

Applied Photovoltaics

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CREST



Outline

- CREST
- Applied Photovoltaic
- Some key pieces of research
- Conclusion



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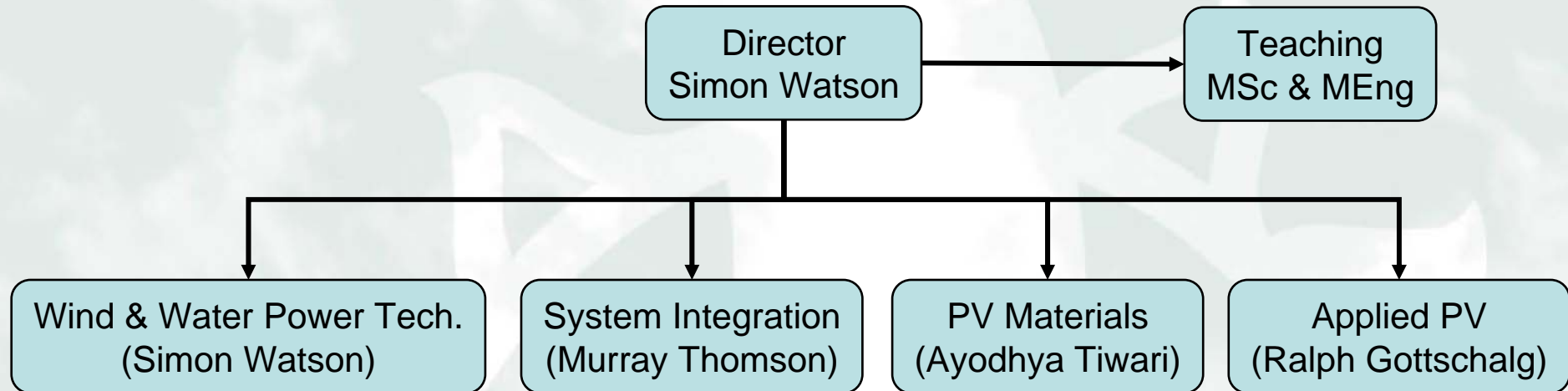


Loughborough
University

CREST-general

- Founded in 1993 by donation
- CREST is a research centre within the department of Electronic and Electrical Engineering
- Aims at Research and Teaching in RE
- Started with MSc training in 1994
- Distance learning in 1998
- Today ~ 60 on campus students and ~240 DL
- ~45 staff and PhD students

Structure of CREST



- Wind forecasting and integration of wind energy
- Energy storage technology
- Wind resource modelling
- Condition monitoring of wind turbines
- Control and system integration of wind turbines
- Structural dynamics of wind turbines
- Wind turbine aerodynamics and design
- Building mounted wind turbines
- Investigation of novel wave energy devices

- Network integration – embedded generation
- Stand-alone systems
- Hydrogen electrolyser and fuel-cell systems
- Desalination by reverse osmosis

- Measurement and modelling of PV-systems, modules and devices
- Development of PV measurement systems (laboratory tests as well as outdoor)
- Energy yield of PV modules and systems, effect of environment on energy production
- Modelling of device structures
- Measurement technology of PV devices, with emphasis on quality evaluation
- Building-integrated photovoltaics (BIPV)

