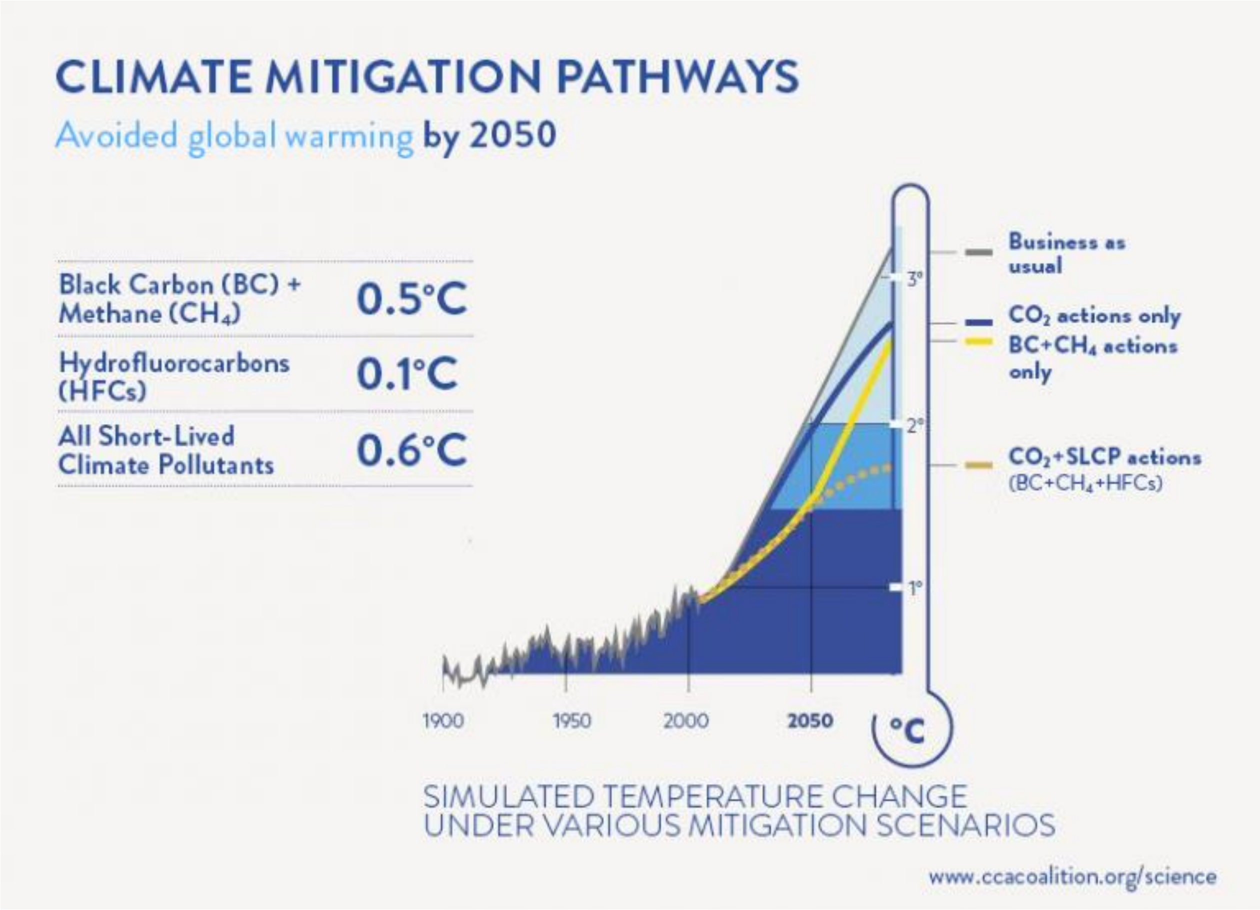
	DELIVERABLE 1.1.3	

A DOCUMENT THAT CONSOLIDATES THE PROCESS OF VALIDATION AND GENERATION OF MITIGATION SCENARIOS.



