**Sustainability Guidelines, Frameworks, Methods, Models, Metrics, Prototypes – TO BE ENHANCED BY ASPECTS of SECOMO paper!!!??**

## 1 Metrics / Measures / Measurement Tools

* Mainly -> focus on environmental sustainability -> measure ENERGY CONSIMPTION!!

Measurement tools for energy consumption (sources see greensoft paper)

* Amsel 2011 – Measurement TOOL GREENTRACKER
  + Measurement Tool of how much software causes
  + Measure CPU usage.. as it is key component!
  + Also deal with – making USERS aware!!
* Kansel et al (joulemeter) -> Tool to measure power consumption of virtual servers – “virtual machine power measuring” TODO
* Zapico & Turpeinen (31) 🡪 “Greenanalytics” 🡪 tool to visualize environmental impact of websites - TODO
* Naumann et. Al (33)  “Power Indicator”  visualize server power by renewable energy (?) of websites - “how green is the web” paper naumann\_how\_2008
* Noureddine (2012?) -> framework to MONITOR runtime energy consumption! -> PowerAPI
  + (already mentioned by schulze!)
  + Reports on energy consumption of a system / monitoring it!
  + Interesting aspect -> impact of programming languages

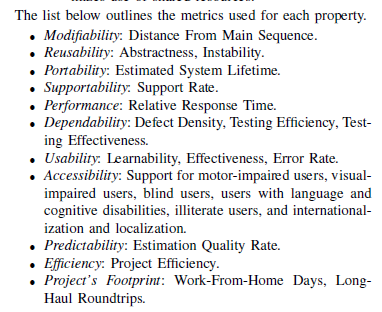
Other actual METRICS / associated calculation method

Capra et al (2012) -> general: how much energy consumed?

* + -> application for a specific case – **how to use in general??**
  + Measure for energy efficiency of sw applications –
  + Blabal (not much?) -> improve? But not soo relevant
  + -> good on code level, to “find resource intensive parts of programs and improve them” (Johann, et al., 2012, p. 1) 🡪 not covered by secomo :/
* Johann et al. (2012) -> “useful work done” -> more generic metric
  + (?) compare the consumed energy to how much actual “useful work” is done!
  + Also good to find resource intense code like capra
  + Methods not really applicable in practice?! 🡪 set-up “too complex for every-day use in software projects” (p. 4)
* More metrics -> see SLR by bozelli?!
* Kern, Dick et al (2015?) Metric + Calculation method for CARBON FOOTPRINT (Co2 kg per person)
  + Relatively new -> aims at providing finally a practical approach TO INTEGRATE in DEV processes
  + Tackles impact of development phase and later impact of software product itself (name categories!!) -> make product itself greener and even production process greener -> even though less important the more the sw is used
  + Method: calculate how much the CURRENT carbon footprint (of project / software product? Overall?) – based on a number of inputs
* (here SECOMO would fit?)
  + Similar in many ways: calculation method & metric, integrated in soft dev process, for AWARENESS and Transparency, EARLY in the process
  + In comparison: more specific: can be adapted to many different dimensions, not just this overall metric
  + Other inputs – more specific, and related to software itself, not these abstract? factors
  + Not limitied to one unit
  + ONLY usage phase – other one for whole lifecycle (mention before) – but as mentioned in their paper itself – (and also by penzenstadler in her categorization) -> usage phase becomes more important over time and has biggest influence!!

Measures of Sustainability in general – bigger scope

* Bell / Morse – Sustainability Indicators, Measuring the Immeasurable (sth about that in penzenstadler – what does SUST mean IN and FOR?) - TODO
* Albertao (?) – often reused!
  + “Albertao measures sustainability performance of a software project according to standard quality properties” (what does SUST mean IN and FOR … penzenstadler)
  + List of measures – actually are related to all 3 dimensions of



* + Method: asses metric AFTER SW is release, analyze & define “sustainability improvement goals for next dev cycle!
  + ++++ method to monitor it and continuously improve -> but: always only after the implementation phase -> **late :/ -> secomo can do it a) EARLIER and b) with mathematical models -> concrete BUT -> secomo only focus on environmental sustainability**

TODO – add everything from SECOMO paper?!

NOTHING on estimates yet!

