Powering the Future: Harnessing Brazil´s Clean Energy and Green Hydrogen Potential

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Summary

The northeast region of Brazil is rich in wind and solar resources, but electricity demand fluctuates.

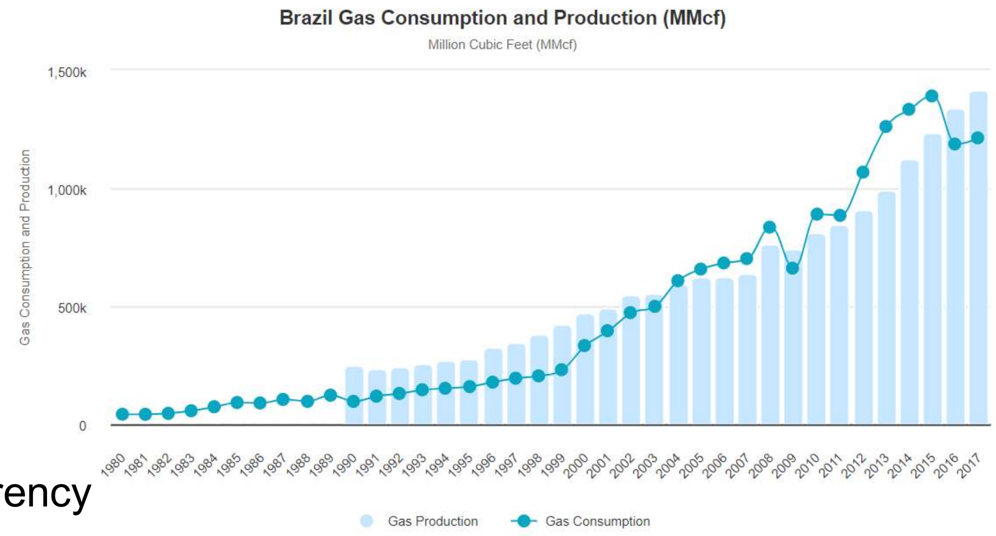
Excess energy has the flexibility to be converted into green hydrogen.

Green hydrogen is a clean and renewable energy source that can be used to store electricity or be directly used as fuel.

This helps to manage the variability of the wind and solar resources and provides a long-term storage solution for the excess energy.

Brazil´s Energy Matrix

- Brazil has no coal, and no gas until recently.
- But has a large land mass with plenty of water, wind and sun.
- Energy matrix mostly renewable so no need to switch energy sources to decarbonize
- But there are still opportunities to switch inputs and outputs
  - Wind Energy: Sell electricity or mine cryptocurrency
  - Biofuels: Soy or Castor beans as inputs
  - Switch to diferent storage forms: hydropower x hydrogen



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The value of switching inputs in a biodiesel production plant

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There has been a growing concern in recent years about the quality of the environment and dependence on fossil fuels to supply the world's energy needs, which has created an interest in the development of renewable and less polluting energy sources. One of these alternatives is the biodiesel fuel, which has many advantages over the fossil based diesel, or petro diesel. In this paper we use the real options approach to determine the value of the managerial flexibility embedded in a biodiesel plant that has the option to switch inputs among two different grain commodities. Our results indicate that the option to choose inputs has significant value if we assume that future prices follow stochastic processes such as Geometric Brownian Motion and Mean Reversion Models, and can be sufficient to recommend the use of input commodities that would not be optimal under traditional valuation methods. We also show that the choice of model and parameters has a significant impact on the valuation of this class of projects.

Keywords: biodiesel; real options, Monte Carlo simulation; mean reverting models

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Hedging renewable energy investments with Bitcoin mining

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ABSTRACT

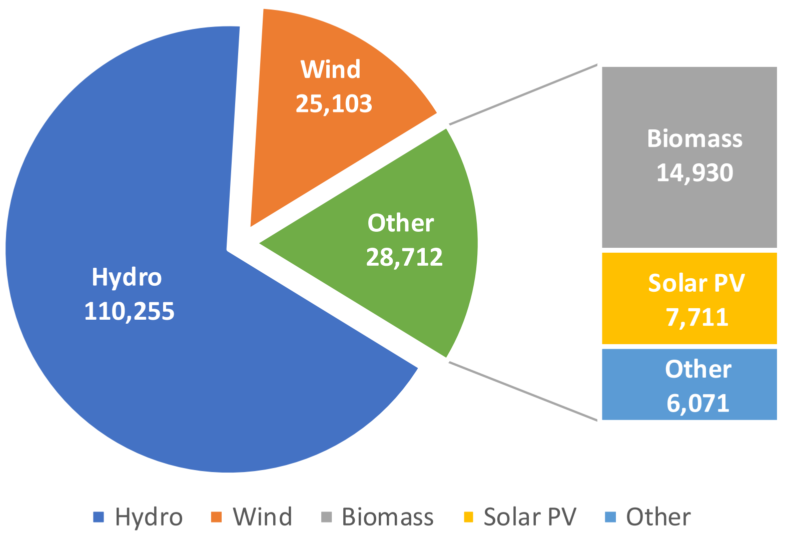
Renewable energy sources such as wind power are increasing their share of the world energy matrix. In Brazil, the regulator promotes reverse bid auctions where the winner agrees to begin production a number of years ahead under a long-term contract. If a wind farm project chooses to anticipate construction, it can sell its energy in the short-term market but becomes subject to electricity price volatility. In order to create incentives for early investment, we propose that wind farm investors can hedge electricity price risk by simultaneously investing in a cryptocurrency mining facility that uses electricity as input to produce newly minted Bitcoins. As electricity and Bitcoin prices are uncorrelated, the ability to switch between these outputs allows the wind farm to maximize revenues and minimize losses. We develop a numerical application under the real options approach to determine the financial impact of the investment in a Bitcoin facility for the wind energy producer that will allow it to optimally switch outputs depending on the relative future prices of electricity and Bitcoins. The short-term energy price and Bitcoin price/mining-difficulty ratio are modeled as distinct stochastic diffusion processes. The results indicate that the option to switch outputs significantly increases the generator's revenue while simultaneously decreasing the risk of anticipating the construction. These findings, which can also be applied to other renewable energy sources, may be of interest to both the energy generator as well as the system regulator as it creates an incentive for early investment in sustainable and renewable energy sources.

Brazil and Clean Energy

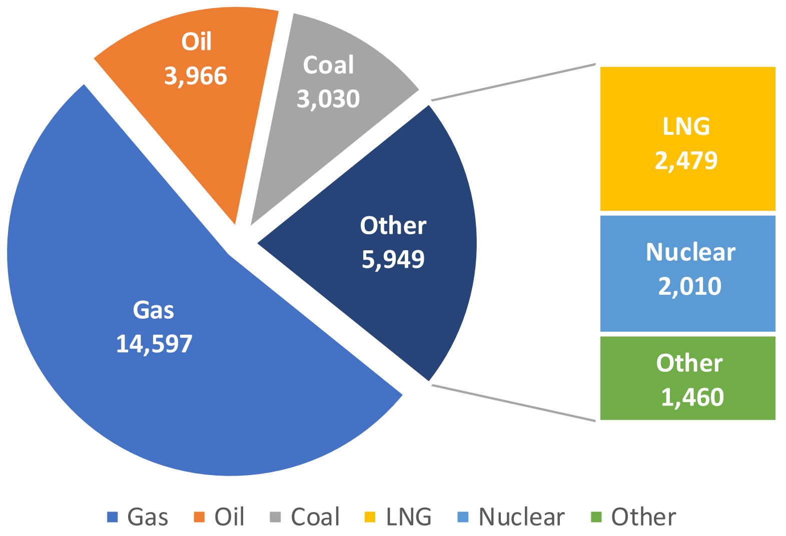
- Sixth largest in electricity generation worldwide
- 192.6 GW in centralized installed capacity
- 16.2 GW in distributed installed capacity
- 680,000 GWh generated 2022
- 86% in renewable generation