COALICIÓN CLIMA Y AIRE LIMPIO PARA REDUCIR CONTAMINANTES DE VIDA CORTA	DELIVERABLE 1.1.3	caem CORPORACIÓN AMBIENTAL EMPRESARIAL

CORPORACIÓN AMBIENTAL EMPRESARIAL - CAEM

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Introduction.

The Corporación Ambiental Empresarial, within the framework of its activities and commitments as a member of the Climate and Clean Air Coalition for the Reduction of Short-Lived Climate Pollutants, advances the first multiple benefits analysis to know the impacts in terms of mortality and morbidity associated with poor air quality resulting from the implementation of the main measures (defined in a tentative or official manner) to reduce emissions of the main greenhouse gases, criteria pollutants and black carbon from the brick sector in Colombia..

Further technical inputs will be consolidated in the months following the preparation of the study documented in this document, so it is expected that the figures, assumptions and scenarios described here will change soon. However, this exercise represents an estimate of the positive impacts in terms of air quality and climate change from the implementation of emissions mitigation measures, and, having been carried out in the LEAP-IBC tool, it is meant to incorporate the new data as it is consolidated.

The supporting technical documentation aims to clarify the methodology and assumptions used to arrive at the results obtained in order to ensure the transparency and replicability of the exercise. The results obtained are also shown.

Estimation of fuel consumption and energy intensity.

Based on the study "final national baseline 2016" which, by type of brick kiln, relates the production of bricks in tonnes per energy used, the energy intensity of each type of kiln was calculated, expressed in tonnes of oil equivalent consumed per tonne of brick produced. The greater the energy intensity of the kiln, the more inefficient it is.

		FUEL									
Kiln type	Units	**Coal**	**Wood**	**Sawdust**	**Coffee dust**	**Rice dust**	**GLP**	**Natural GAS**	**Production**	**Total TOE**	**Energy Intensity**
Energetic content[1] →	*GJ/Ton*	*29,31*	*15,5*	*15,5*	*12,5*	*12,5*	*47,3*	*42,75[2]*	**(ton/year)**	**(toe)**	**(toe/ton)**
Arab	ton/year	49.017,60	235231,20	18740,64	36903,24	0,00	0,00	0,00			
	toe/year	**34.315,13**	**87.085,21**	**6.937,99**	**11.017,73**	**0,00**	**0,00**	**0,00**	2.001.078	*139.356,07*	**0,0696**
	share	**25%**	**62%**	**5%**	**8%**	**0%**	**0%**	**0%**			
Artisanal	ton/year	61.296,00	0,00	0,00	0,00	0,00	0,00	0,00			
	toe/year	**42.910,71**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	532.347	*42.910,71*	**0,0806**
	share	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**			
Wagon	ton/year	2.940,00	2246,40	0,00	168,00	0,00	0,00	0,00			
	toe/year	**2.058,17**	**831,64**	**0,00**	**50,16**	**0,00**	**0,00**	**0,00**	36.523	*2.939,97*	**0,0805**
	share	**70%**	**28%**	**0%**	**2%**	**0%**	**0%**	**0%**			
Dome kiln	ton/year	253.380,00	0,00	0,00	0,00	0,00	0,00	0,00			
	toe/year	**177.380,52**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	2.177.231	*177.380,52*	**0,0815**
	share	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**			
Wagon (+ than 4)	ton/year	14.808,00	0,00	0,00	5644,80	0,00	0,00	0,00			
	toe/year	**10.366,45**	**0,00**	**0,00**	**1.685,30**	**0,00**	**0,00**	**0,00**	150.504	*12.051,75*	**0,0801**
	share	**86%**	**0%**	**0%**	**14%**	**0%**	**0%**	**0%**			
Chambers continuous (up to 8)	ton/year	2.496,00	0,00	0,00	0,00	0,00	0,00	0,00			
	toe/year	**1.747,34**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	29.771	*1.747,34*	**0,0587**
	share	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**			
Hoffman semi continuous (Short kiln)	ton/year	4.654,32	0,00	0,00	0,00	0,00	0,00	0,00			
	toe/year	3.258,29	0,00	0,00	0,00	0,00	0,00	0,00	90.504	*3.258,29*	**0,0360**
	share	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**			
zigzag	ton/year	13.944,00	0,00	0,00	0,00	0,00	0,00	0,00			
	toe/year	9.761,60	0,00	0,00	0,00	0,00	0,00	0,00	195.348	*9.761,60*	**0,0500**
	share	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**			
Chambers continuous (+ than 8 chambers)	ton/year	3.456,00	0,00	0,00	0,00	0,00	0,00	0,00			
	toe/year	2.419,40	0,00	0,00	0,00	0,00	0,00	0,00	53.251	*2.419,40*	**0,0454**
	share	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**			
Hoffman (big kiln)	ton/year	102.052,80	0,00	0,00	6660,00	0,00	0,00	0,00			
	toe/year	71.442,81	0,00	0,00	1.988,39	0,00	0,00	0,00	1.849.863	*73.431,20*	**0,0397**
	share	**97%**	**0%**	**0%**	**3%**	**0%**	**0%**	**0%**			
Tunnel	ton/year	172.134,48	0,00	0,00	0,00	0,00	0,00	1308,00			
	toe/year	120.504,00	0,00	0,00	0,00	0,00	0,00	1.335,55	2.735.855	*121.839,56*	**0,0445**
	share	**99%**	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**			
Rodillos (ceramic production)	ton/year	2.196,00	0,00	0,00	0,00	0,00	1052,00	1561,00			
	toe/year	1.537,33	0,00	0,00	0,00	0,00	1.188,49	1.593,88	127.224	*4.319,70*	**0,0340**
	share	**36%**	**0%**	**0%**	**0%**	**0%**	**28%**	**37%**			

