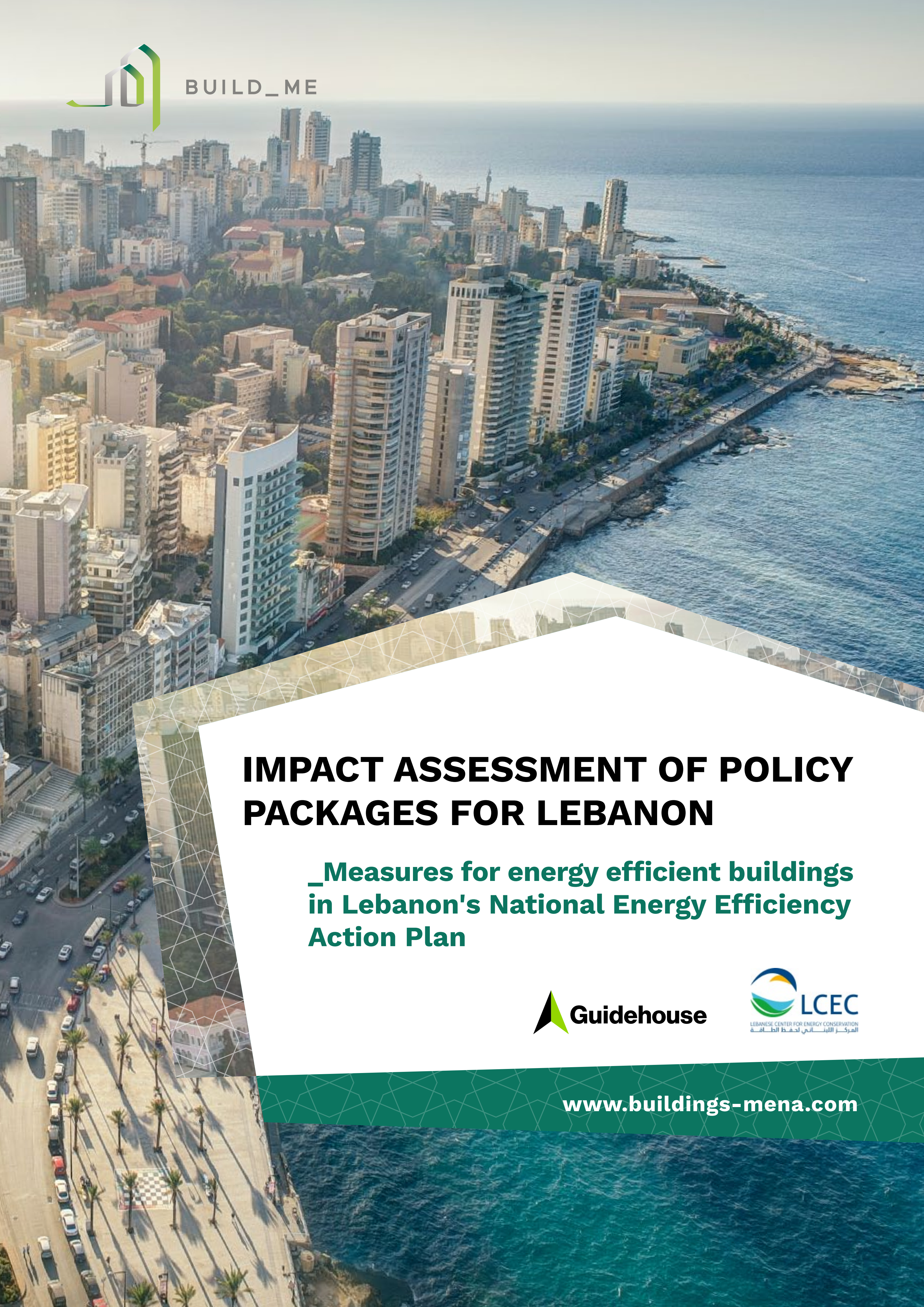

BUILD_ME

IMPACT ASSESSMENT OF POLICY PACKAGES FOR LEBANON

_Measures for energy efficient buildings in Lebanon's National Energy Efficiency Action Plan

Guidehouse

LCEC
LEBANESE CENTER FOR ENERGY CONSERVATION
المركز اللبناني لحفظ الطاقة

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Impact Assessment of Policy Packages for Lebanon

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based on a decision of
the German Bundestag

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1. Introduction

Continuous population and economic growth and accelerated urbanization have increased the demand for residential areas in urban centers in Lebanon. Since 2010, Lebanon develops the National Energy Efficiency Plan (NEEAP) in five-year steps to meet the growing energy demand by improving energy efficiency in the building sector, thus providing a strategic roadmap for the development of this vital sector. Transforming the building sector is one of the major challenges to achieve national energy targets.

This report was prepared by Guidehouse Energy, Sustainability and Infrastructure (Guidehouse ESI) in cooperation with the Lebanese Center for Energy Conservation (LCEC) and supports the development of a new NEEAP for the period 2021-2025.

This impact assessment has the aim of estimating the energy and emission savings of policy packages affecting the new construction sector. For this purpose and as part of the development of the next NEEAP, the project team has developed a set of policy modules and packages to confront the identified barriers for moving the building sector in the Lebanon towards zero-emission.

For policy makers, it will be essential to also get indications about the potential impacts of these policy packages, therefore, the present report has the main objective to provide this kind of information. The impact assessment (IA) quantifies the expected energy savings and emission reductions compared to a “Business-As-Usual“ (BAU) path. The BAU path is defined as a “Frozen Technology Reference Level,” meaning that the energetic quality of today‘s new constructions remain stable during the assessed period. The period of the assessment is 2021-2030 and covers new residential buildings that are expected to be erected during this time. For the assessment, a set of policy packages are considered that increase the energy performance of the buildings through an improvement of the building envelope, more energy-efficient or on renewable energies-based heating and cooling systems and thus reduce the energy demand for space heating, space cooling and hot water generation.

The methodology incl. the central calculation tool is presented in more detail in chapter 2. As part of that section, sub-chapter 2.4 explains how the calculation tool is calculating the impacts of a potential integrated module that considers that several policy modules might be present in a market at the same time and therefore are affecting each other have overlaps. Usually, it is not possible to just sum up the impacts of each single policy module or package to estimate the overall impact on the new construction market.

The BUILD_ME project which is financed by the International Climate Initiative (IKI) aims to increase ambitions towards achieving climate-neutral building standards in the MENA region by providing technical assistance for pilot projects and facilitating policy dialogue. The main target countries are Lebanon, Jordan, and Egypt.

2. Methodology

This chapter describes the methodology of the impact assessment. It provides all relevant calculation steps that have been conducted to come from an input to an output. All country-specific background and input parameters are provided as well.

2.1 General approach

The overall approach is following the different steps and logic as illustrated in the figure below. The rough steps are:

1) Based on the evaluation of the building sector measures proposed in the NEEAP 2016-2020, a set of recommendations have been developed by Guidehouse and LCEC teams. More details can be found in the report entitled" Towards the 3rd NEEAP 2021-2025 for the Republic of Lebanon: Evaluation of energy efficiency measures for the Lebanese built environment".

2) Based on recommendations from step 1, policy modules and packages containing a description of the different measures were developed, their qualitative impacts and approach how to implement.

3) For each of these packages, the impact on the future system distribution in new constructions is estimated (determining shares) for three time periods and the affected share of all new constructions for the envisaged future distribution of space heating technologies, hot water generators, space cooling systems, ventilation systems and different envelope measures. These estimations result in reference building configurations (efficiency cases) representing each policy package.

4) Considering the different technology distributions, efficiencies and affected shares, Guidehouse's Building Energy Performance (BEP) Model is used to calculate the energy demand and resulting emissions of the different building configurations. This model is further described in chapter 2.4.

5) Combining the results of the efficiency cases (policy packages) with results of the BAU case allows the calculation of energy and emission reductions.
   Definition BAU: The BAU distribution represents the standard distribution in new constructions under current market conditions if no new policy instruments would change the situation. Therefore, values represent an average or typical new building in the market. The BAU path is defined as a "Frozen Technology Reference Level", meaning that the energetic quality of today's new constructions remain stable until 2030.

For determining the number of new constructions in the three countries, Guidehouse's Global Building Stock (GLOBUS) Model is used that contains building stock data and projections of these stocks for all countries of the world until 2050 and beyond. This model is further described in chapter 2.6.

The structure of the impact assessment calculation tool including the required inputs and calculation steps is presented in the following figure.

Impact assessment calculation tool

Structure and methodology

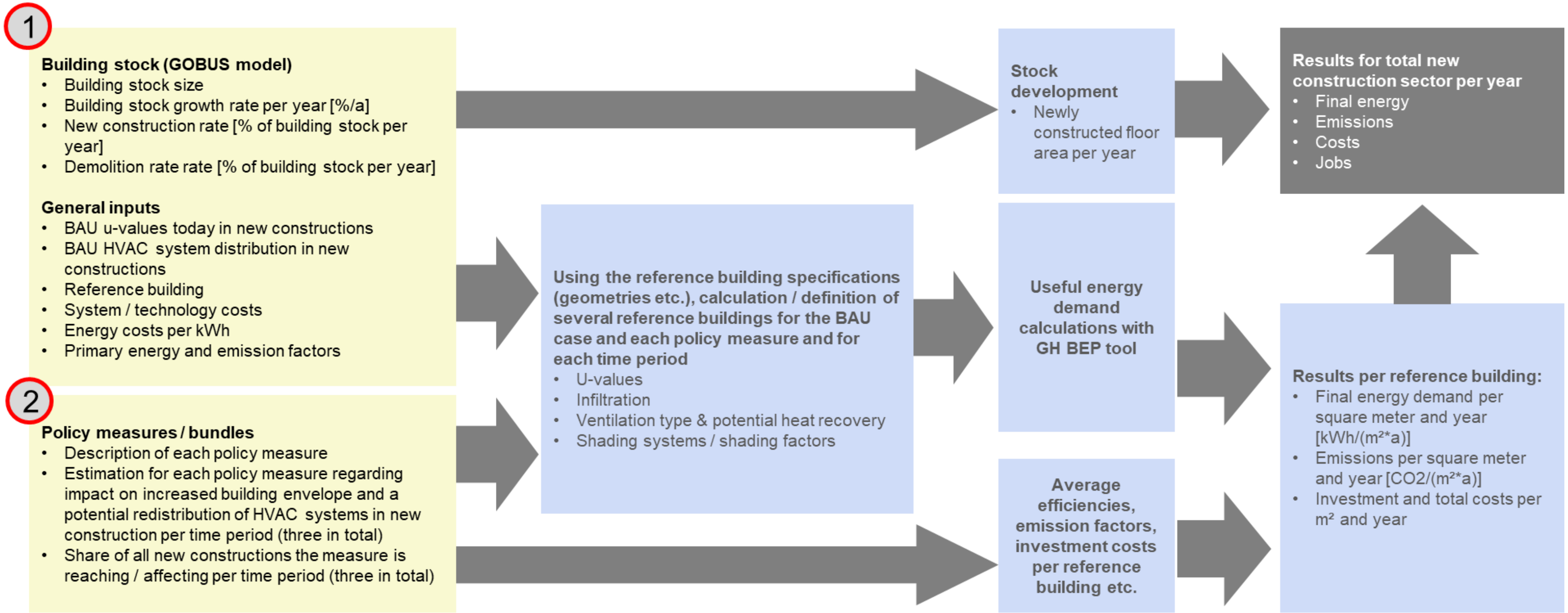


Figure 1. Impact assessment calculation tool. Structure and methodology

Yellow coloured boxes represent required inputs, blue boxes calculation steps done by the tool and grey boxes represent final results.

The current version of the impact assessment calculation tool considers the following technologies:

Table 1. Technologies considered in the current version of the IA calculation tool

Space heating technologies	Gas boilers
	Diesel Boilers
	Direct electricity
	Heat Pumps (any source) - COP 3
	Heat Pumps (any source) - COP 4
	Heat Pumps (any source) - COP 5
	Solar water heaters (space)
	Biomass Boilers
Water heating technologies	Diesel boilers (HW)
	Gas+Biomass boilers (HW)
	Electric+Heatpumps (HW)
	Solar water heaters (HW)
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery
	Mechanical ventilation w heat recovery 50%
	Mechanical ventilation w heat recovery 90%
Space cooling technologies	Space cooling technologies
Windows	Windows
Infiltration rate	Infiltration rate
Insulation Thickness	Facade
	Rooftop
	Ground
Shadowing measures (window shading)	Shadowing measures (window shading)

It should be noted that these technologies can be adapted according to the market requirements.

2.2 Future technology distributions and affected shares

As already described in chapter 2.1, for each of the developed policy packages, future technology distributions and the affected shares of all new constructions are estimated. The assumptions are based on a) interviews conducted with stakeholders b) data collected from pilot projects c) BEP tool to estimate which technologies will be most cost-effective in the future given future energy price and capital cost developments of energy efficiency technologies.

The starting point for future distributions is the current BAU distribution in the country. BAU distribution in this sense means the currently present shares of different technologies that on average can be found in all new constructions of one year. Based on the type of policy package, the project team is estimating the effect of these packages on the technologies to be used in the future.

Example: In case the measure is a promotion program for Solar Water Heaters (SWH), the impact direction is clear. You could assume 100% SWH (see Table 2 for more information), then just still need to think about the affected share of this measure. Considering the size of the measure (e.g., program) but also the addressed stakeholder target group and implementation strategy for example the assumption could be that the program will affect 20% of all new constructions. This would mean, that the model would use a 20% share of all new constructions using the 100% SWH technology distribution and 80% BAU distribution (see chapter 2.3.3 showing how this case could be put into the model. This would relate to bullets 2 and 3 of Figure 1, input box 2).

For the overall calculation approach, the assessment considers different developments in the following three periods:

- 2021-2024.
- 2025-2027.
- 2028-2030.

This way, the tool also allows a “movement” in the future development of the impacts of the measures. Related to the technology distributions and affected shares, this means that the tool requires input to all three periods. For some of the packages, this option can be used to consider a potential change in the future distribution, e.g., increasingly towards high performance heat pumps. But also, the affected shares of the measures can be adjusted. An example could be that it is assumed that a measure is just starting slowly e.g., due to different market barriers or the initially small size of the program but then over time is getting increasingly impactful, therefore the assumed affected share is growing.

