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A comparative meta-analysis of residential green building policies and their impact on overall energy consumption patterns

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Abstract

Data shows residential energy consumption constituting a significant portion of the overall energy end use in the European Union (EU), ranging between 15% and 30%. Furthermore, the EU's dependency on foreign fossil fuel-based energy imports has been steadily increasing since 1993, constituting approximately 60% of its primary energy. This paper provides an analytical review of diverse residential building/energy policies in targeted EU countries, to shed insight on the impact of such policies and measures on energy use and efficiency trends. Accordingly, the adoption of robust residential green and energy efficient building policies in the EU has increased in the past decade. Moreover, data from EU energy efficiency and consumption databases attributes 44% of total energy savings since 2000 to energy upgrades and improvements within the residential sector. Consequently, many EU countries and organizations are continuously evaluating residential building energy consumption patterns to increase the sector's overall energy performance. To that end, energy efficiency gains in EU households were measured at 1% in 2000 compared to 27.8% in 2016, a 2600% increase. Accordingly, 36 policies have been implemented successfully since 1991 across the EU targeting improvements in residential energy efficiency and reductions in energy use. Moreover, the adoption of National Energy Efficiency Actions Plans (NEEACP) across the EU have been a major driver of energy savings and energy efficiency. Most energy efficiency plans have followed a holistic multi-dimensional approach targeting the following areas, legislative actions, financial incentives, fiscal tax exemptions, and public education and awareness programs and campaigns. These measures and policy instruments have cumulatively generated significant energy savings and measurable improvements in energy performance across the EU since their inception. As a result, EU residential energy consumption trends show a consistent decrease over the past decade. The purpose of this analysis is to explore, examine, and compare the various green building and energy-related policies in the EU, highlighting some of the more robust and progressive aspects of such policies. The paper will also analyze the multiple policies and guidelines across targeted European nations. Lastly, the study will assess the status of green residential building policies in Lebanon, drawing from the comprehensive European measures, in order to recommend a comprehensive set of guidelines to advance energy policies and building practices in the country.

Key Words: Building Policies; Residential Energy Patterns; Residential Energy Consumption; Energy Savings

Introduction

Worldwide residential energy consumption and demand has experienced steady growth in the past decade. Modern day necessities and standard of living expectations have yielded higher energy consumption patterns. This holds true to the Europe, where residential buildings accounted for 25-40% of total energy consumption in 2016 and 20-35% of greenhouse gas emissions [1]. The ever-increasing trends of larger homes and the proliferation of electronic equipment and appliances have amplified energy and electricity demand within the Europe's residential sector. However, Europe have successfully offset these trends by adopting

robust energy conservation and efficiency policies. These policy measures call for action on a global, regional, national, and local level. To that end, the European countries utilized the following measures and instruments to improve efficiency and reduce overall energy consumption: high-performance design, energy labelling, energy efficiency directives, energy performance benchmarks and metrics, targeted subsidies, educational campaigns, energy supplier obligations, and various monetary tools and incentives [2]. Accordingly, many policies and initiatives have been implemented in the EU since the early 1990s to reduce energy use in the residential sector. Most policies align with the EU's energy and climate "20-20-20" targets adopted in 2007 and encompassing the following three pillars: reducing energy consumption by 20%, reducing greenhouse gas emissions by 20%, and increasing renewableenergy coverage of the EU's final energy consumption to 20% [3]. Hence, energy efficiency has become a key driver of sustainable energy and building policy objectives in the EU. Accordingly, the EU adopted an Energy End-use Efficiency and Energy Services Directive (ESD) in 2008 to advance, promote, and adopt energy saving measures [2]. The ESD was the first directive requiring member states to adopt energy efficiency targets and benchmarks. The ESD also mandated that member states enact and adopt National Energy Efficiency Action Plans (NEEAP), outlining the specific measures and mechanisms implemented to achieve the directive goals and objectives. To further advance energy efficiency policies across the EU and various member states, the Energy Efficiency Directive (EED) was adopted in 2012, replacing the ESD. In addition to energy efficiency targets, the EED introduced binding national processes encompassing legal obligations. Furthermore, the new directive established the following energy efficient mechanisms: efficient cogeneration, mandatory energy audits, promotion of energy service, energy saving obligation schemes, metering, and consumer behaviour programs [3]. One of the primary energy-saving instruments adopted in the EU in 2002 was the Energy Performance of Buildings Directive (EPBD) [2]. The directive targeted the building sector primarily focusing on both residential and non-residential structures. The directive required member states to implement measures such as energy performance certificates for rented and sold buildings. It also mandated that all new buildings must be Nearly Zero Energy Buildings (NZEBs) by December 31st, 2020. Moreover, the directive offered member states a methodology for establishing cost-optimal Minimum Energy Performance requirements (MEPs) for major renovations and new buildings. The EPBD also required member states to adopt mechanisms to improve energy efficiency of their existing national building stock [3]. To close the loop, the EU adopted the Eco-design Directive introducing energy labelling and efficiency standards, to improve and enhance energy performance of residential appliances and equipment [2]. Cumulatively, the adopted policy measures and directives helped create an environment that drove energy consumption significantly down across Europe. The purpose of this analysis is to review, examine, and compare the various green building and energy-related policies in Europe, highlighting some of the more robust and progressive aspects of such measures, to emphasize the importance of policies in shaping a comprehensive and holistic approach to energy consumption. Furthermore, this section aims to extrapolate policy best practices that could be transferred to the Lebanese residential building market.

