Prospects for Photovoltaics in Sunny and Arid Regions: A Solar Grand Plan for Chile

Part I –Investigation of PV and Wind Penetration

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[1]Columbia University, [2]Brookhaven National Laboratory,
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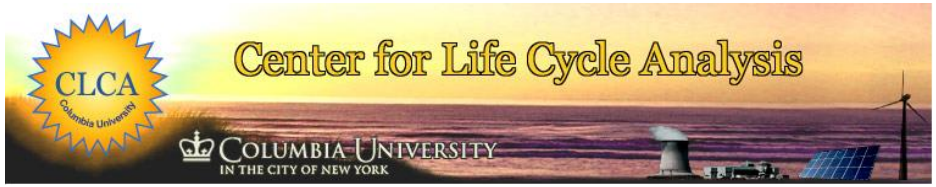

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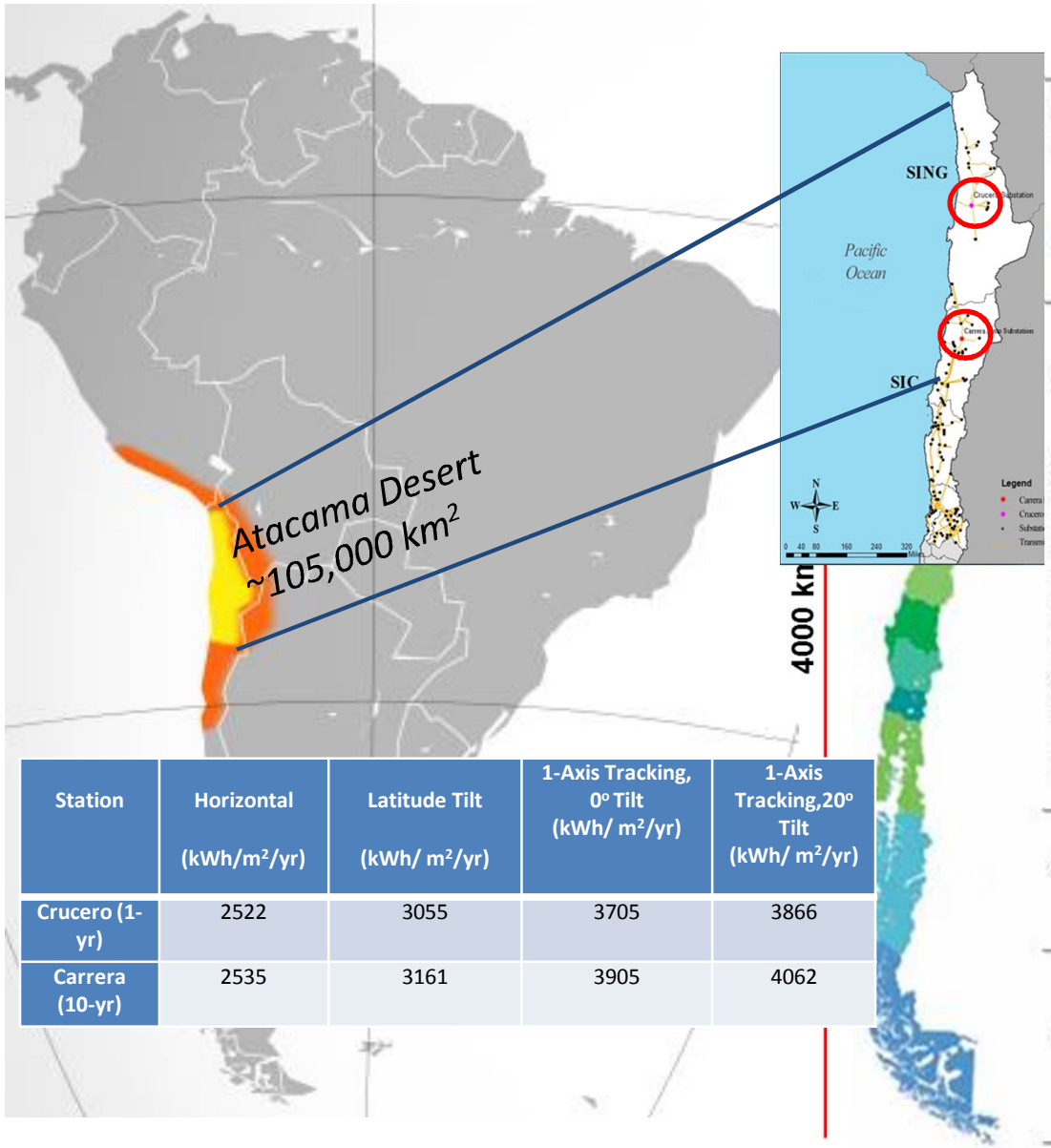
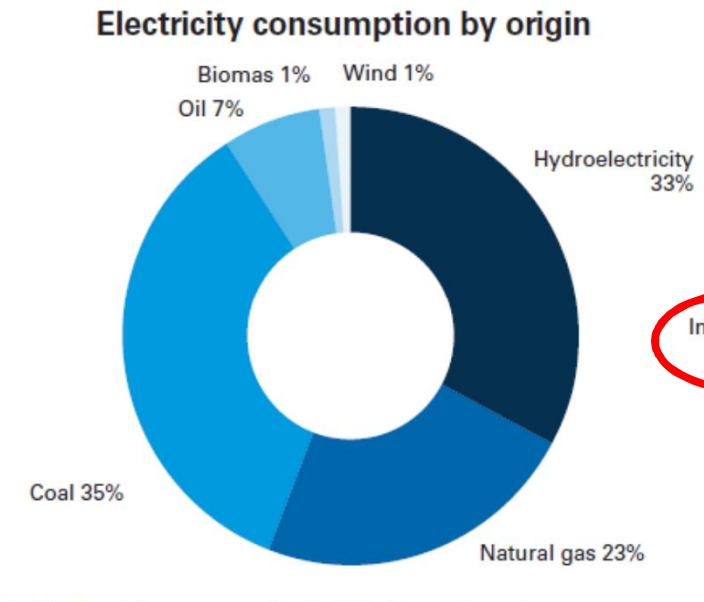
Chile: The Atacama Solar Resource

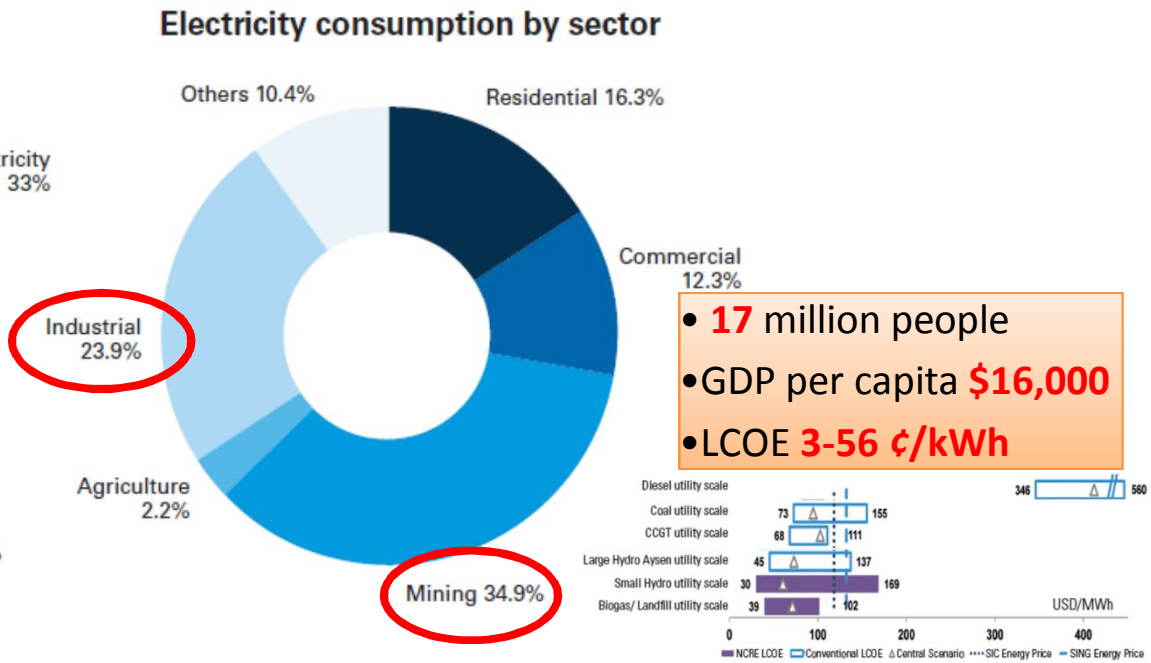


Station	Horizontal (kWh/m²/yr)	Latitude Tilt (kWh/ m²/yr)	1-Axis Tracking, 0° Tilt (kWh/ m²/yr)	1-Axis Tracking,20° Tilt (kWh/ m²/yr)
Crucero (1-yr)	2522	3055	3705	3866
Carrera (10-yr)	2535	3161	3905	4062

