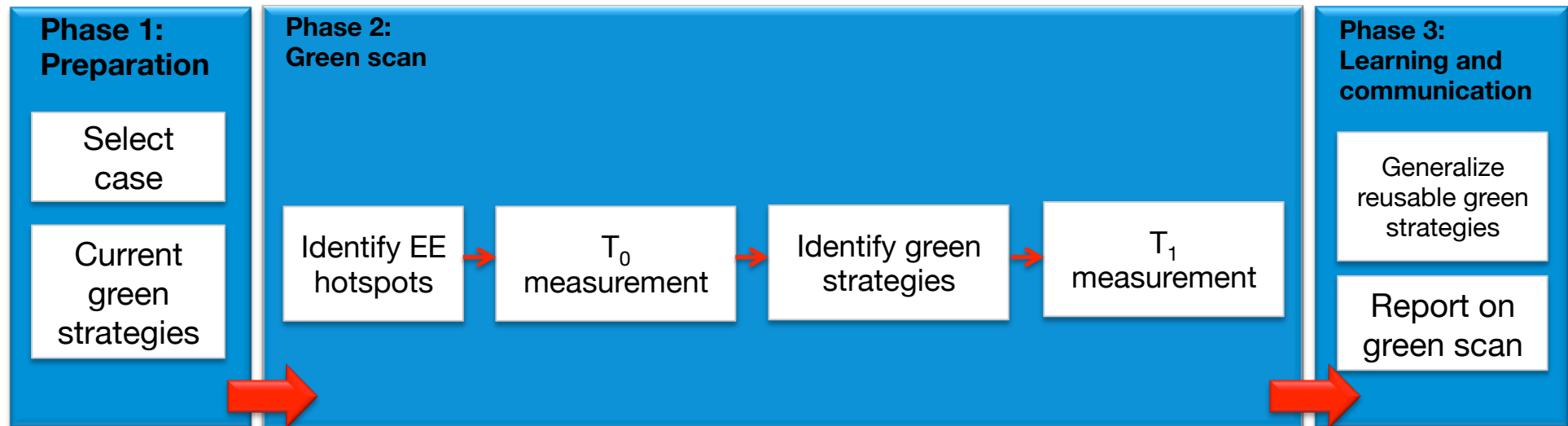
Measure: model, estimate, monitor



Scan: uncover, identify energy hotspots



Energy hotspot: element or property, at any level of abstraction of the system architecture, that has a (potential) measurable and significant impact on energy consumption [Procaccianti et al.]



[Lago & Procaccianti, Green Scan Methodology,
http://www.slideshare.net/patricia_lago/green-scanmethodology]

