

# Potential for Wind and Solar Energy Hybrid Power Generation: The case of Brazil

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## ABSTRACT

Developing new renewable energy is a key factor for the transition from fossil fuel-based global energy sources to alternative and diversified resources with lower environmental impacts. In this context, wind and solar photovoltaic energy have stood out significantly in recent years in terms of investments, research and expansion of the world's installed capacity. The objective of this work is to show the panorama of wind and solar energy in Brazil and demonstrate its undeveloped strategic potential for centralized combined generation of electricity. The methodology used is based on the analysis of official studies, research and thematic maps and the presentation of two pilot projects of hybrid power plants. The preliminary results indicate that there is great potential for the realization of future centralized hybrid generation, combining wind and solar photovoltaic energy sources in several regions of Brazil, especially in the Northeast Region, with an emphasis on the State of Bahia.

## METHODOLOGY

The methodology applied is descriptive, exploratory, qualitative and quantitative. This article presents a literature review, data and analyses of official studies, data and thematic maps of some national and international agencies and associations, academic researches and the presentation of two case studies of hybrid power plants. The hypotheses presented for Brazil are: (i) The existence of great expansion potential of wind and solar energy; (ii) Current national regulations are functional for wind and solar energy separately, but they don't exist for hybrid power plants; (iii) The existence of a great potential to implement hybrid power plants; (iv) Need of regulatory framework enhancement in order to make wind-PV solar hybrid power plants more feasible.

## COST COMPARISON OF RENEWABLE ENERGIES SOURCES

In 2018, according to IRENA (2019) the global weighted-average Levelized Cost of Energy (LCOE) for commissioned onshore wind and PV solar energy projects were all competitive with the fossil-fuel cost range, even in the absence of financial support (Fig. 1).

