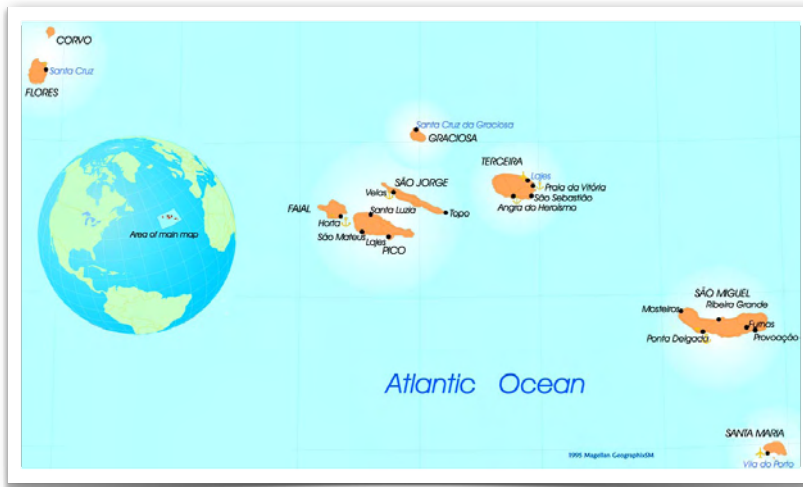




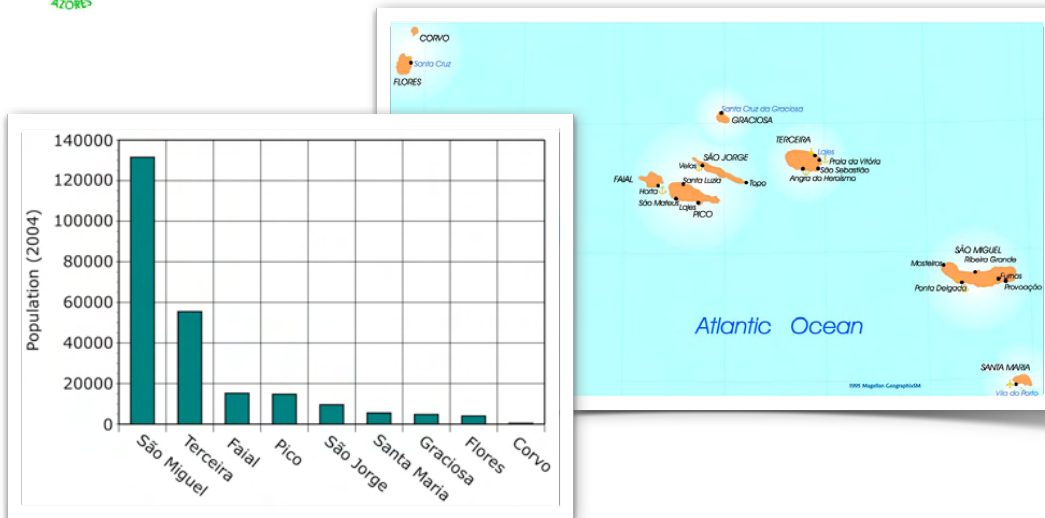
# Big Winds for Small Islands: Renewables Integration in the Azores



