SOFTWARE ENERGY CONSUMPTION OF MOBILE DEVICES

Gabriele Kotsis, Andreas Hannes Schuler

JOHANNES KEPLER UNIVERSITY LINZ

Institut für Telekooperation

Reflecting the Energy Demand of ICT

- Digitalization and energy consumption. Does ICT reduce energy demand?
- Evolution of IT Energy Demand
- Power Consumption of Mobile Devices

Characterizing Software Energy Consumption in Mobile Application Development to Support Third-Party-Library Selection

- A systematic review on mobile software energy profiling
- A generic approach to profiling software energy consumption at a fine-granularity
- API utilization profiles (uapi) as proxy for the energy characteristics of Third Party Library (TPL) dependencies

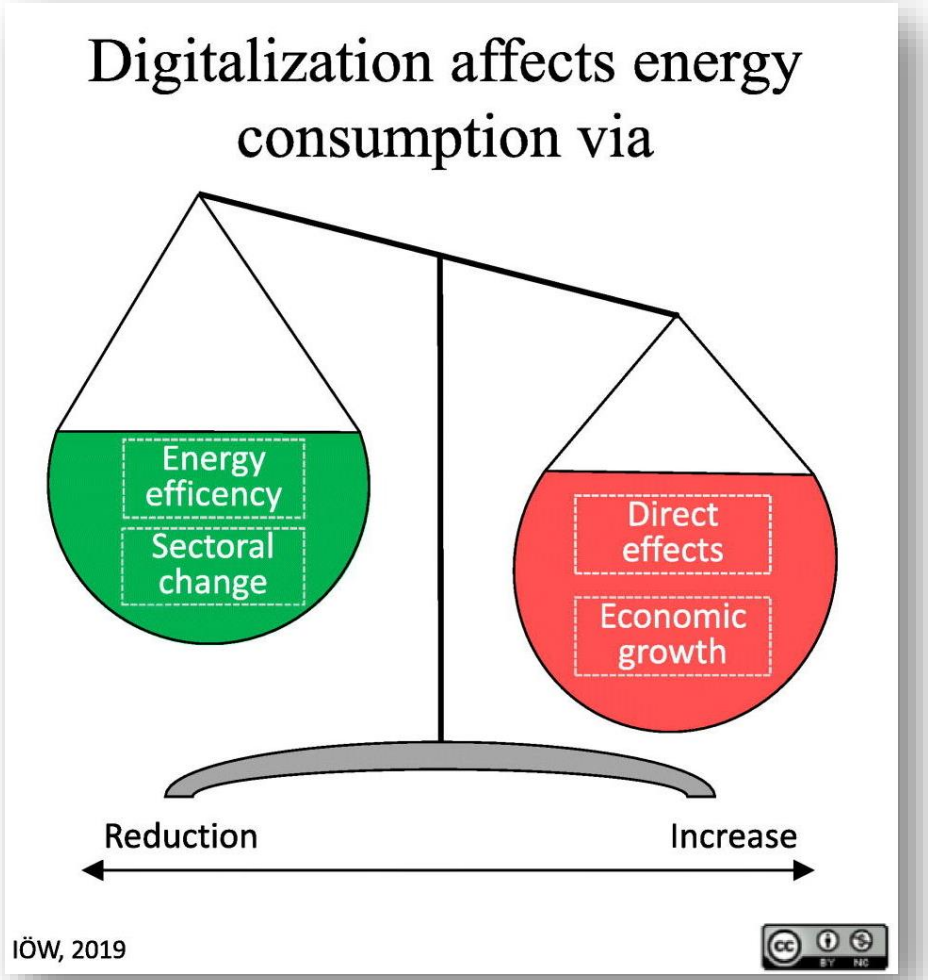
Reflecting the Energy Demand of ICT

- Digitalization and energy consumption. Does ICT reduce energy demand?
- Evolution of IT Energy Demand
- Power Consumption of Mobile Devices

Characterizing Software Energy Consumption in Mobile Application Development to Support Third-Party-Library Selection

