4 INDUSTRIAL PROCESSES & ENERGY USE IN INDUSTRY

Greenhouse gas emissions in Lebanon mainly come from energy activities, which are responsible for 85% of all CO_2 emissions. The CO_2 emissions from energy use in manufacturing industries and construction represent 24% of the total emissions of the energy sector. Lebanese manufacturers' accounted for 39.15 million of gigajoules of fuel consumption for heat and power generation in 1994, including both fuel used directly and fuel burned remotely to generate electricity used in the sector. In addition to being processed by combustion, CO_2 is generated in calcining of carbonates in the manufacture of cement, iron and glass. Electricity, the most expensive form of energy, represented 25.87% of all fuel used for heat and power. Residual fuel oil and diesel, which are used mainly in direct combustion processes, represent 26.85 % and 26.55% of all energy use by industry, respectively. Manufacturing industries and construction, as have used 10.14 x 10^6 GJ (2816.6 GWh) of electricity in the base year of 1994.

Baseline scenarios at low and high economic growth rates for future energy use and CO_2 emissions are developed for the industrial sector in Lebanon. Scenarios relied on available data on major plants' outputs, and on reported amounts of fuels used by the industrial sector. Energy use in industry in Lebanon is projected in baseline scenarios that reflect technologies, activities and practices that are most likely to evolve from the base year 1994 to year 2040. Two baseline scenarios are created using a low economic growth rate (case BA) and a high economic growth rate (case CA). The scenarios are linked to the economic conditions in the country. The future projections of energy demand are shown in Table 7 for both scenarios. The low growth rate scenario shows that energy consumption will increase by the year 2005 by 28% over the current level, and will triple by the year 2040. This implies an average annual growth of 2.5% for the whole period in scenario BA. The high growth rate scenario shows that the energy consumption will increase by year 2005 by 70% over the current level and by 950% by year 2040. This implies an average annual growth of 5.94% for the whole period in scenario CA.

Table 7. Energy Demand: Fuel by Year, Industrial Sector (10^6 GJ) Scenario BA

Scenario BA	1994	2000	2005	2015	2040
ELECTRICITY	10.13	11.75	13.54	17.98	35.26
DIESEL/GAS OIL	10.39	11.79	13.12	16.31	28.74
RESIDUAL/FUELOIL	10.52	12.30	14.26	19.13	35.26
LPG/BOTTLED GAS	0.96	1.14	1.33	1.78	3.73
COAL BITUMINOUS	7.68	7.47	8.66	11.58	16.80
TOTAL	39.67	44.47	50.92	66.77	119.79
SCENARIO CA					
ELECTRICITY	10.13	13.96	18.57	32.84	128.14
DIESEL/GAS OIL	10.39	12.75	15.31	22.85	74.20
RESIDUAL/FUELOIL	10.52	14.62	19.56	34.85	118.58
LPG/BOTTLED GAS	0.96	1.36	1.82	3.26	13.98
COAL BITUMINOUS	7.68	8.88	11.88	21.00	42.00
TOTAL	39.67	51.56	67.14	114.80	376.91

All the fuel sources are linked properly to the Environmental Database in the LEAP program and the amount of GHG emissions and environmental effects are calculated for Lebanon. Table 8 presents the GHG emissions due to all industrial activities, including electricity use, for both scenarios BA and CA.

Table 8. Environmental Effects by Year: Physical Units (Gg), All Fuels Including Effect of Electricity Generation

	GHG TYPE	1994 (Gg)	2000 (Gg)	2005 (Gg)	2015 (Gg)	2040 (Gg)
Scenario BA (3%)						
	Carbon Dioxide (CO_2)	4,830	5,110	5,600	7,160	12,410
	Carbon Monoxide	8.81	6.64	5.51	7.23	13.82
	NMVOC	2.589	1.849	1.441	1.879	3.657
	Methane	0.04	.051	.061	.076	0.132
	Nitrogen Oxides NO_x's	837.93	976.56	1,078	1,342	2,374
	Sulfur Oxides	2.535	1.818	1.423	1.855	3.604
	Particulates	2.702	1.930	1.504	1.961	3.817
Scenario CA (6%)						
	Carbon Dioxide (CO_2)	4,830	5,890	7,400	1,217	39,190
	Carbon Monoxide	8.81	7.42	7.34	12.42	47.99
	NMVOC	2.589	2.05	1.91	3.26	12.85
	Methane	0.04	0.06	0.081	0.121	0.411
	Nitrogen Oxides NO_x's	837.93	1,056	1,262	1,894	6,200
	Sulfur Oxides	2.535	2.01	1.89	3.21	12.61
	Particulate	2.702	2.14	2	3.4	13.41

