



fib
feria internacional
industrial de Bogotá
XXXIII

The Energy Transition as a Business Opportunity

Alain Clappier



Effects of Climate Change



fib
feria internacional
industrial de Bogotá
XXXIII

2022: heat wave, record temperature, drought and fires

France 2022



Recurrent heat waves and record droughts have put forests and the wildfires engulfing them at the heart of this summer's political news cycle. This urgency has been illustrated by the data provided by the European Forest Fire Information System, on Tuesday, August 2. **47,286 hectares have already burned in France** since January in 243 fires, **more than for the entire year of 2019, the most intense of the decade, where 43,602 hectares was lost in 12 months.**

Published on August 4, 2022 in "Le Monde"

Effects of Climate Change



fib
feria internacional
industrial de Bogotá
XXXIII

2021: Extreme rainfall and flooding

Germany and Belgium 2021



More than 200 people killed and billions of euros worth of damage: the heavy toll of the floods that ravaged Germany and Belgium in mid-July must be blamed on climate change. According to a study published on Tuesday, August 24, **this extreme episode was made up to 9 times more likely by warming due to human activity.** Climate change also "increased the amount of rainfall on a day by between 3% and 19%," according to scientists at the World Weather Attribution (WWA), which includes experts from various research institutes around the world.

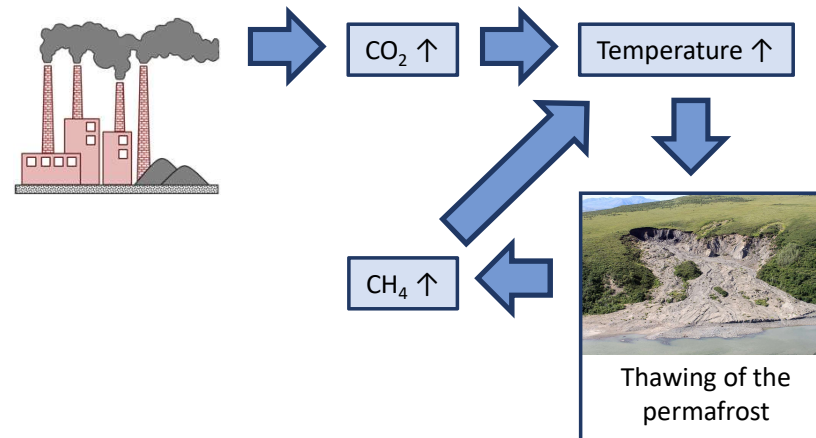
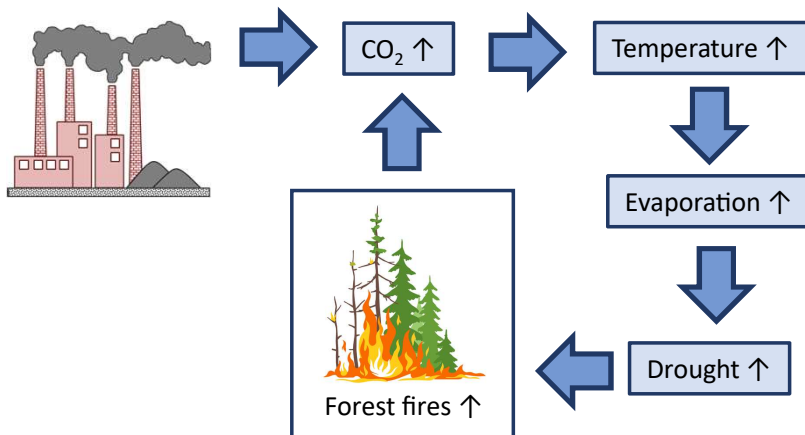
Published on August 24, 2021 in "Le Monde"

Effects of Climate Change

Why are the IPCC conclusions optimistic?

Climate scientists had predicted global warming, more intense droughts and more frequent extreme precipitation, but the change appears to be faster than expected.

- ❑ Several processes are not included (or partially included) in the climate models



Effects of Climate Change

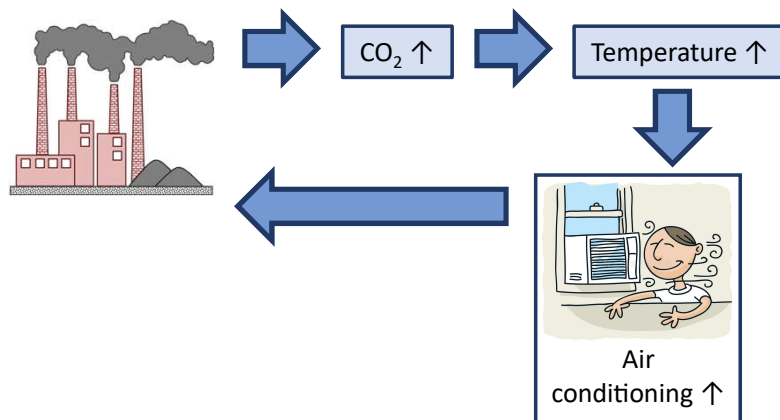


fib
feria internacional
industrial de Bogotá
XXXIII

Why are the IPCC conclusions optimistic?

Climate scientists had predicted global warming, more intense droughts and more frequent extreme precipitation, but the change appears to be faster than expected.

- ❑ Several processes are not included (or partially included) in the climate models



Effects of Climate Change



fib
feria internacional
industrial de Bogotá
XXXIII

Why are the IPCC conclusions optimistic?

Climate scientists had predicted global warming, more intense droughts and more frequent extreme precipitation, but the change appears to be faster than expected.

- Several processes are not included (or partially included) in the climate models
- At large scales (i.e. global scale), computational fluid dynamics models linearize reality.**

Effects of Climate Change



fib
feria internacional
industrial de Bogotá
XXXIII

Why are the IPCC conclusions optimistic?

Climate scientists had predicted global warming, more intense droughts and more frequent extreme precipitation, but the change appears to be faster than expected.

- Several processes are not included (or partially included) in the climate models
- At large scales (i.e. global scale), computational fluid dynamics models linearize reality.
- The IPCC scientists already have a hard time convincing politicians and the population with the current messages, it would be even harder with more pessimistic messages.**

The World is Changing



fib
feria internacional
industrial de Bogotá
XXXIII

Changes that we will undergo

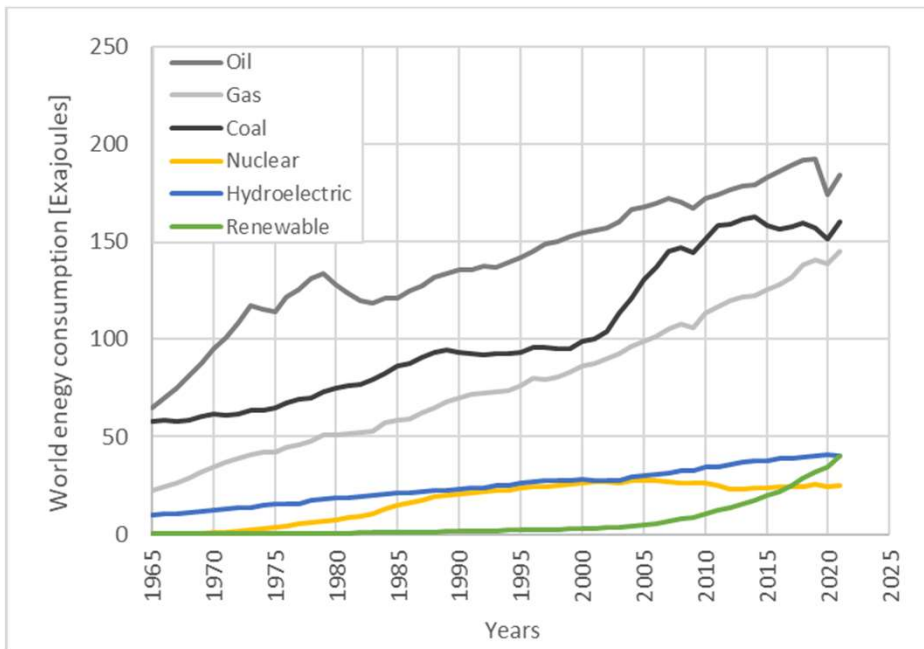
- World agricultural production will be increasingly affected
- Biodiversity will be reduced more and more
- Entire regions will become uninhabitable resulting in the migration of hundreds of millions of people

The World is Changing



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Our economy is changing to mitigate the causes of global warming (especially in the energy sector)



Renewable energy consumption is the consumption that is growing the most during the last 10 years (especially wind and solar)

	2011-2016	2016-2021
Oil	0.7%	-0.1%
Gas	1.0%	1.4%
Coal	-0.1%	0.2%
Nuclear	-0.4%	0.5%
Hydroelectric	1.1%	0.4%
Solar	38.5%	20.8%
Wind	11.2%	8.9%
Geothermal, biomass	3.9%	3.7%

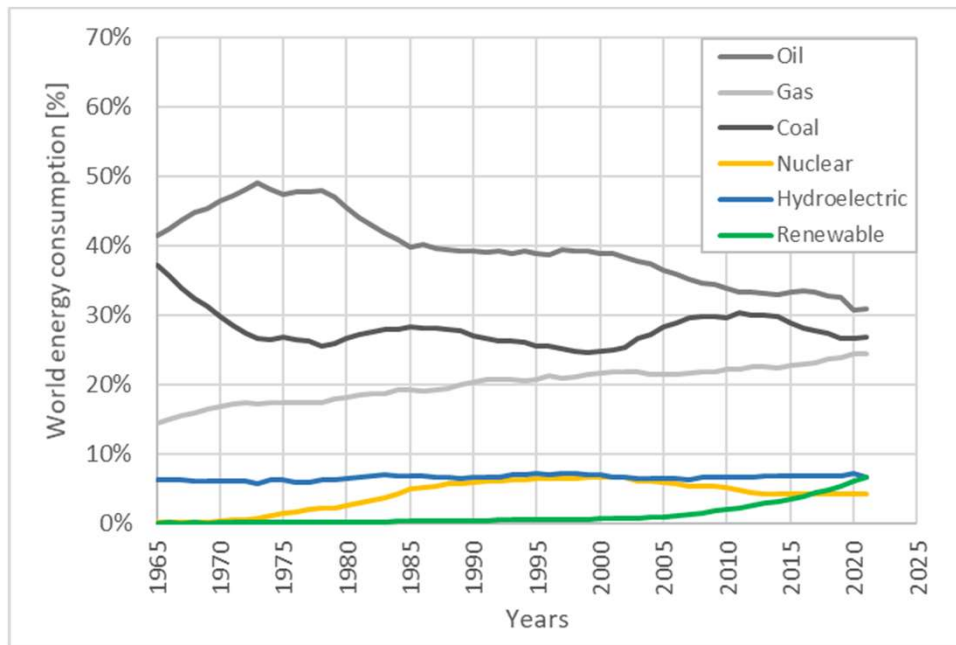
from BP Statistical Review of World Energy 2021