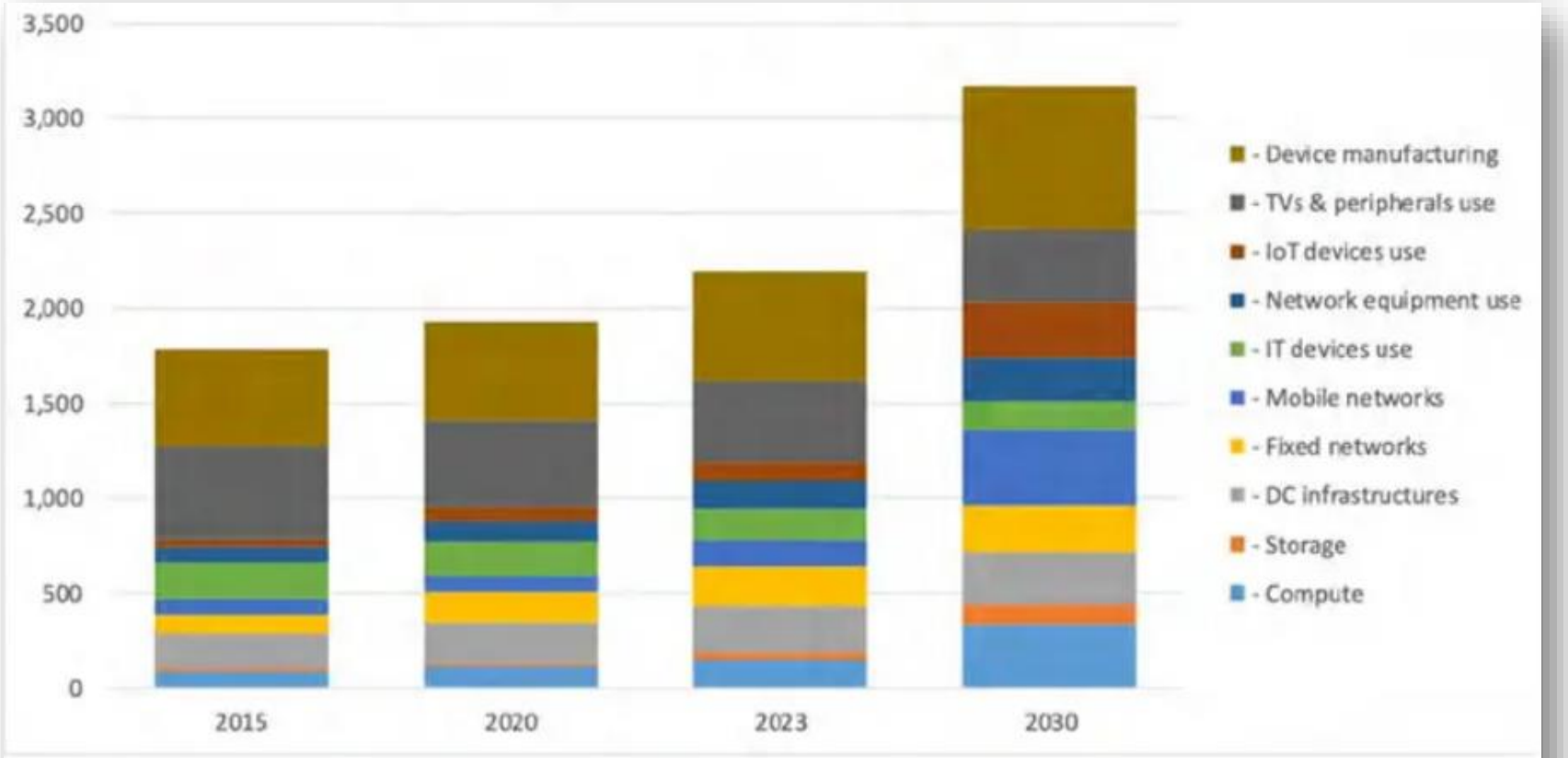
- A systematic review on mobile software energy profiling
- A generic approach to profiling software energy consumption at a fine-granularity
- API utilization profiles (uapi) as proxy for the energy characteristics of Third Party Library (TPL) dependencies

Digitalization and energy consumption – Does ICT reduce energy demand?



Lange et.al. 2020 (Ecological Economics)