Baseline year construction.

Although the base year of the year is 2010, the available data is only for 2016, and can be consolidated as follows:

Technology	Production per type of kiln Ton/year	Subtotal percentage of participation	Percentage of participation
	INTERMITTENT		
Arab	2.001.078		**40,61%**
Artisanal	532.347		**10,80%**
Wagon	36.523		**0,74%**
Dome kiln	2.177.231		**44,19%**
Wagon (+ than 4)	150.504		**3,05%**
Chambers continuous (up to 8)	29.771		**0,60%**
SUBTOTAL	*4.927.453*	*49,38%*	***100,00%***
	CONTINUO		
Hoffman semi continuous (Short kiln)	90.504		**1,79%**
zigzag	195.348		**3,87%**
Chambers continuous (+ than 8 chambers	53.251		**1,05%**
Hoffman (big kiln)	1.849.863		**36,62%**
Tunnel	2.735.855		**54,15%**
Rodillos (ceramic production)	127.224		**2,52%**
SUBTOTAL	*5.052.045*	*50,62%*	***100,00%***
TOTAL	**9.979.498,54**	**100 %**	

The percentages of participation of each of the different brick kiln technologies, divided between those of the intermittent and continuous types, are given according to the tons produced by each type of kiln in 2016 with respect to the total for that same year. These percentages are assumed to be constant between 2010 and 2016.

According to an exercise developed by CAEM on the technological conversion of dormant fire ovens, pampas and hives to continuous chambers, the growth rate of GHG emissions for brick kilns up to 2030 is 4.18% per year. Assuming that this rate is constant between 2010 and 2030, it is possible to extrapolate backwards in time to find, from the 9979498 tons produced in 2016, the corresponding value for 2010, which is 8131805 ton

Baseline construction.

For the baseline projections it is assumed that the sector's growth rate of 4.18%, measured in tons of bricks produced annually, is equal to the growth rate of its GHG emissions and that there will be no change in the percentage share of different types of kilns in the total. From the total production of bricks in tons given by the CAEM study, a forward and backward projection was made based on that growth rate; maintaining the proportion of participation of the different types of brick kilns within the annual national production. This means that the base line assumes that there will be no technological reconversion.

