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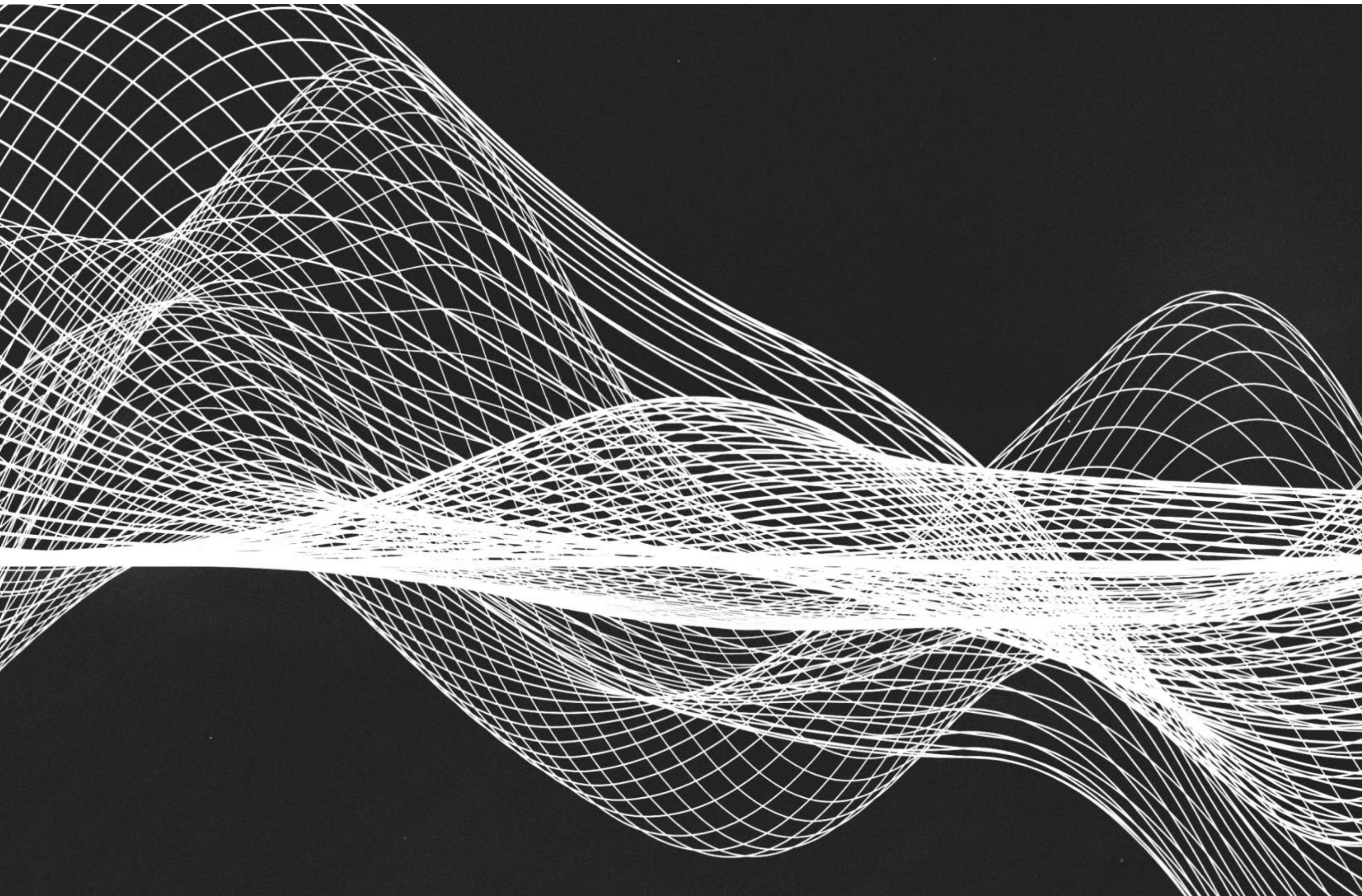
World Energy Scenarios | 2017



LATIN AMERICA & THE CARIBBEAN ENERGY SCENARIOS

In Partnership with CAF - Development Bank of Latin America, Eletrobras, UPME and the Paul Scherrer Institute

ABOUT THE WORLD ENERGY COUNCIL

The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

Formed in 1923, the Council is the UN-accredited global energy body, representing the entire energy spectrum, with over 3,000 member organisations in over 90 countries, drawn from governments, private and state corporations, academia, NGOs and energy stakeholders. We inform global, regional and national energy strategies by hosting high-level events including the World Energy Congress and publishing authoritative studies, and work through our extensive member network to facilitate the world's energy policy dialogue.

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ABOUT LATIN AMERICA & THE CARIBBEAN ENERGY SCENARIOS REPORT

The *Latin America & the Caribbean Energy Scenarios* report is a first exploration of regional deep-dive scenarios that provides the basis and framework for the Latin America and the Caribbean (LAC) region.

The framework which consists of Modern Jazz, Unfinished Symphony and Hard Rock – *World Energy Scenarios 2016: The Grand Transition*, which has been produced by the World Energy Council in collaboration with Accenture Strategy and the Paul Scherrer Institute – is used as a lens to test and explore how the key driving forces manifest and to investigate possible development trajectories for the LAC region, resulting in three scenarios: *Samba, Tango and Rock*.

The report is the product of a three-year process, which was developed by the very active involvement of the World Energy Council's LAC National Member Committees and Project Partners – CAF, Eletrobras and UPME. Feedback was also gathered at the Council's World Energy Leaders' Summit and workshops / conference calls around the region ensuring the inclusion of key insights from industry, governments, experts and civil societies.

The Paul Scherrer Institute (PSI) quantified the scenario storylines using its global multi-regional energy system model. The iteration between development of the narratives and the quantification provided the foundation for a set of scenarios.

Note: The World Energy Scenarios are designed to be useful. The Council reviews its scenarios work on a regular basis to check for continued relevance, plausibility and challenge.

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EXECUTIVE SUMMARY

LATIN AMERICA & THE CARIBBEAN (LAC) PERSPECTIVE: WORKING TOGETHER TO UNLOCK A BETTER ENERGY FUTURE

Regional integration is urgently needed to unlock new sustainable growth opportunities and to improve the resilience of energy systems across the region.

The *Latin America & the Caribbean (LAC) Energy Scenarios* report examines the future of the regional energy context in 2030 and to 2060. Three plausible, relevant and challenging regional scenarios are presented, which provide a clear and enabling framework for decision making under deep uncertainty and a platform to guide the development and consideration of more and better solutions to the challenges of robust energy transition and sustainable energy for all.

A GLOBAL GRAND TRANSITION AND REGIONAL DYNAMICS

Energy systems are in transition. As the pace of global connectivity increases, it is combining with an accelerating and uncertain pace of innovation technology, and wider geopolitical, societal and global environmental changes. The outlook for future energy systems is unclear and unpredictable: different pathways are possible and already emerging, shaped by many and new actors, within and beyond the global energy system.

The Grand Transition is underway and characterised by four predetermined and four critical, and uncertain, drivers of change. The four predetermined factors shaping energy systems are: a slowing of global population growth; a range of new technologies; increasing appreciation of planetary limits; and a shift in economic and geopolitical power to Asia. The four critical and uncertain factors are below:

- Pace of innovation and productivity
- Evolution of international governance and geopolitical change
- Priority given to sustainability and climate change
- The selected 'tools for action' – the balance between the use of markets and state directive policy

Energy transition is not simply a global matter. Regional energy systems are diverse and preparing for new and different energy futures benefits from understanding how global, regional and local energy systems and dynamics are co-evolving.

After a period of prosperity, the Latin America and the Caribbean (LAC) region is facing a more difficult external context and slower economic growth. Regional population has doubled between 1970 and 2014. Based on the UN median projections, population growth is expected to slow due to lower fertility rates, reaching 627 million in 2060. Brazil's population is expected to peak around 2050, reaching 238 million.

Although a few countries have started structural economic and energy reform programmes to raise productivity and competitiveness, it is clear that the recent slowdown of economic growth has made the reform process more difficult. Meanwhile, the increased frequency and severity of extreme weather events are of particularly concern to the resilience of energy systems in the LAC region.

Critical Uncertainties in LAC

Critical Uncertainties	Samba	Tango	Rock
Productivity and Structural Reform	▪ Successful reform and innovation ▪ Economic Growth 3.7% p.a. (2014–2030) 3.1% p.a. (2030–2060) ▪ GDP per capita in 2060 US$ 30,175	▪ Growth with focus on sustainability ▪ Economic Growth 2.8% p.a. (2014–2030) 2.7% p.a. (2030–2060) ▪ GDP per capita in 2060 US$ 23,513	▪ Low economic growth ▪ Economic Growth 1.5% p.a. (2014–2030) 1.4% p.a. (2030–2060) ▪ GDP per capita in 2060 US$ 13,095
Climate Challenge and Resilience	▪ Medium priority ▪ Cumulative emissions from fuel combustion 73 Gt CO_2 (2015-60) → 4.9% of the world	▪ High priority ▪ Cumulative emissions from fuel combustion 56 Gt CO_2 (2015-60) → 4.8% of the world	▪ Low priority ▪ Cumulative emissions from fuel combustion 65 Gt CO_2 (2015-60) → 4.3% of the world
Regional Energy Integration	▪ Key projects driven by market economics	▪ Broad-based regional governance	▪ Fractured regional system
Tools for Action	▪ Markets	▪ States	▪ Patchwork of states and markets

Source: World Energy Council and Paul Scherrer Institute

Three Possible Futures for Energy in LAC

Samba	LAC shaped by successful reform and strong innovation and high productivity with market forces	▪ Innovation and economic diversification beyond commodity exports ▪ Energy access for all
Tango	LAC shaped by governments to achieve sustainable growth and resilient energy system	▪ Strong regional integration ▪ High investment on regional adaptation and mitigation
Rock	LAC shaped by weak economic growth and waning support from global and regional institutions	▪ Limited infrastructure investment ▪ Policies inwardly focused and reform process delayed

Source: World Energy Council

The extensive use of hydro power, particularly in Brazil and Colombia, has enabled lower CO_2 emissions and faster electrification rates. However, the region's strong reliance on hydro power is also a risk in a future in which climate change impacts will combine with resource scarcities and intensify the challenges of an energy-water-food resource stress nexus.

Whilst the future shape, mix and price of the global and LAC regional energy system are unpredictable, world energy leaders and their organisations can prepare for the new, different and faster moving energy landscapes by using a set of plausible, alternative and memorable scenarios.

THREE LAC ENERGY SCENARIOS: SAMBA, TANGO AND ROCK

Scenario planning is an approach used by world energy leaders to better prepare in uncertain times and to identify new and better options for action. Scenarios are not the same as a strategy but can be used to test, challenge and inform the strategic planning process. Scenarios are also not the same as the vision of a better future. A set of scenarios describes new and different stories of energy futures that are already emerging, whether or not anyone wants them to happen.

Three regional energy scenarios – *Samba, Tango and Rock* – have been developed by the Word Energy Council in collaboration with regional energy partners and experts to examine plausible pathways for robust energy transition in the LAC region.

The three regional scenarios use the Council's World Energy Scenarios 2016 archetype framework – *Modern Jazz (Samba), Unfinished Symphony (Tango), and Hard Rock (Rock) – a*s their starting point. Through enrichment with regional dynamics, the customised regional scenarios reflect the diversity and different political and economic realities across the region. Samba resembles the market-based flexibility of Modern Jazz; Tango represents the top-down coordination found in Unfinished Symphony; Rock describes the difficult possibility of a return to national security interests and how these constrain new opportunities for robust national transition and the role of regional integration in enhancing energy resilience.

In SAMBA, the LAC region undergoes successful structural reform with high levels of innovation and productivity gains, enabled through the stronger role of energy markets. The combined effects of structural reform and digitalisation stimulate new forms of economic diversification, beyond commodity exports. Open economies are well positioned for global competition and new regional growth prospects.

Chile's current structural reform programme provides an illustrative example of what success looks like in a Samba world. There are more opportunities to promote renewable energy, diversify the national energy mix, and meet Chile's clean energy mandate of 20% of electricity generation by 2025. Chile has opened its energy future to the involvement of over 100 international companies. In a Samba world, other countries attract private sector investment to meet new national energy visions and finance long-term energy goals. According to Climatescope 2016, Chile ranks second in an assessment of clean energy market conditions and opportunities in 58 emerging counties.

In TANGO, governments across the LAC region and beyond work together to achieve sustainable growth. An effective system of broad-ranging global and regional energy governance emerges, founded on strong collective climate change policies and the promotion of regional integration to enable the enhanced resilience of national energy systems.

Uruguay's wind policy provides an illustrative example of what success looks like in a Tango world. In Uruguay, 1,455 MW wind power is being installed in 2017, which is enough to meet in excess of 35% of electricity demand. Energy policy is cornerstone for rapid wind energy development in Uruguay, introducing goals and clear actions to achieve them.

In ROCK, the region is impacted by weak economic growth and a decline in trust and support for global and regional institutions. Pulled by populism, national governments focus on energy self-sufficiency policies. Despite the promise of medium- and long-term structural reform, volatility in commodity prices and financial markets and the threat of recession contribute to political and policy risk.

Argentina's energy market reform provides an illustrative example of how to avoid a Rock world. The government is determined to rebuild markets and enable a return to effective and sustainable regulatory frameworks. But the task is not easy. The law of economic emergency and the tangle of subsidies and regulations that followed since 2002 cause great uncertainty as to what rules to apply.

KEY FINDINGS FROM LAC ENERGY SCENARIOS

1. Energy demand in LAC is expected to grow at a slower rate. However, LAC energy demand growth will stay at a relatively high level, compared to most other regions. LAC economic growth is expected to be relatively slow, but the energy intensity improvement will be also limited.

2. Demand for electricity in LAC will rise more than double by 2060 in line with global developments that see an increasing electrification of society. Corresponding investment needs for electricity generation in LAC between 2010 and 2060 range from US$ 2.0-2.5 trillion (based on the 2010 market exchange rate).

3. Hydro power in LAC is expected to dominate new electricity generation growth by 2030. Beyond 2030, wind and solar power generations will increase significantly, but their shares will stay below the world averages as the share of hydro power in LAC is far higher than the world average.

4. In transport, the use of biofuels in LAC is expected to grow 5-6 times from 2014 to 2060, leading to a substantial diversification of the transport fuels. Beyond 2030, the electricity of transport energy is also expected to grow dramatically. However, its share will stay below the world average as biofuels play a more significant role within the LAC region compared to other regions of the world.

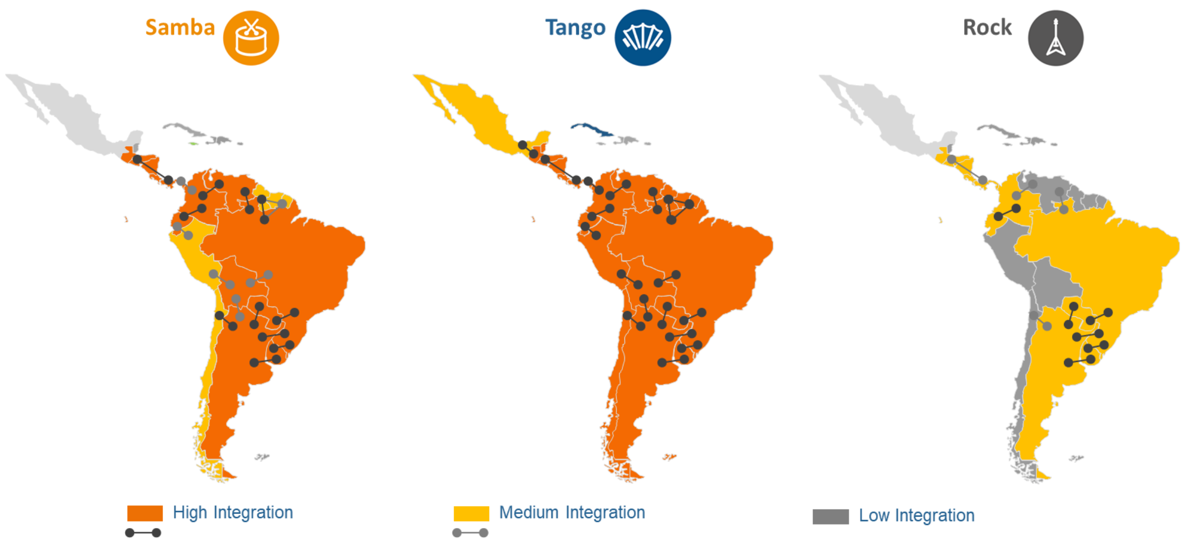
5. Demand for oil in LAC will peak or reach a plateau after 2040. In Tango, it is expected to peak between 2030 and 2040 at 7.0 mb/d. In Samba, it will peak in 2040 at 8.1 mb/d. In Rock, demand for oil will reach a plateau after 2050, settling at 7.9 mb/d in 2060. Natural gas plays a key role in LAC, but its growth varies broadly across scenarios.

6. The LAC energy sector is the least carbon intensive within the developing world due to a high share of hydro power. Accelerated carbon intensity reductions will drive CO_2 emissions (from fuel combustion) to peak around 2030 at 1.4 Gt CO_2 in Tango, and between 2040 and 2050 at 1.7 Gt CO_2 in Samba. In Rock, CO_2 emissions (from fuel combustion) will continue to grow and reach 1.7 Gt CO_2 in 2060.

7 In all scenarios, LAC countries should work on improving its energy system's resilience, while at the same time improving energy equity and security. Diversifying energy mix is critical and regional integration of energy systems is a further key element that can balance the Energy Trilemma and enhance energy system's resilience.

8 Regional integration in LAC can be shaped by the presence of strong regional governance structures. Regional interconnection is already a focus of attention in the LAC energy sector, as evidenced through projects like Arco Notre, SINEA, SIEPAC II and others. Regional integration is expected to be strongest in Tango and weakest in Rock.

The Potential of LAC Regional Integration Development across Scenarios



- Progress on Arco Norte and SIEPAC II interconnection projects
- More progress on gas integration projects
- Mexico develops its relationship with the US

- All countries of LAC are integrated as a result of full progress on projects like Arco Norte, SINEA and SIEPAC II
- Mexico wants electricity interconnection to the Caribbean

- Risk increases in the existing regional integration
- Less progress on new regional integration projects
- Mexico explores new export / collaboration opportunities with LAC

Source: World Energy Council

ACTION IS NEEDED TO ADDRESS EMERGING RISKS AT THE REGIONAL SCALE

THE HEAVY COSTS OF A ROCK SCENARIO

In the face of economic adversity and low commodity prices, some countries across the world are experiencing a rise of populism and resorting to nationalistic approaches, which prioritise energy security and self-sufficiency at the heart of their policies. In turn, less economic cooperation results in lower economic growth, undermines energy resilience, and increases vulnerability to unwelcomed global changes, including climate change impacts. A Rock world will increase the already significant level of social inequity across the region and leave many more people, as well as energy systems, vulnerable to extreme weather events. To avoid this scenario, leaders in the LAC region should use the other scenarios – Tango and Samba – to explore new options for more effective energy policy, cooperation and regional integration which are becoming possible due to wider developments within and beyond the region and conventional energy system.

LARGE SCALE INVESTMENTS IN ENERGY INFRASTRUCTURE

Over the next decades, LAC governments will need to make massive investments in infrastructure – energy, roads, ports and communications – in order to promote economic growth in their fast growing urban areas, as well as avoid energy poverty in rural areas. Decisions taken by governments on issues like structural reforms and private sector participation will play a crucial role in determining the sources of funding and the total amounts available for making those investments. Failure to raise the necessary funds will lead to a continuation of social inequity, lack of easy access to energy, and a generally lower level of resilience of existing energy systems. This is a particular risk in the Rock.

CLIMATE CHANGE VULNERABILITY

According to the Council's annual *World Energy Issues Monitor*, LAC energy leaders worry more than others about climate change, since the region is already prone to natural disasters and extreme weather events. Ensuring the resilience of energy systems – to emerging financial-, cyber-, environmental-, climate-related risks and shocks – will require new frameworks and tools and unprecedented cooperation between the energy industry and policymakers. Policies to bolster resilience include: increasing regional integration, using smart energy solutions for urban areas, and increasing the share of decentralised power generation.

POTENTIAL FOR "STRANDED RESOURCES"

Oil demand is expected to peak in LAC, as well as globally, by 2040 – which requires regional oil producers to address the risk of "stranded resources" now, given the interim of sunk costs and the increase in climate change momentum. Compared to producers in the Middle East, production costs of oil are significantly higher in the LAC region, and the closest export market, the US, is set on achieving energy self-sufficiency by increasing domestic production of unconventional hydrocarbon resources and maintaining coal production and generation. It is also set to become a net exporter of oil and gas. The still emerging contours of new energy geopolitics will require a significant strategic shift of LAC oil and gas producers, putting more emphasis on expanding positions along the hydrocarbon value chain into refining and integrated petrochemicals, also increasing inter-regional trade of petroleum and chemical products.

CALL TO ACTION FOR LAC ENERGY LEADERS

The LAC region is unique in energy terms – keywords are "heterogeneity and complexity." Not surprisingly, many different types of solutions are emerging at local and national levels. However, the future of the regional energy system requires greater cooperation in three areas:

ACCELERATE REGIONAL INTEGRATION TO ENHANCE ENERGY RESILIENEC OF ALL

The scenarios clearly demonstrate that the LAC region has enormous potential to benefit economically from regional integration and cooperation, but the region is slow to reap the long-term benefits in the face of short-term political and economic priorities. LAC's success in adapting to changing weather patterns and the energy-water nexus will impact its path to greater energy sustainability. Regional integration is also expected to play an increasingly important role in the region's ability to improve energy system's resilience.

FOCUS ON NEW OPPORTUNITIES FOR WIND, SOLAR AND ELECTRIC VEHICLES

The LAC region's impressive clean energy share in the energy mix is boosted by an abundance of hydro power. However, big hydro dams are increasingly controversial. In recent years, Brazil and Chile have blocked hydro power projects in environmentally sensitive areas. Alternative energy sources, such as wind and solar, account for only 2% of LAC electricity generation, compared to the world average of 4%. Nonetheless, the LAC scenarios show that this share will grow quickly, also offering investment opportunities for the private sector. Additionally, biofuels dominate transport energy shares in LAC, but electric vehicle is expected to grow dramatically.

PROMOTE NEW ENERGY GOVERNANCE WITH GOVERNMENT LEADERSHIP

The role of governments and policymakers to resolve critical uncertainties is crucial in the LAC region, more so than in some other areas of the world. Full understanding and a strong focus on balancing the objectives of the Energy Trilemma will be needed to ensure effective policymaking on a local and regional level. LAC cities will most likely be testbeds for new energy technologies and a source of new regulatory approaches to energy policy.

Chapter 1

The Situation in the LAC Region

1. CHALLENGES IN THE LAC REGION

The population in the Latin America and the Caribbean (LAC) region in 2014[1] was 502 million people (7% of the world), GDP US$ 4.3 trillion (6% of the world) and GDP per capita US$ 8,515 (US$ 9,686 for the world)[2]. Brazil stands for more than 50% of the LAC economy, so it has a tremendous impact on the regional economic growth.

Although no two countries in the region are the same, the LAC region faces some common challenges:

- High level of external economic dependence
- Reliance on the primary sector (energy and mining sectors) and lack of economic diversification in most of countries in the region
- High socio-economic inequality caused by high level of income disparity and concentration of wealth
- Weak long-term planning and investments
- Weak institutions due to strong bonds between politics and business (witness the recent cases of corruption in the region)
- Lack of vision for the region despite regional integration requiring viable cooperation and partnership

Primary energy demand 697 MTOE in LAC in 2014 accounted for 5% of the world and carbon emission from fuel combustion 1.3 Gt CO_2 for 4% of the world. Fossil fuel share was 72% (81% for the world). Energy demand has continued to rise in the region. Hydro power remains the dominant source of power generation and biofuels play a key role in the transport sector. Some of the challenges particular to the energy sector in the LAC region are:

- Weak diversification in power generation
- Limited interconnections and poorly developed grid infrastructure
- Weakness of governmental and regulative institutions to provide frameworks for the energy sector
- Energy subsidies are common in the region and government attempts to reduce fuel subsidies have mostly failed due to large public protests
- Extreme weather phenomena, El Niño and La Niña, have a high impact on the region due to the high reliance on hydro power
- Deforestation of the rainforests

The challenges are manifold and interdependent. The low GDP per capita and a high income disparity form the base for political instability; additionally, a low degree of trust in governmental institutions, managed by 'politics' perspective, creates uncertainties for long-term planning in a broader sense. The energy sector faces a rising energy demand, which requires enormous investments in power generation and infrastructure. The proliferation of energy subsidies and low energy prices makes for an unattractive investment environment: to turn this around requires collective action from government, industry and society.

[1] 2014 is set as a base year with considering the energy data availability.

[2] Source: World Energy Council and Paul Scherrer Institute (US$ 2010 market exchange rate)

2. ECONOMIC GROWTH

The average annual growth rate (AAGR) for the LAC region from 2004 to 2013 was 4.2%. The commodity price boom was able to sustain growth trends in the region despite low productivity, little diversification of production and persistent structural problems. Colombia's energy sector, Peru's mining industry and Uruguay's forestry business were notable foreign direct investment targets. Energy infrastructure developments boomed in Brazil.

After a period of prosperity, the LAC region is facing a more difficult external context and slower economic growth. In 2014 and 2015, economic activity in the region hit hard and marked two consecutive years of negative growth, which is shown in Figure 1. In fact, in terms of economic growth slowdown, the region has been the hardest hit among the developing regions. Many countries in the LAC region are commodity exporters and their international financial integration has historically made them prone to the global boom and bust cycles. In addition, fluctuations in economic growth across the region have been closely associated with volatility in commodity prices as well as other external conditions driven by China's economic slowdown.

Figure 1: Economic Growth – LAC and the World

Source: IMF (April 2017), World Economic Outlook Database

Significant differences in growth outcomes across the LAC countries are driven by differing influences of external conditions and domestic fundamentals. Although a few countries have initiated the structural reforms necessary for increased productivity and competitiveness, it is clear that recent slowed economic growth has made the reform process more difficult, and, in some cases, even halted it. Table 1 illustrates how the different countries of the region display a variety of GDP development. While some countries are better prepared for a global slowdown and can sustain economic growth, countries with political and economic crises, such as Venezuela, Brazil and Argentina, are strongly hit by the slowdown and also affected by low commodity prices.

The global recovery has turned out to be slower than expected, constraining demand for the region's exports and making external adjustment more difficult despite sizable currency depreciations. China's economic slowdown has provoked a sharper decline in imports relative to the more modest deceleration of its economy, reducing demand for the region's exports, particularly for commodities. Declines in commodity prices have added to the marked downturn. The economic effect varies according to the relative importance of fuel exports as part of the overall exports in the economy – very large for Venezuela (98% of total exports), sizable for Bolivia (52%), Colombia (53%) and Ecuador (36%) and even smaller for Argentina (3%) and Brazil (7%). Chile and Uruguay have fuel export shares of the overall exports below 0.5%.[3]

Table 1: Economic Growth in the LAC Countries

Country	2004-2013 AAGR	2014	2015	2016	2017
Argentina	5.1%	-2.5%	2.7%	-2.3%	2.2%
Bolivia	4.9%	5.5%	4.9%	4.1%	4.0%
Brazil	4.0%	0.5%	-3.8%	-3.6%	0.2%
Chile	4.7%	2.0%	2.3%	1.6%	1.7%
Colombia	4.8%	4.4%	3.1%	2.0%	2.3%
Ecuador	4.9%	4.0%	0.2%	-2.2%	-1.6%
El Salvador	1.9%	1.4%	2.5%	2.4%	2.3%
Guatemala	3.6%	4.2%	4.2%	3.0%	3.3%
Honduras	4.1%	3.1%	3.6%	3.6%	3.4%
Nicaragua	3.9%	4.6%	4.9%	4.7%	4.5%
Panama	7.9%	6.1%	5.8%	5.0%	5.8%
Paraguay	4.9%	4.7%	3.0%	4.1%	3.3%
Peru	6.4%	2.4%	3.3%	3.9%	3.5%
Trinidad & Tobago	3.8%	-0.6%	-0.6%	-5.1%	0.3%
Uruguay	5.5%	3.2%	1.0%	1.4%	1.6%
Venezuela	5.9%	-3.9%	-6.2%	-18.0%	-7.4%

Source: IMF (April 2017), World Economic Outlook Database

Colombia's economy continues to grow at a relatively healthy rate, but it is projected to decelerate as a result of needed policy tightening and less favourable global financial conditions. Chile's economic growth is expected to slow down, reflecting subdued confidence and sluggish investment in the mining sector. Peru's economy has strengthened faster than expected. Growth in Bolivia is expected to remain strong, but it is mainly supported by a high level of public investment and a sizable fiscal deficit. In Uruguay, growth is slowing, while inflation remains above target, despite the tight monetary policy stance. Paraguay's economy is expected to remain relatively resilient, despite a loss of momentum in trade related sectors last year.

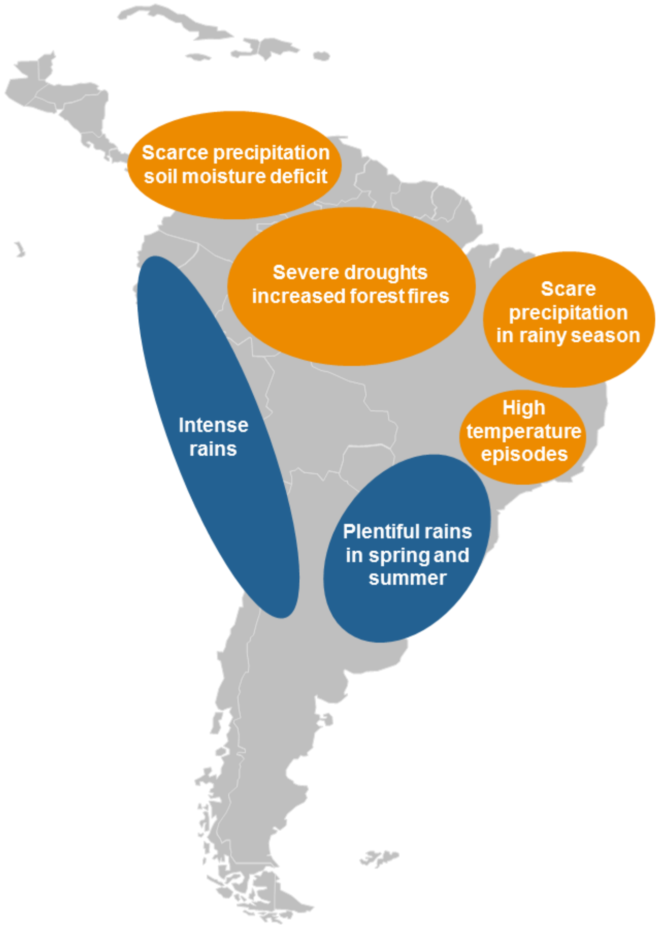
In Brazil, a combination of macroeconomic fragilities and political problems has dominated the economic outlook. The main domestic risks for Brazil are linked to the political tensions. Venezuela's economic conditions have deteriorated with policy distortions and fiscal imbalances remaining unaddressed. Both exports and imports have been declining as a result of the decline in oil prices. In Ecuador, macroeconomic rigidities prevented a smooth adjustment. The outlook remains highly uncertain and is dependent on the extent of shocks and particularly on the availability of external financing. In Argentina, the new government has embarked on an ambitious transition to remove macroeconomic imbalances and distortions that had stifled investment and eroded competitiveness.

[3] IDB Statistics
https://data.iadb.org/ViewByCountry/ViewByCountry?languageId=en&type=C&startYear=2010&endYear=2014&first=&second=&isSocial=0&page=1&topicId=0&subtopicId=0&identifier=2

3. EL NIÑO

The LAC region is particularly vulnerable to the damaging side effects of climate change in the world. The global weather event known as El Niño has been blamed for droughts in Central America and the northern part of South America and record breaking floods in Argentina, Brazil and Paraguay. LAC countries were already facing economic slowdown when along came El Niño. This cyclical weather phenomenon, involving the formation of a band of warm water in the Pacific Ocean, kicked off in late 2015 and brought everything from droughts to heavy rains to the region. The individual bands are shown in Figure 2. The region and the world have been much better prepared for this event, but the socio-economic shocks can still be profound.

Figure 2: Impacts of El Niño in the LAC Region



Source: GRID-Arendal (2015), Vital Climate Change Graphics for Latin America and the Caribbean

The recent El Niño conditions in LAC have been strong and weather experts expected them to rival the 1997-98 episode leading to a severe or super El Niño. The 1997-98 El Niño caused more than US$ 18 billion in damages in the LAC region (54% of the world's damages) and affected an estimated 27 million persons in the region. In the Andean region − Bolivia, Colombia, Ecuador, Peru and Venezuela, the impact of heavy rainfall and flooding brought on by the intense El Niño caused losses of approximately US$ 7.4 billion. The majority of these losses were a result of an indirect impact on the economy. These losses represented 13% of the Andean community's 1997 GNP and more than 58% of the foreign investment that these countries received in the same year.[4]

El Niño represents the warm phase of the El Niño Southern Oscillation (ENSO) cycle, and is sometimes referred to as a Pacific warm episode. It originally referred to an annual warming of sea surface temperatures along the west coast of tropical South America. On the other hand, La Niña represents the cool phase of the ENSO cycle, and it is sometimes referred to as a Pacific cold episode which originally denoted an annual cooling of ocean waters off the west coast of tropical South America.

El Niño in 2016 has posed major challenges for LAC governments, some of which are in the midst of economic and political crises. The weather phenomenon is also testing their ability to face the growing threat of climate change. The Southern Cone – Argentina, Chile, Paraguay and Uruguay – faced heavy rains, causing widespread flooding. The Pacific Ocean flooded the coast of Chile, while the Paraguay, Paraná state of Brazil and Uruguay rivers overflowed, requiring evacuations. The Brazilian southeast and the northeast faced heat waves and droughts; meanwhile much of the rest of the country saw heavy rains. Brazilian agriculture might also suffer as rains in the western region pushed back the harvest dates for soy and corn.

In January 2016, drought caused Colombia's two main rivers to drop to record low levels. Some 70% of Colombia's electricity comes from hydro power stations, which were working at just 60% of capacity. El Niño impacted Peru moderately, but while rains showered the north, high temperatures and droughts dried out the south of the country. This would affect agriculture and the cattle industry and economists expected food prices to rise by at least 30% as a result. The country was also spending US$ 20 million building infrastructure along the coast to protect the fishing industry from El Niño's heavy rains and abnormal waves. El Niño hit Venezuela with drought starting in December 2015 and the government had mandated water and energy rationing throughout the country. Reservoir levels in the country's biggest 18 dams were down to the minimum level needed to operate. At least 60% of Venezuela's electricity comes from hydro power.

[4] Source: OCHA (2015), Latin America and the Caribbean: El Niño, Rainfall and Drought

4. ENERGY CONTEXT

PRIMARY ENERGY DEMAND grew fast at a rate of 3.2% p.a. from 2000 to 2014, reaching 697 MTOE. As shown in the Table 2, LAC economy grew at a rate of 3.4% p.a. in the period, but the primary energy intensity of GDP – an indicator that is sometimes used as a proxy for the overall efficiency of energy use – declined only at a rate of 0.2% p.a. Upward pressure on primary energy demand has been driven by the commodity price boom, strong economic growth and the emergence of a new middle class. Strong growth in electricity consumption and in demand for transport fuels has led the way in the region. Brazil, the region's largest economy, accounted for more than 40% of the regional energy demand.

