TOWARDS A LOW CARBON ENERGY SYSTEM IN MEXICO

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FORO IBEROAMERICANO ENERGÍAS RENOVABLES NO CONVENCIONALES

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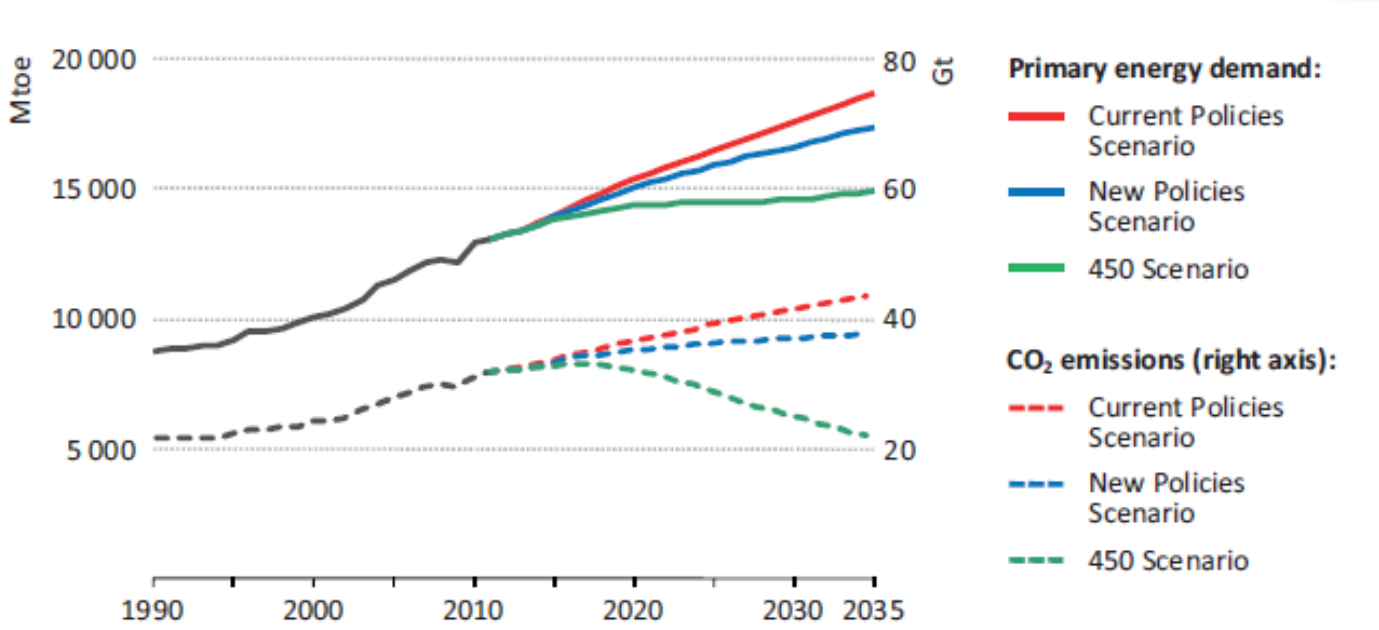
PROJECTIONS



Note: Mtoe = Million tonnes of oil equivalent; Gt = gigatonnes.

Source: World Energy Outlook, IEA (2013).

MEXICAN POLICY OF CLIMATE ACTION

- The General Law on Climate Change, enacted in October 2012.
  - Establishes an institutional framework of public policy on climate action.
  - Establishes a set of ambitious goals on climate action
    - 30% reduction in emissions of greenhouse gases by 2020 regarding to a baseline.
    - 50% reduction in greenhouse gases by 2050 regarding to national emissions in 2000.
    - By 2024, 35% of electricity will come from clean energies.
    - In 2018 all cities with more than 50,000 inhabitants should not emit methane from municipal solid waste management.

MEXICAN POLICY OF CLIMATE ACTION

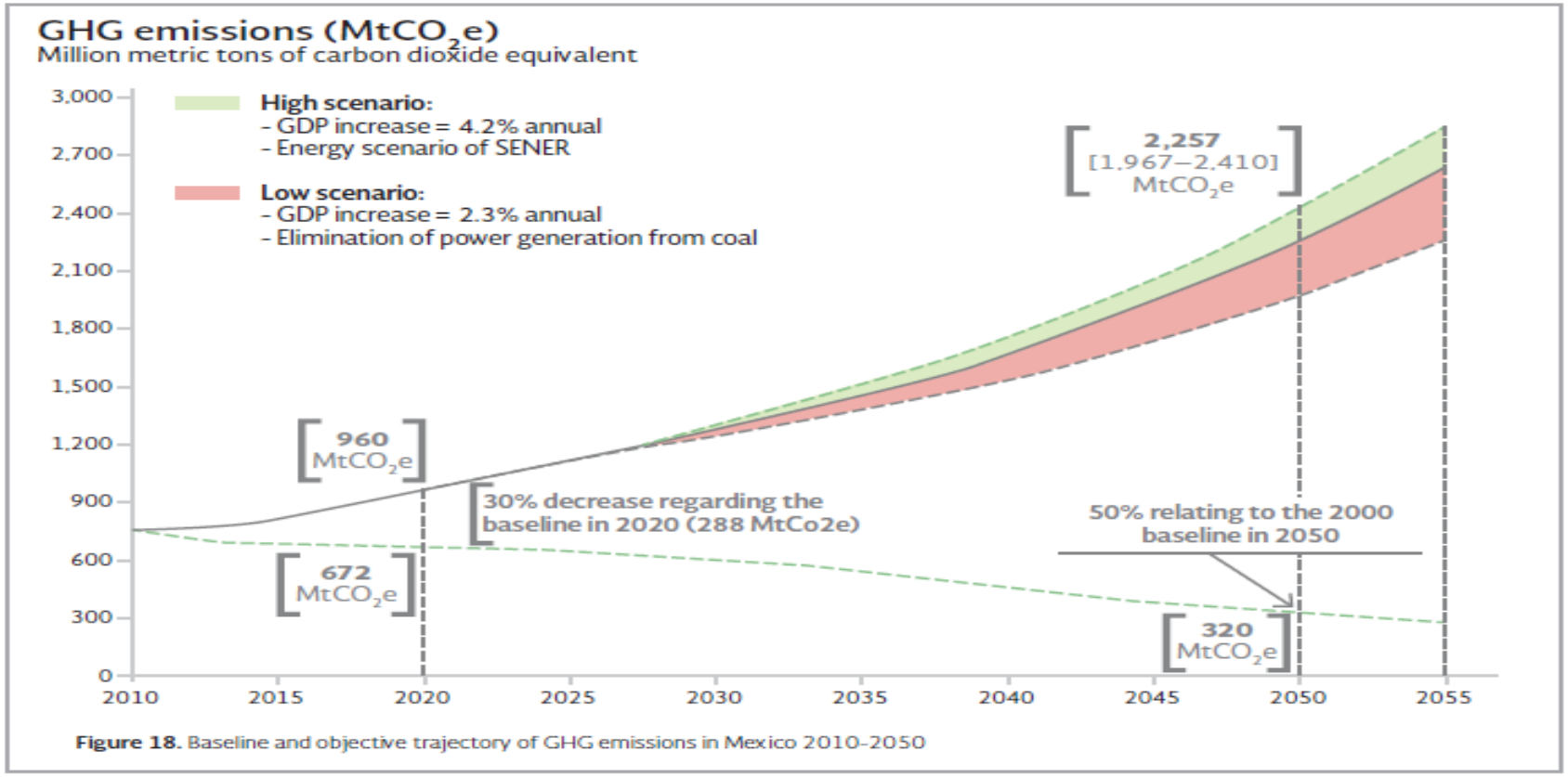
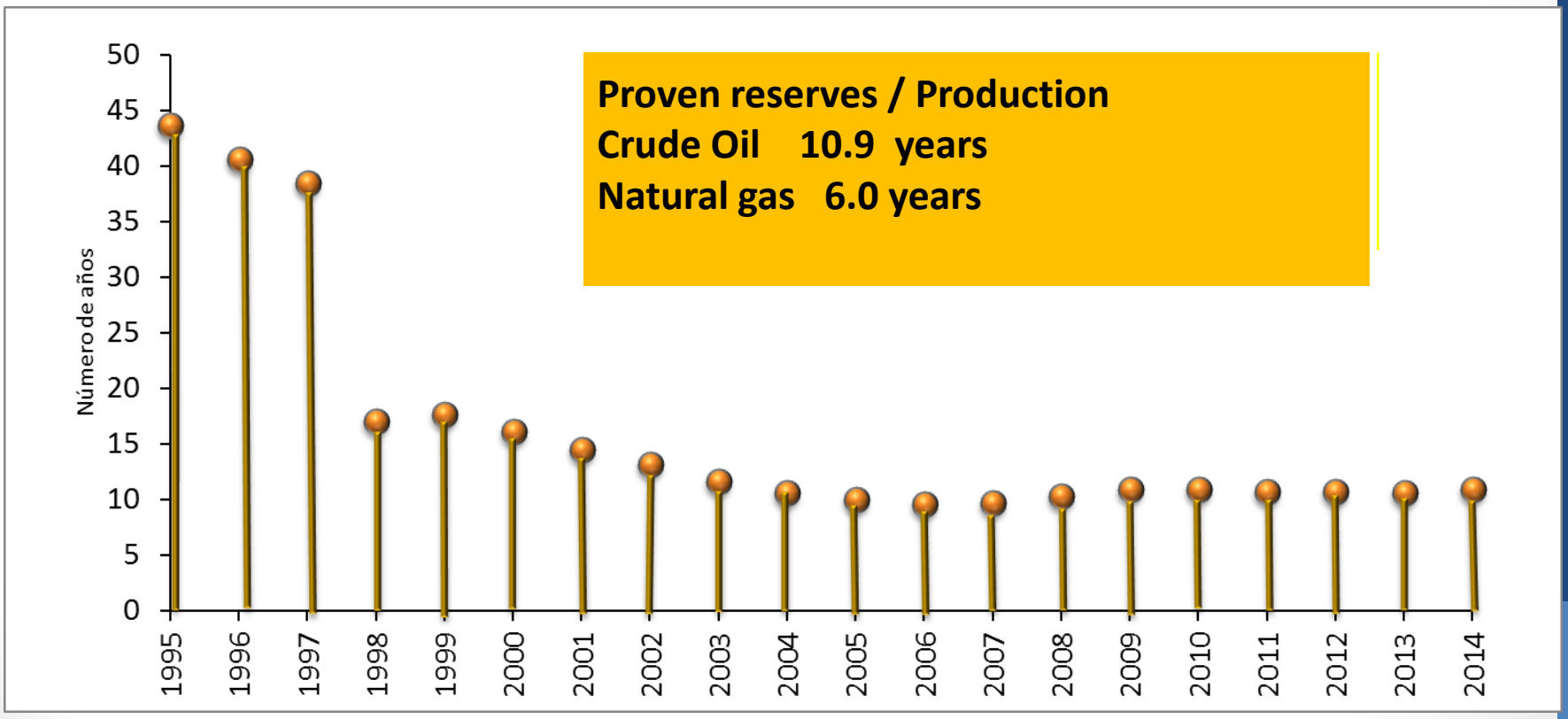


Figure 18. Baseline and objective trajectory of GHG emissions in Mexico 2010-2050

Source: National Strategy on Climate Change

CONTEXT OF SCENARIO CONSTRUCTION
THE PROBLEMATIC OF NATIONAL ENERGY SECTOR

- The energy efficiency impulse should be an important part of the package of public policies to prolong the proven reserves.