The mitigation scenarios for reducing CO_2 emissions are presented at the most likely discount rate of 10% for the two baseline scenarios BA and CA. The various single effect scenarios are given in Table 9. Most of the mitigation options for the industrial sector are concerned with improvement of energy efficiency either in electricity use for motors and lighting or in cleaner combustion processes in boilers and furnaces by fuel switching or replacement with efficient systems.

Table 9. List of Baseline and Mitigation Scenarios

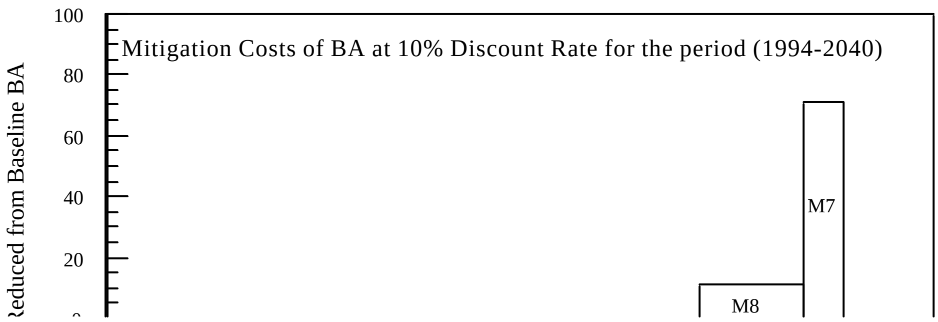
SCENARIO NO.	SCENARIO NAME	DESCRIPTION
	BA	Baseline (Growth Rate 3%)
	CA	Baseline (Growth Rate 6%)
1	C1	Cement 10% Reduction with Pre - Heat
2	C2	Cement 20% Reduction with Pre - Heat
3	M1A	Efficient Electric Motors Replace Old Motors
4	M1B	Efficient Electric Motors Replace New Standard Motors
5	M2	Advanced Lighting
6	M4	Efficient Boilers
7	M7	Bakeries Fuel Switching from Diesel to LPG
8	MB	Bakeries (Efficient Furnaces)
9	M8	Natural Gas Replace Fuel Oil
10	M9	Natural Gas Replace Diesel
11	CG	Co-generation

The environmental effects of various mitigation options can be clearly seen from the percentage of CO_2 reduction from the corresponding baseline scenarios and their transformation scenarios and the amount of CO_2 reduction for the year 2005 and the year 2040 as presented in Table 10.

The average emission reduction of CO_2 and the Levelized Cost of CO_2 Reduction (US$ / tonne of CO_2 reduced) CO_2, over the period 1994-2040, are calculated for the various mitigation options on the baseline scenarios BA and CA at the discount rate 10%. Figure 8 shows the discrete step cost curve of the cost in $/tonne of CO2 reduced from baseline BA versus the corresponding CO_2 emission reduction from baseline BA in Million tonnes over the study interval of 46 year (1994-2040) and at the discount rate of 10%. Figure 9 shows the discrete-step cost curve of the cost in $/tonne of CO_2 reduced from baseline CA versus the corresponding CO_2 emission reduction from baseline CA in Million tonnes over the study interval of 46 year (1994-2040) and at the discount rate of 10%. Mitigation options M1B, M1A and M2 that conserve in electricity use have a good cost-effectiveness prospects where the benefits in the long term exceed the implementation costs. Also the use of efficient boilers (M4) and co-generation (CG) are another negative cost options with substantial CO_2 emission reduction from both baseline scenarios BA and CA. Fuel switching in boilers and furnaces from fuel oil to LPG or natural gas has a substantial effect on reducing CO_2 emissions, but with a high cost because fuel oil is a cheaper than other forms of fuels like gasoil. Switching from diesel to natural gas or LPG had only marginal reductions of CO_2 with less cost per CO_2 emissions' reduction. Fuel switching from diesel to LPG in bakeries involved a very high cost compared with just using efficient diesel furnaces. When all single effect mitigation scenarios are implemented, the cumulative total reduction of CO2 from baseline scenario BA reaches about 126 Million tonnes while the total reduction of CO2 from baseline CA is estimated as 365 Million tonnes.