Table 2: Decomposition of Primary Energy Demand Growth (2000-2014 CAGR)

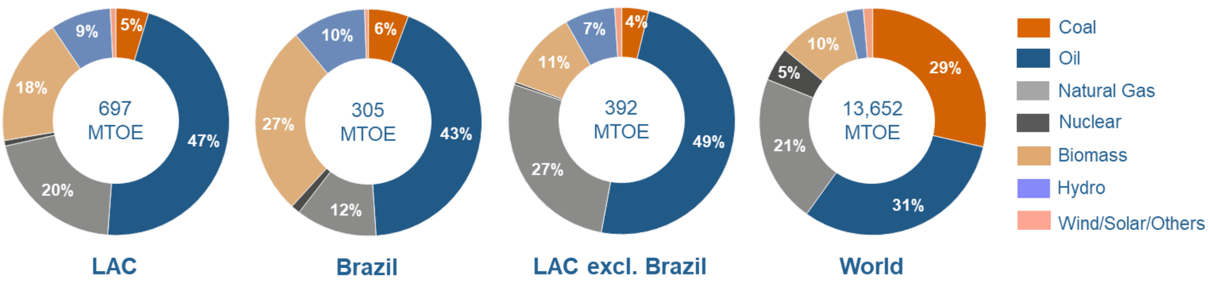
	Primary Energy Demand	≅	GDP		Energy Intensity
			Population	GDP per capita	
LAC	+3.2%		+1.3%	+2.1%	-0.2%
Brazil	+3.6%		+1.1%	+1.9%	+0.6%
LAC excl. Brazil	+2.9%		+1.4%	+2.4%	-0.9%
World	+2.2%		+1.2%	+1.5%	-0.5%

* Primary Energy = Population × (GDP / Population) × (Primary Energy / GDP) = GDP × (Primary Energy / GDP)

Source: World Energy Council and Paul Scherrer Institute

THE SHARE OF FOSSIL FUELS increased slightly from 70% in 2000 to 72% in 2014. While the role of coal in the LAC region was limited outside of Colombia and Chile and coal accounted for only 5% of primary energy demand, oil and natural gas accounted for 47% and 20%, respectively. Hydro had also a meaningful share 9% in LAC. Nuclear and wind/solar/others accounted for less than and approximately 1%, respectively. In Brazil, biomass played a significant role. Figure 3 shows the share of biomass in Brazil in 2014 was 27%.

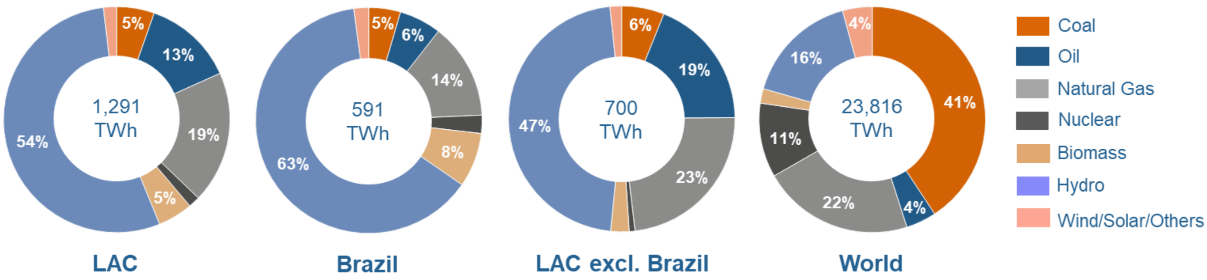
Figure 3: Primary Energy Demand Mix in 2014



Source: World Energy Council and Paul Scherrer Institute

ELECTRICITY GENERATION grew 1.6 times from 2000 to 2014. The electricity generation in LAC in 2014 was 1,291 TWh and Brazil accounted for 46%. Hydro power was the predominant source of electricity generation: 54% in LAC and 63% in Brazil, as shown in Figure 4. Biomass in Brazil had a meaningful role for electricity generation, 8% in 2014.

Figure 4: Electricity Generation Mix in 2014

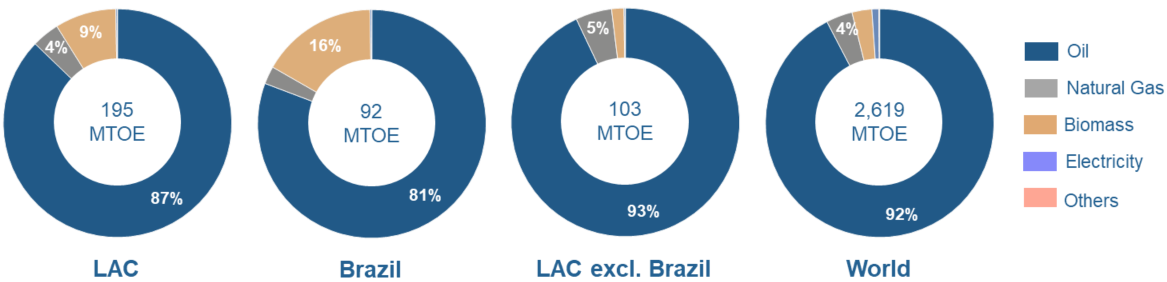


Source: World Energy Council and Paul Scherrer Institute

ENERGY IN TRANSPORT grew fast at a rate of 3.5% p.a. from 2000 to 2014 on the back of strong economic growth and a burgeoning middle class. It settled at 195 MTOE in 2014 and Brazil accounted for 47%. Due to diversification of transport fuels led by biofuels, oil share of transport energy fell from 92% in 2000 to 87% in 2014. Figure 5 shows biofuels and natural gas accounted for 9% and 4%, respectively, of the transport fuels in 2014. In Brazil, biofuels share increased to 16% in 2014 to have a meaningful role in transport energy. In LAC excl. Brazil, biofuels share was less than 2% in 2014, but natural gas share increased to 5%.

Brazil faced a significant growth in passenger vehicle sales between 2010 and 2014 because slower economic growth following the international financial crisis was offset by credit expansion and fiscal incentives to encourage vehicle sales.[5] As a result, transport energy grew fast at a rate of 8.9% in the period although economy slowed down at a rate of 1.6% p.a.

Figure 5: Transport Energy Mix in 2014



Source: World Energy Council and Paul Scherrer Institute

CARBON EMISSIONS from fuel combustion grew at a rate of 2.9% p.a. from 2000 to 2014, reaching 1.3 Gt CO_2 (= 0.5 Gt CO_2 in Brazil + 0.8 Gt CO_2 in LAC excl. Brazil). Although the carbon intensity of GDP declined at a rate of 0.5% p.a. in the period, the commodity price boom provided high economic growth in the region at a rate of 3.4% p.a., as shown in Table 3. More than 50% of the electricity generation was met by hydro power, making LAC energy sector the least carbon intensive in the developing regions. Hydro power is carbon free and there are no, or only very limited, conversion losses.

[5] ICCT (2015), Brazil Passenger Vehicle Market Statistics

Table 3: Decomposition of CO_2 Emissions Growth (2000-2014 CAGR)

	CO_2 Emissions	≅	GDP		Carbon Intensity of GDP**	
			Population	GDP per capita	Energy Intensity	Carbon Intensity of Energy**
LAC	+2.9%		+1.3%	+2.1%	-0.2%	-0.3%
Brazil	+3.5%		+1.1%	+1.9%	+0.6%	-0.1%
LAC excl. Brazil	+2.6%		+1.4%	+2.4%	-0.9%	-0.3%
World	+2.3%		+1.2%	+1.5%	-0.5%	+0.1%

* Kaya Identity: CO_2 Emissions = Population ⨯ (GDP / Population) ⨯ (Energy / GDP) ⨯ (CO_2 / Energy)

** Carbon Intensity of GDP = CO_2 / GDP and Carbon Intensity of Energy = CO_2 / Energy

Source: World Energy Council and Paul Scherrer Institute

THE ENERGY ACCESS deficit in the world in 2014 was 1.06 billion people – three times the population of the US, according to the UN Sustainable Energy for All - Global Tracking Framework 2017. Electrification, which stands globally at 85%, varies widely across continents. Access to electricity in the LAC region[6] reached 97% in 2014 due to high economic growth and urbanisation. LAC is the only developing region to bring its electricity access rate close to 100%, but 18.5 million people still lack access to electricity (equivalent to the population of Chile). Table 4 summarises energy access rates of the LAC countries.

Table 4: Access to Electricity in the LAC Countries

Country	2000	2014
Argentina	95%	100%
Bolivia	70%	90%
Brazil[7]	94%	100%
Chile	98%	100%
Colombia	95%	98%
Ecuador	93%	99%
El Salvador	85%	95%
Guatemala	73%	85%

Country	2000	2012
Honduras	68%	89%
Nicaragua	73%	82%
Panama	81%	92%
Paraguay	89%	99%
Peru	72%	93%
Trinidad & Tobago	91%	100%
Uruguay	98%	100%
Venezuela	98%	99%

Source: UN SE4All – Global Tracking Framework (2017)

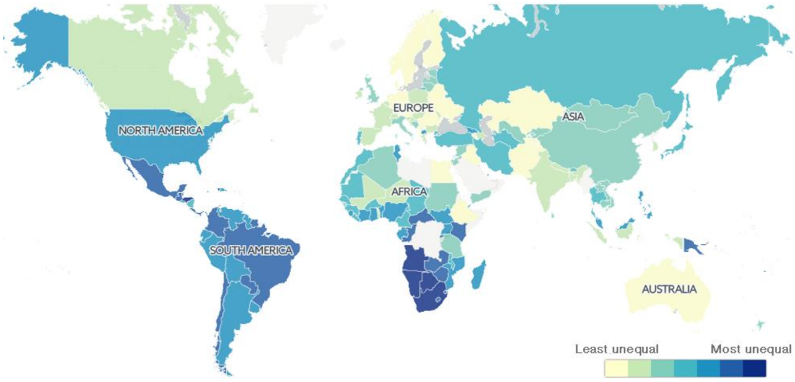
The LAC region is very close to achieving universal energy access. However, LAC remains the most unequal region in the world. In 2014, the richest 10% of people in Latin America amassed 71% of the region's wealth. Its high levels of income and wealth inequality have stymied sustainable growth and social inclusion.[8] So the reality is that the big problem is related to affordability.

[6] Mexico is included.

[7] According to IBGE (Instituto Brasileiro de Geografia e Estatística) data, Brazil's access to electricity rate was 97.8% in 2010.

[8] https://www.weforum.org/agenda/2016/01/inequality-is-getting-worse-in-latin-america-here-s-how-to-fix-it/

Figure 6: GINI Index Measure of Inequality



Source: World Bank GINI Index estimates[8]

THE ENERGY SUBSIDY (pre-tax) projected for the year 2015 in the LAC[9] region is US$ 35 billion[10] (0.7% of GDP and 2.3% of tax revenue of the LAC region). Energy subsidies impose fiscal costs, hurting state-owned enterprises (SOEs), competitiveness and distribution. The reform of the fossil fuel subsidy regime allows benefitting from the favourable economic, fiscal, social and environmental impacts resulting from the removal of the existing subsidies. Table 5 summarises energy subsidies of the LAC countries in 2015.

Table 5: Energy Subsidy (pre-tax) Projected for 2015

Country	% GDP	% Tax Revenue	Country	% GDP	% Tax Revenue
Argentina	1.6	4.2	Honduras	0.0	0.0
Bolivia	1.9	5.8	Nicaragua	1.9	9.4
Brazil	0.1	0.2	Panama	0.3	1.7
Chile	0.0	0.0	Paraguay	0.1	0.5
Colombia	0.2	0.8	Peru	0.0	0.0
Ecuador	1.5	4.4	Trinidad & Tobago	2.6	9.0
El Salvador	2.0	11.4	Uruguay	0.0	0.0
Guatemala	0.2	2.4	Venezuela	10.5	46.2

Source: IDDRI (2015), Fossil Fuel Subsidies in Latin America

[9] Mexico is included.

[10] According to IMF (2015), pre-tax global subsidies were 0.7% of global GDP in 2011 and 2013, and are projected to decline to 0.4% of global GDP (US$ 333 billion) in 2015.

Chapter 2

LAC and the Grand Transition

1. LAC TRANSITION

Since 1970, as noted in *World Energy Scenarios 2016: The Grand Transition*, the world has seen rapid growth in energy demand, mainly satisfied by fossil fuels. The future will be different. Disruptive trends are emerging that will create a fundamentally new world for the energy industry, characterised by much lower population growth, new powerful technologies, greater environmental challenges, and a shift in economic and geopolitical power towards Asia. These underlying drivers will re-shape the economics of energy. We call this uncertain journey into the new world of energy – *The Grand Transition*.

There is much we do not understand about the energy sector's trajectory and how the energy industry would work in the new world. In particular, the outcome of the following uncertainties will be critical in determining the specifics of the future world of energy: the pace of innovation and productivity; the priority given to sustainability and climate change; the evolution of international governance and geopolitical change; and the selected 'tools for action' − the balance between the use of markets and state directive policy.

In the context of the Grand Transition, *Latin America & the Caribbean Energy Scenarios* examine the future of LAC energy context in 2030, and beyond to 2060. It is useful in future analysis to distinguish between those elements that are relatively forecastable over the scenarios horizon and those that are critical and uncertain.

We first look at what is relatively predictable in LAC − that is, predetermined:

- Slower population growth
- A range of new technologies
- Vulnerability to climate change
- High potential for regional integration

But not everything is predictable and much that will determine the future context for energy in LAC is uncertain. We turn to these matters – that is, the critical uncertainties:

- Productivity and structural reform
- Climate challenge and resilience
- Regional energy integration
- Dominant tools for action

2. WHAT ARE PREDETERMINED?

2.1. SLOWER POPULATION GROWTH

The world's population has grown by 81 million annually from 2000 to 2014, reaching 7.3 billion people. According to the UN, in its medium variant forecast, the world's population will grow more slowly than in the past. The world's annual average population growth is projected to be 77 million within the next 16 years and 56 million from 2030 to 2060, reaching 10.2 billion people in 2060.

The population of LAC was 502 million people in 2014. It was equivalent to 7% of the world population and Brazil accounted for 41%. LAC annual average population growth also continues to slow down from 5.9 million (2000-2014) to 4.4 million (2014-2030) and 1.8 million (2030-2060). Brazil's population is expected to peak around 2050, reaching 238 million people.

Demographic changes have also intensified in the LAC region in recent decades. The region is experiencing substantial changes in the age structure of its population. These changes consist of a significant decrease in the share of the child population (those aged 0-14) from 25% in 2015 to 21% in 2030 and 16% in 2060 and increases in the share of the old population (those aged 65 and over) from 8% in 2015 to 12% in 2030 and 23% in 2060.[11] Despite the decline in mortality, the decline in fertility will be the main factor affecting population size and age structure. This will have negative impacts on economic growth, investment and consumption patterns, which in turn will have consequences for the energy sector.

LAC is more urbanised than any other developing region, almost 80% of its population resided in cities in 2015 and is expected to increase to 83% by 2030. The shift from country to town has contributed much to LAC's growth as economies of scale have boosted the productivity of expanding cities and reduced the cost of delivering basic services to its inhabitants.

2.2. A RANGE OF NEW TECHNOLOGIES

New technologies will have the potential to re-shape economic and social options. The pace at which these new technologies develop continues to accelerate at an exponential rate whilst technology costs tumble and the technologies become ubiquitous. Furthermore, the combinatorial effect of these technologies is creating the environment for fundamental change. For example, fully driverless electric vehicles are fast becoming a reality. The combinatorial effect of battery technology, GPS, machine learning and analytics have created the right environment to accelerate what was previously seen as niche development or a longer-term change.

As these technologies mature, combine and are deployed across the economy, in the broadest sense, we will see major changes in the energy industry, including smart cities, automation, artificial intelligence and robotics, digital productivity, energy efficiency and demand side behaviour, automated zero carbon mass transit innovation, wind and solar, and integrated grid and storage, electric vehicles (EVs). In the Grand Transition, the dominant technologies that will drive the energy industry in the LAC region as well as the world will be very different from those employed in recent history.

[11] Mexico is included.

2.3. VULNERABILITY TO CLIMATE CHANGE

The global energy industry's environmental priorities will be shaped by choices the public, informal networks and governments make with respect to ensuring the integrity of planetary boundaries. Four are of particular concern: climate change, biodiversity loss and species extinction, biogeochemical flows, and land system change. In the Grand Transition, managing environmental challenges will be a central policy concern.

LAC is home to around 7% of the world's population, makes up more than 14% of the total global land area, and contains roughly 23% of the world's forests and 30% of freshwater resources. It contributes 4% of global CO_2 emissions from fuel combustion and this figure rises to more than 10% once agriculture and land use change – i.e. emissions resulting from deforestation – are taken into account.

When it comes to the damaging side effects of climate change, the LAC region finds itself among the most vulnerable in the world. Many of these impacts are in line with those to be found elsewhere: increased frequencies of extreme weather events, droughts, floods and heatwaves, resulting in desertification, failing crops, infrastructure damage from extreme events, melting glaciers and rising sea levels.

In particular, parts of Central America and north-eastern Brazil are set to become even more vulnerable to severe drought, while inhabitants of the Andean uplands in Peru, Bolivia, Ecuador and Colombia are already experiencing livelihood difficulties as a result of melting glaciers and changing hydrological cycles. Not only are many millions of people at risk from these effects in the present as much as in the future, but the economic cost to the region is also forecast to be extremely high.

2.4. HIGH POTENTIAL OF REGIONAL INTEGRATION

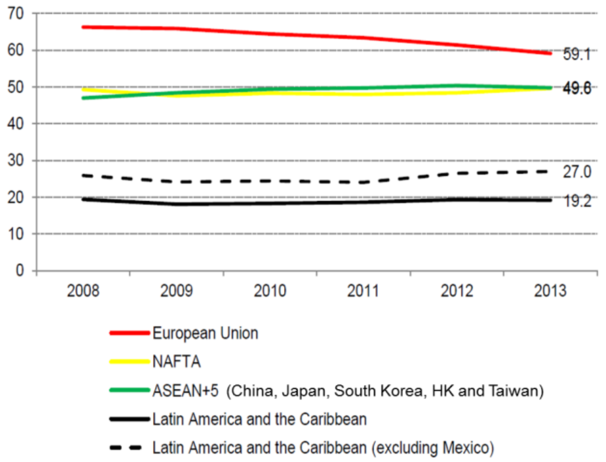
Today, about a third of the world's middle-class consumption takes place in Asia, a share that will double by 2060. China will probably have the largest economy, surpassing that of the US around 2040. India will also have an overarching impact on global dynamics as it is set to become the most populous country globally by 2030. The choices Asia makes particularly with respect to economic, energy and climate change policies will be central to global development in the Grand Transition.

Many LAC economies have experienced significant reductions in growth recently, as a result of the end of the commodity super cycle and the rebalancing of China's economic growth. A number of global banks have been leaving the region and downsizing operations.

The region continues to trade little with itself, showed in Figure 7, and with low levels of production. The timing is now good for LAC economies to work towards greater regional integration. It could also facilitate inward investment, enable markets to achieve minimum viable size, and add a dimension of diversification, such that these economies would not rely solely on domestic or global developments, but could reap benefits from the economic stability of other countries in the region.

Therefore, regional integration, by creating greater markets and investment opportunities, can help businesses of all sizes and also provide advantages for a resilient infrastructure. If trade among LAC countries, currently only 27% of its total exports, were to grow towards Asia's 50%, the region would take a huge step toward realising its enormous potential.

Figure 7: Share of Intra-Region Exports in Total Exports (%)

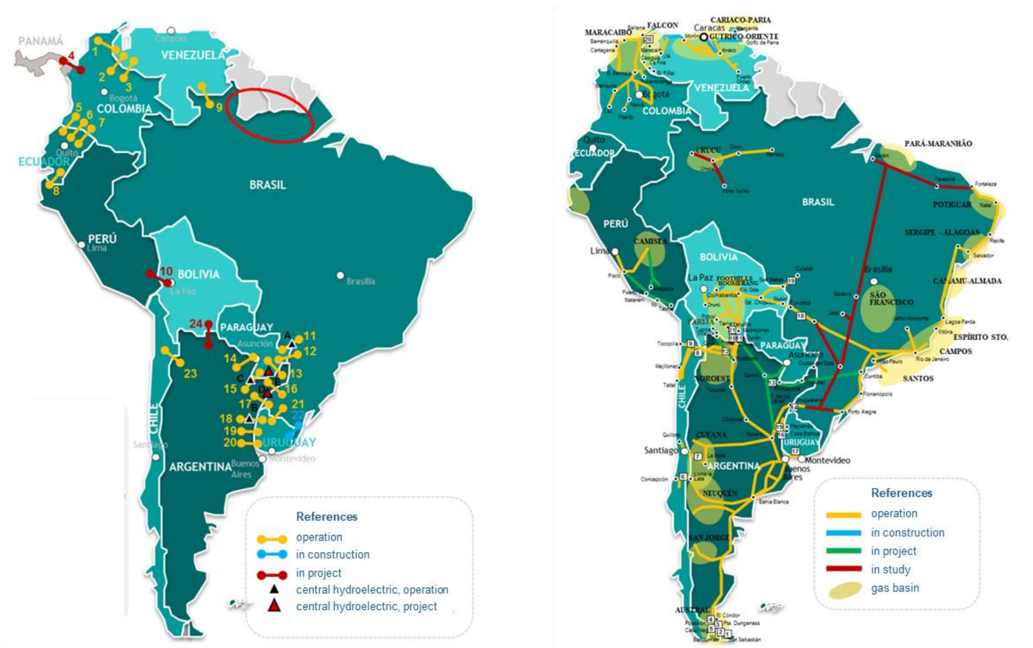


Source: ECLAC (2014), Regional Integration and Value Chains in Challenging External Environment

LAC has abundant reserves of petroleum, natural gas and uranium. There are large shale gas fields in the region and massive hydro power opportunities. However, energy resources are unevenly distributed and so regional energy integration is a feasible option for meeting concrete needs and a powerful instrument for securing energy sustainability in the region. Figure 8 shows energy integration situation in the LAC region.

Figure 8: Regional Energy Integration in LAC

Electricity Interconnections **Gas Pipelines**



Source: CIER (2014), Información del sector energético en países de América del Sur, América Central y El Caribe

3. WHAT ARE THE CRITICAL UNCERTAINTIES?

3.1. PRODUCTIVITY AND STRUCTURAL REFORM

Economic growth in LAC is expected to remain below historical trends for the foreseeable future due to slower population growth, inadequate infrastructure networks, shortcoming in quality education and relatively low export diversity, in addition to lower commodity prices. Structural policies aimed at resolving some of these bottlenecks could help raise potential output. Growth stagnation in the region can potentially be reversed by a renewed effort on the structural reform front.

The region, therefore, should explore opportunities to diversify its economies, invest in infrastructure and skilled labour, create an environment for innovation, and integrate to build a dynamic economy that will bring prosperity to all its inhabitants. Throughout the region, policies and economic reforms should be designed to manage this transition.

The LAC countries must continue to diversify their economies beyond commodity exports, which are vulnerable to global cycles. Brazil has had some success in creating strong manufacturing and services sectors, but more work is needed to make these and other countries more competitive globally.[12]

Some sectors of the LAC economy, such as agriculture in Brazil, are so competitive that they are succeeding globally despite the region's limited infrastructure. However, a much-needed improvement of roads, railways, ports and telecommunications infrastructure should unleash an export boom and boost overall regional competitiveness.

Despite large investments in social and physical infrastructure, no economic modernisation will be completed without the establishment of innovation systems. Changes in regulations, tax systems, intellectual property laws and labour laws will encourage flexibility and risk-taking, attract talent from all over the world and facilitate collaboration. Improving productivity will become critical to sustaining economic growth and the way to increase it indefinitely is through innovation.

At present, the region needs a growth strategy based on increased productivity. Given that in the short-term the international context is not going to improve, failure to implement such a strategy risks hampering LAC with low economic growth much longer than advisable from either an economic, political or social perspective. LAC faces major challenges in the short- and medium-term. The region needs to resume faster growth as soon as possible, for both economic and political reasons.

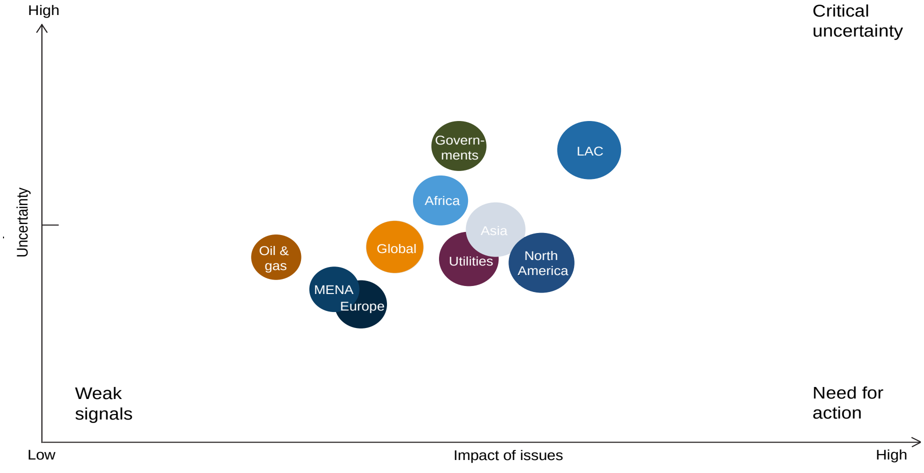
Although a few countries have started down the path of structural reform required to raise productivity and competitiveness, it is clear that the recent slowdown of economic growth has made the reform process more difficult. When growth slows or stops, societies tend to shy away from processes of structural reform, despite the promise of positive results in the medium- and long-term. At times of economic uncertainty, the short-term rules and attention to the medium- and long-term fades. Preventing this from happening is the main challenge facing LAC today.

[12] WEF (2014), World Economic Forum on Latin America - Opening Pathways for Shared Progress

3.2. CLIMATE CHALLENGE AND RESILIENCE

While much attention is naturally focused on the biggest players – the US, China, the EU and India, who together account for more than 60% of annual global CO_2 emissions from fuel combustion and almost two of thirds of accumulated historical emissions – the nations of LAC collectively have a sizeable stake in the climate negotiations, not only for their potential contributions to a global deal but also because of the considerable risk that the effects of climate change will pose to them in the future. As noted by the Council's *World Energy Issues Monitor 2016*, the increased frequency and severity of extreme weather events is a key issue for energy leaders around the world and particularly in the LAC region.

Figure 9: Risk Assessment for Climate Challenge



Source: World Energy Council (2016), World Energy Issues Monitor

New emerging risks are posing threats to the energy sector, impacting both the physical structures and the investment needed to evolve the energy system to a more sustainable future. Although the energy sector has focused on transitioning in the long-term, the understanding of the vulnerability to risks now has been largely unaddressed, leaving energy systems exposed and the financial risk in energy investments increased.

Resilience for energy infrastructure refers to its robustness and ability to recover operations to minimise interruption to service. Resilience also implies the ability to withstand extraordinary events, secure the safety of equipment and people, and ensure the reliability of the energy system as a whole. While in the past impact-resistant – 'fail-safe' – structures were built, today's system complexity and increased incidence of extreme weather events require a shift towards having energy infrastructures operating under a 'safe-fail' approach.[13]

The solution appears to be smarter, not stronger. This soft resilience approach can make energy supplies more secure, more reliable and can contribute to the quicker restoration of services in case of disruptions. Soft adaptation measures are increasingly complementing traditional hard resilience measures. However, going forward what is uncertain is how to create resilient energy infrastructures and how to finance them.

[13] World Energy Council (2015), The Road to Resilience − Managing and Financing Extreme Weather Risks

3.3. REGIONAL ENERGY INTEGRATION

LAC possesses abundant but unevenly distributed energy resources. Consequently, the potential benefits of full integration are substantial, compared to what can be obtained in other regions. Integration of national energy systems in the region would lead to economies of scale, reducing costs, increasing the reliability of supply and improving resilience.

Although some important results have been achieved, there are still barriers of different types that have prevented energy integration from being pursued as a beneficial option in the broadest sense. The greatest barrier is the contradiction between self-sufficiency goals and the concept of integration, and lack of political will. Security of supply and reduction of energy dependency are the core concerns for governments. There is also a marked tendency for countries that have energy resources to protect them, as they are now perceived as scarce and dear, so that there is less willingness to share them with other countries. What is lacking is a vision of a common energy region. Main challenges include political will, policy stability and government support, infrastructure and investment uncertainty.

What is uncertain for moving forward is the form and focus of state rivalry, and whether a collaborative governance structure can be built. This raises some key questions, which cannot easily be answered: Will regional governance be integrated or fractured? Will the transition be smooth or bumpy? There is value in examining the following range of possibilities:

- Broad-based regional governance, covering security, decarbonisation and resilience
- Market economics focused regional governance ensuring that capital markets, technology transfer and trade continue to function well
- Fractured and weak regional system with country investment inwardly focused

Boxes 1, 2 and 3 show three regional energy integration projects: Arco Norte, SINEA and SIEPAC. The future of these projects depends on whether the regional governance will be integrated or fractured and whether the transition will be smooth or bumpy.

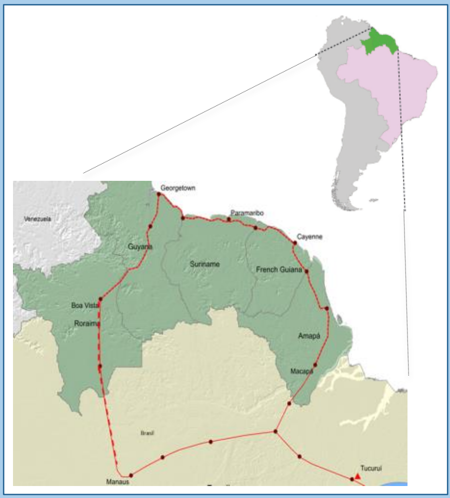
3.4. DOMINANT TOOLS FOR ACTION – MARKET AND STATE

The key tools for enabling change are state directives and markets. All states have a mixture of both, but the question is “Where will the balance lie going forward?”

The tailwinds, which would strengthen the role of state directives, would be strong public support for addressing environmental and social concerns. States’ enunciation of a clear vision and policy direction can assist in enabling solidarity. Headwinds can occur when strong state actions lead to unproductive investment, picking the wrong winners, ineffective and costly subsidies and bureaucratic failure including corruption.

The tailwinds, encouraging markets, are efficient investment, high levels of innovation, productivity and reduced costs. Markets can respond quickly to consumer needs. Headwinds are the risks of creating inequity, decision-making can be short-sighted and markets can fail, for example, by being too concentrated.

Box 1: Arco Norte Project



The idea for the Arco Norte project originated when Eletrobras identified, following inventory studies of hydro power projects undertaken in Guyana, Suriname and French Guiana, the need to consider the construction of a large transmission system to interconnect the target countries and connect them to Brazil.

As a result of the Rio+20 in 2012, the Inter-American Development Bank (IDB) considered this project as part of the Initiative of Sustainable Energy for All in Latin America and the Caribbean (LAC SE4ALL) of the UN. 2013 marked the execution of a MOU between the entities representing the involved countries, with the participation of IDB, Eletrobras, the Guyana Energy Agency, N.V. Energiebedrijven Suriname, EDF and the Agence Française de Développement (AFD).

The Arco Norte Project was initiated in 2013 with the aim to develop pre-feasibility studies. The project purpose is to investigate the feasibility of a power transmission system to interconnect Brazil and the Guyana region (Guyana, Suriname and the French Guyana). From 2014 to 2016 the project partners have identified and accessed several pre-existing studies.

The Arco Norte project will enable the development of several hydro power resources, particularly in Guyana and Suriname, favouring power interchanges with Brazil. (1) The project will have a direct impact on the reduction of generating costs due to the replacement of thermal energy by hydro power; (2) There is the expectation of improvements in energy efficiency, safety and flexibility, increased system stability, and improvements in frequency control; (3) The project will also help to reduce environmental impacts, such as dependence on thermal generation and decreased emissions of CO_2; (4) Societal interests will be served − significant economic growth associated with business and job opportunities is expected and rural and isolated communities will benefit directly from access to the transmission lines.

While the economic case for the interconnection is clear, it can also represent potential environmental and social risks, depending on the selected project criteria. The largest environmental and social impacts would evolve from new hydro power plants, which would be built in the region. Diverting rivers and building new reservoirs to store water would disrupt ecosystems and displace some indigenous communities, and these large impacts may prevent new generation projects during the planning and licensing stages.

Revision and improvements of regulatory milestones of the involved countries must be taken with the purpose of implementing and/or adopting new rules, in order to allow the interconnection of the different systems with a coordinated regional operation. The involved countries also have to agree the need of specific, bilateral or multilateral agreements, in order to facilitate the identification of the rights and obligations of each party as well as to provide guarantees to all steps and particularities of the project. Assessment and follow-up of other integration projects can improve the interregional cooperation, such as in the case of the Sistema de Interconexión Eléctrica de los Países de América Central (SIEPAC), which works as a role model to develop similar studies.

Source: Eletrobras

Box 2: SINEA Project

The SINEA (Andean Electrical Interconnection System) project has arisen from the desire to achieve a regional electricity interconnection between the countries which comprise the Andean Community of Nations (CAN) − Colombia, Chile, Ecuador, Peru and Bolivia.

The project was established in 2011 with the aim of assessing the construction of the necessary regional interconnection infrastructure and the design of a regulatory framework to facilitate exchanges and transactions of electricity. In April 2014, five energy ministers of the SINEA project signed the Declaration of Lima with the roadmap for the progressive power integration in the Andean area.

The project is the foundation of a large electricity grid that spreads from Colombia to Chile, contributing to economic integration and making a more competitive region with a secure supply. The challenge is great as electricity transactions should be conducted within a regulatory framework that provides legal certainty, efficiency and equity for the participating countries.

Colombia is actually strengthening its grid in order to upgrade the actual electric interconnection with Ecuador, Ecuador is working together with Peru, and Chile is working together with Peru in a roadmap to create an electric interconnection.

Source: UPME

Box 3: SIEPAC Project

The SIEPAC (Central American Electrical Interconnection System) project is an interconnection of the power grids of six Central American nations − Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama. The project has been discussed since 1987 and SIEPAC I project was completed in 2013, with the prospect of Mexico, Colombia and Belize joining as well. There are, however, problems with the market coordination and the capacity of the lines, and so SIEPAC II project is now discussed.

Clearly, challenges remain. To fully realise the potential, SIEPAC needs to account for the dynamics and the heterogeneity of the electricity sectors of the various countries of Central America. SIEPAC will enable the development of larger and more efficient regional generation projects, including generation powered by natural gas. It is also going to facilitate the preparation of a larger number of renewable energy projects, traditional and non-traditional, thus contributing to a diversification of the regional energy matrix.