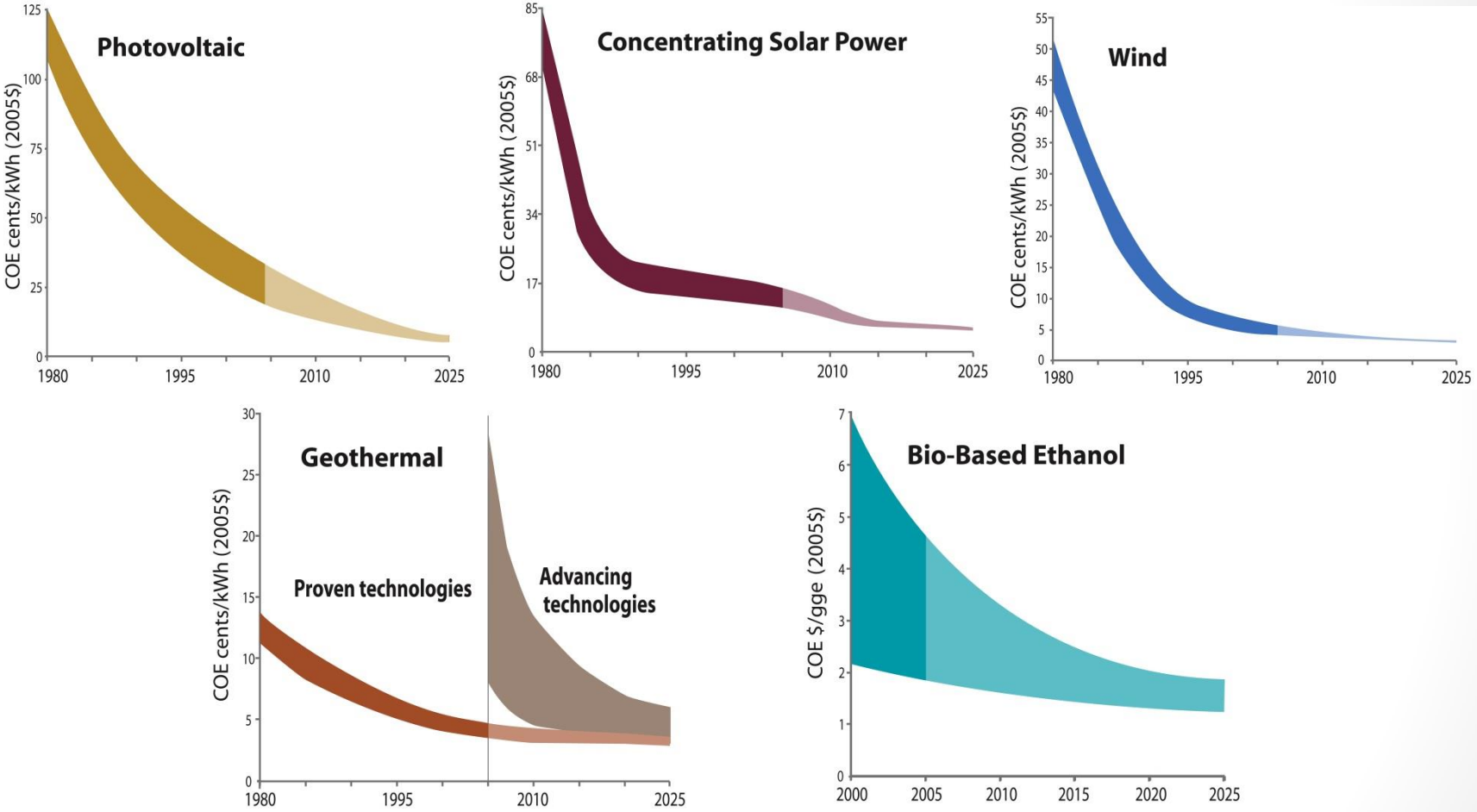
Source: PEMEX (several years).

CONTEXT OF SCENARIO CONSTRUCTION
STATE OF THE ART OF RENEWABLE ENERGY SOURCES

- Development of new technological trajectories to decarbonise energy systems.
- Several countries have boosted the development of renewable energy to implement policies to combat climate change, energy diversification and sustainable development.
- Renewable energies face entry barriers such as fossil fuels subsidies, omission of negative externalities and the energy systems conservatism.

LEVELIZED COST OF RENEWABLE ENERGY IN THE WORLD

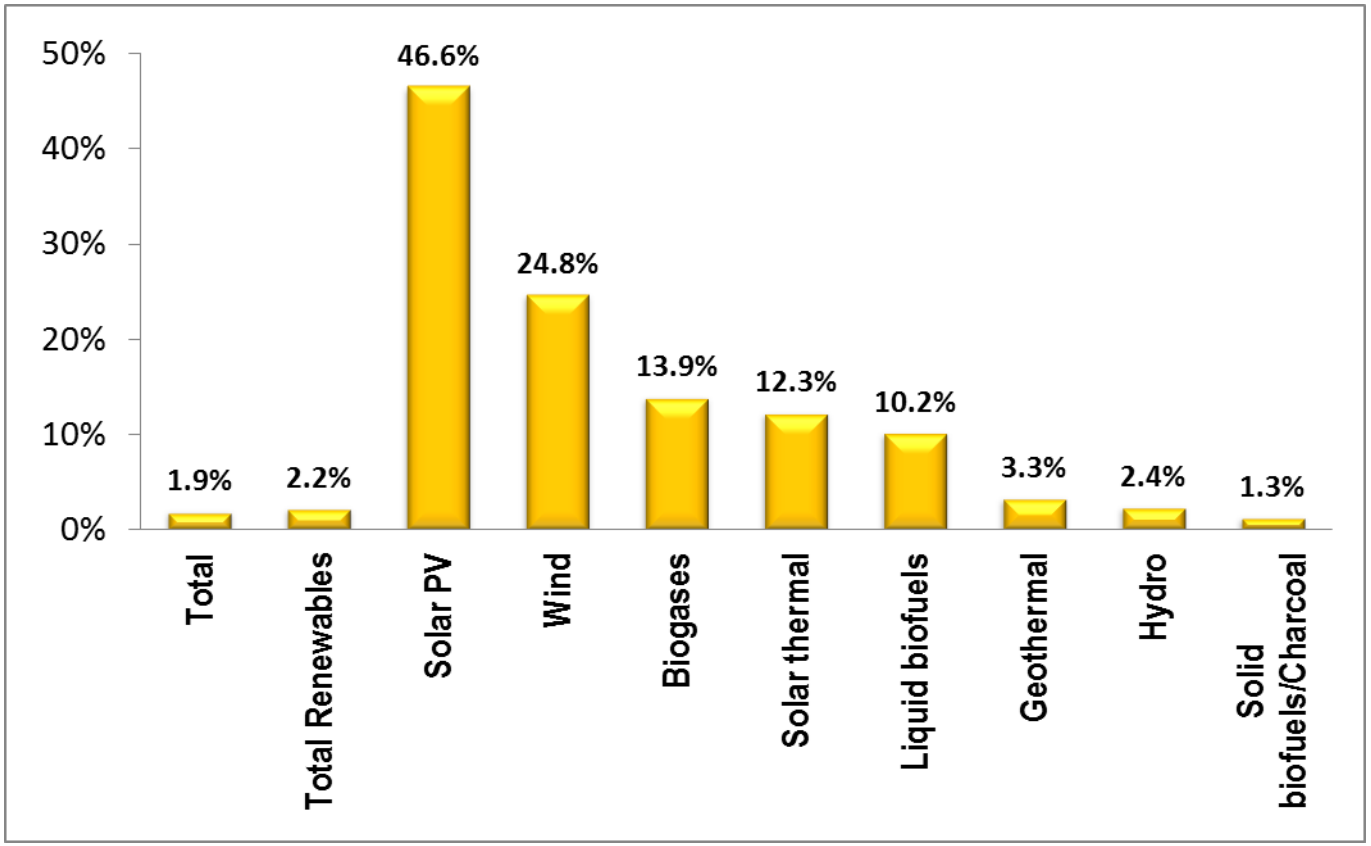
Levelized cost of energy in constant 2005$[1]



Source: NREL Energy Analysis Office (www.nrel.gov/analysis/docs/cost_curves_2005.ppt)

[1]These graphs are reflections of historical cost trends NOT precise annual historical data. DRAFT November 2005

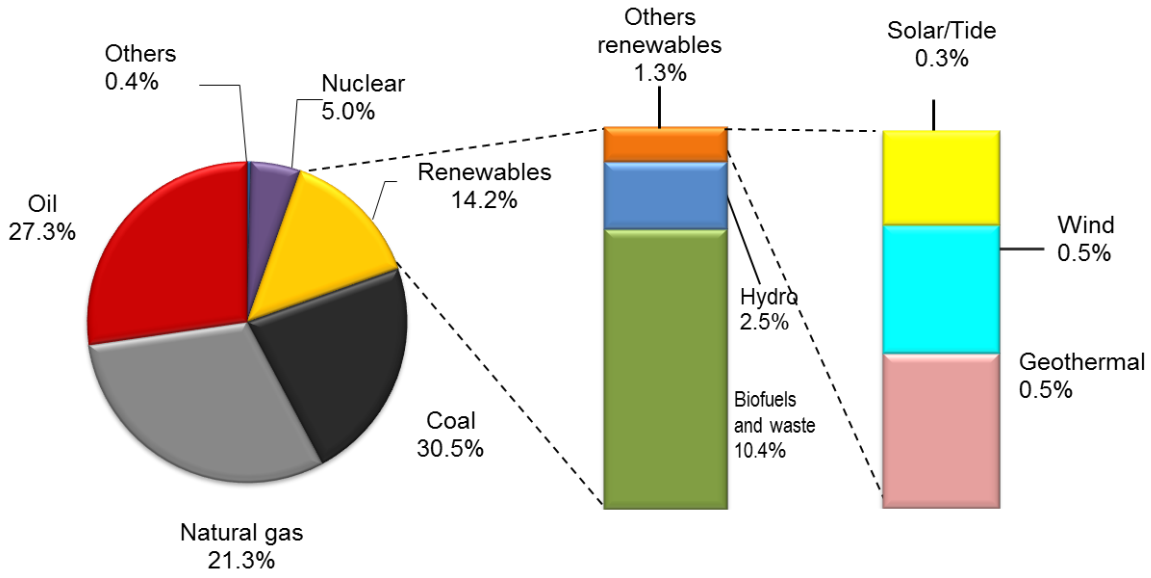
FORMATION OF GLOBAL MARKETS FOR RENEWABLE ENERGY



Annual growth rates of world renewables supply from 1990 to 2013.

