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Energy efficiency trends by sector

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Goal 7 on energy

- Among the sustainable goals, Goal 7 addresses energy and aims at "ensuring access to affordable, reliable, sustainable and modern energy for all" with three quantified targets.
- Goal 7.3 addresses energy efficiency.

- It states to "double the rate of improvement in energy efficiency by 2030".

- The question is how to measure energy efficiency improvement?

- This is a complex question without simple answers and is the core of dedicate projects such as ODYSSEE for EU countries or BIEE in LACs.

- The monitoring of this goal is presently done by UN with the "global energy intensity", which corresponds to the "primary (or total) energy intensity".

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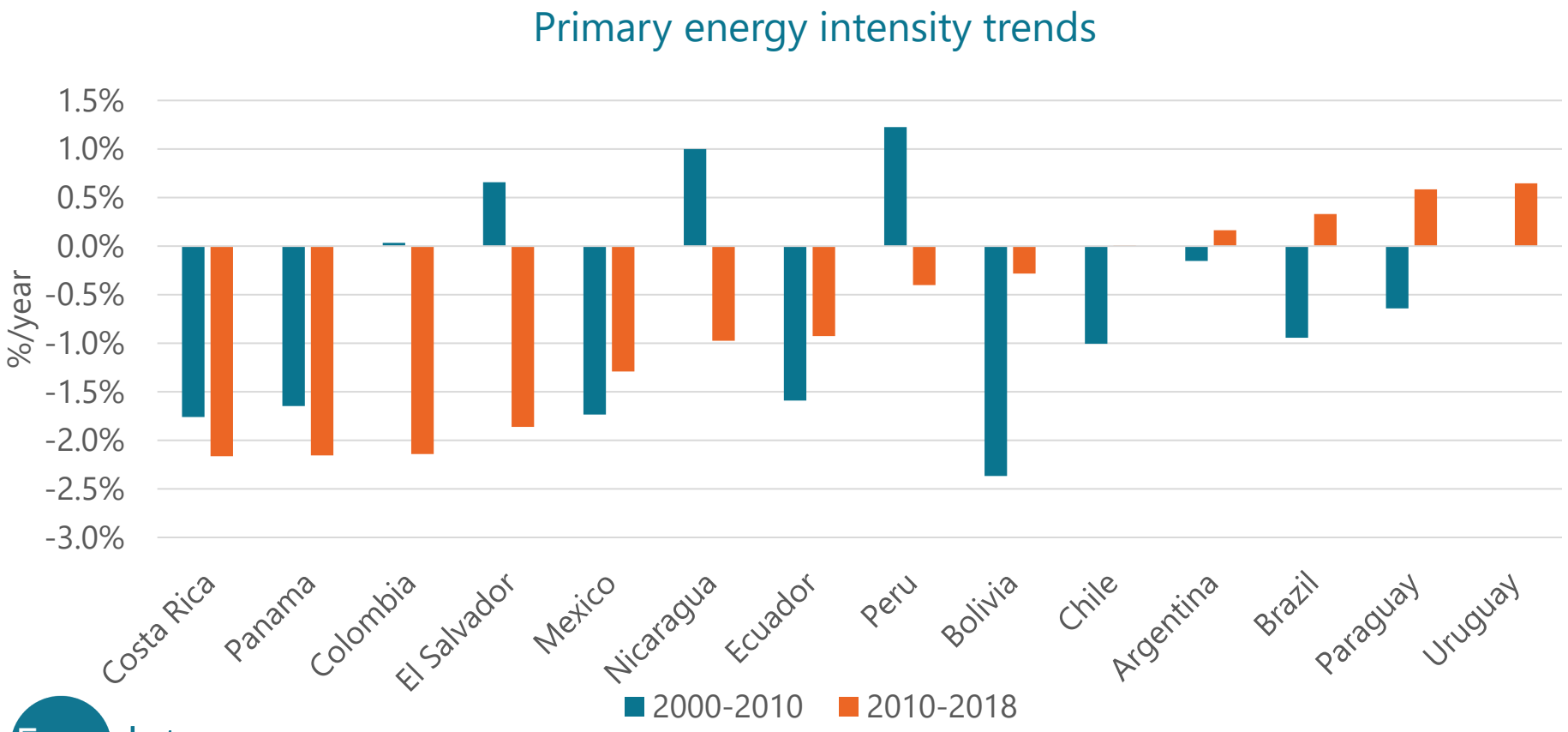
Overall energy intensity trends

- If energy efficiency progress is measured with the primary energy intensity, 6 countries have significantly increased the rate of "EE improvement" since 2010, : Costa Rica, Panama, Colombia, El Salvador, Peru and Nicaragua, with for the 3 later a reversing of the increasing trend observed before 2010.

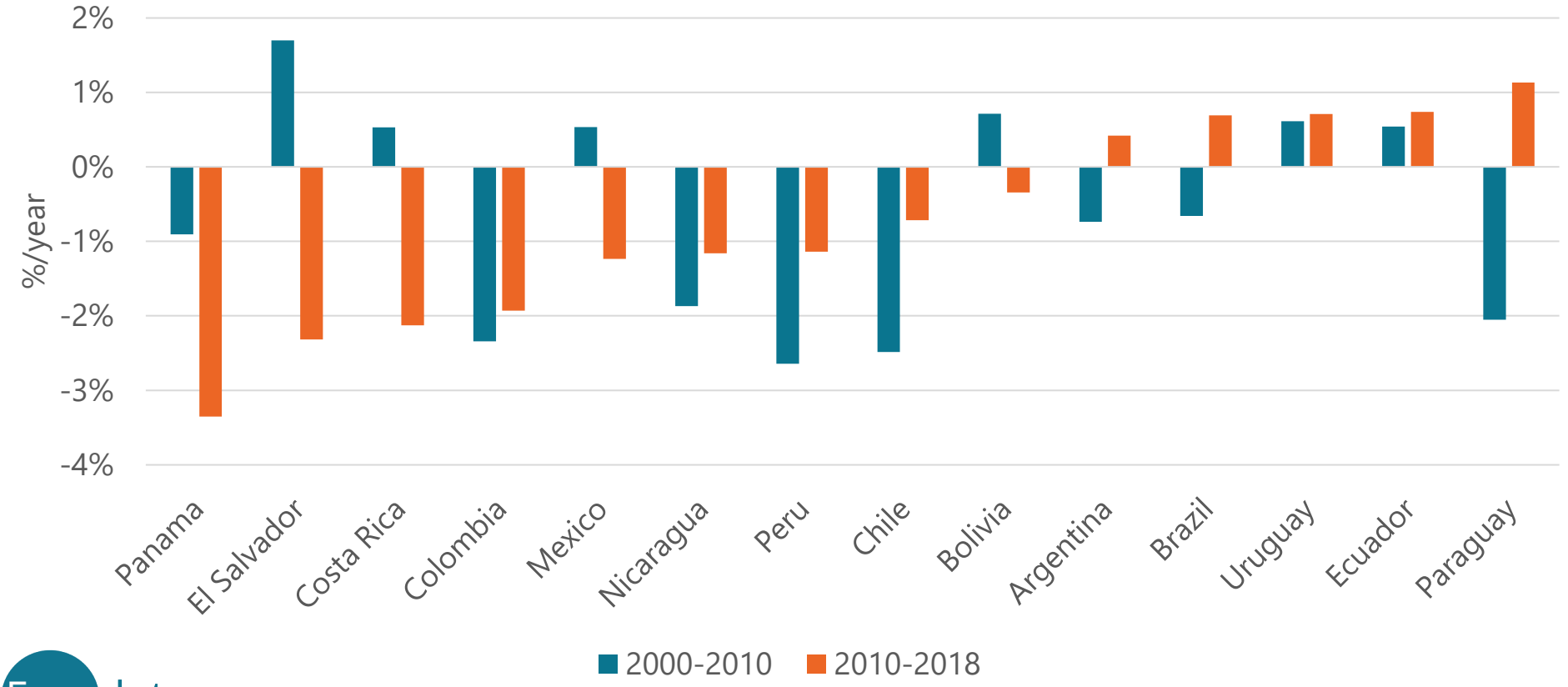
- However, most LACs are not in line with SDG7.3 goal, with 4 countries with an increasing trend.



Source: BIEE https://biee-cepal.enerdata.net

- Trends in primary intensity are influenced by changes in energy transformations, and mainly in the power mix, whereas trends in final intensity reflect changes at sector level, where most energy efficiency actions take place.
- Since 2010, final intensity has been decreasing in 2/3 of countries with a rhythm of 2%/year in 4 countries (Panama, El Salvador, Costa Rica, Colombia) .
- The trend has much intensified in 4 countries (vs 6 countries for primary intensity): Panama, Salvador, Costa Rica and Mexico (reverse of past trend for the 3 later).

