KASDI MERBAH UNIVERSITY OUARGLA

FACULTY OF APPLIED SCIENCES

MECHANICAL ENGINEERING DEPARTMENT

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# Dissertation

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**Specialty: Mechanical Engineering**
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Presented by

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**Theme**

# EVALUATION OF ENERGY IN THE RESIDENTIAL SECTOR IN ALGERIA AND 2040 OUTLOOK

*Publicly supported on: 9/6/2014*

*In front of the jury:*

| | | | |
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**ACADEMIC YEAR: 2013/2014**

**Abstract:**

In this study, we evaluate the energy in the residential sector by follow a bottom up method, before we start the calculations, we analyze the factors which have an influence in the energy consumption, then we start the evaluation by estimating the energy needed in the houses. To estimate the cooling and heating by dividing the Algerian surface to 7 zone using degree days method and ArcGIS (geographic information system) and Google earth.

After the evaluation of the energy in the residential sector, we study the energy outlook to 2040 through two scenarios, Business as Usual scenario which counting in the same path without modification, and with alternative scenario, which inject modification by assuming a new paths for the future, after that we analysis the results, we find that we have to treat the houses according to the specification of the zones it located in, when the heating and cooling are respectively represent 6.4% and 19% in zone 1 while it's 16% and 1% in zone 7. The results shows that the injection of a new kind of lighting and cooling can provide us with a good economic gain which is 458 million € in lighting, while the absorption chiller gain is 24 million € in 2015 and 203 million € in 2040 with the cop of 1.5 and with cop of 1 the gain was 4 million € in 2015 and 36 million € in 2040.

**ملخص :**

في هذه الدراسة، نقوم بتقييم الطاقة في القطاع السكني من خلال اتباع أسلوب أسفل إلى أعلى، قبل أن نبدأ الحسابات، نحن نحلل العوامل التي لها تأثير في استهلاك الطاقة، ثم نبدأ عملية بالتقييم من خلال تقدير الطاقة اللازمة في المنازل خلال استعمال الجزائرية إلى 7أيام درجة المنطقة باستخدام أسلوب ونظام) ArcGIS نظام المعلومات الجغرافية (وجوجل الأرض.
بعد تقييم الطاقة في القطاع السكني، نقوم بدراسة توقعات الطاقة إلى 2040من خلال اثنين من السيناريوهات، سيناريو التجارية كما السيناريو المعتاد الذيعد في نفس المسار دون تعديل،ومع السيناريو البديل الذي حقن التعديل بافتراض مسار اتجديدة لل المستقبل، وبعد تحليل النتائج نجد انه علينا معاملة المنازل على حسب تموقعها الجغرافي اخذا بعين الاعتبار خصائص هذا التموقع وبخصوص ادماج التحسينات ان هذه الدراسة تظهر الربح في الاضاءة كان 458 مليون اورو بينما كان الربح في التبريد فكان 24 مليون اورو سنة 2015 واصبح 203 مليون اورو 2040 مع معامل اداء 1.5 بينما كان 4 مليون اورو سنة 2015 واصبح 36 مليون اورو 2040 مع معامل اداء 1.

## SUMMARY

## CHAPTER IV: Projection to 2040

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## NOMENCLATURE

| Symbols | Definition | unit |
|---|---|---|
| R | Thermal resistances of layers | W/m²°C |
| h | Combined heat transfer coefficient | W/m²°C |
| Th | Thickness | m |
| CDD | Cooling degree days | C° |
| HDD | Heating degree days | C° |
| $\lambda$ | Thermal conductivity | W/m K |
| LHV | Lower heat value | Mj/m3 |
| $T_{electcity}$ | Electricity EU tariff | € |
| $T_{gas}$ | Gas EU tariff | € |

| | | |
|---|---|---|
| $C_{coolig}$ | Cooling cost | €/m² |
| $C_{heating}$ | Heating cost | €/m² |
| $F_{cooling}$ | Annual fuel consumption | Wh/m2 |
| $F_{heating}$ | Annual fuel consumption | Wh/m2 |
| $h_7$ | Enthalpy of the super heated | Kj/kg |
| $h_6$ | Enthalpy of the strong liquid solution | Kj/kg |
| $h_8$ | Enthalpy of the weak liquid solution | Kj/kg |
| h1 | Enthalpy of saturated liquid | Kj/kg |
| $h_3$ | Enthalpy of the saturated refrigerant | Kj/kg |
| $h_2$ | Liquid enthalpy at the temperature | Kj/kg |
| $X_s$ | Concentration of strong solution | % |
| $X_w$ | Concentration of weak solution | % |
| $v_6$ | Specific volume of the strong refrigerant solution | kg/m |
| $t_g$ | Generator temperature | C° |
| $\dot{m}_7$ | Mass flow rate of the refrigerant | Kg/s |

## 1. General introduction:

The global energy consumption in Algeria has being increasing fast during the last decades; the households sector represent more than the third of that global energy. That increasing has being interrupted from 2005 by a constant values of oil and gas reserves, which is a dangerous indicator of demand-supply problem.

With an expected increasing in the number of population and housing which are the main effective factors of the consumption in the households sector, that demand supply problem can be even more dangerous.

Thus, ever-increasing attention has been given to public policy in providing more aggressive and effective responses to reduce energy demand sustainably. Within this context, the use of bottom-up energy-economy models for evaluating ex-ante energy efficiency policy has gained widespread recognition for supporting policy-making. Models provide critical insights, nevertheless the growing complexities of energy systems, environmental problems and technology markets are driving and testing most energy-economy models to their limits.

Energy-economy models are of prime importance to support the most suitable design of policies by assessing whether they are capable of achieving the impacts that would justify their implementation. However, there is limited detailed literature on the development and use of models and corresponding assessments addressing energy efficiency policy – in particular for the buildings sector, which is responsible for at least 40 per cent of energy use in most countries and offers the largest economic potential for the mitigation of greenhouse gases (GHG) globally, In Algeria the buildings sector represent 41% of the final energy consumption.

The purpose of this study is to show how, thanks to the widespread adoption of various current technical solutions on a scale of30 years, domestic energy consumption in Algeria can move towards better integration of intermittent energy without sacrificing comfort households. We base our study on the estimation of energy consumption in the residential sector today, then 2040, and see how this consumption can be modulated by the combined use of systems management energy. We show that these intelligent systems energy management lie at the heart of a broader evolution of the entire current energy system, from source of production, to consumers who may become involved in the balance energy network.

The first chapter is describe the energy global situation in Algeria, it is include an analyses all of residential and industry and transport production and consumption and it's repartitions, it's also include the transformation and energy exchange, and it's also give a look about the renewable energy potentials passing by solar potential, wind potential geothermal potential and it's provide us with an information about the information about the efficiency program and $CO_2$ emission in Algeria.

The second chapter is a further look about the residential sector, it the beginning of the chapter it give us a retrospective about the residential energy consumption in Algeria, it is also include the factors which have an influence of that consumption, beginning with the house stock factors like the housing, and houses space, then it's include the economic factors like electricity and gas tariffs.

The third chapter is about is include the zoning of Algeria using a lot of degree days method and tools like ArcGIS and Google earth, and that's for the purpose of calculating the cooling and heating needs for each zone then to estimate the specific consumption for each zone then the END USE of Algeria by following a bottom up methodology.

The forth chapter is the projection of the residential sector consumption to 2040 in Algeria by using a projection model in tow scenario, the 1et scenario is business as usual which is a trend to the future by the past path, and 2ed scenario which is a an alternative scenario which suggested an substitution solution, the substantial solution suggested for this study is to change the mechanical comparison air conditioner with absorption chiller with 2 values of coefficient of performance plus changing the old lamps with less consumption lamps, then it's describe the deferent between the two scenario.

## I.1.Introduction:

Algeria is one of the major oil and gas producing countries of Africa it is still considered to be relatively under-explored. Its hydrocarbon industry is a key to its economy. Algeria has experienced a significant economic upturn in recent years, in large part aided by strong oil and natural gas export revenues. This comes after years of political turmoil and civil war within the country. In 2007, Algeria's real gross domestic product (GDP) growth rate was 4.8%. Oil and natural gas exports, which made up 98% of Algerian exports (by value) in 2006, are the main driver of Algerian economic growth. With continuing investments being made in Algerian oil and gas development, both sectors have potential for increasing production capacity over the next few years (the 2012 BP Statistical Energy Survey).

The other forms of energy are mobilized only when natural gas and oil cannot be used. The production of energy in all its forms occupies today the economic and political debates. Its production is strategic for the development of a nation. Energy is a vital product, it is used in human activity in various forms including mechanical, thermal, chemical, and electrical and nuclear energy, allowing for the different uses. Considered also as a social good, energy sustains us and keeps us well-being.

## I.2.Algeria energy reserves:

Algeria had proved oil reserves of 12.199 billion barrels at the end of 2011, equivalent to 19.3 years of current production and 0.73 % of the world's reserves, while it had 2011 proved natural gas reserves of 4,5 trillion cubic meters, and recently it's still discovering new reserves from time to time and that what make Algeria one of the richest countries in Algeria and the world. (BP Statistical Energy Survey2012)

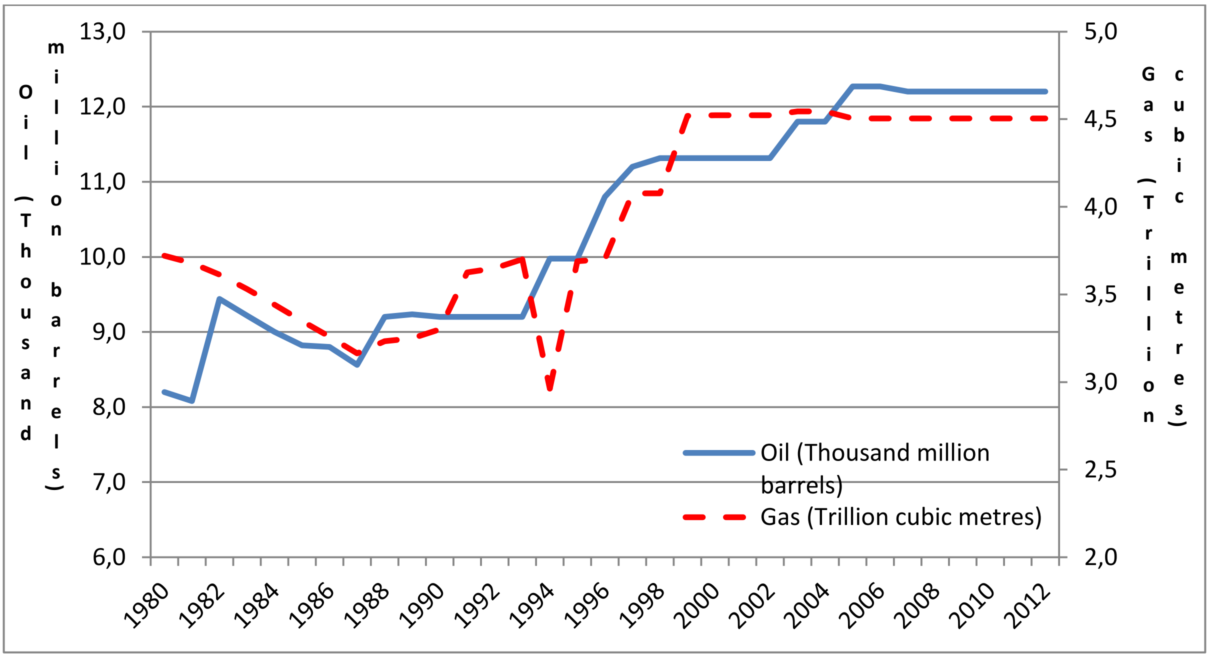



**Figure I.1: Hydrocarbon proved reserves (1980-2012) (BP Statistical Energy Survey2012)**

## I.3. Evaluation retrospective of the energy production in Algeria (1980 - 2012):

### I.3.1. Evaluation of the primary energy production:

The Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process. It is energy contained in raw fuels, and other forms of energy received as input to a system.

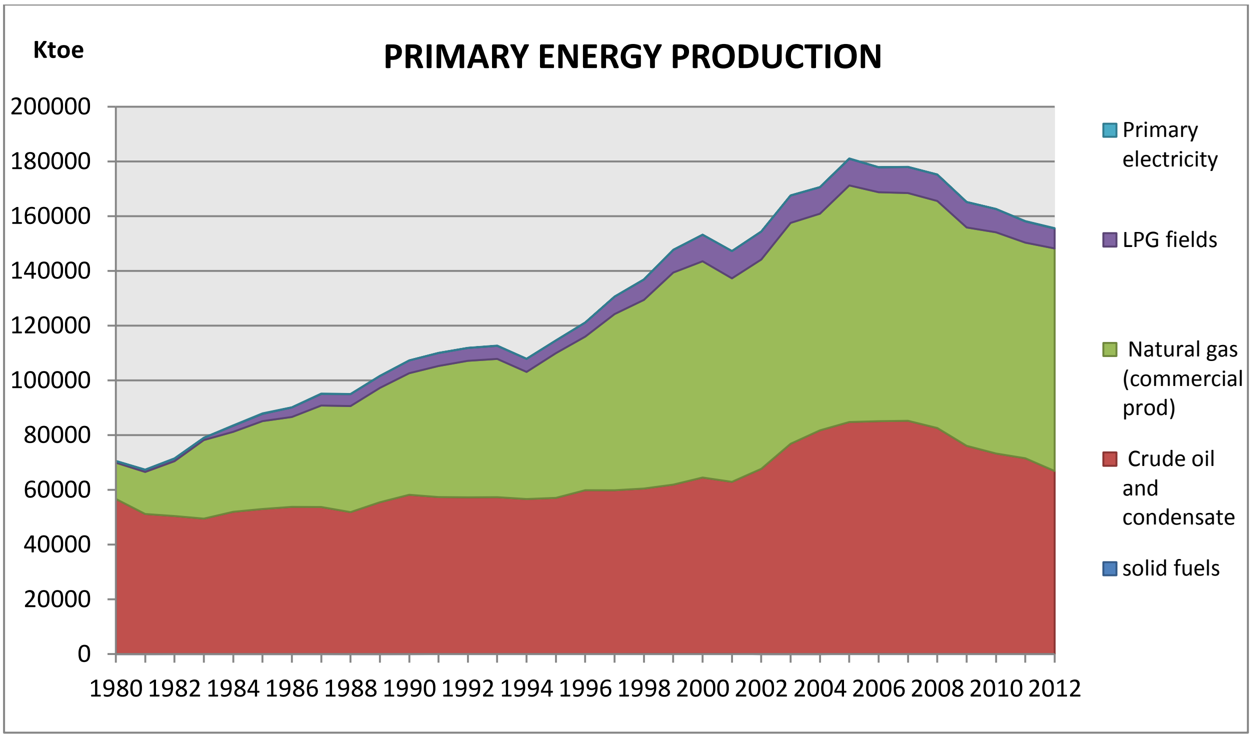



**Figure I.2: Primary energy production by Ktoe (1980 – 2012) (MEM, 1980 to 2012)**

The primary energy products in Algeria are: crude oil – condensate - natural gas – LPG fields - solid fuels – Primary electricity.

The primary energy production generally continue to increase slightly during the years between 1980 – 1993 from 70.5 Mtoe to 112.7 Mtoe by AAGR of 3.66% per year, but in 1994 we notice small decrease in the primary energy production by AAGR of 4.44% to start increasing again between 1995 – 2005 by AAGR of 4.62% per year to reach the maximum value of the primary energy production during (1980-2012) in 2005 which is 179.7 Mtoe, after that the primary energy production started to decrease by AAGR of 2.07% to reach 155.6 Mtoe in 2012 (MEM, 1980 to 2012).

### I.3.2. Repartition of the primary energy production by products:

| primary energy production by products | 1980 | | 2012 | | AAGR (%) |
|---|---|---|---|---|---|
| | Quantity ($10^3$toe) | (%) | Quantity ($10^3$toe) | (%) | |
| solid fuels | 2 | 5.34 | 16 | 0.01 | 6.71 |
| Crude oil and condensate | 56692 | 80.31 | 66876 | 43 | 0.51 |
| Primary electricity | 80 | 0.11 | 157 | 0.03 | 2.12 |
| Natural gas | 13250 | 18.77 | 81323 | 52.3 | 5.83 |
| LPG | 563 | 0.7 | 7255 | 0.1 | 8.31 |
| Total | 70587 | 100 | 155627 | 100 | 23.48 |

**Table I.1: Primary production by product (MEM, 1980 to 2012)**

Crude oil and condensate production increased during the years (1980 - 2007) to reach the maximum value in 2007 by AAGR of 1.52% per year which is 85.1 Mteo, and then it started to decrease by 4.96% per year to reach 66.8 Mteo in 2012.

The natural gas and LPG started to increase during the years (1980 - 2005) respectively by AAGR of 7.79% per year &12% per year tell its reach the maximum values in 2005 which are respectively 86.4 Mteo & 9.7 Mteo, after that it’s started to decrease by 0.87% per year & 4.25% per year to reach 81.3 Mteo & 7.2 Mteo in 2012.

Solid fuels production is not stable, it started to increase from 2 Mteo in 1980 to reach the max (77 Mteo) between (1998 – 2001) then it fall to reach 2 between the yeas (2002 – 2004) to start rising again to reach 69 Mteo in 2006, then it decreased to be 16 Mteo in 2012.

Primary electricity production is also not stable cause in the 80's to 90's it was depend only in the dams, if dams was full, the Primary electricity production will be high and vice versa but lately, the Primary electricity production is including hydraulic +Solar(solar hybrid plant villages) Calculated on the basis of equivalence to production.

The Primary electricity production increased from 80 Mteo in 1980 by AAGR OF 2.7% per year to 159 Mteoin2005 to start decreasing to be 45 Mteo in 2010 then, it started to increase again to be 157 in 2012, The large increase in the production of primary electricity (21.3%) is mainly due to the increase in electricity production from solar hybrid power Hassi R'Mel, which reached 232GWh (including the production of solar villages) (MEM, 1980 to 2012).

The share of renewable energy today consists of primary electricity (hydro and solar) is only 0.1% in the national energy mix (MEM, 20010-2012).

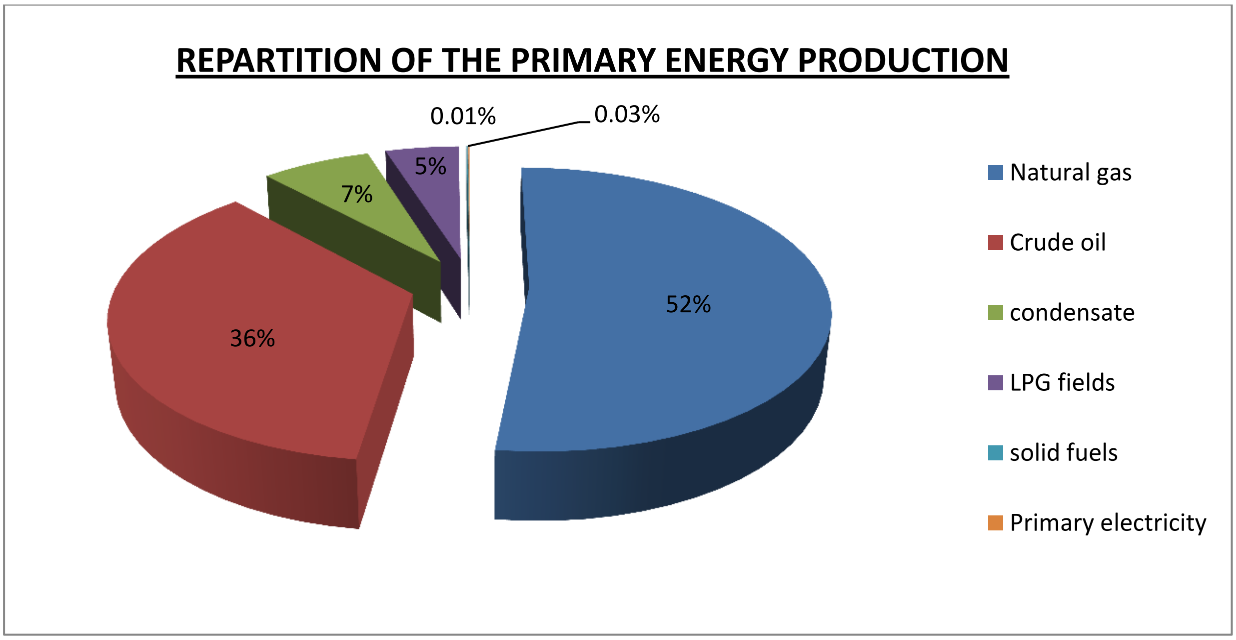



**Figure I.3: Repartition of the primary energy production by products (2012) (MEM, 1980 to 2012).**

The natural gas and the crude oil represent respectively 52% and 36% of the primary energy products because it's the major available primary products in Algeria, followed by the condensate and LPD fields represent respectively 7% and 5% of the primary energy products, then the primary electricity and solid fuels respectively by 0.1 % for each.