## The Green Islands Project



# The Green Islands Project



## Nine Unique Islands - Population, Economy, Topography, Energy Demand, Renewable Resources



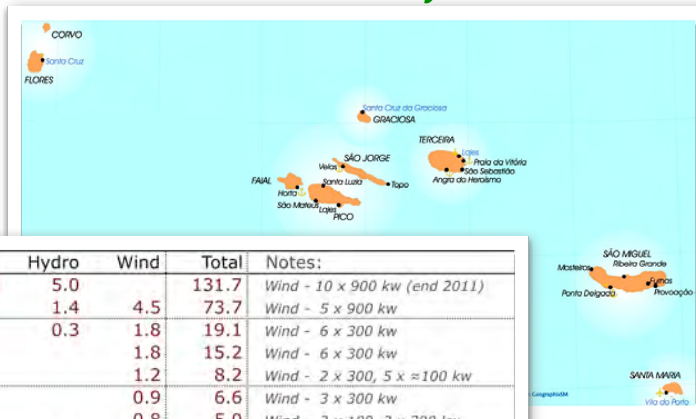
# The Green Islands Project



Electricidade dos Açores

## Existing Generation (MWs)

(End 2008)	Diesel	Geoth.	Hydro	Wind	Total	Notes:
São Miguel	98.1	27.8	5.0		131.7	Wind - 10 x 900 kw (end 2011)
Terceira	67.8		1.4	4.5	73.7	Wind - 5 x 900 kw
Faial	17.0		0.3	1.8	19.1	Wind - 6 x 300 kw
Pico	13.4			1.8	15.2	Wind - 6 x 300 kw
São Jorge	7.0			1.2	8.2	Wind - 2 x 300, 5 x ≈100 kw
Santa Maria	5.7			0.9	6.6	Wind - 3 x 300 kw
Graciosa	4.2			0.8	5.0	Wind - 2 x 100, 2 x 300 kw
Flores	2.3		1.5	0.6	4.4	Wind - 2 x 300 kw
Corvo	1.0				1.0	
<b>All Azores</b>	<b>216.5</b>	<b>27.8</b>	<b>8.2</b>	<b>11.6</b>	<b>264.9</b>	



Nine Unique Islands  
 Population, Economy, Topography,  
 Energy Demand, Renewable Resources

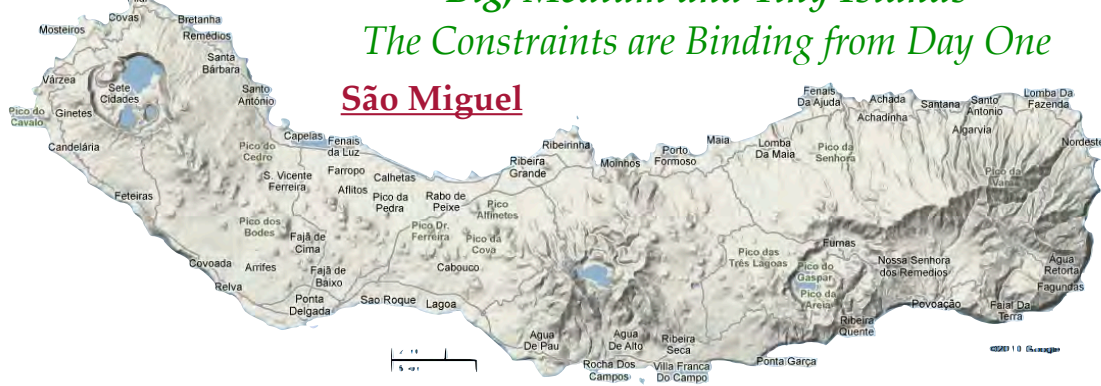
75% Renewables Target - 2018  
 Political Target – Average across  
 the Islands. How to do?



# The Green Islands Project

*“Big, Medium and Tiny Islands”*

*The Constraints are Binding from Day One*



## São Miguel

**São Miguel - 130k People**

**– The BIG Metropolis**

- Geothermal Generation
- Wind Under Construction

## Santa Maria





# The Green Islands Project

*"Big, Medium and Tiny Islands"*

*The Constraints are Binding from Day One*

## The North Central Group



Graciosa



Terceira

- *Geothermal Exploration on Terceira*
- *Electric Vehicle Deployment Demonstration on Terceira*
- *Flywheels on Graciosa*
- *Younicos Physical Simulator of Graciosa*