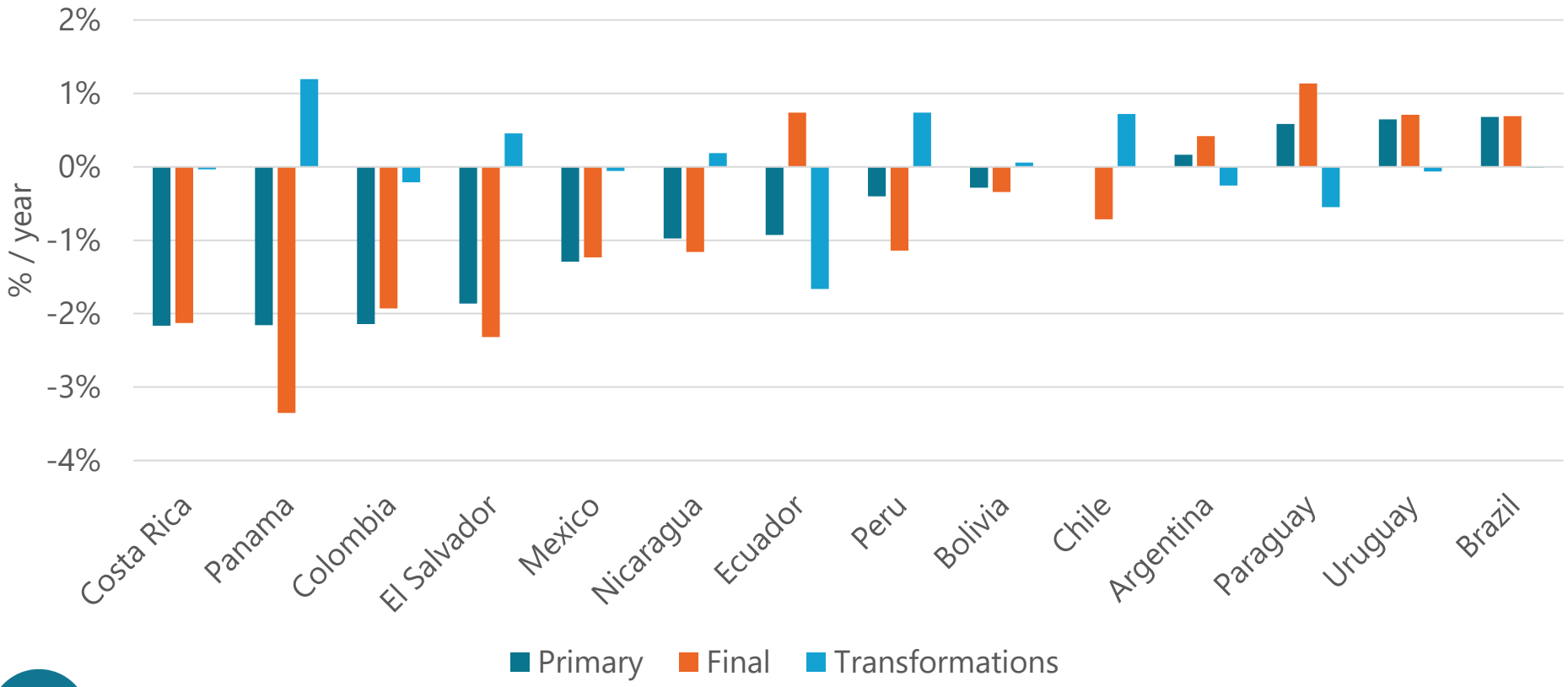
Final energy intensity trends



Source: BIEE https://biee-cepal.enerdata.net

- Since 2010, the final intensity decreased faster than primary intensity in 4 countries : very significantly in Peru and Panama (+ El Salvador and Nicaragua); this is due to increased losses in energy transformations*, mainly linked to a higher share of thermal in the power mix.
- In Ecuador, the final intensity has increased while the primary intensity has decreased, because of a higher share of renewables in the power mix.

Trends in primary and final energy intensity (2010-2018)



*Source: BIEE https://biee-cepal.enerdata.net; *Difference primary / final intensity: consumption & losses in energy transformations, mainly in power.*

Energy intensity and energy efficiency

- The total energy intensity indicates how much energy is consumed to produce one unit of GDP : a decrease indicates that less energy is required but it may not be the result of energy efficiency improvements only.

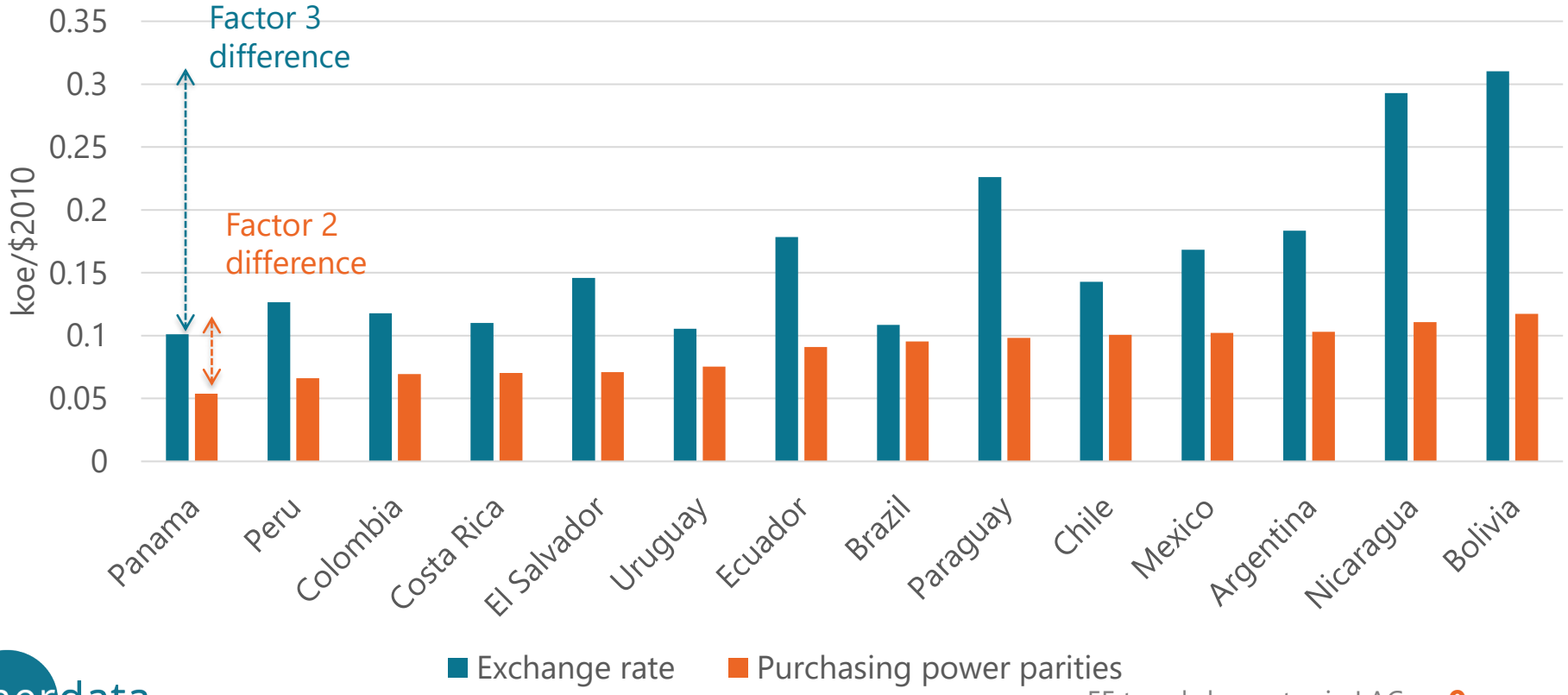
- The final energy intensity would be a better indicator as it not affected by changes in supply, in particular in the power mix, but it will be still influenced by other factors not linked to energy efficiency (e.g. "structural changes" as explained in Annex 1).

- Trends in total or final energy intensities provide an economic assessment of energy consumption but do not tell anything about the factors behind this trend, in particular energy efficiency.

- To better understand what is going on and better measure the impacts of energy efficiency programmes more detailed indicators are required, such as the indicators developed in the framework of BIEE (see Annex 2).

- Comparison of energy intensities is more relevant at ppp and gives a better assessment of the relative overall energy efficiency performance (see Annex 3)
- PPP narrows the gap between countries (from a factor 3 to 2 in LACs).
- Panama is the country with the lowest primary energy intensity. Argentina, Mexico, Chile have an intensity twice higher because of energy-intensive industries, as well as Nicaragua, because a large consumption of biomass, which has a low efficiency.

Primary intensity: exchange rate VS purchasing power parities (ppp) (2018)



Source: BIEE https://biee-cepal.enerdata.net

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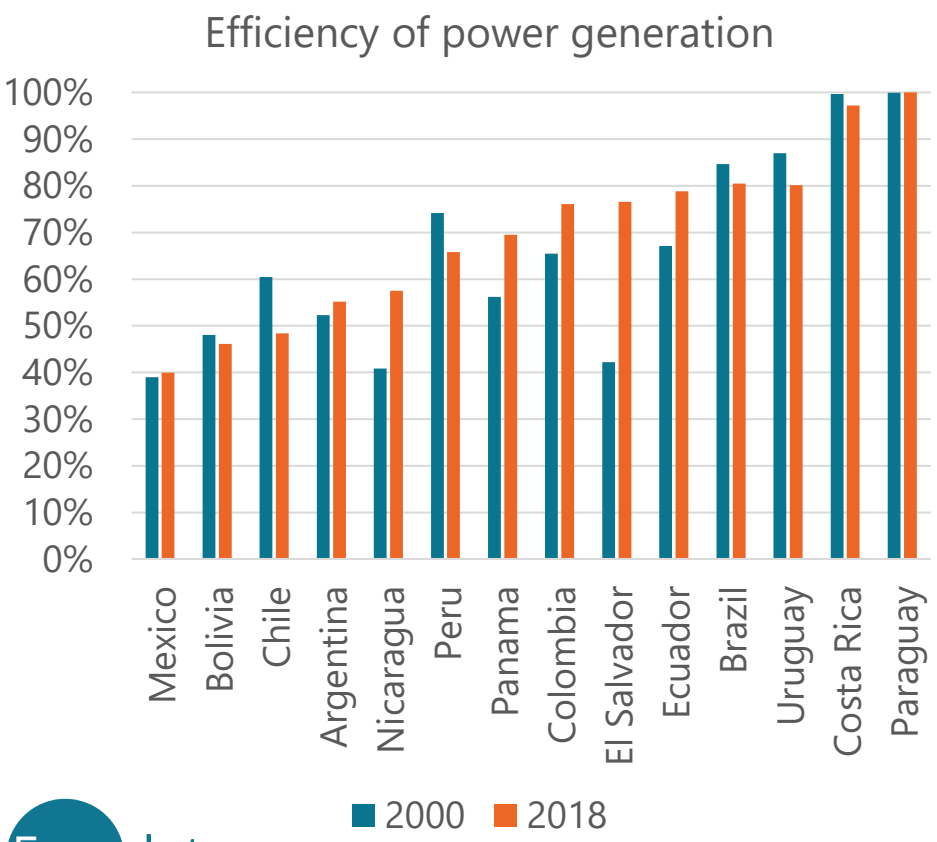
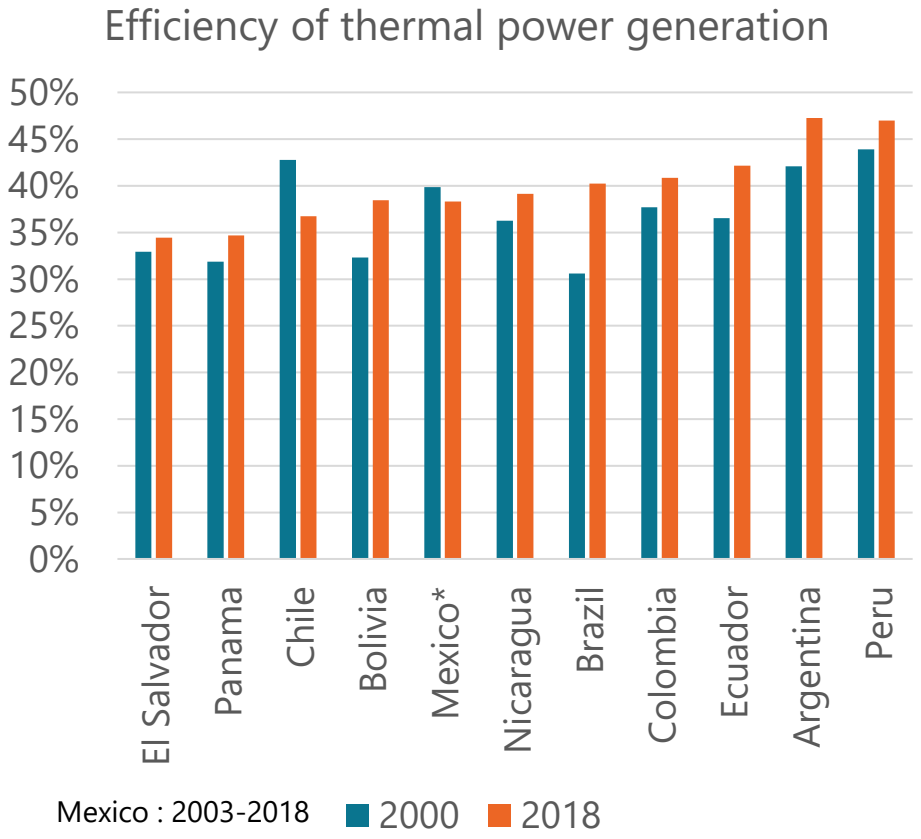
Power sector