The primary electricity represent only 0.1% of the primary energy production because Algeria depend only in the natural gas and the crude oil but lately Algeria start to put renewable energy under consideration and put plans for invests and develop this kind of energy.

**I.3.3. the evaluation of the derived energy production:**

The derived energy refers to the more convenient forms of energy which are transformed from other, primary, energy sources through energy conversion processes. For example, the electricity, which is transformed from primary sources such as coal, raw oil, fuel oil, natural gas, wind, sun, streaming water, nuclear power, gasoline etc., but also refined fuels such as gasoline or synthetic fuels such as hydrogen fuels.

The derived energy products in Algeria are (MEM, 1980 to 2012):

- petroleum products
- electricity
- Gas blast furnaces and coke oven gas.
- Ethane
- PLG
- LNG

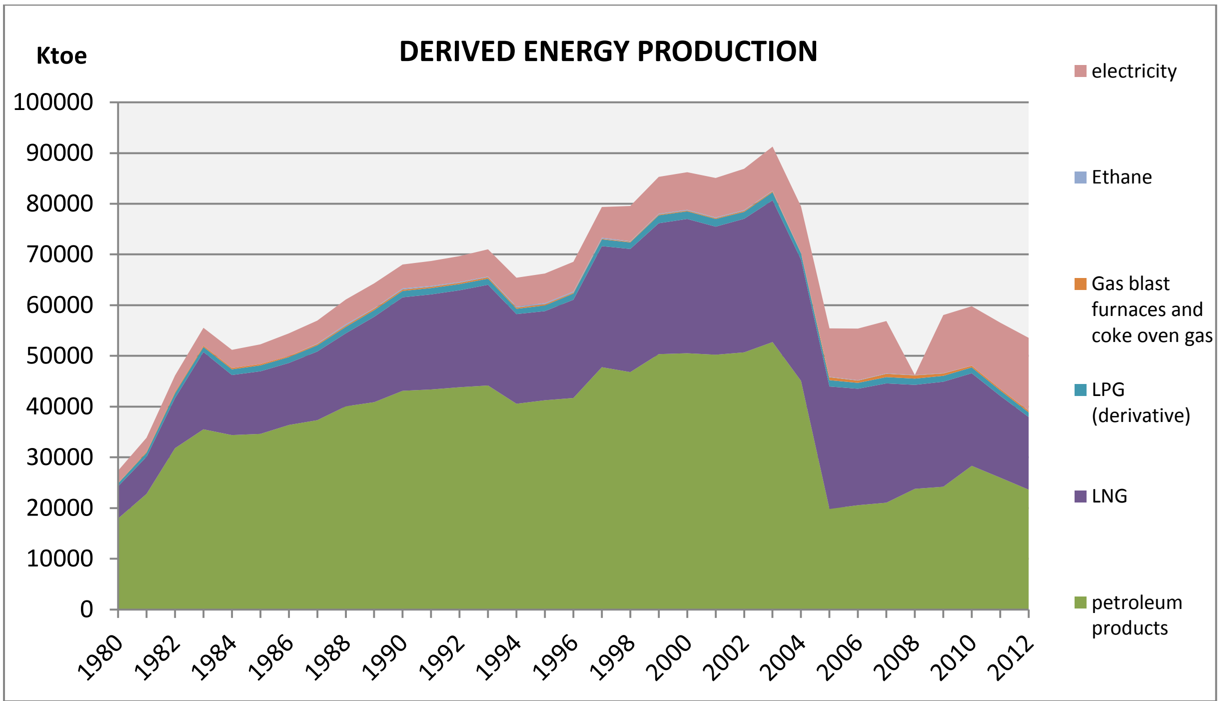



**Figure I.4: Derived energy production by Ktoe (1980 – 2012) (MEM, 1980 to 2012).**

The thermal electricity production was increasing during the years from 2.4 Mtoe in 1980 by AAGR of 5.7% per year to reach 14.3 Mtoe in 2012, while the petroleum products and LNG production was increasing respectively by AAGR of 4.7% per year and 6.66% per year tell 2003 when its reached the max (52.7 Mtoe and 27.9 Mtoe) then it started to decrease by AAGR of 9.3% per year and 7.7% per year to be 23.6 Mtoe and 14.3 Mtoe in 2012. The LPG production was also increasing by AARG of 5.3% tell 1999 when it start dropping by AARG of 4.2% per year to mark a value of 909 Ktoe in 2012. From 1980 tell 1986 the Ethane production was zero then it started to increase in 1987 to reach 159 Ktoe in 2000 than it decline to 33 ktoe in 2012 (MEM, 1980 to 2012).

### I.3.4. Repartition of the derived energy production:

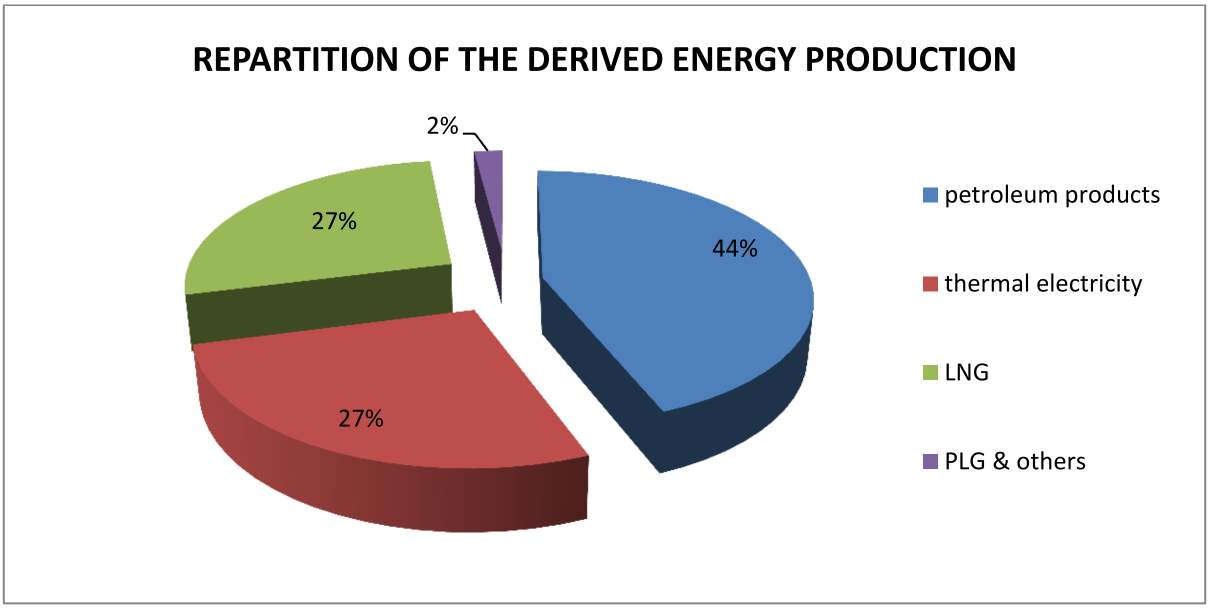



**Figure I.5: The repartition of the derived energy production by products (2012) (MEM, 1980 to 2012).**

The petroleum products are the main derived products (representing 44%) because, the crude oil which is the primary energy for it are also represent a big share of the primary energy products, the thermal electricity also represent a big share by 27%, and this can be explained by the availability of the natural gas and others primary energies. the LNG also represent 27% of the derived products, when the PLG and others only represent 2%.

## I.4. The evaluation of the final energy consumption in Algeria (1980 - 2012):

### I.4.1. The evaluation of the primary energy consumption:

Final energy consumption fluctuated between56% and 73% of national energy consumption, so it is a major objective for any initiative in the direction of rationalizing consumption and consequently it becomes the key element of all national strategies for economic and social development, energy policy and its derivatives.

Final energy consumption has increased from 8.5 Mtoe in 1980 to 36.4 Mtoe in the period in 2012.

Its evolution by sector for the period is on average 4.53% per year, it has undergone three phases:

- The first is increasing between 1980 and 1988 with average annual growth rate of 6.82%.
- The second, relatively stable with only0.72% average annual growth rate between 1989 & 1997.
- The last decade has seen against economic recovery to reach 5.8% of AAGR from 1998 to 2012.

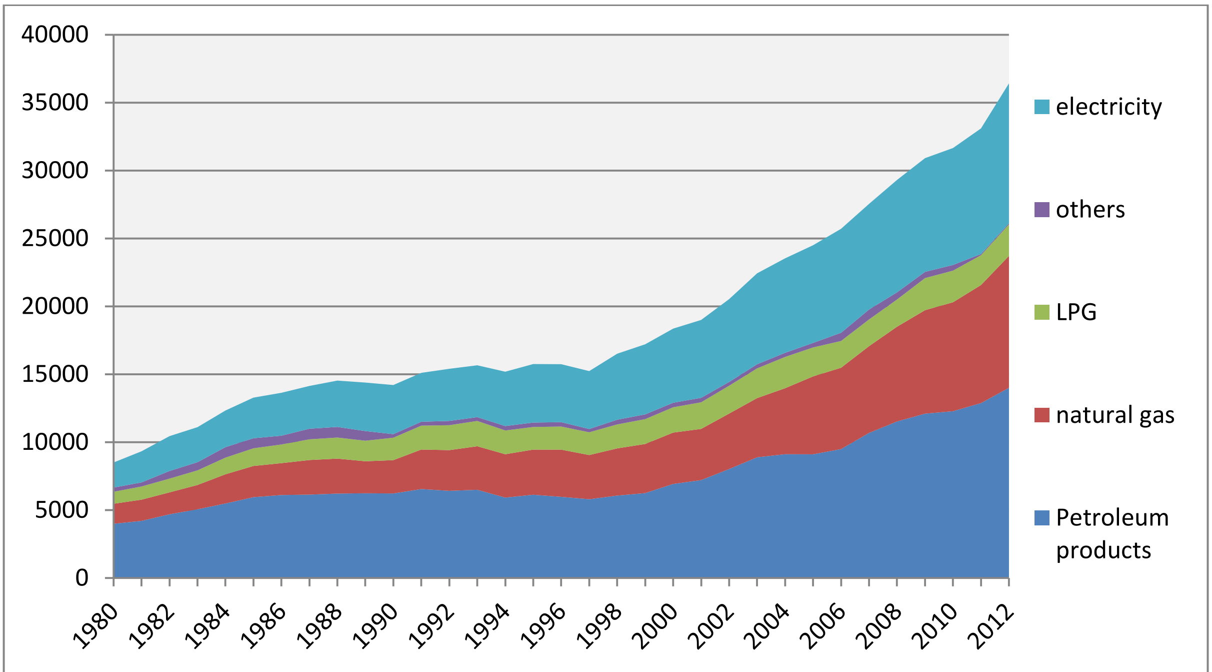



**Figure I.6: Final energy consumption by Ktoe (1980 – 2012) (MEM, 1980 to 2012)**

The analysis of the evolution of the final energy consumption by product as shown in Figure1.5 reflect that electricity recorded a high AAGR of 14.35% between 1980 and 2009 with an acceleration in the rate between 1997 & 2012 AAGR of 9.4%), this is partly explained by the electrification fort sand improving the comfort of households in terms of equipment and appliances.

Natural gas and fuel products recorded respective AAGR of 17.5% and 7.85% between 1980 & 2012 the rate of connection to NG for public distribution and the development of the industrial fabric made that consumption of NG recorded his highest score since 1980in recent years with an AAGR of 9.39% between 2001 & 2009.

Petroleum products it is mainly diesel. In fact this product is used in many different forms and uses and in almost all sectors, recorded an AAGR of around 4%, with a faster between 1997 & 2009 around 6.5%.

The LGP consumption increased by 1.55%, from 1.9 Mteo in 2001 2.3 Mteo to in 2012.

The share of consumption of Gas blast furnaces and coke oven gas is low it declined by 7.22% to be 47 Mtoe in 2012 by 7.22% (MEM, 2001-2012).

### I.4.2. Repartition of final energy consumption by products:

| Final energy consumption by products | 2001 | | 2012 | | AAGR (%) |
|---|---|---|---|---|---|
| | Quantity ($10^3$toe) | (%) | Quantity ($10^3$toe) | (%) | |
| **natural gas** | **3774** | **19.9** | **9710** | **26.7** | **8.97** |
| **LPG** | **1959** | **10.3** | **2320** | **6.4** | **1.55** |
| **electricity** | **5732** | **30.2** | **10304** | **28** | **5.47** |
| **Petroleum products** | **7200** | **37.9** | **13999** | **38.5** | **6.32** |
| **Gas blast furnaces and coke oven gas** | **229** | **1.2** | **47** | **0.1** | **-15.48** |
| **others** | **102** | **0.5** | **16** | **0.01** | **-22.7** |
| **Total** | **18996** | **100** | **36395** | **100** | |

**Table I.2: Final consumption by product (MEM, 2001-2012)**

The structure of the final energy consumption shows the importance of the share of petroleum products39%, including road transport accounts for more than 90% (MEM, 2012).The electricity and the natural gas represent respectively 28% and 27% of the final energy consumption which can be explained by the mainly usage of households and industry sectors, the LPG represent 6%, when Gas blast furnaces and coke oven gas and others are only representing 0.1%.

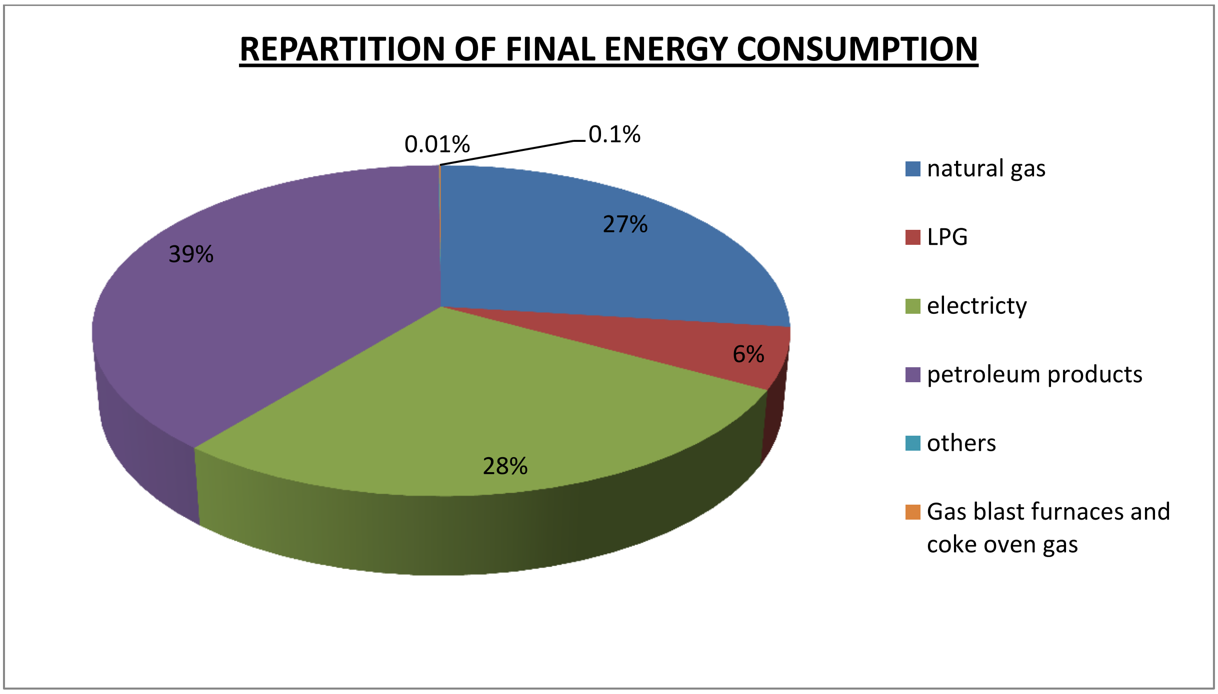



**Figure I.7: The repartition of the final energy consumption by products (2012) (MEM, 1980 to 2012)**

## I.5. Energy transformation and exchange:

### I.5.1. Energy transformation:

The activity of transformation of energy fell by 5.9%in 2012. The transformed volume was 54.7 million toe, against 58.1 million toe the previous year.

The volume of oil and condensate treated fell 8.7% to 26.3 million toe. The volume of processed natural gas decreased by 3.2% due to the sharp fall -11,4%) of the liquefaction activity, partially offset by a8.2% growth needs gas thermal power stations.

The table below provides detail by product quantities transformed energy.

| | unit | 2011 | | 2012 | | Evolution | |
|---|---|---|---|---|---|---|---|
| | | Quantity | % | Quantity | % | Volume | % |
| **Crude oil** | K tep | 24 068 | 41 | 21 609 | 39,5 | -2 459 | -10,2 |
| **Condensate** | K tep | 4 693 | 8,1 | 4 661 | 8,5 | -32 | -0,7 |
| **Natural gas in:** | K tep | 29 320 | 50,5 | 28 388 | 51,9 | -933 | -3,2 |
| LNG units | K tep | 16 999 | 29,3 | 15 055 | 27,5 | -1 945 | -11,4 |
| electric power stations | K tep | 12 321 | 21,2 | 13 333 | 24,4 | 1 012 | 8,2 |
| **total** | K tep | 58 081 | 100 | 54 658 | 100 | -3 423 | -5,9 |

**Table I.3: Energy transformation (MEM, 2011 to 2012)**

The overall losses, consisting of 50% transmission losses and electricity, rose 12.4% in 2012 to 3.9 million toe.

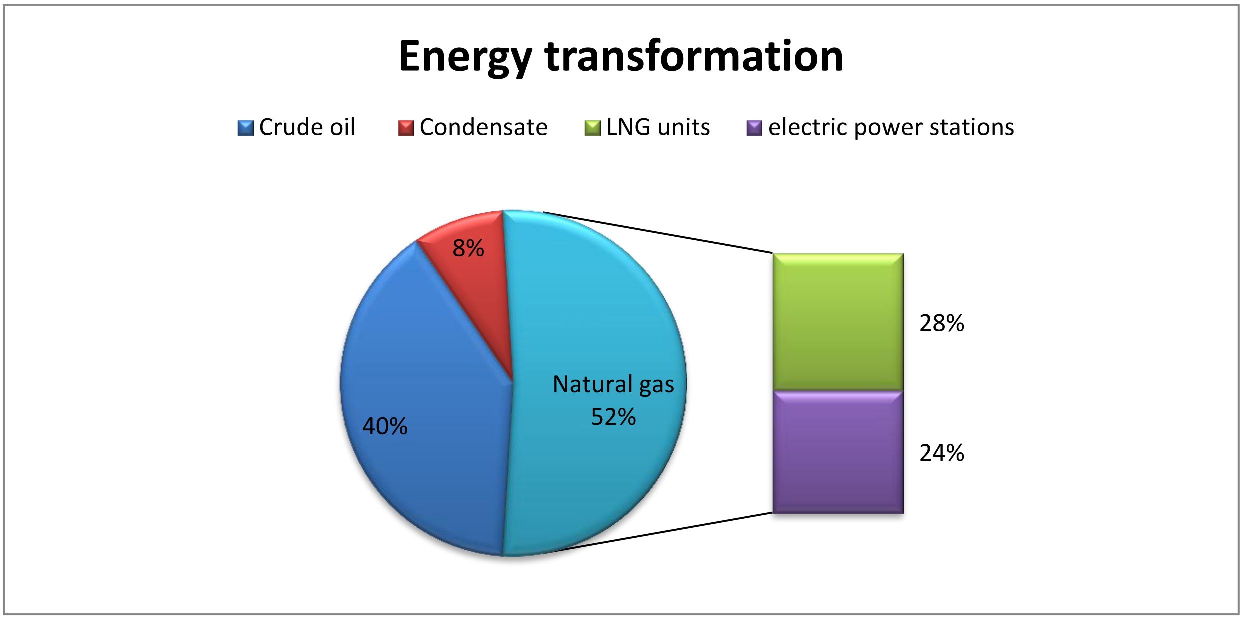



**Figure I.8 : Energy transformation of 2012 (MEM, 2012)**

Electricity losses, estimated at about 2.8 million toe, due respectively to:

- Distribution Losses (77%), including non-technical losses caused by the phenomenon of piracy mains (38%);
- Transmission losses (23%).