Contents

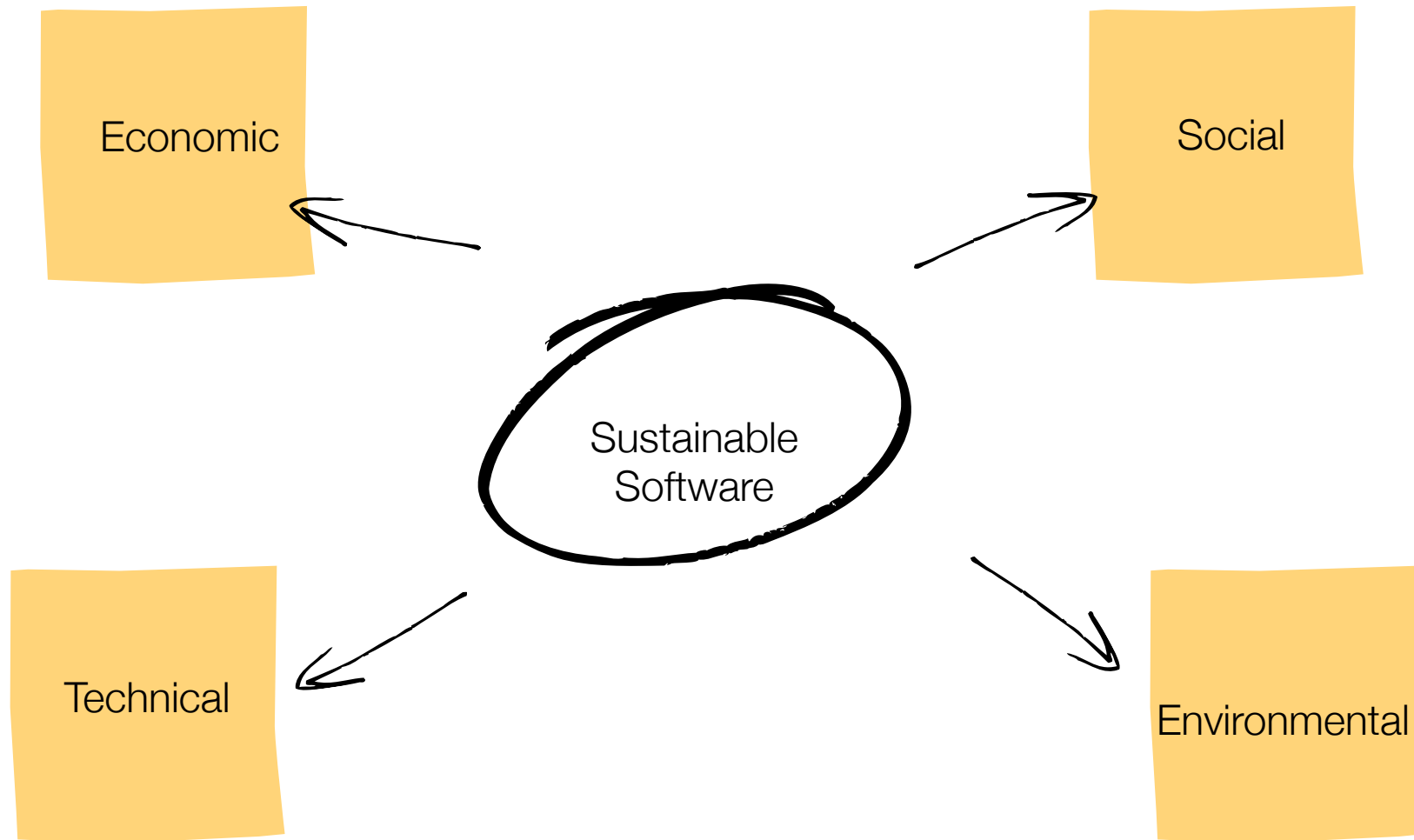
- Why energy efficiency is a software engineering problem
- Emerging results
- The challenges ahead

Statement #1:

SE researchers and practitioners need *c/loser* collaboration

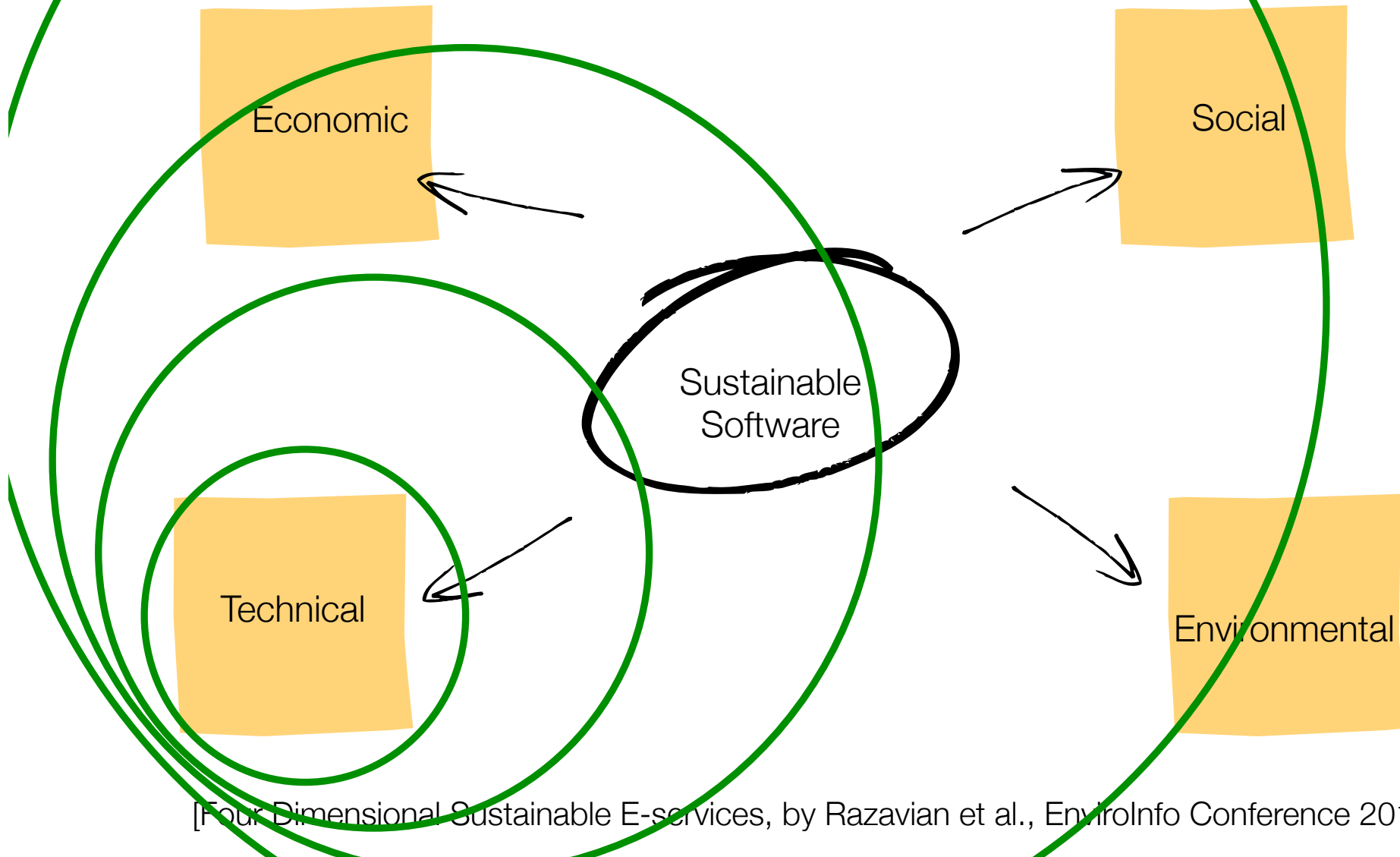


Statement #2: Sustainability in Software Engineering is necessary



[Four Dimensional Sustainable E-services, by Razavian et al., EnviroInfo Conference 2014]

