

Enspect: a tool to aid the design of energy harvesting systems

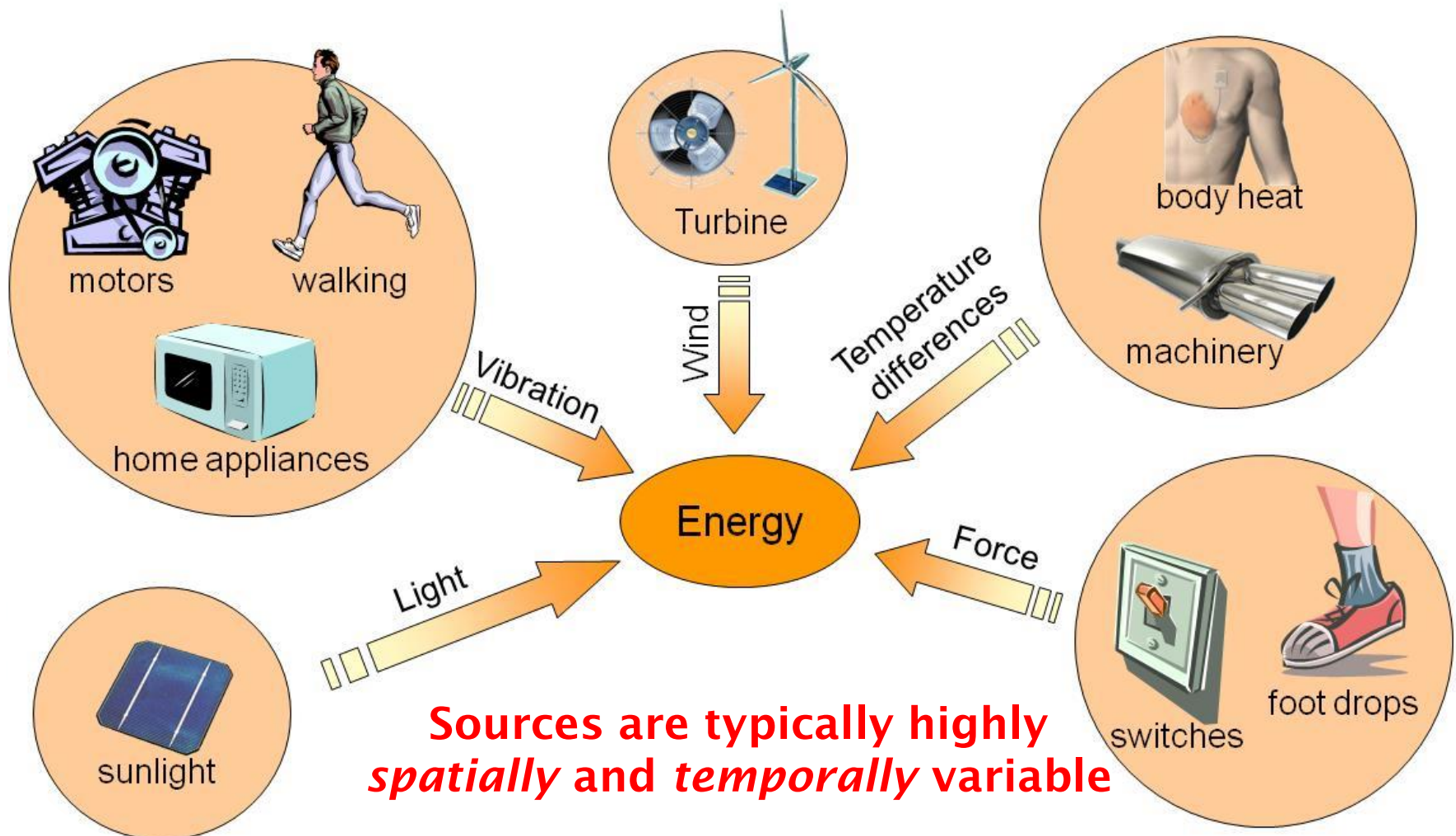
Alex Weddell

11 May 2016, Energy Harvesting 2016, London

Overview

- **Background and Motivation**
 - *Issues with creating EH systems*
- **Enspect**
 - *Enspect Hardware Platform*
 - *Enspect Software Tool*
 - *Illustrative Results*