**I.5.2. Energy exchanges:**

Exports of primary energy reached 82,3 Mtoe in 2012, in fall of 0,7% compared to the level recorded in 2011. This light fall is explained by a reduction in the oil exportations rough (-1,7%), condensate (- 14,1%) and LPG (- 8,5%). By contrast, natural gas exports increased by 4,5%.

| | unite | 2011 | | 2012 | | Evolution | |
|---|---|---|---|---|---|---|---|
| | | Quantity | % | Quantity | % | Volume | % |
| **Exports of primary energy :** | **K toe** | 82 863 | 100 | 82 270 | 100 | -593 | -0,7 |
| **Crude oil** | **K toe** | 35 763 | 43 | 35165 | 42,7 | -599 | -1,7 |
| **Condensate** | **K toe** | 6 731 | 8,1 | 5 779 | 7 | -952 | -14,1 |
| **Natural gas** | **K toe** | 33 754 | 40,7 | 35 277 | 42,9 | 1 523 | 4,5 |
| **LPG**, of which: | **K toe** | 6 615 | | 6 050 | 7.4 | | |
| Propane | **K tonnes** | 3 600 | 8 | 3 385 | 3 385 | -565 | -8,5 |
| Butane | **K tonnes** | 2 419 | | 2 120 | 2 120 | | |
| **Importation of primary energy :** | **K toe** | 227 | 100 | 324 | 100 | 97 | 42,8 |
| **Crude oil** | **K toe** | 227 | 100 | 324 | 100 | 97 | 42,8 |

**Table I.4: Exports of primary energy (2011-2012)1012**

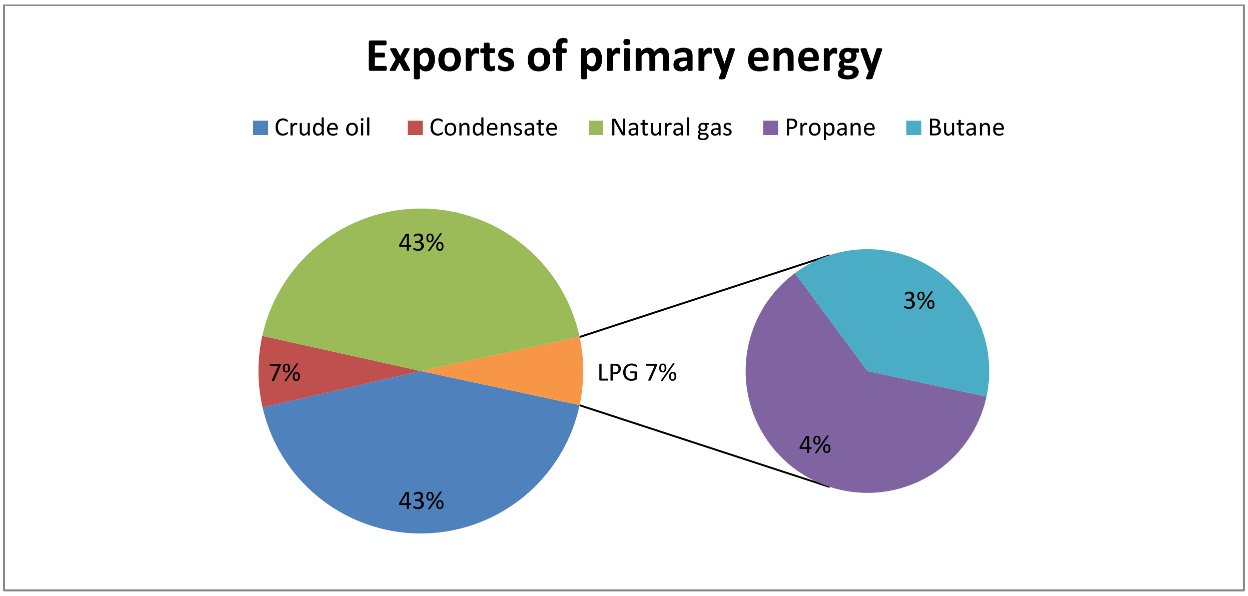



**Figure I.9: Exports of primary energy (2012) (MEM, 2012)**

The imported quantities of crude oil increased by 43% to 324 M toe, because of the butane strong demand on the national market.

| | unite | 2011 | | 2012 | | Evolution | |
|---|---|---|---|---|---|---|---|
| | | **Quantity** | **%** | **Quantity** | **%** | **Volume** | **%** |
| **Exports of derived energy** | **K toe** | 30 483 | 100 | 27 514 | 100 | -2 969 | -9.7 |
| **LPG** | **K toe** | 15 991 | 52.5 | 14 183 | 51.5 | -1 808 | -11,3 |
| **Oil products :** | **K toe** | 14 286 | 49.9 | 13 083 | 47.5 | -1 203 | -8.4 |
| Naphta | **K tonnes** | 7 042 | | 6 549 | | 1 523 | -6.1 |
| Fuel oil | | 5 694 | | 5 127 | | -565 | -8,5 |
| Jet A1 | | 750 | | 683 | | | |
| Other special products | | 17 | | 0 | | | |
| **Electricity** | **K toe** | 206 | 0.7 | 249 | 0.9 | 43 | 20.7 |

**Table I.5: Exports of derived energy (MEM, 2011 to 2012)**

## I.6. potential for renewable energy in Algeria:

**I.6.1. Solar potential**: The solar potential in the country is very high; the average energy received per year over the surface of the country is 170,000 TWh.

The Sahara region is especially rich in this respect. With its ideal location, Algeria has the largest solar potential in the world. The average annual duration of sunshine on Algerian territory exceeds 2,000 hours, to reach 3,500 hours of sunshine in the Sahara desert, which represents 86% of the Algerian territory.

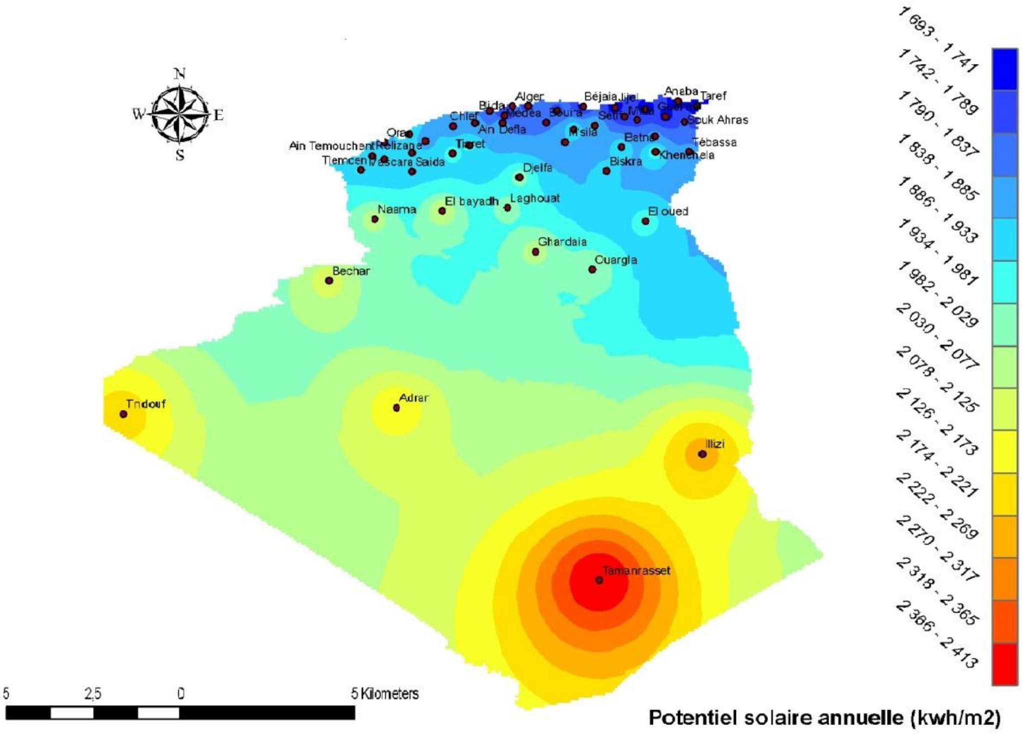



**Figure I.10: The annual solar potential in Algeria**

**I.6.2. Wind potential**: Algeria has a moderate wind potential, with speeds ranging from 2 to 6 m/s. The area between Adrar–Tindouf and Timimoun in the southwest of the country has been shown to have the best prospects.

The contribution of wind energy in the Algerian energy balance is not high. At the present time the resource is harnessed to good effect in isolated sites and the main applications are for water pumping, especially in the high plains.

However, three projects are currently in progress: the completion of a wind atlas, the completion of a 10 MW hybrid power station (6 MW wind / 4 MW diesels at Tindouf and the hybridization of an existing diesel plant at Tindouf. (World Energy Council, 2007)

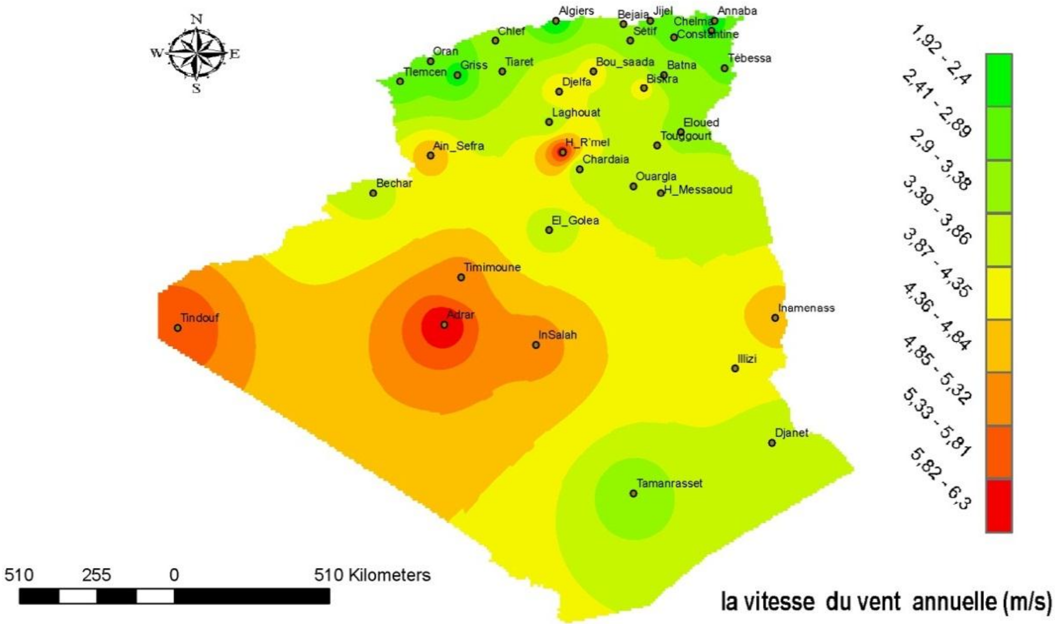



**Figure I.11: Wind potential in Algeria**

**I.6.3.Geothermal potential:** There is substantial geothermal potential in Algeria. More than 200 hot springs were surveyed in the north of the country. About one-third (33%) of them have temperatures above 45°C. Further south there is a vast geothermal reservoir extending over several thousand km2. This reservoir is commonly called the 'Albian table' and has an average temperature of 57°C. The total potential of the geothermal resource in terms of electricity generation is estimated at 700 MW.

**I.6.4.Hydraulic potential:** There are many dams on the rivers of Algeria, but they are mainly used for irrigation and drinking water and produce little power. The share of hydraulic capacity in power production is 5% (installed capacity of 286 MW).

**I.6.5.Biomass potential:** The biomass potential is relatively limited. In broad terms Algeria is divided into two parts. The wooded areas cover about 250 million hectares or a little more than 10% of the total area of the country. The Saharan areas cover almost 90% of the territory. In the north of Algeria, forests cover 1.8 million hectares and scrub around 1.9 million hectares. The total theoretical biomass potential is estimated at 37 Mtoe, of which about 10% may be recoverable. Some 5 million tons of urban and agricultural waste are produced each year. The theoretical energy potential is about 1.33 Mtoe/year.

## I.6.6. Renewable Energy and Efficiency Programs in Algeria:

Algeria has created a green momentum by launching an ambitious program to develop renewable energies (REn) and promote energy efficiency. This program leans on a strategy focused on developing and expanding the use of inexhaustible resources, such as solar energy in order to diversify energy sources and prepares Algeria of tomorrow. Through combining initiatives and the acquisition of knowledge, Algeria is engaged in a new age of sustainable energy use.

The renewable energy and energy efficiency program is organized in five chapters:

- Capacities to install by field of energy activity
- Energy efficiency program
- Industrial capacities to build in order to back up the program.
- Research and development.
- Incentives and regulatory measures.

The program provides for the development by 2020 of about sixty solar photovoltaic and concentrating solar power plants, wind farms as well as hybrid power plants (DIB Djalel, 2012).

## I.6.7. Renewable Energy Program:

Algeria is firmly committed to the promotion of renewable energy in order to provide comprehensive and sustainable solutions to environmental challenges and to the problems regarding the conservation of the energy resources of fossil origin.

The strategic choice is motivated by the huge potential in solar energy. This energy is the major focus of the program of which solar power and photovoltaic systems constitute an essential part. Solar should achieve by 2030 more than 37% of national electricity production (http://www.iea.org/).

Despite its relatively low potential, wind energy is not excluded from the program as it constitutes the second axis of development with a share in electricity production expected to reach about 3% in 2030.

Algeria also plans to install some experimental size units to test the various technologies in renewable energies such as biomass, geothermal energy and desalination of brackish water.

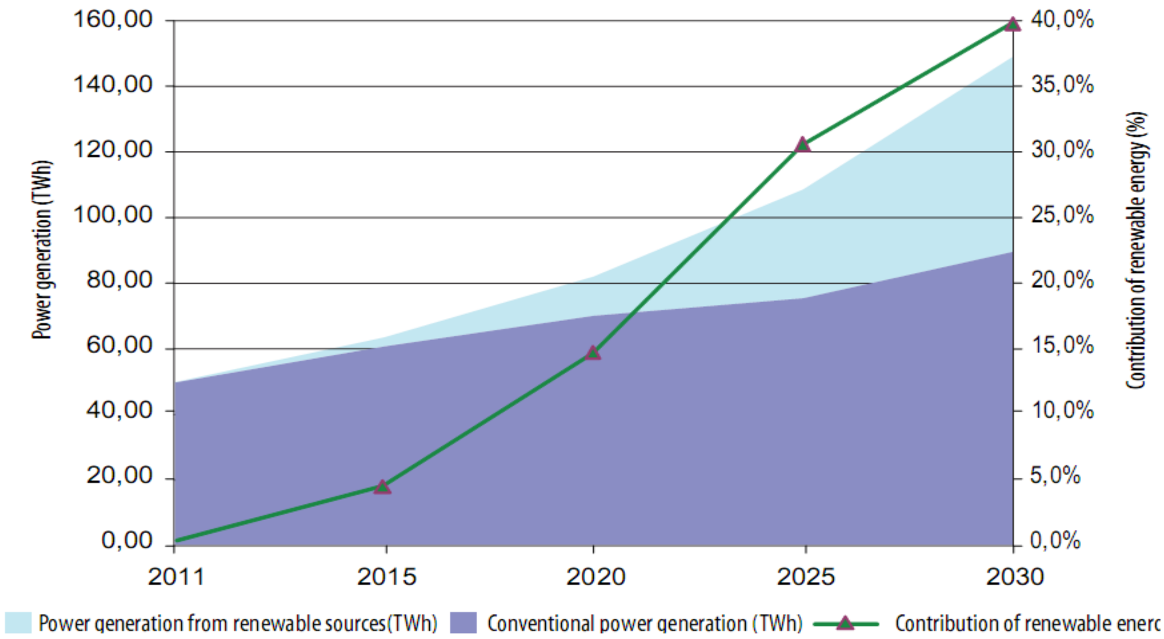



**Figure I.12: Contribution of renewable energies for power generation in TWh**

The renewable energy program is defined through different phases:

- Installation of a total power capacity of 110 MW by 2013;
- Installed power capacity to reach 650 MW by 2015;
- Installed power capacity to reach about 2600 MW by 2020 and a possibility of export of 2000 MW;
- An additional capacity of about 12000MW is expected to be installed by 2030 and a possibility of export up to 10 000 MW. (ttp://www.iea.org/)

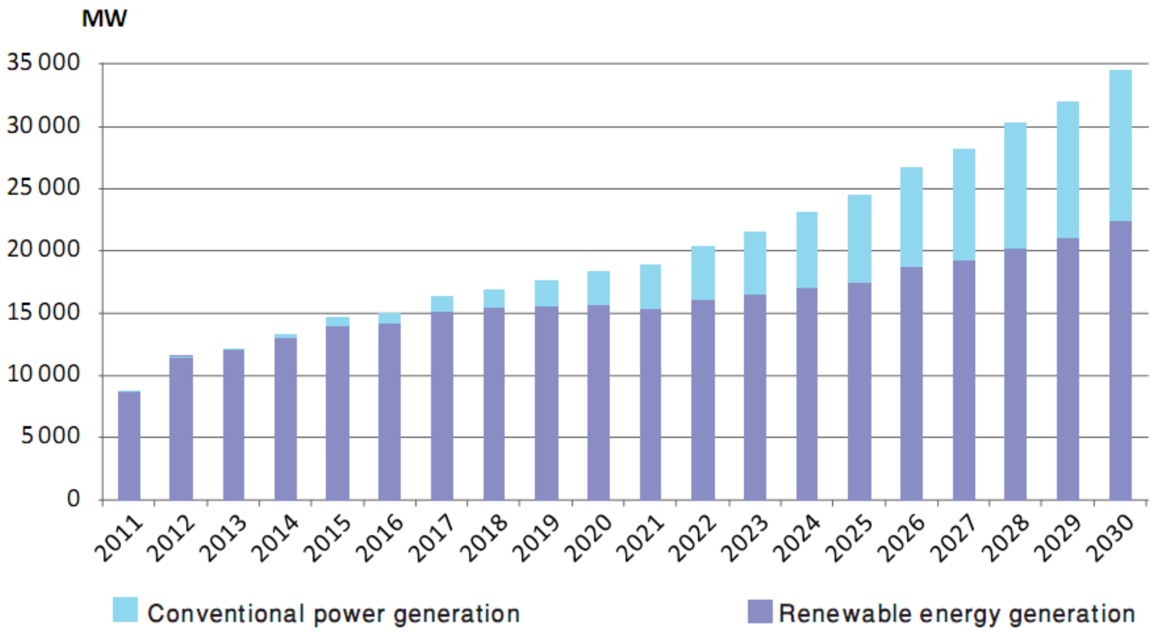



**Figure I.13: Structure of the national power generation in MW**

The program, by sector of energy production, is summarized as follows:

**a) Photovoltaic solar energy:**

Photovoltaic solar energy refers to the energy recovered from sunlight and transformed directly into electricity through photovoltaic panels. It results from direct photon-to-electron conversion in a semiconductor. In addition to the advantages related to the fact that photovoltaic systems do need low cost maintenance, this energy fully meets the needs of facilities in remote areas where connection to the grid is too expensive.

Photovoltaic solar energy is a non-polluting source of energy. The modularity of the photovoltaic solar system allows for innovative and aesthetic use of its components in architecture.

The energy strategy of Algeria is based on the acceleration of the development of solar energy. The government plans launching several solar photovoltaic projects with a total capacity of 800 MWp by 2020. Other projects with an annual capacity of 200 MWp are to be achieved over the 2021-2030 period. (MEM, 2012)

**b) Solar thermal energy:**

Solar thermal energy is a technology that converts solar radiation into thermal energy. It can be used directly (for example to heat buildings) or indirectly (to produce steam to power turbo alternators that will in turn generate electric power). By using the heat produced by solar radiation rather than the radiation itself, the solar thermal energy system differs from other solar energy systems like the photovoltaic cells.

Direct solar radiation is concentrated by a collector on an absorber where it is transferred into a fluid that is either sprayed directly or drives the heat to a steam generator. All solar energy systems have a number of elements in common: a collector that concentrates the heat, a liquid or gas that transfers the heat to an extraction point, an evaporator, a turbine and a generator.

More commonly known as « Concentrating Solar Power » (CSP) system, the solar thermal energy technology can meet demand in electricity 24 hours a day if it is coupled with a thermal storage system or if production is combined with other energies like natural gas. Algeria seeks to develop its solar potential, which is one of the most important in the world, by launching major projects in solar thermal.

Pilot projects for the construction of two solar power plants with storage of a total capacity of about 150MW each, will be launched during the 2011-2013 period. These will be in addition to the hybrid power plant project of Hassi R'Mel with a total power capacity of 150 MW, including 25 MW in solar. (MEM, 2012)

Four (4) solar thermal power plants with a total capacity of about 1 200 MW are to be constructed over the period 2016-2020.

The 2021-2030 program provides for the installation of an annual capacity of 500 MW until 2023, then 600 MW per year until 2030. (MEM, 2012)

**c) Wind energy:**

By definition, wind energy is the energy produced by wind. It is the result of the action of wind turbines, wind-driven electrical machines and whose function is to produce electricity.

Blades pulled in rotation by the strength of the wind allow the mechanical or electric power production in any sufficiently windy site. The energy that the mill rotating pulls out of the wind drives the rotor which converts mechanical energy into electrical energy through a generator.

The amount of energy produced by a wind turbine depends primarily on the speed of wind but also on the area swept by the blades and the air density.

The Algerian REn program plans at first, in the period 2011-2013, the installation of the first wind farm of a power of 10 MW in Adrar. Between 2014 and 2015, two wind farms with a capacity of 20 MW each are to be developed. Studies will be led to detect suitable sites to realize the other projects during the period 2016-2030 for a power of about 1 700 MW.(MEM, 2012)

## I.7. Energy efficiency program:

The energy efficiency program consists mainly in the achievement of the following:

- Improving heat insulation of buildings;
- Developing solar water heating;
- Spreading the use of low energy consumption lamps;
- Substituting all mercury lamps by sodium lamps;
- Promoting LPG and NG fuels;
- Promoting co-generation;

- Conversing simple cycle power plants to combined cycle power plants, wherever possible;
- Developing solar cooling systems;
- **Thermal insulation of buildings:**

In Algeria, the construction sector is the most energy intensive sector. It uses more than 42% of overall energy consumption. Proposed measures to achieve energy efficiency in this sector include the introduction of thermal insulation of buildings, which will reduce energy consumption related to home heating and cooling by about 40%.