Source: IDB http://www.iadb.org/en/news/webstories/2013-06-25/energy-integration-in-central-america,10494.html

4. BUILDING THE SCENARIOS

We note two radically different types of futures − the uplands and lowlands. In the uplands of the Grand Transition, sustainable economic growth and productivity are strong, and environment issues are addressed in the context of a collaborative international framework. Weak economic growth, inadequate attention to climate change, and a policy focus that is more nationally oriented define the lowlands of the Grand Transition.

Of the four critical uncertainties, three are important drivers of the potential for sustainable economic growth: productivity and structural reform, climate challenge and resilience, and regional energy integration. The last uncertainty – the dominant tools for action – is of special importance for energy leaders.

We have chosen three scenarios. The first and second scenarios explore the uplands, each with a different set of dominant tools – one which utilises predominantly state directives and the other predominantly markets. The third scenario explores the lowlands of weak and unsustainable economic growth and investment with inward-looking policies.

These three scenarios that have been selected are titled Samba, Tango and Rock. The LAC region shows some variations when it comes to the application of the framework – Modern Jazz, Unfinished Symphony and Hard Rock, which has been developed for the *World Energy Scenarios 2016: The Grand Transition*. To reflect this and the unique culture and passion of the region, it seems an apt requirement to adjust the names of the scenarios as well. While Samba resembles the flexibility of Jazz, Tango represents the structure and control found in Symphony. Rock has a music style which describes the difficult situations faced in the transition.

A broad description and the key features of the three scenarios are outlined in Table 6 and 7 below:

Table 6: Three Possible Futures for Energy in LAC

Scenario	Description	Key features
Samba	LAC shaped by successful reform and strong innovation and high productivity with market forces	▪ Innovation and economic diversification beyond commodity exports ▪ Energy access for all
Tango	LAC shaped by governments to achieve sustainable growth and resilient energy system	▪ Strong regional integration ▪ High investment on regional adaptation and mitigation
Rock	LAC shaped by weak economic growth and waning support from global and regional institutions	▪ Limited infrastructure investment ▪ Policies inwardly focused and reform process delayed

Source: World Energy Council

Table 7: Critical Uncertainties and LAC Three Scenarios

Critical Uncertainties	Samba	Tango	Rock
Productivity and Structural Reform	▪ Successful reform and innovation ▪ Economic Growth 3.7% p.a. (2014–2030) 3.1% p.a. (2030–2060) ▪ GDP per capita in 2060 US$ 30,175	▪ Growth with focus on sustainability ▪ Economic Growth 2.8% p.a. (2014–2030) 2.7% p.a. (2030–2060) ▪ GDP per capita in 2060 US$ 23,513	▪ Low economic growth ▪ Economic Growth 1.5% p.a. (2014–2030) 1.4% p.a. (2030–2060) ▪ GDP per capita in 2060 US$ 13,095
Climate Challenge and Resilience	▪ Medium priority ▪ Cumulative emissions from fuel combustion 73 Gt CO_2 (2015-60) → 4.9% of the world	▪ High priority ▪ Cumulative emissions from fuel combustion 56 Gt CO_2 (2015-60) → 4.8% of the world	▪ Low priority ▪ Cumulative emissions from fuel combustion 65 Gt CO_2 (2015-60) → 4.3% of the world
Regional Energy Integration	▪ Key projects driven by market economics	▪ Broad-based regional governance	▪ Fractured regional system
Tools for Action	▪ Markets	▪ States	▪ Patchwork of states and markets

Source: World Energy Council and Paul Scherrer Institute

Chapter 3

LAC Energy Scenarios: Samba, Tango and Rock

1. SAMBA

1.1. THE INTERNATIONAL CONTEXT

World Energy Scenarios 2016: The Grand Transition has developed the Modern Jazz scenario, which serves as a basis for Samba in the LAC regional scenarios. Modern Jazz explores a competitive world shaped by market mechanisms and an economic and energy landscape that is evolving due to rapid technology innovation. Amplified globalisation and the continued penetration of digital technologies lead to new markets across industries, driving strong productivity gains and strong economic growth. Lifestyles are urban, mobile and highly dependent on technology.

Emerging technologies are exceptionally disruptive to energy systems and lead to substantial diversification of primary energy. In transport, natural gas, biofuels and electric vehicles (EVs) penetrations lead to a diverse fuel mix. Wind, solar and energy storage solutions increase distributed systems' penetration in the power sector. Utilities are forced to adapt to changing demand patterns and adopt new business models.

Policymakers, supported by the values of civil society, enable an energy transition through light-touch policy intervention. In the absence of an international climate framework, carbon pricing and taxation schemes grow more slowly, from the bottom-up, based on regional, national and local initiatives. However, with technology innovation, rapid improvements are possible in the economics of modern renewable energy and storage technologies. This leads to drastic shifts in energy and carbon intensity without substantial economic disruption.

1.2. FOCUS ON LAC

In Samba, the LAC region is a world of successful structural reform and high levels of productivity and innovation, with strong market forces. Regional economic growth rate of 3.3% p.a. to 2060 enable high levels of infrastructure and human capital investment. Led by strong economic growth in Chile and Peru, other countries increasingly open their markets to foreign investment with the aim of diversifying the economy beyond commodity exports and moving more towards a manufacturing and service sector based economy. Adoption of new technologies throughout the energy value chain accelerates and increases pressure on traditional energy providers. These range from smart energy technologies leading to rapid energy efficiency improvements, to digital connectivity and energy storage options in the midstream and increased energy supply availabilities − this underpins large shifts in energy mix towards renewables, biofuels and natural gas.

PRODUCTIVITY AND STRUCTURAL REFORM: The combinatorial effects of structural reform and digitalisation bring revolutionary change in many industries and help to upskill the workforce. Open economies make global competition and growth in new geographies possible. The LAC economy is expected to grow fast at 3.7% p.a. from 2014 to 2030 (2.8% p.a. for Brazil, 4.6% p.a. for LAC excl. Brazil) and 3.1% p.a. from 2030 to 2060 (2.5% p.a. for Brazil, 3.5% p.a. for LAC excl. Brazil).

CLIMATE CHALLENGE AND RESILIENCE: Based on the consensus on the importance of making modern renewables more reliable and more competitive, continued policy support for renewable energy projects creates fiscally attractive terms for utility companies. There is also progress to create more resilient energy infrastructure.

REGIONAL ENERGY INTEGRATION: With rapid economic growth driven by open economies and digital technologies, the global and regional governance system is shaped by market economics-focused governance, ensuring that capital markets, technology transfer and trade continue to function well. While the economic case for the interconnection and energy integration projects is clear, regional integration projects should solve the challenges related to large environmental and social impacts.

DOMINANT TOOLS FOR ACTION: With market forces dominating technology choices, developments are driven by competitiveness, cost and reliability. Markets give a stronger voice to consumers, whose values drive a behavioural shift to products and services that meet environmental and social compliance. Policymakers respond by enabling light-touch policies to account for externalities.

Box 4 provides Chile's strategy to promote renewable energy as an illustrative example of what success looks like in a Samba world.

Box 4: Chile's Renewable Energy

The Government of Chile, as a result of the National Energy Strategy 2012-2020, made a commitment to diversify the country's energy mix promoting non-conventional renewable energy (NCRE) and pledged a clean energy mandate of 20% of electricity generation by 2025.

The procedures and criteria were established in order to create the conditions that allow the private sector to invest in these long-term projects. It allowed more than 100 international companies engaged in these projects, including developers, large generators, associated services and builders. According to the Climatescope 2016, an assessment of clean energy market conditions and opportunities in 58 emerging nations, Chile ranks second.

In March 2014, the total installed capacity of NCRE in Chile amounted to 1,352 MW (bioenergy 33%, wind 31%, mini-hydro 25% and Solar 11%), which is equivalent to 7.2% of the total installed electricity capacity. The Minister of Energy stated that "It has successfully completed the largest power tender held in the country, which has called for a level of competition never seen before, that will mark future trends and produce a paradigm shift in the Chilean electricity market, translating all in lower prices to the benefit of our families and small and medium enterprises in Chile … Today we have taken a definitive boost to the electricity market with more players, better prices, more investment, more competition and concern for better service and a more secure, reliable and efficient electricity system."

Source: Rodrigo Andrade, Director, Dialogo Energetico

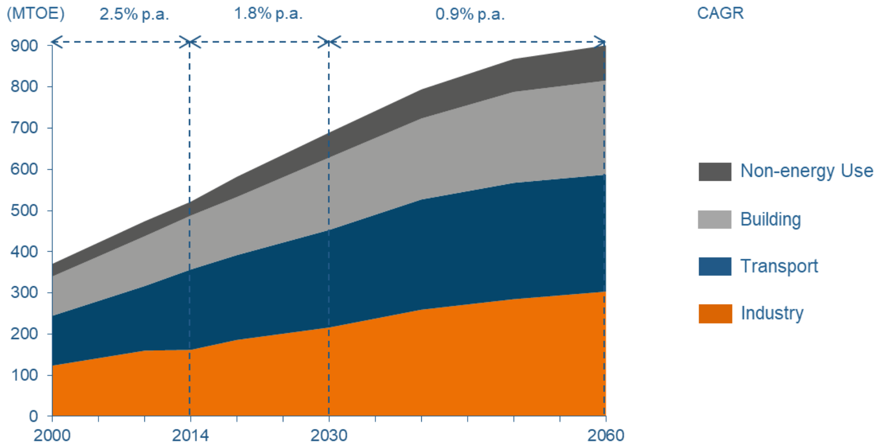
1.3. ENERGY LANDSCAPE

1) Final Energy Consumption

Although higher economic growth and abundant and cheap energy supplies drive the final energy consumption increase, the LAC countries continue to diversify their economies beyond commodity exports and create manufacturing and services sectors. Technologies also make industrial activity more efficient, while the growing penetration of renewables helps to enable more efficient conversion.

As shown in Figure 10, final energy consumption in LAC is expected to grow at a slower rate of 1.8% p.a. from 2014 to 2030 and increase from 522 MTOE to 690 MTOE. Technology developments that disrupt traditional energy systems boost efficiency. As a result, the final energy consumption growth rate will begin to decrease beyond 2030, slowing to 0.9% p.a. and settling at 901 MTOE in 2060. This is 73% higher than 2014 final energy consumption.

Figure 10: Samba Final Energy Consumption by Sector in LAC



* Figure 46 in Appendix provides Samba Final Energy Consumption by Sector in Brazil and LAC excl. Brazil.

Source: World Energy Council and Paul Scherrer Institute

2) Transport Energy

Transport energy growth in LAC is expected to slow down to 2020 because of difficult times following a period of prosperity driven by a decade-long commodity price boom. However, energy in transport will be reversed back to grow at a rate of 1.4% p.a. from 2020 to 2030, as rapid economic growth, open economies and freedom of mobility translate into high volumes of car ownership, air traffic and freight. Beyond 2030, adaptation of new technologies lead to rapid energy efficiency improvements and transport energy growth will slow down significantly at a pace of 0.6% p.a. Transport energy in LAC is expected to reach a plateau after 2050.

Diversification of transport fuels in LAC is dominantly driven by biofuels. Biofuels growth is accelerated due to plentiful feedstocks and advances in next generation biomass technologies. Biofuels will grow more than 5 times from 2014 to 2060 and the share of transport energy will increase from 9% in 2014 to 17% in 2030 and 31% in 2060.

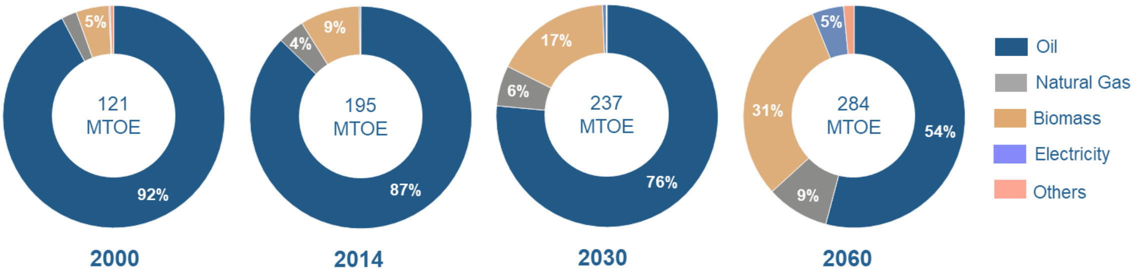
EVs, supported by technology breakthroughs in battery and growing availability of charging, underpin the growth of electricity in transport beyond 2030. As a result, electricity share of transport energy in LAC will grow from 0.2% in 2014 to 4.6% in 2060. However, it will be below the world average as the biofuels share in LAC is almost double the world average.[14]

[14] In 2060, the electricity share of transport energy in the world will be 8% and biofuels share 16%.

Transport demand for oil will peak around 2040 at 183 MTOE (3.7 mb/d) as transport fuels diversification accelerates. Figure 11 shows oil share of transport energy will fall from 87% in 2014 to 76% in 2030 and 54% in 2060.

In heavy-duty freight and marine transport, an abundance of natural gas supplies and regional emission standards lead to demand for CNG and LNG technology penetration. This drives natural gas shares to reach 9% of transport energy by 2060, in particular, 13% for LAC excl. Brazil.

Figure 11: Samba Transport Energy Mix in LAC



* Figure 48 in Appendix provides Samba Transport Energy Mix in Brazil, LAC excl. Brazil and the World.

Source: World Energy Council and Paul Scherrer Institute

3) Electricity Generation

With improvements in quality of life, increasing technology and economic growth, lifestyles demand more electricity. By 2060, electricity generation in LAC will grow 2.3 times (2.1 times for Brazil, 2.5 times for LAC excl. Brazil). Electricity generation investment from 2010 to 2060 is estimated to be US$ 2.3 trillion based on 2010 market exchange rate (US$ 1.1 trillion for Brazil and US$ 1.2 trillion for LAC excl. Brazil).

Hydro power will dominate the electricity generation growth by 2030. Beyond 2030, however, hydro power growth will slow down due to environmental and social concerns and so its share of electricity generation will decline from 54% in 2014 to 43% in 2060.

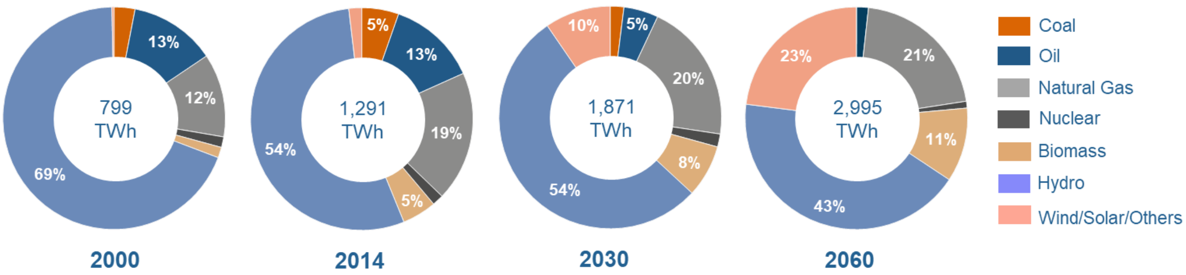
Beyond 2030, new electricity generation growth will be dominated by wind/solar/others. Wind/solar/others share of electricity generation will increase dramatically from 2% in 2014 to 23% in 2060. However, it will be far below the world share as the hydro power share in LAC is triple the world average.[15]

Although natural gas plays a transitional role to meet the electricity demand growth, Figure 12 shows fossil fuel share of the electricity generation will decrease from 37% in 2014 to 23% in 2060.

In Samba, growing electricity demand, falling technology costs, increasing penetration of new market entrants and new innovative financing models lead to continued momentum for distributed energy systems that generate power close to where it is used to provide new opportunities for electrifying rural regions. Distributed systems include stand-alone, as well as community mini-grids, which may be off-grid or grid connected.

[15] In 2060, wind/solar/others share of electricity generation in the world will be 32% and hydro share 14%.

Figure 12: Samba Electricity Generation Mix in LAC



* Figure 49 in Appendix provides Samba Electricity Generation Mix in Brazil, LAC excl. Brazil and the World.

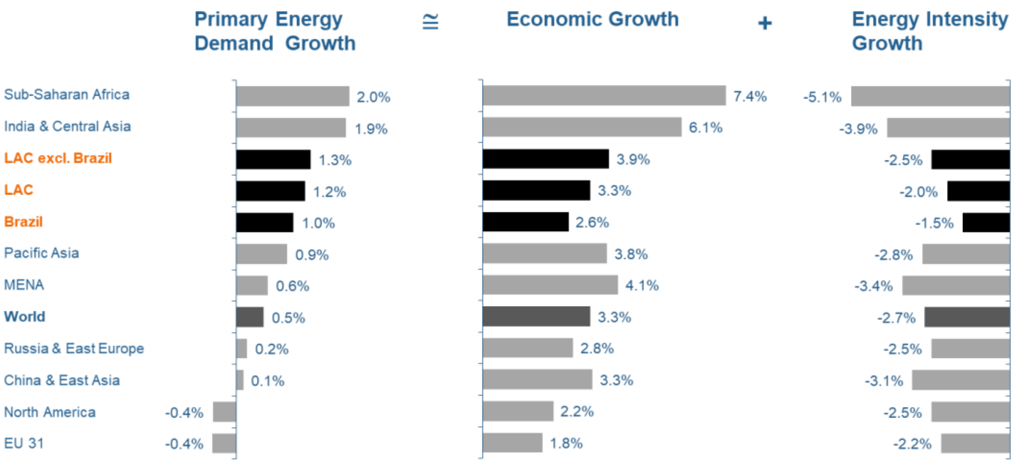
Source: World Energy Council and Paul Scherrer Institute

4) Primary Energy Demand

Driven by successful structural reform and high levels of productivity and innovation, LAC economy will grow at a rate of 3.3% p.a. to 2060. High economic growth drives energy demand in LAC to increase, but there continue to be strides in reducing the primary energy intensity of GDP. Less energy intensive economic growth and smarter use of energy boost energy efficiency. LAC will diversify the economy beyond commodity exports and moving more towards a manufacturing and service sector based economy. Adoption of new and smart energy technologies will lead to rapid energy efficiency improvements.

Primary energy demand in LAC is expected to grow at a rate of 1.7% p.a. from 2014 to 2030 and it will grow slowly at 0.9% p.a. from 2030 to 2060. Figure 13 shows primary energy demand growth by region. LAC primary energy demand growth will stand at a relatively high level, compared to most other regions and the world. LAC economic growth is expected to be relatively slow, but energy intensity improvement to be also limited.

Figure 13: Samba Primary Energy Demand Growth by Region (2014-2060 CAGR)

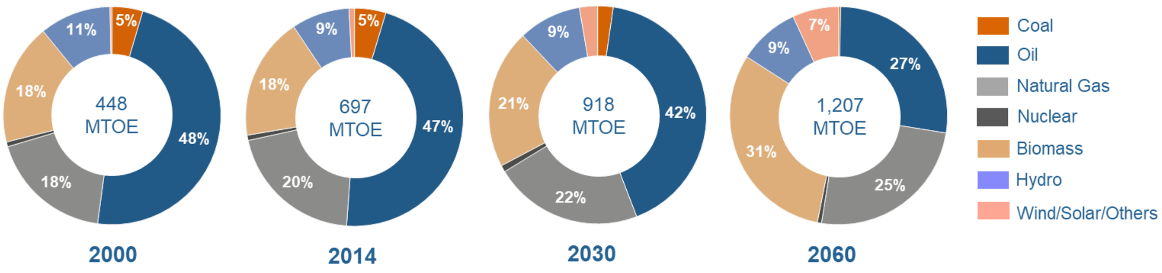


* Primary Energy = GDP ╳ (Primary Energy / GDP)

Source: World Energy Council and Paul Scherrer Institute

Although natural gas plays a role in LAC, the growing use of hydro and wind/solar/others in the power sector and biofuels in transport sector will drive down the share of fossil fuels from 72% in 2014 to 66% in 2030 and 53% in 2060, as shown in Figure 14. In LAC, the share of hydro in primary energy in 2060 will be about triple the world average and the share of biomass will be twice the world average.

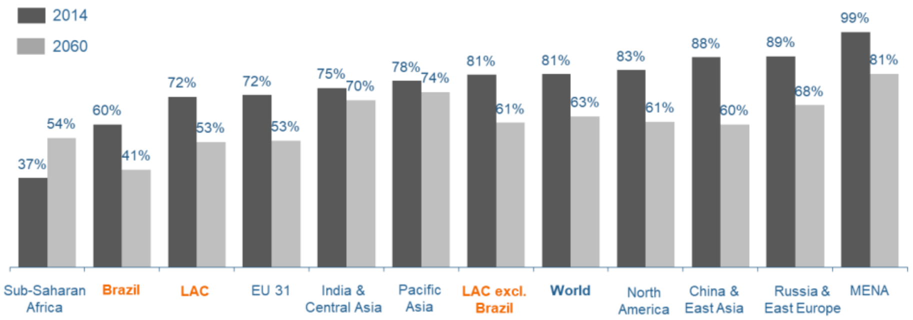
Figure 14: Samba Primary Energy Demand Mix in LAC



* Figure 50 in Appendix provides Samba Primary Energy Demand Mix in Brazil, LAC excl. Brazil and the World

Source: World Energy Council and Paul Scherrer Institute

Figure 15: Samba Fossil Fuel Share by Region



Source: World Energy Council and Paul Scherrer Institute

5) Primary Energy Demand by Fuel

Despite high economic growth, oil demand growth in LAC is tempered by increased competition from alternative transport fuels – biofuels, EVs and natural gas. This trend will lead to a peak in demand for oil in 2040 at 403 MTOE (8.1 mb/d). The subsequent decline will occur and oil demand in LAC is expected to settle at 329 MTOE (6.6 mb/d) in 2060.

Consumers increasingly see natural gas as a cleaner and lower cost source and natural gas takes share from coal and oil in power generation. In LAC, favourable conditions will lead natural gas demand in primary energy to grow rapidly. Natural gas demand in LAC will double up by 2060, settling at 301 MTOE. In particular, natural gas demand will surpass oil demand to be the largest primary energy source in LAC excl. Brazil after 2050.

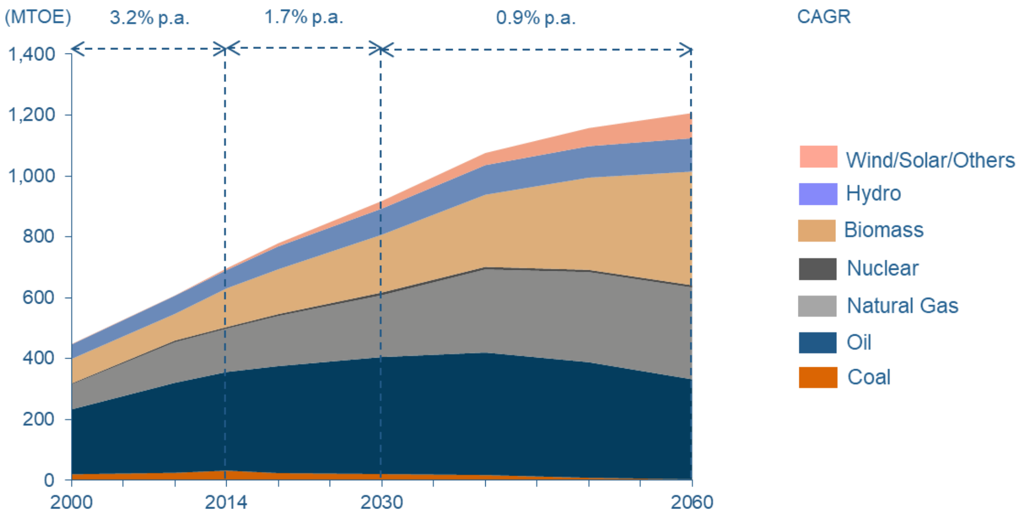
The use of biomass in LAC will rise almost 3 times in the period from 2014 to 2060, reaching 373 MTOE. Substantial pull comes from both transport and power generation demands, driven by plentiful feedstocks that are available at low cost and next generation biomass technologies led by Brazilian innovation. In particular, biomass demand will surpass oil demand to be the largest primary energy source in Brazil after 2050.

Hydro power will dominate the electricity generation growth by 2030. Beyond 2030, however, hydro power growth will slow down due to environmental and social concerns. Hydro demand in LAC will almost double by 2060, reaching 110 MTOE.

Wind/solar/others in LAC will grow most rapidly than any other primary energy to 2060. Continued technology advances lead cost declines and innovation in small-scale battery based storage solutions and distributed systems such as micro-grids that enable balancing intermittent renewables in energy systems. Wind/solar/others will grow almost 15 times by 2060, reaching 83 MTOE.

In the LAC region, nuclear has a very limited role and accounted for 0.8% of primary energy and 1.6% of power generation in 2014. Nuclear demand will stagnate after 2030 as nuclear struggles to compete against natural gas and renewables additions. Despite high economic growth and growing energy demand, the role of coal in LAC outside of Colombia and Chile will also be limited.

Figure 16: Samba Primary Energy Demand by Fuel in LAC



* Figure 47 in Appendix provides Samba Primary Energy Demand by Fuel in Brazil and LAC excl. Brazil.

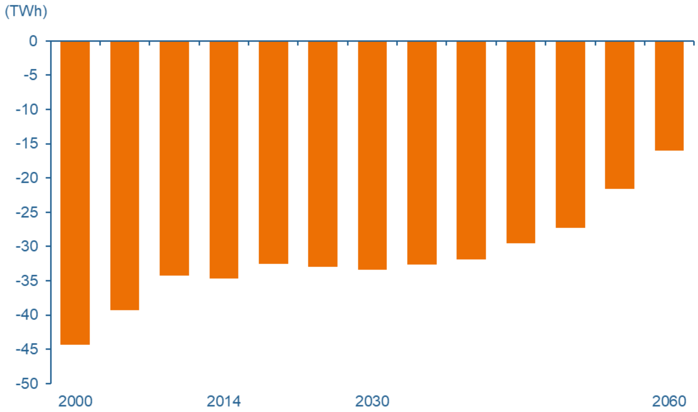
Source: World Energy Council and Paul Scherrer Institute

6) Intra-Regional Electricity Interconnection

In a highly globalised and technology-driven Samba, people, goods and money flow more rapidly than ever before across borders. Economic and social connectivity make the public, industry and policy leaders more supportive of regional cooperation. This fosters innovative partnerships and interest from a variety of stakeholders. In LAC, key regional projects will be driven by market economics. The market economics focused regional governance system drives the regional electricity interconnection.

Brazil's electricity import from LAC excl. Brazil was 35 TWh in 2014, which met 5-6% of total electricity demand in Brazil. The largest amount of imported electricity comes from the bi-national Itaipu hydro power plant in Paraguay, which straddles the border between the two countries. Brazil's electricity demand continues to increase rapidly and it will be satisfied by domestic production and net imports from LAC excl. Brazil. In the long-run, Brazil's net import of electricity will decrease as domestic capacity grows, as shown in Figure 17.

Figure 17: Samba Electricity Net Exports from Brazil to LAC excl. Brazil



Source: World Energy Council and Paul Scherrer Institute

7) Productions and Net Exports

As the lowest cost supplier, the MENA is able to boost production, but a lower oil price climate creates challenges for funding the needed upstream investments to sustain production growth. Oil production also climbs upward in North America driven by unconventional liquids production. US light tight oil (LTO) will lead production growth to 2030. Oil production in LAC will increase from 412 MTOE (8.3 mb/d) in 2014 to 493 MTOE (9.9 mb/d) in 2030. Inter-regional net export of oil in LAC will also increase to 109 MTOE (2.2 mb/d) in 2030. However, global oil demand is expected to peak at 5,123 MTOE (103 mb/d) in 2030 and LAC oil demand is also expected to peak at 403 MTOE (8.1 mb/d) in 2040. Demand peaks for oil have the potential to take the world and LAC to "stranded resources."

To 2030, MENA natural gas supplies will grow fastest to meet global demand growth, followed by the US and Pacific Asia. Beyond 2030, MENA will dominate supply additions and RD&D and gas exploration lead to continued rapid growth of unconventional gas supplies driven by the US, Canada, Australia, Argentina and China. Natural gas production in LAC will increase from 149 MTOE in 2014 to 211 MTOE in 2030. LAC inter-regional net export in 2030 will stay at the same level as LAC natural gas demand grows fast.

LAC leads a substantial growth in terms of biomass in both the transport and power sectors, driven by plentiful feedstocks that are available at low cost. Europe and Sub-Saharan Africa also see an increase in biofuels supply for transport. Beyond 2030, next generation biomass technologies will become commercially viable, led by Brazil and China. Biomass production in LAC will increase from 129 MTOE in 2014 to 194 MTOE in 2030. Inter-regional net export of biomass in LAC will increase to 4 MTOE in 2030.

Table 8: Samba Productions and Inter-Regional Net Exports in LAC

	Production (MTOE)		Net Export (MTOE)	
	2014	2030	2014	2030
Oil	412	493	88	109
Natural Gas	149	211	7	7
Biomass	129	194	2	4

Source: World Energy Council and Paul Scherrer Institute

8) Carbon Emissions from Fuel Combustion

The carbon intensity of GDP is expected to fall at an unprecedented rate of 2.5% p.a. from 2014 to 2030. It is, however, not enough to counteract the upward pressure on emissions from high economic growth at a rate of 3.6% p.a., so carbon emissions from fuel combustion will grow at a pace of 1.1% p.a. Carbon intensity will decline at a rate of 3.3% p.a. from 2030 to 2060. Accelerated carbon intensity reductions will drive carbon emissions from fuel combustion to peak between 2040 and 2050 at 1.7 Gt CO_2. The subsequent decline will occur and carbon emissions from fuel combusions settle at 1.5 Gt CO_2 in 2060.

Technology affects both the energy intensity of GDP and the carbon intensity of primary energy. Less energy intensive economic growth and smarter use of energy boost energy efficiency. Rapid penetration of biofuels in transport, growing investments in natural gas, wind and solar power generation lead to substantial decarbonisation of energy systems.

Light-touch policy support is the underlying driver for the shifts in technology adoption in the regions. Collaboration between national and local governments encourages the use of renewable energy sources and support energy efficiency and efforts to reduce pollution.

Table 9: Decomposition of CO_2 Growth in Samba (CAGR)

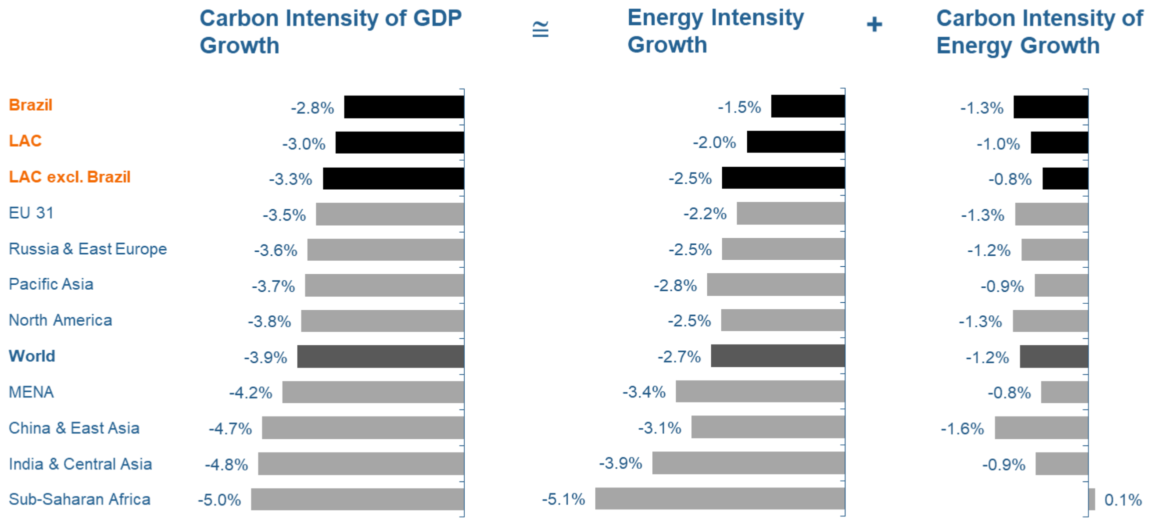
		CO_2 Emissions*	≅	GDP		Carbon Intensity of GDP**	
				Population	GDP per capita	Energy Intensity	Carbon Intensity of Energy**
LAC	2014-2030	+1.1%		+0.8%	+2.8%	-1.9%	-0.6%
	2030-2060	-0.2%		+0.3%	+2.8%	-2.1%	-1.2%
Brazil	2014-2030	+0.4%		+0.7%	+2.1%	-1.2%	-1.2%
	2030-2060	-0.6%		+0.1%	+2.4%	-1.7%	-1.3%
LAC excl. Brazil	2014-2030	+1.5%		+0.9%	+3.6%	-2.6%	-0.3%
	2030-2060	-0.1%		+0.4%	+3.1%	-2.4%	-1.1%
World	2014-2030	+0.6%		+1.0%	+2.5%	-2.4%	-0.4%
	2030-2060	-1.4%		+0.6%	+2.6%	-2.9%	-1.6%

* Kaya Identity: CO_2 Emissions = Population ⨯ (GDP / Population) ⨯ (Energy / GDP) ⨯ (CO_2 / Energy)

** Carbon Intensity of GDP = CO_2 / GDP and Carbon Intensity of Energy = CO_2 / Energy

Source: World Energy Council and Paul Scherrer Institute

Figure 18: Samba Carbon Intensity Improvement by Region (2014-2060 CAGR)



Source: World Energy Council and Paul Scherrer Institute

2. TANGO

2.1. THE INTERNATIONAL CONTEXT

World Energy Scenarios 2016: The Grand Transition has developed the Unfinished Symphony scenario, which serves as the basis for Tango in the LAC regional scenarios. In Unfinished Symphony, national governments unite and take effective policy action on climate change, supported by the values of civil society and an effective system of international governance. Economic growth is moderated, but also more environmentally sustainable. The world is 'ticking on the same clock' and has shifted to a low-carbon and resilient energy system.

Drastic policy changes on global and national levels push political institutions and business models to their limits as new, more stringent regulatory requirements are imposed. Surviving companies find new operating models with more sustainable environmental outcomes. Beyond 2030, policies to control carbon emissions become increasingly stringent, pushing economic models to their limits. More and more pressure builds to develop circular business models and create circular economies.

Cooperation frameworks extend beyond climate change into the broader economic system. Regional and global cooperations are the driving force for accelerating knowledge transfer and standardisation, both of which enable more efficient technology transfer across regions. An extensive network of fiscal incentives emerges, such as green subsidies and carbon pricing, with first regional then global standardisation across sectors. This enables unified action on climate change, which levels the playing field for developing nations.

2.2. FOCUS ON LAC

Tango describes a LAC region shaped by governments to achieve sustainable growth of 2.7% p.a. to 2060. This is underpinned by an effective system of broad-ranging regional and international governance, including strong collective climate change policies and the regional integration of energy systems. There is the emergence of a critical mass of new solutions to address energy supply, demand and climate change stresses. Initiatives first take root locally as individual cities or nations take the lead. These initiatives link up progressively as LAC governments harmonise a diversity of measures and take advantage of the opportunities, resulting in increasing regional integration. As a result, effective demand-side efficiency measures diffuse quickly and CO_2 management practices spread. Energy efficiency improvements and the emergence of low-carbon transport solutions for sprawling mega-cities are accelerated. Strong infrastructure development and high regional cooperation support the private sector in the development of integrated grid solutions. Uruguay and Ecuador are models of how governments operate in this scenario.