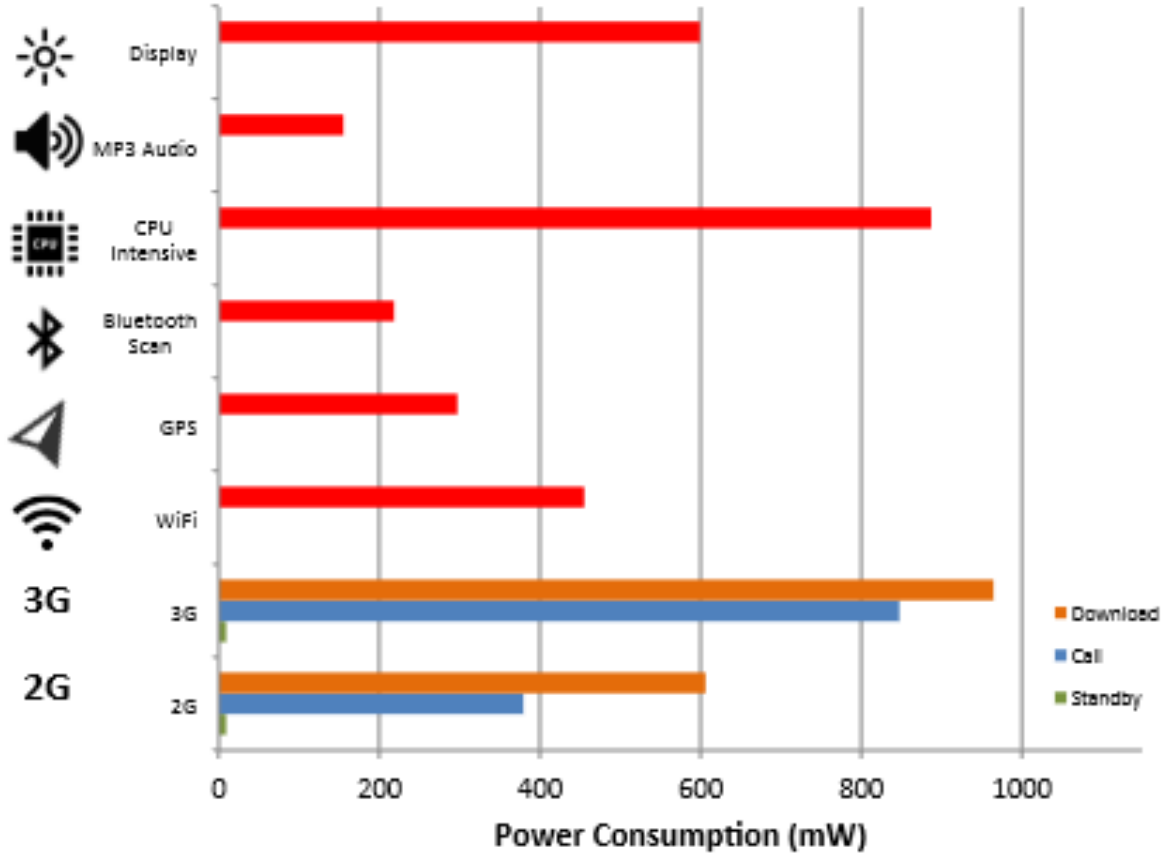
Evolution of IT Energy Demand (TWh)



Schneider Electric estimates that IT sector electricity demand will grow by 50 percent by 2030, reaching 3,200TWh, equivalent to 5 percent Compound Annual Growth Rate (CAGR) over the next decade – evolution of IT energy demand in TWh

https://www.i-scoop.eu/sustainability-sustainable-development/it-sector-electricity-demand/

Power Consumption of Mobile Devices based on Usage Scenarios



Ardito et.al 2015

Reflecting the Energy Demand of ICT

- Digitalization and energy consumption. Does ICT reduce energy demand?
- Evolution of IT Energy Demand
- Power Consumption of Mobile Devices

Characterizing Software Energy Consumption in Mobile Application Development to Support Third-Party-Library Selection

- A systematic review on mobile software energy profiling [1]
- A generic approach to profiling software energy consumption at a fine-granularity [2,3]
- API utilization profiles (u_{api}) as proxy for the energy characteristics of Third Party Library (TPL) dependencies [4,5]

[1] A. Schuler, G. Kotsis, A Systematic Review on Techniques and Approaches to Estimate Mobile Software Energy Consumption, 2022, submitted to Sustainable Computing: Informatics Systems Journal, 2022, [currently being processed after minor revisions]

[2] Examining the energy impact of sorting algorithms on android: an empirical study, A. Schuler, G. Kotsis, Proceedings of the 16th EAI International Conference on Mobile and Ubiquitous Systems, 2019.

[3] Towards a framework for detecting energy drain in mobile applications: an architecture overview, A. Schuler, G. Kotsis, ISSTA '18: Companion Proceedings for the ISSTA/ECOOP 2018 Workshops, 2018

[4] Mining API Interactions to Analyze Software Revisions for the Evolution of Energy Consumption, A. Schuler, G. Kotsis, MSR '21: Proceedings of the 18th International Conference on Mining Software Repositories, 2021