Figure 2 presents the two main sections of the policy package assessment sheet. Section 1 requires input for a qualitative assessment of each policy measure and section for the quantitative assessment of each measure.

		1 Qualitative Assessment			2 Quantitative Assessment		
		Target distribution/Expert judgement 2018-2022 Current energy prices Current EE capital technology cost	Target distribution/Expert judgement 2023-2026 Current electricity prices + 50% Current gas price constant Current EE capital technology cost - 5%	Target distribution/Expert judgement 2027-2030 Current electricity prices + 100% Gas price - 50% Current EE capital technology cost - 10%	Affected share new construction [%] 2019-2022	Affected share new construction [%] 2023-2026	Affected share new construction [%] 2027-2030
New Constructions		o	o	o	0	0	0
Space heating technologies	Gas boilers - conventional						
	Gas boilers - condensing	50.0%	50.0%	50.0%			
	Direct electricity						
	Heat Pumps (any source) - COP 3						
	Heat Pumps (any source) - COP 4	35.0%	32.5%	30.0%	15	25	35
	Heat Pumps (any source) - COP 5	15.0%	17.5%	20.0%			
	Solar water heaters (space)						
	Biomass boilers - conventional						
	Biomass boilers - efficient						
Water heating technologies	Fossil - conventional						
	Fossil - efficient	45.0%	42.5%	40.0%	15	25	35
	Electric	5.0%	5.0%	5.0%			
	Solar water heaters	50.0%	52.5%	55.0%			
Mechanical Ventilation	Natural ventilation (windows) or						
	Mechanical ventilation w heat recovery				2.5	5	7.5
	Mechanical ventilation w heat recovery	100.0%	100.0%	100.0%			
Space cooling technologies	Space cooling technologies	++	++	++	20	25	30
Windows	Windows	+	+	++	15	20	25
Infiltration rate	Infiltration rate	o	o	o	0	0	0
Insulation Thickness	Facade	+	+	++	10	15	15
	Rooftop	+	+	++	10	15	15
	Ground	+	+	++	10	15	15
Shadowing measures (windc	Shadowing measures (window shading)	+	+	+	10	10	10

Figure 2. Main sections of the policy measure assessment sheet: 1) qualitative assessment section; 2) quantitative assessment section

As can be seen in Figure 2, both the qualitative and the quantitative assessment sections comprise three columns, each relates to one future time period which information is required.

2.2.1 Qualitative assessment section

For each policy measure it needs to be estimated which technologies this measure is promoting or influencing also in a negative way. Considering this, for each policy measure target shares per technology segment (space heating, water heating and mechanical ventilation) need to be entered that sum up to 100%.

In case policy measures are assessed that promote certain technologies (e.g., by defining new minimum requirements related to technology efficiencies or whole building performance requirements that can just be reached by installing efficient systems), just values for these technologies are entered that sum up to 100%. Values for technologies that are not directly affected by the specific policy measure should not be entered. The target shares per technology that are affected by the measure should be estimated depending on the focus of the measure (e.g., more heat pumps or more condensing boilers etc.).

A general guideline for setting realistic assumptions for technology distributions could be as follows:

Table 2. Guideline for setting realistic assumptions for technology distributions

Type of measure / package	Technology distribution	Rationale
Single technology measure	100%	If a measure is just directly influencing (e.g., promoting or restricting) one technology, the technology distribution should be set to 100% for this technology (all other technologies are not directly affected, therefore share is 0% there).
Multi-technology measure	Various but in sum 100%	If a measure is directly addressing and therefore affecting the market application of several technologies, the technology distribution shares should be determined according to the expected relevance of how the measure will finally affecting each technology. If it is expected that a specific measure will have the largest direct impact on gas condensing boilers (e.g., by introducing minimum efficiency requirements), and equal minor impact on heat pumps - COP 4 and heat pumps - COP 5, the shares could be set to e.g., 50%, 30% and 20% for these three technologies. With this distribution we would therefore assume that the other technologies are not benefitting from the measure.

For the technologies space cooling to shadowing measures, it is just specified from o to -- / - / + / ++ if the measure is affecting these applications. In case these applications are not affected or targeted by the measure, a “o” is specified. What the -- / - / + / ++ exactly mean, is specified in the tool section “Market data & definitions.”

2.2.2 Quantitative assessment section

In the quantitative assessment section, the user must enter an estimated affected share of all new constructions in a respective period in [%] for each measure that affects a specific technology segment. Example: When a measure is affecting the space heating technologies, then a share must be entered in the merged cells field of the space heating technology segment.

Which percentage to enter depends on several aspects. If the policy measure defines mandatory requirements for a specific technology segment, then the affected share should be 100% (in case also full compliance can be assumed). In case it is rather an incentive program, it should be estimated how well or intensively the program will be accepted, used, or requested by new building owners. A share of 20% for example would mean that 20% of all new constructions would use the incentives.

In Germany for example there exists a KfW, Kreditanstalt für Wiederaufbau ("Credit Institute for Reconstruction") incentive program for new constructions that according to statistics ~80% of all new constructions are using (affected share = 80%). However, this also depends on the availability of funds. In case funds are already empty by mid-year, this would of course also influence the affected share. In case it is just a niche program for a quite a special or expensive technology (e.g., stationary fuel cells or ventilation systems with heat recovery), the affected share could also just be 5% or even less. A thorough estimation by someone who knows the perception of end customers and the market should be done.

Over time (meaning from period to the other), the affected share could be assumed to increase e.g., due to a continuously improving market environment as a result of the proposed policy measure.

The tool afterwards will use these assumptions on the affected share in combination with the quality input and the BAU distribution (see chapter 2.3.2) to calculate the resulting technology mix in new constructions resulting from this measure (for more information about the calculation approach, see chapter 2.3.3). As can also be seen in Figure 1 The resulting shares will be used by the tool to calculate reference building specifications that afterwards will be used to calculate energy and emission savings and other outputs.

2.3 Input data

2.3.1 Emission factors

Table 3. Used emission factors

Energy carrier	gCO_2e/kWh	Source
Natural gas	209.88	BEP Tool 9-6 (Input LCEC)
Electricity	806	BEP Tool 9-6 (Input LCEC)

2.3.2 BAU technology distribution and specifications

The following two table present the BAU technology distribution and technical specifications of available technologies in Lebanon.

Table 4. BAU technology distribution and specifications

Technology		BAU distribution
Space heating technologies	Gas boilers – conventional	27.5%
	Diesel boilers	30.0%
	Direct electricity	20.0%
	Heat Pumps (any source) - COP 3	0.0%
	Heat Pumps (any source) - COP 4	0.0%
	Heat Pumps (any source) - COP 5	0.0%
	SWHs	0.0%
	Biomass boilers – conventional	22.5%
Water heating technologies	Diesel boilers (HW)	18.75%
	Gas+Biomass boilers (HW)	42.50%
	Electric+Heatpumps (HW)	20.00%
	Solar water heaters (HW)	18.75%
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	100%
	Mechanical ventilation w heat recovery 50%	0%
	Mechanical ventilation w heat recovery 90%	0%

Technical specification				Efficiency / U-value
Space cooling technologies	Air conditioners	o	Efficiency (COP)	2.50
		+	Efficiency (COP)	3.50
		++	Efficiency (COP)	4.50
Building envelope	Windows*	o	g value 0.8	4.90
		+	g value 0.65	2.10
		++	g value 0.55	1.10
	Infiltration rate	o	volume per hour	0.30
		+	volume per hour	0.20
		++	volume per hour	0.10
	Insulation thickness Façade*	o	U-value [W/m^2.K]	1.40
		+	U-value [W/m^2.K]	0.75
		++	U-value [W/m^2.K]	0.45
	Insulation thickness Roof*	o	U-value [W/m^2.K]	2.30
		+	U-value [W/m^2.K]	1.15
		++	U-value [W/m^2.K]	0.45
	Insulation thickness Slab/Ground*	o	U-value [W/m^2.K]	2.80
		+	U-value [W/m^2.K]	1.15
		++	U-value [W/m^2.K]	0.65
	Shadowing measures	o	Shadowing factor	1.00
		+	Shadowing factor	0.75
		++	Shadowing factor	0.50

*: u-values including heat bridge factor

2.3.3 Used parameters of the efficiency cases

A good example for explaining which calculation parameters are used for efficiency cases is a solar thermal subsidy program or even an obligation. This program is designed to subsidize solar thermal systems in new constructions for hot water generation. Therefore, the only effect this policy measure will have is to increase the share of solar thermal systems in new constructions. But instead of estimating the resulting technology shares in this segment, the assessment would look as follows:

		BAU	2021-2025
Water heating technologies	Diesel Boilers	18.8%	0%
	Gas Boilers	20.0%	0%
	Electric	20.0%	0%
	Biomass boilers	22.5%	0%
	Heat Pumps (any source) - COP 3	0.0%	0%
	Heat Pumps (any source) - COP 4	0.0%	0%
	Heat Pumps (any source) - COP 5	0.0%	0%
	Solar water heaters	18.8%	100%

It can be seen that the new program does not affect any other technology as it is just promoting solar thermal systems (therefore 100% on solar thermal). The tool will later combine this “quality input” with the “quantity input” which is the “Affected share new construction [%] “:

		Affected share new construction [%] 2021-2025
Water heating technologies	Diesel Boilers	10%
	Gas Boilers	
	Electric	
	Biomass boilers	
	Heat Pumps (any source) - COP 3	
	Heat Pumps (any source) - COP 4	
	Heat Pumps (any source) - COP 5	
	SWHs	

In case the program is a subsidy program, the question is which share of the new constructions will be touched (reached) by this program. This could for example be 10%, meaning that 10% of all new construction would use this solar thermal subsidy program to install a solar thermal system on the roof. In case it is an obligation to install solar thermal system, the affected share would be 100% if we assume the compliance rate would be 100%. The tool afterwards will use this assumption on the affected share in combination with the quality input and the BAU distribution to calculate the resulting technology mix in new constructions. Assuming the solar thermal subsidy program example above and using the BAU distribution presented in chapter 2.3.2, the tool would conduct the following calculation to determine the share of technologies in new constructions as a result from the solar thermal subsidy program:

10%*

		2021-2025
Water heating technologies	Diesel Boilers	0%
	Gas Boilers	0%
	Electric	0%
	Biomass boilers	0%
	Heat Pumps (any source) - COP 3	0%
	Heat Pumps (any source) - COP 4	0%
	Heat Pumps (any source) - COP 5	0%
	Solar water heaters	100%

+90%*

		BAU
Water heating technologies	Diesel Boilers	18.8%
	Gas Boilers	20.0%
	Electric	20.0%
	Biomass boilers	22.5%
	Heat Pumps (any source) - COP 3	0.0%
	Heat Pumps (any source) - COP 4	0.0%
	Heat Pumps (any source) - COP 5	0.0%
	Solar water heaters	18.8%

Result

		Result
Water heating technologies	Diesel Boilers	16.9%
	Gas Boilers	18.0%
	Electric	18.0%
	Biomass boilers	20.2%
	Heat Pumps (any source) - COP 3	0.0%
	Heat Pumps (any source) - COP 4	0.0%
	Heat Pumps (any source) - COP 5	0.0%
	Solar water heaters	26.9%

2.4 Integrated module

Calculating target distribution and affected share of the Integrated Module

Policy bundle	Type	Technology	Target distribution	Affected share new construction [%]
2	Voluntary	Gas boilers - conventional	10%	25%
		Gas boilers - condensing	60%	
		Direct electricity	0%	
		Heat Pumps (any source) - COP 3	5%	
		Heat Pumps (any source) - COP 4	15%	
		Heat Pumps (any source) - COP 5	9%	
		Solar water heaters	1%	
		Biomass boilers - conventional	0%	
		Biomass boilers - efficient	0%	

Target distribution of the Integrated Module

- In general: Target distribution shares per technology are weighted according to the affected shares of the different measures / packages of measures.
- Exception: Prioritize mandatory measures: consider phased out technologies with maximum share from single mandatory measures as basis. Just remaining share (if any) will be considered for weighting with other technologies.
- Total sum of new calculated target shares will be adjusted to 100%.

Affected share of the integrated module

a) Minimum limitation = Maximum share of single measures/packages' affected share
b) Maximum limitation = 100%
c) Final affected share can be entered manually between a) and b) if not due to a) already at 100%

2.5 Guidehouse's Building Energy Performance (BEP) Tool

The tool allows to calculate the energy demand (useful, final and primary energy) and greenhouse gas emissions as well as the global costs for several energy efficiency measures for buildings. This includes the investments for heating, ventilation and air-conditioning (HVAC) systems, photovoltaics / solar thermal, insulation and shading measures, but also their maintenance and the resulting energy costs over the calculation period. Potential residual values of investments and earnings through PV feed in are considered in the costs. Figure 3 shows the inputs, calculation steps and the relevant results in the present case.