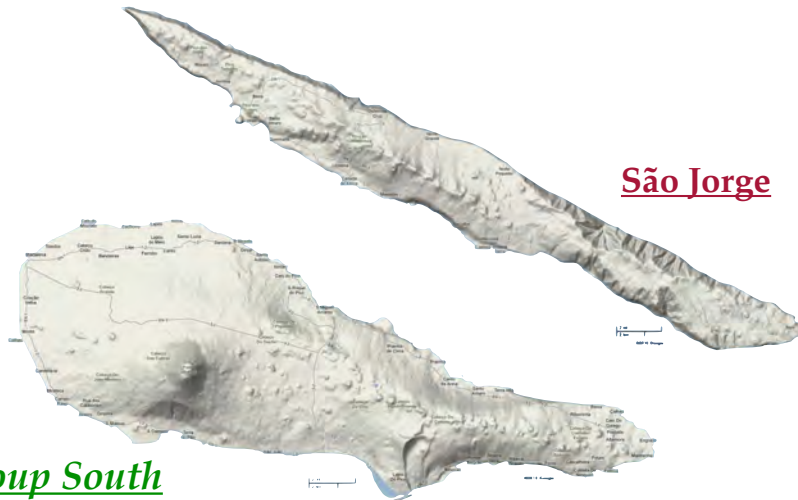
# The Green Islands Project

*"Big, Medium and Tiny Islands"*

*The Constraints are Binding from Day One*



Faial



São Jorge

Pico

## The Central Group South

- *A Diversity of Topographies*





# The Green Islands Project

*“Big, Medium and Tiny Islands”*

*The Constraints are Binding from Day One*

Corvo



Flores



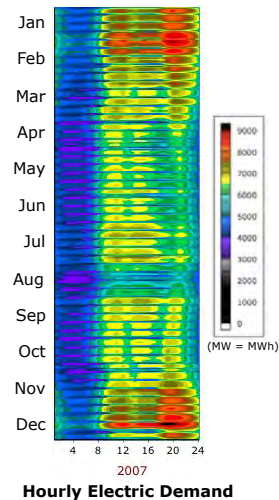
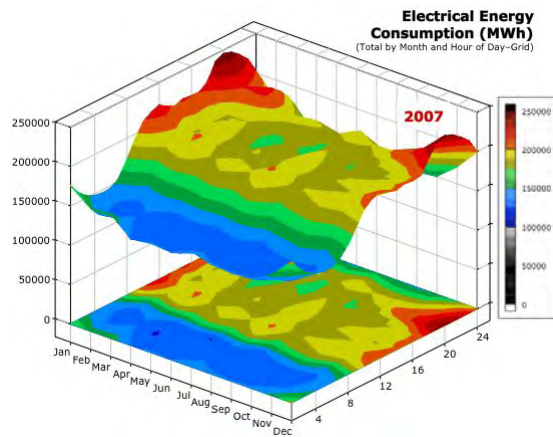
## The Western Group

- Flores – the “Most” Hydro  
*Flywheels on Flores*
- Corvo – the Smallest, all Fossil (right now)  
*Fossil Free Corvo?*