Table 10. Reduction of CO_2 Emissions (Gg) and their Percent Reduction of Mitigation Options from the Baseline Scenario BA for the years 2005 and 2040.

SCENARIO	ECONOMIC GROWTH 3%				ECONOMIC GROWTH 6%			
	% Red. From Baseline BA		Emission Reduction Gg		% Red. From Baseline CA		Emission Reduction Gg	
	2005	2040	2005	2040	2005	2040	2005	2040
Baseline	0	0	0	0	0	0	0	0
C1	1.93	1.6	108.21	200.89	1.99	1.26	147.1	492.53
C2	3.71	3.18	208	394	3.91	2.53	289.4	991.7
M1A	2.59	8.5	345.1	1055	2.61	9.45	192	3625
M1B	0.83	1.77	46.77	219.52	.84	1.92	62.14	754.3
M2	1.18	1.26	65.96	155.79	1.18	1.37	87	535
M4	2.64	10.29	147.9	1276.99	2.74	12.21	203	4783
M7	0.95	2.57	53	319	0.95	2.57	53	319
MB	0.95	2.4	53.14	298.3	0.95	2.4	53.14	298.3
M8	1.94	7.28	108.5	903	3.32	14.24	245.6	5582
M9	1.3	5.13	73.03	636.86	1.35	6.09	100.1	2385
CG	0.81	4.71	45.66	584.1	1	5.76	74	2258



