World Economic Forum

In collaboration with Accenture

Shaping the Future of Energy and Materials
System Value Framework – Brazil Market Analysis
October 2020

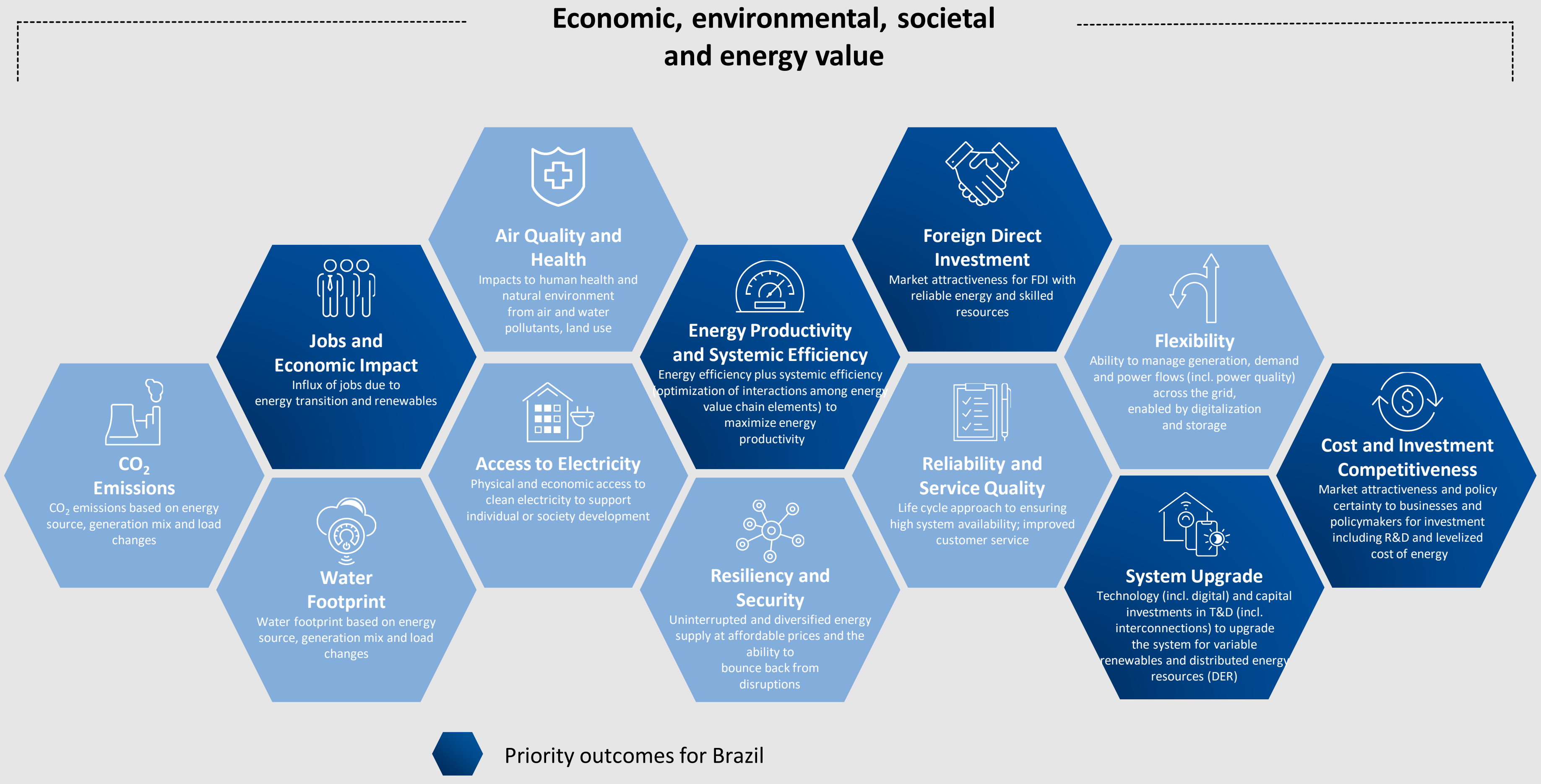
Contents

System Value of the clean energy transition in Brazil

The System Value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to **shift political and commercial focus beyond cost to include value**.

Using the System Value framework, the World Economic Forum, supported by Accenture, conducted analysis across several geographies as part of market evaluations **that examined recovery opportunities to accelerate economic growth and the clean energy transition**.

Key system value dimensions for Brazil have been prioritized across the framework based on current market dynamics and its relative maturity of transition towards net-zero integrated energy system.



Brazil recovery solutions

Solutions to deliver power sector modernization

Non-Hydro Renewables Expansion

Accelerate non-hydro renewables expansion (~7 GW wind and solar) through multiple initiatives such as fostering the liberalized market (ACL) with **innovative power purchase agreements (PPAs)**, **developing a new structured solution for the Energy Reallocation Mechanism (MRE)**, and **fossil thermo-plant substitution**.

34 Mt
Less CO_2 emissions from electricity generation through 2025

>132k
Direct and indirect jobs created from wind and solar through 2025

$2.8bn
Human health benefits from air quality improvements through 2025

Note: Above CO_2 and human health benefit figures represent cumulative, incremental savings in addition to 2025 base case projections.

Digitalization of Transmission and Distribution (T&D)

Address reliability and power quality issues through foundational **distribution network investments**, then digitize and modernize Brazil's grid through **smart grids**, **smart meters**, **internet of things (IoT)** and **distributed energy resources (DER)**.

14 Mt
Less CO_2 emissions from electricity generation through 2025

Up to 29k
Potential jobs created by grid digitalization initiatives

$1bn
Human health benefits from air quality improvements through 2025

Note: Above CO_2 and human health benefit figures represent cumulative, incremental savings in addition to 2025 base case projections. Estimated job potential based on US figures, adjusted for population.

Smart and Efficient Cities

Invest in smart cities via development of a **digital energy network**, enabling **energy efficiency and new business models** to support **distributed generation**, DERs and electric mobility, as well as public services such as **public lighting and vegetation management**.

45 Mt
Less CO_2 emissions from electricity generation through 2025

1m
Potential jobs across smart buildings, appliances, efficient lighting

$3.4bn
Human health benefits from air quality improvements through 2025

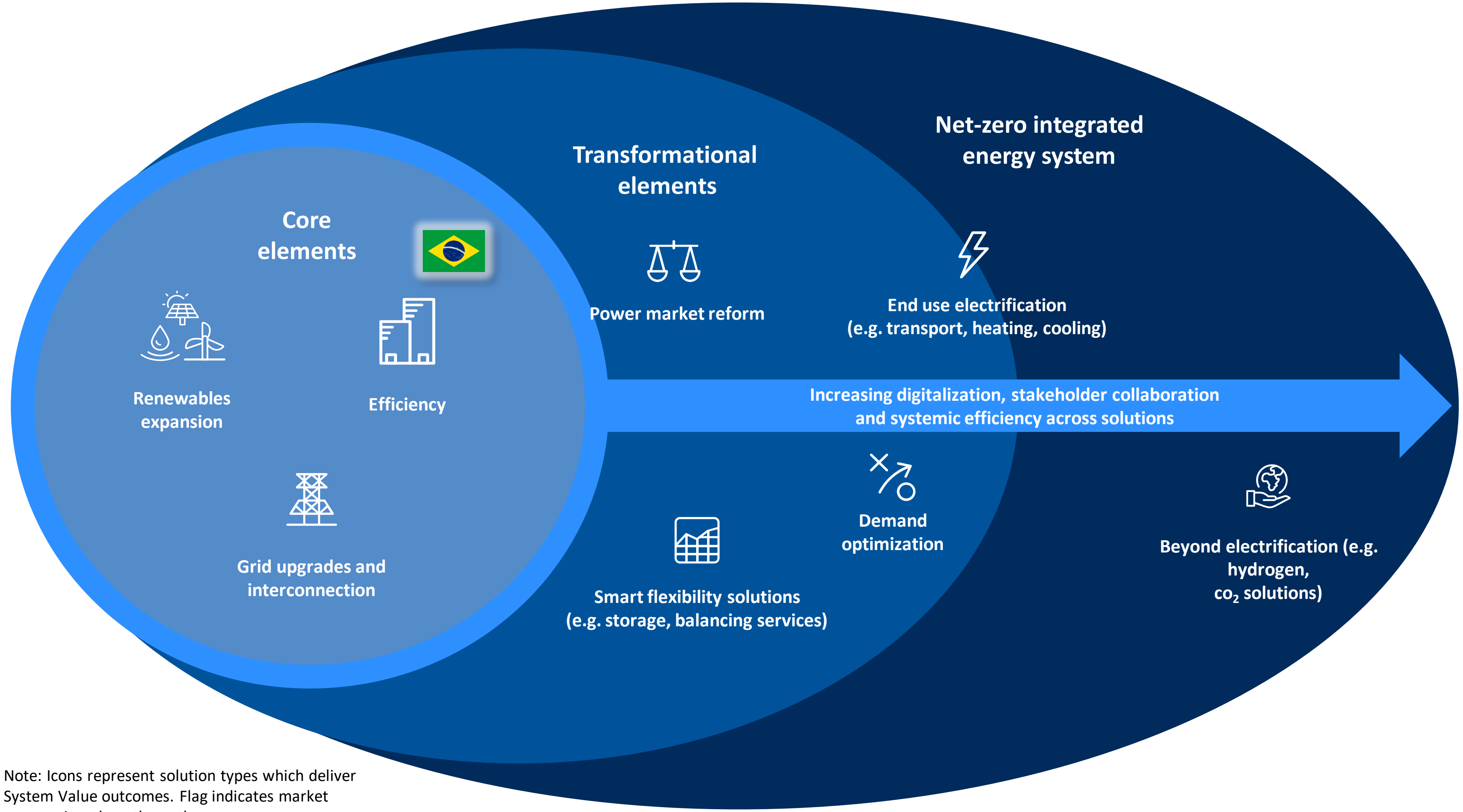
Note: Above CO_2 and human health benefit figures represent cumulative, incremental savings in addition to 2025 base case projections. Estimated job potential based on US figures, adjusted for population.

Brazil’s path to maximize System Value

Markets are moving from addressing core elements of the electricity sector transition…

…through “pivot points” where generation mix hits 20-30% annual variable renewables (>50% instantaneous) and transformational elements enable…

… acceleration to a net-zero integrated energy system with a strong focus on systemic efficiency



Brazil is advancing core transition elements towards a pivot point.

Recovery solutions deliver against **core transition elements** and **push forward past the pivot point** towards elements of an integrated energy system.

Brazil’s large hydropower resources can be leveraged to maximize System Value outcomes throughout the transition.

Note: Icons represent solution types which deliver System Value outcomes. Flag indicates market progression along the path.

Analysis purpose and overview

The World Economic Forum, supported by Accenture, has developed the **System Value framework** to move beyond cost to a **more holistic evaluation** of energy sector opportunities **across economic, environmental, societal and energy system value dimensions**.

Brazil's electricity market was one of several markets chosen to demonstrate how the System Value framework can be used to evaluate opportunities that **accelerate economic recovery and a clean energy transition**.

The following analysis of Brazil's electricity market aims to answer several key questions for energy industry leaders and can be leveraged to consider opportunities to pursue and prepare for conversations with a range of stakeholders.

- What is the state of COVID-related stimulus and recovery activity for Brazil?
- What short-term growth opportunities exist that can spur economic recovery and accelerate the clean energy transition?
- How can stakeholders move beyond a cost-centric dialogue to consider the value of outcomes to the economy, environment, society and energy system?

WORLD ECONOMIC FORUM

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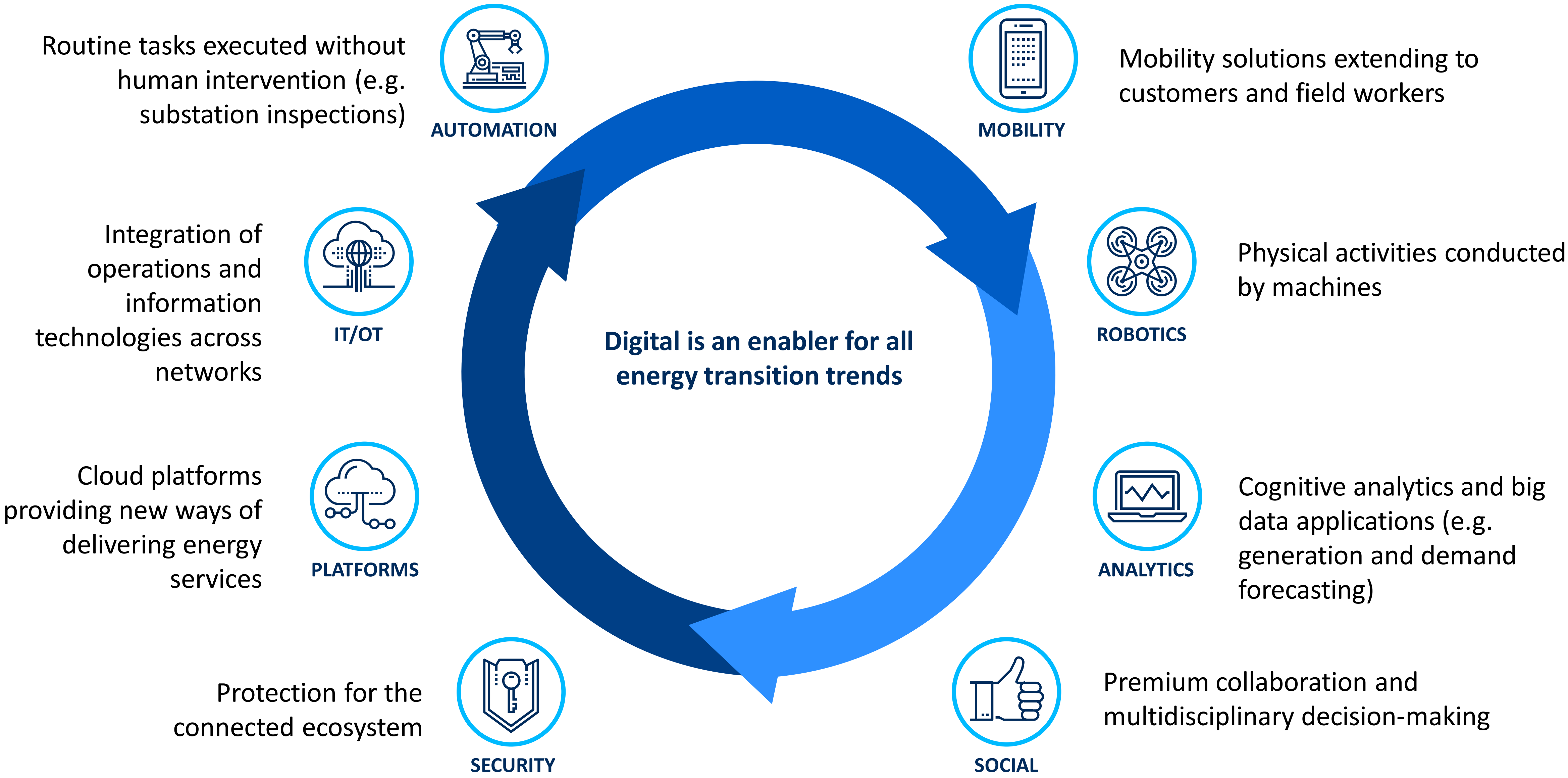
Energy transition trends shaping Brazil's electricity industry