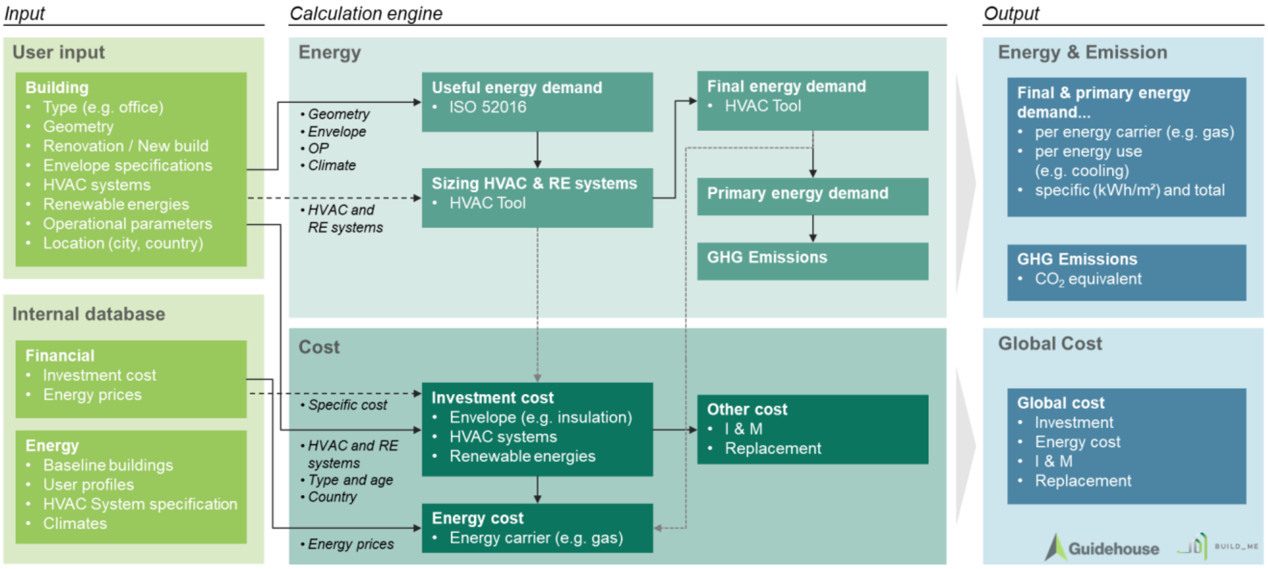


Figure 3. BEP Tool calculation procedure

Relevant **inputs** for the energy performance of the building are the geometries of the envelope, the number of inhabitants, the assumed operational parameters and the HVAC systems to consider. The climate data is, like the entire energy calculation, hourly based and extracted from Meteonorm 7. Furthermore, the country's primary energy factors and a reality factor are mandatory input parameters. As the consumption does not equal the calculated energy demand of a building (which is normal), the reality factor considers typical user behaviour to avoid too high energy costs including a conditioning factor that represents the average share of the building unit that is being conditioned (heated and cooled). Many low-income households are living in cold parts of the country, having limited financial means for heating up their houses. In those cases, often not all parts of the building are heated in the same way and people do not heat their building during the entire heating period to e.g., 20°C. Often, e.g., sleeping rooms, kitchens, bathrooms etc. are not heated or cooled. Therefore, a significant discrepancy between theoretical demand and actual consumption can occur.

The subsequent cost calculation is based on system investment cost and energy prices - collected from local country experts – and assumptions for price increase as well as the country's inflation and interest rate. The first step of the energy calculation is determining the useful energy demand, which depends on the envelope of the building, internal heat gains and operational parameters as well as the climate conditions. This step is calculated according to the international standard for building calculation norm (ISO 52016). Consequently, the final energy demand is determined based on the defined HVAC system. The dimensioning of the systems is calculated by the tool, considering the useful energy demand and the building's size. The reality factor considers that non- or partly refurbished buildings often have less real energy consumption than calculated by the ISO norm, since they adapt their heating and cooling behaviour.

2.6 Guidehouse's Global Building Stock (GLOBUS) Model

The prediction of the future building stock development has been done with Guidehouse's Global Building Stock Model (GLOBUS). GLOBUS uses an algorithm for calculating the size of the building stock applying correlations between economic strength (measured in Gross domestic product per capita) and available floor space per capita based on literature and own research projects. Population growth data is extracted from the "United States Census Bureau" and GDP growth assumptions from the International Energy Agency´s World Energy Outlook (WEO).

The methodology allows the calculation of residential and non-residential floor space separately and is based on Guidehouse` experiences in building stock research. The model and its underlying formulas are based on building stock statistics from about 50 countries worldwide and has continuously improved over recent years.

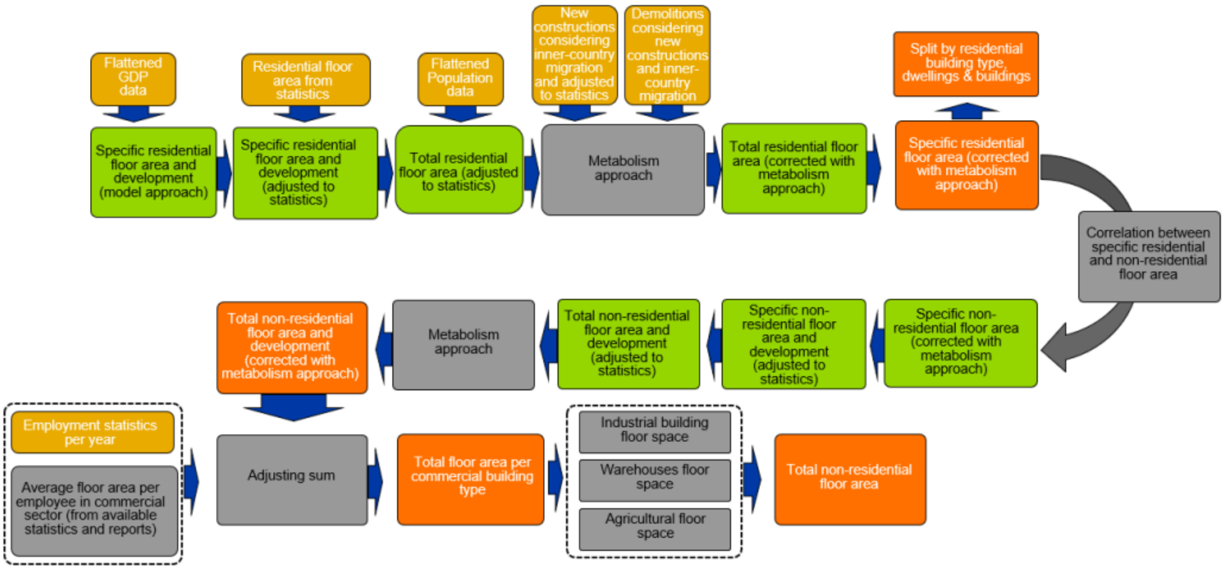


Figure 4. Illustration of the overall approach of Guidehouse's GLOBUS Model

The original model is based on Isaac et al. (2009) that used country-specific correlations between economic strength (measured in GDP/capita) and residential living space per capita to estimate the overall residential building stock size. This average floor space indication does not differentiate between different building categories such as detached and attached single- and multi-family houses. Over time, also other literature was identified that used a similar methodology (Bertraud, 2010 and Bloom, Wheelock, 2011). The author during this time working on his own scientific research compared the different data points and formulas provided in the literature and complemented with his own collected data points. Based on all described sources and his own research, the author developed the green curve presented in Figure 5 and building his own correlation between economic strength and residential living space. Over time, the underlying formula has been used and validated in several research projects.

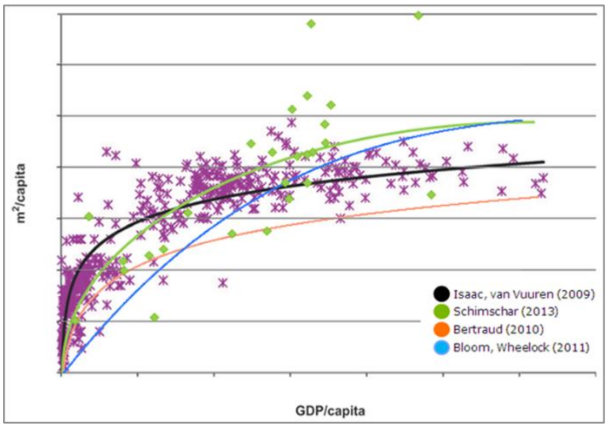


Figure 5. Correlation between GDP per capita and available floor space per capita

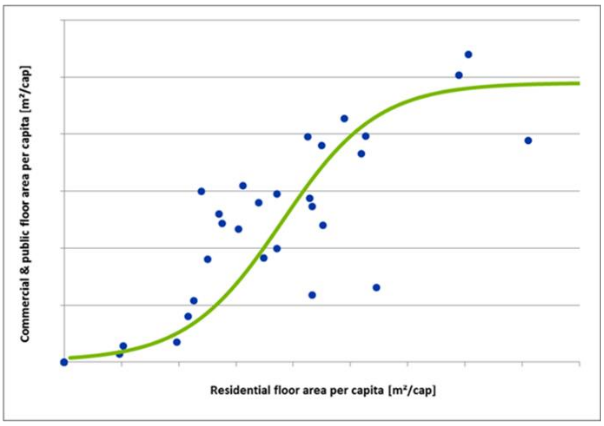


Figure 6. Illustration of floor area correlation between the residential and the non-residential sector

For international studies, the model uses population growth data from the UN World Population Prospects and GDP growth assumptions from the OECD Economic Outlook – "Long-term growth scenarios" and the IEA WEO.

In GLOBUS, we define non-residential buildings as those buildings of the tertiary economic sector (commercials), the secondary economic sector (industry) and the primary economic sector (agriculture, forestry and fishing). Using NACE activities (Statistical classification of economic activities in the European Community) for defining the relevant building types, the tertiary economic sector covers NACE sections G to S, the secondary economic sector covers sections B to F and the primary sector is represented by section A.

Over a considerable period, the author has analysed many correlations the literature indicated as relevant for characterizing non-residential building stocks, but finally no generally valid mathematical relationship between these values could be found. Analysed parameters comprised

- services value-added per capita in this sector,
- services electricity use per capita,
- energy use per service sector value added,
- GDP per capita,
- share of non-residential sector output compared to total GDP,
- the electricity price and household living area per capita.

Although the results of some developed formulas seemed to be applicable to about half of the analysed countries, they were never transferable to all the considered countries. Therefore, a more pragmatic approach had to be developed and one relationship was always visible: The non-residential floor area per capita is proportionally large or small when also the residential living area per capita is large or small. Hence, this connection was analysed in more detail and finally it was possible to develop a formula leading to a high grade of conformity for most of the countries. The identified correlation between the residential and non-residential floor space is presented in Figure 6.

2.7 Reference building specifications

We considered information from partners and experiences from other building sector related projects in the MENA region and therefrom designed one reference building with an average geometry that suits the requirements of the impact assessment and allows calculating representative results. It is a six story multi-family house with one attached wall as often constructed in the urban centers of the MENA region. The details of the geometry etc. are presented in Table 5.

Table 5. Reference building specifications

Building parameter	Unit	Value
Inhabitants	-	69
Thermal building class	-	Very light (80,000 J/K)
Building levels (floors)	-	6
Floor height (Floor to ceiling)	M	2.90
Net floor area (i.e., living area)	m²	2,073
Roof area	m²	350
Façade area opaque	m²	928
Thereof north	m²	382
Thereof east	m²	0
Thereof south	m²	382
Thereof west	m²	164
Window area transparent	m²	242
Thereof north	m²	92
Thereof east	m²	0
Thereof south	m²	100
Thereof west	m²	50
Area floor slap	m²	350

2.8 Reference climate used

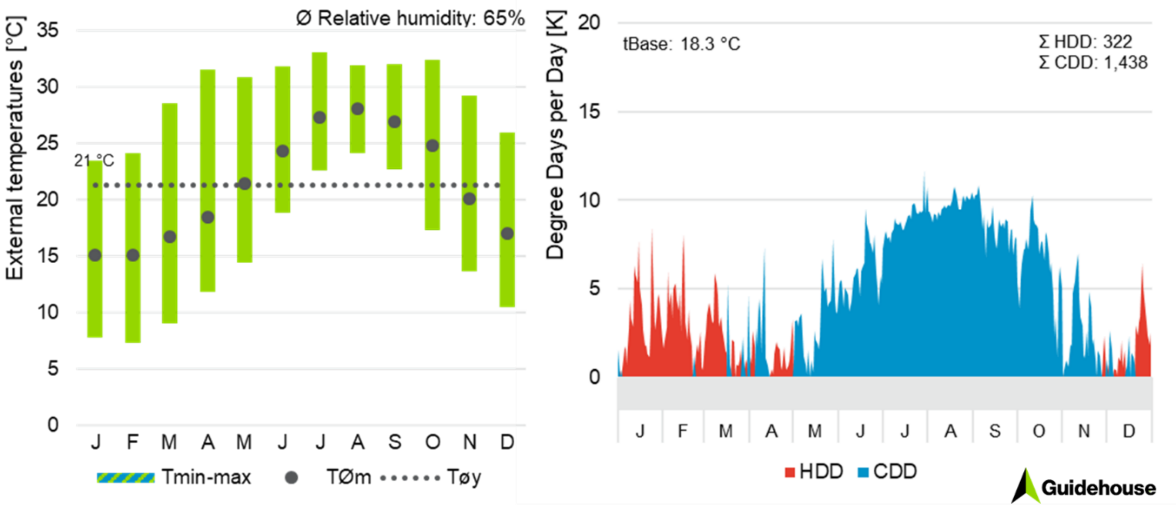
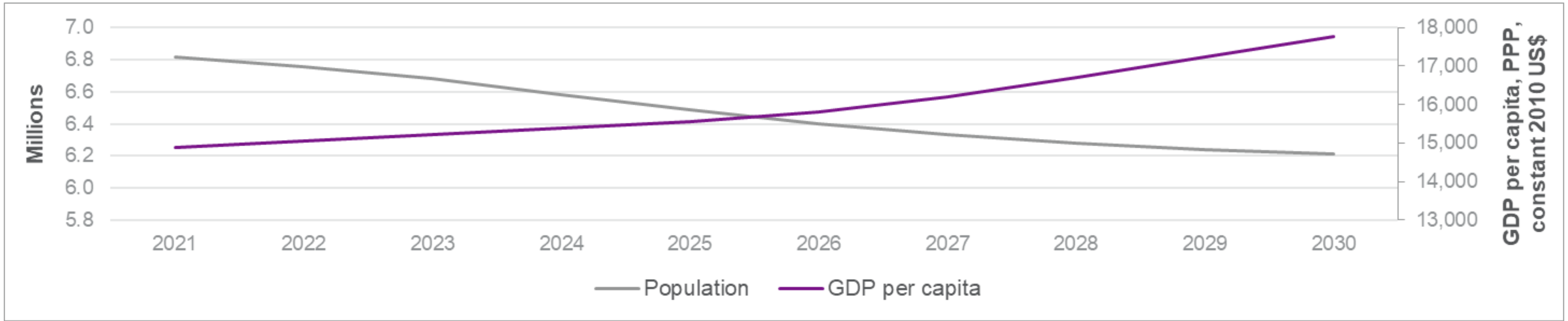