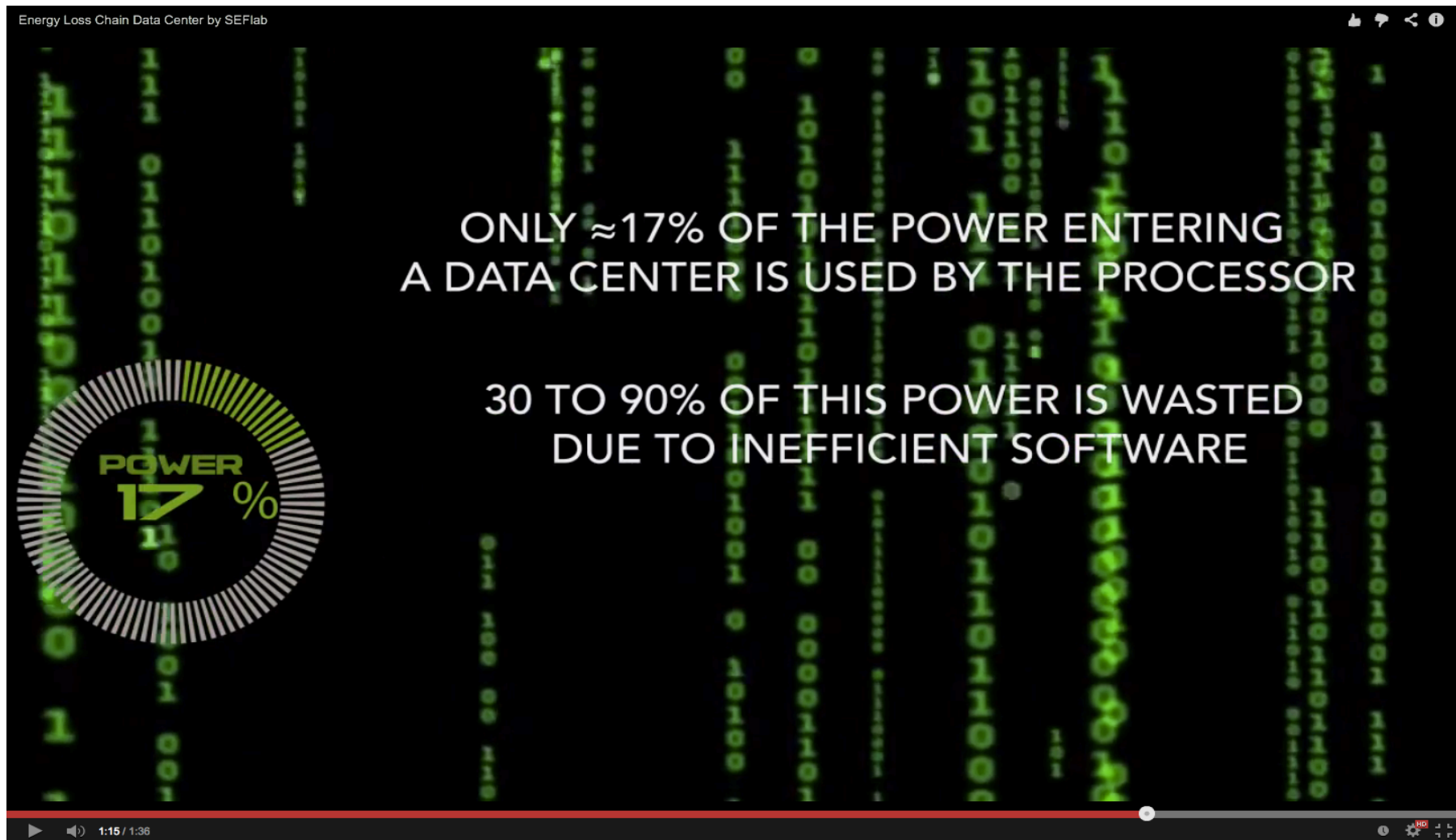
Statement #2: Sustainability in Software Engineering is necessary



[Four Dimensional Sustainable E-services, by Razavian et al., EnviroInfo Conference 2014]

