Building energy simplified software compliance tool, TSBC

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Abstract:
Building energy codes are the main policy instrument to reduce the energy demand of the building sector. The Energy Performance of Building Directive (2010/31/EU) introduced the cost optimum methodology to determine the energy performance requirement. EPBD requires from Member States to include in the update of their building energy codes minimum energy performance requirements and to develop 2020 building national plans with the aim to reach nearly zero-energy buildings by 2021 for all new buildings. This paper presents the technical structure and aspects of energy building codes and energy performance certificate. The consequences of poor compliance lead to a gap between the intended goals of energy building codes and its actual outcomes. To simplify and clarify energy code compliance and to improve its implementation Software applications are developed in many countries. In Lebanon, the implementation at large scale of the Thermal standard for buildings (TSBL2010) will lead to energy saving, CO_2 emissions reduction and the creation of new business opportunities. This paper introduces software for Building Energy Compliance Tool, TSBC (Thermal Standard Building Compliance Tool). TSBC makes it easy for architects, builders, designers, building officials, plan checkers, and inspectors to determine whether new residential or non-residential buildings, additions, and alterations meet the requirements of the TSBL2010. The proposed TSBC performs energy efficiency rating of the building's envelop and generates an energy performance certificate. TSBL2010 as well TSBC are presented in this paper.

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***Abstract*— Building energy codes are the main policy instrument to reduce the energy demand of the building sector. The Energy Performance of Building Directive (2010/31/EU) introduced the cost optimum methodology to determine the energy performance requirement. EPBD requires from Member States to include in the update of their building energy codes minimum energy performance requirements and to develop 2020 building national plans with the aim to reach nearly zero-energy buildings by 2021 for all new buildings. This paper presents the technical structure and aspects of energy building codes and energy performance certificate. The consequences of poor compliance lead to a gap between the intended goals of energy building codes and its actual outcomes. To simplify and clarify energy code compliance and to improve its implementation Software applications are developed in many countries. In Lebanon, the implementation at large scale of the Thermal standard for buildings (TSBL2010) will lead to energy saving, CO2 emissions reduction and the creation of new business opportunities. This paper introduces software for Building Energy Compliance Tool, TSBC (Thermal Standard Building Compliance Tool). TSBC makes it easy for architects, builders, designers, building officials, plan checkers, and inspectors to determine whether new residential or non-residential buildings, additions, and alterations meet the requirements of the TSBL2010. The proposed TSBC performs energy efficiency rating of the building's envelop and generates an energy performance certificate. TSBL2010 as well TSBC are presented in this paper.**

Keywords- Energy code, Thermal standard, Compliance Tool, Software.

I. BACKGROUND

The residential and commercial sectors account almost 40 % of the final energy use in the World. Energy demand in Southern and Eastern Countries (SEMCs) is likely to expand by 220% in the next 20 years relying on 87% on fossil fuels. The drivers of energy demand in SEMCs are [1]: i) population growth, ii) rapid urbanization, and iii) economic growth. This unsustainable scenario increases dependence on depleted resources and raise energy burden. The bulk of the SEMCs' population will be concentrated in Egypt, Turkey, Algeria and Morocco, which together will represent 81% of the total population in SEMCs.

Energy building codes are the main policy instrument to reduce the energy demand of the building sector. Over time, energy building codes have proved their effectiveness in reducing the energy demand of new buildings when effectively implemented.

Energy building codes also known in some countries as energy efficiency building codes (EEBC) or as thermal building regulations (RT in French) are a set of energy requirements that are applied to building envelopes, building systems and equipments.

In Europe, there is a long tradition with using energy building codes to ensure policy targets. Several countries around the world developed Energy Building codes to ensure energy efficiency of new buildings.

All Mediterranean countries have, or have started development of energy building code.

Many building energy efficiency regulations started with requirements for the building's envelope. As the building's envelope improves, regulations focus on the energy efficiency of HVAC including lighting systems and domestic hot water. Finally, when all parts of building and systems are covered, regulations address renewable energy.

II. TECHNICAL ASPECTS OF ENERGY BUILDING CODES

Energy efficiency requirements for new buildings are set in different ways [2]. Based on national or local traditions they can either be integrated in the general building codes or standards for new buildings, or they can be set as separate standards for energy efficiency (envelope, lighting, HVAC, etc.).