Source: IEA (2015).

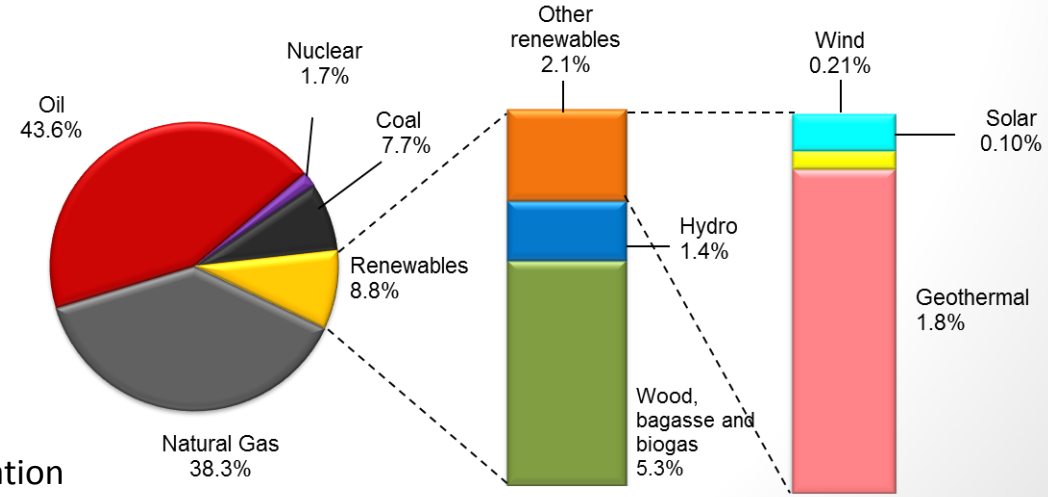
Fuel shares in world total primary energy supply, 2013



567,521 PJ

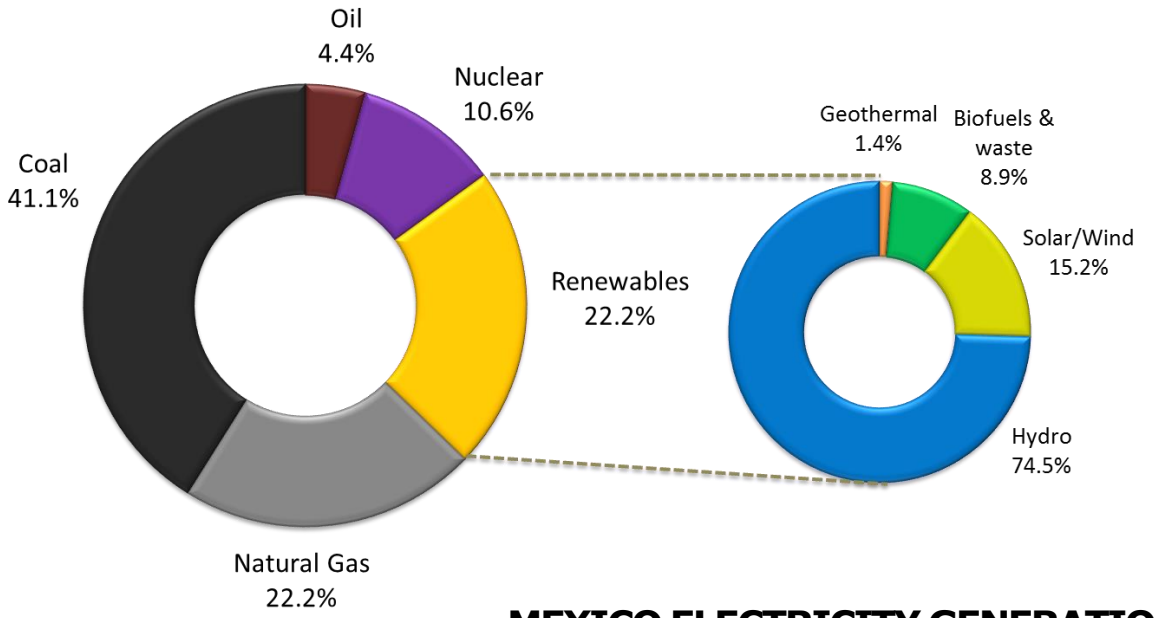
Fuel shares in Mexico total primary energy supply, 2013