- **Solar water heating development:**

The penetration of solar water heaters in Algeria remains undeveloped but the potential is significant. There are plans to develop the solar water heating system to gradually replace the conventional system.

The plans are supported by the National Fund for Energy Efficiency (NFEE).

- **Spreading the use of low energy consumption lamps:**

The objective of the action strategy is to gradually prohibit the marketing of incandescent lamps (conventional lamps commonly used by households) on the domestic market to reach a total ban by 2020. In parallel, there are plans to put several million low-energy bulbs on the market. Furthermore, local production of low consumption lamps will be encouraged in particular through partnerships between local and foreign producers. (MEM, 2012)

- **Introducing energy performance in street lighting:**

Street lighting is the most energy consuming sector in the municipalities. Municipal officers are often poorly informed about the opportunities for improving and even reducing energy consumption in public lighting. The program for energy efficiency in the municipalities consists of replacing all mercury (energy consuming) lamps by sodium (low energy) lamps. (MEM, 2012)

- **Promoting energy efficiency in the industrial sector:**

The industrial sector accounts for about one fourth of the country's overall energy consumption. For more energy efficiency, there are plans for:

- Co-financing energy audits and feasibility studies that will enable companies to precisely define technical and economical solutions best suited for reducing energy consumption;
- Co-financing additional costs linked to the introduction of energy efficiency into technically and economically viable projects.

- **Promoting Liquefied Petroleum Gas fuel:**(MEM, 2012)

There are plans to increase by 20% the market share of Liquefied Petroleum Gas Fuel (LPG/F) in the automobile feet by 2020.

This will be accompanied by the provision of direct financial assistance to individuals wishing to convert their vehicles to LPG/F.

- **Promoting Natural Gas fuel:**

As early as the beginning of the 90s, a research program was initiated to convert vehicles using diesel fuel to natural gas fuel.

Stations were developed by Sonelgaz for the distribution of this fuel to an experimental foot.

By 2013, it is planned to put on in NG / Fuel several tens of bus in the city of Algiers and to extend the operation to the other big cities of Algeria before 2020.

- **Introduction of key technologies for solar air conditioning:**

Solar energy for air conditioning is a technology that should be promoted particularly in the south of the country, as far as the needs for cooling mostly coincide with the availability of solar radiation (conversion of sunrays into energy). Moreover, solar collectors may also be used for hot water production and room heating during the cold season. The overall performance of a solar cooling system is therefore of a great interest.

By 2013, studies will be launched to acquire and harness solar cooling technologies and choose the system best suited to the Algerian context. Two pilot projects for air cooling using absorption and adsorption chillers will be launched for the cooling of buildings in the south of the country.

## I.8.CO2 Emission:

Fossil-fuelled power generation is responsible for major greenhouse gas emissions worldwide in the energy sector. Greenhouse gases mitigation should therefore focus on this sector.

The environmental performance of the power generation sector measured by the emission factor is defined per Capita Carbon Dioxide Emissions from the Consumption of Energy (Metric Tons of carbon Dioxide per Person). (R. Missaoui, 2012)

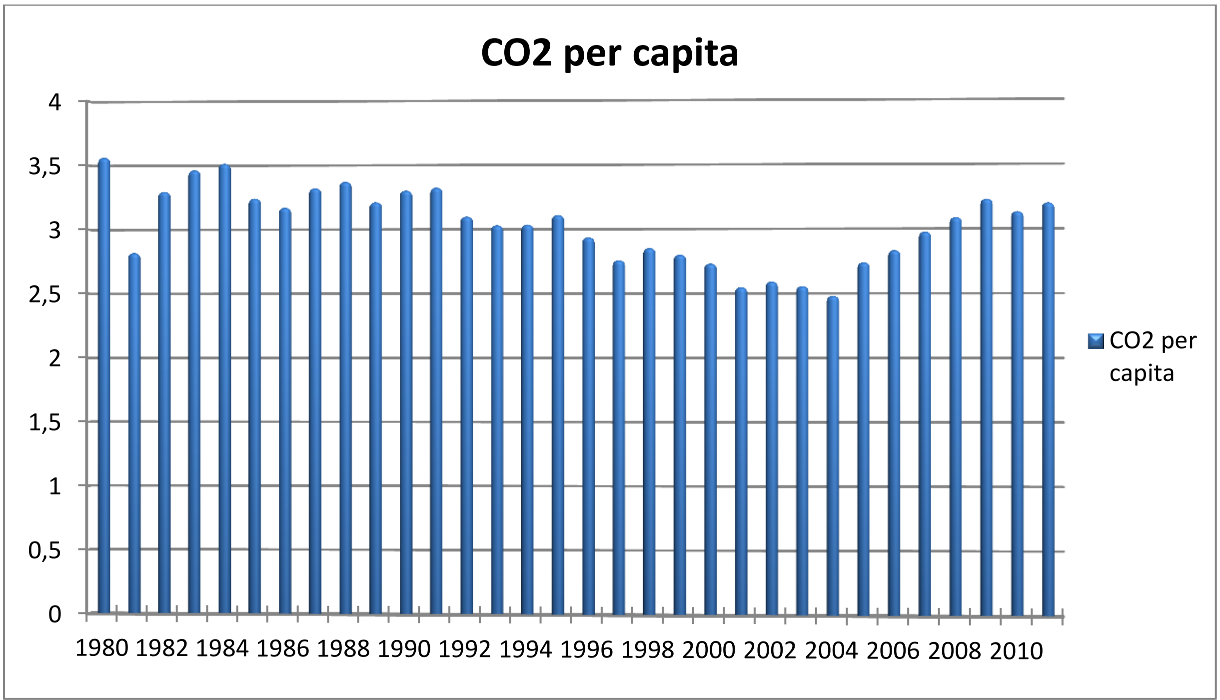



**Figure I.14: CO2 emission per capita (enerdata)**

The figure I.14 shows the $CO_2$ emission per capita in Algeria which decreased from 3,56 Mtco2 per capita (Metric Tons of Carbon Dioxide per Person) in 1980 to be 3,19Mtco2 per capita in 2012.

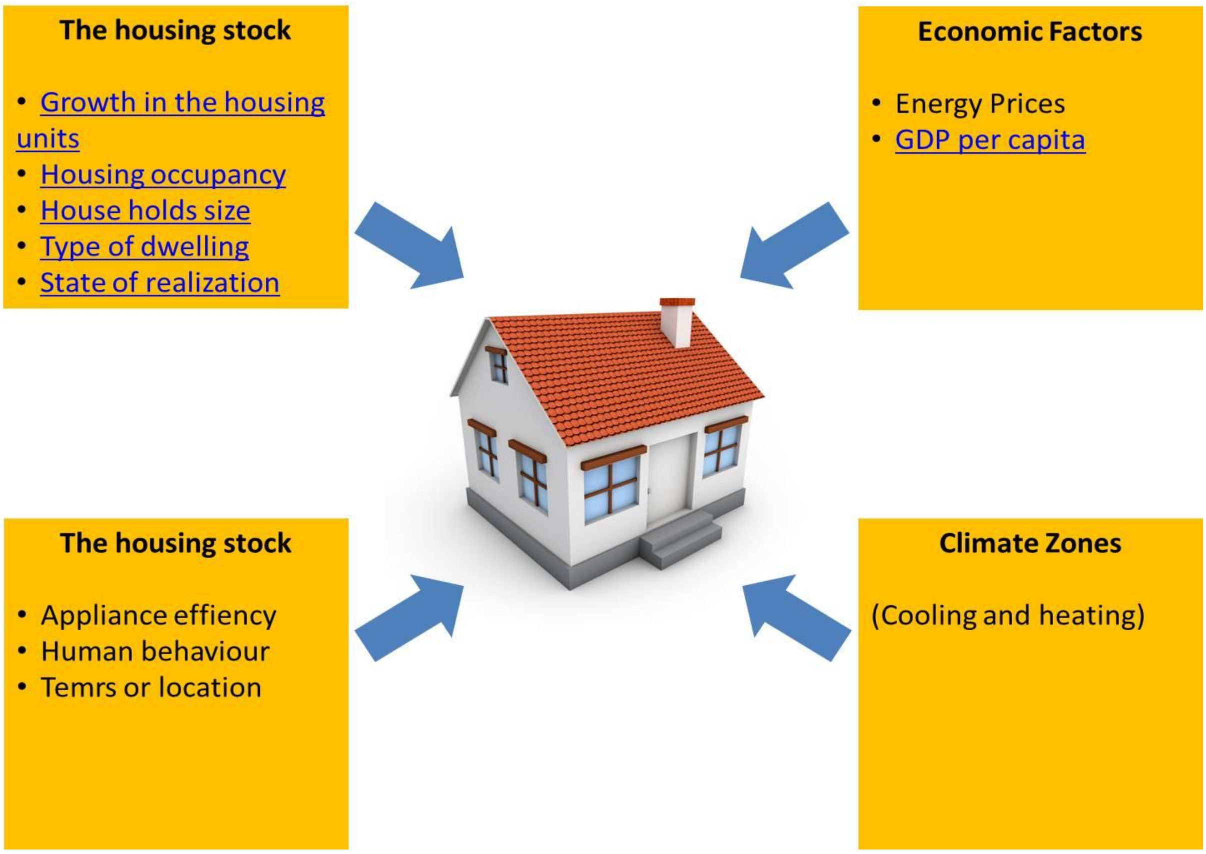
All energy efficiency improvement measures leads to reduction of fossil fuel consumption as kind of primary energy source. Since the emission of $CO_2$ is a direct result of combustion of fossil fuels, the reduction of fossil fuel consumption can be used to reduce the level of $CO_2$ emission in the atmosphere. Therefore the energy efficiency is widely viewed as one of most accessible and cost-effective opportunities to mitigate the climate changes (Prishtina, October 2011).

## II.1.Introduction:

The services demanded of buildings — lighting, cooling in the summer, warmth in the winter, cooling in the summer, water heating, electronic entertainment, computing, refrigeration, and cooking require significant energy use, about 13 Mtoe in 2012. Energy consumption in buildings has been growing in aggregate over time.

The nation3 7,45 million people and more than 7.7 million houses consume more energy than the transportation or industry sectors, accounting for nearly 40 percent of total Algeria energy use.

This energy use is driven by:




## II.2.Energy consumption in the residential sector:

The final consumption is presented in a three sectors, it is the industry sector, transport sector and households & others sector.

The final energy consumption levels for each sector increased:

- 3.3 Mtoe in 1980 to15 Mtoe in 2012with 4.48% per year growth for the household sector and others.

- 2.6 Mtoe in 1980 to7.9 Mtoe in 2012 with 3.54% per year growth for the sector of industry and construction.
- 2.6 Mtoe in1980 to 13,3 Mtoe in 2012, 5.64 %per year growth in the transport sector.

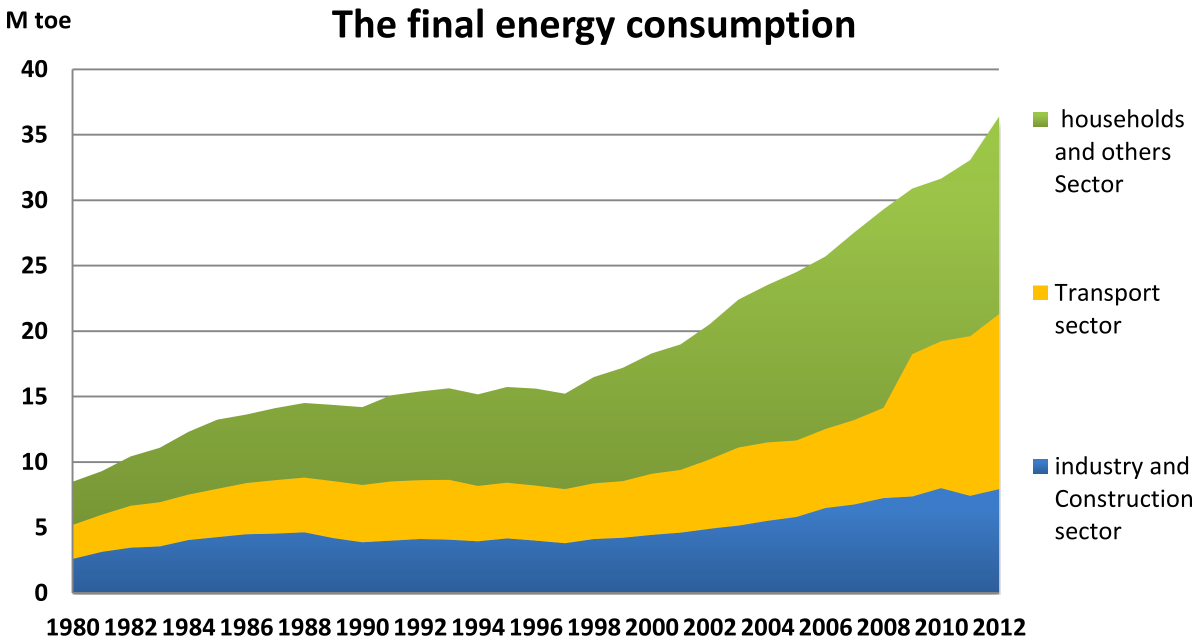



**Figure II.1: Final energy consumption by sector (1980-2012) (MEM, 1980 to 2012)**

## II.3.Repartition of the residential energy consumption:

The figure below shows that the household sector and others represent 41% of the repartition of the final energy consumption while the sector of industry and construction and the transport sector represent respectfully 37% and 22%.

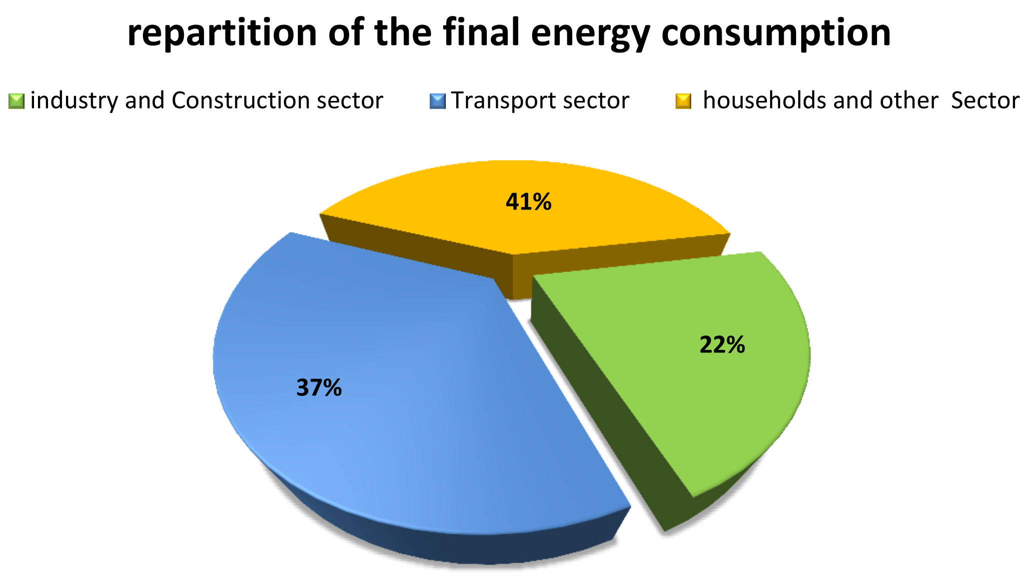



Figure II.2: Repartition of the residential energy consumption of 2012(MEM, 1980 to 2012)

However, the fast growing speed of residential energy consumption has pushed the Algerian government to realize the importance of energy conservation and emissions reductions in the residential sector. In the five-year plan, Algeria has explicitly required household energy consumption reductions and building energy conservation through planning, legislation, technology, standards, and design. (General Office of the State Council, 2011).

## II.4. Residential energy consumption by products:

In Algeria the products utilized in by the households are represented in electricity, natural gas, LPG and biomass (wood).

As it's shown in the figure II.5 natural gas consumption have been rising during the years, while it moved from 4.085Mtoe in 2010 to 5.63Mtoe 1012 by 4.2% per year, the electricity demand also increased by to reach 3.73 Mtoe, when it was 30.2 in 2010, but it's noticed a decline in the consumptions of LPG and biomass, while it were respectively 17.4 Mtoe and 0.17 Mtoe in 2010 to be 17.2 Mtoe and 0.03 in 2012, and that can be explained as reflection of the rising of electrification and gas penetration rate in Algerian houses, what leads Algerian households to abandon using LPG and biomass more and more.(MEM, 2010 to 2012)

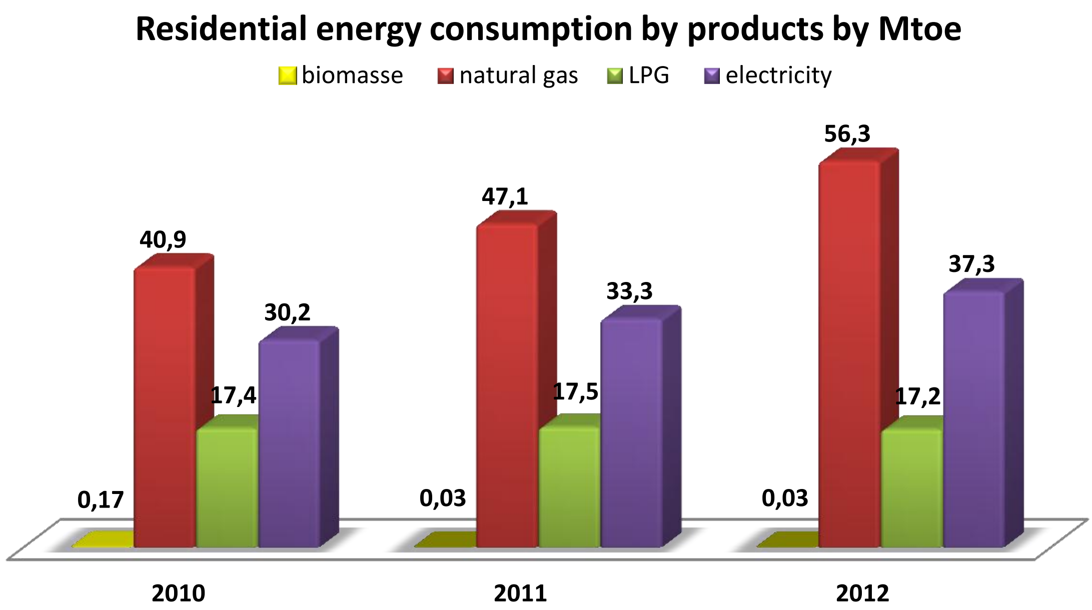



**Figure II.3: Residential energy consumption by products by Mtoe (MEM, 2010 to 2012)**

## II.5.Repartition of the residential energy consumption:

As it's appear in the figure II.4, which shows the repartition of the residential energy consumption, the natural gas is the major energetic product consumed by the households, which represent 51% of the total, followed by electricity with 34% then LPG with 15%, when the biomass only represent 0.02% (MEM, 2010 to 2012).

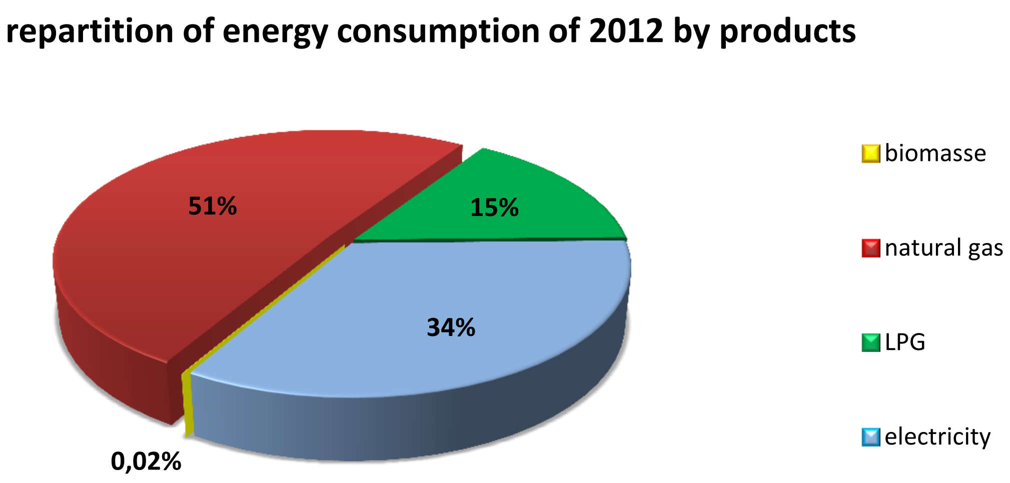



**Figure II.4: Repartition of the residential energy consumption by product (MEM, 2012)**

## II.6.Housing Stock:

### II.6.1.Growth in Housing Units:

One of the major determinants of total residential energy use is the number of households. The number of Algeria households rose nearly 292 percent (1.9 million to 7.7 million) from 1966 to 2012. Households and housing are, in turn, driven by population growth. Overall, Algeria population rose from about 12 million in 1966 to nearly 73.4 million by 2012. This growth — about 511.6 percent — is speeder than the growth in households.