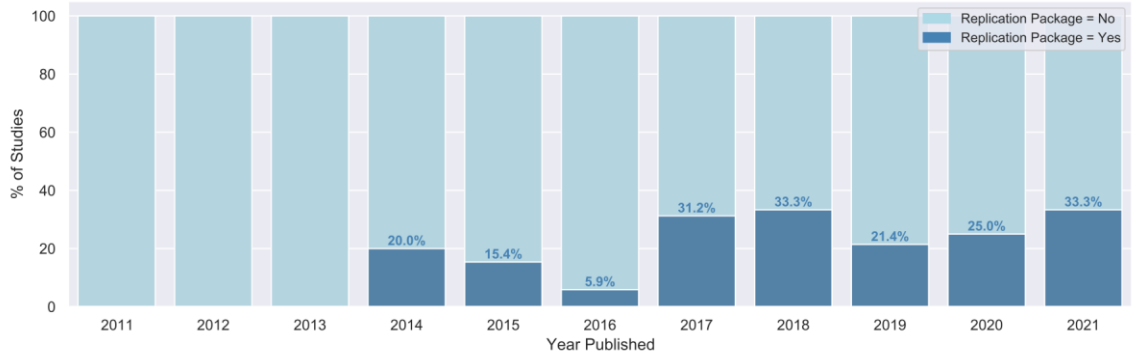
[5] Characterizing Energy Consumption of Third-Party API Libraries using API Utilization Profiles – A. Schuler, G. Kotsis, Proceedings of the 14th ACM/IEEE International Symposium on Empirical Software Engineering, 2020.

Systematic Literature Review

„What types of contributions are provided by the selected research?“

- Key Insights
  - Since 2014 increase in availability of replication packages
  - Only 5 of the tools are actively maintained and publicly available
  - Potential for future research regarding energy efficiency guidelines, patterns and metrics

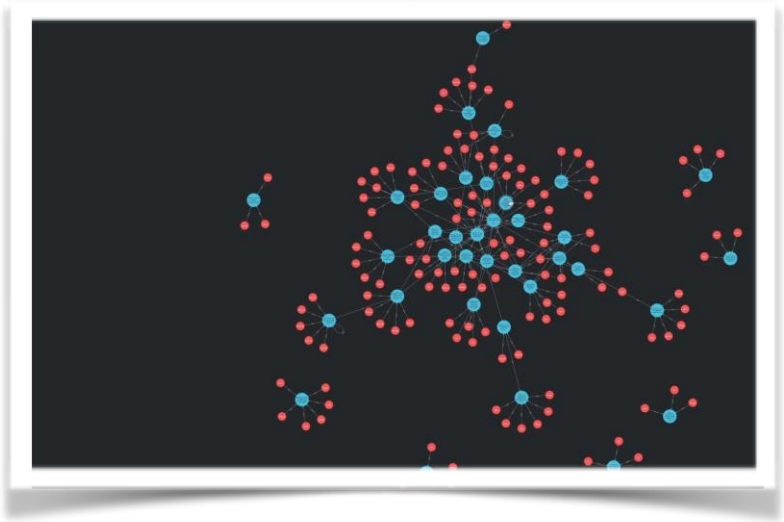
Systematic mapping of contribution types over power modelling approaches.



Availability of replication packages in relation to selected studies per year.

Systematic Literature Review – Replication Package

- Search-and-Queryable graph database containing the studies covered by the review [1]

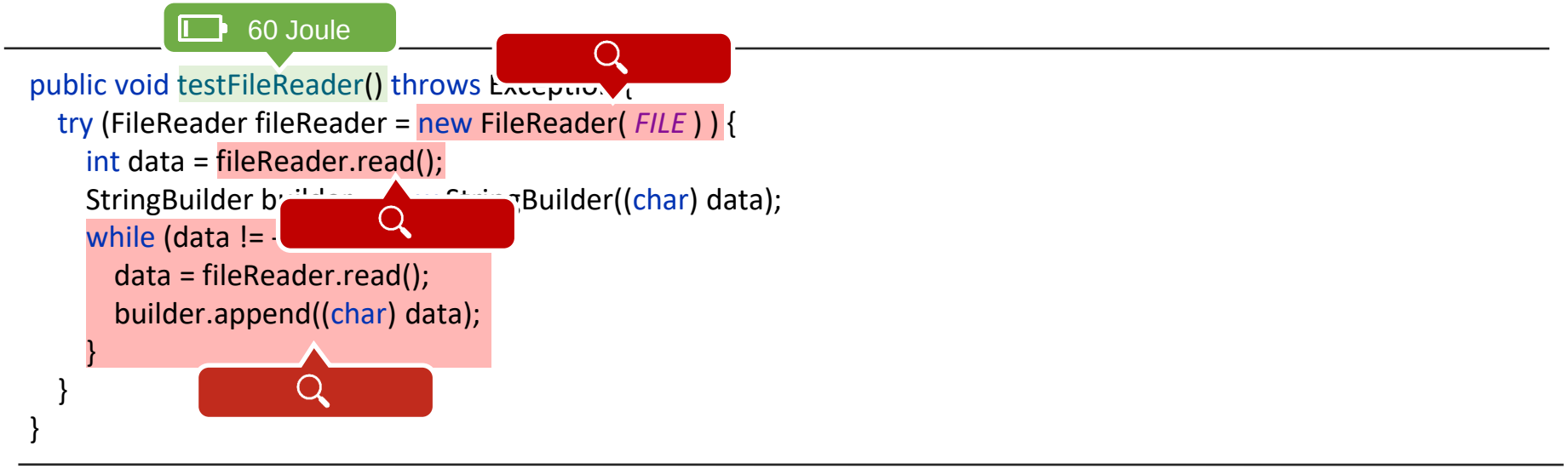


Explore the articles, authors and their relations in mobile software energy research.