PRODUCTIVITY AND STRUCTURAL REFORM: Policy direction that attempts to balance growth with environmental and social outcomes shapes a more sustainable model for economic growth. The LAC economy will grow modestly at 2.8% p.a. from 2014 to 2030 (2.4% p.a. for Brazil, 3.3% p.a. for LAC excl. Brazil) and 2.7% p.a. from 2030 to 2060 (2.2% p.a. for Brazil, 3.1% p.a. for LAC excl. Brazil).

CLIMATE CHALLENGE AND RESILIENCE: LAC and all regions make unprecedented progress in mitigating carbon emissions and reducing the carbon footprint of lifestyles and economies. The UNFCCC successfully establishes a framework and supports technology transfer and funding for sustainable development. As extreme weather events are a growing threat, LAC countries focus on the creation and financing of resilient energy infrastructures.

REGIONAL ENERGY INTEGRATION: Tango is shaped by the presence of a strong governance structure and an emphasis on diplomacy, leading to a LAC of increasing regional and global cooperation. In many countries, developments focus on building regional partnerships that support increased integration of energy systems and funding for infrastructure projects.

DOMINANT TOOLS FOR ACTION: With strong global and state directives on climate and other issues, markets are shaped by national and global policy to achieve the equilibrium that more accurately reflects the cost of environmental and social externalities. Business models adapt to meet increasingly stringent requirements for compliance with environmental and social standards.

Box 5 provides Uruguay’s wind power policy as an illustrative example of what success looks like in a Tango world. The Appendices include four more examples including Bolivia’s regional energy hub plan, Brazil’s wind power programme, Colombia’s Proure and TransMilenio CDM programme and Ecuador’s transition plan.

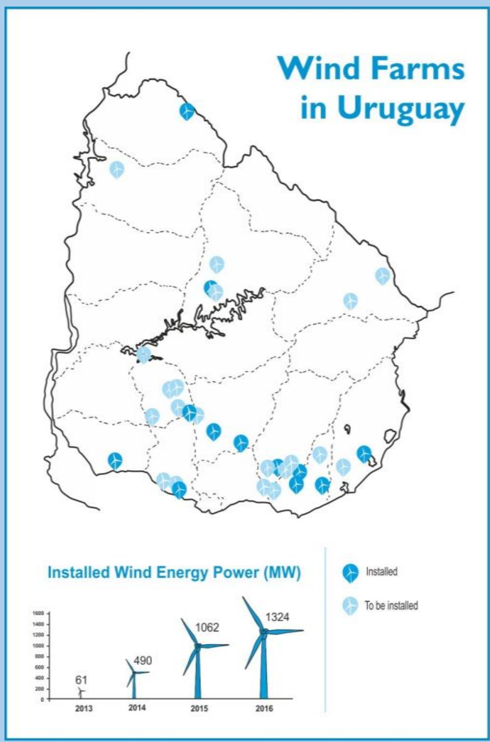
Box 5: Uruguay’s Wind Power

In Uruguay, 1,324 MW wind power is installed today and 1,455 MW is expected by 2017 enough to cover more than 35% of electricity demand. Uruguay had no wind power until 2005, so the question is what happened in the meantime?

Uruguay has a long tradition in hydro power since the 1930s, combined with fossil fuel thermal plants. It seemed to run smoothly, but the technical limit of hydro power was reached during the 1990s and a new framework was needed in order to meet increased electricity demand.

Discussions on renewables as an alternative started in 2005 and led to the first National Energy Policy in 2008. Wind potential proved to be sufficient to install thousands of MW, showing it to be the most promising energy source together with biomass.

There is no single answer for what were the key drivers of the rapid wind power development in Uruguay, but certainly planning was one of them. Energy policy features a cornerstone for wind in Uruguay, introducing goals and clear actions to achieve them.



Source: Uruguay National Member Committee, World Energy Council

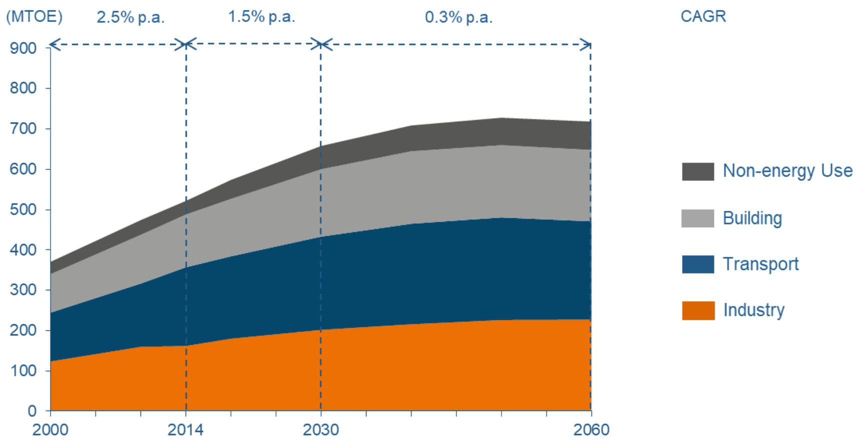
2.3. ENERGY LANDSCAPE

1) Final Energy Consumption

A top-down push towards more sustainable economic growth results in slower growth of final energy consumption. Significant breakthroughs in storage technologies open the door to a revolution in transit and policy mandates substantially impact consumer demand for transport energy. Top-down energy mandates require increasing efficiency standards for commercial and residential buildings. Governments also subsidise a transition to more efficient appliances, lighting, heating and air conditioning solutions. Centrally managed smart cities that are integrated with smart buildings are critical to such efficiency gains.

As shown in Figure 19, final energy consumption in LAC is expected to grow at a slower rate of 1.5% p.a. from 2014 to 2030 and increase from 522 MTOE to 658 MTOE. Beyond 2030, final energy consumption growth will slow down significantly to 0.3% p.a. It will reach a plateau at about 720-730 MTOE after 2050. This is 38-40% higher than 2014 final energy consumption.

Figure 19: Tango Final Energy Consumption by Sector in LAC



* Figure 51 in Appendix provides Tango Final Energy Consumption by Sector in Brazil and LAC excl. Brazil.
Source: World Energy Council and Paul Scherrer Institute

2) Transport Energy

Transport energy growth in LAC is expected to slow down to 2020 because of difficult times following a decade-long commodity price boom. However, energy in transport will be reversed back to grow at a rate of 1.2% p.a. from 2020 to 2030 due to move towards more sustainable economic growth. Beyond 2030, transport energy growth will be drastically slower at a pace of 0.2% p.a. Driven by policy mandates, significant breakthroughs in battery technologies open the door to a revolution in transit. Transport energy in LAC is expected to peak after 2050.

Biofuels will lead to diversify the transport fuel mix, as it grows almost 6 times from 2014 to 2060. Growth is accelerated due to policy mandates, advances in technologies and plentiful feedstocks. Biofuels share of transport energy will increase from 9% in 2014 to 18% in 2030 and 41% in 2060.

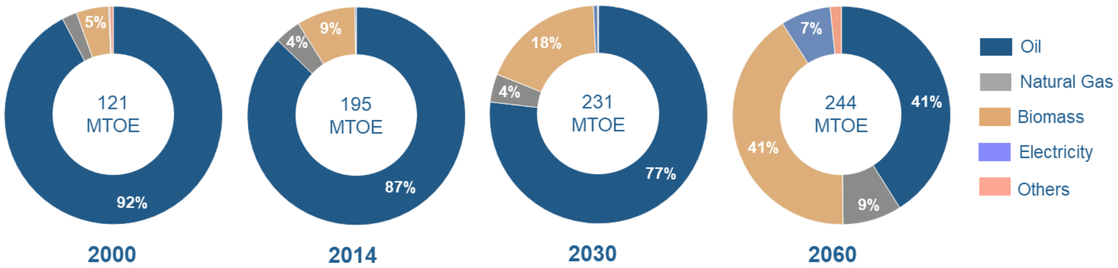
Through fuel efficiency and emissions standards and the build-out of smart infrastructure, the electrification of transport energy continues to build momentum. Electricity share of transport energy is expected to grow from 0.2% in 2014 to 7.4% in 2060. However, it will be below the world electricity share of transport energy as the biofuels share is twice the world average.[16]

[16] In 2060, the electricity share of transport energy in the world will be 10% and biofuels' share 21%.

As transport fuels diversification accelerates due to policy mandates, transport demand for oil will peak at 179 MTOE (3.6 mb/d) in LAC in 2040. Figure 20 shows oil share of transport energy will fall from 87% in 2014 and 41% in 2060.

In heavy-duty freight and marine transport, global and regional emission standards lead to demand for CNG and LNG technology penetration. This will drive natural gas shares to reach almost 9% of transport energy by 2060, in particular, 10% in LAC excl. Brazil.

Figure 20: Tango Transport Energy Mix in LAC



* Figure 53 in Appendix provides Tango Transport Energy Mix in Brazil, LAC excl. Brazil and the World.
Source: World Energy Council and Paul Scherrer Institute

3) Electricity Generation

Moderated economic growth and higher electricity prices dampen electricity demand, however, improvements in quality of life and lifestyles demand more electricity. By 2060, electricity generation in LAC will grow 2.1 times (2.1 times for Brazil, 2.1 times for LAC excl. Brazil). Electricity generation investment from 2010 to 2060 is estimated to be US$ 2.5 trillion based on 2010 market exchange rate (US$ 1.2 trillion for Brazil and US$ 1.3 trillion for LAC excl. Brazil).

Hydro power will dominate the electricity generation growth by 2030. Beyond 2030, however, hydro power growth will slow down due to environmental and social concerns and so its share of electricity generation will decline from 54% in 2014 to 48% in 2060.

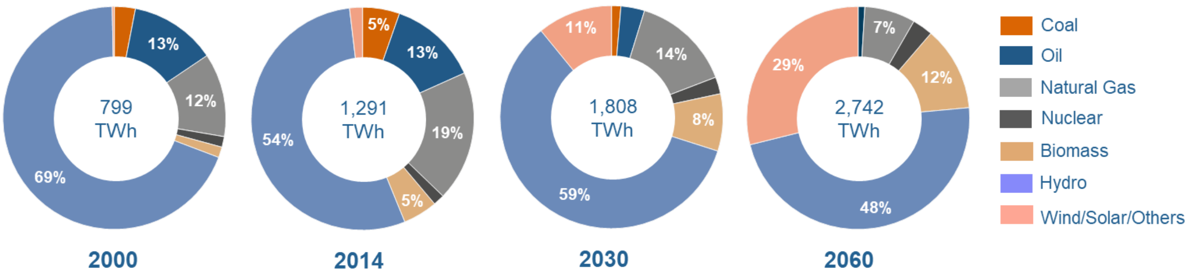
Beyond 2030, new electricity generation growth will be dominated by wind/solar/others. Wind/solar/others share will increase dramatically from 2% in 2014 to 29% in 2060. However, it will be still far below the world share as the hydro power share in LAC is triple the world average.[17]

Because of tightening emissions standards, Figure 21 shows fossil fuel share of the electricity generation will decrease dramatically from 37% in 2014 to 19% in 2030 and 8% in 2060. CCS will account for 6% of total electricity generation in 2060.

In Tango, the effect of near-zero marginal cost operators is countered by growing system costs associated with renewables. These include storage and back-up solutions, balancing, grid connection, extension and reinforcement costs. The approach to allocating system costs influences the degree to which the zero-marginal cost effect distorts energy markets.

[17] In 2060, wind/solar/others share of electricity generation in the world will be 42% and hydro share 16%.

Figure 21: Tango Electricity Generation Mix in LAC



* Figure 54 in Appendix provides Tango Electricity Generation Mix in Brazil, LAC excl. Brazil and the World.

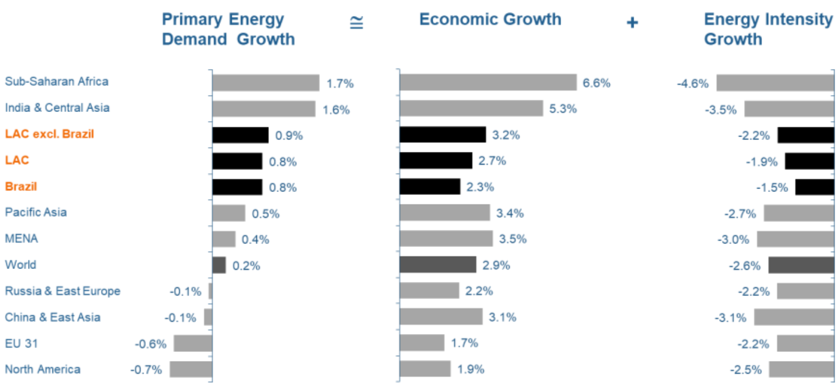
Source: World Energy Council and Paul Scherrer Institute

4) Primary Energy Demand

Economic growth is moderated, but more environmentally sustainable. LAC region will achieve sustainable growth of 2.7% p.a. to 2060. Although economic growth drives energy demand to increase, there continue to be strides in reducing primary energy intensity of GDP. LAC economies will make the transition to sustainability-led growth. Drastic policy changes on the global and national level push energy and economic systems to be smarter, resilient, and more efficient. High regional cooperation will support the development of integrated infrastructure solutions.

Primary energy demand in LAC is expected to grow at 1.4% p.a. from 2014 to 2030 and it will grow more slowly at 0.5% p.a. from 2030 to 2060. Figure 22 shows primary energy demand growth by region. LAC primary energy demand growth will stand at a relatively high level, compared to most other regions and the world. LAC economic growth is expected to be relatively slow, but energy intensity improvement to be also limited.

Figure 22: Tango Primary Energy Demand Growth by Region (2014-2060 CAGR)

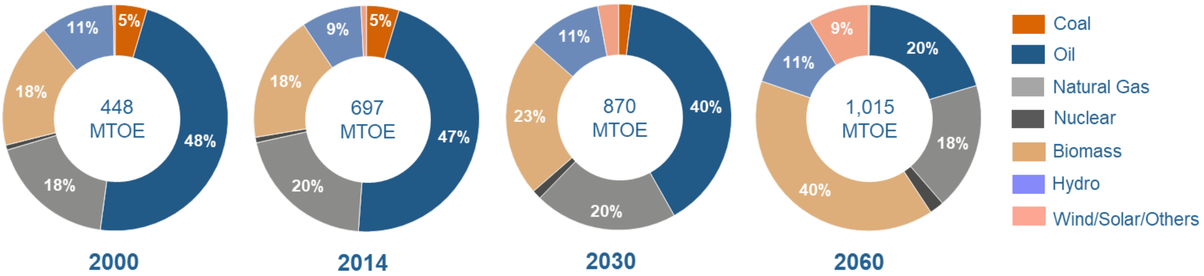


* Primary Energy = GDP ⨉ (Primary Energy / GDP)

Source: World Council and Paul Scherrer Institute

The growing use of biofuels, hydro and wind/solar/others in transport and power sectors will drive down the share of fossil fuels from 72% in 2014 to 62% in 2030 and 39% in 2060, as shown in Figure 23. In LAC, the share of biomass in primary energy in 2060 will be twice the world average and the share of hydro will be almost triple the world average.

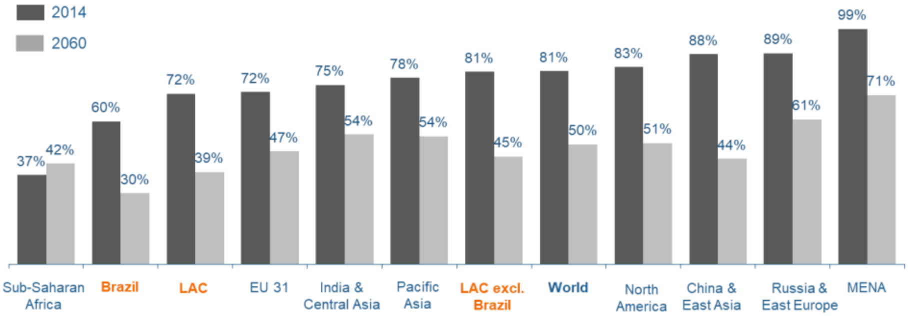
Figure 23: Tango Primary Energy Demand Mix in LAC



* Figure 55 in Appendix provides Tango Primary Energy Demand Mix in Brazil, LAC excl. Brazil and the World.

Source: World Energy Council and Paul Scherrer Institute

Figure 24: Tango Fossil Fuel Share by Region



Source: World Energy Council and Paul Scherrer Institute

5) Primary Energy Demand by Fuel

The unified action on climate change will lead to strong restrictions on carbon emitting transport fuels. Oil demand growth in LAC will be significantly tempered by competition from biofuels and EVs. This trend will lead to a peak in oil demand between 2030 and 2040 at 347 MTOE (7.0 mb/d). The subsequent decline is expected to occur rapidly, settling at 205 MTOE (4.1 mb/d) in 2060.

Moderate economic growth and increasingly stringent emissions standards will dampen growth for natural gas. This trend will lead natural gas demand to stagnate after 2040 and settle at 185 MTOE in 2060. It is just 30% higher than 2014 consumption value.

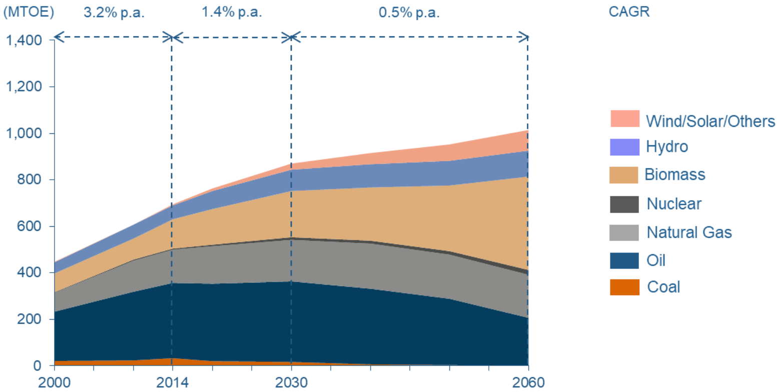
Biomass growth in LAC is accelerated due to policy mandates, advances in technologies and plentiful feedstocks. Rapid growth comes from both transport and power sectors. The demand for biomass in LAC is expected to grow more than three times by 2060, reaching 402 MTOE. In particular, biomass demand will surpass oil demand to be the largest primary energy source from 2040 in Brazil and from 2050 in the LAC region.

Based on policy support, LAC hydro in primary energy is expected to grow rapidly to 2030. Beyond 2030, the growth of hydro will significantly slow down as hydro power competes with wind/solar/others to meet the new growth of electricity needs. Hydro demand in LAC will almost double by 2060, reaching 112 MTOE.

Wind/solar/others in LAC will grow most rapidly than any other primary energy to 2060. Strong policy mandates, subsidy schemes and growing demand for clean energy will drive the deployment of modern renewables. Government financed RD&D fosters advances in standardisation, modularisation and materials science innovation. Wind/solar/others will grow almost 16 times by 2060, reaching 88 MTOE.

In the LAC region, nuclear has a very limited role. In Tango, however, nuclear in primary energy expects to grow more than four times by 2060 due to stringent emissions standards. Nuclear power will account for 3% of power generation in 2060 (3.4% for Brazil, 2.6% for LAC excl. Brazil).

Figure 25: Tango Primary Energy Demand by Fuel in LAC



* Figure 52 in Appendix provides Tango Primary Energy Demand in Brazil and LAC excl. Brazil.

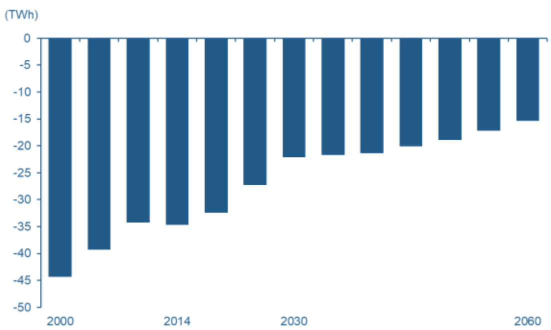
Source: World Energy Council and Paul Scherrer Institute

6) Intra-Regional Electricity Interconnection

Broad-based regional governance, covering security, decarbonisation and resilience is a key for strong regional integration in Tango. Strong policy support for infrastructure development and high cooperation at a regional level allow companies to develop integrated grid solutions. All LAC countries are integrated as a result of full progress on the projects like Arco Norte, SINEA, SIEPAC II and others which have been studied. Mexico is also expected to want electricity interconnection to the Caribbean region.

In Brazil, more hydro and nuclear power capacities are expected to be installed in Tango, compared to Samba, which is driven by the climate goals and governmental support for large scale power generation. However, electricity demand is below Samba and so intra-regional net import of electricity in Brazil will continue to decrease from 35 TWh in 2014 to 15 TWh in 2060, as shown in Figure 26.

Figure 26: Tango Electricity Net Exports from Brazil to LAC excl. Brazil



Source: World Energy Council and Paul Scherrer Institute

7) Productions and Net Exports

Implicit carbon prices slow oil supply additions and drive oil prices higher. Stagnated demand for transport and falling capital spending in exploration and production will cause a steep decline in global supplies beyond 2030. MENA will maintain its position as the dominant global supplier. Oil production in LAC will increase from 412 MTOE (8.3 mb/d) in 2014 to 484 MTOE (9.2 mb/d) in 2030. Inter-regional net export of oil in LAC will also increase to 137 MTOE (2.8 mb/d) in 2030. However, global oil demand is expected to peak at 4,671 MTOE (94 mb/d) in 2030 and LAC oil demand will also peak at 347 MTOE (7.0 mb/d) between 2030 and 2040. Demand peaks for oil have the potential to take the world and LAC to “stranded resources.”

Production of natural gas will grow fastest in Russia and China to 2030. MENA and North America will dominate growth to 2060. Natural gas production in LAC will also increase from 149 MTOE in 2014 to 183 MTOE in 2030. As LAC natural gas demand grows fast to 2030, the inter-regional net export of natural gas in LAC will decrease slightly, reaching 5 MTOE in 2030.

Emissions mandates accelerate biomass growth in both transport and power generation. LAC leads in overall biomass use and production driven by plentiful, low cost feedstocks. National emission standards continue to tighten in every region, which will sustain the growth of biomass globally to 2060. Supplies will be increasingly available as next generation biomass technologies, led by Brazil and China, become commercially viable. Biomass production in LAC will increase from 129 MTOE in 2014 to 203 MTOE in 2030. Inter-regional net export of biomass in LAC will increase slightly to 4 MTOE in 2030.

Table 10: Tango Productions and Inter-Regional Net Exports in LAC

	Production (MTOE)		Net Export (MTOE)	
	2014	2030	2014	2030
Oil	412	484	88	137
Natural Gas	149	183	7	5
Biomass	129	203	2	4

Source: World Energy Council and Paul Scherrer Institute

8) Carbon Emissions from Fuel Combustion

Carbon intensity of GDP will fall at an unprecedented rate of 2.5% p.a. from 2014 to 2030. It is, however, slightly short of counteracting the upward pressure on emissions from economic growth at a rate of 2.8% p.a., so carbon emissions from fuel combustion will grow at a pace of 0.3% p.a. Beyond 2030, carbon intensity will accelerate to a decline of 4.9% p.a. Accelerated carbon intensity reductions drive carbon emissions from fuel combustion will peak around 2030 at 1.4 Gt CO_2. The subsequent decline will occur and carbon emissions from fuel combustion settle at 0.7 Gt CO_2 in 2060.

Strong government mandates and rising carbon prices will force a rapid transition in energy technologies to improve energy and carbon intensity. Top-down mandates and technology support the development of intelligent infrastructure and smarter buildings, homes and offices that enable consumers to use energy more efficiently. Technology support is also instrumental in deploying the low-carbon energy system.

Table 11: Decomposition of CO_2 Growth in Tango (CAGR)

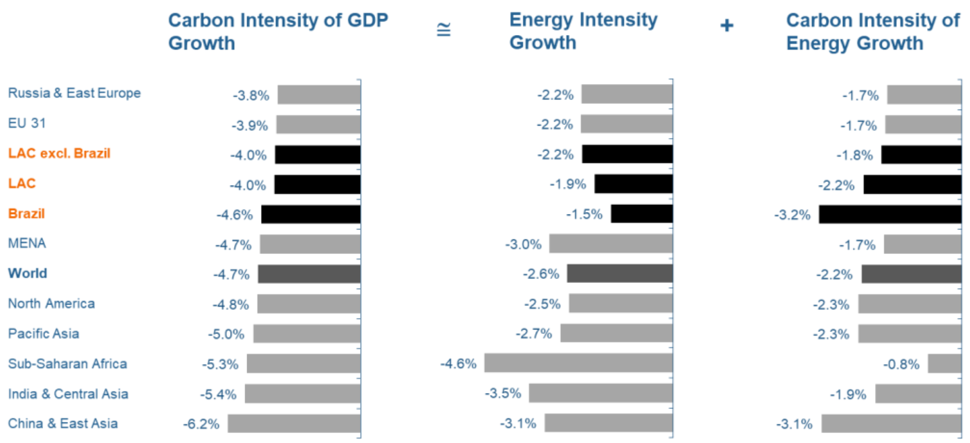
		CO_2 Emissions*	≅	GDP		Carbon Intensity of GDP**	
				Population	GDP per capita	Energy Intensity	Carbon Intensity of Energy**
LAC	2014-2030	+0.3%		+0.8%	+2.0%	-1.4%	-1.1%
	2030-2060	-2.3%		+0.3%	+2.4%	-2.1%	-2.8%
Brazil	2014-2030	-0.4%		+0.7%	+1.7%	-0.9%	-1.8%
	2030-2060	-3.5%		+0.1%	+2.1%	-1.8%	-3.9%
LAC excl. Brazil	2014-2030	+0.7%		+0.9%	+2.3%	-1.9%	-0.7%
	2030-2060	-1.8%		+0.4%	+2.7%	-2.4%	-2.4%
World	2014-2030	-0.3%		+1.0%	+2.1%	-2.3%	-1.0%
	2030-2060	-3.0%		+0.6%	+2.1%	-2.7%	-2.9%

* Kaya Identity: CO_2 Emissions = Population ⨉ (GDP / Population) ⨉ (Energy / GDP) ⨉ (CO_2 / Energy)

** Carbon Intensity of GDP = CO_2 / GDP and Carbon Intensity of Energy = CO_2 / Energy

Source: World Energy Council and Paul Scherrer Institute

Figure 27: Tango Carbon Intensity Improvement by Region (2014-2060 CAGR)



Source: World Energy Council and Paul Scherrer Institute

3. ROCK

3.1. THE INTERNATIONAL CONTEXT

World Energy Scenarios 2016: The Grand Transition has developed the Hard Rock scenario, which serves as the basis for Rock in the LAC regional scenarios. Hard Rock explores a world where the geopolitical tensions weaken international governance systems. Governments establish policies that balance security, equity and environmental concerns based on the local context. Rising nationalist policies weaken international trade agreements. Export-oriented growth becomes less important as an economic growth strategy, which leads to stagnating global economic growth. Consequently, national policies emphasise consumption-led growth driven by diversified local economies.

Although in many regions environmental concerns remain a priority on national agendas, weak economic performance and low international cooperation make it more challenging for the world to tackle climate change. On a national level, energy policy often emphasises energy security and climate concerns, which creates strong demand for solar and wind generation. It also creates more policy support for nuclear energy.

With low economic growth limiting funding capacity and without a global climate framework in place, countries struggle to meet the UN climate commitments. Fossil fuels remain the dominant source of energy and the issue of climate is not adequately addressed. Governments are shifting their focus to infrastructure resilience and adaptation to climate impacts.

3.2. FOCUS ON LAC

Rock is shaped by a world of weak economic growth and waning support for global institutions, within which countries encourage more self-sufficient policies. In the LAC region there is a more protectionist response, with regional growth of 1.4% p.a. to 2060. Countries develop a broad range of internally focussed policies with limited regional cooperation. Fossil fuels remain an important source of energy and governments are forced to shift their focus to infrastructure resilience and adaptation as the number of extreme climate events increase. National governments, the principal actors in Rock, emphasise supply levers as energy demand grows broadly in line with economic growth. Across the region there is a relatively uncoordinated range of national mandates and incentives for developing indigenous energy supplies. Given the wide variety of fuel resources within countries, there is substantially diversity in country energy patterns. This leads to a patchwork of local standards, resource flows and technologies. At the regional level, Rock is a world of bilateral government deals between energy producers and energy consumers, with national governments competing with each other for favourable terms of supply or for access by their energy companies. National energy companies play key intermediary roles.

PRODUCTIVITY AND STRUCTURAL REFORM: Despite the promise of medium- and long-term structural reform, volatility in commodity prices and financial markets and the threat of recession make the LAC economies wary about the near future. As economies struggle to develop structural reform and technological innovation, the LAC economy will grow slowly at a rate of 1.5% p.a. from 2014 to 2030 (1.2% p.a. for Brazil, 1.9% p.a. for LAC excl. Brazil) and 1.4% p.a. from 2030 to 2060 (1.1% p.a. for Brazil, 1.6% p.a. for LAC excl. Brazil).

CLIMATE CHALLENGE AND RESILIENCE: As a result of an emphasis on resolving national economic and security concerns first, the climate mitigation target slides down the list of priorities for national governments. Consequently, in most regions including LAC, countries do not meet the Intended Nationally Determined Contributions (INDC) commitments set at COP21. The physical and economic destruction caused by the impacts of climate change make adaptation and resilience the primary focus.

REGIONAL ENERGY INTEGRATION: Fragmentation in political and economic systems weakens regional and international governance systems, resulting in trade relationships driven by both economic and energy security concerns. Within this context, national governments promote their national agendas and the fractured and weak regional system is unable to address challenges to regional energy integration.

DOMINANT TOOLS FOR ACTION: Market structures and policy systems increasingly fragment and focus on local needs. Diversifying local economies and adapting to a new world with high geopolitical tensions become the primary focus areas. Continued instability plagues the LAC region and security drivers and power balancing alliances dominate cooperation. Strong national governments, societal values and state-owned enterprises thus become the predominant tools for action.

Box 6 provides Argentina's energy market reform as an illustrative example of how to avoid a Rock world.

Box 6: Argentina's Energy Market Reform

As a result of a profound regulatory reform, between 1990 and 1992, Argentina went from an energy system controlled by state-owned companies to a system of private companies disintegrated vertically and horizontally. The system allowed the creation of transparent gas and electricity markets with free prices and multiple suppliers.

Everything, however, changed drastically from the economic and political crisis of 2002. The new government imposed export duties on oil and regulated the domestic price. Gas exports were banned and the domestic price was set by the government at very low levels which discouraged investments. Regarding electricity, prices were fixed at a level that only recognised the operative costs of the generators. Distribution tariffs were also frozen, placing the integrity of the networks at serious risk.

The new government launched in December 2015 determined to rebuild markets and return to regulatory frameworks prior to 2002. But the task is not easy. The law of economic emergency and the tangle of de facto subsidies and regulations that followed since 2002 cause great uncertainty as to what rules to apply. The process of ending subsidies and returning to the gas and electricity markets will continue progressively to the end of 2019.

Source: Argentina National Member Committee, World Energy Council

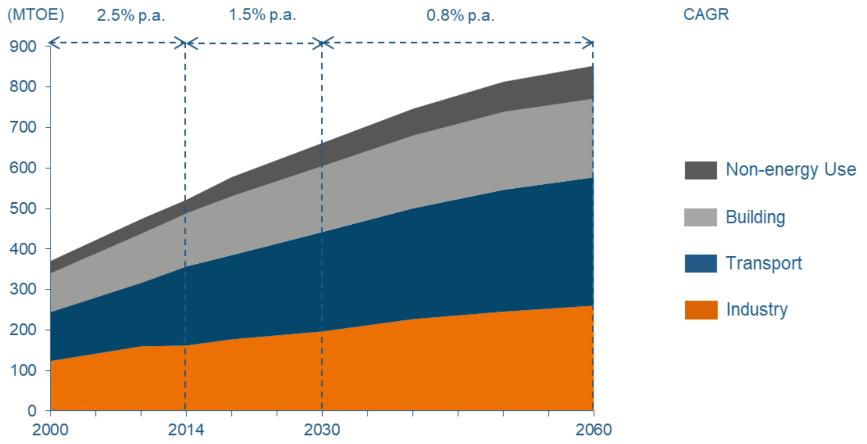
3.3. ENERGY LANDSCAPE

1) Final Energy Consumption

Despite a slowdown in economic growth in Rock, final energy consumption in LAC continues to increase at a moderate rate because of industrial activity using less-advanced technologies, dominant ICE vehicles and ineffective top-down mandates for energy conservation.

As shown in Figure 28, final energy consumption in LAC is expected to grow at a slower rate of 1.5% p.a. from 2014 to 2030 and increase from 522 MTOE to 662 MTOE. Beyond 2030, its growth rate will moderate further to 0.8% p.a., reaching 853 MTOE in 2060. This is 63% higher than 2014 final energy consumption.

Figure 28: Rock Final Energy Consumption by Sector in LAC



* Figure 56 in Appendix provides Rock Final Energy Consumption by Sector in Brazil and LAC excl. Brazil.

Source: World Energy Council and Paul Scherrer Institute

2) Transport Energy

Transport energy growth in LAC is expected to slow down to 2020 because of difficult times following a decade-long commodity price boom. However, energy in transport will be reversed back to grow. With reduced capacity for transport infrastructure build-out, demand for personal transport will remain high. As a result, energy in transport in LAC is expected to grow at a rate of 1.7% p.a. from 2020 to 2030 and will continue to grow at a rate of 0.9% p.a. beyond 2030.

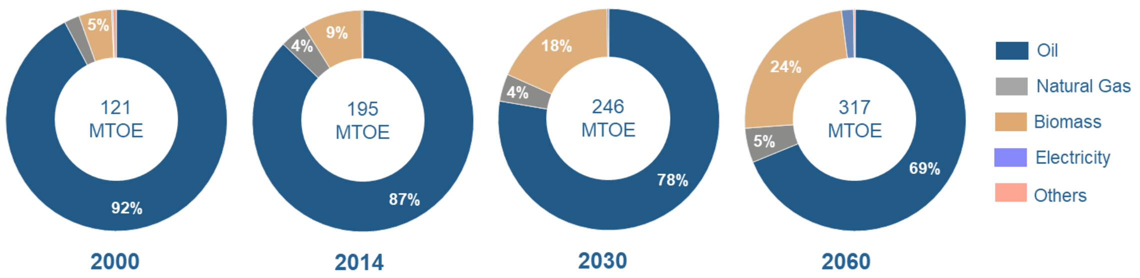
Lower economic growth and reduced capacity for transport infrastructure build-out mean transport fuels are slow to diversify. Transport demand for oil will continue to grow from 170 MTOE (3.4 mb/d) in 2014 to 218 MTOE (4.4 mb/d) in 2060. Figure 29 shows the oil share of transport energy will fall from 87% in 2014 to 78% in 2030 and 69% in 2060 as biofuels penetration accelerates.

The security concerns and economics of transport fuels favour the penetration of biofuels over natural gas and electricity. Biofuels will capture half of the transport energy demand increment and grow 4.5 times from 2014 to 2060. Consequently, the biofuels share of transport energy will increase from 9% in 2014 to 18% in 2030 and 24% in 2060.