The World is Changing



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Our economy is changing to mitigate the causes of global warming (especially in the energy sector)



Renewable energy consumption is the consumption that is growing the most during the last 10 years (especially wind and solar)

	2011-2016	2016-2021
Oil	0.7%	-0.1%
Gas	1.0%	1.4%
Coal	-0.1%	0.2%
Nuclear	-0.4%	0.5%
Hydroelectric	1.1%	0.4%
Solar	38.5%	20.8%
Wind	11.2%	8.9%
Geothermal, biomass	3.9%	3.7%

from BP Statistical Review of World Energy 2021

The World is Changing



fib
feria internacional
industrial de Bogotá
XXXIII

How will these changes affect Colombia

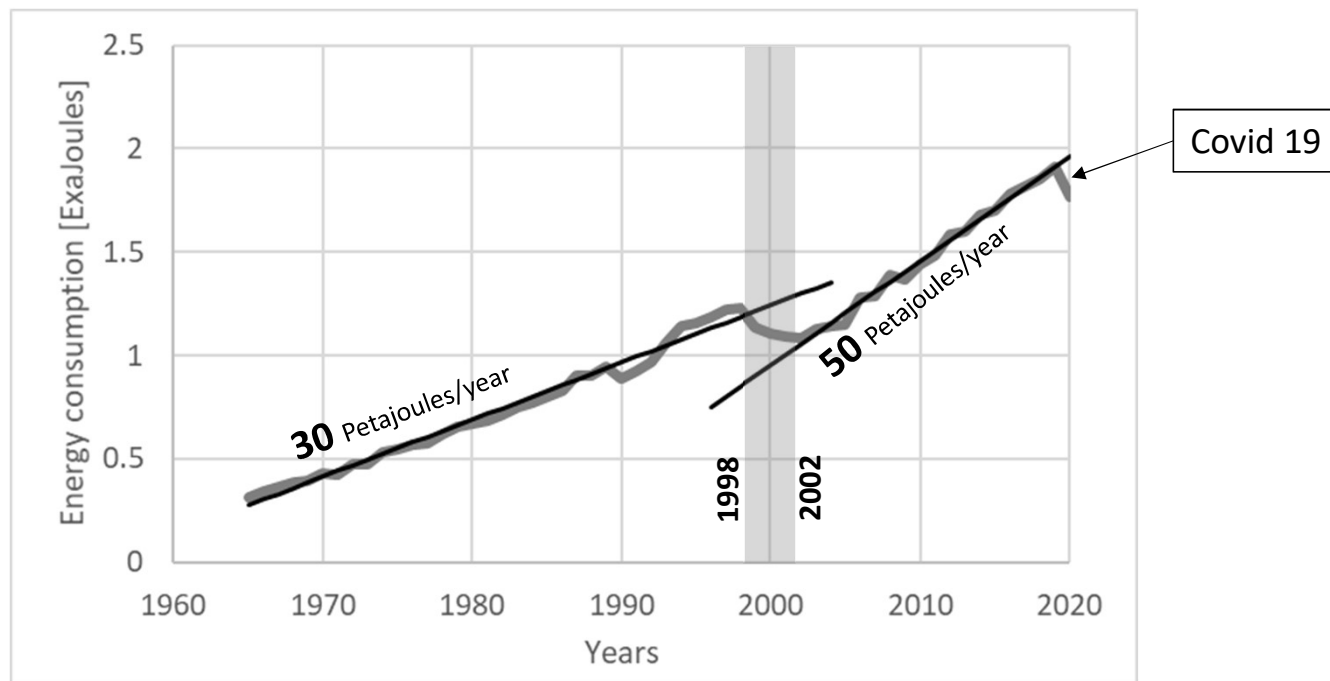
and how can the country adapt?

Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

Energy demand is increasing in Colombia



Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

Electric technologies are disrupting the transportation sector.

90% of new cars sold in Norway are now electric or plug-in hybrids

The goal is to get to 100% EV sales by 2025.



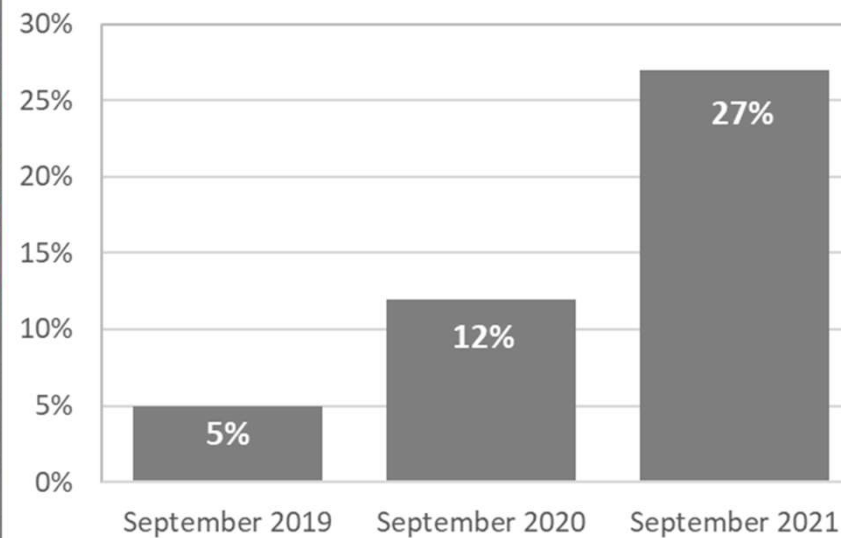
[Photo: bruev/Stock]

Tesla Model 3 Was The Top Selling Model In Europe In September

It's the first time ever when an all-electric car is also the best selling car in a month.



Percentage of EV Cars Sales in Europe-26

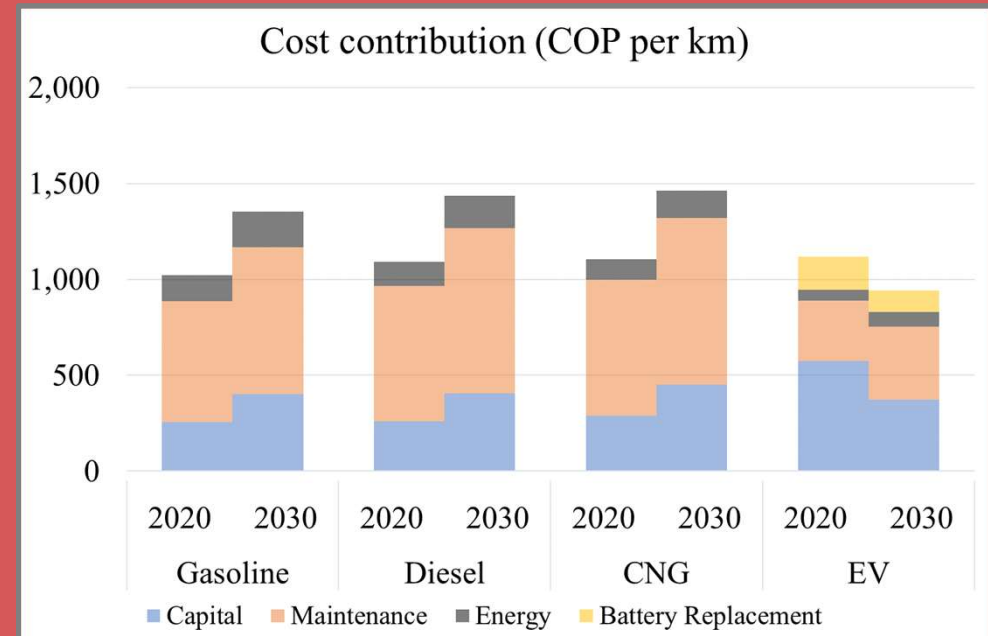
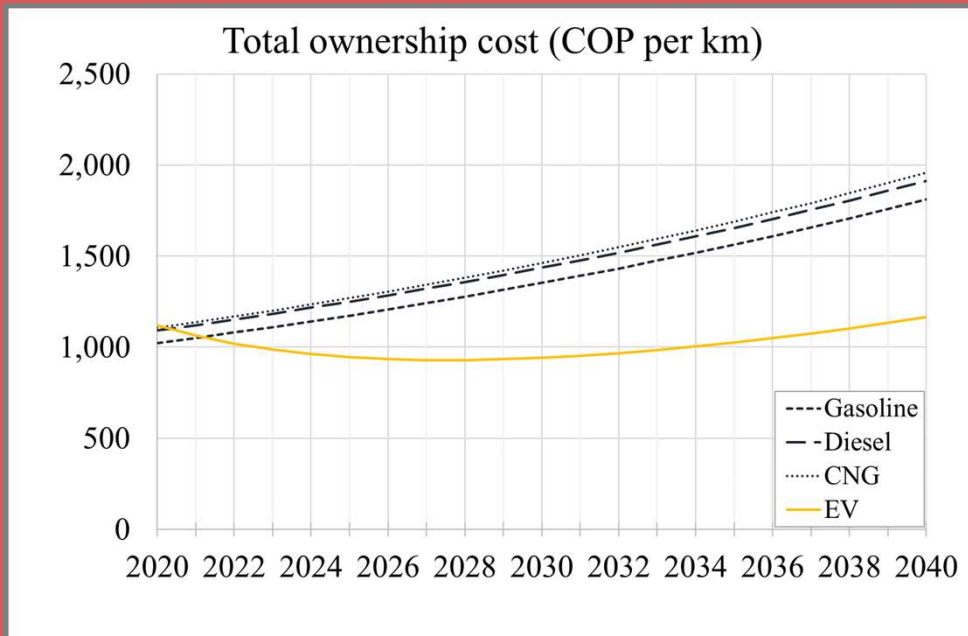