Energy Harvesting

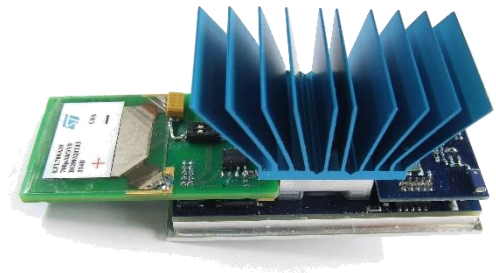
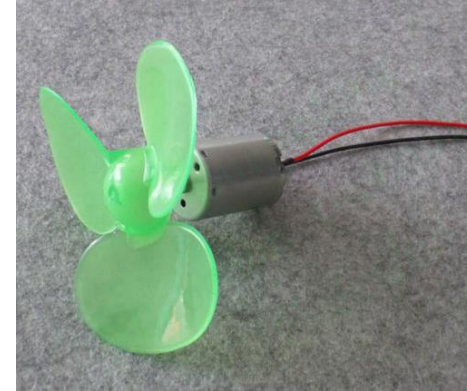
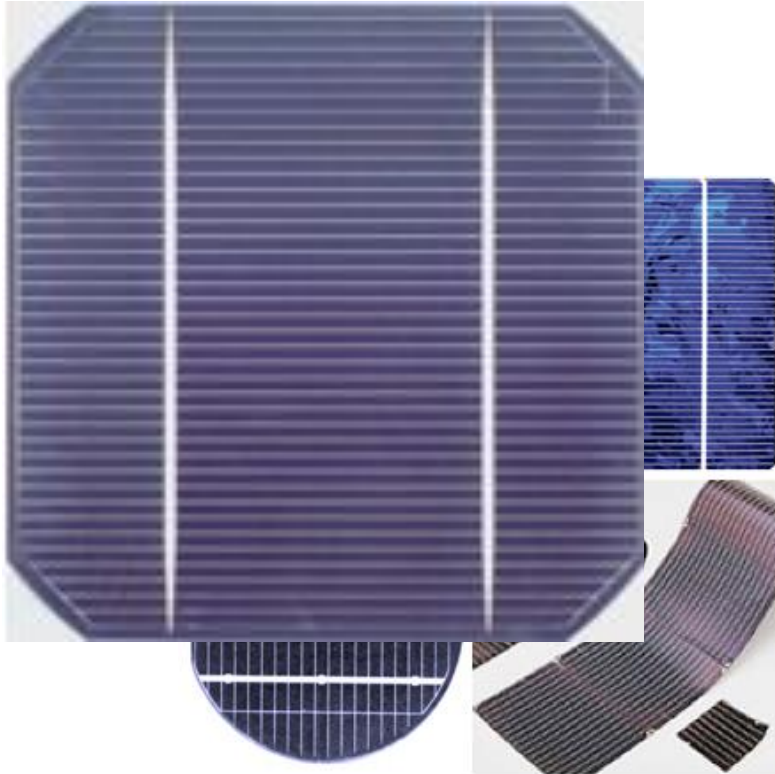




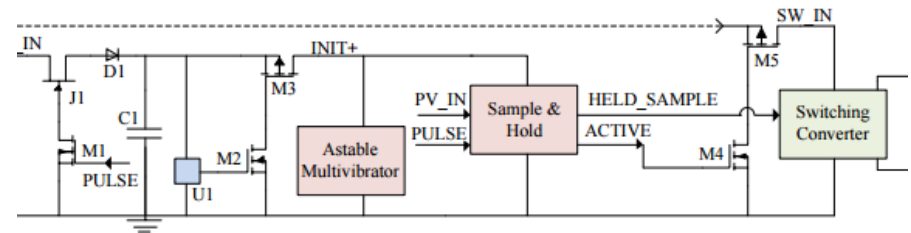
Accommodating Variance

- Accommodating *temporal* variance at run-time
 - Add a larger energy buffer (e.g. supercapacitor)
 - Dynamically adjust duty-cycle, sampling rate etc.
- Accommodating *spatial* variance at run-time
 - Load balancing through energy-aware routing, resource reallocation etc.
- But a lot has to be decided at **design-time...**

Design Decisions



Design Decisions



http://brain-images.cdn.dixons.com/3/9/19314393/L_19314393_002.jpg

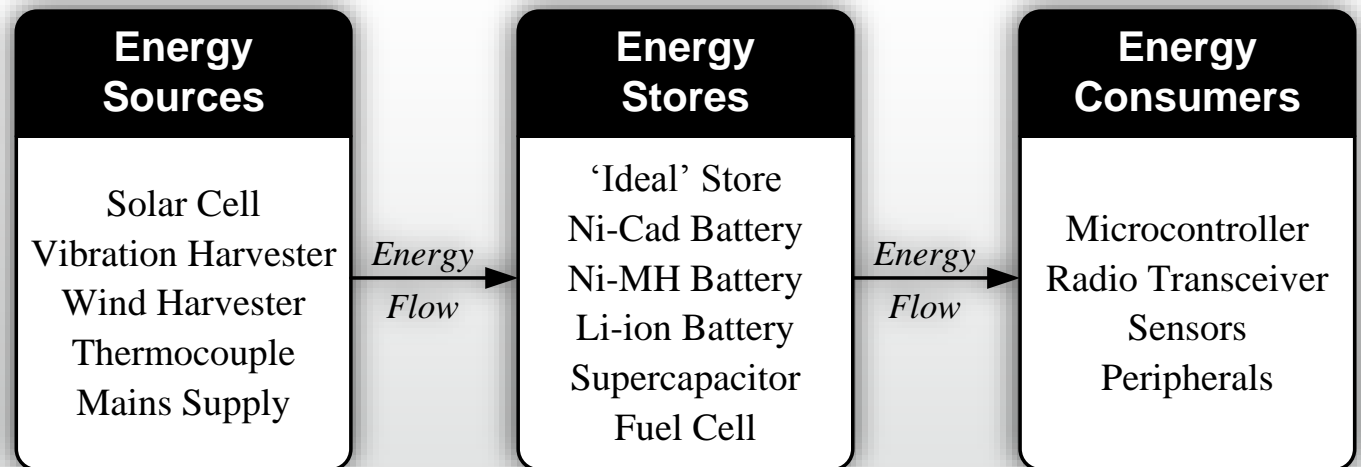
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<http://svc082.wic031v.server-web.com/images/ElectrolyticCan.jpg>

Weddell, A. S., Merrett, G. V., & Al-Hashimi, B. M. (2012). Photovoltaic sample-and-hold circuit enabling MPPT indoors for low-power systems. *Circuits and Systems I: Regular Papers, IEEE Transactions on*, 59(6), 1196-1204.

