

Understanding the Factors that Affect the Utilization of Photovoltaics in High Atmospheric Dust Concentration Regions, Abu Dhabi as an Example

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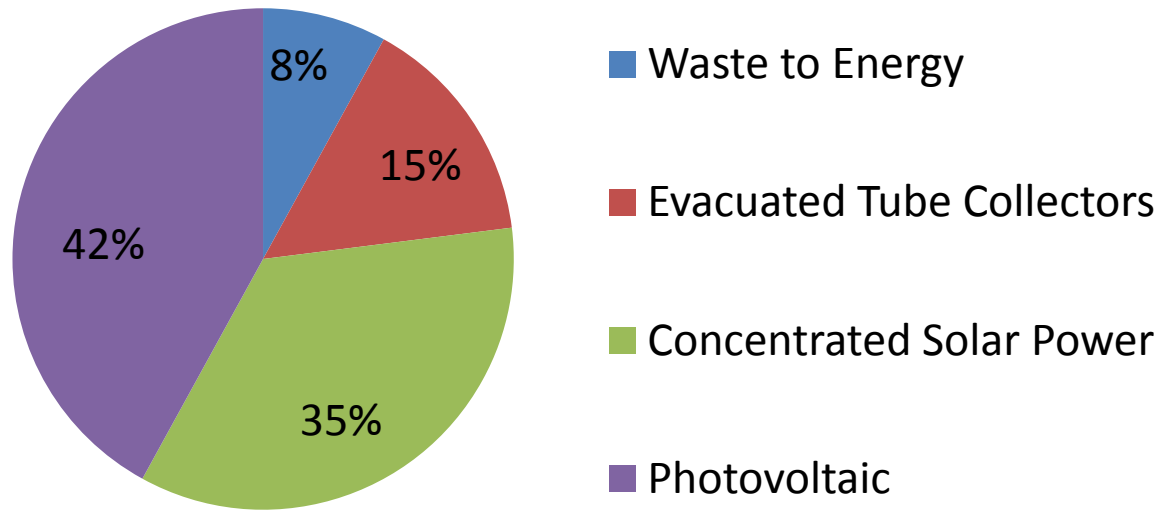
RSC Committee: Dr. Peter Armstrong, Dr. Marco Stefancich

OUTLINE

1. Introduction
2. Motivation
3. Experiments
4. Modeling PV's power output
5. Modeling dust accumulation
6. Testing a functionalized coating

