ENERGY PROFILERS

AN EVALUATING STUDY

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PROBLEM

- Basic measurements of energy consumption can be done on hardware-level
- (Software product) organizations require more in-depth measurements
  - Determine what part is due to the (software)application?
- Not everyone has a 'SEFLab-like' environment

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* Kabbedijk, Pors, Jansen and Brinkkemper (2014)

ENERGY PROFILERS

"Software tools that estimate the power consumption induced by software, based on the hardware resources the software is using."

- Each energy profiler has its own unique energy model
- A possible, 'low-budget' *solution* to the problem, provided that energy profilers are accurate

RESEARCH QUESTION

Can energy profilers be used to accurately estimate the energy consumption of software?

Sub-questions:
1. Are we able to get the profilers fully operational?
2. Are the reported energy consumption estimations accurate compared to the SEFLab?

EXPERIMENT

- Evaluate energy profilers in the light of the research (sub-) question(s)
  - The SEFLab provides ‘the truth’ in measurements
  - Determine whether the reported figures from the energy profilers differ significantly
  - Determine whether the timeliness of the measurements is accurate
- Test 3 scenario’s:
  - **Idle**; system is idle
  - **Varying load**; random loads are generated
  - **Full load**; the system is pushed to its maximum stress level
- 1 SEFLab test-server (Dell PowerEdge SC1425)
- Multiple platforms:
  - Windows 7
  - Ubuntu 12.04

PROFILER INCLUSION CRITERIA

- an 'alpha' version of the profiler is available online
- the profiler must be able to log the energy consumption with one second intervals between measurement
- the profiler must not require specific, specialized hardware to operate
- the profiler must has to function on Ubuntu Linux, Microsoft Windows or both
- the profiler must be able to operate in combination with the hardware available in the SEFLab

Profiler	Measurement level	Measurement detail	Calibration required	Additional hardware required	Measurement interval =<1 second	Log	OS	SEFLab compatible	Decision
Energyaware profiler	System	CPU, memory, hard disk, base	Unknown	Toolkit	Yes	Yes	Windows	No	Exclude
Computer Power Log	System	Total system	Unknown	No	No	Yes	Windows	Yes	Exclude
Powometer	Total system	System	Unknown	Unknown	No	Yes	Windows	Yes	Exclude
Active Energy Manager	IT environment	Hardware dependent	Unknown	No	Yes	Yes	Windows, Linux	Yes	Exclude
Hardware Sensors Monitor	System	CPU, memory, hard disk, mainboard (voltages only)	Unknown	No	Yes	Yes	Windows	No	Exclude
Sensorsview	System	CPU, GPU, memory, hard disk, mainboard (voltages only)	Unknown	No	Yes	Yes	Windows	Yes	Exclude
eprof	System, application, line of code	CPU, memory, hard disk, mainboard	Yes	No	Unknown	Unknown	Unknown	Unknown	Exclude
PowerAPI	System, process	CPU, hard disk, memory	No	No	Yes	Unknown	Windows, Linux	No	Exclude
Joulemeter	Application, system	CPU, monitor, memory, hard disk, base	Optional	Optional: WUP	Yes	Yes	Windows	Yes	Include
pTop	Application, System	CPU, network, display, hard disk	Yes	No	Yes	Yes	Linux	Yes	Include
pTopW	Application, system	CPU, network, display, hard disk	Yes	No	Yes	Yes	Windows	Yes	Include
powerTOP	Device, process	Power estimation per item	Yes	No	Yes	Yes	Linux	Yes	Include
Energy Consumption Tools	Application	system	Yes	Yes	Yes	Yes	Linux	Yes	Include
ESSaver	Application, system, IT environment	CPU, memory, hard disk, network, total power	Yes	No	Yes	Yes	Windows	Yes	Include

FIRST RESULTS

- Joulemeter; installation easy, optional calibration
- pTop; tooling did not store and report measurements
- pTopW; difficult configuration, unrealistic figures
- PowerTop; works on laptops, external device required for desktop
- Energy Consumption Tools; requires external device for calibration
- ESSaver; difficult configuration and retrieval of measurements