Thermal power and overall generation efficiency

- The efficiency of thermal power plants varies from 47% in Argentina and Peru (high share of gas CCGT) to 35% in Panama, El Salvador, and Chile because of coal.
- It has improved the most in Peru and Bolivia, (shift to gas CCGT), but has decreased significantly in Chile, El Salvador, and Panama (use of coal). It.
- Countries with a high share of renewables have the highest overall power efficiency (e.g. Paraguay and Costa Rica).





Source: BIEE https://biee-cepal.enerdata.net

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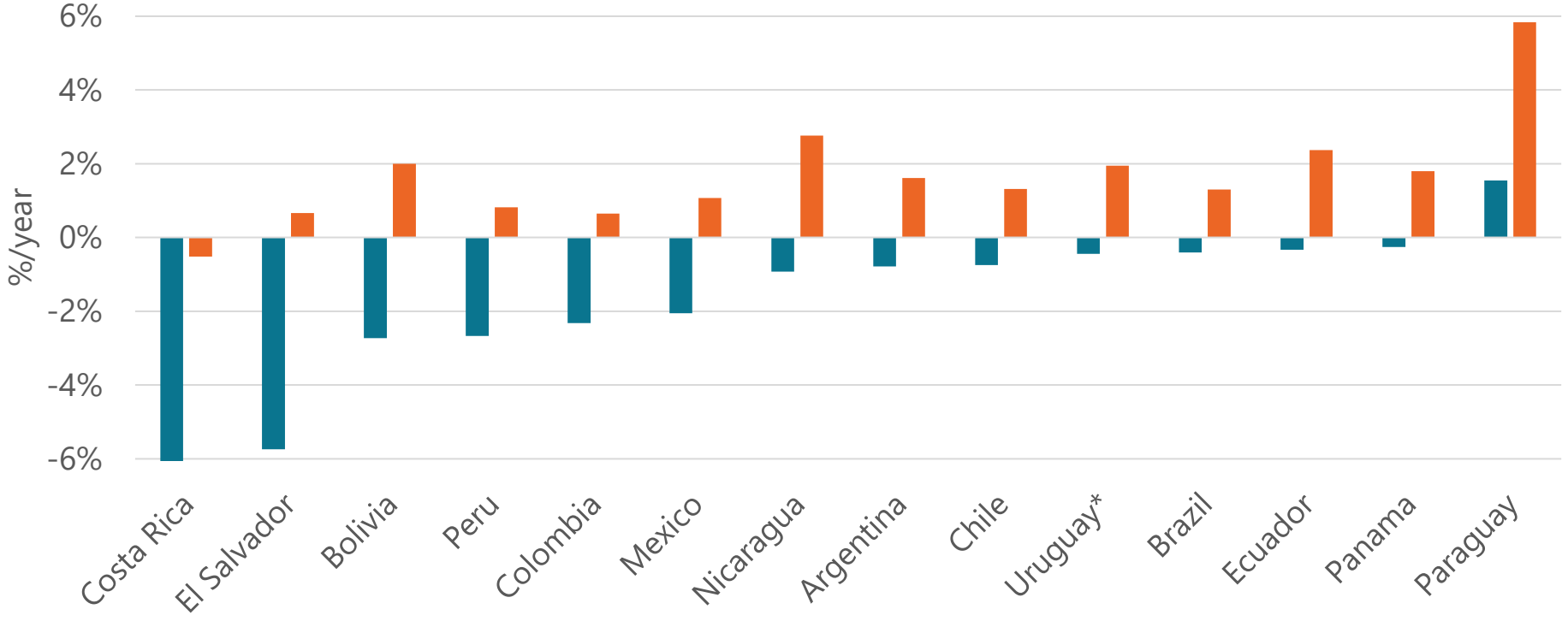
Households

- The average consumption per household has been decreasing in almost all LACs mainly because of the substitution of biomass by clean fuels for cooking.
- The electricity consumption per household has increased significantly in Paraguay (~6%/yr) and to a lesser extent in other countries (1-3%/yr) with the growth in equipment rate (refrigerators, TV, ICT, AC, water heater) and electrification. In Costa Rica, the decrease may be linked to EE measures for appliances and lighting.

Variation of total and electricity unit consumption of households (2010-2018)

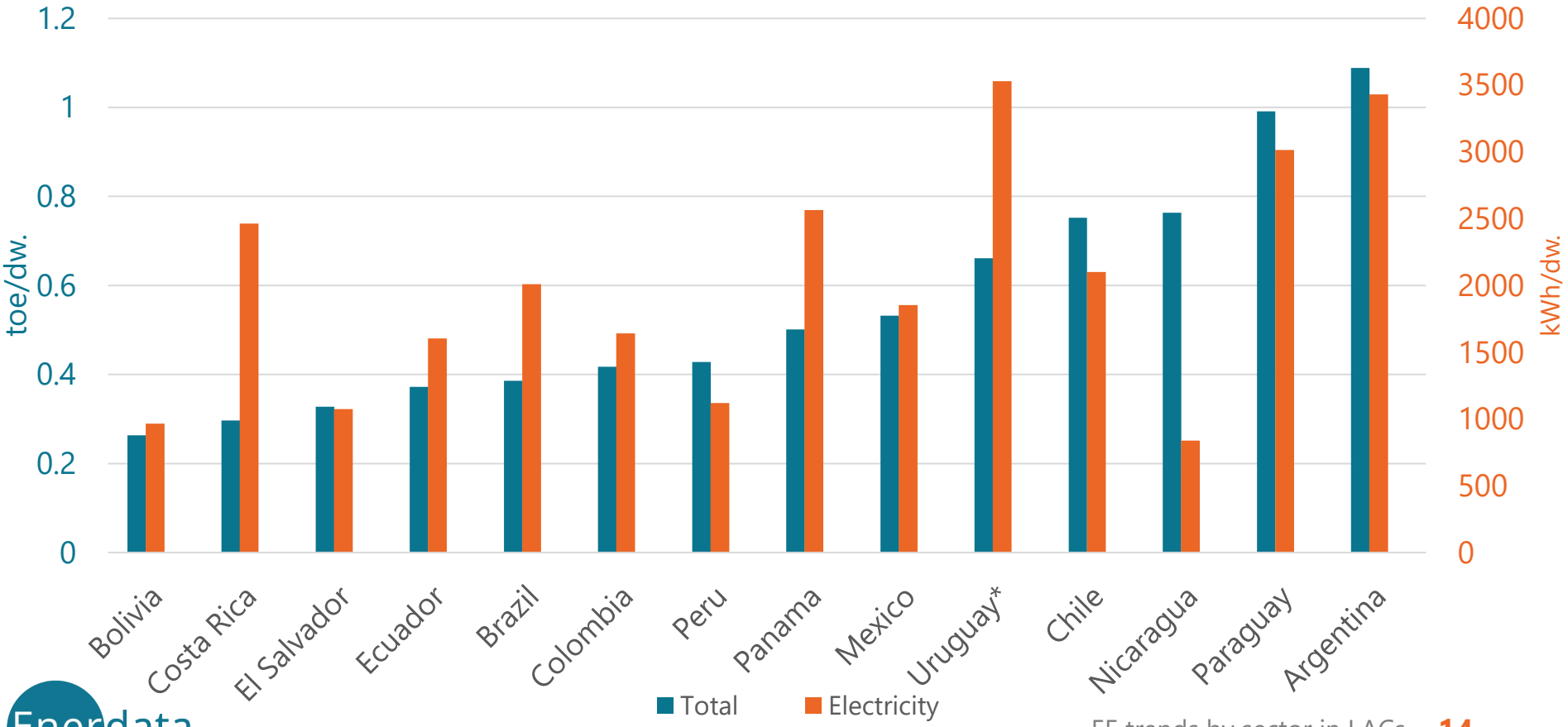


*Uruguay : 2006-2018 Total Electricity

Source: BIEE https://biee-cepal.enerdata.net

- The average unit consumption per household varies a lot among LACs, from 0.26 toe in Bolivia to around 1 toe in Paraguay (because of large use of biomass) and 1.1 toe in Argentina (space heating heating needs).
- The average electricity consumption per household varies from around 850 kWh in Nicaragua to around 3500 kWh in Argentina and Uruguay.