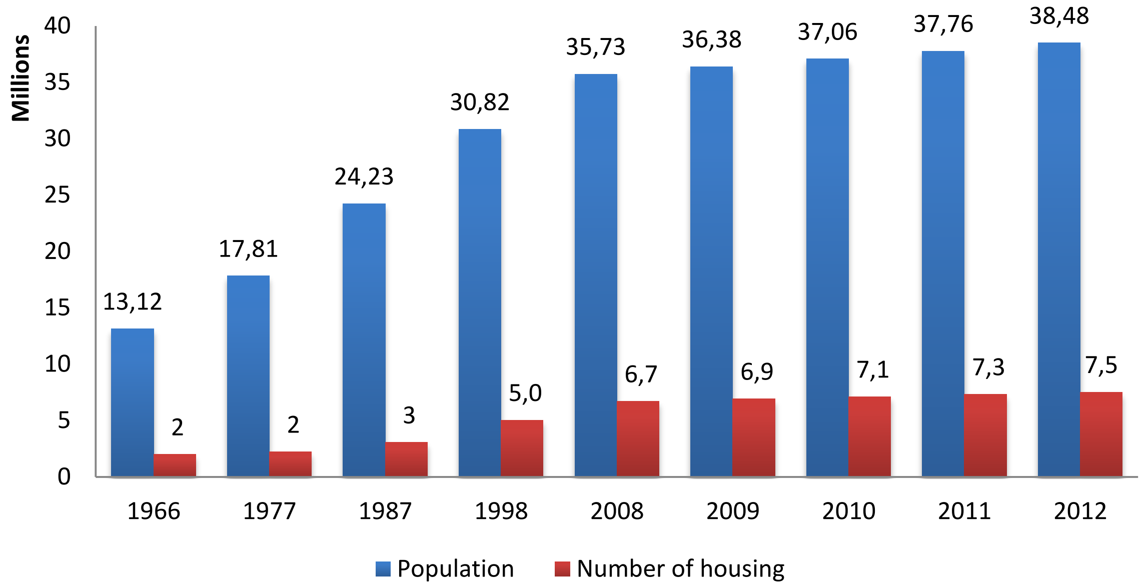



**Figure II.5: Growth in Housing Unit (1966 – 2012) (heraou abdelkrim, 2011) (ONS.com)**

#### II.6.1.1.housing occupancy:

As it's showing in Figure II.5  the number of occupied houses have been increasing in parallel with the number of houses from 3.5 million occupied houses of 5 million houses in 1998 to 6 million occupied houses of 7.5 million houses in 2012, with average annual growth rate of 0.5% per year.

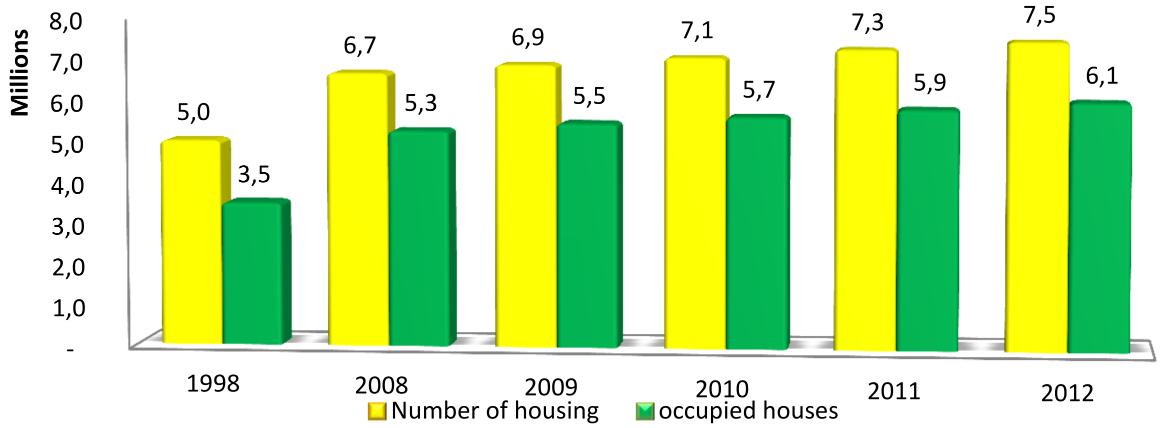



**Figure II.6: Housing occupancy**

## II.6.1.2.rates for electrification and gas penetration:

As it's appear in the figure II.7 the rate of electrification and gas penetration in houses have been rising by time passage respectively from 40% and 24% in 1969 to 99% and 47% in 2011, and the rest of the 53% without natural gas, they use the LPG or butane as source of gas.

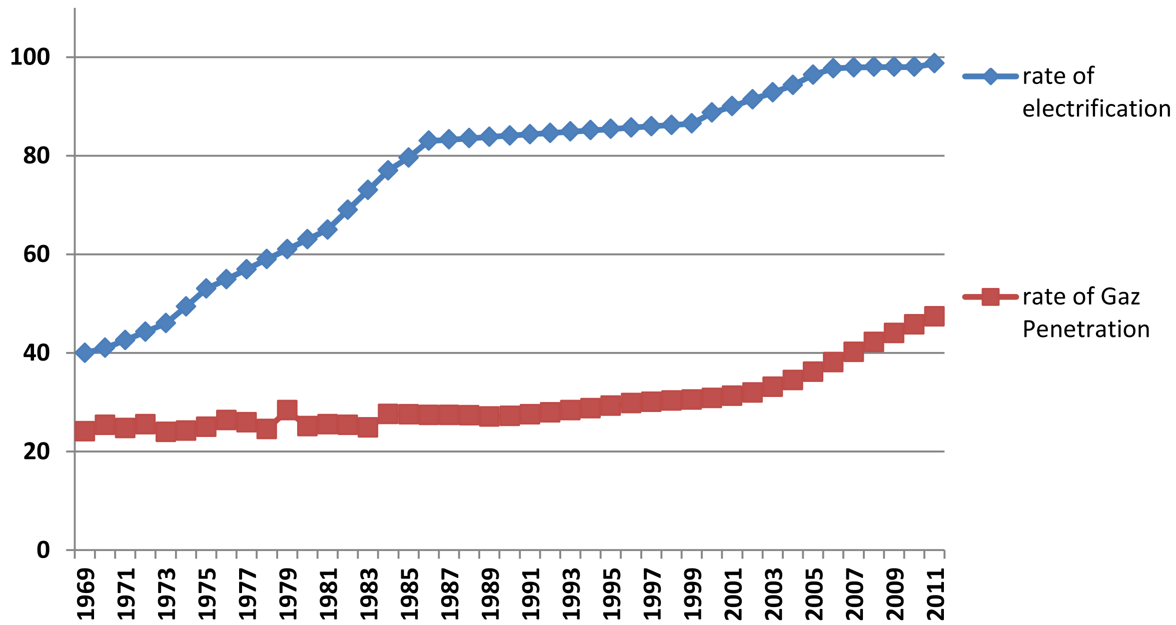



**Figure II.7: Electrification and gas penetration (1969-2011)** (sonelgaz)

## II.6.1.3.household size (persons per household):

The figure II.8 below shows the Household size comparing to housing number, we remark that the number of persons per household is decreasing over the years from (7.6 p/h in 1977 to 6.4 in 2008 (heraou abdelkrim, 2011) (www.premierministre.gov.dz)

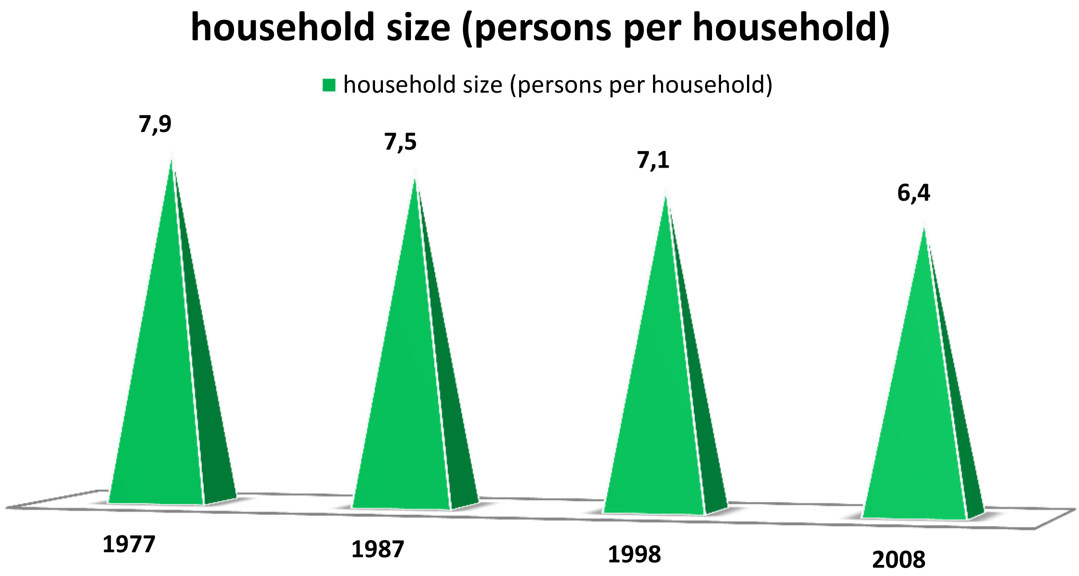



**Figure II.8: Household size (persons per household)** (heraou abdelkrim, 2011)

This decreasing means a less energy consumption per household in these years comparing to several years ago.

**II.6.2.Type of Dwelling:**

In addition to the number of households, a key variable impacting on energy consumption in the residential sector is the type of dwelling. Flats and or apartments, hereafter referred to as flats, are typically expected to have the lowest heat loss (as a result of their smaller size) while detached houses will have the largest as a result of having a larger surface ratio. It has been estimated that important part of the heat from a dwelling can be lost through its walls. (SEI, 2008) It follows that a dwelling with a larger surface area will be expected to have a greater potential for heat loss. If the proportion of flats in the stock is increasing it may therefore be assumed that the stock is becoming less energy intensive.

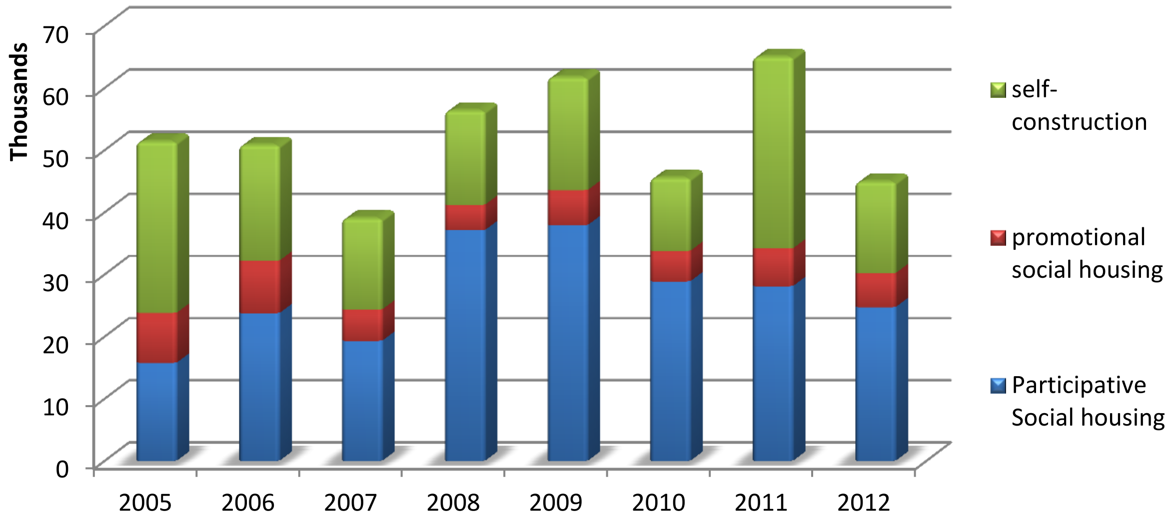



**Figure II.9: Type of Dwelling (2005-2012)**

Table II.1 below shows that for participative social housing projects, the living space housingF4: 75.70m²Living area and housing type F3: 68.50m² (http://afad-dz.com/),while promotional social housing, the living space housing F4: 85 m² and F3: 70 m² (forum chefs d'entreprises, Février 2003) , but for self-construction houses space are not limited to such guides (it depend on the owner).

| | Surface (m²) | |
|---|---|---|
| Type of Dwelling | F4 | F3 |
| participative social housing | 75.70 | 68.50 |
| promotional social housing | 85 | 70 |
| self-construction | not limited | |

**Table II.1: Type of Dwelling (2005-2012)**

**II.6.3.State of realization:**

The table below shows the number of houses realization in the last periods and the next period, which is keep increasing period after period, (around 35 thousand units per year in the 80's to be around 64 units per year thousand in 90's to 200 thousand units per year in 00's).

| state of realization | | | | |
|---|---|---|---|---|
| 1980 | 1988 | 1990 | 1998 | 2012 |
| 34.918 | 68.862 | 64.205 | 151.374 | 199 179 |

**Table II.2: State of realization**

This rising in the number of houses realization will be effective in the residential energy consumption which will logically increase too.

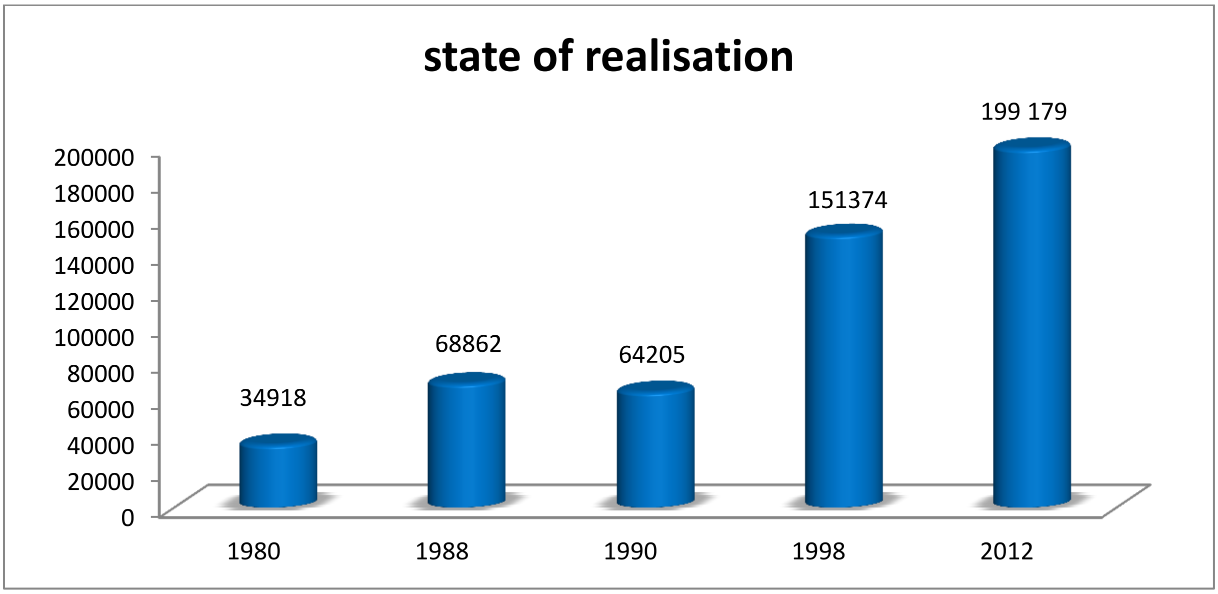



**Figure II.10: State of realization**

## II.7.Economic Factors:

### II.7.1.Energy prices:

Price is clearly an important factor in discussing energy usage and Table II.3 presents the prices in residential energy prices for electricity, natural gas. These were chosen as these fuels make up the majority in residential sector. The different fuels are presented per kilowatt hour (kWh).

| | Electricity prices for households by c€/kWh | GAS prices for households by c€/kWh |
|---|---|---|
| **Algeria** | **1.72 – 4.05** | **0.0055** |
| **Portugal** | **020.8** | **8.4** |
| **Spain** | **22.3** | **7.3** |
| **France** | **17.4** | **6.8** |
| **Italy** | **22.9** | **8.3** |
| **Greece** | **15.6** | **7.7** |
| **Euro area** | **21.3** | **7.4** |

**Table II.3:** Half-yearly electricity and gas prices 2013

(http://epp.eurostat.ec.europa.eu/ 17/2/2014 22:07)

In Table II.3 which shows the electricity prices and gas semester 1 of 2013 prices, the ratio of electricity prices between Algeria and Euro areais12.38 times, when the ratio of gas prices is 1480 times, which indicate very low prices of electricity and gas in Algeria, and this very low prices are effecting the energy consumption in encouraging the households to consume more.

**II.7.2.Gross domestic product per capita:**

The Gross domestic product **(**GDP) per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. GDP is expressed in current U.S. dollars per person. Data are derived by first converting GDP in national currency to U.S. dollars and then dividing it by total population. (Ref:http://knoema.com/atlas/Algeria/GDP-per-capita)

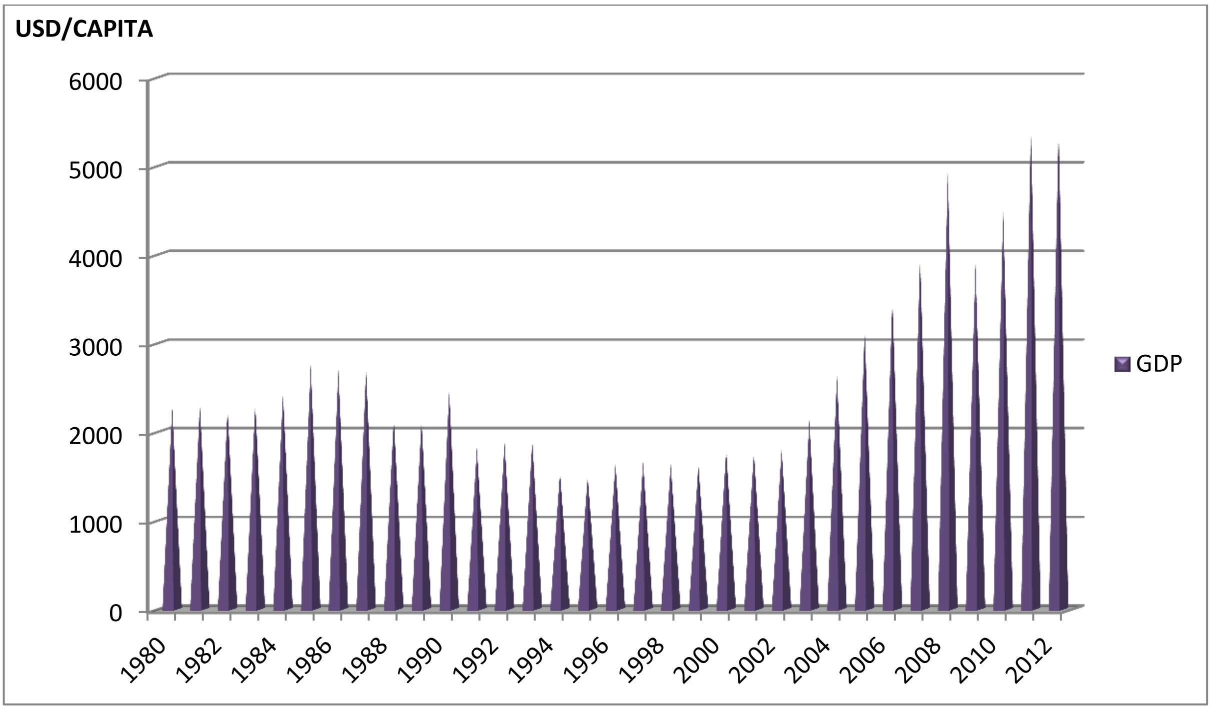



**Figure II.11: Gross domestic product per capita**

In Algeria the Gross domestic product per capita is 5448,44 us dollar per capita in 2012 comparing to 2268,61 us dollar per capita in 1980, which is a sign of improvement in the economic satiation of Algerian families, which will logically reflect by rising on the energy consumption.

The energy stagnated from 1985 to 1994 with falling energy prices. With oil and gas production in decline the economy has been kept going since 2005 by rising energy prices.

## II.8.Climatic zones:

as long as the energies required for cooling and heating is always have a large part of energy consumption of the households all over the world, the climatic zones then play an important role in the evolution of that consumption, and because Algeria is so large, so there are places need a grand energy for cooling, while there some other places which need a large energy for heating, for the determination of that energy in accurate way, the climatic zones should be studied specifically for that matter, by the determination of the heat loss, using degree days method, and Arc-Gis (geographic information system), more details about that will be explained the next chapter.