SEFLAB EXPERIMENTS

- Only 2 profilers could actually be tested on accuracy:
  - Joulemeter (Windows)
  - Energy Consumption Tools (ectools) (Linux)
    - After altering the source code to work with WattsUp Pro
- Per profiler:
  - 3 aforementioned scenario's
  - 35 runs of 1 minute per scenario
  - 1 measurement per second from both SEFLab and profiler
- Only total power is considered for the experiment
  - Difficult to keep control of individual components

DATASET EXAMPLE

Measurement # (around 2300 per file)

Measurement timestamp

SEFLab total

Profiler total

Differen

	A	B	C	D	E	I	J	K	O	P	Q
1		TIME	wattsup.tc	joulemete	diff.total	seflab.cpu	joulemete	diff.cpu	seflab.hdc	joulemete	diff.hdd
2	1	04-06-13 14:13:59	200	190.3	-9.7	59.3397	7.1	-52.2397	10.557	2.8	-7.75697
3	2	04-06-13 14:14:00	187.8	193.6	5.8	54.2304	11.7	-42.5304	9.4261	1.5	-7.9261
4	3	04-06-13 14:14:01	187.7	187.1	-0.6	47.084	6.6	-40.484	8.74931	0.1	-8.64931
5	4	04-06-13 14:14:02	187.5	182	-5.5	52.5691	1.7	-50.8691	8.71992	0	-8.71992
6	5	04-06-13 14:14:03	187.5	187.5	0	46.9668	7.1	-39.8668	8.70951	0	-8.70951
7	6	04-06-13 14:14:04	187.4	182	-5.4	52.3414	1.7	-50.6414	8.74711	0	-8.74711
8	7	04-06-13 14:14:05	181.7	186.4	4.7	46.4412	6	-40.4412	8.63965	0	-8.63965
9	8	04-06-13 14:14:06	189.1	182	-7.1	51.8888	1.7	-50.1888	8.76832	0	-8.76832
10	9	04-06-13 14:14:07	183.8	186.9	3.1	48.6509	6.5	-42.1509	8.69955	0	-8.69955
11	10	04-06-13 14:14:08	190.2	182.6	-7.6	49.377	2.2	-47.177	8.6637	0	-8.6637
12	11	04-06-13 14:14:09	183.8	187	3.2	49.7245	6.6	-43.1245	8.65891	0	-8.65891
13	12	04-06-13 14:14:10	190	182	-8	49.5589	1.7	-47.8589	8.92535	0	-8.92535
14	13	04-06-13 14:14:11	183.4	186.4	3	49.3439	6	-43.3439	8.63484	0	-8.63484
15	14	04-06-13 14:14:12	190.8	182	-8.8	50.1639	1.7	-48.4639	8.64406	0	-8.64406
16	15	04-06-13 14:14:13	182.8	185.9	3.1	49.9301	5.6	-44.3301	8.53899	0	-8.53899
17	16	04-06-13 14:14:14	189.8	182	-7.8	49.6323	1.7	-47.9323	8.62954	0	-8.62954
18	17	04-06-13 14:14:16	194.2	186.9	-7.3	51.9248	6.5	-45.4248	8.86675	0	-8.86675
19	18	04-06-13 14:14:17	186.2	187.1	0.9	52.3697	6.7	-45.6697	8.64641	0	-8.64641