[1] A. Schuler, G. Kotsis, A Systematic Review on Techniques and Approaches to Estimate Mobile Software Energy Consumption (*SUSCOM Dataset*), Submitted to the Sustainable Computing Journal, 2022.

Open Source Data https://zenodo.org/record/7140240

Motivation


60 Joule
public void testFileReader() throws
try (FileReader fileReader = new FileReader(FILE)) {
int data = fileReader.read();
Builder((char) data);
while (data !=
data = fileReader.read();
builder.append((char) data);
}
}
}

Profiling software energy consumption at a fine-granularity

- A generic app
  - Series of st periments
  - Comprises
  - Algorithm to hods in source code)

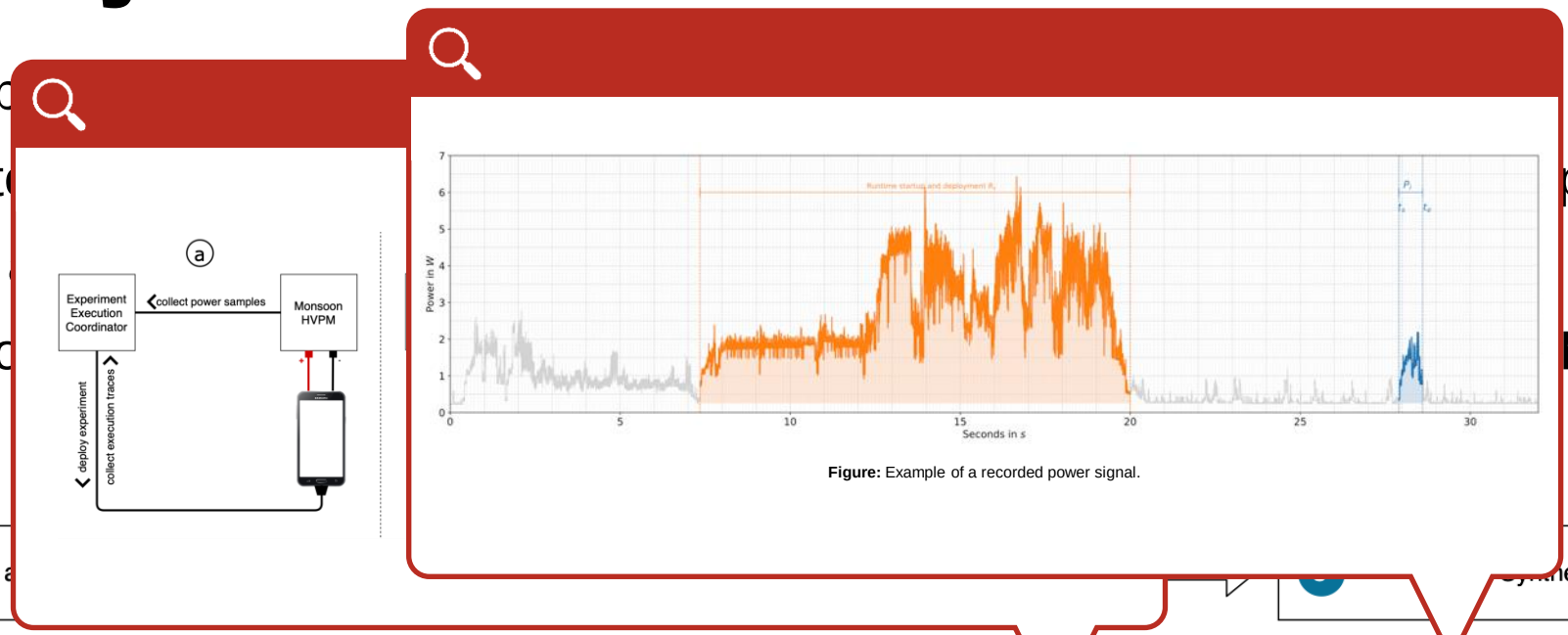
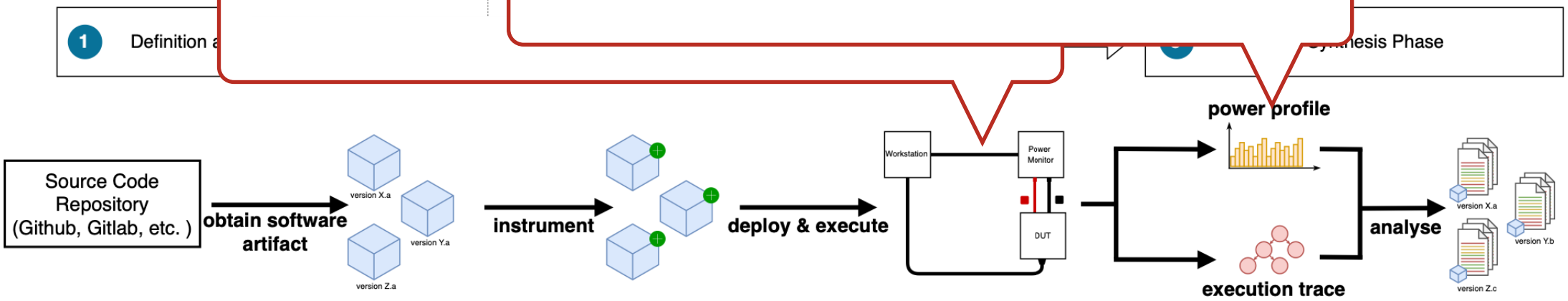
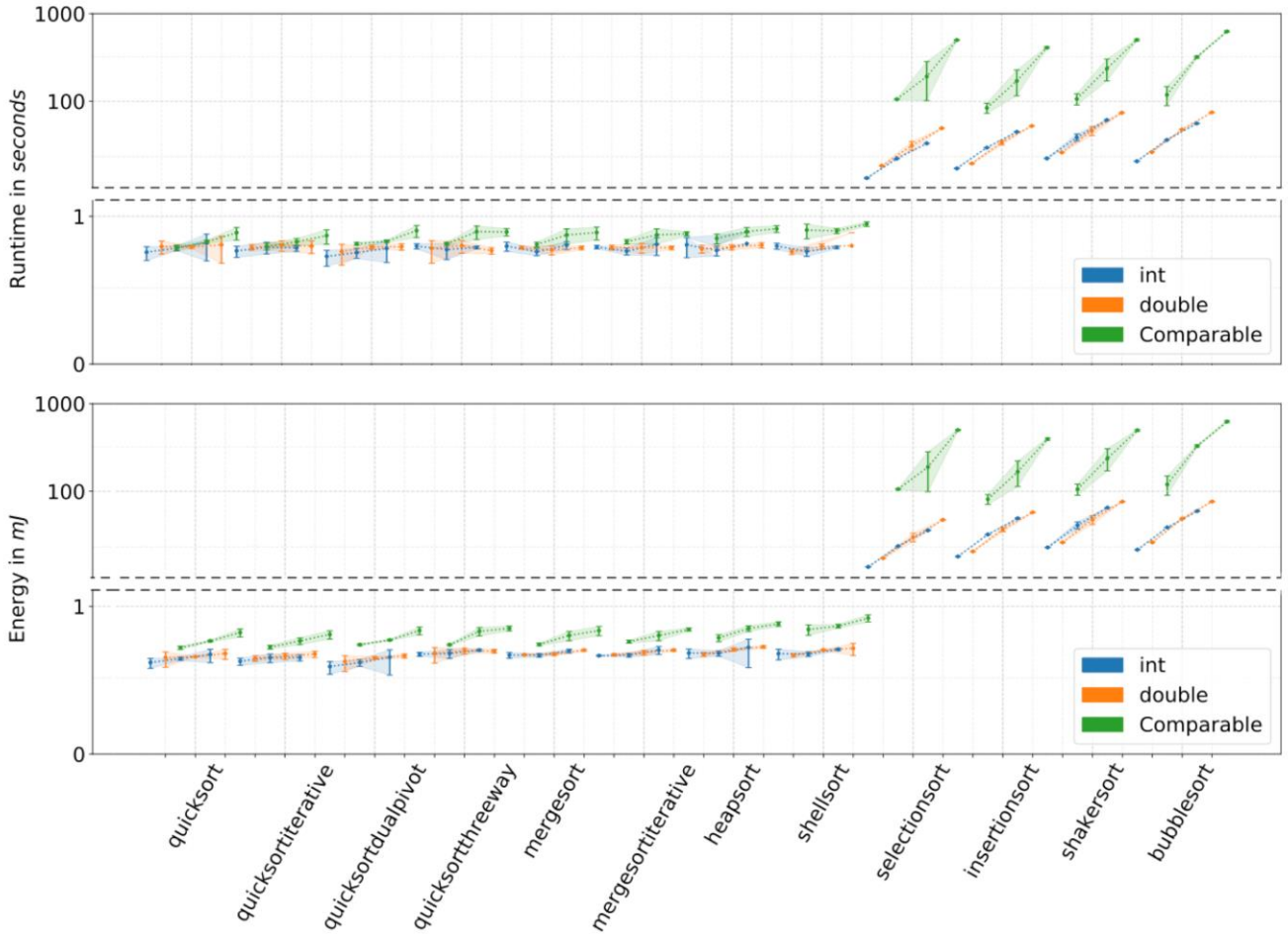


Figure: Example of a recorded power signal.