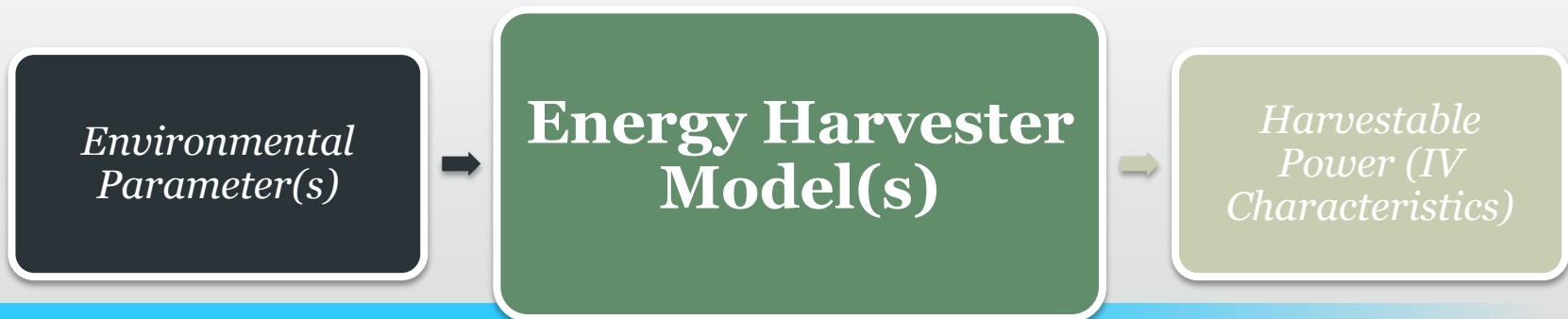
Design Techniques

- Expert knowledge
- Trial and error
- Simulation tools



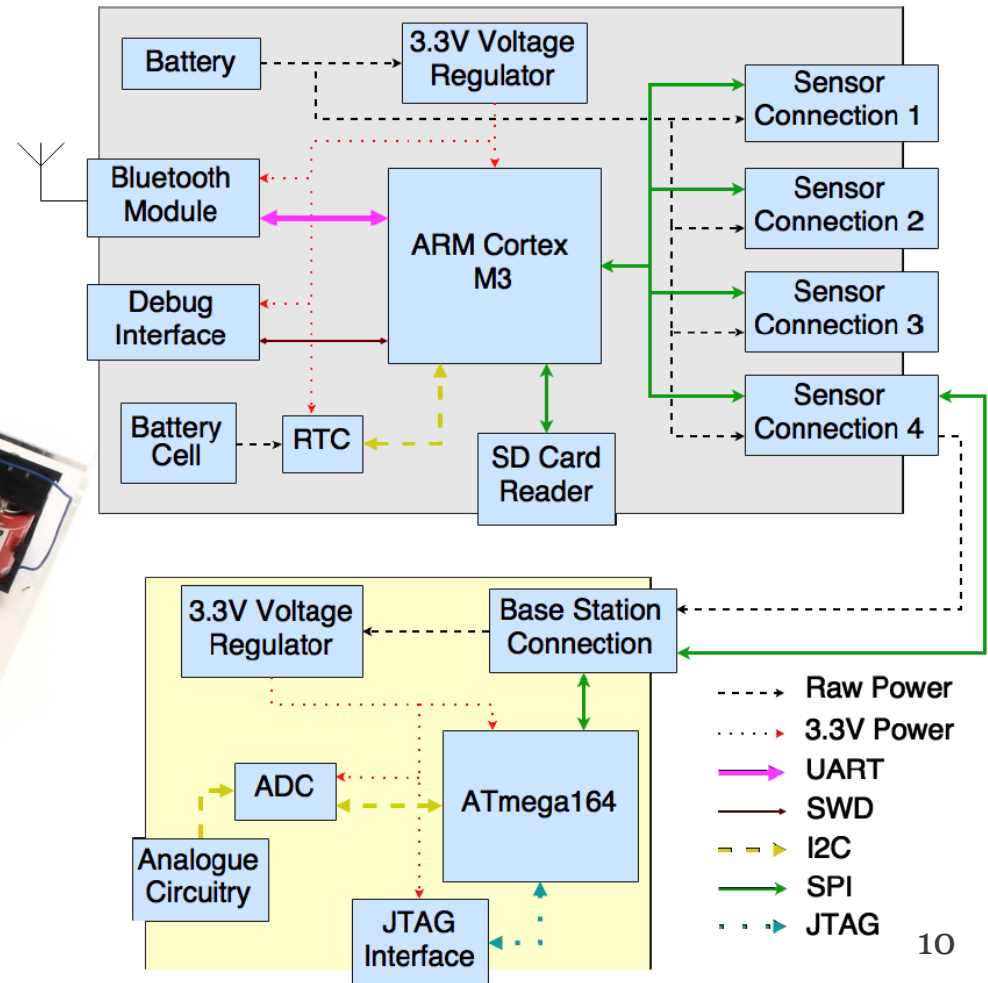
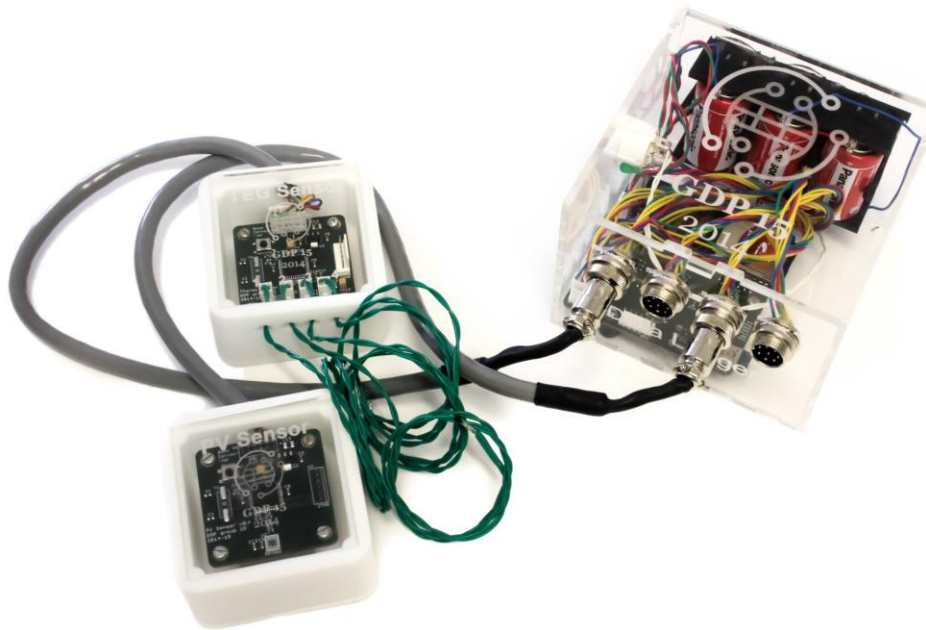
Our Solution: Enspect