Digitalization

Increasing electrification	• **Demand growth**: According to Brazil's Energy Research Office (EPE), annual electricity demand in Brazil is set to triple by 2050 to 1,605 TWh. • **Access to electricity**: Although Brazil has achieved almost universal access to electricity, quality of supply measured by frequency and duration of outages still lags behind developed countries.
Growth of green technology	• **Non-hydro renewable goals**: Targets of 27 GW of onshore wind and 9 GW of utility-scale solar targeted by 2030. • **Increasing distributed energy generation**: Expected to grow from <300 MW in 2018 to 3.3 GW by 2030. • **Energy efficiency policies**: Brazil expects to reduce 10% of business-as-usual consumption via energy efficiency programs by 2030.
Network of the future	• **Lack of smart meter support**: Brazil currently has no policies supporting smart meters and the associated technology is still in its infancy. • **Transmission investment**: Studies by EPE show the country will need at least 38 new lines over 5,000 km in the coming years, representing a R$10.6 billion ($2 billion) investment.
Enterprise customer goals	• **Progress in sustainability reporting**: The rise of sustainability indexes, implementation of social responsibility and sustainability standards, and increased foreign investment have driven a growth in sustainability reporting and commitments. • **Boycotts over deforestation**: Companies are taking action not to contribute to deforestation, ending contracts with Brazilian producers over environmental risks within retail supply chains.
Consumer Activism	• **Youth activism**: Youth-led climate activists and indigenous population campaign for action on deforestation and air pollution. • **Consumer DER investment**: Increased consumer DER participation, with over 335,000 consumer units across residential, industrial, commercial and public sector, totalling more than 3.2 GW, with the majority coming from solar power.
Investor activism	• **ESG investment**: Brazilian brokerage XP Inc. is creating two investment funds totalling R$100 million ($18.6 million) focused on companies with superior ESG practices. • **Deforestation concerns**: Nordea Asset Management, which controls more than €200 billion of funds, announced it was quarantining Brazilian government debt due to environmental risks and concerns.
Cities in transition	• **Smart city demonstration projects**: Increased investment in the digitalization of electricity networks in cities, energy-efficient buildings and urban infrastructure, and social innovation practices (e.g. affordable housing). • **Public lighting**: The integration of efficient LED infrastructure with smart monitoring systems is integral to the development of "smart cities", improving energy efficiency while increasing security and reducing crime.
Investment in clean energy technology	• **New technologies**: Growing demand and flexibility needs, i.e. storage technologies beyond lithium-ion, new materials. • **R&D spend lag**: Brazil R&D spending as a percentage of GDP is 1.3%, compared to China at 2.2% and the US at 2.8%. • **Mobility**: The National Biofuel program remains very competitive and may be a barrier for electric vehicle (EV) penetration; however, the government is evaluating the potential of domestic EV component production, announcing an IPI[1] tax exemption.

Notes: (1) Imposto Sobre Produtos Industrializados (IPI) tax applied to industrial products produced in Brazil or imported.
Sources: Agora; World Bank (1, 2); Smart Cities World; World Economic Forum; IHS Markit; FT; Reuters; BNAmericas; IADB; DLA Piper; BBC; SustainAbility; Brazilian Biofuel Program; ABSOLAR

Digitalization underpins the energy transition



COVID-19 impacts to energy transition trends in Brazil

Digitalization

Increasing electrification	• **Electricity demand drops**: Electricity demand falls 12% and 10% in April and May 2020, respectively. • **Low oil prices hurt EV adoption**: Cost competitiveness of electric vehicles weakened by steep decline in oil prices.
Growth of green technology	• **Government turns to green finance**: Support for a green bond program will help channel funding towards solar PV (8 GW), wind (25 GW), small hydro installation (3 GW) and energy-from-waste facilities. • **Calls for recovery through solar**: Brazil witnessed a 53% surge in solar generation in April 2020. Solar association ABSOLAR and manufacturers urge for the sector to become a key pillar for pandemic recovery, proposing low-income tariff scheme.
Network of the future	• **Distribution companies receive bailout**: Brazil's energy sector regulator, ANEEL, approved a $3.1 billion bailout package for power distribution companies suffering from drop in demand and high consumer delinquency rates. • **Auctions postponed**: Scheduled for May 2020, auctions for both generation and transmission capacities have been indefinitely delayed by the Ministry of Mines and Energy.
Enterprise customer goals	• **Delay of privatization**: Having already faced multiple delays, the Brazilian government has pushed back the privatization of state-owned utility Eletrobras until 2021 in order to focus its efforts on handling the COVID-19 pandemic. • **Cost-cutting focus**: Brazilian companies take measures to cut costs and protect their bottom lines.
Consumer activism	• **Community organizations take lead**: Community groups, health workers, local officials and private donors have set up campaigns, developed response measures and set up quarantine centres to combat the virus.
Investor activism	• **Company finance focus**: As a result of COVID-19, greater focus on company financial health and improving operational efficiencies than additional capital expenditures. • **ESG investors**: Investment funds managing close to $4 trillion in assets called on Brazil to halt deforestation of the Amazon in an open letter warning that biodiversity loss and carbon emissions pose a systemic risk to their portfolios.
Cities in transition	• **Air quality improves**: During the partial lockdown, São Paulo saw drastic reductions in NO (~77%), NO_2 (54%) and CO (~65%) concentrations, compared to pre-lockdown levels and five-year monthly average. • **Irregular access to water**: Inconsistent water access, particularly in cities such as Rio de Janeiro, threatens efforts to contain the pandemic and heighten risks for favela residents.
Investment in clean energy technology	• **R&D expenditures likely to fall**: Balance sheet difficulties could curtail corporate R&D efforts in sectors such as automotive. • **COVID impact on ethanol competitiveness**: Lower gasoline prices reduced the price competitiveness of ethanol, where hydrous ethanol experienced a 40% drop in price from February to April 2020.

Sources: Accenture analysis; Economic Times; Globo; Latin Finance; PV Magazine; T&D World; MercoPress; PV Tech (1, 2, 3); Science of the Total Environment; RioOnWatch; Independent; The New Humanitarian; Dialogo Chino

Overview of Brazil’s electricity market

Structural components of Brazil’s market

- As per the New Industry Law, electricity sector was unbundled, i.e. separation of generation, transmission, distribution
- Eletrobras, directly and via subsidiaries, is the largest entity, owning 31% of generation and 48% of transmission
  Installed capacity in Brazil is ~172 GW with 63% share from conventional hydropower

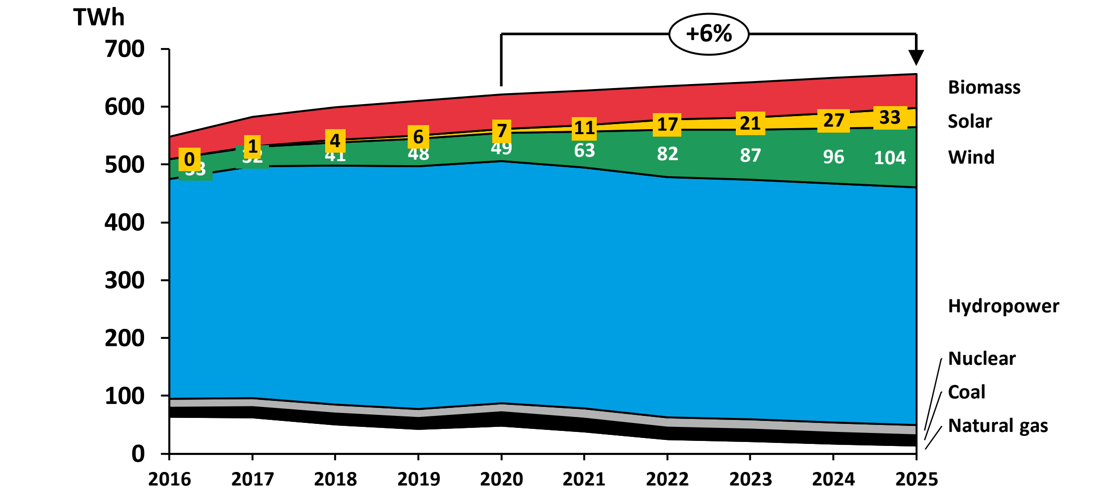
Growing demand and diversifying generation

- Electricity demand is expected to grow modestly by 1% annually until 2025 to 654 TWh
- Demand growth expected to triple to 1,605 TWh by 2050
- While the generation share of hydro is expected to maintain its dominance, the share of solar and wind is expected to double by 2025

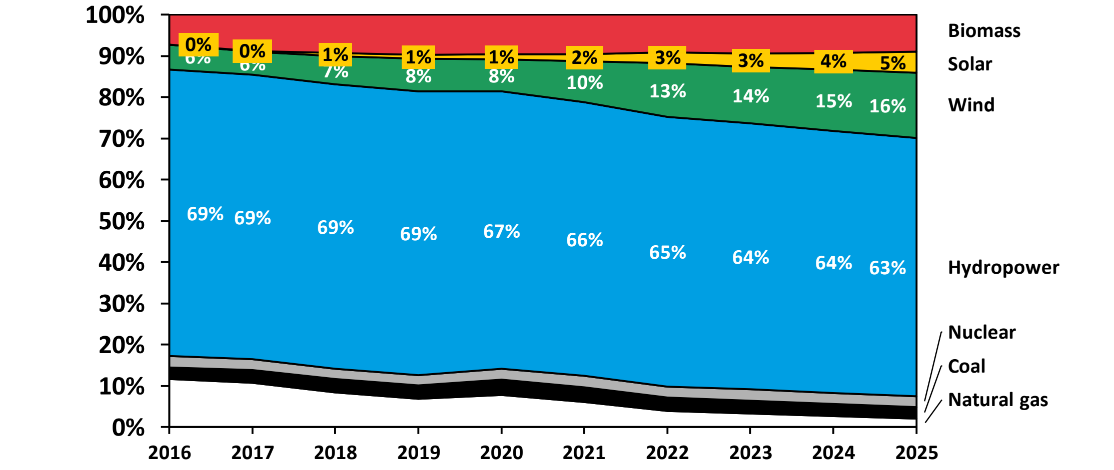
Climate and renewable energy goals

- Renewable energy targets
  - 27 GW wind deployed by 2026 (15 GW as of end of 2019)
  - 9 GW utility-scale solar deployed by 2026 (3.7 GW as of end 2019)
  - 23% share of non-hydro renewables in energy mix by 2030
- CO_2 emission goal
  - Economy-wide reduction in CO_2 emissions of 37% by 2025

Brazil electricity generation projected to increase 6% by 2025



Share of wind and solar generation projected to double by 2025



Sources: Central Electricity Authority; Agora; EPE; US EIA; UNFCCC; BNEF; Accenture analysis

Brazil electricity market structure

Several rounds of reforms have allowed for separation of generation, transmission and distribution; Eletrobras controls large parts of the value chain, with 31% of generation and 52% of transmission market shares, respectively.

Generation

Other Public Concessionaries, IPPs[1] and Self Producers

69% of generation; market is fragmented with largest private company having ~5% market share

Eletrobras

31% of generation directly and via subsidiaries

Transmission

Private Transmission Companies

48% market share including foreign companies such as China's State Grid (5% share)

Eletrobras

52% market share directly controlled

Distribution and Retail

Traders → Free Market (ACL)

Concessionaries → Regulated Market (ACR)

Total of 63 concessionaries with top ten companies accounting for 68% market share

End Consumption

Free market participants can directly negotiate bilateral purchase agreements with generators

Free Market (ACL)

32% of overall consumption and 78% of industrial consumption

Regulated Market (ACR)

68% of overall consumption (includes households, commercial and small industrial); ACR customers have no choice over their retail power provider

Legend: Private companies | Government companies | Public + private Cos

[1] IPPs refer to both private standalone generation companies as well as private industrial companies that invest in generation capacity for captive purposes

Source: Central Electricity Authority

COVID-19 impact on Brazil's electricity market

Electricity demand down across sectors

- Electricity demand down double digits year-on-year in the month of May 2020.
- Decline in free market (proxy for industrial consumption) down by 10% with automotive and services sectors falling 47% and 38% respectively.