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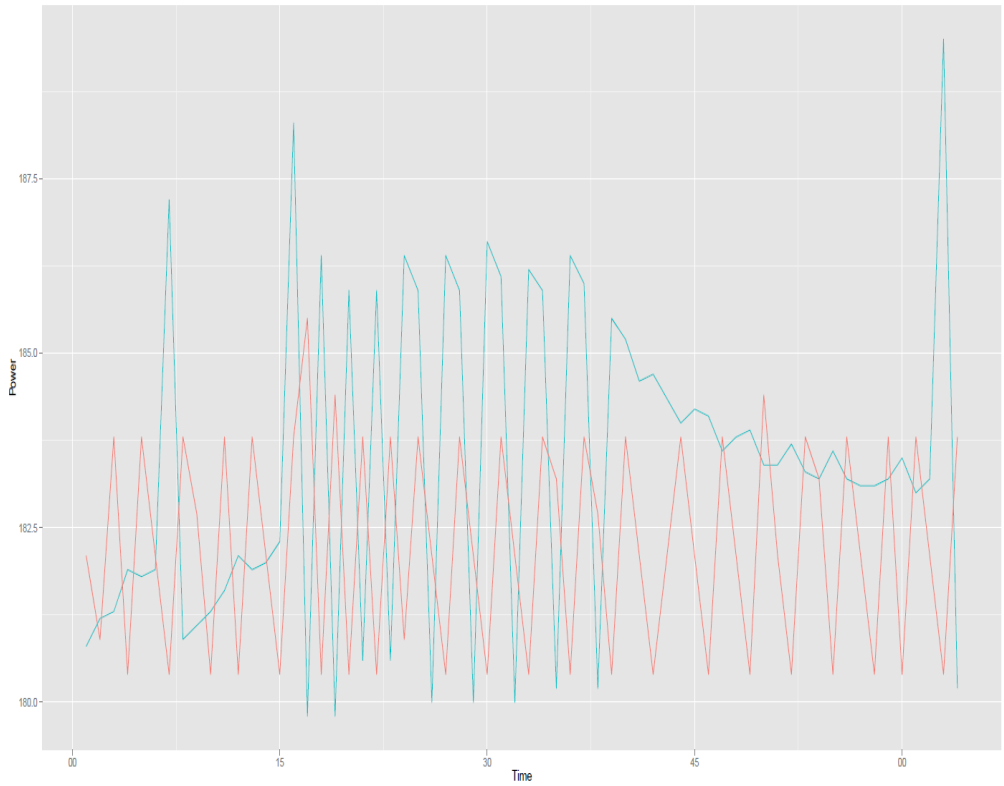
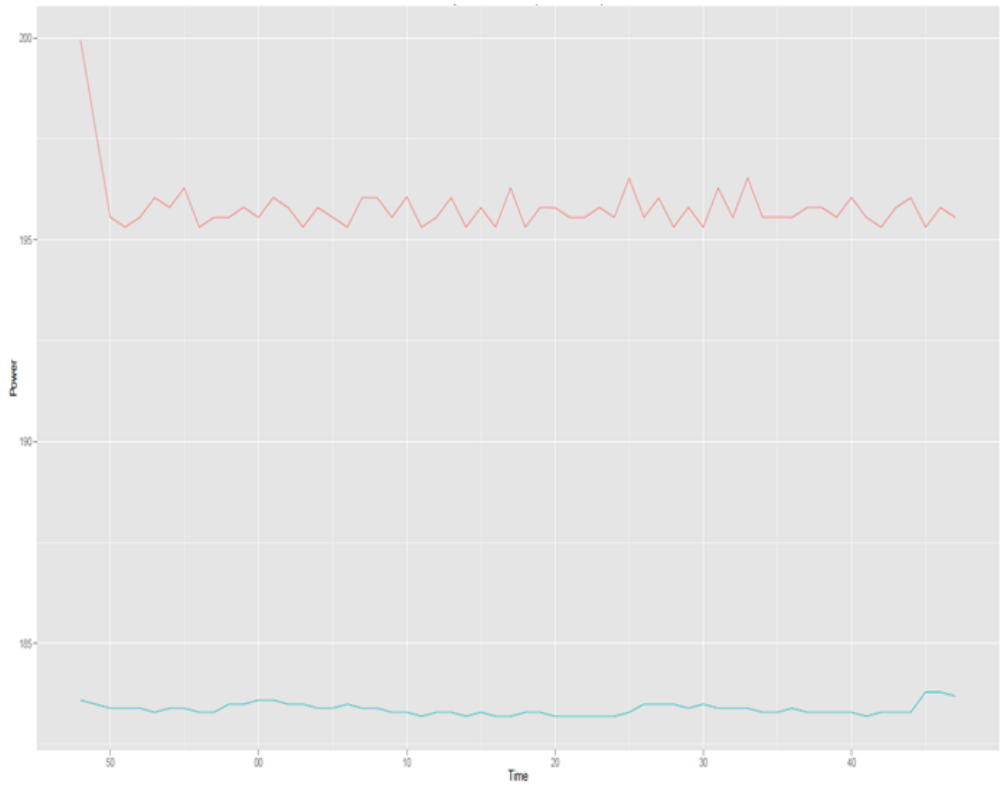
GRAPHS EXAMPLE - IDLE