Arica y Parinacota Tarapacá Antofagasta	Sistema Interconectado del Norte Grande (SING) ***Capacity: 4.6 GW*** ***Load: 15.4 TWh***
Atacama Coquimbo Valparaíso Región Metropolitana Lib. B. O'Higgins Maule Bío Bío Araucanía Los Rios Los Lagos	Sistema Interconectado Central (SIC) ***Capacity: 14.1 GW*** ***Load: 47.8 TWh***
Aysén	Sistema de Aysén **50 MW**
Magallanes	Sistema de Magallanes **99 MW**

Chile 2010 Electricity Consumption

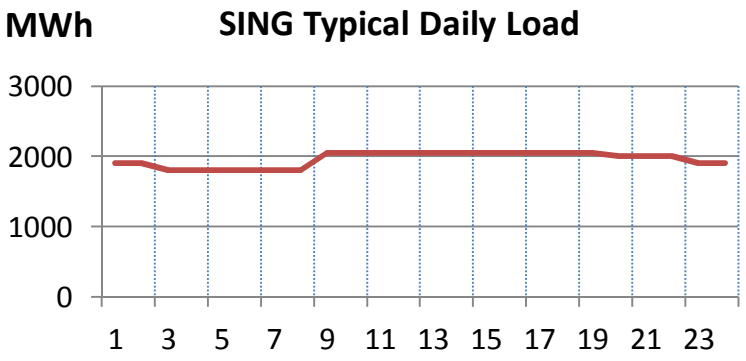


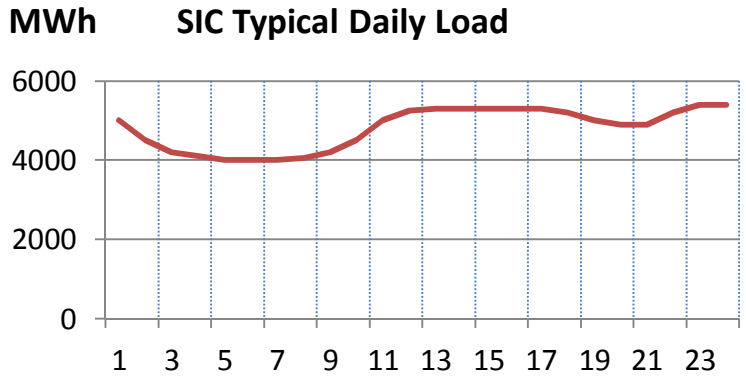


- **17** million people
- GDP per capita **$16,000**
- LCOE **3-56 ¢/kWh**

Source: www.pv-insider.com/chile

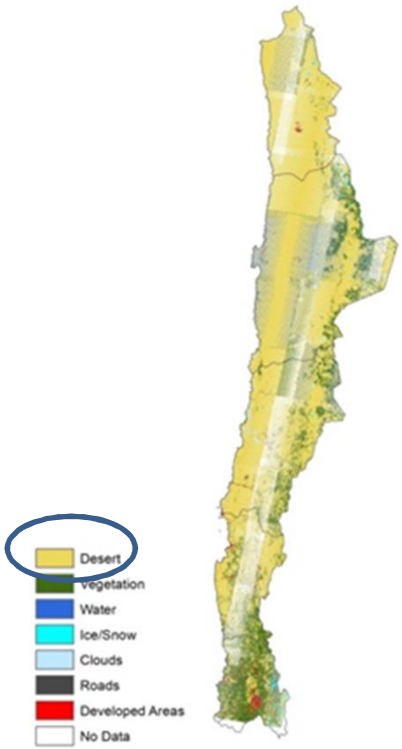
Source: Bloomberg 2011



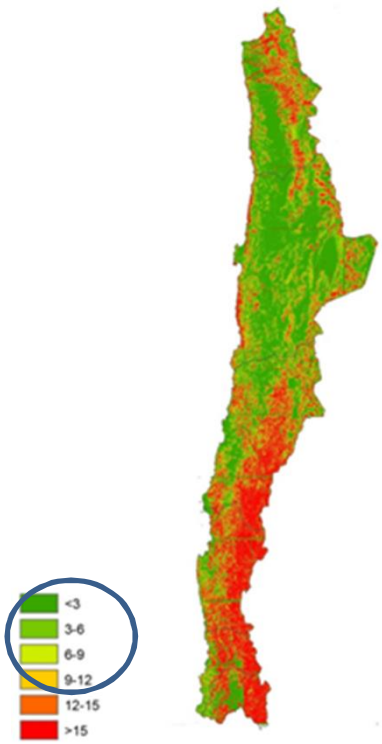


PV Site Suitability Study

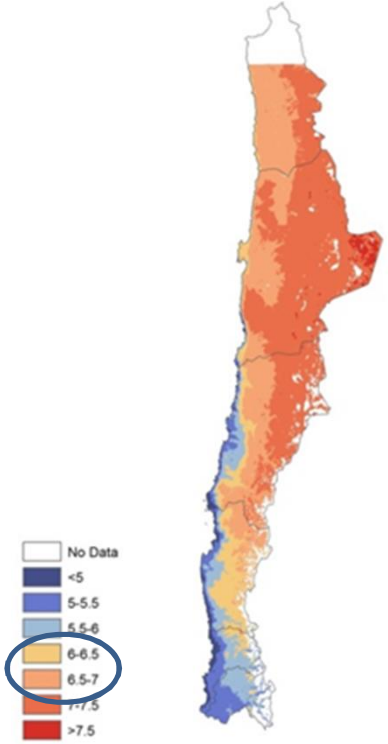
Land cover



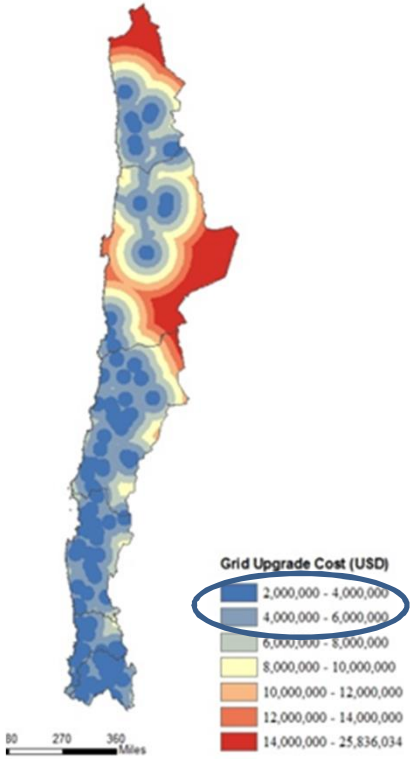
Degree of slope



Solar irradiation



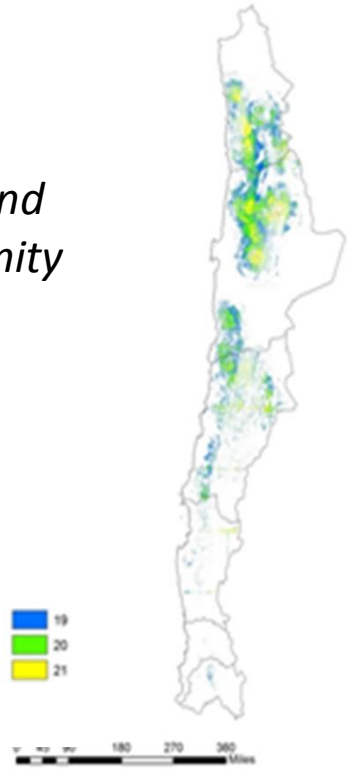
Cost to upgrade transmission