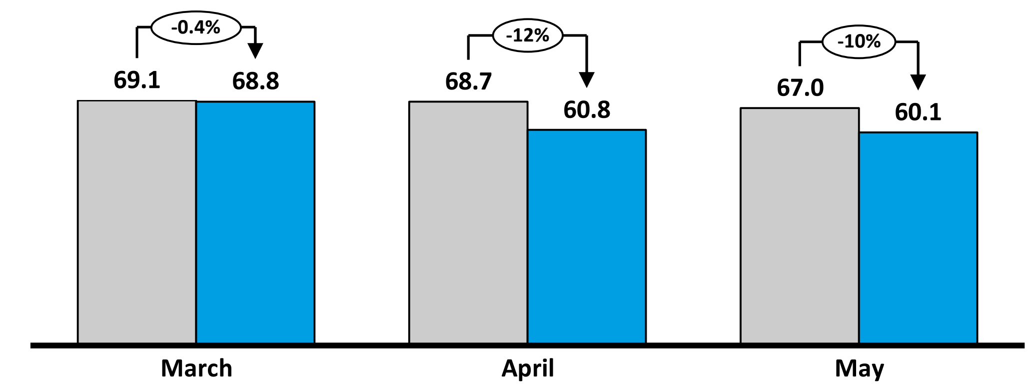
Deteriorating health of distribution companies

- Distribution companies estimated to see a 10% reduction in revenues with the majority of malaise coming from industrial and commercial customer segments.
- Energy traders expect a negative impact of c. R$5 billion due to requests for flexibility and lower consumption by their customers.
- Brazilian government has negotiated a package of R$10 billion in loans.

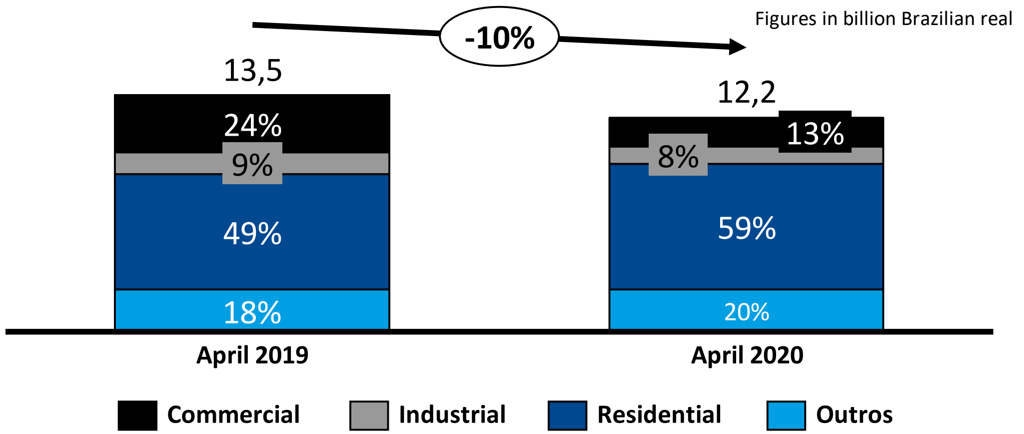
CO_2 emissions not expected to fall

- Brazil could produce 10-20% more CO_2 emissions in 2020 due to deforestation and farming compared to 2018.
- The principal source of emissions, land use change (44% of emissions in 2018), is booming due to the rise in Amazon deforestation, which is advancing despite the pandemic.

Brazilian daily load change in TWh (2020 vs. 2019)



Estimated distribution companies revenue from customer segments



Source: Accenture Analysis

Sources: *Terra*; *Reuters*; *Globo*; *Instituto Acende Brasil, White Paper Edition 23; EPE; Canal Energia; Accenture analysis*

COVID-19 impact on Brazil's economy

Severe GDP impacts in Q2

- GDP projected to contract by 9.1% in 2020 according to the IMF as of June 2020.
- However, local market expectations paint a relatively more bullish outcome projecting a c.6% decline in GDP for 2020 followed by a rebound of c.3% in 2021.
- Most significantly impacted sectors were the provision of services and the extractive industry.

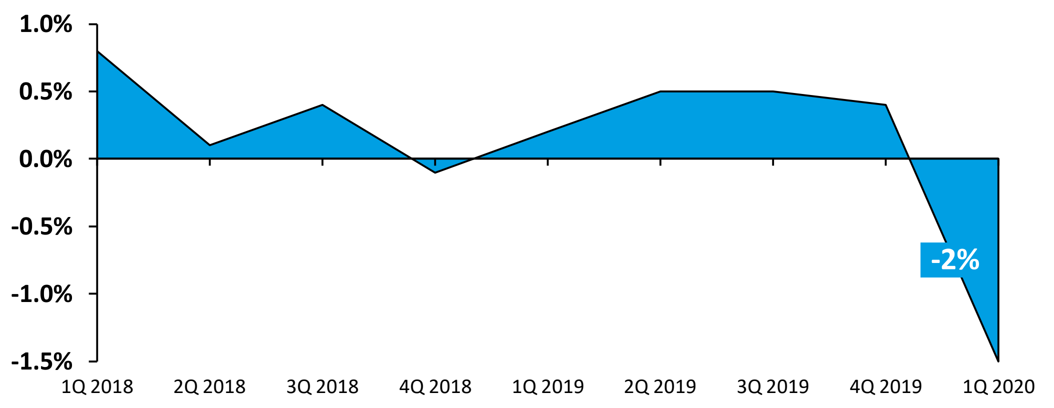
Fiscal deficit rises with stimulus packages and economic pain

- Due to fiscal stimulus from Brazilian government, debt to GDP is now projected at 82% by end of 2020 and is expected to rise to 93% by end of 2021.

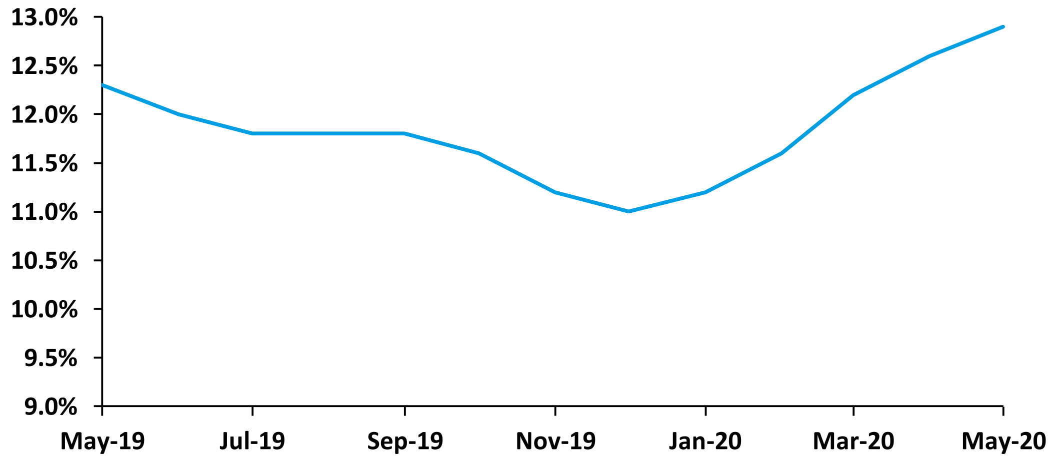
Unemployment remains stubbornly high

- Unemployment rate in the three months leading to May spiked to 12.9% vs 12.2% during the same period last year.
- Labour force fell 7% in quarter ending May 2020 compared to prior quarter ending February 2020.

Quarterly GDP turns negative in Q1 2020



Brazil unemployment rate (three-month moving average)



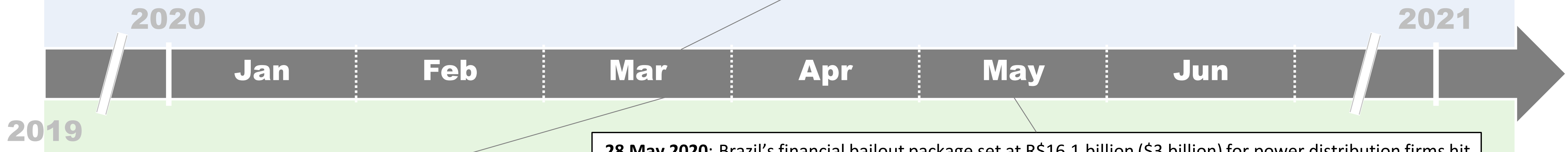
Sources: IMF; UOL via Reuters; CNBC; Globo; Cronista

Brazil COVID-19 stimulus timeline

Brazil's R$750 billion ($150 billion) stimulus package to counteract the economic impacts of COVID-19 is projected to comprise 11% of the country's GDP.

Lockdown

24 March 2020: Several states enter lockdown for initial 15 days, despite President Jair Bolsonaro downplaying the danger of the virus and focusing on its economic impact. Reactions among Brazil's 27 state and district governments varied widely.



Stimulus

26 March 2020: Economic stimulus package of R$750 billion ($150 billion) announced. Most aid measures (72%) affect financial markets.

28 May 2020: Brazil's financial bailout package set at R$16.1 billion ($3 billion) for power distribution firms hit by liquidity issues in the economic slowdown caused by the COVID-19 pandemic.

- A total of 61 Brazilian power distribution firms will take advantage of the financial bailout.
- The companies will be able to access loans from 19 banks, with an 11-month grace period which will come due in 54 months and annual interest of 2.9% over the Brazilian interbank rate (CDI).
- Funds will be repaid through consumer power bills for five years but is structured in a way to avoid further rate hikes for the next 12 months. This mechanism has been hailed to facilitate a solution to the crisis without the need to access federal resources.

ANEEL (National Electric Energy Agency) authorised the transfer of R$2.02 billion ($400 million) to guarantee liquidity to companies in the electricity sector during the crisis generated by the coronavirus pandemic. The funds will come from a reserve fund composed of charges from electricity bills.

Sources: Reuters; KPMG

Power sector modernization (1 of 2)

PLS 232 is a milestone regulatory approach for the Brazilian power sector

Key issues addressed by PLS 232

PLS 232 (2016)

- Market liberalization
- Hydrological risk management
- Tariff rationalization
- Cost reallocation
- Spot price formation
- Alternative energy subsidies review
- Commercialisation model review
- Contracting model review
- Tariff transparency

Purposes

- Better symmetry of cost and risk allocation between captive and free markets
- Subsidies rationalization
- Market-driven price formation

Sources: PLS 232, Accenture analysis

Power sector modernization (2 of 2)

PLS 232 highlights a number of issues and considerations that must be mentioned when considering modernization

Issue	Measure	Implications
Market liberalization	• Gradual reduction of load/voltage requirements for consumers to choose their power suppliers	• Allows small load consumers to be able to choose their power suppliers
Tariff rationalization	• Guidelines for use of locational signal in transmission and distribution tariffs	• Potential transportation costs reduction
Cost reallocation	• Migration costs (from regulated to free market) split among all consumers (regulated and free) • Mechanisms to deal with over contracting by distribution companies • Guidelines for the payment of grants when extending the concession period for existing power plants, alleviating taxes over tariffs • Clarity over charges to be paid by self producers	• Migration costs presently allocated mostly to regulated consumers • Potential cost reduction for consumers • Reduction of disputes around costs charged to self producers that were not forecasted in the original investment
Spot price formation	• Hourly spot price through bid/ask process	• Market-driven spot price
Rationalization of subsidies	• Substitution of transportation discounts by valuing the benefits of alternative generation sources • Subsidies should be granted in exchange for environmental and social requirements for those who benefit from them	• Dependent on valuation criteria to be established
Commercial model	• Improvement of financial guarantees for spot market • Fostering the development of power exchange hubs	• Enhance safety for short-term market • Better liquidity and power price visibility
Contracting model	• Separating capacity and energy prices; capacity to be paid by all consumers (free and captive)	• More isonomic cost allocation (free consumers presently do not pay for systemic security)

Source: Accenture analysis

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Recovery solution selection criteria

Selected recovery solutions are required to meet the following criteria:

1 Accelerates the energy transition

The recovery solution moves the market closer to net zero

2 Stimulates economic recovery

Implementation of the recovery solution should stimulate job creation by 2021+

3 Enables meaningful System Value assessment

It should be possible to model and assess the recovery solution for meaningful results within a 2025 horizon

Three recovery solutions for Brazil to support the economy and advance the clean energy transition

Enabled by PLS 232 market reforms

	Non-Hydro Renewables Expansion	Digitalization of Transmission and Distribution	Smart and Efficient Cities
Solution overview	Brazil can accelerate non-hydro renewables expansion through multiple initiatives such as fostering the liberalized market (ACL) with **innovative PPAs**, **developing a new structured solution to MRE**, and **fossil thermo-plant substitution**	Brazil can pursue several opportunities to improve network quality and digitize and modernize its grid ranging from basic investments and incentives in distribution to **smart grids**, **smart meters**, **internet of things**, and **distributed energy resources**	Brazil can invest in smart cities via setting up a **digital energy network,** enabling **energy efficiency and new business models** schemes to support **distributed generation**, DERs and electric mobility, as well as public services such as **public lighting**, **vegetation management**
Capacity and generation impact	• 3.5 GW incremental wind capacity through 2025 • 3.3 GW incremental solar capacity through 2025	• Technical loss reduction by 0.8% (5 TWh) • Non-technical loss reduction by 1.6% (11 TWh)	• ~7% efficiency gains by 2025 • Reduced generation by 41 TWh (6 TWh coal, 8 TWh natural gas and 27 TWh hydropower)
CO_2 emissions	↓ 34 Mt Cumulative reduction in electricity base case CO_2 emissions through 2025	↓ 14 Mt Cumulative reduction in electricity base case CO_2 emissions through 2025	↓ 45 Mt Cumulative reduction in electricity base case CO_2 emissions through 2025
Water footprint	↓ 62bn litres Cumulative reduction in electricity base case water footprint through 2025	↓ 1,888bn litres Cumulative reduction in electricity base case water footprint through 2025	↓ 6,156bn litres Cumulative reduction in electricity base case water footprint through 2025
Jobs impact	↑ >132k Direct and indirect jobs created from incremental wind and solar through 2025	↑ Up to 29k Potential jobs created by grid digitalization initiatives based on US figures	↑ >1m Potential jobs across smart buildings, appliances, efficient lighting based on US figures
Air quality and health	↑ $2.8bn Cumulative human health benefits from lower air pollutants through 2025	↑ $1bn Cumulative human health benefits from lower air pollutants through 2025	↑ $3.4bn Cumulative human health benefits from lower air pollutants through 2025

Notes: Figures in above solutions assume each initiative is enacted in isolation. CO_2 emissions represent cumulative reduction through 2025 relative to 2025 base case total from coal and natural gas. Water footprint represents cumulative reduction through 2025 relative to 2025 base case total, excluding biomass. Estimated human health benefits in $US from reduced coal generation and associated air pollutants. Mt = million (metric) tonnes.

