High Level
Energy Efficiency Guidelines
For Building Reconstruction and Upgrades in Lebanon

Greenfield Cities, LCEC & Energy Transition Facility
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List of Abbreviations

Abbreviation	Meaning
A/C	Air Conditioner
ACH	Air Changes per Hour (air refreshment rate) [ACH or h-1]
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CDD	Cooling Degree Days
CFL	Compact Fluorescent Lamp
CO2	Carbon Dioxide
COP	Coefficient of Performance
ECN	Energy research Centre of the Netherlands
EDL	Électricité du Liban (national integrated Lebanese electricity utility)
EV	Electric Vehicles
G	Solar heat gain coefficient: the fraction of incoming sunlight that passes through glazing. In the US a similar (but slightly different) indicator is SHGC
GBC	Green Building Council
GWP	Greenhouse Warming Potential
HDD	Heating Degree Days
HFC	Hydro-Fluoro-Carbon
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
LBP	Lebanese Pound (Lira)
LCEC	Lebanese Center for Energy Conservation
LIBNOR	The Lebanese Standards Institution

Abbreviation	Meaning
Loil eq	Liters of oil equivalent
NEEREA	National Energy Efficiency and Renewable Energy Action
OEA	Order of Engineers and Architects
OEM	Original Equipment Manufacturer
PCM	Phase Change Material
PV	Photovoltaic
R&D	Research and Development
RH	Relative Humidity
Rw	Reduction factor of noise [dB] used to indicate sound reduction efficacy of different types of glazing
SHAMCI	Solar Heating Arab Mark and Certification Initiative
SME	Small or Medium Enterprise
SWAC	Seawater Air Conditioning
SWH	Solar Water Heater
TES	Thermal energy storage
TFC	Total Final Consumption
TSBL	Thermal Standard for Buildings in Lebanon
U	Thermal transmittance [W/m²K]
WB	World Bank

I. Energy Renovation Guideline Sheets for Architects & Engineers

A. Introduction

This document contains Energy Renovation Guideline Sheets and is intended primarily for architects and engineers who are involved or interested in renovating existing residential buildings & reducing their energy consumption at the same time. Building owners, residents' associations, lawmakers, construction sector companies, administrators and vocational & polytechnic education institutes can also benefit from these sheets.

Improving the energy efficiency of existing residential buildings is a continuous challenge in every country. Renovating these buildings provides unique opportunities for reducing their energy consumption and the resulting costs for occupants. This would as well contribute to the National targets in reducing the energy consumption.

Fortunately, experience and solutions are becoming increasingly available. This leads to better business cases and interesting opportunities for people making a living in the built environment sector.

Figure 1: Beirut
Source: GreenfieldCities

B. Best practices for building energy renovations in Lebanon

The developed Guideline Sheets are brochure type documents that aim to provide the architect and engineering community of Lebanon with high-level, yet practical information to inspire and assist them in considering energy efficiency measures as part of renovation projects for residential buildings.The following five criteria will ensure that these sheets bring positive return to the Lebanese renovation market:

1. Develop the sheets with renovation in mind.
2. Base the content on international best practices.
3. Include rough quantitative indicators for energy savings and pay back times.
4. Distinguish between Lebanon's different climate zones.
5. Consider different building types, to a limited extent.

The sheets contain generic information. Every renovation project is unique and requires careful consideration and planning at project level. Nevertheless, the Guideline Sheets help provide a first feasibility indication when considering energy efficiency improvements. They also have limitations when predicting the exact business opportunities for architects and engineers. Not all components for international best-practice energy efficiency measures may be available off the shelf in Lebanon for example. Despite these limitations, the Guideline Sheets aim to increase the level of confidence of people with energy efficient renovation ideas in mind and help them to include these ideas in their plans. Annex discusses the various assumptions used for making the Guideline Sheets.

II.

Benefits, Drivers and Barriers of Energy Efficient Renovation

A. Benefits and drivers for energy efficient renovation

1. There are many reasons to consider energy renovation of a house or a building. Renovation of a building is often more environmentally friendly than demolishing it and building a new one. Renovation provides a natural moment for the incorporation of insulation and other measures. Whether the renovation of a residential building is used as an opportunity for making it energy efficient or improving the energy efficiency itself is a motivation for a renovation, benefits of opting for energy efficient renovation include:

A. First, energy efficiency measures are financially attractive with the right approach. Many of the options earn back their upfront cost in a few years and continue to save on the energy bill for decades. Thus, the occupants retain more money for other purposes and more importantly, they become less vulnerable to fluctuations in energy prices.

B. Second, occupants can live in a more comfortable house. Smart, energy efficient renovation will not only increase the thermal comfort (buildings that are cool in the summer and warm in the winter) but also reduce outdoor noise and problems related to draft and humidity.

C. Third, energy efficient housing reduces the consumption of electricity and the CO2 emissions associated with combustion of fossil fuels, thus contributing to battling the climate change effect.

D. Fourth, a wider experience and a variety of solutions with post construction energy retrofits are available now more than a few decades ago.

E. Finally, renovated houses keep more value on the property markets. All residences need maintenance more or less regularly and those moments are opportunities to improve energy performance as well. The houses of the future are the ones that are built and renovated today.

B. Barriers for energy efficient renovation

1. Common barriers hindering the roll out of energy efficient measures in residential buildings include:

A. Energy renovation competes with other options for limited budgets. For instance, energy renovations often are not very visible, whereas cosmetic repairs or a new kitchen are.

B. Financial return is not always clear without careful planning. It's easy to determine the output and financial earnings of a solar panel, but for wall insulation and many other measures energy savings are more case specific, requiring a building specific assessment.

C. Short-term costs come before the long-term financial savings. Owners and occupants need to have a longer-term mindset as well as the financial means and stability to do the investments, even if they know that in the long term, they will save money.

D. Lebanon's period of economic hardship, makes energy efficient renovations harder to plan and less of a short-term priority for people.

E. Decision-making is delayed in some apartment buildings when some of the measures need to be taken together by all residents/owners.

F. The financial savings arrive at the tenants while owners carry the investment when house are rented. The previous barrier is aggravated by the so-called split incentive.

G. The incentive for energy efficiency measures, if houses are only occupied part of the time (used as second house), will be lower than with full occupation.

2. Solutions to reduce these barriers include:

A. Planning and boosting the level of confidence that benefits are achieved.

B. Experiencing best practice examples through visualization and opportunities.

C. Providing confidence, financing, and warrantees through specialized energy renovation companies.

D. Specific Energy Renovation Financing (energy mortgage plus government incentives).

E. Introducing simple regulation on minimum energy performance in existing buildings.

F. True cost-based energy pricing.

U. Improving collaboration between public (policy) and private (execution/roll out) sectors through aligned and joint programs involving all main stakeholders such as the Order of Engineers and Architects, LCEC, LIBNOR, GBC etc.

H. Allowing for a transparent relation between building energy performance and rental price or building price through a building labeling system.

I. Working on achieving a more energy conscious mindset in the public.

III. Choosing Energy Saving Measures for Building Renovations

A. Introduction

In Chapters IV and V, measures for energy efficient renovation of residential buildings are described. In this chapter, general recommendations reveal how to choose the best combination of measures in energy efficient renovation projects.

Every building and every renovation is different. Often, the reason for renovating is to improve the living standards, but refurbishing can also start out of the desire to improve energy performance. What to do depends largely on several aspects mainly as on the climate, the characteristics of the building, and its location and surroundings. Also on whether the residential building[1] or the house will only be lightly improved, or will it be stripped and deeply renovated? What are the financial position and the ambitions of the owners and occupants? Are they interested in making the building green and energy efficient? Will they accept higher renovation costs to obtain financial gain in the longer term and increased comfort? What to do depends largely on these aspects, as well as on the climate, the characteristics of the building, and its location and surroundings.

B. Reduce energy demand first

Technically, the best approach is to first reduce the energy demand. The Trias Energetica[2] , a general design strategy developed in the Netherlands but used all over the world by engineers and architects, corresponds partly to 'passive building' strategies and describes a general three-step approach to sustainable energy projects:

1. Minimize the energy demand needed for comfortable living with insulation measures, shading, and reduction of ventilation losses.

2. Use sustainable energy sources like solar power and solar heat for the remaining energy demand.

3. Cover the remaining energy demand in an efficient way, for instance with efficient boilers instead of conventional ones.

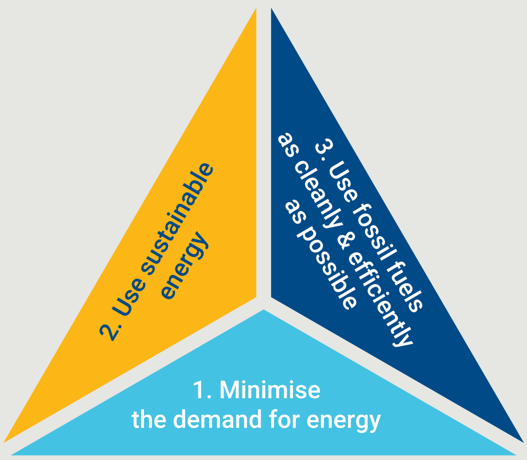


Figure 2: Trias Energetica
Source: ECN

[1] This report mentions the terms building and residential building to indicate both.

[2] In the text, various references are underlined: these are clickable links that directly connect to mentioned resources on the Internet. The links were operational at the time of writing.

Inspired by this strategy, this chapter proposes a general approach to improve the energy efficiency of residential buildings for each climate zone in Lebanon (see Annex for more information on the Lebanese Climate Zones).

A rough separation is made between 'light' renovations with only the most profitable and easy to apply measures, and thorough, 'deep' renovations, resulting in residential buildings with low energy consumption. 'Deep' renovations require the involvement of an expert engineer to determine the best options and their expected cost, energy savings and other benefits.

Section C describes general measures to be considered in each climate zone. Chapter IV provides Guideline Sheets for specific measures that could be quickly effective in Lebanon. These guideline sheets will also be published as standalone documents. Chapter V provides short descriptions of other energy measures that (while also good options) were not selected for the Guideline Sheets. Some of these measures are already widely applied in Lebanon and others were deemed promising but too innovative for quick adoption. In the Guideline Sheets, the focus lies on energy efficiency measures but in accordance with the Energy Triangle and general green building practice. Recommendations below include renewable energy measures.

C. General recommendations for different Lebanese climate zones

1. Coastal climate: mostly cooling

In the warm and humid climate along the coast, the focus is to keep residential buildings cool with minimal use of active cooling. Except for shading and night ventilation, measures that keep a building cool in summer will also help reduce its energy consumption for heating in the winter.

For light renovations, consider relatively simple 'add on' measures such as shading, air tightening, simple measures for night ventilation, energy efficient glazing (always together with good shading and ventilation), solar power, solar water heating and LED lighting. These may lower the energy bill and increase comfort considerably.

If the building is going to be renovated deeply, the first measures to consider are a combination of outside shading, energy efficient glazing, air tightening, exterior roof insulation or green roofs, and exterior or cavity wall insulation. These measures will result in a well-insulated building with strongly reduced cooling load in summer and heating demand in winter. Make sure the windows on south, east and west facades are properly shaded against the direct sunlight, because otherwise the insulation and energy efficient glazing may result in problematic overheating. If not already done, replace existing lighting by LED lighting.

If most of these measures are adopted, consider also smarter ventilation and avoiding thermal bridges. These will result in a 'complete' insulation of the building shell. If the building has a heavy construction (stone, concrete), increased night ventilation in cooler nights will cool down the thermal mass and save on energy for air conditioning the next day.

For townhouses and low apartment buildings, contingent on roof space being (made) available-solar power can often cover most or all of the electricity demand, and solar water heaters will be able to cover most of the hot water demand. In high-rise buildings except very high towers, solar power can contribute to the shared electricity consumption for elevators and lighting, while hot water production can be supplied by solar water heaters for the top floors and efficient air-to-water heat pumps for lower levels.

Additionally, consider installing efficient heat pumps. Using the heat from ground water (without disrupting the sensitive drinking water supply) may sometimes be an option if the necessary permits can be obtained within the strict ground water regulations. Over time, central heat pumps can turn out much cheaper, because the occupants will not need to add and maintain their own, often inefficient, split units for air conditioning. For the humid coastal climate, evaporative cooling would need the more sophisticated two- stage technology combined with heat pumps in order to be considered for ambitious projects. For very large projects, a central cooling network or seawater air-conditioning can bring huge energy savings.

2. Western Mid-Mountain and Inland Plateau climate: heating and cooling

In Western Mid Mountain and the Inland Plateau zones, residential buildings face a heating demand in winter, autumn and spring, and a still significant cooling demand in the summer. The measures suggested for energy efficient renovation in these climates are similar to those described above for the coastal climate, with some adjustments for the larger seasonal and daily swings in temperatures.

For light renovations, consider air tightening, night ventilation, energy efficient glazing, solar power, solar water heating and LED lighting. Shading and night ventilation will be very useful for energy saving and comfort. If the building is going to be renovated deeply, the first measures to think about are again shading, energy efficient glazing and insulating window frames, air tightening, exterior roof insulation or green roofs, and exterior or cavity wall insulation. If not already done, replace existing lighting by LED lighting. If most of these steps are taken, consider ventilation measures and avoiding thermal bridges. For buildings with a heavy construction, night ventilation will work very well in these climates, because of the generally cooler nights.

For generating sustainable energy, solar power and solar water heaters are attractive and can visualize the green renovation.

For the installations, add-on direct evaporative (pre) cooling will work relatively well in the inland plateau. A two-stage technology or hybrid system is recommended for the western mid-mountain climate in case of evaporative cooling as the main cooling installation. Central heat pumps are again often more efficient than individual split units.

Figure 3: Mid mountain dwellings
Source: GreenfieldCities

3. High Mountain climate: heating

In the high mountains, there is little need for cooling, however buildings have a high-energy consumption for heating, which can be strongly reduced with good insulation measures.

For light renovations, air tightening, energy efficient glazing, LED lighting, solar power and solar water heating are the best to consider here. Whereas for deep renovations, consider measures against the cold: energy efficient glazing and air tightening. Roof insulation and wall insulation applied from the outside, in the cavity or from the inside. Properly reducing ventilation to the amount that is needed and avoiding thermal bridges will pay off well here. Some shading may still help overheating in larger, well-insulated buildings. If not already done, replace existing lighting by LED lighting.

As everywhere in Lebanon, solar power and solar water heaters are also an attractive and visible, sustainable option. Water source heat pumps (for instance using water from nearby rivers or lakes) can be an option.

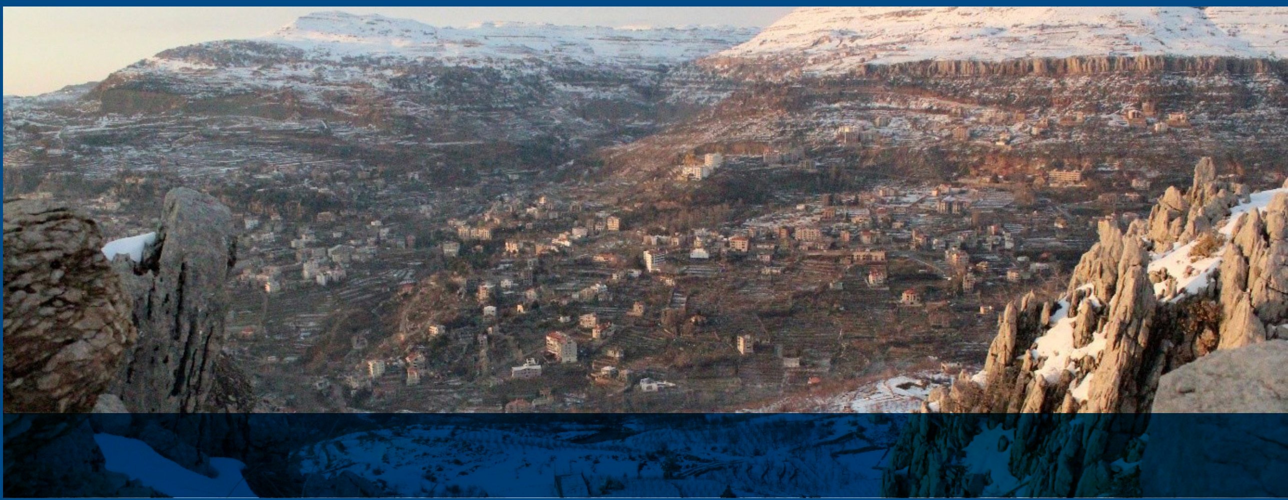


Figure 4: High mountain zone in winters
Source: GreenfieldCities

IV. Guideline Sheets for energy efficiency renovation measures

This chapter contains nine Guideline Sheets for the following interventions / measures:

1. Air Tightening
2. Ventilation and Night Cooling
3. Shading
4. Energy Efficient Glazing
5. Wall Insulation
6. Roof Insulation
7. Avoiding Thermal Bridges
8. Heat Pumps
9. Evaporative Cooling

Each sheet has the following general structure:

1. Introduction to the Intervention/Measure

Main messages and a short introduction to the intervention.

2. Intervention Features and Applicability

Features (of technology or measure)
More detailed description of (technology) options and features / working principles / Overall heat transfer coefficients and thermal resistances (U/R values) before/after renovation / typical materials.

Applicability
Indications for the degree of applicability of the intervention in different climate zones and building types in a retrofit context.

3. Expected Benefits

Energy
High level estimates of benefits either in kWh or percentage including qualitative remarks on the different climate zones and building types.

Economy
Rough order of magnitude indication of financial attractiveness of the intervention based on the energy savings in the previous paragraph and an educated guess on intervention costs in a mature market.

Qualitative remarks on the different climate zones & building types may be included. General assumptions made for obtaining indications are discussed in Annex.

Other Benefits
Mentioning other benefits like increased comfort, building value, noise reduction, indoor health, and productivity increase.

4. Recommendations

Concepts and Design Definition
Considerations for the design of a project or program around the intervention.

Practical Considerations
Bullet style lists of things to keep in mind to get to good results.

In the text, various references are underlined: these are clickable links that directly connect to mentioned resources on the Internet. The links were operational at the time of writing.

A. Air tightening

When insulating a building, always consider reducing the air leaks (infiltration and exfiltration). It is simple and cost efficient. But care should be taken to maintain sufficient (and controlled) ventilation to keep indoor climate healthy.

Table 1: Air tightening application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Relatively easy

1. Introduction to the intervention

Sufficient ventilation is essential for buildings to be cool, healthy, and pleasant. However, excessive, or uncontrolled ventilation - draft - leads to considerable energy losses. When a building is heated in a cool season, or when it is cooled by air-conditioning in a hot summer, too much ventilation will lead to unnecessary energy costs and less comfortable living. Controlling the ventilation, while still letting enough air in, is an integral part of making buildings more energy efficient. Uncontrolled ventilation can lead to excessive air leaks in windy conditions, as well as insufficient ventilation when the wind is not blowing.