When energy efficiency requirements are set as part of the general rules, it is natural to include their enforcement in the general system for building approval, while separate energy standards impose a separate system for energy efficiency enforcement more complex and costly, so better to have integration with obligatory EEBC.

Energy efficiency requirements can be set in different ways and the basic types are:

- Prescriptive. This method sets separate energy efficiency requirements for each building part and for each equipment. Individual components must achieve compliance with their specific targets

- Trade-off. Values are set for each part of the building, but a trade-off can be made so some values are better and some are worse than the requirements.
- Model building. Values are set as in the trade-off, and a model building with the same shape is calculated with those values. A calculation has to demonstrate that the actual building will be as good as the model building.
- Energy or thermal frame. An overall framework establishes the standard for a building's maximum energy loss. A calculation of the building has to show that this maximum is respected.
- Performance. Energy performance requirements are based on a building's overall consumption of energy or fossil fuel or the building's implied emissions of greenhouse gas.

The technical structure of an energy building code [3] contains chapters covering the mains following issues:

- General and Nomenclatures
- Scope
- Climatic zones
- Compliance
- Describes options for compliance
- Mandatory Provisions that must be used
- Requirements for:
    - Building Envelope (thermal insulation, windows to wall ratio, solar shading)
    - Heating, Ventilating, and Air-Conditioning
    - Service Water Heating
    - Power
    - Lighting
    - Other Equipment
    - Energy management
- Product Information and Installation Requirements.

III. Energy Performance Buildings directive

The European Commission (EC) developed a comprehensive policy package to reduce the energy demand in the buildings sector.

The cornerstone of this policy package is the Energy Performance Buildings Directive (EPBD, 2002/91/EC), first published in 2002. This Directive requires EU Member States to enhance their buildings regulations by introducing mandatory minimum energy performance requirements for new and existing buildings when they undergo major renovation. The Directive also introduced a mandatory labelling scheme called Energy Performance Certificate (EPC) for new and existing buildings (fig. 1) as well as a mandatory inspection of HVAC systems.

The directive was revised in 2010. The EPBD recast [4], Directive (2010/31/EU), extended the mandatory minimum energy performance requirements to all buildings and introduced the cost optimum methodology to determine the energy performance requirements. The aim is to shift focus from upfront investment costs to life cycle costs. The EPBD has also made it mandatory for Member states to include alternative systems from renewable energy. Member States are required to include in the update of their building energy codes minimum energy performance requirements and to develop 2020 building national plans with the aim to reach nearly zero-energy buildings by 2021 for all new buildings.

The methodology requires energy performance to be referred to as primary energy demand per year and expressed in square meters of useful floor area of a reference building.

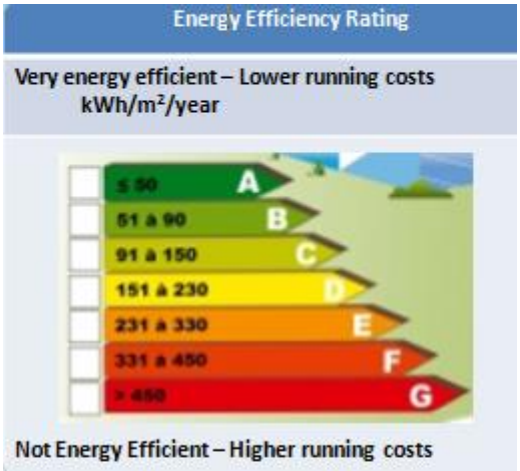

Fig.1. Energy Performance Certificate of Buildings

IV. Energy Buildings Codes Requirements in Southern Mediterranean Countries

Thermal Standard and/or Energy Efficiency Building are enforced in Algeria, Tunisia, Egypt, Jordan, Syria and Turkey, voluntary in Palestine and Lebanon, under enforcement in Morocco. The implementation and the control of application of the thermal standard are very low except for Turkey. Table 1 gives a comparison of the requirements for thermal transmittance of components of building envelop in some Southern Mediterranean countries. Solar shading and thermal bridges are not well considered in these thermal standards.

V. Thermal Standard For Buildings in Lebanon TSBL2010

A. Requirements of the TSBL2010

The thermal standard for buildings in Lebanon [5] consists of two parts, first dealing with the maximum value of the thermal transmittance of the envelope elements (U-value) and second dealing with the solar heat gain coefficient of window (SHGC).

The maximum reference U-values for roofs, walls, glazing and exposed and semi-exposed floors are presented in table 2.