Installed Centralized Capacity

Centralized Renewable Capacity: 164,070 MW



Centralized Non-Renewable Capacity: 27,541 MW

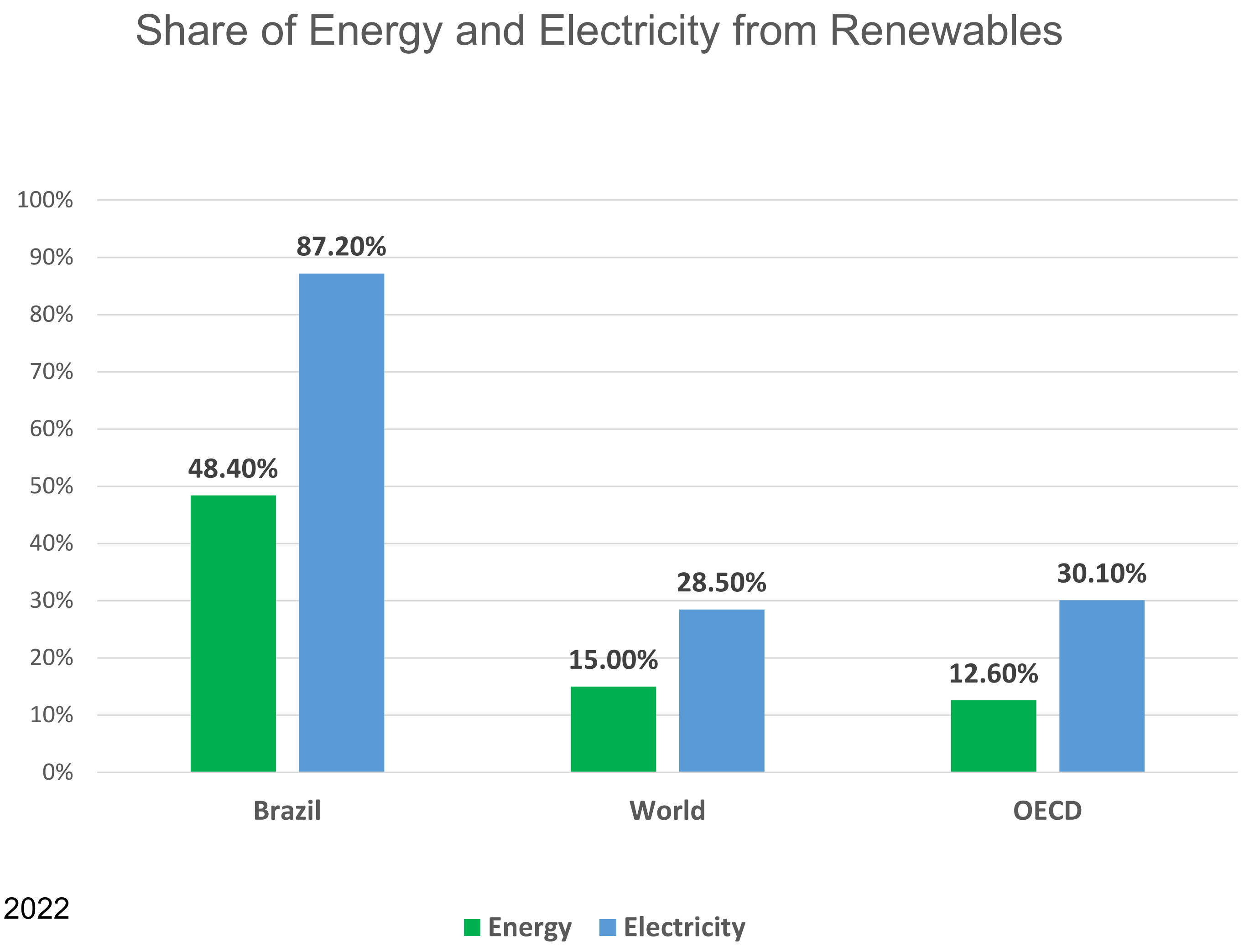


Source: BEN – Balanço Energético Nacional 2022 in www.epe.gov.br

Growth in renewable generation

- Electricity generation in Brazil is mostly from hydro sources
- 2013 to 2022 were years of lower than expected rainfall
- To cope with this energy shortage, significant investments in capacity were added to the system during this period, totaling 58.83 MW, or a 36.7% increase, bringing the total to 191.61 MW.
- Increase in centralized generation (MW):
  - Hydro: 18.32 | Wind: 25.10
  - Solar: 7.66 | Biomass: 5.52
  - Thermal: 5.42 (non-renewable)
- In addition, 16.28 GW of distributed generation capacity were also added to the grid
- As rainfalls returned in 2023, there is now significant excess generation capacity and electricity prices are at historical low prices

Worldwide Comparison



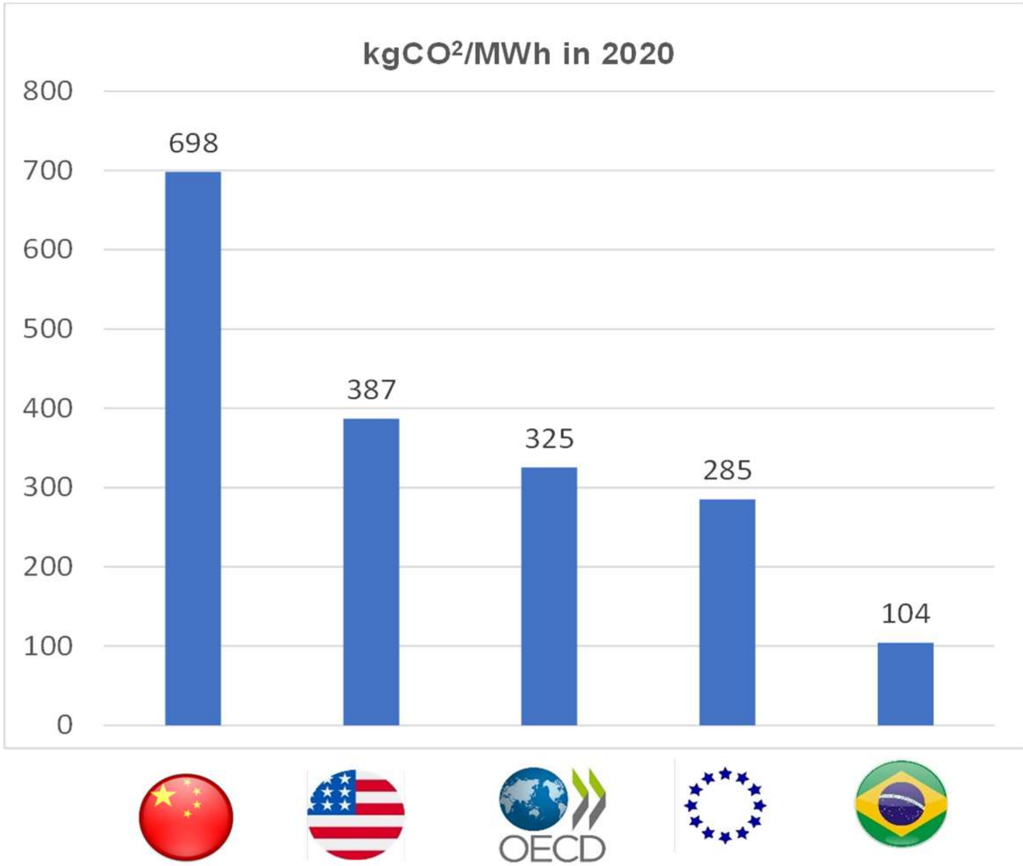
Source: IEA Energy and Electricity Information 2022

Worldwide Comparison

Amount of CO_2 emitted per MWh generated as of 2020:

- 85% lower than of China,
- 73% lower than the United States,
- 68% lower than the OECD
- 64% lower than the European Union

Source: IEA (2022) $kgCO_{2eq}$/MWh in 2020

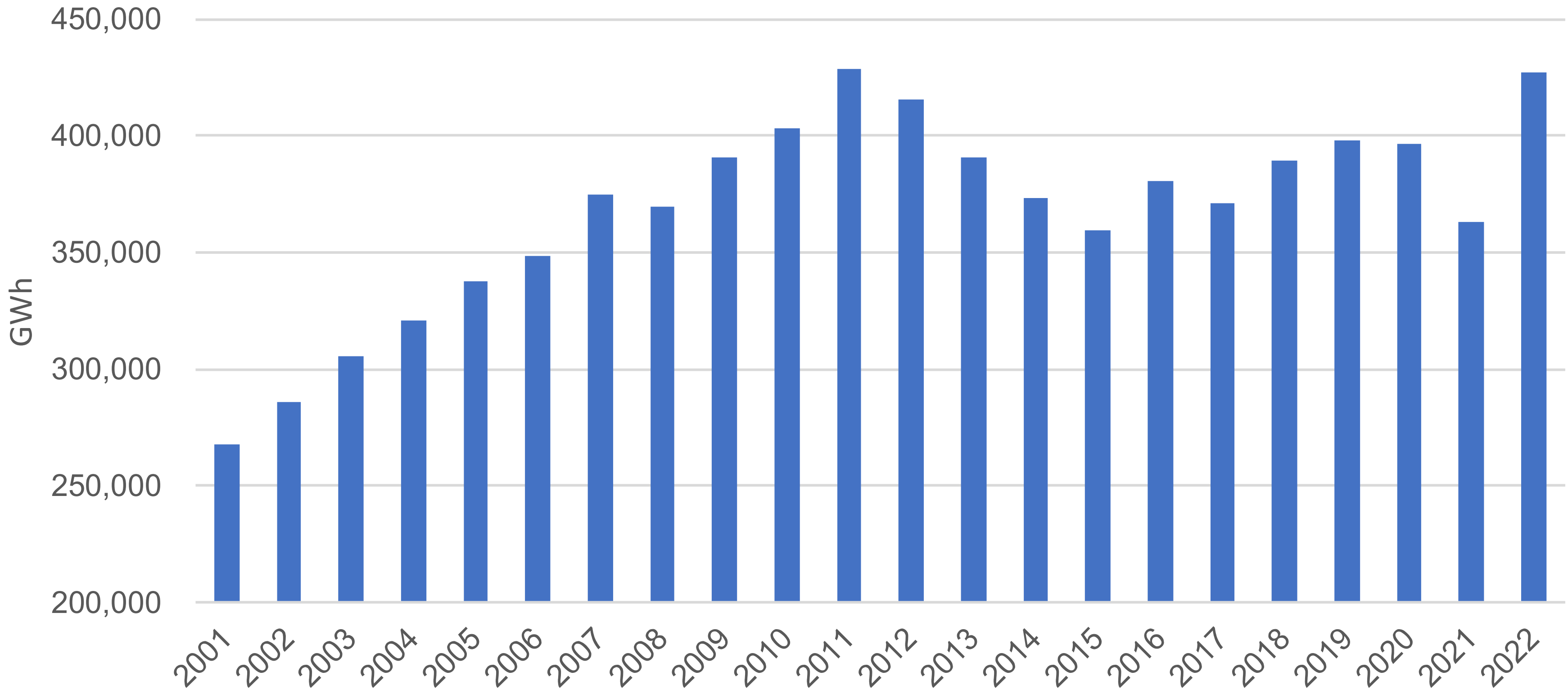


Hydroelectric Power

Brazil's hydroelectric power capacity is crucial for its clean energy mix.