Total and electricity unit consumption per household (2018)



*Uruguay : 2006-2018

Source: BIEE https://biee-cepal.enerdata.net

Interpretation of trends in EEI by sector combining different indicators

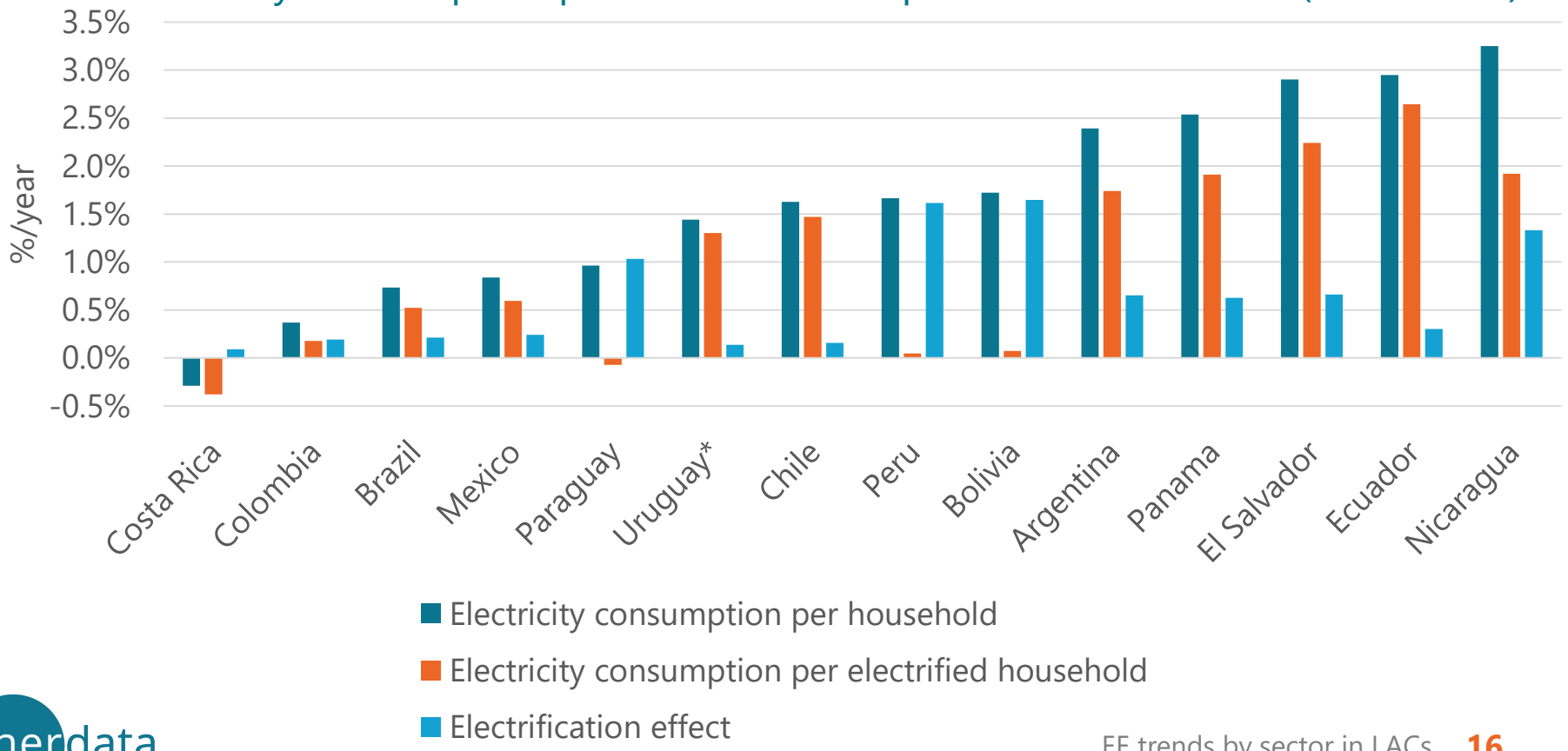
- The interpretation of EEI trends is much enriched by comparing the trends in two different indicators:
  - The observed one
  - And a second indicator that is cleaned from the variation of a factor.

End-use	Indicators to be compared	Interpretation of differences
Cooking	toe/household in useful and final energy	Effect of change in fuel mix
Electricity	kWh per household and kWh per electrified household	Effect of electrification

- In Peru, Bolivia and Paraguay, most of the increase in the electricity consumption per household is due to the electrification of rural households: the consumption per electrified household has almost not changed.

- In Nicaragua, the household's electrification explain 1/3 of the increase in the consumption per electrified household.

Unit electricity consumption per household : impact of electrification (2000-2018)



Source: BIEE https://biee-cepal.enerdata.net

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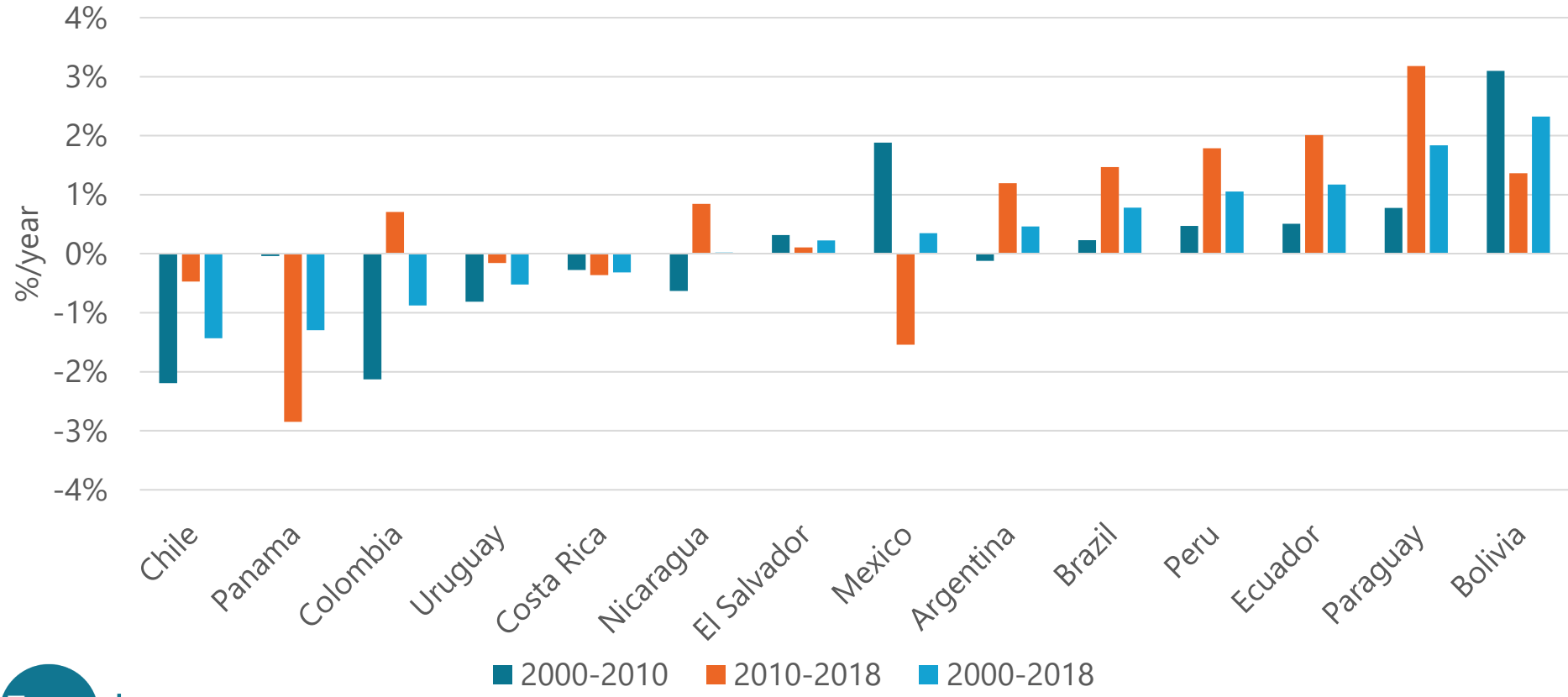
Transport

- Transport consumption grew more rapidly than GDP in two thirds of LACs

- Increasing trends can be explained by several factors:
  - number of road vehicles increasing at a faster rate than economic growth
  - a poor availability of public transport
  - monopoly of road transport for goods.

Trends in transport intensity

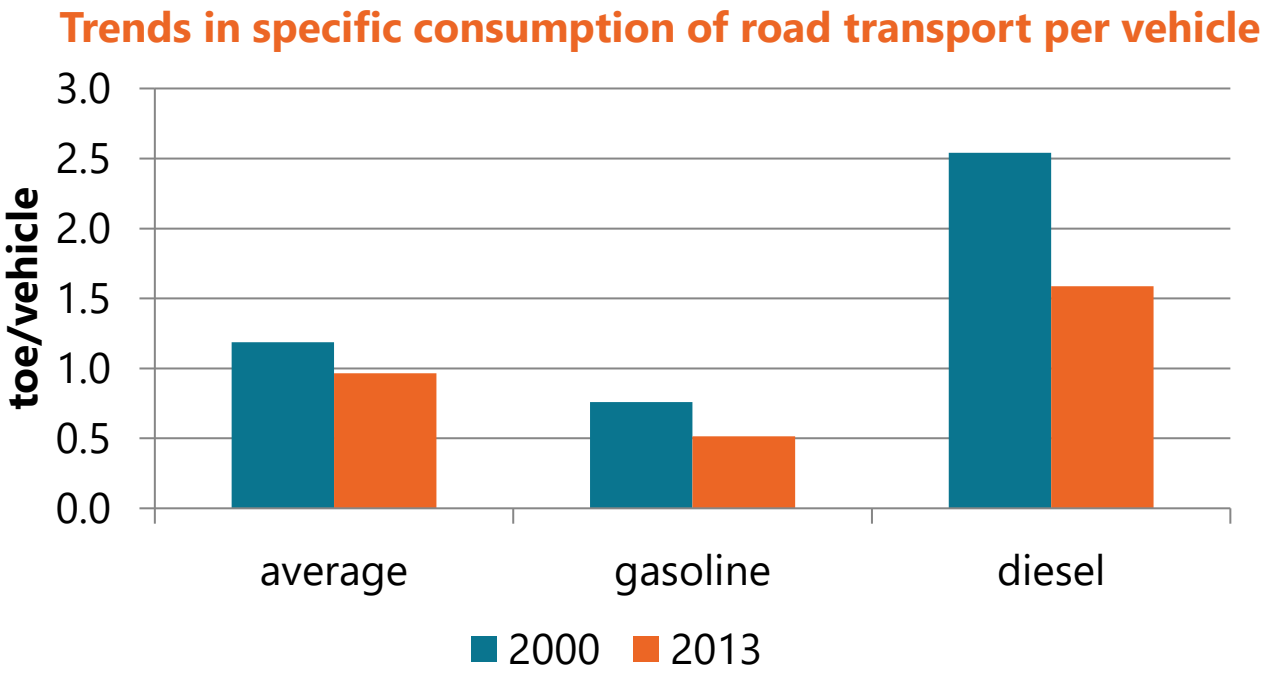


Source: BIEE https://biee-cepal.enerdata.net

Consumption of road transport per vehicle

- General decrease in the average specific energy consumption of road transport per vehicle, due to the increased efficiency of vehicles and to the shift to smaller vehicles in the total stock.

- Strong decrease for diesel vehicles, mainly linked to the rapid growth of the stock of cars and light duty vehicles.