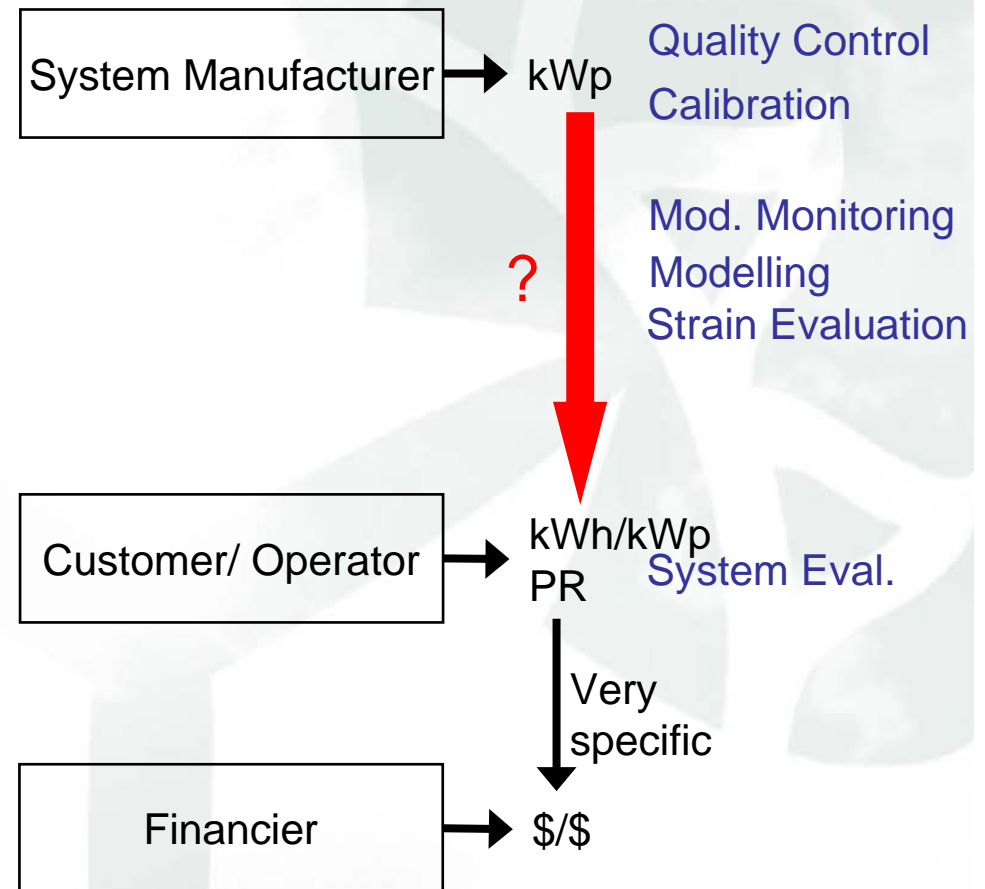
- Development of new TCO
- Development of CIGS cells
- Development of Dye Cells
- Development of c-Si cells
- Electrolytic plating

What is Applied Photovoltaics?

- Applied Photovoltaic is concerned with the outcome of photovoltaics, i.e. its performance
- Performance is not an unambiguous word
- The various steps in understanding performance are
 - Device structures
 - Device quality (inc. manufacturing)
 - Device installation
 - Device operation
 - System design
 - System operation
 - System and device longevity
- Work on measurements as well as modelling
- APV can be described as Performance Evaluation

Photovoltaic Performance

- Performance has a different meaning for different stakeholders
- Main Stakeholders
 - Cell, Module, System manufacturer typically are interested in Wp
 - Customer/Operator typically interested in PR or kWh
 - Bankers will be more interested in the financial return
- APV works along the entire value chain



Accuracy of Performance Determination

		c-Si	Thin Films
Peak Power	<i>Calibration</i>	$\pm 2\%$	$\pm 7-10\%$
Yearly Yield	<i>Energy Rating</i>	$\pm 10\%$	$\pm 10-20\%$
Solar Radiation	<i>Resource Assessment</i>	$\pm 30\%$	$\pm 30\%$
Equivalent Lifetime	<i>EoL testing?</i>	$\pm 50\%$?

- $\pm 2\%$ equivalent to ± 500 Mio\$ revenue in 2010, when 10 GW are produced

After: H. Ossenbrink, "International Standardization," in *Performance Annual Meeting*. Ispra, 2007.