In 2022, 63% of the electricity generated came from this source.

Hydroelectric Power Generation



Source: BEN – Balanço Energético Nacional 2022 in www.epe.gov.br

Wind and solar farms in the Brazilian Northeast

- Region with abundant wind resources and strong solar irradiation
- Large land availability
- Fully connected to the national electricity grid

Wind

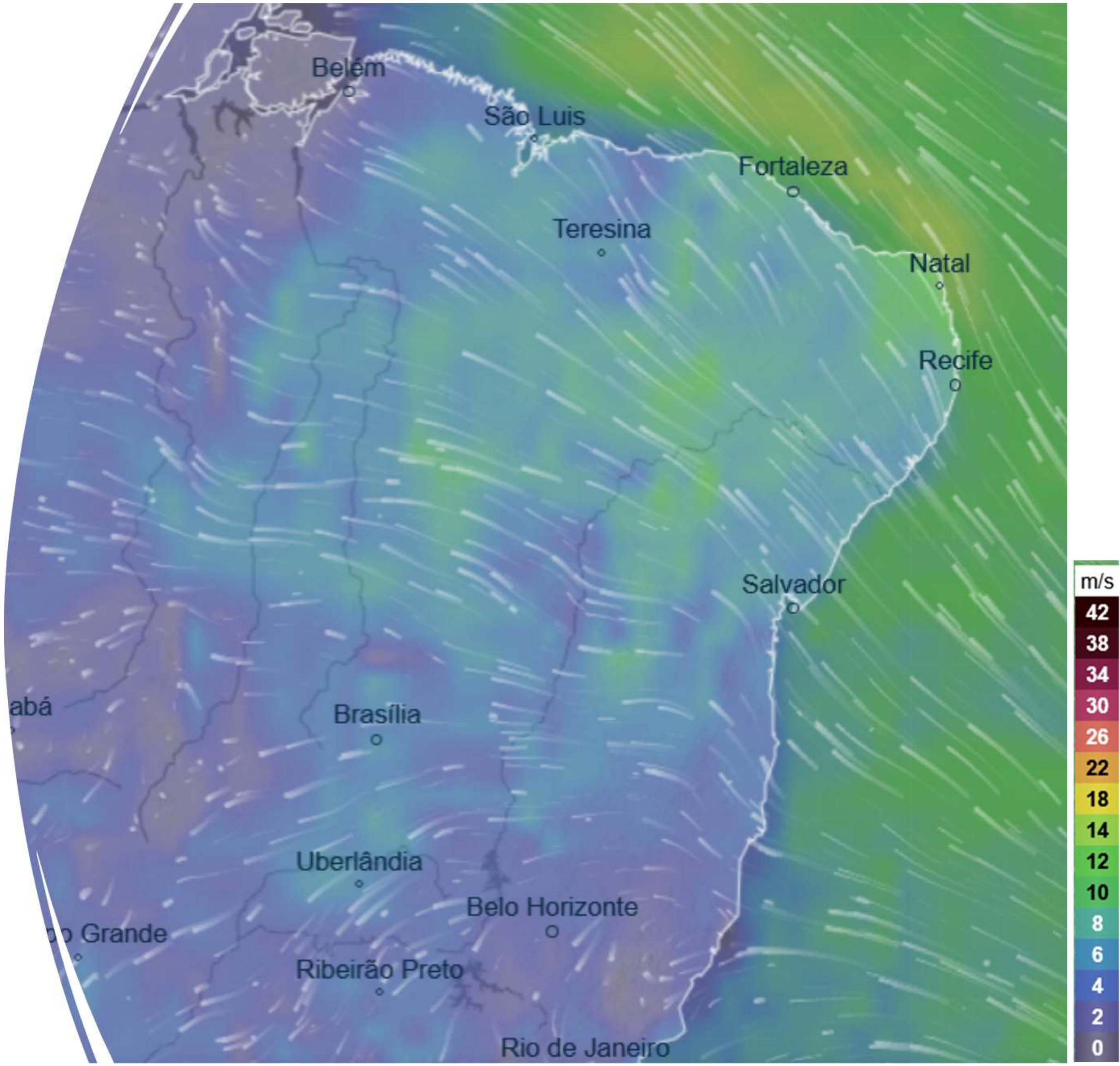
The northeast region of Brazil has significant wind energy potential

80% of the wind farms are located in this region.

Turbines typically occupy 6-8% of the wind farm area.

This allows for continued use of the area for farming or animal husbandry.

Source: CEPEL – Electric Energy Research Center (2013)
UFRJ in http://novoatlas.cepel.br/



Solar

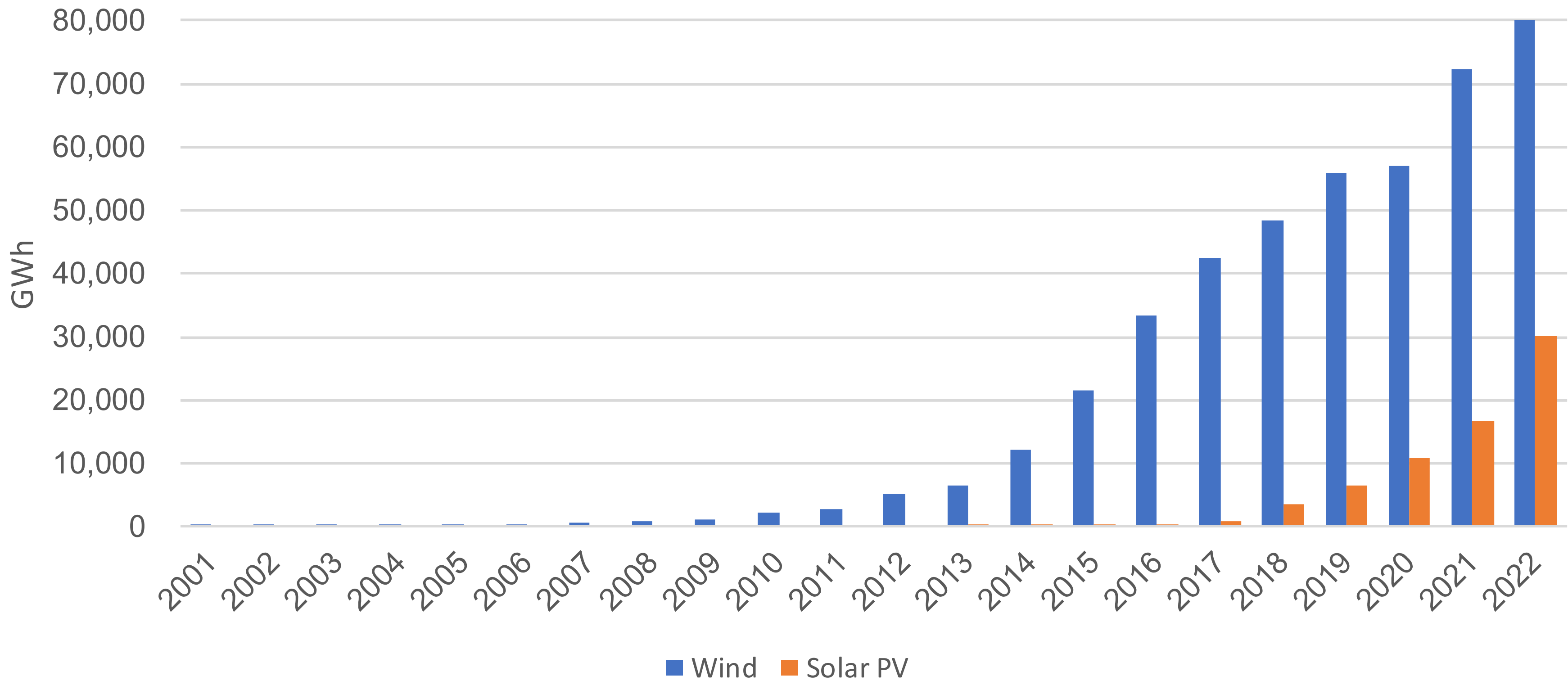
The Northeast is also known for its high solar radiation levels, averaging 5.5-6.5 kWh/m² per day.

It also has relatively low cloud cover, making it one of the best places in the world to place photovoltaic power stations

The best irradiation rates are found between the backlands of Bahia and part of Minas Gerais.