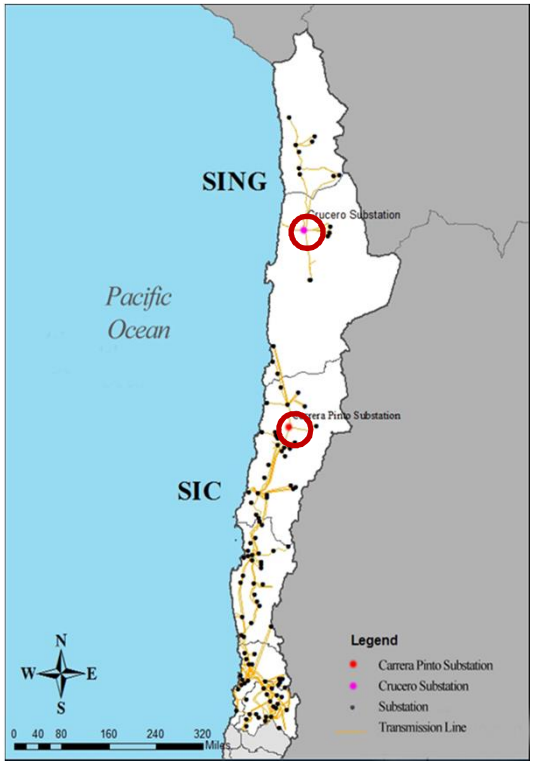


Twenty-five LANDSAT 7 images from December-March of 2010-2013 from the Peruvian border through the Santiago Metropolitan Region were mosaicked together in ArcMap

PV Site Suitability Study

Best regions for deploying PV based on a Combination of Land Cover & Tilt, Insolation, Proximity to Roads & Substations





Solar Irradiation & Wind Speed Data

Hourly Horizontal Global Solar irradiation data were accessed from Chile's Solar Explorer portal for two substations:

- Crucero (SING)
- Carrera (SIC)

Hourly Wind (ASOS) data, from Iowa State University web-site for:

(SING)

- Arica,
- Iquique,
- Calama,
- Antofagasta
- Desierto

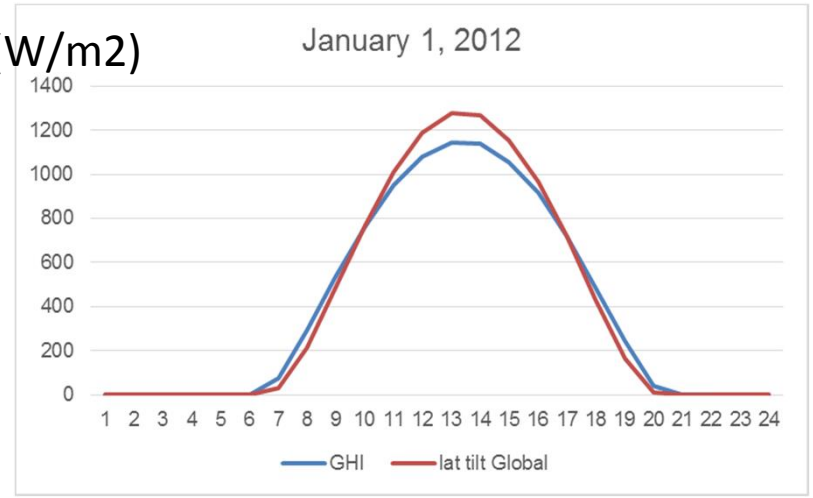
(SIC)

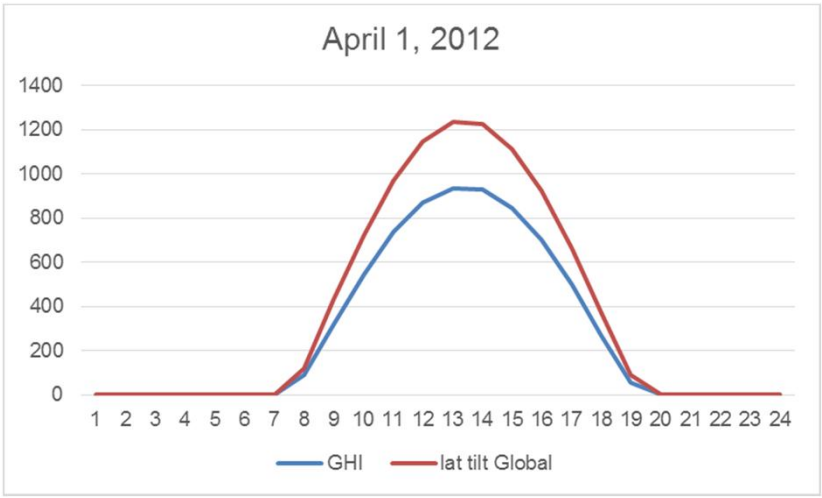
- Viña del Mar
- Concepción
- Futaleufú (SIC)

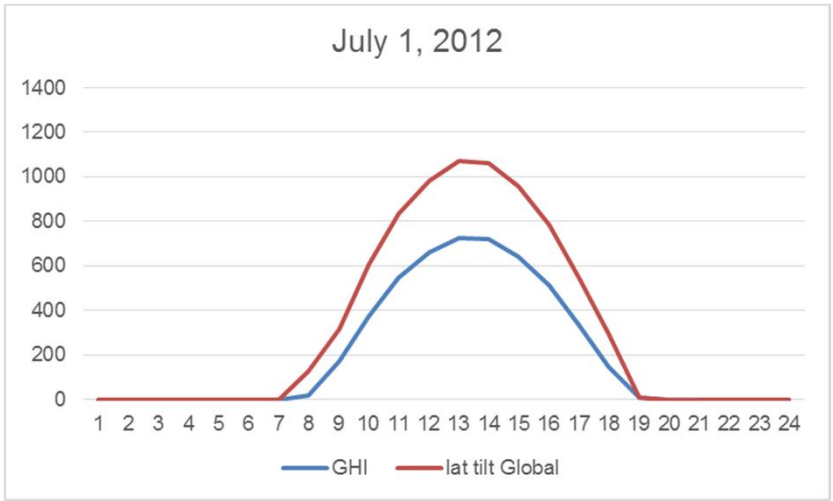
Global Horizontal Irradiation (W/m^2)

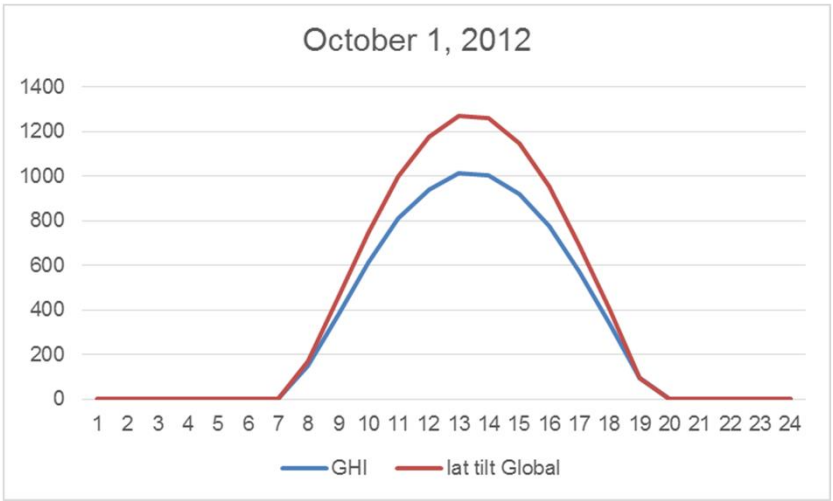
and Latitude Tilt Global Irradiation (W/m^2)

(W/m2)