Electricity will account for only 2% of transport energy in 2060. It will be below the world electricity share of transport energy as the biofuels share is far ahead of the world average.[18]

[18] In 2060, the electricity share of transport energy in the world will be 4% and biofuels share 10%.

Figure 29: Rock Transport Energy Mix in LAC



* Figure 58 in Appendix provides Rock Transport Energy Mix in Brazil, LAC excl. Brazil and the World.

Source: World Energy Council and Paul Scherrer Institute

3) Electricity Generation

Despite slower economic growth coupled with restricted funding capacity for infrastructure build-out, electricity demand in LAC continues to grow. By 2060, electricity demand in LAC will grow 2.1 times (1.9 times for Brazil, 2.4 times for LAC excl. Brazil). Electricity generation investment from 2010 to 2060 is estimated to be US$ 2.0 trillion based on the 2010 market exchange rate (US$ 0.9 trillion for Brazil and US$ 1.1 trillion for LAC excl. Brazil).

Hydro power will play a dominant role in meeting increased demand for electricity until 2030. Beyond 2030, hydro power generation growth will slow down and so its share of electricity generation will decline from 54% in 2014 to 46% in 2060.

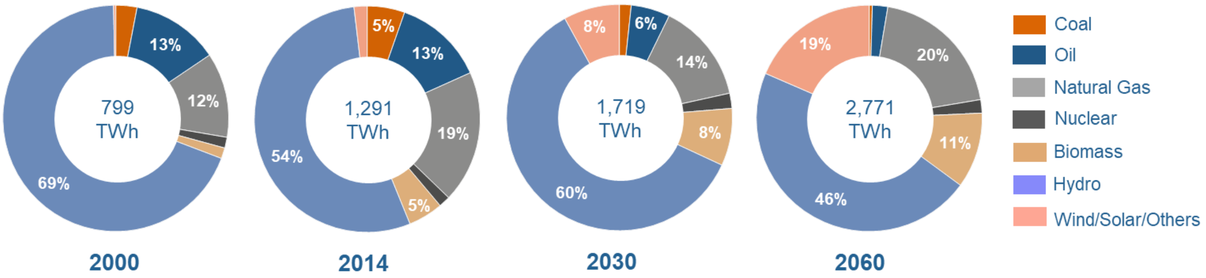
Beyond 2030, the new generation increment will be dominated by wind/solar/others and natural gas. Wind/solar/others share of electricity generation will increase dramatically from 2% in 2014 to 19% in 2060. However, it will be slightly below the world share as the hydro power share in LAC is triple the world average.[19]

Figure 30 shows fossil fuel share of the electricity generation will decrease from 37% in 2014 to 22% in 2030. However, it will stay at 22% in 2060 as natural gas, together with wind/solar/others, will also play a dominant role to meet the electricity demand growth beyond 2030.

In Rock, utility companies are at a tipping point of change. Clean energy technology is being adopted more aggressively as prices fall. The potential for customers to deploy distributed generation looms large. However, with slower economic growth, technology support for renewables is declining: utilities will struggle to navigate through demand disruption and many will fail to effectively engage with regulators to define new models to secure long-term viability.

[19] In 2060, wind/solar/others share of electricity generation in the world will be 21% and hydro share 15%.

Figure 30: Rock Electricity Generation Mix in LAC



* Figure 59 in Appendix provides Rock Primary Energy Demand by Fuel in Brazil, LAC excl. Brazil and the World

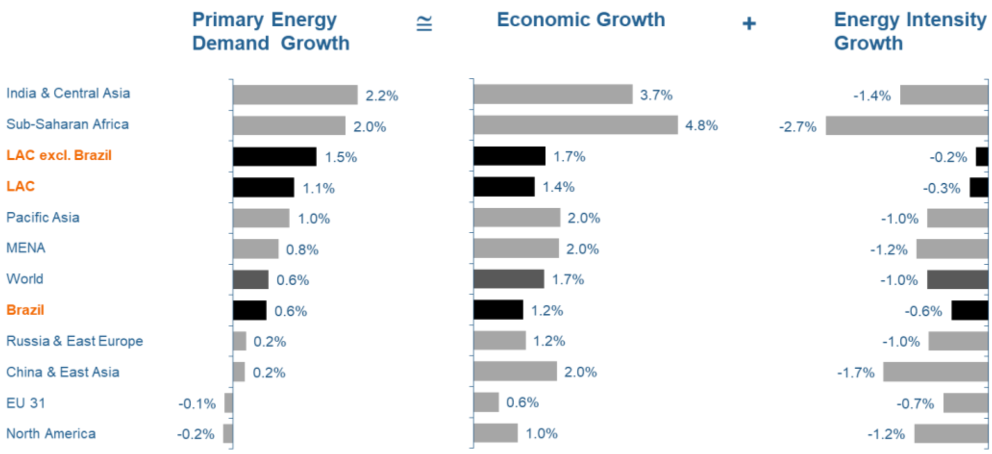
Source: World Energy Council and Paul Scherrer Institute

4) Primary Energy Demand

Geopolitical tensions weaken international governance systems and there is a more protectionist response in LAC, with regional growth of 1.4% p.a. to 2060. Although LAC economic growth is expected to be weak, stagnant progress on energy intensity translates into primary energy growth. With consumption patterns remaining status quo and industries following the same historical energy intensive trajectories, the reduction of energy intensity will stagnate.

Primary energy demand in LAC is expected to grow at a low rate of 1.4% p.a. from 2014 to 2030 and more slowly at a rate of 1.0% p.a. from 2030 to 2060. Figure 31 shows primary energy demand growth by region. In Brazil, primary energy demand growth will stand at the world average level as its economic growth is expected to be relatively slow, but energy intensity improvement to be also limited. In LAC excl. Brazil, primary energy demand growth will stand at a relatively high level, compared to most other regions and the world. Although its economic growth is expected to be relatively slow, energy intensity improvement to be stagnant.

Figure 31: Rock Primary Energy Demand Growth by Region (2014-2060 CAGR)

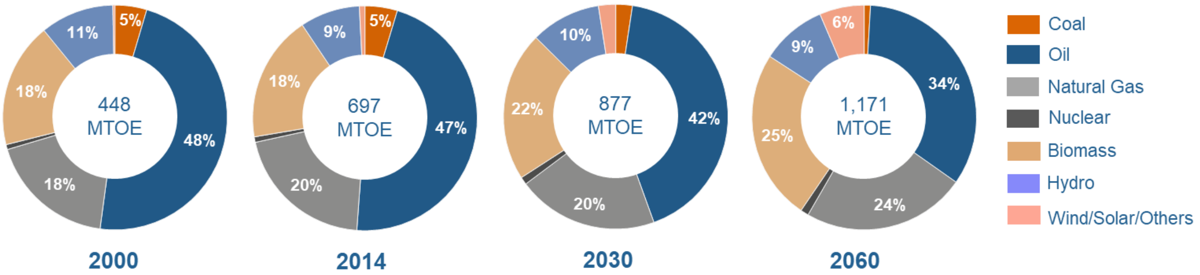


* Primary Energy = Population ╳ (GDP / Population) ╳ (Primary Energy / GDP)

Source: World Council and Paul Scherrer Institute

Reduced funding capacity leads to lower investment in clean energy technologies, so the primary energy demand mix remains dependent on fossil fuels to meet demand. However, progress is expected to be made as energy security concerns increase the focus on domestic energy resources including biomass, hydro, wind and solar. The share of fossil fuels in LAC will fall from 72% in 2014 to 65% in 2030 and 58% in 2060, as shown in Figure 32. In LAC, the share of biomass in primary energy in 2060 will be more than twice the world average and the share of hydro will be triple the world average.

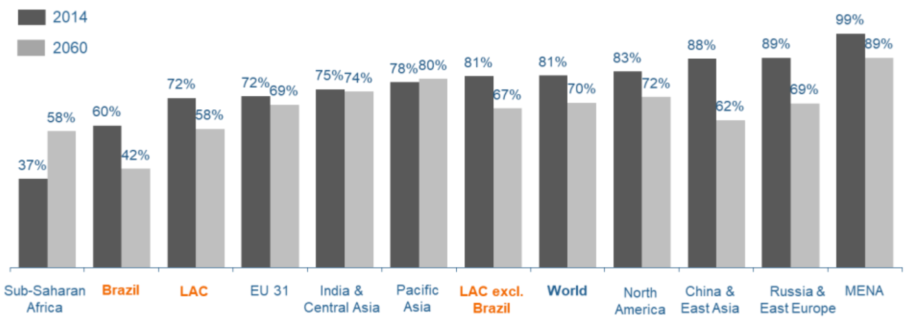
Figure 32: Rock Primary Energy Demand Mix by Fuel in LAC



* Figure 60 in Appendix provides Rock Primary Energy Demand Mixes in Brazil, LAC excl. Brazil and the World

Source: World Energy Council and Paul Scherrer Institute

Figure 33: Rock Fossil Fuel Share by Region



Source: World Energy Council and Paul Scherrer Institute

5) Primary Energy Demand by Fuel

Transport energy will remain heavily dependent on oil because weak economic growth and reduced financing capacity limit infrastructure investments for an energy transition in the transport sector. However, oil demand growth in LAC is tempered by increased penetration from biofuels due to energy security concerns. This trend will lead to a plateau in oil demand in LAC after 2050, reaching 396 MTOE (8.0 mb/d).

Despite low economic growth, an energy security concerns and decline in global trade will drive LAC regional production of natural gas. As a result, natural gas will play an important role to meet the electricity demand growth in LAC. Natural gas demand in LAC will double up by 2060, settling at 276 MTOE.

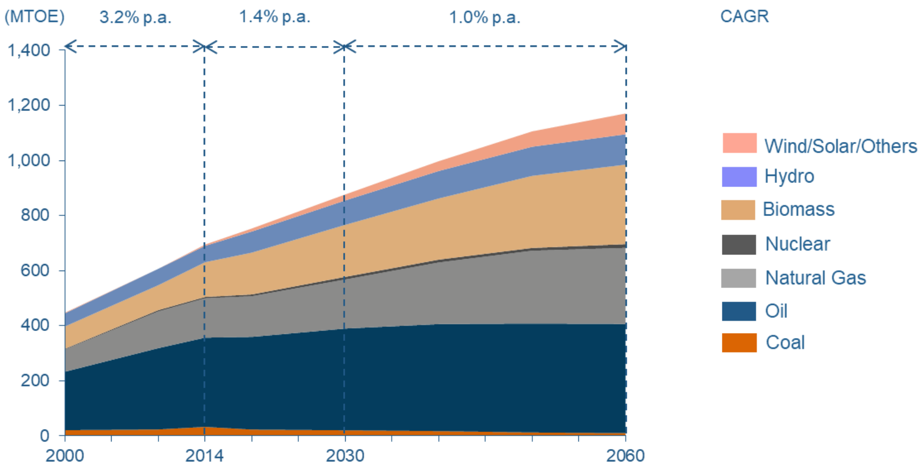
Energy security concerns and plentiful feedstocks position biomass well in LAC. Substantial pull comes from both transport and power sectors. The demand for biomass in LAC is expected to grow more than double by 2060, reaching 288 MTOE.

Hydro in primary energy in LAC is expected to grow fast to 2030 as new electricity generation growth will be dominated by hydro power due to energy security concerns. Beyond 2030, however, the growth of hydro power will slow down significantly due to a range of social and environmental concerns. Hydro demand in LAC will almost double by 2060, reaching 110 MTOE.

As international energy trade declines, widely fluctuating oil and gas commodity prices will persuade national governments to look to modern renewables as a domestic source of electricity generation. Wind, solar and other renewable energies are expected to grow more rapidly than any other source in primary energy. Wind/solar/others will grow more than 13 times by 2060, reaching 75 MTOE.

Nuclear has a very limited role in LAC, however, nuclear in primary energy is expected to grow 2.5 times by 2060 with national government support due to energy security concerns. Nuclear power will account for 1.9% of total power generation in 2060 (3.4% for Brazil, 1.0% for LAC excl. Brazil). The role of coal in LAC outside of Colombia and Chile will be limited.

Figure 34: Rock Primary Energy Demand by Fuel in LAC



* Figure 57 in Appendix provides Rock Primary Energy Demand in Brazil and LAC excl. Brazil.

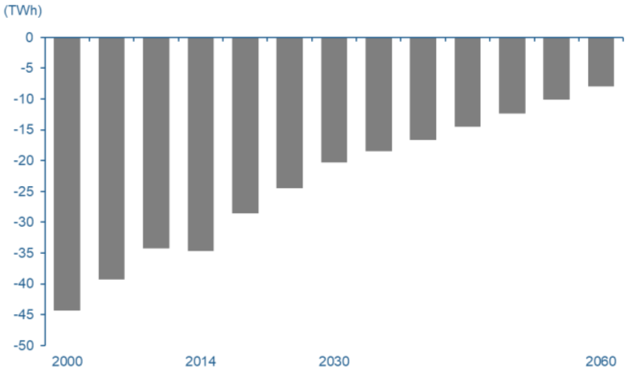
Source: World Energy Council and Paul Scherrer Institute

6) Intra-Regional Electricity Interconnection

Nationalist and protectionist policies that create a climate of low regional cooperation, as well as concerns about security, pose a challenge for regional governance systems. LAC faces challenges with continued divergence in political systems. Risk in the existing regional interconnection will increase and there will be less progress on new interconnection projects.

In Rock, steady economic growth in Brazil translates into significant slowdown of electricity demand. Hence intra-regional net import of electricity in Brazil will continue to decrease, as shown in Figure 35.

Figure 35: Rock Electricity Net Exports from Brazil to LAC excl. Brazil



Source: World Energy Council and Paul Scherrer Institute

7) Productions and Inter-Regional Net Exports

An overwhelming emphasis on security will lead to a steep decline in energy trade, resulting in a substantial fall in liquidity and transparency in global markets. As a result, energy commodity prices will become increasingly volatile and pricing at regional hubs will see widening differentials.

MENA will remain the number one producer and exporter of oil. Oil production in LAC will increase from 412 MTOE (8.3 mb/d) in 2014 to 547 MTOE (11.0 mb/d) in 2030. Inter-regional net export of oil in LAC will also increase to 178 MTOE (3.6 mb/d) in 2030. However, global oil demand is expected to reach a plateau at 5,180 MTOE (104 mb/d) between 2040 and 2050 and LAC oil demand will also reach a plateau at 396 MTOE (8.0 mb/d) after 2050.

Natural gas production growth will be seen in North America, China and MENA to 2030 and Russia will struggle to boost supplies in a low trade climate. China and MENA will lead the way from 2030 to 2060. Unconventional gas production will grow rapidly in North America, China, Australia and Argentina. Natural gas production in LAC will increase from 149 MTOE in 2014 to 174 MTOE in 2030. As LAC natural gas demand grows rapidly, the inter-regional trade of natural gas in LAC will turn from net export to net import, reaching 6 MTOE in 2030.

Air pollution and energy security concerns position biomass well in Europe, LAC, India, China and North America. National security concerns mean many nations are keen to reduce their dependency on imported oil, which will result in sustained growth in biomass consumption globally to 2060. Biomass production in LAC will increase from 129 MTOE in 2014 to 193 MTOE in 2030. Inter-regional net export of biomass in LAC will increase slightly to 4 MTOE in 2030.

Table 12: Rock Productions and Inter-Regional Net Exports in LAC

	Production (MTOE)		Net Export (MTOE)	
	2014	2030	2014	2030
Oil	412	547	88	178
Natural Gas	149	174	7	-6
Biomass	129	193	2	4

Source: World Energy Council and Paul Scherrer Institute

8) Carbon Emissions from Fuel Combustion

Carbon intensity of GDP will fall at a historical rate of 0.8% p.a. from 2014 to 2030. It is, however, not enough to counteract the upward pressure on emissions from economic growth at a rate of 1.5 p.a., so carbon emissions from fuel combustion will grow at a pace of 0.7% p.a. Between 2030 and 2060 carbon intensity will decline at a rate of 0.9% p.a., but carbon emissions from fuel combustion will continue to grow at a rate of 0.4% p.a. and reach 1.7 Gt CO_2 in 2060.

Table 13: Decomposition of CO_2 Growth Rate in Rock (CAGR)

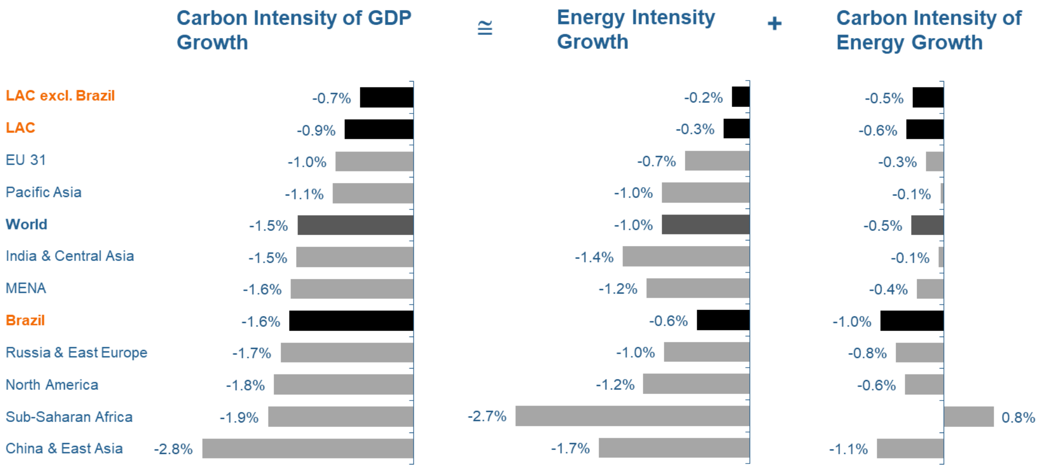
		CO_2 Emissions*	≅	GDP		Carbon Intensity of GDP**	
				Population	GDP per capita	Energy Intensity	Carbon Intensity of Energy**
LAC	2014-2030	+0.7%		+0.8%	+0.7%	-0.1%	-0.7%
	2030-2060	+0.4%		+0.3%	+1.1%	-0.4%	-0.5%
Brazil	2014-2030	-0.5%		+0.7%	+0.6%	-0.2%	-1.5%
	2030-2060	-0.5%		+0.1%	+1.0%	-0.8%	-0.8%
LAC excl. Brazil	2014-2030	+1.4%		+0.9%	+0.9%	-0.1%	-0.4%
	2030-2060	+0.7%		+0.4%	+1.2%	-0.3%	-0.6%
World	2014-2030	+0.7%		+1.0%	+0.7%	-0.7%	-0.4%
	2030-2060	-0.2%		+0.6%	+1.0%	-1.2%	-0.6%

* Kaya Identity: CO_2 Emissions = Population × (GDP / Population) × (Energy / GDP) × (CO_2 / Energy)

** Carbon Intensity of GDP = CO_2 / GDP and Carbon Intensity of Energy = CO_2 / Energy

Source: World Energy Council and Paul Scherrer Institute

Figure 36: Rock Carbon Intensity Improvement by Region (2014-2060 CAGR)



Source: World Energy Council and Paul Scherrer Institute

Chapter 4

Comparative Review of the Energy Scenarios

1. PRIMARY ENERGY DEMAND

Primary energy demand in LAC grew at a rate of 3.2% p.a. from 2000 to 2014, reaching 697 MTOE. Upward pressure on primary energy demand has been driven by the commodity price boom and fast economic growth in the region.

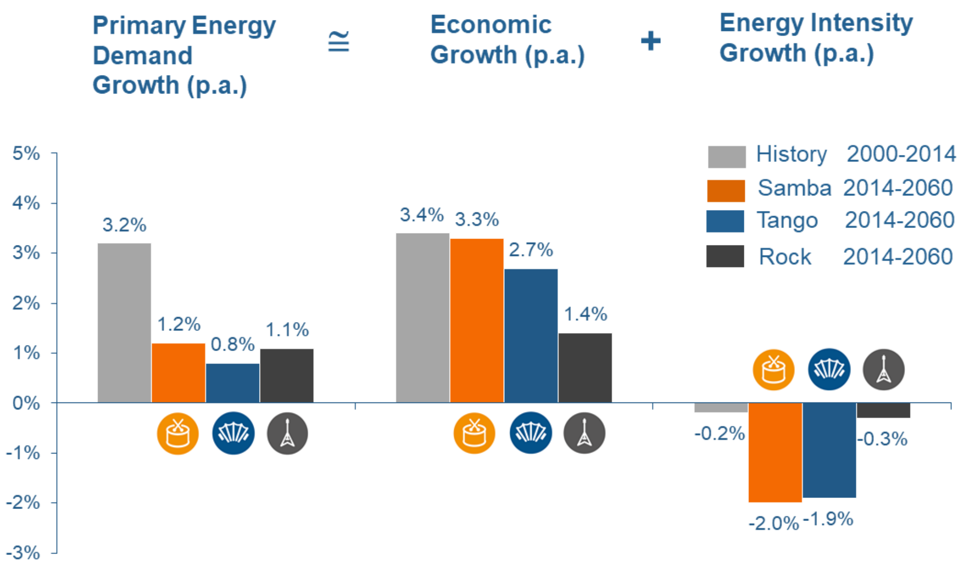
Primary energy demand is expected to grow at a slower rate of 1.4-1.7% p.a. from 2014 to 2030 and more slowly at a rate of 0.5-1.0% p.a. from 2030 to 2060. Figure 37 shows primary energy demand growth in LAC across scenarios. Although economic growth drives primary energy demand to increase, there continue to be strides in reducing primary energy intensity in Samba and Tango. In Rock, economic growth will be slower than Samba and Tango, but slow progress on energy intensity translates into primary energy demand growth.

In Samba, LAC economies will grow fast, driven by successful structural reform and high level of and innovation. Although high economic growth and abundant and cheap energy supplies drive the energy demand increase, less energy intensive economic growth and adoption of new and smart energy technologies will lead to rapid energy efficiency improvements.

In Tango, LAC economies will make the transition to sustainability-led growth. Top-down policy mandates push energy and economic systems to be smarter, resilient, and more efficient. As a result, primary energy intensity of GDP will reduce.

Despite a slowdown in economic growth in Rock, primary energy demand in LAC continues to increase at a moderate rate because of industrial activity using less-advanced technologies, dominant ICE vehicles and ineffective top-down mandates for energy conservation. With consumption patterns remaining status quo and industries following the same historical energy intensive trajectories, the reduction of energy intensity will stagnate.

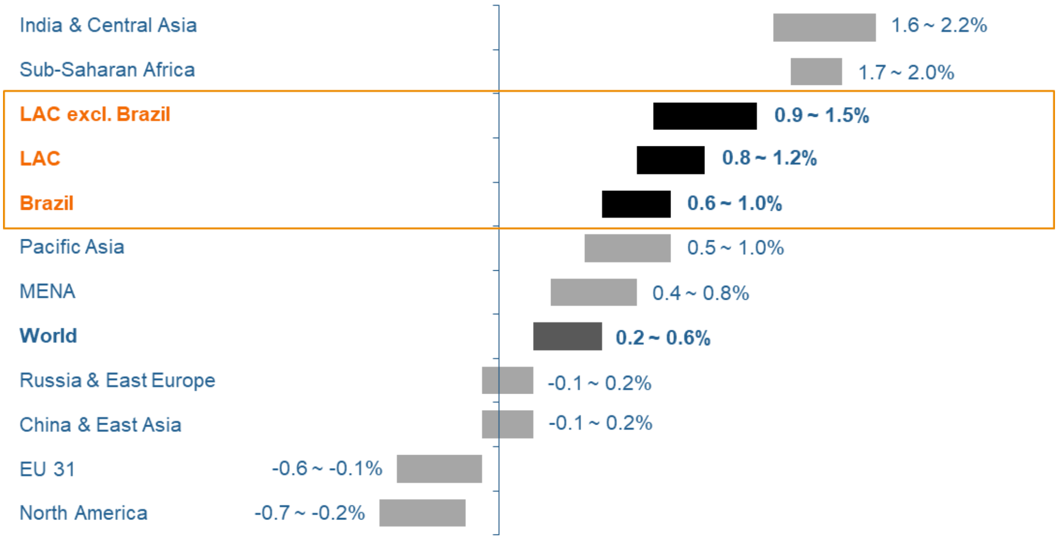
Figure 37: LAC Primary Energy Demand Growth across Scenarios



Source: World Energy Council and Paul Scherrer Institute

As shown in Figures 38, the LAC primary energy demand growth rate will stand at a relatively high level compared to most other regions. LAC economic growth is expected to be relatively slow, but the energy intensity improvement will also be limited.

Figure 38: Primary Energy Demand Growth by Region (2014-2060 CAGR)



Source: World Energy Council and Paul Scherrer Institute

2. ELECTRICITY GENERATION

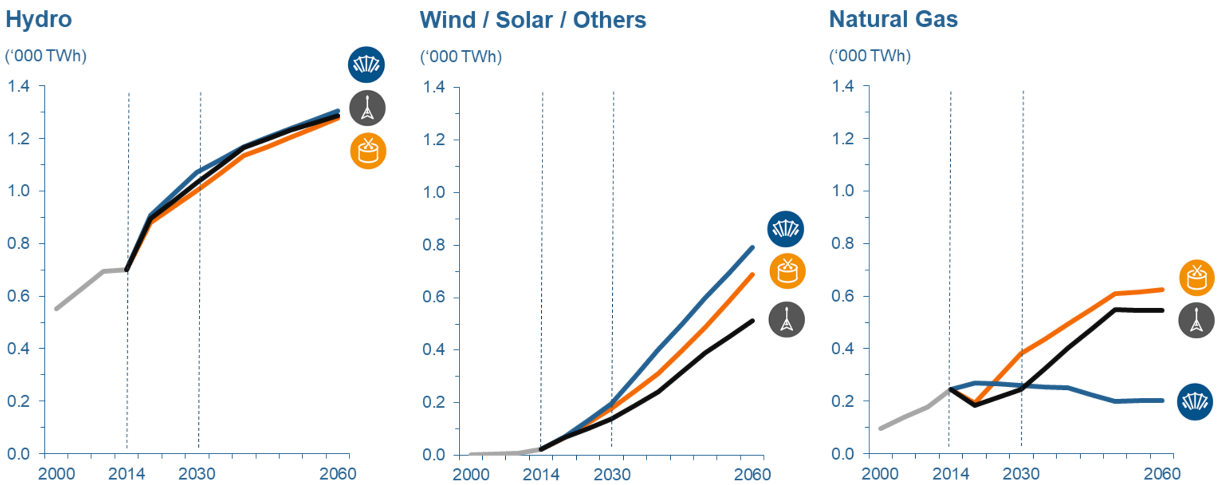
Demand for electricity in LAC grew at a rate of 3.5% p.a. from 2000 to 2014, reaching 1,291 TWh. With rapid economic growth and improvements in quality of life, lifestyles demand more electricity. By 2030, growth in demand for electricity will average 1.5-1.8% p.a. and beyond 2030, demand for electricity will continue to climb at a rate of 1.4-1.6% p.a. to 2060. Demand for electricity in LAC will rise more than double by 2060. Electricity generation investment from 2010 to 2060 is estimated to be US$ 2.0-2.5 trillion based on 2010 market exchange rate.

By 2030, hydro power will dominate new power generation growth in LAC and so hydro power share of electricity generation will increase from 54% in 2014 to 54-60% in 2030. Beyond 2030, however, hydro power contribution to new electricity generation will slow down due to environmental and social concerns and so its share of electricity generation will decline to 43-48% in 2060.

Beyond 2030, new power generation growth in LAC will be dominated by wind/solar/others and so the share of electricity generation will increase dramatically from 2% in 2014 to 19-29% in 2060. In Samba, continued technology advances will lead cost declines and innovation in battery based storage solutions and distributed systems that enable balancing intermittent renewables in energy systems. In Tango, strong policy mandates, subsidy schemes and growing demand for clean energy will drive the deployment of wind/solar/others. In Rock, security concerns will persuade national governments to look to modern renewables as a domestic source of electricity generation.

The role of natural gas in power sector will vary across the scenarios. In Samba and Rock, natural gas share of electricity generation in 2060 will increase slightly from 19% in 2014 to 20-21% in 2060. In Tango, because of tightening emissions standards, natural gas share of power generation will decrease significantly to 7% in 2060.

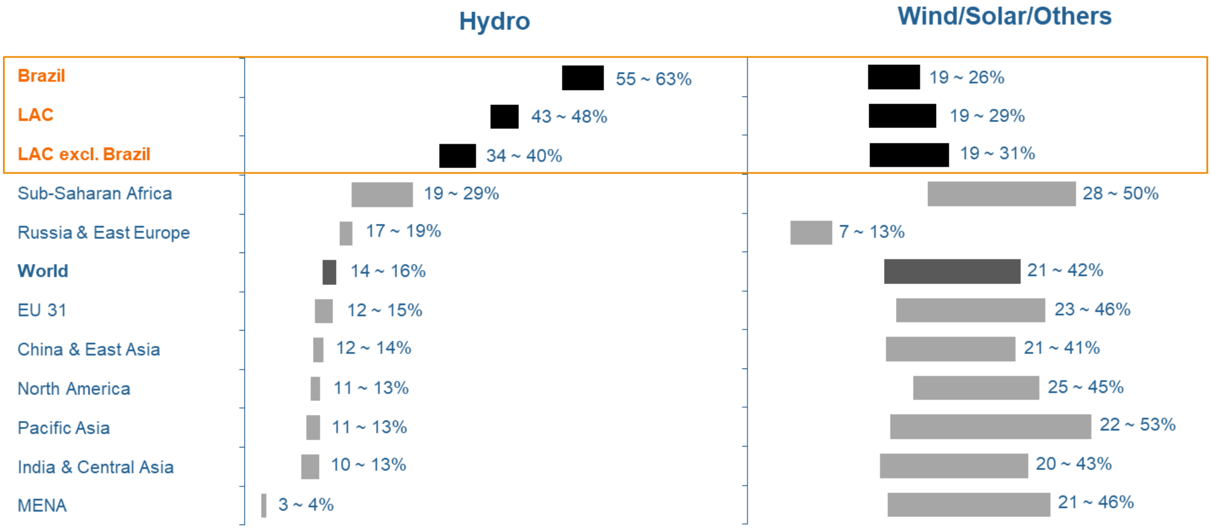
Figure 39: Electricity Generation by Fuel in LAC across Scenarios



Source: World Energy Council and Paul Scherrer Institute

Although wind/solar/others increase dramatically, their share of electricity generation will be below the world average as the hydro power share is three times that of the world, as shown in Figure 40.

Figure 40: Electricity Generation Shares by Region across Scenarios



Source: World Energy Council and Paul Scherrer Institute

3. TRANSPORT ENERGY

Demand for transport energy in LAC grew at a fast rate of 3.5% p.a. from 2000 to 2014, reaching 195 MTOE. Transport energy demand growth is expected to slow down to 2020 because of difficult times following a period of prosperity driven by a decade-long commodity price boom. However, energy in transport will be reversed back to grow at a rate of 1.2-1.7% p.a. from 2020 to 2030.

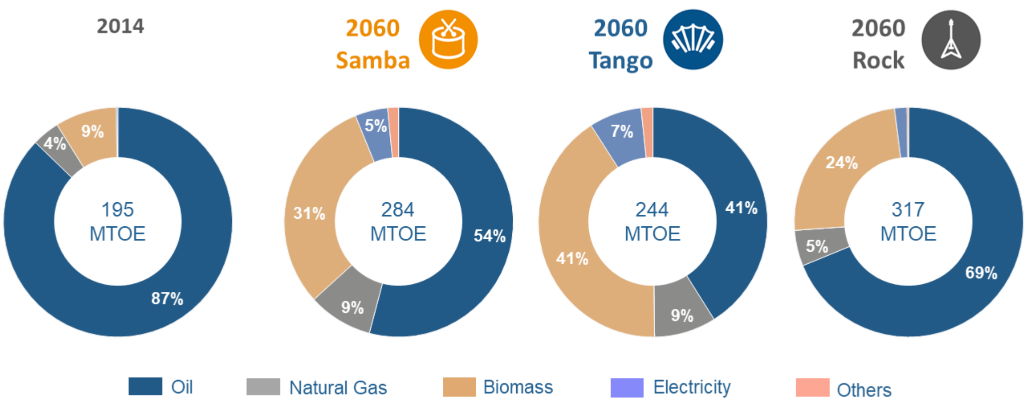
Beyond 2030, transport energy demand growth in LAC will slow down significantly at a pace of 0.2-0.9% p.a. In Samba, adaptation of new technologies lead to rapid efficiency improvements and transport energy in LAC is expected to reach a plateau after 2050. In Tango, driven by policy mandates, significant breakthroughs in battery technologies open the door to a revolution in transit and transport energy in LAC is expected to peak after 2050. In Rock, with reduced capacity for transport infrastructure build-out, demand for personal transport remains high. As a result, transport energy in LAC continues to grow.

Biofuels use in transport will grow 5-6 times from 2014 to 2060, leading to a substantial diversification of the transport fuel mix. Biofuels share of transport energy will increase from 9% in 2014 to 17-18% in 2030 and 24-41% in 2060. In Samba, biofuels growth is accelerated due to plentiful feedstocks and advances in next generation biomass technologies. In Tango, growth is accelerated due to policy mandates, advances in technologies and plentiful feedstocks. In Rock, the security concerns and economics of transport fuels favour the penetration of biofuels over natural gas and electricity.

Beyond 2030, diversification will also be driven by EVs, supported by technology breakthroughs and fuel efficiency standards. As a result, the electricity share of transport energy will grow from 0.2% in 2014 to 2-7% in 2060. In Samba, through technology breakthroughs in battery and growing availability of charging, EVs underpin the growth of electricity in transport. In Tango, due to fuel efficiency and emissions standards and the build-out of smart infrastructure, the electrification of transport energy continues to build momentum. In Rock, transport fuels are slow to diversify.

In Figure 41, oil share of transport energy will fall from 87% in 2014 to 76-77% in 2030 and 41-68% in 2060. As transport fuels diversification accelerates, transport demand for oil will peak around 2040 at 183 MTOE (3.7 mb/d) in Samba and 179 MTOE (3.6 mb/d) in Tango. In Rock, transport demand for oil will continue to grow to 218 MTOE (4.4 mb/d) in 2060.