Non-Hydro Renewables Expansion

Solution areas to stimulate non-hydro renewables generation investment

Innovative PPAs: As a key pillar of financing renewables in Brazil, developers are investigating several trends in PPAs applicable to Brazil:

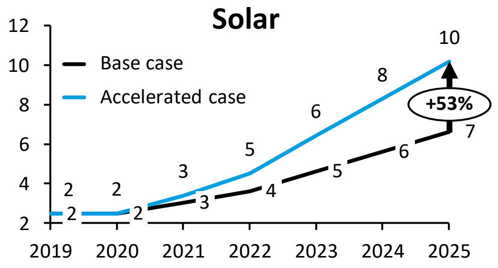
- *Dollar-indexed PPAs*: Inflation indexed to $US to hedge against currency risk
- *Downward price curves*: A pricing option to reduce the impact of Brazilian inflation indexation in future years, where the PPA price decreases throughout the PPA tenor
- *Self-generation PPAs*: Incentives to self-generate and sell power back to grid
- *EACs*: Mechanisms to easily trade environmental attribute certificates from PPA contracts

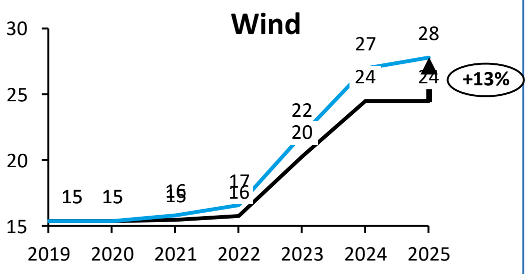
Structural solution for MRE: The MRE (energy relocation mechanism) is an accounting hedging mechanism by which a country-wide pool of hydro-generation resources is drawn from to cover shortfalls for hydro plants in need. However, the MRE was designed over 20 years ago and did not anticipate conditions such as such as large-scale implementation of wind and solar capacities, the ability to contract reserve energy at zero variable (marginal) cost, limitations to reviewing the physical guarantees of generation ventures, reduction of storage capacity, changes in hydrological conditions and consumptive uses. Additionally, the MRE uses outdated parameters to calculate physical guarantees.

To support renewables growth at utility scale and integrate into the National Integrated System (SIN), the MRE structure must be revised. A structural solution for the MRE would be to rescale the physical guarantee and solve for the GSF (Generation Scale Factor), which is an integral issue in Brazilian power market and has contributed to approximately R$8 billion in defaults.

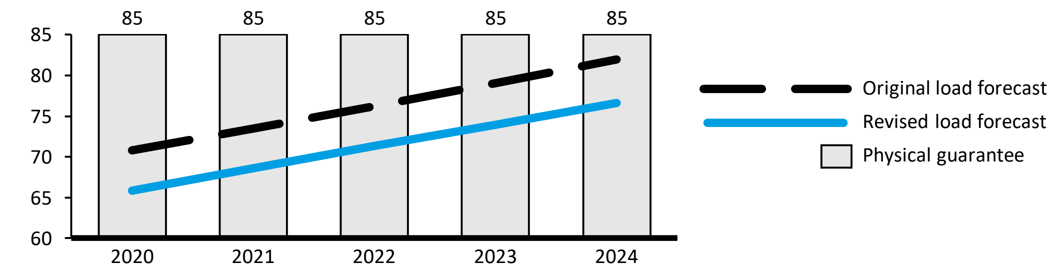
Fossil thermo-plant substitution: Phased decommissioning of coal and oil power plants is needed in order to comply with emissions targets. Power capacity should be replaced with non-hydro renewable sources such as solar and wind. According to José Goldemberg, former Secretary of Environment of the State of São Paulo, terminating PPA contracts with thermo plants (up to 1.5 GW) could lead to a reduction in approximately 10 Mt of CO_2 and eliminate ~R$1 billion in subsidies.

Projected utility-scale solar and wind capacity additions (GW)





Physical guarantee and revised load forecast



System Value impacts of Non-Hydro Renewables Expansion

34 Mt
Cumulative reduction in electricity base case CO_2 emissions through 2025,
13 Mt CO_2 emission reduction in 2025

62bn L
Cumulative reduction in electricity base case water footprint through 2025,
24 billion litre reduction in 2025

132k
Direct and indirect jobs created from incremental wind and solar through 2025

$2.8bn
Cumulative human health benefits from lower air pollutants through 2025

Sources: Instituto Acende Brasil, Accenture analysis

Digitalization of Transmission and Distribution

Overview

Despite having almost universal access to electricity, Brazil struggles with power supply quality. Power outages are far longer and more frequent than in developed nations. Additionally the average electricity price on a purchasing power basis is among the highest in Latin America and is on par with European peers such as Germany and Italy.

Modernising the transmission and distribution (T&D) network through basic investments and incentives in distribution and digital initiatives can improve quality of power supply, reduce energy losses and enhance O&M efficiency of T&D companies. Additionally, modernization of the T&D network would be conducive to increasing penetration of variable renewable energy sources such as wind and solar as well as improving system reliability. However, to scale up digital initiatives to achieve such benefits, mitigating impediments (tariff structure, cost and risk allocation) and creating a conducive incentive structure for investing in digital technologies (e.g. smart meters) must be considered to stimulate private investment.

Smart grid and digitalization initiatives

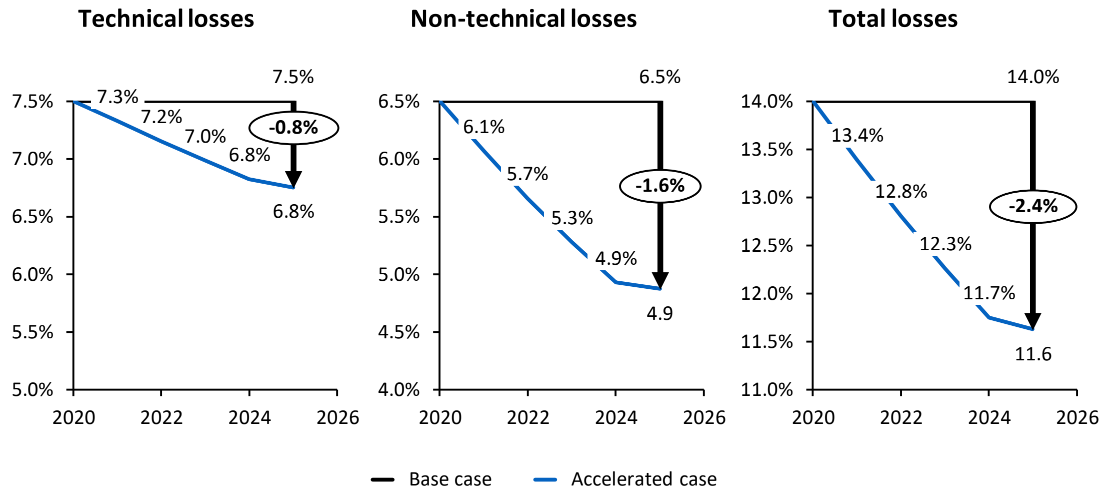
Smart meters: Investment in smart meters in Brazil is mainly restricted to pilot smart grid projects, although some companies are planning for more significant deployments. Smart meters would enable reduction of electricity losses and theft, ultimately contributing to reduced energy prices and increased affordability. However, incentives for large-scale implementation of smart meters should be considered based on international experience. For example: tax/depreciation benefits to distribution companies to write off existing analogue meters from their balance sheet.

Internet of things (IoT): Using IoT ensures that utilities would digitally connect to most sources of power, users of power, and wires and transformers – enabling data flows across all these assets. IoT would enable utilities to reduce operational costs and increase overall system reliability, as well as optimize system operations and reduce energy transport losses.

Distributed energy resources (DER): DER encompasses distributed generation, demand response, distributed storage, microgrids and electric vehicles, and have the potential to reduce overall system cost and losses by providing power closer to demand. Fostering DER within a smart, digital grid would increase overall efficiency of the electricity system. To sustainably grow penetration of DER, several factors must be considered: regulation surrounding net metering, capex assistance for low-income households and the revision of the current volumetric-only tariff structure. Policy-makers should be cognizant of the potential for unintended consequences of DER adoption in order to avoid creating unintended subsidies for high-income consumers that can afford installation of rooftop solar panels to the detriment of all other users of the grid.

Modernization of control systems and control centres: The increased digitalization of the T&D grid will imply more complexity and thus require modernised control applications, supported by modern advanced distribution management system (ADMS) solutions.

T&D losses (% of total generation)



System Value impacts of Digitalization of T&D via reduction in losses

14 Mt
Cumulative reduction in electricity base case CO_2 emissions through 2025,
4 Mt CO_2 emission reduction in 2025

1,888bn L
Cumulative reduction in electricity base case water footprint through 2025,
558 billion reduction in 2025

29k[1]
Potential jobs created via smart grid and micro grid initiatives based on US figures

$1bn
Cumulative human health benefits from lower air pollutants through 2025

Sources: Smart Energy, IEA, Global Data, Elsevier, Stanford University, EESI
[1] Job calculations are based on US figures adjusted for population, with US as a proxy for a mature market that has undergone a high degree of digitisation

Smart and Efficient Cities

Overview

With more than 80% of Brazil's population living in cities, the deployment of a modern, reliable and affordable power infrastructure in urban hubs is mandatory to create a smart, efficient and sustainable system to boost the economy, while achieving Brazil's climate pledge[1] and transitioning to net-zero cities. According to the Brazilian Observatory of Smart Cities (OBCI), smart cities are expected to generate $59 billion in investments in Brazil in the coming years.

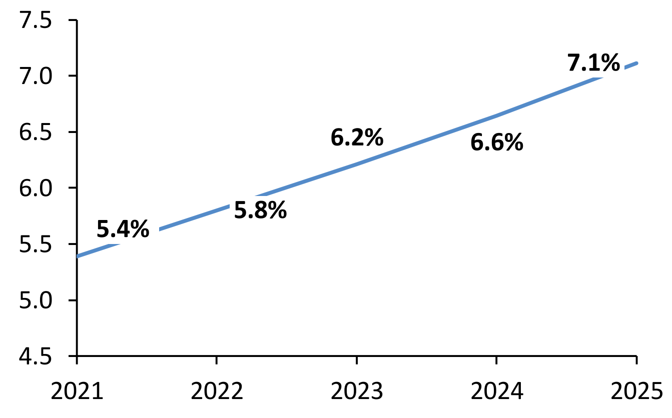
Smart cities require a digital energy network which is highly connected, flexible, open and interoperable to foster collaboration, value sharing and new business models among all stakeholders, facilitating further integration of renewables, DER and other public services, such as traffic control (via intelligent traffic lights), security and vegetation management. While biofuels account for majority of transport decarbonisation, a nascent e-mobility sector is developing.

Digitalization and efficiency initiatives for smart cities

- *Network digital twins*: A digital twin is a 3D virtual replica of the local electricity infrastructure comprised of sensors. The use of digital twins enables energy savings through greater understanding of energy use and energy efficiency, given access to dynamic data from IoT/smart network devices. This improves service quality through real-time status communication, predictive maintenance, remote assistance and other augmented reality (AR) and artificial intelligence (AI) capabilities. For example, The Urban Futurability digital twin demonstration project involves the full digitalization of the Vila Olimpia district in Sao Paulo, paving the way for smart cities, where the project can further integrate built environment applications for smart city infrastructure, such as sustainable construction and smart street lighting to address affordable housing and energy efficiency.
- *Distributed generation*: Brazil has surpassed 250,000 DER systems connected to the network, including solar panels, use of biomass and small-scale hydro plants of up to 5 MW. DER projects such as solar PV installation are particularly strong job creators. However, a revision of resolution RN 482 is needed to provide appropriate cost allocation among prosumers and other customers.
- *Net-zero carbon buildings (ZCB) certification*: Unlike the EU or US, there are currently no government incentive programs or deadlines in place for ZCBs. However, Brazil's Green Building Council has set up voluntary ZCB certification tracks (i.e. building labels), which involve implementing high levels of energy efficiency combined with on- or off-site renewable energy.
- *Public street lighting financing*: As municipalities take ownership of lighting assets from utility companies, the energy efficiency improvements of their lighting assets become a strong motivator to reduce costs. Standardising financing mechanisms such as COSIP[2] increase the attractiveness of efficiency investments in the sector.
- *Electrification of transport*: Brazil can benefit from increased electrification of its transport sector, especially with further incentives for public transportation as Brazil deploys electric buses.

Impact of energy efficiency investments

Estimated energy efficiency gains through 2025



Estimates based on the national electricity energy efficiency target of 10% by 2030.

7.1% efficiency gains by 2025 would reduce demand by 41 TWh, with reduced generation split across coal (6 TWh), natural gas (8 TWh) and hydropower (27 TWh).

An estimated **$1.3B+**[4] incremental investment through 2025 is expected in order to achieve efficiency targets.