EU Policies and Measures

Local, national, and regional policy initiatives are key drivers in the proliferation and implementation of progressive energy efficiency and green building measures in the EU. Robust policies and measures such as Energy Efficiency Directive, Energy Efficiency in Buildings Directive, Energy Performance of Buildings Directive, and National Energy Action Plans have all had significant impacts on energy consumption patterns across the EU. The following section will outline some of the EU's overarching policy measures and initiatives, followed by a specific focus on policies within targeted EU countries.

The Energy Efficiency Directive (EED)

The EED establishes uniform and comprehensive frameworks setting energy efficiency policies and measures in the European Union (EU), to help meet the "2020" targets (20% energy efficiency target). Accordingly, the following measures have been implemented to increase energy efficiency across the EU: consumer access to energy consumption data, smart metering (200 million), 1.5% annual decrease in national energy sales, energy efficient retrofits to a minimum of 3% of government buildings, mandatory energy efficiency certificates, energy efficiency standards and labeling (household appliances), obligation schemes for energy companies (1.5% energy savings of annual sales), national long-term building renovation strategies, and planning of National Energy Action Plans every 3 years [4].

Energy Performance in Buildings Directive (EPBD)

This directive initiated new mechanisms moving the building industry towards nearly zero energy status (nZEB). It mandated all member states require new buildings achieve nearly-zero energy status by the end of 2020. The directive also introduced cost-optimal methodologies establishing baseline requirements for both technical systems and building envelopes. Furthermore, the directive required routine inspections of heating, ventilation, and air-conditioning systems. Lastly, the directive also plans to apply nZEB standards to building renovations. The directive's objective is to promote overall energy conservation measures and improve efficiency, as well as increase the adoption of renewable energy strategies in buildings. The EPBD also required mandatory certification of all existing and new buildings via Energy Performance Certificates (EPC). The directive mandates that EPCs must be shown to prospective buyers or renters. To that end, EPCs encompass recommendations for cost effective and cost optimal enhancements of a building's energy performance [1].

Energy Labeling Directive (ELD)

The directive mandates energy labels must be clearly displayed on items for sale or rent. This is primarily intended to provide consumers with ample data to help make an educated and informed purchase. The label includes an overall rating, amount of energy consumed, and performance ratings. Currently, energy labels are available to many products groups including the following household items: lamps, televisions, washing machines, drying machines, refrigerators, household air conditioners, space and water heaters, and ovens [1].

Eco-design Directive (EDD)

This directive establishes minimum energy efficiency standards and requirements for various products. The directive is enforced via commission regulations and voluntary arrangements with manufactures. The majority of products covered in the directive encompass household items. The following are few of the products covered by the directive: heaters, water heaters, computers, dishwashers, washers, and air conditioners [1].

Minimum Levels of Energy Taxation Directive

The EU has adopted wide ranging monetary instruments including environmental taxation mechanisms to shape and change societal behavioral patterns and trends. Those taxes encompass 4 major categories: pollution, resources, transport, and energy. Energy taxation constitutes the largest portion of taxation, totaling approximately 75% of all environmental tax receipts in the EU [5]. To that end, energy taxes apply to various heating fuels and electricity (Table 1). The directive also includes a 15% value added tax (VAT) on energy used by households [1].