7,195 PJ



Source: IEA, 2015. Renewables information

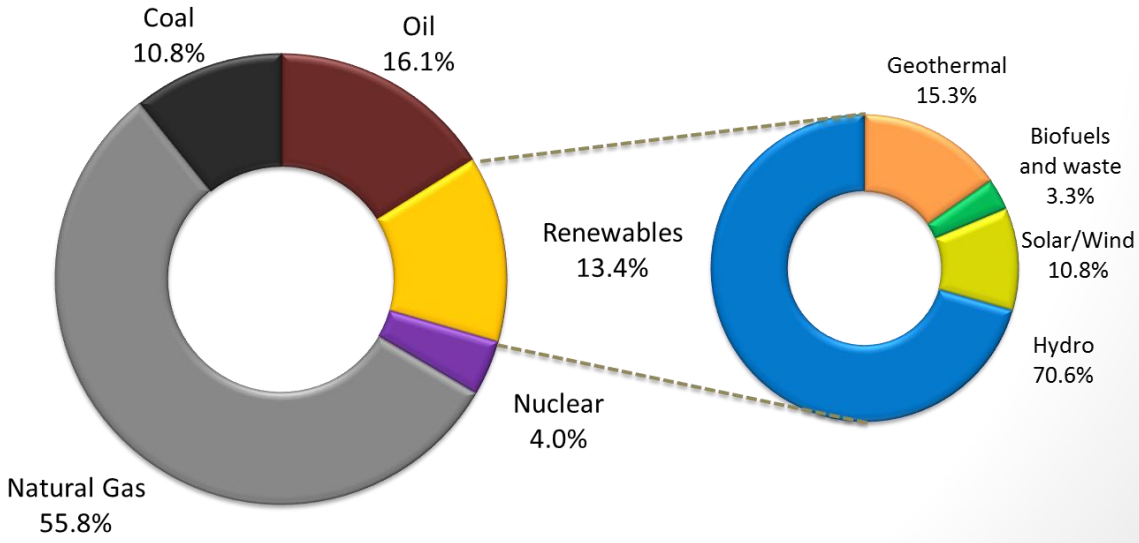
WORLD ELECTRICITY GENERATION BY SOURCE, 2013



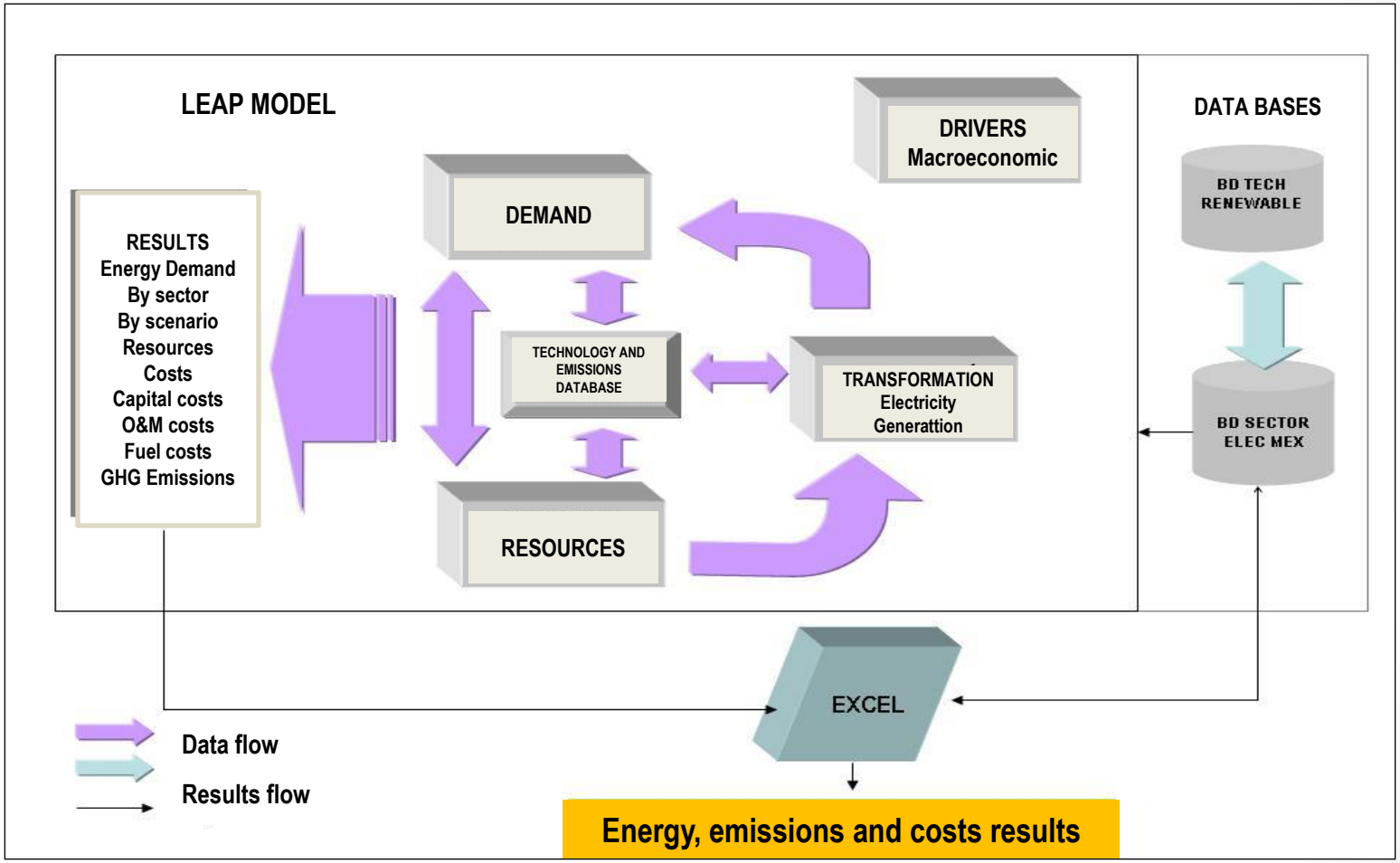
23,391 TWh

MEXICO ELECTRICITY GENERATION BY SOURCE, 2013

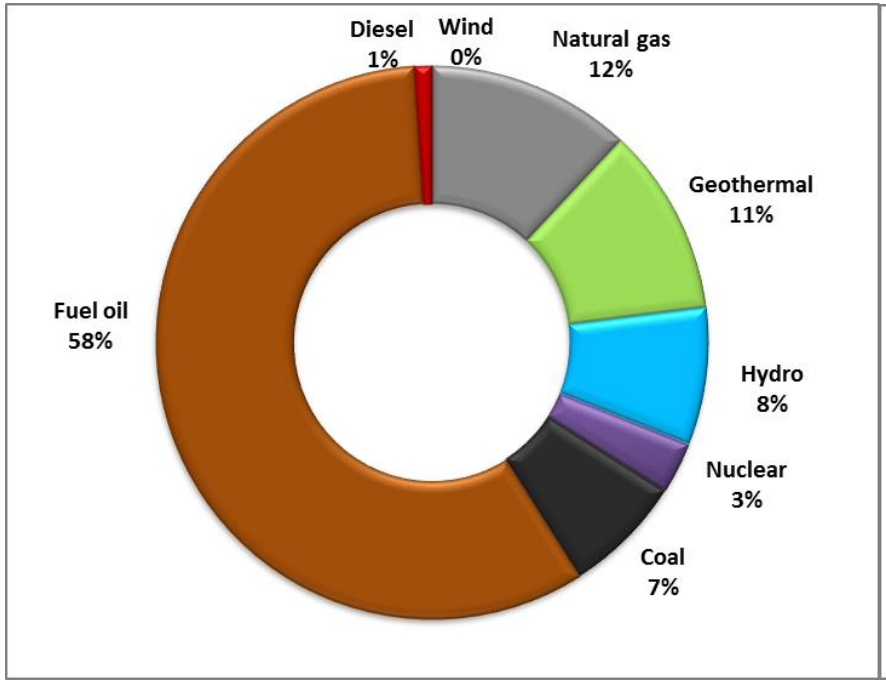
297 TWh

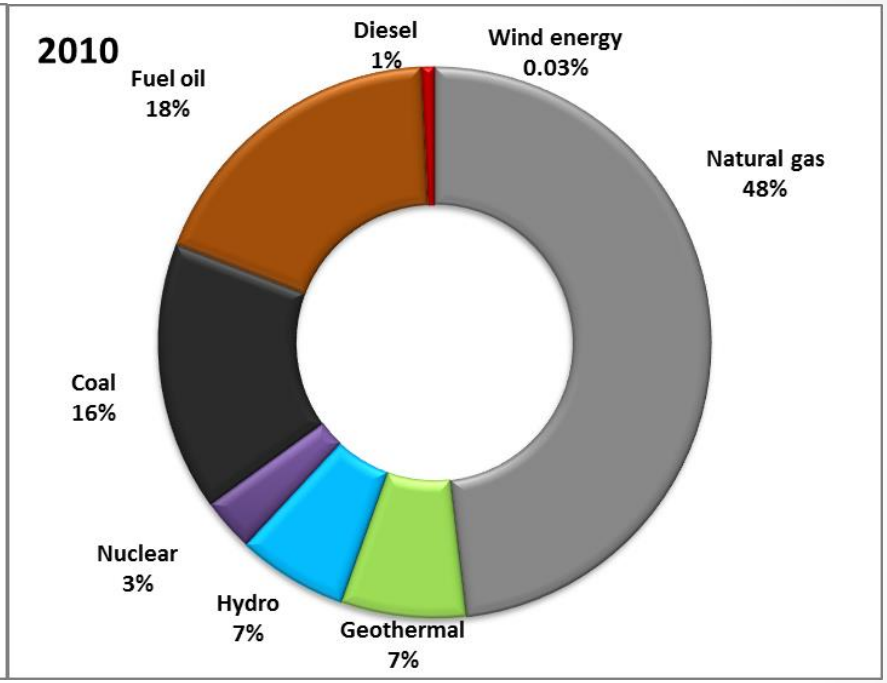


CONSTRUCTION OF ALTERNATIVE SCENARIOS 2035



HISTORICAL EVOLUTION OF MEXICAN ELECTRICITY SECTOR



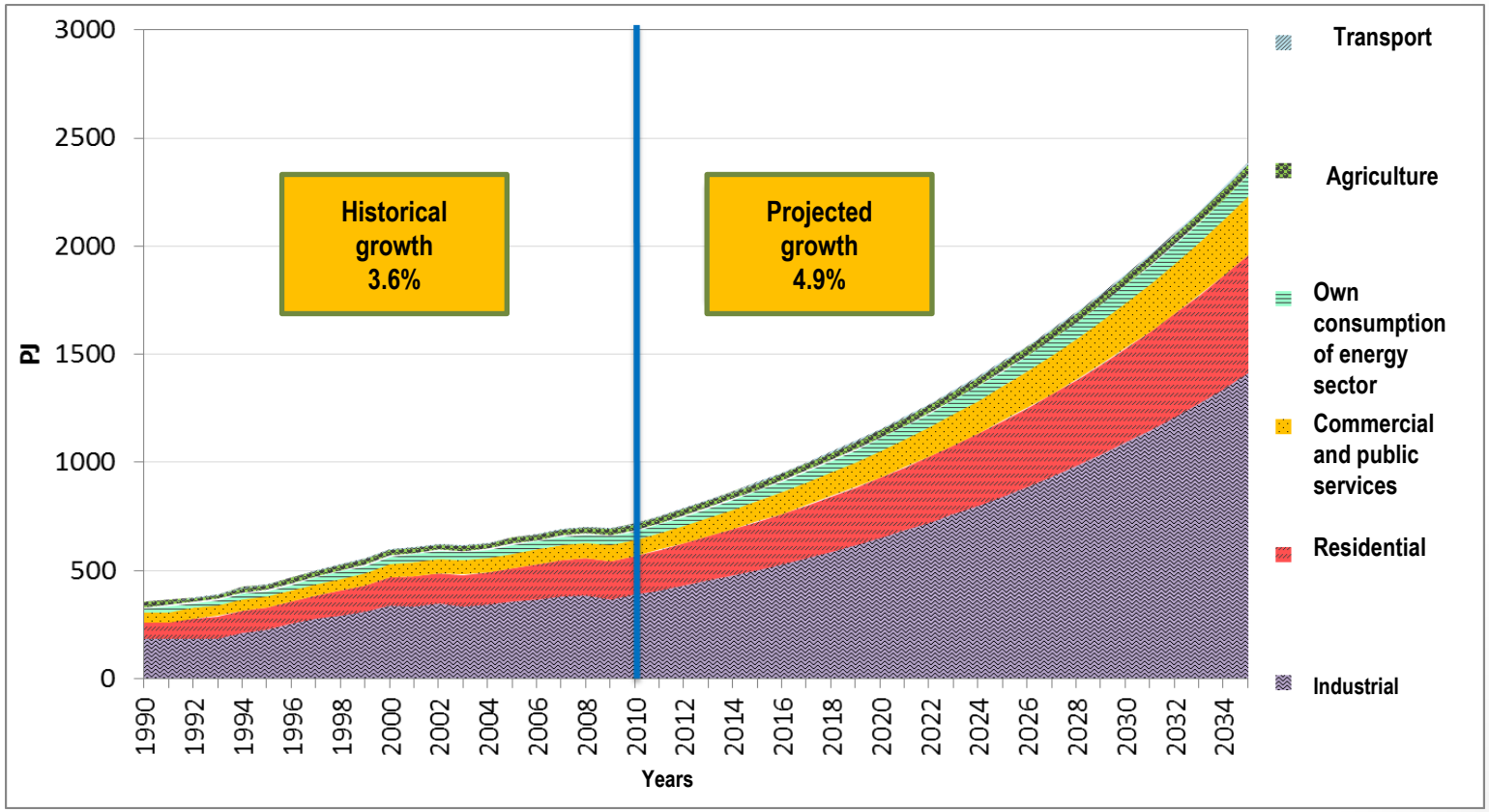


Source: National Energy Balance

Structure of primary energy consumption for electricity generation, 1990 and 2010