Source: Brazilian Atlas of Solar Energy, INPE (National Institute for Space Research), 2017. Available at: http://labren.ccst.inpe.br/

Wind and Solar Power Generation



Source: BEN – Balanço Energético Nacional 2022 in www.epe.gov.br

Biomass and Waste Power

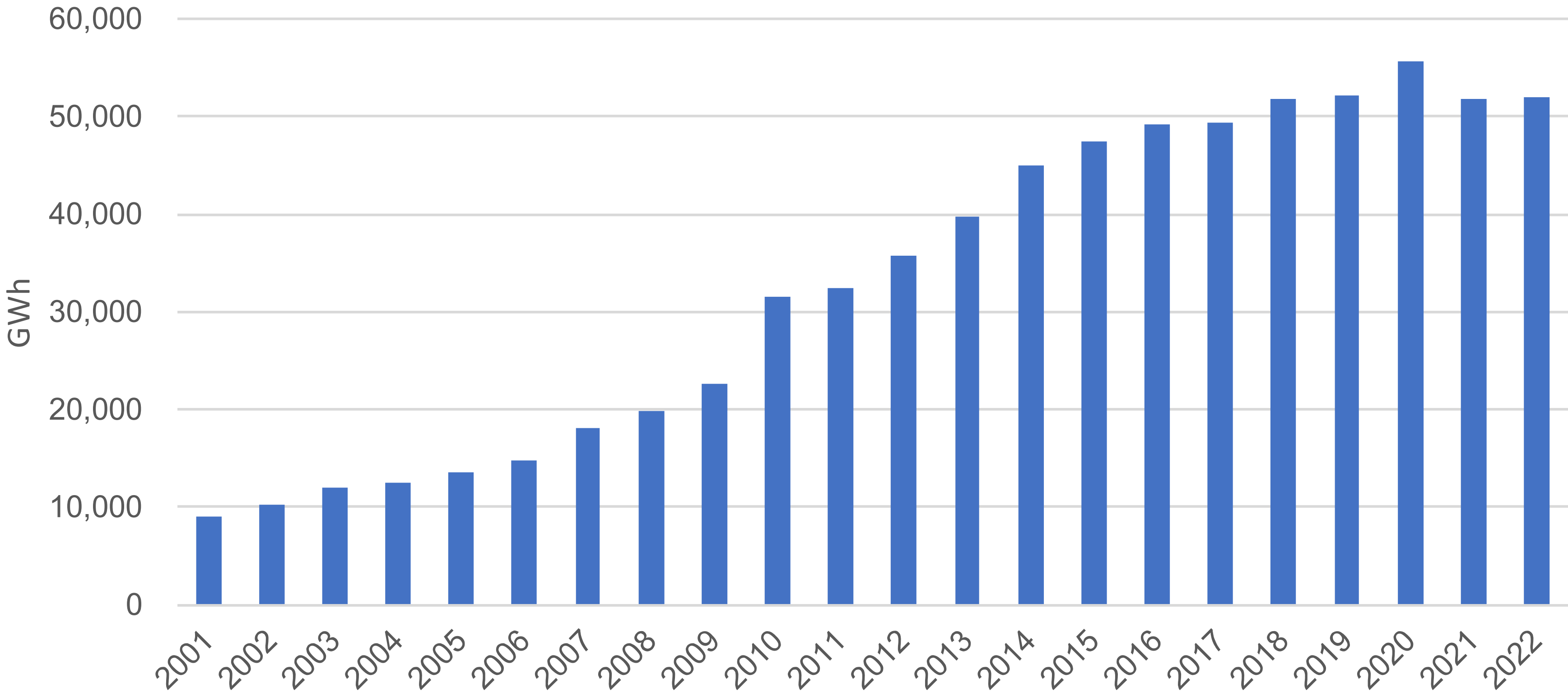
A significant power generation source in Brazil is biomass

Sugarcane bagasse is the main fuel source for this form of electricity generation

Bagasse is a byproduct of the sugar and ethanol production process

This is a carbon net-zero fuel source as carbon is recaptured in the sugarcane fields

Biomass Power Generation



Source: BEN – Balanço Energético Nacional 2022 in www.epe.gov.br

Electricity Transmission Grid

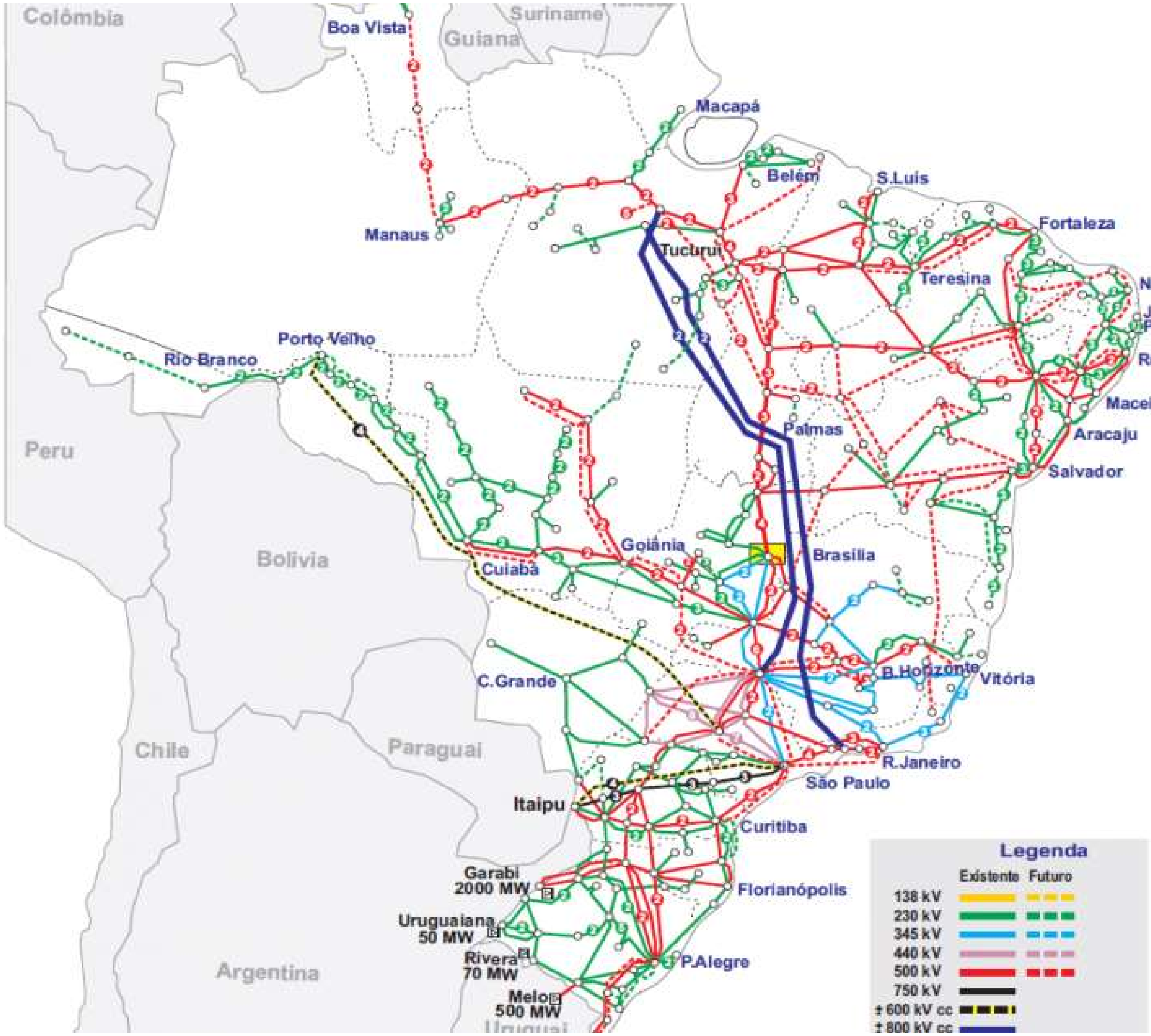
A single integrated national electricity grid

A large interstate HV transmission network of over 150,000 km allows the system operator to ship energy across thousands of km.

This includes the three of largest HVDCs lines in the world.

It´s continental size allows for regions with different rain, wind and solar climates

This increases the security, resilience and optimization of system operation



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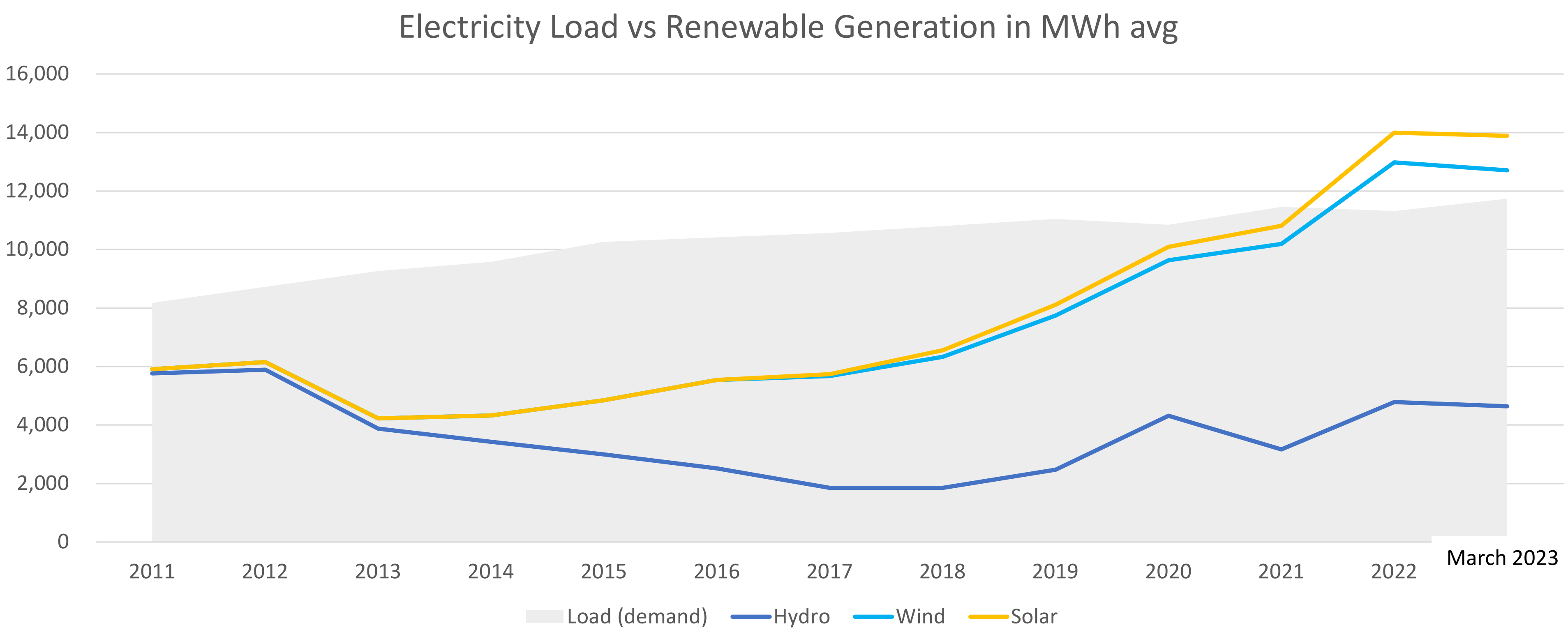
There is currently an excess of green energy in Northeast Brazil.