INTRODUCTION

Energy Generation Share at Masdar City



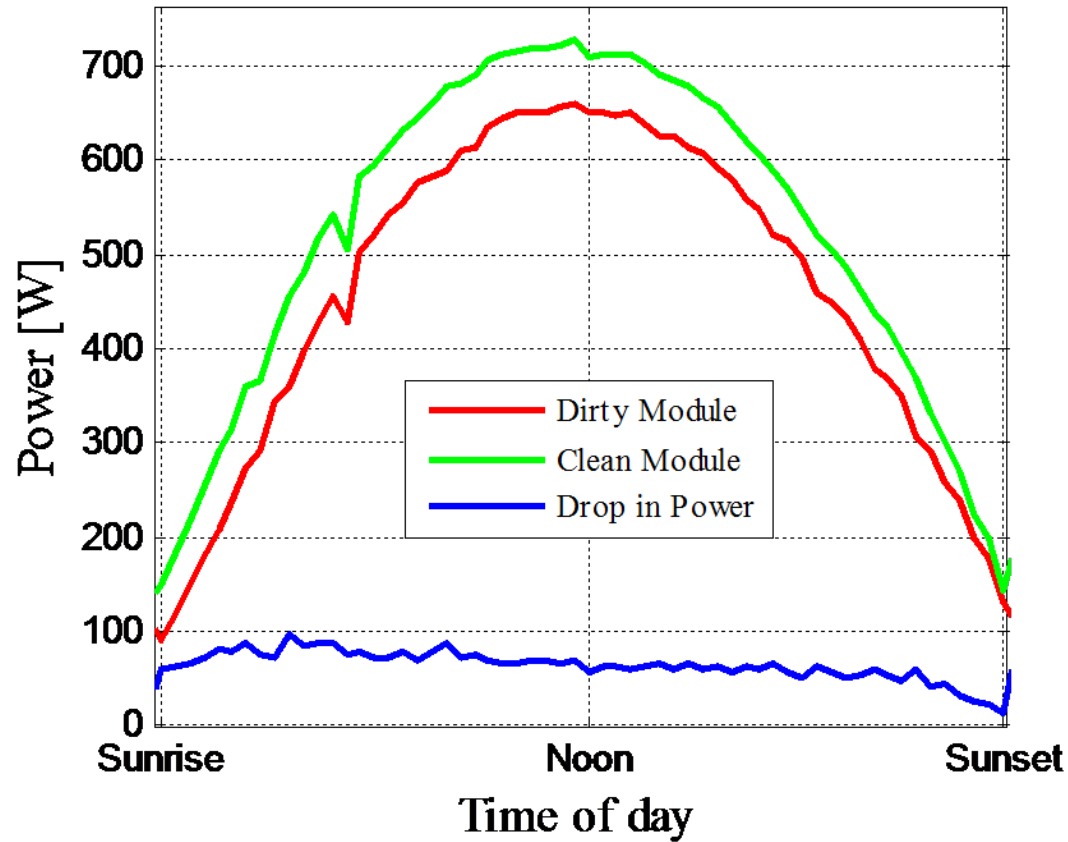
Rooftop Mounted PVs – 10 MW PV Farm



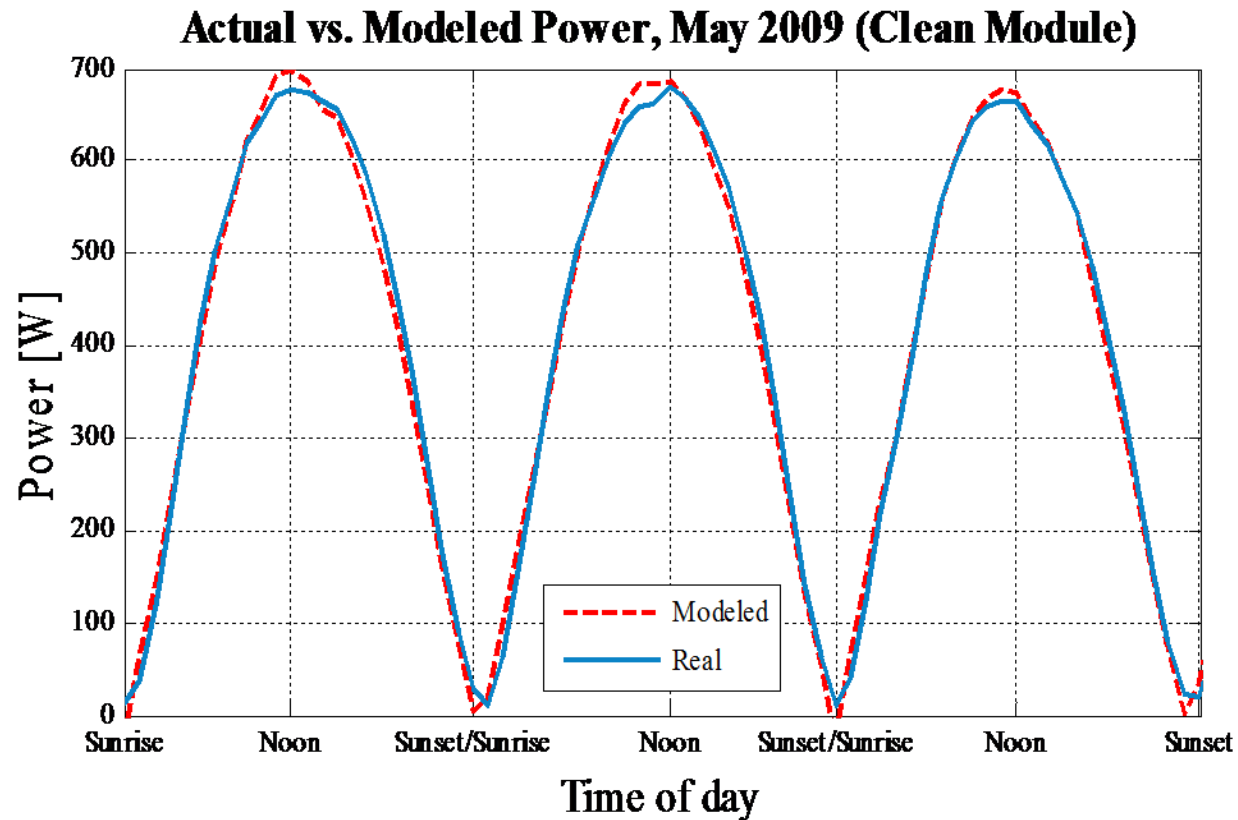
MOTIVATION

Drop in Power due to Dust

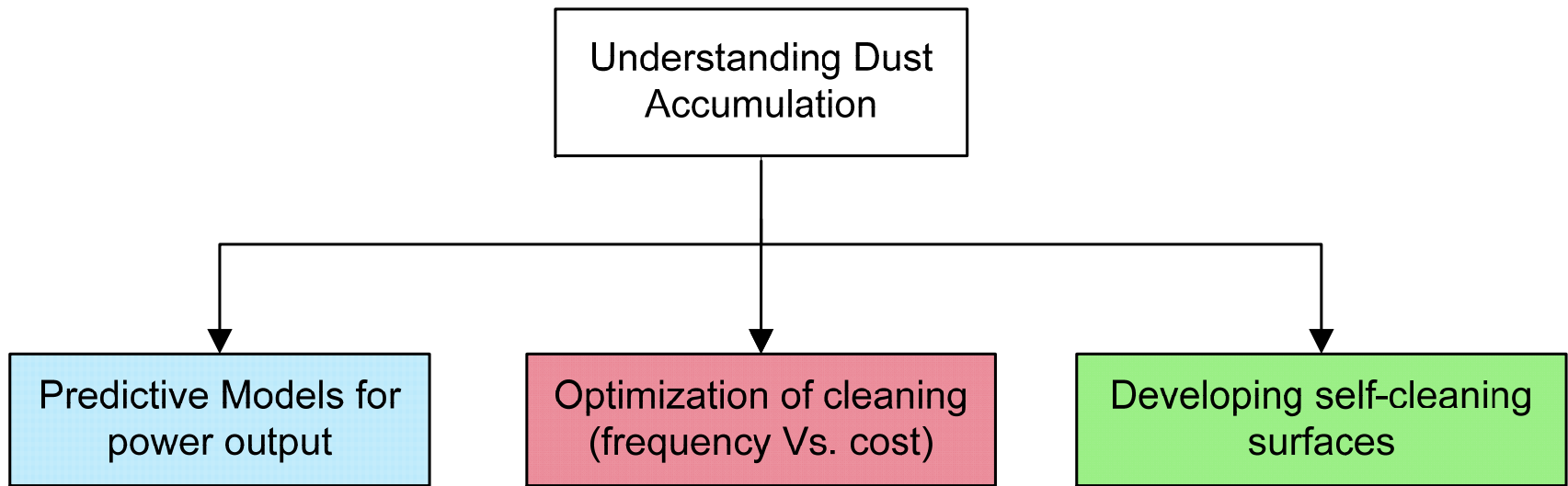
Power output for one day in April, 2009



Power Prediction



Understanding Dust Accumulation



EXPERIMENTS

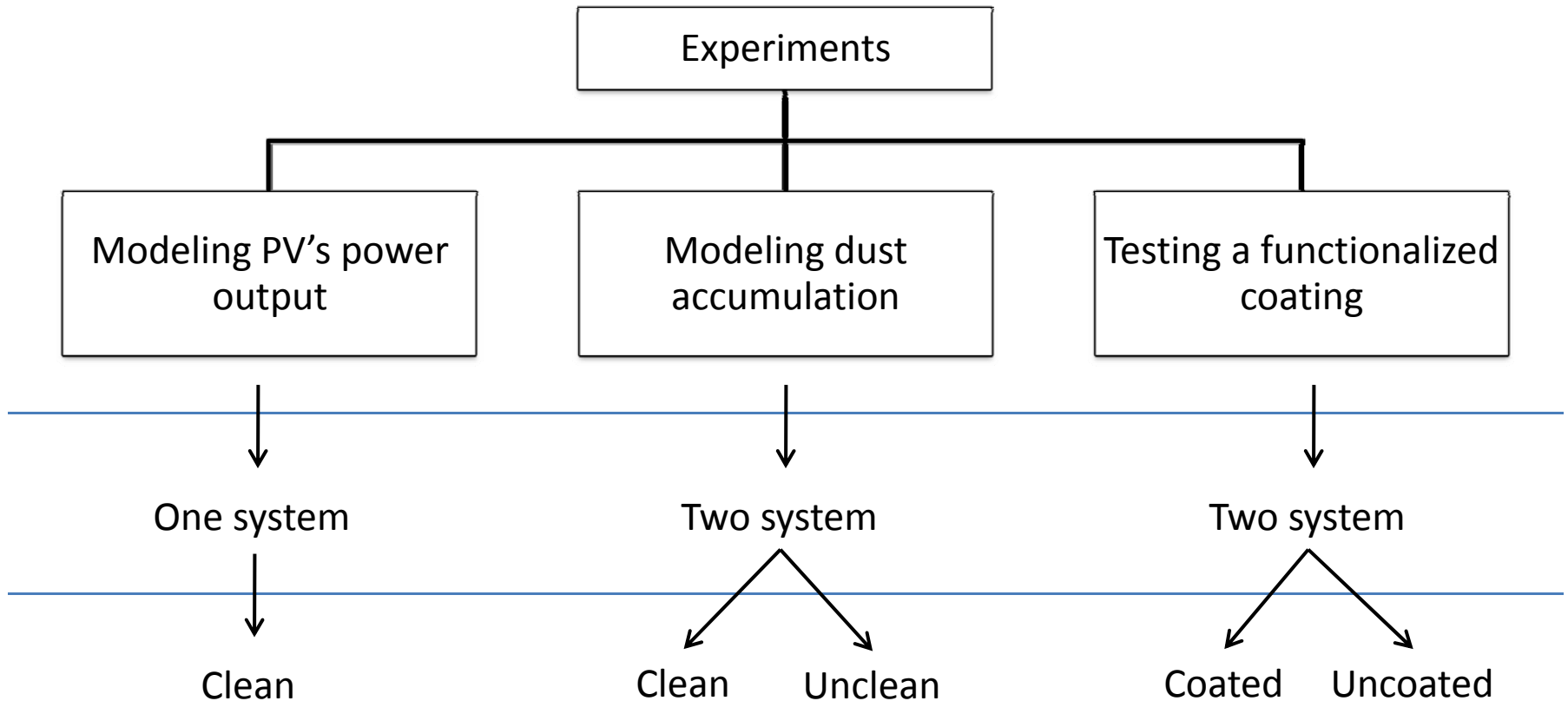
Two Identical Systems