Evolution of the Energy Demand



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Electric vehicles become the cheapest



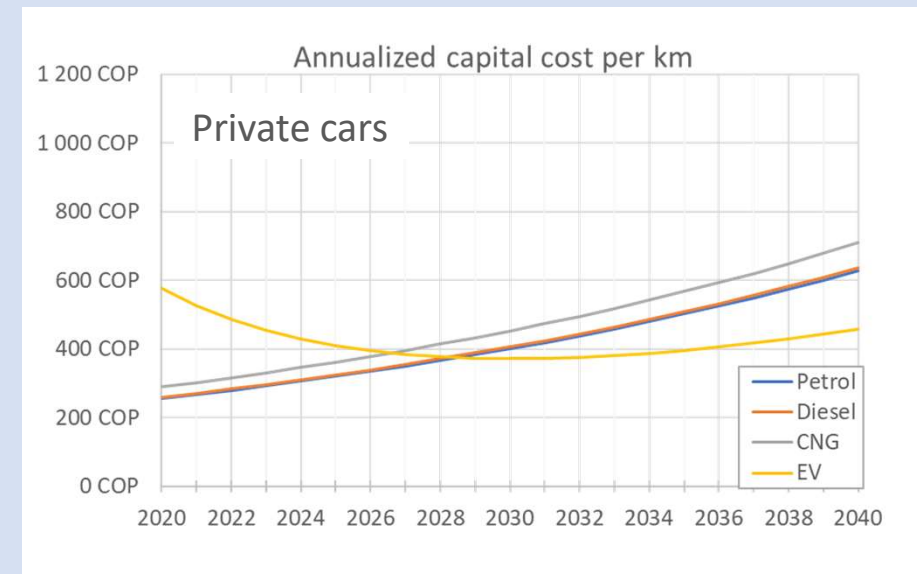
Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

Despite a cost which is already low, the fraction of electric car in Bogota is still very low. That can be due to a number of barrier which prevents a faster renewal:

- ✓ The **capital cost** of an electric car is currently significantly higher than for a conventional car.
- ✓ The **refueling time** of an electric car is much higher than for a conventional car
- ✓ The **autonomy** of electric cars is still significantly lower than for a conventional car
- ✓ The **charging stations** are still scares and difficult to find in Bogota and more generally in Colombia



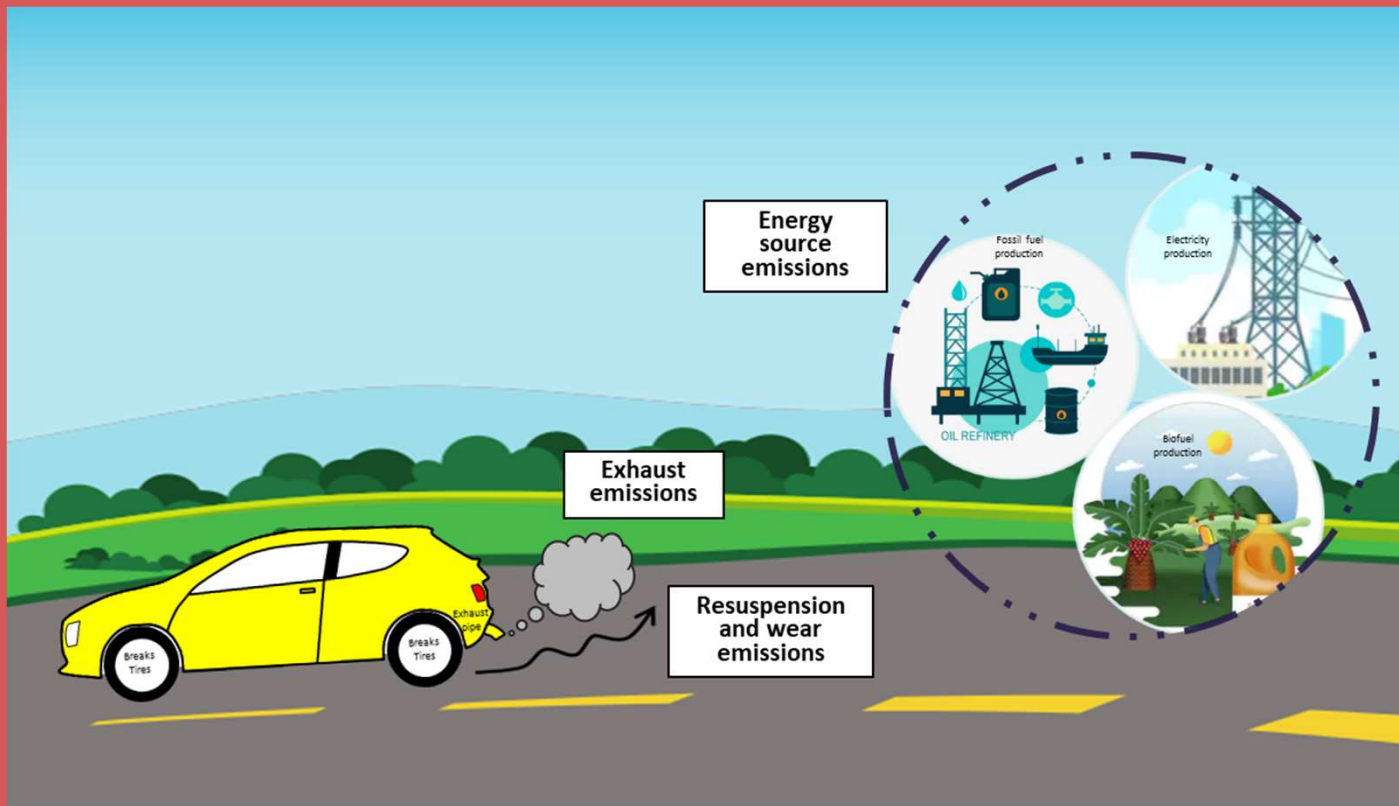
All these barriers should be removed in the future. The performance of the charging stations and the autonomy of the electric cars are constantly improved. A large number of charging stations can easily be implanted all over the country. The capital cost of electric cars is decreasing and should become lower than for the conventional car in the next 6 to 9 years.

Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

Well to wheel emissions

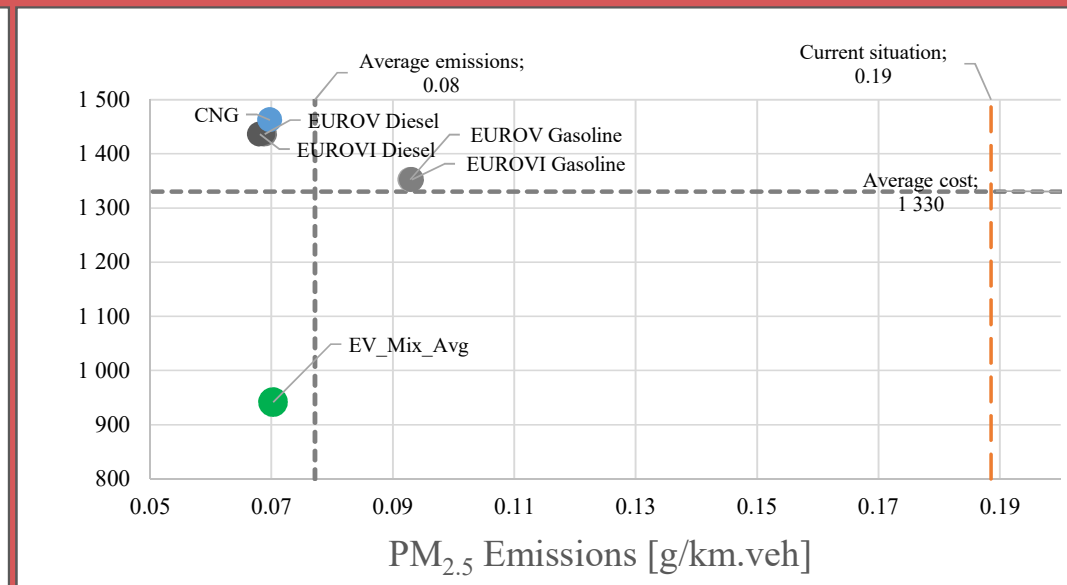
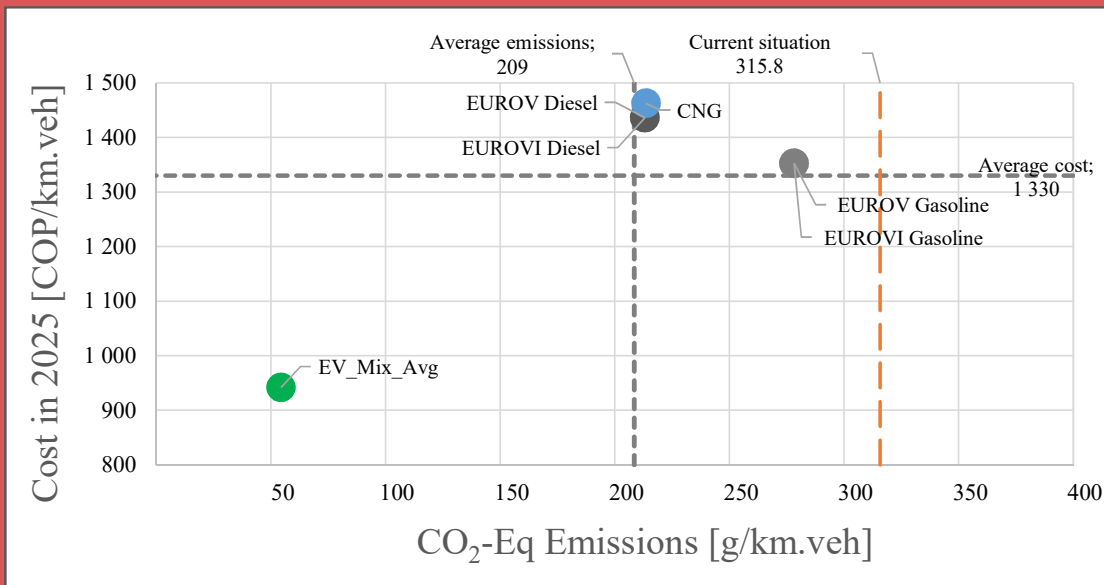


Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

The introduction of electric cars will lead to a decrease in CO₂ emissions, but not in PM_{2.5}.