### II.8.1.Appliance efficiency:

The growth in housing unit size and demand for energy services has been countered by improvements in appliance efficiency. Some energy end uses have become much more efficient in the past years, such as refrigeration and clothes washing. Efficiency gains also have been made in heating, ventilation, and air conditioning equipment, as well as in windows and insulation. As a result, from2005 to 2010, the energy consumption of the residential sector decreased by 6.95 percent as measured by energy use per household (3917.8 kWh in to 3645.4 kWh) Nevertheless, the growth in the number of households and size of houses increased total energy use.

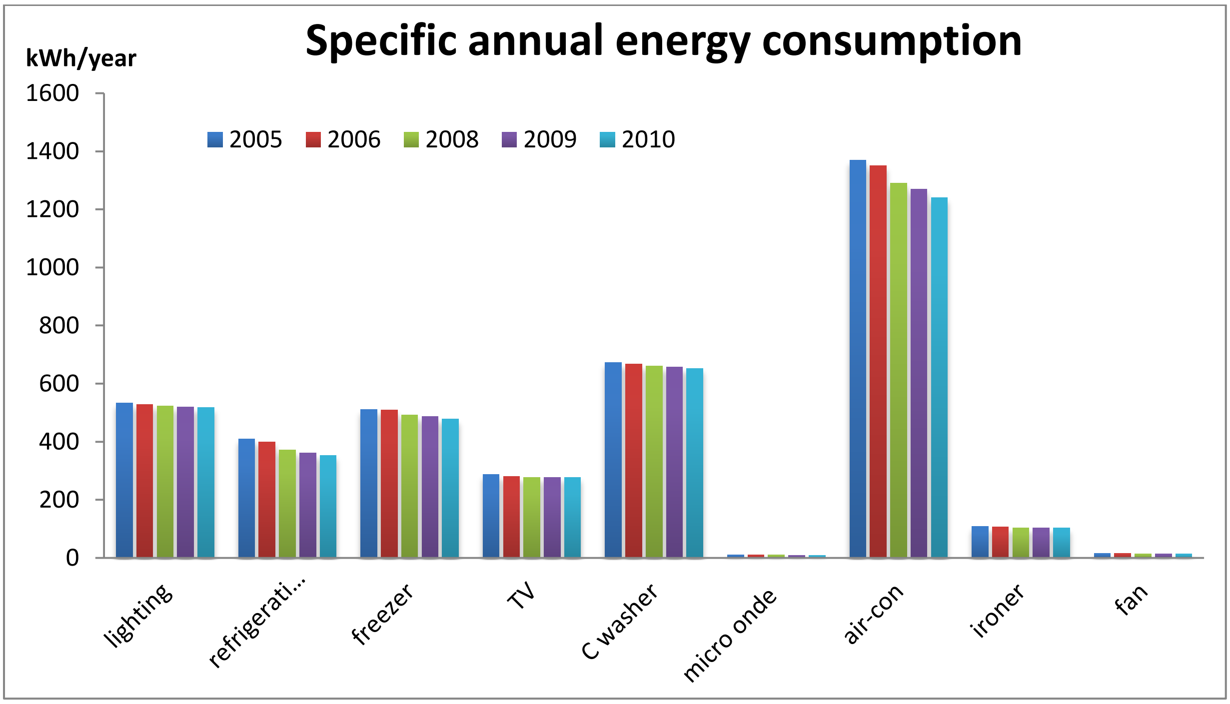



**Figure II.12: Specific annual energy consumption by household appliances in kWh (APRUE2010)**

| KWH | 2005 | 2006 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| lighting | 533 | 529 | 524 | 520 | 518 |
| refrigeration | 409 | 400 | 372 | 361 | 353 |
| freezer | 511 | 510 | 493 | 487 | 478 |
| TV | 287 | 280 | 278 | 278 | 278 |
| C washer | 673 | 668 | 660 | 657 | 653 |
| Microwaves | 10,8 | 10,6 | 10 | 9 | 8,4 |
| air-con | 1370 | 1350 | 1290 | 1270 | 1240 |
| ironer | 108 | 106 | 103 | 103 | 103 |
| fan | 16 | 16 | 14 | 14 | 14 |

**Table II.4: Specific annual energy consumption by household appliances in kWh (APRUE2010)**

## II.8.3.other factors:

### II.8.3.1.persones behivior:

### II.8.3.2.Tenure /location

## II.9.Conclusion:

Some energy end uses have become much more efficient in the past years, such as refrigeration and clothes washing. Efficiency gains also have been made in, heating, ventilation, and air conditioning equipment, which improve the energy efficiency, but it's not enough cause it has been countered by the growth in population, houses realization, and housing unit size and as well as in windows and insulation. So more of procedures are required to improve energy efficiency.

## III.1.Introduction:

The households sector accounted for more than the third of all the energy used in Algeria in 2012 and, it's the largest energy using sector. To provide further understanding it is Useful to examine the demand for all residential energetic services. The data is not available but estimated, using a calibrated model SIMED (Simulation Model for Energy Demand) by AIEA (International Atomic Energy Agency, Vienne).Energy use in the sector includes energy for cooling, heating, lighting, cooking, washing, and other appliance. To estimate the final energy use, it's necessary to determining energy use for each one of these components alone.

For that purpose it will be used degree days method and some tools (ArcGIS and Google Earth), following a methodology which will lead to the final use passing by a many procedures.

**Note:** Because there are electric appliances which use kWh as unite and gas usage appliances which use Therms as unite, and to work in united unite the results will be presented by kWh as energy unite, and by cost (€) in EU tariffs for gas and electricity.

## III.2.Methodology:

This estimation of annual energy consumption involves the determination of the climatic zones to determining the space load for cooling and heating due to heat transfer through the building envelope, the efficiency of the heating system where the fuel is burned and the COP of cooling. The climatic zones will be represented in term of sum energy consumption cost per area unite (€/m²) in the international Tariffs of both heating (gas) and cooling (electricity), and that's because this study is not directed just for the specialist but it's also aimed ordinary people who they are daily the consumers, and who do not grasp the technical terms.

The space heat load is usually based on the average temperature difference between the indoors and the outdoors. There are various methods for calculation of annual energy consumption. The simplest and most intuitive way of estimating the annual energy consumption of cooling and heating in a building is the degree-days (or degree-hours) method. It is based on constant indoor conditions during the heating or cooling season and assumes the efficiency of the heating or cooling equipment is not affected by the variation of outdoor temperature.

The energy use of the rest of the components will be determining by the specific consumption each appliance for one household then for the aggregate number of households in each zone.

The method will be applied is this study is based on the following:

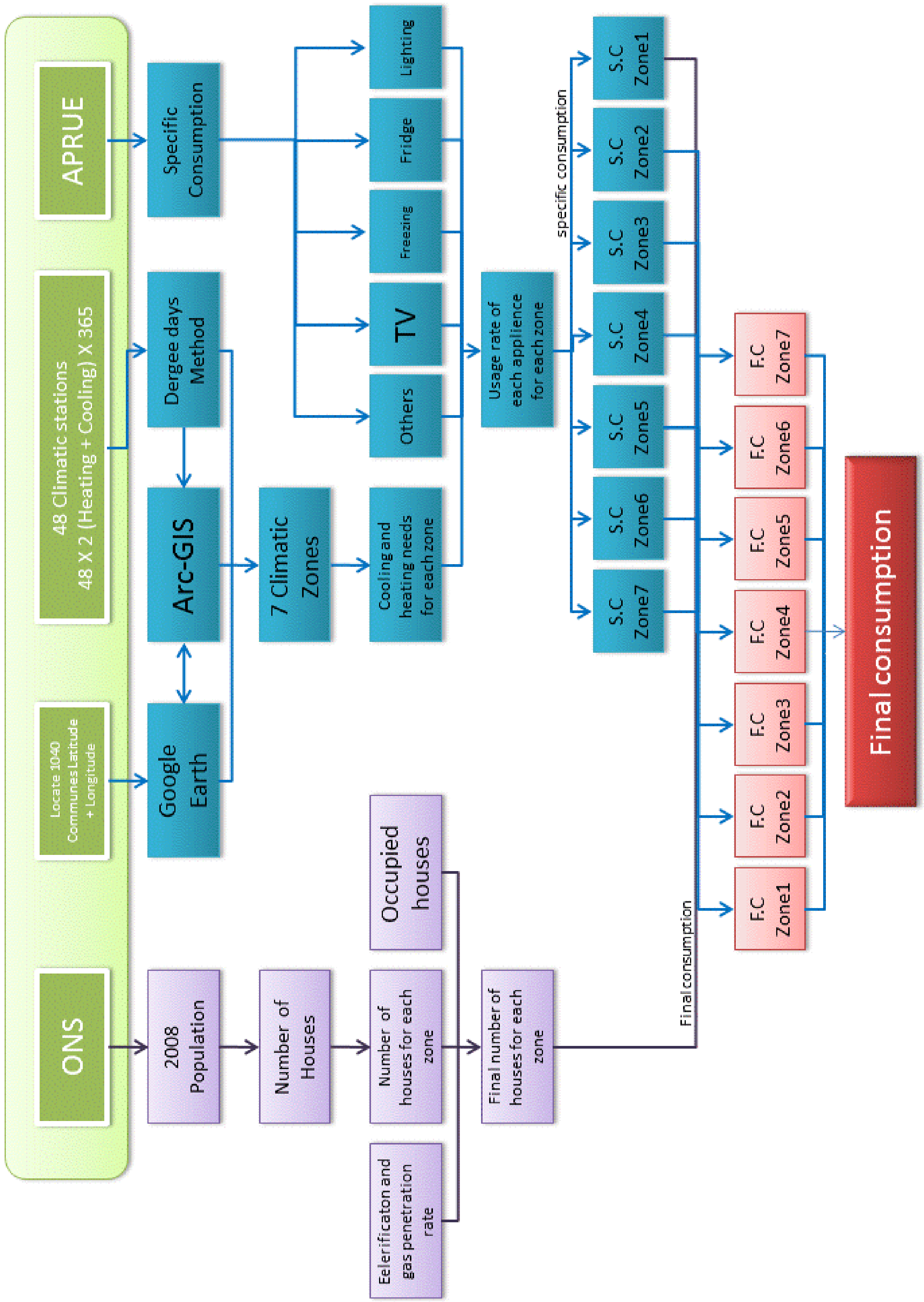
$$\mathbf{fin\ cons} = \mathbf{specif\ cons} \times \mathbf{number\ of\ housholds}$$ (AIEA, 2007)

Where:

**fin cons**:Final consumption

**specif cons:** Specific consumption

This following figure shows the methodology plane:


ONS
Locate 1040 Communes Latitude + Longitude
48 Climatic stations 48 X 2 (Heating + Cooling) X 365
APRUE
2008 Population
Google Earth
Arc-GIS
Dergee days Method
Specific Consumption
Number of Houses
7 Climatic Zones
Eelerificaton and gas penetration rate
Number of houses for each zone
Occupied houses
Cooling and heating needs for each zone
Others
TV
Freezing
Fridge
Lighting
Final number of houses for each zone
Usage rate of each applience for each zone
specific consumption
S.C Zone7
S.C Zone6
S.C Zone5
S.C Zone4
S.C Zone3
S.C Zone2
S.C Zone1
Final consumption
F.C Zone1
F.C Zone2
F.C Zone3
F.C Zone4
F.C Zone5
F.C Zone6
F.C Zone7
Final consumption

## III.3.Climatic zones:

- **III.3.1.degree days:**

The term cooling (or heating) degree days (CDD or HDD) is defined as the positive deviation of the daily mean outdoor temperature Tm from a base temperature Tb, below (or above) which cooling (or heating) is needed to sustain the indoor temperature to a comfortable level. (Marina Stathopoulou, 2006)

$$\mathrm{CDD\ (or\ HDD)} = \sum_{i=1}^{365} |\mathrm{T_m} - \mathrm{T_b}|$$ (Omer Kaynakli, 2012)

In this study the comfort temperature assumed:

- **18°** is the comfort temperature in heating season.
- **26°** is the comfort temperature in cooling season.

The temperatures used to calculate the cooling and heating degree days are pooled from the following48 Algerian airport and weather stations represented in Table IV.1

Provided by (http://www.meteociel.com/climatologie)

| N° | station | N° | station | N° | station | N° | station |
|---|---|---|---|---|---|---|---|
| 1 | ADRAR | 13 | CONSTANTINE | 25 | IN SALAH | 37 | OUM EL BOUAGHI |
| 2 | AIN SEFRA | 14 | DAR EL BEIDA | 26 | KSAR CHELLALA | 38 | SETIF |
| 3 | ANNABA | 15 | DJANET | 27 | MAGHNIA | 39 | SIDI BEL ABBES |
| 4 | BATNA | 16 | DJELFA | 28 | MASCARA MATEMORE | 40 | SOUK AHRAS |
| 5 | BECHAR | 17 | EL GOLEA | 29 | MECHERIA | 41 | TAMENRASSET AEROPORT |
| 6 | BEJAIA AEROPORT | 18 | EL KHEITER | 30 | MEDEA | 42 | TEBESSA |
| 7 | BENI ABBES | 19 | EL OUED | 31 | MILIANA | 43 | TIARET |
| 8 | Beni-Saf, TLE | 20 | GHARDAIA | 32 | MOSTAGANEM | 44 | TIMIMOUN |
| 9 | BISKRA | 21 | GUELMA | 33 | M'SILA | 45 | TINDOUF |
| 10 | BORDJ B. MOKHTAR | 22 | HASSI MESSAOUD | 34 | NAAMA | 46 | TIZI OUZOU |
| 11 | BORDJ BOU ARRERIDJ | 23 | ILLIZI | 35 | ORAN SENIA | 47 | TLEMCEN ZENATA |
| 12 | BOU SAADA | 24 | IN AMENAS | 36 | OUARGLA | 48 | TOUGGOURT |

**Table III.1: Airport and weather stations**

**Remark:** At first, this study includes about 60 airport and weather stations, but some of them have been excluded because there are not enough data about all around the year.

- **III.3.2.Envelope wall thermal resistances:**

In Algeria, they usually use the sandwich wall in the envelope wall of the houses; the sandwich wall consists of an air space as insulation in the middle of the two brick layers, plaster layer on the inside and cement layers on outside surfaces.

In the calculations, as insulation we choose 0,05mas insulation in the calculations. The structure of sandwich wall consists of 0,015m inner plaster (k = 0.35 W/mc), hollow brick of 0.15 m (k = 0.48 W/mc) on inside and hollow brick of 0.1 m (k = 0.48 W/mc) in outside, and 2 cm of cement layer outside (k = 1.4 W/mc).

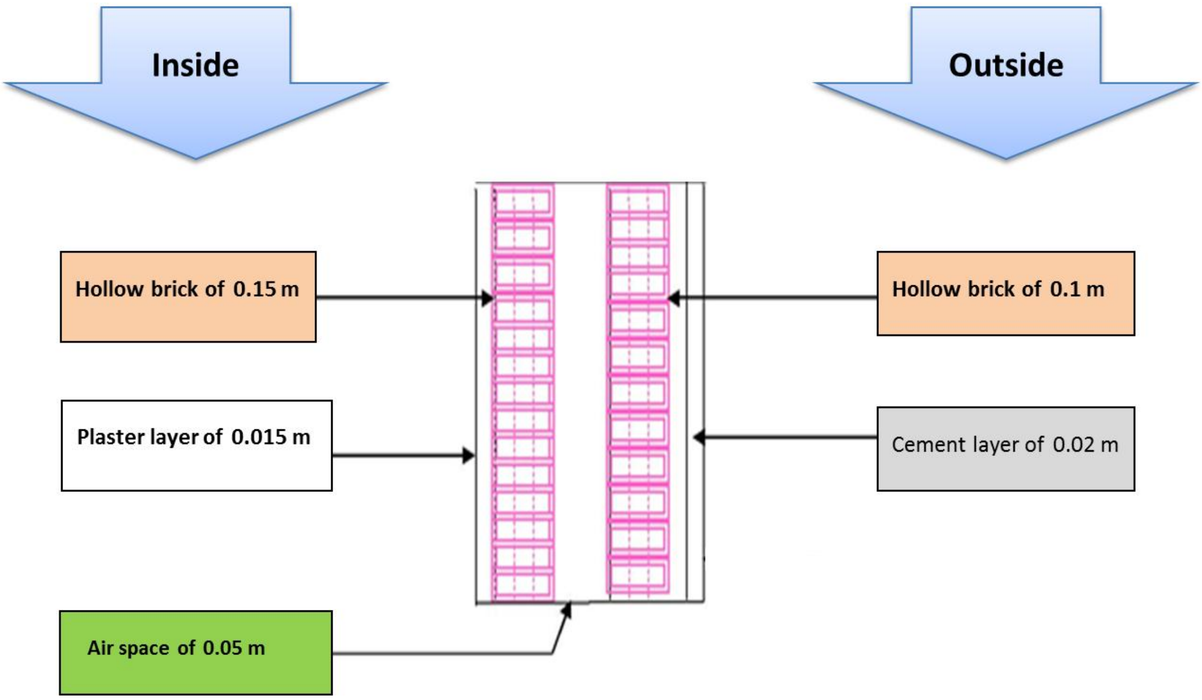



**Figure III.2: Envelope wall**

This structure is used for calculation for all the cities considered.

**a. Calculation of thermal resistances :**

The wall conductance U for a typical wall that includes a layer of insulation is given by:

**Thermal resistances of layers:** $$R = \frac{th}{\lambda}$$

**Superficial resistance:** $$\frac{1}{h_e}+\frac{1}{h_i}$$

**The wall conductance:** $$\frac{1}{k}=R+\frac{1}{h_e}+\frac{1}{h_i}$$

Where:

th: Thickness

$\lambda$: Thermal conductivity (W/m K)

h: Combined heat transfer coefficient (W/m²K)

The table III.2 represents the results of thermal resistance calculated:

| Compositions | th (m) | λ (W/m²°C) | R (W/m²°C) | 1/hi + 1/he (W/m²°C) | 1/K (W/m²°C) | K (W/m²°C) |
|---|---|---|---|---|---|---|
| Layer of cement | 0,02 | 1,4 | 0,014 | 0,14 | 0,8695 | 1,15 |
| hollow brick | 0,15 | 0,48 | 0,3125 | | | |
| Air space | 0,05 | | 0,16 | | | |
| hollow brick | 0,1 | 0,48 | 0,2 | | | |
| Layer of plaster | 0,015 | 0,35 | 0,043 | | | |

**Table III.2: Calculation of thermal resistances (CNERIB, 2000)**

- **III.3.3.Annual heat loss:**

The annual heat loss per unit area can be obtained from:

$$\mathbf{Q_{heating}} = \mathbf{24} \times \mathbf{HDD} \times \mathbf{k}$$ (Ali Bolattürk, 2006)

$$\mathbf{Q_{cooling}} = \mathbf{24} \times \mathbf{CDD} \times \mathbf{k}$$ (Ali Bolattürk, 2006)

**Where:**

**Q** $_{heating}$ and **Q** $_{cooling}$ are by **(Wh/m²)**

- **III.3.4.Annual fuel consumption:**

The annual fuel consumption can be calculated by dividing the annual heat loss to the efficiency ηS and $LHV_{gas}$ of heating, by dividing the annual heat loss COP to the cooling system.

$$\mathbf{F_{heating}} = \frac{\mathbf{E_{heating}}}{(\mathbf{LHV_{gas}} \times \mathbf{\eta_{Sheating}})}$$ (Ali Bolattu, 2005)

$$\mathbf{F_{cooling}} = \frac{\mathbf{E_{cooling}}}{\mathbf{COP}}$$ (Ali Bolattu, 2005)

**$LHV_{gas}$ = 35.22 Mj/$m^3$** (Iain Staffell, 2011)

**COP = 2.5** (MeralOzel, 2011)

**$\eta_S$= 0.93** (NaouelDaouas, 2011)

Where:

**LHV** is lower heating value of the fuel.

**COP** is Coefficient of Performance for cooling system.

**$\eta_S$** is heating system Efficiency.

The lower heating value (also known as net calorific value) of a fuel is defined as the amount of heat released by combusting a specified quantity (initially at 25°C) and returning the temperature of the combustion products to 150°C, which assumes the latent heat of vaporization of water in the reaction products is not recovered. The LHV are the useful calorific values in boiler combustion plants and are frequently used in Europe.
(cta.ornl.gov/bedb/)

- **III.3.5.Annual cooling and heating cost per unit area:**

The annual cooling and heating cost per unit area may be determined from:

$$\mathbf{C_{coolig}} = \mathbf{F_{cooling}} \times \mathbf{T_{electcity}}$$ (Ali Bolattürk, 2006)

$$\mathbf{C_{heating}} = \mathbf{F_{heating}} \times \mathbf{T_{gas}}$$ (Ali Bolattürk, 2006)

Where:

**C**: Cooling and heating cost in **€/$m^2$.**

***T***: Electricity and gas cost in **€/kWh** and **€/$m^3$.**

- **III.3.6.Interpolation by Arc-Gis version 9.3:**

As we know, Algeria has surface of 2.38 million $km^2$, so this information can not cover that wide surface, so it's necessary to extend the information gotten from the 48 airports and weather stations to all Algerian area using one of the geographic information systems.