Joulemeter



ectools

* Mind the scaling of the graphs

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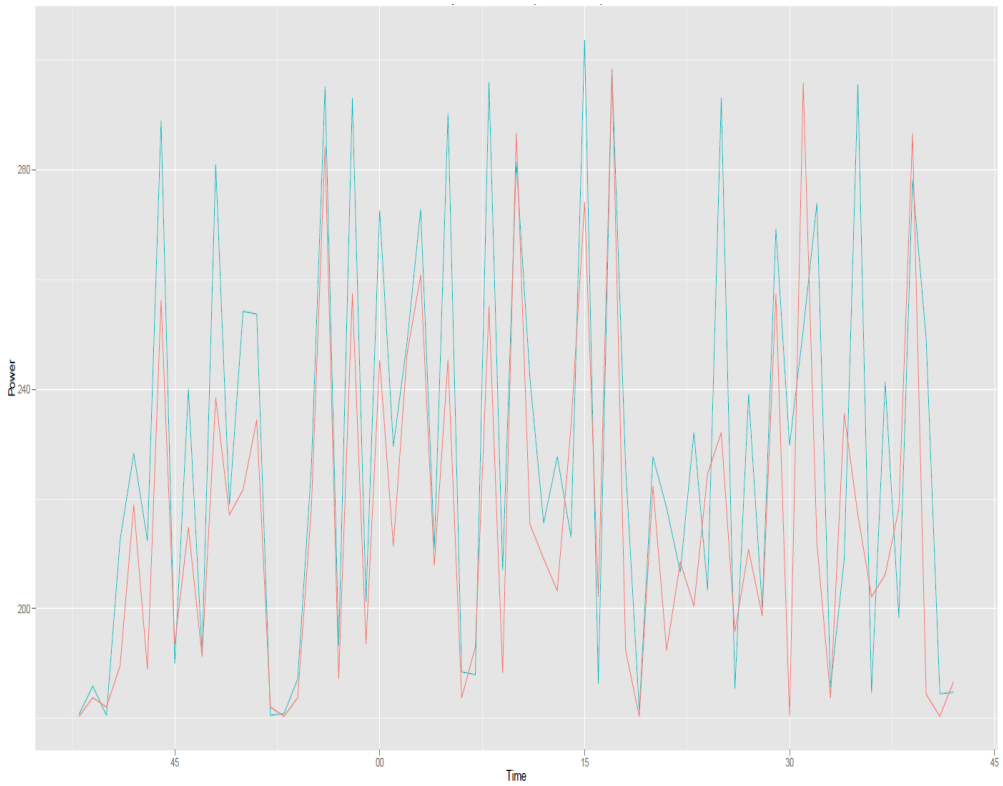
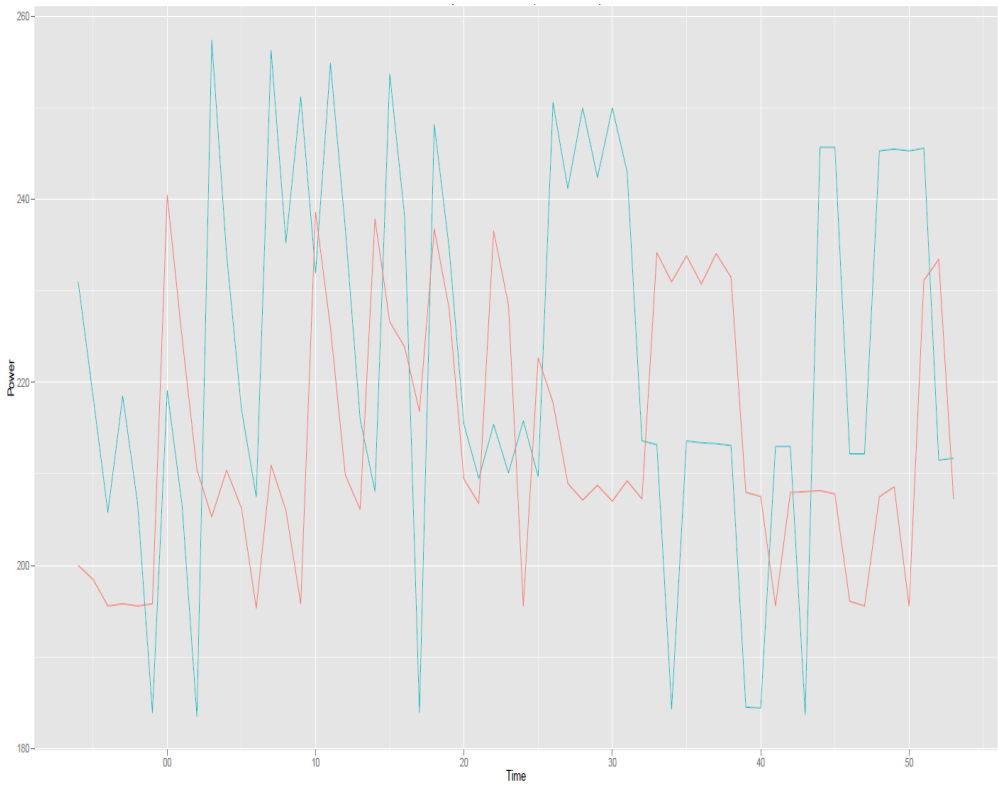
GRAPHS EXAMPLE – VARYING LOAD