Construction of mitigation scenario

The mitigation scenario assumes the same brick production in tons per year with respect to the baseline; that is, year by year, total brick production will grow by 4.18%. The difference lies in the incorporation of technological conversion criteria that affect the percentage participation of different types of brick kilns, displacing part of the brick production towards cleaner technologies. Likewise, an energy efficiency improvement component is incorporated.

Technological reconversion

In order to evaluate the number of kilns that can be technologically reconverted from the year 2015, CAEM proposes that:

- A quarter of the total number of dormant fire and pampas furnaces by 2015 have the potential to be converted to continuous chamber furnaces by 2030;

- Half of all dome kilns have the potential to be converted to continuous chamber kilns.

With these data, the percentage decrease in the participation of the artisanal, Arab and dome kilns was projected due to the technological reconversion to continuous chamber furnaces from 2015 to 2030 with a uniform decrease during 15 years. Furthermore, it is assumed that there will be no more construction of the artisanal, Araba and dome kiln from 2015, and that this growth will take place in the continuous chamber kilns.

Energy Efficiency

In addition, an energy efficiency criterion was adopted for the total number of brick kilns, which takes into account the implementation of best practices within the sector, even without conversion, resulting in a reduction in energy intensity of 0.5% per year.

Emission Factors

Intermittent kiln technology:

Branch	Effect	2010	Expression	Units	Per	Method
Carbon Dioxide Non	Carbon Dioxide (CO2)	89,10	89,1 ?c	Metric Tonne	Terajoule	Per unit energy consumed
Carbon Monoxide	Carbon Monoxide (CO)	1.842,00	1842 ?c	Kilogramme	Terajoule	Per unit energy consumed
Methane	Methane (CH4)	10,00	10 ?a	Kilogramme	Terajoule	Per unit energy consumed
Non Methane Volatil	Non Methane Volatile Organi	88,80	88,8 ?b	Kilogramme	Terajoule	Per unit energy consumed
Nitrogen Oxides	Nitrogen Oxides (NOx)	173,00	173 ?b	Kilogramme	Terajoule	Per unit energy consumed
Nitrous Oxide	Nitrous Oxide (N2O)	1,50	1,5 ?a	Kilogramme	Terajoule	Per unit energy consumed
Sulfur Dioxide	Sulfur Dioxide (SO2)	0,01	SulfurContent*(1-SulfurRetention)*(SO2/	Kilogramme	Kilogramme	Per unit energy consumed
Particulates PM10	Particulates PM10 (PM10)	4,10	4,1 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Particulates PM2p5	Particulates PM2pt5 (PM2.5)	3,70	3,7 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Black Carbon	Black Carbon (BC)	2,70	2,7 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Organic Carbon	Organic Carbon (OC)	0,11	0,11 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Ammonia	Ammonia (NH3)	0,00	0,00028 ?d	Kilogramme	Metric Tonne	Per unit energy consumed

Continuous kiln technology:

Branch	Effect	2010	Expression	Units	Per	Method
Carbon Dioxide Non	Carbon Dioxide (CO2)	95,40	95,4 ?c	Metric Tonne	Terajoule	Per unit energy consumed
Carbon Monoxide	Carbon Monoxide (CO)	1.190,00	1190 ?c	Kilogramme	Terajoule	Per unit energy consumed
Methane	Methane (CH4)	10,00	10 ?a	Kilogramme	Terajoule	Per unit energy consumed
Non Methane Volatil	Non Methane Volatile Organi	88,80	88,8 ?b	Kilogramme	Terajoule	Per unit energy consumed
Nitrogen Oxides	Nitrogen Oxides (NOx)	173,00	173 ?b	Kilogramme	Terajoule	Per unit energy consumed
Nitrous Oxide	Nitrous Oxide (N2O)	1,50	1,5 ?a	Kilogramme	Terajoule	Per unit energy consumed
Sulfur Dioxide	Sulfur Dioxide (SO2)	0,01	SulfurContent*(1-SulfurRetention)*(SO2/S)	Kilogramme	Kilogramme	Per unit energy consumed
Particulates PM10	Particulates PM10 (PM10)	1,03	1,03 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Particulates PM2p5	Particulates PM2pt5 (PM2.5)	0,93	0,93 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Black Carbon	Black Carbon (BC)	0,22	0,223 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Organic Carbon	Organic Carbon (OC)	0,11	0,11 ?c	Kilogramme	Metric Tonne	Per unit energy consumed
Ammonia	Ammonia (NH3)	0,00	0,00028 ?d	Kilogramme	Metric Tonne	Per unit energy consumed

a) IPCC 2006 Guidelines - Tier 1 default EFs

b) Derived from EMEP/EEA (2016) Tier 1 emission factors for combustion

c) Mean of 3 values for Forced Draft Zig-Zag (FDZ) kiln reported by Weyant et al., 2014. For VSBK use 96.7 t/TJ for CO2, 2969 kg/TJ for CO, 1.3 kg/t for PM2.5, 0.06 kg/t for BC and 0.69 kg/t for OC.

d) Battye et al. (1994) defaults (no NOx controls).

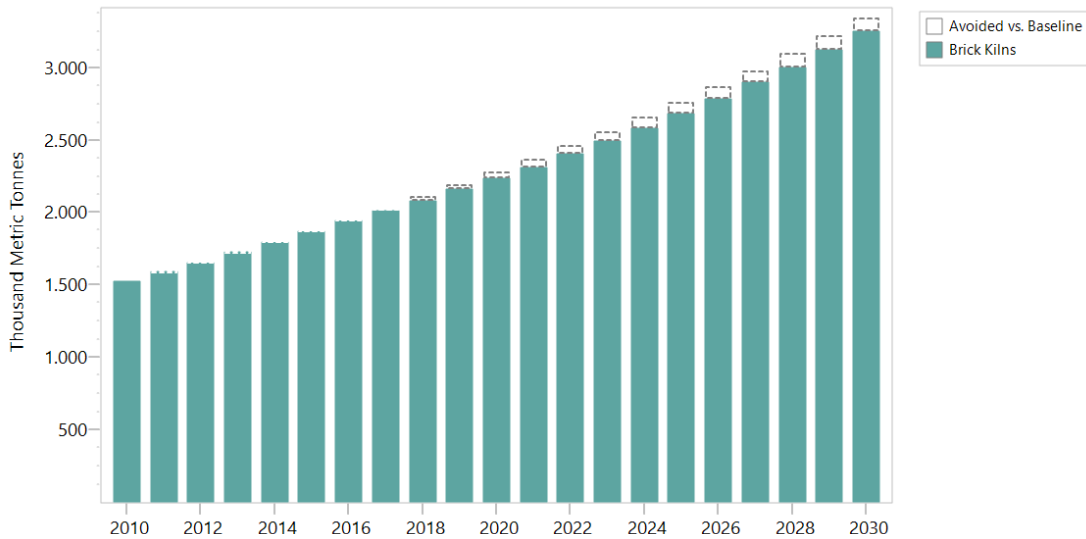
Results.

Reduction of carbon dioxide emissions

In the inertial scenario, total emissions are expected to increase from 1.6 to 3.3 million tons of CO2 between 2010 and 2030, i.e., within 20 years, emissions will double. The implementation of the mitigation measure described above would achieve a reduction of approximately 100,000 tons of CO2 by 2030 compared to the reference scenario, i.e., a reduction of 3% compared to what is expected.