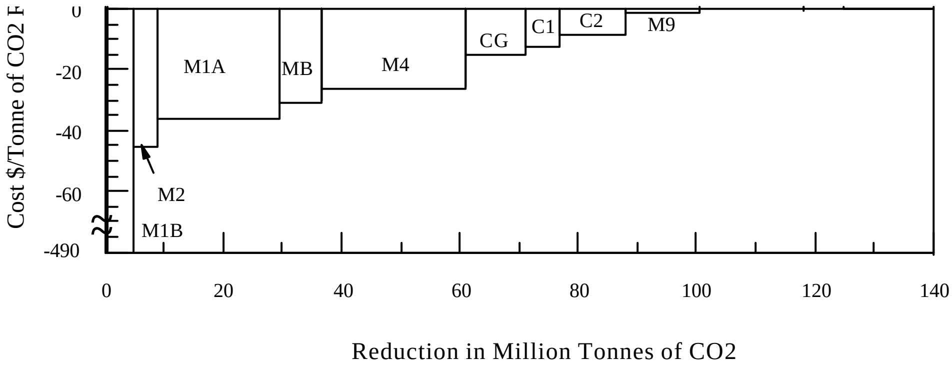


Figure 8 Cost in $/ton of CO2 reduced from baseline BA

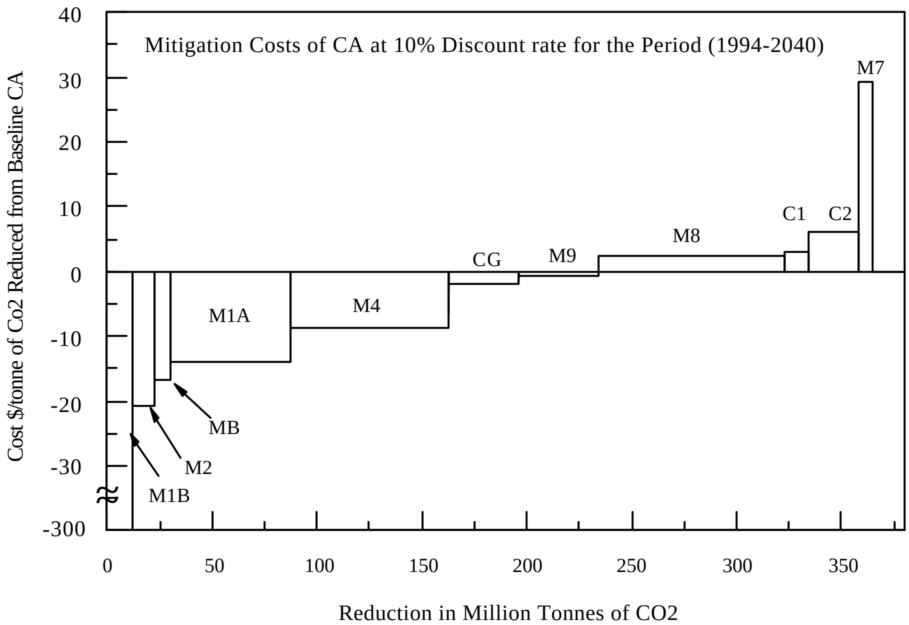


Figure 9 Cost in $/ton of CO2 reduced from baseline CA

4.1 Project Proposals for Industrial Sector:

4.1.1 Motor Drive System Improvement and Replacement M1A and M1B

Motor-driven systems are the backbone of industrial operations such as fluid handling and movement, and material processing and fabrication. These systems account for more than 70% of all electricity used by the industrial sector in Lebanon. Improvements in the efficiency of these electric motor systems can translate directly into enhanced productivity, competitiveness and environmental performance. Electric motors are generally regarded as very efficient, with first law efficiencies of order of 90%. Yet, in the aggregate, losses are considerable. In Lebanon, a large number of motor drive systems are relatively old, or second-hand. Replacing old motors with new ones represents a great opportunity for improving the system efficiency. But this has to go hand in hand with motor control improvements, particularly for variable frequency drives of induction motors, which can cut internal losses by a factor of 2, at least. In order to carry an accurate analysis, data should be available on the number of current motors in use by the industrial sector in Lebanon, their power rating, years of operation and efficiency. Such data were not available, so a few assumptions have to be made in order to arrive at a reasonable model for this mitigation option. Two scenarios for electric motor replacement are considered. The first scenario "M1A" considers replacement of old electric motors with new efficient ones. The second scenario "M1B" considers that the new standard motors added to the industry each year are replaced by new efficient motors.

The replacement of old electric motors by new energy efficient ones is proposed according to the following schedule: year 2000: 10 % of old motors is replaced by new ones, year 2005: 25% of old motors is replaced by new ones, year 2015: 50% of old motors is replaced by new ones, year 2040: 100% of old motors is replaced by new ones. The replacement of added new standard motors by efficient ones will be considered done for all new imported motors starting year 2000.

The average implementation current cost of the new energy-efficient motor is estimated as $66/HP for the 20-50 HP range and $61/HP for the 50-100 HP range. The motor rewind cost has an average value of $16/HP, and the average standard motor cost is estimated as $56/HP for the 20-50 HP range and $61/HP for the 50-100 HP range. Industries in Lebanon use motors for periods of time that are far beyond the motor lifetime and rewind old motors once they breakdown. For the first motor scenario, the modified annualized life cycle cost is then based on the incremental cost of the new electric motor of which the motor rewind cost is subtracted rather than incremental cost between an energy efficient new motor and a standard base-case new motor. The calculated life cycle cost is then equal to $50/HP for the 20-50 HP range and $45/HP for the 50-100 HP range. In the second motor replacement scenario where the new standard motors are replaced by energy efficient ones, the modified annualized life cycle cost is then based on the incremental cost between an energy efficient new motor and a standard base-case new motor. The calculated life cycle cost difference is then equal to $10/HP for the 20-50 HP range and $12/HP for the 50-100 HP range. The energy savings are calculated based on 3600 hours of operation of the motors per year.

The proposed mitigation options costs and benefits for electric motors are shown in Table 11, where the cost in Million of real 1994 $ is given over selected years and the discounted cost over the selected study period are presented. The expected carbon dioxide emission reductions over the study interval (1994-2040) are shown in Table 12.