Source: Oxford Energy, Accenture Analysis

System Value impacts of Smart and Efficient Cities

45 Mt	6,156bn L	>1M+	$3.4bn
Cumulative reduction in electricity base case CO_2 emissions through 2025, 11 Mt CO_2 emission reduction in 2025	Cumulative reduction in electricity base case water footprint through 2025,1,469 billion litres reduction in 2025	Potential jobs across smart buildings, appliances and efficient lighting based on US figures[3]	Cumulative human health benefits from lower air pollutants through 2025

Notes: (1) Nationally determined contribution (NDC) of 37% reduction by 2025, and indicatively 43% by 2030. (2) Contribution for Costs of the Public Lighting Service (COSIP). (3) EESI Energy Efficiency Jobs by Sector; job calculations are based on US figures adjusted for population, with US as a proxy for a mature market. (4) Based on previous period of PROCEL investments (IEEE, Procel Edifica; Accenture analysis)

Sources: Enel; Energy and Buildings; Carbon Brief; World Economic Forum; WRI (1, 2, 3); WGBC; IEEE; ICCT; WBG; World Bank; Polemica Paraiba; Electrive

Contents

System Value of clean energy transition

System Value benefits are seen across Brazil's recovery solutions

Economic, environmental, societal and energy value

- System Value dimension with quantitative analysis
- System Value dimension with qualitative analysis
- Priority System Value dimension

CO_2 Emissions CO_2 emissions based on energy source, generation mix and load changes

Water Footprint Water footprint based on energy source, generation mix and load changes

Access to Electricity Physical and economic access to clean electricity to support individual or society development

Jobs and Economic Impact Influx of jobs due to energy transition and renewables

Air Quality and Health Impacts to human health and natural environment from air & water pollutants, land use

Resiliency and Security Uninterrupted and diversified energy supply at affordable prices and the ability to bounce back from disruptions

Energy Productivity and Systemic Efficiency Energy efficiency plus systemic efficiency to maximize energy productivity

Foreign Direct Investment Market attractiveness for FDI with reliable energy and skilled resources

Reliability and Service Quality Life cycle approach to ensuring high system availability; improved customer service

Flexibility Ability to manage generation, demand and power flows (incl. power quality) across the grid, enabled by digitalization and storage

System Upgrade Technology (incl. digital) and capital investments in T&D to upgrade the system for variable renewables and DERs

Cost and Investment Competitiveness Market attractiveness and policy certainty for investment incl. R&D and levelized cost of energy

	CO_2 Emissions	Water Footprint	Access to Electricity	Jobs and Economic Impact	Air Quality and Health	Resiliency and Security	Energy Productivity and Systemic Efficiency	Foreign Direct Investment	Reliability and Service Quality	Flexibility	System Upgrade	Cost and Investment Competitiveness
Non-Hydro Renewables Expansion	**34 Mt** Cumulative reduction in electricity base case emissions through 2025, 13 Mt in 2025	**62bn litres** Cumulative reduction in electricity base case water footprint through 2025, 24 billion reduction in 2025	○	**132k** Direct and indirect jobs created from incremental wind and solar through 2025	**$2.8bn** Human health benefits through 2025 from decreased air pollution	◐	◐	●	◐	○	○	Top onshore wind projects in Brazil expected to operate at LCOE of **$24/MWh**; solar and wind dropping to $20 MWh by 2030
Digitalization of T&D	**14 Mt** Cumulative reduction in electricity base case emissions through 2025, 4 Mt in 2025	**1,888bn litres** Cumulative reduction in electricity base case water footprint through 2025, 558 billion reduction in 2025	●	**Up to 29k** Potential job creation by grid digitalization initiatives based on US figures	**$1.0bn** Human health benefits through 2025 from decreased air pollution	●	●	●	●	●	●	
Smart and Efficient Cities	**45 Mt** Cumulative reduction in electricity base case emissions through 2025, 11 Mt in 2025	**6,156bn litres** Cumulative reduction in electricity base case water footprint through 2025, 1,469 billion reduction in 2025	○	**>1m** Potential jobs across smart buildings, appliances and efficient lighting based on US figures	**$3.4bn** Human health benefits through 2025 from decreased air pollution	◐	●	●	○	●	●	

Analysis performed for given System Value dimension and recovery solution. For more detail, please see specific solution and/or relevant System Value dimension slide(s).

System Value dimension not as relevant to geographic market or not considered with given recovery solution.

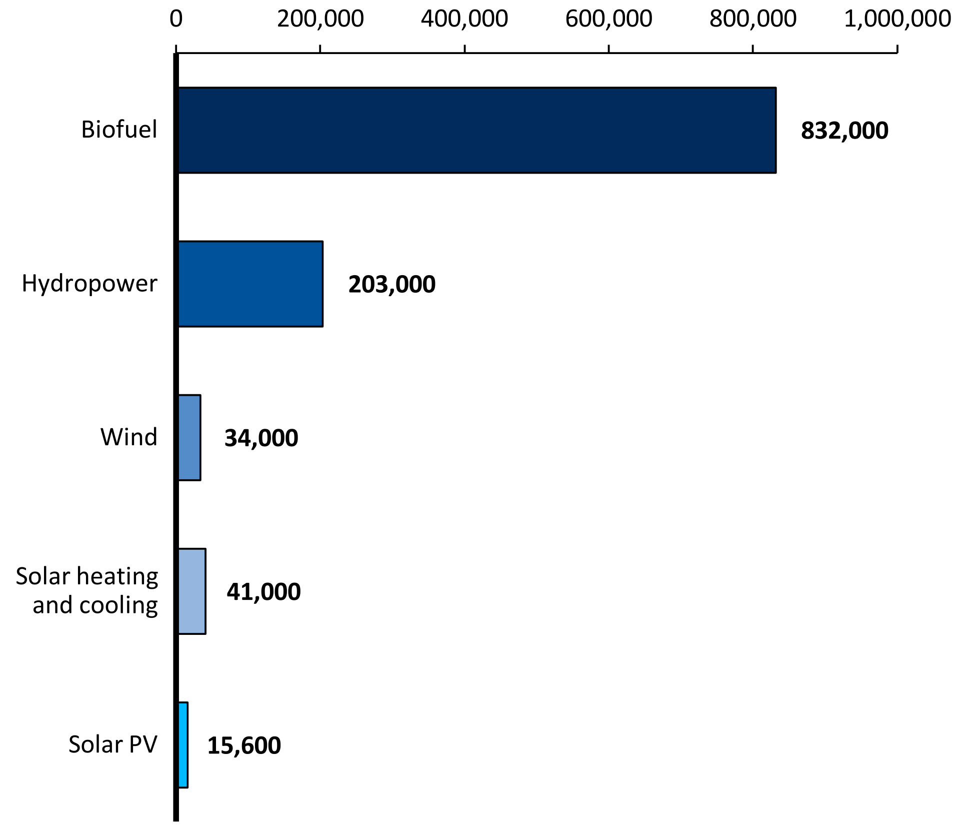
<u>Relative System Value dimension benefit for given recovery solution within market</u>

● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

System Value dimension: Jobs impact

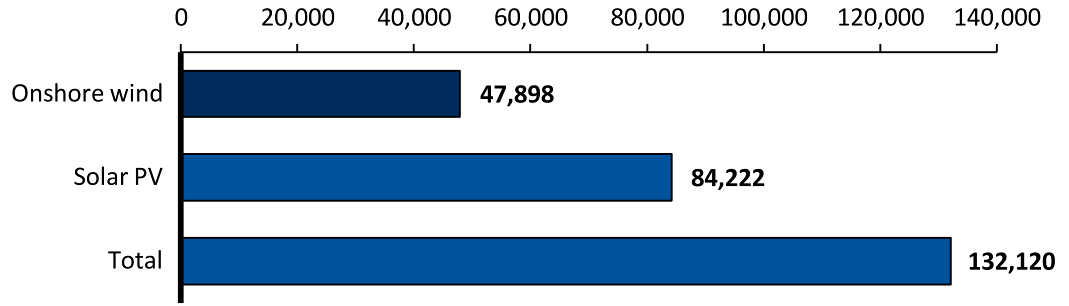
Given the relatively high unemployment in Brazil, investments in non-hydro renewables, grid digitalization and smart cities can be strong drivers of high-quality job creation.

Pre-COVID direct and indirect renewable energy and fuels jobs



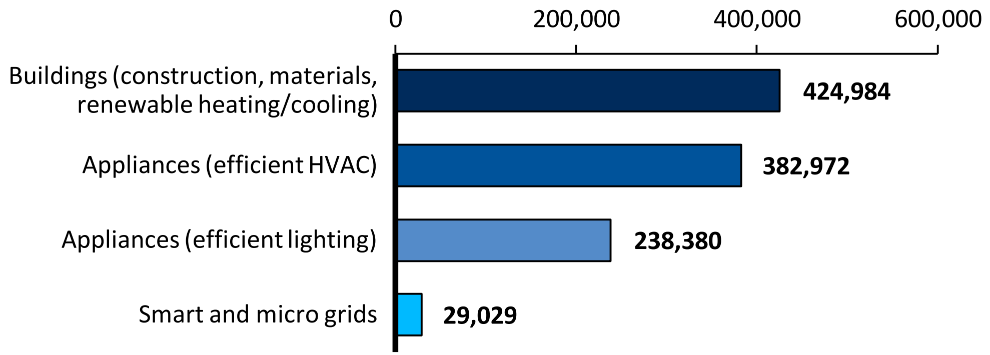
Source: IRENA 2019

Direct and indirect jobs created by incremental wind and solar through 2025



Sources: *Sustainability*, ABSOLAR, Accenture analysis

Potential job impact across Digitalization of T&D and Smart and Efficient Cities recovery solutions



Note: Based on US jobs in the energy efficiency sector in 2018 (*EESI*)

Note: Job figures for Digitalization of T&D and Smart and Efficient Cities recovery solutions are based on US figures adjusted for population, with US as a proxy for a mature market that has undergone a high degree of digitisation

System Value dimension: Energy productivity and systemic efficiency

Efficiency improvements to remove waste and optimize the electricity system across the value chain can be achieved through identified recovery solutions.

Energy productivity and systemic efficiency benefits by recovery solution		
Non-Hydro Renewables Expansion	◐	• Leveraging the existing hydropower to complement the load profile of wind and solar and support variable renewables growth will create systemic efficiencies on the supply side
Digitalization of Transmission and Distribution	●	• Digitalization initiatives such as smart metering would reduce non-technical losses as well as improve efficacy of invoicing and bill collection for power distribution companies (discoms) • Increased penetration of distributed generation has potential to lower T&D losses due to more local generation in remote areas
Smart and Efficient Cities	●	• The use of digital twins, a 3D virtual replica of the local electricity infrastructure made up of sensors, enables energy savings through greater awareness of energy use and energy efficiency opportunities, given access to dynamic data from IoT/smart network devices

Relative System Value dimension benefit for given recovery solution within market — ● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

System Value dimension: Foreign direct investment

FDI into the power sector represented 5.5% in 2018, lagging behind the oil and gas sector; many areas can benefit from additional foreign investment

Overview

Brazil represents an attractive destination for foreign direct investment (FDI) given its large population, favourable demographics and extensive natural resources. FDI inflows increased by 20% between 2018 and 2019 and reached $72 billion. Brazil is the 9th largest recipient of FDI in the world in terms of inflows, and the largest in Latin America and the Caribbean.

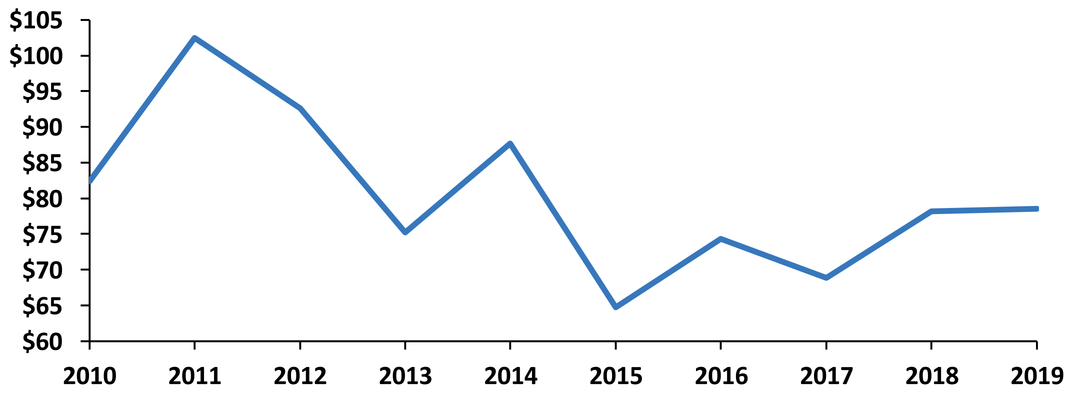
However, Brazil has complex tax, labour and information security systems that need to be revised and improved in terms of process and transparency to facilitate and attract more investments.

In 2018, power and gas sector in Brazil represented 5.5% of FDI inflows, which is half that of oil and gas extraction at 11.4%. Given the current conditions, there are several areas that can still benefit from domestic and foreign investment.

Key highlights of PDE 2029 (10-year energy plan)

- PDE 2029 indicates that the investments required for the next 10 years in the energy sector amount to approximately R$2.3 trillion, of which R$1.9 trillion in oil, natural gas and biofuels and R$456 billion in electricity generation and transmission.
- Total investments in transmission lines projected to reach approximately R$103 billion over the decade, with R$73 billion in lines of transmission and R$30 billion in substations including border facilities.
- PDE foresees an increase of 55,800 km in transmission lines, and an increase of 172 GVA in transformation capacity.
- Expansion of the installed capacity of electric generation of the National Interconnected System (SIN) forecast for the 10-year horizon is 75.5 GW, of which 60 GW is centralized generation and 15.5 GW is self-production and distributed generation.