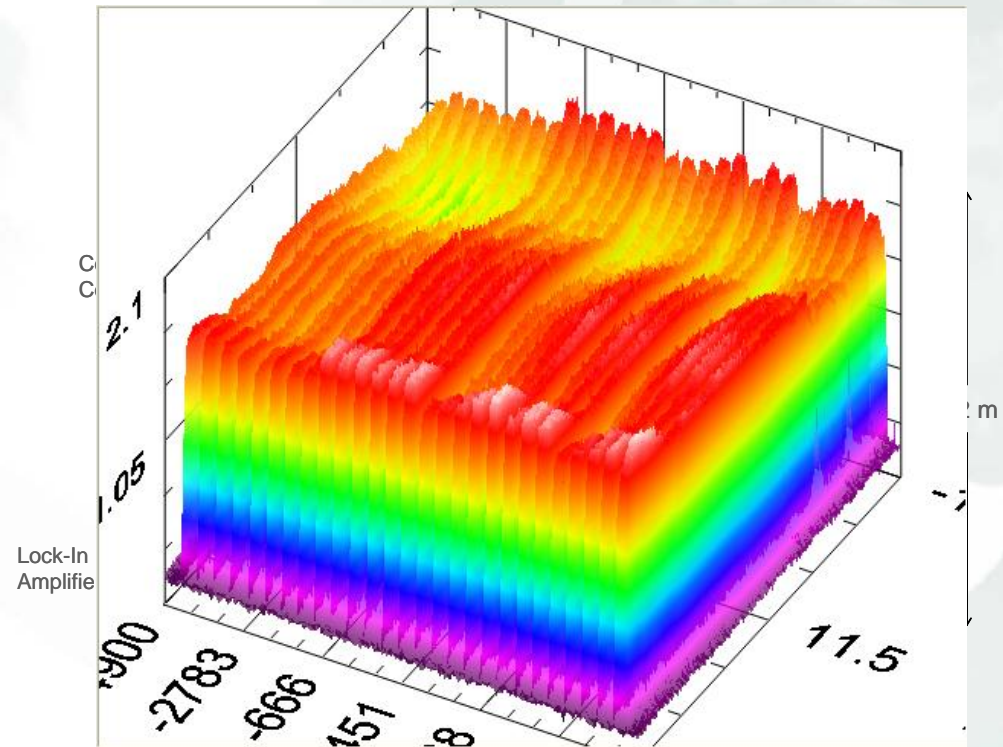
APV in the UK

- CREST (Loughborough University)
 - Work along the entire value chain
- NPAC (Northumbria University)
 - Device measurements
 - System monitoring
- Southampton (Southampton University)
 - Module mismatch
 - System monitoring
- New and Renewable Energy Centre, Blyth

Photovoltaic Measurement Technology

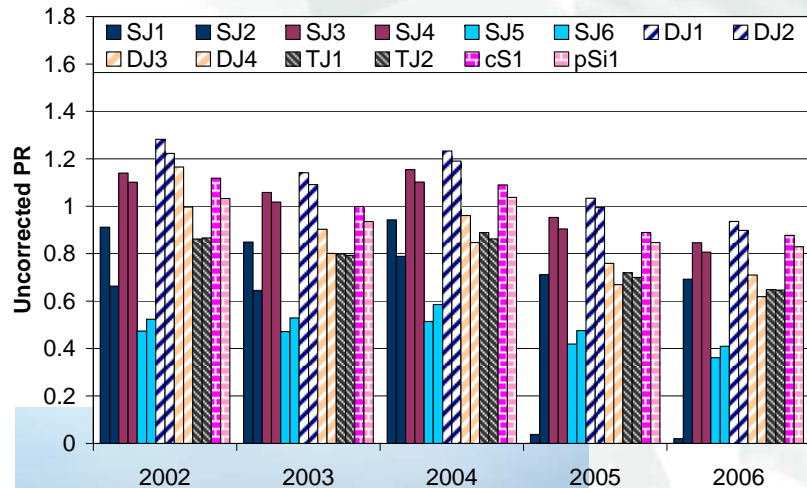
Quality Assurance - Example LBIC

- Need for tests for identifying weak areas in the cell
- Development of spatially resolved measurements
- Non-destructive testing
- Gives insights into material properties and production issues
- Method: run laser across module, measure minute response – graphical analysis
 - Identify weak areas
 - Identify localised defects
 - Identify production issues



Device Monitoring

- How much energy is generated by PV (modules) in realistic operation?
- What is the influence of the environment
 - Irradiance profile
 - Temperature profile
 - Spectral profile
 - Angle of incidence
- Do devices age or recover?
- How do different installation methodologies affect energy yield



Device Calibration

- What is the performance of different solar simulators
- How much do procedures affect overall measurement accuracy
- How can devices which are difficult to measure be calibrated accurately
 - Pre-conditioning effects
 - Capacitive effects
 - Metastable materials
 - Multi-junctions
- Intercomparison between laboratories