Case Study: Sorting Algorithms

- Empirical study on the energy characteristics of sorting algorithms on Android [2]
  - Compared *12 sorting algorithms* for datatypes (int, double, Comparable) for problem sizes *50k*, *75k* and *100k*
  - Sampled each test 20 times, averaged results
  - Choice of datatype has *significant* impact on *energy characteristics*
    - Kruskal-Wallis, *df = 2, p < .001*, Dunn's Post-Hoc Test

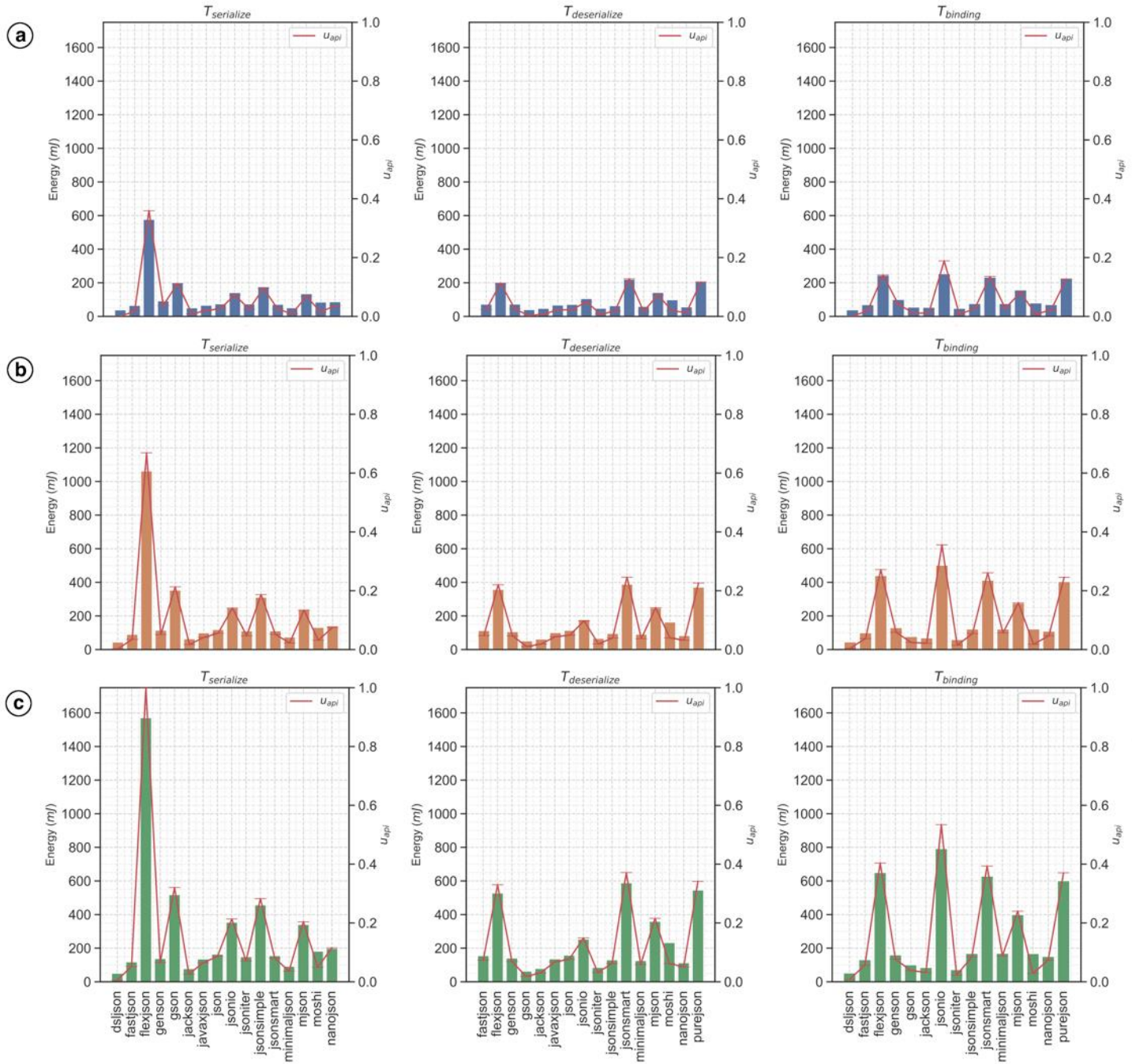


[2] Examining the energy impact of sorting algorithms on android: an empirical study, A. Schuler, G. Kotsis, Proceedings of the 16th EAI International Conference on Mobile and Ubiquitous Systems, 2019.