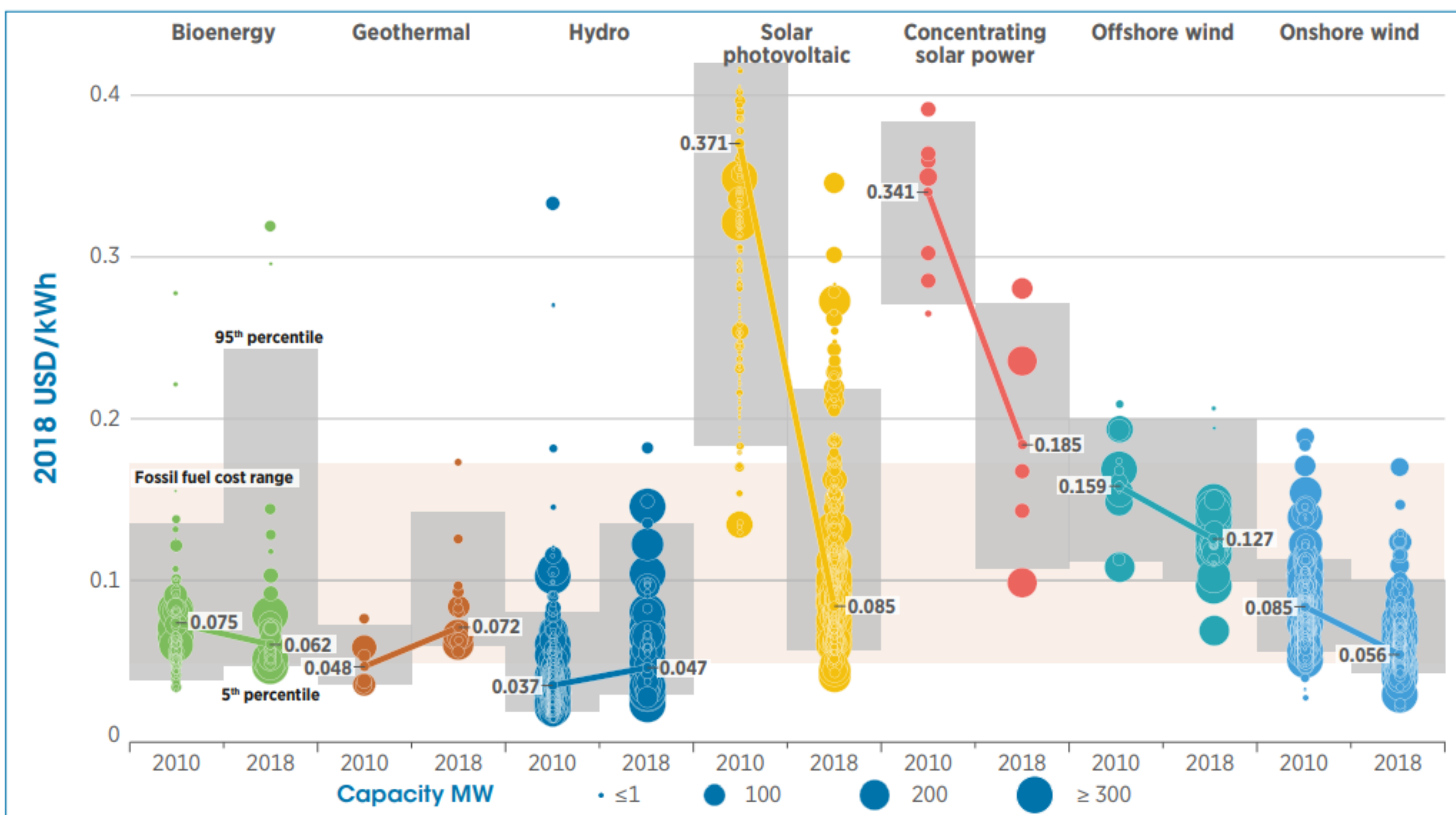


Fig. 1. Global LCOE (USD/kWh) of utility-scale renewable power generation technologies: 2010–2018.

## REGULATORY FRAMEWORK IN BRAZIL

The main references of centralized power generation regulatory framework that influenced and influence the development of wind energy in the BES are described in the Table 1:

Table 1. Regulatory Framework of BES in Brazil.

| References of Legal Framework   | Date / Reference | Definition   |
|---|------------------|--|
| Resolution Nº 24 of the Assembly of Energy Crisis Management. (Emergency Program for Wind Energy - PROEÓLICA) | 07/05/2001 [47]  | The aim of which was to add 1,050 MW of wind power to the national grid by the end of 2003. It wasn't regulated by Federal government and was absorbed by the next program (PROINFA).  |
| Law Nº. 10.438/2002: Program for Alternative Sources of Electricity (PROINFA)                                 | 04/26/2002 [48]  | The Federal government intended to install a capacity of 3300 MW through: small hydroelectric plants (1,100 MW), wind power plants (1,100 MW) and biomass (1,100 MW). Subsequently, the initial target was changed and it were contracted: 1,423 MW of wind farms, 1,192 MW of small hydroelectric plants and 685 MW of biomass. |
| Law Nº. 10.848/2004 of Presidency of the Republic   | 03/15/2004 [49]  | Provides for the commercialization of electricity, amends previous laws and makes other provisions. This law creates the contracting for "energy auctions".  |
| Decree Nº. 5,163/2004 of Presidency of the Republic   | 07/30/2004 [50]  | Regulates the commercialization of electric energy, the process of granting of concessions and authorizations of electricity generation, and other measures.   |
| Decree Nº. 6,353/2008 of Presidency of the Republic   | 01/16/2008 [51]  | Regulates the contracting of reserve energy that is dealt with in previous laws, changes some previous laws and gives other measures.  |

There is no regulation on hybrid generation in Brazil, but a review of the regulatory framework is necessary to meet the enabling conditions of this type of generation: i) Regularity and Annual Predictability of Contracting, ii) Appropriate Funding Conditions, iii) Investments in Transmission Infrastructure, iv) Favorable Regulation, Investments in Research and Development (R&D) and Human Resources (RH) Training. Thus, Federal government should adopt new regulatory framework to enable these conditions.

## ENERGY COMPLEMENTARITY

The Northeast region, several areas with high solar radiation and good wind energy potential overlap (Fig. 2) and presents the highest levels of complementarity between wind and solar energies (Fig. 3 and 4).