In this study the geographic information system is Arc-Gis version 9.3because it's a platform for designing and managing solutions through the application of geographic knowledge.

**III.3.6.1.ArcGIS:**

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database.(http://en.wikipedia.org/wiki/ArcGIS)

The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web.

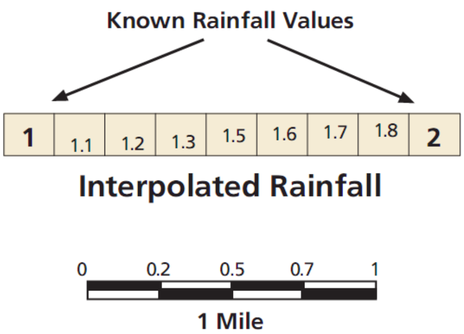
(resources.ArcGIS.com/)

- **III.3.6.2.Interpolation Methods:**

To create a surface grid in ArcGIS, the Spatial Analyst extension employs one of several interpolation tools. Interpolation is a procedure used to predict the values of cells at locations that lack sampled points. It is based on the principle of spatial autocorrelation or spatial dependence, which measures degree of relationship/dependence between near and distant objects. (Colin Childs, 2004)

Spatial autocorrelation determines if values are interrelated. If values are interrelated, it determines if there is a spatial pattern. This correlation is used to measure:

- Similarity of objects within an area.
- The degree to which a spatial phenomenon is correlated to itself in space.
- The level of interdependence between the variables.
- Nature and strength of the interdependence.
- Different interpolation methods will almost always produce different results.




*Interpolation is the procedure used to predict cell values for locations that lack sampled points.*

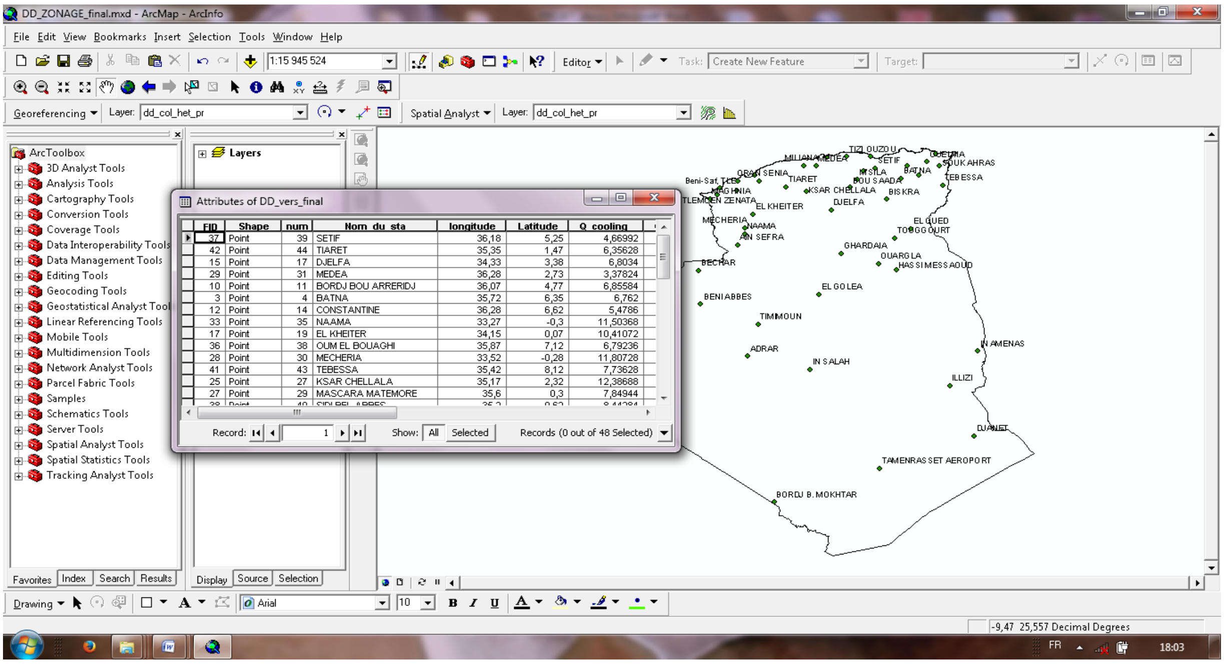
There are two categories of interpolation techniques: deterministic and geostatistical. Deterministic interpolation techniques create surfaces based on measured points or mathematical formulas. Methods such as Inverse Distance Weight (IDW) are based on the extent of similarity of cells while methods such as Trend fit a smooth surface defined by a mathematical function. Geostatistical interpolation techniques such as Kriging are based on statistics and are used for more advanced prediction surface modeling that also includes some measure of the certainty or accuracy of predictions. (Colin Childs, 2004)

The interpolation method used in this study is IDW method because it provides the appropriate specifications for our purpose.

- **Insuring data:** insuring data of the annual cooling and heating cost per unit area to excel page in the following shape:

| N | Nom dustation | longitude | Latitude | Q_cooling_Kwh_m2 | Q_heating_Kwh_m2 | cooling_cost_€_Kwh | heating_cost_€_Kwh |
|---|---|---|---|---|---|---|---|
| 1 | ADRAR | 27,82 | -0,18 | 45,80 | 16,43 | 3,60 | 0,015 |
| 2 | AIN SEFRA | 32,77 | -0,6 | 15,45 | 41,38 | 1,21 | 0,038 |
| 3 | ANNABA | 36,83 | 7,82 | 2,61 | 29,71 | 0,21 | 0,027 |
| 48 | ………… | …… | ……. | ……. | ……. | ……. | ……… |

**Injecting the excel page:** injecting the excel page in Arc-Gis, and follow the instructions required, we get the following results:



**III.3.6.3.Step 3:**after interpolate, it's automatically divide the zoning to 9 zones, what make the zoning not useful as it's required, soit was chosen to dividing it to 7 zones by dividing the interval of cooling and heating sum costs to equal interval of 0,629 €/m² as it has shown in the figure III.3:

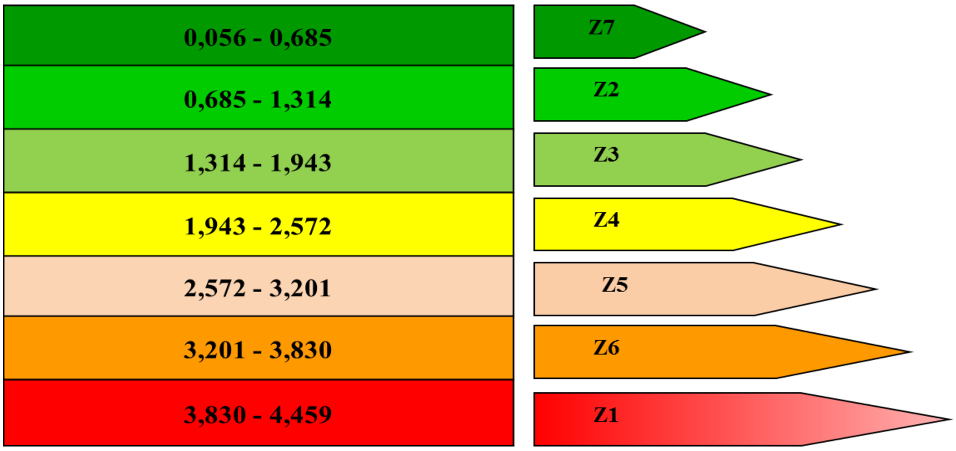



**Figure III.3: Zoning cost interval**

The figures III.3 and III.4, shows the final zoning map in 7 zones, by the sum of cost of cooling and heating in EU electricity and gas tariffs.

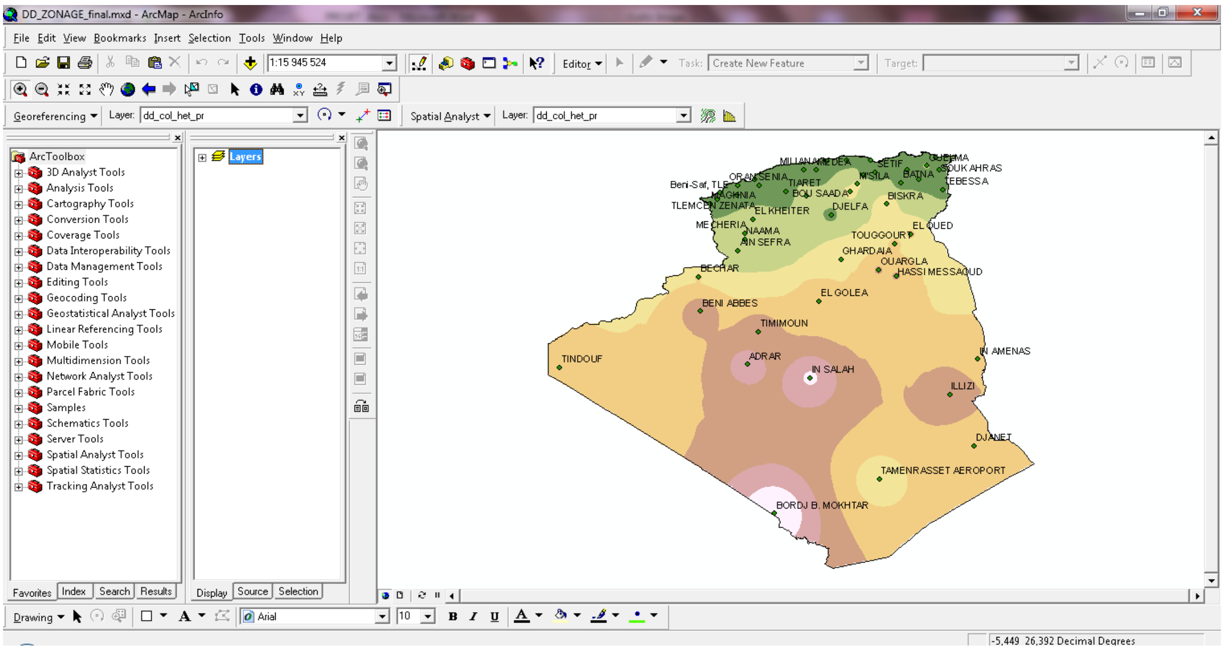



**Figure III.4: The climatic zones in Arc-GIS**

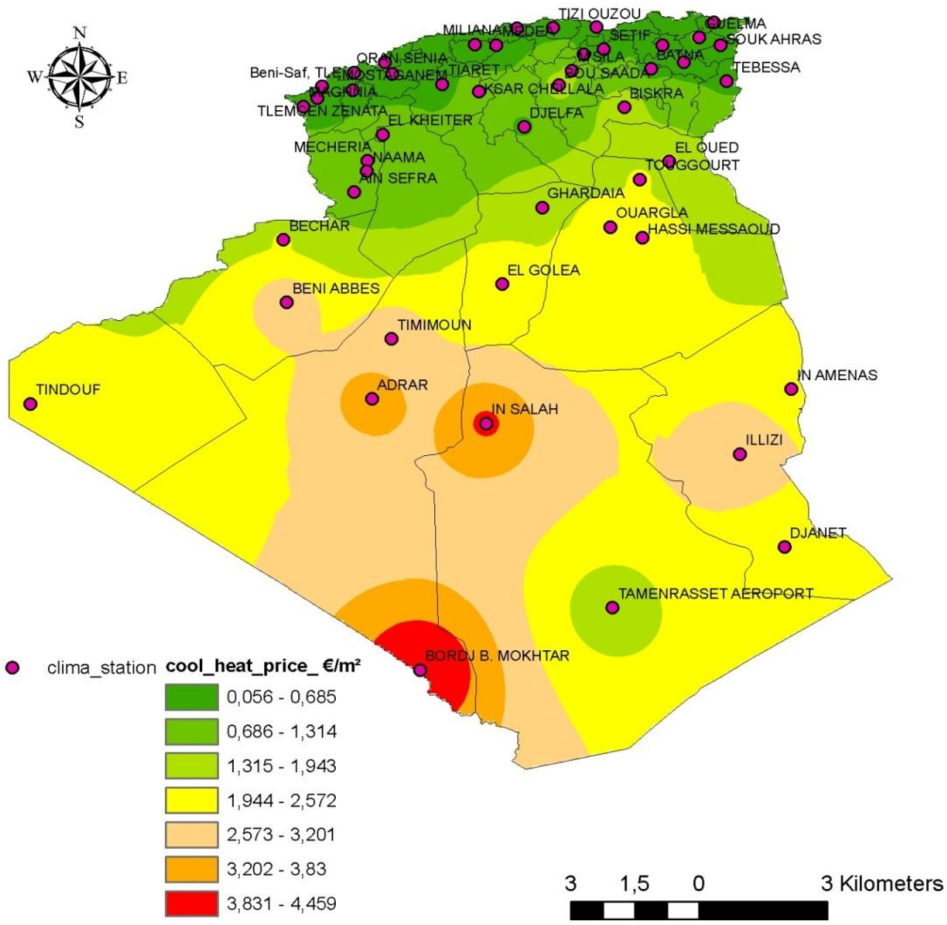
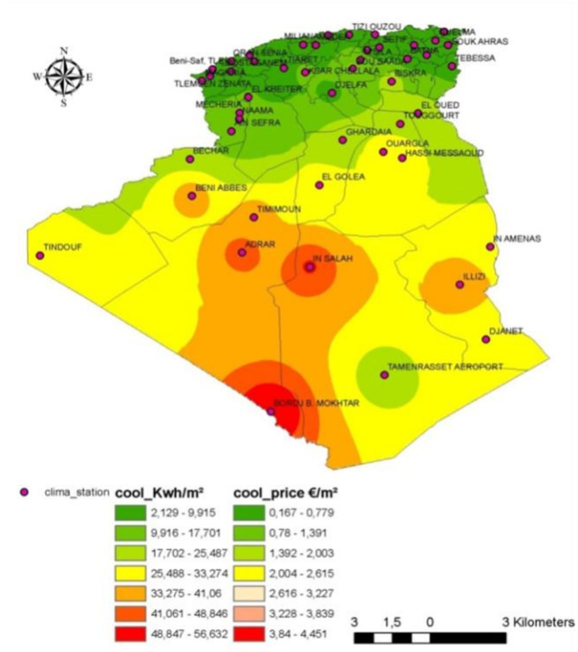
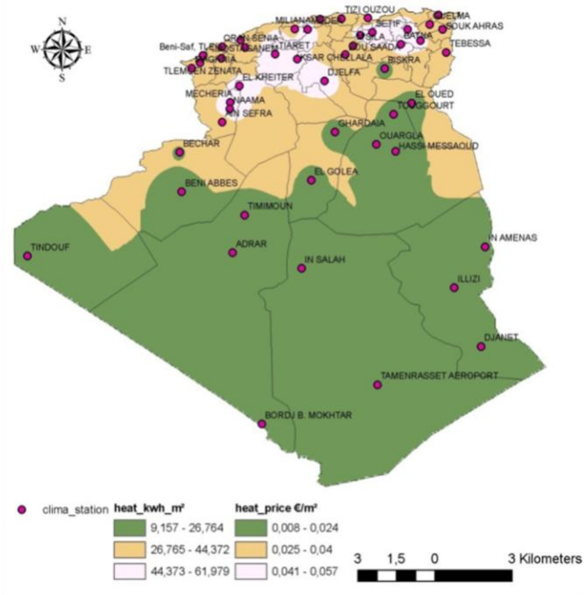



**Figure III.5: The climatic zones**

**III.3.7.Determining cooling and heating energy use in each zone:** to determining the energy use in each zone for cooling and heating, it should treat cooling and heating separately by dividing the previous zoning to secondary zonings repeating the same operation for both.

The cooling zoning will be divided to 7 zones, while the heating zoning will be divided only to 3 zones because it have small rang (0,0083 - 0,0565).




| | intervals(€/m2) | |
|---|---|---|
| zones | cooling | heating |
| zone 1 | 3,821305 - 4,451135635 | 0,008352552 -0,024414151 |
| zone 2 | 3,191474364 - 3,821305 | 0,024414151 - 0,04047575 |
| zone 3 | 2,561643729 - 3,191474364 | 0,04047575 - 0,056537349 |
| zone 4 | 1,931813093 - 2,561643729 | |
| zone 5 | 1,301982458 - 1,931813093 | |
| zone 6 | 0,672151822 - 1,301982458 | |
| zone 7 | 0,042321187 -0,672151822 | |

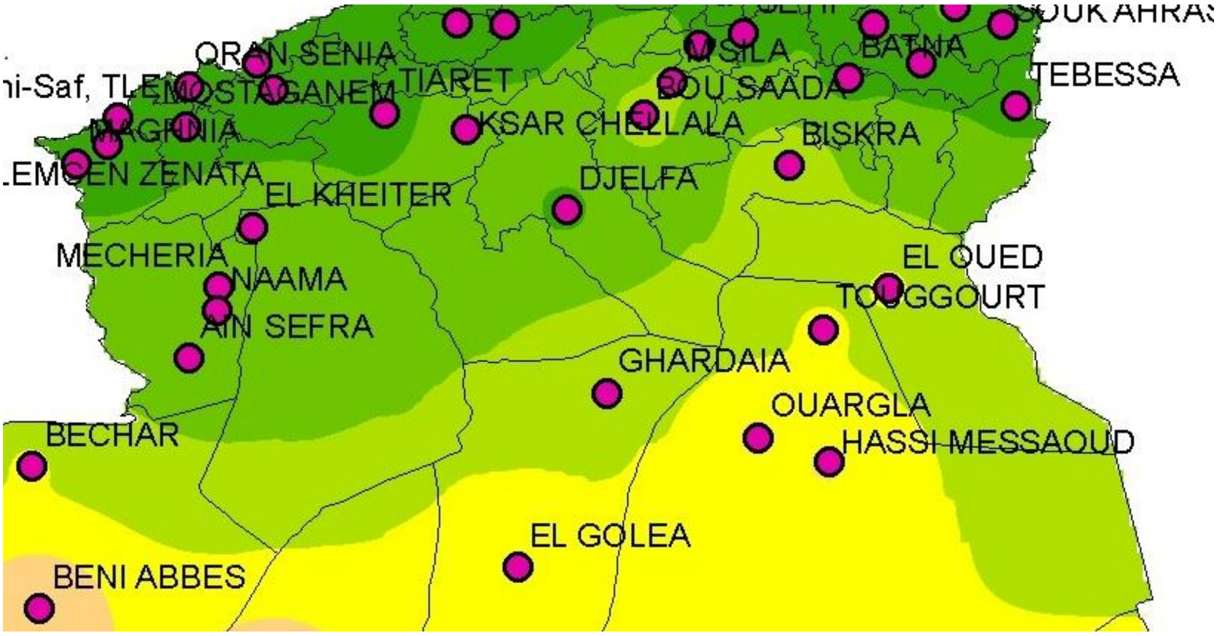
**Table III.3: Cooling and heating intervals**

**Remark**: the cooling zoning is so similar to the sum energy consumption cost, which mean the heating consumption cost have no influence in zoning comparing with cooling consumption cost, and that can be explained with the big different between electricity and gas Tariffs, since the gas Tariffs(0.074 €/kWh) is almost the third of electricity Tariffs (0.213 €/kWh).

## III.4.Estimation of houses number in each zone:

### III.4.1.multi-zones wilayas problem:

According to the method, to calculate the energy use for one zone, it should know the number of houses in that zone, but the Problematic as it appears in the figure is some wilayas is include 2 or 3 zones in its area.




22 wilayas of 48 Algerian wilayas have problem of multi-zones, to solve this problem we have to be more precise by treating the zones in communes level which mean that we have to locate 1070 communes of using Google Earth to get the geographic coordinates of each communes.