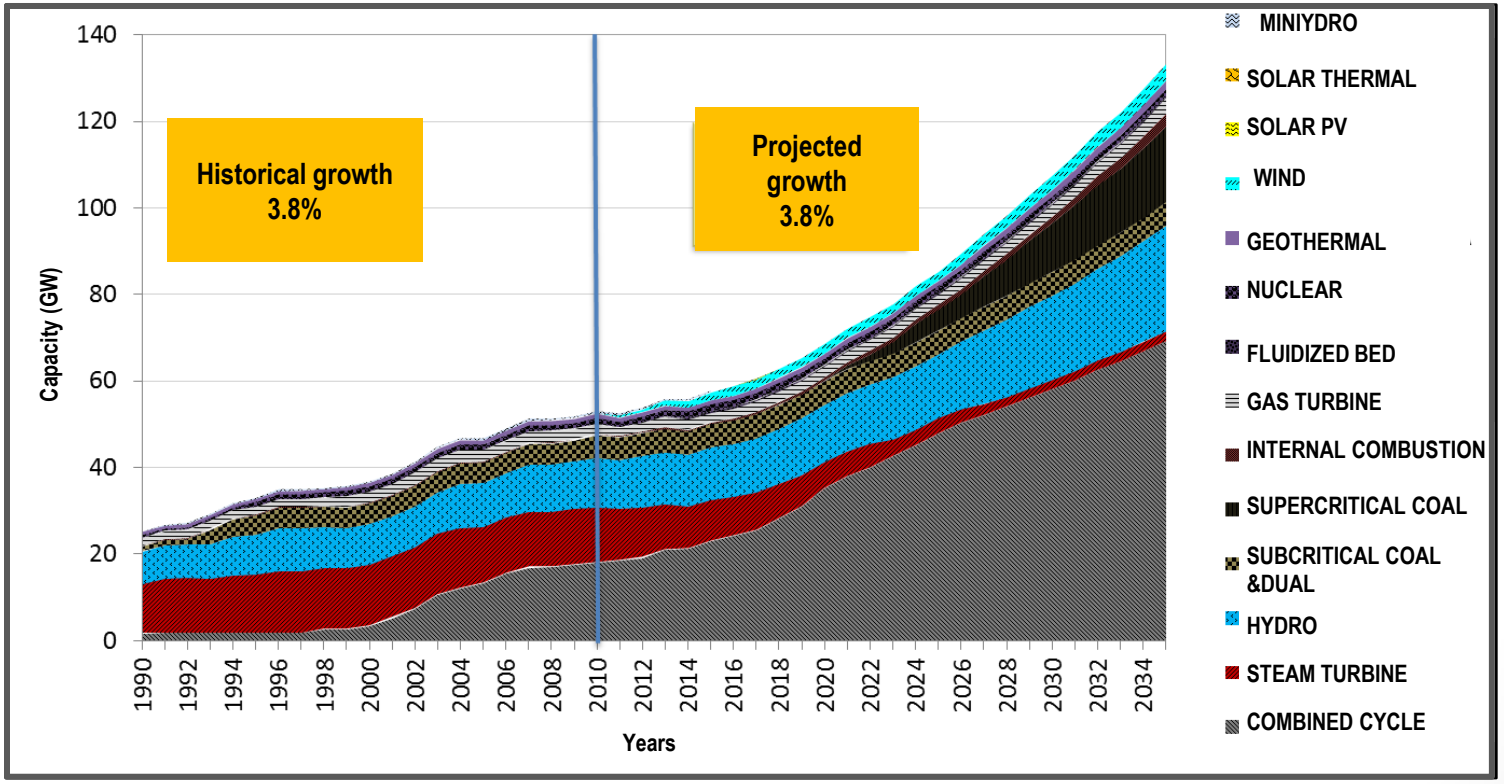
CONSTRUCTION OF SCENARIOS TO 2035 BASE LINEOF MEXICAN ELECTRICITY SECTOR

- Reference Scenario Electricity Demand



CONSTRUCTION OF SCENARIOS TO 2035 BASE LINEOF MEXICAN ELECTRICITY SECTOR

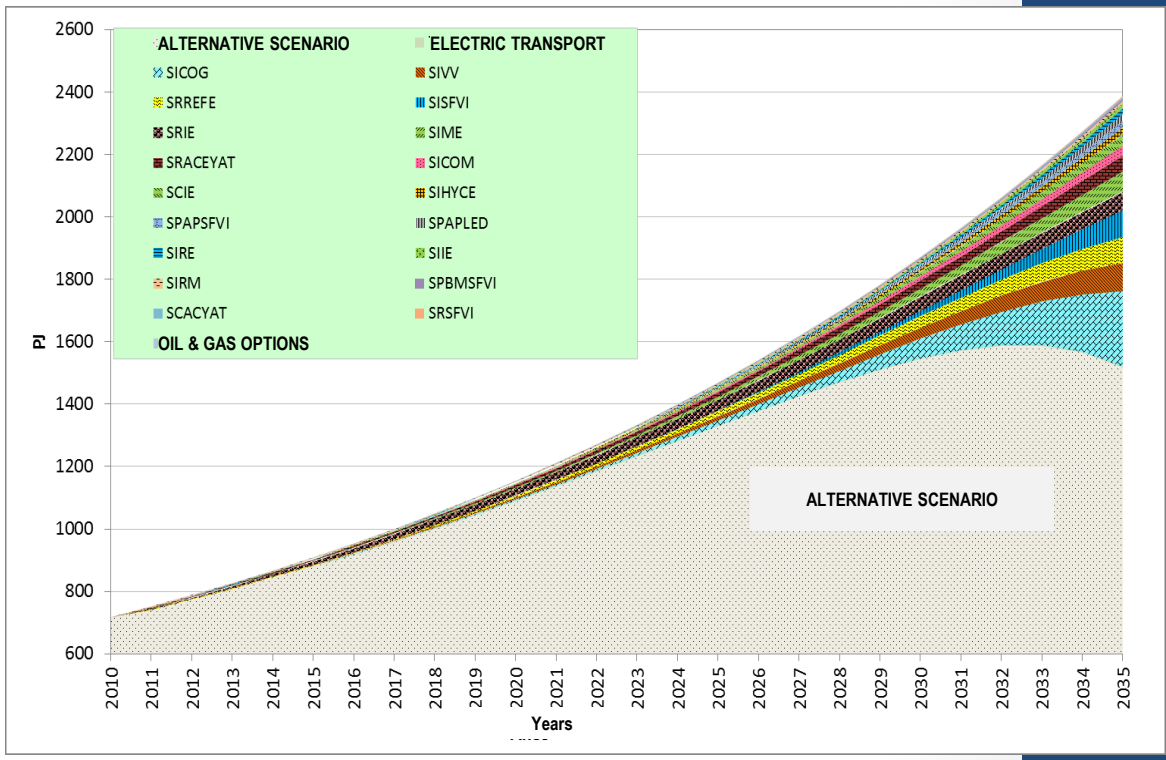
- **Reference Scenario Electricity Supply**



CONSTRUCTION OF MITIGATION SCENARIOS TO 2035 ELECTRICITY SECTOR

- **Alternative Scenario (demand side: energy saving measures, efficient use of electricity and distributed generation and others)**

Sector	ID	Mitigation option
Residential	SRIE	Residential efficient lighting
	SRREFE	Efficient refrigerators
	SRACEYAT	Residential efficient air conditioning and thermic insulation
	SRSFVI	PV systems interconnected
Industrial	SIME	Energy savings (electricity) - Motors
	SIVV	Energy savings (electricity) – Speed variators
	SICOM	Energy savings (electricity) – Air compressors
	SIRE	Energy savings (electricity) - Coolers
	SIIE	Energy savings (electricity) - Lighting
	SIHYCE	Energy savings (heat generation and distribution systems) - Furnaces and electric heaters
	SIRM	Recycling (Siderurgy, aluminum, glass, paper)
	SICOG	Combined heat and power
	SISFVI	Solar photovoltaics
Commercial	SCIE	Efficient lighting commercial
	SCACYAT	Commercial efficient air conditioning and termic insulation
Public services	SPAPLED	Leds in street lighting
	SPAPSFVI	PV in street lighting
	SPBMSFVI	PV to pump water
Oil and Gas sector	SEOPT	System optimization for associated and non-associated gas production
	SELIMT	Inline pipeline cleaning tools (Pipeline pigs)
	SEMESEE	Onsite measurements for improved energy efficiency
	SEORC	Optimization of compression ratio
	SEAVCOPT	Optimizing compressor efficiency by adjusting valve position
	SECMR	Resizing of compressed air systems for minimizing recirculation and adjusted inlet gas flow
	SEAMVL	Manual or automatic adjustment of compressor cylinder clearance for adjusted inlet gas flow
	SEACCVOP	Adjustment of compressor cylinder clearance for improved efficiency
	SEEIIE	Intra and inter-stage coolers
	RMP	Enhanced oil recovery
Transport	STVE	Transport electric systems
	STVHEN	Plug-in hibrid electric vehicles
	STVH	Electric Vehicles



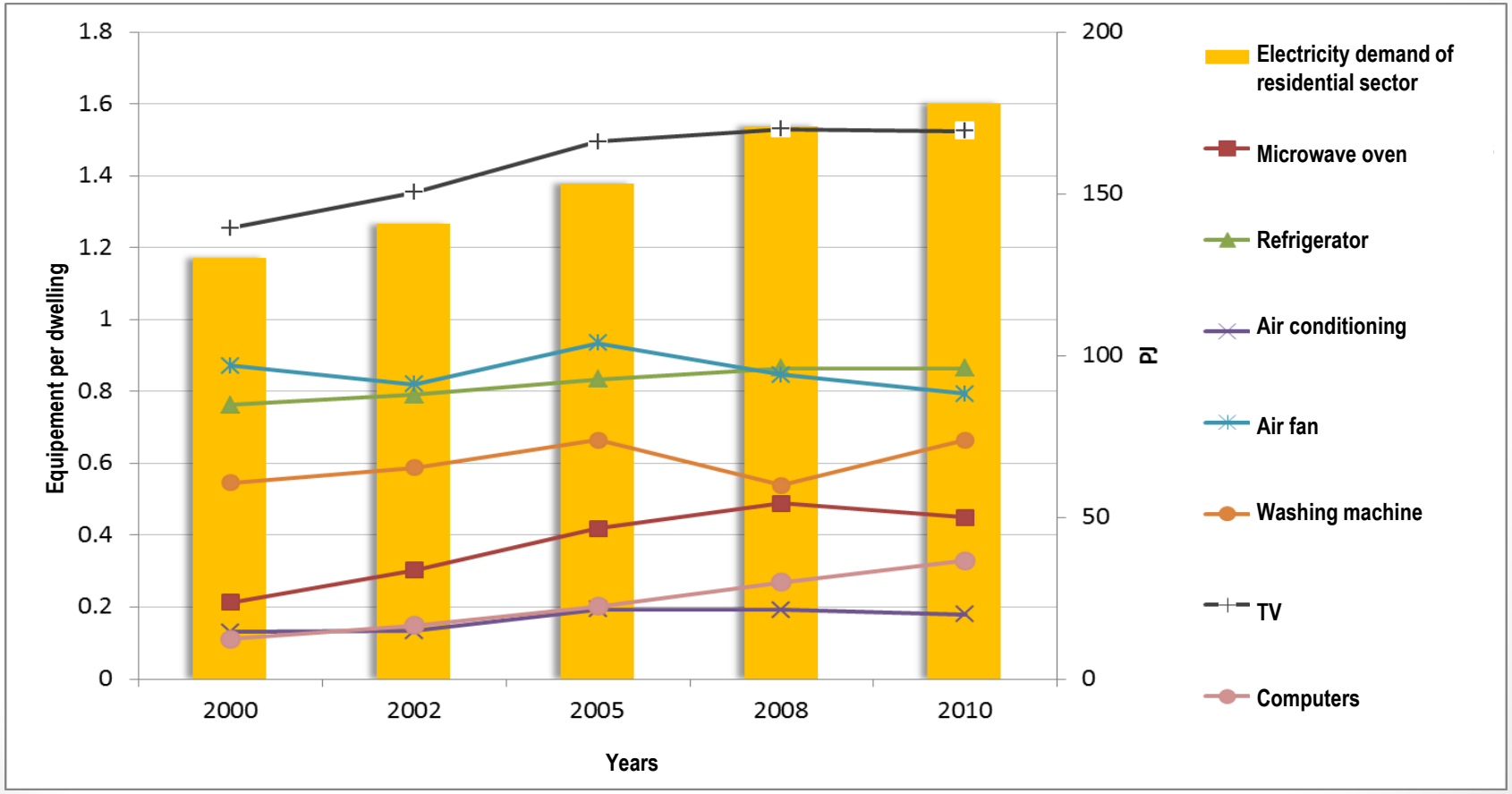
CONSTRUCTION OF MITIGATION SCENARIOS TO 2035 ELECTRICITY SECTOR

- Residential Sector. Demand Side: Saving measures, efficient use of electricity and distributed generation

Residential sector mitigation options	Potential mitigation (Millions T CO_2e)	Mitigation cost (USD 2007/T CO_2e)	Capital (Millions USD 2007)	O&M (Millions USD 2007)	Fuel (Millions USD 2007)	Cost-benefit (Millions USD 2007)
Residential efficient lighting	87.6	-55.9	291.8	0.0	-5189.6	-4897.8
Efficient refrigerators	65.0	-8.8	2296.8	0.0	-2871.1	-574.3
Residential efficient air conditioning and thermic insulation	48.5	-1.6	2384.3	0.0	-2460.1	-75.8
PV systems interconnected	2.4	106.3	420.5	2.0	-168.5	254.0