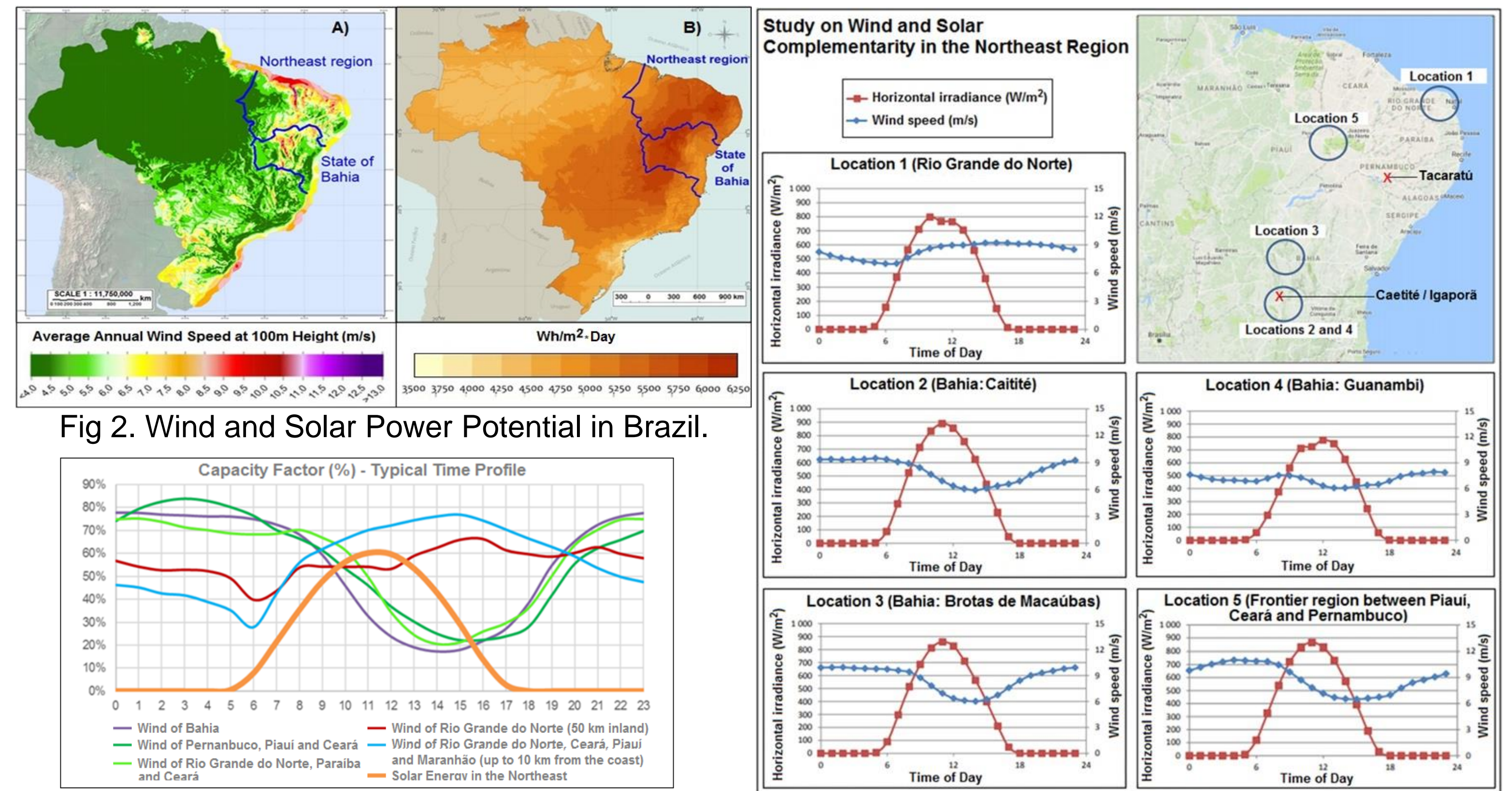


Fig. 2. Wind and Solar Power Potential in Brazil.

Fig. 3. 5 studied points of Complementarity.