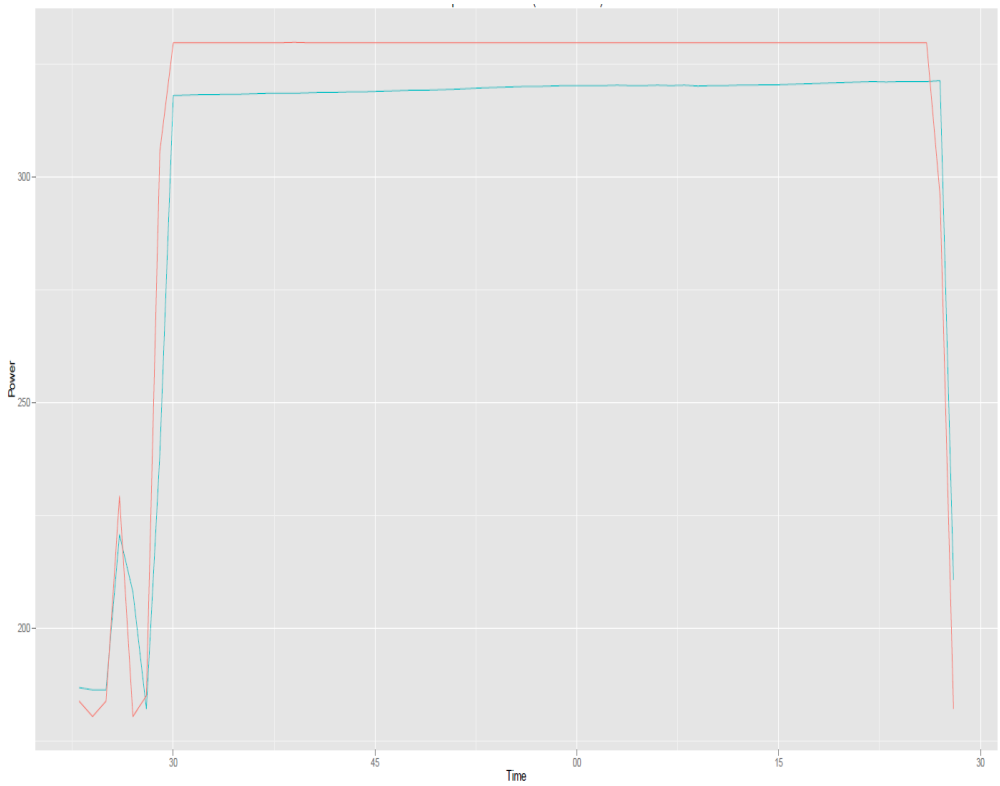


Joulemeter

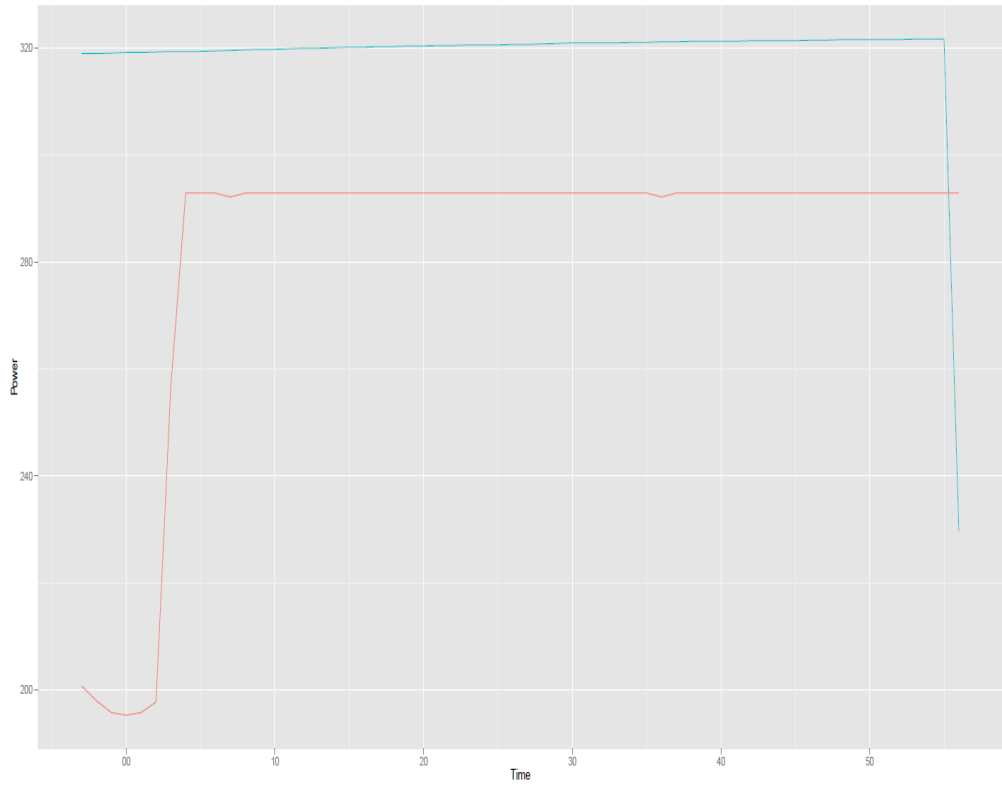


ectools

GRAPHS EXAMPLE – FULL LOAD



Joulemeter



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RESULTS (1/3)

- ‘Energy profilers’ is a general term also used for tools with different energy-related purposes
- Not all software energy profilers can be used to measure the energy consumption of software
  - Clear difference in detail of measurements
  - Clear difference in maturity
- Specialized hardware is still required by some energy profilers
- Installation is easy, configuration often is not

RESULTS (2/3)

- Profiler measurements not always stable
  - Multiple runs containing invalid measurements
  - Multiple runs longer than 1 minute

- In terms of accuracy we considered:
  - Reported averages (power in W)
  - Energy consumption (in kWh)

	Averages		
	Idle	Varying load	Full load
