# Energy consumption optimization of embedded systems software

In scientific literature, efforts have been made to estimate and measure energy consumption of software. In this questionnaire, we wish to learn if these estimations and measurements would be useful when optimizing the energy consumption of embedded systems software.

In the first part of this questionnaire, we present different options for these estimations/measurements and ask you to evaluate these. We regularly ask you to elaborate on your answers to get more insight into your reasoning. In the second part we have a few more questions and give you the opportunity to share any relevant options or ideas that were left undiscussed. We close the questionnaire with a third and last part, consisting of a few questions regarding your professional experience.

Please enter the identifier provided to you by the researcher

_____

To optimize software energy consumption, one can rely on proxies (e.g. execution time). Other methods have instead tried to estimate or measure software energy consumption directly. Please indicate your agreement with the following statement:

Energy estimations or measurements are useful for optimizing energy consumption of embedded systems software.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

_____

Please explain your reasoning for your answer to the previous question in 1 to 5 sentences

_____

_____

_____

_____

_____

**End of Block: Proxies**

**Start of Block: Power**

Energy = Power * Time, therefore previous approaches have tried to estimate or measure either energy consumption or power draw.

_____

Are measures of energy consumption or power draw more useful in optimizing energy consumption of embedded systems software?

○ Power draw is much more useful

○ Power draw is slightly more useful

○ Energy consumption is slightly more useful

○ Energy consumption is much more useful

---

Please explain your reasoning for your answer to the previous question in 1 to 5 sentences

_____

_____

_____

_____

_____

**End of Block: Power**

**Start of Block: Executions**

**From now on we will refer to measurements or estimations of either energy consumption or power draw as "energy measures".** Energy measures can be collected for a single execution, several executions or all possible executions of software.

---

When would energy measures be most useful in optimizing energy consumption of embedded systems software? If energy measures are collected for

○ A single execution

○ Several executions

○ All possible executions

Please explain your reasoning for your answer to the previous question in 1 to 5 sentences

_____

_____

_____

_____

_____

Energy measures can be collected for the central processing unit of the system (e.g. the CPU) or for external hardware components controlled by this central processing unit.

In order to optimize the energy consumption of embedded systems software, would it be more useful if energy measures are collected for the central processing unit, or for the external hardware components controlled by this central processing unit?

○ Central processing unit is much more useful

○ Central processing unit is slightly more useful

○ External hardware components is slightly more useful

○ External hardware components is much more useful

Please explain your reasoning for your answer to the previous question in 1 to 5 sentences

_____

_____

_____

_____

_____

Energy measures can be related to different program abstractions.

------------------------------------------------------------------------

Please rank the following program abstractions in descending order of their usefulness for optimizing the energy consumption of embedded systems software. You can drag and drop the abstractions to change the order (Top = 1 = most useful, Bottom = 6 = least useful)

_____ Code statements
_____ Code branches
_____ Functions
_____ Source code files
_____ The complete project
_____ Libraries

------------------------------------------------------------------------

Please explain your reasoning for your answer to the previous question in 1 to 5 sentences

_____

_____

_____

_____

_____

In the previous question, we assumed that energy measures are related to a single program abstraction. However, energy measures can also be related to multiple different program abstractions. Please indicate your agreement with the statements and select two or more answers in the multiple choice question.

---

In order to optimize the energy consumption of embedded systems software, it would be useful if energy measures are related to multiple different program abstractions.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

\*

If the energy measures are related to multiple different program abstractions, these should be:

☐ Code statements

☐ Code branches

☐ Functions

☐ Source code files

☐ The complete project

☐ Libraries

---

If the energy measures are related to multiple different program abstractions, it would be useful if they are shown **simultaneously using their hierarchical relation**.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

Please explain your reasoning for your answers to the previous questions in 1 to 5 sentences

_____

_____

_____

_____

_____

Energy measures related to program abstractions can be shown close to or in conjunction with the source code in a code editor. Please indicate your agreement with the following statement:

---

In order to optimize the energy consumption of embedded systems software, it would be useful if the energy measures are shown close to or in conjunction with the source code in a code editor.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

Please explain your reasoning for your answer to the previous question in 1 to 5 sentences

_____

_____

_____

_____

_____

**End of Block: Proximity**

**Start of Block: HardwareCombinations**

The same embedded systems software might be executed on different **hardware combinations**. Energy measures could be collected for different hardware combinations.