## HYBRID ENERGY SYSTEM (HES): WIND-PV SOLAR HYBRID POWER PLANTS

There are 2 pilot projects of Wind-PV hybrid power plants in Brazil: one located in Tacaratu (Fig. 5-A and 6; Table 2) and another in Caitité/Igaporã (Fig.5-B and 7; Table 3):

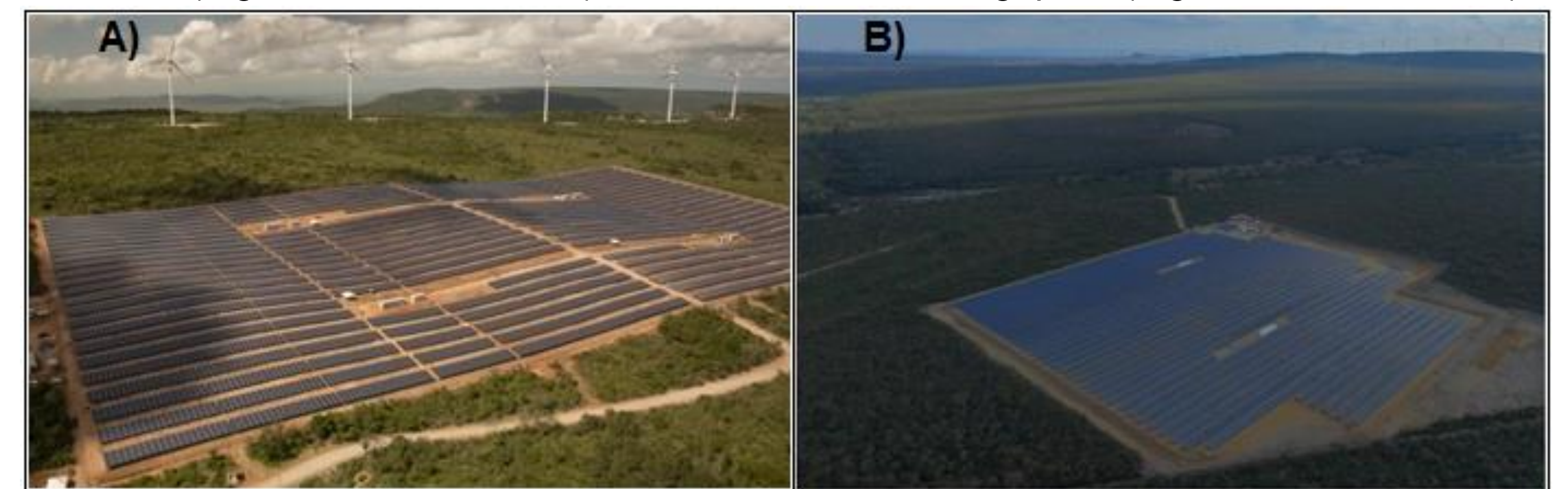


Fig 5. A) Tacaratu HES Power Plant; B) Caitité/Igaporã HES Power Plant.

Table 2. Installed Capacity of Tacaratu.

| Tacaratu Hybrid Power Plant  |                    |                   |            |                  |
|------------------------------|--------------------|-------------------|------------|------------------|
| Power plants                 | Installed Capacity | Guaranteed Energy | Generation |                  |
| Fontes dos Ventos 1          | Pedra do Gerônimo  | 30.6 MW           | 16.4 MWmed | 13 wind turbines |
| 2                            | Pau Ferro          | 30.6 MW           | 16.8 MWmed | 13 wind turbines |
| 3                            | Tacaico            | 18.8 MW           | 11.1 MWmed | 8 wind turbines  |
| Fontes Solar 4               | I                  | 5.5 MWp           | 1.0 MWmed  | 17,765 PV panels |
| 5                            | II                 | 5.5 MWp           | 1.0 MWmed  | 17,765 PV panels |
| Total Installed Capacity     |                    | 91 MW             | 45.3 MWmed |                  |
| Investment US\$ 148 millions |                    |                   |            |                  |

Table 3. Installed Capacity of Caitité/Igaporã.

| Caitité/Igaporã Hybrid Power Plant |                    |                   |                  |                  |
|------------------------------------|--------------------|-------------------|------------------|------------------|
| Power plants                       | Installed Capacity | Guaranteed Energy | Generation       |                  |
| 1                                  | Saboeiro           | 13.5 MW           | Data unavailable | 5 wind turbines  |
| 2                                  | Jurema Preta       | 8.1 MW            | Data unavailable | 3 wind turbines  |
| 3                                  | Caitité Va         | 4.8 MWp           | Data unavailable | 19,200 PV panels |
| Total Installed Capacity           |                    | 26.4 MW           |                  |                  |
| Investment US\$ 32 millions        |                    |                   |                  |                  |