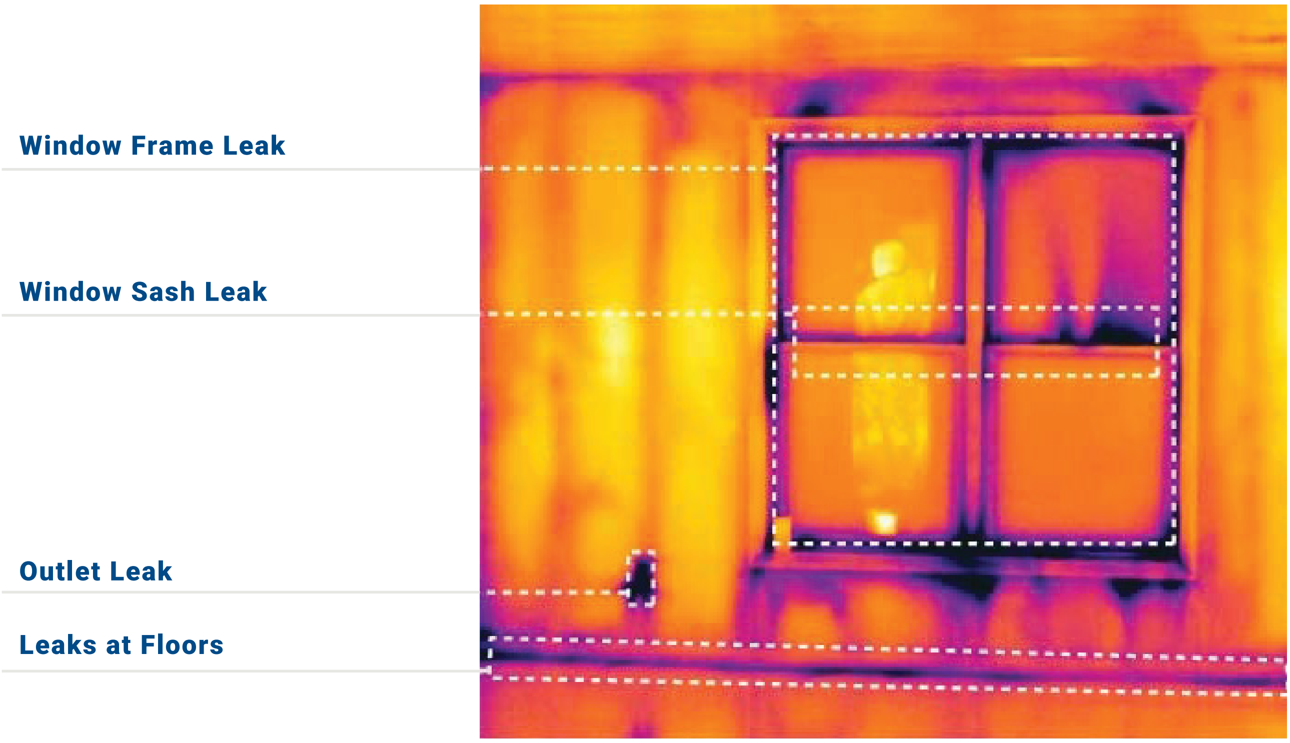


Figure 5: Infrared imagery can help identify air leaks[3]
Source: Infrared Image Services

[3] In this picture, yellow and red areas have higher temperatures than the purple, blue and black areas. However, thermal images must be taken and judged very carefully, because many effects, such as direct sunshine on a wall or thermal reflections, can distort the images.

2. Intervention features and applicability

(a) Features

Unintentional air transfer toward the inside is referred to as infiltration, and unintentional air transfer toward the outside is referred to as exfiltration. However, infiltration is often used to imply air leakage both into and out of a home. According to Energy Star, a typical home loses 25 - 40 per cent of its HVAC energy through infiltration. Infiltration also affects concentrations of indoor pollutants and can cause uncomfortable drafts.

When buildings are insulated to reduce their energy consumption for heating or cooling, attention should be paid to sources of unnecessary draft. Typical infiltration openings are:

i. Opening windows and doors.

ii. Window/door frame to wall interfaces.

iii. Wall to wall, wall to ceiling and wall to floor junctions.

iv. Porous and semi-porous building materials.

v. Perimeter leaks around penetrations such as service ducts.

vi. Open chimneys, ducts and other flues.

vii. Open doorways.

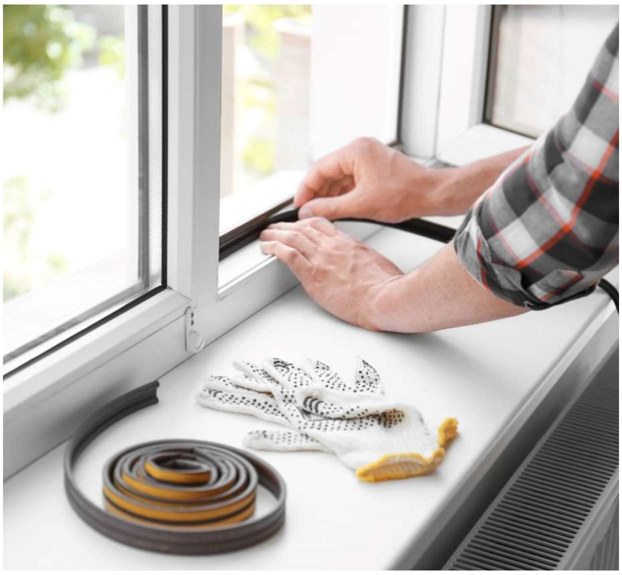


Figure 6: Reducing unnecessary ventilation is often simple and uses cheap materials like weather strip or seal tape
Source: Milieucentraal

Air leaks can be found in several ways. The easiest way is by means of visual inspection of the whole building, or by watching the flame of a lighter or candle near potential spots on a windy day. Infrared thermometers or infrared photography can be used at moments with very low or very high outdoor air temperatures, but the results need careful analysis because the imagery is often influenced by other factors such as shading, thermal bridges or reflection. ASHRAE provides guidelines to find the relation of air leakage-to-leakage area. Finally, a 'blower door test' can be used to accurately measure the amount of air leakage through the building at a given pressure. The remedy is often simple: close or reduce leaks using draft exclusion tape, seal strips, kit, foam, cement, or other suitable materials. Private residents can even implement this measure themselves.

(b) Applicability

Air tightening and reducing air leaks will always reduce heating and cooling energy costs but it is especially important in buildings that are going to be well-insulated (roof, walls, windows). The savings will be highest in locations where buildings need considerable active heating (for instance the mountain climates in Lebanon) and/or active cooling (areas with warm summers). In areas with mild climates and buildings with little or no active heating and cooling, reduction of the infiltration may hamper natural ventilation and cooling effects and is therefore not recommended. In all cases, sufficient controlled ventilation needs to be ensured.

3. Expected benefits

(a) Energy

If (as mentioned above) 25 to 40 per cent of the HVAC energy is lost through uncontrolled air leaks, and that a third of that amount could be reduced while still maintaining sufficient controlled ventilation, the energy savings would be about 8 to 13 per cent of HVAC energy.

(b) Economy

The energy savings of air tightening measures are modest, but so are the costs. This means that draft reduction measures can earn their money back quickly in areas with significant heating and/or cooling demand, as the following table illustrates.

Table 2: Indication of average energy savings and simple pay back times for air tightening

Air Tightening	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	190 - 300	100 - 200	200 - 200	100 - 100
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	10 - 20	40 - 60	60 - 100	80 - 130
Simple Pay Back Time (years)	0.7 - 5	0.5 - 3	0.3 - 2	0.3 - 2

(c) Other benefits

Air tightening often leads to better thermal comfort: in the heating season, the building may feel warmer because there is no cold draft over the floors and in the cooling season, the air-conditioning may be switched off more often and will achieve pleasant temperatures more quickly. Moreover, air- tightening measures may help reducing exterior noise problems and dust collecting in the building.

4. Recommendations

(a) Concepts and design definition

Air tightening can be easily applied in existing buildings, but it is essential as part of a comprehensive, energy efficient renovation design that also includes wall and floor insulation and energy efficient glazing. Standards for necessary ventilation of residential buildings vary depending on the type of occupancy. The Criteria for Green Buildings in Lebanon report recommends minimum ventilation rates for acceptable indoor quality (Order of Engineers and Architects, 2017). Rooms with natural ventilation are required to have an open net area in each regularly occupied room of 4 per cent of the gross internal floor area, with extra requirements for rooms over seven meters deep. For residential buildings with mechanical ventilation, the minimum ventilation specified in these criteria is 0.3 L/s per m² of floor area and 2.5 L/s per person. Also, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) provides standards on minimum acceptable ventilation levels.

(b) Practical considerations

Air tightening is about reducing uncontrolled and unnecessary ventilation. But proper and controlled ventilation is necessary in all buildings. Therefore, do not reduce the draft without considering sufficient, controllable ventilation. For instance, add user-controllable or self-controlling ventilation openings and grilles. Also consider electric fans to ventilate where it is needed (bathroom, kitchen, toilet). In hot areas, always consider air tightening together with ventilation (especially night ventilation) as a cooling measure. Inadequate reduction of ventilation openings may increase overheating problems. Finally, indoor gas or oil heaters such as furnaces or gas-fired water heaters should have sealed combustion chambers and/or fan-forced draft channels in order to avoid carbon monoxide poisoning dangers.

Figure 7: A dropseal attachment can be an effective air tightening and sound proofing measure for wooden doors

Source: Elton (See video for working principle)

B. Ventilation and night cooling

Controlled ventilation reduces energy losses. Extra ventilation at night is an energy efficient way to reduce the need for air-conditioning.

Table 3: Ventilation and night cooling application

Saves on	Climate Zone	Building Type	Difficulty
Cooling and heating	All (but only for heating from in High Mountain)	All	Ranging from simple to advanced / specialist

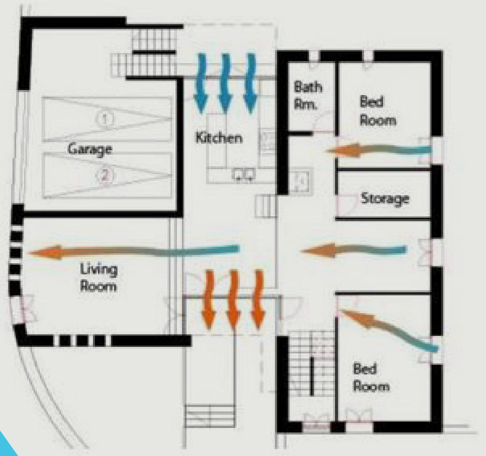
1. Introduction to the intervention

Ventilation is important for controlling the indoor temperature and humidity and for providing sufficient outdoor air. When renovating a residential building, ventilation in a controlled way can be an energy saver, even if it is achieved with simple measures such as closeable ventilation grills. The first step should be air tightening to gain basic control over the ventilation. In summer, ventilation can help save energy for cooling, and in winter, it can help reduce heat losses while keeping the indoor climate healthy.

2. Intervention features and applicability

(a) Features

During summer, increased night ventilation can add to thermal comfort and energy savings. The principle is that the cool air in the night is used for cooling down the building mass. The next day, the building will stay cool longer and air-conditioning is needed less.



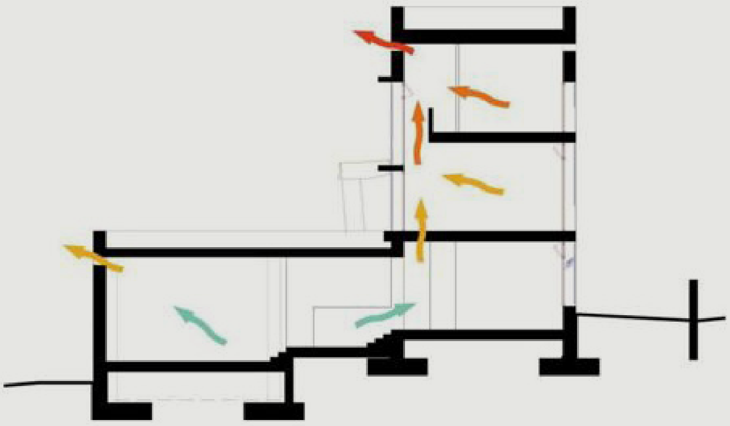


Figure 8: Principle of night cooling by natural ventilation
Source: Aqaba Residence Energy Efficiency

Each building is different and needs a careful assessment of ventilation options and effects. The following rules of thumb should therefore only be used as such:

i. Night ventilation, or night cooling, works best when the difference between day and night temperatures are more than 6 -10 °C.

ii. Night cooling requires high airflows. A rule of thumb is to have a flow that refreshes the volume of air inside the building 5-10 times per hour (5-10 ACH). This air can be circulated through the building mechanically (fans), by using an outdoor breeze, or by using the stack effect: using the principle that warm air is lighter than cold air and rises. Opening windows or ventilation openings on the ground floor and on the top floor, e.g. achieve the stack effect, using a stairwell (see also Figure 8). A working rule is that a temperature difference of 4 °C and a height difference between the opened windows of six meters will provide 2000 m³/h of air flow for normal sized windows. This does not consider wind, which can amplify or reduce the effect. In renovations of apartment buildings, the building configuration may limit the applicability of stack ventilation.

iii. Night cooling works better in buildings with a relatively high building mass so that the cooling at night can have a lasting effect the next day.

During winter, controlling and reducing ventilation saves energy. But sufficient ventilation is needed to keep the indoor climate healthy.

The most efficient system is ventilation with heat recovery (see Figure 9). When refurbishing an insulated and reasonably airtight building with existing mechanical ventilation, heat recovery ventilation units can be a good option. In buildings without existing central ventilation, it may be possible to install heat recovery ventilation units with efficient fans in different rooms.

Alternatively, window frame solutions that include heat recovery and CO2 -or humidity- controlled ventilation are coming to the market.

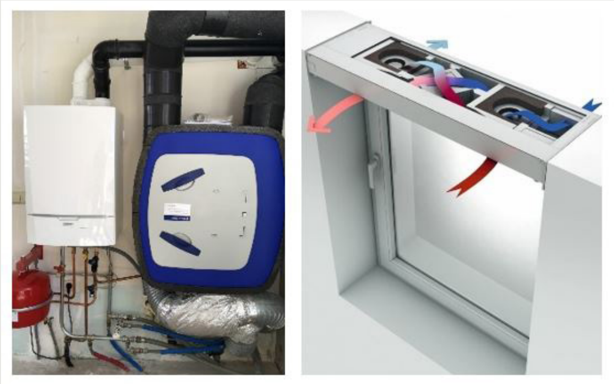


Figure 9: Heat recovery ventilation with over 90 per cent efficiency can be used in buildings of every size. The blue box on the left is a single home systemAqaba Residence Energy Efficiency
(Source: Itho) and on the right is a retrofit window unit
(Source: Siegenia)

(b) Applicability

The best climate zones for applying night cooling in Lebanon are the Western Mid Mountain and Inland Plateau zones. Night cooling may also add to reducing cooling loads in spring, early summer and autumn in the Coastal climate zone. For buildings with a central HVAC system, it is worthwhile checking (aside from checking and replacing filters which is often neglected) if the existing controls (control unit, sensors, valves, etc.) are functioning well and if the control can be improved to use night cooling. In such cases, adding evaporative pre-cooling (see the separate guideline sheet on evaporative cooling) may also lower the costs of cooling. In the high mountain climate, ventilation with heat recovery and/or CO_2 and humidity sensors can reduce the energy consumption for heating.

3. Expected benefits

(a) Energy

Energy savings of night cooling can be high, although it is hard to provide generic numbers. Assessments for the EU Venticool program show that energy savings can range up to 95 per cent of compressor cooling energy. Energy savings in the range of 50-90 per cent of cooling energy seem possible in the Mid Mountain and Inland Plateau climate zones. For the Coastal climate zone, energy saving potential is less but still likely to be in the range of 10-50 per cent for many buildings.

In winter conditions, adding heat recovery units and CO_2 and humidity sensors to an existing central ventilation system can result in 15-25 per cent energy savings on heating energy. Additionally, in an existing HVAC system, replacing old ventilators using Alternating Current motors with new ventilators using Direct Current motors can save up to 50 per cent of ventilation energy.

(b) Economy

The cheapest night cooling approach is to just open opposite windows or openings during the night. Of course, more sophisticated interventions cost money. It is hard to provide generic pay back times, but even more complex interventions can be economically very attractive.

Casa Batroun

A well-studied building on ventilation cooling is Casa Batroun in the coastal climate zone. Even in mid-summer conditions, night ventilation resulted in up to 9°C cooler inside temperatures. Casa Batroun is a thoroughly refurbished traditional house; with high building mass and a favorable orientation towards the sun it has representative value for other traditional buildings in Lebanon.

Figure 10: Casa Batroun
Source: Breeam

Table 4: Indication of average energy savings and simple pay back times for ventilation and night cooling

Shading	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	200 - 1000	500 - 900	600 - 1100	100 - 200
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	20 - 30	70 - 120	110 - 180	150 - 250
Simple Pay Back Time (years)	> 7	4 - 19	3 -14	3 - 16

(c) Other benefits

Using only the wind and the temperature stack effect, natural night cooling can be 100 per cent independent from the electricity grid. So even if there exists centralized chillers and mechanical ventilation in place, it makes sense to add natural night cooling options as discussed above, to increase comfort levels without having to rely on the grid.

4. Recommendations

(a) Concepts and design definition

Night cooling principles are simple, but there are quite a few factors to consider for delivering a good project. Working with these factors is an acquired skill. The EU Venticool program provides useful guidelines and tools that include:

- Overview of stakeholders, roles and responsibilities.
- How to prioritize thermal comfort targets in a project.
- Quantifying the project and make it data driven.
- Combinations of ventilation with shading, heat gain control, evaporative cooling, etc.
- Example analysis of investments and operational costs.

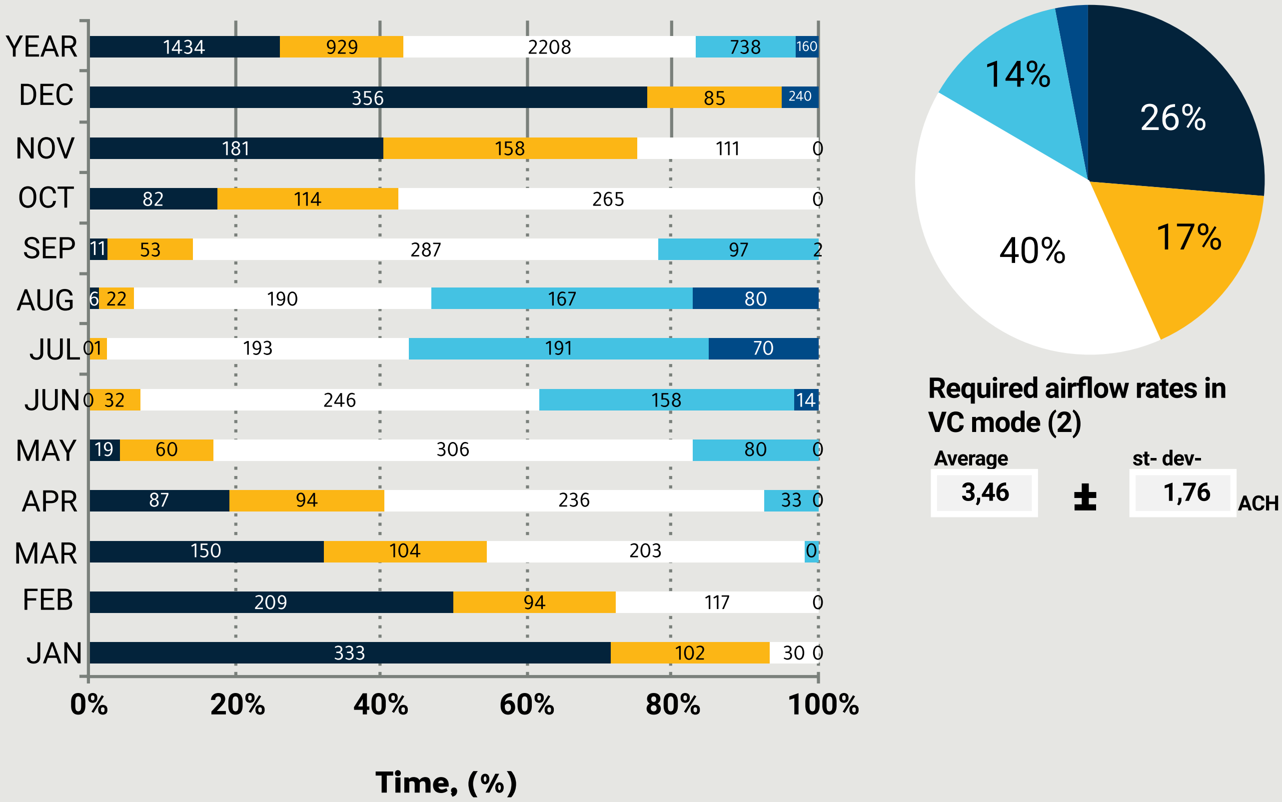
(b) Practical considerations

An elaborate quick scan tool was developed under the EU Venticool program. This tool helps to assess the potential effectiveness of ventilation (also called 'ventilative') cooling strategies for different climate conditions, building envelope properties, internal gains and ventilation needs. The tool evaluates the night cooling potential for a given climate and building typology, identifies the most efficient night cooling strategy and provides a rough estimation of the airflow rates needed to cool down the building.

With forced ventilation, pay attention to noise levels. While designing the control of ventilation systems, consider the air quality (see also the sheet on Air Tightening).

In many cases, night cooling needs to be based partly or fully on mechanical driving forces for air distribution, but assessing if mechanical ventilation can be responsibly reduced, is always a good idea. In areas with high air pollution levels, pay attention to filtering outside air. The IEA Air infiltration and Ventilation Centre (AIVC) has a useful library of resources and documents accessible online. Finally, it's worth noting that ventilation measures are more effective combined with other measures, like solar shading and thermal mass activation.