Table 1: Minimum taxation levels related to electricity & heating fuels [6]

Fuel	Current minimum excise rates for businesses use	Current minimum excise rates for non-businesses use
Heating oil (E/1000 liters)	21	21
Heavy fuel oil (E/1000 Kg)	15	15
Kerosene (E/1000 liters)	0	0
LPG (E/1000 Kg)	0	0
Natural gas (E/GJ)	0.15	0.3
Coal & coke (E/GJ)	0.15	0.3
Electricity (E/MWh)	0.5	1.0

Renewable Energy Directive (RED)

This directive targets both large scale and small-scale renewable energy generation. It covers the energy supply industry and the end-user. The directive places a large emphasis on end-user renewable energy production to reduce fossil fuel energy consumption. Member states are also required to introduce measures into building codes and regulations, to enhance the percentage of renewable energy used in buildings. To that end, member states are mandated to include in their building codes and regulations minimum requirements of energy use sourced from renewable sources in existing and new buildings. The directive also requires member states to provide guidance for information sharing amongst various stakeholders such as architects, planners, homeowners, and builders [1].

EU Household National Policy Measures

MURE and ODYSSEE databases, EU online repositories on energy efficiency policies, contain approximately 600 measures adopted in the residential sector [6]. The policies encompass legislative, information, training, education, financial, co-operative, new market-based, and cross-cutting measures (Figure 1). Furthermore, many of the measures also focus on behavioral patterns. To that end, two behavioral typologies are identified to affect energy efficiency trends, habitual behavior (patters of space use) and investment behavior (choice of housing type). A 2009 behavioral study identified the following three factors as key drivers influencing behavioral change and adjustment: motivating factors (individual & internal), enabling factors (external constraints), and reinforcing factors (Consequences of actions) [1].

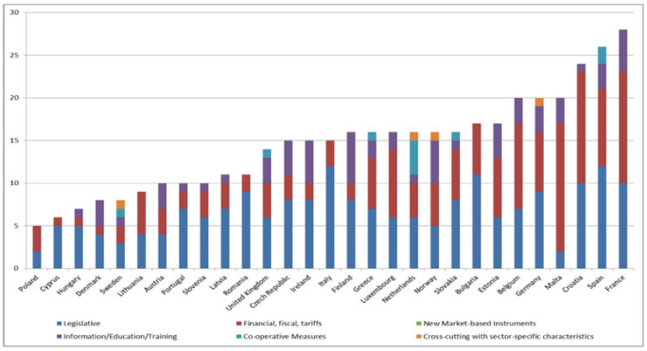

Figure 1: EU residential policy measures by typology [6]

Specific Policy Measures- Germany, France, UK

Germany adopted a National Energy Efficiency Action Plan (NEEAP) as an overarching mechanism to promote energy conservation measures. The country's policy initiatives are broken down into three main categories, energy, building, and supporting measures. Furthermore, the policies cover measures at the local, national, and regional scales. Accordingly, the country established The Energy Efficiency Fund (EEF), which consists of 23 policies and initiatives including funding structures and educational programs, to reduce overall energy use and greenhouse gas emissions. The specific policy measure calls for 20% reduction in energy consumption by 2020 and 50% reduction by 2050 compared to 2008 levels. It also requires a 40% reduction in GHG emissions by 2020 and an 80-95% reduction by 2050 compared to 1990 levels [6]. Furthermore, Germany's Climate Action Program also mandates a 40% reduction in GHG emissions by 2020. On the building front, Germany initiated the Energy Efficiency Incentive Program (APEE) in 2016, providing funding for the modernization of HVAC systems in residential buildings, totaling 165 million Euros per year. An energy saving ordinance was also introduced to promote energy conservation measures. The Energy Conservation Regulation (EnEV) is a performance-based regulation mandating energy calculation to set anticipated primary energy use in residential structures [6]. The regulation mandates an annual 20% reduction in energy use for new buildings. Moreover, Germany established two programs to promote renewable energy technologies and climate-friendly buildings: CO2 Building Rehabilitation Program and Market Incentive Program. Alongside all of the aforementioned regulations,

policies, and programs, Germany provided monetary incentive to encourage residents to exceed the minimum requirement. To that end, $16.9 billion in subsidies were provided in 2009 encompassing energy efficiency and renewable energy subsidies. Similarly, 3.1 million residences were beneficiaries of monetary subsidies in the same year. The government also provided supporting measures such as educational programs, energy labeling schemes, and free access to code [6].