1. Portable tool enabling the **collection** of real environmental data for periods of >1 day
2. Analysis software **models** the performance of different energy harvesters under varying environmental conditions
3. Analysis software uses collected data and models to predict EH performance, and make **design recommendations**
4. Software *and* hardware are **open-source** and available for download (www.enspect.ecs.soton.ac.uk)



Enspect Hardware Platform

- Modular
 - up to 4 different sensors
- or*
- 4 identical sensors

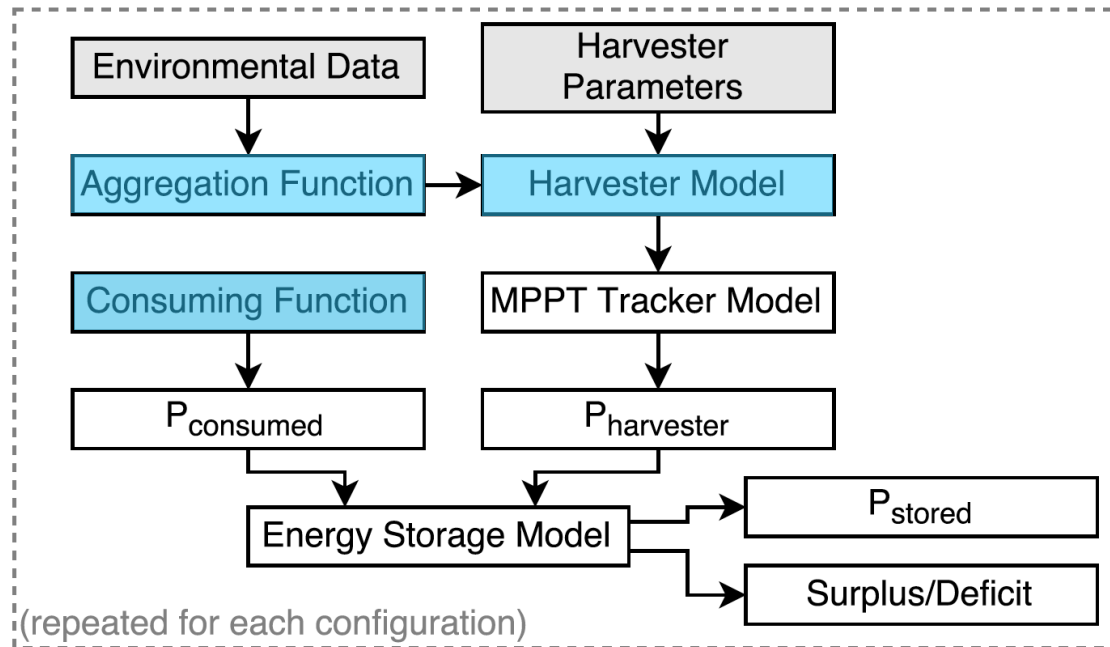


Enspect Hardware Tool

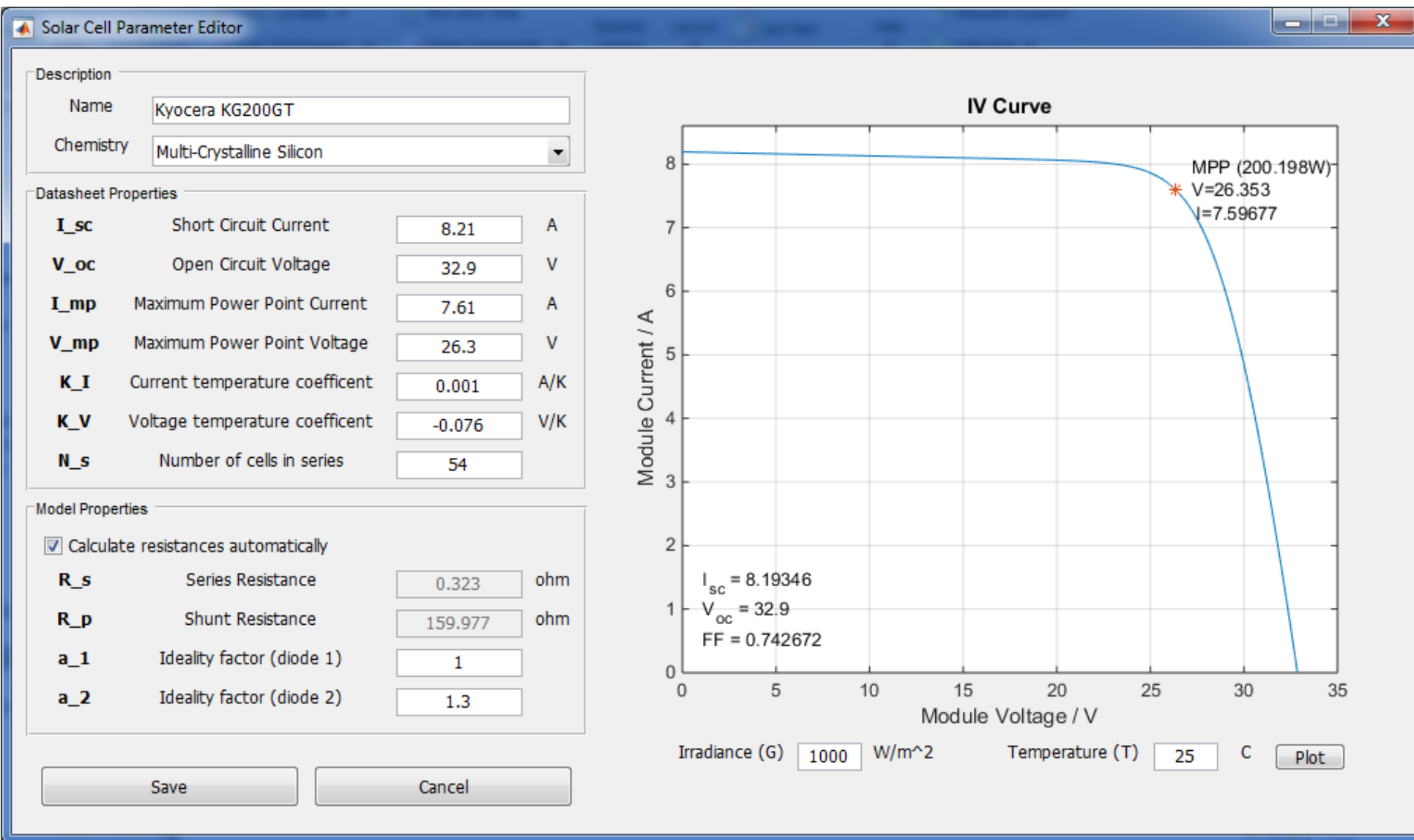
- PV Sensor Module, measures:
 - Ambient temperature
 - Ambient light level
 - RGB/IR levels
- TEG Sensor Module, measures:
 - Hot and cold side temperatures
(*thermistors*)