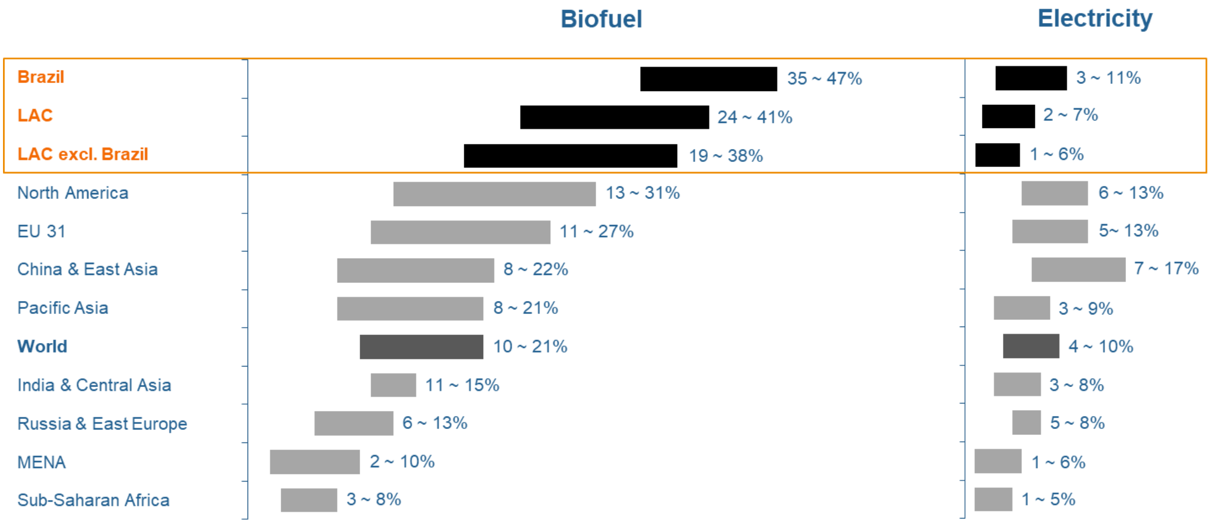
Figure 41: LAC Transport Energy Mix across Scenarios



Source: World Energy Council and Paul Scherrer Institute

Although electricity in transport energy increase dramatically, the electricity share of transport energy will be below the world average as the biofuels share is far ahead of the world average, as shown in Figure 42.

Figure 42: Transport Energy Shares by Region across Scenarios



Source: World Energy Council and Paul Scherrer Institute

4. FOSSIL FUELS

Although natural gas plays a role in Samba and Rock, the growing use of hydro and wind/solar/others in the power sector and biofuels in transport sector will drive down the share of fossil fuels in LAC from 72% in 2014 to 62-66% in 2030 and 39-58% in 2060. In LAC, the share of hydro in primary energy in 2060 will be about triple the world average and the share of biomass will be about twice the world average.

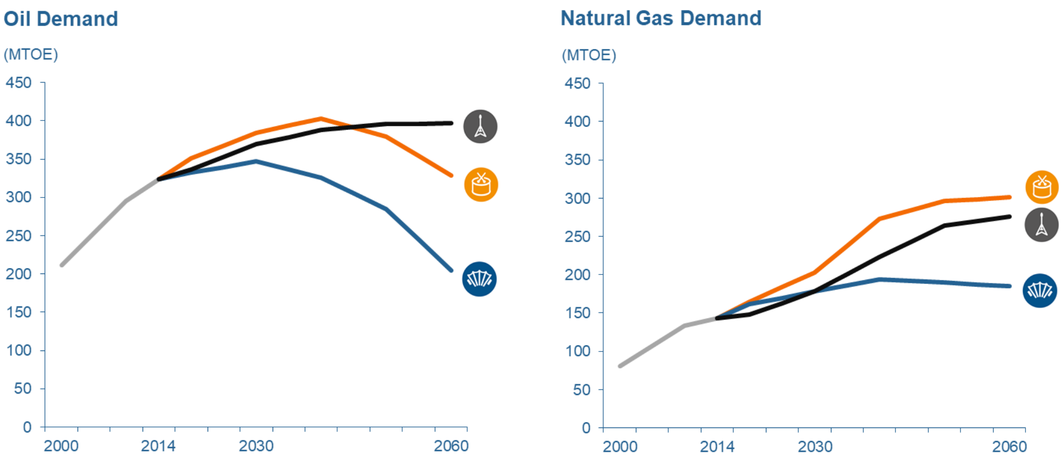
Demand for oil in primary energy in LAC grew at a rate of 3.0% p.a. from 2000 to 2014, reaching 324 MTOE (6.5 mb/d). Oil demand is, however, expected to grow more slowly at a rate of 0.4-1.1% p.a. from 2014 to 2030 and it will peak or reach a plateau after 2040.

In Tango, through the unified action on climate change, oil demand growth in LAC will be significantly tempered by competition from biofuels and EVs. This trend will lead to a peak in oil demand in LAC between 2030 and 2040 at 347 MTOE (7.0 mb/d). In Samba, despite high economic growth, oil demand growth in LAC is tempered by increased competition from alternative transport fuels. This will lead to a peak in demand for oil in LAC in 2040 at 403 MTOE (8.1 mb/d). In Rock, transport energy will remain heavily dependent on oil as weak economic growth and reduced financing capacity limit infrastructure investments. However, oil demand growth is tempered by increased penetration from biofuels due to energy security concerns. This will lead to a plateau in oil demand in LAC after 2050, reaching 396 MTOE (8.0 mb/d).

Natural gas demand grew at a rate of 4.0% p.a. from 2000 to 2014, reaching 142 MTOE. The rate of natural gas growth is expected to vary broadly across the three scenarios: 1.4-2.3% p.a. from 2014 to 2030 and 0.1-1.5% p.a. from 2030-2060.

In Samba, consumers increasingly see natural gas as a cleaner and lower cost source and natural gas takes share from coal and oil in power generation. Favourable conditions will lead natural gas demand to double up by 2060, settling at 301 MTOE. In Rock, an energy security concerns and decline in global trade will drive natural gas demand to double up by 2060, settling at 276 MTOE. In Tango, however, moderate economic growth and increasingly stringent emissions standards will dampen growth for natural gas. This trend will lead natural gas demand to stagnate after 2040 and settle at 185 MTOE in 2060. It is just 30% higher than 2014 consumption value.

Figure 43: LAC Demands for Oil and Natural Gas across Scenarios



Source: World Energy Council and Paul Scherrer Institute

5. CO_2 EMISSIONS

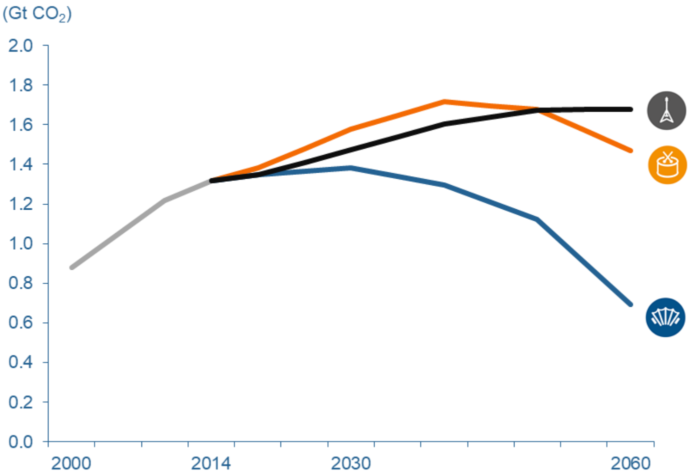
CO_2 emissions from fuel combustion in LAC grew at a rate of 2.9% p.a. from 2000 to 2014, reaching 1.3 Gt CO_2. Although carbon intensity of GDP declined in the period, the commodity price boom provided high economic growth in the LAC region.

Carbon intensity of GDP is expected to fall at an unprecedented rate in Samba and Tango, but at a historical rate in Rock from 2014 to 2030. It is, however, not enough to counteract the upward pressure on emissions from economic growth, so carbon emissions from fuel combustion will grow at a pace of 0.3-1.1% p.a. in the period.

Beyond 2030, accelerated carbon intensity reductions will drive carbon emissions from fuel combustion to peak around 2030 at 1.4 Gt CO_2 in Tango and between 2040 and 2050 at 1.7 Gt CO_2 in Samba. In Rock, carbon emissions from fuel combustion will continue to grow and reach 1.7 Gt CO_2 in 2060. Cumulative carbon emissions from fuel combustion in LAC from 2015 to 2060 will account for 4.3-4.9% of the world cumulative emissions.

In Tango, strong government mandates and rising carbon prices force a rapid transition in energy technologies to improve energy and carbon intensities. Top-down mandates and technology support for intelligent infrastructure and smarter buildings, homes and offices enable the deployment of a low-carbon energy system. In Samba, less energy intensive economic growth and smarter use of energy will boost energy efficiency. Rapid penetration of biofuels in transport, growing investments in natural gas, hydro, wind and solar power generation will lead to substantial decarbonisation of energy systems. Light-touch policy support is the underlying driver for the shifts in technology adoption. In Rock, as a result of an emphasis on resolving national economic and security concerns first, the climate mitigation target slides down the list of priorities.

Figure 44: CO_2 Emissions across Scenarios



Source: World Energy Council and Paul Scherrer Institute

6. ENERGY TRILEMMA AND RESILIENCE

Many LAC countries with higher performance on the Trilemma Index owe their success to leveraging strong hydro power. In Brazil and Colombia, in particular, the extensive use of hydro power has led to low-carbon emissions and higher electrification rates. However, the region's strong reliance on hydro power is also a risk for energy security as it is highly susceptible to extreme weather events. For example, in 2015 and early 2016, the region's hydro power generation was significantly affected by El Niño related droughts. The resulting power shortages led to spikes in energy prices and the use of less efficient and more polluting short-term back-up energy sources to manage the power shortages.

LAC's success in adapting to changing weather patterns and the energy-water nexus will impact its path to greater energy sustainability. LAC countries must develop and implement substantial soft and hard resilience measures. Diversifying the energy supply with low-carbon sources such as wind and solar will be important and regional interconnection is expected to play an increasingly important role in the region's ability to increase resilience.

As most of these LAC countries' economies are still developing, the challenge they shift away from hydro power will be to meet a growing demand for electricity while maintaining a low environmental footprint. While urbanisation continues throughout the region, mitigating and adapting to the exacerbated impacts of extreme weather events in mega-cities, which are largely based around ports and require substantial energy infrastructure, will be a great challenge.

The main highlights of the Energy Trilemma for the region, across the three scenarios, are shown below.

Table 14: LAC Energy Trilemma across Scenarios

	Samba	Tango	Rock
Energy Security	▪ Higher energy production and greater trading	▪ Wider diversity of energy resources ▪ Government-led infrastructure investment	▪ More domestic production and lower trade ▪ Increasing vulnerability to extreme weather events
Energy Equity	▪ Energy access for all	▪ Significant progress	▪ Limited progress
Environmental Sustainability	▪ Progress on adaptation	▪ Progress on adaptation and mitigation	▪ Limited progress

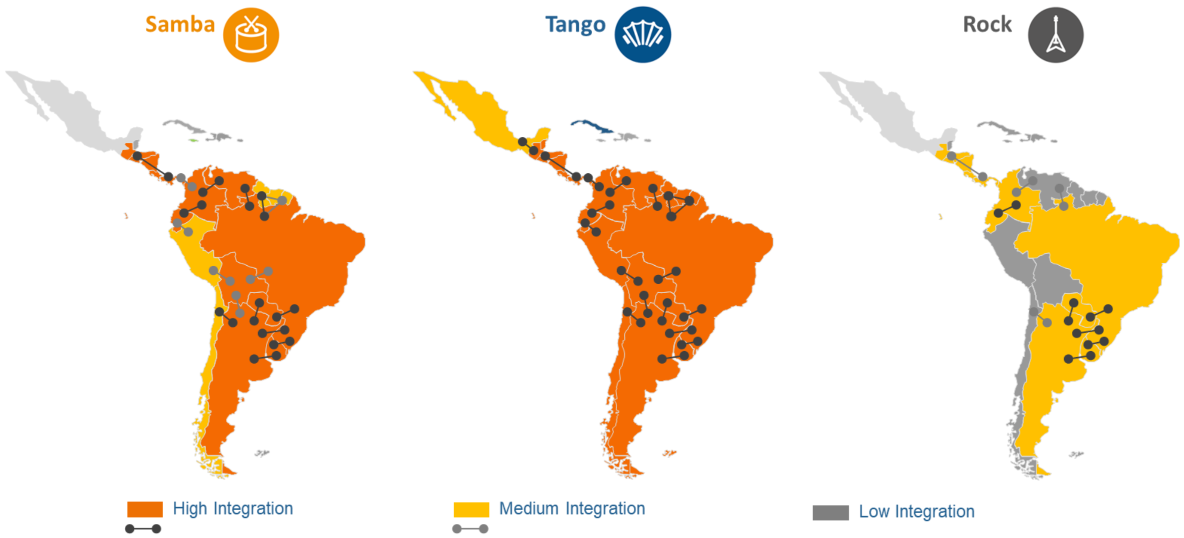
Source: World Energy Council

7. REGIONAL INTEGRATION

The LAC region has enormous potential to benefit economically from regional integration and cooperation, but is slow to reap the long-term benefits in the face of short-term political and economic concerns. Especially Brazil is well positioned to benefit from increased regional integration of power systems.

Regional integration is already a focus of attention in the energy sector, as evidenced through projects like Arco Norte, SINEA, SIEPAC[20], and other projects which have been studied in LAC countries. An increasing regional cooperation in the LAC region can be shaped by the presence of strong regional governance structures, covering energy security, decarbonisation and resilience. This would be strongest in Tango and weakest in Rock.

Figure 45: LAC Regional Integration Development across Scenarios



- Progress on Arco Norte and SIEPAC II interconnection projects
- More progress on gas integration projects
- Mexico develops its relationship with the US

- All countries of LAC are integrated as a result of full progress on projects like Arco Norte, SINEA and SIEPAC II
- Mexico wants electricity interconnection to the Caribbean

- Risk increases in the existing regional integration
- Less progress on new regional integration projects
- Mexico explores new export / collaboration opportunities with LAC

Source: World Energy Council

[20] See Boxes 1, 2 and 3 for more details on the Arco Norte, SINEA and SIEPAC projects.

Appendices

TANGO CASE STUDIES

Bolivia: Energy Heart of South America

The goal of the Bolivian government is turning the country into "Energy Heart of South America" − a regional hub for electricity and commodity. In that sense the ministry in charge works, alongside its operational arms ENDE and YPFB, in several energy agreements with the countries of the region towards that goal.

With the goal of making Bolivia the powerhouse of the region, ENDE has planned an investment of US$ 30 billion in various projects of power generation that will be used not only for domestic consumption but also for export of surplus. With the budgeted investment plans until 2025 generating a surplus of between 8,000 and 9,000 MW which would be exported to the markets of Argentina, Brazil, Paraguay, and the Andean Community of Nations through Peru. Aiming to increase oil production to ensure supply to the domestic market and maintain the export of natural gas to Brazil and Argentina, in addition to selling fuel to Paraguay and Peru, among others, YPFB plans to invest more than US$ 7 billion by 2020.

Source: Bolivia National Member Committee, World Energy Council

Brazil's Wind Power

The Brazilian wind industry has developed over the last two decades. To promote alternative sources in the energy mix, an incentives programme was introduced in 1994. The program focused on communities which were not supplied by conventional electricity. In 2001, the first Atlas of Brazilian Wind Potential was published, which forecasted a potential of 143 GW of wind power capacity for Brazil. It brought the Program to Incentive Alternative Electric Power Sources in 2003, which aimed the implementation of 1,100 MW of wind power capacity via the new incentive scheme. The federal government zeroed import taxes for most of the required equipment.

Since 2012 local content policies have evolved and the Brazilian Development Bank (BNDES) supported projects with locally produced goods, which allowed a number of large aero-generators suppliers in Brazil to be established. By the end of 2014, there were two local factories (Impsa and WEG) and other five foreign companies with factories, which were fully accredited by BNDES. Furthermore, the local content policies helped to create a full range value chain, from all steps of the production process of wind energy plants, to applications of distribution network and technical research. A range of auction schemes introduced from 2007 helped wind energy to become cost competitive and supported the growing share of renewables, particularly wind power.

According to the Global Wind Energy Council, Brazil is the country with 10th largest installed capacity of wind power in the world in 2014. Brazil's wind power capacity reached 8.7 GW (6.2% of the energy matrix) in 2015 and possibly 11 GW in 2016.

The outlook for the wind power industry still has room for improvement and good development prospects. As the challenges are remaining, it´s known that the competition needs to be strengthened, and the production, service capacity and experience of the local assemblers have to be improved continuously.

Source: Eletrobras

Colombia's Proure and TransMilenio CDM

Proure (Program for the Rational and Efficient use of Energy) was created in order to: improve energy efficiency through identifying and defining potential targets for energy saving; improve participation of efficient technologies and unconventional sources in the energy mix of the country. Proure has helped to change the vision of energy as an important key to a sustainable world, helping to lower both CO_2 emissions and production costs. It has also allocated funding for energy efficiency projects including brickworks, cement industries, etc. Through this programme started in 2013, more than 400,000 tCO_2 per year has been lowered.

TransMilenio CDM (Clean Development Mechanism) project is the first mass transit project in the world with methodology approved and registered since 2006 by the UN under the Kyoto Protocol. The estimations of GHG reduction of the project was 4 million tCO_2e in 7 years (46.8% less than baseline). TransMilenio´s CDM project has been replicated in several major Colombian cities.

Source: UPME

Ecuador's Energy Transition

Ecuador is transforming its energy sector fundamentally by the end of 2017. 93% of its electricity generation will be derived from hydro power and this radical shift is accompanied by far-reaching energy efficiency programmes, radical changes in the oil, gas and transport sectors and the integration of energy systems with its neighbouring countries.

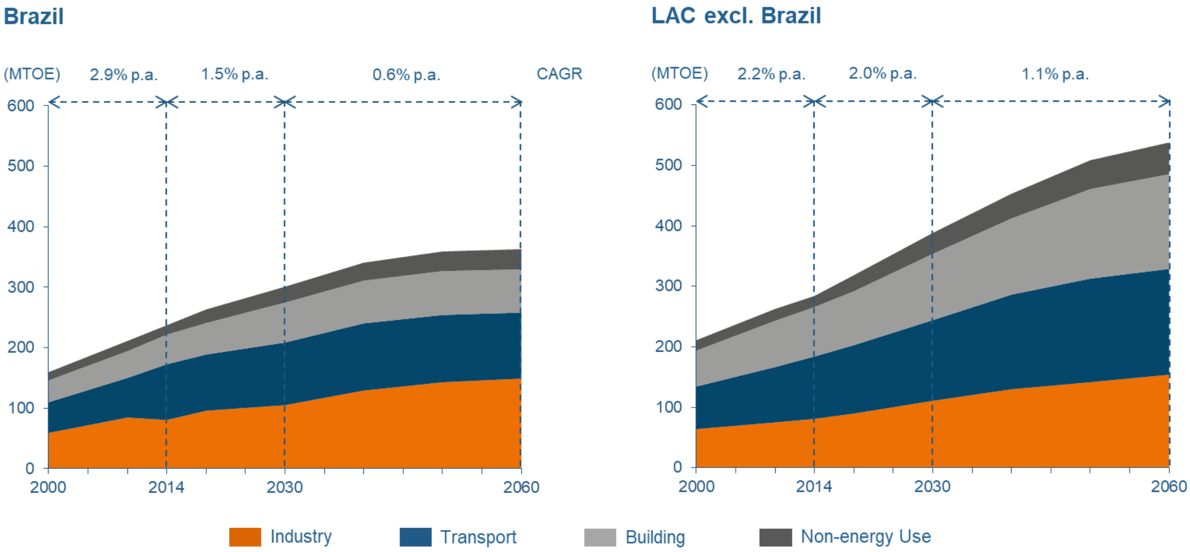
Currently eight new hydro power projects are being built in Ecuador under direct management of the State. When they are ready, 93% of electricity consumed in Ecuador will come from hydro power. Thermal generation will have been reduced from 44% in 2007 to only 8% in 2017. Furthermore, Ecuador's energy transition includes promotion of electric cars, reduction of losses in the power generation and distribution, and more efficient use of energy in industry and households including a large-scale changeover from gas-based cooking to induction based cooking appliances – so they replace 5,800 gas-based cooking stoves every week – as well as a complete replacement of incandescent lamps with compact fluorescent lamps.

The country is also investing in other forms of renewable energy, including wind power – the 16.5 MW wind farm in Villonaco in the south is one of the few in high hills in the world – and in solar, e.g. in the Galapagos Islands. And Ecuador is making some radical changes to its fossil fuel sector: it is constructing new efficient combined-cycle gas plants and a big oil refinery that will allow the country to export higher value oil products. Ecuador also participates in the great interconnection project SINEA.

Source: Ecuador National Member Committee, World Energy Council

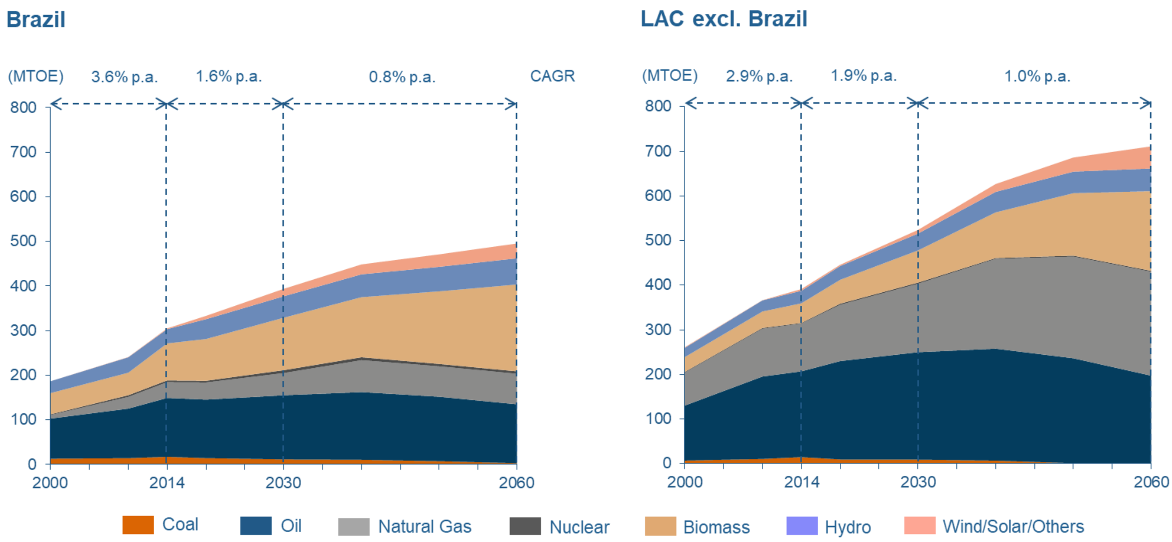
SUPPLEMENTARY FIGURES

Figure 46: Samba Final Energy Consumption by Sector in Brazil and LAC excl. Brazil



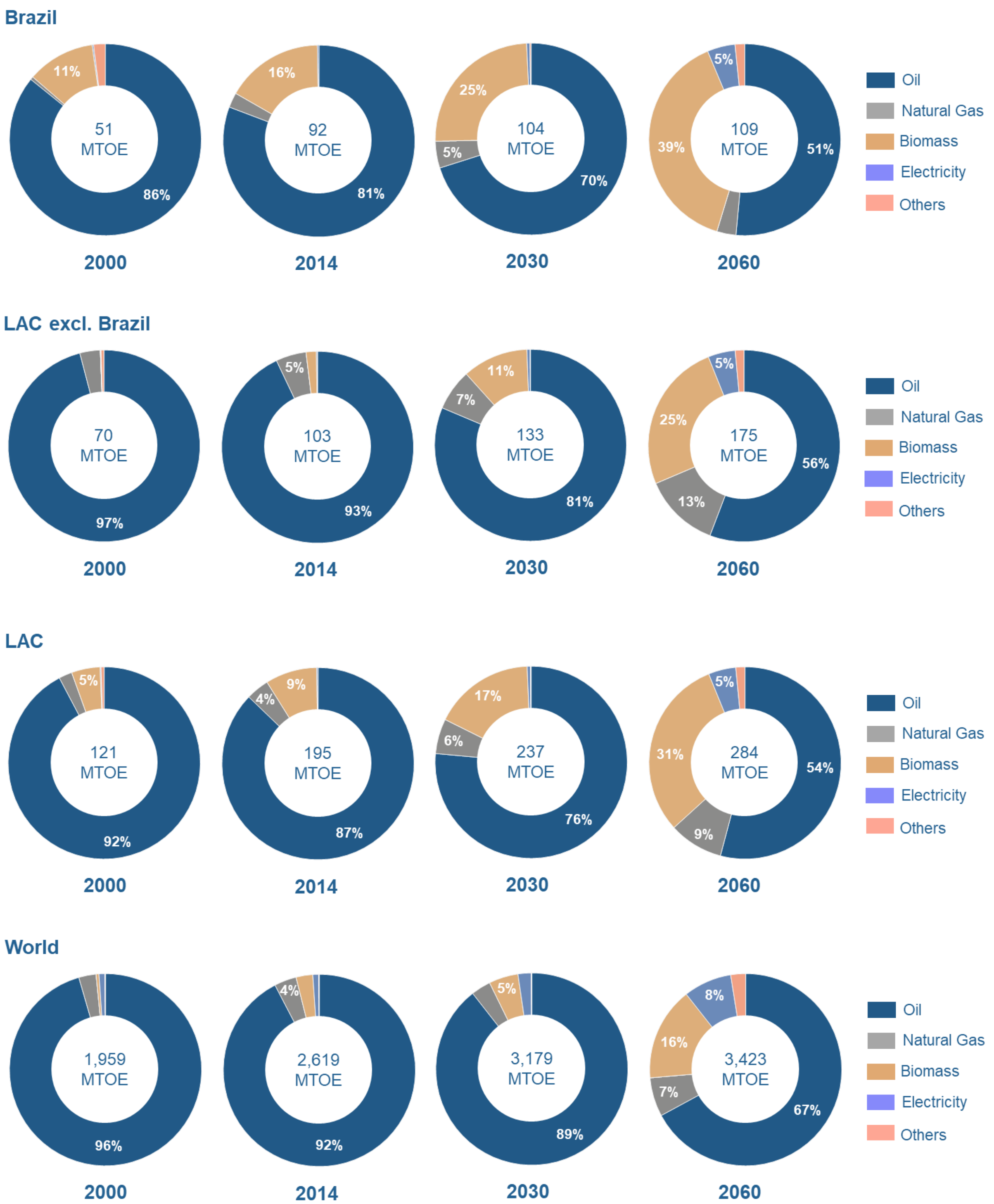
Source: World Energy Council and Paul Scherrer Institute

Figure 47: Samba Primary Energy Demand by Fuel in Brazil and LAC excl. Brazil



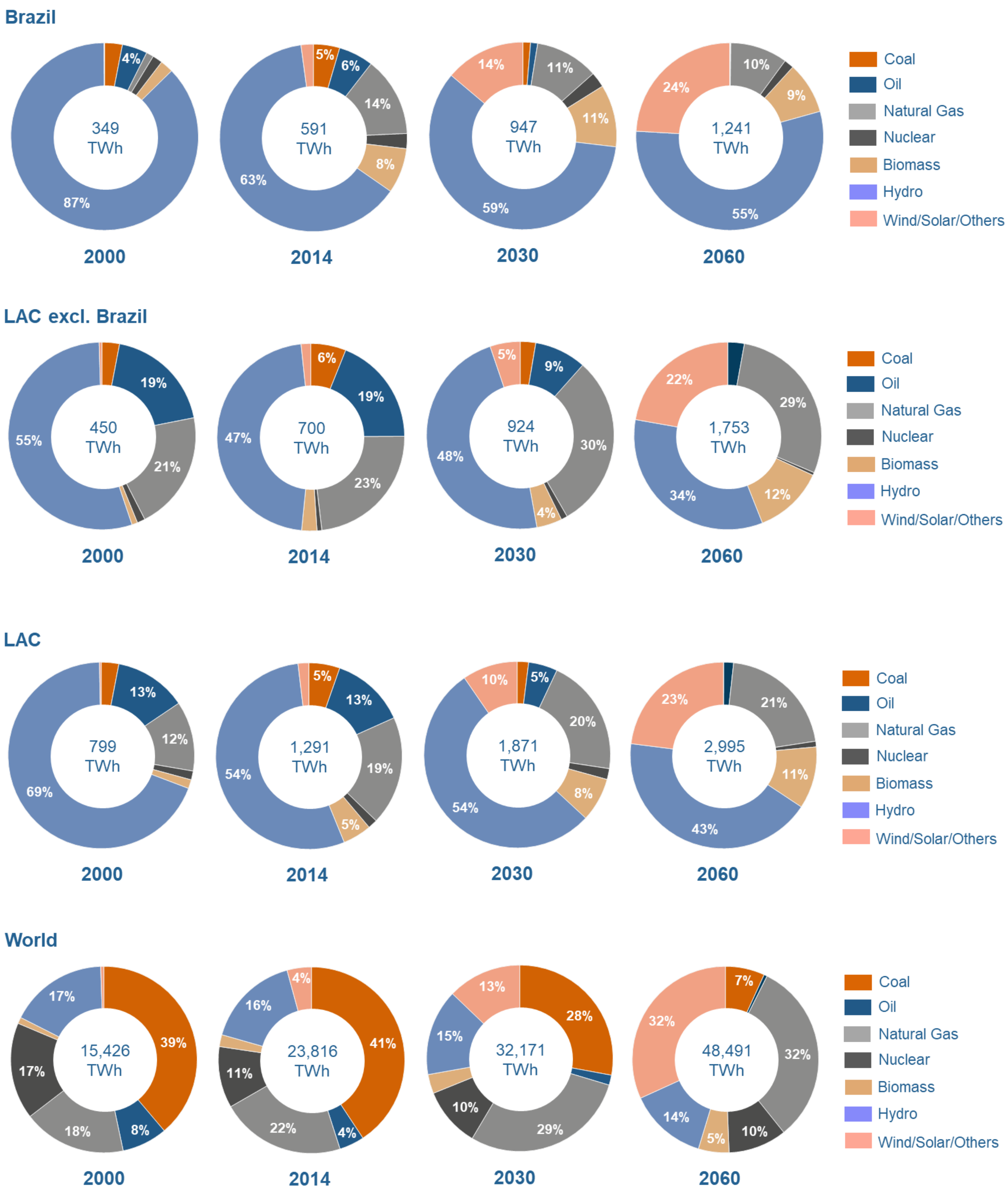
Source: World Energy Council and Paul Scherrer Institute

Figure 48: Samba Transport Energy Mix by Fuel



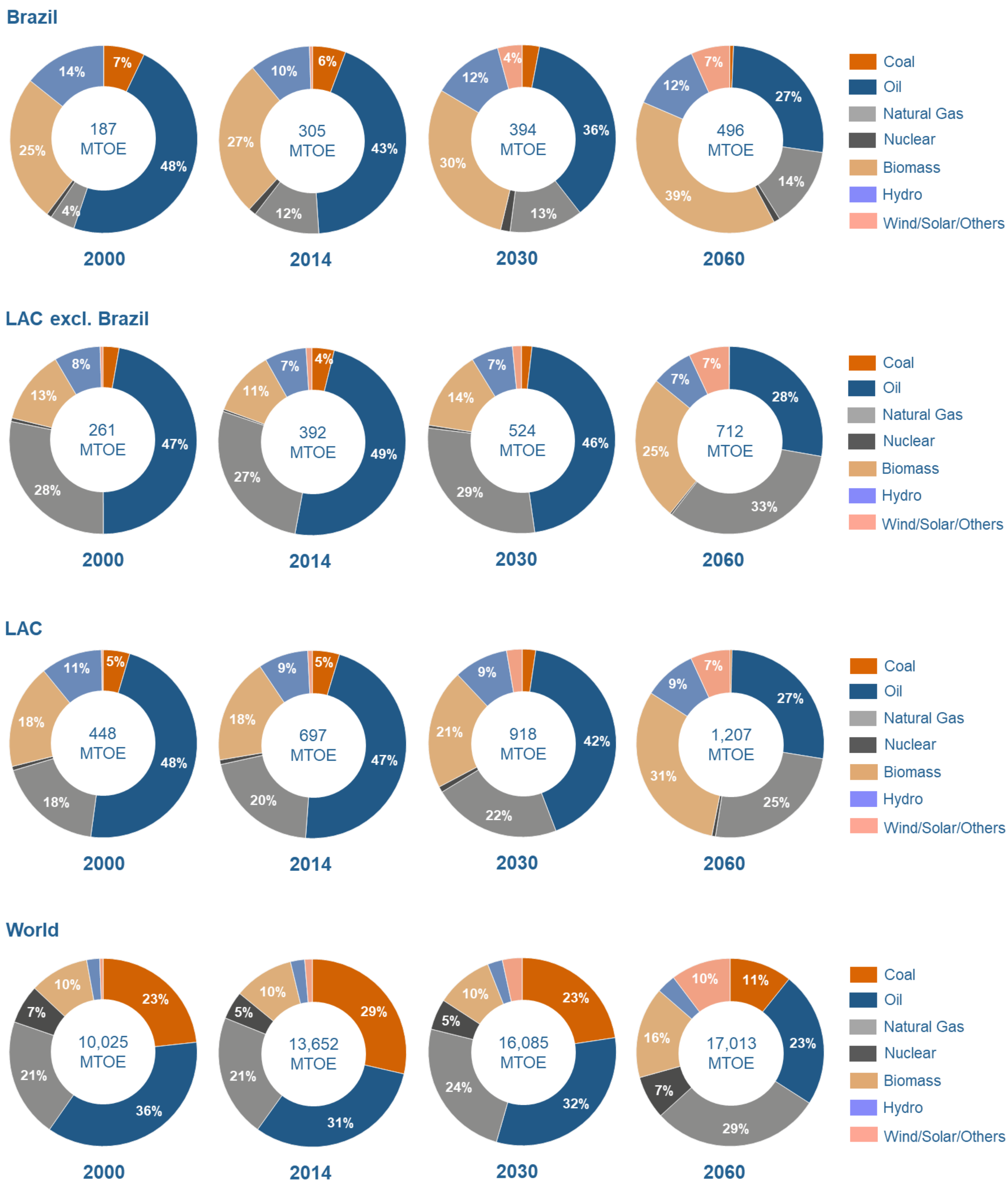
Source: World Energy Council and Paul Scherrer Institute

Figure 49: Samba Electricity Generation Mix by Fuel



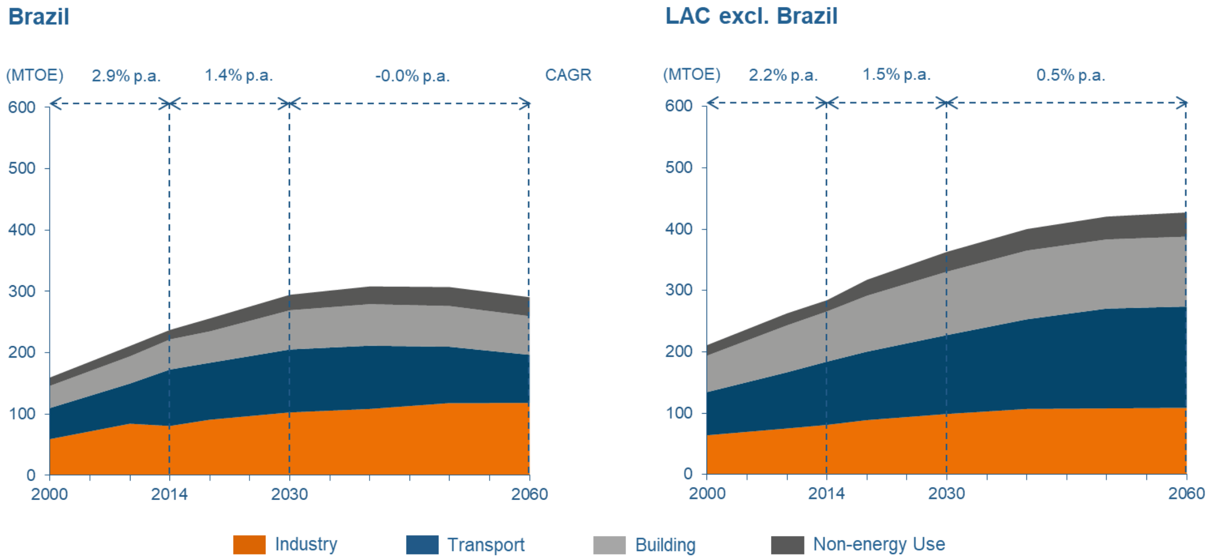
Source: World Energy Council and Paul Scherrer Institute