Source: BIEE https://biee-cepal.enerdata.net

Interpretation of trends: combination of EEI by sub-sector: transport sector

- For road transport we can indicator a specific energy consumption of road transport per vehicle.

- Such an indicator is generally decreasing, due to the increased efficiency of vehicles , but also and to the shift to smaller vehicles in the total stock (higher share of cars or even motorcycles) .A better aggregate indicator is the **specific consumption of road transport per equivalent car**, which relates the total consumption of road transport to a fictitious stock of vehicles, measured in terms of number of equivalent cars*.

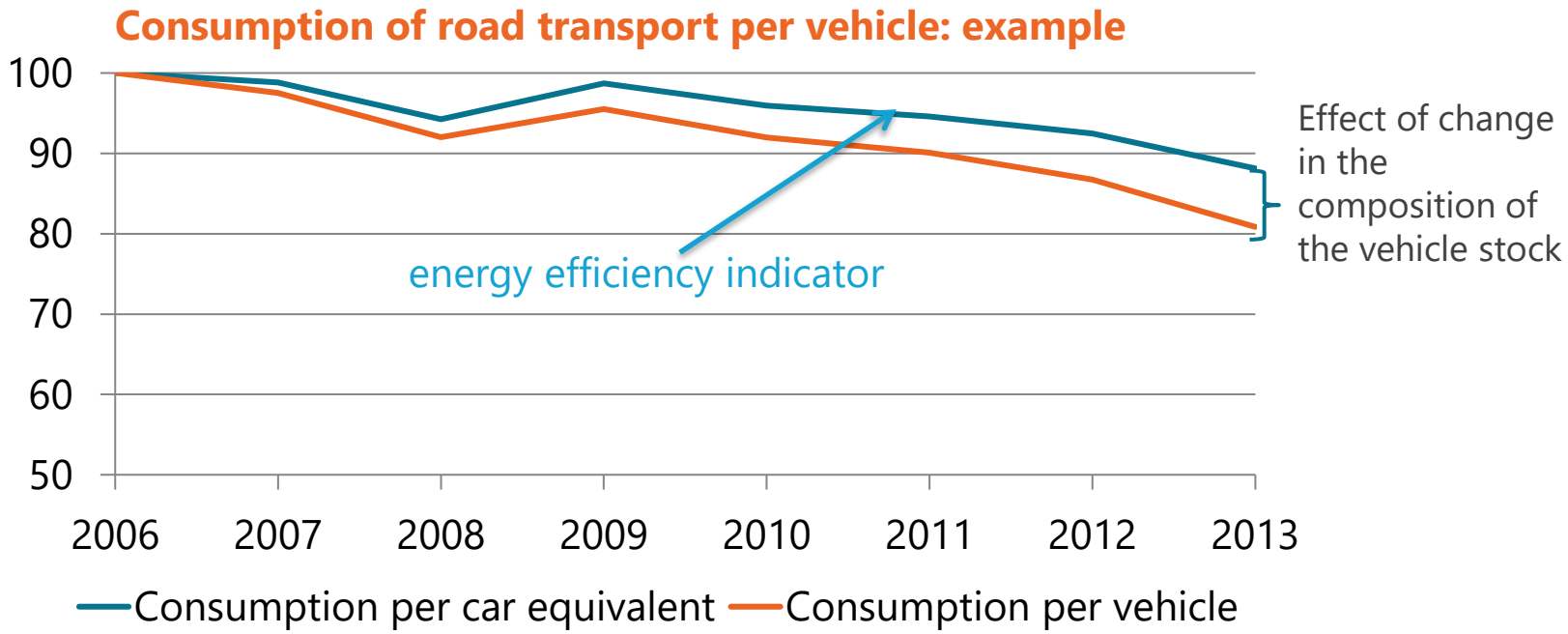
End-use	Indicators to be compared	Interpretation of differences
Road transport	Consumption per vehicle and consumption per equivalent car	Effect of change in the mix of road vehicles between light and heavy vehicles

**For instance, if a motorcycle consumes 0.2 toe/year on average and a car 1 toe/year, one motorcycle is considered to be equivalent to 0.2 cars. If buses consume 10 toe/year , they are equivalent to 10 cars.*

Consumption of road transport per car equivalent

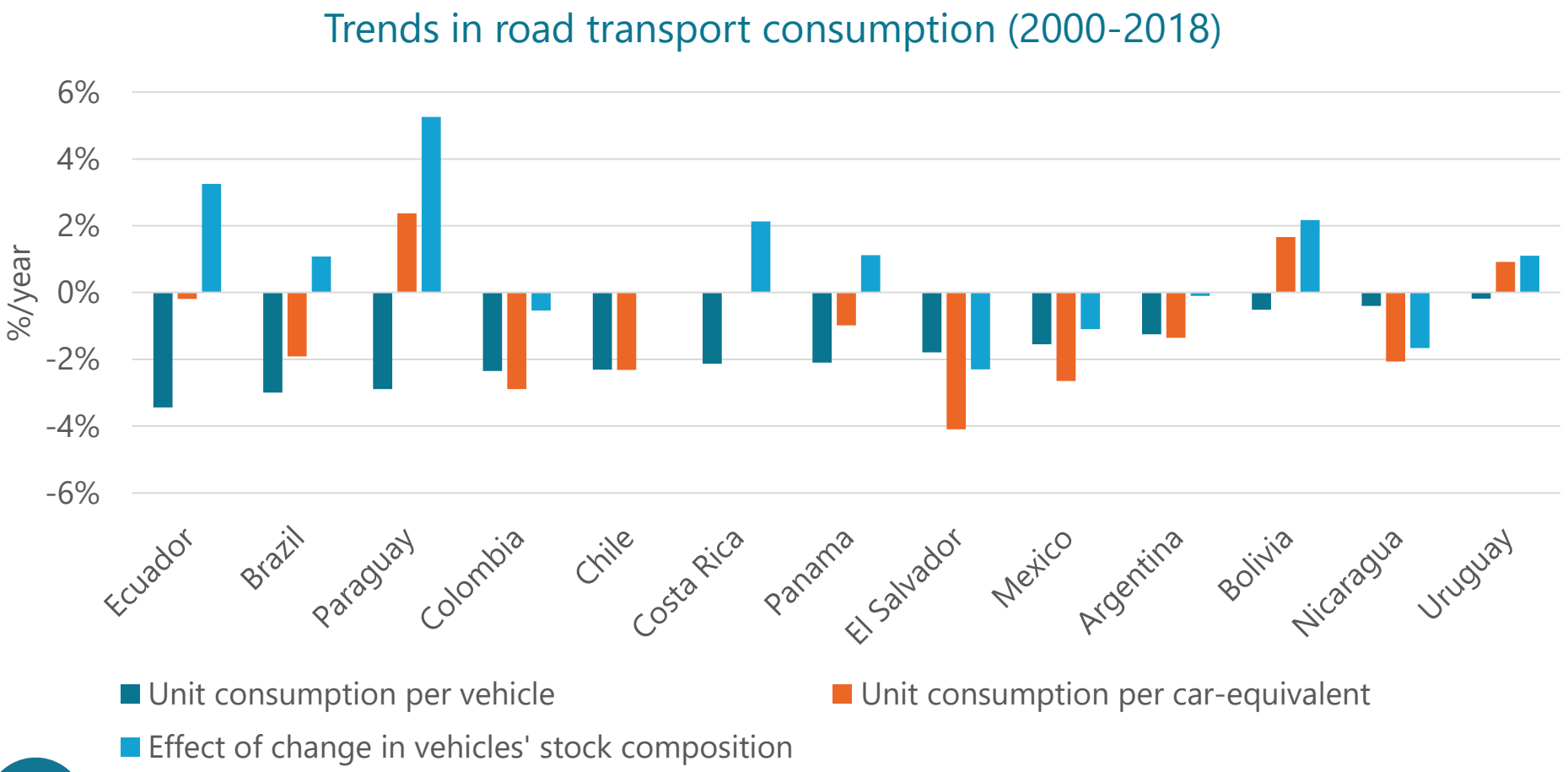
- In the example, the consumption of road transport per car equivalent decreased by 0.8%/year since 2006 (proxy of energy efficiency).

- This consumption per car equivalent has been decreasing twice less rapidly than the consumption per vehicle (1.5%/year compared to 0.8%/year) ➔ the growth in the share of light vehicles in the total stock explains half of the reduction in the consumption per vehicle.



- In all countries, the unit consumption per vehicle is decreasing, often thanks to changes in vehicles' stock composition, especially in Paraguay and Ecuador.

- Decreasing trends overall reflect mainly improvements in energy efficiency of all vehicles.



Source: BIEE https://biee-cepal.enerdata.net

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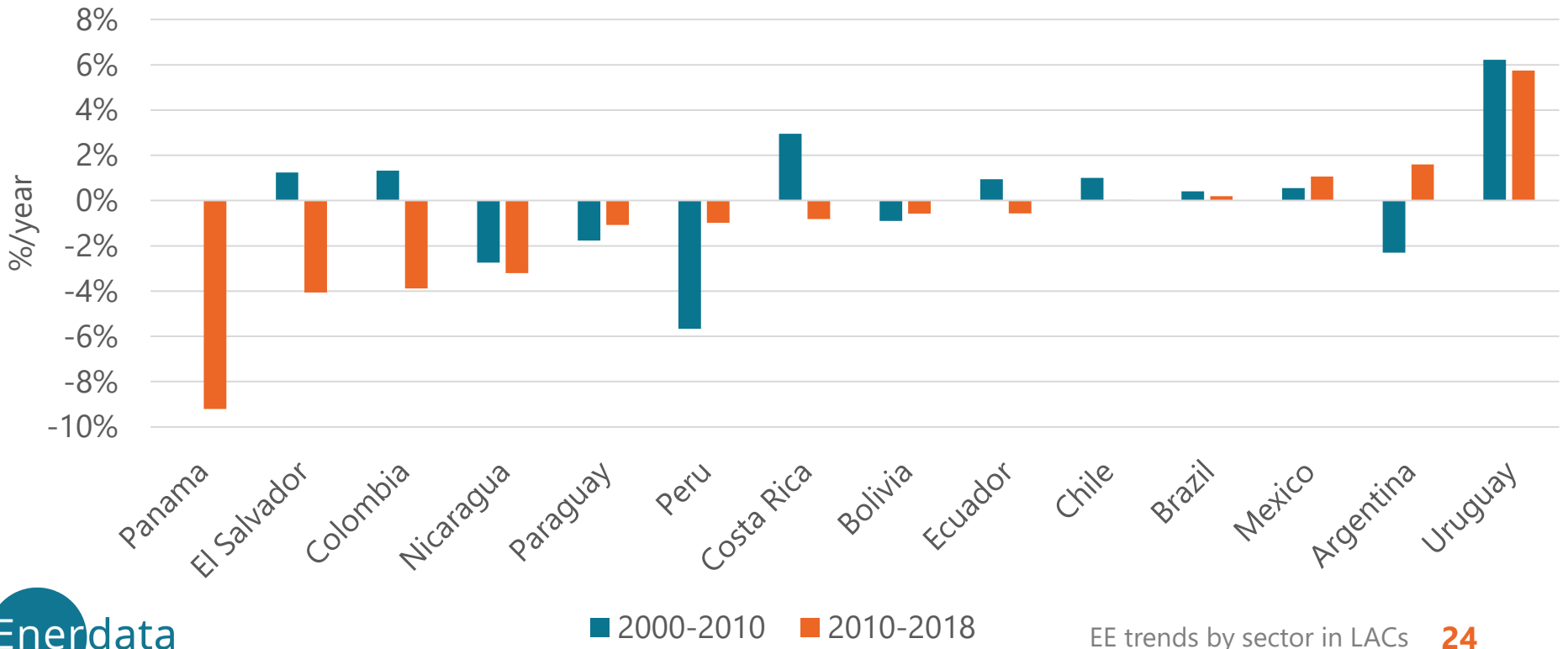
Industry