The overall facade U-value of the proposed building (UF) should be less than or equal to the overall reference facade U-value of a similar hypothetical reference facade (UFref). Table 3 gives the values of UFref.

For any building with fenestration, one can evaluate the ratio of the total amount of solar radiation entering the building to the total solar radiation reaching the fenestration areas over an entire year. This ratio is used to determine the impact of the solar load on the heating and cooling energy usage of a building. This ratio depends on the following factors: ratio of windows to gross wall areas, ratio of skylight to roof area, glass solar heart gain coefficient and architectural shading factor. It is defined at the equivalent Window to Wall Ratio, WWR-eq.

TABLE I. COMPARISON OF THE REQUIREMENTS FOR THERMAL TRANSMITTANCE OF BUILDING'S ENVELOP COMPONENTS IN REGIONAL EEBC

Countries	Thermal standard or EEB code	Climatic Zone	U Walls $W/m^2.K$	U roof $W/m^2.K$	U Windows $W/m^2.K$	U gross wall $W/m^2.K$
Lebanon	Thermal Standard for Buildings	Z1	2.1	0.57	6.2	-
		Z2	0.54	0.57	4.3	-
		Z3	0.54	0.41	4.3	-
		Z4	0.31	0.32	2.8	-
Jordan	Thermal Standard for Buildings	Z1	-	1.0	-	1.8
		Z2	-		-	
		Z3	-		-	
		Z4	-		-	
Palest-ine	Thermal Standard for Buildings	Z1	-	0.9	-	1.8
		Z2	-		-	
		Z3	-		-	
		Z4 et Z5	-		-	
Egypt	Thermal Standard for Buildings	Z1	1.0	0.6	-	-
		Z2			-	-
		Z3			-	-
Egypt	Energy Residential Building Code	Z1	0.8	1.0	-	1.0
		Z2	1.5	0.9	-	1.7
		Z3	0.7	0.5	-	0.9
Syria	Thermal Insulation Standard	All Zones	0.8	0.5	- 5.2 if Awn<0.2Afac	1.5
					3.5 if Awn>0.2Afac	

The maximum allowable Reference Window to Wall Ratio WWR-ref (presented in table 4) was determined from a review of the current average fenestration ratio of existing buildings in Lebanon and the economics of using improved glazing and architectural shading devices to control the solar cooling load in cooling season and to optimize the beneficial solar heat gain during the heating season.

TABLE II. THERMAL TRANSMITTANCE VALUES PER COMPONENT U-REF (W/M2.K) VS. CLIMATIC ZONE

Climatic Zone	Building category	U-value Roof	U-value Wall	U-value Window & Skylight*
1 Coastal	1 Residential	0.71	1.60	5.80
	2 N Resid.	0.71	1.26	5.80
2 Mid Mountain	1 Residential	0.63	0,77	4.00
	2 N Resid.	0.55	0,65	3.30
3 Inland Plateau	1 Residential	0.63	0,77	4.00
	2 N Resid.	0.55	0,65	3.30
4 High Mountain	1 Residential	0.55	0.57	3.30
	2 N Resid.	0.55	0.57	2.60

*U-value for window assembly (including frame) – Source TSBL2010

TABLE III. REFERENCE U-VALUE OF FAÇADE OF BUILDINGS VS. CLIMATIC ZONE UFREF

Climatic Zone	Building Category	U_{Fref} $(W/m^2.K)$
1.Coastal Zone	1 Res.	2.5
	2 N Res*.	2.2
2. Western mid mountain	1 Res.	1.5
	2 N Res.	1.3
3. Inland Plateau	1 Res.	1.5
	2 N Res.	1.3
4. High Mountain	1 Res.	1.2
	2 N Res.	1.0

(Source: TSBL2010)

TABLE IV. REFERENCE WINDOW TO WALL RATIO (WWR-REF)

Climatic Zone	Building Category	Maximum Reference Window to Wall Ratio WWR-ref
1.Coastal Zone	1 Res.	0.22
	2 N Res.	0.21
2. Western mid mountain	1 Res.	0.21
	2 N Res.	0.20
3. Inland Plateau	1 Res.	0.20
	2 N Res.	0.19
4. High Mountain	1 Res.	0.21
	2 N Res.	0.20

(Source: TSBL2010)

B. Economic and Energetic Impacts of the TSBL2010

The economic and energetic parametric study [6] related to the development of the TSBL 2010 shows that requirements of the standard may reduce: thermal cooling energy needs by + 23 to 41% and the heating energy needs by +47 to 70% according to building type and climatic zone. The payback time of proposed requirements will be from 2.7 to 8 years for residential buildings and from 2.2 to 6.5 years for commercial buildings according to the climatic zone for end users.