System # 1

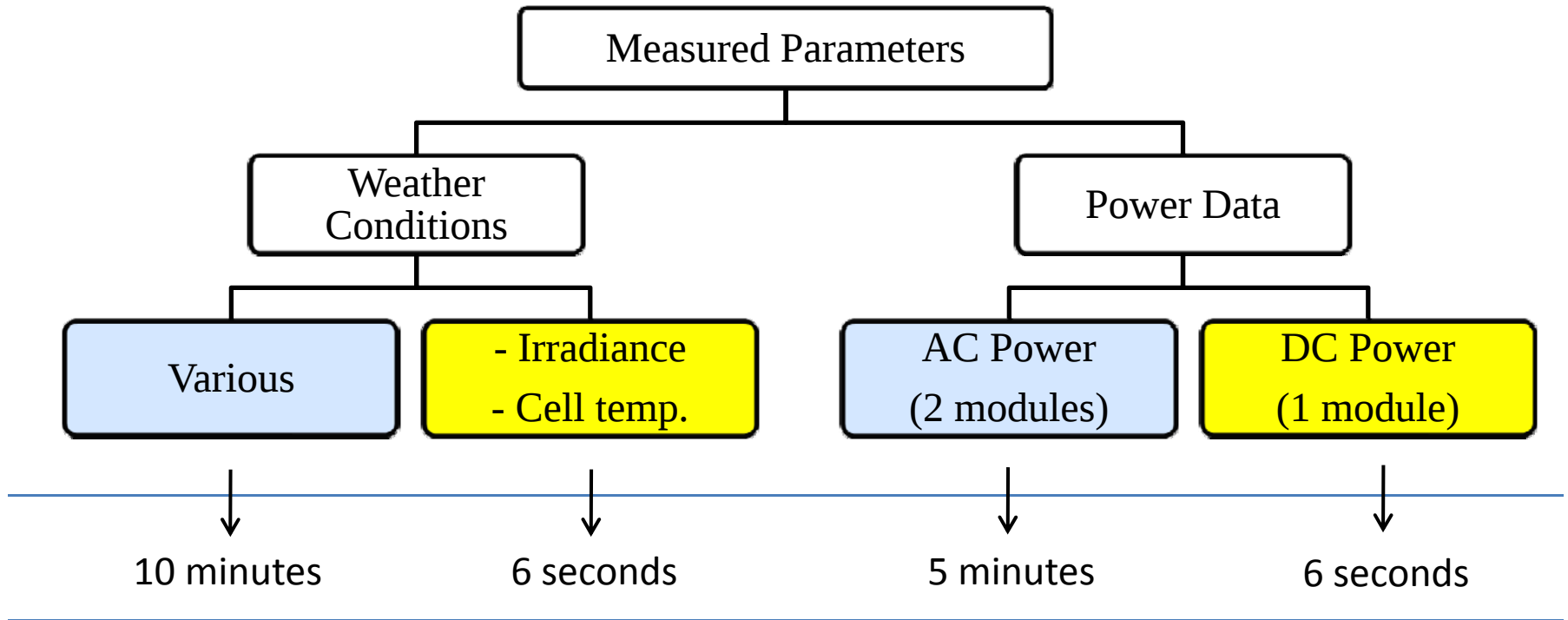
System # 2



Three Experiments



Measured Parameters



-  Original setup – All experiments
-  Modified setup – Modeling PV power output

MODELING PV'S MAXIMUM POWER OUTPUT

Maximum Power Point Model

$$P = A_1 G \ln(G) + A_2 G^2 + A_3 G T_c + A_4 G$$

P : Maximum power output of a PV [W/m²]

G : plane of array irradiance [W/m²]

T_c : cell temperature [°C]