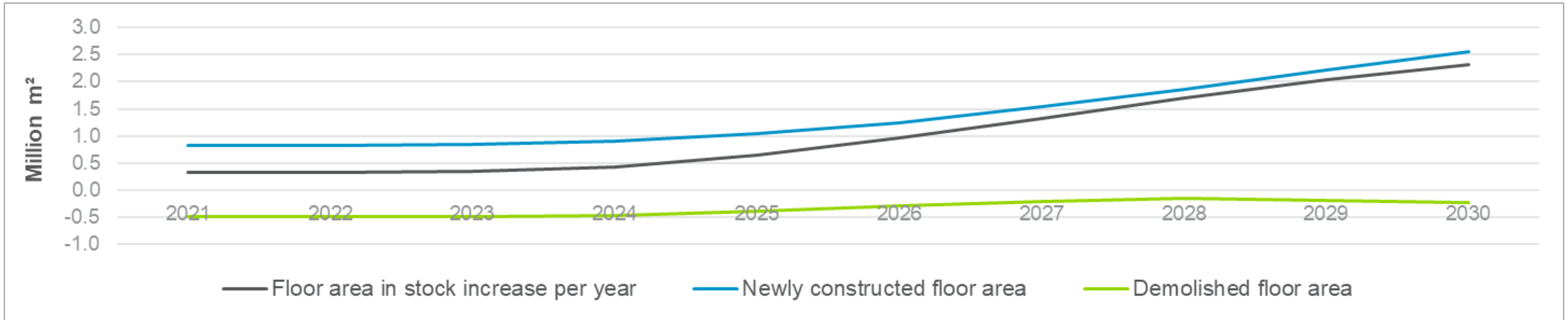
Figure 7. Reference climate - Beirut

Source: Guidehouse based on Meteonorm data

Temperatures in Beirut historically range from above 5°C to about 35"C with a mean temperature of ~21°C. Cooling degree days of more than 1,400 CDD compared to only 320 heating degree days indicate high cooling loads and low need for heating. With dry summers and rainy winters, the average relative humidity is ~65%.

2.9 Building Stock Projections (GLOBUS)





Parameter	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Floor area in stock [m²]	m²	197,310,120	197,642,593	197,995,197	198,429,691	199,078,437	200,032,340	201,354,527	203,060,469	205,088,990	207,412,132
Growth rate	%/a	0.17%	0.17%	0.18%	0.22%	0.33%	0.48%	0.66%	0.85%	1.00%	1.13%
Demolition rate	%/a	-0.25%	-0.25%	-0.25%	-0.24%	-0.19%	-0.15%	-0.11%	-0.08%	-0.09%	-0.11%
New construction rate	%/a	0.42%	0.42%	0.43%	0.46%	0.52%	0.63%	0.77%	0.92%	1.09%	1.24%
Demolished floor area		-492,448	-493,275	-494,106	-475,461	-386,612	-294,893	-211,066	-156,380	-183,994	-220,740
Newly constructed floor area	m²	823,471	825,749	846,710	909,955	1,035,358	1,248,796	1,533,253	1,862,322	2,212,515	2,543,883

3. Policy packages assessed

3.1 Introduction

3.1.1 Methodology of assessed policy packages

The assessed policy packages are prepared by Guidehouse in cooperation with the LCEC in an iterative process consisting of:

- an evaluation of the implementation status of all building specific measures of the National Energy Efficiency Action Plan for Lebanon (NEEAP 2016- 2020),
- an evaluation of the implementation status of BUILD_ME phase 1 recommendations, and
- additional discussions between LCEC and Guidehouse experts.

In the first step the NEEAP 2016-2020 building specific measures were evaluated in terms of the extent to which they have been implemented in the Lebanese policy cycle in recent years. All information available at the time of writing has been used for this evaluation. In addition, relevant statistics on the implementation and information on ongoing activities of each measure were provided by LCEC wherever data availability made this possible. Based on the evaluation, some of the building specific NEEAP 2016-2020 end-use measures are recommended to be re-initiated to reaffirm their relevance and are therefore part of the assessed policy packages.

In a next step the BUILD_ME phase 1 recommendations were evaluated regarding their status of implementation and potential barriers. The BUILD_ME phase 1 recommendations were assessed between 2016 and 2018 with many stakeholders to create a broad and robust fact base on energy efficiency in buildings in Lebanon. Based on these findings, a set of policy modules per stakeholder group was compiled to address the identified barriers for the development of the building sector in Lebanon towards a sustainable future. In a three-part approach, the rationale, implementation status and impacts were analysed. The overall approach of the impact assessment was to develop policy modules containing a description of the different measures, their quantitative impacts and an outline on how to implement them.[1]

To complement the already existing measures for the building sector, further measures were specified in joint meetings between Guidehouse and LCEC, whose implementation in the Lebanese building sector has not yet been achieved. In order to get a better overview, the measures were grouped into the following policy packages with different characteristics and unique code:

- Information and training on financing energy efficiency projects (Code: PP_02)
- Mandatory standards for energy-efficient equipment (Code: PP_03)
- Mandatory standards for energy efficiency in new constructions (Code: PP_06)
- (Financial) incentives for energy efficiency (Code: PP_08)

[1] For more detailed information on the methodology of the following policy recommendations of the first project phase findings of BUILD_ME visit https://www.buildings-mena.com/info/progress-reports-2016-2018 and download the Lebanese progress report 2016-2018.

3.1.2 Projected impact shares of technologies for space heating and DHW 2021-2030

The calculation of the projected shares of impact of each of the packages on each technology contributing to the space heating and domestic hot water is based on the measures included in each package. The baseline technology shares for space heating and domestic hot water (DHW) are those used in the National Renewable Energy Action Plan (NREAP 2020-2025) under preparation. Given the current circumstances in Lebanon, only the optimistic scenario considers the installation of heat pump technologies whereas the other scenarios realistic and pessimistic do not consider any growth in the heat pumps market. The SWH technologies are considered in the three scenarios with different penetration rates. The NREAP projections are not final, however they give an idea about the market expectations.

3.1.3 Proposed initiatives for the building sector in the NEEAP 2020-2025

The section below details the impact of each proposed initiative on the integration and withdrawal of several technologies in the Lebanese market. It should be noted that the impact of each package is considered separately. The percentage shares represent how much this package has an impact on the corresponding technology. For each field, there is a share estimated of new construction affected. The integration of the impact assessment share and the share of affected building is later to estimate the new shares of each technology for space heating, DHW, ventilation, space cooling, and other building configuration measures.

3.2 Information and training on financing energy efficiency projects (Code: PP_02)

3.2.1 Included measures

Information and training on financing energy efficiency projects

- Raise awareness of the end user on the social, economic and environmental benefits of energy-efficient and renewable energy solutions in the building sector
- Offer training and capacity building to support bank officers in understanding the context and business opportunities of Energy Efficiency lending, with a focus on efficient heating and cooling
- Implement faster methods for loan approvals

Table 6. Measure of policy package PP_02 (Source: BUILD_ME phase 1)

Raise awareness of the end user on the social, economic and environmental benefits of energy-efficient and renewable energy solutions in the building sector	
Short description:	Lack of awareness of the added benefits for the country for every kWh saved or produced with renewable power compared to business-as-usual and how reduction in energy subsidies could translate in improved public services. Lack of awareness on the impacts of climate change in Lebanon for future generations. Lack of awareness of end-users on the existence of loans and the possibility to retrofit their residents to reduce their energy consumption. Advertisements should raise the awareness of citizens in their role in reducing the public debt of the country by reducing their energy consumption by investing today in energy-efficient and renewable solutions. A national website grouping all information on the potential of energy efficiency measures in residential households and the contacts of certified Energy Service Companies (ESCOs) able to implement these measures should be built. Lessons from the campaign “Deutschland Macht Effizienz” (Germany goes for Efficiency) can be transferred. To be most effective at changing traditional ideologies, campaigns should target universities and schools and introduce curriculums on impacts of climate change and mitigation measures. Finally, all new public buildings should have at their entrance their Energy Performance Certificate and market how energy-efficient solutions are reducing the energy bill of the building and saving CO_2 emissions. This measure has been taken in Germany and proven to be effective at raising awareness.
Type of policy:	Informational
Target group:	End user (e.g., homeowners)
Potential barriers of measure:	Economic situation which might affect National Energy Efficiency and Renewable Energy Action (NEEREA) loans
Part of NEEAP 2016-2020?	Yes
Implementation for NEEAP 2021-2025 recommended?	Yes

Table 7. Measure of policy package PP_02 (Source: BUILD_ME phase 1)

Offer training and capacity building to support bank officers in understanding the context and business opportunities of Energy Efficiency lending, with a focus on efficient heating and cooling technologies	
Short description:	Because of the non-conventionality of the cash flows of an energy-efficient asset, bankers do not understand how to value energy-efficient solutions and consider their applications similar to normal goods, instead of depreciable assets.
Measure proposed by:	Banks
Type of policy:	Informational / Organizational
Target group:	Bank officers
Potential barriers of measure:	The current economic situation might affect the issuing of NEEREA loans.
Part of NEEAP 2016-2020?	Yes
Implementation for NEEAP 2021-2025 recommended?	Yes

Table 8. Measure of policy package PP_02 (Source: BUILD_ME phase 1)

Implement faster methods for loan approvals	
Short description:	The application for a NEEREA loan can be time consuming. Applications need to go first through a commercial bank, then to Banque de Liban (BDL) for approval and then BDL transfers the technical report to LCEC who acts as the technical arm for BDL and reviews the applications. The application is then reviewed and shared back and forth between the consultant in charge of the application and LCEC. Bankers lacked the knowledge to take an educated opinion once they received the application and transfer any issue to LCEC. Since there existed no list of eligible technologies and products that could qualify for a NEEREA loan at the time when the loan was initiated, every application came with a new technology from a certain supplier. LCEC had to cross check the quality of supply and ensure that applications from the consultants are complete and up to standard, which may have caused delays in application approval.
Measure proposed by:	Banks
Type of policy:	Organizational / Administrative
Target group:	Loan approval processes
Potential barriers of measure:	Economic situation which might affect NEEREA loans
Part of NEEAP 2016-2020?	No
Implementation for NEEAP 2021-2025 recommended?	Yes

3.2.2 Technology distribution and affected shares

In order to estimate the penetration rate of each of the proposed technologies in this package, it was assumed that awareness will be risen on the technologies with the highest cost benefit analysis and that can benefit from financial incentives. Package 2 should focus on introducing new technologies to the market; thus, the impact of this package is distributed on the different levels of heat pumps for space heating in addition to the SWH technology for DHW generation.

Table 9. IA Distribution of impact shares for space heating technologies of policy package 2

Space heating technology	Gas boilers	Diesel Boilers	Direct electricity	Heat Pumps (any source) - COP 3	Heat Pumps (any source) - COP 4	Heat Pumps (any source) - COP 5	Solar water heaters (space)	Biomass Boilers
Target distribution 2021-2024	0.00%	0.00%	0.00%	35%	45%	20%	0.00%	0.00%
Target distribution 2025-2027	0.00%	0.00%	0.00%	30%	45%	25%	0.00%	0.00%
Target distribution 2028-2030	0.00%	0.00%	0.00%	25%	40%	35%	0.00%	0.00%

As expressed in Table 9, the shares of the impact of package 2 for space heating technologies is distributed among the heat pumps (all COPs). The main target of the measures of package 2 will be dedicated to introducing heat pump technology into the market and increase its momentum.

Table 10. Assumed affected shares of policy package 2 for space heating technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
15	25	35

It is expected that the share of the affected new construction from package 2 to start with 15% in the first period of the implementation of the measures of package 2 and to grow linearly until it reaches 35% at the end of third interval.

Table 11. IA Distribution of impact shares for DHW technologies of policy package 2

DHW	Diesel boilers (HW)	Gas Boilers	Electric	Biomass boilers	Heat Pumps (any source) - COP 3	Heat Pumps (any source) - COP 4	Heat Pumps (any source) - COP 5	Solar water heaters (HW)
Target distribution 2021-2024	0.00%	0.00%	0.00%	30%	10%	10%	0.00%	50%
Target distribution 2025-2027	0.00%	0.00%	0.00%	20%	15%	8%	5%	53%
Target distribution 2028-2030	0.00%	0.00%	0.00%	10%	15%	13%	8%	55%

The distribution of the shares of the impact for DHW technologies are represented in the table above, already running awareness programs for biomass and SWHs causes the high share of the impact of this package for these two technologies. However, the measures of package 2 are expected to focus more on heat pumps (all COPs).

Table 12. Assumed affected shares of policy package 2 for DHW technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
15	25	35

It is expected that the share of the affected new construction from package 2 to start with 15% in the first period of the implementation of the measures of package 2 and to grow linearly until it reaches 35% at the end of third interval.

The total percentage share of the impact of package 2 and the affected new construction will be used to calculate the projected shares of each technology for the same period.

The impact of this package is represented in the increasing share of biomass boilers (financed by NEEREA), heat pumps (all COPs) and the decreasing share of the diesel and gas boilers as well as the share of direct electricity on the long run-in comparison to the projected shares.

Table 13. IA Distribution of impact shares for mechanical ventilation technologies of policy package 2

	Mechanical Ventilation		
	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	Mechanical ventilation w heat recovery 50%	Mechanical ventilation w heat recovery 90%
Target distribution 2021-2024	0.0%	50.0%	50.0%
Target distribution 2025-2027	0.0%	40.0%	60.0%
Target distribution 2028-2030	00.0%	30.0%	70.0%

Table 14. Assumed affected shares of policy package 2 for mechanical ventilation technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
2.5	7.5	12.5

The measures of package 2 target the introduction of mechanical ventilation with heat recovery. In the later intervals, the focus increases on mechanical ventilation with 90% heat recovery since the cost increment is relatively low.