The total primary energy savings over the period 2010-2030 by the implementation of the TSBL 2010 are 7600 kToe, as illustrated in table 5.

The evolution of the primary energy consumption of the residential sector according to the trend scenario of continuation of the current situation and the rupture scenario is given in fig. 2. The energy saving potential related to the implementation of energy efficiency measures (thermal improvement of building envelope, lighting, equipment) and diffusion of Solar water heater are estimated around 1573 kToe by 2030, compared with the trend scenario.

The aggregate savings, subsequent to a reduction of the oil products importation bill, for the time frames 2020-2030, are given in table 6.

TABLE V. ENERGY SAVING POTENTIAL BY EE MEASURES IN LEBANON (HORIZON 2030, IN KTOE)

Measure	2020	2030
TSBL2010 – Heating (in kToe)	1344	5700
TSBL2010 - Cooling (in kToe)	532	1900
Total (in kToe)	1876	7600

TABLE VI. AGGREGATE SAVINGS IN LEBANON, ESTIMATES IN MUSD

Measure	2020	2030
TSBL2010 – Heating (in MUS$)	1050	4856
TSBL2010 - Cooling (in MUS$)	415	1619
Dissemination of solar water-heaters (in MUS$)	390	1275
Efficient lighting (in MUS$)	627	1542
Efficient refrigerator (in MUS$)	600	2176
Other	137	475
Total (in MUSD)	**3219**	**11943**

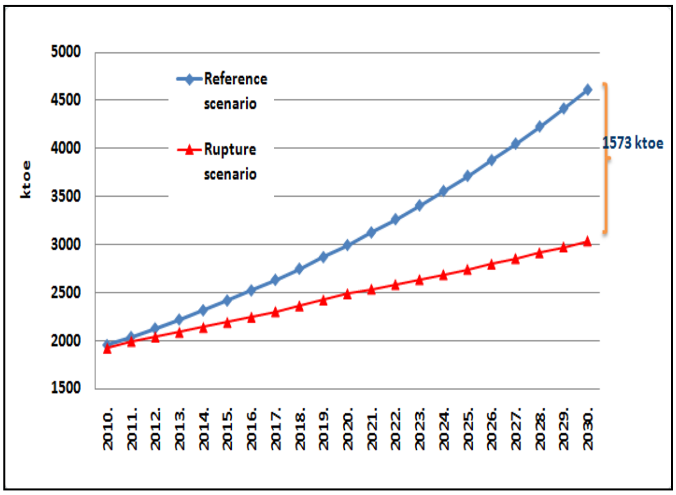

Fig.2. Curves of primary energy consumption in buildings in Lebanon - Reference & Rupture scenarios

The implementation at large scale of the measures recommended will lead to the creation of new business opportunities. Taking into consideration the pace of dissemination of the measures, the number of additional jobs generated in the case of the energy efficiency scenario may be estimated as 12000 jobs by 2030.

By 2030, the avoided electric power would be around 1800 MWe. This avoided power corresponds to a investment in the order of 2160 MUS$, based on the assumption of 1.2 MUS$ per MW of conventional plants. The benefits of the action, according to three energy price scenarios at international level, are given in table 7.

The financial needs for the various measures in new buildings over a 20-year period have been estimated as 4543 MUSD. To this, there must be added 575 MUSD for other pilot measures (PV, solar air-conditioning, etc.), that is, a total of 5118 MUSD over a 20-years time period.

TABLE VII. PAYBACK PERIOD OF THE ACTION, ACCORDING TO OIL BARREL PRICE

Measures	Barrel price in US$	Return time in years	Barrel price in US$	Return time in years	Barrel price in US$	Return time in years
Wall insulate-on	60	4.9	110	2.7	130	2.3
Roof insulation	60	16.9	110	9.2	130	7.8
Wind-ow double-glazing	60	19.3	110	10.5	130	8.9
Effic-ient lighting	60	1.9	110	1.0	130	0.9
Window solar protect-ion	60	4.5	110	2.5	130	2.1
Effic-ient air-conditi-oning	60	2.8	110	1.5	130	1.3
Effici-ent refriger at-ion	60	5.3	110	2.9	130	2.4
Solar hot water	60	6.1	110	3.3	130	2.8

VI. IMPLEMENTATION AND COMPLIANCE

The consequences of poor compliance lead to a gap between the intended goals of energy building codes and its actual outcomes.