Brazil historical FDI inflows ($ billion)



Recovery solution impact on System Value dimension

Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities
High benefit	High benefit	High benefit
Strong intent and supportive policy to grow capacity in non-hydro renewable sources of power will attract foreign direct investment	Large-scale programs to modernize/digitize grid infrastructure would attract global players in this space to invest in Brazil	Smart city demonstration projects and dedicated efficiency initiatives attract further investment into building low-carbon cities

Relative System Value dimension benefit for given recovery solution within market: High benefit; Medium benefit; Minimal-to-no benefit

Sources: World Bank, Santander, MME

System Value dimension: System upgrade

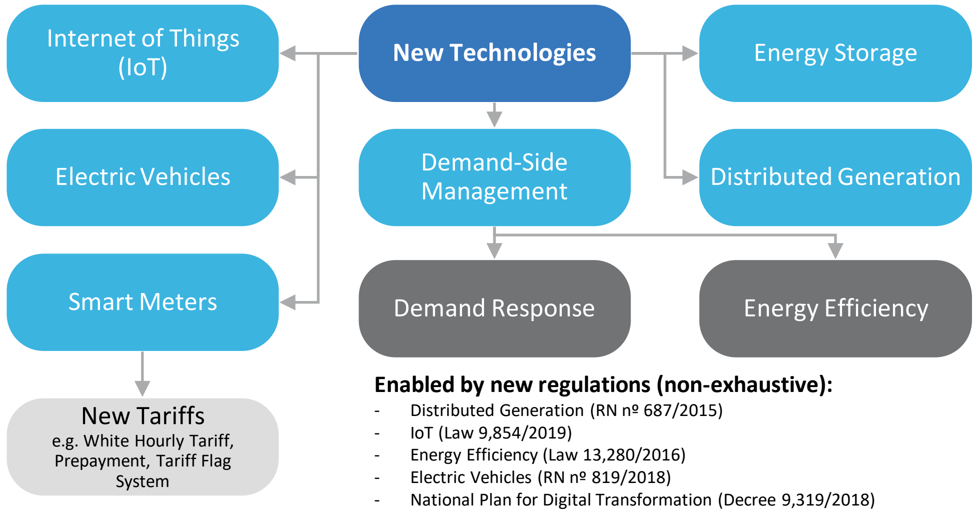
Challenges

- Brazil struggles with its reliability of supply, with power outages longer and more frequent than developed nations.
- The average electricity price on a purchasing power basis is among the highest in Latin America and is on par with European peers such as Germany and Italy.
- Brazil's energy intensity, measured as primary energy consumption per unit of GDP, continues to increase by 2% per year.
- Increasing variability of Brazil's energy mix will require more active grid management including demand side response only possible with smart grid.
- Greater electrification is needed to lower CO_2 emissions particularly in transport.

Modernising Brazil's energy system

- Brazil expects to have invested $86 billion in its transmission networks between 2013-2023, with a key goal to increase power system flexibility while maintaining reliability.
- For distribution, massive investments into basic grid infrastructure are needed alongside better renumeration and incentives to improve network quality.
- Solutions and smart grid technologies are needed that will optimize grid management and improve network congestion. Policies for distributed generation (DG), demand-side management (DSM) and new tariff schemes are on a path of accelerated deployment in Brazil.
- This, coupled with data and digitalization will improve the visibility of networks allowing for better prediction and management of faults. Digitalization can also reduce grid congestion and allow for demand to be matched with local generation, improving resilience and reducing costs.
- Technology adoption plays a crucial role, where the introduction of IoT and smart meters allows for more demand-side initiatives. Demonstration projects such as the Urban Futurability digital twins project and growing interest in smart cities will play a crucial role in upgrading infrastructure to decarbonise transport and the built environment.

Energy system technologies supported by new regulation and tariffs



Enabled by new regulations (non-exhaustive):

- Distributed Generation (RN nº 687/2015)
- IoT (Law 9,854/2019)
- Energy Efficiency (Law 13,280/2016)
- Electric Vehicles (RN nº 819/2018)
- National Plan for Digital Transformation (Decree 9,319/2018)

Source: *Dranka and Ferreira (2020)*

Recovery solution impact on System Value dimension

Non-Hydro Renewables Expansion

No material impact

Digitalization of T&D

Grid digitalization will bring material benefits through better planning, active management, and efficiency

Smart and Efficient Cities

Efficiency and e-mobility initiatives will deliver critical infrastructure required to decarbonise transport and the built environment

Relative System Value dimension benefit for given recovery solution within market — High benefit — Medium benefit — Minimal-to-no benefit

Sources: *IEA*, *Energy Policy*, *International Energy Efficiency Scorecard*, *CCEE*

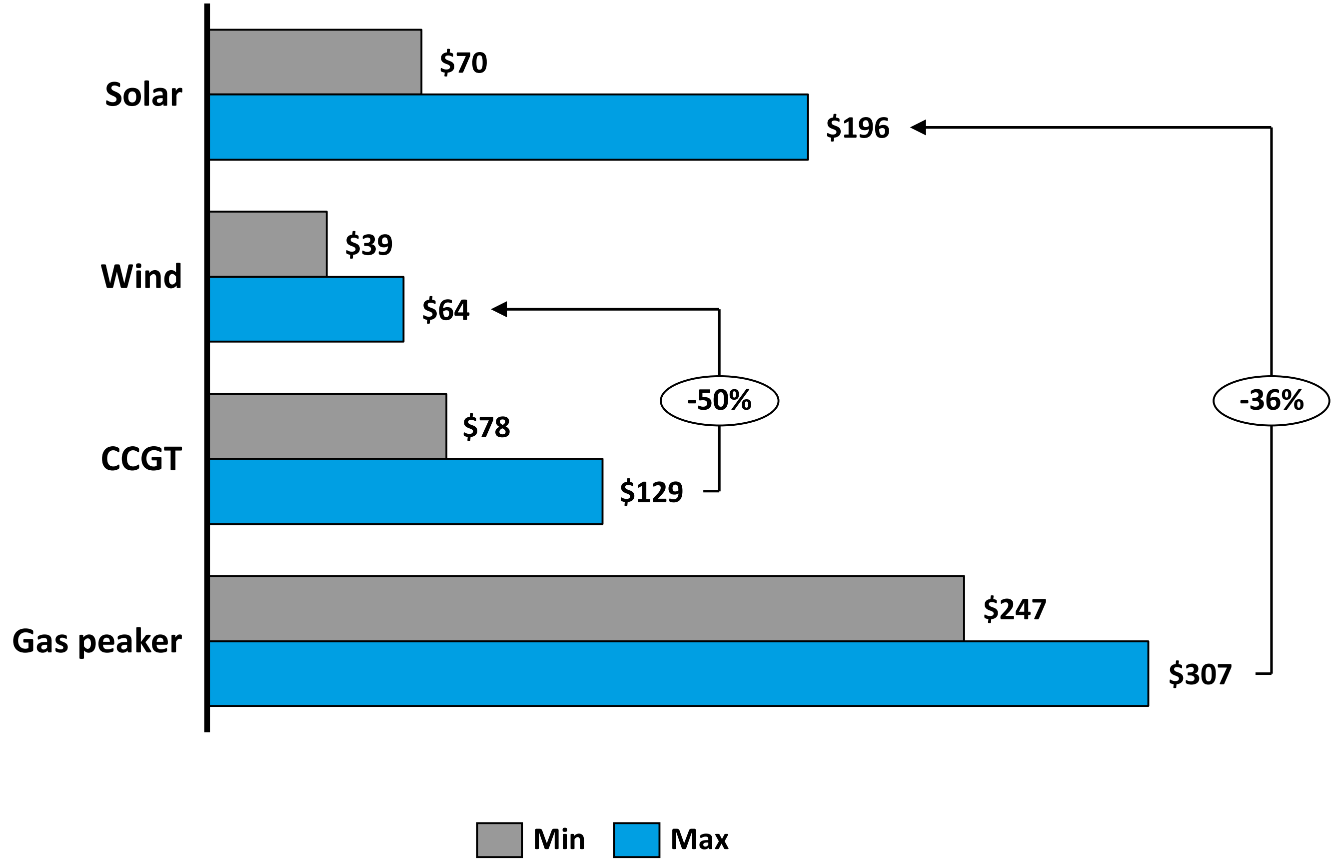
System Value dimension: Cost and investment competitiveness

Onshore wind and solar are competitive to Brazil's existing coal and oil power plants, and to natural gas.

Levelized cost of energy (LCOE) [$/MWh]

- According to BNEF, LCOE of wind and solar is expected to drop below $20/MWh by 2030.
- Top onshore wind projects in Brazil are expected to operate at LCOE of $24/MWh – lowest in the world ahead of the US at $26/MWh.
- The cost of equity and debt financing amounts to 60% of the LCOE for solar PV and wind projects.
- LCOE can be driven down further through lower cost of capital from foreign institutional investors if risks associated with renewable projects are mitigated.

2018 LCOE[1] ($/MWh)



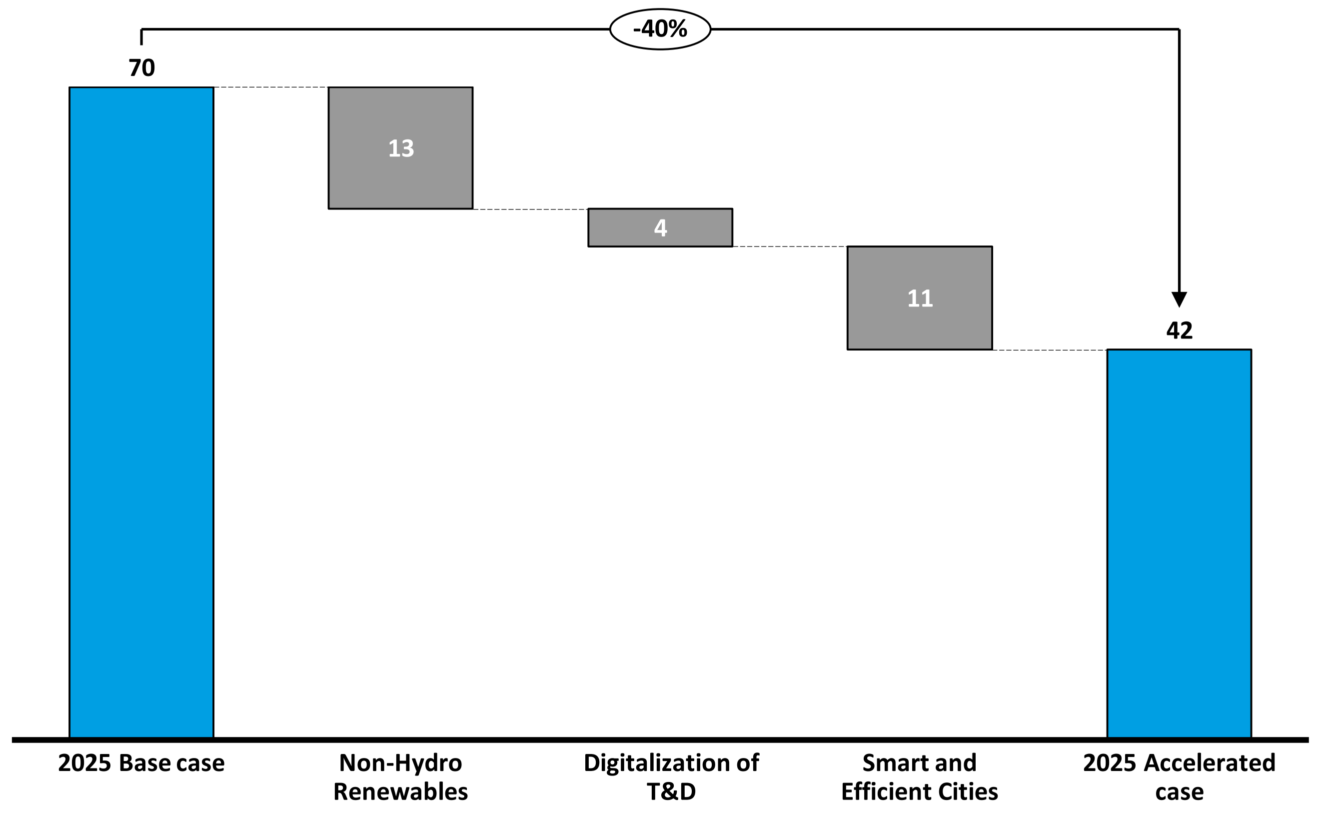
Note(s): 1. LCOE costs do not include transmission
Sources: Lazard, BNEF

System Value dimension: CO_2 emissions

Brazil can decrease its CO_2 emissions from fossil fuel electricity generation (relatively low due to high presence of hydro) through implementing the three recovery solutions, with combined effect of 40% lower emissions compared to base case by 2025.

