A2b BUILDING ENVELOPS

A2b.1 INTRODUCTION

This section of the *Building sector* analysis takes up the issue of the thermal performance of building envelopes, and looks at the energy consumed in the form of space heating and cooling for the provision of occupant thermal comfort.

Building envelopes are the mediators between outdoor and indoor environments. As such, and depending on their characteristics, they play a key role in determining the amount of heat loss and gain to and from an indoor space, and consequently, play a major role in influencing the amount of energy used to achieve the desired indoor thermal comfort ranges.

In the base year 1994, the *Building sector* consumed for space heating and cooling 13.77 x 10^6 GJ which resulted in the emissions of 1016 Gg of CO_2. (Table 2.7) This energy was obtained from three sources: electricity, gas/diesel oil and wood, with electricity accounting for 44% of the energy used, gas/diesel oil 39% and wood 17%. (Fig. A2b.2)

The following analysis builds upon a study on summer and winter thermal comfort in buildings in Lebanon commissioned by the "Council for Development and Reconstruction" (CDR). The study entitled "Guide de L'isolation Thermique et du Comfort D'ete des Batiments au Liban" [5].

A2b.2 METHODOLOGY

Issues associated with the thermal performance of building envelopes and concepts pertaining to the potential of energy conscious building design are numerous. This study however, will limit itself to the thermal assessment of three building envelope components: wall, window and roof, and will analyze their potential as cost-effective energy conservation measures.

To do this, the analysis first looks at the thermal specifications of the current construction practice. For this, a computer program, "Pascool PEM", is used. Then the analysis looks at the specifications suggested by the above-mentioned "guidelines". The "guidelines" suggested upgrading in the thermal performance of building envelope components is estimated to bring about an average 25% energy reduction per household for space heating and cooling.

Afterwards, the study puts forward a baseline scenario representing the most likely penetration rate of "guideline" application and its resulting energy reduction. The baseline scenario is then measured against proposed achievable mitigation scenarios. Both the baseline and mitigation scenarios are developed using the LEAP computer model.

A2B.3 SECTOR DESCRIPTION

A2b.3.1 CLIMATE

Although Lebanon can be said to exhibit a typical mild Mediterranean climate, the marked variety of its topography, in addition to the variety of wind regimes to which it is exposed give rise to a considerable variability in temperature, humidity and rainfall among its various regions depending on location.

There has been one official national climatic study performed in the 1960s, documented under the publication “Atlas Climatique du Liban” [1]. This atlas indicates the climatic specificity of the various Lebanese regions. For the purpose of this analysis, these can be grouped into four general climatic zones:

- Coastal zone: (altitude 0 to 500m) exhibiting a Mediterranean maritime climate characterized by hot humid summers and mild winters.

- Mid-mountainous zone: (altitude 500 to 900m) a region characterized by mild summers and cool to cold winters.

- High mountainous zone: (altitude over 900m) a region characterized by cool summers and cold snowy winters.

- Inland zone: (variable altitude) a valley plane exhibiting continental tendencies characterized by a marked diurnal temperature drop.

The general climatic characteristics of these zones can be seen in fig. A2b.1. Moreover, the estimated average compensation needs for temperatures falling outside thermal comfort ranges can be seen in table A2b.1.

Fig A2b.1: Climatic data

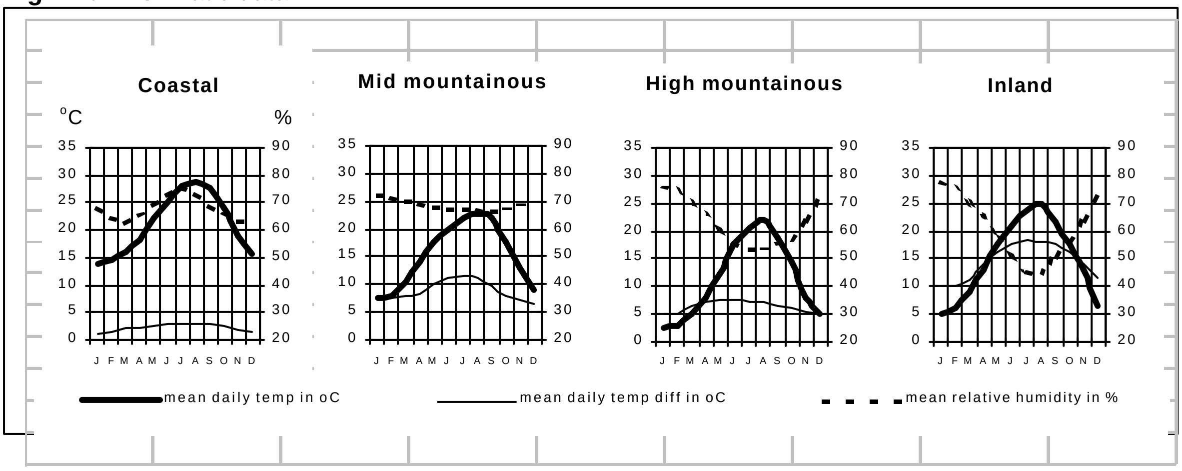


Table A2b.1: Estimated average annual temperature compensation needs in degree-days

	Coastal	Mid-mountainous	High mountainous	Inland
Ave. annual heating deg. days	800	1400	3000	2000
Ave. annual cooling deg. days	2000	100	---	600

Note: Heating base was taken as 18^{o}C, and cooling base as 22^{o}C. Also to be noted is that the single measure degree-day method is only a rough indication tool and does present some + /– 15% inaccuracy.