Many examples worldwide exist to indicate that it is possible to ensure effective and cost efficient compliance, monitoring and evaluation procedures.

It is important to highlight the urgent need for policy makers and program designers to take steps to improve compliance, monitoring and evaluation of existing EE buildings Codes. The costs of improving compliance and evaluation appear modest while the additional savings potential is considerable – suggesting that investment in compliance and enforcement regimes are likely to be one of the most cost-effective means to increase energy savings.

Effective compliance regimes require a multi-layered approach (prescriptive and performance approaches), with the ability to identify breaches and respond in a manner commensurate with the transgression. Making all stakeholders fully aware of their responsibilities and undertaking compliance monitoring are relatively low-cost activities that can support enforcement action, however, this need to be backed up by clear responsibilities schemes for different actors and institutions. Implementation and compliance actions are:

- the integration of compliance and evaluation procedures into the design of new policies and measures from the outset;
- appropriate legal and institutional infrastructure for ensuring compliance with energy efficiency buildings codes requirements;
- transparent and fair procedures for assessing compliance, including specification of the methods, frequency and scope of check drawing and construction activities;
- regular and public reporting of monitoring activities, including instances of non-compliance.

VII. Thermal Standard Building Compliance Tool

A. General presentation of TSBC

The TSBC (Thermal Standard Building Compliance Tool developed by ECOTECH Engineering) makes it easy for architects, builders, designers, and contractors to determine whether new residential or non-residential buildings, additions, and alterations meet the requirements of the TSBL2010. TSBC also simplifies compliance for building officials, plan checkers, and inspectors by allowing them to quickly determine if a building project meets the code.

TSBC is a simplified tool which provides an analysis of a building's thermal cooling and heating needs for the purposes of assessing compliance with the TSBL2010 and can be adapted for many energy building codes (as in Morocco and Tunisia) and can be expend to cover energy building systems and primary energy consumption. Actually it is the only existing tool in Lebanon developed to assess compliance with TSBL2010. TSBC calculates yearly thermal cooling and heating needs of a building given a description of the building's geometry, and construction. It is based on simulation results by TRNSYS (fig. 3) that were compiled and modeled for several building types and four climatic zones. TSBC makes use of standard sets of data for different activity areas and calls on databases of construction elements. It is accompanied by a friendly user interface.

TSBC consists of a calculation methodology which runs together with a three Compliance Checking Modules (Prescriptive – Trade-off and Performance). The TSBC interface integrates these components together and interacts with a series of databases to provide consistent data to the calculation while simplifying the user's need to obtain detailed building data.

Inputs. Inputs are the building geometry and the thermal characteristics of constructions. The program contains some default values, such as for, thermal characteristics of materials, HVAC system set-points, but some parameters are required.

Output. annual thermal cooling and heating needs of the building and the energy performance class of the building.

Weaknesses. TSBC is not a design tool. If the performance of a particular feature is critical to the design, even if it can be represented in TSBC, it is prudent to use the most appropriate modelling tool for design purposes. In any case, TSBC should not be used for system sizing or making critical design decisions.

B. Energy Model of TSBC

Comprehensive dynamic building simulations were used in order to conduct sensitivity analyses on the influence of building shell parameters to the heating and cooling demands of a variety of building types in Lebanon. Height building types are being investigated and for this reason modelled using the simulation software TRNSYS. TRNSYS is a complete and extensible simulation environment for the transient simulation of systems, including multi-zone buildings. This building model therefore is still one of the most accurate and comprehensive simulation tools worldwide in this respect.

For selected climatic locations and each of the height buildings types, the following resulting figures were generated:

• Specific heating energy demand for heating to 20°C room temperature in kWh/(m².year)

• Specific cooling energy demand for cooling to 24°C room temperature in kWh/(m².year)

• Specific heating load in W/m²

• Specific cooling load in W/m².

Afterwards, more than 20 single parameter (fig. 3) variations for each building type and each climate zone were performed and analyzed in such a way, that suitable promising combinations were also analyzed and multidimensional regression were developed.