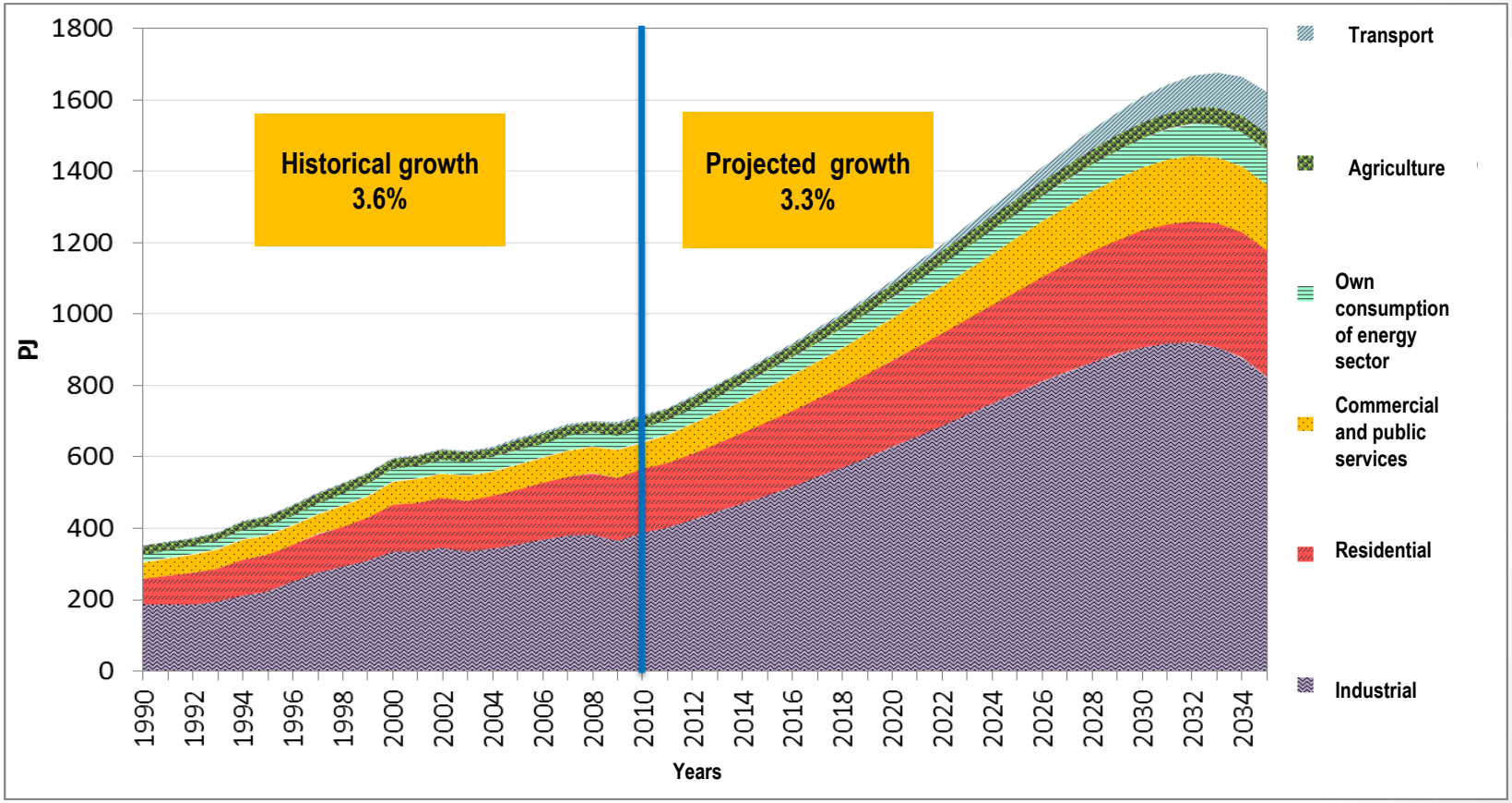
CONSTRUCTION OF MITIGATION SCENARIOS TO 2035
ELECTRICITY SECTOR
SATURATION OF ELECTRIC APPLIANCES IN THE RESIDENTIAL SECTOR

RESIDENTIAL SECTOR



CONSTRUCTION OF MITIGATION SCENARIOS TO 2035
ELECTRICITY SECTOR

ELECTRICITY DEMAND WITH ENERGY SAVINGS MEASURES AND ENERGY EFFICIENT USE



CONSTRUCTION OF MITIGATION SCENARIOS TO 2035 ELECTRICITY SECTOR

Alternative Electricity Scenario (Supply Side: Renewable Energy Sources)

Technology	Annual growth 2010-2035	CAPACITY IN 2010 (MW)	CAPACITY IN 2035 (MW)
HYDRO	3.8%	11,240	28,717
GEOTHERMAL	11.0%	965	12,401
WIND	40.6%	85	19,985
SOLAR PHOTOVOLTAIC	69.4%	-	4,000
SOLAR THERMAL	21.3%	-	1,092
BIOMASS FR*	17.5%	-	8,250
BIOMASS EP**	11.9%	-	1,218
BIOGAS	31.8%	-	1,397
MINIHYDRO	12.5%	263	4,550
TOTAL	7.8%	12,553	81,609

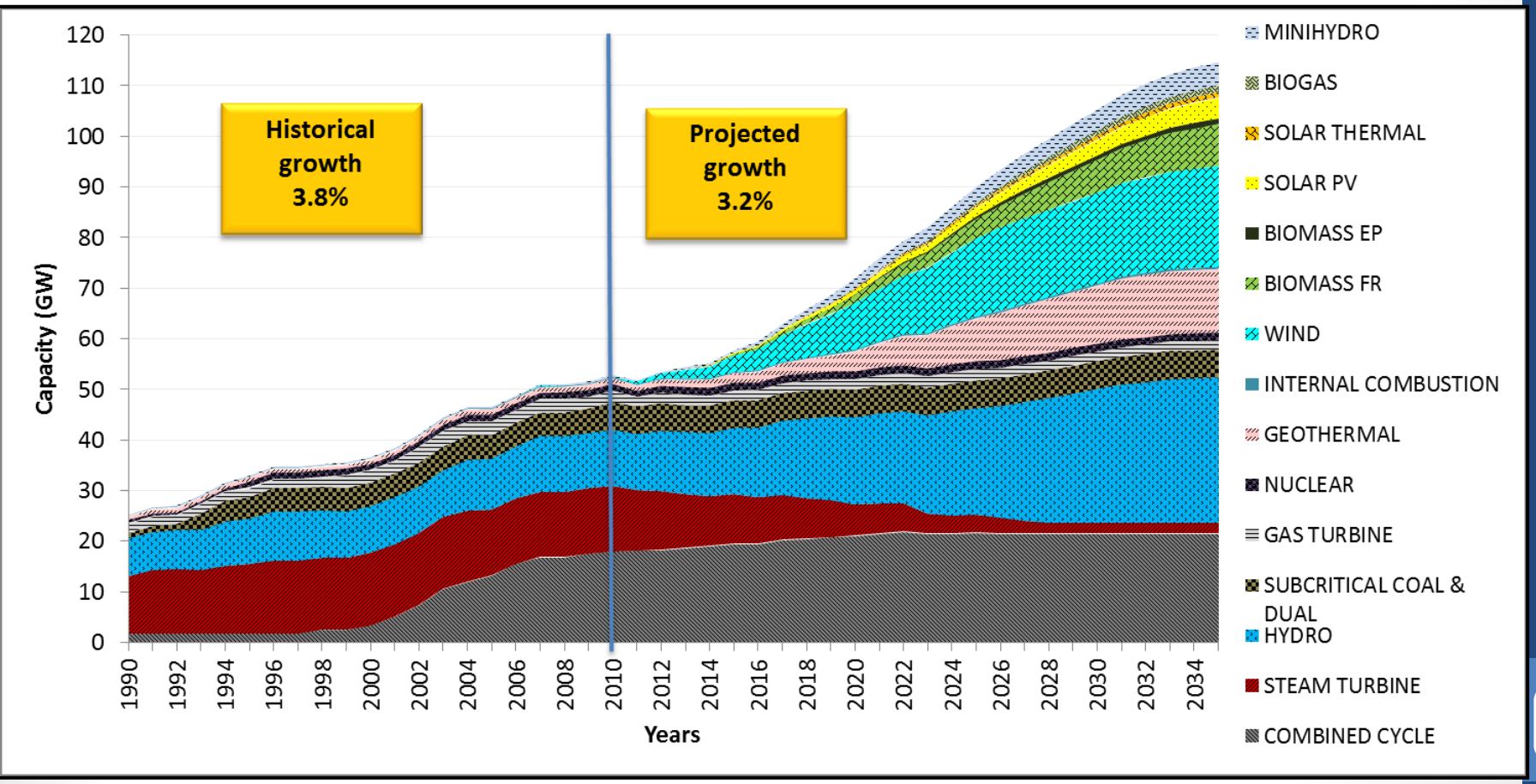
*Biomass FR = Biomass from forestry residues

**Biomass EP = Biomass from energy plantations

In the alternative scenario 21% of capacity in 2035 comes from wind and PV technologies (23,985 MW). This capacity increases 41% annually in the analysis period.

CONSTRUCTION OF MITIGATION SCENARIOS TO 2035
ELECTRICITY SECTOR

- Alternative Electricity Scenario Supply



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CONSTRUCTION OF MITIGATION SCENARIOS TO 2035
ELECTRICITY SECTOR

- **Alternative Electricity Scenario Supply**
- Levelized Generation Cost

Generation technology	Generation Cost (USD2007/kWh)
Wind	0.07
Solar photovoltaic	0.23
Solar thermal	0.20
Geothermal	0.06
Biomass FR*	0.08
Biomasa EP**	0.10
Hydro >30 MW	0.06
Minihydro <30 MW	0.08
Biogas	0.08

*Biomass FR = Biomass from forestry residues
**Biomass EP = Biomass from energy plantations

COST-BENEFIT ANALYSIS OF THE ALTERNATIVE ELECTRICITY SCENARIO SUPPLY

Technology	Additonal capital cost (MUSD2007)	Additional O&M cost (MUSD2007)	Additional fuel cost (MUSD2007)	Additional Total cost (MUSD2007)	Emissions evited (MT CO_{2e})	Abatement cost (USD2007/ T CO_{2e})
Wind	$7,138	($1,828)	($5,529)	($219)	400	($0.5)
Hydro	$4,498	($593)	($3,234)	$672	225	$3.0
Solar PV	$2,111	($12)	($450)	$1,649	39	$42.7
Solar Thermal	$711	($7)	($239)	$464	20	$23.6
Biomass FR*	$3,084	($266)	($3,854)	($1,036)	321	($3.2)
Biomass EP**	$382	$54	($510)	($73)	48	($1.5)
Minihydro	$1,953	($655)	($1,891)	($593)	139	($4.3)
Geothermal	$4,904	($1,230)	($6,620)	($2,946)	517	($5.7)
Biogas	$474	$8	($622)	($140)	55	($2.5)
Total	**$25,255**	**($4,528)**	**($22,949)**	**($2,223)**	**1763**	**($1.3)**