A2b.3.2 BUILDING STOCK

In order to determine the composition of the prevalent building stock in terms of age, use and geo-climatic distribution, the analysis relied on the 1996 building survey conducted by the Lebanese “Administration Centrale de la Statistique” [2]. From this survey, one can determine that the existing number of buildings until the base year 1994, was in the order of 480 000 buildings. The age distribution of the 1994 building stock is shown in table A2b.2.2.

Table A2b.2: Distribution of building stock according to age.

Buildings*	Prior to 1951	1951-1960	1961-1970	1971-1980	1981-1990	1991-1994	Unde-termined
480 000	80 000	60 000	70 000	105 000	85 000	50 000	30 000
100 %	16.6 %	12.4 %	15.2 %	21.8 %	18.0 %	10.0 %	6.0 %

* Building numbers have been rounded

The 1994 building stock comprised 1.34 million building units. Their pattern of use is shown in table 2.3. However, it should be noted that out of the 1.34 million building units present in 1994, around 15% was empty.

Table A2b.3: Distribution of building stock according to use.

Building units	Residential*	Commercial & Institutional
1 340 000	1 005 000	335 000
100%	75%	25%

* Both primary and secondary residential use.

In terms of geo-climatic distribution, it should be mentioned that the building survey classified buildings in relation to their municipal contexts, but based on this, the building stock was recalculated according to climatic zones, and the following results found: (Table A2b.4)

Table A2b.4: Estimated distribution of building stock according to climatic zones.

Buildings	Coastal	Mid-mountainous	High mountainous	Inland
480 000	250 000	130 000	60 000	40 000
100 %	52.0 %	27.0 %	12.5 %	8.5 %

Note: The ratio of building unit to building is much higher in the coastal zone.

Moreover, a review of the 1985/1994 statistical bulletins of the Order of engineers & architects [3] revealed that the average yearly built-up area over the last 10 years prior to 1994 was 10 million m^2/yr representing 12 000 building permits/yr.

A2b.3.3 ENVELOP THERMAL CHARACTERISTICS

Three building envelope components have been considered: wall, roof and window. To be noted is that the ground floor has not been included in the assessment since the occupied space in Lebanon is usually not the ground floor. Buildings predominantly sit over a basement floor typically used for car parking, and/or are built on a column “piloti” level.

In order to determine the thermal characteristics of the three considered building envelope components for the prevalent construction practice, a simulation program was used:

Pascool P.E.M [4]. Examples are shown in (Annex A2b-1) and results are shown in table A2b.5.

Table A2b.5: Building envelop U-values / current practice.

	Construction description	Average U-value ($W/m^2.K$)
Wall	- Single layer of hollow concrete blocks (12,15 or 20 cm), finished with plaster and paint both from within and without. - Single layer of hollow concrete blocks (12,15 or 20 cm), faced with stone stuck on mortar from without, and finished with plaster and paint from within.	2.5 – 3.5
Roof	- Roof terrace consisting of a concrete slab (15 cm), topped by 8 cm of sand and 2 cm of roof tiling. - Pitched roof consisting of 10 cm poured on site slab, topped by wooden planks and clay roof tiles. (10 cm)cavity	2.5 – 4.0
Window	- Typical windows used in residential buildings are aluminum framed with single clear 6mm glazing. - The commercial sector uses the above, in addition to a variation of aluminum framed 6 mm tinted or coated glazing.	3.5 – 5.5

A2b.3.4 REGULATIONS AND INITIATIVES

The Lebanese Building Law has so far lacked any reference to the thermal performance of buildings, and as a result, has lacked any consideration for the energy consumption of buildings.

In 1995 however, the Lebanese "Council for Development and Reconstruction" (CDR) has commissioned a study on summer and winter thermal comfort in buildings. The study entitled "Guide de L'isolation Thermique et du Comfort D'ete des Batiments au Liban" [5] was performed by "Centre Scientifique et Technique du batiment" (CSTB) under the supervision of the "Lebanese Norms Institute" (LIBNOR). The preliminary version (2.0) of the guidelines is to be published in 1999 for public review and feedback.

These guidelines are intended for voluntary application. At present, there exists numerous market, institutional, information and human capacity barriers that impede the adoption and application of the thermal building guidelines. In light of these barriers, there are no governmental plans to transform these guidelines into building standards, nor to activate market demand in order to increase the voluntary application of these guidelines.

The "guideline" is intended as a first step in order to initiate the Lebanese building sector to the possibilities of building envelope energy conservation measures, and was not based on an economic assessment. The proposed specifications regarding building envelope components are shown in table A2b.6, and examples of their implications on building construction are shown in (Annex A2b-1).

The listed specifications match the 1982 French norms and are expected to achieve an estimated 25% energy reduction per household. (Annex A2-2)

Table A2b.6: Building envelop U-values / as suggested by "guidelines".

	Coastal	Mid-mountainous	High* mountainous	Inland
U-value/Wall ($W/m^2.^oC$)	1.35	1.25	1.00	0.85
U-value/Window ($W/m^2.^oC$)	2.60	2.60	2.60	2.60
U-value/Roof ($W/m^2.^oC$)	0.95	0.85	0.65	0.45

* The "guidelines" further subdivided the high mountainous zone into two regions.