France also adopted a National Energy Efficiency Action Plan (NEEAP) as an overarching mechanism to promote energy conservation measures. The plan sets a final energy consumption target of 131 Mtoe by 2020. France policy initiatives are broken down into three main categories: energy, building, and supporting measures. Furthermore, the policies cover initiatives at the local, national, and regional scales. Accordingly, the country introduced the Energy Saving Certificates (ESC), requiring energy providers and fuel suppliers meet specific energy saving thresholds. A heat fund was also established as a mechanism to support the development of alternative fuels and energies such as biomass energy, geothermal energy, solar thermal, and recovery energies. France also introduced building-specific policy measures such as RT2012, which mandates all new buildings meet the nearly zero energy standard established by the EU. Furthermore, new residential buildings are mandated to establish a primary energy consumption lower than 50 KWh/m^2/year [6]. The RT2012 further reinforces the EU's Energy Performance of Buildings Directive (EPBD), requiring buildings to be 40% more efficient than their 2005 counterparts. The RT2012 also promotes a performance-based approach to building codes and regulations. The measure targets a goal of energy positive buildings by 2020. The government also provided supporting measures including subsidies, monetary incentives, tax breaks, educational programs, energy labeling schemes, and free access to code [6].

Similarly, the United Kingdom (UK) also adopted a National Energy Efficiency Action Plan (NEEAP) as an overarching mechanism to promote energy conservation measures. The UK's policy initiatives are broken down into three main categories: energy, building, and supporting measures. Furthermore, the policies cover initiatives at the local, national, and regional scales. Accordingly, an Energy Company Obligation (ECO) was introduced to establish energy efficiency obligations. The ECO enforces lifetime carbon saving targets on large energy providers to be realized at the residential end-user. Energy Savings Opportunity Scheme (ESOS) was also established as a main instrument to enforce the EU's Article 8 of the Energy Efficiency Directive (EED). The program mandates energy audits for large enterprises. The UK's building sector was also given ample consideration via the introduction of several building regulations. To that end, L1A and L2A were established as mandatory performance-based codes, requiring energy calculation to make sure Design Emissions Rates (DER) don't exceed Target Emissions Rates (TER). The codes also address thermal envelope requirements. Furthermore, the regulations set a national benchmark for all homes to achieve zero carbon status by 2016. Moreover, the codes required new buildings meet a minimum standard for thermal transmittance for roofs, walls, windows, and doors, as well as efficient heating systems. Smart metering and billing for households were also introduced as mechanisms to provide transparency and incentives towards energy efficiency. The government also employed monetary incentives such as tax exemptions for zero carbon homes. Feed in tariffs (FiTs) were also introduced for onsite generated electricity from small scale renewable systems. The government also initiated a Renewable heat Incentive (RIH), to promote renewable energy sources. The government also provided supporting measures including subsidies, monetary incentives, tax breaks, educational programs, and labeling schemes [6].

EU Residential Energy Patterns

The residential sector consumed approximately 26% of the total primary energy in the EU, the second largest behind the transportation sector [14]. Nonetheless, the residential sector experienced the largest energy consumption reductions in 2016 compared to the year before at 3.1% [3]. Comprehensive and robust legislative measures and policy initiatives introduced and implemented at the regional, national, and local levels in the European Union (EU) are key factors in driving overall residential energy consumption significantly down [7]. As a result, EU final residential energy consumption patterns show a clear trend towards energy savings and reductions over the past decade. This is directly attributed to the adoption of mandatory energy conservation measures (ECMs) and green building policies (Figure 6). The EU experienced a 2.1% per year reduction in final residential energy consumption between 2000 and 2016 (Figure 7). To that end, EU residential primary energy consumption decreased from 290 Mtoe in 2000 to 284 Mtoe in 2016 [3]. Cumulatively, residential energy consumption is at its lowest rates of the last two decades. Similarly, final residential energy consumption per capita decreased by 11% from 2005 to 2016 (Figure 8) [3]. Furthermore, residential energy use per dwelling has also experienced significant reductions in the EU (average rate of 1.5% per year), directly accredited to the adoption of mandatory ECMs and green building policies paired with financial investments and public awareness campaigns (Figure 9 & 10). Following similar trends, residential energy consumption per m^2 also experienced significant reductions in the past decade (Figure 11). Residential electricity consumption has also seen consistent reductions at the EU level (-0.4% per year) (Figure 12 & 13). Cumulatively, the residential sector in 2015 amounted for 44% of the total final energy use savings (230 Mtoe) in the EU, the largest percentage amongst all contributing sectors [8] (Figure 14). Accordingly, EU household energy efficiency improved by approximately 28% since 2000. The next section highlights the impact of the various policies on energy consumption patterns in several EU nations: Germany, France, and United Kingdom.