Figure 11: The Royal Chelsea Hospital in London, retrofitted with wind catchers for natural ventilation. Wind catchers originate from Middle East traditional architecture
Source: Monodraught



- VC mode(0) ventilative cooling not required
- VC mode(1) potential comfort hrs by direct ventilative cooling with minimum airlow rates
- VC mode(2) potential comfort hrs by direct ventilative cooling with increased airlow rates
- VC mode(3) potential comfort hrs with evaporative cooling
- VC mode(4) residual discomfort hrs

Figure 12: The overview screen of the Venticool cooling assessment tool with an example for Madrid. The tool also contains data for Lebanon. The conclusion is twofold.
1) Ventilation cooling requires a careful planning.
2) When done properly, the potential for natural cooling is large

C. Shading

In all climate zones except the high mountain area, shading is an essential element of energy efficient buildings in Lebanon. Use horizontal shading devices on south facades and vertical shading devices on east and west facades.

Table 5: Shading application

Saves on	Climate Zone	Building Type	Difficulty
Cooling	Coastal, mid mountain, inland plateau	All	Relatively easy

1. Introduction to the intervention

Located at about 34 degrees latitude, Lebanon is heavily exposed to the sun. The solar heat gain through windows can create uncomfortably high interior temperatures and/or increase the cooling load for air- conditioning systems. A very efficient way to protect a building from the solar radiation is by window shading.

2. Intervention features and applicability

(a) Features

Good shading keeps sunlight out, avoiding or reducing overheating (mostly in summer), though it admits daylight, and even sunlight at moments when it is useful (mostly in winter). The best application is shading on the outside of the building. Depending on circumstances, an unshaded part of a window admits 11 times more heat into a building than an externally shaded part of the same window. Indoors shading still results in unwanted heat load within the building. Advanced systems feature light sensors and motorized moving shades to maximize shading effects.

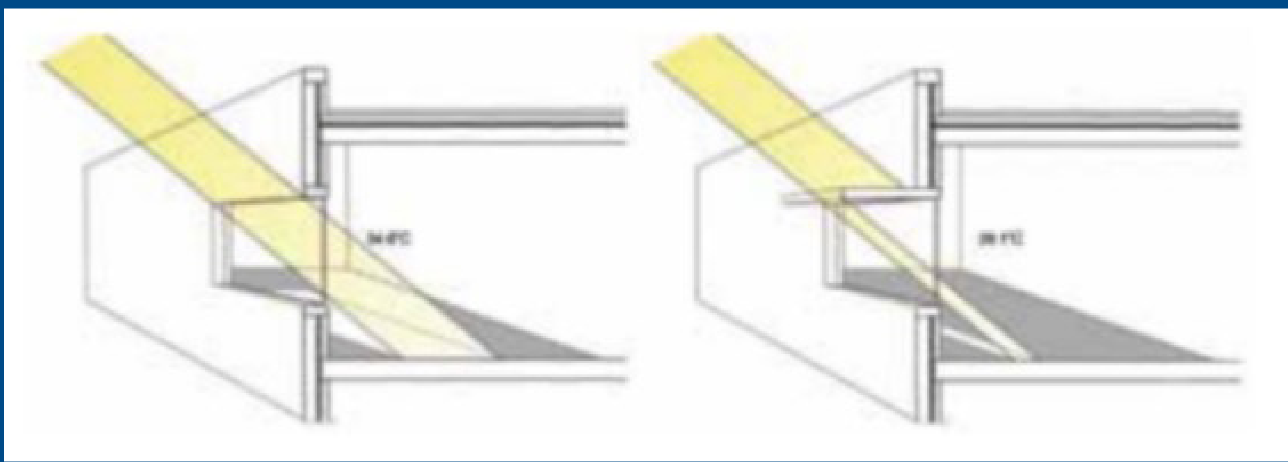


Figure 13: Window shading can strongly reduce solar heat gain
Source: MED-ENEC

(b) Applicability

Pergolas or canopies and other horizontal shading devices can shade roofs. South-facing facades generally require horizontal shading (see Figure 13). On east and west-facing facades, vertical shading panels often work best to avoid room overheating in the morning or afternoon. Houses can have closeable shading hatches (see also Figure 16). In modern buildings, double skin facades are equipped with integrated shading. Automatic / movable shading devices can optimize the shading effect further. Lastly, trees and bushes are also used as shading device – to a degree; they provide the desired seasonal effect. In cities, possibilities for outside shading are often limited because the building may not extend outside its regulated limits.

Figure 14: Examples of shading balconies and aluminum shading devices in Lebanon
Source: Dr. Samir Traboulsi

3. Expected benefits

(a) Energy

The actual amount of electricity from air-conditioning units saved by shading devices, depends completely on the situation and design of the building and the design of the shading devices. As a rule of thumb, good shading devices can achieve energy savings of around 5 to 15 per cent of the cooling energy consumption. The best effects are expected in the warmer climates in the Coastal, Western Mid Mountain and Inland Plateau climate zones.

Figure 15: Shading measures on the Dutch Embassy Amman-Rudy Uytenhaak Architects
Source: Pieter Kers

(b) Economy

Depending on the situation and the materials used, shading devices are cheap to install and consequently have short pay back periods. Indications are given in Table 6.

Figure 16: South facades and glazing-openings have been sheltered with horizontal overhang devices, sometimes with greeneries, allowing for ventilated/shaded buffers to be pleasant outdoor seating areas

Table 6: Indication of average energy savings and simple pay back times for shading

Shading	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	90 - 280	40 - 120	50 - 150	-
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	-	-	-	-
Simple Pay Back Time (years)	> 3	> 8	> 6	-

(c) Other benefits

As a secondary energy effect, outdoors shading devices can improve the indoor light quality, reducing the need for shading indoors and even the use of artificial light.

4. Recommendations

(a) Concepts and design definition

The best impact of shading will take place in the hot seasons, mostly in June, July and August. In the winter, sunlight should be admitted so that it can help keep the rooms warm. Shading devices can help achieve this by shading the sun at high angles and admitting it at low angles (see Figure 17). One must consider shading by surrounding buildings, trees and/or mountains when designing shading devices.

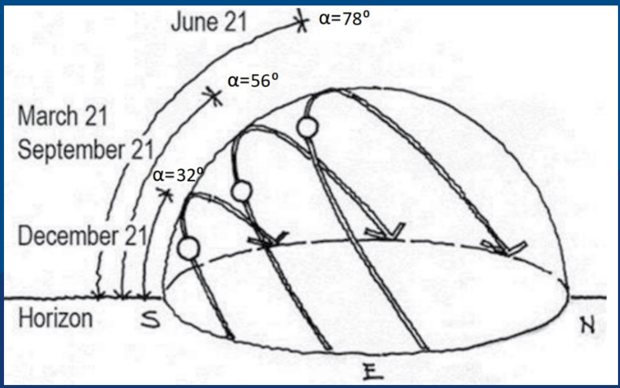


Figure 17: In Lebanon, the sun angle at noon varies between 32° in the winter to 78° in midsummer. Shading devices should block the sun at higher angles (in the summer season) but admit it at lower angles (in the winter)
Source: MED-ENEC

(b) Practical considerations

Insulating a building without sufficient attention for shading can cause severe overheating problems. Shading devices can be combined with solar panels or even consist of solar panels, providing an extra energy bonus. The Thermal Standard for Buildings in Lebanon (TSBL 2005) gives requirements and calculation methods for Effective Fenestration Ratio and shading factors. International building rating systems limit the window/wall ratio, sometimes not more than 50 per cent and depending on the facade orientation. In a deep renovation project, this ratio can be easily attained. More insight in the path of the sun can be gained using tools like SunCalc, SunAngle, Sun Path or SunEarthTools. Many drawing programs such as Revit feature a shading-rendering component. For advanced designs, there are Three-dimensional ray-tracing models that can provide accurate calculations of the shading effect of a given configuration over a whole year.

D. Energy efficient glazing

Together with wall and roof insulation, energy efficient glazing is important for insulating a building. Simple add-on secondary windows are affordable and adequate solution in many cases. To prevent overheating or high cooling energy use, combine such glazing with adequate shading in all climate zones, except the high mountains, where shading is less needed.

Table 7: Energy efficient glazing application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Advanced

1. Introduction to the intervention

Single pane windows are a major source of heat gain and loss or condensation, causing damp or mold. When replacing them with energy efficient, double pane windows, preferably with insulated frames, energy consumption will be reduced, and thermal comfort increased.

2. Intervention features and applicability

The energy impact of glazing in buildings has two aspects: heat transfer and solar heat gain.

(a) Heat transfer

Replacing single glazing by double glazing will reduce the heat gain entering the building in summer, and the heat loss in winter, by about half: the U-value of about 5.9 W/m²K for single glazing is reduced to about 2.9 W/m²K with double glazing. For more energy efficiency there is 'low-e' glazing, reducing the heat transfer further to 1.2 W/m²K or even lower, by adding a gas (argon) into the air cavity between the glass layers, and/or using heat- and sunlight- reflecting coatings. In this document, the term 'energy efficient glazing' is used to indicate double-glazing as well as low-e glazing. An interesting option for Lebanon could be improving U and G factors with affordable add-on window frames with a single glass or acrylic pane. Compared to single pane windows, adding such secondary windows will reduce the U-value with up to 50 per cent. An optional reflective coating would also help reduce heat gain. Overall costs of add-on windows could be as much as 50 per cent lower than replacing single glass with industrial double pane windows.

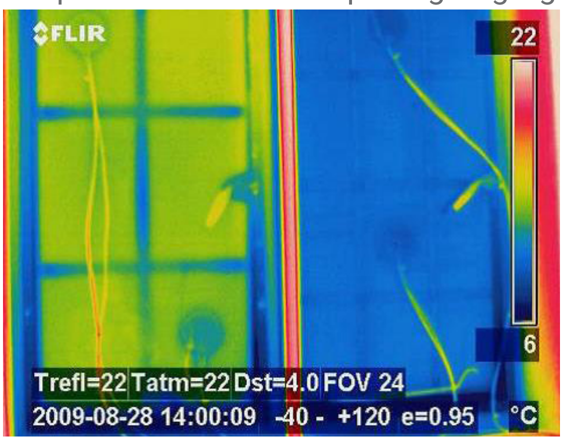


Figure 18: A traditional metal window (left) vs the same window with an acrylic secondary window mounted in front (right), photographed by an infrared camera
Source: Historic England

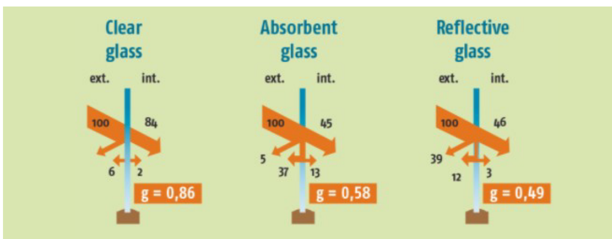


Figure 19: Solar Heat Gain (G) factors for different types of glass
Source: Shuttervoice

(b) Solar heat gain

Direct sunlight entering buildings can cause unwanted heat gain in summer. To reduce this 'Solar Heat Gain', the reflective coating on low-e glazing reflects a portion of the incoming light. The G-factor represents the fraction of the incoming sunlight that gets through the glass. The lower the G-factor, the less heat the window (or skylight) allows to pass through it. While limiting solar heat gain is beneficial in summer, such coatings can, however, also reduce solar heat gain and daylight entry in winter, when it is desired. In areas with heating as well as cooling demands, it is especially important to consider combining energy efficient glazing with shading elements that keep out direct sunlight in summer and allow it in in winter – this combination will work more effectively than using only glazing with a low G-factor. For an example of a combined product, see Figure 20.

Figure 20: Example of a retrofit window frame featuring energy efficient glazing combined with an integrated shading device
Source: Multiwindow

3. Expected benefits

Retrofitting an existing building with new windows will have several impacts; these are described in the sections below.

(a) Energy

Provided that also effective shading solutions are implemented, retrofitting glazing will significantly reduce the heating demand as well as the cooling demand of residential buildings. International studies indicate a range of 5-15 per cent of savings on the energy costs for heating and cooling when applying energy efficient windows. In cases where the existing glazing is causing a lot of solar heat gain or conductive losses, the savings can be much higher. In extreme cases, for instance if a building in the Coastal zone with a large façade facing South and consisting of 90 per cent glass is renovated with shading devices and double-glazing, the combined measures could save up to 50 per cent on the total energy bill.

(b) Economy

Low-e glass has become a global commodity. Competition, technology improvements, and scale have driven down low-e glass prices over the last 3 decades. Lebanese construction businesses can easily order low-e glass according to project specifications on the global wholesale markets. There may be a small mark-up on prices compared to larger EU markets, but that could be offset by lower costs of labor in Lebanon.

The cost of changing to energy efficient glazing depends strongly on whether the existing window frames can be used or if they need to be replaced. This has two aspects: the energy efficient glazing might not fit into existing frames because it is thicker and heavier, and a simple metal window frame may have a high heat transfer and reduce the energy saving effect of the glazing. Replacing single glass windows with energy efficient glazing in new window frames is the best option if the window frames are nearing their technical end-of-life, or in case of major building upgrades.

Table 8: Indication of average energy savings and simple pay back times for energy efficient glazing

Energy efficient glazing	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	110 - 300	100 - 200	100 - 300	0 - 100
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	10 - 20	20 - 70	40 - 110	50 - 150
Simple Pay Back Time (years)	> 10	> 7	> 5	> 4

(c) Other benefits

Energy efficient glazing and frames can greatly increase the indoor comfort, especially when new window frames are added as well, improving the building's airtightness. This can increase comfort and reduce energy bills if ventilation and heat gain effects have been considered.

Energy efficient glazing can also help reduce outdoor sounds. If that is a desired effect, it is important to also reduce cracks or unnecessary ventilation openings. Calculating noise reduction impact is not simple, but all EU produced window glazing have a sound performance certification number expressed as Rw in Decibels (dB) reduction including two corrections: (Rw + C and Rw+ Ctr) for specific noise sources. As an indication, standard low-e glazing will have Rw values between 30 and 33 and lead to a noticeable improvement of sound comfort. Window solutions that are optimally configured for noise reduction can have Rw values between 40 and 50 and reduce perceived noise with up to 50 per cent compared to single glazing. Most major glass producers have online examples and free tools to calculate and experience the impact of their solutions. Finally, energy efficient glazing can improve the general daylight comfort in a building, for instance by reducing glare disturbance from excessive daylight indoors.

4. Recommendations

(a) Concepts and design definition

Based on current low-e glass performance (variety of U and G factors), low global product prices, sample logistics options, and e-learning capacity building options, low-e glazing can technically and economically be applied in any type of residential building and in any climate zone in Lebanon. Energy efficient glazing is mandatory for buildings with double walls. It is important to carefully consider not only to replace glazing, but to also include adequate shading.

(b) Practical considerations

Glazing retrofitting is generally done most effectively:

A. In Coastal climate zone, mainly to reduce heat gain in summer.

B. In Mid-Mountain and Inland Plateau zones to reduce heat gain in summer and heat loss in winter.

C. In all facades in the High Mountain region to reduce heat loss in winter.

D. By using adjustable blinds using light sensors, reducing the need for artificial light use.

E. When overheating is avoided using shading or other devices, especially in buildings with large, glazed areas. The reduced heat transfer may increase ‘green house’ effects.

F. When considering upgrading window frames, be aware that the building may lose ventilation openings. Always make sure that sufficient ventilation possibilities remain to avoid problems with the indoor heat gain, air quality and/or moisture.

G. The standard aluminum single pane frames that are common in Lebanon may be less easy to retrofit. On the other hand, these existing simple aluminum frames may have high heat losses, justifying complete frame and glass replacements.

H. In historic / heritage buildings, retrofitting windows will need to comply with extra rules to conserve the typology and visual aspects.

I. Retrofitting buildings with low-e glazing requires combining assessment capabilities (what is the right glazing solution in a certain climate zone and specific building), craftsmen for execution and a reliable and affordable supply of glazing solutions that are usually made to specification for each individual window. Manufacturers offer many combinations of standard components (glass module types, number of layers, coatings, frame materials, hinges, fittings, etc.) with high precision in virtually any size.

J. In many buildings, occupants and owners glaze their balconies and use the room as indoor room. This can create large additional heating and cooling demands and should therefore be discouraged.

Figure 21: Example of a window retrofit measurement equipment

Source: Prodim

E. Wall insulation

Wall insulation reduces the energy consumption for cooling and heating. Filling the cavity of a double wall can be a cheap and easy option but also exterior insulation is a good option.

Table 9: Wall insulation application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Easy/advanced

1. Introduction to the intervention

Wall insulation materials reduce heat transfer through the building envelope. Small air bubbles in the material reduce the heat transfer, so insulation materials are light in weight and have low density. Insulating materials are classified as fiber or cellular insulation. Insulation can be applied at different positions in the building envelope: on the inside, outside, and between double walls.

2. Intervention features and applicability

Walls can be insulated in three ways: interior, exterior or by filling a double wall cavity with insulation material. The (voluntary) Thermal Standard for Buildings in Lebanon (TSBL 2005) prescribes a maximum U-value for walls of 2.10 W/m²K for the Coastal climate zone, 0.77 W/m²K for the Western Mid-Mountain and Inland Plateau zones and 0.55 W/m²K for the High Mountain climate zone[4]. In practice, a layer of 2 - 10 cm of insulation material will often be sufficient to achieve these values. For advanced green building projects, thicker layers may be necessary.

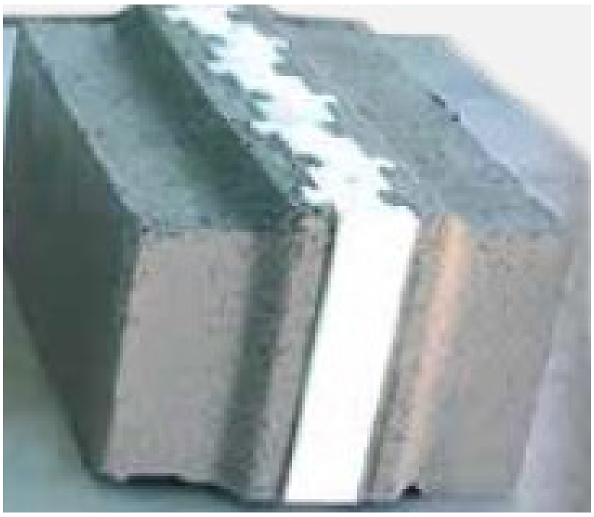


Figure 22: Lebanese companies offer insulated building blocks Multiwindow
Source: Takara

(a) Cavity filling

Filling the air cavity between double walls, is probably the preferred option when there is a suitable cavity wall with a cavity at least 50 mm wide. The cavity should be inspected (for instance by inserting a small camera through a hole) and clean (no building debris inside).

The procedure is simple and affordable, as the insulation materials are injected through drilled holes in the outer wall. Cavity filling for a house can be completed in a few hours. From a construction point of view, it is a good solution, since the two wall layers protect the insu-

Figure 23: Cavity filling
Source: HGT Geveltechniek

[4] Excluding the effects of interior and exterior air films.

lation material. However, the insulation material is difficult to replace. In Lebanon, there are companies that offer insulated building blocks (see Figure 22).

(b) Exterior wall insulation is preferred when there is no cavity. This way of insulating is very effective and will also give the building a new look and excellent insulation values. Inside, there is no loss of space; the thermal mass of the wall inside the insulation will help rooms to cool, and occupants to enjoy wide windowsills. Outside insulation is a good option in case of a more thorough building overhaul / 'facelift'.

(c) Interior insulation is the least preferred from building physics perspective, but it could still be a good option and is the most prevalent option in Lebanon. In this case, one should take care in respect to preventing condensation and moisture issues. The picture shows a frame-based solution, but it is also possible to use ready-made insulation panels (with integrated moisture barrier) that can be fitted directly to the wall. The U-values are usually better than with cavity filling, but the thermal mass effect of the building is reduced, which means that one must be more careful against overheating. This way of insulating is labor intensive and requires redecorating walls on the inside.

