

# Energy Efficient Computing Research at STFC Hartree Centre





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## Bootstrapping EEC Research

ICT has a significant impact on the environment

- Operational emissions: Carbon released due to running data centres, PCs & embedded devices. Estimated that US-based cloud data centres to consume 73 billion kW-hrs by 2020 [1]
- Embodied emissions: Carbon released during manufacture and disposal
- Other environmental footprint aspects such as high use of water (washing PCBs) and use of exotic materials

## Hartree's EEC Research

	Funder & Project Time	Project Aims	Hartree EEC Aims
 COMPAT [2]	H2020 2016-18	energy efficient placement of components of multi-scale codes	Requires ability to MEASURE & PREDICT
 TSERO [3]	Innovate UK 2014-17	use of Machine Learning to determine compiler flags leading to lower energy-to-solution; instrumentation of data centre	Requires ability to MEASURE; aims to REDUCE
 VINEYARD [4]	H2020 2016-19	quantification of emerging tech alternatives to CPU for lowering energy-to-solution	Requires ability to MEASURE & MONITOR
Energy Efficient - HPC Working Group [5] & ETP4HPC [6]		working with leading HPC providers to understand & tackle challenges of energy efficient supercomputers & data centres	Requires ability to MONITOR & PREDICT
 EuroEXA [7]	H2020 2017-20	aiming to build an exascale prototype	Requires ability to PREDICT & REDUCE

The EEC research group aims to work with manufacturers and industry to provide solutions that enable

1. Processor/chipset to run any given code with lower amounts of energy
2. Any given code to run with least amount of energy on any given platform
3. Every data centre to be more efficient in the running of user codes

In order to tackle these, the EEC group is exploring each level of its mantra

### measure – monitor – predict – reduce

as applied to energy consumed.

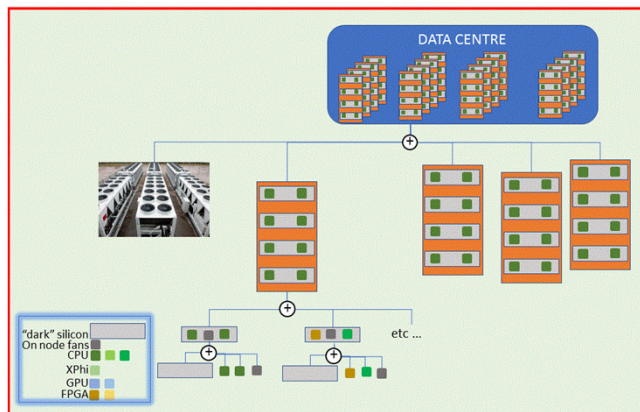
**Expected energy savings:** due to the wide nature of codes (& their current energy optimisation) etc it is hard to quantify predicted savings but we look to save 20%.

## References

- [1] Muhammad Zakarya, Lee Gillam, "Energy efficient computing, clusters, grids and clouds: A taxonomy and survey", Sustainable Computing: Informatics and Systems, 14, 2017
- [2] <http://www.compat-project.eu/>
- [3] <http://tsero.org/>
- [4] <http://vineyard-h2020.eu/en/>
- [5] <https://eehpcwg.llnl.gov/>
- [6] <https://euroexa.eu/>
- [7] <http://www.etp4hpc.eu/>



## Provision of HIERARCHICAL Measurements...

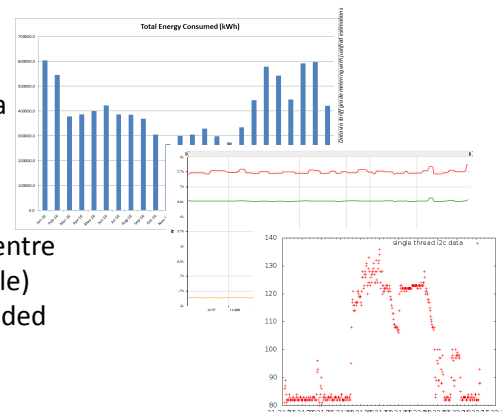


..for compute, network and storage, supplemented by an array of temperature and humidity sensors and data from schedulers.

The hierarchy of measurements needs to consider two axes:

- **Functional Resolution** - where energy is being consumed; represented as a tree with the 'root' measurement being the total energy consumed (by the data centre)
- **Accuracy & Temporal Resolution** - the accuracy of a given "leaf" measurement and its temporal resolution; summing over leaves gives error at any required level

We will empower researchers and data centre managers to "drill down" to the most appropriate level eg from data centre (blue), to rack (middle) and to a single threaded application (red).



A trusted measurement system

- ✓ to ensure monitoring is reliable for its chosen purpose
- ✓ to enhance models to accurately predict energy consumed under various scenarios
- ✓ to provide faith that *in silico* explorations of energy savings within a chip, a rack or a data centre
- ✓ to empower policy makers (energy caps & charging models)

## A hierarchy of measurements but also of energy savings

Current research ideas to reduce energy consumed at each level of the hierarchy include

- modelling of data transfer and cache coherence protocols: to reduce energy consumed at the chip-set level
- extending TSERO by inclusion of expert knowledge to reduce ML requirements (number of input data points), increase the average energy saved: to reduce energy for any given code
- extension of batch schedulers to include DVFS, automatic power off of "unwanted" nodes, and migration to more energy efficient platforms.
- lessons from social science to ensure acceptance of energy caps