Table 15. IA on other qualities of policy package 2

	Space cooling technologies	Windows	Infiltration rate	Insulation Thickness			Shadowing measures (window shading)
				Facade	Rooftop	Ground	
Target distribution 2021-2024	++	+	o	+	+	+	+
Target distribution 2025-2027	++	+	o	+	+	+	+
Target distribution 2028-2030	++	++	o	++	++	++	+

For space cooling technologies we can see fast improvement since package 2 targets highest efficiency equipment which is easier to adopt by project developers than the other building configuration which in turn improves over the projection period.

3.3 Mandatory standards for energy-efficient equipment (Code: PP_03)

3.3.1 Included measures

Mandatory standards for energy-efficient equipment

- Enforce mandatory energy performance standards for heating and cooling equipment being imported in the country
- Incentivize suppliers to import energy-efficient technologies by facilitating import procedure
- Build capacity at the supplier's floor staff level on the economic and environmental benefits of energy-efficient technologies imported in the country (after finalizing MEPS)
- Promote heat recovery system on diesel generators (accounts for only 1 % of NEEREA projects) for the heating of DHW (target military barracks)

Table 16. Measure of policy package PP_03 (Source: BUILD_ME phase 1)

Enforce mandatory energy performance standards for heating and cooling equipment being imported in the country	
Short description:	One of the main barriers project developers are facing in implementing energy-efficient solutions is the fear of losing a competitive edge with other developers, who chose low-cost equipment to sell apartments at minimum upfront cost to their customers. By banning the import of technologies that do not respect the Minimum Energy Performance Standards (MEPS) from entering the market, authorities can ensure project developers have the same level playing field. In addition, MEPS would facilitate the sales of efficient equipment in retail stores as equipment will be using energy labelling. Stakeholders involved: Ministry of Energy and Water, Ministry of Economy and Trade, the Ministry of Industry (for local manufacturing) and the Ministry of Finance through the Directorate of General Customs
Type of policy:	Regulation
Target group:	Heating and cooling equipment / Technology suppliers
Potential barriers of measure:	Commitment from Ministry of Economy and high cost of EE solutions
Part of NEEAP 2016-2020?	No (not explicitly for imported products)
Implementation for NEEAP 2021-2025 recommended?	Yes

Table 17. Measure of policy package PP_03 (Source: BUILD_ME phase 1)

Incentivise suppliers to import energy-efficient technologies by facilitating import procedure	
Short description:	One of the main barrier's suppliers are facing in importing energy-efficient technologies is the fear of losing the competitive advantage over other suppliers who have chosen low-cost equipment in order to sell it to their customers at minimal upfront costs. By banning the import of technologies that do not respect the MEPS from entering the market, authorities can ensure suppliers have the same level playing field. In addition, MEPS would facilitate the sales of efficient equipment in retail stores as equipment will be using energy labelling. The first step would be to impose high fines on products not meeting requirements or producers' labels, then to enforce MEPS to ban products with low energy performance. Furthermore, to upgrade Industrial Research Institute (IRI) laboratory facilities to facilitate the testing procedures and standards, then to upgrade IRI's testing facility to test energy performance measures (IRI to follow international standards and certifications to reduce the level and time of testing), and to increase its capacity in order to decrease response time. In the meantime, LIBNOR - The Lebanese Standards Institution would prepare standards for efficiency requirements. Products that are already certified from accredited laboratories abroad, and that have the correct energy performance labels would benefit from reduced testing requirements.
Type of policy:	Regulation / Financial incentive
Target group:	Technology suppliers
Potential barriers of measure:	Cooperation with the Ministry of Finance; training of customs personnel to identify products that are eligible for tax waive off
Part of NEEAP 2016-2020?	No
Implementation for NEEAP 2021-2025 recommended?	Yes

Table 18. Measure of policy package PP_03 (Source: BUILD_ME phase 1)

Build capacity at the supplier's floor staff level on the economic and environmental benefits of energy-efficient technologies imported in the country (after finalizing MEPS)	
Short description:	Our interviews with 300 consumers carried out in the BUILD_ME project phase 1 (2016-2018) in Lebanon proved that the biggest driver for them to purchase an energy-efficient heating or cooling technology at a retail store is the ability of the vendor to present convincing arguments to defend the case. Vendors should guide customers in their purchase, explaining that the benefits of energy efficiency pay off over the lifecycle of the equipment and how the present value of the technology should be their decision factor for a profitable investment. They should inform them about the possibility of a financing mechanism to cover the additional upfront cost. The second factor driving consumers in Lebanon to purchase energy-efficient technologies was the presence of an energy efficiency label, hence the importance of finalizing the MEPS in Lebanon. Intensive capacity building activities for the suppliers' floor staff level is needed to equip them with the correct knowledge to better sell and favour heating and cooling technologies with higher energy efficiency even at higher costs, informing consumers about available financing options. This needs to be combined with a labelling scheme and a widespread public awareness campaign.
Type of policy:	Regulation / Organizational
Target group:	Technology suppliers
Potential barriers of measure:	Requires approval of Council of Ministers and Member of Parliament to become mandatory
Part of NEEAP 2016-2020?	No
Implementation for NEEAP 2021-2025 recommended?	Yes – Can be consolidated with Measure of policy package PP_03 (Source: BUILD_ME phase 1) and Measure of policy package PP_03 (Source: BUILD_ME phase 1).

Table 19. Measure of policy package PP_03 (Source: Additional measure)

Promote heat recovery system on diesel generators	
Short description:	With the widespread use of private diesel generators in Lebanon, as a result of the supply shortage of electricity from the main utility, promoting heat recovery systems on diesel generators with long operational times could play a major role in decreasing energy consumption related to space and water heating. Possible lock-in effects of other renewable energy systems (e.g., solar thermal) should definitely be considered.
Type of policy:	Regulation
Target group:	Equipment
Potential barriers of measure:	Adoption of a regulation imposing the mandatory installation of heat recovery systems for private diesel generators with long operational times.
Part of NEEAP 2016-2020?	No

3.3.2 Technology distribution and affected shares

In order to estimate the projected shares of each technology for the different end-use, the impact of the package was distributed among the technologies as follows:

Table 20. IA Distribution of impact shares for space heating technologies of policy package 3

Space heating technology	Gas boilers	Diesel Boilers	Direct electricity	Heat Pumps (any source) - COP 3	Heat Pumps (any source) - COP 4	Heat Pumps (any source) - COP 5	Solar water heaters (space)	Biomass Boilers
Target distribution 2021-2024	25.00%	15.00%	0.00%	15.00%	10%	10%	0.00%	25.00%
Target distribution 2025-2027	20.00%	15.00%	0.00%	10.00%	20.00%	15.00%%	0.00%	20.0%
Target distribution 2028-2030	20.00%	15.00%	0.00%	5.00%	25.00%	20.00%	0.00%	15.00%

Table 21. Assumed affected shares of policy package 3 for space heating technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
80	85	95

Table 22. IA Distribution of impact shares for DHW technologies of policy package 3

DHW	Diesel Boilers	Gas Boilers	Electric	Biomass boilers	Heat Pumps (any source) - COP 3	Heat Pumps (any source) - COP 4	Heat Pumps (any source) - COP 5	Solar water heaters
Target distribution 2021-2024	15.00%	20.00%	0.00%	15.00%	10.00%	10.00%	5.00%	25.00%
Target distribution 2025-2027	10.00%	15.00%	0.00%	15.00%%	10.00%	15.00%	10.00%	25.00%
Target distribution 2028-2030	10.00%	10.00%	0.00%	10.00%	10.00%	20.00%%	15.00%	25.00%

Table 23. Assumed affected shares of policy package 3 for DHW technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
80	85	95

The measures included in this package affect the efficiency of the systems within a certain technology. Hence, all the technologies are affected by this package. We assume that by enforcing MEPS on energy efficiency in heating and cooling, conventional boilers will retire gradually, and thus higher efficiencies will be used. However, the shares of boilers are classified for condensing and conventional which yields results better than those estimated. As for heat pumps, the focus of the package will increase gradually with time for the sake of higher efficiencies.

The measure of the package is set to be compulsory, so it is expected to have high shares of affected new construction. With proper follow-up, the affected share of new construction is expected to approach full compliance towards the last period of projection.

Table 24. IA for space cooling technologies and affected shares of policy package 3 in new constructions

	Target distribution 2021-2024	Target distribution 2025-2027	Target distribution 2028-2030
Space cooling technologies	+	+	++
Affected share new construction [%]	85	90	95

Since this package is targeting the minimum efficiency of systems, space cooling technologies are subjected to the most significant impact. Note that this package has no impact on the ventilation system used as well as the other building configuration as this package focuses on the efficiency of the equipment and systems.

3.4 Mandatory standards for energy efficiency in new constructions (Code: PP_06)

3.4.1 Included measures

Mandatory standards for energy efficiency in new constructions

- Double wall ordinance
- Building code to improve the energy efficiency standard of new buildings
- Reduce window fraction of new constructions
- Update Lebanese building code to include an energy-efficient code for heating and cooling. The code becomes mandatory for all new buildings' construction
- Set a requirement for advance modelling and energy simulations of new buildings (criteria to be set) in order to predict the energy consumption footprint prior to new construction (i.e.: Building Information Modeling – BIM)
- Strengthen enforcement systems in the construction and maintenance phase, applying severe penalties to the engineering design company for non-compliance to the energy efficiency building code and to the facility manager of the residential building for not reporting annual energy consumption

Table 25. Measure of policy package PP_06 (Source: NEEAP 2016-2020)

Double wall ordinance
Short description of measure
This measure aims to: • Set the double wall ordinance that improves a building's envelope performance • Implement the ordinance in 100 buildings (total floor area of 100,000 m^2). Double wall insulation as stated in the Lebanese building code is optional. The aim of this measure is to make the double wall configuration mandatory in the new buildings in Lebanon, by considering the double wall composition as follows: Air, plaster, 10 cm concrete, 5 cm insulation air cavity, 15 cm concrete, 2 cm plaster and air. The overall U_w-value envisaged is 1.57 W/m^2K.
Status of measure implementation
☐ pending ☒ in progress ☐ achieved
Ongoing activities
The adoption of a double wall ordinance is currently still in the legislative process. The ordinance has been implemented in 100 buildings, mostly through the NEEREA financing mechanism. The corresponding statistics have therefore been included in the evaluation of measure "use of efficient equipment."
Suggestion for further development
Accelerate the legislative process and the engagement of the stakeholders involved. It has been shown that the double wall measure can save significant amounts of energy. We suggest, as a measure for the next NEEAP, making this a mandatory measure in new buildings. This aim should be clearly stated in the NEEAP.

Table 26. Measure of policy package PP_06 (Source: NEEAP 2016-2020)

Building code
Short description of measure
This measure aims to improve the energy efficiency standard of new buildings.
Status of measure implementation
☐ pending ☒ in progress ☐ achieved
Ongoing activities
A report to improve the existing building thermal standards including an analysis of the Thermal Standards for Buildings in Lebanon (TSBL 2005), which is the only thermal standard for buildings available in Lebanon is currently being prepared. The analysis is carried out in cooperation with LCEC, LIBNOR and with consultation of several national experts. In addition, a revision and contribution to the draft of the new Building Environmental Performance-Principles, Requirements and Guidelines which was planned to be issued in 2020 but due to the recent developments in the country, it has been postponed being published in 2021. This is also prepared in cooperation with the Lebanese Standards Institutions (LIBNOR) and the LCEC which is currently in the process of drafting a building code.
Suggestion for further development
A building code should be finalized and approved within the period of the coming NEEAP. This building code should be mandatory for all new buildings. A concept on how to ensure the monitoring and enforcement of the building code should be developed.

Table 27. Measure of policy package PP_06 (Source: Additional measure)

Reduce window fraction of new constructions	
Short description:	Solar gains are directly connected to a building's window fraction. Increasing the window fraction increases the demand for cooling and reduces the demand for heating. Decreasing the window fraction has the opposite effect. In areas with a high cooling demand, the southern window fraction should be reduced in order to save cooling energy. Regions with low cooling demand and higher heating demand should increase the southern window fraction and decrease the northern window fraction. Usually, varying the southern window fraction has larger effects than other directions.
Type of policy:	Technical
Target group:	New constructions
Potential barriers of measure:	Architects might be opposing to the idea since it would alter the design. Preference given to natural ventilation and lighting.
Part of NEEAP 2016-2020?	No

Table 28. Measure of policy package PP_06 (Source: BUILD_ME phase 1)

Update Lebanese building code to include an energy-efficient code for heating and cooling. The code becomes mandatory for all new buildings' construction	
Short description:	Engineers in Lebanon oversize heating and cooling systems, prioritizing safety and comfort over efficiency, and do not design control systems to optimise operation and cut energy costs. Heating and cooling load modelling is rarely conducted, back on the envelope calculations are common practice. The Lebanese building code needs to be updated in order to include an energy-efficient code for heating and cooling installations. LIBNOR, the Order of Engineers, LCEC and the Higher Council for Urban Planning cooperate to update and ensure the implementation of the building code. LIBNOR takes the lead to create Lebanese green standards for building codes. The code shall require engineers to submit detailed calculation of the heating and cooling demand of the building, considering passive and active measures in energy efficiency and limiting safety factors to international standards like American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE). LCEC supports LIBNOR in preparing the codes and the Order of Engineers and Architects (OEA) forms a technical committee to review the new codes. Reviewing the building code is crucial for accelerating EE measures at the design level. This recommendation is the base or the starting point for other recommendations such as enforcement, incentives differentiation and accelerating the permitting process as it sets the rules for EE measures and designs.
Type of policy:	Regulation
Target group:	New constructions
Potential barriers of measure:	Potential barrier is to make it mandatory
Part of NEEAP 2016-2020?	In progress
Implementation for NEEAP 2021-2025 recommended?	Yes

Table 29. Measure of policy package PP_06 (Source: Additional measure)

Set a requirement for advance modelling and energy simulations of new buildings (criteria to be set), in order to predict the energy consumption footprint prior to new construction (i.e.: BUILD_ME BEP tool)	
Short description:	To set a requirement for all new buildings to perform energy simulations for new buildings in order to predict the energy consumption footprint prior to the start of construction.
Type of policy:	Regulation
Target group:	Project developers
Potential barriers of measure:	Adoption of regulation; lack of expertise in building modelling
Part of NEEAP 2016-2020?	No

Table 30. Measure of policy package PP_06 (Source: BUILD_ME phase 1)

Strengthen enforcement systems in the construction and maintenance phase, applying severe penalties to the engineering design company for non-compliance to the energy efficiency building code and to the facility manager of the residential building for not reporting annual energy consumption	
Short description:	Most of the projects present an initial plan for the authorities and then undergo multiple modifications without notice. In addition, municipalities inspectors lack the engineering knowledge to inspect the compliance of innovative energy-efficient solutions e.g., air to water heat pumps. Enforcement systems in the construction and maintenance phase need to be strengthened. Severe penalties must be imposed on the engineering design firm in case of improper planning leading to non-compliance with the rules on energy-efficient buildings and on the building manager of the residential building in case of failure to report the annual energy consumption.
Type of policy:	Regulation / Organizational
Target group:	New constructions
Potential barriers of measure:	Lack of financial resources from building owners and facility managers
Part of NEEAP 2016-2020?	No
Implementation for NEEAP 2021-2025 recommended?	Yes

3.4.2 Technology distribution and affected shares

Package 6 focus on limiting the specific energy consumption of buildings which promotes project developers to use the most efficient measures to reach the optimal consumption. However, this package is set to focus on building space cooling systems, ventilation systems, and building configuration.