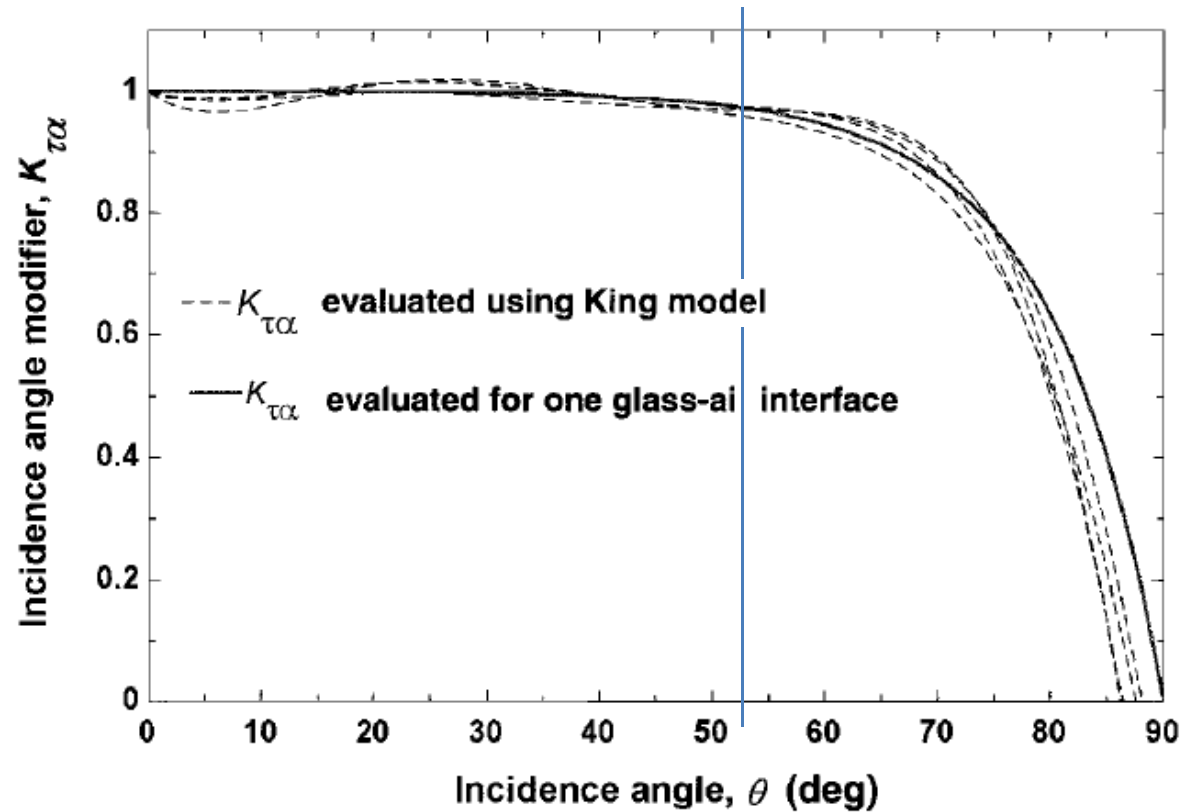
$$T_c = T_b + (G/G_o) \Delta T$$

T_b : Measured PVs back-surface temp. [°C]

G_o : Reference solar irradiation [1000 W/m²]

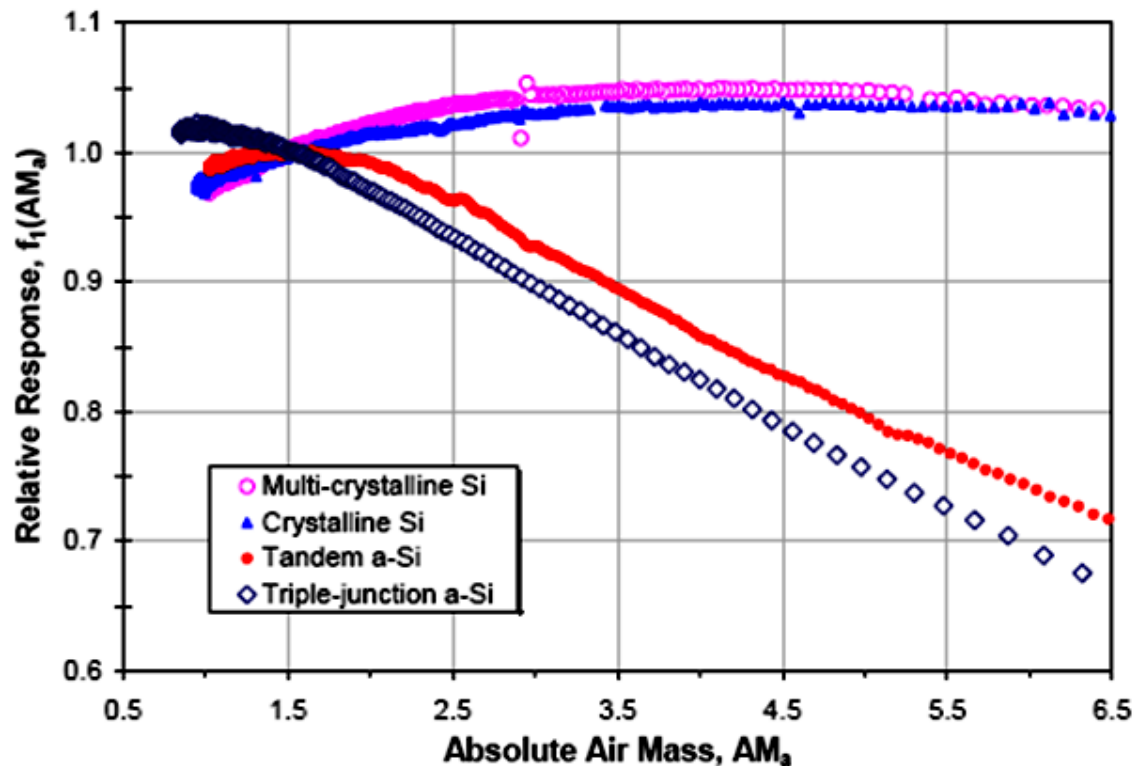
ΔT :Temp. difference between the cell and the module back-surface **G_o**