Source: ONS in www.ons.org.br

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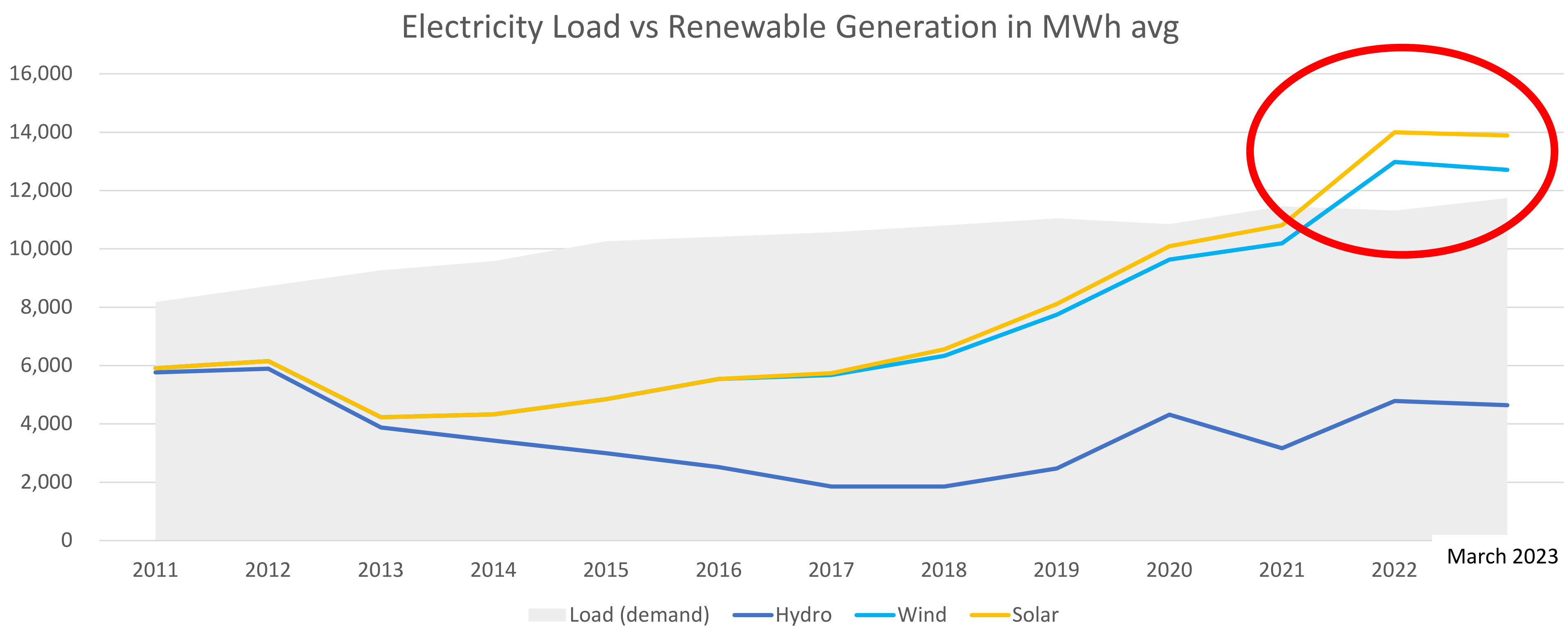
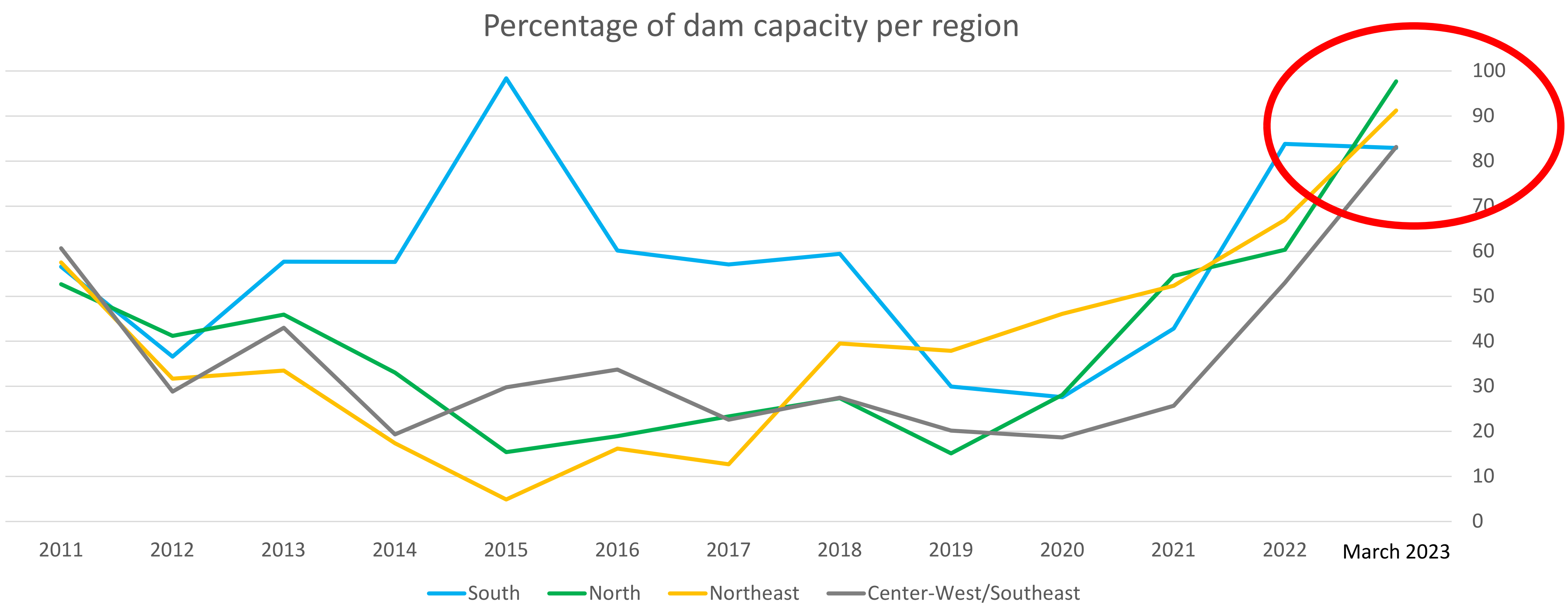


Source: ONS in www.ons.org.br

Reservoirs have limited storage capacity



Source: ONS in www.ons.org.br

Reservoir capacity

- Once a reservoir reached maximum capacity, production is curtailed by spillage of renewable energy.
- On the right: Itaipu dam spillway releasing surplus water

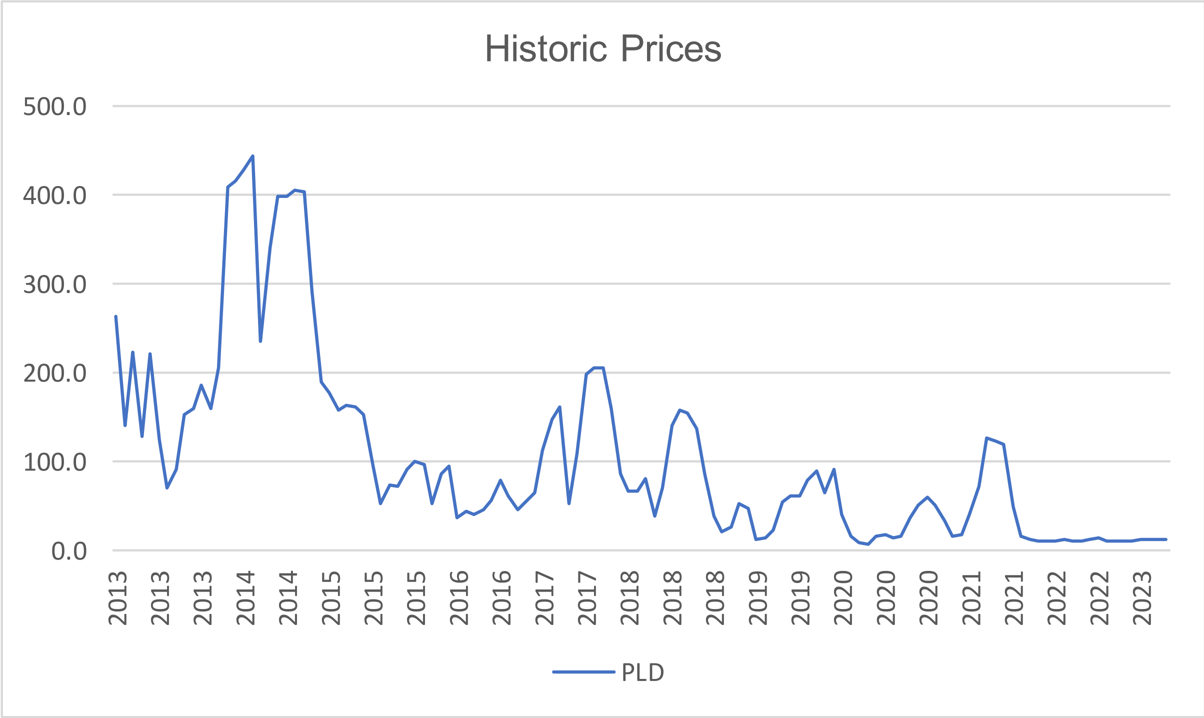
Price Effects

This surplus of green energy led to a significant fall in electricity prices in the last ten years