Table 11: Electric Motor Improvement and Replacement Project Costs and Benefits

MITIGATION OPTION	Cost Million Real 1994 $ (2000)	Cost Million Real 1994 $ (2005)	Cost Million Real 1994 $ (2015)	Cost Million Real 1994 $ (2040)	Costs Discounted To 1994 $ At 10% Dr (1994-2040)	Benefits Discounted To 1994 $ At 10% Dr (1994-2040)	Benefit To Cost Ratio
Scenarios associated with low economic growth Baseline BA							
M1A Costs	0.26	1.04	2.91	12.75	12.42	84.51	6.8
M1B Costs	46.42	55.87	81.86	214.46	99.42	599.33	6.03
Scenarios associated with high economic growth Baseline CA							
M1A Costs	0.31	1.42	5.32	47.76	25.52	216.36	8.47
M1B Costs	55.15	76.6	149.5	803	168.91	1027	6.3

Table 12: Emission Reductions of Electric Motor Improvement and Replacement Project

Mitigation Option	CO_2 Reduction (Gg) (2000)	CO_2 Reduction (Gg) (2005)	CO_2 Reduction (Gg) (2015)	CO_2 Reduction (Gg) (2040)	Total CO_2 Reduction (Gg) (1994-2040)
Reductions from Baseline BA					
M1A	2.59	8.5	345.1	1055	20,633
M1B	29.45	46.77	79.39	219.52	4,640
Reductions from Baseline CA					
M1A	2.61	9.45	192	3625	57,822
M1B	33.95	62.14	134.56	754.34	12,512

4.1.2 Efficiency Improvement of Boilers and Furnaces by Replacement and Fuel Switching Options

The burning of fossil fuels in boilers, to raise high temperature and high-pressure steam that have been used for various heating and power generation processes, produces a problem source of carbon dioxide and other green house gases. Efforts to increase the efficiency of industrial processes should also focus on improving the efficiency of boilers and furnaces. Many industrial processes involve the use of direct thermal heating either from steam or using electricity directly. Examples vary from food processing industries, chemicals, plastics, glass and steel manufacturing. Conventional boilers used in industry are mostly operated using fuel oil followed by gas oil and a small percentage of LPG. Heating furnaces are also operated using fuel oil. Accurate data on age distribution and age-efficiency of boilers used in the industrial sector in Lebanon are not available. The current state of boiler equipment in industry is similar to that of electric motors, where the average age of boilers would easily exceed 20 to 30 years. In absence of an energy code for boiler-efficiency standards, engineering estimation and sizing of boilers to the respective application is not properly administered. The mitigation option of replacing old boilers in the industrial sector with cleaner and more efficient systems, these options are divided into two main categories. The first category considers only improvement in boiler efficiency where old boilers are replaced with new efficient ones operating on the same fuel type. The second category considers replacing inefficient industrial boilers with efficient ones that operate on a cleaner fuel such as LPG or natural gas.

- Replacement of old boilers by new energy efficient according to the following schedule:
  Year 2000: 10 % of old boilers is replaced by new ones.
  Year 2005: 25% of old boilers is replaced by new ones.
  Year 2015: 50% of old boilers is replaced by new ones.
  Year 2040: 100% of old boilers is replaced by new ones.

- Fuel switching from fuel oil and from diesel to natural gas and LPG is according to the following schedule for boilers and furnaces:
  Year 2000: 10 % of old boilers are replaced by new ones.
  Year 2005: 20% of old boilers is replaced by new ones.
  Year 2015: 40% of old boilers is replaced by new ones.
  Year 2040: 60% of old boilers is replaced by new ones.

The proposed mitigation options costs and benefits for boilers and furnaces are shown in

Table 13, where the cost in Million of real 1994 $ is given over selected years and the discounted cost over the selected study period are presented. The expected carbon dioxide emission reductions over the study interval (1994-2040) are shown in Table 14.

Table 13: Boilers and Furnaces Improvement and Replacement Project Costs and Benefits

MITIGATION OPTION	COST Million Real 1994 $ (2000)	COST Million Real 1994 $ (2005)	COST Million Real 1994 $ (2015)	COST Million Real 1994 $ (2040)	COSTS Discounted To 1994 $ AT 10% DR (1994-2040)	BENEFITS Discounted To 1994 $ AT 10% DR (1994-2040)	Benefit To Cost Ratio
Scenarios associated with low economic growth Baseline BA							
M4 Costs	0.2	0.8	2.41	9.76	9.87	84	8.5
MB Costs	.07	0.24	0.77	1.92	2.86	30	10.3
M8 Costs	.35	1.17	3.1	47	111.41	66	1.68
M9 Costs	1.14	3.73	12.5	30.24	69.38	75	1.09
Scenarios associated with high economic growth Baseline CA							
M4 Costs	0.24	1.09	4.41	36.56	20.25	173	8.54
MB Costs	.07	0.24	0.77	1.92	2.86	30	10.3
M8 Costs	.42	0.161	5.4	175	233.85	185	0.79
M9 Costs	0.6	2.06	8.3	64.67	144.95	151	1.04