Effect of Incident Angle Modifier – Optical Losses



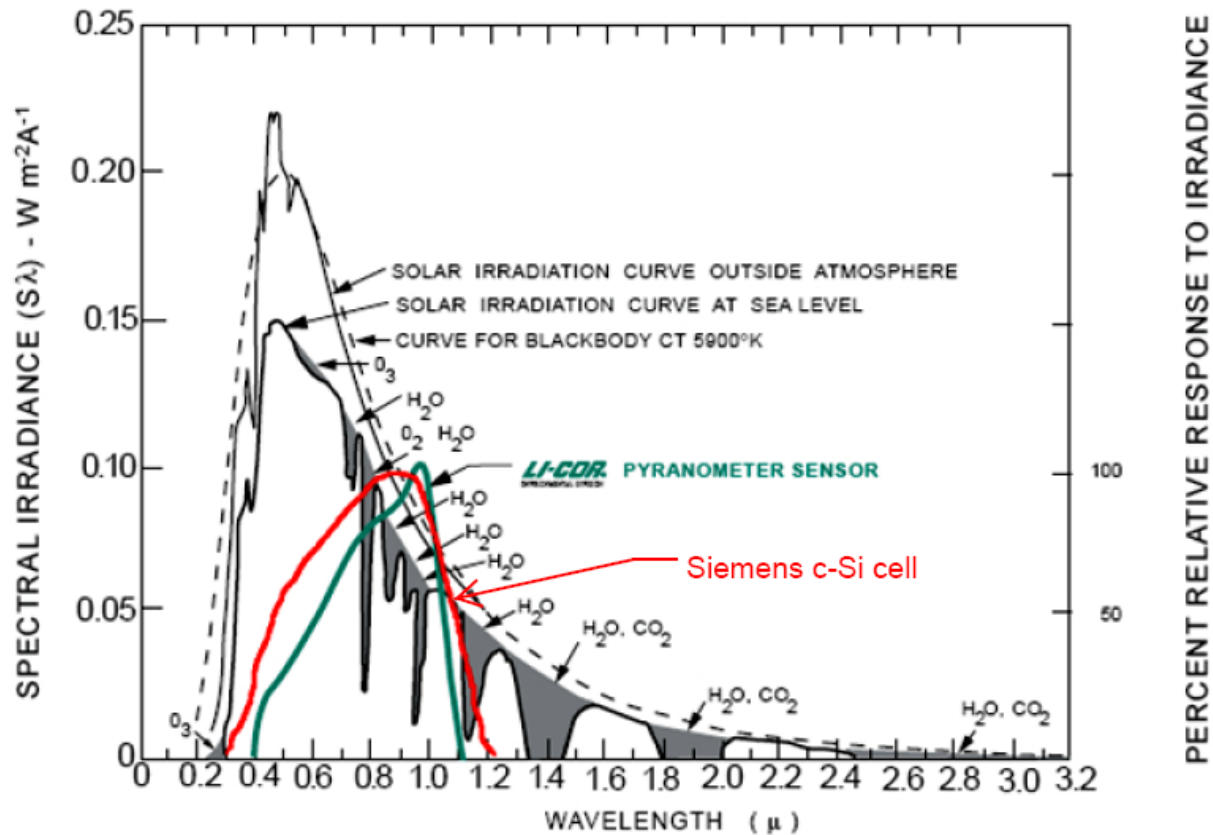
J. A. Duffie and W. A. Beckman, *Solar engineering of thermal processes*. Wiley, 2006.

Effect of Solar Spectrum - Air Mass



D. L. King, J. A. Kratochvil, and W. E. Boyson, *Photovoltaic array performance model*.
United States. Dept. of Energy, 2004

Correcting for Solar Spectrum Mismatch



Courtesy of LI-COR® Bioscience, Siemens c-Si cell response adapted from D. L. King in *Photovoltaic Specialists Conference, 1997., Conference Record of the Twenty-Sixth IEEE*, pp. 1113–1116, 1997.