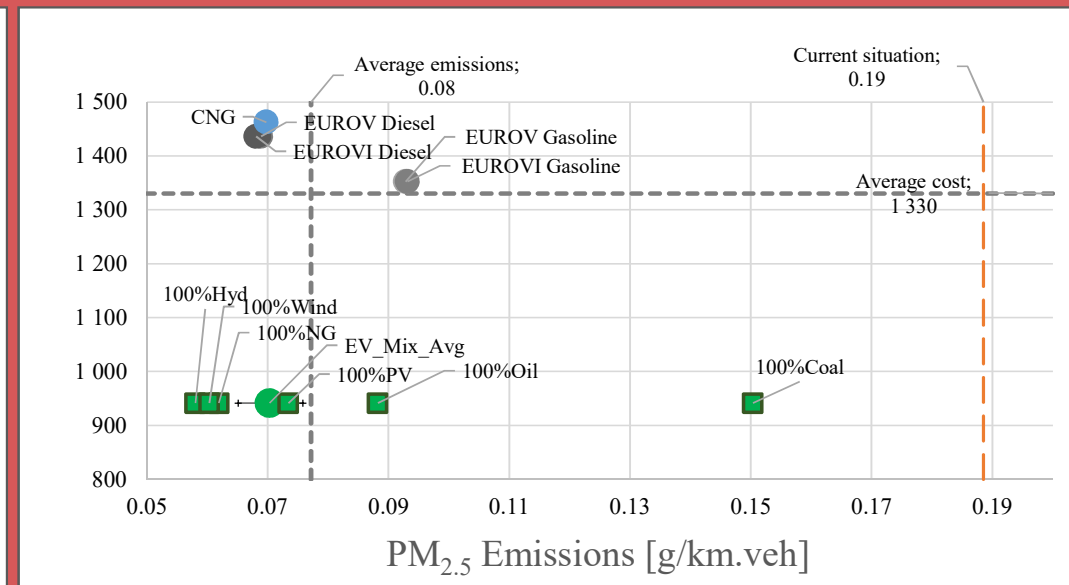
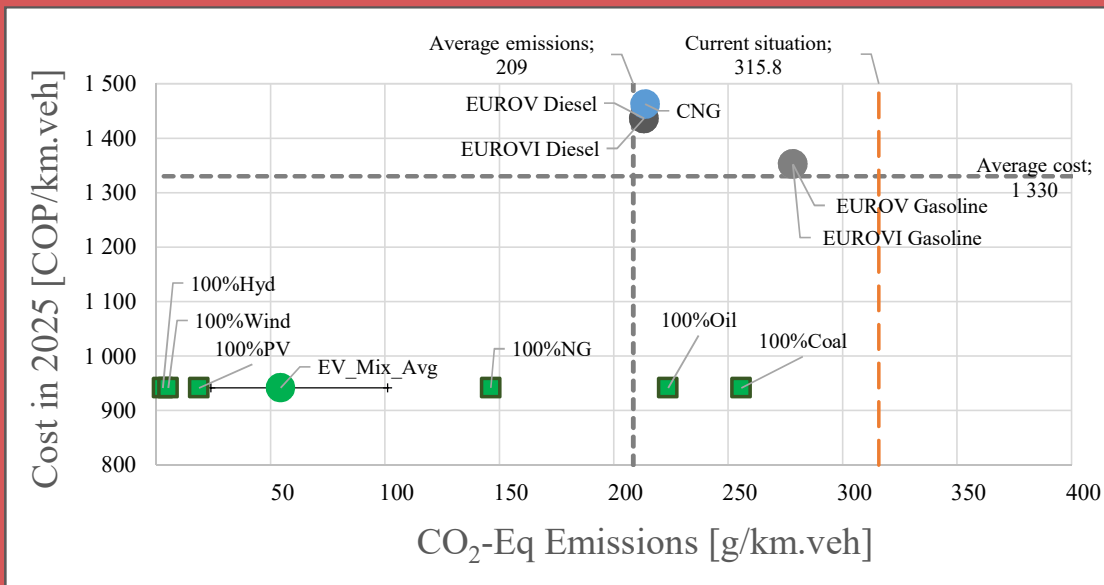


Evolution of the Energy Demand



fib
 feria internacional
 industrial de Bogotá
 xxxiii

Emissions resulting from the use of electric vehicles depend on the electricity generation mix.



Evolution of the Energy Demand



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Electricity required by the electric vehicles in Bogota.

Energy used [GWh]	Passenger cars	Taxis	Rigid buses	Articu. buses	Motorcycles
by the current vehicle fleet	17 440	3 335	3 611	600	2 000
by electric vehicles	4 011	767	975	126	220
Energy reductions	77%	77%	73%	79%	89%

Current energy consumption in Bogota: 10 398 GWh/yr

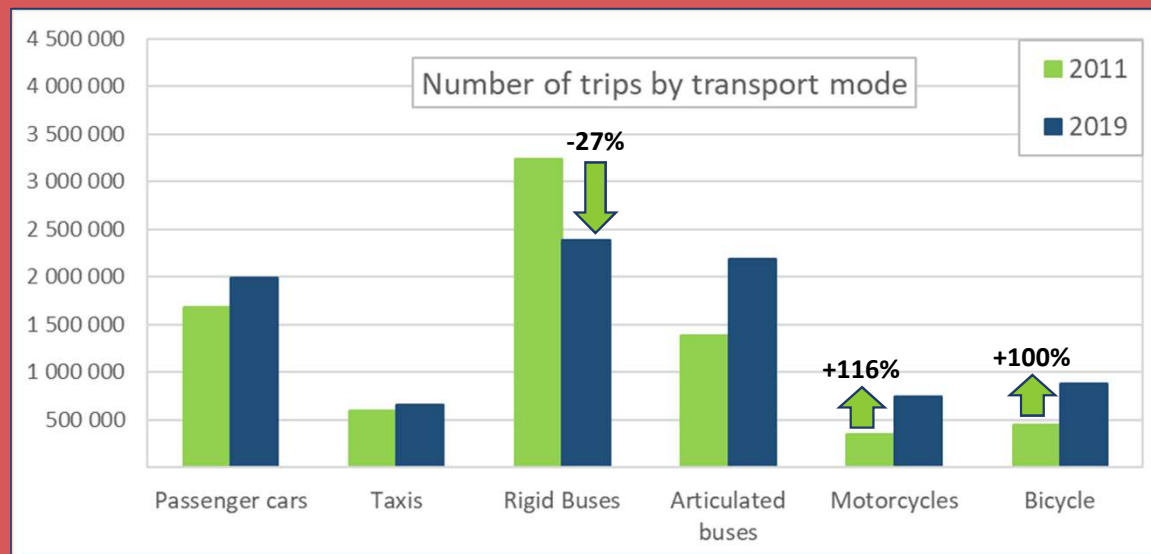
Increase of electric consumption due to electric vehicles (%)	
Passenger car	39%
Passenger cars + Taxis + Moto	48%
All passenger vehicles	59%

Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

Trends of the repartition between the different transport modes.

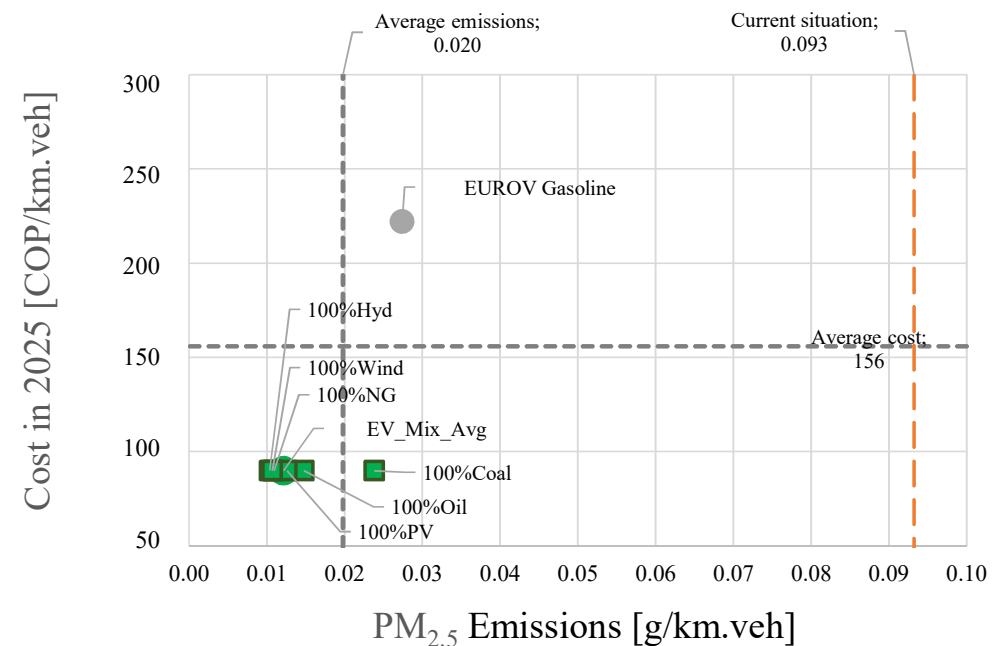
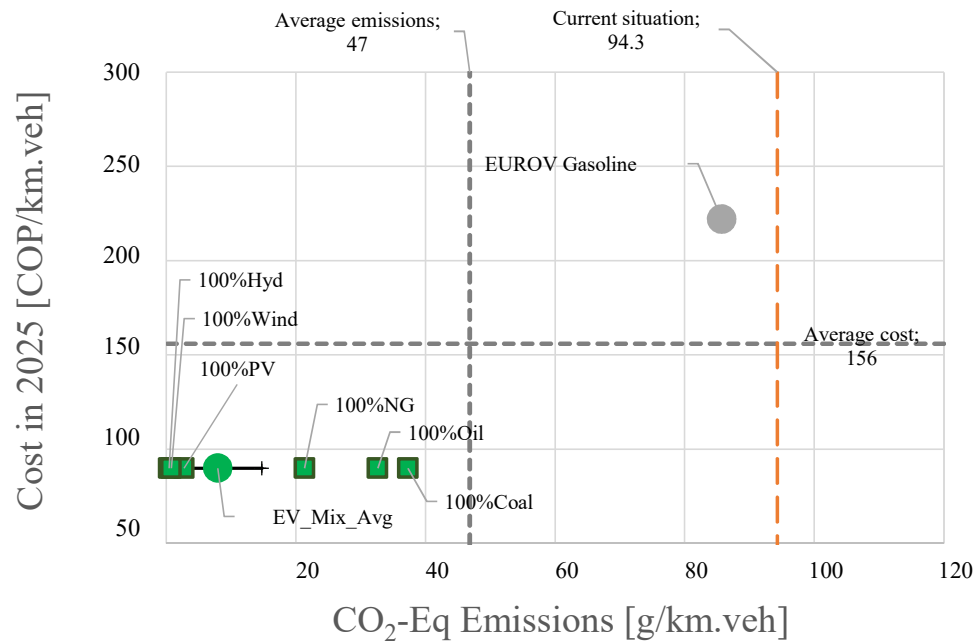


Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

Electric motorcycles are cheaper and will reduce CO₂ and PM emissions of more than a factor 2



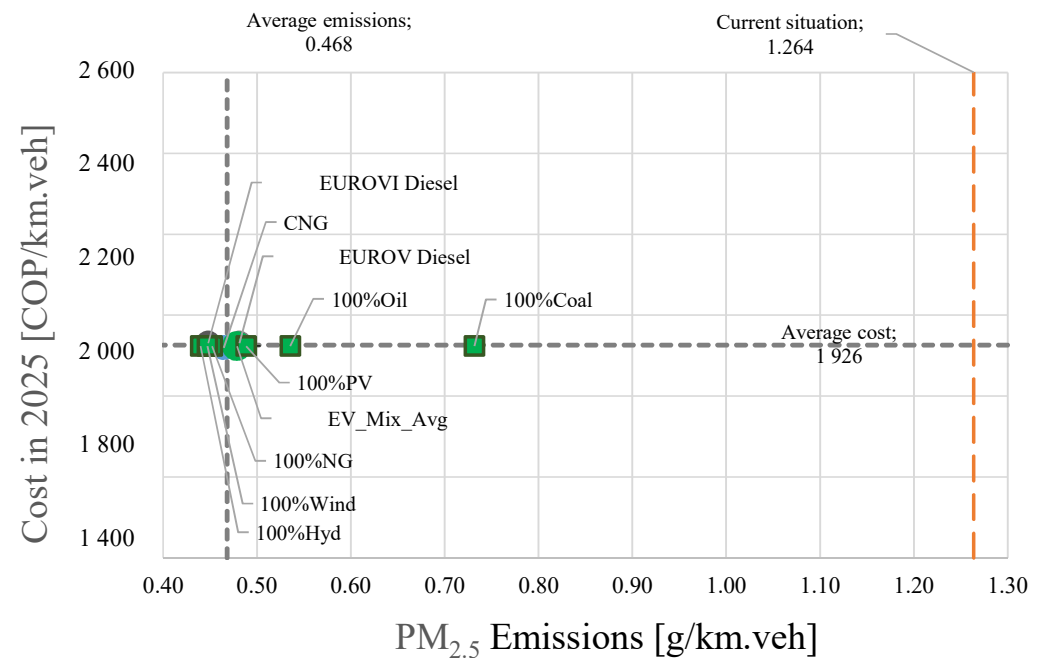
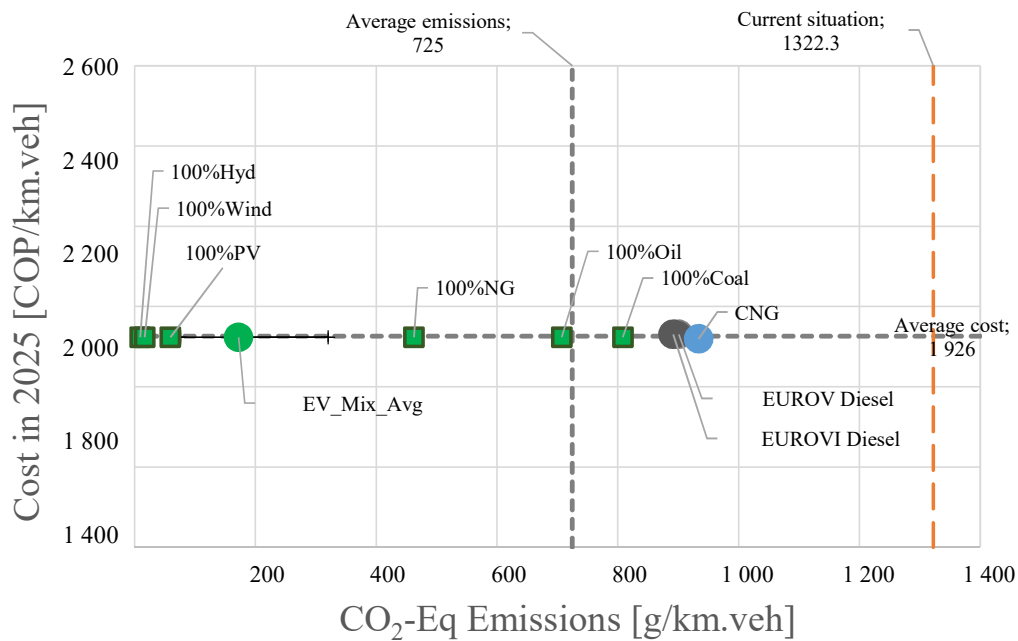
Motorcycles can be a good alternative but mortality is more than 20 times greater than for cars. Investment on infrastructure for security is necessary.

Evolution of the Energy Demand



fib
 feria internacional
 industrial de Bogotá
 XXXIII

In 2025, electric buses are still not cheaper, they reduce CO₂ emissions but not PM emissions



Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

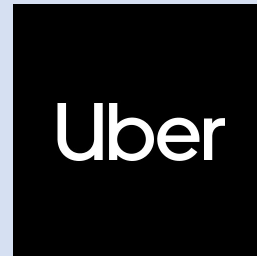
Share the vehicles is one the issue to reduce the gas emissions.

Car pooling

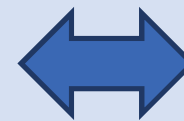


BlaBlaCar connects individuals through an application. Drivers wishing to make available, in exchange for a fee, places available in their car for a specific journey.

Cab service



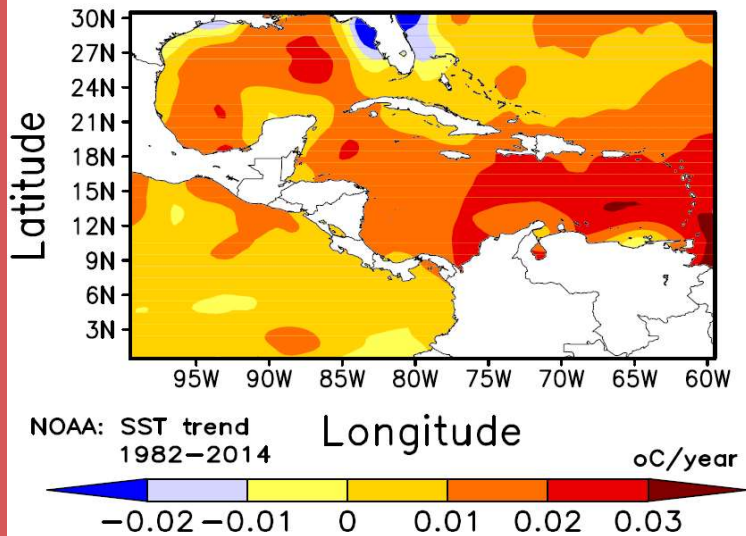
Uber connects individuals with drivers through an application. In exchange for a fee, individuals ask a driver for a specific destination.



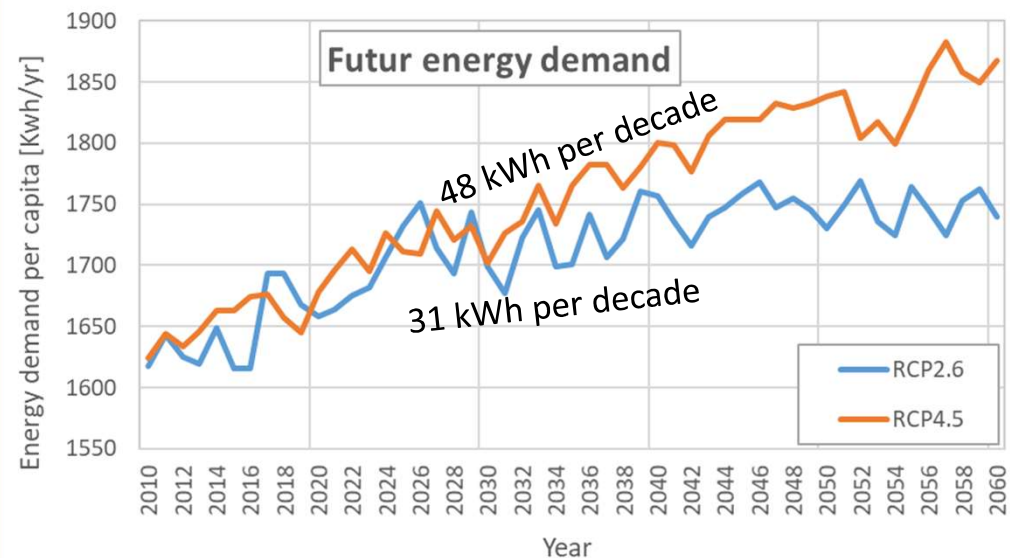
Evolution of the Energy Demand

Climate change will lead to temperature elevations and an increase of energy consumption in the residential sector (air conditioning).