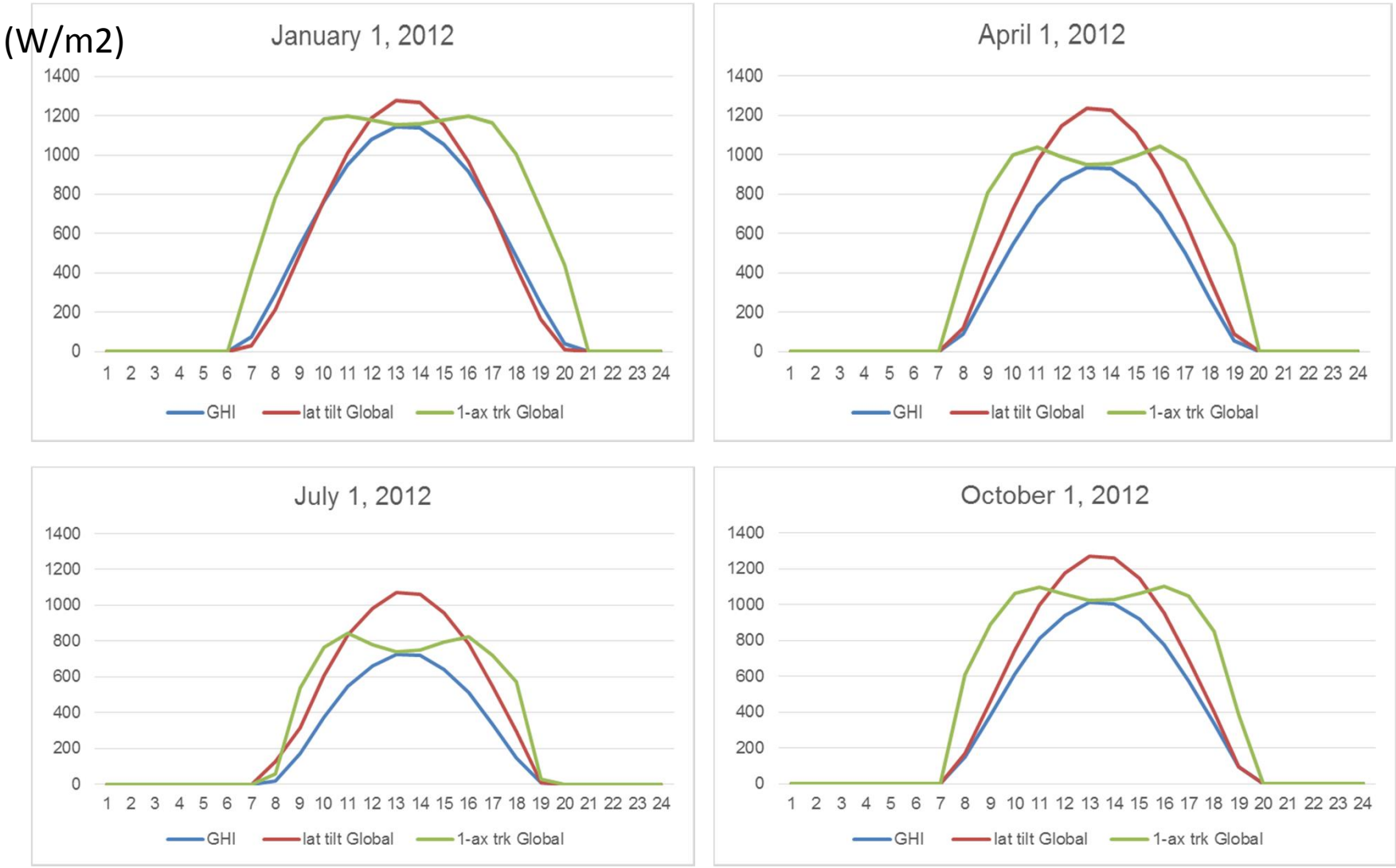








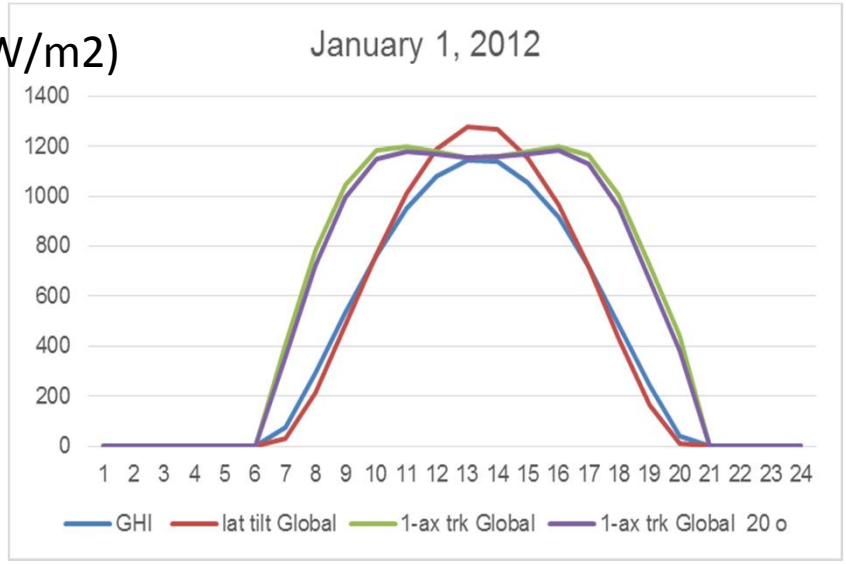
and 1-axis Tracking axis Global Irradiation (W/m^2)

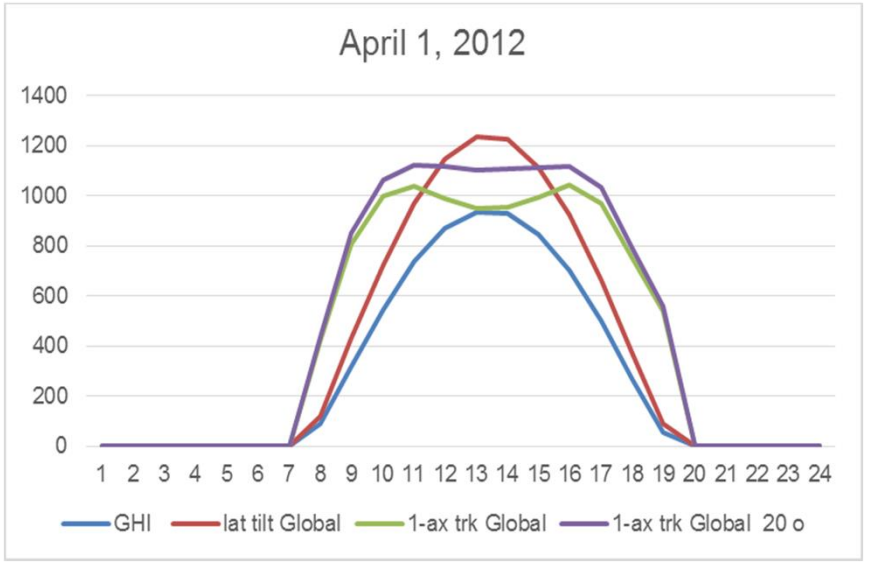


One-axis systems were modeled after First Solarôs 5 kW tracker with rotational limits of ±45 degrees

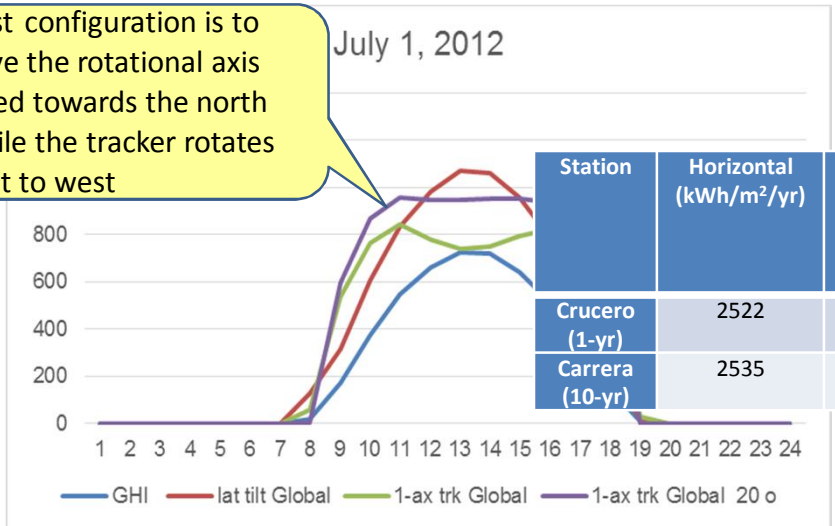
and 1-axis Tracking axis at 20 degrees Global Irradiation (W/m2)