Enspect Analysis Software



- Consuming function:
 - can be a constant or a function (e.g. square wave)
- Aggregation function:
 - can compare between days/locations, or aggregate to get an ‘average’ day



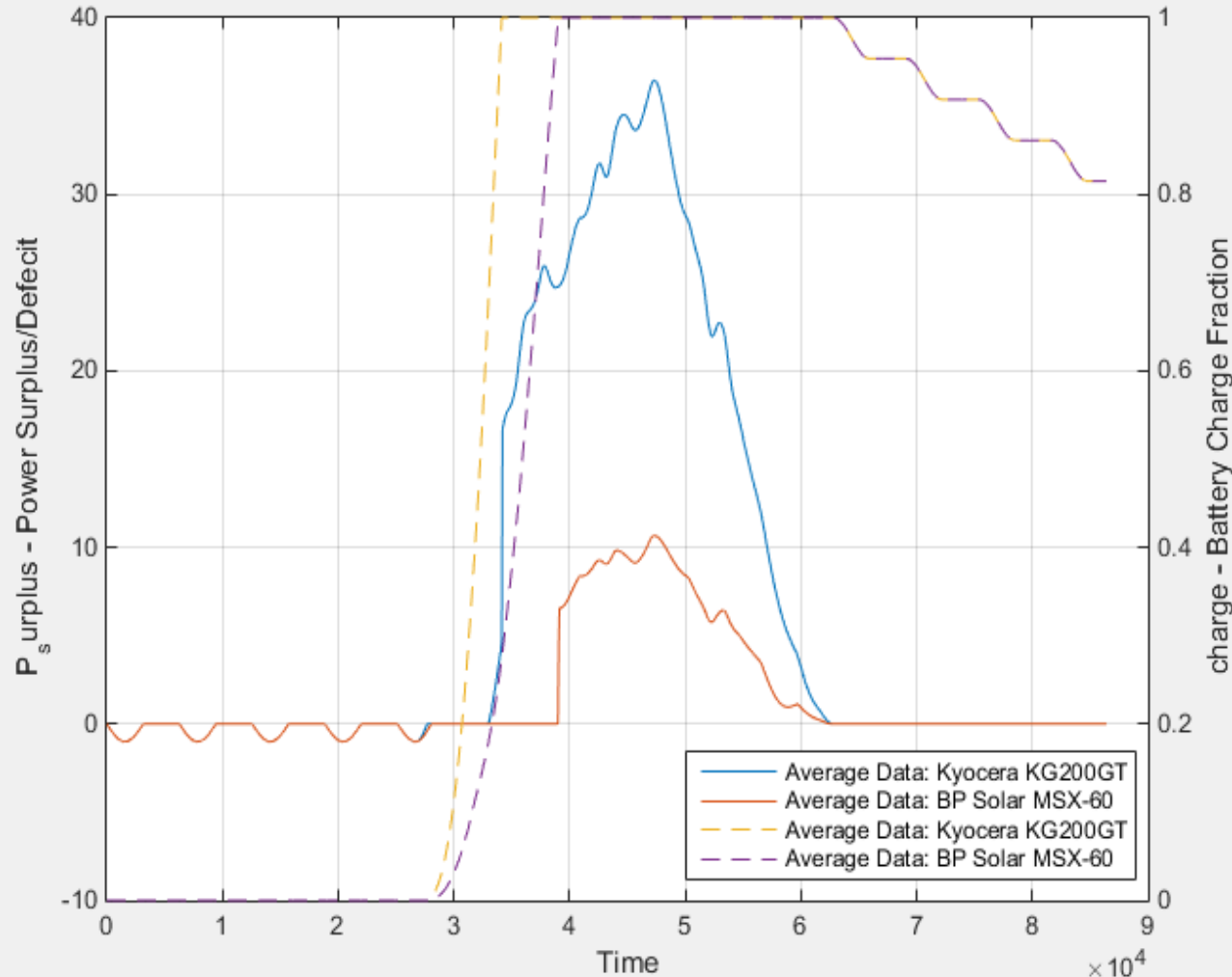
Enspect Analysis Software

- New concept: energy *surplus* and *deficit*
 - Surplus: Battery is full; harvested power wasted
 - Deficit: Battery is empty; load not fully powered
- Helps to size harvester and energy store
 - Always a deficit: under-sized harvester
 - Surplus and deficit: under-sized storage
- Recursive design to eliminate deficit



