Overview of Solar Energy in Brazil

1st Workshop Solar Energy, FAPESP

13/11/2017

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LABREN - Laboratory for Modelling and Studies of Renewable Energy Resources
INPE – National Institute for Space Research
Brazil’s NDC
Nationally Determined Contributions
Brazil’s Commitment to the Paris Agreement

Greenhouse gas emissions

2005
-37%

2030

Brazil commits to sourcing 23% renewable non-hidro electricity generation by 2030

- Land Use and Forests 46%
- Agriculture 22%
- Energy Generation 24%
- Industrial Processes 5%
- Waste Treatment 3%

2015

14/11/2017 1st Workshop Solar Energy - FAPESP
Brazil’s electricity energy matrix

Wind and photovoltaic may be the answer to achieve the NDC goal for non-hydro renewable energy generation along with biomass.
Solar irradiance in Brazil
Information barrier

• Variables energy source

• Energy planning and investments demand secure science-based information to assure the return of their investments and to obtain financing for their projects

• Stakeholders are interested in the knowledge of the influence of climate variability on
  • solar resource;
  • solar variability and trends;
  • Hydro-solar-wind complementarity, etc.
New science sector: **Energy Meteorology**

- Influence on local/regional climate
  - Long-term influence: CLIMATE
  - Short-term influence: WEATHER
- Global climate change
  - Energy conversion
  - Energy distribution
  - Energy use

- Power plants, Wind farms, PV plants, ...
- Electricity grid
- Consumer
LABREN - Laboratory for Modelling and Studies of Renewable Energy Resources

http://labren.ccst.inpe.br

The multidisciplinary laboratory LABREN-CCST-INPE, carries out research and teaching activities in energy meteorology and in the climate system influence on energy resources making use of satellite data, computational modelling and observational data.

**Research Topics:**

- Assessment of solar and wind energy resources
- Short and medium-term forecast of solar and wind generation
- Energy and global climatic changes
- Site-specific measurements, characterization and modelling of solar and wind resources
Solar resource assessment
Large areas – available information

• Most of the available information sources for Brazilian territory are State Governments initiatives through bidding contracts

• Available information are based on statistical interpolation of ground observations
Ground data versus model data

Interpolation error (%) vs. Distance between stations (km)

- Interpolation
- Extrapolation

Break-even (20 – 40 km)

An INPE accomplishment in association with several national universities

- 17 years of satellite data
- Spectral radiation transfer model
- Validation by using more than 500 ground sites
- National coverage

Download pdf and shape format data at:
http://labren.ccst.inpe.br/atlas_2017.html
Site-specific solar assessment

Model development
Feasibility of projects
Due-diligence

- Ground measurements
- Public solarimetric stations and/or networks
- Site-specific from projects - proprietary data
SONDA network
http://sonda.ccst.inpe.br/
A BSRN/WMO associate

- INMET network
http://www.inmet.gov.br/

Data acquisition sites managed by LABREN

<table>
<thead>
<tr>
<th>Estação</th>
<th>Tipo</th>
<th>UF</th>
<th>Altitude (m)</th>
</tr>
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<tbody>
<tr>
<td>Belo Jardim</td>
<td>A</td>
<td>PE</td>
<td>718</td>
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<tr>
<td>Brasília</td>
<td>SA</td>
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<td>MA</td>
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<tr>
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<td>PB</td>
<td>891</td>
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<tr>
<td>São Martinho da Serra</td>
<td>SA</td>
<td>RS</td>
<td>58</td>
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<tr>
<td>Triunfo</td>
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Data acquisition sites managed by partners and collaborators

<table>
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<th>Tipo</th>
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<th>Altitude (m)</th>
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<td>Curitiba</td>
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</tr>
<tr>
<td>Florianópolis</td>
<td>S</td>
<td>SC</td>
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<tr>
<td>Joinville</td>
<td>S</td>
<td>SC</td>
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<tr>
<td>Natal</td>
<td>S</td>
<td>RN</td>
<td>58</td>
</tr>
<tr>
<td>Sombrio</td>
<td>S</td>
<td>SC</td>
<td>15</td>
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</table>
PV yield (kWh/kWp)
Global latitude tilted irradiation
Global latitude tilted irradiation
Maximum percentage deviation between modeled and observed monthly average of daily global irradiation for the percentiles of 10% and 90%
## Model Uncertainties (daily totals of global horizontal irradiation)