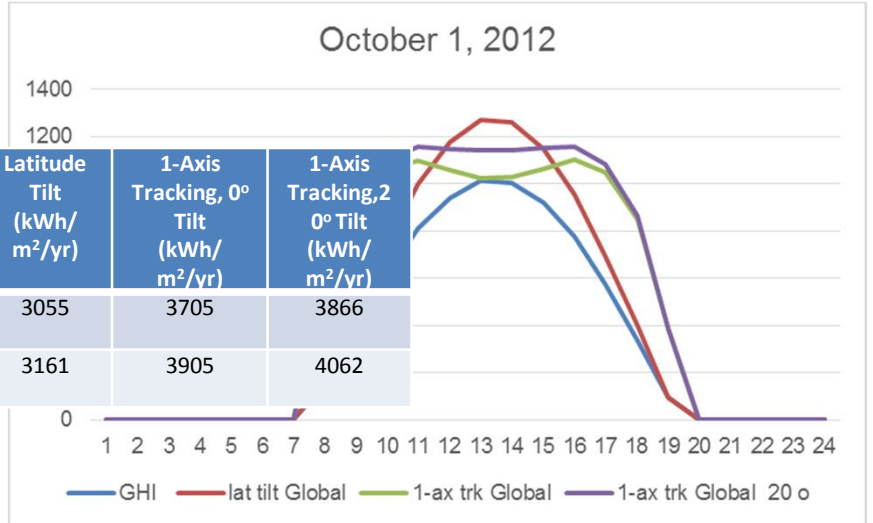
(W/m2)





Best configuration is to have the rotational axis tilted towards the north while the tracker rotates east to west





Station	Horizontal (kWh/m²/yr)	Latitude Tilt (kWh/ m²/yr)	1-Axis Tracking, 0° Tilt (kWh/ m²/yr)	1-Axis Tracking,2 0° Tilt (kWh/ m²/yr)
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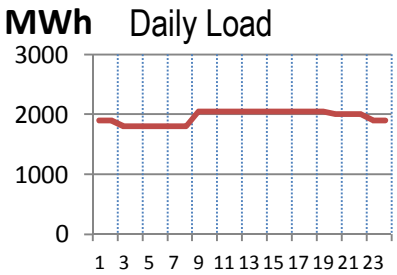
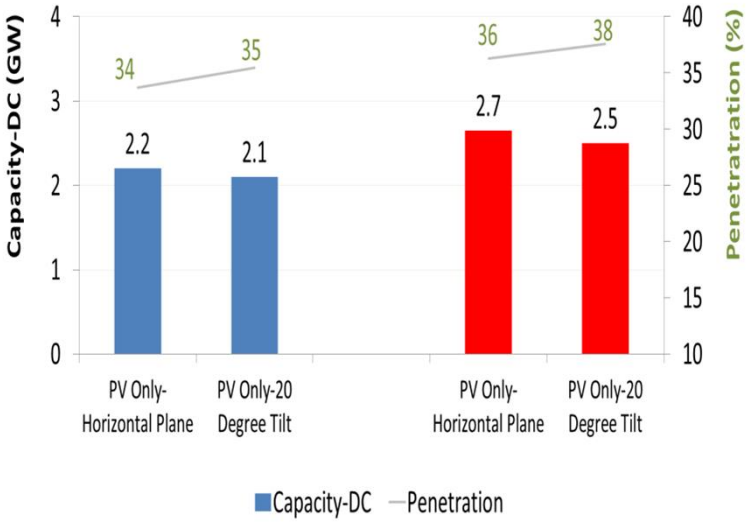
Capacity and Grid Penetration PV and Wind Separately at SING