- Decreasing energy intensities are observed in most countries, reflecting a growing share of less intensive industrial branches.
- Uruguay is an exception with a sharp increase in the energy intensity, following the commissioning of a large paper mill combined to a chemical plant (2008).
- Argentina, Mexico, and Brazil also have a more intensive industry structure.
- Part of these variations may be due to structural changes in industry (see Annex 1)

Trends in industry intensity



Source: BIEE https://biee-cepal.enerdata.net

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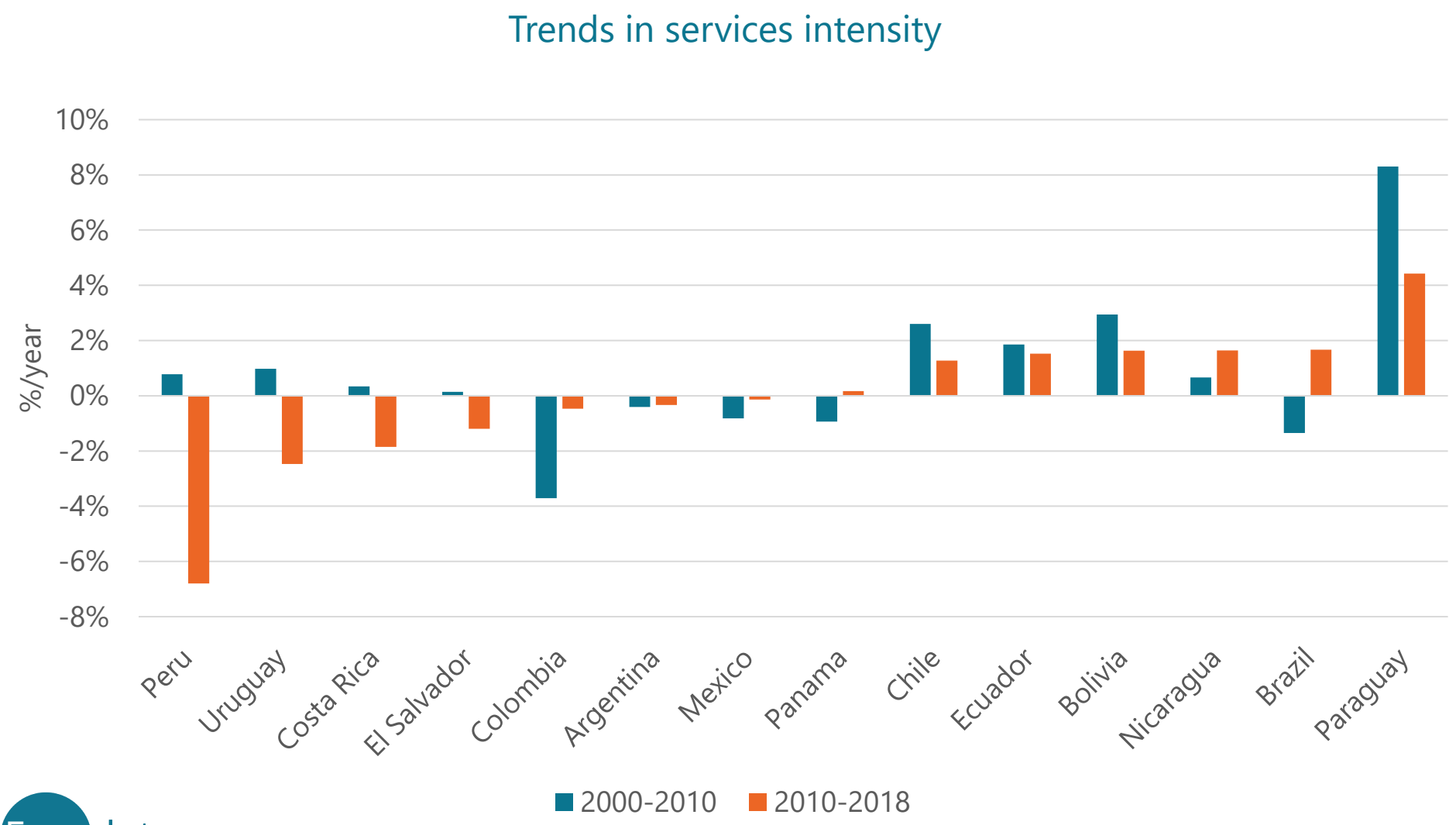
Services

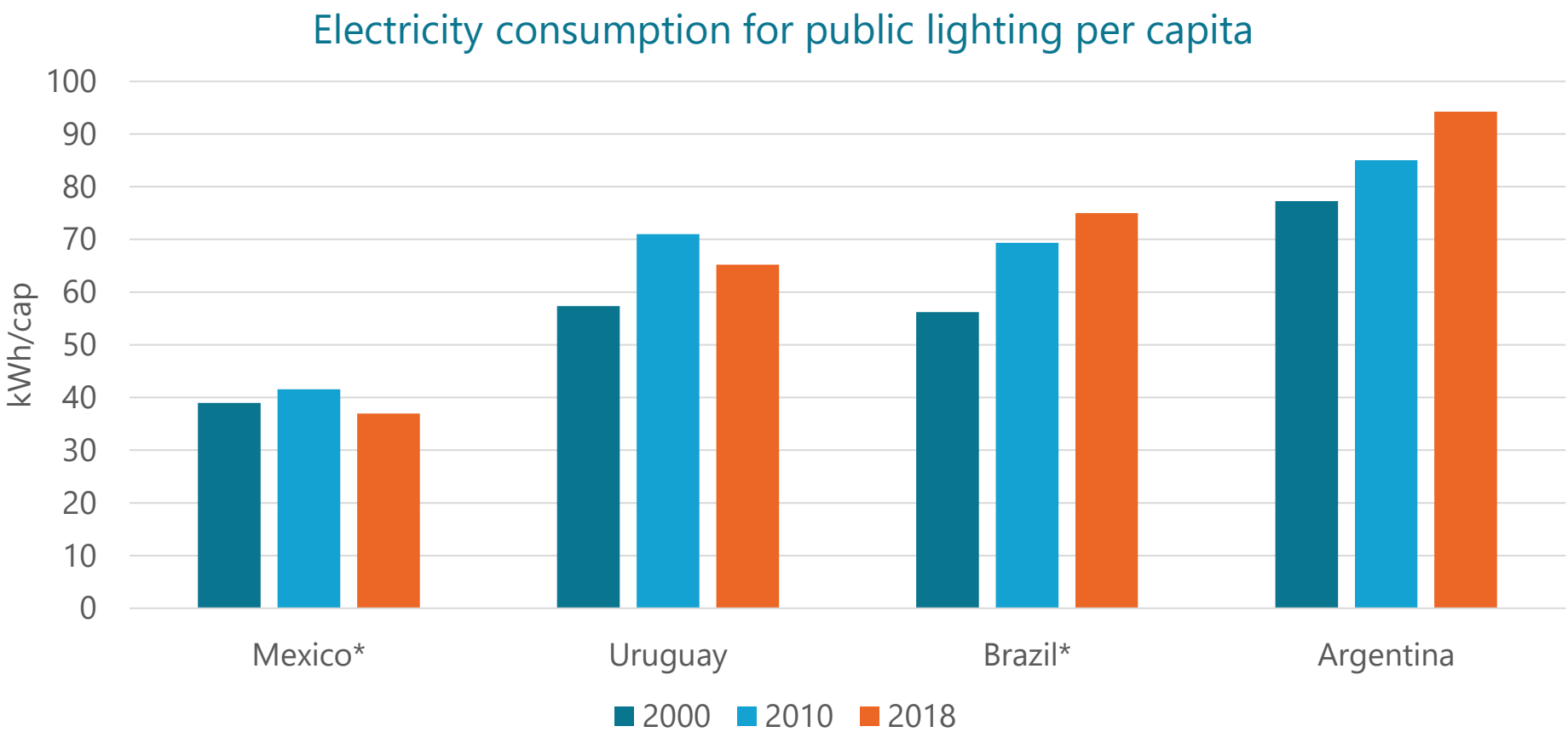
- The trends in energy intensity of services vary significantly across LAC countries from around -6.8%/year in Peru to +4.4%/year in Paraguay.



Source: BIEE https://biee-cepal.enerdata.net

- Since 2010, the electricity consumption for public lighting per capita has started decreasing in Mexico and Uruguay and is progressing slower in Brazil, probably as a result of national energy savings policies.

- It is still increasing in Argentina.