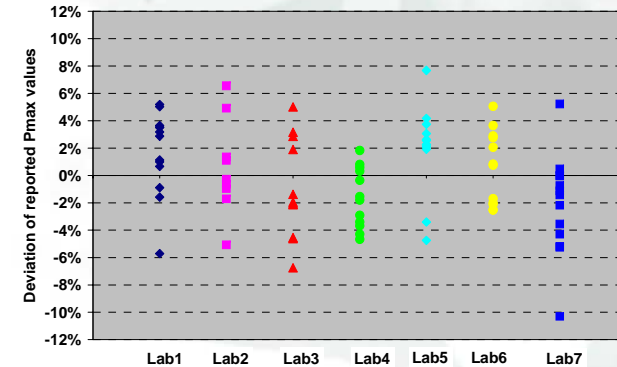
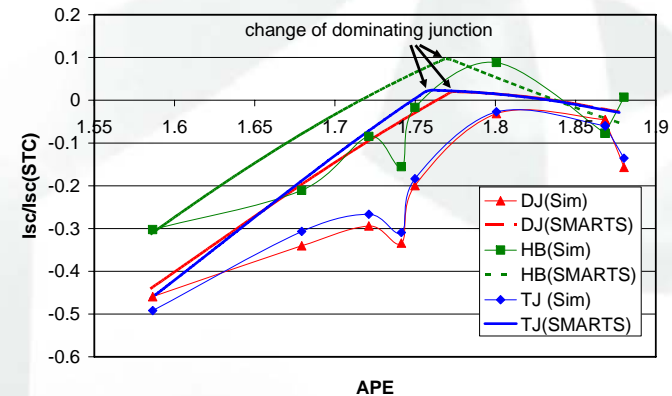
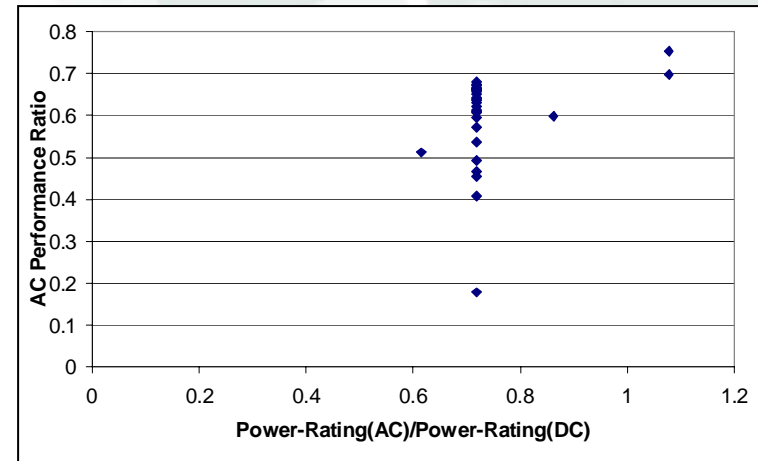


Figure courtesy of W.Herrmann, Intermediate report for Performance Sub-Project 1 'Traceable performance measurement of PV devices', Jan 2008