Sea surface temperature trend between 1980 to 2013 in Carribean region



Energy trend between 2010 to 2060 in Carribean region



Moises E. Angeles et al.: Impacts of climate change on building energy demands in the intra-Americas region, Theor Appl Climatol (2018) 133:59–72

Evolution of the Energy Demand



fib
feria internacional
industrial de Bogotá
XXXIII

In the future, Colombian energy demand will continue to increase especially the electric demand of the transport and residential sectors.

How will it possible to supply it?

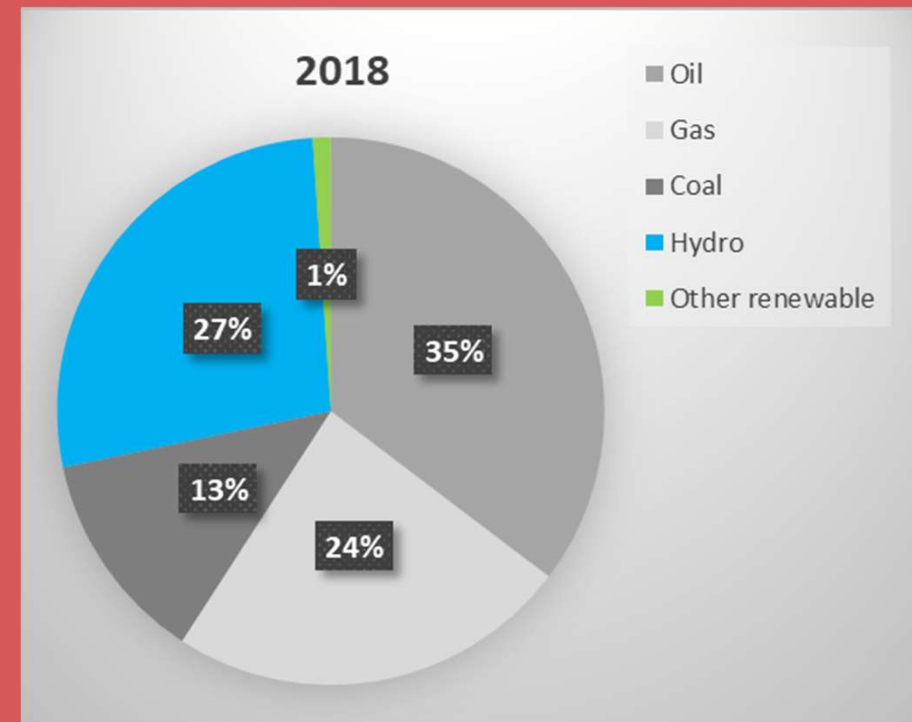
Colombian Energy Mix: Strengths and Weaknesses



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Colombia is fully energy independent,

2018	Production	Consumption
Oil [barrels per day x 1000]	866	342
Gas [billion cubic meter]	12.9	13.0
Coal [million tonnes]	84.3	5.9

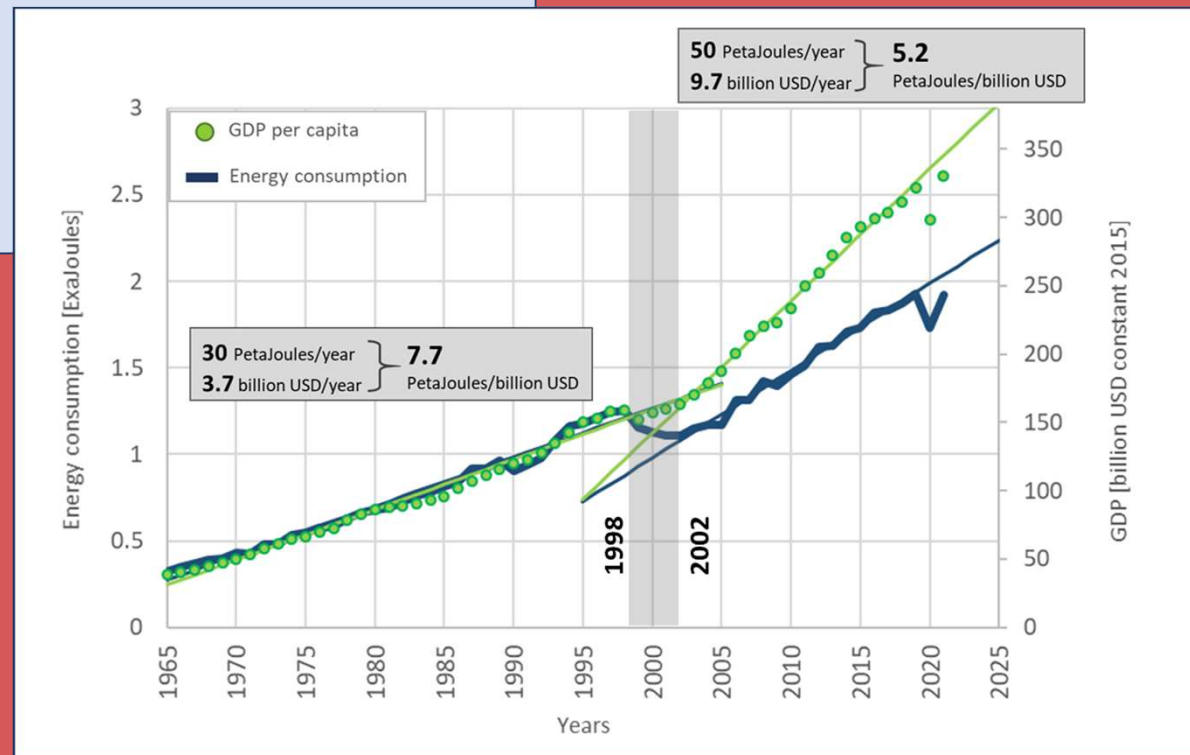


Colombian Energy Mix: Strengths and Weaknesses



fib
feria internacional
industrial de Bogotá
XXXIII

Colombia is fully energy independent, and its energy efficiency in terms of economic growth has improved but...



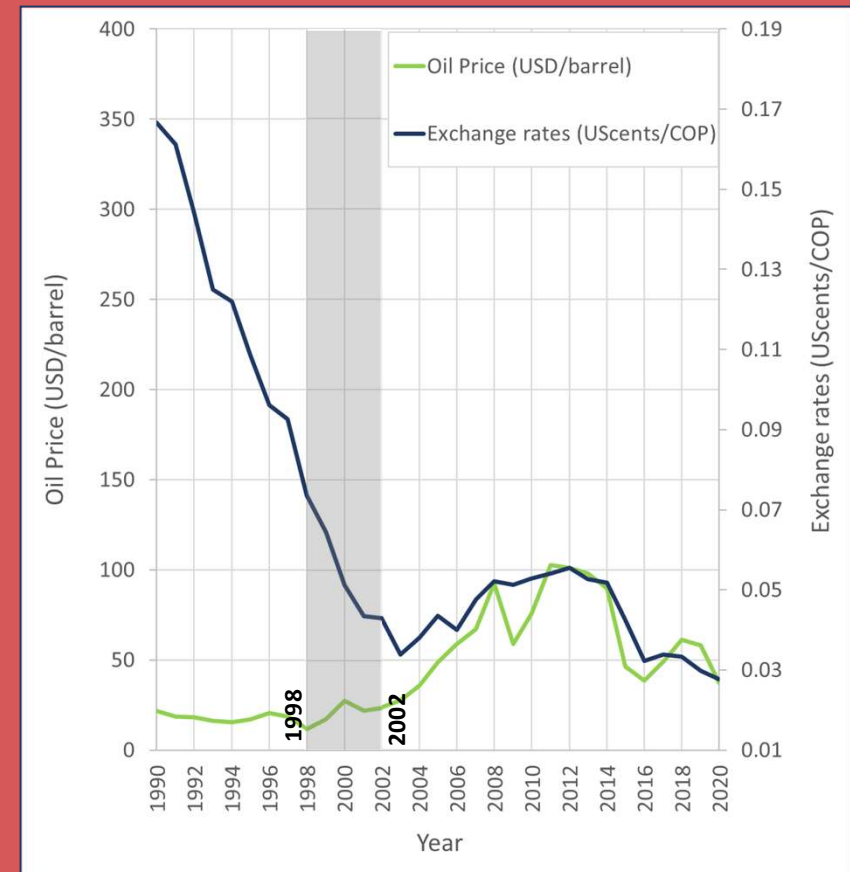
Colombian Energy Mix: Strengths and Weaknesses



fib
feria internacional
industrial de Bogotá
XXXIII

Colombia is fully energy independent, and its energy efficiency in terms of economic growth has improved but...