2025 CO_2 emission impact by recovery solution	
Non-Hydro Renewables Expansion	**13 Mt** 18% of projected 2025 base case footprint
Digitalization of T&D	**4 Mt** 6% of projected 2025 base case footprint
Smart and Efficient Cities	**11 Mt** 16% of projected 2025 base case footprint

Total impact of recovery solutions on 2025 power sector CO_2 emissions (Mt)

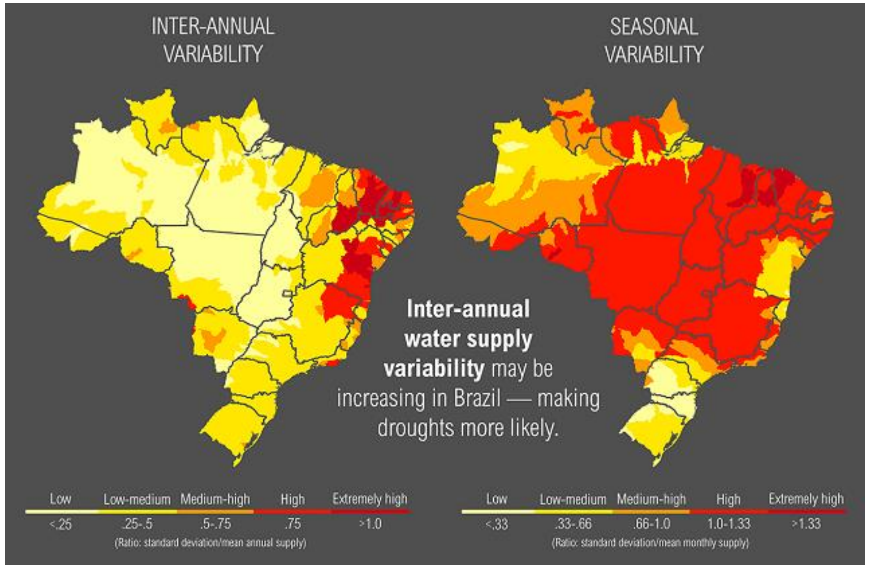


Note: Emissions from energy sources outside coal, natural gas, oil and hydro were not evaluated for this analysis. Mt = million (metric) tonnes.

System Value dimension: Net water footprint

Brazil could reduce its power sector’s water footprint – relatively high due to the large generation share of hydro – by 3.6% if all three recovery solutions are implemented.

Water supply variability in Brazil



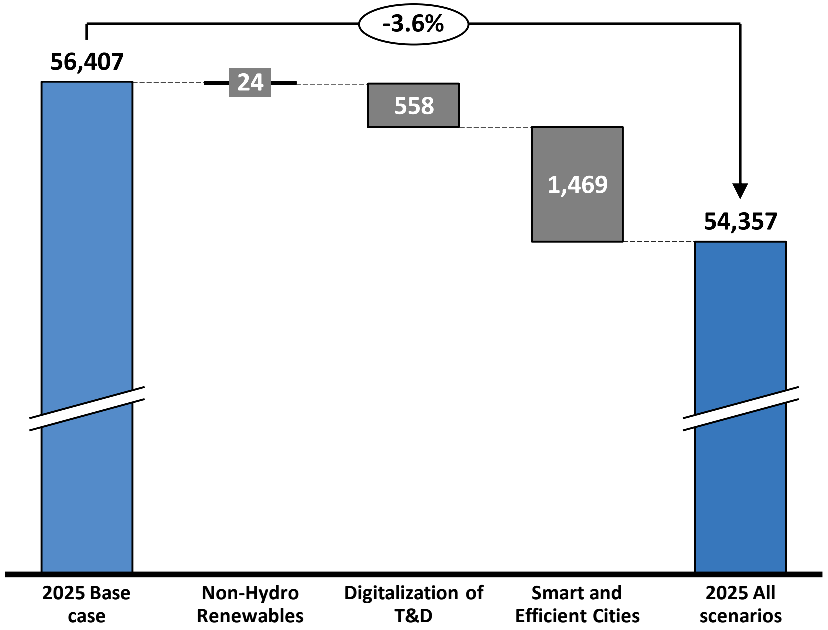
Inter-annual variability: *measures YoY water supply variation*

Seasonal variability: *measures water supply variation among the months of the year*

Source: WRI Aqueduct project

- Brazil’s water resources and population are unevenly distributed, as ~50% of available water resources are based in the Amazon River basin serving only 4% of the population. About 40% of the urban population faces medium to extremely high water stress, as they rely on local river basins.
- Water supply variability is another issue, with Brazil’s pronounced wet and dry seasons. Areas of high variability store freshwater underground and in reservoirs during wet periods.
- Deforestation is a major driver of drought and other serious dry periods, where initiatives to restore forests can help boost resilience to growing water crises. For example, restoring 2% of São Paulo's forestland could generate a 28% return on investment over 30 years in the form of reduced water treatment costs, removing one-third of sediment pollution and reducing turbidity by 50%.

Total power sector annual water footprint across recovery solutions[1]



Cumulative water footprint impact by recovery solution

Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities	All focus areas
24bn litres Reduction in electricity base case water footprint in 2025	**558bn litres** Reduction in electricity base case water footprint in 2025	**1,469bn litres** Reduction in electricity base case water footprint in 2025	**2,051bn litres** Reduction in electricity base case water footprint in 2025

Sources: WRI (1, 2); Accenture analysis

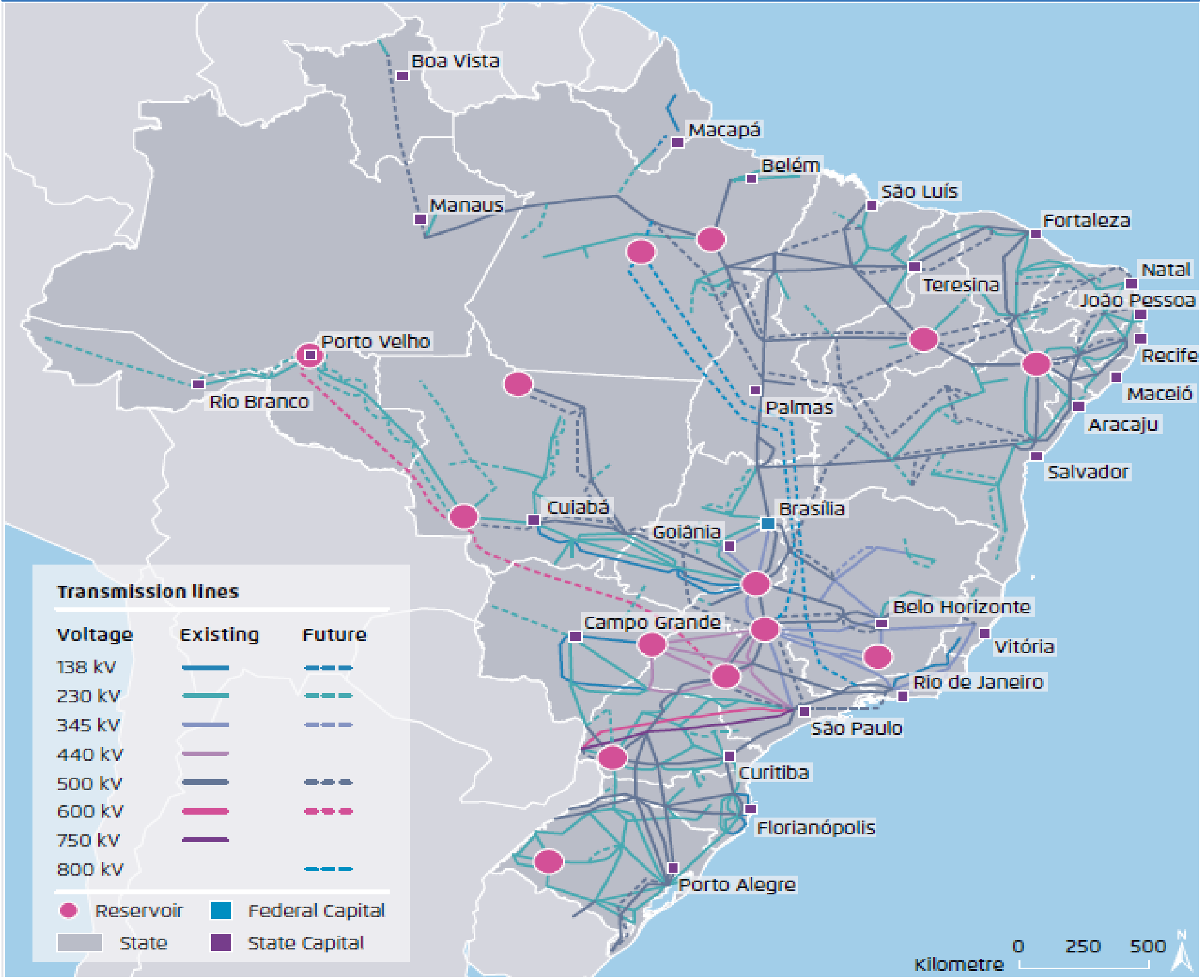
System Value dimension: Access to electricity

Brazil has near universal access to electricity for its citizens

Universal access to power

- As of 2018, Brazil has recorded 100% access to electricity, according to the World Bank (global average of 89%).
- Brazil has a large transmission grid, the National Interconnected System (SIN), which is operated by the National System Operator (ONS) and comprises 99% of the country's transmission lines with only parts of the northern substations that are unconnected.
- Unconnected regions usually rely on diesel generators to provide electricity.

Brazil's grid at a glance



Recovery solution impact on System Value dimension

Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities
No material benefit	Implementation of smart grids is likely to reduce technical losses and improve grid reliability which will improve quality of power supply	No material benefit

Relative System Value dimension benefit for given recovery solution within market: High benefit; Medium benefit; Minimal-to-no benefit

Sources: World Bank, Agora

System Value dimension: Air quality and health

Recent revisions to national air quality standards support further reduction in PM2.5 concentrations.

Brazil overview

- Air pollution kills approximately 49,000 Brazilians annually, with 50% of deaths attributed to outdoor air pollution.
- Deaths related to air pollution represent 1 in 26 deaths across all causes, the ninth largest mortality risk for Brazilians.
- PM2.5 causes the greatest risk, and major cities such as São Paulo have measured double the World Health Organization's (WHO) 10µg/m^3 limit. Approximately 7,000 lives could be saved by reducing the maximum outdoor PM2.5 exposure in cities to the WHO third interim target of 15µg/m^3.
- Given the high concentration of hydro in the generation mix, the electricity sector is far less culpable for air quality concerns relative to industries such as transport.

Policy and enforcement

- Brazil updated their National Air Quality Standards (NAQS) in November 2018, considering the WHO 2005 guidelines. The NAQS now include PM2.5 as a criteria pollutant, and interim targets were proposed for each pollutant.

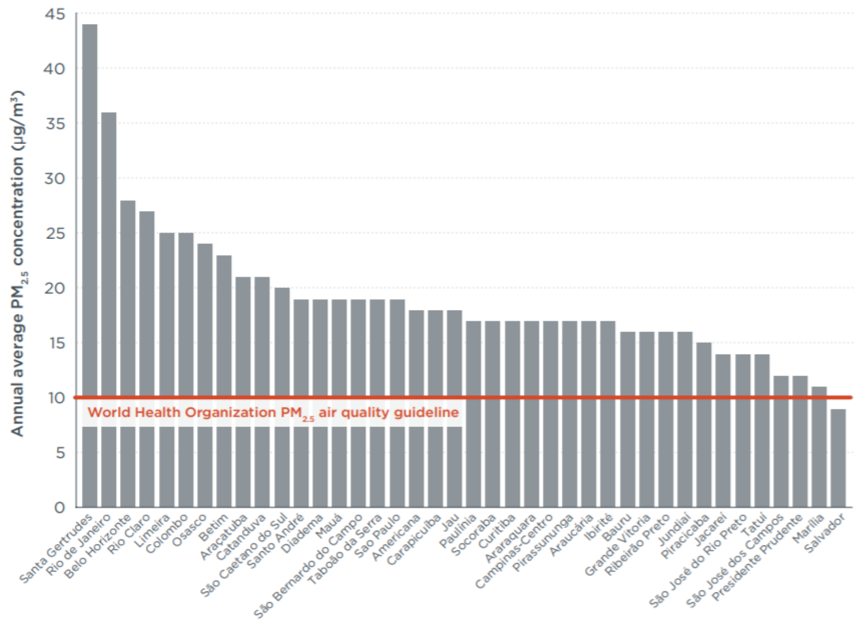
COVID-19 impact

- During the partial lockdown, São Paulo saw drastic reductions in NO (~77%), NO_2 (54%) and CO (~65%) concentrations, compared to pre-lockdown levels and a five-year monthly mean.

Recovery solution analysis

- The cost of air pollution was estimated based on oil, natural gas and coal related $PM_{2.5}$ emissions.

Nearly all of Brazil's cities have $PM_{2.5}$ levels above WHO air quality guidelines



Source: ICCT

Cumulative air quality and health impact by recovery solution

Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities	All solutions
$2.8bn Human health benefits cumulative through 2025	**$1bn** Human health benefits cumulative through 2025	**$3.4bn** Human health benefits cumulative through 2025	**$7.3bn** Human health benefits cumulative through 2025

Sources: Copenhagen Consensus, WRI, Science of the Total Environment, Scielo
Note: Differences in figure summation result from rounding

System Value dimension: Resiliency and security

Modernization of the distribution infrastructure system and increased investment in renewables can bolster resiliency as Brazil's electric grid faces challenges from natural disasters and an overdependence on hydropower.

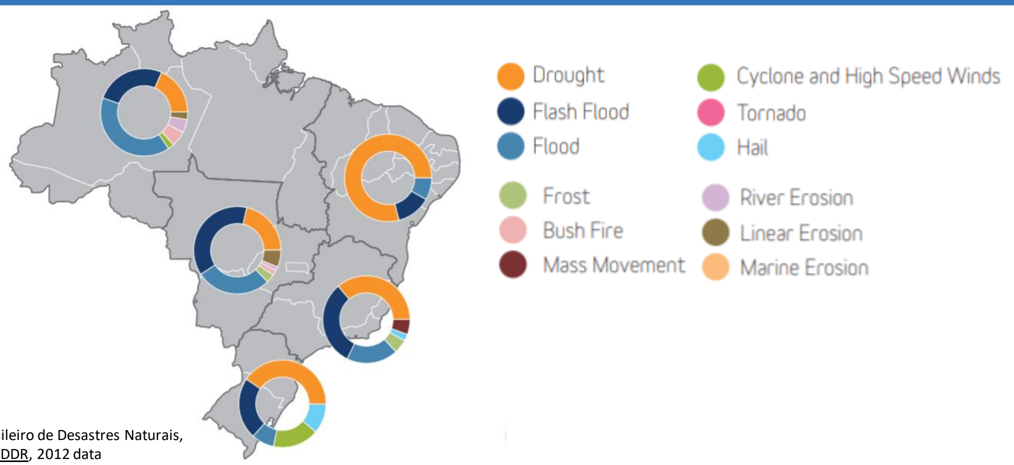
Challenges to Brazil's electrical system resiliency

- *Natural disasters*: Brazil faces both droughts and excess rainfall resulting in recurrent floods and landslides. This especially impacts urban areas, as the severity of natural disasters grows with climate change. Average annual losses from natural disasters amounts to an estimated $3.9 billion.
- *Reliance on hydro*: Brazil has seen increases in droughts and water shortages in recent years, making hydropower vulnerable to supply shortages.
- *COVID-19*: The current pandemic places restrictions on movement, affecting ongoing construction of transmission lines and distribution services.
- *Cyber resiliency*: Investment in T&D digitalization and integration of smart grid technologies will increase exposure to potential cyberattacks, through diverse system entry points.