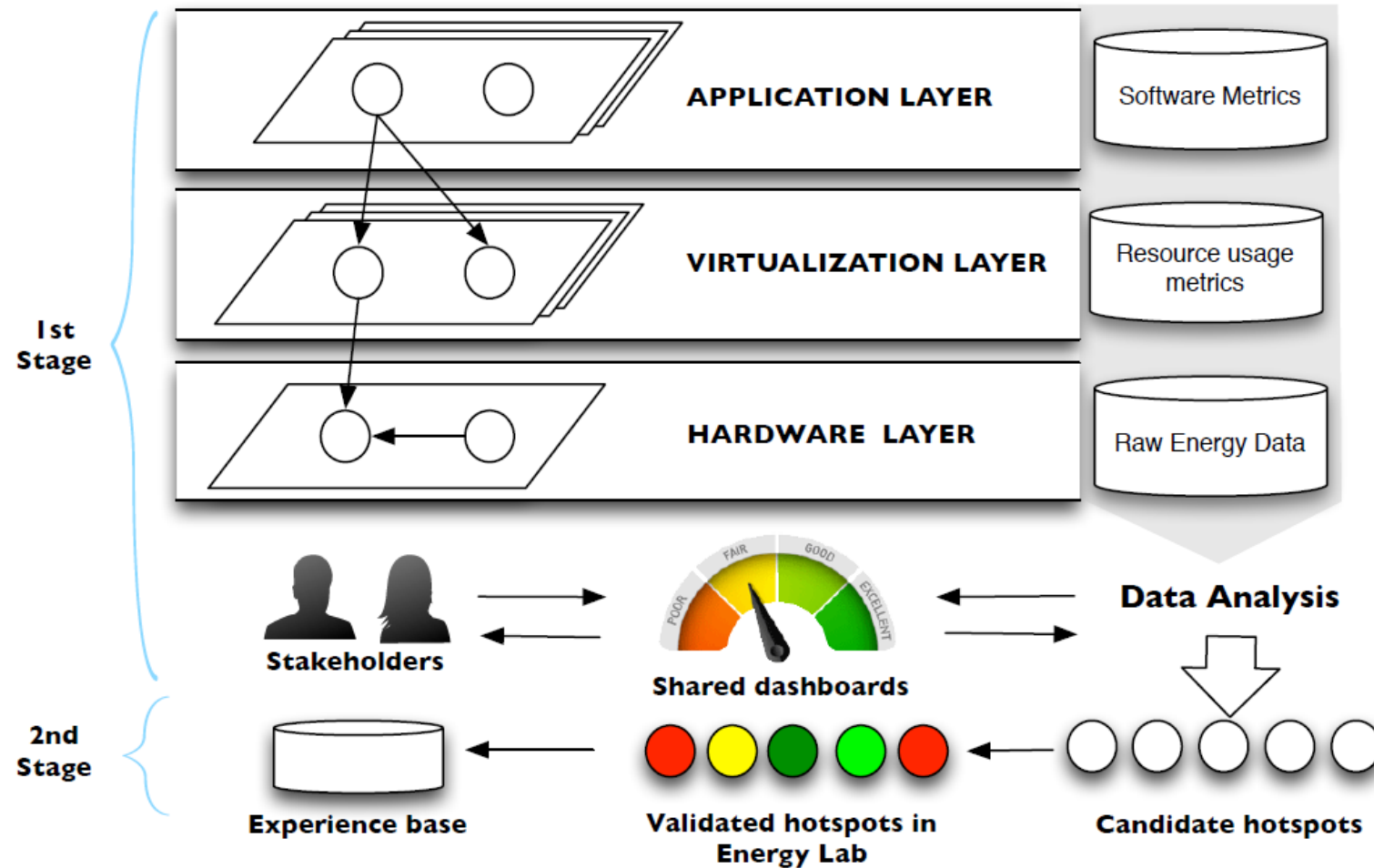
Statement #3:

Energy efficient software needs *more* and *better* research



[Energy Loss Chain Data Center by SEFlab, youtube.com]

The GREENSWEEP Approach



[Procaccianti G., Lago P., Vetrò A., Mendéz Fernández, D., Wieringa, R. (under submission). **The Green Lab: Experimentation in Software Energy Efficiency**. Submitted to the 37th International Conference on Software Engineering (ICSE 2015).]

Statement #4: sound education is needed

Why the Track **Software Engineering and Green IT**?

- *Provide current professionals and future generations*
- *with the appropriate skills and competencies*
- *to engineer energy-aware software and ICT systems*