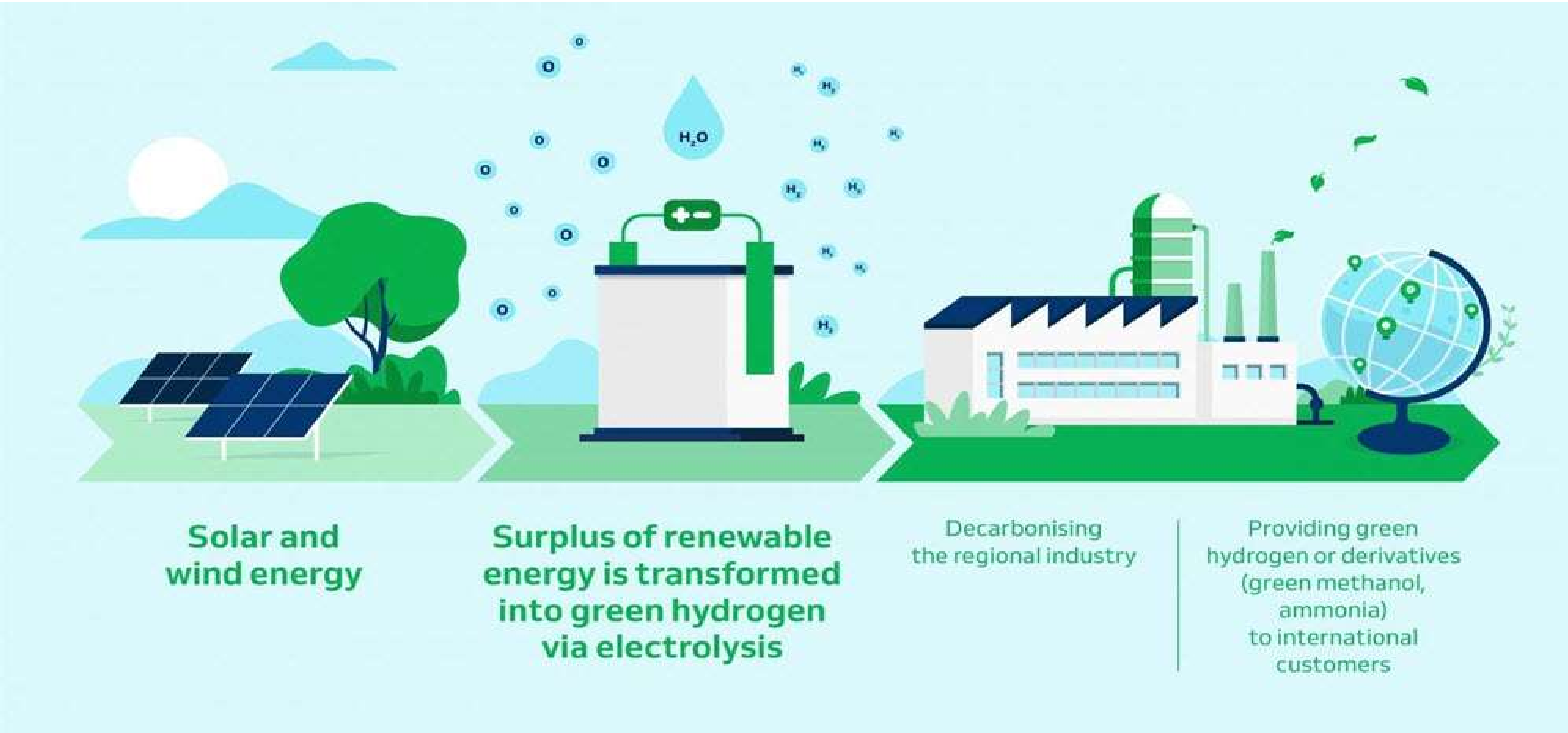
This affects the revenue of renewable energy producers.

The excess green energy can be leveraged for various sectors beyond electricity generation, such as hydrogen production

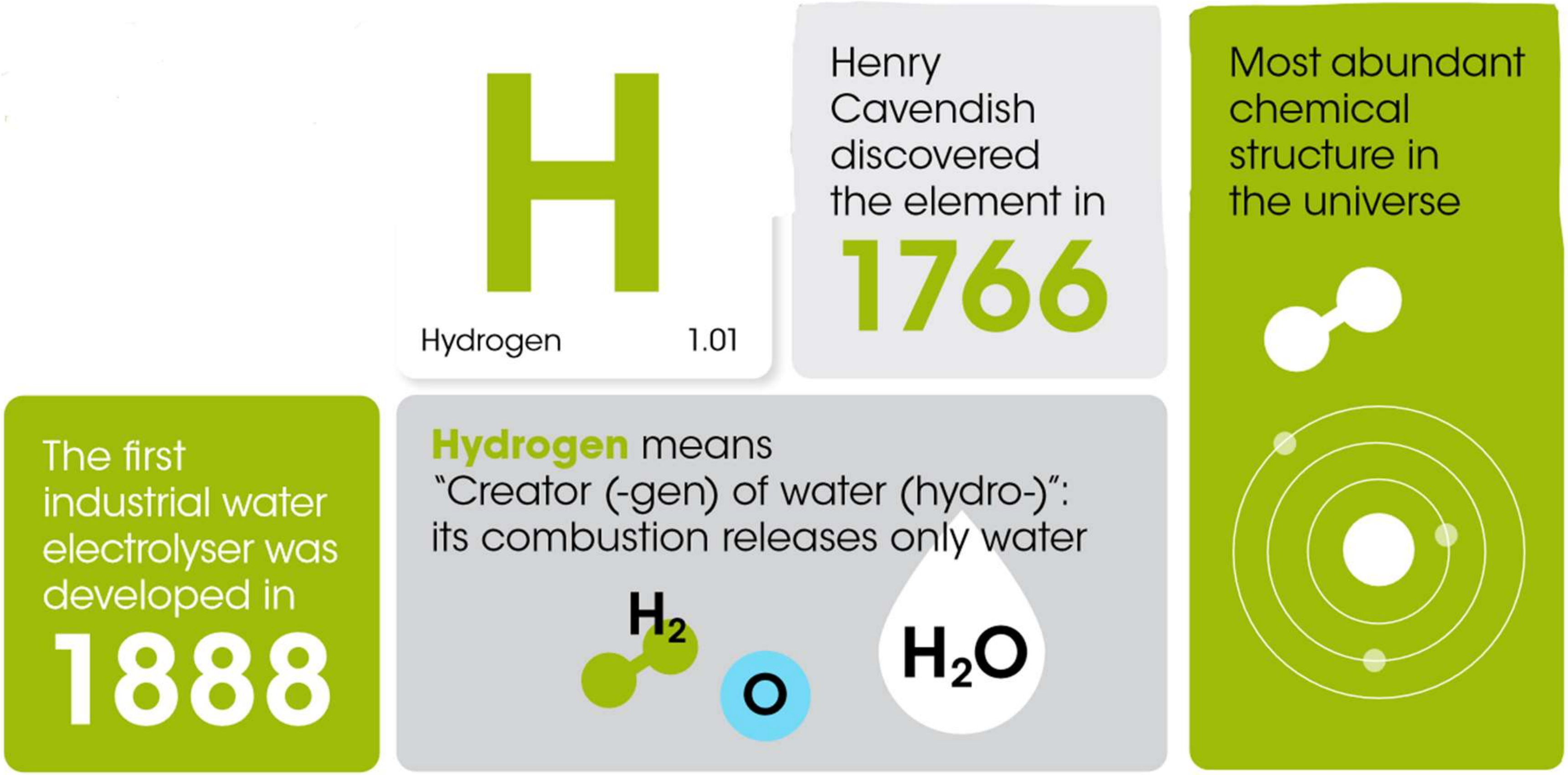
This allows to optimise the utilisation of excess energy and create new economic opportunities



Green Hydrogen Generation



Hydrogen


H
Hydrogen
1.01
Henry Cavendish discovered the element in
1766
Most abundant chemical structure in the universe
The first industrial water electrolyser was developed in
1888
Hydrogen means "Creator (-gen) of water (hydro-)": its combustion releases only water
H_2
O
H_2O