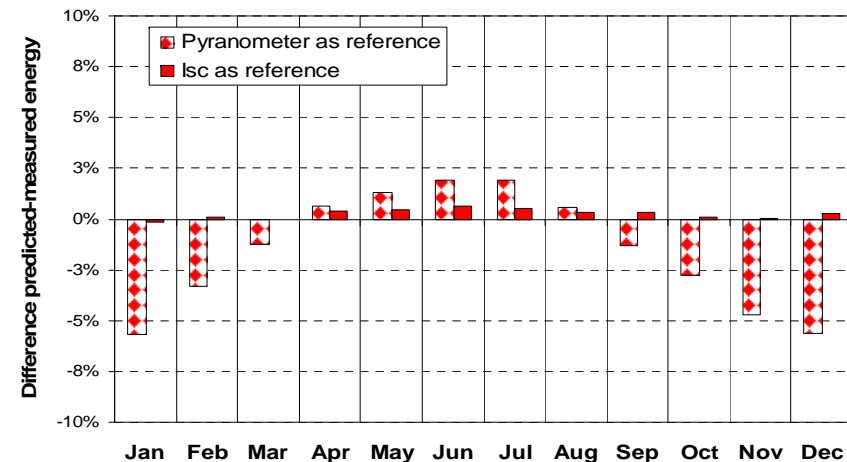
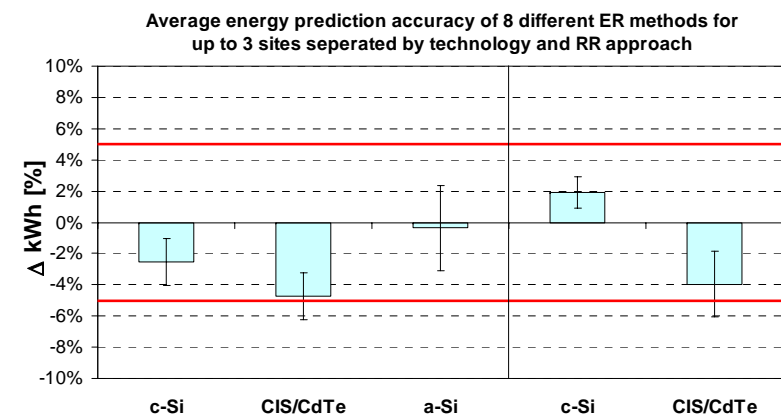
System Monitoring

- How does module performance filter into device performance
 - Depending on environmental effects
 - Depending on production distribution
 - What is the impact of typical system effects (shading, cabling, inverters,...)
- How accurate can we determine energy and other performance indicators
- How does measurement equipment affect device collection



Energy Prediction

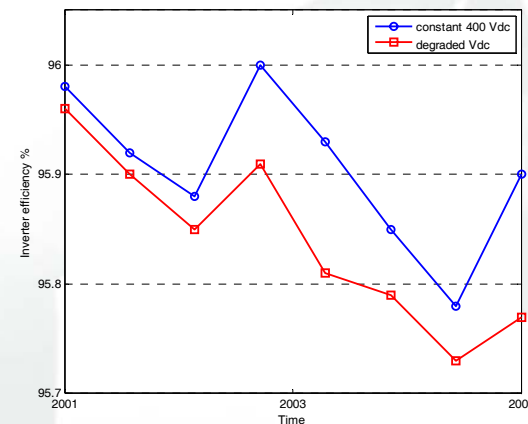
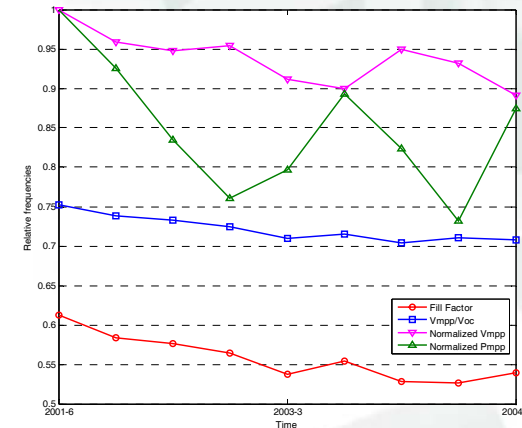
- There is an energy rating standard under development
- Work in EU largely within project 'Performance'
- Emphasis on how neglecting some environmental effects affect prediction accuracy
- Intercomparison with EU partners
- Quality of results largely dependent on accuracy of rating – thus device calibration needs to be investigated
- Second largest impact is quality of irradiance



Pictures courtesy G. Friesen, Intermediate report for Performance Sub-Project 4 'Modelling and Analysis', Jan 2008

Long Term Effects

- Currently largely based on indoor standard tests which are only linked through experience to realistic behaviour
- Differences between locations and materials
- Not only PV devices age, but this also affects the BOS
- Holistic research ongoing
- Standards are continuously improved



Summary

- CREST is the only place in the UK working on device production and APV along the entire value chain
- APV could be viewed as a support science but has significant challenges and is highly interdisciplinary
- Work is on accurate determination of performance – independent of the definition of performance