Graph Information

Primary: P_surplus - Power Surplus/Defecit Secondary: charge - Battery Charge Fraction Update



Editing: Average Data

Configurations

☒ Average Data
☐ Worst Case

Add Rename Delete

Data

Solar Cell(s)

MPPT Method

Energy Storage

Initial Charge 0 Ah
Capacity 1 Ah
Nominal Voltage 12 V
Charging Voltage 12 V
Max. Charge Current 1 A
Charge Efficiency 1

Consuming Device

Type of function:

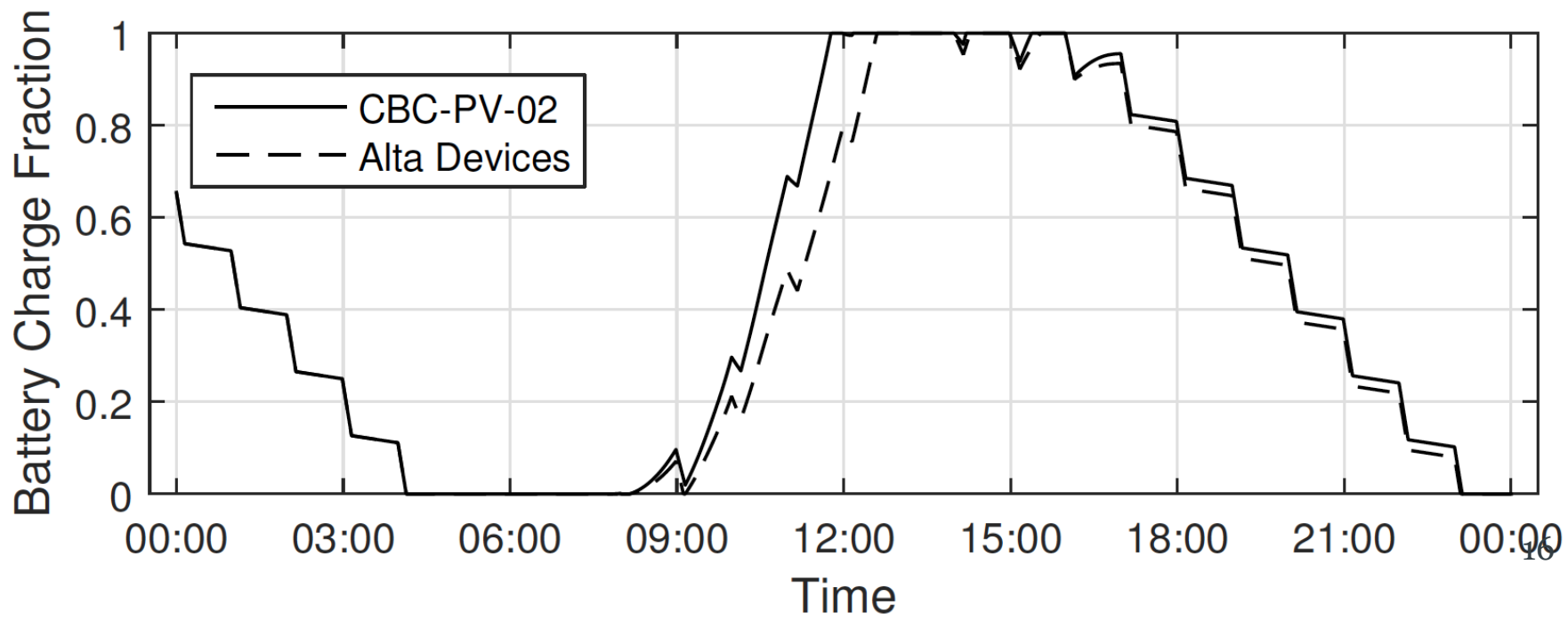
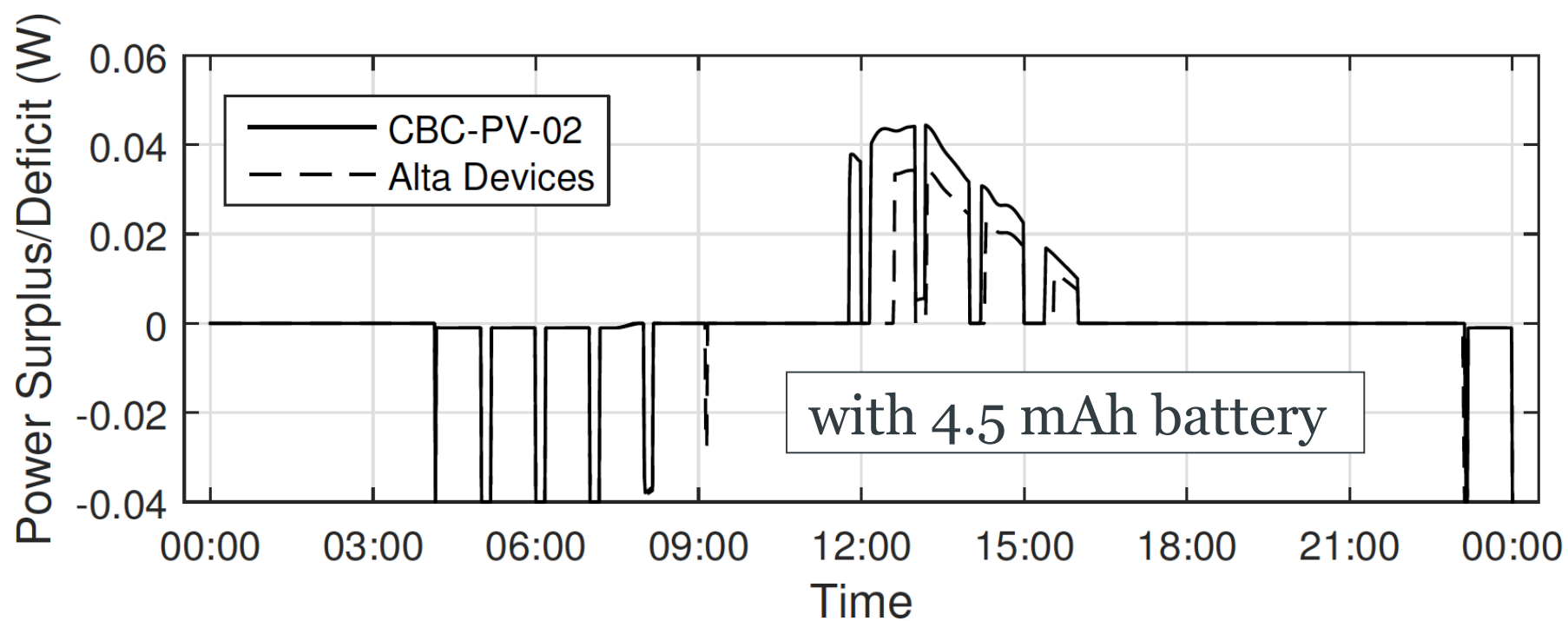
☒ Evaluated Code