Germany

German households account for about 25% of total primary energy demand in the country. Space heating constituted the majority of that demand at 68%. Germany utilized several energy conservation regulations to reduce its energy consumption and associated greenhouse gas emissions. The first such performance-based code was initiated in 2002. The EnEV required energy calculations to set anticipated measurable benchmarks for residential energy consumption. The regulation focussed on both energy using systems and thermal envelope components. Furthermore, the country set a nationwide goal of carbon-free

buildings by 2020. Germany's residential energy policy approach adopted a hybrid paradigm, encompassing a bottom-up and top-down framework system. The framework model utilized market-driven policies, focusing on demand-side and augmented with a robust level of public engagement. The end result of these measures and policies set forth by the German government was an 8% reduction of residential energy consumption between 1990 and 2014 (Figure 6). Furthermore, German households consumed less energy than their English and French counterparts. Over the period between 200 and 2016, total energy consumption per dwelling experienced a cumulative 30% reduction (Figure 9) [9].

France

The French building sector consumed about 45% of total energy generated in the nation, the largest by far in comparison with other sectors. Similarly, the residential sector also consumed the largest amount of electricity, constituting approximately 36%. Accordingly, 21% of CO2 emissions were attributed to the residential sector in 2015. Consequently, the French government introduced rigorous building regulations, such as RT2012, to set specific building performance requirements to reduce energy consumption patterns and curb greenhouse gas emissions. The measure requires residential buildings use no more than 40-65KWh/m2/pa. France started introducing performance-based codes in 2005 [10]. RT2012 covered several building components including thermal envelope, domestic hot water systems, HVAC, lighting, and heat recovery. In aggregate, the code aimed to yield buildings that are 40% more efficient than their 2005 counterparts. Furthermore, it calls for energy positive buildings by 2020. Cumulatively, France experienced a 26% reduction in residential energy consumption between 1990 and 2010 (Figure 6) [11].

United Kingdom

The residential building sector in the United Kingdom consumed approximately 30% of the total primary energy. Accordingly, the United Kingdom introduced and adopted comprehensive policies such as updated building regulations, EU product standards, smart metering, and supplier obligations. The main objective of all these policies and measures is to reduce energy consumption patterns and curb greenhouse gas emissions. Building regulations were introduced as early as the 1970s as a primary method to promote energy efficiency enhancements and energy savings in residences. Supplier energy efficiency obligations were instituted in the early 1990s as a mean to incentivize energy suppliers to install and promote residential energy efficiency measures. The 2010 L1A and L2A performance-based codes required set benchmarks towards achieving certain levels of target emission rates. The codes addressed thermal envelope, HVAC, lighting, and hot water systems performance. As a result of all the policies and measures adopted in the UK over the past decade, residential energy consumption was reduced by 22% since 2000 (Figure 6). Moreover, the residential sector experienced significant energy usage reductions over the period between 2000 and 2017 amounting to a 32% reduction in water heating, 30% in cooking, and 8% in electrical appliances. Consequently, final residential energy consumption was 37 Mtoe in 2017, a reduction of approximately 20% from 2000 (Figure 9). The majority of energy savings can be attributed to the robust energy-efficiency policies and measures adopted within the last decade (Figure 10). Specifically, the downward trend in energy consumption is directly related to the implementation of robust progressive building regulations encompassing heating systems upgrades, improved insulation and thermal transmittance requirements, high performance glazing systems, smart metering and more efficient appliances [12].

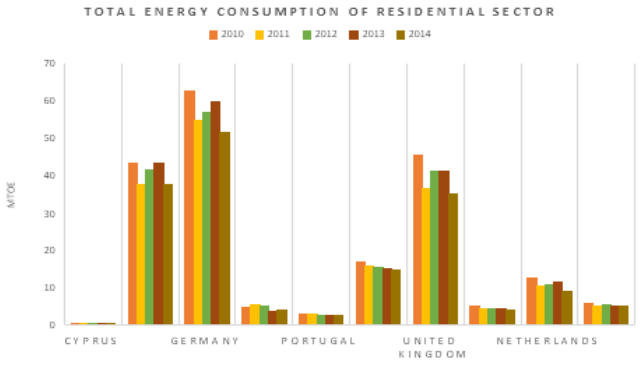

Figure 2: Total residential energy consumption trends in the EU

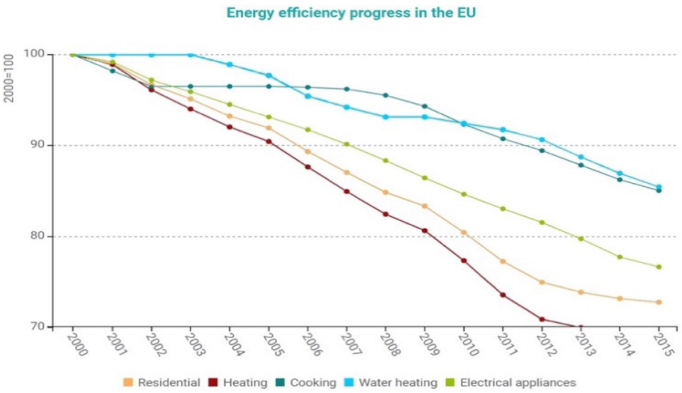

Figure 3: Percentage energy efficiency progress trends in the EU [14]