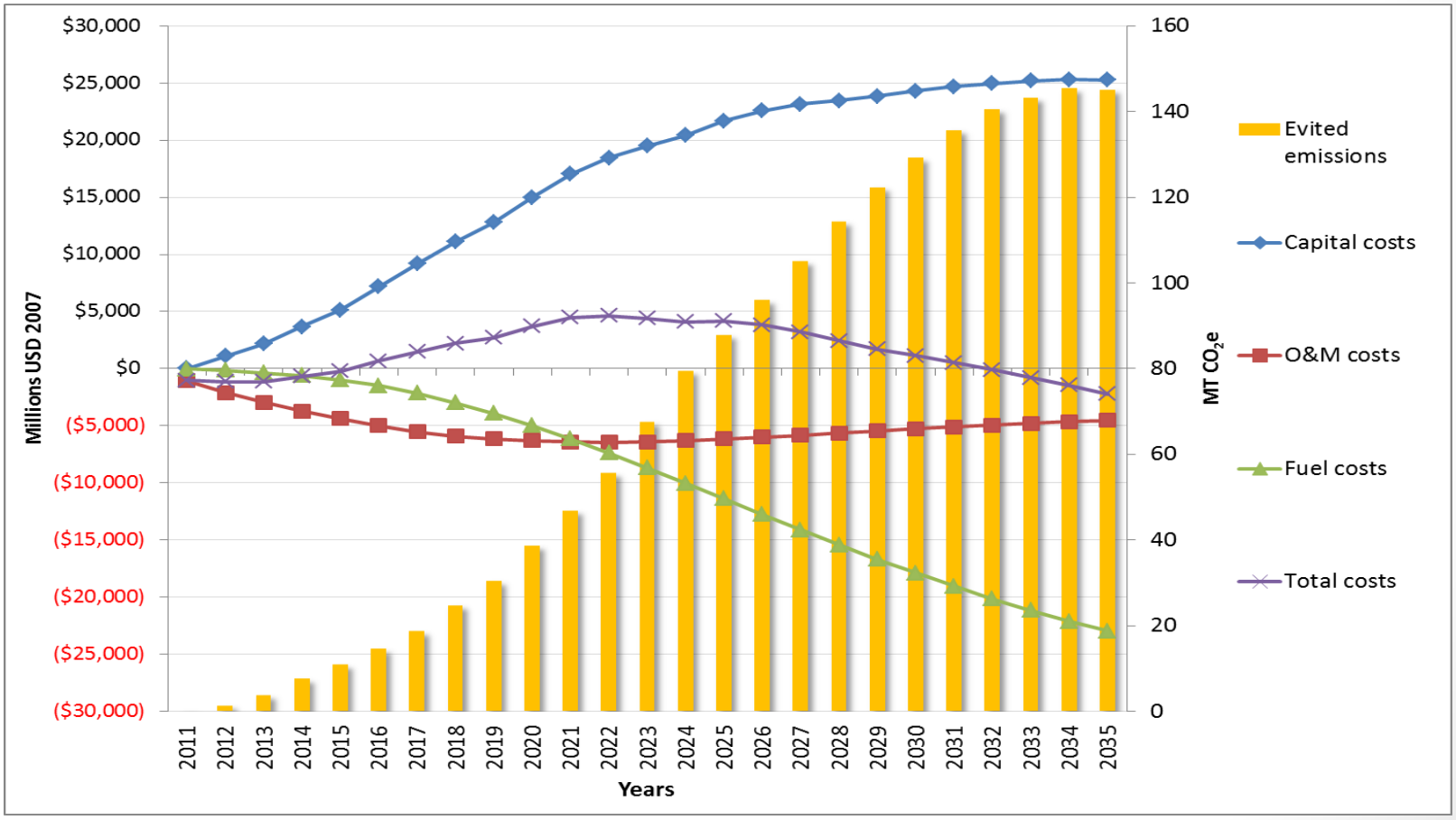
*Biomass FR = Biomass from forestry residues

**Biomass EP = Biomass from energy plantations

*** The amounts in brackets represent economic benefits.

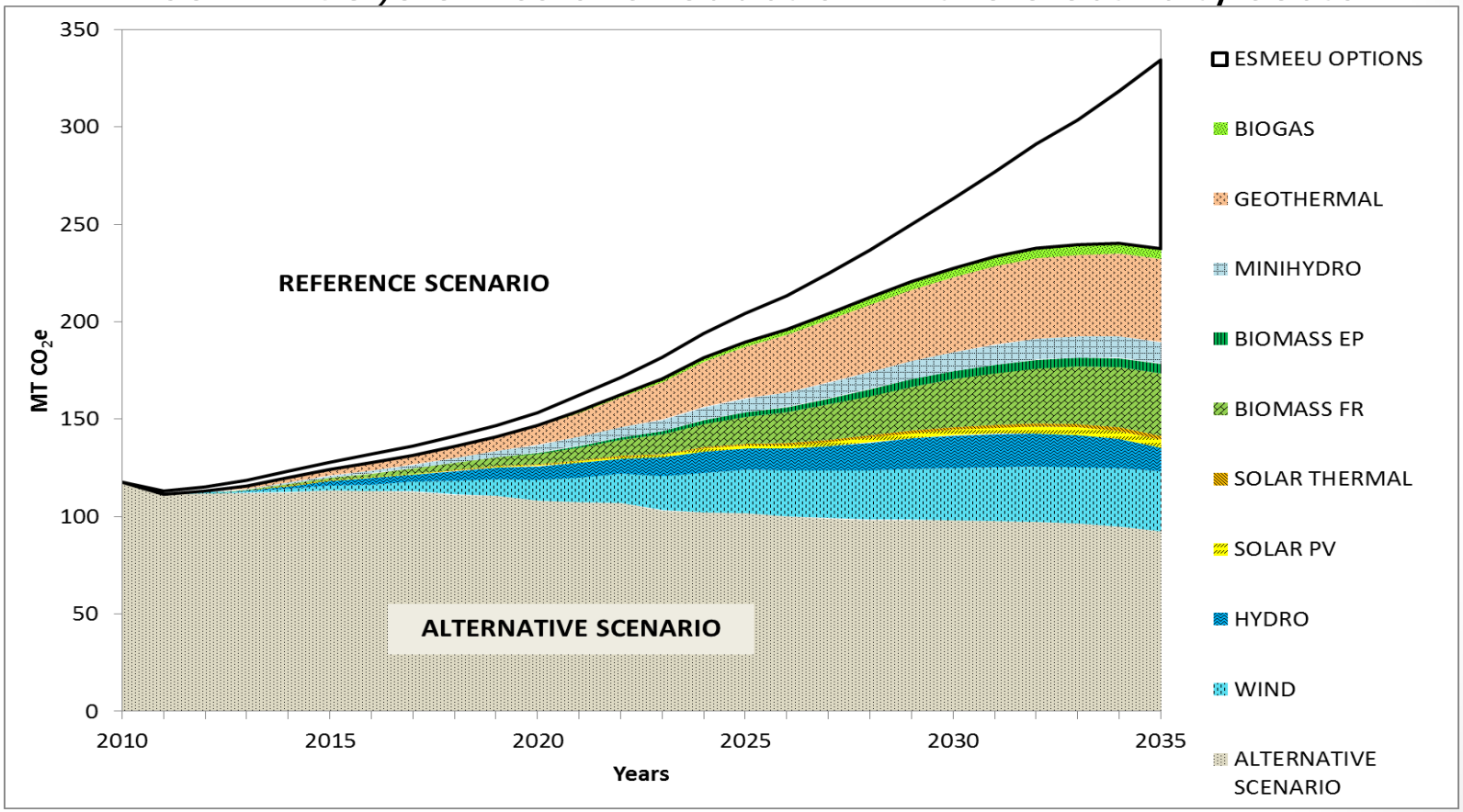
COST-BENEFIT ANALYSIS OF THE ALTERNATIVE ELECTRICITY SCENARIO SUPPLY

- 2,223 MUSD Total benefits



GHG MITIGATION IN THE ALTERNATIVE ELECTRICITY SCENARIO

- 1763 MT CO_2e emissions reduction in the electricity sector.



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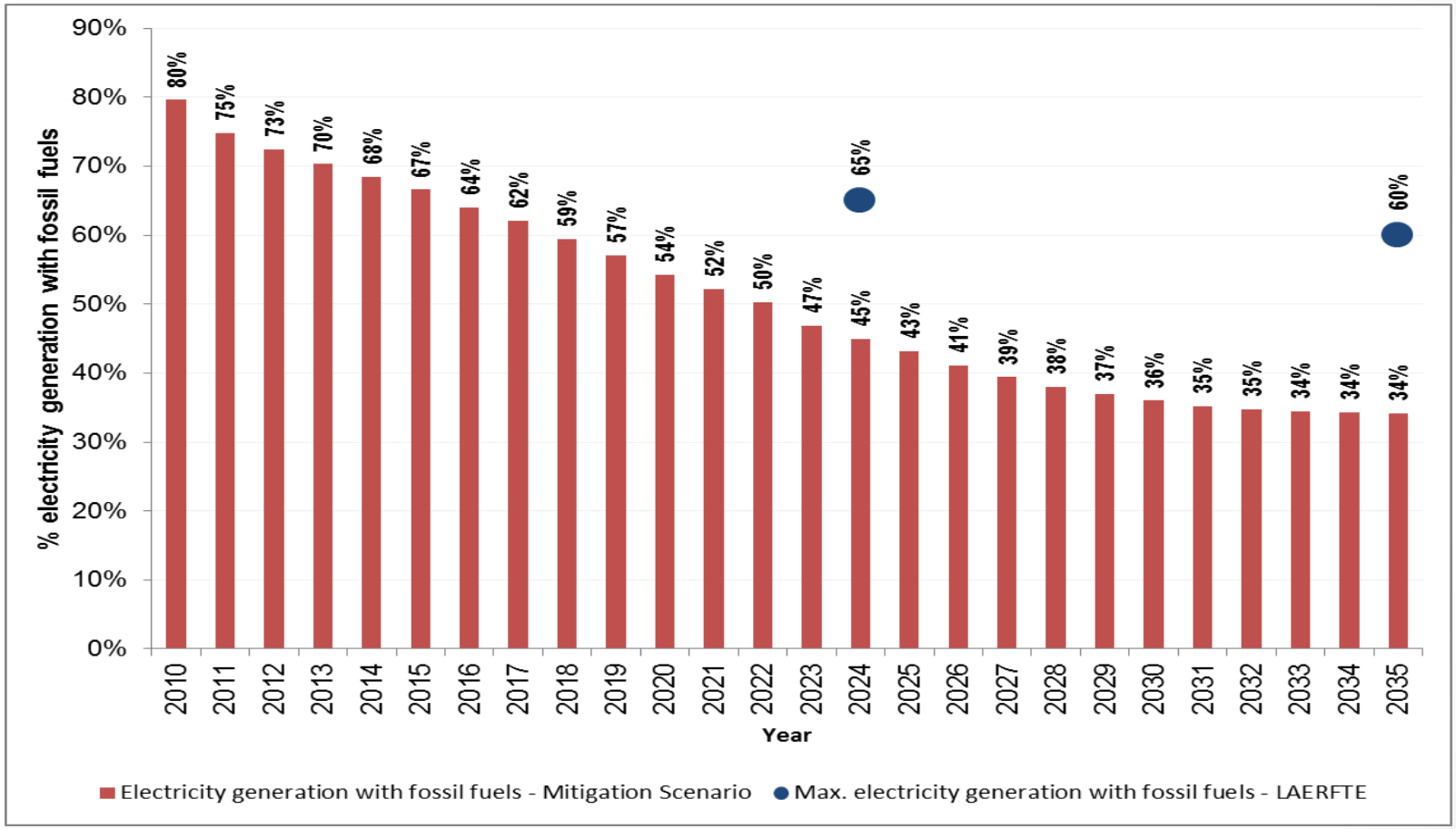
ALTERNATIVE SCENARIO OF ELECTRICITY SECTOR AND THE TARGETS OF RENEWABLE LAW (LAERFTE)



- Accomplishment of renewable law targetS (LAERFTE) about maximal participation of fossil fuels in electricity generation.