u_{api} profiles

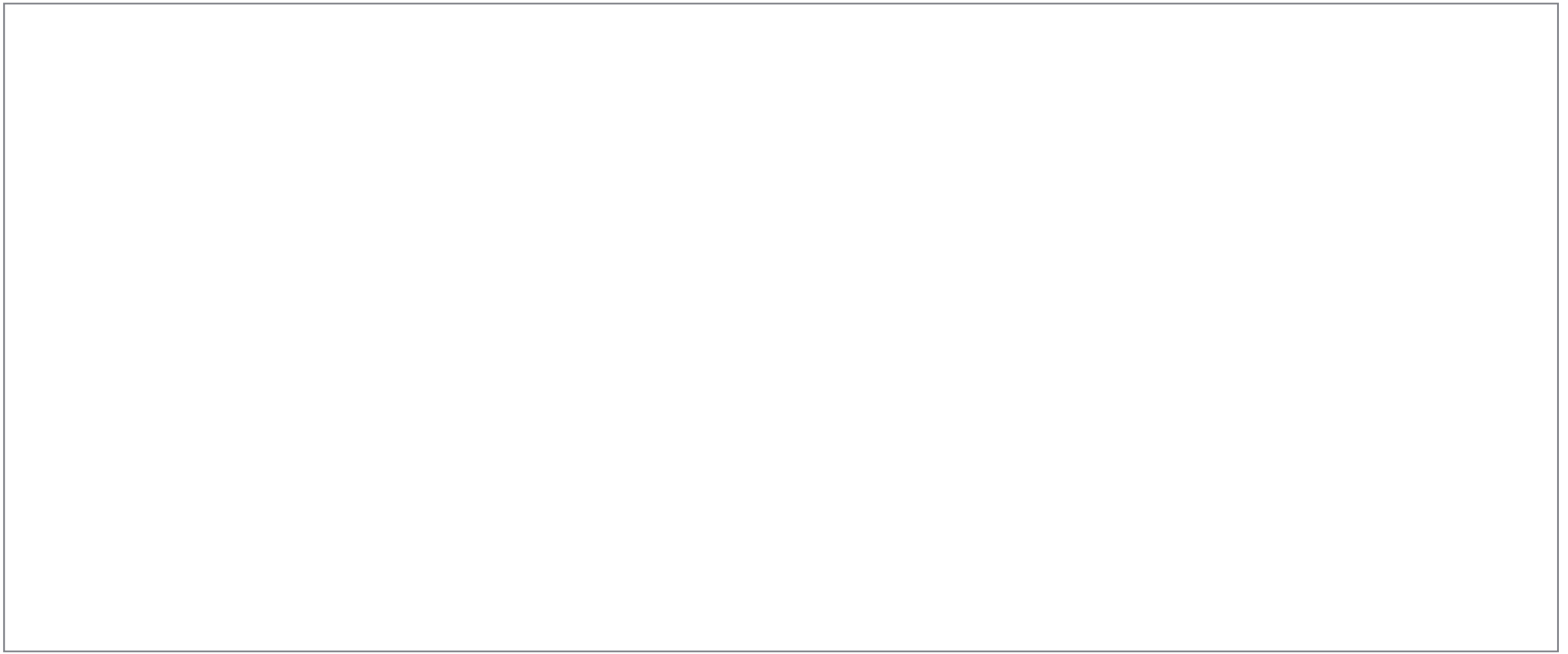
- u_{api} profile follows trend in energy consumption
- Accuracy of using u_{api} as proxy
  - energy consumption - *94.8%*
  - average power - *56.9%*

- Selected candidates show non-uniform energy behavior
  - GSON worse energy performance in serializing scenario
  - Implementations should favor a TPL candidate performs equally well in all scenarios



JOHANNES KEPLER UNIVERSITY LINZ

u_{api} profiles as proxy for the energy characteristics of Third Party Library (TPL) dependencies



[4] Mining API Interactions to Analyze Software Revisions for the Evolution of Energy Consumption, A. Schuler, G. Kotsis, MSR ‘21: Proceedings of the 18th International Conference on Mining Software Repositories, 2021

Take Home Messages and Future Work

- Developing software under sustainable design goals plays crucial role in shaping our future

  Knowledge on „How to develop energy-efficient software solutions“ is limited

- Tools and approaches required to support building awareness

- Facilitate access to software energy profiling for a broad audience
  (e.g. cs students, researchers and practitioners)
  - Provide tools and approaches seamlessly integrated in usual workflows
  - Increase the awareness how energy is dissipated in software

JOHANNES KEPLER
UNIVERSITY LINZ