Table 31. IA Distribution of impact shares for mechanical ventilation technologies of policy package 6

	Mechanical Ventilation		
	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	Mechanical ventilation w heat recovery 50%	Mechanical ventilation w heat recovery 90%
Target distribution 2021-2024	0.0%	50.0%	50.0%
Target distribution 2025-2027	0.0%	30.0%	70.0%
Target distribution 2028-2030	00.0%	10.0%	90.0%

Table 32. Assumed affected shares of policy package 6 for mechanical ventilation technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
5	7.5	10

The impact of package 6 is clear on the ventilation system share distribution, because it enhances updating the building code including the HVAC. Even the measures of package 6 are set to be mandatory, it will focus on promoting mechanical ventilation systems with heat recovery. The affected shares for new construction ranges from 2.5% to 12.5% during the projection period.

Table 33. IA for space other qualities for package 6

	Space cooling technologies	Windows	Infiltration rate	Insulation Thickness			Shadowing measures (window shading)
				Facade	Rooftop	Ground	
Target distribution 2021-2024	+	+	o	+	+	+	+
Target distribution 2025-2027	+	+	o	+	+	+	+
Target distribution 2028-2030	+	+	o	+	+	+	+

For space cooling technologies we can see t improvement since package 6 targets highest standards for building which is easier to adopt by project developers after adopting the measures of package 6. This package will have a significant impact on the qualities mentioned in the table since it targets the implementation of EE measures in new/renovation buildings.

The implementation of the measures of package 6 yields a high compliance rate since the measures are expected to be mandatory. The affected share for the mentioned qualities will be distributed over the projection period as follows:

Table 34. Affected shares for new construction for package 6

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
85	90	100

3.5 (Financial) incentives for energy efficiency (Code: PP_08)

3.5.1 Included measures

(Financial) incentives for energy efficiency

- Regulate laws that enable municipalities to offer incentives for energy-efficient buildings beyond the double wall ordinance
- Differentiate financial incentives between energy efficiency projects, offering highest incentives for projects with highest ambition, and distribute a standard economic tool that can benchmark applications
- Use of efficient equipment

Table 35. Measure of policy package PP_08 (Source: BUILD_ME phase 1)

Regulate laws that enable municipalities to offer incentives for energy-efficient buildings beyond the double wall ordinance

Short description of measure

Municipalities are bound by legislation which restricts their rights to give explicit incentives to energy-efficient buildings. The current building code provides the municipalities the option to give one limited incentive for buildings for the usage of double walls.

Update the law in order to give municipalities a bigger role in the permitting procedure. The municipality, as a local authority, will have a better insight into the projects that are being developed under its authority. After giving the municipalities this power, they could give incentives for new buildings that are more environmentally friendly by prioritizing their applications and giving them incentives such as higher investment opportunities. This needs to be combined with the need to strengthen enforcement systems in order to discourage any free riders.

By offering additional incentives to project developers implementing energy efficiency solutions, municipalities can spur market demand.

Measure proposed by:	Public authorities
Type of policy:	Regulation
Target group:	Municipalities
Potential barriers of measure:	Lack of financial resources at the municipal level
Part of NEEAP 2016-2020?	No
Implementation for NEEAP 2021-2025 recommended?	Yes

Table 36. Measure of policy package PP_08 (Source: BUILD_ME phase 1)

Differentiate financial incentives between energy efficiency projects, offering highest incentives for projects with highest ambition, and distribute a standard economic tool that can benchmark applications	
Short description of measure	
Financial incentives currently exist in Lebanon for applying energy efficiency measures. The current framework does not give an incentive to reach the highest energy savings, it follows a minimum savings only approach. In addition, the financial calculations conducted by engineers in the NEEREA loan application are not detailed enough and simplistic. There is no standard baseline to compare the benefits of the energy efficiency measure to, which makes it impossible for LCEC to benchmark the applications and screen best in class measures. LCEC should develop a standard tool that conducts the cost benefit calculations of different energy efficiency measures, following a) user specific engineering input on the heating and cooling demand of the building b) capital cost of the energy efficiency measure c) technical efficiency of the measure. The tool should be apt to categorize the measures in bronze, silver or gold packages according to the (dynamic) payback period. Measures with shortest payback period are sorted in bronze, longest payback gold. Higher incentives (e.g., increasing grace period, lower interest, increasing floor area) should be granted to gold package. These measures will be the ones with the highest Net Present Value (NPV).	
Type of policy:	Organizational / Financial
Target group:	EE projects
Potential barriers of measure:	Lack of financial resources for incentives
Part of NEEAP 2016-2020?	No
Implementation for NEEAP 2021-2025 recommended?	Yes (Need more information about feasibility and applicability)

Table 37. Measure of policy package PP_08 (Source: NEEAP 2016-2020)

Use of efficient equipment
Short description of measure
This measure aims at using energy-efficient equipment in 200 buildings of 1,000 m^2 each (total floor area tackled around 200,000 m^2 of residential and non-residential buildings excluding public buildings). Energy-efficient equipment in public buildings is covered under “Green procurement for new and existing public buildings” measure and is not included here.
Status of measure implementation
☐ pending ☒ in progress ☐ achieved
Ongoing activities
The LCEC analysed the Lebanese market through extensive surveys that covered both retailers and consumers across all Lebanon and over a period of six months. A national standard and labelling scheme are proposed to be implemented soon as well as resulting policies and measures to incentivise all stakeholders (manufacturers, importers, suppliers and consumers) to promote energy-efficient home appliances. Moreover, the NEEREA financial scheme, an initiative adopted in the first NEEAP, has subsidized energy efficiency projects over the period 2016-2020. The scheme financed over 219 energy efficiency projects delivering a total of 285 GWh of cumulative energy savings. The main technologies/measures financed were building envelope improvement (double wall, thermal insulation, double and triple window glazing), LED lighting systems, efficient HVAC (mainly

VRV[2]/VRF[3] systems), and motion detectors. The projects targeted in particular the commercial and residential sectors, and to a certain extent the industrial sector.
In August 2018 LCEC in partnership with the Italian Ministry of Environment Land and Sea (IMELS) started the Italian Energy-Efficient Home Appliances (IEEHA) Program which aims at reducing the energy demand of Lebanese households by incentivizing the market to shift towards more energy-efficient technologies of Italian brands and/or manufactured in Italy. Consumers will benefit from a financial rebate when purchasing an eligible product from one of the retailers partnering with the program. Expected savings are ~ 0.474 GWh in 2020 and ~ 0.948 GWh in 2021

Suggestion for further development

More awareness campaigns and incentives targeting consumers are needed in order to promote the use of energy-efficient equipment. To promote the use of energy-efficient equipment and the two financing schemes, awareness campaigns should also be conducted for retailers, as they are in direct contact with consumers.

3.5.2 Technology distribution and affected shares

Table 38. IA Distribution of impact shares for space heating technologies of policy package 8

Space heating technology	Gas boilers	Diesel Boilers	Direct electricity	Heat Pumps (any source) - COP 3	Heat Pumps (any source) - COP 4	Heat Pumps (any source) - COP 5	Solar water heaters (space)	Biomass Boilers
Target distribution 2021-2024	20.00%	0.00%	0.00%	30.00%	20.00%	15.00%	0.00%	15.00%
Target distribution 2025-2027	15.00%	0.00%	0.00%	25.00%	25.00%	20.00%	0.00%	15.00%
Target distribution 2028-2030	15.00%	0.00%	0.00%	25.00%	30.00%	20.00%	0.00%	10.00%

Table 39. IA Distribution of impact shares for DHW technologies of policy package 8

DHW	Diesel boilers (HW)	Gas Boilers	Electric	Biomass boilers	Heat Pumps (any source) - COP 3	Heat Pumps (any source) - COP 4	Heat Pumps (any source) - COP 5	Solar water heaters (HW)
Target distribution 2021-2024	0.00%	0.00%	0.00%	5.00%	15.00%	15.00%	5.00%	60.00%
Target distribution 2025-2027	0.00%	0.00%	0.00%	5.00%	10.00%	20.00%	10.00%	55%
Target distribution 2028-2030	0.00%	0.00%	0.00%	5.00%	10.00%	20.00%	15.00%	55%

Financial incentives encourage more developers to go for more efficient measures which is clear from the growth of higher COP heat pumps compared to lower COP heat pumps. Moreover, this package is expected to enhance the efficiency of the gas and biomass boilers.

[2] Variable Refrigerant Volume
[3] Variable Refrigerant Flow

Table 40. Assumed affected shares of policy package 8 for space heating and DHW technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
15	20	25

It is expected that the share of the affected new construction from package 8 to start with 15% in the first period of the implementation of the measures of package 8 and to grow linearly until it reaches 25% at the end of third interval.

Table 41. IA Distribution of impact shares for mechanical ventilation technologies of policy package 8

	Mechanical Ventilation		
	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	Mechanical ventilation w heat recovery 50%	Mechanical ventilation w heat recovery 90%
Target distribution 2021-2024	0.00%	0.00%	100.0%
Target distribution 2025-2027	0.00%	0.00%	100.0%
Target distribution 2028-2030	0.00%	0.00%	100.0%

Table 42. Assumed affected shares of policy package 8 for mechanical ventilation technologies in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
2.5	7.5	12.5

This package will also affect the share of ventilation systems since more project owners will choose more efficient systems for ventilation due to financial incentives. The financial incentives will be oriented totally towards ventilation systems with highest heat recovery.

Table 43. IA for different qualities of policy package 8

	Space cooling technologies	Windows	Infiltration rate	Insulation Thickness			Shadowing measures (window shading)
				Facade	Rooftop	Ground	
Target distribution 2021-2024	++	++	++	++	++	++	++
Target distribution 2025-2027	++	++	++	++	++	++	++
Target distribution 2028-2030	++	++	++	++	++	++	++

Table 44. Assumed affected shares for the qualities above of policy package 8 in new constructions

Affected share new construction [%] 2021-2024	Affected share new construction [%] 2025-2027	Affected share new construction [%] 2028-2030
2.5	7.5	12.5

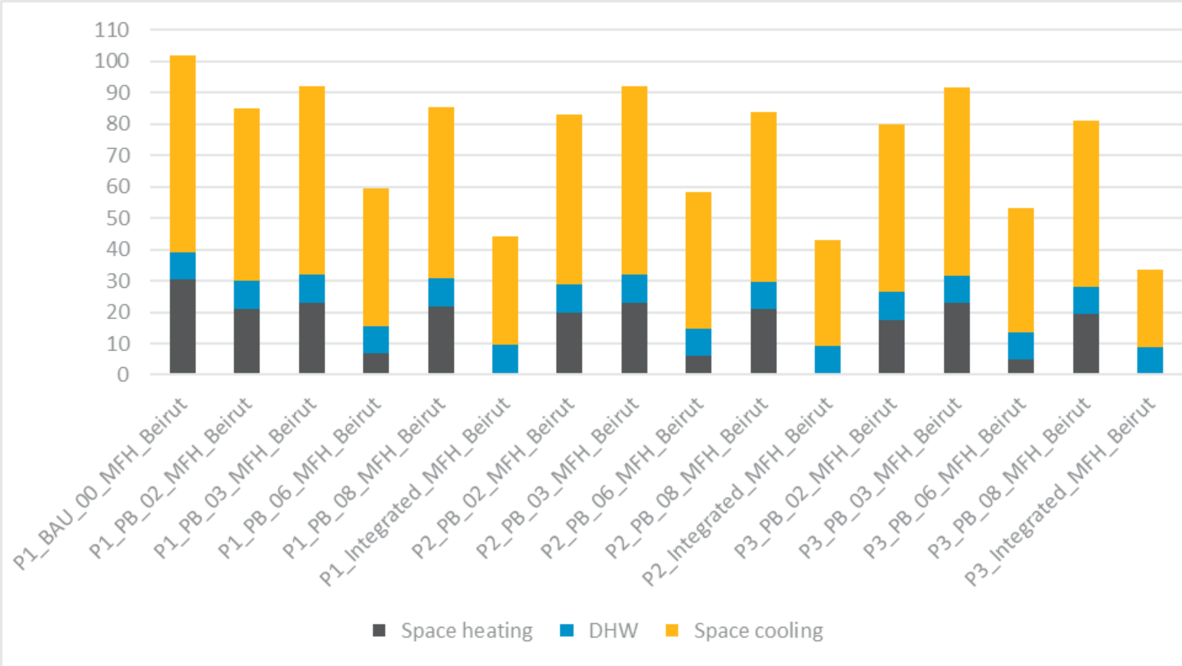
In the presence of financial incentives and enough support of the implementation of energy efficiency measures, the market of the qualities mentioned in the table above will witness significant improvements. Financial incentives targets and support the best-case scenario for each of the mentioned above qualities.