A2b.3.5 ENVIRONMENT AND ENERGY

The energy consumed by the building sector in 1994 for space heating and cooling in order to provide occupant thermal comfort was derived from two sources. The first source is the first national inventory of greenhouse gases conducted in 1998 [6], and the second source is a study performed in 1992 by "Electricite de France" (EDF) for "Electricite du Liban" (EDL) [7] (Figures for 1994 are deduced by ALME). From these, the following can be seen: (Table A2b.7)

Table A2b.7: 1994 energy consumption for the provision of thermal comfort.

		1994 10^6 GJ	**1994** Gg CO_2
RESIDENTIAL	Electricity	4.33	263
	Gas/diesel oil	2.82	208
	Wood	2.40	258
	Sub-total	*9.55*	*729*
COMMERCIAL & INSTITUTIONAL	Electricity	1.71	104
	Gas/diesel oil	2.51	183
	Sub-total	*4.22*	*287*
	TOTAL	**13.77**	**1016**

A2b.3.6 SUMMARY

- The current construction practice for building envelopes leads to a waste of energy, and the potential for improving the thermal integrity of building envelopes is considerable. The proposed thermal building guidelines can lead to an estimated 25% energy reduction for heating and cooling per household.

- In the coastal climatic zone, where currently over half of the building stock is located, the dominant energy requirement is for cooling. Hence the energy conservation strategy should be to reduce summer heat gains, and in the context of this analysis, to place the thermal insulation from without.

- In the medium and high mountainous climatic zones, where currently 40% of the building stock is located, the energy requirement is for heating. Hence the energy conservation strategy should be to reduce heat loss to the outside, and in the context of this analysis, to place the thermal insulation from within.

- In the inland climatic zone, which is characterized by a marked diurnal temperature drop, the strategy would be to increase the thermal storage capacity, in order to increase the time lag of heat dissipation.

A2.4 BASELINE SCENARIOS

A2b.4.1 DEFINITION

This analysis takes up the year 1994 as base year, and considers the following projection years: 2005 for short term, 2015 for medium term and 2040 for long term. Moreover, the analysis considers the most likely chain of events that will occur in the building sector until 2040. In outlining these events, a series of input data and assumptions has been considered. These are the following:

- Population: The population of Lebanon (3.725 million in 1994) was assumed to be entirely urban since already over 90% of the population reside in urbanized areas [8]. The average population growth rate for the study period was assumed to be 1.5% [9], and the number of persons per household has been assumed to be 5 throughout the study period.

- Buildings: An average life span of 75 years has been assumed to both the residential and commercial buildings alike. This gives a building retirement rate of 1.3% per year. Furthermore, and based on historical trends [2], the average overall building growth rate has been assumed to be 2.5% for the projected study period.

- Thermal building guidelines: In light of the presently existing market, institutional, information and human capacity barriers that impede the adoption, application and enforcement of the "thermal building guidelines". The most likely chain of events has been assumed. This being that the "thermal building guidelines" will most likely be approved in the year 2000, but will remain voluntary for an indefinite period of time. Newly constructed buildings have been assumed to start voluntarily applying the "guidelines" at a rate of 2% until 2005, 10% until 2015 and 20% to 2040.

- Energy: The overall energy demand growth rates for heating and cooling have been assumed to be 3% as a lower boundary, and 4% as a higher boundary (reflecting higher economic growth rate). Where as the market share of the energy type used for the provision of thermal comfort has been assumed as shown in table A2b.8. To be noted is that for the purpose of this study, the projected growth in energy demand has been taken as a linear growth, and not as a decaying curve that accommodates for equipment efficiency improvement.

Table A2b.8: Assumptions as to the market share of energy type used for heating and cooling.

		1994	**2005**	**2015**	**2040**
Residential	% market share of electricity	45%	50%	55%	60%
	% market share of gas/diesel	30%	30%	30%	30%
	% market share of wood	25%	20%	15%	10%
Commercial	% market share of electricity	40%	45%	50%	60%
	% market share of gas/diesel	60%	55%	50%	40%

A2b.4.2 ANALYSIS

Based on the previous input data, two baseline scenarios have been adopted:

Low baseline scenario: building growth rate of 2.5%, and energy growth rate 3%. High baseline scenario: building growth rate of 2.5%, and energy growth rate 4%.

Table 2.9 presents the projected building stock growth, and shows that the total number of new building units from 1994 to 2040 is 3.44 million building unit, making up 82% of the 2040 stock.

Table A2b.9: Projected building growth.

	1994 x 10^6 units	2000 x 10^6 units	2005 x 10^6 units	2015 x 10^6 units	2040 x 10^6 units
No. of building units resulting from growth (+ 2.5%)	1.34	1.56	1.76	2.25	4.17
No. of building units remaining from old stock (-1.3%)	1.34	1.24	1.16	1.02	0.73
Resulting no. of new building units		**0.32**	**0.60**	**1.23**	**3.44**

The following tables are the calculation results for the projected energy demand by the building sector for the provision of thermal comfort. (Tables A2b.10 and A2b.11)