Carbon Dioxide (Non-Biogenic)

Scenario: Bricks Avoided vs. Baseline, All Fuels, Effect: Particulates PM10

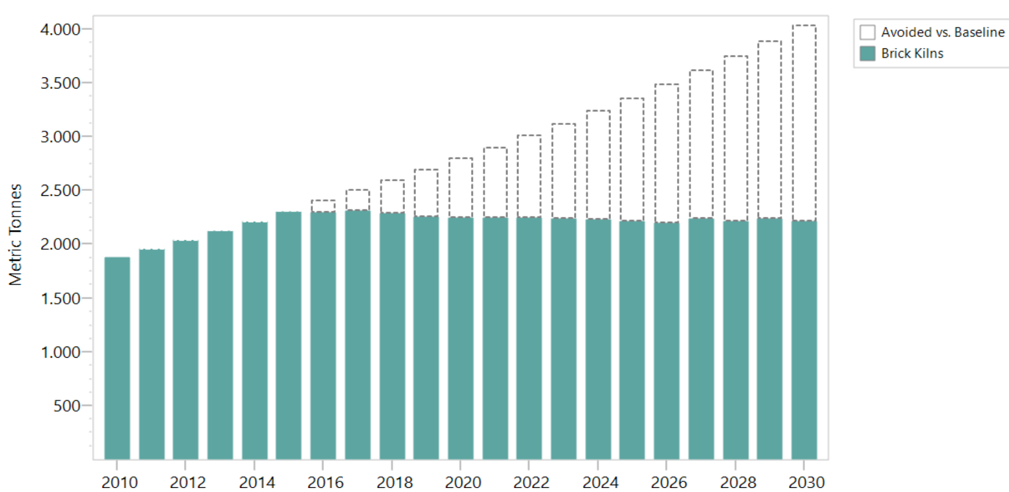


Reduction of PM10 emissions

In the inertial scenario, total particulate matter emissions are expected to increase by less than 10 microns from 1962 tonnes to 4040 tonnes between 2010 and 2030. The implementation of the mitigation measure described above would achieve a reduction of approximately 1835 tons of PM10 by 2030 compared to the reference scenario, i.e., a 45% reduction compared to what was projected

Particulates (PM10)

Scenario: Bricks Avoided vs. Baseline, All Fuels, Effect: Carbon Dioxide

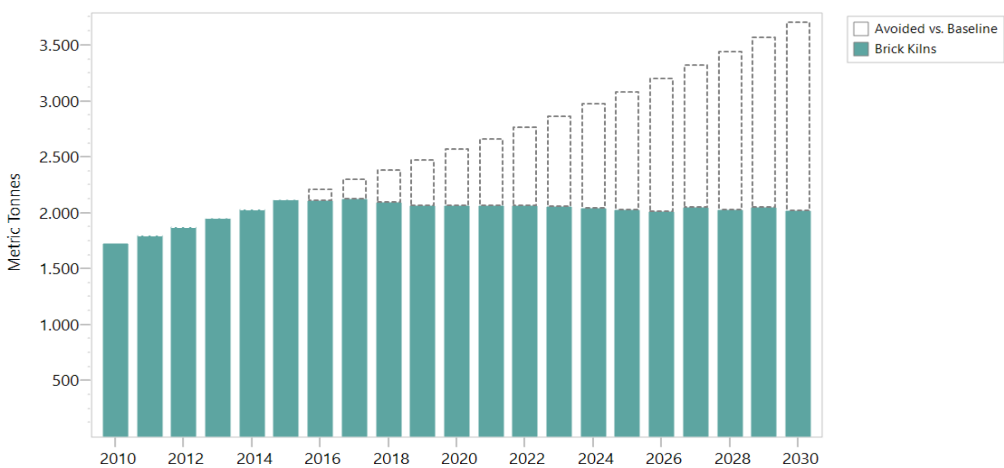


Reduction of PM2.5 emissions

In the inertial scenario, total particulate matter emissions are expected to increase by less than 2.5 microns from 1723 tons to 3715 tons between 2010 and 2030. The implementation of the mitigation measure described above would achieve a reduction of approximately 1,697 tons of PM2.5 by 2030 compared to the reference scenario, i.e., a 45% reduction compared to the projected.