3.6 Integrated module

The “Integrated Module” is a combined package that does not just sum up the results or effects of each single package (2,3,6,8) but considers that in reality there will be overlaps between the packages that of course are just realistic. When a new mandatory building code is implemented, people might still choose for even more ambitious measures e.g., by making use of a support program that is part of another policy package. The integrated module however ensures that the affected share of new constructions cannot exceed 100%, instead it is weighting the effect of the different packages according to their individual affected shares (see chapter 2.4).

4. Results

4.1 Useful-net energy demand calculations on building level



		P1_BAU_00_MFH_Beirut	P1_PB_02_MFH_Beirut	P1_PB_03_MFH_Beirut	P1_PB_06_MFH_Beirut	P1_PB_08_MFH_Beirut	P1_Integrated_MFH_Beirut	P2_PB_02_MFH_Beirut	P2_PB_03_MFH_Beirut	P2_PB_06_MFH_Beirut	P2_PB_08_MFH_Beirut	P2_Integrated_MFH_Beirut	P3_PB_02_MFH_Beirut	P3_PB_03_MFH_Beirut	P3_PB_06_MFH_Beirut	P3_PB_08_MFH_Beirut	P3_Integrated_MFH_Beirut
Total useful specific demand	**kWh/(m²*a)**	102	85	92	60	85	44	83	92	58	84	43	80	92	53	81	34
Space heating	kWh/(m²*a)	30	21	23	7	22	1	20	23	6	21	0	18	23	5	19	0
DHW	kWh/(m²*a)	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Space cooling	kWh/(m²*a)	63	55	60	44	55	35	54	60	43	54	34	54	60	39	53	25

4.2 Final energy demand of policy package reference buildings

4.2.1 Resulting technology shares of policy package 2 (PP_02)

		Bundle result (considering bundle effects and		
		Distribution 2021-2024	Distribution 2025-2027	Distribution 2028-2030
Space heating technologies	Gas boilers - conventional	23.4%	20.6%	17.9%
	Diesel boilers	25.5%	22.5%	19.5%
	Direct electricity	17.0%	15.0%	13.0%
	Heat Pumps (any source) - COP 3	5.3%	7.5%	8.8%
	Heat Pumps (any source) - COP 4	6.8%	11.3%	14.0%
	Heat Pumps (any source) - COP 5	3.0%	6.3%	12.3%
	Solar water heaters	0.0%	0.0%	0.0%
	Biomass boilers - conventional	19.1%	16.9%	14.6%
		0.0%	0.0%	0.0%
Water heating technologies	Diesel boilers (HW)	15.9%	14.1%	12.2%
	Gas+Biomass boilers (HW)	40.6%	36.9%	31.1%
	Electric+Heatpumps (HW)	20.0%	21.9%	25.3%
	Solar water heaters (HW)	23.4%	27.2%	31.4%
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	97.5%	92.5%	87.5%
	Mechanical ventilation w heat recovery 50%	1.3%	3.0%	3.8%
	Mechanical ventilation w heat recovery 90%	1.3%	4.5%	8.8%

4.2.2 Resulting technology shares of policy package 3 (PP_03)

		Bundle result (considering bundle effects and		
		Distribution 2021-2024	Distribution 2025-2027	Distribution 2028-2030
Space heating technologies	Gas boilers - conventional	25.5%	21.1%	20.4%
	Diesel boilers	18.0%	17.3%	15.8%
	Direct electricity	4.0%	3.0%	1.0%
	Heat Pumps (any source) - COP 3	12.0%	8.5%	4.8%
	Heat Pumps (any source) - COP 4	8.0%	17.0%	23.8%
	Heat Pumps (any source) - COP 5	8.0%	12.8%	19.0%
	Solar water heaters	0.0%	0.0%	0.0%
	Biomass boilers - conventional	24.5%	20.4%	15.4%
		0.0%	0.0%	0.0%
Water heating technologies	Diesel boilers (HW)	15.8%	11.3%	10.4%
	Gas+Biomass boilers (HW)	36.5%	31.9%	21.1%
	Electric+Heatpumps (HW)	24.0%	32.8%	43.8%
	Solar water heaters (HW)	23.8%	24.1%	24.7%
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	97.5%	95.0%	92.5%
	Mechanical ventilation w heat recovery 50%	0.0%	0.0%	0.0%
	Mechanical ventilation w heat recovery 90%	2.5%	5.0%	7.5%

4.2.3 Resulting technology shares of policy package 6 (PP_06)

		Bundle result (considering bundle effects and		
		Distribution 2021-2024	Distribution 2025-2027	Distribution 2028-2030
Space heating technologies	Gas boilers - conventional	22.6%	14.4%	4.1%
	Diesel boilers	49.5%	52.5%	55.5%
	Direct electricity	7.0%	5.0%	3.0%
	Heat Pumps (any source) - COP 3	9.8%	11.3%	12.8%
	Heat Pumps (any source) - COP 4	3.3%	7.5%	12.8%
	Heat Pumps (any source) - COP 5	0.0%	3.8%	8.5%
	Solar water heaters	0.0%	0.0%	0.0%
	Biomass boilers - conventional	7.9%	5.6%	3.4%
		0.0%	0.0%	0.0%
Water heating technologies	Diesel boilers (HW)	19.6%	12.2%	2.8%
	Gas+Biomass boilers (HW)	44.1%	48.1%	53.1%
	Electric+Heatpumps (HW)	13.5%	12.5%	11.5%
	Solar water heaters (HW)	22.8%	27.2%	32.6%
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	95.0%	92.5%	90.0%
	Mechanical ventilation w heat recovery 50%	2.5%	2.3%	1.0%
	Mechanical ventilation w heat recovery 90%	2.5%	5.3%	9.0%

4.2.4 Resulting technology shares of policy package 8 (PP_08)

		Bundle result (considering bundle effects and		
		Distribution 2021-2024	Distribution 2025-2027	Distribution 2028-2030
Space heating technologies	Gas boilers - conventional	26.4%	25.0%	24.4%
	Diesel boilers	25.5%	24.0%	22.5%
	Direct electricity	17.0%	16.0%	15.0%
	Heat Pumps (any source) - COP 3	4.5%	5.0%	6.3%
	Heat Pumps (any source) - COP 4	3.0%	5.0%	7.5%
	Heat Pumps (any source) - COP 5	2.3%	4.0%	5.0%
	Solar water heaters	0.0%	0.0%	0.0%
	Biomass boilers - conventional	21.4%	21.0%	19.4%
		0.0%	0.0%	0.0%
Water heating technologies	Diesel boilers (HW)	15.9%	15.0%	14.1%
	Gas+Biomass boilers (HW)	36.9%	35.0%	33.1%
	Electric+Heatpumps (HW)	22.3%	24.0%	25.0%
	Solar water heaters (HW)	24.9%	26.0%	27.8%
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	95.0%	92.5%	90.0%
	Mechanical ventilation w heat recovery 50%	0.0%	0.0%	0.0%
	Mechanical ventilation w heat recovery 90%	5.0%	7.5%	10.0%

4.2.5 Resulting technology shares of the integrated module

		Bundle result (considering bundle effects and		
		Distribution 2021-2024	Distribution 2025-2027	Distribution 2028-2030
Space heating technologies	Gas boilers - conventional	27.4%	27.4%	27.3%
	Diesel boilers	30.0%	30.0%	30.0%
	Direct electricity	19.8%	19.8%	19.8%
	Heat Pumps (any source) - COP 3	0.1%	0.1%	0.1%
	Heat Pumps (any source) - COP 4	0.1%	0.2%	0.3%
	Heat Pumps (any source) - COP 5	0.1%	0.1%	0.2%
	Solar water heaters	0.0%	0.0%	0.0%
	Biomass boilers - conventional	22.5%	22.4%	22.3%
		0.0%	0.0%	0.0%
Water heating technologies	Diesel boilers (HW)	18.7%	18.7%	18.6%
	Gas+Biomass boilers (HW)	42.4%	42.4%	42.4%
	Electric+Heatpumps (HW)	20.0%	20.0%	20.1%
	Solar water heaters (HW)	18.8%	18.9%	18.9%
Mechanical Ventilation	Natural ventilation (windows) or mechanical ventilation w/o heat recovery	99.2%	99.1%	99.0%
	Mechanical ventilation w heat recovery 50%	0.3%	0.3%	0.2%
	Mechanical ventilation w heat recovery 90%	0.5%	0.6%	0.8%

4.2.6 Weighted efficiency and final energy demand per policy package

Efficiency (weighted)

	2024		
ID	Heating	Cooling	DHW
BAU_00	88%	250%	96%
PB_02	99%	274%	98%
PB_03	109%	330%	110%
PB_06	96%	324%	95%
PB_08	94%	268%	100%
Integrated	111%	402%	106%

	2027		
ID	Heating	Cooling	DHW
	kWh/m²	kWh/m²	kWh/m²
BAU_00	88%	250%	96%
PB_02	108%	281%	101%
PB_03	122%	337%	121%
PB_06	104%	330%	95%
PB_08	98%	274%	103%
Integrated	129%	417%	114%

	2030		
ID	Heating	Cooling	DHW
	kWh/m²	kWh/m²	kWh/m²
BAU_00	88%	250%	96%
PB_02	120%	288%	106%
PB_03	138%	433%	140%
PB_06	116%	343%	96%
PB_08	102%	288%	105%
Integrated	162%	433%	126%

Final energy (weighted incl. BAU)

	2024			
ID	Heating	Cooling	DHW	Total
BAU_00	34.75	25.10	10.40	**70.2**
PB_02	21.33	20.04	10.18	**51.5**
PB_03	21.23	18.21	9.13	**48.6**
PB_06	7.08	13.60	10.57	**31.2**
PB_08	23.17	20.44	9.97	**53.6**
Integrated	0.59	8.68	9.44	**18.7**

	2027			
ID	Heating	Cooling	DHW	Total
				kWh/m²
BAU_00	34.75	25.10	10.40	**70.2**
PB_02	18.34	19.36	9.86	**47.6**
PB_03	18.86	17.85	8.26	**45.0**
PB_06	5.73	13.14	10.50	**29.4**
PB_08	21.41	19.73	9.73	**50.9**
Integrated	0.23	8.16	8.80	**17.2**

	2030			
ID	Heating	Cooling	DHW	Total
				kWh/m²
BAU_00	34.75	25.10	10.40	**70.2**
PB_02	14.63	18.58	9.40	**42.6**
PB_03	16.67	13.88	7.16	**37.7**
PB_06	4.18	11.50	10.41	**26.1**
PB_08	18.86	18.35	9.55	**46.8**
Integrated	0.01	5.71	7.96	**13.7**

Final energy by energy carrier

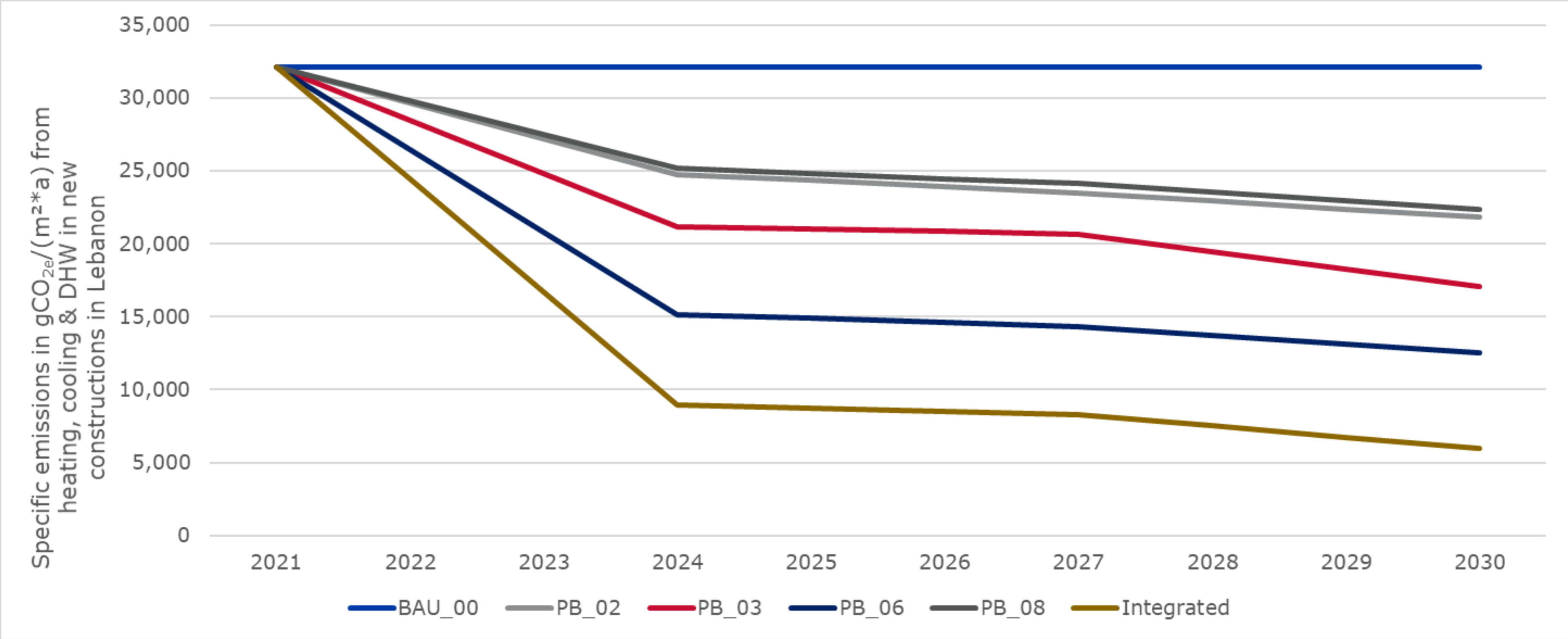
	2024				
ID	Natural gas	Electricity	Biomass	Solar	Total
BAU_00	26.97	32.85	8.56	1.9	**70.2**
PB_02	18.20	25.96	5.04	2.3	**51.5**
PB_03	17.36	21.75	7.08	2.4	**48.6**
PB_06	12.86	15.43	0.67	2.3	**31.2**
PB_08	18.95	26.29	5.85	2.5	**53.6**
Integrated	6.24	9.51	0.18	2.8	**18.7**