How the clean energy transition can bolster system resiliency

- Hydropower has traditionally been used to provide energy security for seasonal use throughout the year, which can be further supported through localization of energy sources via solar and wind investment.
- Investing in a modern regional distribution infrastructure can increase resiliency as a more distributed, digital system can be sectionalized as problems arise from natural disasters. The adoption of new technologies, such as smart grids and demand-side management can enable greater resiliency.
- Digitalization efforts stimulate greater consumer participation and uptake of DERs, such as EVs and storage, which can further support local resiliency in areas where the network has failed.

Spatial distribution of natural disasters in Brazil by region



Source: Atlas Brasileiro de Desastres Naturais, CEPED – UFSC, GFDDR, 2012 data

Recovery solution impact on System Value dimension

Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities
Medium benefit	High benefit	Medium benefit
Increased domestic energy sources improve energy security with less reliance on imports	Digitalized transmission infrastructure, and adoption of IoT wireless systems would enhance resiliency of the grid	On-site generation creates local resiliency during outage events

Relative System Value dimension benefit for given recovery solution within market — High benefit; Medium benefit; Minimal-to-no benefit

Sources: *FSR; World Bank; Technological Innovation for Resilient System; Origami; EJSR; ISRN; GFDRR (1, 2)*

System Value dimension: Reliability and service quality

Renewables and grid modernization investments can help meet growing electricity demand and create a more reliable grid, as Brazil reduces its dependence on hydroelectric power sources.

Overview

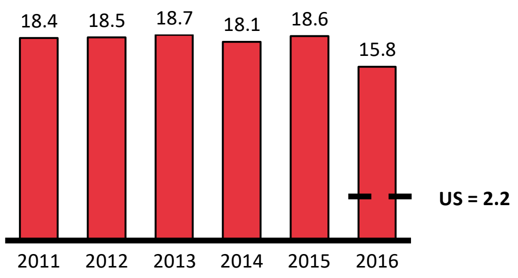
- Brazil generates over 65% of electricity from hydroelectric sources that are mostly located in the country's Amazon River basin in the north and west, while major demand centres lie along the eastern coast.
- The country's reliance on hydropower as well as the distant and disparate locations of its demand centres present reliability challenges for the grid.
- Insufficient investment in the grid, particularly the poor quality of distribution networks, has resulted in more and longer outages.
- Hydrological risks due to persistent drought and other environmental concerns have increased dependence on coal and oil plants that have high CO_2 emissions.

Enhancing grid reliability

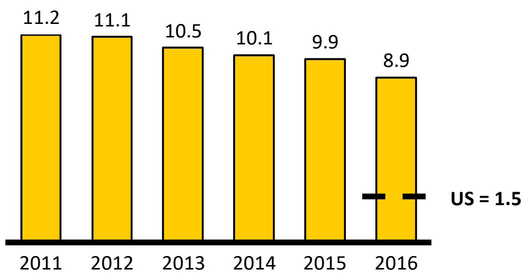
- As part of Brazil's 10-year plan released in 2016, the reliance on hydroelectric sources is expected to be reduced though still above 50% of installed capacity.
- Implementation of DER solutions such as rooftop solar and microgrids can improve reliability of power in unconnected regions of the north and northeast.

Power supply quality in Brazil lags behind developed countries, mainly due to the poor quality of distribution networks

Average duration of outages
Hours per year



Average frequency of interruptions
Times per year



Recovery solution impact on System Value dimension

Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities
Medium benefit	High benefit	Minimal-to-no benefit
Growth in wind and solar to reduce reliance on hydroelectric power	Implementation of smart grid technology to help reduce technical losses and frequency/duration of outages	No material benefit

Relative System Value dimension benefit for given recovery solution within market: High benefit; Medium benefit; Minimal-to-no benefit

Source: *EIA, Accenture analysis*

System Value dimension: Flexibility

With greater need for system flexibility as renewables uptake increases, Brazil’s vast portfolio of hydropower and pumped storage plants can help balance intermittent output from wind and solar installed capacity, along with the adoption of digital technologies.

Greater flexibility needs emerge as variable renewables grow

Ambitious renewable energy targets heighten need for system flexibility

- Grid flexibility refers to the grid maintaining a balance between generation and load.
- If targets are met, non-hydro renewables’ share of generation in Brazil is expected to grow from 7% in 2019 to 23% in 2030. The uptake of variable renewables will cause increased intermittency in supply, creating a greater need for system flexibility.

Repurposing hydropower for flexibility

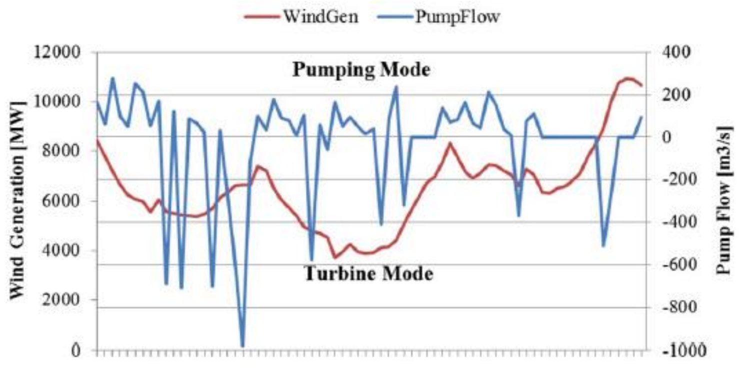
- The planned rising share of non-hydro renewables would lead to a surplus of hydropower generation.
- Hydropower serves as an excellent complement to variable renewable energy as it harbours large volumes of easily controlled energy. Existing surplus reservoir hydro can thus be configured to be used for seasonal pumped hydropower storage (SPHS) to increase long-term flexibility and allow for a larger share of non-hydro renewable power.
- The integration of pumped storage enables reservoir hydropower to support balancing short- and medium-term fluctuations on the power system.

Other technologies to bolster flexibility

- The digitalization of the T&D network and increased visibility over grid systems, through use of sensors, greater access to data and implementation of demonstration projects such as network digital twins can support grid flexibility.

Pumped hydro can support VRE[1] system participation

Pumped storage power plants (PSP) can support further integration of wind and solar. The graph to the right shows how PSPs can operate in turbine mode to complement generation deficits in case of reduced wind generation, enabling greater system flexibility.



Source: Department of Energy and Automation, Univ. of Sao Paulo, IEEE, 2017

Recovery solution impact on System Value dimension

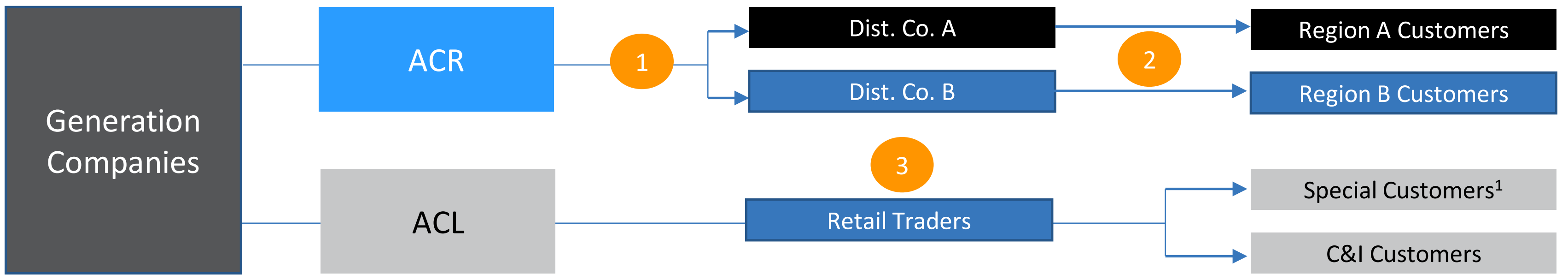
Non-Hydro Renewables Expansion	Digitalization of T&D	Smart and Efficient Cities
No material benefit	Adoption of smart grid technologies would enable flexibility gains, particularly via greater access to data as well as DER investment	Implementation of digital twins enables greater visibility of energy demand, where data can feed into flexibility markets

Relative System Value dimension benefit for given recovery solution within market — High benefit — Medium benefit — Minimal-to-no benefit

[1] *Variable renewable energy*
Sources: IEA (1, 2), Cleantech Group, Tech Xplore, Hydro Review

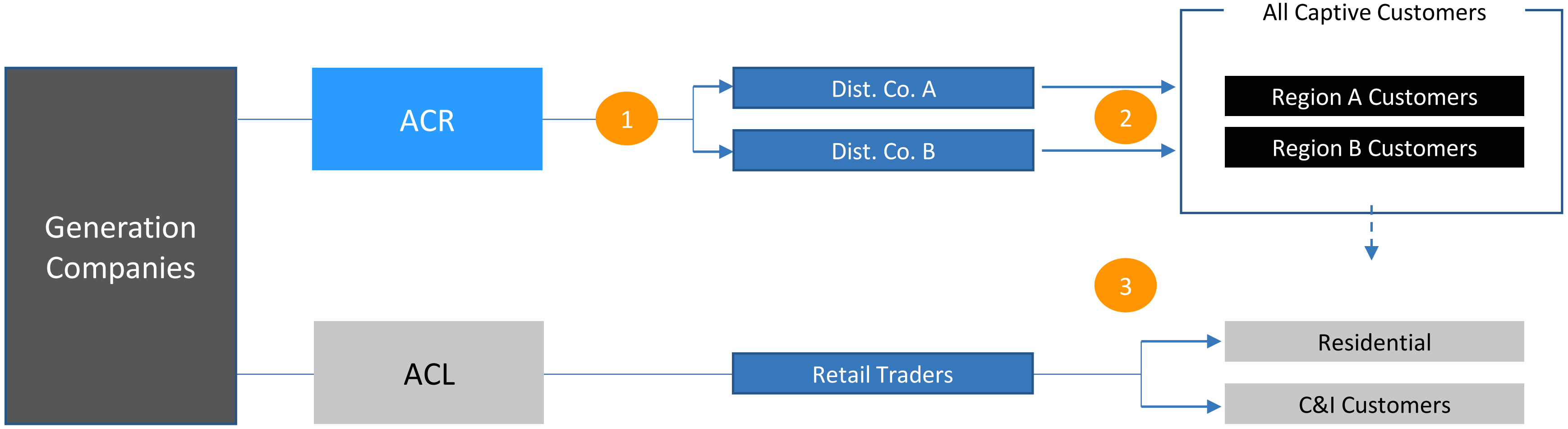
Appendix: Market liberalization overview

Current state



1. Distribution companies negotiate PPAs with generation companies
2. ACR customers are forced to buy power from regional distribution companies at regulated tariffs
3. ACL customers are free to negotiate prices and source/technology of power directly with generation companies

Possible future state



1. Distribution companies negotiate PPAs with generation companies and are incentivized to optimize cost and generation mix to respond to market competition
2. Customers are free to choose their retail electricity provider based on any criteria such as price, generation type, customer service, etc.
3. ACL customers are free to remain in the ACR or opt into the ACL where they can procure power directly from generators or via retail traders based on negotiate prices and source/technology, etc.

Note(s): 1) Special customers are defined as customers with a minimum electricity demand of 500 kW that are allowed to partidpate in the ACL
Sources: Accenture analysis

Appendix: Market liberalization System Value benefits

System Value element	Impact	Description
CO_2 emissions	◑	- Greater proportion of non-hydro and renewables in the generation mix is likely to lead to reduced CO_2 emissions
Jobs	●	- Competition at the retail level is likely to see rise of new entrants hence creating jobs across functions: finance, marketing, operations, etc.
Water footprint	◑	- Greater proportion of non-hydro and renewables in the generation mix is likely to lead to reduced water footprint
Air quality and health	◑	- Greater proportion of renewables in the generation mix is likely to lead to improved air quality
Access to electricity	◑	- Will improve ability to raise consumption - Quality of supply would increase
Systemic efficiency	◕	- Greater competition is likely to incentivise participants across the value chain to optimize efficiency across the value chain
Flexibility (grid services)	◕	- Greater competition is likely to incentivise participants to offer a greater range of flexibility and/or grid balancing services
Reliability	◕	- As consumer expectations of power supply increase due to existence of competition, reliability will become an imperative offering for all participants in the electricity value chain
Resiliency	○	- No material benefit
Investment	●	- Market liberalization would lead to increased investment across value chain including generation (low-cost wind and solar), T&D (digitalization to reduce system losses), and at the retail end (marketing, operations investments)
Cost and investment competitiveness	●	- Competition at the retail end of the value chain will lead to efforts to retain/grow market share by reducing cost to end-user - Efforts include procurement of low cost power such as wind and solar
System upgrade	●	- Competition for the end user is likely to increase quality of services offered, which is likely to incentivise enhancement of the entire value chain

Sources: Smart Energy; IEA; Global Data
Note(s): Coal plant closures will result in some job losses which are not reflected due to data unavailability