Particulates (PM2.5)

Scenario: Bricks Avoided vs. Baseline, All Fuels, Effect: Particulates PM2pt5

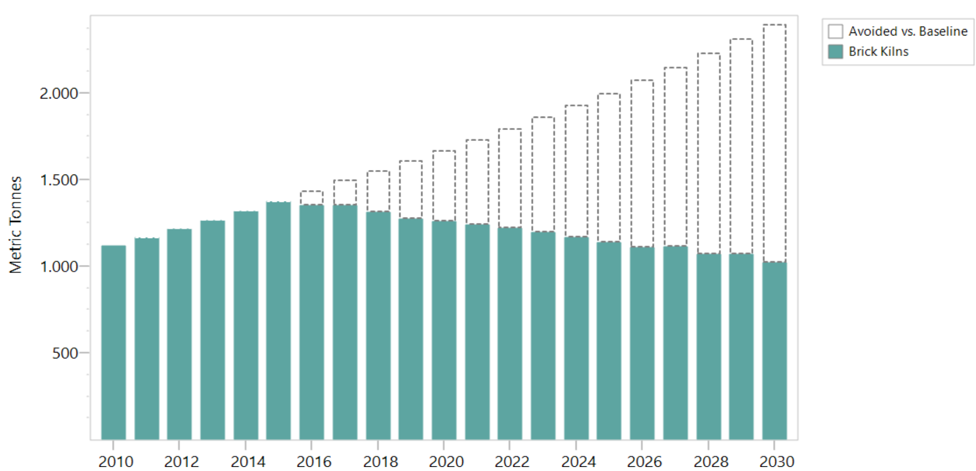


Reduction of black carbon emissions

In the inertial scenario, total black carbon emissions are expected to increase from 1119 tons to 2401 tons between 2010 and 2030. The implementation of the mitigation measure described above would achieve a reduction of approximately 1378 tons of black carbon by 2030 compared to the reference scenario, i.e., a 57% reduction over projections.

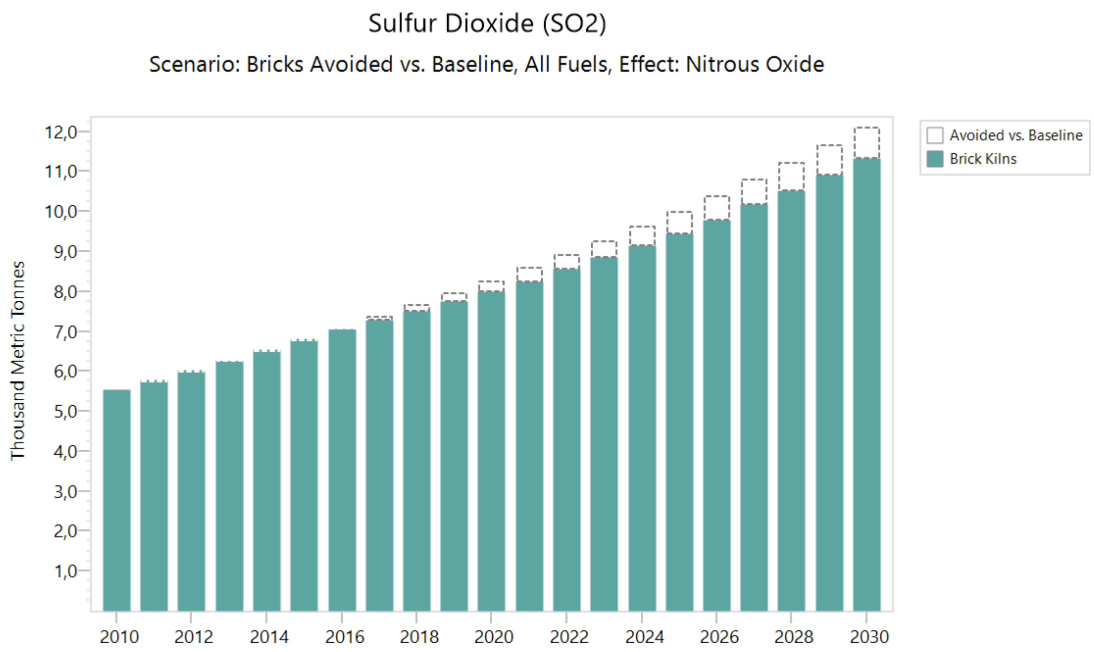
Black Carbon (BC)