	2027				
ID	Natural gas	Electricity	Biomass	Solar	Total
	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²
BAU_00	26.97	32.85	8.56	1.9	**70.2**
PB_02	15.58	25.07	4.20	2.7	**47.6**
PB_03	14.95	21.75	5.87	2.4	**45.0**
PB_06	11.41	14.82	0.42	2.7	**29.4**
PB_08	17.40	25.38	5.50	2.6	**50.9**
Integrated	5.03	8.95	0.05	3.2	**17.2**

	2030				
ID	Natural gas	Electricity	Biomass	Solar	Total
	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²
BAU_00	26.97	32.85	8.56	1.9	**70.2**
PB_02	12.43	23.82	3.22	3.1	**42.6**
PB_03	13.02	17.82	4.41	2.5	**37.7**
PB_06	9.62	13.01	0.20	3.3	**26.1**
PB_08	15.65	23.66	4.67	2.8	**46.8**
Integrated	3.48	6.49	0.00	3.7	**13.7**

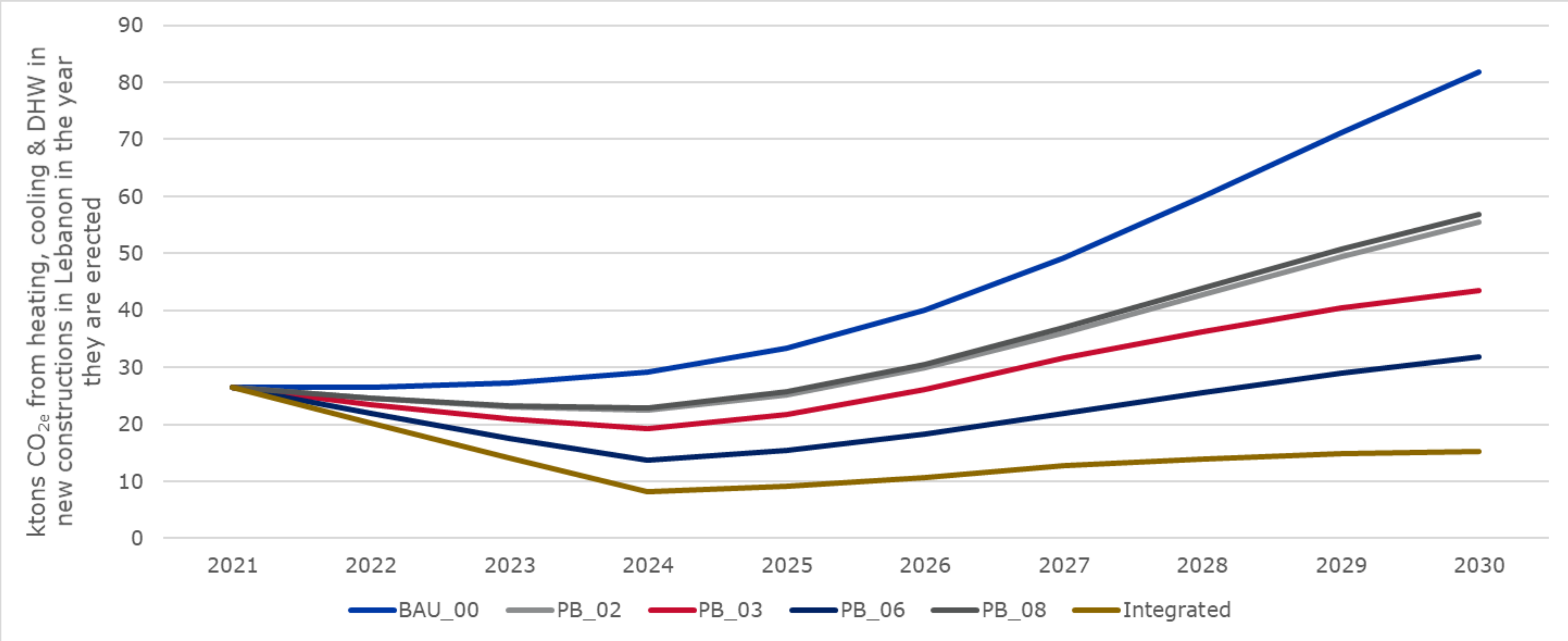
4.3 CO_2-emission forecast of the Lebanese new construction sector 2021-2030

4.3.1 Specific emissions in new constructions



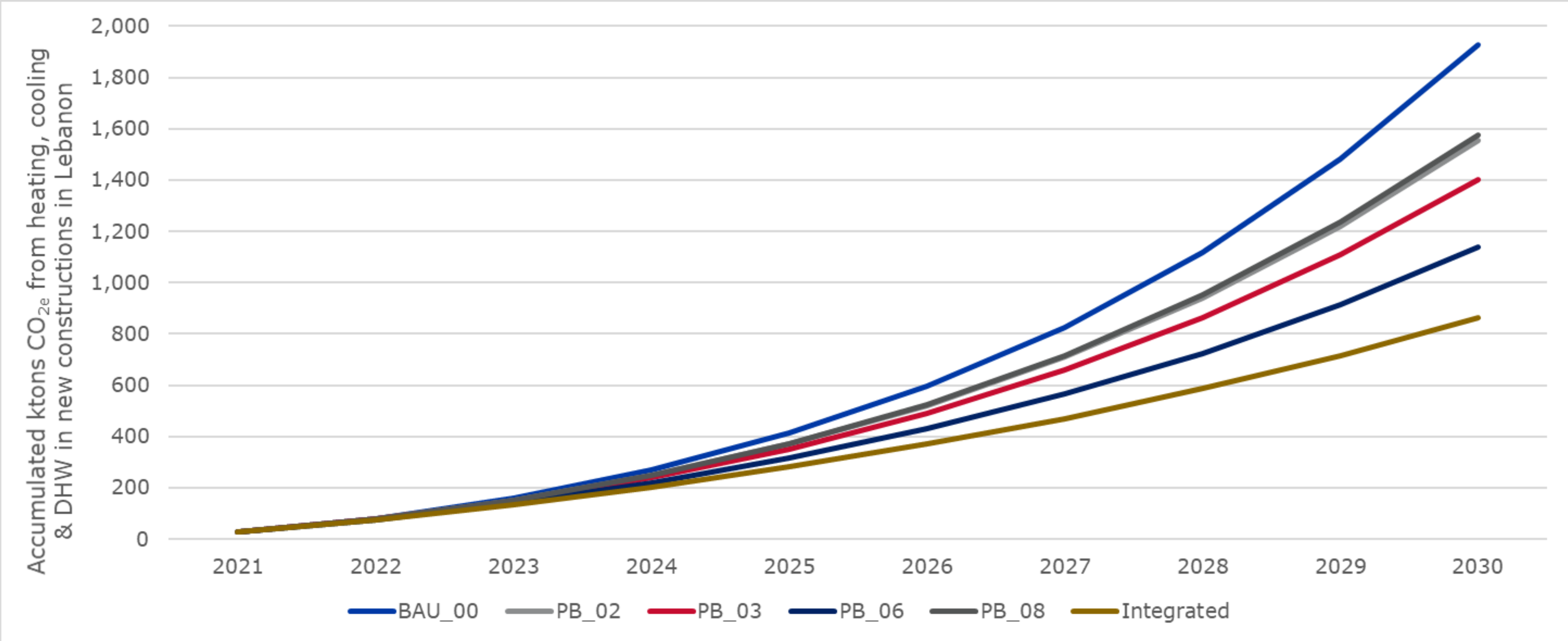
Case	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)	gCO2e/(m²*a)
BAU_00	32,134.85	32,134.85	32,134.85	32,134.85	32,134.85	32,134.85	32,134.85	32,134.85	32,134.85	32,134.85
PB_02	32,134.85	29,671.27	27,207.68	24,744.09	24,320.81	23,897.53	23,474.25	22,917.30	22,360.36	21,803.42
PB_03	32,134.85	28,480.35	24,825.85	21,171.35	21,004.78	20,838.20	20,671.63	19,480.60	18,289.57	17,098.54
PB_06	32,134.85	26,469.42	20,803.99	15,138.55	14,873.04	14,607.52	14,342.00	13,730.67	13,119.34	12,508.01
PB_08	32,134.85	29,812.75	27,490.66	25,168.56	24,813.77	24,458.98	24,104.19	23,521.02	22,937.85	22,354.68
Integrated	32,134.85	24,414.09	16,693.32	8,972.56	8,737.22	8,501.88	8,266.54	7,496.88	6,727.21	5,957.55

4.3.2 CO_2-emissions from newly constructed buildings in the year they are erected



Case	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e
BAU_00	26,462,120,424	26,535,307,807	27,208,905,092	29,241,275,145	33,271,086,536	40,129,875,398	49,270,870,011	59,845,428,477	71,098,837,582	81,747,293,157
PB_02	26,462,120,424	24,501,004,611	23,037,017,358	22,516,014,608	25,180,753,067	29,843,138,088	35,991,967,114	42,679,387,330	49,472,626,544	55,465,330,491
PB_03	26,462,120,424	23,517,609,043	21,020,299,340	19,264,979,354	21,747,469,484	26,022,663,728	31,694,843,362	36,279,137,111	40,465,938,380	43,496,669,914
PB_06	26,462,120,424	21,857,084,710	17,614,946,043	13,775,404,945	15,398,921,765	18,241,811,709	21,989,922,825	25,570,927,362	29,026,740,436	31,818,917,252
PB_08	26,462,120,424	24,617,838,083	23,276,615,924	22,902,257,692	25,691,141,699	30,544,278,412	36,957,836,445	43,803,710,740	50,750,343,218	56,867,694,040
Integrated	26,462,120,424	20,159,897,241	14,134,405,089	8,164,624,834	9,046,151,267	10,617,112,271	12,674,699,444	13,961,594,335	14,884,058,558	15,155,307,338

4.3.3 Accumulated CO_2-emissions from newly constructed buildings 2021-2030



Case	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e	gCO2e
BAU_00	26,462,120,424	79,459,548,654	159,665,881,977	269,113,490,444	411,832,185,448	594,680,755,850	826,800,196,263	1,118,765,065,153	1,481,828,771,624	1,926,639,771,253
PB_02	26,462,120,424	77,425,245,459	151,425,387,851	247,941,544,852	369,638,454,920	521,178,503,076	708,710,518,346	938,921,920,946	1,218,605,950,089	1,553,755,309,724
PB_03	26,462,120,424	76,441,849,890	147,441,878,697	237,706,886,857	349,719,364,501	487,754,505,874	657,484,490,608	863,493,612,454	1,109,968,672,679	1,399,940,402,818
PB_06	26,462,120,424	74,781,325,558	140,715,476,734	220,425,032,856	315,533,510,742	428,883,800,337	564,224,012,757	725,135,152,538	915,073,032,755	1,136,829,830,224
PB_08	26,462,120,424	77,542,078,931	151,898,653,361	249,157,485,483	372,107,459,305	525,601,711,538	716,053,800,217	950,309,599,635	1,235,315,742,272	1,577,189,578,948
Integrated	26,462,120,424	73,084,138,089	133,840,560,842	202,761,608,429	280,728,807,283	369,313,118,408	470,572,128,976	585,792,733,880	715,897,397,341	861,157,368,140

4.4 Summary and conclusions

The assessment has shown that on single package level, package 6 can already save ~41% accumulated emissions compared to a BAU path between 2021 and 2030. The integrated module, considering all packages would be implemented, could even mitigate up to 55% accumulated emissions. The specific emissions as a result from the different policy measures could be reduced by ~61% from policy package 6 and ~81% from the integrated module compared to a BAU case. The other main results are shown in Table 45.

Table 45. Main emission results 2030

Policy package	Specific emissions in new constructions in 2030 [kgCO2e/(m²*a)]	Emissions from newly constructed buildings in 2030 [ktons CO2e]	Accumulated emissions from newly constructed buildings 2021-2030 in 2030 [ktons CO2e]
BAU_00	32.1	81.7	1,926.6
PP_02	21.8	55.5	1,553.8
PP_03	17.1	43.5	1,399.9
PP_06	12.5	31.8	1,136.8
PP_08	22.4	56.9	1,577.2
Integrated	6.0	15.2	861.2

Interesting is also a slightly more detailed analysis of the useful-net energy and final energy demands of the different packages for the year 2030 that can be found in Table 46.

Table 46. Main energy results 2030[4]

Policy package	Useful-net energy demand [kWh/(m²*a)]				Final energy demand [kWh/(m²*a)]			
	Heating	Cooling	DHW	Total	Heating	Cooling	DHW	Total
BAU_00	30.4	62.7	8.8	102.0	34.7	25.1	10.4	70.2
PP_02	17.6	53.6	8.8	80.0	21.3	20.0	10.2	51.5
PP_03	22.9	60.0	8.8	91.8	21.2	18.2	9.1	48.6
PP_06	4.8	39.5	8.8	53.1	7.1	13.6	10.6	31.2
PP_08	19.3	52.9	8.8	81.0	23.2	20.4	10.0	53.6
Integrated	0.0	24.7	8.8	33.5	0.6	8.7	9.4	18.7

In cases where the building envelope is particularly good (policy package 6 and as a result also the integrated module) and reducing the energy demand to almost 0 it does not make sense to still install an expensive heating system. In the concrete case of policy package 6, the planned heating systems still foresee a share >30% of heat pumps that however, from the author's perspective would not be a reasonable focus of the package. When the demand is reduced to almost 0, just the cheapest systems should be allowed to be installed.

[4] **Useful-net energy demand** represents the physical energy demand of a building for reaching / holding a specific internal temperature. The useful-net energy demand results from the energy losses through the building envelope thus depends on the quality of windows, insulation thickness, heat bridges, air tightness, construction materials etc.
The **final energy demand** in addition considers the efficiency of the supply system for generating heat or cold and therefore is the quotient of useful-net energy demand and efficiency of the supply system. Is the efficiency lower 100%, the final energy demand is higher than the useful-net energy demand, is the efficiency greater than 100% (heat pumps and ACs), the final energy demand is lower.

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