*Mexico : 2002-2018 *Brazil : 2004-2018

Source: BIEE https://biee-cepal.enerdata.net

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Conclusion

From simple energy efficiency indicators to advanced indicators

- Usual energy efficiency indicators are useful to describe trends, but cannot explain the observed trends.
- For instance the energy consumption per household shows how the overall energy efficiency of households is changing but a decrease does not necessary mean that energy efficiency is improving from a technical viewpoint.
- To enrich the interpretation and better monitor energy efficiency trends, more complex indicators are needed ("advanced indicators").
- These indicators need more disaggregate data: by household end-use, by mode of transport, by industrial branch….
- Such data are still limited in the majority of LACs: they are well monitored in Brazil, Mexico and Uruguay; they are being updated for a few other countries.
- Advanced indicators will be presented in the next meeting ,

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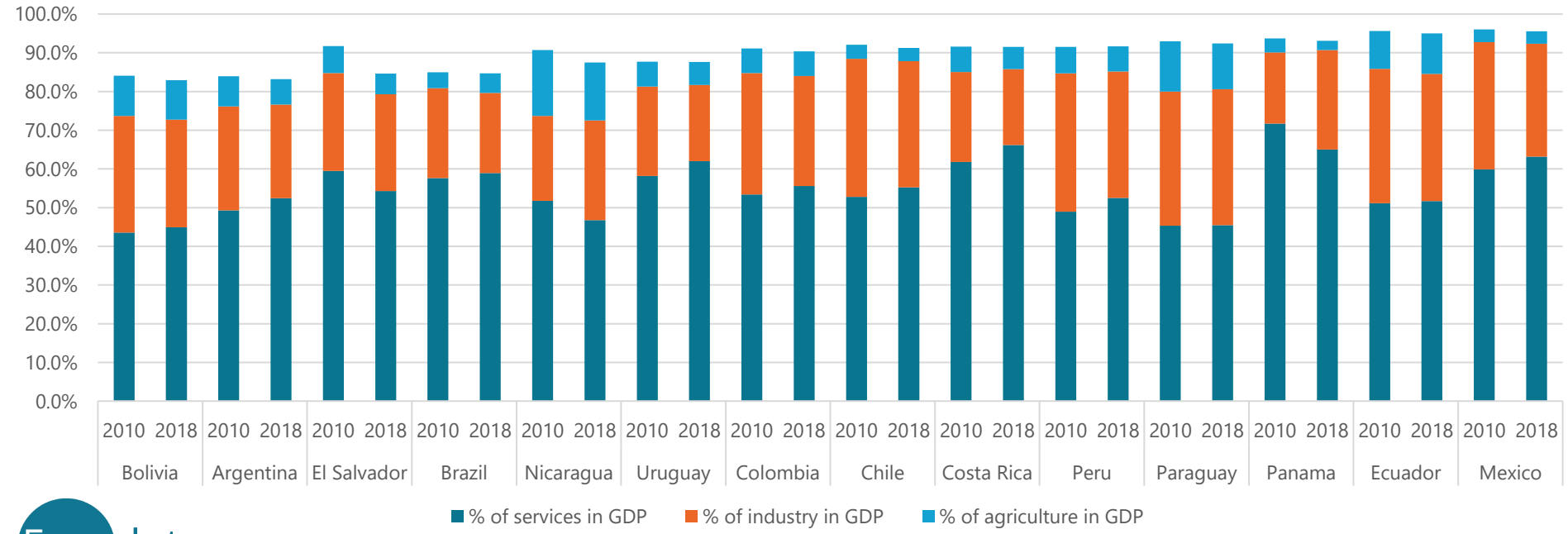
Annex 1: How to measure the impact of structural changes in the economy an industry

Impact of structural changes in the economy an industry on energy intensities

- Change in economic structures, i.e. in the share of sectors in the GDP (agriculture, industry, services) impact the final energy intensity, which has nothing to do with energy efficiency .
- If the share of services in the GDP increases, which is generally the case in most countries, this reduces the final intensity, as services have a much lower intensity than industry or agriculture.
- If the share of industry increases, this will raise the intensity.
- The same phenomenon also exist within industry: if the share of less intensive branches in the tola value added of industry increases, this will lower the energy intensity of industry, all things being equal .

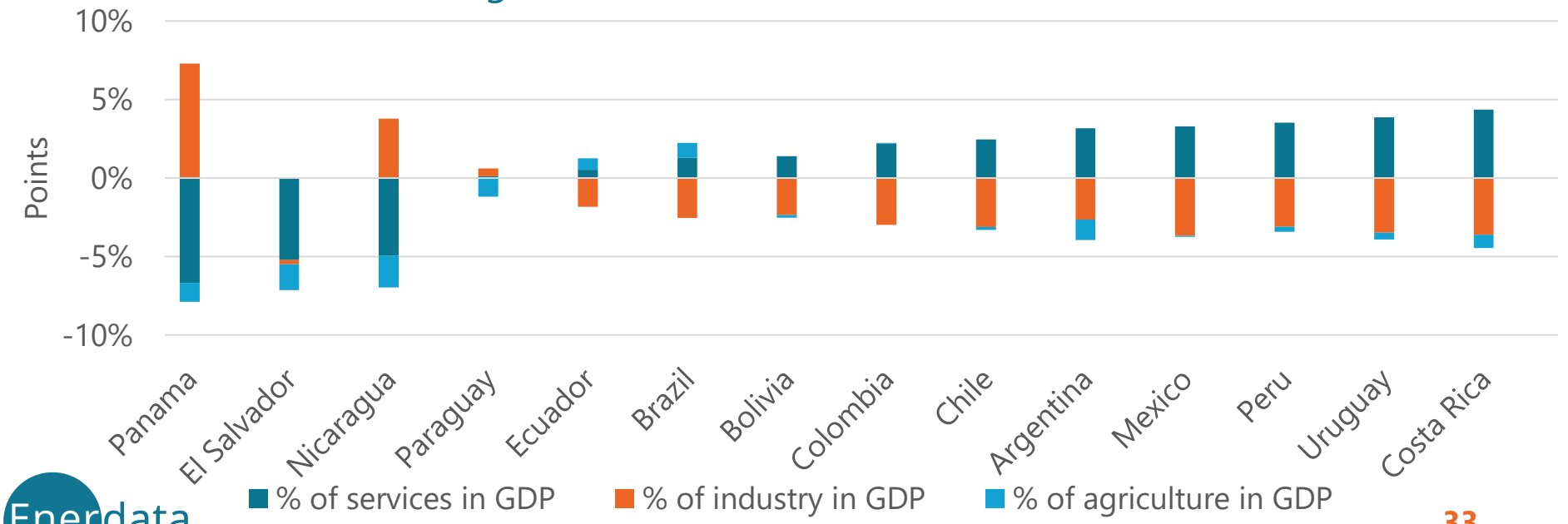
Change in economic structures (“structural changes”) are characterised by changes in the share of sectors in the GDP (agriculture, industry, services) .

Structural changes: variation of the sectors’ share in GDP



- Since 2010, structural changes were significant in 9 countries:
  - Higher share of less intensive sectors in 7 countries (Colombia, Chile, Argentina, Mexico, Peru, Uruguay and Costa Rica), with an increase in the share of services by more than 3 points implying a contribution to decrease the final intensity.
  - Reverse trend with an increase in the share of industry in Nicaragua and Panama, which contribute to raise the final intensity.

Structural changes: variation of the sectors' share in GDP (2010-2018)



Source: BIEE https://biee-cepal.enerdata.net

Measuring the impact of structural changes in the economy or industry

- To quantify the impact of structural changes on the energy intensity of industry or final intensity, a simple approach is to calculate a fictive energy intensity at constant structure, i.e. assuming that the structure did not change compared to a base year (i.e. 2010 here)*.

- This intensity at constant structure (IES) is calculated at year t with the sectoral intensities of year t and the value added structure of the base year (2010):

$$IES_t = \Sigma(VAi/VA)_{2010} * (Ei/VAi)_t$$

- This intensity at constant structure is a better indicator of energy efficiency than final intensity, as structural changes have nothing to do with energy efficiency.

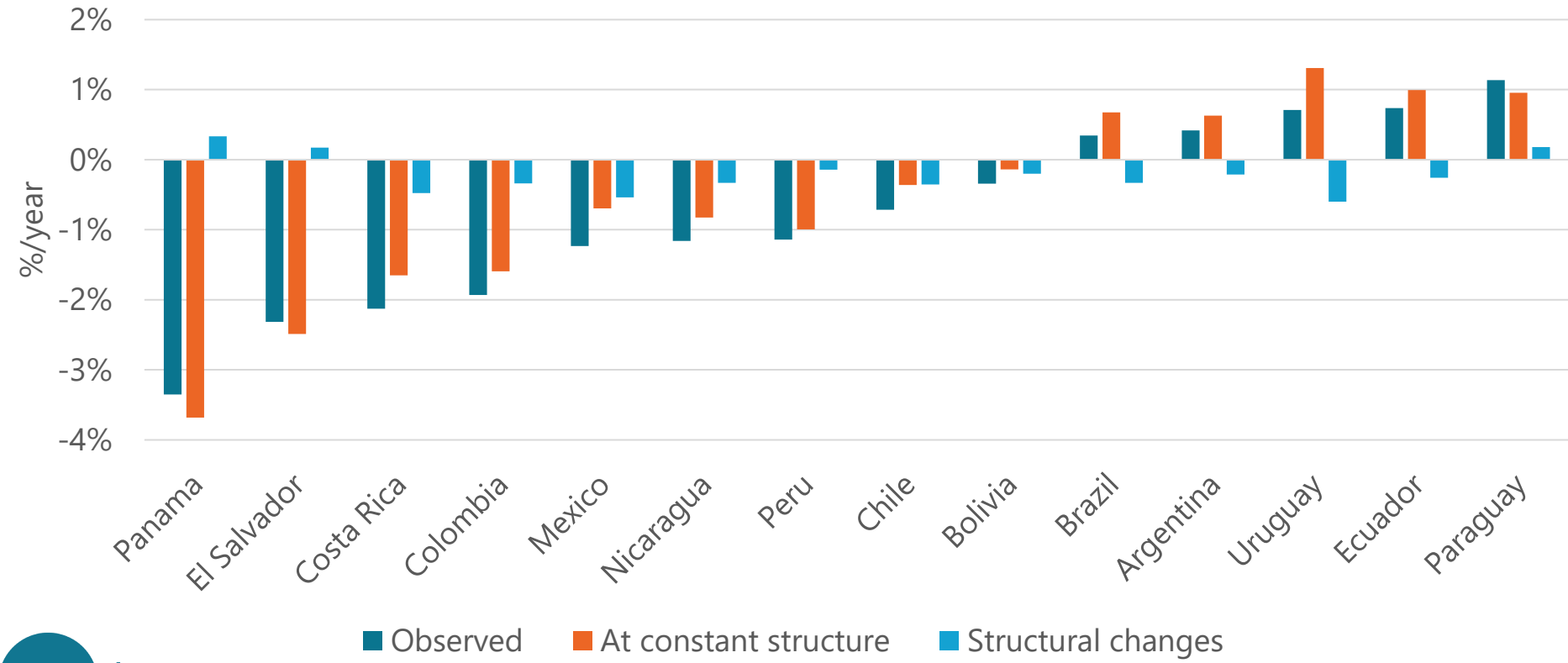
- Comparing the trend in the actual intensity with that of the intensity at constant structure measures the impact of structural changes.