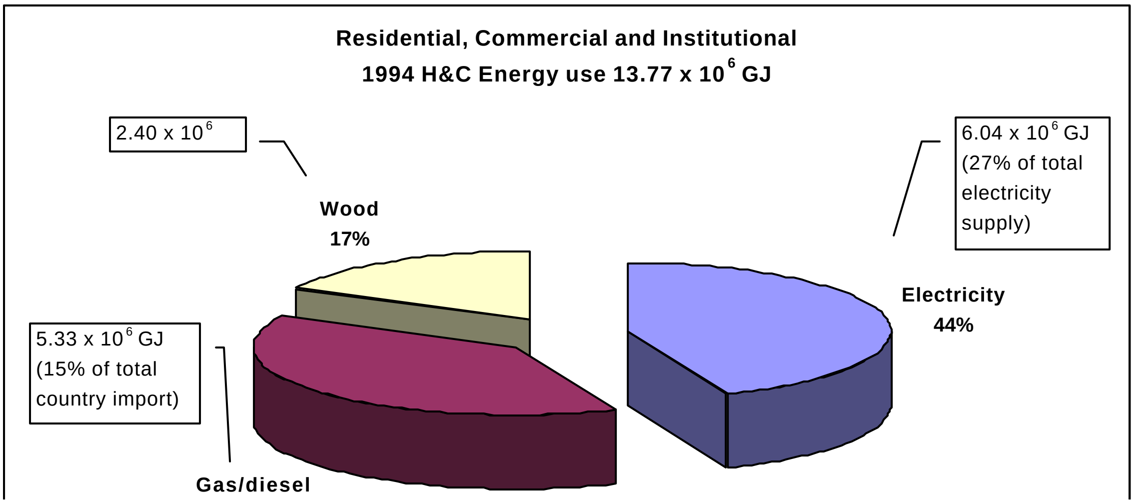
Table A2b.10: Energy demand for space heating and cooling under a 3% energy growth rate.

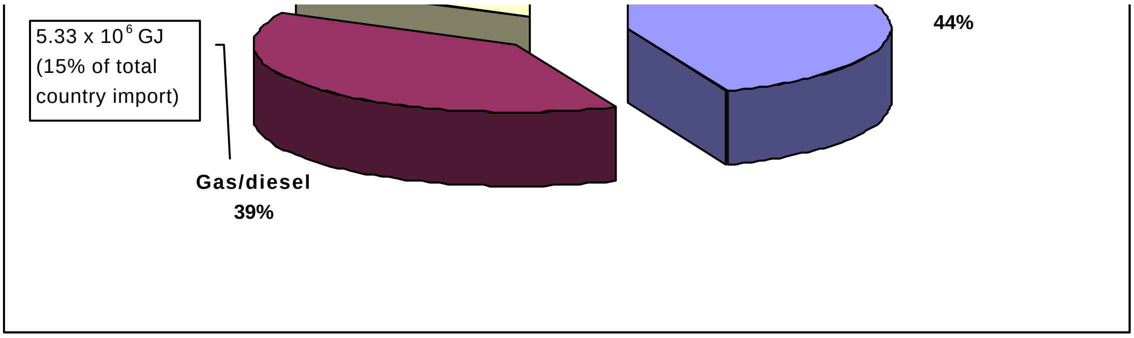
		1994 10^6 GJ	**2005** 10^6 GJ	**2015** 10^6 GJ	**2040** 10^6 GJ
RESIDENTIAL	Electricity	4.33	6.61	9.77	22.32
	Gas/diesel oil	2.82	3.96	5.33	11.16
	Wood	2.40	2.65	2.67	3.72
	Sub-total	9.55	13.22	17.77	37.20
COMMERCIAL	Electricity	1.71	2.63	3.93	9.87
	Gas/diesel oil	2.51	3.21	3.93	6.58
	Sub-total	4.22	5.84	7.86	16.45
Total (Without baseline "guidelines")		**13.77**	**19.06**	**25.63**	**53.65**

Table A2b.11: Energy demand for space heating and cooling under a 4% energy growth rate.

		1994 10^6 GJ	**2005** 10^6 GJ	**2015** 10^6 GJ	**2040** 10^6 GJ
RESIDENTIAL	Electricity	4.33	7.35	11.97	34.81
	Gas/diesel oil	2.82	4.41	6.53	17.41
	Wood	2.40	2.94	3.26	5.80
	Sub-total	9.55	14.70	21.76	58.02
COMMERCIAL	Electricity	1.71	2.93	4.81	15.38
	Gas/diesel oil	2.51	3.57	4.81	10.26
	Sub-total	4.22	6.50	9.62	25.64
Total (Without baseline "guidelines")		**13.77**	**21.20**	**31.38**	**83.66**

Fig A2b.2: 1994 Heating and cooling energy demand by type.