Correcting for Incident Angle

Model power around noon



Minimal Incident angle effects



Use the model around noon to predict all time of the day

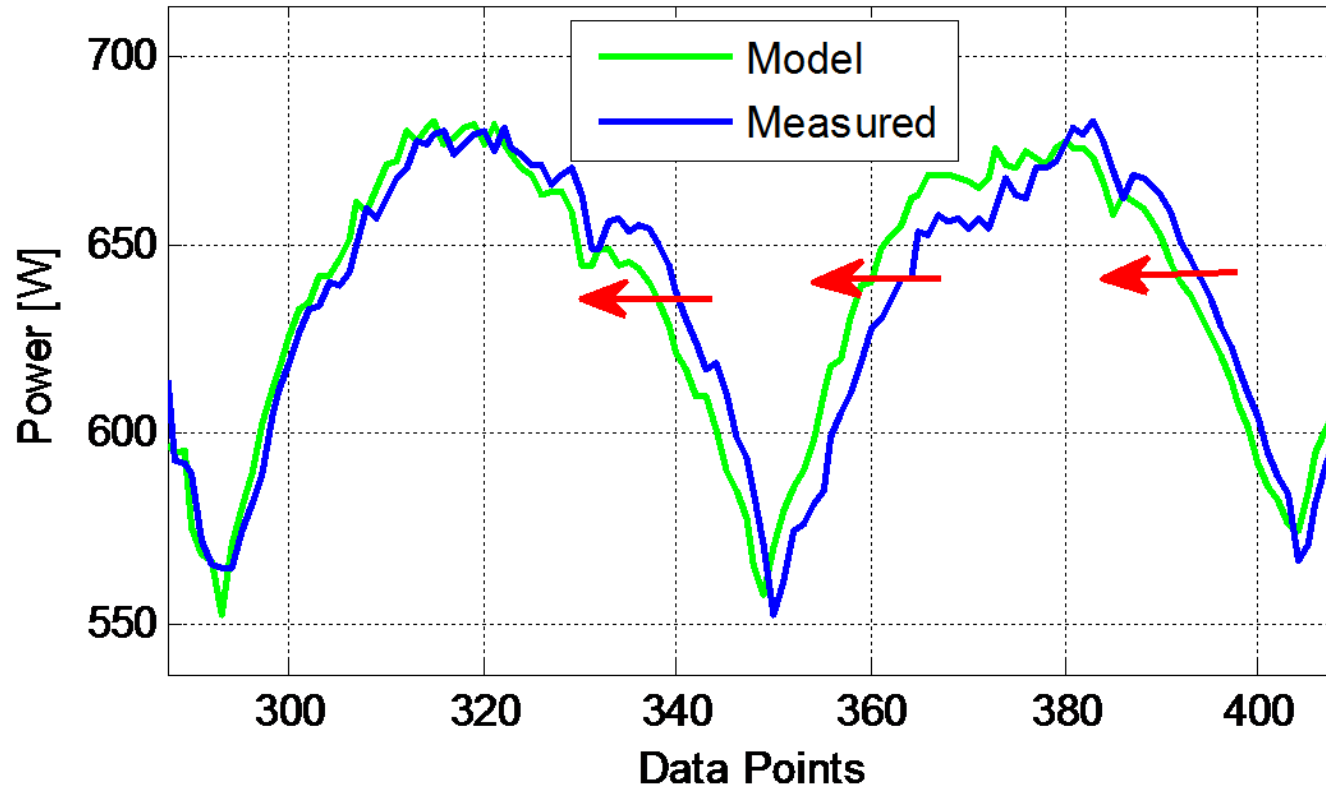


The model will over predict power output in the mornings and evenings

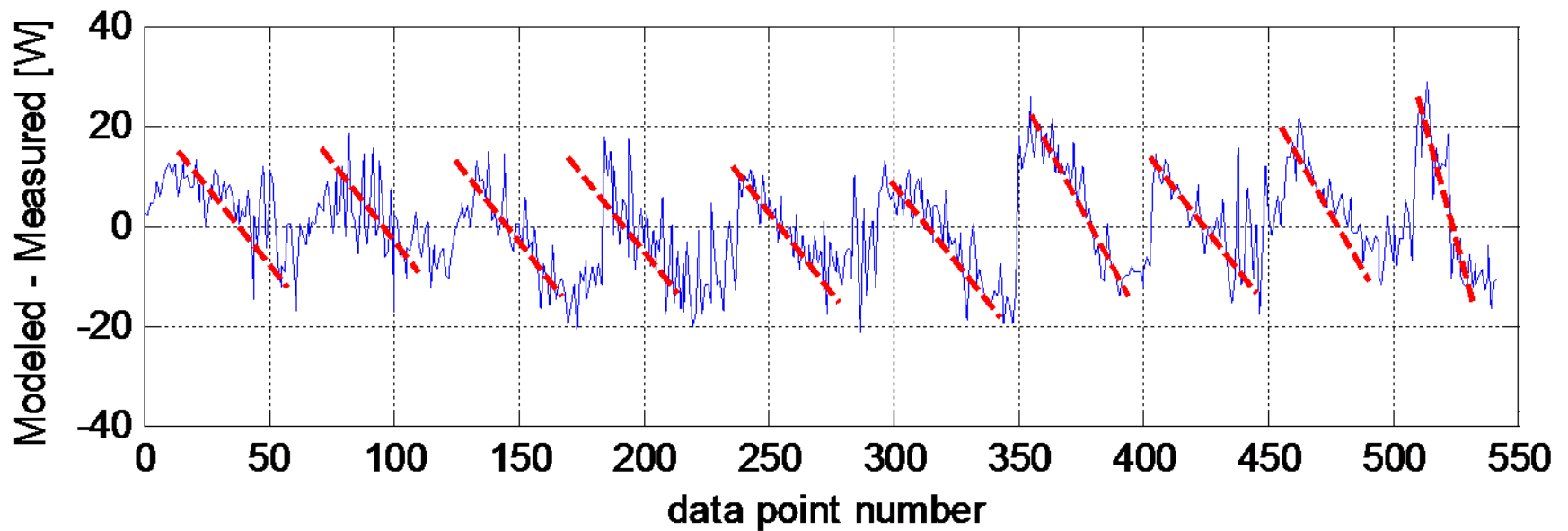


Incident angle modifier = Measured output / modeled output (using data around noon)