---

Does the software that you write for embedded systems need to function on one specific hardware combination or multiple different hardware combinations?

○ Always one specific hardware combination

○ Often one specific hardware combination

○ Often different hardware combinations

○ Always different hardware combinations

---

In order to optimize the energy consumption of embedded systems software, it would be useful to see **energy measures for different hardware combinations**.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

Please explain your reasoning for your answer(s) to the previous question(s) in 1 to 5 sentences

_____

_____

_____

_____

_____

**End of Block: HardwareCombinations**

**Start of Block: UsageScenarios**

The same embedded systems software might be executed under different **scenarios of use**. Energy measures could be collected for different usage scenarios.

---

Should the software that you write for embedded systems work under one usage scenario or multiple different usage scenarios?

○ Always one usage scenario

○ Often one usage scenario

○ Often different usage scenarios

○ Always different usage scenarios

---

In order to optimize the energy consumption of embedded systems software, it would be useful to see **energy measures for different usage scenarios**.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

Please explain your reasoning for your answer(s) to the previous question(s) in 1 to 5 sentences

_____

_____

_____

_____

_____

**End of Block: UsageScenarios**

In this second part, we ask you about any options that we have missed. Furthermore, we are curious to hear about any challenges that you face when optimizing the energy consumption of embedded systems software which energy measures can help to overcome. Additionally, we ask you to reflect on which goals would be useful steps towards optimizing the energy consumption of embedded systems. Lastly, we are curious about any final ideas or thoughts that you might have had during the questionnaire which you would like to share.

In the first part of this questionnaire we have asked you to evaluate different options for energy measures. The list of options that we have presented might not be exhaustive.

Are there options for energy measures that have not been mentioned, but that you think would be very **useful**?

_____

_____

_____

_____

_____

Are there options for energy measures that have not been mentioned, but that you think would be very **counterproductive**?

_____

_____

_____

_____

_____

Energy measures have been proposed to help to understand the energy related behavior of embedded systems software or find energy consumption hotspots in it. Please indicate your agreement with the following two statements:

---

**Understanding the energy related behavior of** embedded systems software is a useful step in the process of optimizing its energy consumption.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

**Finding energy consumption hotspots in** embedded systems software is a useful step in the process of optimizing its energy consumption.

○ Strongly disagree

○ Somewhat disagree

○ Somewhat agree

○ Strongly agree

---

\*

Are there other subgoals which are useful steps in the process of optimizing the energy consumption of embedded systems software?

◯ No

◯ Yes, namely _____

---

Please explain your reasoning for your answers to the previous questions in 1 to 5 sentences

_____

_____

_____

_____

_____

**End of Block: Goals**

**Start of Block: Challenges**

Are there any challenges which you currently face when optimizing embedded systems software for performance, or energy consumption in particular, which energy measures (can) help to overcome?

_____

_____

_____

_____

_____

Do you have any other final ideas or thoughts that you wish to share?

_____

_____

_____

_____

_____

**End of Block: Challenges**

**Start of Block: Part3**

In this third and final part we have a few questions about your prior experience in developing and optimizing embedded systems software.

**End of Block: Part3**

**Start of Block: Experience**

For how many years have you developed software for embedded systems?

_____

How regularly do you optimize the **performance** of embedded systems software?

○ Never

○ Rarely

○ Sometimes

○ Often

How regularly do you optimize the **energy consumption** of embedded systems software?

○ Never

○ Rarely

○ Sometimes

○ Often

---

For **which sector** have you optimized embedded systems software?

_____

---

For **what kind of applications** have you optimized embedded systems software?

_____

---

What is your current job title and role?

_____

**End of Block: Experience**