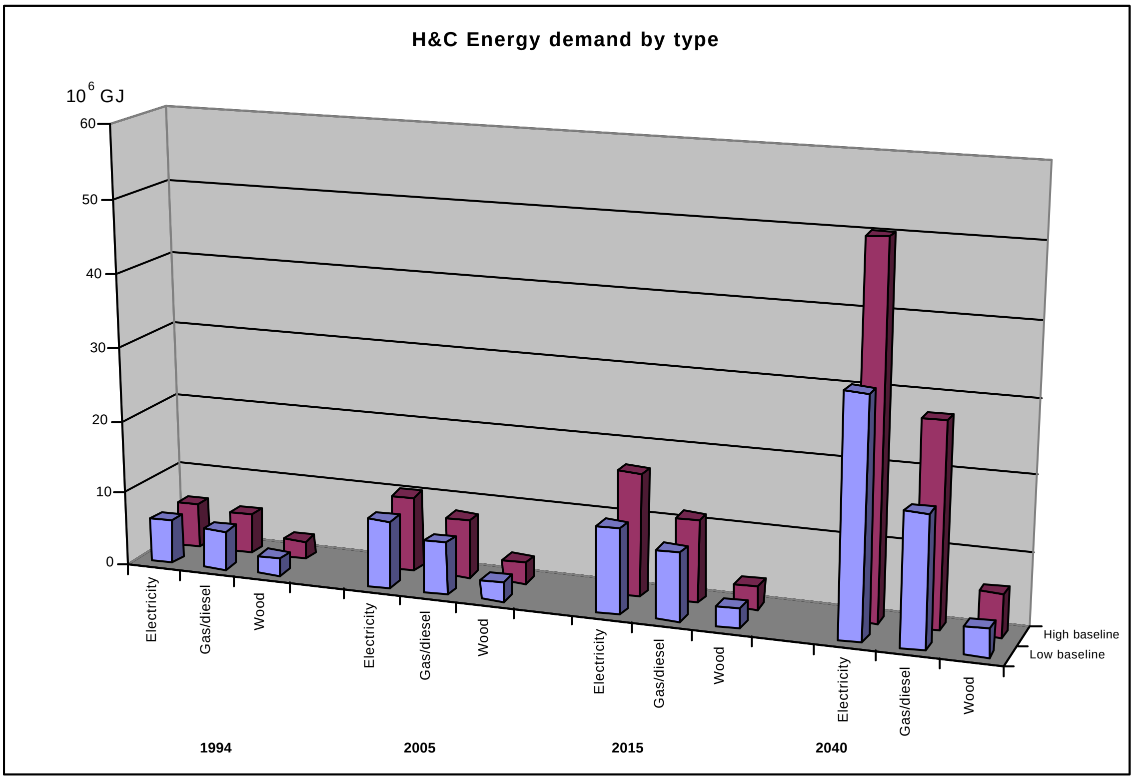


Fig. A2b.3: 1994 – 2040 Forecast of energy demand by type

Table A2b.12 shows the implications of the baseline application of the “thermal building guideline” on energy demand.

Table A2b.12: Total energy demand for space H&C. (with & without baseline “guideline”)

H&C Energy demand 1994 - 2040	**Low baseline scenario** 10^6 GJ	**High baseline scenario** 10^6 GJ
Total Electricity	761	1007
Total Gas/Diesel oil	484	640
Total wood	138	183
(without baseline guidelines) Total	**1383**	**1830**
(with baseline guidelines) TOTAL	**1339**	**1771**
% reduction	**3.2%**	**3.2%**
(without baseline guidelines) Ave/yr	29.43	38.94
(with baseline “guidelines”) Ave/yr	28.48	37.68

A2b.4.3 ENVIRONMENTAL IMPLICATIONS

From the electricity-supply sector analyzed in chapter 1, it can be seen that between 1994 and 2040, (under a 4% energy growth rate) a total of 781094 Gg of CO_2 will be emitted from the 3600 x 10^6 GJ (1 milliion GWh) electricity generated. The average CO_2/year emissions was16619 Gg/yr for an average of 77 x 10^6 GJ/yr of electricity produced.

Table A2b.13: Total CO_2 emissions from space H&C. (with & without baseline "guideline")

CO_2 emissions 1994 - 2040	**Low baseline scenario** Gg CO_2	**High baseline scenario** Gg CO_2
Total Electricity	165 115**	218 489**
Total Gas/Diesel oil	35 700	47 206
Total wood	14 835	19 673
(without baseline guidelines) Total	**215 650**	**285 368**
(with baseline guidelines) TOTAL	**208 750**	**276 236**
% reduction	**3.2%**	**3.2%**
(without baseline guidelines) Ave/yr	4588	6072
(with baseline "guidelines") Ave/yr	4442	5877

**The carbon emissions due to electricity are derived from the electricity-supply analysis of chapter 1, where by for every 1KWh produced, 780g of CO_2 are emitted.

A2b.4.4 RESULTS

- As shown in table A2b.12, both under low and high baseline scenarios of energy demand growth, the most likely chain of events, in terms of application of "guidelines", will result in 3.2% energy reduction for heating and cooling.

- As shown in table A2b.13 and fig.A2b.3, under both baseline scenarios, the greatest share of growth in energy demand for heating and cooling is from electricity. This means that the environmental implications in terms of CO_2 emissions will be dependent on the form of electricity production.

A2b.5 MITIGATION SCENARIOS

A2b.5.1 DEFINITION

The mitigation scenarios center around the promotion and advancement of the adoption and application of the recently developed "Thermal building guideline". As mentioned previously, application of proposed efficiency measures can achieve an estimated 25 % energy reduction of heating and cooling energy demand per building unit. However, due to existing barriers, the adoption and application of these guidelines are placed on hold.

The mitigation strategy aims at lifting these barriers, and consists of providing the needed capacity building in order to activate the application of the "guideline". Two mitigation scenarios are proposed. The first considers that the "guideline" will remain voluntary throughout the study period, while the second considers that the "guideline" will remain voluntary until 2015 only, but will become a mandatory building standard from that date forward. Both mitigation scenarios have maintained the conservative estimation of 25% energy reduction on space heating and cooling needs per building unit. (Tables A2b.14)

Table A2b.14: mitigation scenario parameters

Parameters		2005	2015	2040
Mitigation scenario 1	Application rate of guidelines*	10 %	30 %	70 %
Mitigation scenario 2	Application rate of guidelines*	20 %	60 %	100 %

* The % application of guidelines is from new building units only.