Figure 50: Samba Primary Energy Demand Mix by Fuel



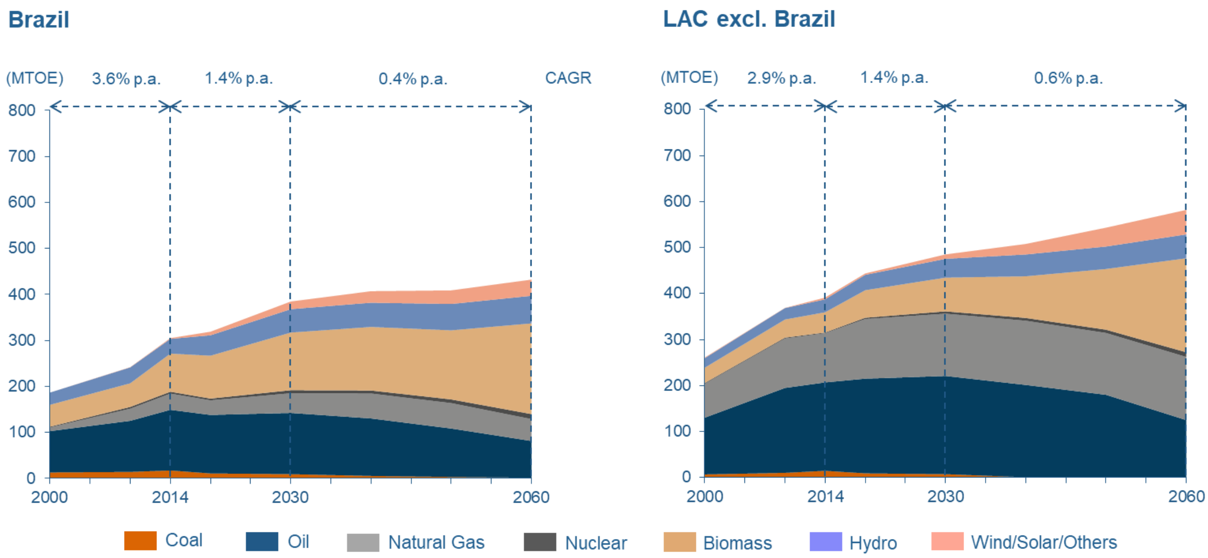
Source: World Energy Council and Paul Scherrer Institute

Figure 51: Tango Final Energy Consumption by Sector in Brazil and LAC excl. Brazil



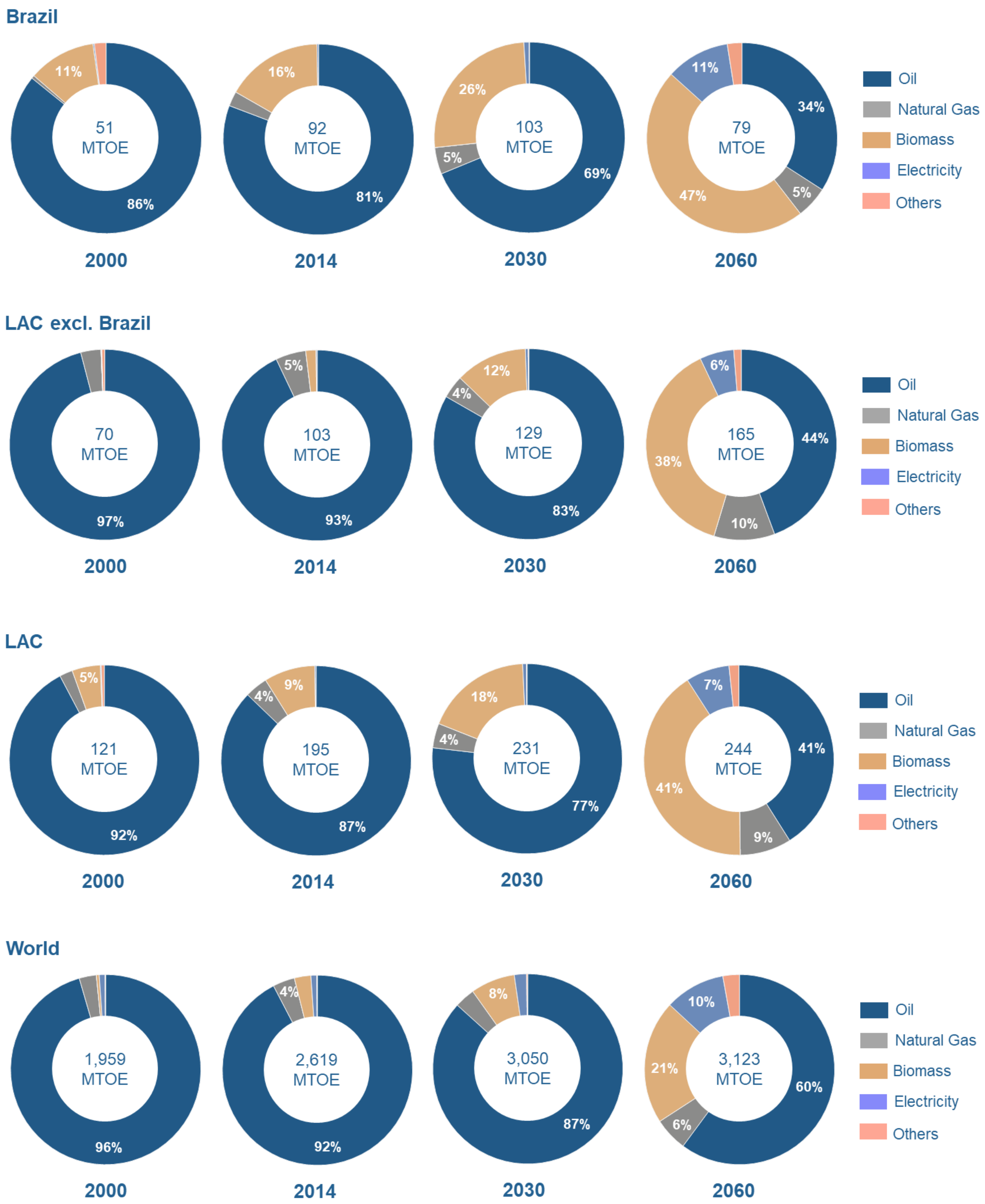
Source: World Energy Council and Paul Scherrer Institute

Figure 52: Tango Primary Energy Demand by Fuel in Brazil and LAC excl. Brazil



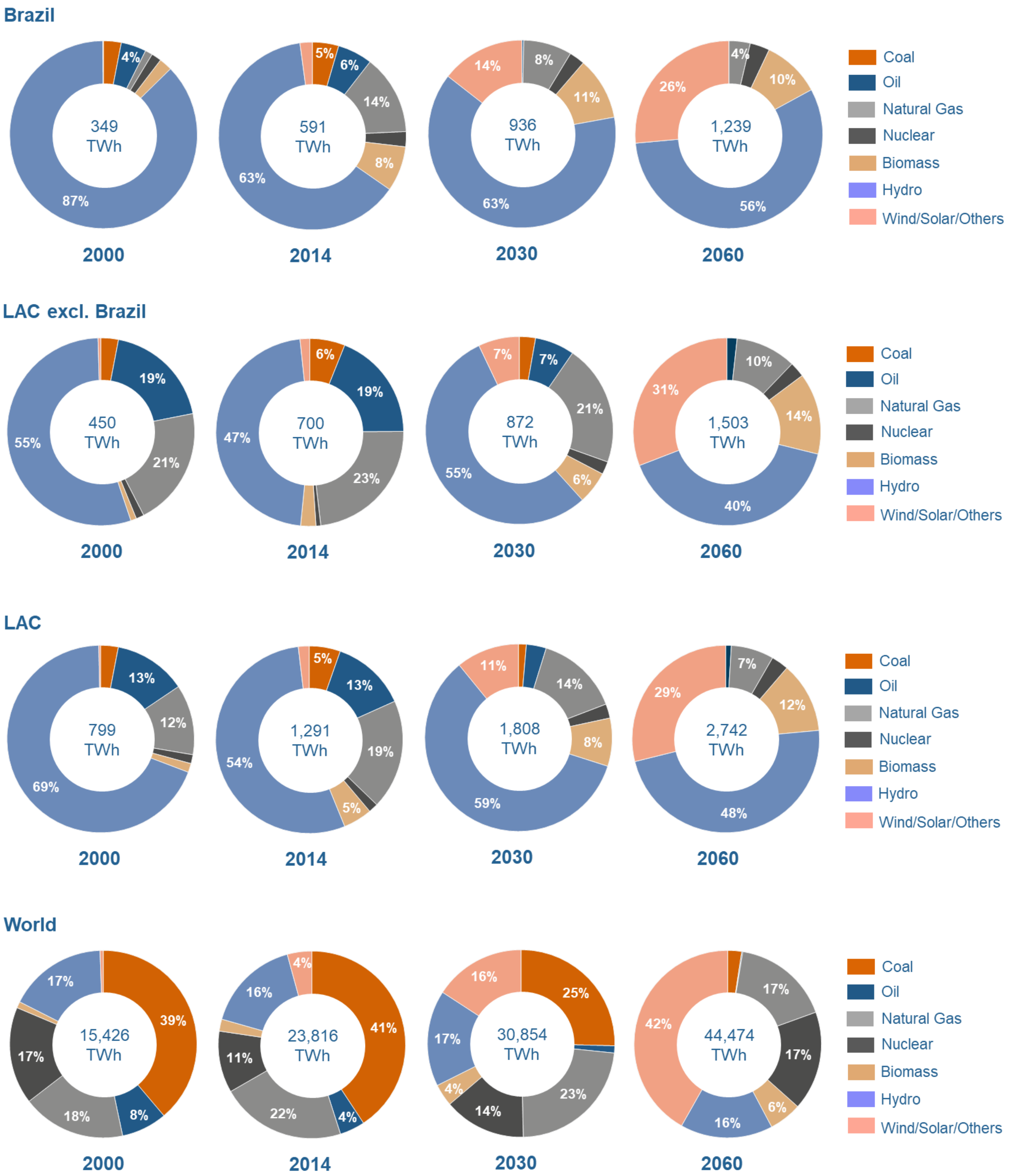
Source: World Energy Council and Paul Scherrer Institute

Figure 53: Tango Transport Energy Mix by Fuel



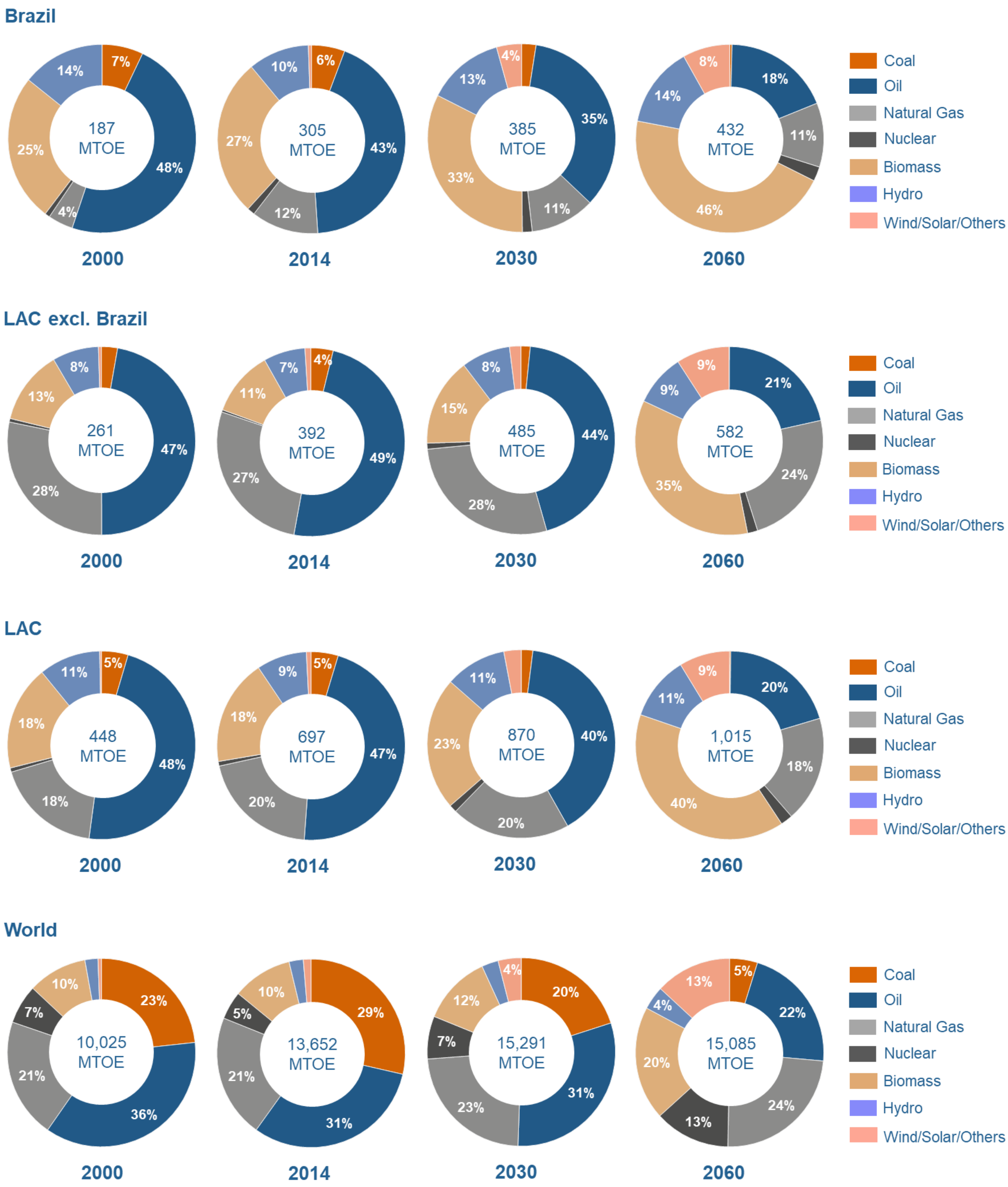
Source: World Energy Council and Paul Scherrer Institute

Figure 54: Tango Electricity Generation Mix by Fuel



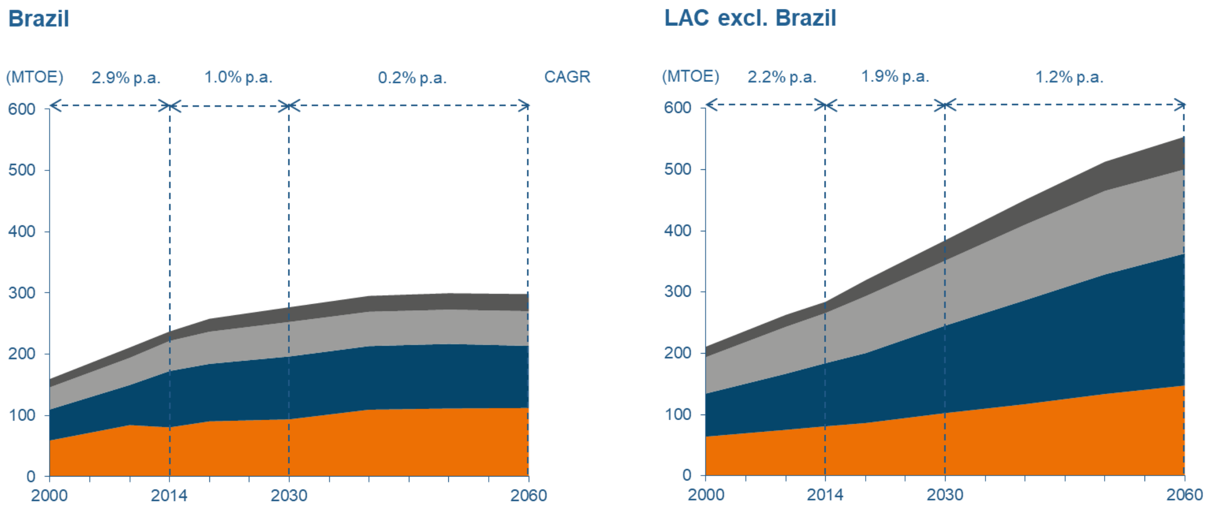
Source: World Energy Council and Paul Scherrer Institute

Figure 55: Tango Primary Energy Demand Mix by Fuel



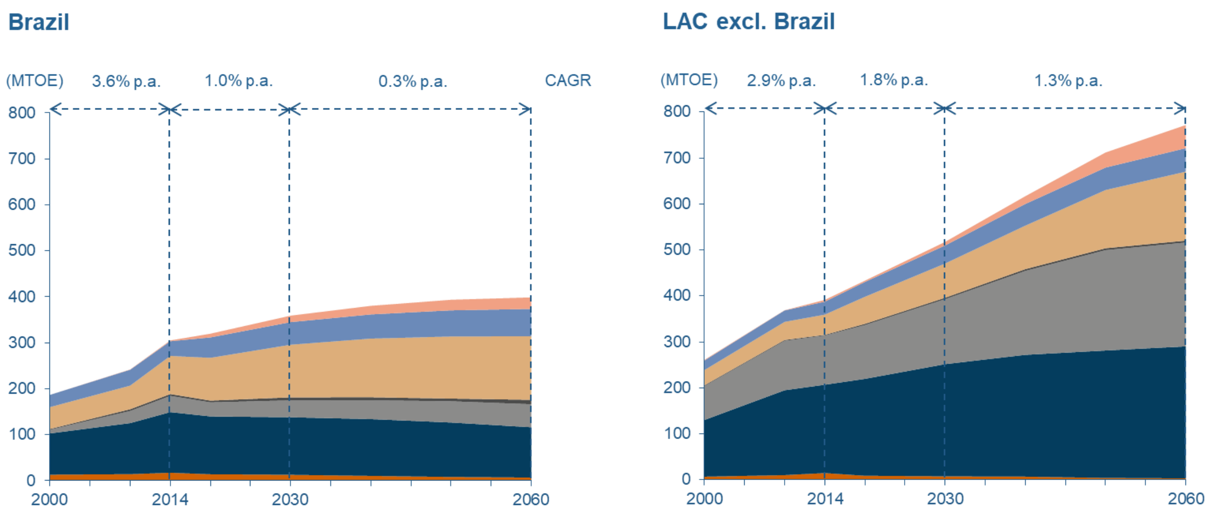
Source: World Energy Council and Paul Scherrer Institute

Figure 56: Rock Final Energy Consumption by Sector in Brazil and LAC excl. Brazil



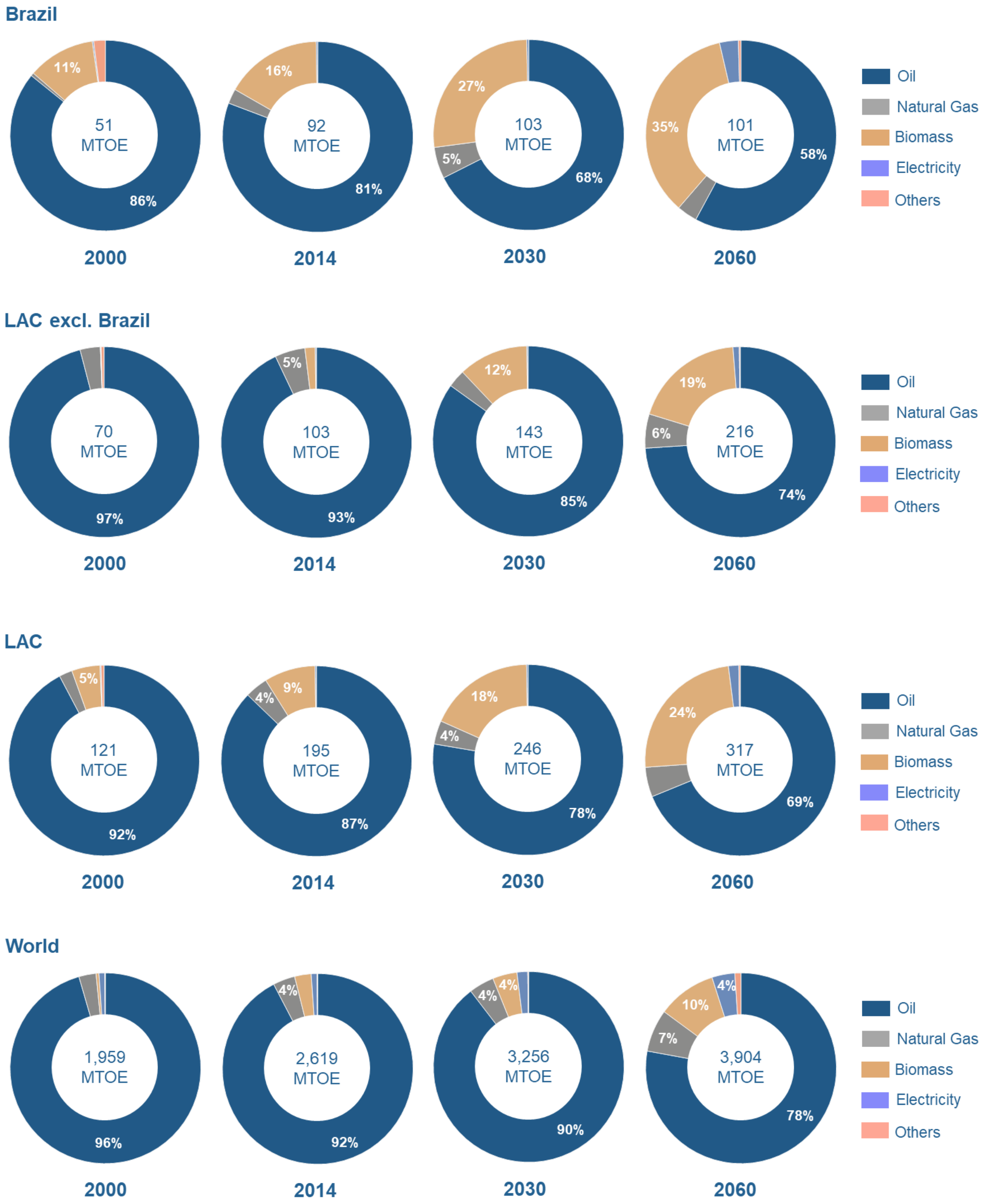
Source: World Energy Council and Paul Scherrer Institute

Figure 57: Rock Primary Energy Demand by Fuel in Brazil and LAC excl. Brazil



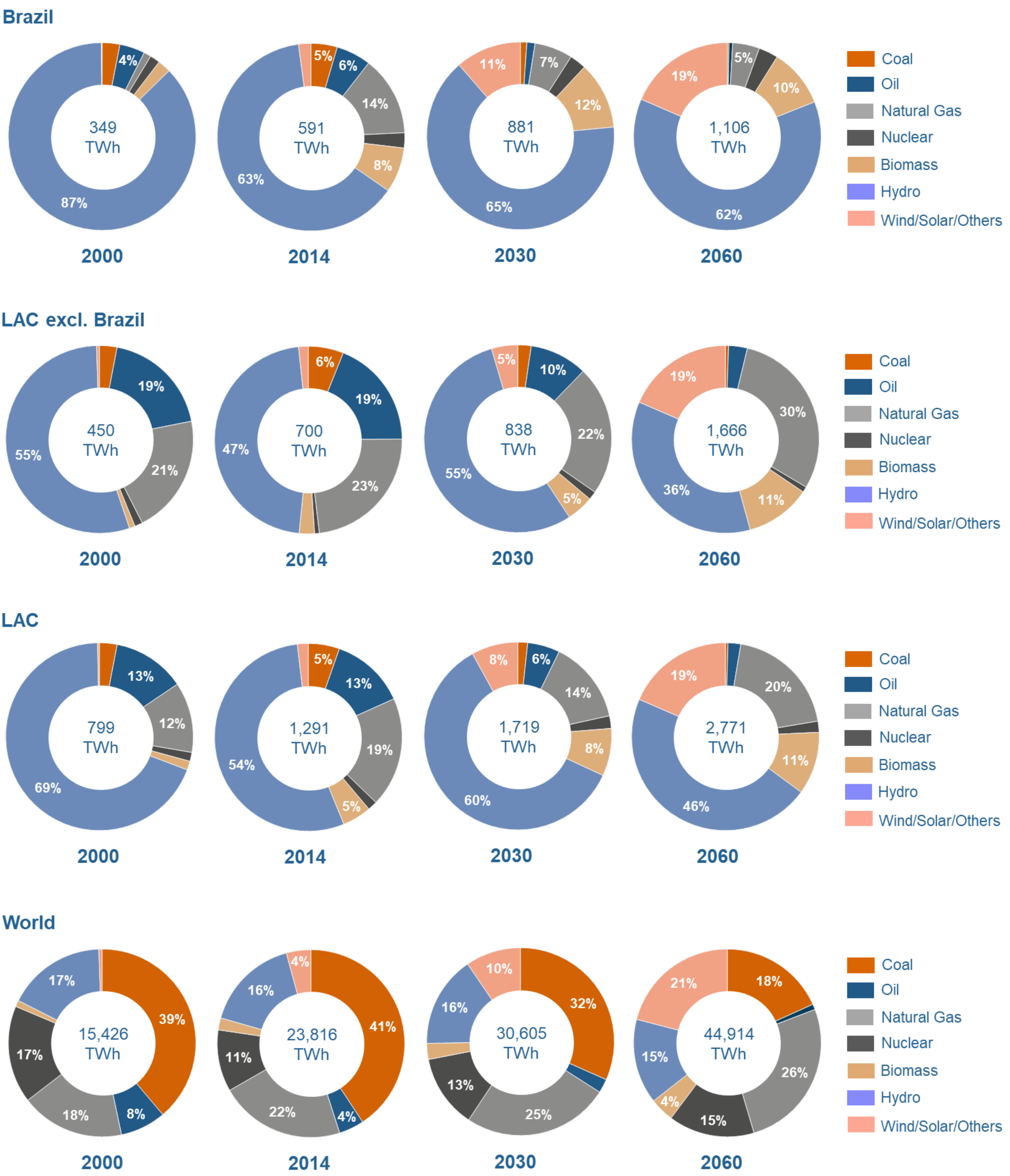
Source: World Energy Council and Paul Scherrer Institute

Figure 58: Rock Transport Energy Mix by Fuel



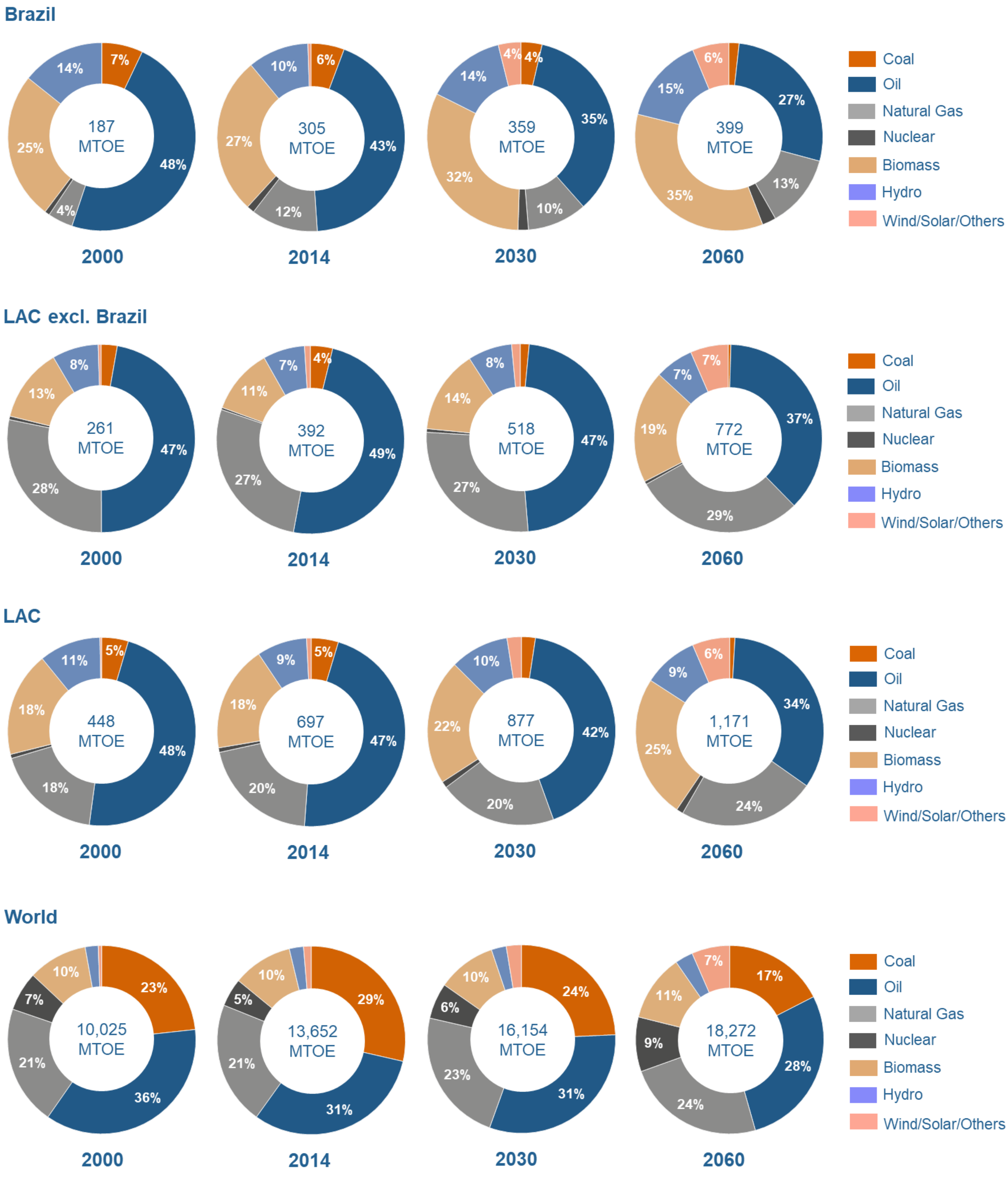
Source: World Energy Council and Paul Scherrer Institute

Figure 59: Rock Electricity Generation Mix by Fuel



Source: World Energy Council and Paul Scherrer Institute

Figure 60: Rock Primary Energy Demand Mix by Fuel



Source: World Energy Council and Paul Scherrer Institute

DATA TABLES

SAMBA in LAC

Table 15: Samba Economic Indicators in LAC

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	502	532	573	603	621	627
GDP (billion US$ 2010 MER)	4,278	5,107	7,611	10,783	14,589	18,918
GDP per capita (US$ 2010 MER)	8,515	9,603	13,281	17,887	23,508	30,175
Primary Energy Intensity (TOE / ’000 US$ 2010 MER)	0.16	0.15	0.12	0.10	0.08	0.06
Final Energy Consumption Intensity (TOE / ’000 US$ 2010 MER)	0.12	0.11	0.09	0.07	0.06	0.05

Source: World Energy Council and Paul Scherrer Institute

Table 16: Samba Primary Energy in LAC

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	697.2	779.4	918.1	1,075.7	1,157.7	1,207.1
Coal	32.5	24.4	21.1	17.8	9.0	3.7
Oil	324.1	351.5	384.4	402.8	379.6	328.9
Natural Gas	142.2	164.6	203.1	272.6	296.1	301.3
Nuclear	5.5	6.3	9.1	8.5	7.4	7.6
Biomass	127.0	147.2	189.8	237.1	302.9	373.3
Hydro	60.1	75.3	85.8	97.1	103.2	109.6
Wind / Solar / Others	5.6	10.2	24.8	39.8	59.6	82.7
Net Imports of Electricity	0.3	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 17: Samba Final Energy Consumption in LAC

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	521.9	582.3	689.6	794.4	868.3	901.5
Industry	161.9	186.0	216.2	259.5	284.9	303.3
Transport	195.3	206.1	237.0	267.7	282.5	284.2
Building	130.8	141.1	175.8	196.6	220.8	228.2
Non-energy Use	33.8	49.1	60.7	70.6	80.1	85.8
Coal	11.5	14.9	12.1	11.8	8.2	2.7
Oil	267.0	287.3	317.1	326.2	307.5	281.8
Natural Gas	63.1	81.7	109.5	150.8	182.9	195.2
Electricity	88.3	95.2	126.2	154.4	185.1	214.2
Heat	0.0	0.5	1.1	2.0	3.1	4.6
Biomass	91.3	98.4	113.8	134.8	161.4	174.7
Others	0.6	4.4	9.9	14.3	20.1	28.3

Source: World Energy Council and Paul Scherrer Institute

Table 18: Samba Transport Energy in LAC

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	195.3	206.1	237.0	267.7	282.5	284.2
Liquid fuels - fossil	170.3	167.8	181.2	182.7	172.5	153.8
Liquid fuels - biogenous	17.0	28.5	39.2	51.5	66.2	82.6
Gaseous fuels - fossil	7.6	9.3	14.0	28.0	33.2	25.9
Gaseous fuels - biogenous	0.0	0.0	1.0	2.0	3.0	4.3
Electricity	0.4	0.6	1.3	2.6	5.5	13.1
Hydrogen	0.0	0.0	0.3	0.9	2.1	4.4
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 19: Samba Electricity Generation in LAC

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	1,291	1,424	1,871	2,245	2,637	2,995
Coal	69	39	37	25	3	1
Coal with CCS	0	0	0	0	0	0
Oil	167	136	94	70	60	51
Natural Gas	244	195	381	493	608	623
Natural Gas with CCS	0	0	0	0	0	0
Nuclear	21	25	35	33	29	29
Hydro	701	878	1,001	1,133	1,204	1,279
Biomass	64	84	142	178	242	323
Biomass with CCS	0	0	0	0	0	0
Wind	19	56	120	182	268	365
Solar	1	9	49	112	194	287
Geothermal	4	3	11	19	27	37
Others	1	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 20: Samba Carbon Emissions in LAC

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	1.32	1.38	1.58	1.72	1.68	1.47
CO_2 per capita (t CO_2)	2.62	2.60	2.75	2.85	2.70	2.34
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.31	0.27	0.21	0.16	0.11	0.08
Carbon Intensity of Primary Energy (t CO_2 / TOE)	1.89	1.77	1.72	1.60	1.45	1.22

Source: World Energy Council and Paul Scherrer Institute

SAMBA in Brazil

Table 21: Samba Economic Indicators in Brazil

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	206	216	229	236	238	236
GDP (billion US$ 2010 MER)	2,282	2,487	3,542	4,760	6,094	7,501
GDP per capita (US$ 2010 MER)	11,073	11,514	15,491	20,170	25,574	31,783
Primary Energy Intensity (TOE / ’000 US$ 2010 MER)	0.14	0.14	0.11	0.09	0.08	0.07
Final Energy Consumption Intensity (TOE / ’000 US$ 2010 MER)	0.10	0.11	0.08	0.07	0.06	0.05