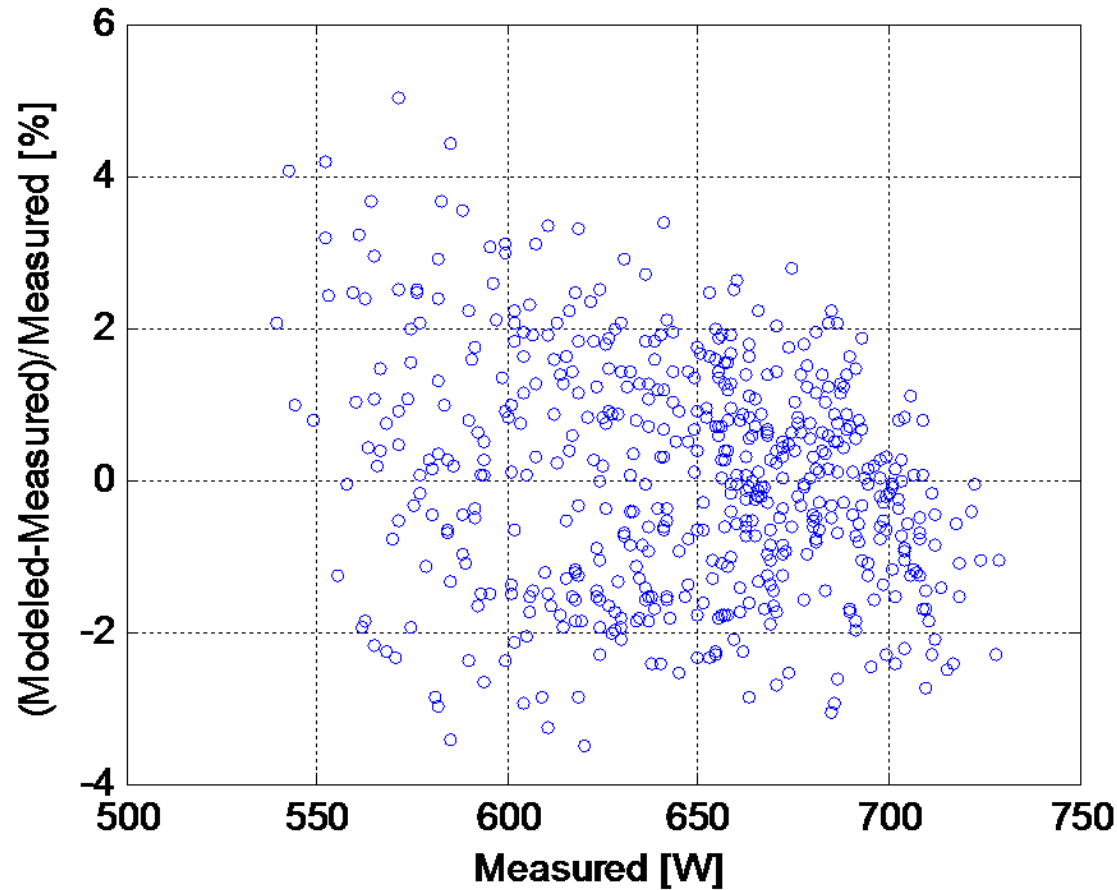
Original Data Set – Lag in model



Original Data Set – Structure in Residuals



Original Data Set – Normalized Residuals vs. Measured



MODELING DUST ACCUMULATION

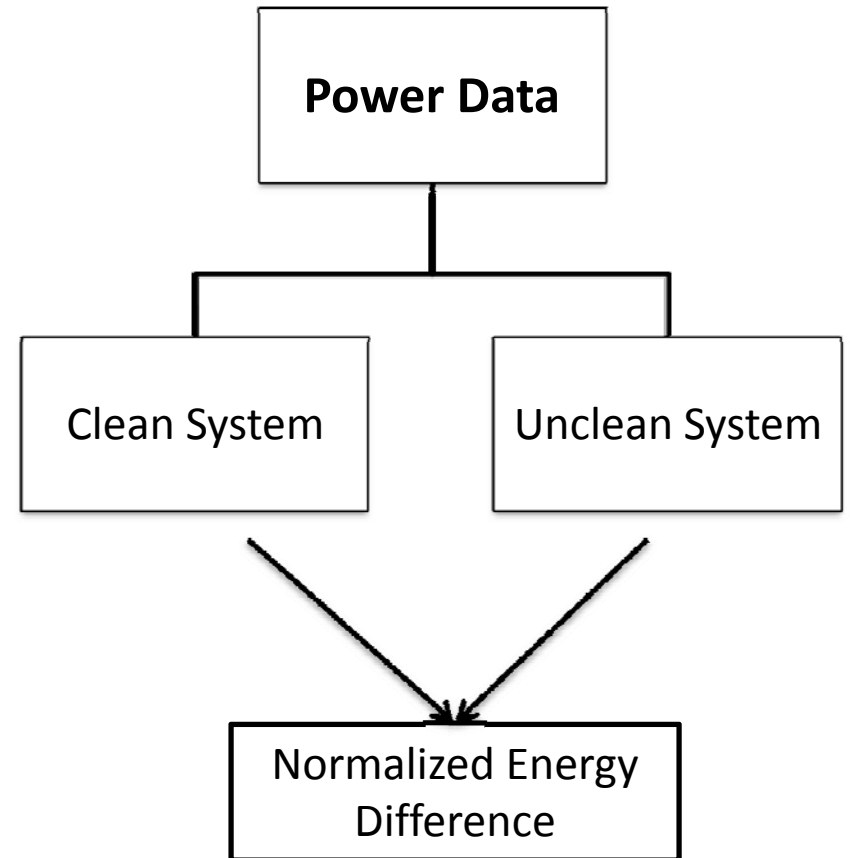
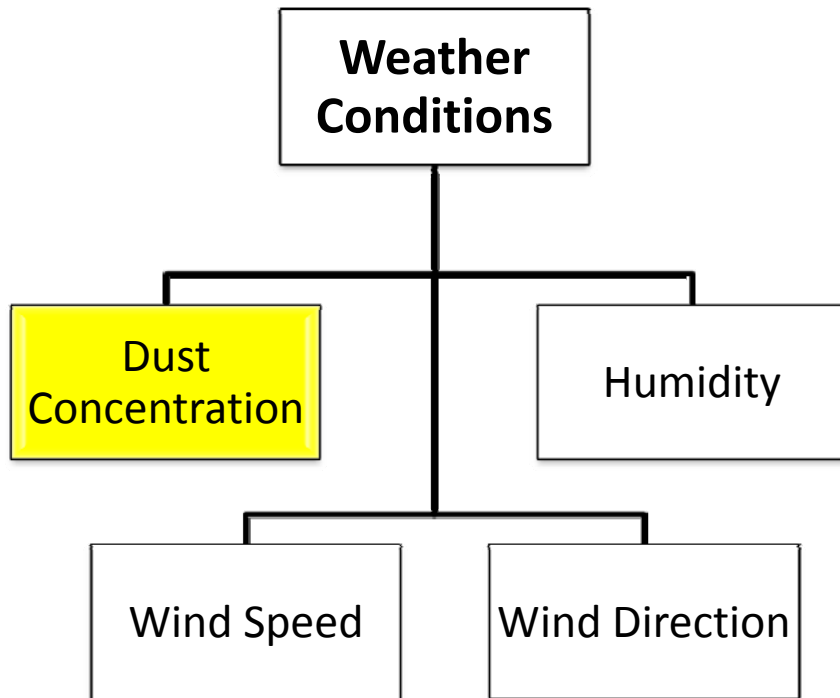
Two Identical Systems