Joulemeter	SEFLab Mdn = 184.16 Joulemeter Mdn = 182.84 U = 314, z = -3.506, s	SEFLab M = 227.31, SE = .567 Joulemeter M = 216.12, SE = .566 t(68) = 13.957,p < .05	SEFLab Mdn = 304.91 Joulemeter Mdn = 313.39 U = 95, z = -6.079, s
ectools	SEFLab Mdn = 183.37 ectools Mdn = 195.82 U = .00, z = -6.765, s	SEFLab Mdn = 225.7 ectools Mdn = 215.194 U = 10, z =-6.855, s	SEFLab Mdn = 318.27 ectools Mdn = 282.18 U = .00, z =-7.09, s

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RESULTS (3/3)

- Energy consumption calculated using “E(kWh) = (P(W) × t(hr)) / 1000”

	Energy consumption		
	Idle	Varying load	Full load
Joulemeter	SEFLab Mdn = .181 Joulemeter Mdn = .180 U = 315, z = -3.494, s	SEFLab Mdn = .260 Joulemeter Mdn = .247 U = 305, z =-3.612, s	SEFLab Mdn = .345 Joulemeter Mdn = .355 U = 470, z =-1.674, ns
ectools	SEFLab Mdn = .180 ectools Mdn = .193 U = .00, z = -6.765, s	SEFLab (M = .223, SE = .001 ectools (M = .212, SE = .0004 t(52) = 12.939,p < .05	SEFLab M = .313, SE = .0002 ectools M = .278, SE = .00007 t(43.9) = 176.322,p < .05