Scenario: Bricks Avoided vs. Baseline, All Fuels, Effect: Particulates PM2pt5



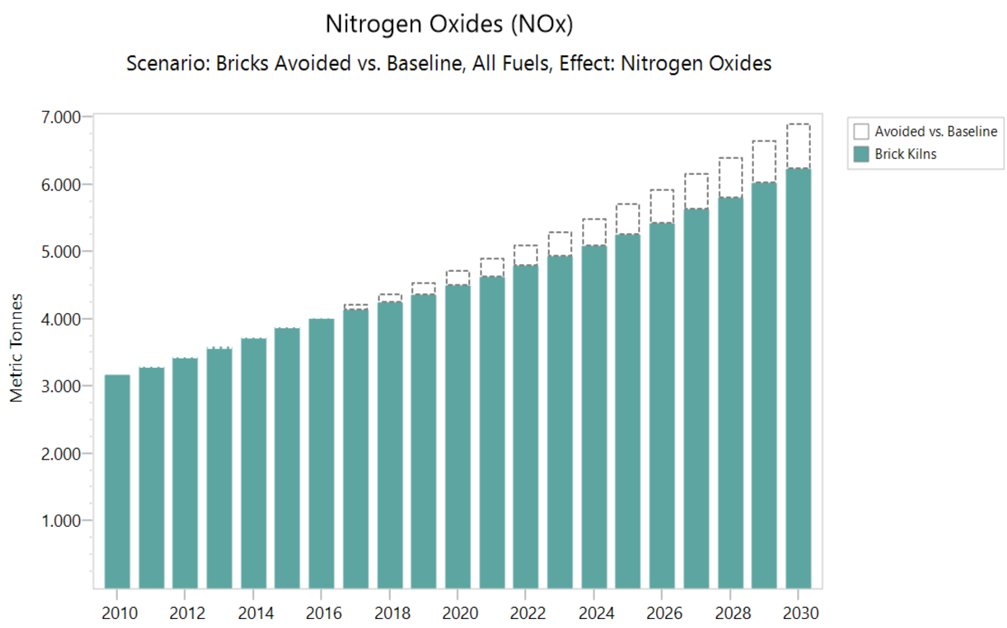
Reduction of sulphur dioxide emissions

In the inertial scenario, total SO2 emissions are expected to increase from 5500 tonnes to 12100 tonnes between 2010 and 2030. The implementation of the mitigation measure described would achieve a reduction of approximately 800 tonnes of SO2 by 2030 compared to the reference scenario, i.e. a reduction of 6% compared to the projected.



Reduction of nitrogen oxide emissions

In the inertial scenario, total NOX emissions are expected to increase from 3156 tonnes to 6903 tonnes between 2010 and 2030. The implementation of the mitigation measure described above would achieve a reduction of approximately 691 tonnes of NOX by 2030 compared to the reference scenario, i.e. a reduction of 10% over projections



Reduction of carbon monoxide emissions

In the inertial scenario, total CO emissions are expected to increase from 33300 tonnes to 72300 tonnes between 2010 and 2030. The implementation of the mitigation measure described above would achieve a reduction of approximately 20400 tons of CO by 2030 compared to the reference scenario, i.e. a reduction of 28% compared to the projected.