# The Green Islands Project

## Matching Electricity Demand Dynamics to Diverse Renewable Supplies

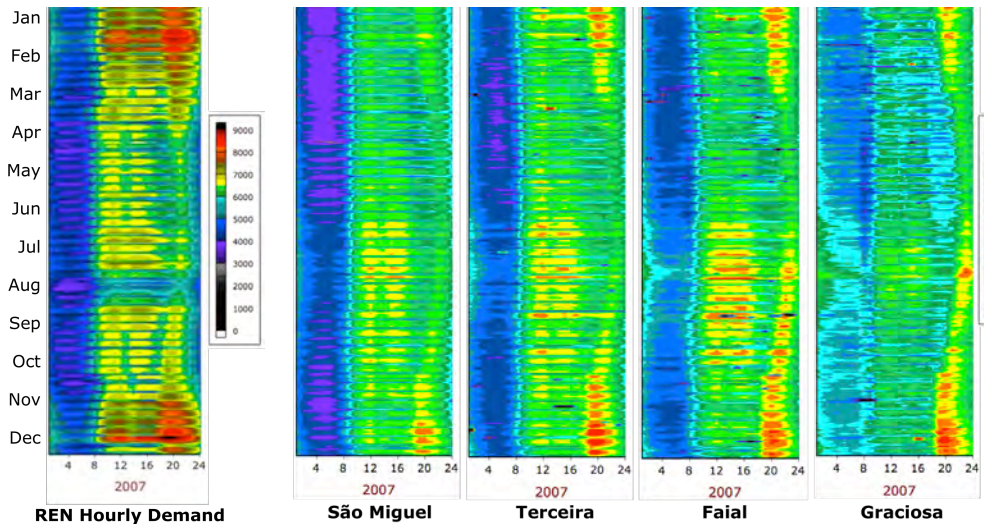




# The Green Islands Project



## Matching Electricity Demand Dynamics for Each Island

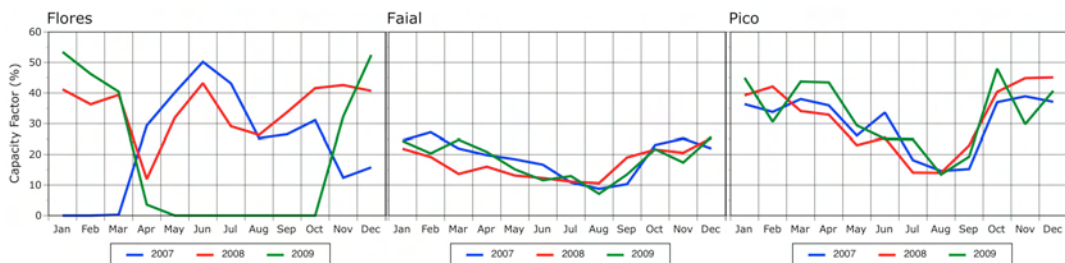


# Design Dynamics - Wind

Pam DeAmicis- TPP



- Monthly Capacity Factors – Flores, Faial and Pico Wind Farms





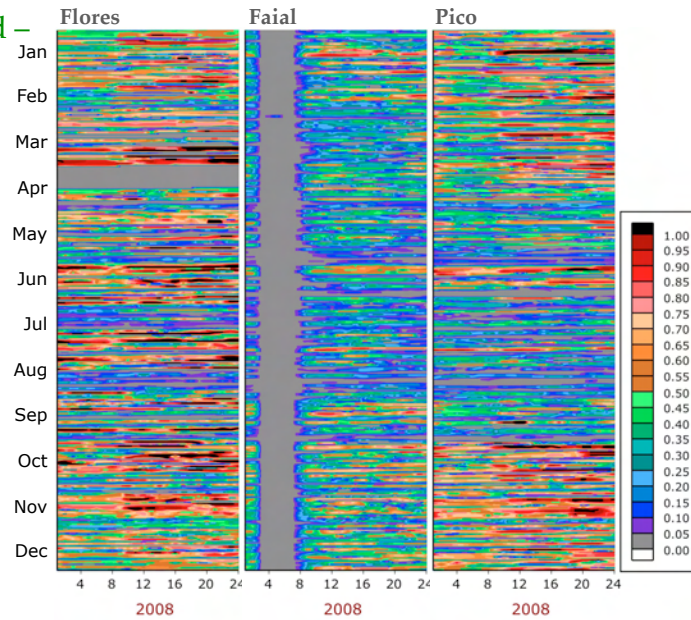
# Design Dynamics - Wind

Pam DeAmicis- TPP



- Hourly Variability of Wind – Flores, Faial and Pico Wind Farms

Hourly Generation – kWh per Hour



# Design Dynamics - Wind

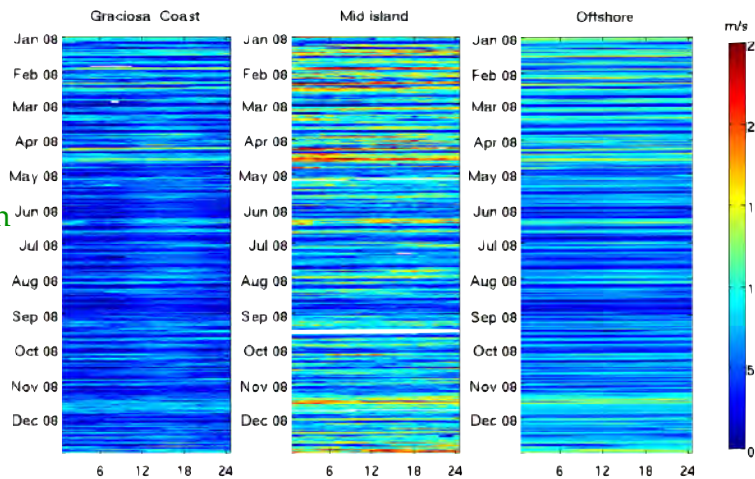
Kiti Suomalainen – IST



- Identifying Diurnal Patterns in Wind from Time-Series Wind Speed Data

## Five Daily Profiles

- Flat days
- Non-Flat days
  - Night (00:00-06:00)
  - Morning (06:00-12:00)
  - Afternoon (12:00-18:00)
  - Evening (18:00-24:00)
- Determining Transition Probability Matrices.
- Synthesizing a Sequence of Daily Profiles (365 days)
- Adding Hourly Variability to Each Daily Profile.