<table>
<thead>
<tr>
<th>Região</th>
<th>r</th>
<th>Viés (Wh/m²)</th>
<th>Viés (%)</th>
<th>REQM (Wh/m²)</th>
<th>REQM (%)</th>
<th>Irradiação Global Horizontal Média Observada (Wh/m²)</th>
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</thead>
<tbody>
<tr>
<td>Norte</td>
<td>0,81</td>
<td>30</td>
<td>0,6%</td>
<td>467</td>
<td>9,7%</td>
<td>4825</td>
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<tr>
<td>Nordeste</td>
<td>0,87</td>
<td>12</td>
<td>0,2%</td>
<td>456</td>
<td>8,3%</td>
<td>5483</td>
</tr>
<tr>
<td>Centro-Oeste</td>
<td>0,86</td>
<td>23</td>
<td>0,5%</td>
<td>421</td>
<td>8,3%</td>
<td>5082</td>
</tr>
<tr>
<td>Sudeste</td>
<td>0,91</td>
<td>4</td>
<td>0,1%</td>
<td>416</td>
<td>8,4%</td>
<td>4951</td>
</tr>
<tr>
<td>Sul</td>
<td>0,98</td>
<td>-4</td>
<td>-0,1%</td>
<td>395</td>
<td>8,9%</td>
<td>4444</td>
</tr>
<tr>
<td>Médio</td>
<td>0,89</td>
<td>12</td>
<td>0,2%</td>
<td>421</td>
<td>8,2%</td>
<td>5153</td>
</tr>
</tbody>
</table>
Model Validation (mean daily totals for global horizontal irradiation)

Good agreement of distribution curves between observed and modelled values
Space variability
daily totals of global horizontal irradiation

The 25 percentile values of global solar irradiation, i.e. **75 % of the days** present daily totals of global horizontal solar irradiation above these values.
Annual Variability
daily totals of global horizontal irradiation
(kWh/m².dia)
Seasonal Variability
daily totals of global horizontal irradiation (kWh/m².dia)
Trends (mean daily totals for global horizontal irradiation)

Mann-Kendall trend analysis at 95% confidence level
Comparison (Brazilian regions versus Europe)
Solar Hot-Water
(standard sized system)

Yearly specific thermal energy production - kWh/m³

- Standard systems in North and Northeast became oversized and saturates the thermal energy production because of the absence of demand.
- Higher thermal energy production causes higher money savings in South and Southeast.
Potential for CSP (kWh/m².year)
Fast growing PV Distributed Generation Market

PV distribute market

Source: Instituto IDEAL, 2017

Number of companies in the PV sector

- 8,114 residential
- 1,541 commercial
- 213 industrial

N = 373

Number of PV systems:
- 0
- 7 - 83
- 100 - 200
- 223 - 556
- 894 - 1,180
- Above 2,000
Installed Capacity of Distributed PV Installations by Consumption Type

- Commercial: 38%
- Public Lighting: 4%
- Industrial: 10%
- Public Buildings: 5%
- Residential: 10%
- Rural: 0%
- Public Services: 1%
- 42%

Prices R$/Wp of distributed PV in 2016

3.81R$ = 1€
Large-Scale PV Power Plants in Electricity Auctions

<table>
<thead>
<tr>
<th></th>
<th>Leilão PE 2013</th>
<th>LER 2014</th>
<th>1º LER 2015</th>
<th>2º LER 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contracted (MWp)</td>
<td>92,0</td>
<td>719,9</td>
<td>1.043,7</td>
<td>1.075,7</td>
</tr>
<tr>
<td>Cumulative Contracted (MWp)</td>
<td>92,0</td>
<td>811,9</td>
<td>1.855,6</td>
<td>2.931,3</td>
</tr>
<tr>
<td>Average Price (US$/MWh)</td>
<td>103,0</td>
<td>88,0</td>
<td>85,0</td>
<td>78,0</td>
</tr>
</tbody>
</table>

Location of authorized ventures in PV energy auctions
The Brazilian market for flat plates solar heaters

Fast growing: 3rd place in added capacity behind only of Turkey and China

Source: ABRAVA, 2017
PV potential from degraded areas

Questões:
- Critério para definir áreas degradadas
- Percentual útil para geração de energia
Theoretical potential for solar energy
Daily electricity consumption curve

Usina Celso Furtado, BA
potência instalada de 186 MW
Variability – integrated distribution sistem
Challenges to Overcome in Developing the potential of Brazilian Solar PV:

- **Clear demands (ABSOLAR)**
  - Large-scale PV: auction at least 2 GW per year.
  - Distributed PV: set a goal of 1,2 million systems (4.5 GW) by 2024.
  - Establish a national PV goal of at least 30 GW by 2030.
- **Financing**
  - Improve and diversify financing options for small and large projects.
- **Taxation**
  - Promote tax exemption of the main PV components and equipment: IPI, PIS, COFINS and ICMS.
- **Value chain**
  - Improve public awareness
  - Develop and implement a competitive industrial policy for local manufacturing of PV components and equipment.
- **Research**
  - Improve solar energy resource assessment methods
  - Develop new and better methods of solar energy forecast
  - Expand solar radiation measurement network
  - Improve the national capacity building
Thanks!