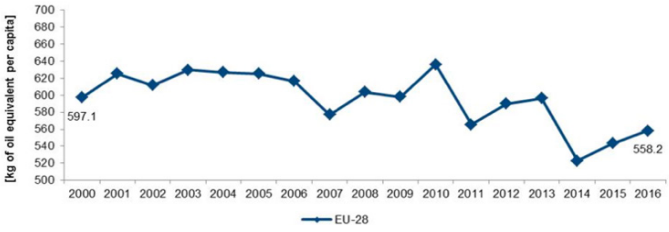

Figure 4: Final residential energy consumption per capita in the EU [8]

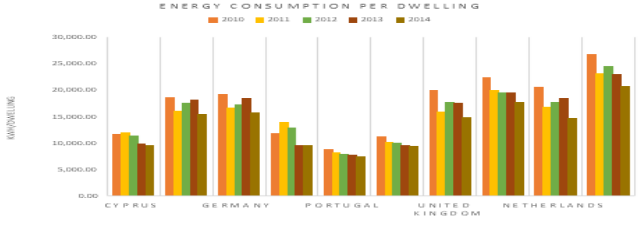

Figure 5: EU Total residential energy consumption per dwelling trends

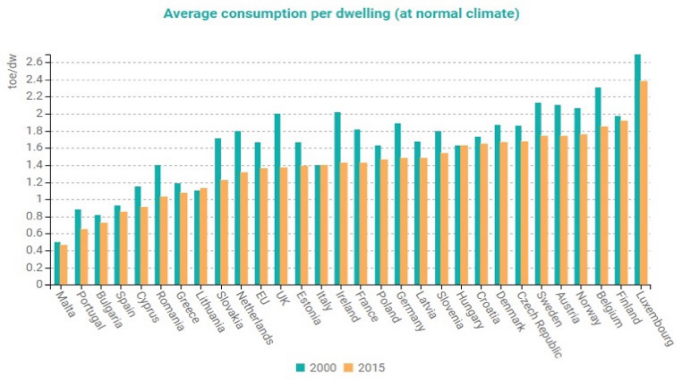

Figure 6: EU average residential energy consumption per dwelling [12]

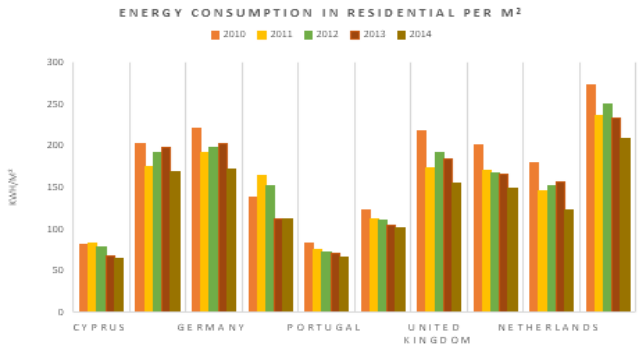

Figure 7: EU Total residential energy consumption per m^2

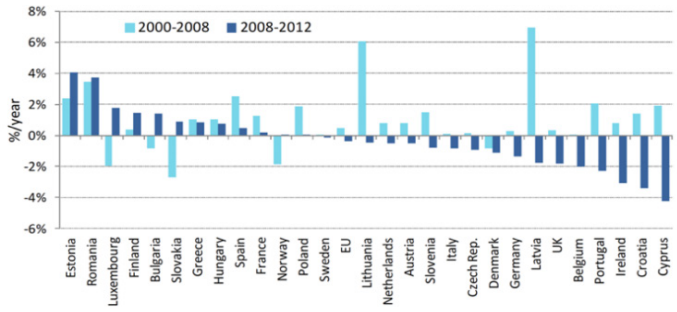

Figure 8: Electricity consumption per dwelling trends in the EU [12]

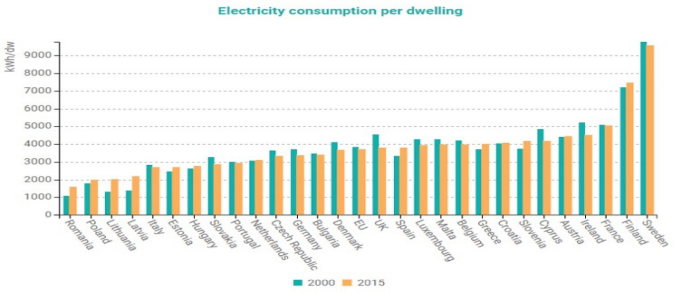

Figure 9: Electricity consumption per dwelling trends in the EU [12]