- Timeliness:
  - Joulemeter accurate
  - Ectools less accurate, but still workable
  - In general profilers not as responsive as the SEFLab

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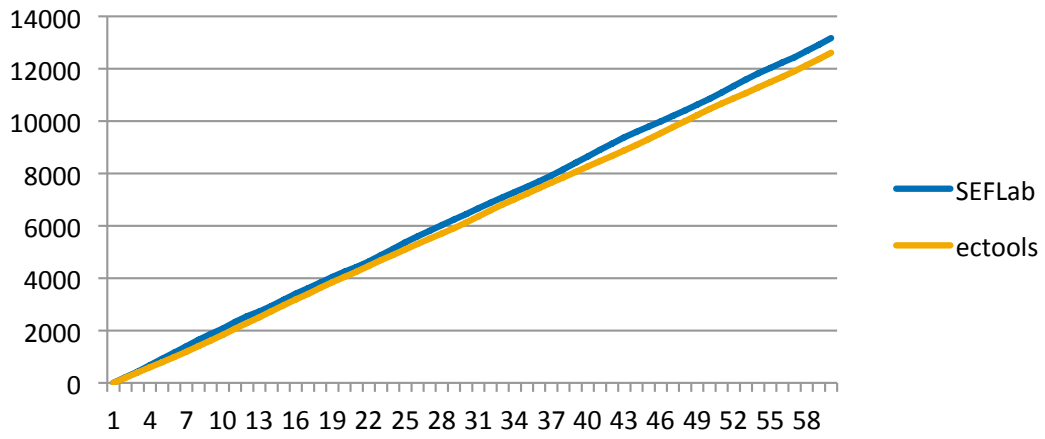
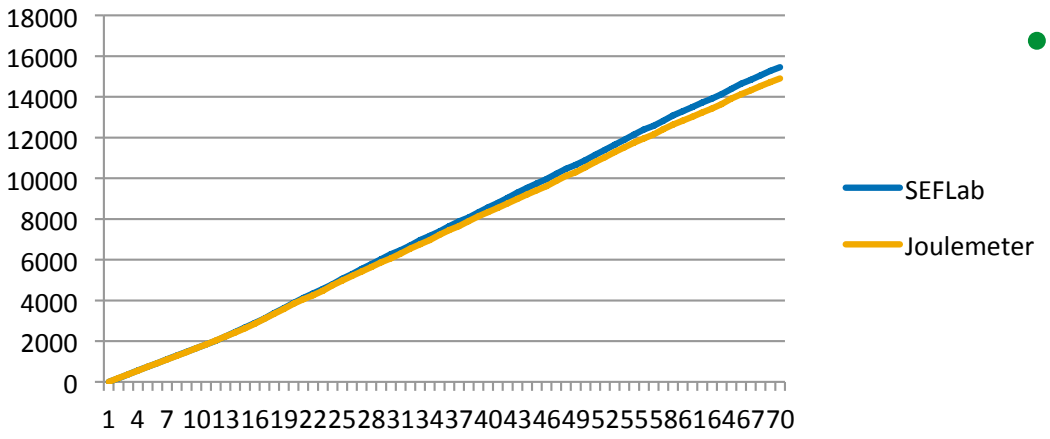
INTERPRETATION OF RESULTS

- Ectools:
  - average difference in energy consumption:
    - Idle: 11 Wh
    - Varying load: 10 Wh
    - Full load: 34 Wh
  - Diverging lines over time
  - Average responsiveness





- Joulemeter:
  - average difference in energy consumption:
    - Idle: 1 Wh
    - Varying load: 12 Wh
    - Full load: 1 Wh
  - Diverging lines over time
  - Good responsiveness

CONCLUSION

- Profilers cannot be used to measure the energy consumption of software yet
  - Currently good enough to provide basic insight into energy consumption behavior
- Getting energy profilers operational is often a bottleneck to actually use the tools
- More research is required to obtain accurate measurements on the level of individual hardware components
- Of the tested profilers Joulemeter is the ‘best bet’
  - Additional measured required to ascertain accuracy over time

QUESTIONS?

THANK YOU FOR YOUR ATTENTION!

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