Results were compiled in empirical equations and integrated into TSBC. Therefore TSBC can give similar results as obtained by dynamic simulation (TRNSYS).

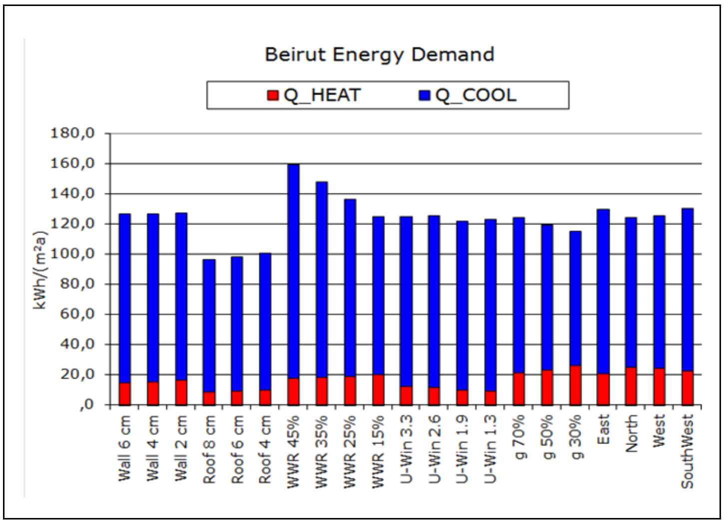

Fig.3. Example of results of dynamic simulation of a low rise typical building using TRNSYS

C. Features of TSBC

Figure 4 shows the "menu" of TSBC. It can give access to project information and definition and allow to select the appropriate approach of compliance check (prescriptive, trade-off or performance). The results of each compliance approach are represented in a table that indicates the state of compliance and in case of non compliance, which component should be reviewed to have compliance (fig. 5, 6 and 7). The building statistics screen gives a standard presentation of all the parameters of the building and allows verifying its correct definition (fig. 8).

TSBC generates a rating energy efficiency certificate of the building (fig. 9), then designers can verify the impact of envelop measures on the cooling and heating energy demand of the project and choose the appropriate options to attend compliance with TSBL2010.

TSBC generates a compliance statement report ready to be inserted into the dossier of permit demand.

Fig.4. Menu of TSBC

	U-Roof W/m2.K	U-Wall W/m2.K	U Windows W/m2.K	U-Floor Exposed W/m2.K	U-Floor Semi Exp.W/m2.K	SHGC North	SHGC All
Reference Values	0,63	0,77	4,00	0,77	1,20	NR	0,70
Proposed in the project	2,77	0,95	4,86	1,04	1,32	0,53	0,73
Proposed ≤ Requirem. Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☑ Yes	☐ Yes
Proposed ≤ Requirem. No	☑ No	☑ No	☑ No	☑ No	☑ No	☐ No	☑ No

*SHGC : Solar Heat Gain coefficient

Fig.5. TSBC Prescriptive Approach: partial results

Building-Envelope Trade-off Option

A.1. Thermal Transmittance of Envelope

Calculation of Uenv and Uref	U-value W/m2.K
Uenv = (ΣUi x Ai) / A	1,97
Uref = (ΣUi-ref x Ai) / A	1,02
Uenv ≤ Uref	☐ Yes
	☑ No

A.2. Thermal Transmittance of Facades

Calculation of UF and UFref	U-value W/m2.K
$U_F = \Sigma$ (Ui x Ai) / A	1,57
U_{Fref} From Table 5	1,50
$U_F \leq U_{Fref}$	☐ Yes
	☑ No

A.3. Equivalent Window to Wall Ratio

Calculation of WWR-eq & WWR-ref	WWR-eq & WWR-ref
WWR-eq = Σ (Awi x SHGCwi x ASFwi) / Av + 2 Σ (Asi x SHGCsi) / Ah	0,13
WWR-ref from Table 9	0,20
WWR-eq ≤ WWR-ref	☑ Yes
	☐ No

Fig.6. TSBC Trade-off Approach: partial results

Verification of conformity: Performance Path

Detailed results of compliance check

	ECool kWh/m2.year	EHeat kWh/m2.year	Ebuild kWh/m2.year
Reference Values	31,00	54,00	85,00
Ebuild Project	21,95	81,38	103,33
Proposed ≤ Requirements			☐ Yes
			☑ No