Table 14: Boilers & Furnaces Improvement and Replacement Emission Reductions

MITIGATION OPTION	CO_2 Reduction (Gg) (2000)	CO_2 Reduction (Gg) (2005)	CO_2 Reduction (Gg) (2015)	CO_2 Reduction (Gg) (2040)	Total CO2 Reduction (Gg) (1994-2040)
Reductions from Baseline BA					
M4	40	150	400	1270	24473.84
MB	10	60	150	290	6913.8
M8	40	110	300	900	17552.22
M9	30	80	210	630	12416.32
Reductions from Baseline CA					
M4	40	210	740	4780	75265.66
MB	10	60	150	290	6912.88
M8	60	250	890	5580	88475.48
M9	20	100	390	380	37913.66

4.1.3 Cement Mitigation Option

The cement industry is the single largest source of Lebanese process CO_2 emissions and a major energy user. Energy related CO_2 emissions are of similar magnitude depending on the cement kiln technology. Of the process emissions, about 60% of the direct emissions are from calcination of lime stone and the other 40% are from combustion products of fossil fuels that directly or indirectly supply the energy for calcination. Grinding is the other major energy consumer in the manufacturer, which is usually a low efficiency process. According to the baseline scenario on cement demand, 38% of 1994-cement production is coming from an old technology while 62% of the production is already producing cement with retrofit and new plants.

The proposed mitigation option includes conservation and preheating in the pyroprocessing, which can save 10% in fuel energy, and include improvements in the grinding process, which is reported to have made small but significant gains through use of mill liners, grinding media and the use of more complex grinding circuits. Implementing such an improvement would save at least 5% of the electric energy use.

The proposed mitigation options costs and benefits for boilers and furnaces are shown in Table 15, where the cost in Million of real 1994 $ is given over selected years and the discounted cost over the selected study period are presented. The expected carbon dioxide emission reductions over the study interval (1994-2040) are shown in Table 16.

Table 15: Cement Production Improvement Project Costs and Benefits

MITIGATION OPTION	COST Million Real 1994 $ (2000)	COST Million Real 1994 $ (2005)	COST Million Real 1994 $ (2015)	COST Million Real 1994 $ (2040)	COSTS Discounted To 1994 $ AT 10% DR (1994-2040)	BENEFITS Discounted To 1994 $ AT 10% DR (1994-2040)	Benefit To Cost Ratio
Scenarios associated with low economic growth Baseline BA							
C2 Costs	.07	10.11	14.92	27.8	61.38	42.01	0.688
Scenarios associated with high economic growth Baseline CA							
C2 Costs	1.84	13.9	27.14	69.62	113.22	74	0.65

Table 16: Emission Reductions of Cement Production Improvement Project

MITIGATION OPTION	CO_2 Reduction (Gg) (2000)	CO_2 Reduction (Gg) (2005)	CO_2 Reduction (Gg) (2015)	CO_2 Reduction (Gg) (2040)	Total CO2 Reduction (Gg) (1994-2040)
Reductions from Baseline BA					
C2	20	210	270	390	11331.64
Reductions from Baseline CA					
C2	40	290	500	980	23626.98

4.2 RECOMMENDATIONS FOR FUTURE WORK

The mitigation efforts in industry should focus on long term support for energy efficiency measures and fuel switching in boilers and furnaces to cleaner types. A comprehensive energy audit for the industrial sector is a first step. Subsidy support should enable companies even those with limited financial resources to afford comprehensive efficiency measures, given the lack of resources to invest in new equipment by manufacturers. Policies should focus on increasing the speed with which technology is replaced. Standards for energy efficiency for equipment should be mandatory along with a mechanism for monitoring energy use and CO_2 emissions. More accurate data are needed to assess the industrial sector for each type of product or process. Training should be provided to managers and professionals to increases their awareness about GHG emissions and benefits associated with energy savings and measures taken to reduce these emissions.

For technologies where natural gas is to be used, the government must insure uninterrupted supply.

Although the proposed mitigation projects suggest a substantial reduction in CO2 emissions associated with manufacturing activities, it would require a strong, well-designed policy package involving a political will.