- ❑ the national economy depends strongly from the oil market



Colombian Energy Mix: Strengths and Weaknesses

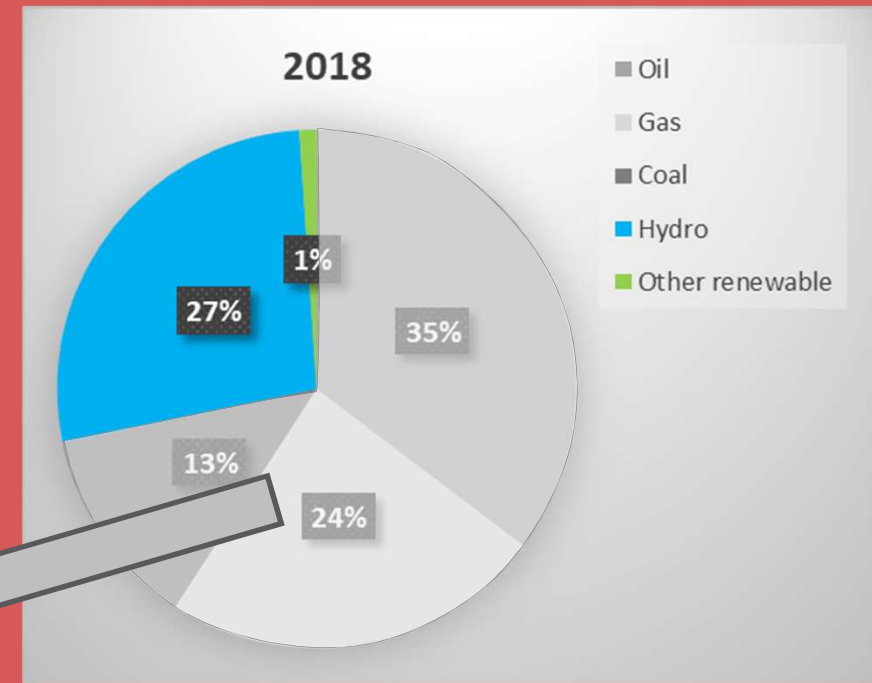


fib
feria internacional
industrial de Bogotá
XXXIII

Colombia is fully energy independent, and its energy efficiency in terms of economic growth has improved but...

- ❑ the national economy depends strongly from the oil market
- ❑ the sustainability of energy resources is weak:
less than 10 years of oil and gas reserves remain.

2018	Years
Oil	5.6
Gas	8.3
Coal	58



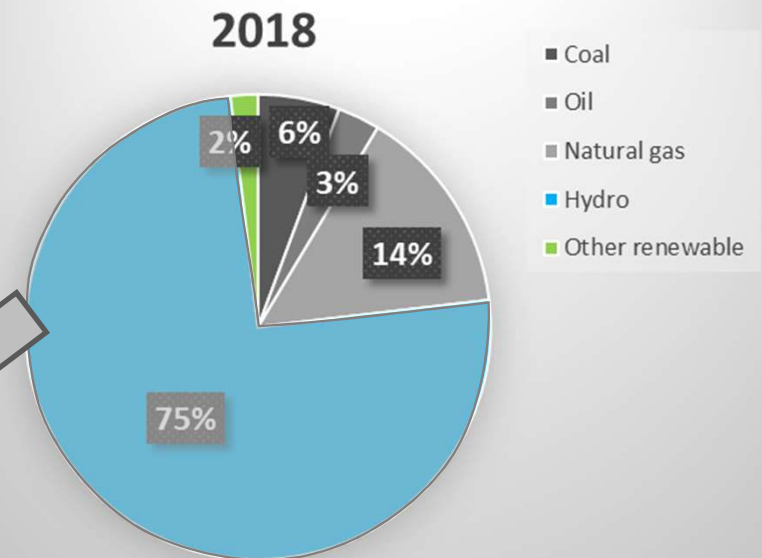
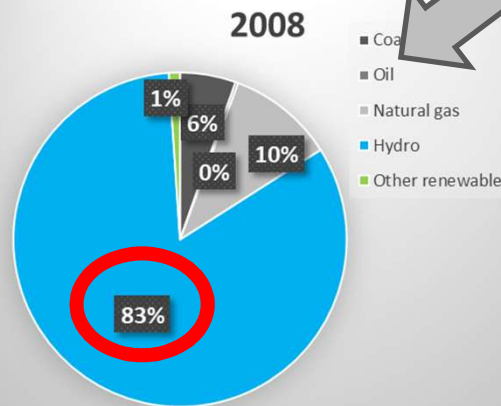
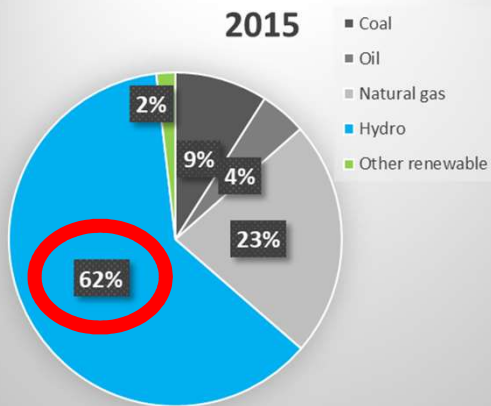
Colombian Energy Mix: Strengths and Weaknesses



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Colombia is fully energy independent, and its energy efficiency in terms of economic growth has improved but...

- ❑ the national economy depends strongly from the oil market
- ❑ the sustainability of energy resources is weak:
less than 10 years of oil and gas reserves remain.
hydrological resources are affected by climate change



Alternative Energy Mix in Colombia



fib
feria internacional
industrial de Bogotá
XXXIII

How to move to a sustainable and environmentally friendly energy mix in Colombia?

- Oil and Gas : less than 10 years of reserves and it emit greenhouse gases
- Coal : more reserves but it emit more greenhouse gases (low energy efficiency) and other pollutants (Particulate Matter)
- Hydroelectricity: can be further developed (17 GW to 57 GW, UPME, 2018) but remain vulnerable to climate change.
- Biomass** : ?

Alternative Energy Mix in Colombia



fib
feria internacional
industrial de Bogotá
XXXIII



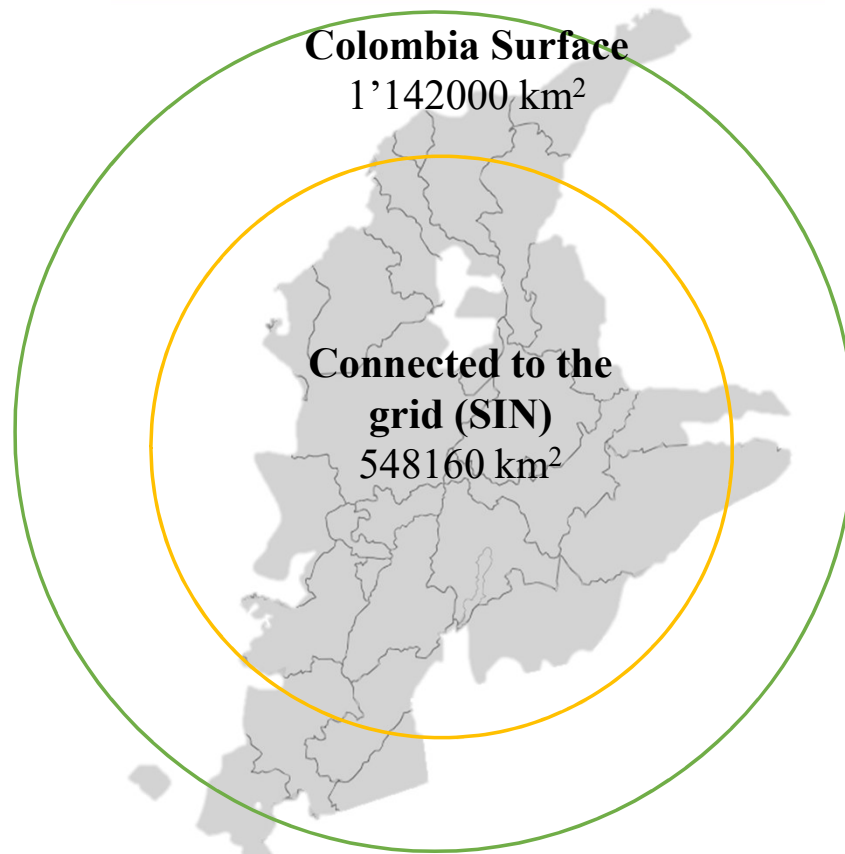
Areas needed to supply 100% of the **Cuban** electricity demand (projection in 2030) with

- biomass (bagasse and Marabu wood)
- wind turbines
- PV panels

Wind and Solar Resources



fib
feria internacional
industrial de Bogotá
XXXIII



Colombia Surface
1'142000 km²

**Connected to the
grid (SIN)**
548160 km²

Off-grid regions (ZNI) (52% - 593840 km²)

Areas needed to supply 100% of the **Colombian** electricity demand with:

- wind turbines
- PV panels



Onshore Wind Turbines

1637-6197 km²
(0.30% - 1.13%) of the “interconnected country surface”



Utility Solar Photovoltaic

931-1008 km²
(0.17% - 0.18%) of the “interconnected country surface”

Wind and Solar Resources



fib
 feria internacional
 industrial de Bogotá
 XXXIII

Cost compared to other technologies.

Technologies	Total Annual Cost (USD/MWh)	Carbon Cost (USD)	Comp. Cost (USD)
Solar Photo Voltaic (PV)	55	0	55
Wind Turbine Onshore	46	0	46
Geothermal	112	0	112
Water - Hydroelectric	38	0	38
Biomass	136	0	136
Gas Turbine (CCGT)	133	21	154
Thermoelectric oil	91	36	126
Thermoelectric coal	43	35	78
Generation Set Diesel	108	42	150
Generation Set Gas	263	30	293
Generation Set Oil	108	42	150
Cycle Nuclear	69	0	69

Wind and Solar Resources



fib
 feria internacional
 industrial de Bogotá
 xxxiii

Cost compared to other technologies.