*A more accurate calculation is to use the Divisia approach using the structure at t-1 as reference (i.e. moving reference structure)

- The impact of structural changes were generally marginal in most LACs over the period 2010-2018.

- They may vary from one year to the other and should always be considered to well understand the observed trends in energy intensity.
- They were mainly visible in Uruguay and Mexico.

Impact of structural changes in the GDP on the final intensity (2010-2018)

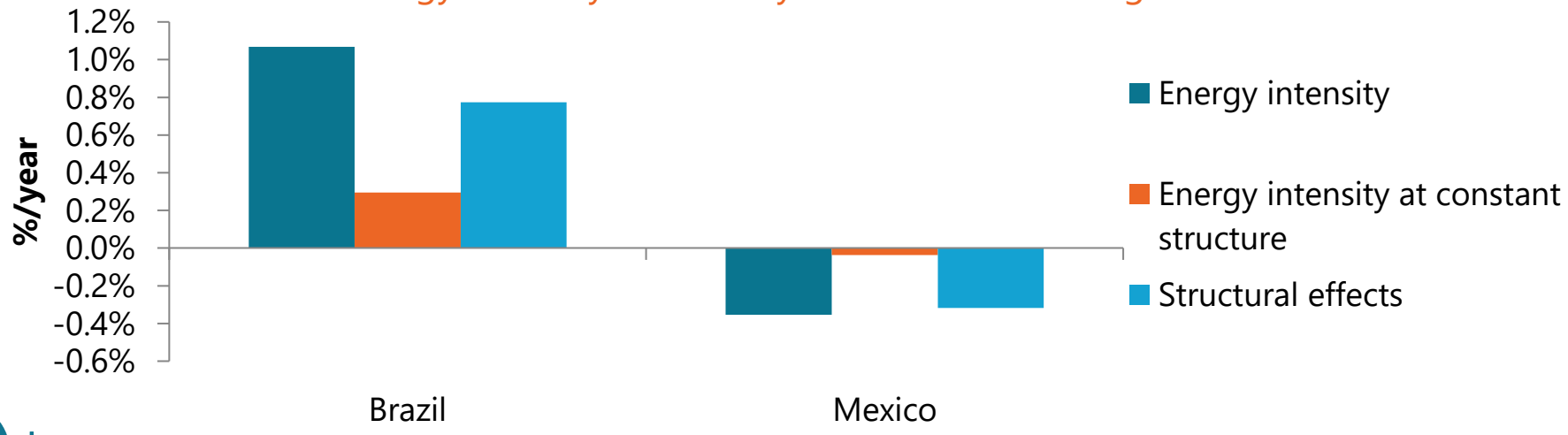


Source: BIEE https://biee-cepal.enerdata.net

Impact of structural changes on industry intensity

- All industrial branches do not require the same amount of energy inputs to produce 1 € of value added. Some are more energy intensive than others.
- Industrial growth is not uniform: some branches grow faster than others and, as a result, the share of each branch in the total value added of industry change over time: this is what is called **structural changes**.
- If less energy intensive branches grow faster than energy intensive ones, this will reduce the energy intensity of industry, and this is not linked to energy efficiency improvements.
- In the example below, the energy intensity of Mexico's industry decreased by 0,4%/yr; at constant structure, it would have only slightly decreased (less than -0,1%/yr) ➔ structural changes towards less energy intensive branches contributed to decrease the energy intensity by 0,3%/yr, which explain 80% of the reduction.

Energy intensity of industry and structural changes



Source: BIEE https://biee-cepal.enerdata.net

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Annex 2: Overview of BIEE indicators

BIEE indicators to monitor energy efficiency

- BIEE indicators are of two kinds:
  - Simple indicators that can be easily calculated for all countries.
  - Advanced indicators, that are more powerful to explain the role of energy efficiency, but require more detailed data (e.g. by end-use or type of vehicles).

- The simple indicators relate by sector the energy consumption to an indicator of activity, measured :
  - either in monetary units (GDP, Value Added) ➔ energy intensities (e.g. kWh/€, toe/€);
  - or in physical values (tons, employee, m2), usually at sub sector level ➔ specific or unit energy consumption.

- These simple indicators can also include indicators of market penetration of energy saving technology or practice.

Examples of simple sectoral energy efficiency indicators

Types of indicator	Examples
Energy intensity	Indicators in monetary value related to GDP or value added (e.g. toe/€2015)
Specific/ unit energy consumption	litre/100km, household electrical appliance (kWh/year), heating consumption per m^2 or household (eg kWh/m^2 or household), consumption per employee or m2 in services (eg kWh/m^2 or /employee)
Market penetration of energy saving technology or practice	Share of public transport for passengers, of rail/water for goods, of solar water heaters, of cogeneration, of LED etc…

Monitoring policies with EEI : why are so many indicators needed?

For a given sector or end-use several indicators can be considered, for different reasons:

- Energy efficiency has different meaning and frontiers (economic versus technical efficiency).

- EE P&Ms are designed and implemented at the level of end-use and equipment (e.g. labels or standards on heating, lighting), or branch (e.g. voluntary agreements, audits). Therefore, the monitoring of each P&M requires detailed indicators (eg kWh/m2 for new buildings with building codes; kWh per refrigerators for labels/standards; gCO2 or toe per km for Bonus-malus).

- Interpretation of indicators is more powerful when combined; for instance comparing trend in energy use per household and per m2 will show the impact of change in dwelling size.

- Alternative indicators are often necessary to cope with possible data gaps.

Six types of advanced energy efficiency indicators

1. Energy efficiency index to measure EE improvements at sector level.
2. Energy savings to quantify the amount of energy saved at sector level.
3. Financial indicators to show the financial benefit of energy savings.
4. Avoided CO2 emissions to show what is the effect of energy efficiency improvement on CO2 emissions.
5. Benchmarking indicators to compare energy efficiency performances among countries.
6. Decomposition analysis to explain energy consumption variation over a period.

What use of EE indicators?

- All countries aim to increase energy efficiency, especially in the context of climate policies : the question is how to express this goal, i.e. to set targets, and how to monitor trends in energy efficiency, i.e. whether countries are going to reach their targets .

- EEI are also used to assess the impact of the policy and measures implemented, i.e. for policy monitoring.

- They enable to understand trends in energy consumption and in the penetration of EE technologies and practices (i.e. "market insights").

- They are also useful to compare countries and identify the best practices.

- Finally they have different other benefits, such as to help organising the information, provide reference data for forecasting long term energy demand, for dissemination purposes and for showing the multiple benefits of energy efficiency

Aggregate macro indicators: interpretation of trends in total energy intensities

Indicators to be compared	Interpretation of differences
Primary and final energy intensities	Effect of change in the power mix
Final intensity and final intensity at constant structure	Effect of change in the GDP structure (% of industry, agriculture and services in the GDP)

- *Final energy intensity: relates the final energy consumption of to the GDP: it assesses energy efficiency at the level of final consumers, i.e. of industry (excluding energy industries), transport, households, services & agriculture*
- *Difference primary / final energy intensity: consumption and losses in energy transformations , mainly in power sector.*

Aggregate sectoral indicators: households

Indicator	Comment
Energy consumption per household	Very aggregate; includes change in equipment ownership
Electricity consumption per household	Very aggregate; includes change in equipment ownership and electrification
Electricity consumption per electrified household	Very aggregate; includes change in equipment ownership
Energy consumption of dwelling per unit of private consumption (energy intensity)	Very aggregate ; measures the relative variation between energy use by household and their private consumption (a proxy for income)

Private consumption of households: key indicator of macro economic accounts; corresponds to the household final consumption expenditure;

Aggregate sectoral indicators: industry

Indicator	Comment
Energy intensity of industry (Energy consumption/VA)	Very aggregate; includes change in industry structure and other economic influences.
Energy intensity of manufacturing	Same as above but restricted to the most energy intensive part of industry (i.e. manufacturing).
Unit consumption of industry related to IPI	Very aggregate; includes change in industry structure
Unit consumption of manufacturing related to IPI	Same as above

Industry includes manufacturing, construction and mining
VA: value Added
IPI: Industrial Production Index.
Note: Output value not a good indicator= VA +value of inputs (which can vary a lot with the price of inputs)

Aggregate sectoral indicators: transport

Indicator	Comment
Energy consumption of transport per capita	Very aggregate ; includes change in vehicles ownership
Energy intensity of transport to GDP	Very aggregate ; measures the relative variation between energy use and GDP
Energy consumption of road transport per vehicle	Includes change in mix of vehicles
Gasoline consumption of transport per gasoline vehicle (including LPG biofuels)	Includes change in mix of vehicles
Diesel consumption of transport per diesel vehicle (including biofuels)	Includes change in mix of vehicles

Aggregate sectoral indicators: services

Indicator	Comment
Energy intensity of services	Very aggregate ; includes change in equipment ownership
Energy consumption per employee	Indicator more interesting than energy intensity as a great part of consumption is directly related to the number of employees (case of ICTs) or linked to the floor area (e.g. heating, AC, lighting), thus somehow to the number of employees, as the ratio m2/employee are changing slowly.
Energy consumption per m2	Implies to have the total floor area

ICTs: Information and Communication Technologies)

Content Table

Annex 3: Why using purchasing power parities for comparing energy intensities

Adjustment for price differences: use of purchasing power parities

- For countries' comparison, energy intensities are measured in the same monetary unit (€, $) by converting national currencies in €,$.

- Conversion with market exchange rates raises two problems:
  - Market exchange rates can vary quite a lot independently of the economic performance of countries which affect the relative energy intensity values between countries (their "ranking") ;
  - The conversion does not reflect the fact that in less developed countries consumer prices are on average much lower than in more developed countries

- The use of Purchasing Power Parities (PPP) improve the comparison as it does not fluctuate and accounts for the real purchasing power of incomes.

- PPP are provided by international organizations (e.g. World Bank, IMF).

Why using Purchasing Power Parities for cross country comparisons of energy performance ?

- Let us take 2 factories producing cars : one in France and one in Romania, with the same technical performance, i.e. the same energy input by car produced (in toe or GJ per car).

- The value added of each car is mainly made from salaries (capital costs and profits also included), whose relative level across countries are mainly influenced by the average difference in the cost of living (around 2 times lower for Argentina)

➔ With the same technical performance, the energy used per unit of value added (« energy intensity ») for the car industry will be twice higher in Argentina than in France with exchange rates but the same at ppp.

➔ Energy intensities differences at ppp are closer to differences in technical performance.