# Design Dynamics - Wind

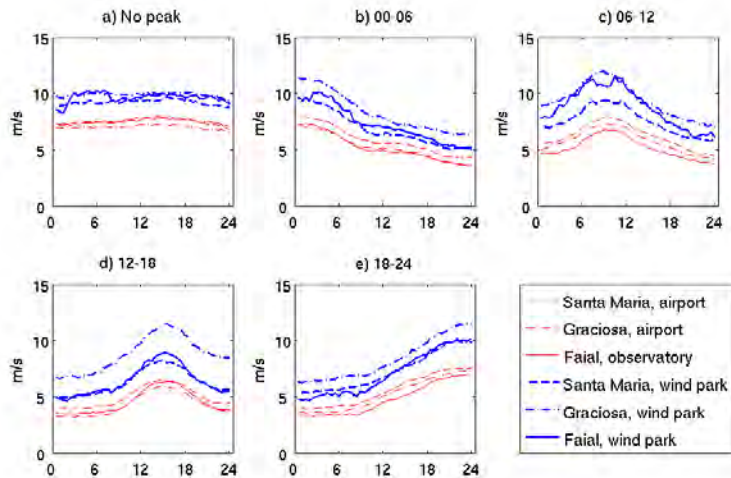
Kiti Suomalainen – IST



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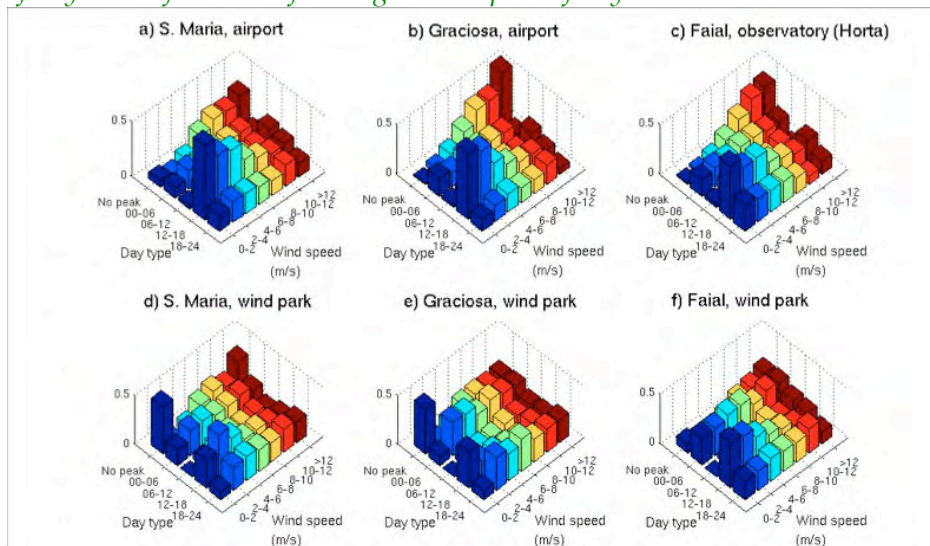


# Design Dynamics - Wind

Kiti Suomalainen – IST



- Transition Probability Matrices for Daily Profile of day  $n$  as a function of average wind speed of day  $n$



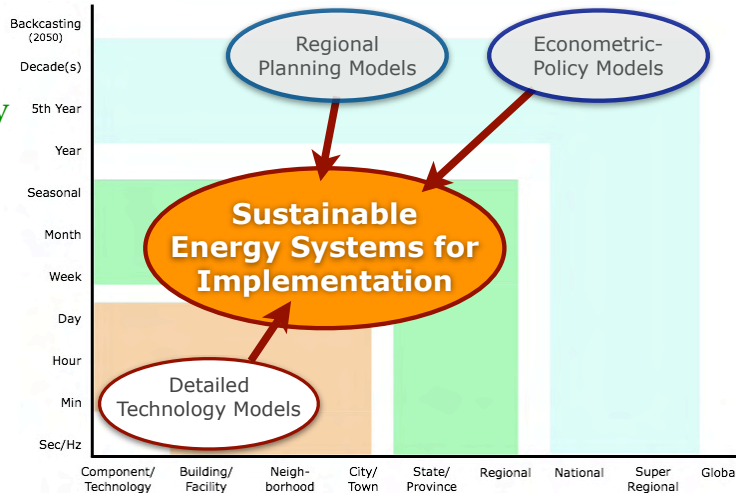


# Need for Meso-Scale Modeling

*“Technology Choice” and “Average Output”*  
*Analysis is Insufficient for Doing the Job Right*

## “Designing for the Dynamics”

- Aggressive End-Use Efficiency
  - Diversify Domestically
  - Modernize Energy Networks
- 50-80% Reduction = Hyper Local Energy



# Challenges and Opportunities

## To Large Scale Integration – in Small Systems

- A Harbinger of What’s to Come? (*Medium Voltage Wind*)
  - The more wind you have, and the longer you’ve had it, the more you know about the “**nodes and modes**” of system operation and what to do (hopefully).
- Multiple Renewables – Too much of a good thing?
  - When are they complementary? When do they compete?
  - What’s an acceptable level of “deferment?”
- Implications for “Electricity Storage”
  - How Much for How Long? Key Storage Questions?
    - Cycles to Seconds • Minutes to Hours • Hours to Day
- Will We Survive?
  - Coordinated Investments in Renewable Generation and “Smart Grids”



Big Renewables – Small Islands

## It’s the Weather – Thanks, Steve