Figure 24: Outside polystyrene insulation
Source: Milieucentraal

Figure 25: Inside wall rockwool insulation
Source: Ikwoonfijn.nl

Figure 26: Extruded polystyrene insulation with wall renovation: new stone cladding in Dutch Embassy Amman-
Source: Florentine Visser

3. Expected benefits

(a) Energy

Depending on the wall area relative to roof and window areas and the energetic quality of all of these elements, wall insulation can often reduce the energy consumption for heating and cooling by 20 to 30 per cent.

(b) Economy

Wall insulation will lower the energy bill of a household significantly and it is therefore often an attractive and profitable option.

Table 10: Indication of average energy savings and simple pay back times for wall insulation

Wall Insulation	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	400 - 700	300 - 400	400 - 500	100 - 200
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	30 - 40	100 - 140	140 - 220	200 - 300
Simple Pay Back Time (years)	> 10	> 7	5 - 14	4 - 12

(c) Other Benefits

Wall insulation provides a better indoor living quality, enhancing comfort and productivity. One can combine exterior insulation with visual upgrading of the building. Also, one can combine exterior insulation with shading measures to save more energy and further reduce overheating.

Table 11: Comparison of the U-values of a single wall consisting of hollow blocks and plaster, a double wall of hollow blocks with air cavity and a double wall with insulated cavity

Calculation of U-values		Thermal	Thermal Resistance		
Element	Thickness	Conductive λ of material	Uninsulated Single Wall	Uninsulated Double Wall	Insulated Double Wall
	(m)	(W/mK)	(W/m²K)	(W/m²K)	(W/m²K)
External Surface (Rso)	-	-	0.05	0.05	0.05
External Block (R1)	0.10	0.55	0.18	0.18	0.18
Cavity with air (R2)	-	-	-	0.18	-
Cavity filled with foam (R2)	0.10	0.04	-	-	2.50
Internal Block (R3)	0.10	0.55	-	0.18	0.18
Plaster (R4)	0.01	0.48	0.02	0.02	0.02
Internal Surface (Rsi)	-	-	0.12	0.12	0.12
Total Thermal Resistance			0.37	0.73	3.05
U-value			**2.68**	**1.36**	**0.33**

4. Recommendations

(a) Concepts and design definition

Retrofitting any existing wall with a U-value of 1.5 W/m²K or higher is a good idea anywhere in Lebanon (see Table 11).

(b) Practical considerations

i. Double wall insulation as stated in the Lebanese building code is optional. In case of double wall, outer walls areas are not accounted within the rate of investment and the factor of public investment. The non-counted outer walls include insulation thickness, if any, and parts of the columns within the exterior walls and ranging in thickness between 22 and 35 cm. The separation between the two walls should not be less than 3 cm and the outer wall thickness not less than 10 cm.

ii. Insulation materials that become part of the building should last as long as the building's lifetime (up to 50 years), especially when applied in places where they are hard to reach.

iii. When considering wall insulation for a renovation, be aware that the building may lose ventilation openings. Always make sure that sufficient ventilation possibilities remain in order to avoid problems with the indoor quality and/or moisture, and that humidity transport in the wall construction is not blocked.

iv. When using external insulation covered by heavy material such as limestone blocks, attention should be taken so that the building structure can absorb the extra weight load. Also, make sure external covering material is non-flammable and non-toxic.

v. If using pre-insulated building blocks, take care that the masonry work is done in a way that is compatible with the product: for instance, layers of cement mortar between the blocks may cause numerous thermal bridges that could destroy the insulation effect.

F. Roof insulation

Insulate the roof to reduce overheating and the energy consumption of air-conditioning and heating. Outside insulation often is the preferred option.

Table 12: Roof insulation application

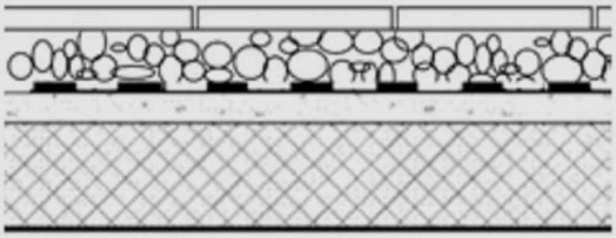
Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Relatively easy

1. Introduction to the intervention

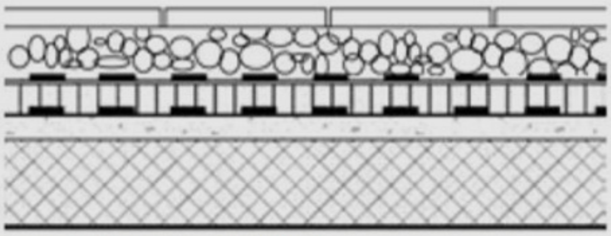
Together with measures like wall insulation and energy efficient glazing, roof insulation reduces heat transfer through the building envelope. The materials used for roof insulation are often the same as for wall insulation, but the practicalities for applying roof insulation differ. The information in the Guideline Sheet for Wall Insulation is for a large part relevant for roof insulation. Roof insulation reduces both the heating load and the cooling load.

2. Intervention features and applicability

Roofs in general are the most exposed component of buildings to solar radiation, wind, rainwater, humidity, and snow. Insulating them is therefore an energy saver. Like wall insulation, one can apply roof insulation in any of the Lebanese climate zones but areas where much energy is used for cooling and/or heating can expect the most impact. The Thermal Standard for Buildings in Lebanon (TSBL 2005) prescribes a maximum U-value for roofs of 0.44 W/m²K for the High Mountain climate zone and 0.57 W/ m²K for the other three climate zones, excluding the effects of interior and exterior air films. In practice, a layer of 2 - 10 cm of insulation material will often be sufficient to achieve these values. For advanced green building projects, thicker layers may be chosen.



a) Un-insulated roof, U=1.89 W/m²K
2 cm tiling
3 cm gravel
0.5 cm waterproof membrane
5 cm screed
20 cm reinforced concrete roof slab



b) Insulated roof, U=1.46 W/m²K
2 cm tiling
3 cm gravel
0.5 cm waterproof membrane
5 cm extruded polystyrene thermal insulation
0.5 cm damp proof membrane
5 cm screed
20 cm reinforced concrete roof slab

Figure 27: A flat concrete roof without (a) and with (b) insulation on top of the concrete. The effect of adding insulation and a damp proof membrane on the U-value is dramatic and heating and/or cooling load is reduced strongly
Source: CBSE

(a) For flat roofs, often-concrete roof slabs, exterior insulation as shown in Figure 28 is common: by adding insulation material (together with a damp proof membrane under it), the U-value is reduced strongly[5].

The energy consumption of, or even the need for, air-conditioning or room heating is reduced accordingly. Some roof insulation materials on the market include a hard plastic top layer that can be directly walked on, reducing the need for an additional top.

Figure 28: Flat roof insulation with the damp proof layer visible
Source: Recticel

[5] Information on the calculation of U- and R-values is given in the Thermal Standard for Buildings in Lebanon 2005, section 6.1.

Insulating flat roofs from the inside is not recommended because it might lead to serious condensation problems; if wood is used in the roof construction, the wood may rot.

(b) Pitched roofs can be a sloped concrete slab or a steel or wood structure with roof tiles. Such roofs can be insulated from the outside (for instance directly under the roof tiles), or from the inside. When insulating from the inside, it is advisable to create a small air gap between the insulation and the damp open roof structure that enables some ventilation. Use a damp proof layer on the inside of the insulation to prevent condensation problems. As a good alternative, the floor of the attic itself can be insulated if the attic is not used.

Figure 29: Insulation of a pitched roof can be done with foam or woolly materials, but also using several layers of heat reflecting foils, separated by air gapsRecticel
Source: Tonzon

3. Expected benefits

(a) Energy

Depending on the roof area, its construction and which insulation is added, this will achieve a considerable energy savings for heating as well as cooling. These are estimated below in Table 13.

(b) Economy

Depending on the roof construction and insulation method chosen, roof insulation is a very economically favorable energy retrofit option. In hot regions, well-insulated buildings have a lower cooling load due to the reduced heat transfer from outside to inside. In areas with cold seasons, badly insulated roofs can be responsible for more than 30 per cent of total building heat losses. Pay back times are building and location specific, but an indication is given in Table 13.

Table 13: Indication of average energy savings and simple pay back times for roof insulation

Roof Insulation	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	500 -800	300 - 400	400 - 600	100 - 200
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	30 - 40	100 - 140	140 - 220	200 - 300
Simple Pay Back Time (years)	> 9	> 6	4 - 18	4 - 16

(c) Other benefits

Roof insulation reduces the use of air-conditioning which also reduces the noise and other discomfort that may be associated with air-conditioning. Another way to insulate a roof is by turning it into a green roof or roof garden. This is recommended if possible, because it can create a pleasant cooling effect on an adjoining terrace (see Figure 30). The thickness of the soil layer can range from 15 to 25 cm and determines which plants can grow on the roof. Make sure that the weight can be carried, the roof remains watertight, geotextile is applied, maintenance can be performed, and the vegetation is well irrigated.

Figure 30: A green roof will work as a cooling element
Source: GreenfieldCities

4. Recommendations

(a) Concepts and design definition

Always apply a damp proof membrane under / inside the insulation layer (apart from the waterproof layer on top). This is important to avoid possible severe problems due to accumulation of condensation. Check beforehand if there is already a damp proof or watertight plastic layer under / in the roof construction. If the insulation layer is to be placed inside that layer, make sure to prevent condensation problems, using for instance a special 'climate foil' or moisture regulating foil, which regulates the moisture of the insulation layer.

(b) Practical Considerations

- **i.** In apartment buildings, the top floor apartments will have the greatest benefits.
- **ii.** The insulation materials should last as long as the building's lifetime (up to 50 years), especially when applied in places where they are hard to reach.
- **iii.** Exterior insulation needs to be correctly sealed at all junctures to avoid leakages. Thermal bridges must also be avoided (see the separate Guidance Sheet). Equipment on the roof such as water tanks, chillers, SWHs, etc. should be taken into consideration as they can make insulation measures harder to implement.
- **iv.** Depending on the products used, exterior insulation may increase roof maintenance.
- **v.** Simply making sure a roof has a light color by for instance painting it, reduces overheating because the sun's rays will be reflected. This will also contribute to reducing the 'heat island' effect within cities.
- **vi.** Shading of roofs can further reduce heat load.
- **vii.** When considering roof insulation for a renovation, be aware that the building may lose ventilation openings.

G. Avoiding thermal bridges

In well-insulated buildings, thermal bridges can spoil the insulation effect, so they need to be taken care of. Sometimes the remedy is easy, more often it requires expertise.

Table 14: Avoiding thermal bridges application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Specialist

1. Introduction to the intervention

Thermal bridges are parts of a well-insulated building where the insulation layer is interrupted, for instance at floor-wall connections, lintels (the beams above windows), windowsills, vertical columns inside walls, or installation piping conduits. Thermal bridges can reduce the effectiveness of insulation by over 30 per cent and may cause other problems like condensation and mold.

2. Intervention features and applicability

(a) Features

The problem of a thermal bridge is that it interrupts the insulation layer, which creates a higher heat transfer at the connection of different building elements such as floor-wall and window-wall connections (see Figure 31). In poorly insulated buildings, thermal bridges will represent low losses (usually below 20 per cent) compared to the total energy losses through the building envelope. However, in humid and cold areas, thermal bridges may cause condensation during winter and associated mold problems. In well-insulated buildings, the percentage of losses due to thermal bridges becomes high (more than 30 per cent), compared to the losses through the envelope. Therefore, in energy efficient buildings, thermal bridges need to be avoided. Like in many MENA countries, a common construction method in Lebanon is the reinforced concrete structure (columns, beams, and floor slabs), filled in with block work, hollow CMU's (concrete masonry units) or hourdis, thus thermal bridges are very common. Thermal bridges can be found by carefully checking the construction of the building and the (existing or planned) insulation. Another method is by using infrared photography (see Figure 34).

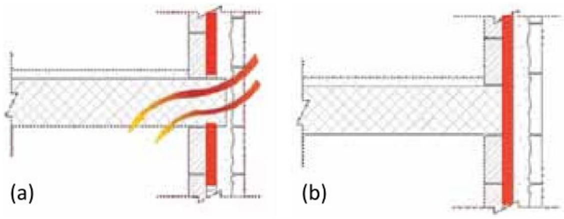


Figure 31: A thermal bridge, here in a floor-wall connection, can cause considerable heat or cold loss and reduce the effectiveness of wall and roof insulation (a). Closing the insulating layer removes the thermal bridge (b)
Source: CBSE

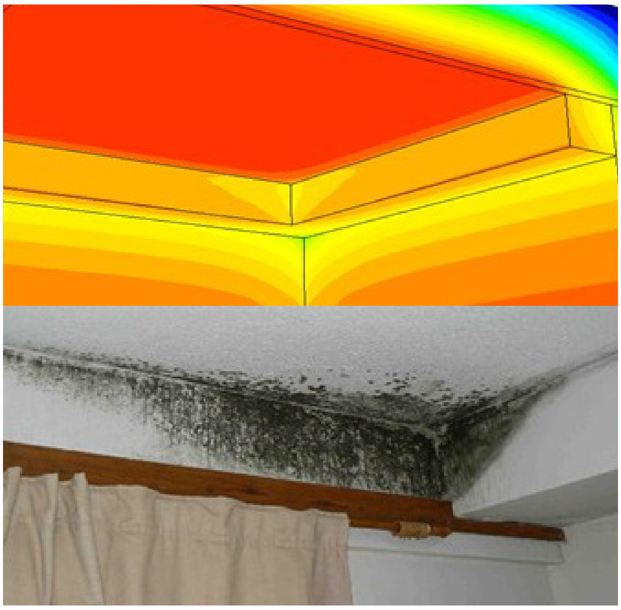


Figure 32: Thermal bridges may be the cause of mold problems
Source: BRE

(b) Applicability

Avoiding thermal bridges depends on the actual construction of the building and on the type of insulation used.

When renovating a building with interior insulation or with insulation between two construction layers, the solution for the thermal bridge is complicated, as the adjoining building parts (for instance the floor and wall) need to be insulated up to around 60 cm from the thermal bridges.

When exterior insulation is used, trying to make the insulation continuous is a good and simple solution to solve thermal bridges at the wall–floor connection. A complication is balcony elements extending through walls. In that case, the can be broken by insulation elements, balcony can be insulated (see Figure 35). In some cases, shown in red here special insulation elements that can handle physical load can Source: Foamglas be used between construction elements to break thermal bridges (see Figure 33).

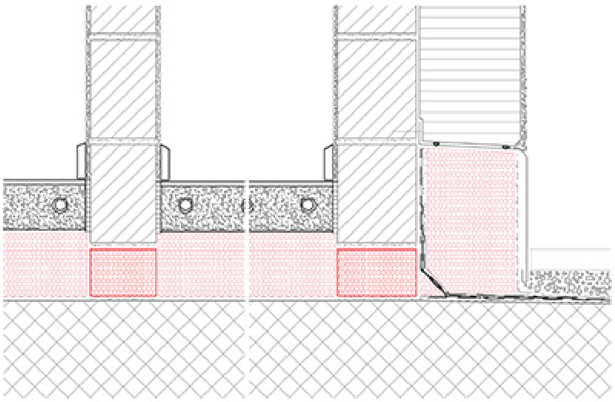


Figure 33: Thermal bridges in constructions can be broken by insulation elements, shown in red here
Source: Foamglas

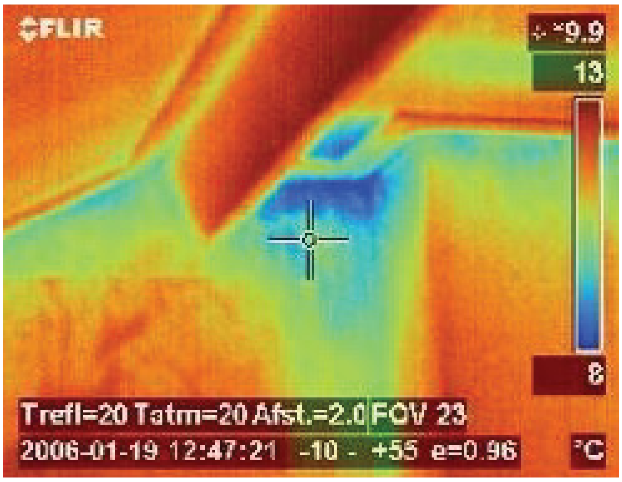


Figure 34: A thermal bridge causing mold near the connection to a balcony (below) is clearly visible in infrared imaging (above)
Source: LBP|Sight

3. Expected benefits

(a) Energy

In extreme cases, thermal bridges could increase the heat loss through walls and roofs by 30 per cent. Removing them could lead to reduction of energy consumption for heating and cooling by up to an estimated 200-300 kWh per year.

(b) Economy

Remedying thermal bridges specific to the building and the insulation measures taken, and the costs may be high. Especially in more ambitious low-energy or zero-energy buildings, thermal bridges could strongly decrease the effectiveness of insulation and should be reduced. In the table, global estimates for savings and economy are given.

Table 15: Indication of average energy savings and simple pay back times for avoiding thermal-bridges

Avoiding Thermal Bridges	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	110 - 200	100 - 100	100 - 200	0 - 100
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	10 - 20	20 - 50	40 - 70	50 - 100
Simple Pay Back Time (years)	> 14	> 9	> 6	> 6

(c) Other benefits

In colder, humid areas, removing thermal bridges can prevent severe problems such as condensation and mold formation.

4. Recommendations

(a) Concepts and design definition

Identifying and remedying thermal bridges, especially in existing buildings, is specialist work. The figures in this guideline sheet show that advanced technologies such as thermal imaging and computational methods are used regularly. Thermal bridges should be part of any ambitious energy efficient building construction or renovation project.

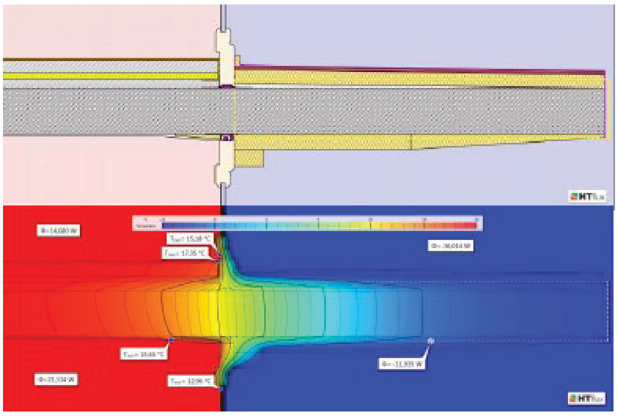


Figure 35: A floor element extending into a balcony can become a major thermal bridge. This can be avoided by insulating the balcony (yellow) as shown by model calculations
Source: HTflux

(b) Practical considerations

In Lebanon, the following LIBNOR standards support avoiding thermal bridges and give engineers guidelines on how to assess them:

i. NL 10211 Thermal bridges in building construction - Heat flows and surface temperatures - Part 1: General calculation methods NO 2006.

ii. NL 14782 Thermal bridges in building construction - Linear thermal transmittance - Simplified methods and default values NO 2005.

iii. Capacity building actions are strongly needed for penetration of these measures: improvement of building codes, establishment of a system of building inspectors to check building insulation levels including thermal bridges.

H. Heat Pumps

Together with insulation and ventilation measures, heat pumps are part of the recipe for advanced energy efficient renovation. In a building with adequate heat pumps, (either central heat pump installations or pre- installed good quality split units), occupants will not need to mount their own split units or electric heaters and much energy and costs can be saved.

Table 16: Avoiding thermal bridges application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Advanced

1. Introduction to the intervention

Heat pumps are well known in the form of domestic refrigerators and air-conditioning units. They can also be a valuable part of an energy efficient heating and cooling system, and domestic hot water production, for residential buildings. Experts see heat pumps as the future lead technology for the use of renewable energy and energy efficiency in buildings and for the improvement of the urban environment. Heat pumps redistribute heat from the air, ground, or water and use a refrigerant to transfer the heat. In cooling mode, a heat pump absorbs thermal energy - heat - inside a building and releases it outdoors. In heating mode, the heat pump absorbs heat from the ground or outside air (even cold air) and releases it indoors. Most heat pumps are powered by electricity and transfer heat using refrigerant, but there are also absorption heat pumps that are driven by heat, for instance from solar heat collectors.