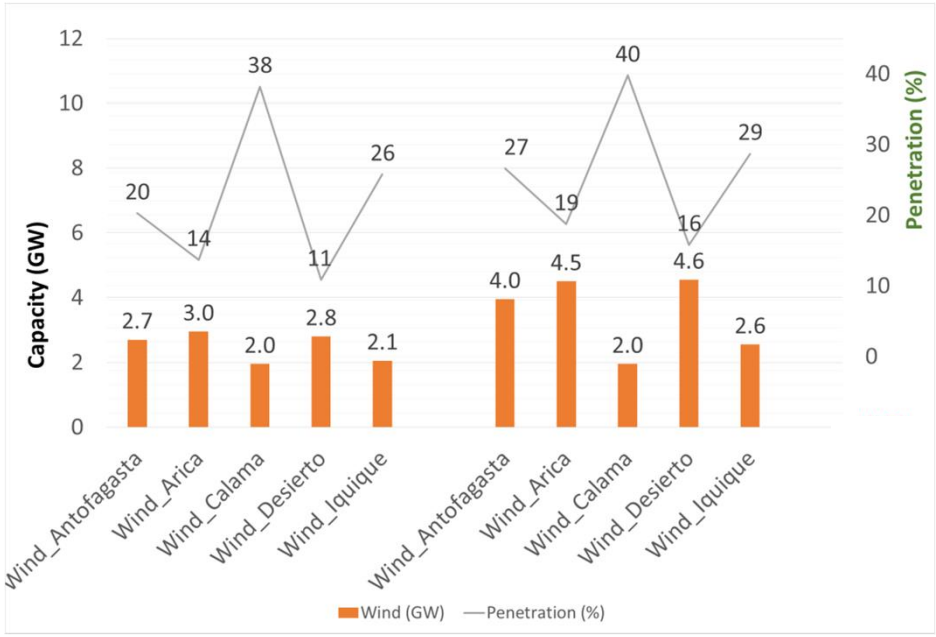
Photovoltaics

5% Curtailment *15% Curtailment*

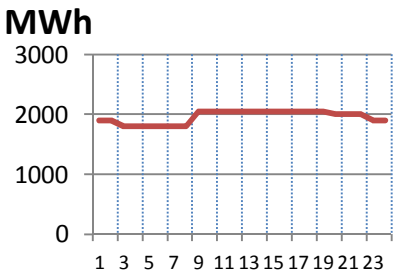


Wind

5% Curtailment *15% Curtailment*

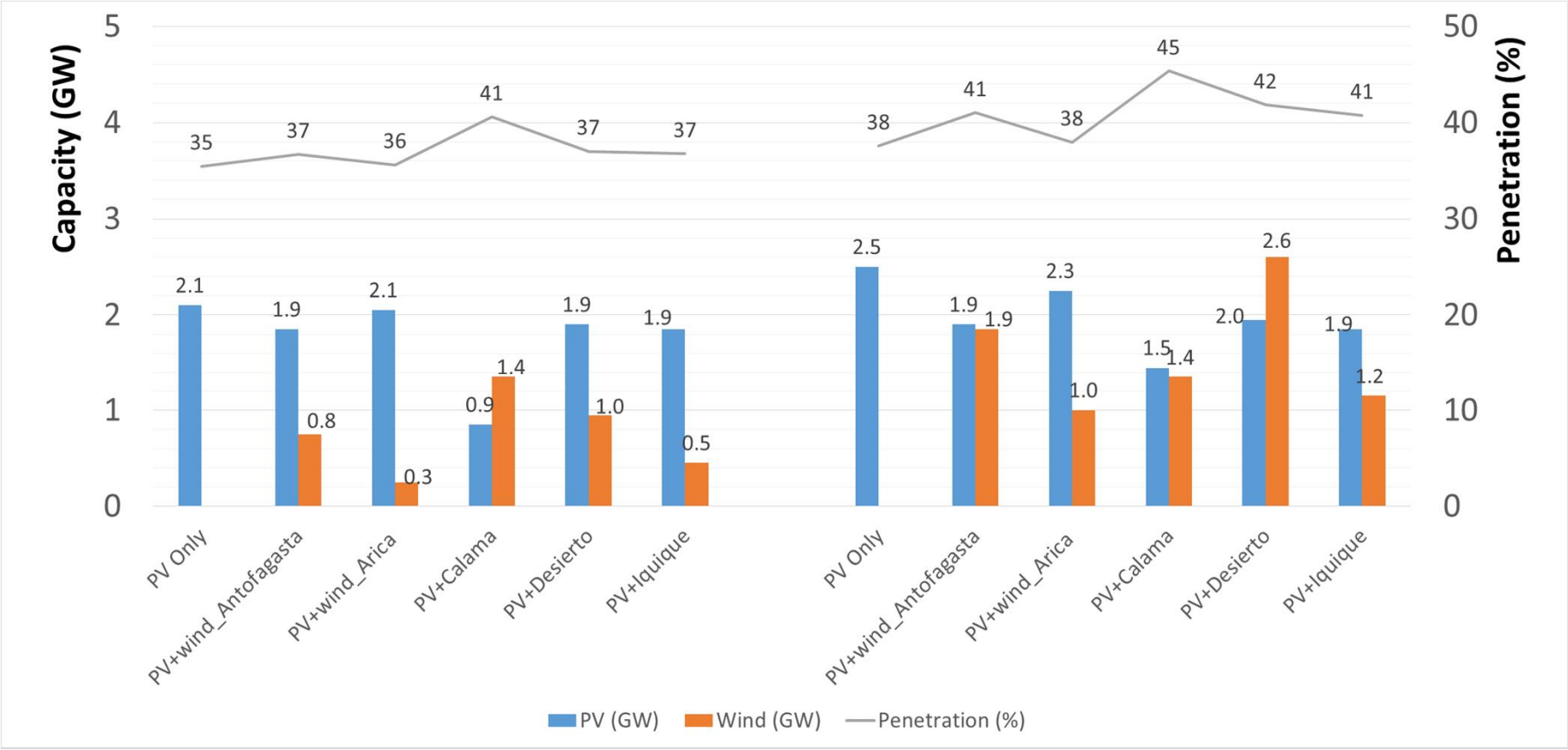


Capacity and Grid Penetration PV and Wind Together at SING

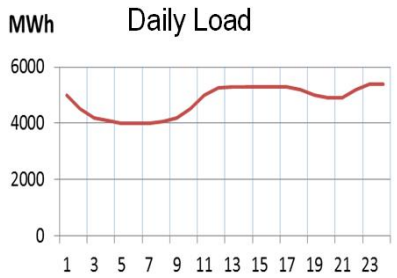


5% Curtailment

15% Curtailment



Capacity and Grid Penetration PV and Wind Separately at SIC



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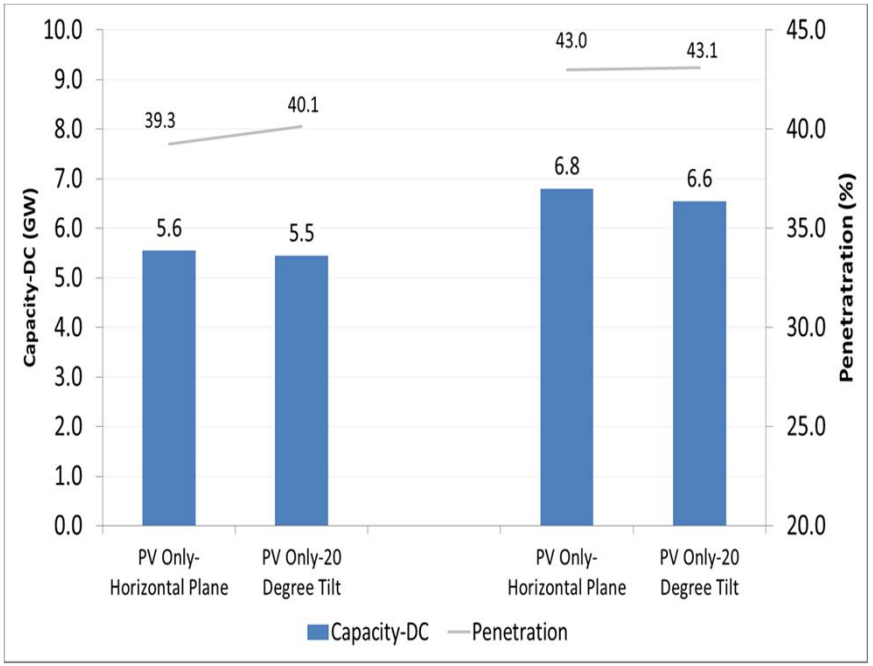
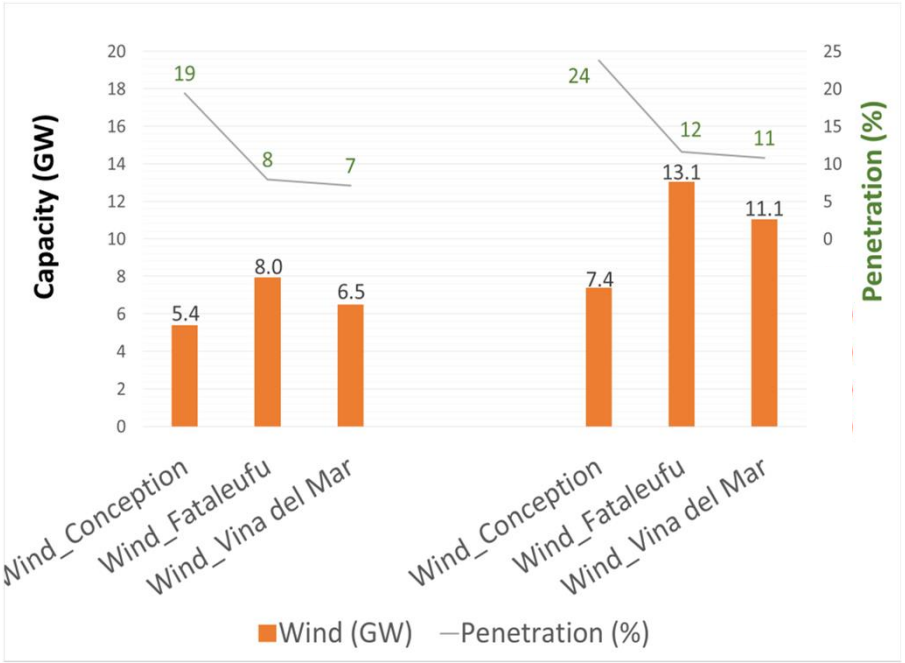
5% Curtailment *15% Curtailment*