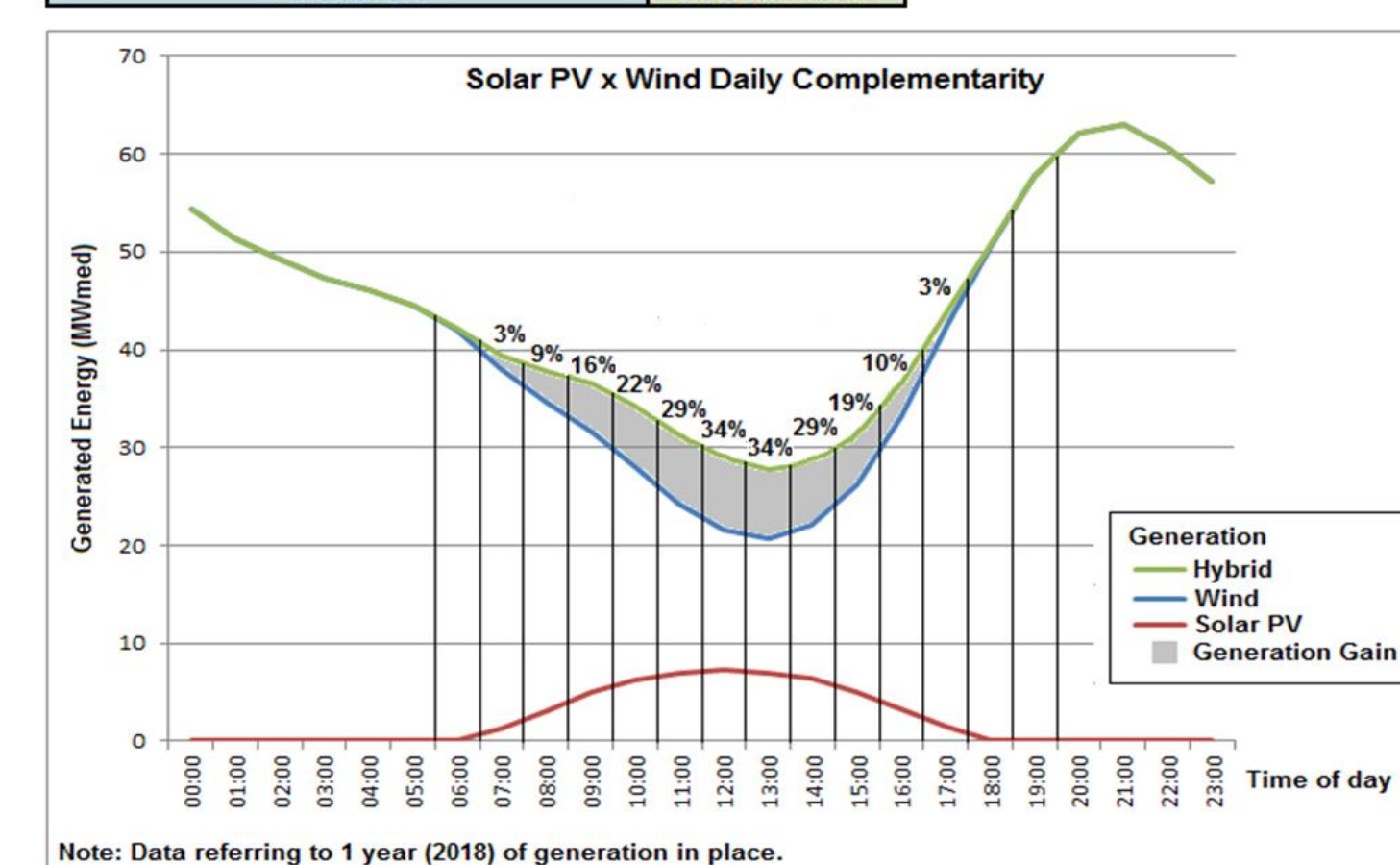


Fig 6. Gain Complementarity of Tacaratu HES in 2018.