A2b.5.2 ANALYSIS

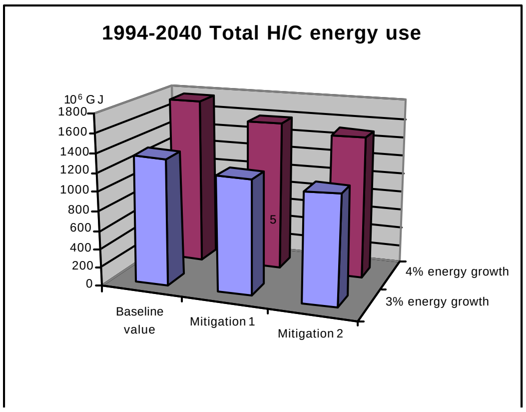
The following table shows the amount of energy demand reduction for the proposed mitigation scenarios, and the resultant decrease in CO_2 emissions.

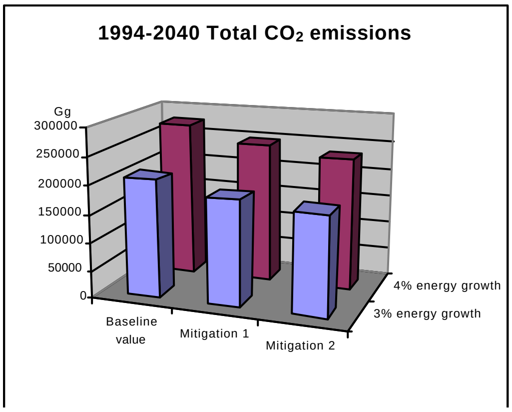
Table A2b.15: Mitigation scenarios.

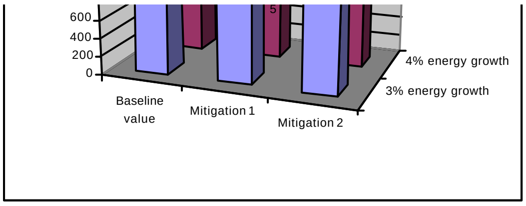
H&C Mitigation scenarios 1994 - 2040	**(A) Wrt. Low Baseline scenario**		**(B) Wrt. High baseline scenario**	
	10^6 GJ	Gg CO_2	10^6 GJ	Gg CO_2
Baseline Total energy demand	1339	208 750	1771	276 236
Mitigation scenario 1	**1205**	**187 875**	**1594**	**248 612**
Total amount saved	134	20 875	177	27 624
Average saved / year	2.85	444	3.77	588
Mitigation scenario 2	**1138**	**177 438**	**1505**	**234 800**
Total amount saved	201	31 313	266	41 435
Average saved / year	4.28	666	5.66	882

A2b.5.3 RESULTS

Mitigation scenario 1 can lead to an average 10% reduction of energy utilization between 2000 and 2040. Mitigation scenario 2 can lead to an average 15% reduction of energy utilization between 2000 and 2040. (Figs. A2b.4 and A2b.5)







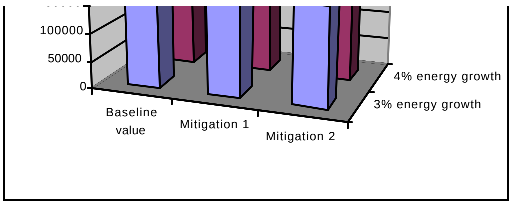


Fig A2b.4: Total heating and cooling energy reduction.

Fig A2b.5: Total resultant CO_2 reduction.

A2b.5.4 COST-BENEFIT EVALUATION

The cost-benefit analysis has been performed using the concept of annualized or levelised Cost of Saved Energy (CSE)*. In order to calculate the latter, the following assumptions have been considered: (table A2b.16)

*

$$CSE = [\Delta A + \Delta OM + \Delta ADM] / \Delta E$$

$$CRF = [d\,(1 + d)^{n-1}] / [(1 + d)^{n} - 1]$$

CSE = Levelised cost of Saved Energy
ΔE = Annual Energy Savings
ΔADM = Additional Administrative Cost
ΔAOM = Operation and maintenance Cost
ΔA = Annualized Incremental Capital Cost (Initial incremental cost x CRF)
CRF = Capital recovery factor
d = real discount rate
n = lifetime

Table A2b.16: Assumptions and input data

- Building life span:	75 years
- Discount rates:	5%, 10%, and 15%
- Incremental cost of conservation measure / wall:	6 US$/m^2 (material & labor)
- Incremental cost of conservation measure / window:	36 US$/m^2 (material & labor)
- Incremental cost of conservation measure / roof:	8 US$/m^2 (material & labor)

Incremental construction costs are derived from bulletins from the syndicate of contractors.

To be noted is that for practical purposes, the initial investment cost has been calculated to be the incremental construction cost only. Savings due to the downsizing of HVAC equipment as a result of reduced energy demand have been considered to even off with the cost of the lost area in m^2.