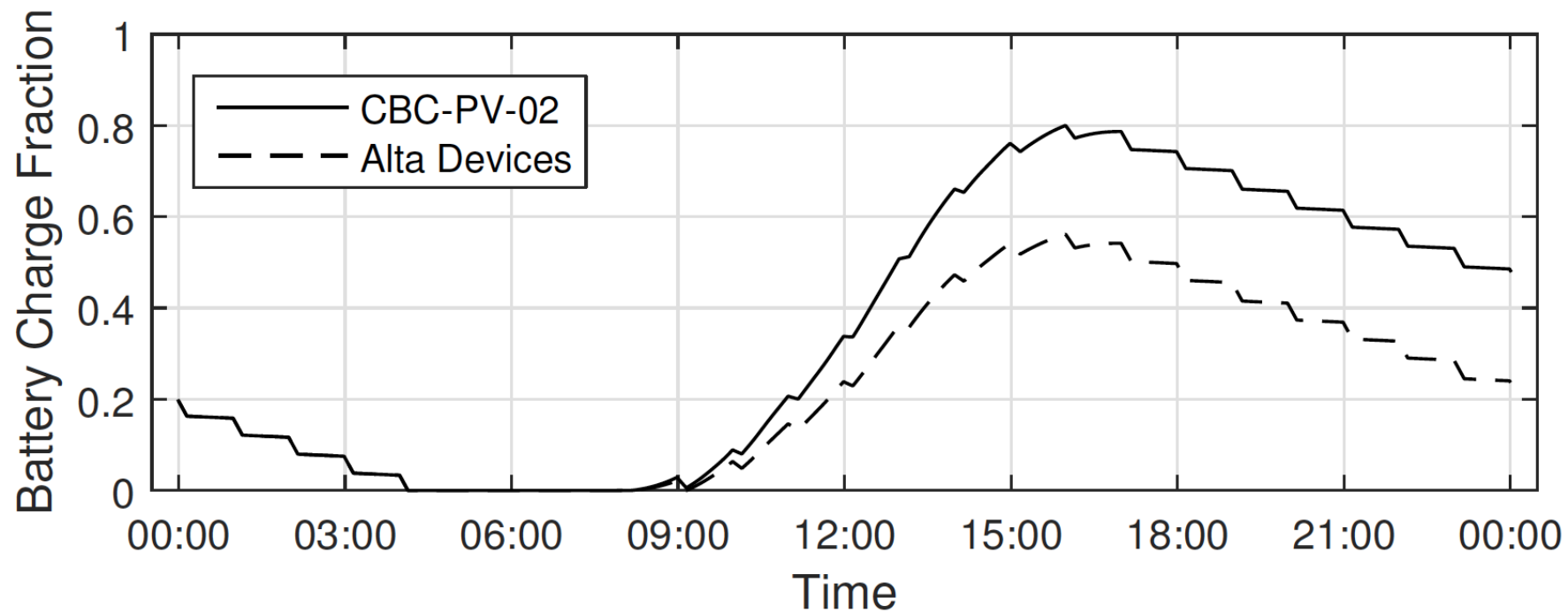
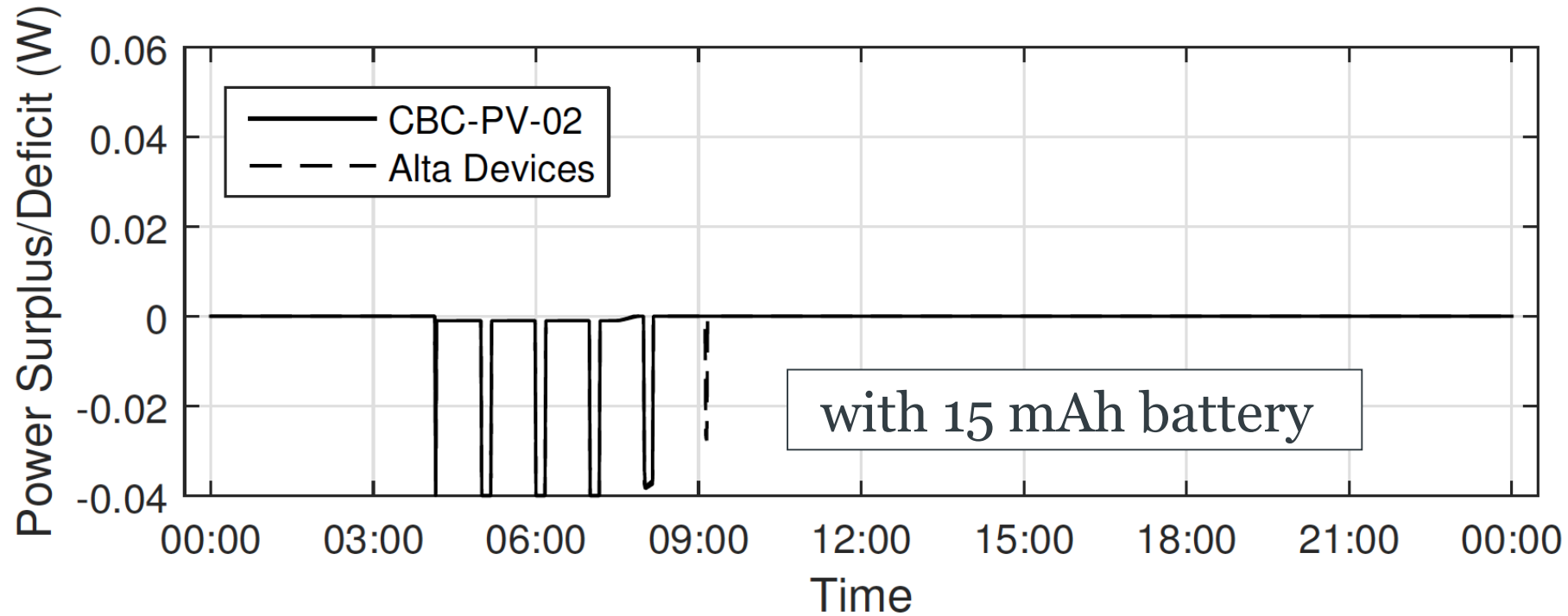
☐ Named Function