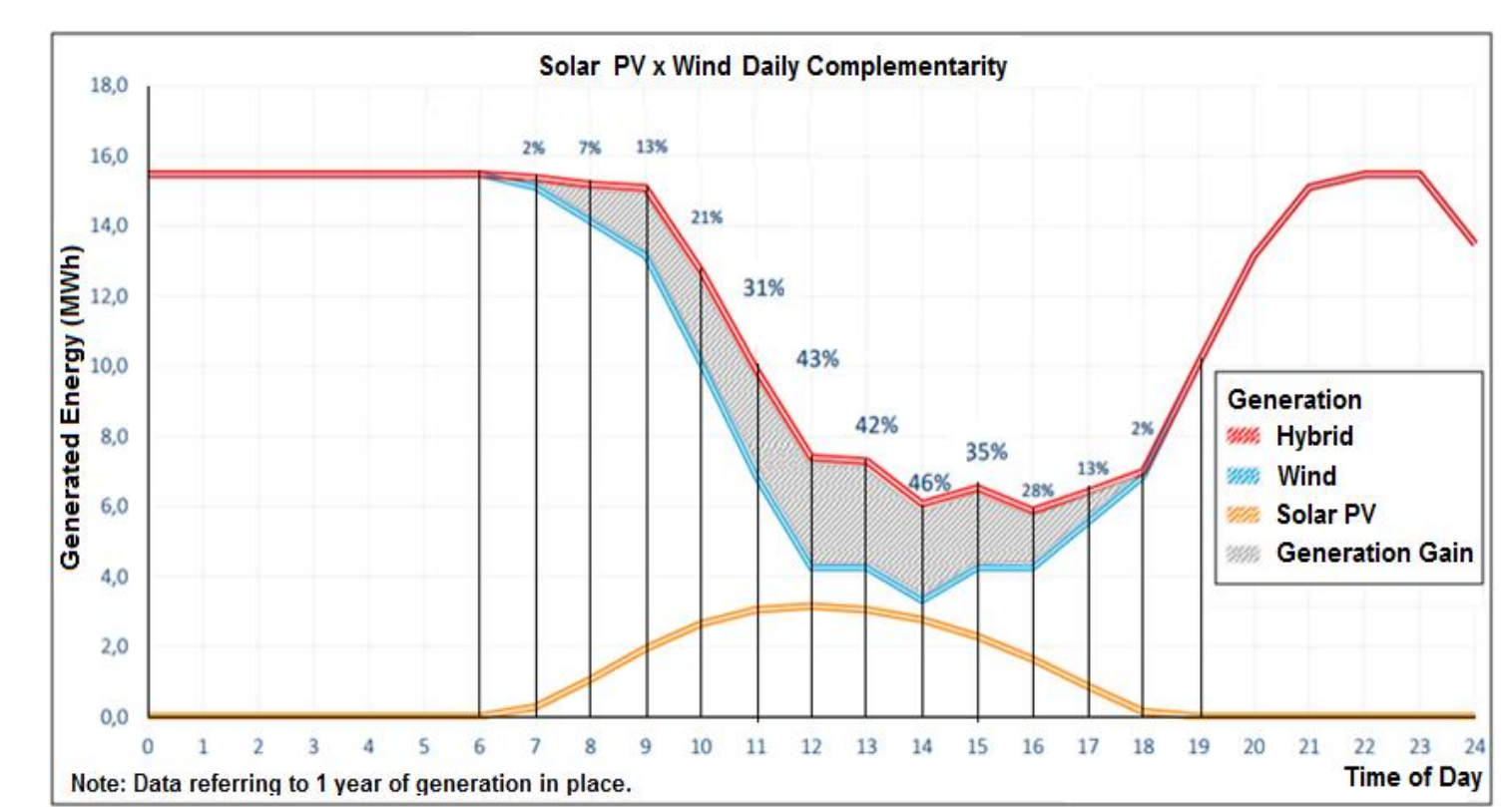


Fig 7. Gain Complementarity of Caitité / Igaporã HES.

## CONCLUSIONS

The hypotheses were proven. The installed capacities in Brazil was 14.4 GW wind power and 2.3 GW PV power in 2018, but exist potentials of 522 GW wind power (heights of 100 m) and 307 GWp PV power to be explored in the future. However, the possibility of centralized combined wind and PV hybrid energy systems is a fairly recent issue in Brazil. Northeast there are favorable characteristics for Wind-PV Solar HES. Development of more hybrid power plants could provide another alternative for more security of energy supply. Hybrid plants reduce project implementation costs and would help maintain the high penetration of RE in the Brazilian electricity matrix.

## ACKNOWLEDGMENT

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