Fig.7. TSBC Performance Approach: partial results

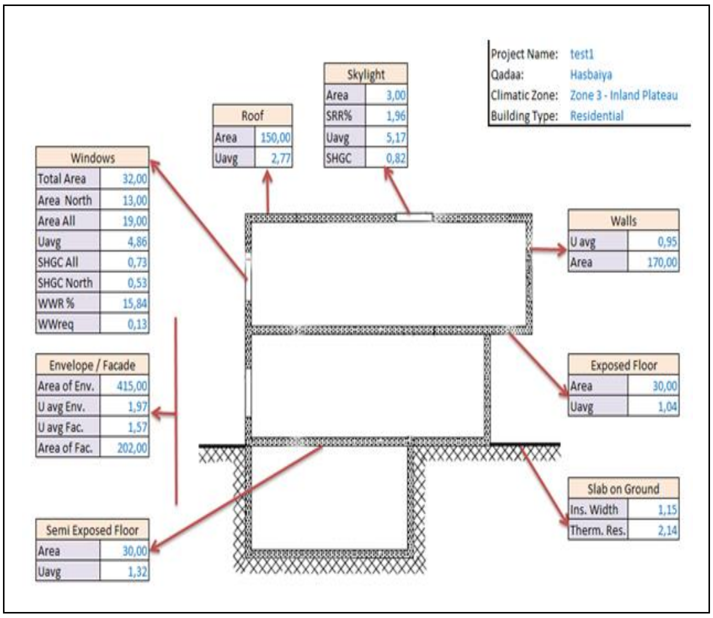

Fig.8. TSBC Building statistics outputs

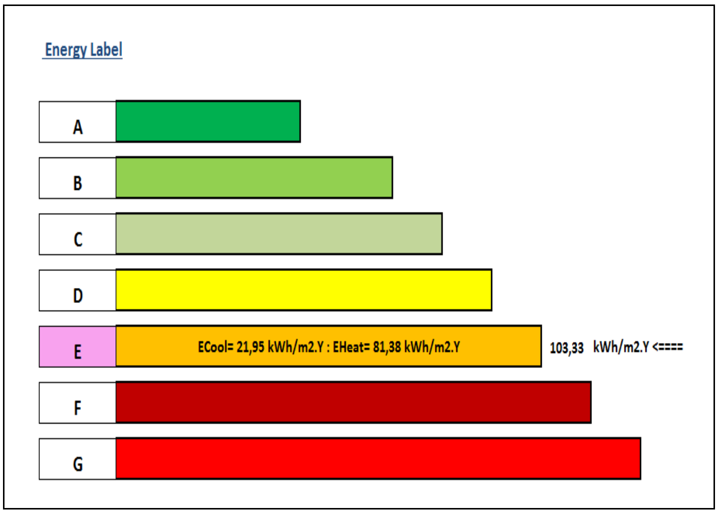

Fig.9. TSBC Energy Performance Certificate

VIII. Conclusion

TSBL2010 has to be mandatory for new and for major renovation of existing building to reduce the energy demand of the overall building stock in Lebanon.

Initial investment, the level of current energy prices and the lack of awareness of Architects and Engineers about TSBL2010 are barriers to the implementation of TSBL2010 in Lebanon. Easy access to credit [7] with appropriate conditions for financing the initial investment and shift subsidies from electricity and fuel to RE and EE measures are a fundamental measure to overcome this barrier.

Building energy codes need to be aligned with the long-term energy national strategy, urban policies, labelling schemes for buildings, appliances and building element as well as R&D and technological development. This will ensure more forcefulness to building energy codes, avoid contradictory targets and delay in the implementation of the overall building energy policy package.

Lack of enforcement of TSBL2010 increases subsidies for energy and incur heavy charges to the national budget.

Roadmap for TSBL implementation should include accompaniments measures such as [8]:

- adoption by LIBNOR of TSBL2010,
- obligation to include in the dossier of demand of permit the TSBC energy performance certificate,
- market survey and certification of insulation material,
- financial mechanisms,
- demonstration projects,
- professional trainings on TSBL2010 and TSBC software.

TSBC is simplified software that can produce consistent and reliable evaluations of energy forecast demand of buildings primarily for the purposes of assessing compliance with TSBL2010 and eventually for building performance certification.

TSBC is under adaptation to cover primary energy demand of building including its energy systems and equipments.

TSBC can be adapted to other energy building codes in Southern Mediterranean countries.

Acknowledgments

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