Source: World Energy Council and Paul Scherrer Institute

Table 22: Samba Primary Energy in Brazil

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	308.2	336.0	396.8	451.3	473.5	496.9
Coal	17.5	14.5	11.7	10.7	7.6	3.2
Oil	131.9	131.1	143.6	151.8	144.5	131.8
Natural Gas	35.3	38.5	49.8	71.6	68.1	68.5
Nuclear	4.0	3.7	6.5	6.5	5.3	5.3
Biomass	82.9	93.7	117.6	134.7	162.8	194.7
Hydro	32.0	44.3	48.1	51.2	54.9	58.8
Wind / Solar / Others	1.7	7.4	16.7	22.2	28.0	33.1
Net Imports of Electricity	3.0	2.8	2.9	2.7	2.3	1.4

Source: World Energy Council and Paul Scherrer Institute

Table 23: Samba Final Energy Consumption in Brazil

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	237.3	263.5	301.0	340.9	359.4	363.2
Industry	80.7	96.0	105.2	129.3	143.0	149.1
Transport	92.1	93.0	103.6	111.2	111.3	109.2
Building	49.0	52.0	66.1	70.7	72.6	71.6
Non-energy Use	15.5	22.5	26.2	29.7	32.4	33.3
Coal	7.7	11.4	8.7	8.5	6.9	2.3
Oil	115.1	120.9	129.8	138.4	128.3	117.2
Natural Gas	12.6	19.3	25.4	34.7	40.3	45.5
Electricity	42.9	49.0	63.3	73.5	82.4	89.1
Heat	0.0	0.3	0.6	1.1	1.8	2.7
Biomass	58.3	59.9	67.4	77.9	91.6	97.1
Others	0.6	2.7	5.8	6.8	7.9	9.4

Source: World Energy Council and Paul Scherrer Institute

Table 24: Samba Transport Energy in Brazil

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	92.1	93.0	103.6	111.2	111.3	109.2
Liquid fuels - fossil	74.4	69.6	72.6	72.1	64.8	56.2
Liquid fuels - biogenous	15.2	18.6	24.5	28.5	34.3	38.3
Gaseous fuels - fossil	2.3	4.5	4.7	6.9	5.8	3.5
Gaseous fuels - biogenous	0.0	0.0	1.0	2.0	3.0	4.3
Electricity	0.2	0.2	0.6	1.1	2.3	5.1
Hydrogen	0.0	0.0	0.2	0.6	1.1	1.8
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 25: Samba Electricity Generation in Brazil

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	591	732	947	1,069	1,168	1,241
Coal	27	12	12	9	3	1
Coal with CCS	0	0	0	0	0	0
Oil	35	14	12	5	3	1
Natural Gas	81	54	103	140	146	123
Natural Gas with CCS	0	0	0	0	0	0
Nuclear	15	15	25	25	21	21
Hydro	373	517	561	597	640	686
Biomass	46	63	102	104	107	111
Biomass with CCS	0	0	0	0	0	0
Wind	12	49	100	129	159	183
Solar	0	6	31	60	90	116
Geothermal	0	0	0	0	0	0
Others	0	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 26: Samba Carbon Emissions in Brazil

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	0.49	0.47	0.52	0.57	0.53	0.44
CO_2 per capita (t CO_2)	2.38	2.18	2.29	2.42	2.23	1.88
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.22	0.19	0.15	0.12	0.09	0.06
Carbon Intensity of Primary Energy (t CO_2 / TOE)	1.59	1.40	1.32	1.26	1.12	0.89

Source: World Energy Council and Paul Scherrer Institute

SAMBA in LAC excl. Brazil

Table 27: Samba Economic Indicators in LAC excl. Brazil

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	296	316	344	367	382	391
GDP (billion US$ 2010 MER)	1,996	2,620	4,069	6,023	8,495	11,417
GDP per capita (US$ 2010 MER)	6,736	8,296	11,814	16,418	22,220	29,204
Primary Energy Intensity (TOE / ’000 US$ 2010 MER)	0.19	0.17	0.13	0.10	0.08	0.06
Final Energy Consumption Intensity (TOE / ’000 US$ 2010 MER)	0.14	0.12	0.10	0.08	0.06	0.05

Source: World Energy Council and Paul Scherrer Institute

Table 28: Samba Primary Energy in LAC excl. Brazil

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	389.0	443.4	521.3	624.4	684.2	710.1
Coal	15.0	9.9	9.4	7.1	1.4	0.5
Oil	192.2	220.4	240.7	251.0	235.1	197.1
Natural Gas	106.9	126.1	153.3	201.1	227.9	232.8
Nuclear	1.5	2.6	2.6	2.0	2.1	2.2
Biomass	44.0	53.5	72.2	102.4	140.1	178.6
Hydro	28.1	30.9	37.7	46.0	48.3	50.8
Wind / Solar / Others	3.9	2.7	8.1	17.6	31.6	49.6
Net Imports of Electricity	-2.7	-2.8	-2.9	-2.7	-2.3	-1.4

Source: World Energy Council and Paul Scherrer Institute

Table 29: Samba Final Energy Consumption in LAC excl. Brazil

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	284.6	318.9	388.6	453.5	508.9	538.3
Industry	81.2	90.0	111.0	130.2	141.9	154.3
Transport	103.2	113.1	133.4	156.6	171.2	175.0
Building	81.8	89.1	109.7	125.9	148.2	156.6
Non-energy Use	18.3	26.6	34.5	40.9	47.6	52.5
Coal	3.8	3.5	3.4	3.4	1.3	0.4
Oil	151.8	166.3	187.2	187.8	179.2	164.6
Natural Gas	50.5	62.4	84.1	116.2	142.6	149.7
Electricity	45.4	46.3	62.9	80.9	102.7	125.1
Heat	0.0	0.2	0.5	0.8	1.3	2.0
Biomass	33.0	38.5	46.4	57.0	69.7	77.6
Others	0.0	1.7	4.1	7.5	12.1	18.9

Source: World Energy Council and Paul Scherrer Institute

Table 30: Samba Transport Energy in LAC excl. Brazil

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	103.2	113.1	133.4	156.6	171.2	175.0
Liquid fuels - fossil	95.9	98.1	108.5	110.6	107.7	97.6
Liquid fuels - biogenous	1.8	9.8	14.8	23.0	31.8	44.3
Gaseous fuels - fossil	5.3	4.8	9.3	21.2	27.3	22.4
Gaseous fuels - biogenous	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.2	0.4	0.7	1.5	3.3	8.0
Hydrogen	0.0	0.0	0.1	0.3	1.0	2.6
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 31: Samba Electricity Generation in LAC excl. Brazil

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	700	691	924	1,175	1,469	1,753
Coal	43	26	25	15	0	0
Coal with CCS	0	0	0	0	0	0
Oil	131	121	82	65	57	50
Natural Gas	163	140	278	353	462	501
Natural Gas with CCS	0	0	0	0	0	0
Nuclear	6	10	10	8	8	9
Hydro	327	361	440	536	564	593
Biomass	18	20	40	74	136	212
Biomass with CCS	0	0	0	0	0	0
Wind	6	7	20	53	109	182
Solar	1	2	18	52	104	171
Geothermal	4	3	11	19	27	37
Others	0	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 32: Samba Carbon Emissions in LAC excl. Brazil

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	0.82	0.91	1.05	1.15	1.15	1.02
CO_2 per capita (t CO_2)	2.78	2.88	3.06	3.12	3.00	2.62
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.41	0.35	0.26	0.19	0.13	0.09
Carbon Intensity of Primary Energy (t CO_2 / TOE)	2.12	2.05	2.02	1.83	1.68	1.44

Source: World Energy Council and Paul Scherrer Institute

TANGO in LAC

Table 33: Tango Economic Indicators in LAC

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	502	532	573	603	621	627
GDP (billion US$ 2010 MER)	4,278	4,818	6,665	9,005	11,618	14,742
GDP per capita (US$ 2010 MER)	8,515	9,059	11,631	14,937	18,720	23,513
Primary Energy Intensity (TOE / ’000 US$ 2010 MER)	0.16	0.16	0.13	0.10	0.08	0.07
Final Energy Consumption Intensity (TOE / ’000 US$ 2010 MER)	0.12	0.12	0.10	0.08	0.06	0.05

Source: World Energy Council and Paul Scherrer Institute

Table 34: Tango Primary Energy in LAC

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	697.2	763.3	870.2	915.4	952.6	1,014.6
Coal	32.5	20.6	17.2	6.7	3.9	2.0
Oil	324.1	333.0	346.7	325.5	285.0	204.9
Natural Gas	142.2	161.4	178.3	194.0	189.7	185.0
Nuclear	5.5	6.6	11.4	12.6	15.1	20.9
Biomass	127.0	153.1	198.8	228.8	282.2	401.5
Hydro	60.1	77.9	91.7	100.1	106.2	111.9
Wind / Solar / Others	5.6	10.8	26.1	47.8	70.5	88.4
Net Imports of Electricity	0.3	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 35: Tango Final Energy Consumption in LAC

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	521.9	573.9	658.0	708.8	728.1	718.3
Industry	161.9	180.0	201.8	215.7	226.3	227.3
Transport	195.3	204.4	231.3	249.4	254.4	243.7
Building	130.8	142.4	167.2	179.7	179.2	177.0
Non-energy Use	33.8	47.0	57.7	64.0	68.1	70.3
Coal	11.5	12.6	9.0	6.6	3.9	2.0
Oil	267.0	272.2	288.4	282.6	250.6	182.1
Natural Gas	63.1	80.3	108.1	131.2	140.9	142.3
Electricity	88.3	101.9	122.5	146.9	167.3	194.5
Heat	0.0	0.5	1.1	2.0	3.1	4.6
Biomass	91.3	101.6	119.3	125.0	141.0	168.2
Others	0.6	4.7	9.6	14.5	21.4	24.7

Source: World Energy Council and Paul Scherrer Institute

Table 36: Tango Transport Energy in LAC

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	195.3	204.4	231.3	249.4	254.4	243.7
Liquid fuels - fossil	170.3	166.3	177.8	178.8	158.0	100.1
Liquid fuels - biogenous	17.0	30.5	42.1	51.7	68.5	98.9
Gaseous fuels - fossil	7.6	6.9	9.6	14.7	18.1	21.3
Gaseous fuels - biogenous	0.0	0.0	0.0	0.0	0.0	1.3
Electricity	0.4	0.7	1.5	3.3	7.7	18.1
Hydrogen	0.0	0.0	0.3	0.8	2.1	4.1
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 37: Tango Electricity Generation in LAC

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	1,290.8	1,515	1,808	2,116	2,393	2,742
Coal	69.3	32	24	0	0	0
Coal with CCS	0.0	0	0	0	0	0
Oil	166.7	122	62	51	39	26
Natural Gas	244.2	270	260	250	181	29
Natural Gas with CCS	0.0	0	0	0	19	173
Nuclear	21.1	25	44	49	59	81
Hydro	700.8	908	1,070	1,168	1,239	1,305
Biomass	64.4	86	150	196	257	335
Biomass with CCS	0.0	0	0	0	0	0
Wind	18.5	57	131	238	334	451
Solar	1.1	9	53	140	225	285
Geothermal	4.0	5	12	25	41	56
Others	0.7	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 38: Tango Carbon Emissions in LAC

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	1.32	1.35	1.38	1.29	1.12	0.69
CO_2 per capita (t CO_2)	2.62	2.53	2.41	2.15	1.81	1.10
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.31	0.28	0.21	0.14	0.10	0.05
Carbon Intensity of Primary Energy (t CO_2 / TOE)	1.89	1.77	1.59	1.41	1.18	0.68

Source: World Energy Council and Paul Scherrer Institute

TANGO in Brazil

Table 39: Tango Economic Indicators in Brazil

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	206	216	229	236	238	236
GDP (billion US$ 2010 MER)	2,282	2,438	3,309	4,361	5,316	6,355
GDP per capita (US$ 2010 MER)	11,073	11,289	14,471	18,479	22,313	26,925
Primary Energy Intensity (TOE / '000 US$ 2010 MER)	0.14	0.13	0.12	0.09	0.08	0.07
Final Energy Consumption Intensity (TOE / '000 US$ 2010 MER)	0.10	0.11	0.09	0.07	0.06	0.05

Source: World Energy Council and Paul Scherrer Institute

Table 40: Tango Primary Energy in Brazil

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	308.2	321.9	386.7	409.0	410.6	433.7
Coal	17.5	11.1	9.5	5.5	3.3	1.7
Oil	131.9	127.2	133.1	125.0	105.4	79.9
Natural Gas	35.3	31.7	42.9	54.3	55.2	47.6
Nuclear	4.0	3.8	6.5	6.5	8.0	10.8
Biomass	82.9	93.3	125.4	138.2	150.2	197.2
Hydro	32.0	44.3	50.9	52.7	57.4	60.0
Wind / Solar / Others	1.7	7.8	16.6	25.0	29.5	35.2
Net Imports of Electricity	3.0	2.8	1.9	1.8	1.6	1.3

Source: World Energy Council and Paul Scherrer Institute

Table 41: Tango Final Energy Consumption in Brazil

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	237.3	256.1	294.6	308.3	307.2	290.7
Industry	80.7	90.9	102.9	108.5	118.1	118.2
Transport	92.1	92.9	102.6	103.1	91.7	78.6
Building	49.0	51.2	63.9	67.7	66.4	63.0
Non-energy Use	15.5	21.1	25.3	28.9	30.9	30.9
Coal	7.7	9.4	7.1	5.5	3.3	1.7
Oil	115.1	117.6	121.9	114.3	95.3	71.2
Natural Gas	12.6	17.5	23.8	32.8	39.7	36.5
Electricity	42.9	49.0	62.1	71.1	78.5	86.6
Heat	0.0	0.3	0.6	1.1	1.8	2.7
Biomass	58.3	59.3	73.9	77.3	81.3	82.9
Others	0.6	3.0	5.1	6.1	7.3	9.1

Source: World Energy Council and Paul Scherrer Institute

Table 42: Tango Transport Energy in Brazil

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	92.1	92.9	102.6	103.1	91.7	78.6
Liquid fuels - fossil	74.4	70.6	70.6	61.7	46.4	26.8
Liquid fuels - biogenous	15.2	18.6	26.4	31.8	33.3	35.7
Gaseous fuels - fossil	2.3	3.2	4.6	7.5	7.2	4.3
Gaseous fuels - biogenous	0.0	0.0	0.0	0.0	0.0	1.3
Electricity	0.2	0.5	0.9	1.8	3.9	8.5
Hydrogen	0.0	0.0	0.1	0.4	1.0	2.0
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 43: Tango Electricity Generation in Brazil

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	591	731	936	1,037	1,141	1,239
Coal	27	6	0	0	0	0
Coal with CCS	0	0	0	0	0	0
Oil	35	13	3	1	0	0
Natural Gas	81	60	78	61	39	28
Natural Gas with CCS	0	0	0	0	14	17
Nuclear	15	15	25	25	31	42
Hydro	373	517	593	615	669	699
Biomass	46	64	101	109	117	124
Biomass with CCS	0	0	0	0	0	0
Wind	12	49	97	149	172	213
Solar	0	6	38	77	100	115
Geothermal	0	0	0	0	0	0
Others	0	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 44: Tango Carbon Emissions in Brazil

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	0.49	0.45	0.46	0.43	0.35	0.16
CO_2 per capita (t CO_2)	2.38	2.06	2.01	1.84	1.47	0.66
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.22	0.18	0.14	0.10	0.07	0.02
Carbon Intensity of Primary Energy (t CO_2 / TOE)	1.59	1.39	1.19	1.06	0.86	0.36

Source: World Energy Council and Paul Scherrer Institute

TANGO in LAC excl. Brazil

Table 45: Tango Economic Indicators in LAC excl. Brazil

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	296	316	344	367	382	391
GDP (billion US$ 2010 MER)	1,996	2,379	3,356	4,644	6,301	8,387
GDP per capita (US$ 2010 MER)	6,736	7,534	9,745	12,659	16,481	21,453
Primary Energy Intensity (TOE / '000 US$ 2010 MER)	0.19	0.19	0.14	0.11	0.09	0.07
Final Energy Consumption Intensity (TOE / '000 US$ 2010 MER)	0.14	0.13	0.11	0.09	0.07	0.05

Source: World Energy Council and Paul Scherrer Institute

Table 46: Tango Primary Energy in LAC excl. Brazil

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	389.0	441.3	483.5	506.4	541.9	580.9
Coal	15.0	9.6	7.7	1.2	0.6	0.3
Oil	192.2	205.8	213.5	200.5	179.6	125.0
Natural Gas	106.9	129.7	135.4	139.7	134.4	137.3
Nuclear	1.5	2.8	5.0	6.0	7.1	10.2
Biomass	44.0	59.8	73.4	90.6	132.0	204.3
Hydro	28.1	33.5	40.9	47.4	48.8	51.9
Wind / Solar / Others	3.9	3.0	9.5	22.8	40.9	53.2
Net Imports of Electricity	-2.7	-2.8	-1.9	-1.8	-1.6	-1.3

Source: World Energy Council and Paul Scherrer Institute

Table 47: Tango Final Energy Consumption in LAC excl. Brazil

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	284.6	317.8	363.4	400.6	420.9	427.6
Industry	81.2	89.0	99.0	107.2	108.2	109.1
Transport	103.2	111.6	128.7	146.2	162.7	165.2
Building	81.8	91.2	103.3	112.0	112.8	114.0
Non-energy Use	18.3	26.0	32.4	35.1	37.2	39.4
Coal	3.8	3.2	1.9	1.1	0.6	0.3
Oil	151.8	154.6	166.5	168.3	155.3	110.9
Natural Gas	50.5	62.8	84.3	98.4	101.1	105.7
Electricity	45.4	52.9	60.4	75.8	88.8	107.9
Heat	0.0	0.2	0.5	0.8	1.3	2.0
Biomass	33.0	42.3	45.4	47.7	59.7	85.3
Others	0.0	1.7	4.5	8.4	14.1	15.6

Source: World Energy Council and Paul Scherrer Institute

Table 48: Tango Transport Energy in LAC excl. Brazil

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	103.2	111.6	128.7	146.2	162.7	165.2
Liquid fuels - fossil	95.9	95.7	107.2	117.1	111.6	73.3
Liquid fuels - biogenous	1.8	11.8	15.7	19.9	35.2	63.2
Gaseous fuels - fossil	5.3	3.8	5.0	7.2	10.9	17.0
Gaseous fuels - biogenous	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.2	0.2	0.6	1.5	3.8	9.6
Hydrogen	0.0	0.0	0.2	0.4	1.2	2.1
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 49: Tango Electricity Generation in LAC excl. Brazil

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	700	784	872	1,078	1,252	1,503
Coal	43	26	24	0	0	0
Coal with CCS	0	0	0	0	0	0
Oil	131	109	59	49	39	26
Natural Gas	163	209	182	189	143	1
Natural Gas with CCS	0	0	0	0	5	156
Nuclear	6	11	19	24	28	39
Hydro	327	391	477	553	570	606
Biomass	18	22	49	87	140	211
Biomass with CCS	0	0	0	0	0	0
Wind	6	8	34	89	162	238
Solar	1	2	15	63	125	170
Geothermal	4	5	12	25	41	56
Others	0	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 50: Tango Carbon Emissions in LAC excl. Brazil

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	0.82	0.90	0.92	0.86	0.77	0.53
CO_2 per capita (t CO_2)	2.78	2.85	2.68	2.35	2.01	1.37
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.41	0.38	0.28	0.19	0.12	0.06
Carbon Intensity of Primary Energy (t CO_2 / TOE)	2.12	2.04	1.91	1.70	1.42	0.92

Source: World Energy Council and Paul Scherrer Institute

ROCK in LAC

Table 51: Rock Economic Indicators in LAC

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	502	532	573	603	621	627
GDP (billion US$ 2010 MER)	4,278	4,524	5,458	6,396	7,316	8,210
GDP per capita (US$ 2010 MER)	8,515	8,507	9,524	10,609	11,788	13,095
Primary Energy Intensity (TOE / ’000 US$ 2010 MER)	0.16	0.17	0.16	0.16	0.15	0.14
Final Energy Consumption Intensity (TOE / ’000 US$ 2010 MER)	0.12	0.13	0.12	0.12	0.11	0.10

Source: World Energy Council and Paul Scherrer Institute

Table 52: Rock Primary Energy in LAC

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	697.2	753.4	877.0	997.6	1,105.9	1,170.9
Coal	32.5	23.4	20.9	17.9	12.9	10.5
Oil	324.1	336.6	369.2	388.5	395.5	396.5
Natural Gas	142.2	147.6	178.2	223.6	264.4	276.1
Nuclear	5.5	6.4	9.6	10.3	10.0	13.6
Biomass	127.0	151.9	188.9	222.2	261.8	288.5
Hydro	60.1	76.6	88.5	99.8	105.7	110.3
Wind / Solar / Others	5.6	10.9	21.7	35.4	55.7	75.4
Net Imports of Electricity	0.3	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 53: Rock Final Energy Consumption in LAC

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	521.9	577.8	662.0	746.3	813.0	852.6
Industry	161.9	177.1	196.6	227.0	245.5	260.2
Transport	195.3	208.0	245.6	273.7	300.8	317.0
Building	130.8	145.4	162.5	179.3	192.2	194.0
Non-energy Use	33.8	47.3	57.4	66.3	74.5	81.3
Coal	11.5	14.9	13.8	11.5	9.8	8.3
Oil	267.0	277.3	302.1	310.9	314.5	309.8
Natural Gas	63.1	82.5	108.6	138.1	159.0	175.9
Electricity	88.3	94.6	116.1	147.5	177.6	192.2
Heat	0.0	0.5	1.1	1.5	2.6	3.9
Biomass	91.3	102.8	109.9	121.4	126.8	130.1
Others	0.6	5.3	10.5	15.3	22.7	32.5

Source: World Energy Council and Paul Scherrer Institute

Table 54: Rock Transport Energy in LAC

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	195.3	208.0	245.6	273.7	300.8	317.0
Liquid fuels - fossil	170.3	169.4	190.7	205.7	216.7	218.2
Liquid fuels - biogenous	17.0	29.6	44.2	55.0	67.2	75.1
Gaseous fuels - fossil	7.6	8.5	9.8	11.2	13.0	16.0
Gaseous fuels - biogenous	0.0	0.0	0.2	0.4	0.9	1.4
Electricity	0.4	0.4	0.6	1.1	2.4	5.5
Hydrogen	0.0	0.0	0.0	0.2	0.5	0.8
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 55: Rock Electricity Generation in LAC

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	1,291	1,413	1,719	2,132	2,553	2,771
Coal	69	34	29	27	16	12
Coal with CCS	0	0	0	0	0	0
Oil	167	126	96	77	68	61
Natural Gas	244	185	246	402	547	546
Natural Gas with CCS	0	0	0	0	0	0
Nuclear	21	25	37	40	39	53
Hydro	701	893	1,033	1,165	1,233	1,286
Biomass	64	81	141	180	258	300
Biomass with CCS	0	0	0	0	0	0
Wind	19	55	95	155	233	307
Solar	1	9	32	69	126	168
Geothermal	4	5	11	17	34	38
Others	1	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 56: Rock Carbon Emissions in LAC

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	1.32	1.35	1.47	1.60	1.67	1.68
CO_2 per capita (t CO_2)	2.62	2.54	2.57	2.66	2.70	2.67
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.31	0.30	0.27	0.25	0.23	0.20
Carbon Intensity of Primary Energy (t CO_2 / TOE)	1.89	1.79	1.68	1.61	1.51	1.43

Source: World Energy Council and Paul Scherrer Institute

ROCK in Brazil

Table 57: Rock Economic Indicators in Brazil

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	206	216	229	236	238	236
GDP (billion US$ 2010 MER)	2,282	2,344	2,774	3,188	3,556	3,890
GDP per capita (US$ 2010 MER)	11,073	10,851	12,132	13,507	14,926	16,481
Primary Energy Intensity (TOE / ’000 US$ 2010 MER)	0.14	0.14	0.13	0.12	0.11	0.10
Final Energy Consumption Intensity (TOE / ’000 US$ 2010 MER)	0.10	0.11	0.10	0.09	0.08	0.08

Source: World Energy Council and Paul Scherrer Institute

Table 58: Rock Primary Energy in Brazil

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	308.2	322.4	360.9	381.9	394.7	399.6
Coal	17.5	14.2	13.0	10.6	8.4	7.0
Oil	131.9	125.8	125.1	123.6	118.4	109.4
Natural Gas	35.3	30.6	36.9	41.0	46.2	50.2
Nuclear	4.0	3.8	6.5	6.5	5.8	9.5
Biomass	82.9	93.0	114.5	127.5	135.1	138.5
Hydro	32.0	44.3	49.2	52.6	56.8	59.2
Wind / Solar / Others	1.7	8.1	14.0	18.6	22.9	25.1
Net Imports of Electricity	3.0	2.5	1.8	1.4	1.1	0.7

Source: World Energy Council and Paul Scherrer Institute

Table 59: Rock Final Energy Consumption in Brazil

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	237.3	258.1	277.0	295.4	299.8	298.4
Industry	80.7	90.6	93.9	109.6	111.6	112.5
Transport	92.1	93.9	102.6	103.9	105.5	101.4
Building	49.0	52.5	56.4	56.0	55.8	56.6
Non-energy Use	15.5	21.2	24.1	25.9	26.9	27.9
Coal	7.7	11.4	10.5	8.8	7.5	6.4
Oil	115.1	117.3	116.5	115.8	110.3	101.0
Natural Gas	12.6	18.1	24.1	29.5	35.4	40.6
Electricity	42.9	48.6	58.1	65.5	70.9	74.4
Heat	0.0	0.3	0.6	1.1	1.8	2.7
Biomass	58.3	59.2	61.6	68.3	66.9	65.4
Others	0.6	3.3	5.5	6.3	7.0	8.1

Source: World Energy Council and Paul Scherrer Institute

Table 60: Rock Transport Energy in Brazil

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	92.1	93.9	102.6	103.9	105.5	101.4
Liquid fuels - fossil	74.4	70.6	69.3	66.8	64.6	58.7
Liquid fuels - biogenous	15.2	19.3	27.3	30.6	33.9	34.8
Gaseous fuels - fossil	2.3	3.8	5.5	5.3	4.7	3.5
Gaseous fuels - biogenous	0.0	0.0	0.2	0.4	0.6	0.8
Electricity	0.2	0.2	0.3	0.7	1.5	3.2
Hydrogen	0.0	0.0	0.0	0.1	0.3	0.5
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 61: Rock Electricity Generation in Brazil

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	591	729	881	967	1,056	1,106
Coal	27	10	10	7	4	3
Coal with CCS	0	0	0	0	0	0
Oil	35	15	12	10	8	7
Natural Gas	81	55	58	58	57	51
Natural Gas with CCS	0	0	0	0	0	0
Nuclear	15	15	25	25	22	37
Hydro	373	517	574	614	663	691
Biomass	46	61	102	106	112	112
Biomass with CCS	0	0	0	0	0	0
Wind	12	49	80	110	131	139
Solar	0	6	20	37	58	66
Geothermal	0	0	0	0	0	0
Others	0	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 62: Rock Carbon Emissions in Brazil

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	0.49	0.45	0.45	0.44	0.42	0.39
CO_2 per capita (t CO_2)	2.38	2.10	1.97	1.87	1.77	1.67
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.22	0.19	0.16	0.14	0.12	0.10
Carbon Intensity of Primary Energy (t CO_2 / TOE)	1.59	1.40	1.25	1.15	1.07	0.99

Source: World Energy Council and Paul Scherrer Institute

ROCK in LAC excl. Brazil

Table 63: Rock Economic Indicators in LAC excl. Brazil

Indicator	2014	2020	2030	2040	2050	2060
Population (million)	296	316	344	367	382	391
GDP (billion US$ 2010 MER)	1,996	2,180	2,683	3,208	3,759	4,320
GDP per capita (US$ 2010 MER)	6,736	6,903	7,792	8,744	9,833	11,051
Primary Energy Intensity (TOE / '000 US$ 2010 MER)	0.19	0.20	0.19	0.19	0.19	0.18
Final Energy Consumption Intensity (TOE / '000 US$ 2010 MER)	0.14	0.15	0.14	0.14	0.14	0.13

Source: World Energy Council and Paul Scherrer Institute

Table 64: Rock Primary Energy in LAC excl. Brazil

Primary Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	389.0	431.0	516.1	615.8	711.2	771.3
Coal	15.0	9.2	7.9	7.3	4.5	3.5
Oil	192.2	210.8	244.1	265.0	277.2	287.1
Natural Gas	106.9	117.0	141.3	182.5	218.2	225.9
Nuclear	1.5	2.6	3.1	3.8	4.2	4.1
Biomass	44.0	58.9	74.4	94.7	126.7	150.0
Hydro	28.1	32.2	39.3	47.2	48.8	51.0
Wind / Solar / Others	3.9	2.8	7.7	16.8	32.7	50.4
Net Imports of Electricity	-2.7	-2.5	-1.8	-1.4	-1.1	-0.7

Source: World Energy Council and Paul Scherrer Institute

Table 65: Rock Final Energy Consumption in LAC excl. Brazil

Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060
Total	284.6	319.7	385.1	450.9	513.2	554.2
Industry	81.2	86.5	102.7	117.4	133.9	147.8
Transport	103.2	114.1	143.0	169.8	195.3	215.6
Building	81.8	93.0	106.1	123.4	136.4	137.4
Non-energy Use	18.3	26.1	33.3	40.4	47.6	53.4
Coal	3.8	3.5	3.3	2.7	2.3	1.9
Oil	151.8	160.0	185.6	195.1	204.2	208.8
Natural Gas	50.5	64.4	84.5	108.6	123.6	135.3
Electricity	45.4	46.0	58.0	82.0	106.8	117.8
Heat	0.0	0.2	0.5	0.4	0.8	1.2
Biomass	33.0	43.6	48.2	53.1	60.0	64.7
Others	0.0	1.9	5.0	9.0	15.7	24.4

Source: World Energy Council and Paul Scherrer Institute

Table 66: Rock Transport Energy in LAC excl. Brazil

Transport Energy (MTOE)	2014	2020	2030	2040	2050	2060
Total	103.2	114.1	143.0	169.8	195.3	215.6
Liquid fuels - fossil	95.9	98.8	121.4	138.9	152.2	159.5
Liquid fuels - biogenous	1.8	10.4	16.9	24.4	33.4	40.3
Gaseous fuels - fossil	5.3	4.7	4.3	5.9	8.3	12.5
Gaseous fuels - biogenous	0.0	0.0	0.0	0.0	0.3	0.7
Electricity	0.2	0.2	0.3	0.5	1.0	2.3
Hydrogen	0.0	0.0	0.0	0.1	0.2	0.4
Others	0.0	0.0	0.0	0.0	0.0	0.0

Source: World Energy Council and Paul Scherrer Institute

Table 67: Rock Electricity Generation in LAC excl. Brazil

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060
Total	700	684	838	1,165	1,497	1,666
Coal	43	23	19	20	12	9
Coal with CCS	0	0	0	0	0	0
Oil	131	111	83	67	60	54
Natural Gas	163	130	188	344	490	495
Natural Gas with CCS	0	0	0	0	0	0
Nuclear	6	10	12	15	16	16
Hydro	327	376	459	550	570	595
Biomass	18	20	39	74	146	188
Biomass with CCS	0	0	0	0	0	0
Wind	6	6	16	46	101	168
Solar	1	2	11	32	68	102
Geothermal	4	5	11	17	34	38
Others	0	0	0	0	0	0

Source: World Energy Council and Paul Scherrer Institute

Table 68: Rock Carbon Emissions in LAC excl. Brazil

Carbon Emissions	2014	2020	2030	2040	2050	2060
CO_2 Emissions (Gt CO_2)	0.82	0.90	1.02	1.16	1.25	1.28
CO_2 per capita (t CO_2)	2.78	2.84	2.97	3.17	3.28	3.28
Carbon Intensity of GDP (kg CO_2 / US$ 2010 MER)	0.41	0.41	0.38	0.36	0.33	0.30
Carbon Intensity of Primary Energy (t CO_2 / TOE)	2.12	2.08	1.98	1.89	1.76	1.66

Source: World Energy Council and Paul Scherrer Institute

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GLOSSARY

AAGR: Average Annual Growth Rate

CAGR: Compound Annual Growth Rate

CCS: Carbon Capture and Storage

CDM: Clean Development Mechanism

CNG: Compressed Natural Gas

COP: Conference of Parties

EU 31: European Union + Iceland, Norway and Switzerland,

EV: Electric Vehicle

GDP: Gross Domestic Product

GHG: Greenhouse Gas

ICE: Internal Combustion Engine

INDC: Intended Nationally Determined Contributions

LAC: Latin America and the Caribbean

LNG: Liquefied Natural Gas

LTO: Light Tight Oil

mb/d: Million Barrels per Day

MENA: Middle East and North Africa

MTOE: Million Tons of Oil Equivalent

NCRE: Non-Conventional Renewable Energy

NGO: Non-Governmental Organization

OPEC: Organization of the Petroleum Exporting Countries

p.a.: per annum

RD&D: Research, Development and Deployment

SIEPAC: Central American Electrical Interconnection System

SINEA: Andean Electrical Interconnection System

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

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THE GLOBAL MULTI-REGIONAL MARKAL MODEL – AN OVERVIEW

The scenarios were quantified using the Global Multi-Regional MARKAL Model (GMM). GMM is a tool used to quantify and enrich the scenario storylines developed by the World Energy Council. GMM's detailed technology representation enables the model to provide a consistent and integrated representation of the global energy system, accounting for technical and economic factors in the quantification of long-term energy transitions. The model is driven by input assumptions reflecting the scenario storylines and applies an optimisation algorithm to determine the least-cost long-term configuration of the global energy system from a social planner's perspective with perfect foresight. GMM belongs to the family of MARKAL (MARKet ALlocation) type of models, where the emphasis is on a detailed representation of energy supply, conversion and energy end-use technologies (i.e. a so-called "bottom-up" model). GMM is a technologically detailed cost-optimisation model that has been developed by the Energy Economics Group at the Paul Scherrer Institute (PSI) over a number of years (Rafaj, 2005; Gul et al., 2009; Densing et al., 2012, Turton et al, 2013, Panos et al. 2015, Panos et al. 2016). The World Energy Council joined as a model partner to support continued development and dissemination of the model with the goal of improving transparency, accessibility and credibility of global energy scenario modelling. In this regard, the Council and PSI have developed GMM into a fully open source model available to all of the Council members (subject to licensing). Such tools do not seek to model directly the economy outside of the energy sector, which is represented as a set of exogenous inputs to the model based on a coherent scenario storyline. GMM is applied to identify the least-cost combination of technology and fuel options to supply energy services using a market-clearing optimisation algorithm. This algorithm simultaneously determines equipment investment and operating decisions, and primary energy supply decisions for each region represented in the model to establish equilibrium between the cost of each energy carrier, the quantity supplied by producers, and the quantity demanded by consumers. Additional information about the model and its methodology can be found at the Paul Scherrer Institute's website (www.psi.ch/eem).

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