2. Intervention features and applicability

(a) Features

Heat pumps can be used for space heating, domestic hot water production, and air-conditioning systems, all by themselves or in hybrid systems with other heating devices (e.g., electrical heaters, gas boilers). They can use air, surface water[6], ground water[7] or the ground as their source of heat or cold, and they can deliver their heat or cold directly to the air of a room or to a water circulation system in a large installation. They are often classified accordingly, for instance an air-to-water heat pump takes its heat or cold from outside air and delivers it to a water circuit/tank for distribution into the building.

(i) Compression heat pumps

Most heat pumps use a vapor compression cycle and are therefore called compression heat pumps. An electric compressor usually drives them and their energy consumption consists of the electricity consumption of that compressor. A well-designed and well-installed heat pump can 'pump' about 3 to 4 times more heat into or out of a building than the amount of electricity it uses. This ratio is called the Coefficient of Performance (COP).

[6] The surface water may be a sufficiently large river or lake or even the sea. Deep seawater is colder than surface seawater and is used in several Seawater Air-conditioning projects.

[7] Ground water heat pumps can be 'closed systems' using heat exchangers or 'open systems' with wells, for instance Aquifer Thermal Energy Storage. Especially open systems require careful engineering and installation to prevent problems with clogging of wells and/or contamination of ground water. Ground water regulations are very strict in Lebanon, making it hard to obtain the necessary permits.

(ii) Coefficient of performance

Compression heat pumps are used in the well known 'split units' but also in large central installations for complete buildings or even complete urban districts. A drawback of electric heat pumps is that their electricity consumption is quite significant and tends to occur during moments of peak load on the electric grid; in hot areas, air conditioners tend to contribute to peak electricity demands on hot days, aggravating blackouts and other associated problems. On the other side, this creates an opportunity for sustainable renovation projects: solar panels have their maximum output at roughly the same moment that air-conditioning units have their maximum demand.

(iii) Absorption heat pumps

Heat pumps can also employ an absorption cycle to produce heat or cold. As the absorption cycle is driven by heat, absorption heat pumps are driven by heat sources: natural gas burners (gas-fired heat pumps) or sustainable heat sources such as solar heat collectors, industrial waste heat or geothermal-heated water (geothermal heat pumps). Absorption heat pumps have a COP in the range of 0.6 to about 2, depending on the temperature levels and technology used. That COP is lower than for compression heat pumps, but the technology may be attractive especially in situations where suitable waste heat is available.

Figure 36: A typical 'split unit' air-conditioning / heating unit for a single room (the efficiency of these units varies strongly; energy efficient buildings use efficient products with for instance good energy labels)

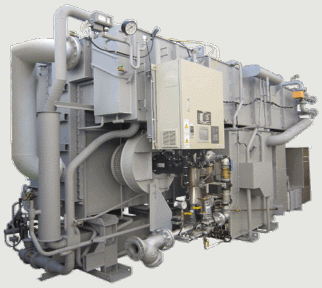


Figure 37: A large absorption heat pump (cooling capacity 422 kW)
Source: Hitachi

(b) Applicability

One can use heat pumps to cool and heat residential buildings and/or to deliver domestic hot water.

1. Introduction to the intervention

(a) Energy

As said above, a good compression heat pump has a COP of about 3-4, which means it is 3-4 times more energy efficient for heating than a resistance electrical heater. This is achieved because the heat pump transfers heat, 'free energy' from outside into the building. If however the electricity grid powers a heat pump, its overall sustainability (CO_2 emission per unit of heat delivered) for heating a building is not much higher than that of good gas or oil heaters, because the electricity is currently produced from fossil fuels (oil) with significant energy losses. Under comparable circumstances, the COP for cooling of a heat pump is equal to the COP for heating minus 1, because the energy used in the heat pump is added to the heat output, not the cold output.

(b) Economy

The economic effects of applying heat pumps may vary widely, depending on the building (insulation, shading, demand for heating, cooling, hot water), the existing installations (type, age, efficiency) and the need for additional comfort. The table below gives very indicative numbers for replacing existing individual split units in an apartment building by a central heat pump for heating and cooling.

Table 17: Indication of average energy savings and simple pay back times for heat pumps

Heat Pumps	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	700 - 900	500 - 700	800 - 900	500 - 500
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	90 - 100	320 - 360	470 - 550	670 - 770
Simple Pay Back Time (years)	> 8	4 - 14	3 - 9	2 - 7

(c) Other benefits

In apartment buildings in warm climates, installing central or good quality decentral heat pumps may have the important benefit that dwellers will not have to install their own air conditioner systems, with often low efficiency and a scattering of brands, even while efficient models are available (see Figure 38). A well-designed, well-installed heat pump system will produce no noise or other uncomfortable effects.

Figure 38: Split unit sprawl is a bad sight and often a waste of energy and money
Source: GreenfieldCities

4. Recommendations

(a) Concepts and design definition

If an energy efficient renovation project involves heat pumps, it should follow the rational Trias Energetica approach. This means in the context of heat pumps:

i. First, reduce the heating and cooling demand with shading, insulation, energy efficient glazing and/or air tightening (see separate guideline sheets), so that the heat pump(s) can be smaller and use less energy - both of which also save money.

ii. Second, prioritize using sustainable electricity or heat (f.i. from solar panels or waste heat) to provide for the energy consumption of the heat pumps and other functions.

iii. Third, use grid, or diesel power efficiently (high COP installations) to fulfil the remaining energy demand for the heat pump.

(b) Practical considerations

If not applied correctly, or if used in poorly insulated buildings, heat pumps may cause excessive energy consumption instead of energy saving. Therefore, heat pump installations should be properly designed and installed, and the following precautions should be taken:

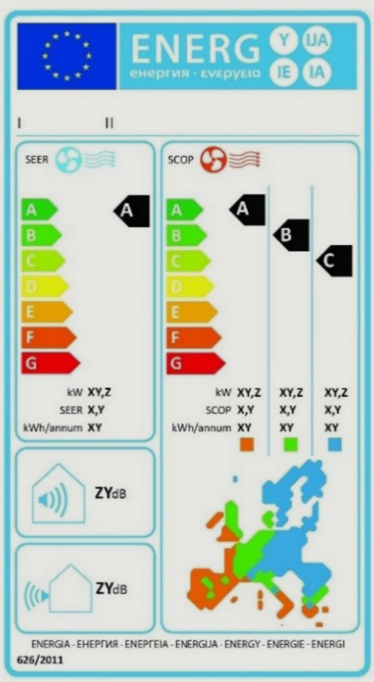


Figure 39: When considering standard air-conditioning units, find products with a green energy label.

i. Always consider 'passive' measures in combination with heat pumps. Shading, insulation, energy efficient glazing, ventilation and building thermal mass activation can greatly reduce the energy consumption for air-conditioning and heating.

ii. Ground water regulations are very strict in Lebanon; it's hard to obtain permits for ground water heat pumps.

iii. The compressor capacity should be designed properly and integration with other components such as auxiliaries and back-up systems should be designed and installed properly. It is recommended to comply with relevant LIBNOR standards, which provide minimum requirements for building air-conditioning equipment, including adoptions of NL EN 14511, NL EN 16147 and EN 14825 (under review)[8] as voluntary standards.

iv. For air source heat pumps, performance is best in mild climatic conditions. In extreme cold or heat conditions, water or ground source heat pumps will have better efficiency. In cold mountain areas, a defrosting function is needed when temperatures below seven °C occur, which can use a significant amount of energy.

v. Replacing electrical resistance heaters with reversible split units can save a lot of energy. Look for products that carry a 'green' energy label. In the absence of a suitable Lebanese energy label, energy labels from Europe or other areas are useful (see Figure 39). Note that the EC labeling system has been revised early 2021.

vi. Heat pumps need proper maintenance, especially periodic checking & refilling of coolant. When renovating buildings with heat pumps or air conditioners older than about 10 years, replacing them with new, more efficient ones will generally save large amounts of energy & money. When refilling refrigerant or replacing a heat pump, consider that refrigerants have a strong negative climate impact & make sure they are not released into the air. Section 1.3 of the Lebanese Installation guidelines provides more details.

vii. Even well-designed heat pumps will often have a high power capacity (amperage). This may limit application in situations with weak electricity supply connections.

viii. Heat pumps used for room heating require low-temperature radiators, floor heating or air coils. After insulating an existing poorly insulated building, existing heating radiators will operate at lower temperature, which may make them suitable to be fed by a heat pump.

[8] A full listing of relevant standards is available at LCEC.

I. Evaporative cooling

Water evaporation is an energy efficient way of cooling. Ranging from traditional measures to advanced multi-stage chillers, evaporative cooling is a green alternative to heat pumps.

Table 18: Evaporative cooling application

Saves on	Climate Zone	Building Type	Difficulty
Cooling	Mid Mountain, Inland plateau, and possibly in Coastal zone for pre-cooling of compressor coolers	All	Advanced/specialist

1. Introduction to the intervention

Evaporative cooling is based on the principle that evaporation of water requires energy. When a person steps out of a swimming pool into a breeze, their skin cools. The ancient Mediterranean civilizations used this principle by putting a wet cloth in front of doors or windows. The wind blowing through the cloth evaporates the water helping to keep the house cooler. Evaporative cooling is also used today in renovation projects.

2. Intervention features and applicability

(a) Features

Direct evaporative coolers are today's version of the aforementioned wet cloth. A fan passes outside air through a wet medium (paper or metal evaporator). The air evaporates some of the water and enters the home cooler and more humid. An interesting solution for hot and dry climates, but in humid climates like in the Lebanese coastal region, direct evaporative coolers are much less effective. The so-called wet bulb temperature limits the lowest temperature that direct evaporative coolers can reach. Figure 41 gives the relationship between outside temperature, relative humidity and output temperature of a high quality direct evaporative cooler. For instance, at a relative humidity of 30 per cent, air of 35 °C can be cooled down to 26 °C. In coastal Lebanon, the average relative humidity during summer is around 70 per cent and subsequently the evaporative cooling effect will be much less. During the hottest hours of the day the relative humidity is lower, for instance around 50 per cent. However, this is still not a favorable local climate for comfortable direct evaporative cooling.

INCOMING AIR TEMPERATURE	RELATIVE HUMIDITY																
	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%
24°C	12°C	13°C	14°C	14°C	15°C	16°C	17°C	17°C	18°C	18°C	19°C	19°C	20°C	21°C	21°C	22°C	22°C
27°C	14°C	14°C	16°C	17°C	17°C	18°C	19°C	19°C	20°C	21°C	22°C	22°C	23°C	23°C	24°C	24°C	25°C
29°C	16°C	17°C	17°C	18°C	19°C	20°C	21°C	21°C	22°C	23°C	23°C	24°C	24°C	25°C	26°C	27°C	
32°C	18°C	18°C	19°C	21°C	21°C	22°C	23°C	24°C	25°C	26°C	26°C	27°C	28°C	28°C	29°C	30°C	
35°C	19°C	20°C	21°C	22°C	23°C	24°C	26°C	26°C	27°C	28°C	29°C	29°C	30°C				
38°C	21°C	22°C	23°C	24°C	26°C	27°C	28°C	28°C	29°C	31°C	31°C						
41°C	22°C	23°C	25°C	26°C	27°C	29°C	30°C	31°C	32°C								
43°C	24°C	25°C	27°C	28°C	29°C	31°C	32°C	33°C									
46°C	26°C	27°C	28°C	30°C	32°C	33°C	34°C										
49°C	27°C	28°C	30°C	32°C	34°C	35°C											
52°C	28°C	30°C	32°C	34°C	36°C												

Figure 41: Outdoor temperature, relative humidity & indicative cooler output air temperature
Source: Dantherm

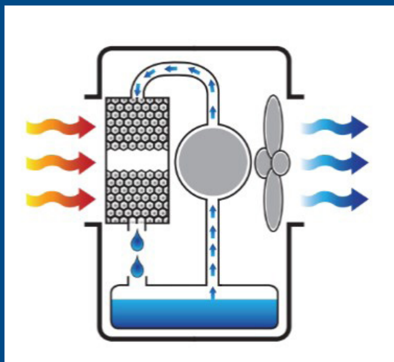


Figure 40: Direct evaporative cooling
Source: Dantherm

Equipment manufacturers developed several solutions that partly overcome these limitations. The first solution is called two-stage indirect/direct evaporative cooling. A first indirect cooling step uses water that is cooled using evaporative cooling and that is pumped through a heat exchanger to pre-cool the ambient air. Thus, the ambient air is pre-cooled without direct contact with water, and it reaches a lower dry bulb and wet bulb temperature. The pre-cooled air is then blown through a second, direct adiabatic cooling step. This cools the air even further through wet pads. As a result of this two-stage process, the air can be brought down to a lower temperature, while the increase in moisture is up to 60 per cent lower compared to a single stage direct evaporative cooler. A high-quality two-step indirect evaporative cooler might be able to deliver supply air of between 23-25 °C on a typical Beirut summer day with 32 °C outdoor temperature and a daytime RH of 50 per cent. Such systems will however still not perform sufficiently in coastal Lebanon during all days of the year.

A further step is to combine direct or indirect evaporative cooling with classical heat pumps or chillers. Such hybrid solutions feature much smaller sizing of the compressor chillers/heat pumps, leading to significant energy savings and a wide range of output temperature and humidity levels. Hybrid systems are available on the market, well tested and reliable.

Yet another option for unfavorable ambient conditions is by adding a desiccant cooling stage. Here, humid ambient air is first dried by passing it through channels covered with a desiccant material, e.g., in a slowly rotating desiccant wheel. Then, the dried air is pushed through the evaporative cooling stages. Such systems use a low temperature heat source (e.g. 60-100 °C) to regenerate the desiccant material, like solar thermal energy.

Desiccant wheels are regularly used in large HVAC installations in Europe. Solar assisted desiccant cooling is not widespread, but it is a major R&D subject with OEMs and research institutes; application is foreseen. A point of attention is contamination of the inlet air from the outlet air, which can be reduced by including a 'purge sector' in the rotating wheels.

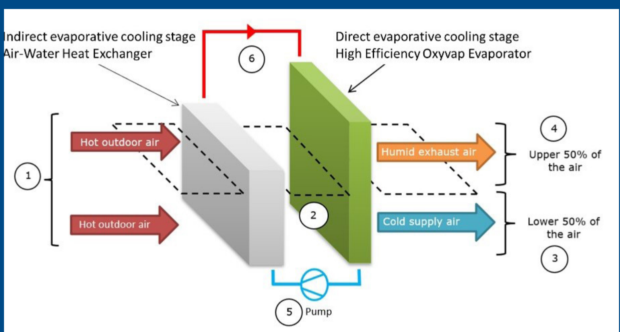


Figure 42: Two-step evaporative cooling
Source: Oxycom

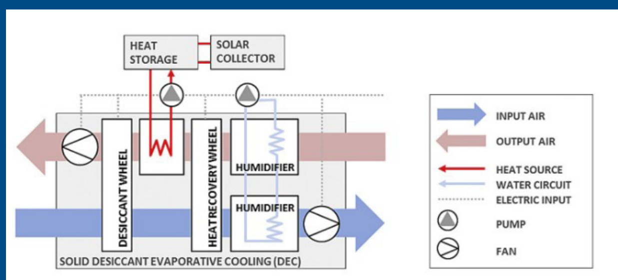


Figure 43: Solid desiccant evaporative cooling
Source: COOLFACADE

(b) Applicability

As a rule of thumb, direct evaporative cooling only makes sense when the relative humidity during the hot hours of the day is consistently below 30-40 per cent. This means that application in the Coastal zone and mid mountain areas under 600-800 meters altitude is not recommended. In Inland Plateau areas such as the Bekaa, direct evaporative cooling may be considered. Two-stage indirect/direct evaporative cooling may be considered in coastal areas, if carefully designed, although performance will be lower than that of conventional chillers. Two-stage indirect/direct evaporative cooling will perform well in the higher Mid Mountains and very well in the Inland Plateau. Hybrid chiller / evaporative cooling systems, if diligently designed, will perform in any climate zone with cooling demand. For single homes, small two-stage evaporative coolers are being developed, but they are not widely available yet. Stand-alone direct evaporative cooling units (desert coolers) are widely for sale, but are only recommended for the inland plateau climate, and maybe the dryer parts in the mid mountain climate. For large buildings with central chillers, existing compressor chillers can be equipped with evaporative pre-cooling and at the end of their technical life, replacing conventional chillers with two step evaporative systems (for mid mountain and Inland Plateau zones) or hybrid systems (for Coastal and Mid mountain zones) is an option.

Figure 44: Two-step evaporative cooling. Integrated central chiller and ventilation unit
Source: Oxycom

3. Expected benefits

(a) Energy

Energy savings compared with traditional compressor chillers are significant but depend widely on local natural climate conditions Figure 45 provides indicative cooling performance (the color indicates if the chosen solution is likely to deliver the desired comfort) and energy savings ranges (the percentages) in the different Lebanese climate zones for state-of-the-art evaporative cooling solutions.

	Lebanese Climate Zone			
	Coastal	Mid Mountain	Inland Plateau	High Mountain
Standalone evaporative cooler	Not Recom.	Not Recom.	>90%	No AC Needed
Pre-cooling, Evap. cooling retrofit added to existing chiller	10-20%	10-30%	20-40%	No AC Needed
2 step indirect/direct evaporative cooler	70-90%	70-90%	80-90%	No AC Needed
2 step indirect/direct evaporative cooler + small HP (hybrid)	60-80%	60-80%	60-80%	No AC Needed

insufficient performance | could perform sufficiently | performs at par with traditional chillers

Figure 45: indicative energy savings (percentages) and performance (colors) of evaporative cooling compared with traditional compression cooling
Source: GreenfieldCities

(b) Economy

In the Inland Plateau climate zone, a standalone evaporative cooler combined with shading measures can be a cost effective, energy efficient and comfortable option. In the coastal, mid mountain and inland areas, upgrading existing central chillers with evaporative precooling is likely to be cost effective as well. Replacing older existing central chillers with new two-step evaporative (and hybrid) systems for all climate zones except the high mountains could also be financially attractive but should be calculated on a case-by-case basis. At comparable investment costs with conventional chillers, operational costs can be up to 80-90 per cent lower.

Table 19: Indication of average energy savings and simple pay back times for evaporative pre-cooling

Heat Pumps	Coastal	Western Mid Mountain	Inland Plateau	High Mountain
Electricity savings (kWh/year)	200 - 400	100 - 200	200 - 400	-
Diesel/gas/biomass savings ($L_{oil\ eq}$/year)	-	-	-	-
Simple Pay Back Time (years)	> 7	> 10	> 6	-

(c) Other benefits

The two-stage indirect evaporative coolers and the hybrid solutions have additional benefits. Firstly, they secure a constant flow of outdoor air. This improves indoor climate and – in education and work environments – labor productivity. A second advantage is that they can be used for heat recovery ventilation and hybrid systems for heating in winter. Such aspects become important when building upgrades reduce natural ventilation and unwanted draft.

4. Recommendations

(a) Concepts and design definition

For architects and engineers that are up to an HVAC challenge for an existing building, it could make sense to consider including a pre-cool or hybrid solution. This is a technical and economical no-regret route that can help to become more familiar with the pros and cons of evaporative cooling.

(b) Practical considerations

i. Applicability in single homes is still limited due to limited availability of products beyond standard direct evaporative coolers. This may change in the coming years.

ii. It is advised to choose first projects wisely. Do not start in the most difficult climate zone, or if you do, pick a hybrid solution including a smaller sized heat pump. Capacity building is needed to roll out this technology as well as research to further verify the above options in the coastal climate zone.

iii. Evaporative coolers use significant quantities of fresh water. For a single home, this may add 10-15 per cent to the current water consumption. Rainwater collection may be an option to compensate for this.

V. Short descriptions of other possible measures

Besides the measures discussed in the guideline sheets, there are other options that can contribute to a more sustainable and energy efficient (residential) built environment in Lebanon. These include:

A LED Lighting/Smart Lighting
B Efficient Split Units
C Solar Water Heaters
D Solar Power (PV)
E Traditional Architecture
F District Cooling Network / SWAC
G Batteries in Buildings
H PCM Heat / Cold Storage
I Aquifer / Ground Water Heating / Cooling

These measures are briefly described in this chapter

A. LED lighting/smart lighting

LED lighting is already common in Lebanon, but people still buy the less expensive incandescent and fluorescent lamps. However, the LED industry is still developing fast. Lumen per Watt efficacies still improve[9] , competition drives down costs and more intelligence is added to LED lighting products[10].