Statement: (t & sc are variables)

`max(0, sin(t/1000))`


Set New Function





Solar Cell Analysis Tool

File Edit View Insert Tools Desktop Window Help



Graph Information

Below is a list of general information about system performance for each configuration. Included are estimated representative cell efficiencies relative to STC for different chemistries, which may aid final selection. Please see documentation for further information.

Update

Field	Average Data	Worst Case
General Information		
Average Irradiance (W/m ²)	40.3307	21.0278
Average Irradiance (lit only) (W/m ²)	103.6354	58.0214
Average Temperature (C)	25	25
Average Temperature (lit only) (C)	25	25
Daylight Period (hours)	9.3333	8.6833
Best Solar Cell Performance		
Best Solar Cell	Kyocera KG200GT	Kyocera KG200GT
Percentage Time Device Powered	82.5121	63.6364
Average Power Produced (W)	7.8118	3.9516
Average Power Produced (lit only) (W)	20.0790	10.9080
Average Chemistry Efficiencies*		
Gallium Arsenide (GaAs)	92.7%	91.7%
Copper Indium Gallium Selenide (CIS)	78.8%	72.6%
Amorphous Silicon (a-Si)	107.6%	108.7%
Mono-Crystalline Silicon (mono-Si)	87.5%	83.2%
Multi-Crystalline Silicon (multi-Si)	76.0%	68.0%

Editing: Average Data

Configurations

☒ Average Data
☒ Worst Case

Add Rename Delete

Data

Solar Cell(s)

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Charge Efficiency 1

Consuming Device

Enspect is a complete package for predicting the output of energy harvesting systems

Software last updated
6th Aug 2015

[Download](#)

Developed as a project of the School of Electronics and Computer Science at the [University of Southampton](#), Enspect aims to predict the power output of an energy harvesting system. It features a data collection unit which logs environmental data, and an analysis tool which processes this data to make predictions. Currently, an advanced photovoltaic cell model and simple thermoelectric generator model are provided.

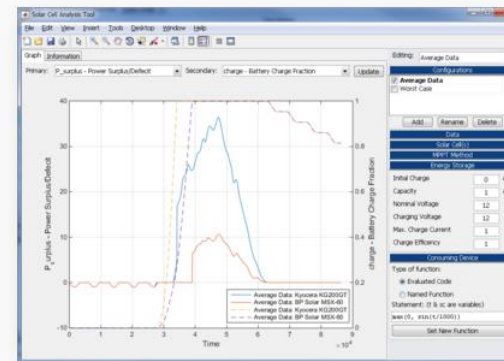
Data Collection Unit



Environmental data is collected via sensor modules collected to a central logger unit. Sensor modules were developed to allow **light irradiance modelling** for solar cells and **temperature sensors** for thermoelectric generators. Data is logged in CSV format to a standard SD card.

- Controlled **wirelessly** via Bluetooth.
- Long **battery life**.
- Modular **plug-and-play** design allows new sensors to be developed.

Analysis Tool



Complementing the data collection unit is an easy to use **graphical simulation tool**, able to predict power outputs from harvesters and take into account the power profile of the consuming device and any battery storage.

- Developed in **MATLAB**.
- Able to **compare** any number of system configurations.
- Models photovoltaic cells and thermoelectric generators.
- Gives a range of **graphical** and **tabular** outputs.

[More details](#)

Acknowledgment...

- Geoff Merrett
- Nick Tinsley
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Thank you!

Any Questions?

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