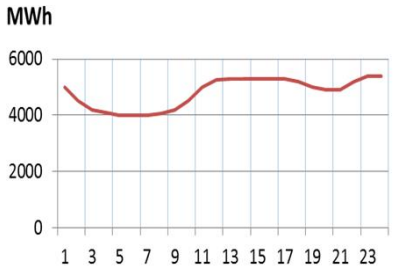


Wind

5% Curtailment *15% Curtailment*



Capacity and Grid Penetration PV and Wind Together at SIC



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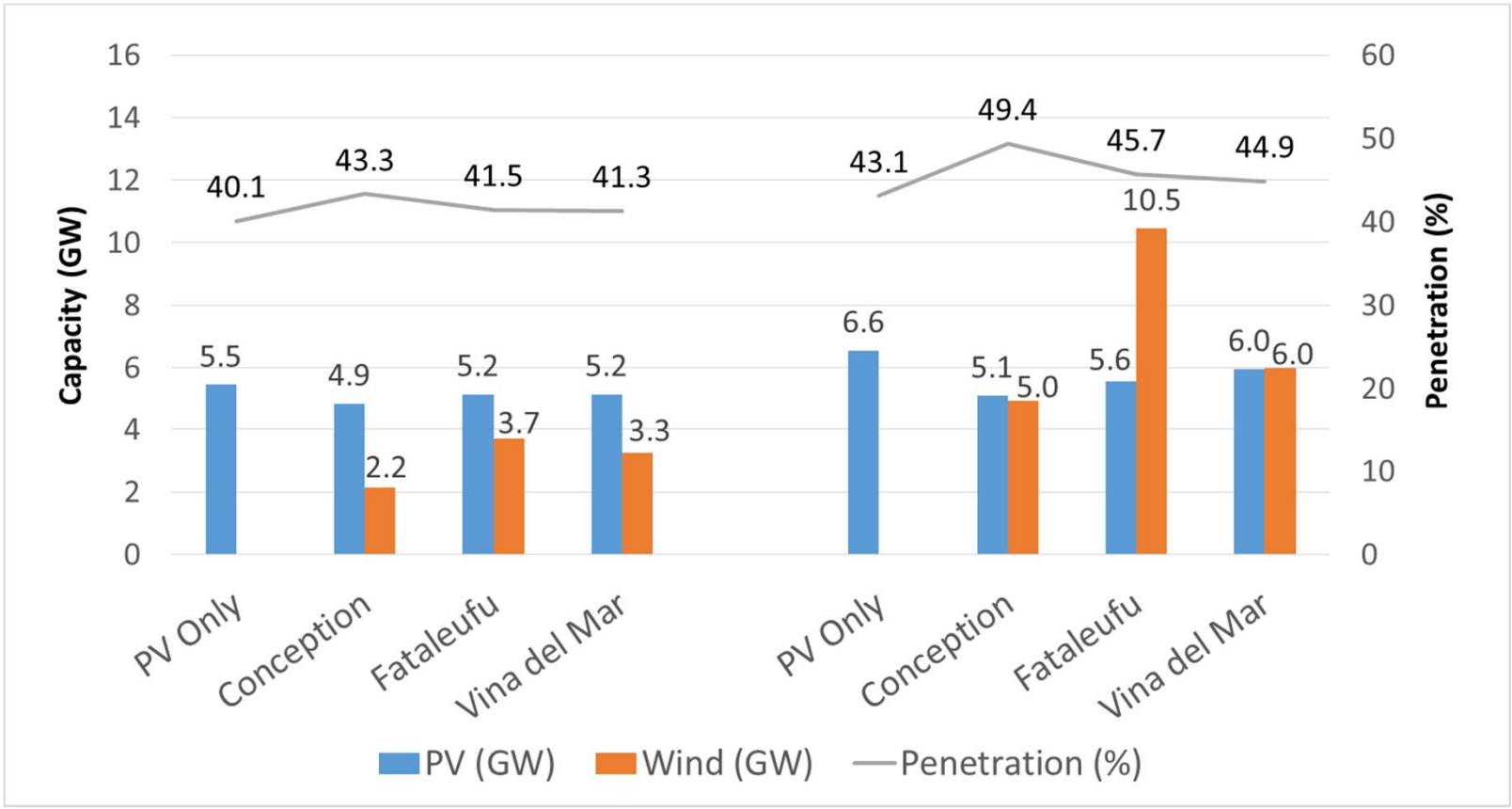
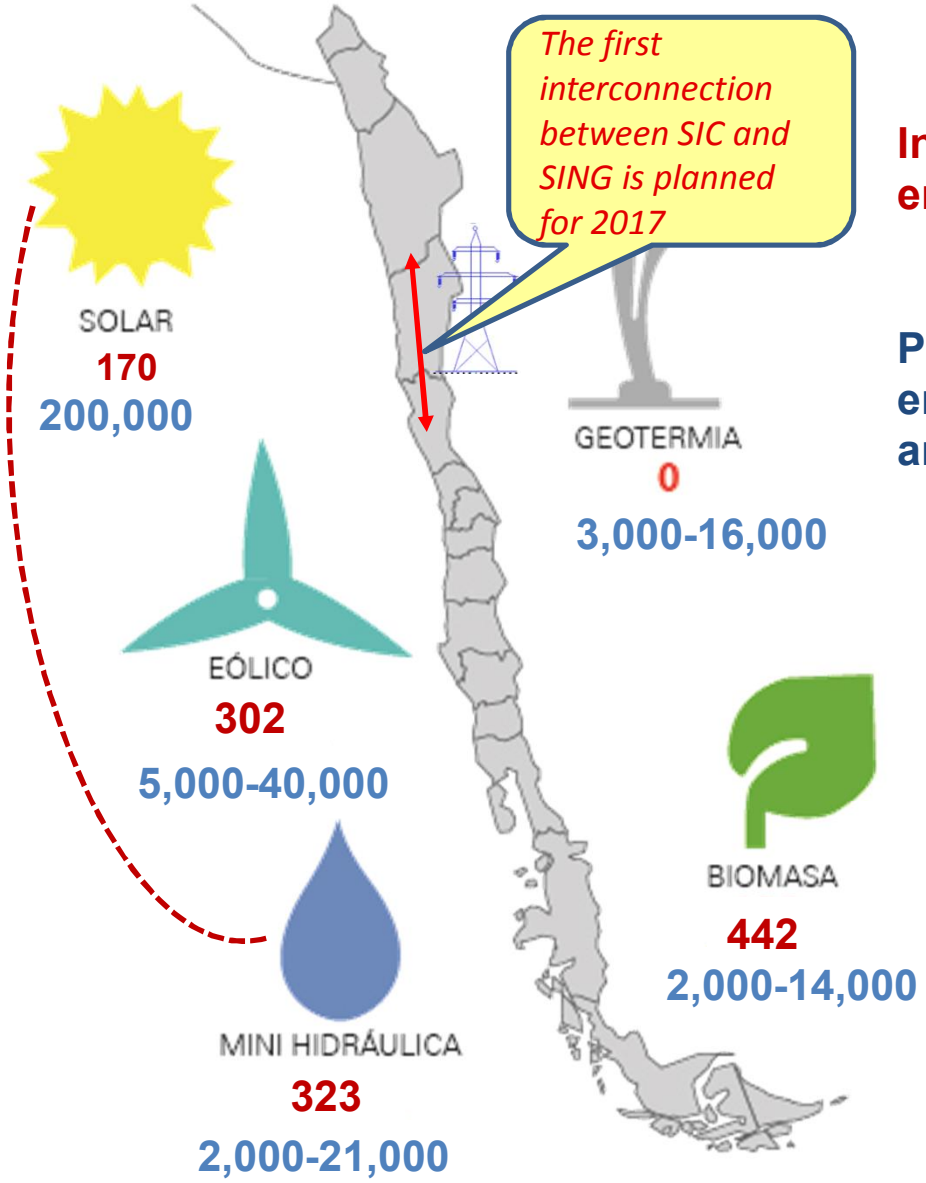