Table 20: LED lighting/ smart lighting application

Saves on	Climate Zone	Building Type	Difficulty
Electricity	All	All	Relatively easy

It is important to keep reminding consumers that LED lighting is the best option, both from an energy as well as from a rational economic consumer point of view. LED is already 10 times more energy efficient than incandescent lamps and almost twice as efficient as CFL's. The pay-back time for Lebanese consumers for LED lamps versus incandescent are in the order of a few months and between 1-2 years for LED versus CFL. LED's have become affordable for everybody; an increasing number of countries are banning the sales of incandescent lamps altogether.

[9] UN Environment – Global Environment Facility | United for Efficiency (U4E), "Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING," U4E POLICY GUIDE SERIES, 2017.
[10] Lighting Europe Secretariat, "Strategic Roadmap 2025 of the European Lighting Industry," 2016.

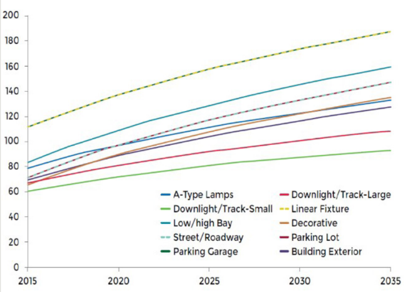


Figure 46: LED lighting efficacies [Lm/W] still improve
Source: EU Lucia 2019

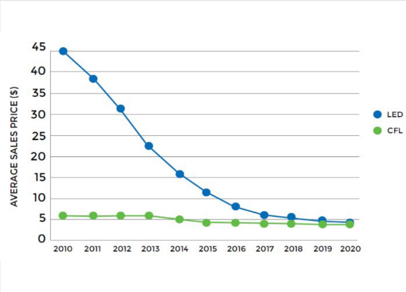


Figure 47: LED prices have dropped. Example for replacing a 60 Watt incandescent by LED or CFL
Source: U_4E

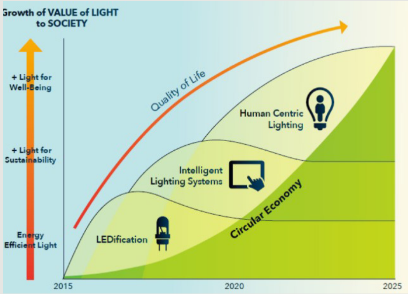


Figure 48: More LED penetration means developing a smarter and more efficient built environment Source: Lighting Europe Secretariat

B. Efficient split units

Air conditioners (A/Cs) alone could account for up to 40 per cent of the world's remaining global carbon budget by 2050 and the increasing numbers of split units have a large impact on these numbers. Split units are actually air source heat pumps. They are popular as they can be installed easily without a lot of ductwork and they can be used both for heating and cooling.

Table 21: Efficient split units application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Relatively easy

Split unit technology has improved considerably over the years. The almost four thousand available domestic air source heat pump systems on the 2021 Energy Star list have an average cooling COP of 6.1. The electricity consumption of a poorly performing product can be 50 per cent higher than that of an efficient unit. Moreover, performance of split units differs in different climatic zones. Some units perform optimally in very hot conditions and some are optimized for moderate climate zones. The EU has increasingly stringent labeling systems and minimum energy performance standards under the Eco-design Program (incl. GWP of refrigerants).

Introducing minimum energy performances standards and an A/C energy labeling system specifically for Lebanon would make Lebanon a front-runner in the MENA region in this field. Together with an ongoing communication campaign, consumers can choose more efficient split units.

A joint Lebanese-EU labeling project (e.g., with EU DG-NEAR) could consist of adopting the EU system for Lebanese climate conditions, including a number of years of manufacturing compliance support from the EU. This could be a steppingstone for rolling out such a system throughout the whole MENA region as an LCEC coordinated initiative with the objective to regulate the requirement for optimum efficiency of equipment.

Figure 49: Principle of a split unit
Source: Energy Star

C. Solar water heaters

Solar Water Heaters (SWHs) are already a success story in Lebanon. Reduced financial support has reduced new installations numbers recently, but there is a strong supply chain in place that still has momentum. SWH is increasingly cost effective and when retail electricity prices increase, the SWH market will most likely bounce back as well.

Table 22: Solar water heaters application

Saves on	Climate Zone	Building Type	Difficulty
Water heating	All	Individual houses, apartment buildings	Relatively easy

Apart from the currently dominant standalone SWH systems, it may be interesting to support developing the market for more integrated systems such as SWH-Heat Pump hybrid systems.

Panels that integrate PV electricity generation with production of warm water in a single device (so called PV-T panels), combined with efficient water-to-water heat pumps are another innovative development. Such systems deliver water at lower temperatures than standalone SWH's, but they gather low temperature heat for the heat pump also when there is no sun or even at night (in the case of The Triple Solar example until minus 7 °C outside temperature). In this way, they significantly increase the CoP of the heat pump. Such systems are especially interesting when roof space is at a premium. International market availability of PVT systems is still limited, and market penetration requires installers that master system integration of various innovative components.

Finally, larger systems for feeding into a small district-heating network may be an alternative in higher Mid Mountain and Inland Plateau areas. Such projects already successfully compete with natural gas heating in Denmark and are now finding their way into other parts of the EU. They normally include central heat pumps and large seasonal underground storage facilities.

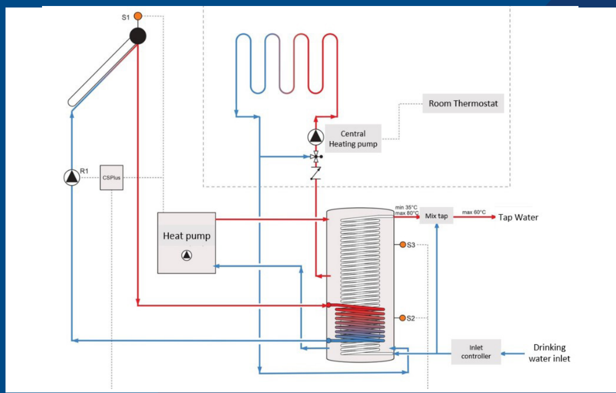


Figure 50: Example of SWH-Heat Pump integration
Source: TechniQ Energy

Figure 51: SWH system in Lebanese military academy
Source: LCEC

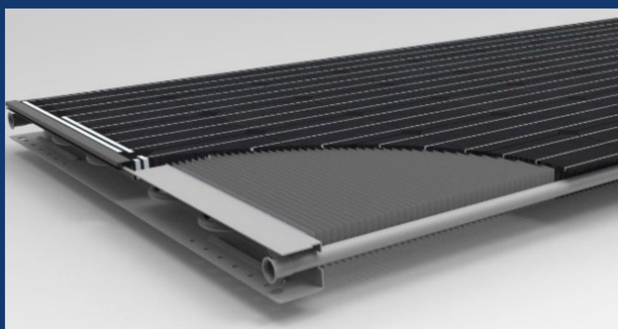


Figure 52: PVT solution
Source: Triple Solar

D. Solar Photovoltaic (PV)

Table 23: Solar Photovoltaic application

Saves on	Climate Zone	Building Type	Difficulty
Electricity	All	All	Relatively easy

Net metering is a driver for the Lebanese residential PV market. This kind of systems has been very successful in different countries. Continued success is depending on a number of factors:

1. Reasonable payback times require retail electricity prices not be too low. PV system prices have come down over the past 5 years. Lebanon does not have web sites where consumers can compare system prices yet. However, since the PV system components are global commodities, using International benchmarks probably has some referencing value for Lebanese prices as well. In the 2021 Dutch market, a small domestic grid connected system can cost well below $1.30/W_p$, including 21 per cent VAT[11]. In Lebanon, the price range for grid connected PV projects acceptable under the NEEREA loan is between $0.99 and 1.28/W_p$. At a system price of $1.28/$W_p$, 1,600 kWh/kW$_p$/yr of production, and a net metering price of $0.16/kWh[12], payback times would be around 5 years.

2. Low soft cost & little hassle. Consumers like easy processes. Net metering (like existing in Lebanon) has been known to be much less successful in countries where soft barriers like construction permits, fire permits, and stamped engineering plans are required for small systems. The advice is to remove such barriers as much as possible. Have trust in certified electrical engineers, the electrical regulatory framework and private citizens' common sense. Things can go wrong with PV, but generally, systems are very safe and easy to install. EDL can keep track of things relevant to them through their metering program.

3. An improving power sector. In order for the consumers to benefit the most of the net metering scheme, the electricity system uptime should see an improvement, as every time the system goes down (especially during sunny summer days), consumers lose not only power, but also money. Installing a PV system with a hybrid inverter, 4-6 hours of storage (for essential loads) and an automatic transfer switch, can reduce generator cost and provide peace of mind. Within NEEREA, such hybrid systems may cost between $2.96 and $3.82 /W$_p$. Payback times are longer compared to simple grid connected systems but could still be within 8-10 years. International prices for hybrid systems are dropping, as net metering is gradually made less attractive in several large international PV markets (making storage more attractive in those markets). Lebanon could benefit from this development for building a more resilient and sustainable electricity system.

Figure 53: A hybrid on/off grid PV system in Baabdat
Source: IBC Solar

Figure 54: Hybrid on/off grid Source: Victron Energy
Source: Victron Energy

[11] Source: Stralendgroen.nl: module $0.4/W$_p$, Grid inverter, $0.23/W$_p$, roof mount $0.20/W$_p$, Cabling and Switches $0.10/W$_p$, Installing and connecting $0.3/W$_p$)
[12] This effective (realistic) price point is explained and estimated in Annex.

E. Traditional architecture (principles)

Table 24: Traditional architecture application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	Individual houses, apartment buildings	Specialist

Lebanon is a melting pot of cultures and climatic zones. It would be shortsighted to just look at one form of traditional architecture. Many passive building traditions go back to Roman and Persian eras. Many traditional architecture solutions are based on careful planning in the fields of natural lighting, control, ventilation, insulation and thermal mass.

When designing a new building, including passive and traditionally inspired elements is relatively easy. However, when retrofitting an existing building, the practical options may be more limited, especially if the owner does not want a complete overhaul. Some easy to implement, low costs retrofit options that can really have broader combined impact in urban areas are, adding shading, improving reflective properties of surfaces, and adding green (plants) to streets, roofs and facades.

Figure 55: Example of a Roman impluvium evaporator
Source: Anca Scaesteanu et al

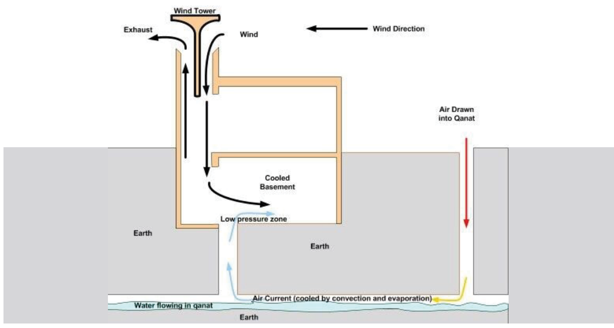


Figure 56: Schedule of a Persian qanat and wind tower cooled home
Source: Kambiz Rakhshan

Figure 58: Advantages of greening cities
Source: Wageningen University and research

Figure 57: White roofs are on average 30 °C cooler than dark colored roofs in summer
Source: White Roofs Project

F. District Cooling Network / SWAC

Table 25: District cooling network application

Saves on	Climate Zone	Building Type	Difficulty
Cooling	Coastal	Apartment buildings, high-rise	Specialist

District cooling is an interesting option in densely built areas with a large demand for cooling. Very efficient central chillers feed a cold-water network and this cold water is distributed to buildings where it is used for cooling. Such systems can save up to 50 per cent on electrical energy, as large cooling installations are more efficient than individual A/Cs per building or apartment. Moreover, operational costs are lower than decentralized solutions. District cooling systems can be complex to develop, as many stakeholders are involved that need to commit for longer periods. In addition, the regulatory implications for making use of seawater for extracting or discarding energy, needs to be clear.

A special form of district cooling is Seawater Air-conditioning (SWAC). It's a form of free cooling that can only be applied when deep and cool seawater is available near the coast. This is the case near Beirut & other coastal locations.

SWAC can reach energy savings of 70-90 per cent compared to conventional air-conditioning. Clients of such systems can save 30 per cent or more on cooling costs and the cooling system becomes less dependent from grid electricity. The Beirut Zaitunay Bay area could be an area to explore the feasibility of a SWAC project for hotels, offices, and residential buildings. Experience states that SWAC projects need a number of – opinion leading – committed private sector lead clients and developers with deep pockets. Such parties could be present in this area.

What could convince investors is that SWAC is a proven technology & that the returns for investors in such projects are typically good, while still leaving on the table 30 per cent cost savings for clients that make use of the SWAC system. Additionally, Carbon Financing or other concessional financing may be interesting to explore while considering large-scale projects like SWAC.

In Lebanon, the authorities own all the seacoast & beaches. It will take significant efforts by developers to lease (permitted) access to sea, to manmade ponds and lakes.

Figure 59: Zaitunay Bay District

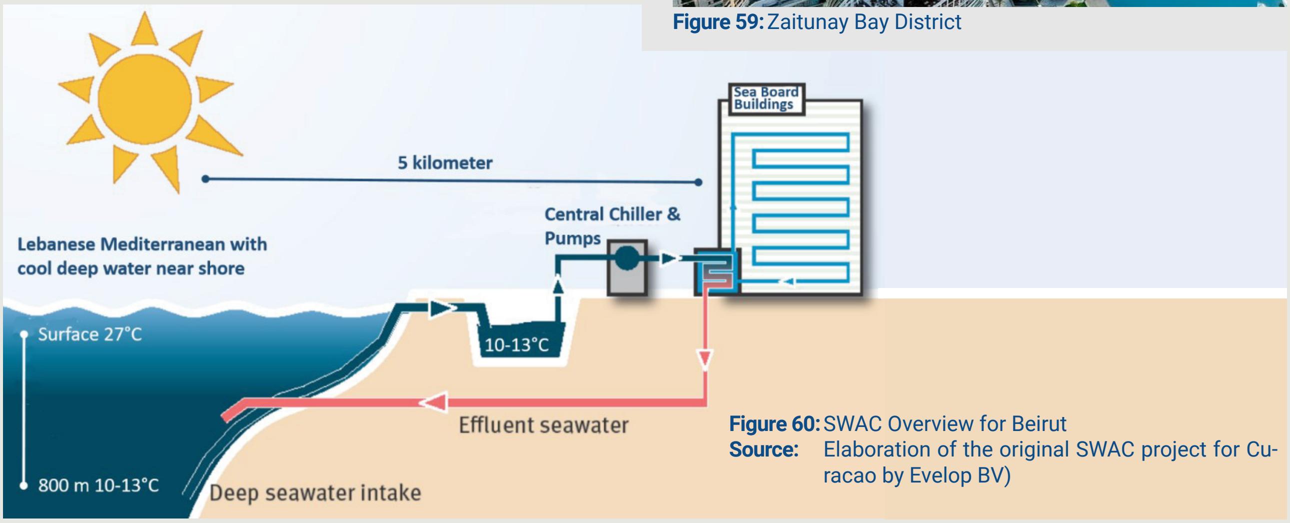


Figure 60: SWAC Overview for Beirut
Source: Elaboration of the original SWAC project for Curacao by Evelop BV)

G. Batteries in buildings

Table 26: Batteries in buildings application

Saves on	Climate Zone	Building Type	Difficulty
Electricity/ Outage costs	All	All	Medium - Advanced

Battery energy storage in buildings in grid-connected areas was long deemed not to be feasible. Until recently, the degradation and charge/discharge losses alone would account for $ 0.20 or more per kWh using battery storage[13]. Several recent developments are improving the technology towards large-scale applicability in buildings:

1. Battery technology and power electronics learning curves

Only 8 years ago, a lithium battery would cost over $600/kWh of storage capacity providing 600 full cycles, a ratio of $1/cycled kWh. In 2020, OEM battery costs were said to be around $125/kWh[14] with 2,000 cycles of life, a ratio of $0.063 per cycled kWh. These are not consumer prices yet, but the learning curve of batteries is impressive. Add to this that the same holds for power electronics and automatic transfer switches. Today, a consumer can buy a complete storage kit with 2 kWh of storage and 2 kW peak output, including an automatic transfer switch for less than $2,000. In 5 years from now, that price is likely to drop further. Such a system can run all essential appliances and lights for at least 24 hours in family home (excluding Air-conditioning). Many OEM's will start selling such solutions over the next years, so competition and awareness are likely to increase.

2. Very low costs for abundant, intermittent renewable energy

Producing residential electricity using PV in Lebanon can be done at a cost price of $0.07/kWh or less. Of course, there is a net metering system in place, but that may not be around forever as the PV share in the mix grows. Fortunately, even when cycling a part of home system production through a battery would

Figure 61: RiSE Solar project in Lebanon

mean adding 10 cents per kWh to the costs per kWh, that is still much less than the (approximately 30 cents) costs per kWh using a small diesel generator.

3. Efforts to reform the electricity system

There are efforts to fix the Lebanese power system. However, like everywhere in the world, also in Lebanon, changing institutions is hard to do. The previous two bullet points could be the foundation of a bottom-up vision on rebuilding the electricity system. Residential and SME PV systems, neighborhood batteries, home batteries and in the future, bi-directional EVs could together decrease stress on the electricity system. Initially, such home and neighborhood systems will be standing alone, but gradually tying them more into the central system could be a game changer. Companies and research institutes worldwide work hard on solutions for recycling of batteries, but presently only about 5 per cent of used batteries are recycled. Despite these major efforts, full recycling of batteries – a prerequisite for sustainability – is still years away.

[13] Derived from BloombergNEF, assuming 600 full cycles of lifetime in 2013 and 1,500 in 2020.
[14] DNV analysis of the Battery Day event in September 2020

H. PCM heat / cold storage

Table 27: PCM/Cold storage application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	All	All	Specialist

Phase Change Materials (PCMs) are chemical compounds with a specifically chosen melting / freezing point. They can be applied in building materials and storage vessels to increase thermal storage capacity / thermal mass. The principle is that changing the state of the material from solid to liquid and vice versa involves a lot of energy. An example is that it takes as much energy to melt a kg of ice as it takes to heat a kg of water from 0 °C to 80 °C. In fact, there are projects that commercially use ice as cold storage, where air conditioners freeze ice during the night, which can shift up to 95 per cent of their electricity consumption to off-peak hours.

Imagine that 300 kg of PCMs with melting point of 25.5 °C is added to a Beirut apartment in the ceiling, floor, and wall panels. This would compare to adding 6,000 kg of concrete to the building mass. The PCMs would prevent temperatures in the apartment from rising above 25.5 °C for much longer as the heat gain is partially absorbed by the melting material. During the night, the opposite would take place. It takes the apartment much longer to cool down below 25.5 °C and if the nighttime temperature does not drop below 25.5 °C or the apartment is not strongly ventilated at night, the PCMs will not “recharge” for the next hot day. On very hot nights, this effect could be partly resolved by running the A/C at night when it has a higher COP than during the day. Similarly, in areas with colder winter climates, that still have solar heat gain opportunities during the day (like in the Bekaa[15] for example), PCMs (e.g., with a 20 °C melting point) could be used to keep homes warmer during the night.

The above example shows benefits and limitations of PCMs. During the past 10 years, application of PCMs worldwide has been growing, as well as in building upgrade projects. This also means there are more proven PCM materials, solution providers and PCM application approaches than 10 years ago.

Before considering applying PCMs, it is important to consider the specific building, climate zone and A comfort aspects. Carefully planning the way PCMs can exchange energy with their environment is critical. Therefore, PCMs are still not an easy to implement measure, requiring professional experience and careful preparation. Immediate residential application options in Lebanon are deemed limited due to the complexity of the measure. It’s more likely that application of PCMs in Lebanon will start with utility building retrofits (offices, factories, hotels).

When applied properly, PCMs are (in many climates) capable of reducing the size of the required installed power of cooling or heating system with up to 50 per cent or increase the cooling or heating capacity of an existing system. Energy savings of 20-40 per cent are realistic and payback times can be as short as 3-5 years (for example in office ceiling retrofits).

Figure 62: A retrofit PCM wall adding more than 10kg PCM material per m² of wall area
Source: OC-Autarkis

Figure 63: Example of a retrofit PCM assisted heating and cooling floor in an apartment
Source: Global-E-Systems

[15] Bekaa governorate is situated between Mount Lebanon to the west and the Anti-Lebanon mountains to the east.