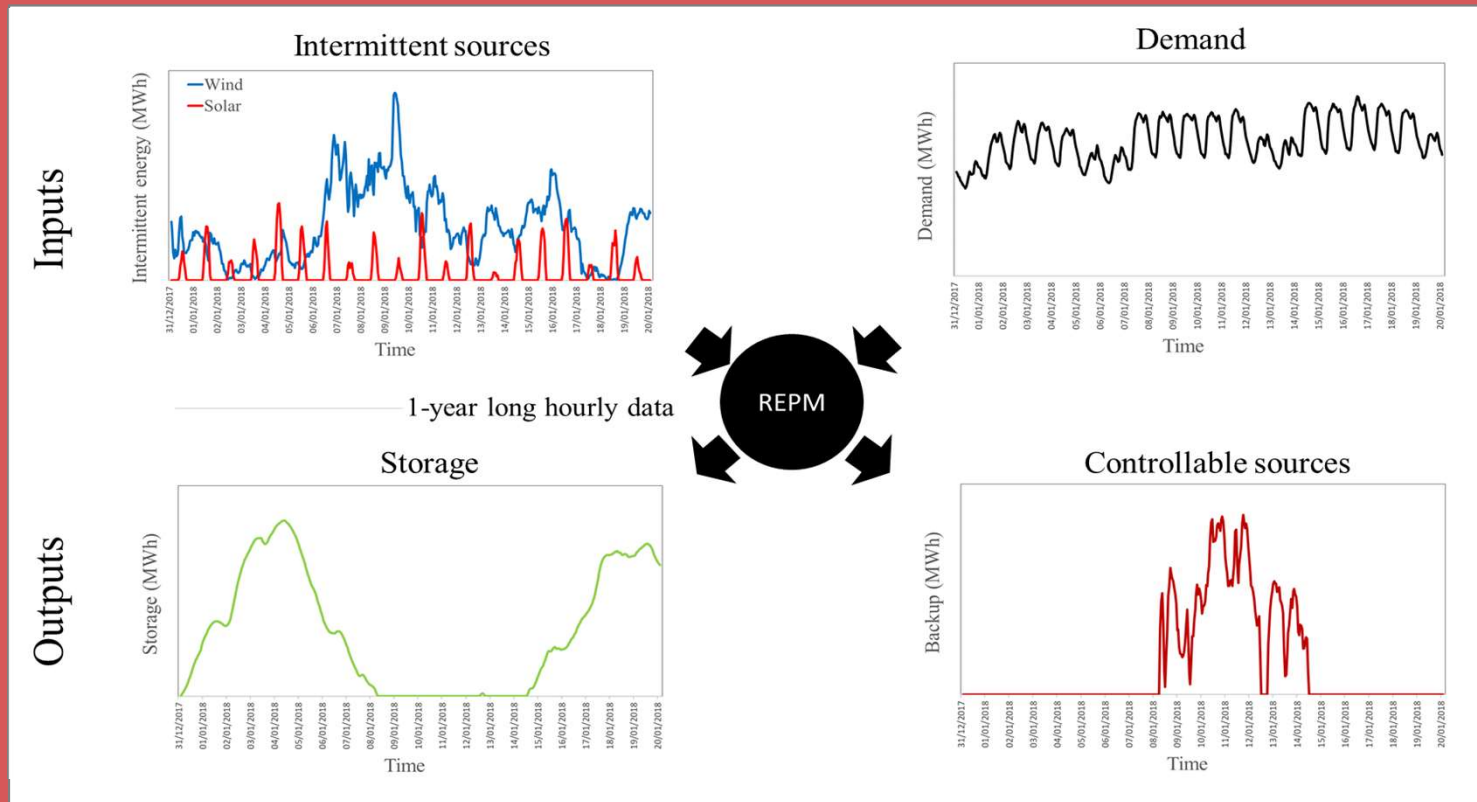
Technologies	Total Annual Cost (USD/MWh)	Carbon Cost (USD)	Comp. Cost (USD)	Capital Cost (%)	Fix Cost (%)	Variable Cost (%)	Fuel Cost (%)
Solar Photo Voltaic (PV)	55	0	55	85.4%	14.6%	0.0%	0.0%
Wind Turbine Onshore	46	0	46	53.1%	46.9%	0.0%	0.0%
Geothermal	112	0	112	82.3%	16.3%	1.3%	0.0%
Water - Hydroelectric	38	0	38	69.5%	22.6%	7.8%	0.0%
Biomass	136	0	136	55.5%	9.8%	0.5%	34.3%
Gas Turbine (CCGT)	133	21	154	5.4%	1.8%	0.8%	92.0%
Thermoelectric oil	91	36	126	23.3%	4.3%	2.2%	70.2%
Thermoelectric coal	43	35	78	47.1%	7.2%	4.2%	41.5%
Generation Set Diesel	108	42	150	22.4%	7.0%	1.8%	68.7%
Generation Set Gas	263	30	293	8.1%	2.5%	0.8%	88.6%
Generation Set Oil	108	42	150	22.4%	7.0%	1.8%	68.7%
Cycle Nuclear	69	0	69	55.7%	14.3%	5.8%	24.2%

Energy Storage



fib
feria internacional
industrial de Bogotá
XXXIII

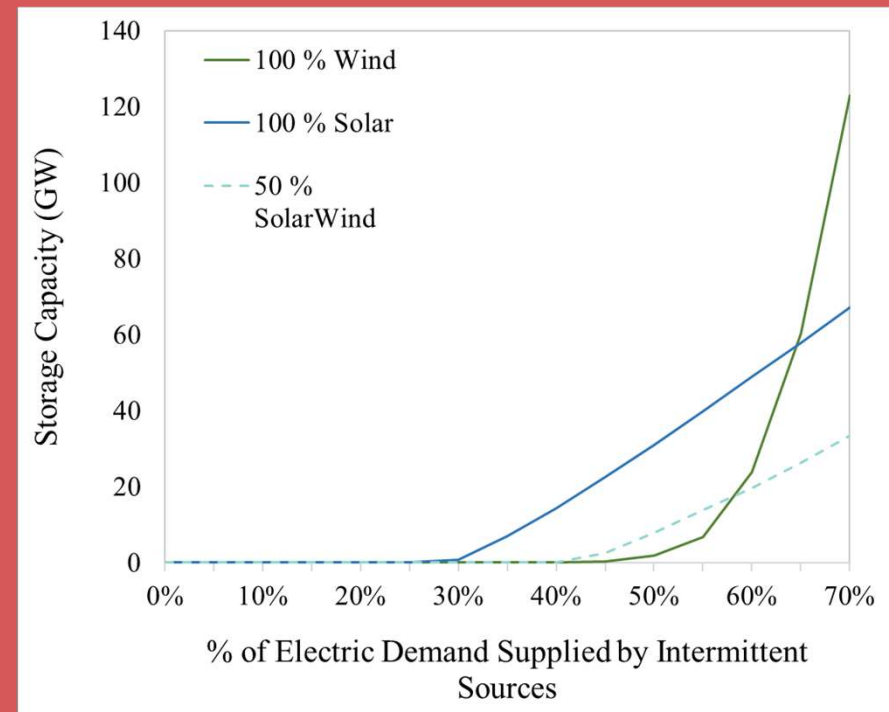
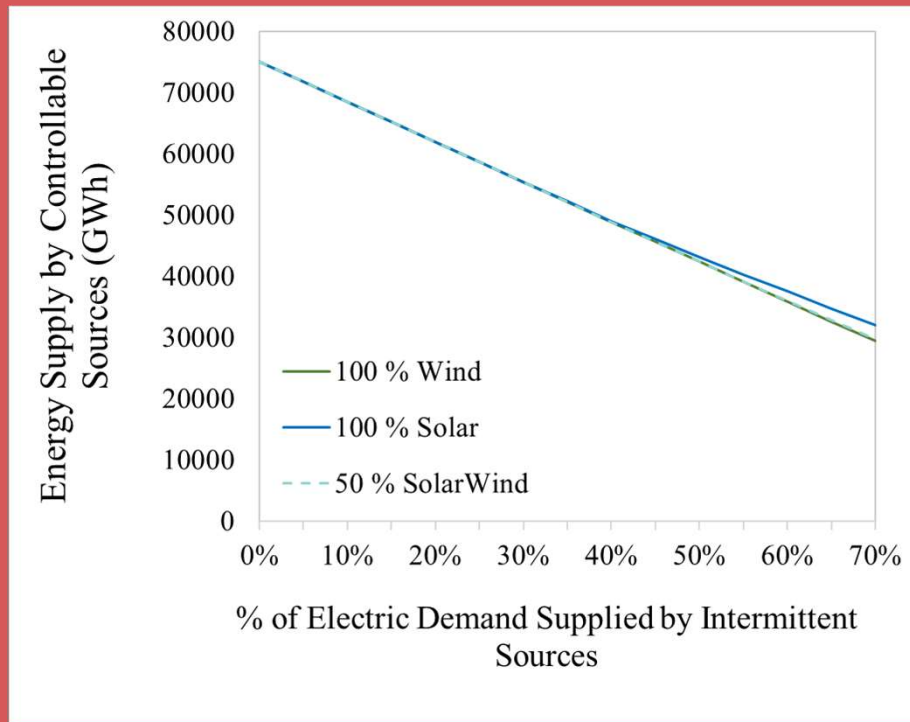
Model to estimate the storage capacity needed by the introduction of Intermittent sources into the energy mix.



Energy Storage



The introduction of intermittent sources into the energy mix requires significant storage capacity.



Energy Storage



fib
feria internacional
industrial de Bogotá
XXXIII

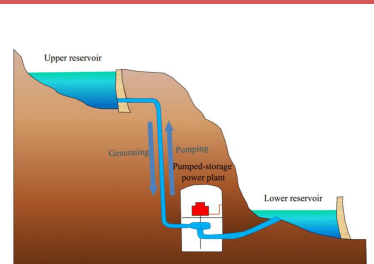
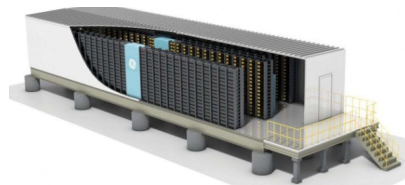
Different storage technologies.

Efficiency

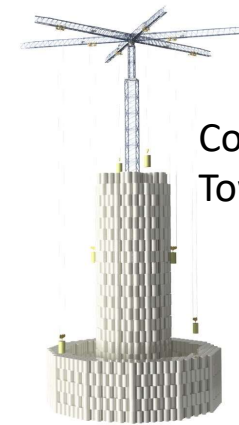


Wheel

Battery



Pumped-storage
hydroelectricity



Concrete
Tower



Power to gas (Hydrogen)

Storage time

Conclusions



fib
feria internacional
industrial de Bogotá
xxxiii

- ❑ Climate change is underway and accelerating. In the very best case, it will take decades to control it.
- ❑ The world economy is adapting to implement the energy transition. The countries that anticipate the transition will strengthen their economy in the long term, the others will suffer the crisis...



fib
feria internacional
industrial de Bogotá
XXXIII

Muchas gracias !