MASTER'S TRACK IN
COMPUTER SCIENCE

**SOFTWARE
ENGINEERING
AND GREEN IT**

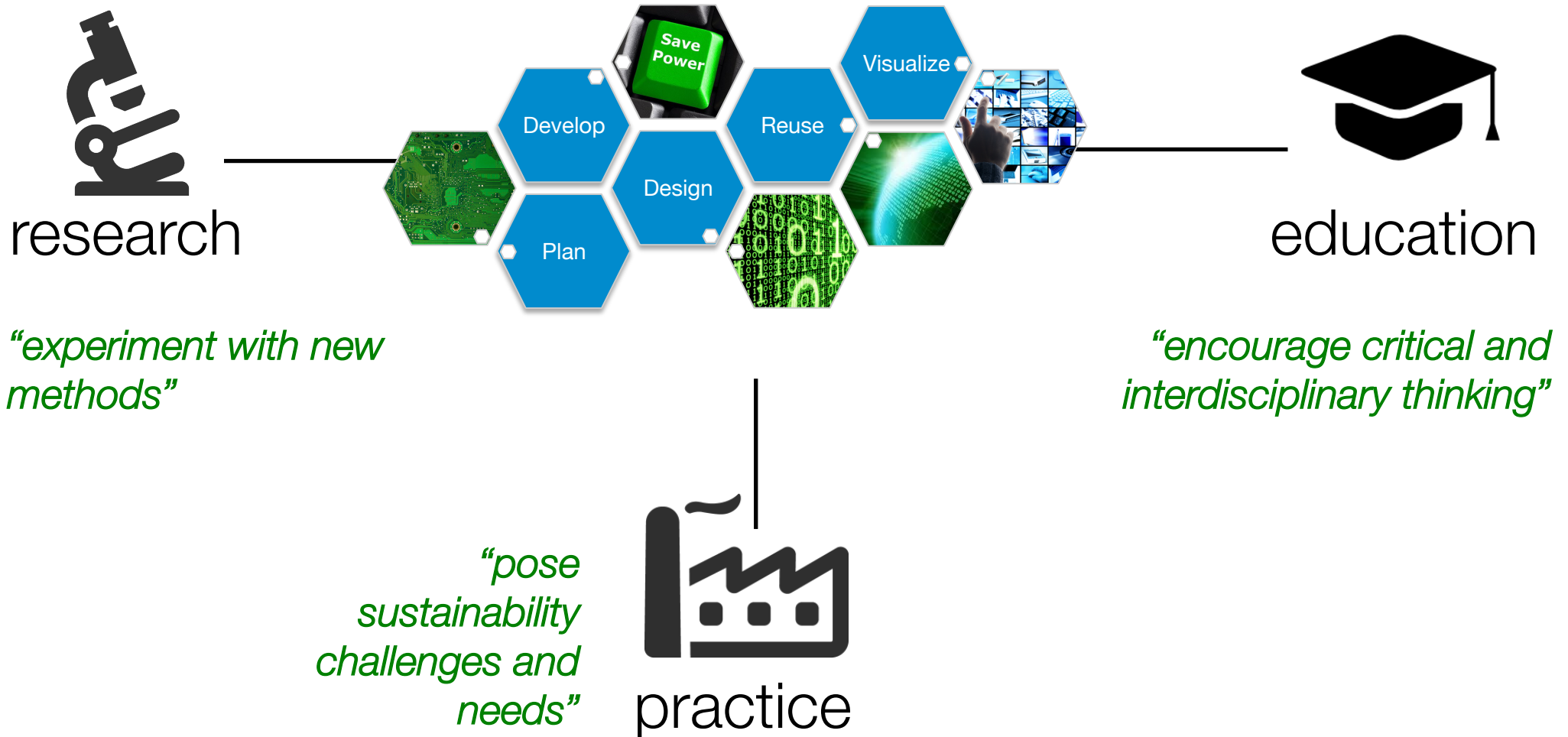
WWW.VU.NL/COMPUTERSCIENCE

VU UNIVERSITY
AMSTERDAM

LOOKING FURTHER

The Green Lab ©

A master course for serious experimentation in software energy efficiency



Credits



Giuseppe
Procaccianti



Grace Lewis



Maryam
Razavian



Paola
Grosso



Nelly Condori-
Fernandez



Fahimeh
Alizadeh



Daniel Méndez
Fernández



Antonio Vetrò



Roel Wieringa



UNIVERSITY OF TWENTE.



Software Engineering Institute
Carnegie Mellon

Software with Energy

Patricia Lago
© 2014



Software and Services