I. Aquifer / ground water heating / cooling

Table 28: Ground water heating and cooling application

Saves on	Climate Zone	Building Type	Difficulty
Heating/cooling	Coastal, maybe mid mountain	Apartment buildings, high-rise	Specialist

In the fossil fuel era, high energy density storage (carriers) like oil and natural gas were taken for granted. In the renewable energy era, the amount of available energy is not the challenge. Efficient conversion, balancing and storage is. Active ground water heating and cooling reservoirs can be such a storage component in future energy systems.

Future energy systems require both short term and long-term storage and balancing. Batteries are a typical storage example to balance daily solar energy supply and demand. Underground (aquifer) heat and cold storage is a candidate for seasonal cycles. This kind of storage comes in different forms. On the right is an example of a system using an aquifer and separate warm and cold wells. Excess heat is pumped into the warm well in summer for use in winter and excess cold is pumped into the cold well for use in summer.

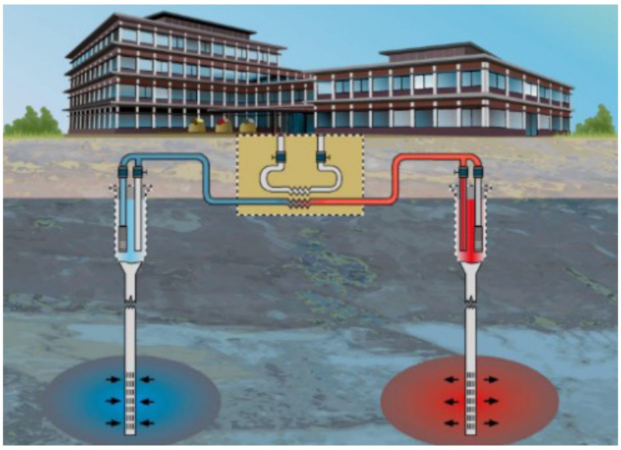


Figure 64: Classic seasonal heat and cold storage using two wells and an aquifer
Source: Duurzame Scheurkalender

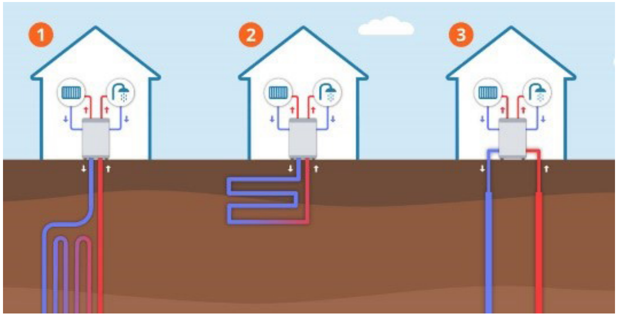


Figure 65: Small-scale systems for residential building.
Source: Slimster

A system like this is mostly shallow (10-500 meters) and requires water-bearing layers with low horizontal flow rates. These will most likely be available in limited regions in Lebanon.

On the other hand, the current regulatory framework in Lebanon doesn't support aquifer thermal storage. It may therefore be necessary to develop additional Lebanese regulation, e.g., to distinguish between traditional deep geothermal extraction activities and this type of shallow geothermal activities. Since there is ample regulatory experience in EU countries, this may be an opportunity for an international partnership.

This type of heat and cold storage became more or less standard in some EU countries for larger offices and new apartment buildings. Consequently, this has helped the industry to mature and brought down the costs. With the growth of (water to air) heat pump applications in Europe, residential applications and solutions for smaller buildings came within reach.

For residential buildings, there are basically three options. In the picture on the right, option number three is similar to the classical system using separate open wells. For Lebanon, closed single well systems may often be more feasible and easier. The first option is a vertical system that can be used if space is scarce. It reaches up to 200 meters of depth and can be done with single drilling. The second option is a shallow horizontal system at one or two meters below the surface that requires about three times the surface of the living space that needs to be conditioned.

Underground heat and cold storage combined with heat pumps will reduce electric energy consumption with around 50 per cent compared to for example using air sourced split units. Payback times differ but are in the range of 10-15 years. In very cold areas, it should be noted that buildings need proper insulation as heat pumps can only efficiently deliver low temperature heating.

J. Other measures

There are still other measures that are used in energy efficient and green buildings that are not mentioned in this document, and innovation moves at a high pace in this field. Also, when contemplating the measures in this chapter, one could also consider the use of other green building strategies such as circular material use, waste minimization, rainwater re-use, green sanitation, and others.

Figure 66: Trees can provide an automatically seasonal adjusted shading solution.
Source: GreenfieldCities

VI. General recommendations for development of EE Renovation in Lebanon

In Chapter III, recommendations for application of measures have been given for energy efficient renovation projects and in Chapters IV and V, a number of these measures have been described. This chapter provides general recommendations for business and market development. The first paragraph gives recommendations related to business opportunities for companies in Lebanese built environment sector, and the second paragraph provides policy and strategy suggestions to policy makers and other institutions, both globally ordered with the easiest options first.

A. Business opportunities for energy efficiency renovation of buildings

In every country, the construction sector provides both a large opportunity and a big obstacle when it comes to improving energy performance in (existing) buildings. It's an obstacle when there is a large number of players and a natural tendency to stick to traditions and short-term cost optimization. Whereas it's an opportunity when private sector companies can adapt and explore quickly when opportunity knocks on the door. Policies can be important tools to provide guidance and structure markets, but in the private sector, there are other, even more powerful mechanisms that can move things in the right direction.

These mechanisms go by different names such as creative destruction, disruptive change, or paradigm shifts. Examples include: Competitive offshore wind generation without need for subsidies in the Netherlands, electric cars that are disrupting the whole automotive industry, steep battery learning curves[16], the massive price drops of Solar PV, and the massive price drops in LED lighting, which has turned them from exotic to mainstream. These disruptive changes go hand in hand with more gradual developments like price drops of low-e glazing, electrical appliances efficiency improvements, affordable smart grid power electronics at every possible scale, widely available insulation materials, and last but not least, the slowly but profoundly changing consumer attitudes with respect to climate change and the environment.

All this means that for smart entrepreneurs who are active in the building sector, new business propositions in the field of energy optimization and comfort are everywhere. Ultimately, businesses adapt to paradigm shifts, or they go out of business. Below is a non-exhaustive list of business opportunities that, even in the present crisis, might grow in Lebanon. Opportunities that are easiest to develop are mentioned first.

[16] E.g. Elestor, Alfen, Victron Energy and lyv.

1. Air Tightening, ventilation and free cooling opportunities

Depending on the building situation, there are many opportunities for installers, architects, and engineers to improve ventilation and free cooling in existing buildings.

Air tightening is a low-cost intervention. In itself it is not a major business opportunity, but it is a very good way to start building a client-supplier relationship. Occupants will normally be happy with the intervention. When an energy efficiency expert has assessed the draft situation and fixed the main problems, he can also advise the client on other measures. This is especially true when the expert has taken the time to survey the buildings and double-checked the desires of occupants and owners to gain understanding about the best airflow control options. Investing in such knowledge by the energy efficiency experts could help to develop this opportunity. After a full assessment of the desired airflows for a specific building, components on the market like sealing strips, ceiling fans, efficient fans, advanced control systems, automatic window openers (actuators), bypass valves, evaporative coolers, heat recovery air units and wind catchers can help make natural cooling easy and comfortable for clients.

Such combinations of services and products can be applied in any reconstruction project and provide a clear opportunity for professionals to differentiate themselves.

2. Insulation opportunities

For roof and wall insulation, the applicability in Lebanon should be easy in practice since the know-how and the needed materials are widely available on the market. There is also an increased awareness in younger generations of home buyers that see energy performance as more important. For developers, architects and engineers, energy performance and insulation are an increasingly attractive design feature a way to differentiate from competitors.

A good way to start doing business may be to do a survey (use students for example) to identify people who suffer from uncomfortable heat gain or cold in their homes. Subsequently, starting with easy measures such as roof insulation (in combination with shading, see below) will lead to satisfied clients. A next step could be to invest in offering cavity-filling equipment and explore more complex indoor or outside wall insulation.

Roof insulation projects could als offered for businesses that are active in roof repair and roof water proofing businesses.

3. Shading and glazing opportunities

Adding improvised shading devices is among the first measures that people themselves consider when trying to reduce heat gain. Businesses could try to develop this market further by offering affordable, easy to use and good-looking outside blinds and screens measures and combinations of shading and glazing products.

There are already businesses in Lebanon that offer add-on coatings for existing windows. These businesses could consider expanding their portfolio with production and sales of add-on secondary windows. This could largely be a domestic value chain without need for many imports. The intervention is less invasive than full window replacement, creates less waste streams, and energy performance is comparable to simple industrial double pane windows.

With respect to industrial glazing, larger Lebanese construction companies can take advantage of the developments in energy efficient glazing taking place in the EU for the past decades. All major EU glass producers offer support schemes for their international agents and they are always looking for opportunities to expand their business. These include some of the necessary product application information for professionals. Many of the larger suppliers also offer capacity building 'Academies' to boost sales in specific markets. Lebanon already has several glazing companies that produce low-e glass in partnership with large EU glass companies.


Figure 67: A traditional split unit (right) and a prototype: two- step evaporative cooling, ventilation and energy recovery unit (left)
Source: Oxycom

4. Efficient cooling and heating opportunities

After considering and implementing measures to reduce cooling and heating demands, heat pumps, evaporative technologies and heat and cold buffering can be innovative elements in energy efficiency renovations. In combination with sustainable sources of electricity or heat, such as solar panels or waste heat, they can make residential buildings 'net zero energy' and much less dependent on external power sources.

In North-West Europe, heat pumps are increasingly used as an environmentally friendly alternative to natural gas or oil heating. Very well insulated buildings with heat pumps and solar panels can become 'net zero energy': on a yearly basis all energy consumed in the building is provided by the solar panels. The EU and other major economies also work towards mandating the use of refrigerants with low Global Warming Potential (GWP) as a part of the offered solution. For businesses, it makes sense to add refrigerant GWP performance to their decision-making checklist, as low GWP alternatives become increasingly available to traditional HFC refrigerants. As a rule of thumb, a good GWP range to look in HFC alternatives for would be between 1 and 150. R290 (propane) is being increasingly used as a refrigerant and has a very low GWP of 3.

Immediate business opportunities in Lebanon could consist of adding new technologies and services to existing product portfolios. This will most likely involve more upfront assessment work in the clients' buildings (for which people may need training). For example, a company currently just selling A/C split units could consider teaching their sales staff to do a more complete quick scan at the client's premises. As a result, they might sell the business case, products and services for an integrated heat pump and PV system, while making an old diesel heater redundant. Larger A/C system vendors might for example offer adding retrofit evaporative pre-coolers to existing chillers which will lead to an increase in the cooling capacity and a reduction of the electricity bill by around 15 - 30 per cent savings in each.

Some specific opportunities could be:

a. Keep tracking the expected market growth of residential two-stage evaporative cooling / ventilation / energy recovery products (2-3 years). These hold a real promise for the retrofit market. Such units are window or wall mounted units that can be installed in a similar way to the traditional wall mounted split units.

b. Consider sharing those specifications / requirements, for companies working at preliminary designs for a central cooling solution, with a reputable supplier that also provides (hybrid) evaporative solutions and ask them for a rough order magnitude quotation for the project including evaporative or desiccant technologies (including references). Such solutions are proven in practice. This allows those companies to differentiate themselves vis-à-vis clients and it increases their knowledge about this solution direction.

c. Consider developing 5 - 10 pilot projects with high-end (hybrid) evaporative cooling products and monitor those projects carefully. International financial and technical support might be available for parties that come up with good project proposals for building reference cases to kick start markets for innovative applications.

5. Neighborhood energy greening opportunities

Existing neighborhood power generator operators could make use of solar PV, battery storage and availability of automatic switches and power electronics to lower their cost of service, improve reliability (seamless transition from grid to neighborhood power) and reduce emissions.

6. Communal infrastructure project opportunities

Costs for neighborhood (or building complex) scale energy systems have come down. When several large building operators or residents' associations share interests in terms of clean affordable comfort, shared infrastructure projects are almost certainly cost effective (when realized). The main challenges for such projects will probably lie in the field of regulatory issues, financing, risk management and securing commitments. The campus of the American University of Beirut is an example of a shared infrastructure project.

7. ESCO business opportunities

Energy Service Companies (ESCO) differ from normal energy equipment and solution providers by including financing in their offering. This could be an important enabler in Lebanon since financing capabilities and lifetime solution optimization are two areas of opportunity in Lebanon. Trusted ESCOs can be interesting counterparts for international donors and NGOs for example. A qualification scheme for ESCOs in Lebanon has been developed and is in effect since 2017. The list of ESCOs is always under review and updated to include the interested companies that meet minimum requirements. In 2020, the ESCO qualification list contained 11 qualified ESCO and 13 qualified energy audit companies. Efforts have been undertaken to boost the ESCOs business such as demanding a mandatory energy audit for all facilities that will be installing a 60 kWp (or larger) PV system and seeking the NEEREA loan.

Further recommendations to improve working conditions for ESCOs in Lebanon could be:

a. Providing ESCOs with international capacity building opportunities;

b. Providing (international) financial guarantees;

c. Introducing favorable regulation, for innovative financing schemes, for example by linking (qualifying) ESCO financing to the real estate itself (a lien on the building, not the owner, dwellers or tenants).

B. Areas of interest for policy and strategy development

Combining input on the Lebanese energy and building sectors with prior knowledge of the energy transition resulted in several suggestions on policy and strategy development. This project delivers mainly practical guidelines for architects and engineers. It is not an extensive energy strategy study, so the following list of ideas should be read as a set of suggestions that may or may not justify further elaboration.

1. Remove subsidies on electricity and diesel prices

As the electricity prices in Lebanon are heavily subsidized, the consumer will not have an incentive to move towards energy efficient measures as the payback time will not be realistic. This is aggravated due to the current economic crisis and the volatility of the exchange rate between LBP to USD. As the bulk of the energy efficiency related measures are imported, the installation price will be related the exchange rate, while the savings are in subsidized LBP for both electricity and oil consumption. Removing or reducing energy subsidies is an inevitable measure to push forward the energy efficiency market. While this will improve the case for energy renovations, it will be a heavy load on low-income households. It may be possible to soften the social impact with additional measures. For instance, The Netherlands has an electricity tax, which is high per kWh, but every household gets a fixed refund on the tax (about 350 euro / year is automatically discounted on the monthly energy bill, independent of consumption). If you have your usage covered a 100 per cent by PV you will also get a refund. This results in a stronger incentive for households to save and produce energy themselves, but relieves low-income households, as it does not only consist of raising energy prices.

2. Set higher minimum standards for insulation and enforce

The current energy performance standards for new buildings in Lebanon are low by international standards. The example in the previously mentioned link is for California since it has several climate zones that are similar to Lebanon, and since the Lebanese engineering community is used to working with ASHRAE and other US engineering practices. Performance levels of walls and roofs in the Coastal and Western Mid Mountain zones, (where most buildings are), could be set a factor of two to four higher without causing major costs increases. Indirectly, such standards for new buildings will also trickle down to the existing building stock as better materials and energy inclusive thinking and processes become more mainstream. It may also be worthwhile to specify minimum comfort levels for new and existing buildings. Specifying such standards and levels requires a stepwise approach and good co-operation between governmental bodies, professional institutions such as the Orders of Engineers and Architects, ESCO's IPP's and organized citizens (like Energy Cooperatives). In this way, markets get a clear perspective when requirements or standards will become stricter. Suppliers can use these standards as guidelines and as supporting arguments in marketing materials and sales pitches.

In many countries, building code compliance has been an important initial market growth driver for glazing with a certain minimal energy performance. Announcing and implementing favorable regulation would be a major incentive for international manufacturers to consider investing in capacity building tools for Lebanon and to develop a local sales and delivery network, including assembly and some manufacturing. Sufficient enforcement of these regulations is essential.

3. Consider the application of the “Trias Energetica” in all energy policies

Many building professionals worldwide apply the “Trias Energetica” (see III.B) as it provides a smart and rational foundation under any policy framework for energy in the built environment.

4. Move towards energy efficient building codes and energy labels for buildings

Connect the national energy performance and climate goals with any upcoming (mandatory) building codes in a single integrated approach for assessing Building Energy Performance for both new and existing buildings. With a visible indicator, such as a Building Energy label, mandatory to supply at sale or rent agreement, to facilitate easy enforcement. It may be possible to form a partnership on this with one of the EU countries that already implemented its own labeling system based on the EU Building Energy Performance Directive. Complement more stringent building codes with capacity building activities, for instance by training building energy performance inspectors.

5. Stimulate EE improvements through building expansion permits

A practical way to stimulate energy efficiency could be to make reconstruction or expansion permits conditional on implementing a certain number of energy performance measures in the whole building. This strategy was followed, for instance, in several Solar Ordinances and in the present European Building Codes that also apply to ‘deep renovations’. A Lebanese solar ordinance is currently in its final conception stages, before being proposed to the Government of Lebanon for adoption. This ordinance mandates the installation of Solar Water Heaters on all types of buildings (new and under major renovation) for domestic hot water production. To avoid cases where roofs cannot accommodate the SWH installations, the ordinance gives the alternative option of opting for an air-to-water heat pump with a minimum COP of 2.8 and compliance with the Montreal protocol and Kigali amendment for the refrigerants. The ordinance deals with multiple scenarios for sizing of the systems, including individual and collective systems for hot water production using both technologies mentioned earlier.

6. Embrace bottom-up energy sector reform to complete central policies on reform

An emergency World Bank report on reform ing the Lebanese Energy sector suggests that a better functioning official power sector should replace the polluting and expensive neighborhood diesel generators. Admittedly small diesel generators are polluting, inefficient and expensive. Those private micro grids are also often unsafe. On the other hand, they function, keep the economy running, and therefore they provide an opportunity as well. The proposed strategy in the 2020 Lebanon Power Sector Emergency Action Plan is based on top-down reform of the formal power sector. That has proven to be a major challenge in Lebanon.

Therefore, it could be worthwhile discussing a parallel strategy that can help to change the power sector organically by including a bottom-up approach that will contribute to all targets related to costs, macro-economic resilience, and emission reductions. This may also help the restructuring of the central power sector. Such an additional strategy can be built on the successful LCEC PV and SWH programs through a stepwise strategy.

It is beyond the scope of this report to shape such a strategy in detail, but it could be built on expanding the possibilities for tying in private PV generation into the grid, including defining low threshold roles and quality criteria for aggregators and small scale IPP’s. There may also be a role for so-called energy communities or local energy cooperatives.

This idea has worked in The Netherlands where there is 10 GW of Solar PV installed now (on an average national 16 GW daily peak demand), of which 90 per cent was added in the last 3 years. Around 70-80 per cent of this installed capacity is small to medium scale roof top systems. Other factors that affected this growth in the Netherlands have been net metering in combination with the earlier-mentioned high-energy tax, and a policy target to get to 50 per cent local ownership of all new large-scale production capacity. This spurred the growth of citizen owned energy cooperatives. This all resulted in an impressive professionalization of local citizen energy cooperatives. In 5 years' time, these entities grew into a part of the energy sector to be reckoned with. There are more than 600 of those citizen-owned energy cooperatives now. In the end it turns out that the key success factors for the energy transition in the Netherlands are soft, community, human, social and governance factors. These are even more important than hard technical and financial factors.

7. Continue feeding momentum in PV and SWH (Remove Soft Permitting Barriers)

The PV and SWH programs in Lebanon are successful. Therefore, it is to be expected that there is a buildup of momentum in these value chains. Suppliers and installers have an interest to continue this. While offering financing is not easy for the government now, businesses may be helped by removing some soft barriers like required permits or obligations to submit a single line diagram with EDL. Removing or limiting soft barriers has proven to be very effective in other countries. Also, the EDL process for applying for and installing meters may be streamlined further. Finally, according to stakeholders, the current Lebanese Construction Laws are partly in conflict with the requirements for solar hot water and PV panels, especially on slanted roofs. Actions between LCEC and the HCUP are being taken to resolve this issue for small scale projects such as setting conditions on the height and inclination of the systems to be installed on the roofs.

In line with these ideas, some work is currently under way on the permitting front, as an easy and clear process for rooftop PV installations requirements is being studied by the Lebanese Higher Council of Urban Planning and will soon be adopted.