Moreover, the operation and maintenance cost was assumed to be zero, and the additional national administrative and implementation cost of the mitigation scenarios was assumed to be 5% and 10% of total incremental cost for scenarios 1 and 2 respectively. In addition to this, and based on a 2.5% building growth rate, the average new built-up area between 1994 and 2040 was found to be 20 million m^2/yr.

The following tables present the annualized costs per GJ of energy saved and the annualized costs per ton of CO_2 saved.

Table A2b.17: Annualized cost of saved energy for mitigation scenario 1

Mitigation scenario	Energy growth rate %	Discount rate %	DA US$/yr	DADM US$/yr	DE GJ/yr	CSE US$/GJ	Total energy saved GJ
1A	3	5	24.5×10^6	1.2×10^6	2.85×10^6	**9.02**	**134×10^6**
1A	3	10	45.0×10^6	2.3×10^6	2.85×10^6	**16.60**	**134×10^6**
1A	3	15	65.0×10^6	3.3×10^6	2.85×10^6	**23.96**	**134×10^6**
1B	4	5	24.5×10^6	1.2×10^6	3.77×10^6	**6.82**	**177×10^6**
1B	4	10	45.0×10^6	2.3×10^6	3.77×10^6	**12.55**	**177×10^6**
1B	4	15	65.0×10^6	3.3×10^6	3.77×10^6	**18.12**	**177×10^6**

Table A2b.18: Annualized cost of saved CO_2 for mitigation scenario 1

Mitigation scenario	Energy growth rate %	Discount rate %	DA US$/yr	DADM US$/yr	DCO_2 Ton/yr	Cost of saved CO_2 US$/Ton	Total CO_2 saved Ton
1A	3	5	24.5×10^6	1.2×10^6	444×10^3	**57.88**	**20.9×10^6**
1A	3	10	45.0×10^6	2.3×10^6	444×10^3	**106.53**	**20.9×10^6**
1A	3	15	65.0×10^6	3.3×10^6	444×10^3	**153.83**	**20.9×10^6**
1B	4	5	24.5×10^6	1.2×10^6	588×10^3	**43.70**	**27.6×10^6**
1B	4	10	45.0×10^6	2.3×10^6	588×10^3	**80.44**	**27.6×10^6**
1B	4	15	65.0×10^6	3.3×10^6	588×10^3	**116.16**	**27.6×10^6**

Table A2b.19: Annualized cost of saved energy for mitigation scenario 2

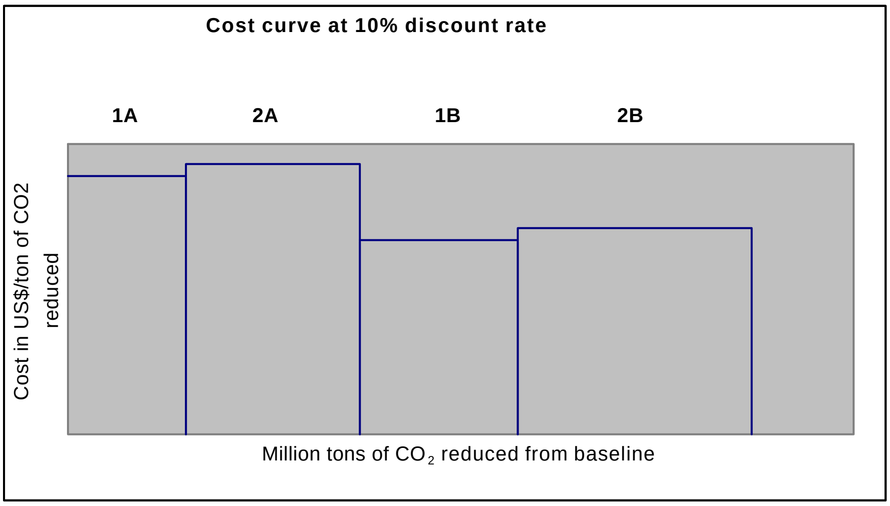
Mitigation scenario	Energy growth rate %	Discount rate %	DA US$/yr	DADM US$/yr	DE GJ/yr	CSE US$/GJ	Total energy saved GJ
2A	3	5	36.75×10^6	3.67×10^6	4.28×10^6	**9.44**	**201×10^6**
2A	3	10	67.50×10^6	6.75×10^6	4.28×10^6	**17.35**	**201×10^6**
2A	3	15	97.50×10^6	9.75×10^6	4.28×10^6	**25.06**	**201×10^6**
2B	4	5	36.75×10^6	3.67×10^6	5.66×10^6	**7.14**	**266×10^6**
2B	4	10	67.50×10^6	6.75×10^6	5.66×10^6	**13.12**	**266×10^6**
2B	4	15	97.50×10^6	9.75×10^6	5.66×10^6	**18.95**	**266×10^6**

Table A2b.20: Annualized cost of saved CO_2 for mitigation scenario 2

Mitigation scenario	Energy growth rate %	Discount rate %	DA US$/yr	DADM US$/yr	DCO_2 Ton/yr	Cost of saved CO_2 US$/Ton	Total CO_2 saved Ton
2A	3	5	36.75×10^6	3.67×10^6	666×10^3	**60.70**	**31.3×10^6**
2A	3	10	67.50×10^6	6.75×10^6	666×10^3	**111.49**	**31.3×10^6**
2A	3	15	97.50×10^6	9.75×10^6	666×10^3	**161.04**	**31.3×10^6**
2B	4	5	36.75×10^6	3.67×10^6	882×10^3	**45.83**	**41.5×10^6**
2B	4	10	67.50×10^6	6.75×10^6	882×10^3	**84.18**	**41.5×10^6**
2B	4	15	97.50×10^6	9.75×10^6	882×10^3	**121.60**	**41.5×10^6**

Fig A2b.6 Shows the cost curve for mitigation options 1 and 2, where by it is seen that with minimal additional cost per ton of CO_2 saved, mitigation scenario 2 can achieve much greater total CO_2 emission reduction.