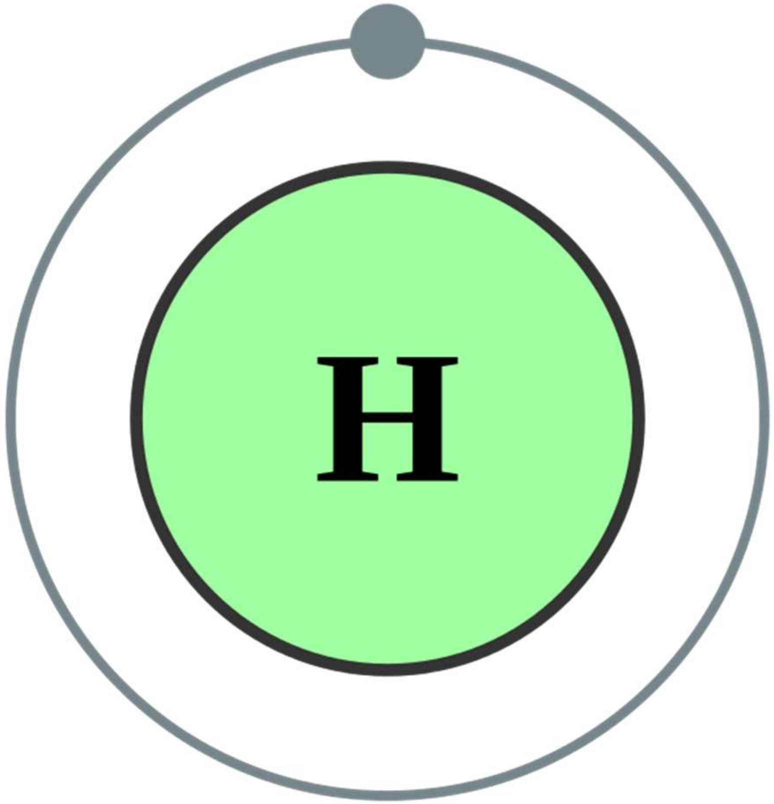
Hydrogen

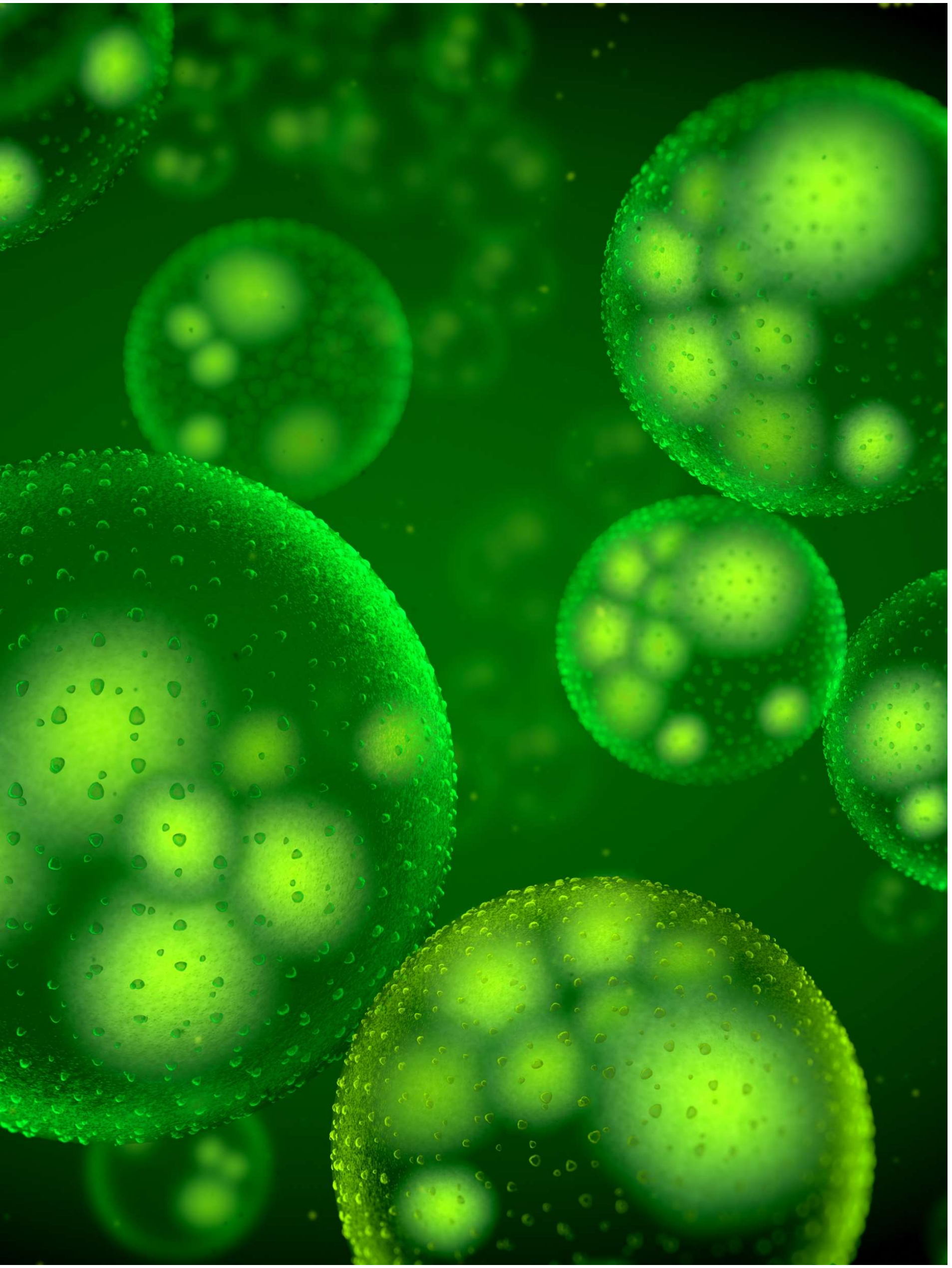
Although a versatile energy carrier, transporting it presents distinctive challenges.

Hydrogen can cause embrittlement in some metals, requiring careful selection of materials for storage and transport infrastructure to prevent degradation and leaks.

It has low energy density per unit volume, necessitating compression or liquefication.

- Liquefies at 20.2K or -252.9 Celsius.
- Energy losses due to compression, liquefaction, or conversion processes, impact overall efficiency and cost-effectiveness.





Ammonia as an H_2 carrier

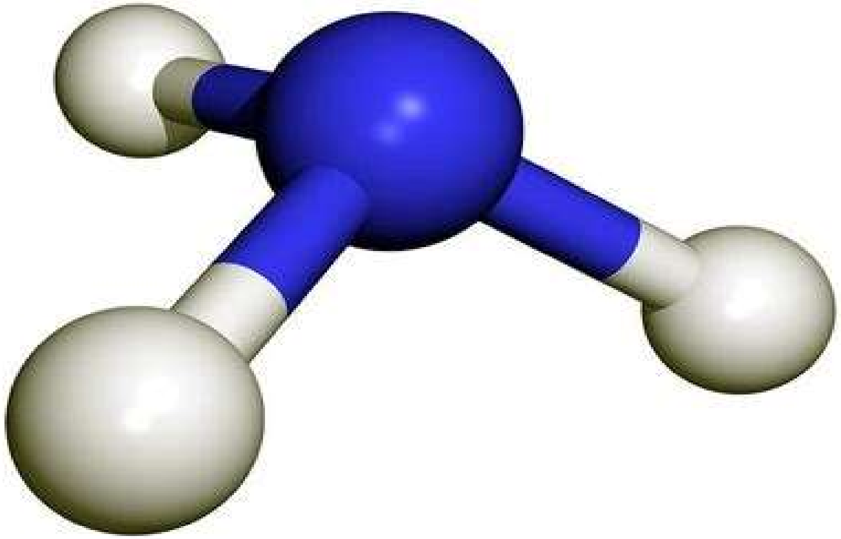
- A solution to these transportation problems is to use liquid organic hydrogen carriers (LOHC), such as Ammonia.
- Ammonia stores H_2 and is easier to handle.
- It can be used for to transport H_2 and releases it at the place of final use.
- Ammonia already has a mature production and logistics chain.
- Ammonia also can be used as an end-product.

Ammonia – NH_3

Ammonia is a versatile chemical compound consisting of three Hydrogen atoms bonded to a Nitrogen atom

Ammonia is colourless, has a pungent odour, and is commonly found in nature and various industrial applications

It is primarily produced through the Haber-Bosch process, which combines nitrogen from the air and hydrogen from natural gas or renewable sources