8. Consider Teaming with a third country on an appliance labeling systems

The EU has a labeling system for electrical appliances such as air conditioners. Tagging along with such an existing scheme (preferably sponsored) could be a valuable capacity building opportunity.

9. Stimulate (sponsored) EE education and organize project competitions

Developing primary school courses on energy efficiency along with higher education project competitions (challenges) are proven methodologies to increase awareness on the subject. Moreover, higher education (design and prototyping) challenges connect the education and businesses. Challenges can grow into serious annual events with (university and student) prestige and price money at stake. Beirut could be a host city for organizing such events, which could be sponsored by international donors. Such projects could become part of the annual Lebanese Sustainability Week event. More generally, ideally, EE should be part of the curriculum of professional Lower, Middle and Higher Education.

10. Seek carbon financing opportunities

Several financing mechanisms are being developed under the Paris Climate agreement, such as the Green Climate Fund. Lebanon could be interesting for such funds because alternatives for oil-based electricity production are attractive both financially and climate wise. Funding cycles are long and require national consensus on projects. Nevertheless, this may be a capacity building opportunity that can lead to real projects in a few years.

11. Certification

Multiple certification schemes are currently being developed such as the SHAMCI certification scheme, which consists of certifying SWH products in the Arab region. Lebanon is currently working towards developing the infrastructure to start implementing this scheme in Lebanon. Additionally, multiple qualification processes are used with the RE and EE fields such as the List of Qualified SWH suppliers and the list of qualified ESCOs that are published by the LCEC[17]. Together, these schemes can form a strong supportive framework.

12. Consistent data gathering and monitoring

Energy data and energy monitoring are the cornerstone of new policies, project feasibility assessment, and in end access to finance. Stakeholders require high levels of confidence to give projects and programs their blessing. MEW/LCEC and others have started to set up programs on data collection and reporting and it would be valuable if this effort could be expanded (possibly with long term support from a donor).

13. A 100 per cent Green Lebanon is a Realistic Goal

In a country that is 95 per cent dependent on imported oil for its energy and presently in crisis, however, Lebanon has extremely favorable natural conditions to build a 100 per cent sustainable energy system. Renewable energy may still have a small penetration rate in this context, but it's the growth rate that matters, and some momentum is clearly building. This momentum will only grow stronger pushed by the larger global energy transition. In most energy investment cases, the green option is the most attractive now, both ecologically and financially.

[17] Information from LCEC

Annex I. Assumptions residential energy in Lebanon

The numbers on energy savings and payback times given in this report are estimations by the authors and based on various sources of information and expert estimations for regular situations and typical application of the relevant measures. They serve as an indication only. Every residential building and every renovation is different and will have different energetic and financial impacts. The most important assumptions are discussed here.

Annex II. Number of people and houses

For the purpose of this study a recent EU-funded CAS study was used, which quotes five million residents living in 1,266,000 residences.

Annex III. Urbanization

Lebanon is highly urbanized. Over 85 per cent of people in Lebanon live in urban areas on or near the coast, over 60 per cent live in the larger Beirut metropolitan area, over 85 per cent of dwellings in Lebanon are apartments, 11 percent are single homes, and 1 per cent are villas.

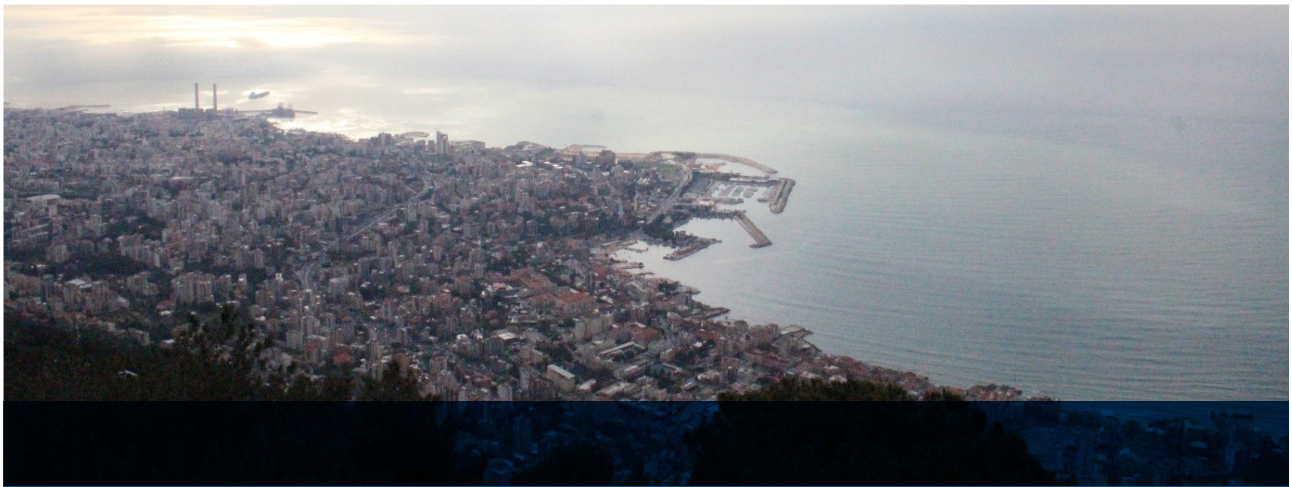


Figure 68: Urbanized coastal zone
Source: GreenfieldCities

The following table is derived from "The First Energy Indicators Report of the Republic of Lebanon" (in the following shortened to Indicators Report).

Table 29: Residential building distributions over the Governorates and Climate Zones (2015)

Governorate	Zone 1 (Coastal)		Zone 2 (Mid-Mount.)		Zone 3 (Inland Plat.)		Zone 4 (High Mount.)	
	%	million m²	%	million m²	%	million m²	%	million m²
Beirut	100%	41	0%	0	0%	0	0%	0
Mtl Lebanon	30%	29	50%	49	0%	0	20%	20
N-Lebanon	40%	14	40%	14	0%	0	20%	7
Bekaa	0%	0	0%	0	80%	32	20%	8
South	50%	7	50%	7	0%	0	00%	0
Nabatiye	50%	6	50%	6	0%	0	20%	0
Total per climate zone	40.6%	97	31.7%	76	13.3%	32	14.4%	35

Source: LCEC

Annex IV. Climate zones

While developing the energy efficiency guideline sheets, a rough indication of the possible national impact of proposed energy efficiency measures was made by estimating the heating and cooling degree days in the different climate zones in Lebanon. Local weather and climate conditions have a big impact on the energy demand for residential buildings. Lebanon has four distinct climate zones, shown in Figure 69.

On top of that, there are significant local differences and microclimates. Being on a North or South-facing slope on the same mountain can mean a big difference. The North Slope can have three winter months of below freezing temperatures while the Southern side enjoys a reasonable pleasant microclimate.

Thus, local building parameters can affect the suitability and worthiness of the different energy efficiency measures. The 'Indicators Report' used several sources for the impact analysis of the suggested energy efficiency measures. It compared the climate tables with other climate data. For the purpose of this report, and in line with the 'Indicators Report,' all HDDs (Heating degree days) have a base temperature of 18 °C and CDDs (Cooling degree days) have a base temperature of 21 °C.

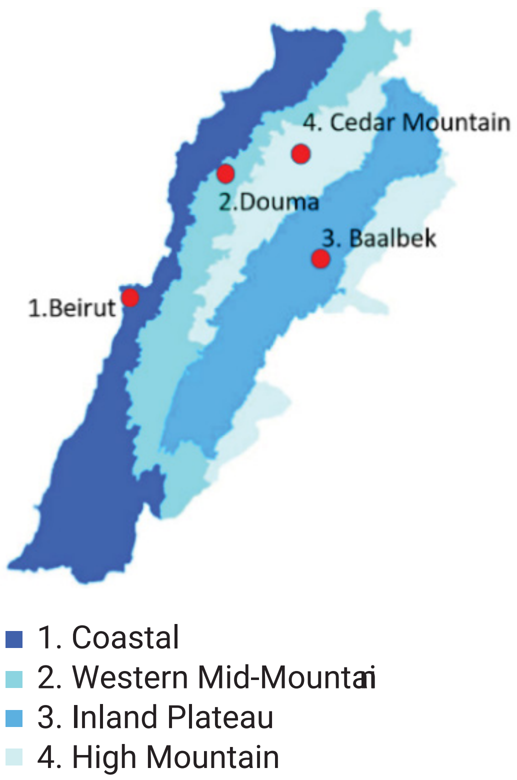


Figure 69: Climate Zones of Lebanon
Source: GEF

1. Coastal

Hot humid summers with relatively limited natural cooling in the nights. In winter there can be cold spells, but most days are fairly mild.

Table 30: Climate data for Beirut International Airport

Climate data for Beirut International Airport													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	17.4	17.5	19.6	22.6	25.4	27.9	30.0	30.7	29.8	27.5	23.2	19.4	24.3
Average low °C	11.2	11.0	12.6	15.2	18.2	21.6	24.0	24.8	23.7	21.0	16.3	12.9	17.7
Average precipitation mm	154	127	84	31	11	1	0.3	0	5	60	115	141	730
Average rainy days	12	10	8	5	2	2	0.04	0.1	1	4	7	11	62
Mean month-ly sunshine hours	131	143	191	243	310	348	360	334	288	245	200	147	2940
Source 1: Pogodaiklimat.ru													
Source 2: Danish Meteorological Institute (sun 1931-1960)													

Source: Pogodaiklimat, DTI

The 'Indicators Report' provides degree-day data for the Coastal zone. This shows a fairly large range since some of the used weather stations in the 'Indicators Report' are above 700 meters in altitude (resembling the Western Mid Mountain zone). This report assumed 350 HDDs and 900 CDDs.

2. Western Mid Mountain

Warm summers, but on average about 0.5 °C cooler per 100 m altitude. Above 300-400 m, the nights are sensibly cooler than on the coast. This effect increases with altitude. In winter, above 500-600 m, cold spells really become winter weather and occasional snow is not uncommon. Between November and March there is a lot of cloud cover and rainfall.

Table 31: Climate data for Douma

Climate data for Douma													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	10.7	11.0	13.8	18.9	23.4	27.2	29.5	30.1	27.2	23.6	17.9	13.3	20.6
Average low °C	2.8	3.1	4.7	8.1	11.6	14.7	16.4	17.2	14.7	12.3	8.4	4.9	9.9
Average precipitation mm	265	222	202	87	35	2	1	1	9	43	124	219	1210
Source: Climate-Data.org, Climate data													

Source: CLIMATE DATA FOR CITIES WORLDWIDE

The 'Indicators Report' provides degree-day data for this climate zone that are higher than our own estimates. This report assumed 1,000 HDDs and 400 CDDs partly because most houses can be expected in the lower altitude areas

3. Inland Plateau

Dry hot summers, but with relatively cool nights. On many summer nights, natural ventilation can be used to keep buildings pleasant. In winter, the weather can be cold, but since the climate is dry and relatively sunny, letting the sunlight in on many days can help reduce heating needs.

Table 32: Climate data for Baalbek

Climate data for Baalbek													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	9.0	9.8	13.7	19.0	24.4	29.6	32.5	33.0	29.0	23.7	16.3	11.1	20.9
Average low °C	-0.1	0.3	2.8	6.6	10.1	14.4	16.2	17.2	13.1	9.7	5.2	1.6	8.1
Average precipitation mm	103	86	60	31	17	1	0	0	2	16	49	79	444
Source: Climate-Data.org, Climate data													

Source: CLIMATE DATA FOR CITIES WORLDWIDE

This report used three different sources as an indication for necessary heating and cooling: the 'Indicators Report,' Degrees.net and The LARI Tal Amara Research Station. This climate zone sees a range of from 1,200 -1,800 Heating Degree Days and 200 – 750 Cooling Degree Days depending on the location. Local circumstances such as a possible urban heat island effect in Baalbek city may be an explanation for the difference in Cooling Degree days. For this report, 1,500 HDDs and 500 CDDs were assumed.

4. High Mountain

The high mountain climate zone, above 1,200 meters with cool summers & cold snowy winters.

Table 33: Climate data for Cedar mountain

Climate data for Cedar mountain													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	2	2	5	9	15	20	22	22	19	15	12	6	12.4
Average low °C	-2	-3	-1	1	6	10	15	13	11	6	3	0	4.9
Source: Climate-Data.org, Climate data													

Source: CLIMATE DATA FOR CITIES WORLDWIDE

The 'Indicators Report' mentions a value of >1,800 Heating Degree Days for a single location. This corresponds well with the average monthly temperatures of the Cedar Mountain meteo data. The report assumed 2,000 HDDs and 0 CDDs.

Annex V. Energy

Lebanon has an energy import dependency that has exceeded 95 per cent between 2010 and 2020. Oil products dominate the primary energy sources with over 95 per cent being liquid fuels. Some 28 per cent of these fuels are used for electricity generation and 62 per cent is for the transport sector[18].

The International Energy Agency (IEA) provides primary energy supply (TES) data for Lebanon as well as data on final energy consumption (TFC). Between 2012 and 2018, IEA registers a 25 per cent growth in residential energy consumption and a share of the residential sector in TFC of 19 per cent (2018). Based on estimates by MEW that around 90 per cent of residential energy use is electricity, and an estimated conversion and distribution efficiency of 35 per cent in the electricity sector, the total share of residential energy in the primary energy terms could be as high as 32 per cent. This underlines the importance of working on energy efficiency measures in the building sector to reduce the energy consumption, and related CO2 emission.

Given the assumed high share of electricity in the residential mix, this study has focused on measures that can help to reduce electricity consumption. Another reason for this focus is the fragile state of the electricity system in Lebanon. Electricity consumption reduction can help to reduce some of the stress on the system.

The 2020 IRENA Renewable Outlook for Lebanon indicates a growing 1.2 GW gap between available installed electricity production capacity and peak demand and 7.4 TWh of unserved electricity demand (2017). This is more than 30 per cent of total demand. In reality, this demand that is not fulfilled by EDL is for "the most critical part" part served by the existing parallel (informal) infrastructure, using small diesel generator sets. A 2016 MDPI article estimated the damages caused by the challenges in the electricity system to the Lebanese economy over the 2009-2014 period at more than $23 Billion. These sets cause additional climate change effects and other harmful emissions as well.

This report identifies the assumptions for the retail electricity prices in order to estimate the payback times associated with the measures proposed in the guideline sheets. It uses the 2020 World Bank report Lebanon Power Sector Emergency Action Plan as a source. Also, it states that EDL's retail tariffs, which currently stand at an average of $0.095/kWh, have not changed since 1994.

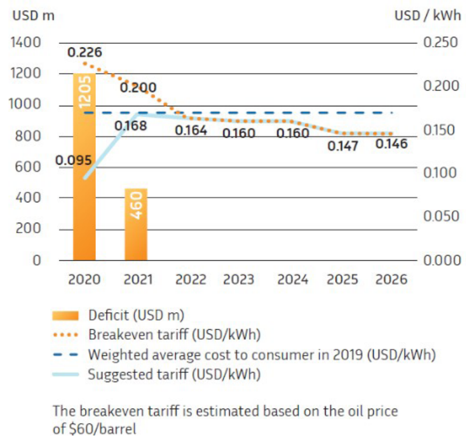


Figure 70: Necessary retail electricity rates for EDL to break even financially. (Figures assume all currently non-billed EDL energy is billed and paid in 2020 and include other efficiency measures in the years ahead)
Source: WB Lebanon Power Sector Emergency Action Plan

Since most consumers also buy part of their electricity from neighborhood generators (with cost up to $0.3/kWh), the combined average cost to consumers from EDL and private generators is estimated to be approximately $0.168/kWh. Moreover, this same report puts the current cost recovery rate that EDL would have to charge to retail consumers to break

[18] Renewable Energy Outlook Lebanon, IRENA

even, at close to $0.3/kWh. The fuel costs of EDL alone amount to $0.12/kWh.

Another major issue is that over 35 per cent of EDL production (costs) is either technically or non-technically lost. Based on the various measures proposed by the World Bank team, EDL should become more efficient and diversify its fuel portfolio. In these plans, the EDL cost recovery tariffs decrease to around $0.16/kWh in 2023. This study assumed $0.16/kWh as the avoided electricity costs by consumers for every kWh of electricity they do not consume.

The World Bank report further states: "An analysis of 2011/12 electricity consumption indicates that the poorest 20 percent of households in Lebanon consume on average 430 kWh/month from the public grid. This number increases to 503 kWh when looking at the poorest 40 percent of households. These consumption levels are significantly higher than international standards, emphasizing the need for implementing demand-side energy efficiency measures and adopting a tariff structure that incentivizes energy conservation".

Finally, all the measures that these sheets proposed have a greenhouse gas (GHG) emission reduction potential and addressing this is interesting to initiate discussions on carbon financing.

The 2012 Lebanon Technology Needs Assessment Report for Climate Change puts the emission factor of the average electricity production park at 0.778 kg of CO_{2eq}/kWh. This leads to an average electricity production efficiency of around 35 per cent. This study assumes that the avoided GHG emissions per reduced kWh of electricity consumption or produced kWh by means of renewable energy are set at 0.778 kg of CO2eq.

Annex VI. Other general assumptions and remarks

This report revealed several other assumptions, including:

A. The total energy consumption of the residential sector in 2020 is 3,100 ktoe/year (IEA World Energy Balances 2020).

B. The market price for diesel for house heating purposes costs $0,81/liter; LPG for heating costs $1.7/kg (source: IPT Group).

C. The average efficiency of the existing diesel boilers is 75 per cent; this efficiency is also used for gas and biomass heating. It also indicated the savings as liters of oil equivalent, $L_{oil\ eq}$.

D. The existing split units have an average COP of 2.5 for cooling (considering a mix of old and new units and of correct and incorrect installations, maintenance and use).

E. This document contains links to resources on the Internet. At the time of writing, all these links worked. Unfortunately, web pages change over time and links can go dead. Nevertheless the project team deemed the value of adding web resources in the form of clickable web links outweighed the disadvantage of some of them going dead over time.

Annex VII. Indicative division of energy use per function of average house

These aforementioned assumptions provided a basic calculation to estimate the energy impact of energy efficiency measures, to arrive at indicative energy uses for the main functions of average houses for the Lebanese climate zone, as given in Figure 71. The guideline sheets offered these indicative figures in order to estimate the energy savings and payback times. The authors are aware that a large part of the input data and assumptions used cannot be substantiated, and that averages have limited meaning for specific projects. Nevertheless, the calculations could serve as a first steppingstone, helping to build more reliable calculation tools and data sets.

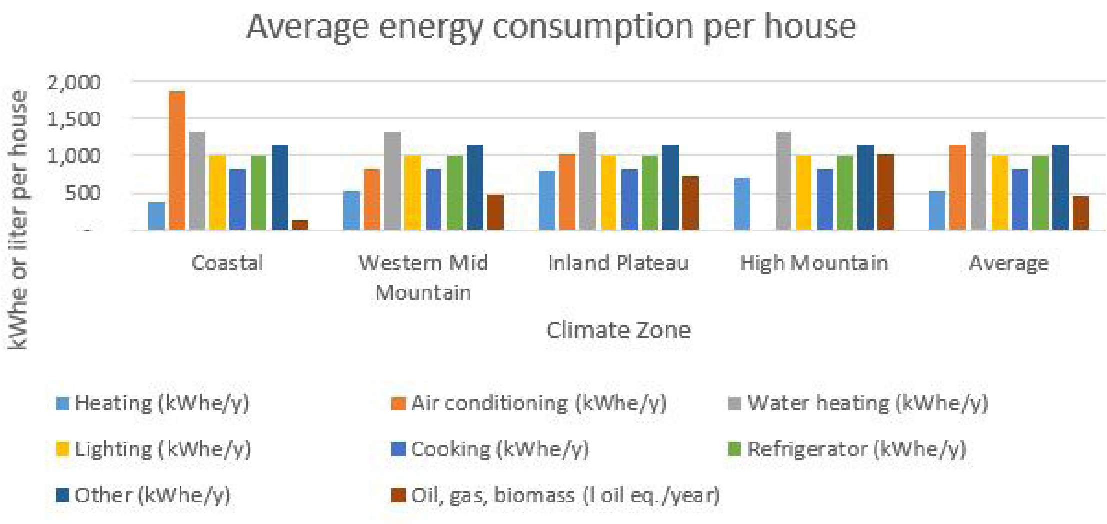


Figure 71: Average energy consumption per function for average house in each Lebanese climate zone
Source: GreenfieldCities