## 2 Frameworks / Methods / Models

* Hility et al (2006) -. “System Dynamics model”
  + Assessment model of the impact of ICT on environmental sustainability
  + More general -> where could ICT have impact as enabler?!
* Generic reference model for sustainability goals (with 5 dimensions) ??  
  (Penzenstadler?)
  + TODO - read

Models with focus on Software (Development) Lifecycle (see lund paper)

* Argarwal et al -> 2012 -> mainly environmental sustainability
  + ENHANCE existing model with activities that promote sustainability
    - Example: collect requirements electronically than with paper
    - Include environment requirements -> NFR demand
    - Writing energy-efficient code
    - Sustainable software design..
    - System resource usage must be part of test -> which metrics?? -> SECOMO
* Shenoy / Eretta -> also focus on the software development lifecycle -> mainly environmental sustainability
  + Integrate aspects in the model to improve SUSTAINABILITY of the development software engineering process itself
  + Essentially also: add some best practices & recommendations to the single phases,
  + + mention need for quality aspects “practice sustainability measures” - >but which? Check in source again?
  + And overall aspect infrastructure – what to keep in mind, like use less paper, minimize travel, etc.
* Betz / Caporale model – other focus:
  + Idea: integrate sustainability aspects into software Lifecycle and business process modeling life cycle
  + (…) read more on that!!!
* **GREENSOFT** – reference model for green software engineering – INCLUDES sdlc / life cycle assessment approach
  + 4 levels
    - Lifecylce model – to ASSESS impacts (3-orders!) -> Dev, Distribute, Use, Deactivation
    - Sustainability Criteria and Metics (use those proposed by Albertao) -> indirect and direct cireria, align with lifeycle model
    - Procedure models -> in-depht models for different phases
      * Development model -> but more process model enhanced with agile aspects & including sustainability considerations (s. unten)  
        “only framework to help MANAGE sustainability”
      * What is missing For development: use further tools to “automatically calculate software metrics”🡪 SECOMO  
         e.g. for software performance.. important “EARLY processin .. 🡪 not really any other tool yet to “allow estimation of energy consumption in [] early stages” (p. 7) 🡪 HERE SECOMO tackles!!!
      * OTHER MODELS: Purchase, Administrate, Use, …
    - Recommendations for different stakeholders
      * For devs for example: (?) reference to external guidelines, calls for “generic knowledge base” for best practices
  + Comprises efforts by johann et al (2011) – Sustainable Development…
    - Lifecycle Model for a product – which effects does it have?
  + And other publications by that research group:
    - Green Software engineering with agile methods -> add sustainability review, retrospective and sustainability journal to scrum process / in sprint 🡪 reach awareness! But not: HOW to make the software sustainable or what actually to do!
* Later models?!  
  Mahmoud / Ahmad -> build on GREENSOFT – enhance with two-level model -> read again & check what can be combined here?!
  + Two-level model
    - Promotes a sustainable software engineering process
    - Model aspect 2: how to develop software the PROMOTES green IT?!

## 3 Requirement Engineering / Assessment Models & Metrics

Concrete Efforts in this area – to be enhanced, many papers left to read :S

[…]

* Reuse: reference model by penzenstadler / femmer 2013, as it supports requirement engineering phase by creating sustainability goals and deriving appropriate requirements?!
* + Sustainability NFR Framework by raturi, Tomlinson, penzenstadler 2014 ????
  + To be read!

Assessment Models & Metrics

* Could use: albertao metrics & respective assessment models
  + For general sustainability
* For energy consumption etc - > mentioned variety of approaches, the “new” one with the calculation method for example
* (more..?)

## 4 Special aspects

Sustainable PROGRAMMING – best practices and even languages

* ECO -> Zhu, et al (2015) -> “energy-aware programming”
* Whitepaper by ibm, mentioned in greensoft?!

## 5 Guidelines / Best practices

* Argawal 12 - best practices
  + Shows problems with existing “current practices” which are rather harmful in the context of sustainability -> e.g. less MAINTENANCE, less UPDATES; criticality of REUSE
  + Green software engineering activities suggestions
* aspects mentioned by Nauman?
* Best practices -> Penzenstadler 13, What does Sust mean IN and For..
  + For development PROCESS
    - How to develop sustainably -> resource-friendly code
    - Optimize resource usage -> for process / project mgmt. -> office infrastructure
    - etc
  + For Software System as PRODUCT
    - LifeCycle analysis -> MEASURE sustainability during different stages -> measures needed -> SECOMO ☺
    - USE software to improve business processes / business models
* Best Practices in GreenSoft model

**Relevant Papers**