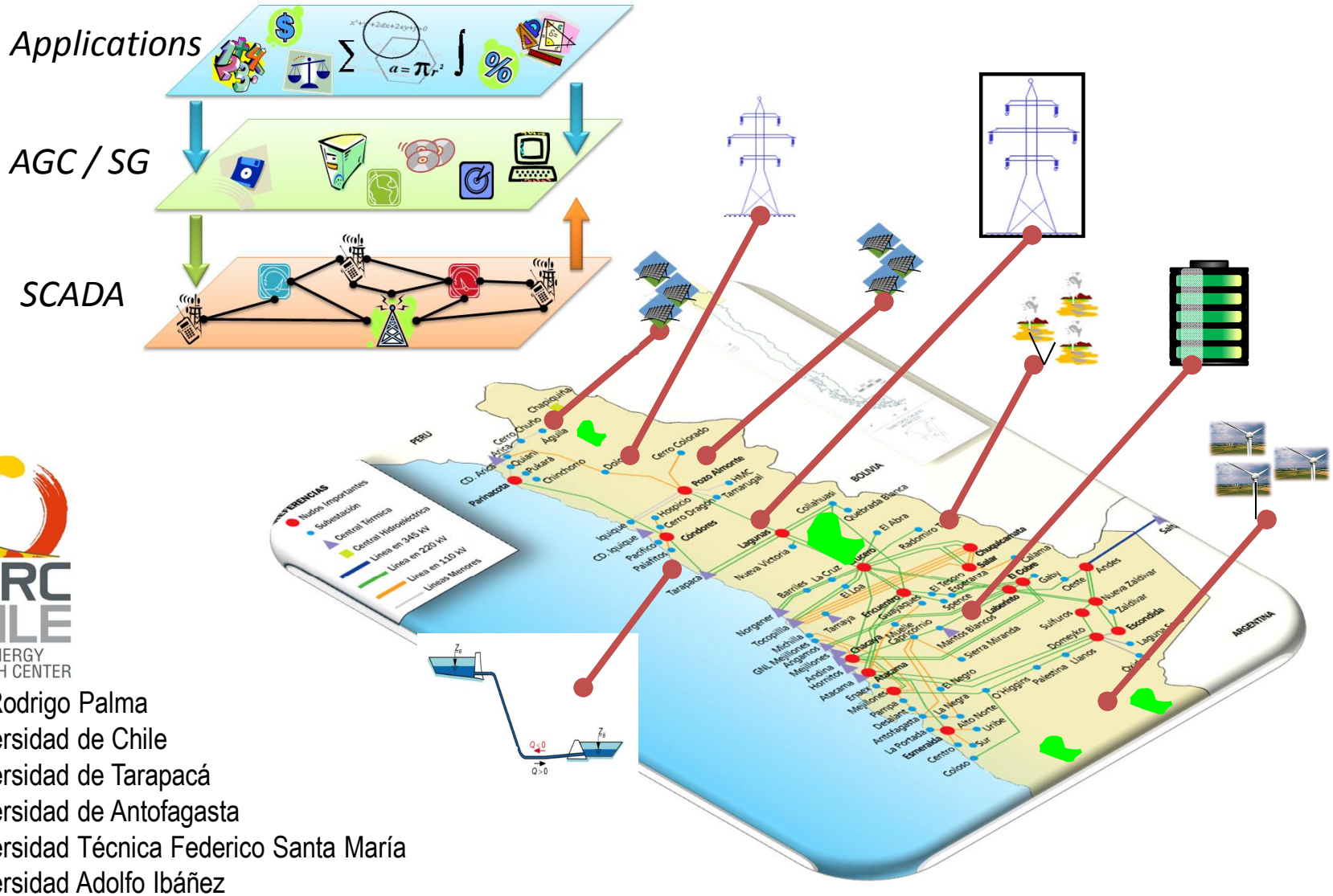
Renewable Energy Status and Potential



Installed capacity of renewable energies 1236 [MW]

Potential of renewable energies between 212,000 MW and 291,000 MW

SERC-Chile Initiatives on the *Integration of Renewables*



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Director Rodrigo Palma

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- Universidad de Tarapacá
- Universidad de Antofagasta
- Universidad Técnica Federico Santa María
- Universidad Adolfo Ibáñez
- Universidad de Concepción
- Fundación Chile

45 faculty researchers, 6 postdoc, 30 graduate, 30 undergraduate

Conclusion -Southamerican 2033 Vision

200 GW ~ 4,800 km²
2 X (49x49 km²)
or
12 X (20x20 km²)

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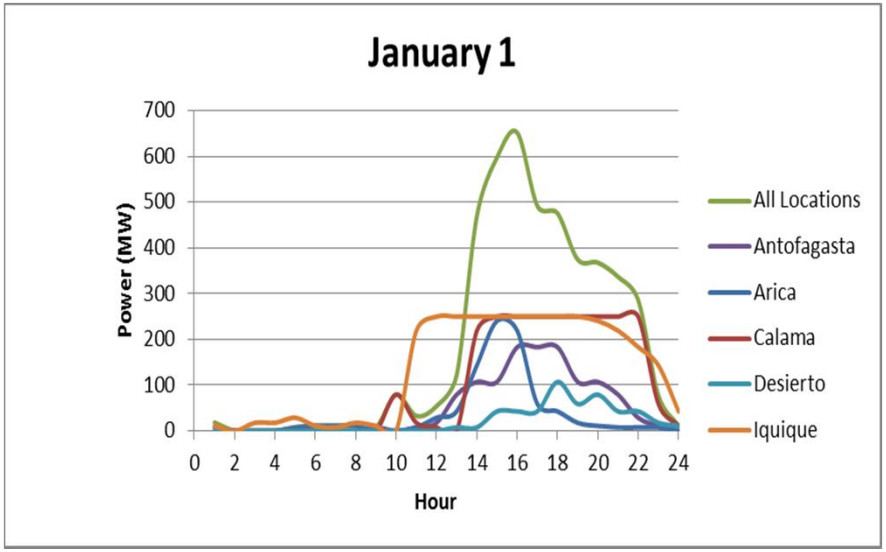
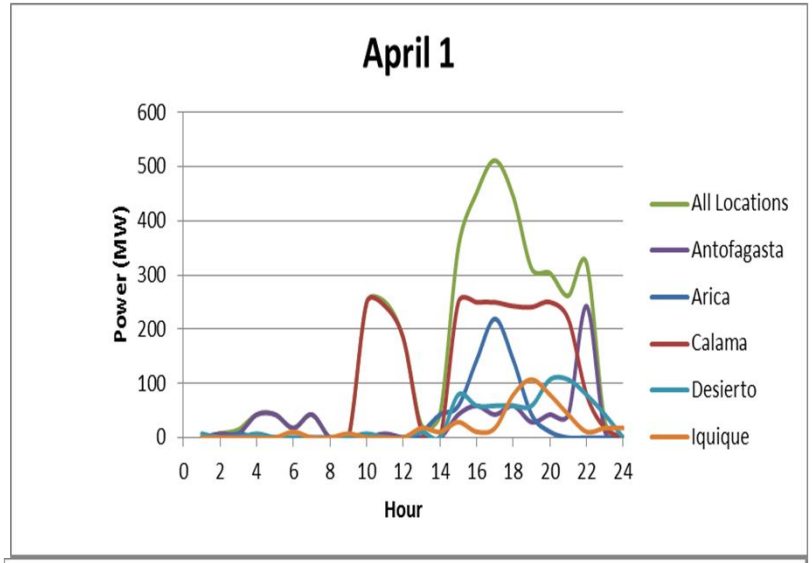
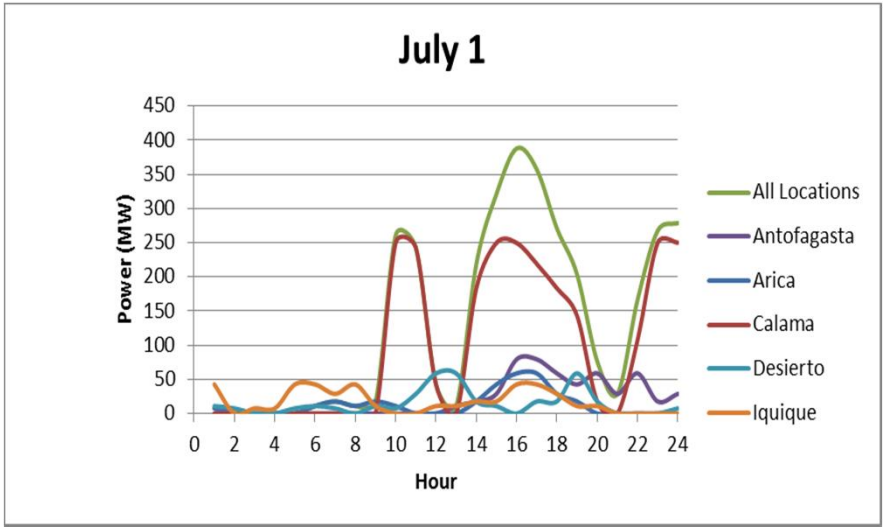
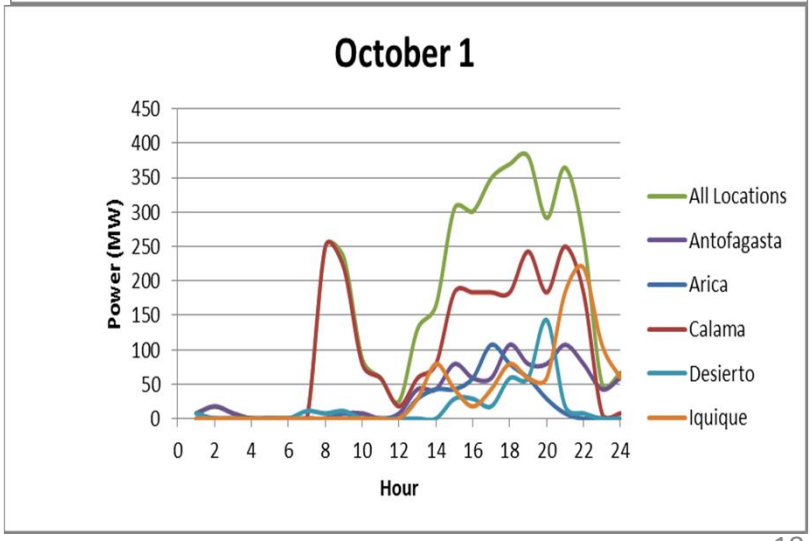
Typical hourly wind turbine outputs at SING









Typical hourly wind turbine outputs at SIC