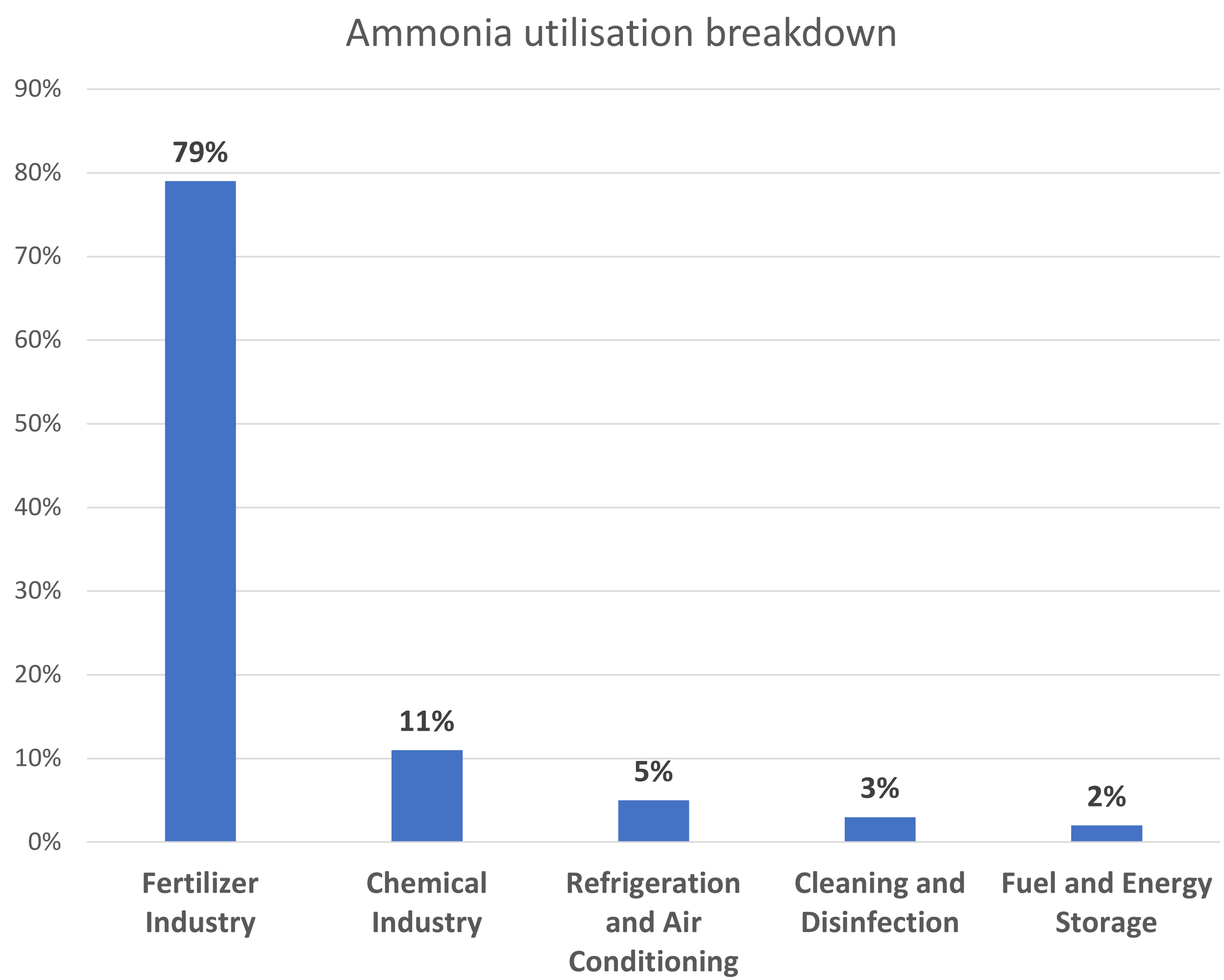


Ammonia as a Tradable Commodity

Ammonia is a key component in fertilisers and industrial processes

It is a valuable tradable commodity in the global market.

Its versatility, green attributes, and potential for various applications have positioned it as a sought-after commodity.



Source: IEA Ammonia Technology Roadmap 2022

Ammonia and carbon markets

- Ammonia has a high energy density, making it suitable for large-scale energy storage and transportation.
- The production and utilisation of green ammonia can generate carbon credits through emission reduction activities.
- By adopting green ammonia, organisations and countries can participate in carbon markets, monetising their emission reductions and profiting from the sale of carbon credits.
- This allows a green energy producer to hedge their price risk by using their energy output to produce Ammonia rather than sell electricity for a low price.
- This is a switch option that the green energy producer can optimally exercise to maximize their profit.

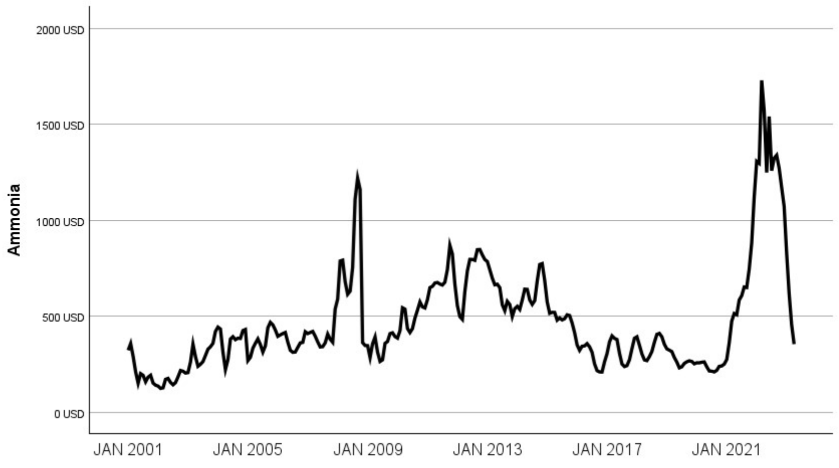
Ammonia and Electricity Prices are uncorrelated

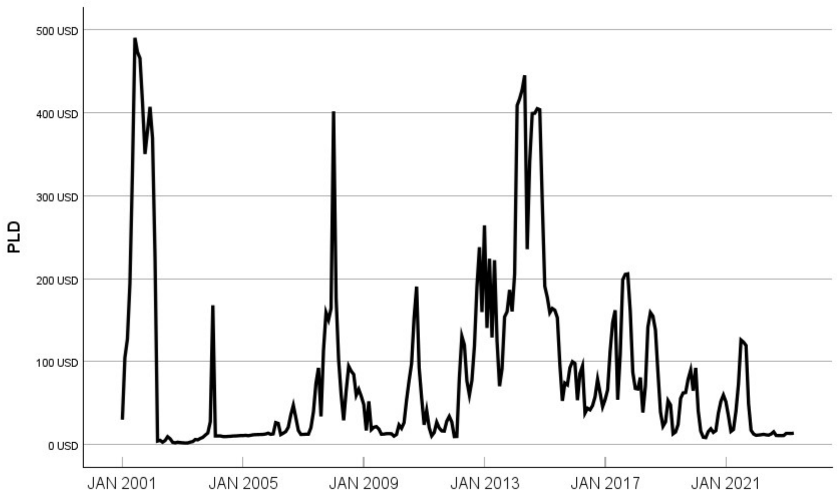
Electricity prices are driven by local supply and demand factors

Ammonia prices are driven by global market conditions and industry-specific factors

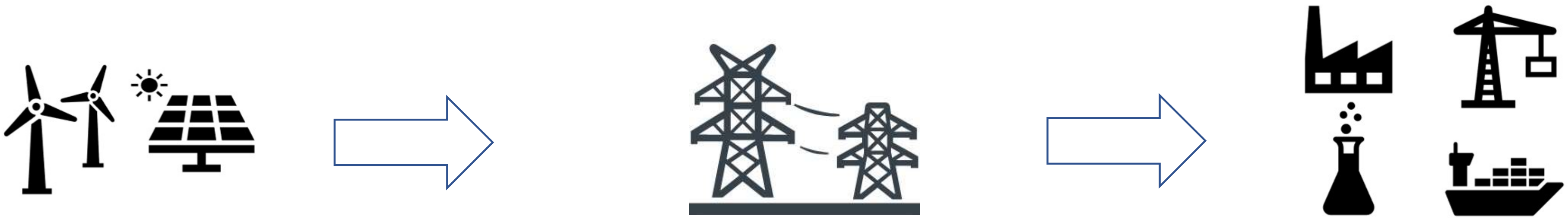
This makes then very loosely correlated

Pearson Correlation	Brent	PLD	Ammonia
Brent	1		
PLD (spot price)	0,110	1	
Ammonia	0,681	0,059	1





Hedging Price Risk with Green Ammonia



Generate Electricity from renewables

Use the transmission grid to send energy to a port

Use the port infrastructure to produce green ammonia from electrolysis and export the ammonia

Ports exporting ammonia from the Northeast

Ports with dedicated terminals for handling chemicals and ammonia

Available area to install electrolysers and equipment to convert H_2 into ammonia.

Port of Pecém

- Deep water harbour
- Dedicated terminal for handling ammonia
- Available area to install electrolysers and equipment to convert H_2 into ammonia.

Port of Aratú

Next to the Camaçarí chemical complex

Dedicated terminal for handling ammonia

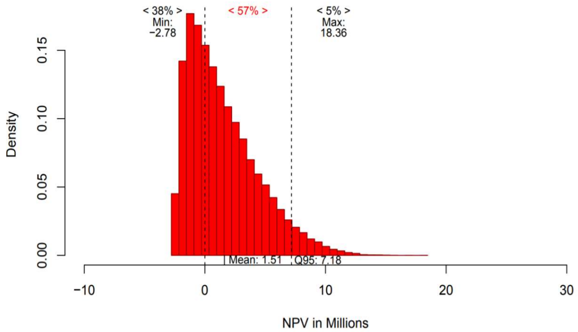
Available area to install electrolysers and equipment to convert H_2 into ammonia.

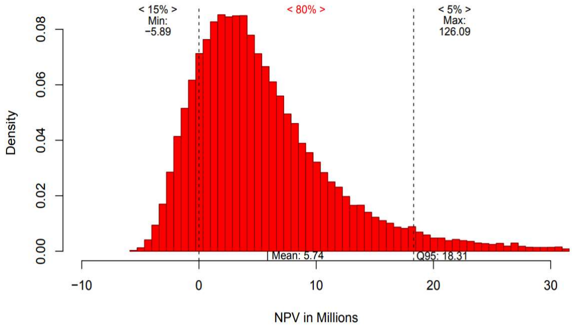
Model

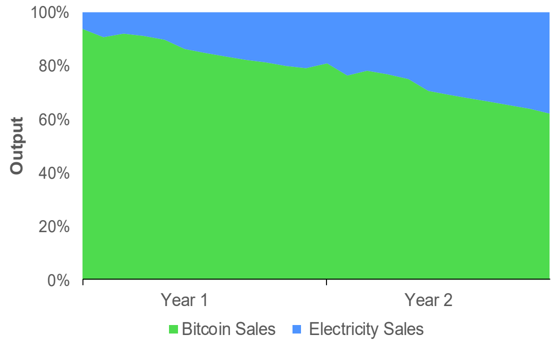
- Financial model of the Green Energy power source (Wind and/or Solar Farm)
- Stochastic model of Electricity Prices in the Brazilian NE
- Stochastic model of Ammonia commodity price
- Investment required for Ammonia electrolysis and storage
- Future cash flows from Electricity and Ammonia sales
- Real options analysis of the Electricity and Ammonia switch option
- Assumptions:
  - Five year horizon
  - Monthly switching
  - Electricity and Ammonia sold through month ahead contracts

Expected Results

- Added value of the option to switch outputs
- Additional incentives for investment in green energy
- Costless increase in reserve capacity for the system operator
- New market for energy export in the form of Ammonia







Durham University Business School

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