ALTERNATIVE SCENARIO FOR THE MEXICAN ENERGY SYSTEM BY SECTOR

Transport sector	Abatement Cost (USD 2007/T CO_2e)
Fuel economy standard (Light vehicles)	-79.4
Real Price of gasoline	-366.2
Vehicle verification program in 20 metropolitan zones and 5 metropolitan areas on the border	-7.4
Fuel economy standard (Heavy trucks)	-51.5
Importation of vehicles subject to environmental regulations	-31.5
Route optimization of public transport	-52.5
Subsidies for hybrid buses	46.3
Electric systems	72.5
Public bycicle share system	-48.1
Bus Rapid Transport (BRT)	43.2
Clean transport federal program	-25.5
Sustainable transit oriented development (TOD)	5.1
Rail freight transport	17.8
Integrated transport companies	-50.8
Ethanol production from Sugar cane	12.7
Ethanol production from sorghum grains	22.2
Biodiesel production from Jatropha curcas	24.5
Biodiesel production from castor oil plant	6.3
Hybrid electric vehicles	17.8
Plug-in hybrid electric vehicles	293.8
Battery electric vehicles	197.5

ALTERNATIVE SCENARIO FOR THE MEXICAN ENERGY SYSTEM BY SECTOR

Oil and gas sector	Abatement Cost (USD 2007/T O_2e)
Annual review and repair of steam traps	-9.5
Improved monitoring of the operation, optimization and service to heaters, including the periodic adjustment of the burners	-16.5
Improved design practices for heaters and boilers and conversion of natural circulation systems to forced air circulation systems	-31.1
Boiler blowdown management	-12.9
Temperature controller for crude oil heating furnaces	-28.6
Increased heat transfer for interchangers	-30.3
Installation of economizers	-5.8
Efficient burners with improved controllers	-6.1
System optimization for associated and non-associated gas production	-29.5
Inline pipeline cleaning tools (Pipeline pigs)	-16.2
Onsite measurements for improved energy efficiency	-7.7
Optimization of compression ratio	-33.1
Optimizing compressor efficiency by adjusting valve position	-38.5
Resizing of compressed air systems for minimizing recirculation and adjusted inlet gas flow	-21.5
Manual or automatic adjustment of compressor cylinder clearance for adjusted inlet gas flow	-39.4
Adjustment of compressor cylinder clearance for improved efficiency	-35.2
Intra and inter-stage coolers	-0.2
Replacing wet seals with dry seals in centrifugal compressors	-10.1
Improved monitoring for operation, optimization and maintenance	-28.6
Optimized operation of the machinery	-30.2
Residual energy utilization	-5.5
Increased residence time in the oxidizer	-16.2
Increase mixing in the burner and oxidation chamber	-14.3
Catalyst switching in the Claus Plant	-21.4
Microturbines	-156.6
Combined heat and power	-43.2
Enhanced oil recovery using CO2 from PEMEX Petrochemical facilities	-29.2

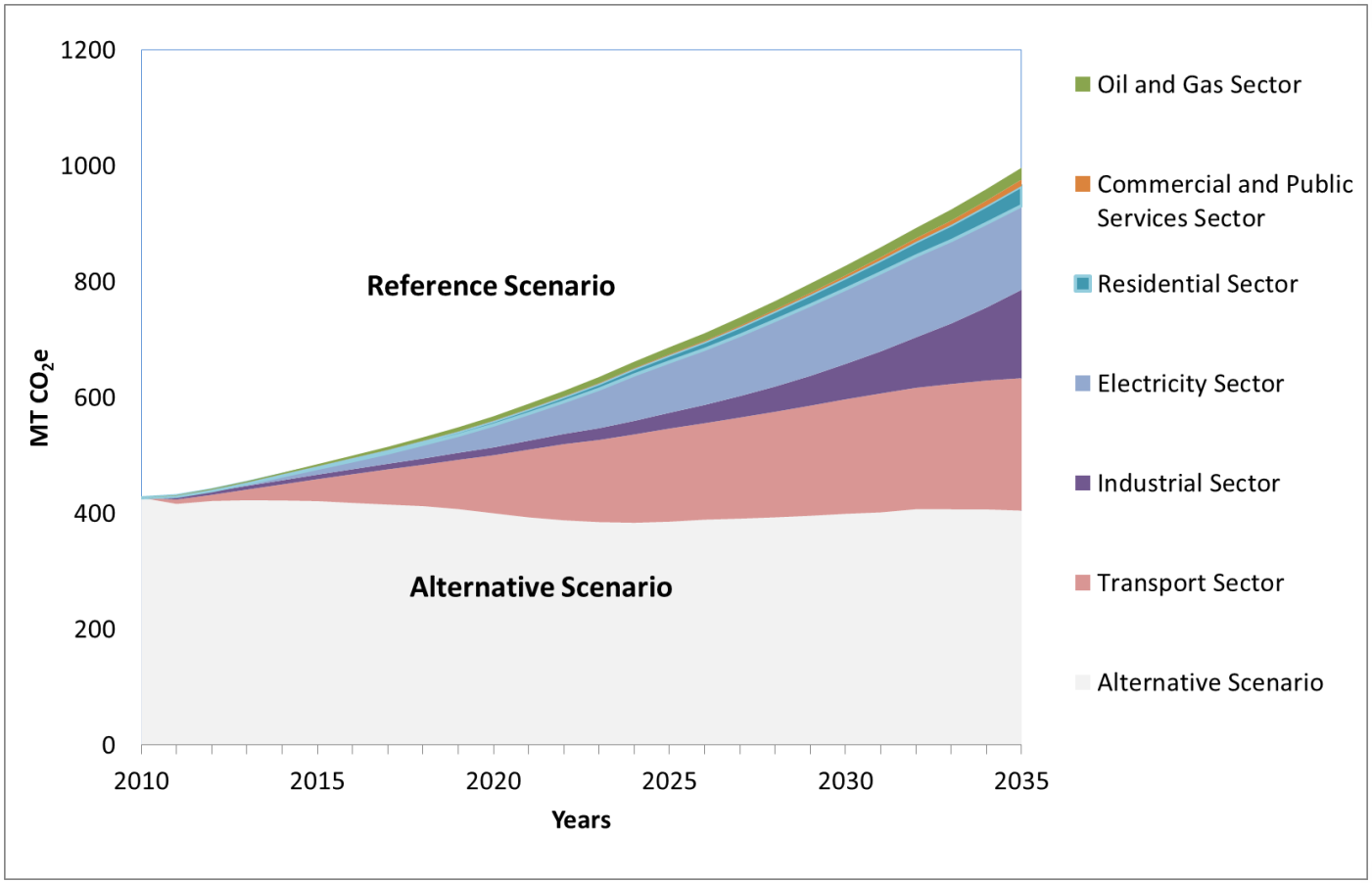
ALTERNATIVE SCENARIO FOR THE MEXICAN ENERGY SYSTEM BY SECTOR

Industry	Abatement Cost (USD 2007/TonCO_2e)
Energy savings (electricity) - Motors	-23.43
Energy savings (electricity) – Speed variators	-4.37
Energy savings (electricity) – Air compressors	-38.97
Energy savings (electricity) - Coolers	-34.94
Energy savings (electricity) - Lighting	-16.66
Energy savings (heat generation and distribution systems) - Boilers and evaporators	-26.15
Energy savings (heat generation and distribution systems) - Furnaces and burners	-20.51
Energy savings (heat generation and distribution systems) - Furnaces and electric heaters	-40.06
Energy savings (heat generation and distribution systems) - Thermal insulation in pipe lines and equipment	-17.27
Recycling (Siderurgy, aluminum, glass, paper)	-28.21
Combined heat and power	-26.59
Solar photovoltaics	221.50
Solar thermal	5.56
Siderurgical vegetable charcoal	26.99
Pellets	-8.56

GLOBAL COST- BENEFIT ANALYSIS OF ALTERNATIVE SCENARIO FOR THE MEXICAN ENERGY SYSTEM

Sector	Capital Cost	O&M Cost	Fuel Cost	Total Cost-Benefit	Evited Emissions	Abatement Cost
	(Millions USD 2007)	(Millions USD 2007)	(Millions USD 2007)	(Million USD 2007)	(MT CO_2e)	(USD 2007/TCO_2e)
Transport	42996	24398	-173542	-106148	3166	-33.5
Electricity	25255	-4528	-22949	-2223	1763	-1.3
Industrial	15603	505	-26731	-10623	959	-11.2
Oil & Gas	3569	299	-7125	-3257	260	-12.5
Residential	6844	399	-13661	-6418	308	-20.8
Commercial	635	0	-1496	-861	32	-26.9
Public Services	3393	0	-1076	2317	29	79.9
Total Cost-Benefit	**98295**	**21073**	**-246580**	**-127213**	**6517**	**-19.5**

ALTERNATIVE SCENARIO: MITIGATION OF GHG EMISSIONS IN THE MEXICAN ENERGY SYSTEM



OFFICIAL NATIONAL TARGETS VS. ALTERNATIVE SCENARIO

	Official National Targets				Alternative Scenario			
	2020	2024	2030	2035	2020	2024	2030	2035
GHG EMISSIONS REDUCTION (%) LGCC + INDC	30%		36%		30%		52%	
ENERGY CLEAN GENERATION (%) LGCC		35%				55%		
FOSSIL GENERATION (%) LAERFTE		65%		60%		45%		34%

CONCLUSIONS

- It is possible to achieve and even surpass all the official national targets set out in the General Law on Climate Change and the Renewable Law
- The alternative scenario would lead to benefits in the amount of 127, 213 MUSD and emissions reduction of 6,517tones at national level.
- Some technologies such as solar photovoltaics, thermal solar power and biomass would require additional costs. Hence, it is necessary to offset these extra costs by implementing public policies that re-distribute the benefits achieved in other sectors.
- It is possible to build up an scenario where economic benefits can be achieved via energy efficiency measures and renewable energy technologies. This scenario could provide useful information for decision making in the context of the 2020 and 2050 goals established in the General Law on Climate Change.

¡Gracias por su atención!

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