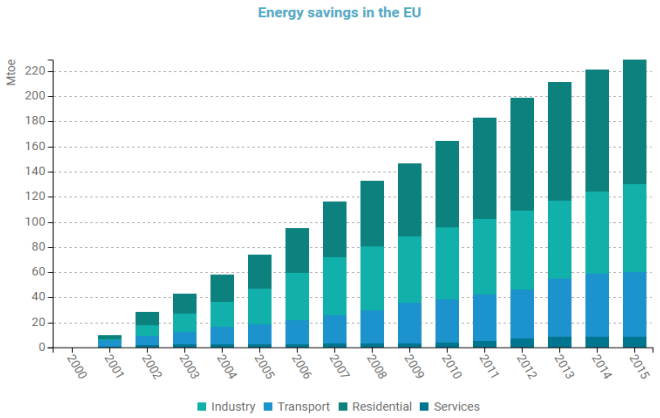

Figure 10: Total final energy savings trends in the EU [12]

Lebanon's Green Building Policies and Measures

Lebanon's sustainable building construction sector has lagged behind for many years. The 15-year civil war significantly damaged the nation's economy, infrastructure, and environment. Moreover, the country has been plagued for the past 20 years with power outages due to an outdated and unreliable energy sector. Nonetheless, Lebanon is an energy intensive country, exceeding many of its neighbouring southern Mediterranean counterparts. To that end, energy consumption patterns have been increasing over the past decade and are projected to continue to grow over the next 10 years [13]. Lebanon imports more than 90% of the fuel it needs for its primary energy demand, mainly petroleum-based products. The heavy dependency on foreign fuel sources paired with unreliable and outdated energy production systems has drastically impacted socio-economic and environmental conditions. The civil war also left its mark on the building construction industry. The decade long conflict enhanced the proliferation of unregulated energy and unpermitted building practices. The result is a chaotic web of endless power lines intermingled with make-shift unsustainable buildings. Consequently, the building industry consumes approximately between 45% and 75% of total electricity generation. The residential sector represents a significant portion of that demand, amounting for approximately 30% of total energy end-use consumption in Lebanon [14], constituting the largest amount amongst all other sectors. The premise of sustainable construction is still relatively unknown and untapped. As a result, the slow proliferation of green construction methodologies within the residential sector have had a major impact on energy consumption trends as well as air pollution. To that end, the role of both governmental and non-governmental agencies in promoting and advancing sustainable building construction is limited and in its infancy. Several public agencies such as the Ministry of Environment, Ministry of Industry, Ministry of Energy and Water, and the Council for Development and Reconstruction have introduced sustainability-driven measures and initiatives, funded by international agencies, aimed at promoting sustainable energy policies in Lebanon. However, most of these initiatives remained voluntary and non-enforceable, resulting in an intermittent and very slow adoption, if any, and without any significant impacts. Furthermore, lack of incentives for green construction paired with un-enforceable legislative regulations have been major obstacles in

the adoption of green building codes. Additionally, the construction law does not take into consideration environmental impacts of construction and design practices in buildings. Nonetheless, Lebanese building code offers marginal guidelines for promoting and implementing sustainable construction. For example, a 2002 Environmental law No.444, encouraging the implementation of building Environmental Impact Assessments remained voluntary and hence, sporadically adopted and used [15]. Consequently, energy efficiency measures and upgrades aren't widely adopted due to the lack of proper legislation systems with adequate monitoring agencies for enforcing and monitoring green construction practices. Moreover, lack of public awareness and absence of robust energy conservation policies have had a detrimental impact on the proliferation of green residential construction in Lebanon. Consequently, most single family detached residential buildings are not properly insulated, and in some instance, not insulated at all [16]. This is directly attributable to the fact that none of the thermal insulation standards were ever adopted and remain primarily voluntary, even though they were introduced and made public [17]. Residential construction is primarily driven by aesthetics in lieu of performance. As a result, the adoption and implementation of residential sustainable construction techniques and green building upgrades have been very slow and, in some instances, non-existent. This could be directly attributed to weak legislative and institutional frameworks, subsidies of energy prices, and absence of a comprehensive national energy strategy [18]. Furthermore, lack of public awareness and educational programs have also contributed negatively to sustainable development and construction.