Unclean System

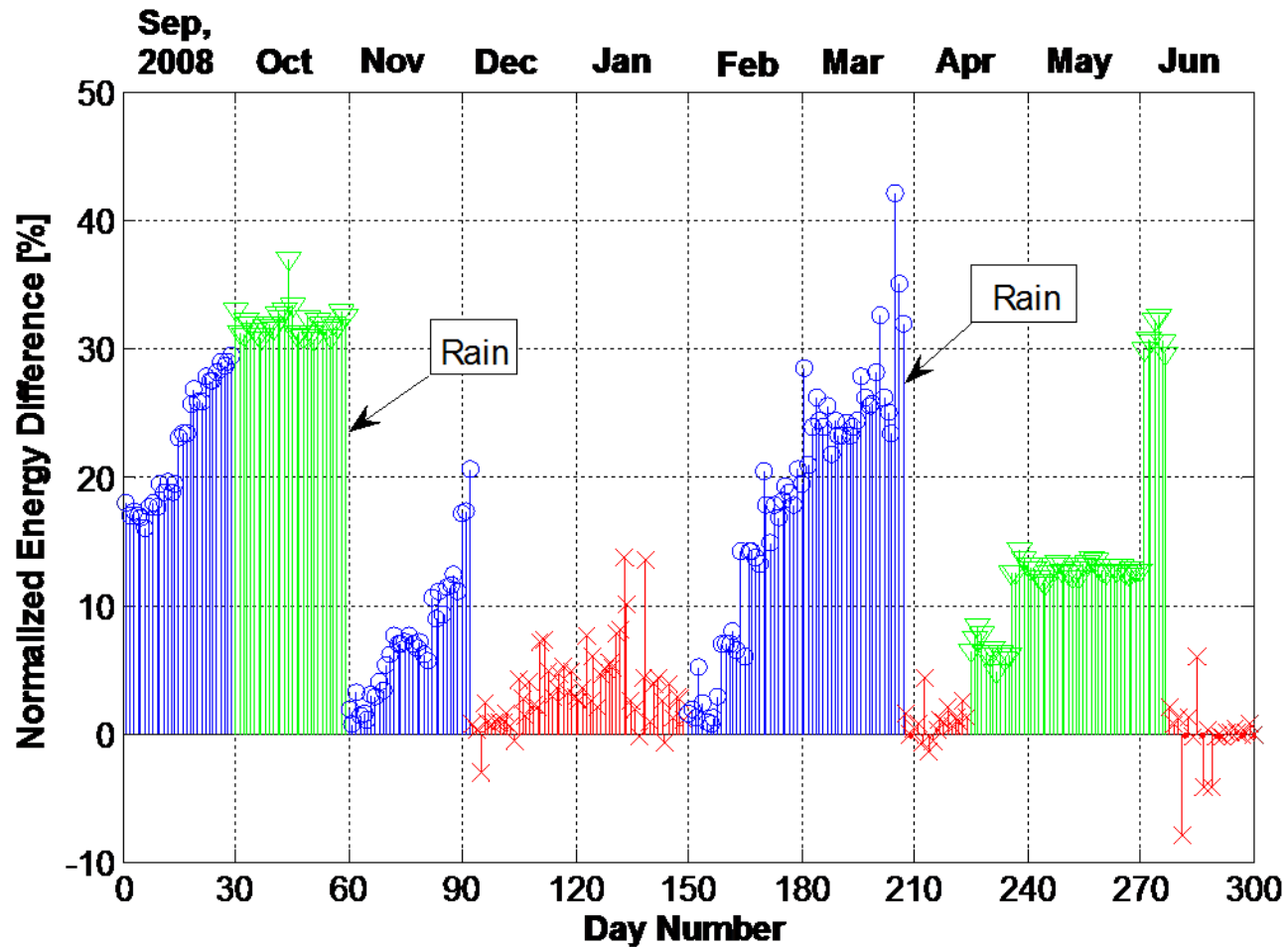
Clean System



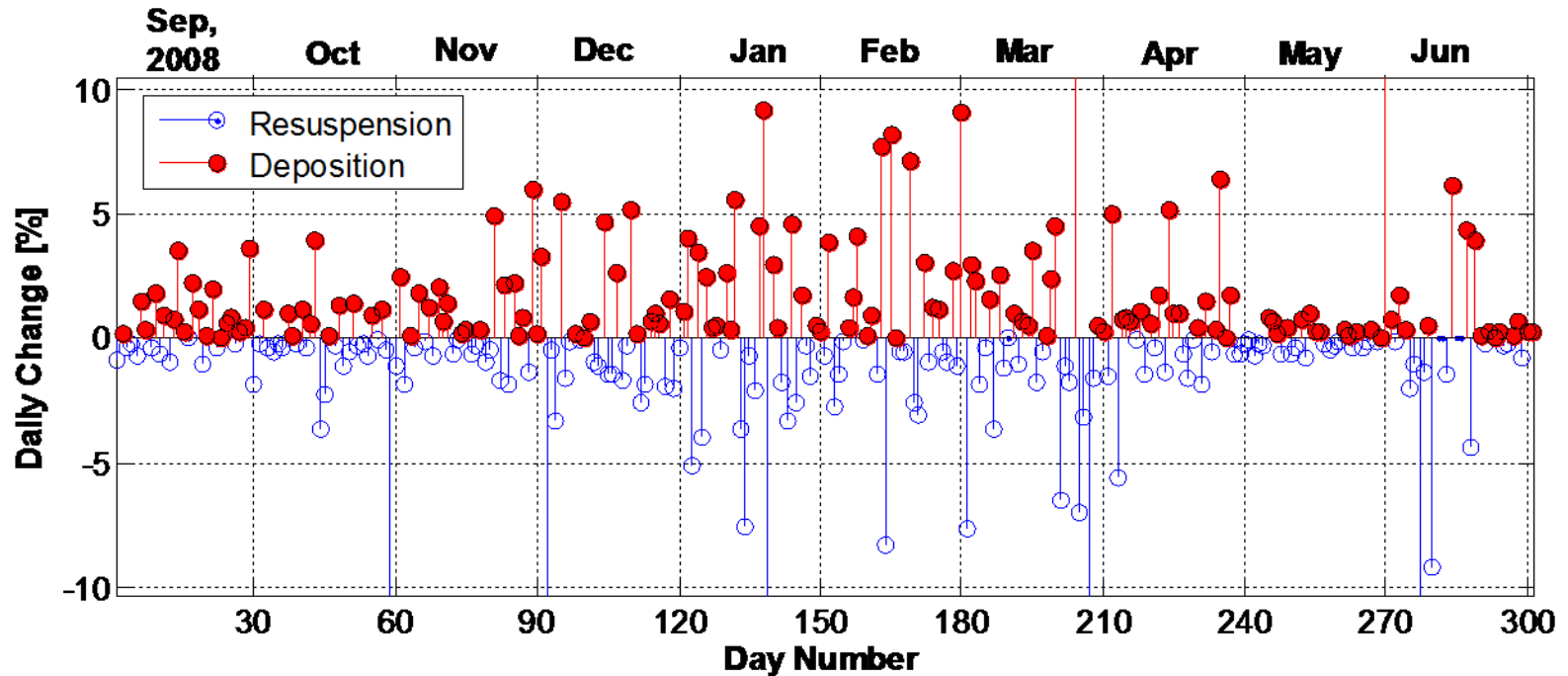
Used Parameters



Normalized Energy Difference



Normalized Energy Difference



TESTING A FUNCTIONALIZED COATING



THANK YOU

QUESTIONS