Fig. A2b.6: Cost curve for mitigation options 1 and 2 at 10% discount rate



1A: Mitigation scenario 1, energy growth rate 3%.
2A: Mitigation scenario 2, energy growth rate 3%.
1B: Mitigation scenario 1, energy growth rate 4%.
2B: Mitigation scenario 2, energy growth rate 4%.

A2b.6 CONCLUSIONS AND POLICIES

- Upgrading the thermal integrity of building envelopes are conservation measures whose consequences in terms of energy reduction are felt on a long-term basis.

- The scenarios adopted of allowing a 15-year span of voluntary "guideline" application in order to create a smooth transformation in the construction industry is sensible and achievable.

- In terms of technology: it is available on the market but not the Know how nor the ability to increase initial construction cost.

- In terms of policy: there seems to be a serious will on the part of the Lebanese government to address the issues of the thermal integrity of building envelopes, hence the commissioning of the "thermal building guideline".

- At present there exists a series of major barriers that will hinder the adoption and application of this "guideline". These barriers are mainly: economic and market barriers, Institutional barriers and human capacity and Information barriers. All of which can be gradually overcome through a series of appropriate interventions.

A2b.7 PROJECT PROPOSALS

The recently developed "Thermal Building Guideline" which aims at enhancing the thermal performance of building envelopes, and thus of reducing the energy consumed for space heating and cooling, faces numerous barriers that hinder its adoption and application. The main barriers are the following:

- *Information and Know-how barrier*: Unfamiliarity with subject matter among professionals, policy makers and consumers; Uncertainty about the effectiveness of the new technology (Energy reduction versus new problems of construction details or space overheating)
- *Economic barrier*: Uncertainty with economic and environmental implications; Initial incremental cost of conservation measure.
- *Institutional barrier*: Lack of trained personnel; Lack of adequate verification mechanism.

Consequently, there seems to be two main projects needed in this sector:

- **Capacity Building project** aimed at providing the needed foundation of supportive policy makers, informed consumers, skilled professionals, and trained personnel.
- **Market based program** aimed at overcoming the initial incremental cost and at activating market demand.

A2b.8 RECOMMENDATIONS FOR FUTURE WORK

- The analysis has been performed based on the assumption of 25% reduction on heating and cooling energy needs per building unit. A detailed simulation of study cases is needed for the various climatic zones in order to determine more accurately the potential of energy reduction.
- The specifications of the “Thermal building guideline” were recommended based on historical precedent in other countries. Further work is needed to update the specifications based on an economic cost-effective approach.
- The analysis has considered the potential of static building envelope conservation measures. A further multi-parameter assessment that looks at the overall potential of passive heating and cooling techniques for the Lebanese climate is needed.
- Assessment of the potential of microclimatic interventions such as increasing green cover along the coastal zone as a means of reducing the urban heat island effect, and thus reducing cooling energy needs.
- This analysis has assumed that both the residential and commercial uses will rely on partial heating and cooling. Further data refinement in terms of differentiating between residential and commercial energy uses and energy growth rates is needed.
- The analysis did not account for additional energy reductions due to the natural improvement of the efficiency of HVAC equipment.
- The cost-benefit assessment of this analysis looked at the national level; a further assessment of the consumer pay back period is needed.

2.9 – REFERENCES

1. Atlas Climatique du Liban, 2nd edition (1977), volumes 1, 2, 3, 4. Published by the Meteorological service of Lebanon.

2. Administration Centrale de la Statistique:
   Etude Statistique (1996), No. 3, 4, 5, 6, 8, 11

Bulletin Statistique, Series 1996, and 1997

3. Order of Engineers and Architects - Beirut
Statistical Bulletins, years 1986, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97.

4. Computer programs: P.E.M version 1.1 Beta, PASCOOL program, University of Geneva C.U.E.P.E 1995.

5. CSTB/CDR/LIBNOR "Guide de L'isolation Thermique et du Confort D'ete des Batiments au Liban" (1999)

6. The first Inventory of Greenhouse Gas Emissions by Sources, and Removals by Sinks, Lebanon. Produced in 1998 under the UNFCCC.

7. 1992 by "Electricite de France" (EDF) for "Electricite du Liban" (EDL). (Figures for 1994 are deduced by ALME).

8. "Population and Housing Survey" conducted in 1995 by the Ministry of Social Affairs in cooperation with UNFPA

9. UN, World resources 1998/99.

10. Statistical "construction cost" bulletins from the syndicate of contractors.

11. Energy conservation of residential buildings in Beirut, N. Ghaddar and A. Bsat, (1998), International Journal of Energy Research.

12. Computer programs: LEAP.

13. The 1994 annual report of the Central bank of Lebanon.

14. Communication with Mr. Jaoudat Abou-Jaoude, Architect/planner, Council for development and reconstruction (CDR).