Conclusion

Global residential energy consumption patterns have been experiencing a consistent growth in the past decade. The European Union is not immune to these forecasts and trends. Moreover, Europe is very suspectable to fluctuations in the energy market. This holds true to the Europe's residential sector, where residential buildings accounted for 25-40% of total energy consumption in 2016 and 20-35% of greenhouse gas emissions. The ever-increasing trends of larger homes and the proliferation of electronic equipment and appliances have amplified energy and electricity demand within the EU's residential sector. However, the EU's adoption of mandatory legislative measures and policy initiatives have successfully offset these trends. The systematic and comprehensive nature of these measures were instrumental in achieving the benchmarks set forth. To that end, the three-prong approach of regional, national, and local policies was a key factor in the overall success of the various measures. The introduction of energy policies and green building measures such as The Energy Efficiency Directive (EED, Energy Performance in Buildings Directive (EPBD), Energy Labelling Directive (ELD), Eco-design Directive (EDD), Minimum Levels of Energy Taxation Directive, and Renewable Energy Directive (RED) were key drivers in shaping a new paradigm for the residential sector. To that end, the EU's all-inclusive bottom-up approach utilized the following measures and instruments to improve energy efficiency and reduce overall consumption: high-performance design, energy labelling, energy efficiency directives, energy performance benchmarks and metrics, targeted subsidies, educational campaigns, energy supplier obligations, and various monetary tools and incentives. Collectively, the introduction and implementation of mandatory robust energy conservation measures and building policies have led to significant reductions in energy consumption in the EU, accounting for a 30% reduction in final residential energy consumption between 2000 and 2016. In total, residential energy savings reached approximately 100 Mtoe since 2000. Consequently, residential energy savings have yielded significant reductions in overall greenhouse gas emissions in the EU. it's imperative to adopt a mandatory all-inclusive comprehensive approach targeting various scales and scopes to effectively change behavioural and consumption patterns. The EU's adoption of such approaches, focusing on robust energy policy measures and green building initiatives, has yielded significant savings over the past decade. Lebanon needs to undergo a paradigm shift, similar to that of the EU, to effectively impact its overall energy consumption patterns and overall building practices. Accordingly, the following measures and initiatives should be adopted: enforceable legislative frameworks for residential green construction and energy conservation, enforceable comprehensive national energy action plan, performance-based building codes, monetary and fiscal incentives towards green construction, and public awareness and educational campaigns.

References

1. ADEME. Energy Efficiency Trends and Policies in the Household and Tertiary Sectors. Brussels: Intelligent Energy Europe Progamme (IEE). 2015.

2. Awwad R, Khoury EK. Assessment of sustainable construction in Lebanon. Byblos: Lebanese American University. 2012;29:1-7.

3. Center for Climate and Energy Solutions. Building Envelope. Retrieved from Climate Techbook. 2017.

4. Energy Consumption Overview. Retrieved from Energy Information Administration. 2017.

5. EL Andaloussi, MM. Energy, Climate change and the Building sector in the Mediterranean. Plan Bleu. 2011.

6. European Commission. Retrieved from Energy efficiency – targets, directive and rules. 2020.

7. European Commission. Energy. Retrieved from EU Buildings Database. 2020.

8. Eurostat. Taxation Trends in the European Union. European Commission. 2013.

9. Eurostat. Energy Consumption in Households. 2020.

10. IECC2016. International Energy Conservation Code. Retrieved from Code Provisions for Low-Rise Residential Buildings. 2016.

11. International Energy Agency. Technology Roadmap: Energy Efficient Building Envelopes. OECD. Paris: International Energy Agency. 2013.

12. Marina E, Nicola L, Luca C, Tiago RS, Strahil P, Paolo Z, et al. Assessment of the National Energy Efficiency Action Plans 2017 under the Energy Efficiency Directive. International Energy Policy & Programme Evaluation Conference. Vienna: Publications Office of the European Union. 2018.

13. R Missaoui, H Ben Hassine, A Mourtada. Energy Efficiency Indicators in the Southern and Eastern Mediterranean countries. Cairo: Plan Bleu. 2012.

14. ODYSSEE-MURE. Retrieved from the ODYSSEE-MURE Project. 2020.

15. Anita Thonipara, Petrik Runst, Christian Ochsner, Kilian Bizer. Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns. Energy Policy. 2019;129:1156-1167.

16. Tzeiranaki ST, Bertoldi P, Diluiso F, Castellazzi L, Economidou M, Labanca N, et al. Analysis of the EU Residential Energy Consumption: Trends and Determinants. Energies. 2019.

17. World Energy Council. World Energy Resources Summit. 2016.

18. Yathreb. Analysis of a Residential Building Energy Consumption. International Journal of Energy. 2016;359-370.