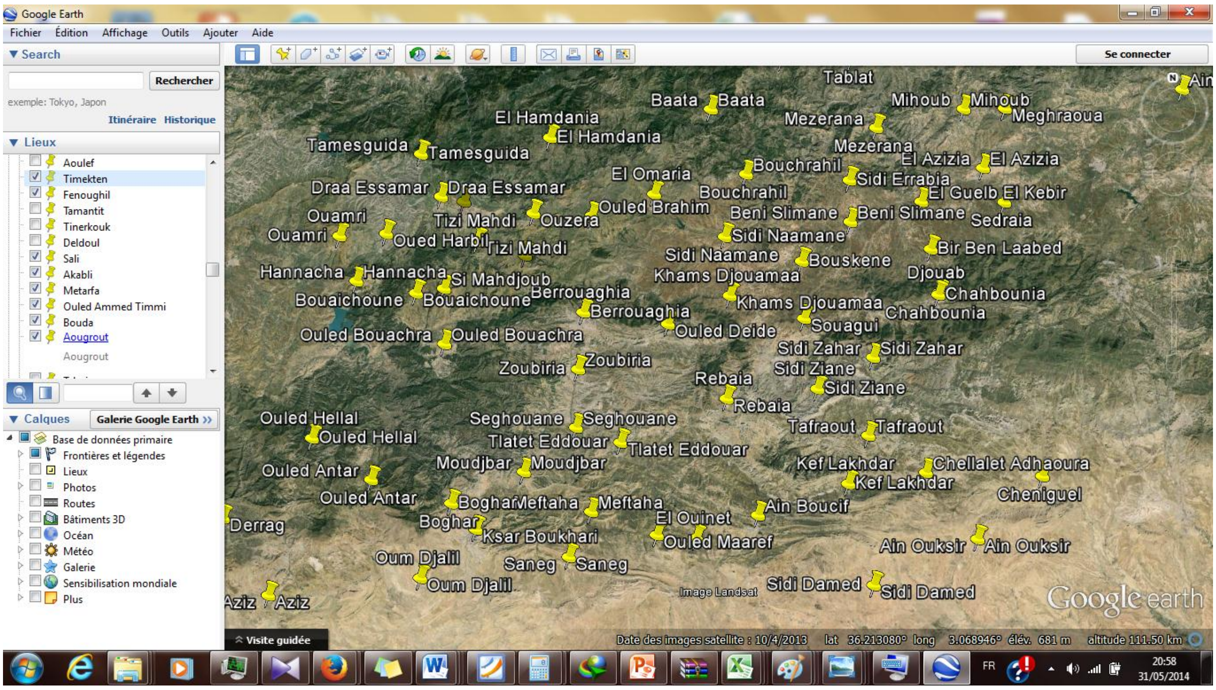


**Figure III.6: Location of the 1040 communes in Google earth**

After getting the geographic coordinates of each communes from Google earth, it have to export them to ArcGIS in kml extension files

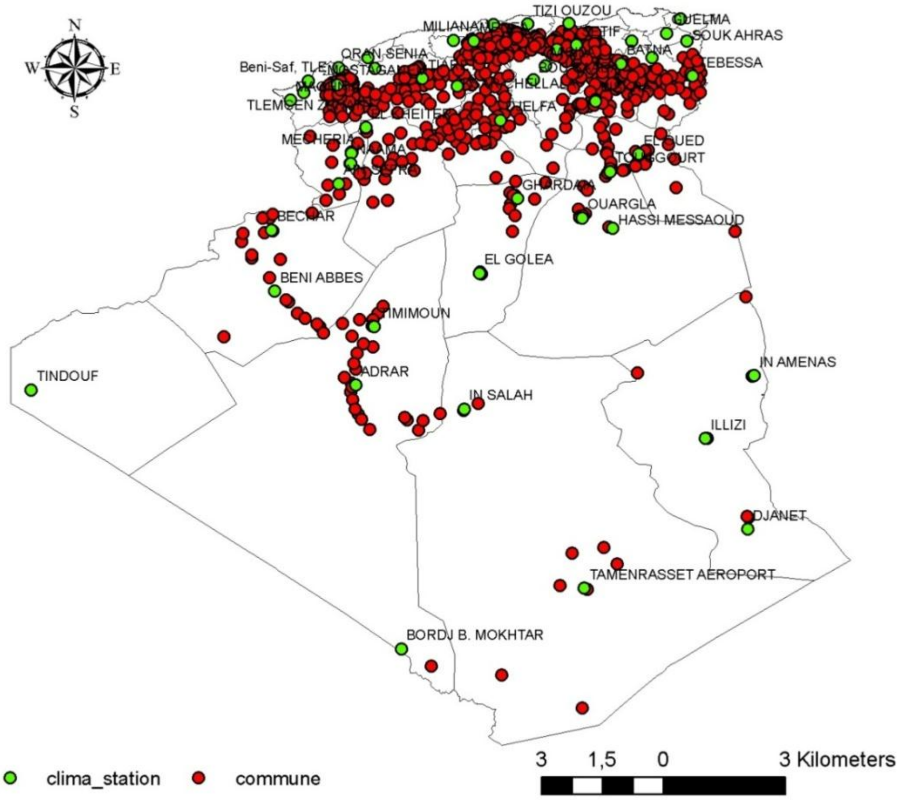



**Figure III.7: The 1040 communes represented in ArcGIS**

The next step is to select in which zone each commune locates by the aide of AcrGis, for example: as it's shown in the figure below, Tiaret and Laghouat located respectively between zone 7 – 6 and 6 – 5.

Tiaret have 11 communes in the zone 6 while the rest is in zone 7, and Laghouat have only one commune in zone 5 while all the rest are in zone 6.

The results will be presented in the annexes

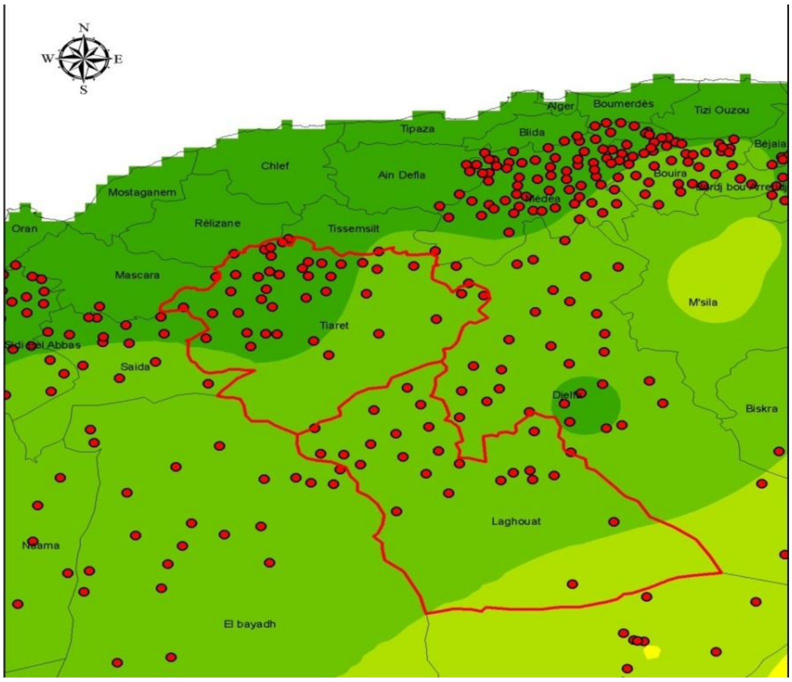



**Figure III.8: Tiaret and Laghouat communes location**

**III.4.2.Number of houses by zone (2010):**

because the number of houses in the communes level is not available, and there only the global number of 2008 houses (6690000 houses) (ONS, 2008), The estimation of houses number in communes is determining from 2008 by communes population (ONS, 2008), assuming that the percentage of the population in each commune is the same percentage of the houses number in it.

After determining the number of houses in the communes, and the location of each communes by zones, it have to determine the number houses in each zone.

| zones | Number of houses |
|---|---|
| **zone 1** | 12 373 |
| **zone 2** | 49 519 |
| **zone 3** | 47 106 |
| **zone 4** | 196 694 |
| **zone 5** | 419 398 |
| **zone 6** | 1 126 895 |
| **zone 7** | 5 246 683 |

**Table III.4: Total number of houses**

**III.4.3.Number of Occupied houses by zone (2010):**

Occupied rate in 2010 was 97.87% so the occupied houses will be by zones in

| zones | Number of occupied houses |
|---|---|
| **zone 1** | 9 871 |
| **zone 2** | 39 506 |
| **zone 3** | 37 580 |
| **zone 4** | 156 920 |
| **zone 5** | 334 590 |
| **zone 6** | 899 021 |
| **zone 7** | 4 185 732 |

**Table III.5: Occupied houses (2010)**

### III.4.4.Electricity and gas supplied houses (2010):

In this study we conceder all the houses are supplied by gas, because even when natural gas are not available of the households, they use the butane as replacement, while the electrification rate is 0.99%, so the houses supplied by electricity are:

| zones | Number of electrified houses |
|---|---|
| zone 1 | **9 770** |
| zone 2 | **39 104** |
| zone 3 | **37 198** |
| zone 4 | **155 323** |
| zone 5 | **331 185** |
| zone 6 | **889 873** |
| zone 7 | **4 143 140** |

**Table III.6: Electricity and gas supplied houses**

## III.5.Specific consumption and Usage rates:

### III.5.1.Cooling and heating consumption:

from the degree days method it have been calculated the energy needed to cool and to heat one meter square of the envelope wall of a house in the 7 zones, so be multiplying that values in the envelope wall surface of the living part of the house, we will get the energy required for cooling and to heating of one house in the each zone.

Like it's shown in figure III.9,The average surface of houses in Algeria are assumed to be 80m², and the living space are assumed to be the half 40m², with 3m of wall height, the involve wall surface become 54m².

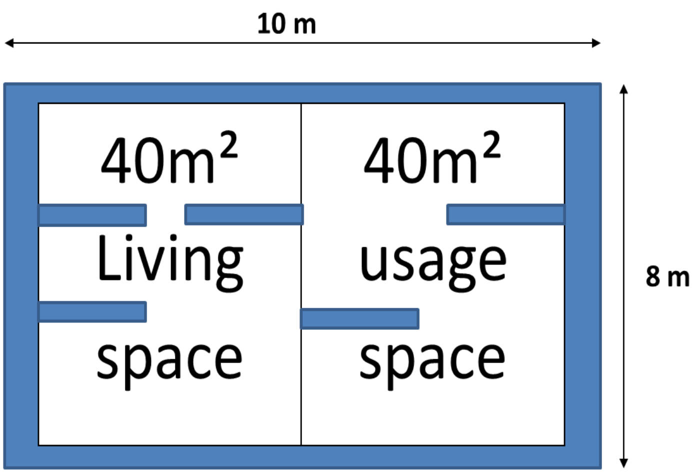



**Figure III.9: House surface**

So cooling demands for one house is:

| zones | cooling | | | |
|---|---|---|---|---|
| | €/m² | kWh/m² | envelope (m²) | kWh/house |
| zone 1 | 4,13622 | 52,6251505 | 54 | 2841,758128 |
| zone 2 | 3,50639 | 44,6118124 | 54 | 2409,037869 |
| zone 3 | 2,87656 | 36,5984743 | 54 | 1976,31761 |
| zone 4 | 2,24673 | 28,5851361 | 54 | 1543,597351 |
| zone 5 | 1,61690 | 20,571798 | 54 | 1110,877091 |
| zone 6 | 0,98707 | 12,5584599 | 54 | 678,1568322 |
| zone 7 | 0,35724 | 4,54512172 | 54 | 245,4365731 |

**Table III.7: Cooling demand for 7 zones**

And heating demands for one house is:

| zones | heating | | | |
|---|---|---|---|---|
| | €/m² | kWh/m² | envelope (m²) | kWh/house |
| zone 1 | 0,16393 | 17,9595089 | 54 | 969,813479 |
| zone 2 | 0,16393 | 17,9595089 | 54 | 969,813479 |
| zone 3 | 0,16393 | 17,9595089 | 54 | 969,813479 |
| zone 4 | 0,20038 | 21,9537128 | 54 | 1185,50049 |
| zone 5 | 0,24602 | 26,9534422 | 54 | 1455,48588 |
| zone 6 | 0,39541 | 43,320712 | 54 | 2339,31845 |
| zone 7 | 0,37442 | 41,0208386 | 54 | 2215,12528 |

**Table III.8: Heating demand for 7 zones**

## III.5.2.The other appliances consumption:

According to (APRUE), the specific consumption is as in the table III.9

| 2010 | | | | | | | |
|---|---|---|---|---|---|---|---|
| lighting | refrigeration | freezer | TV | C washer | Microwaves | ironer | fan |
| 518 | 353 | 478 | 278 | 653 | 8,4 | 103 | 14 |

**Table III.9:** The specific consumption

## III.5.3.Usage rate:

Usage rate is defined as the percentage of households that use the energy source, The usage rate are deferent from zone to another, and that's mainly depend on two factors the climate of zone for cooling and heating, and the necessity for need for the other appliance. The usage rates are determining after a calibration operation by calibrating the values with the values 2010, 2011 and 2012 energy balance.

The table III.10 Shows the comparison enter the results of the electrical appliance usage rate applied In this study and Energy balance values, the usage rates gave a good results 12 571 GWh comparing to 11 757 GWh of the official energy balance in 2010 and 12 969 GWh comparing to 12 915 GWh of the official energy balance in 2011.

| Appliance | usage rate | | 2010 | 2011 |
|---|---|---|---|---|
| | | | KWH | KWH |
| lighting | 1 | | 2 903 697 945 | 3 003 298 571 |
| refrigeration | 1 | | 1 978 774 854 | 1 998 752 490 |
| freezer | 0,4 | | 539 930 861 | 561 634 366 |
| TV | 1 | | 1 558 355 268 | 1 610 847 855 |
| C washer | 1 | | 3 660 453 201 | 3 784 882 490 |
| Microwaves | 0,2 | | 1 883 480 | 1 930 236 |
| ironer | 0,6 | | 207 855 444 | 214 175 901 |
| others | 1 | | 448 447 559 | 466 473 726 |
| air condition | zone 1 | 1 | 1 271 762 604 | 1 327 764 907 |
| | zone 2 | 0,95 | | |
| | zone 3 | 0,95 | | |
| | zone 4 | 0,9 | | |
| | zone 5 | 0,6 | | |
| | zone 6 | 0,4 | | |
| | zone 7 | 0,4 | | |
| total | | | 12 571 161 216,24 | 12 969 760 541,17 |
| Energy balance | | | 11 757 000 000,00 | 12 915 000 000,00 |

**Table III.10: Electricity appliance Usage rates calibration**

The table III.11 Shows the comparison enter the results of gas appliances usage rate applied In this study and Energy balance values, the usage rates gave a good results 67 784 GWh comparing to 67709 GWh of the official energy balance in 2010 and 68 267 GWh comparing to 75211 GWh of the official energy balance in 2011.

| appliance | usage rate | zones | 2010 (kWh) | 2011 (kWh) |
|---|---|---|---|---|
| heating | 1 | zone 1 | 9 475 468,80 | 9 856 352,52 |
| | 1 | zone 2 | 37 923 503,83 | 39 447 908,13 |
| | 1 | zone 3 | 36 075 142,10 | 37 525 248,14 |
| | 1 | zone 4 | 184 135 987,77 | 191 537 669,16 |
| | 1 | zone 5 | 482 035 372,20 | 501 411 661,92 |
| | 1 | zone 6 | 2 081 696 765,00 | 2 165 374 357,86 |
| | 1 | zone 7 | 9 177 574 943,85 | 9 546 484 283,85 |
| cooking | 1 | all zones | 28 027 972 442,30 | 28 027 972 442,30 |
| hot water | 1 | all zones | 27 747 692 717,88 | 27 747 692 717,88 |
| total | | | 67 784 582 343,72 | 68 267 302 641,76 |
| energy balance | | | 67709860000 | 75211210000 |

**Table III.11: Gas appliance Usage rates calibration**

## III.6.Evaluation of consumption by house:

### Consumption by products:

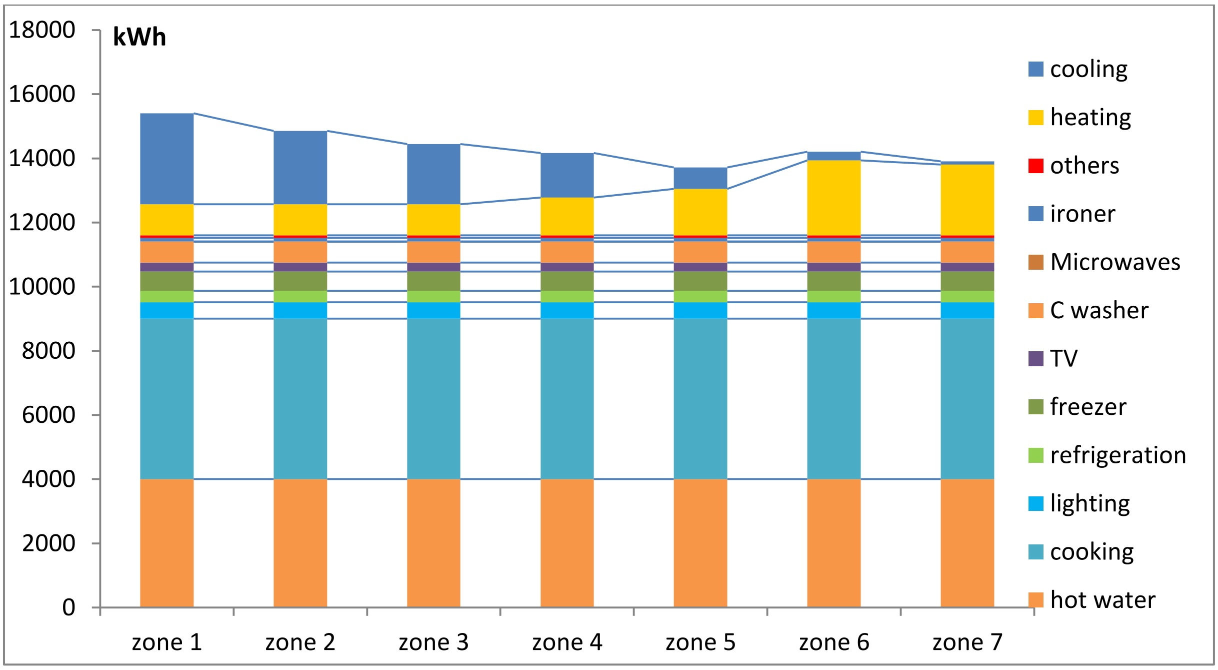



**Figure III.10: House consumption for the 7 zones (2010)**

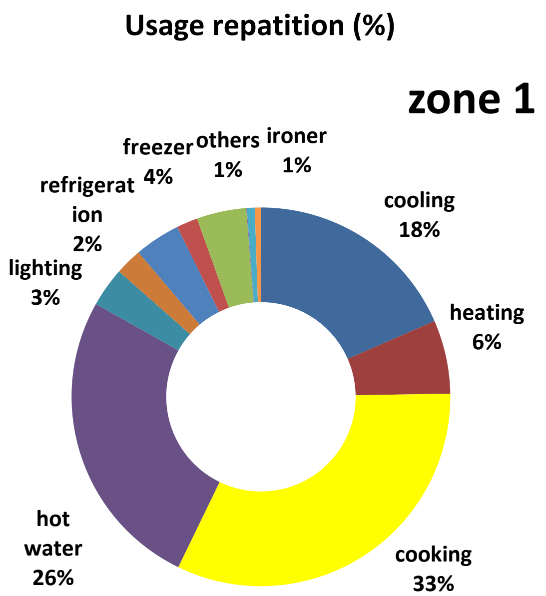
As it appears in figure III.10 the consumption of one house in each zone combines from;

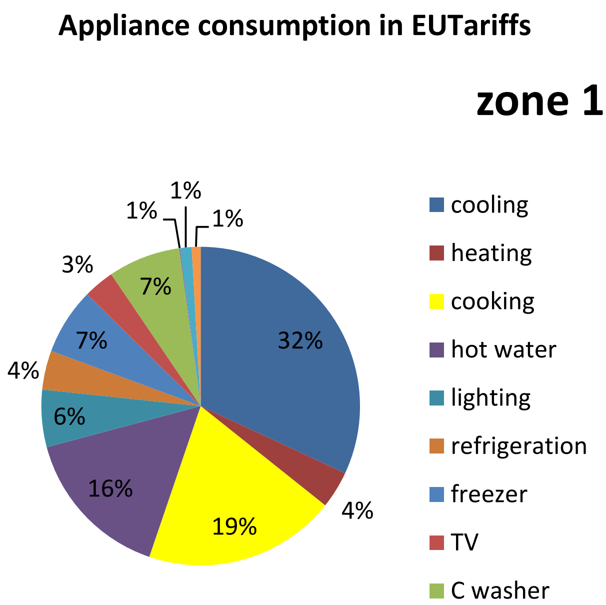
**Fix consumption:** contains cooking 5000 kWh per year, hot water 4000 kWh per year, lighting 518 kWh per year, refrigeration 353 kWh per year, freezer 602 kWh per year, TV 278 kWh per year, microwave 8.4 kWh per year, ironer 103 kWh per year and 80 kWh per year for others.

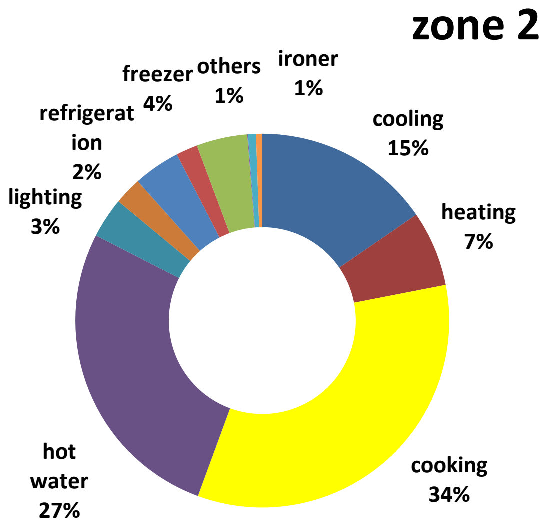
**Variable consumption:** contain cooling and heating which change from one to another as it's shown in table III.12:

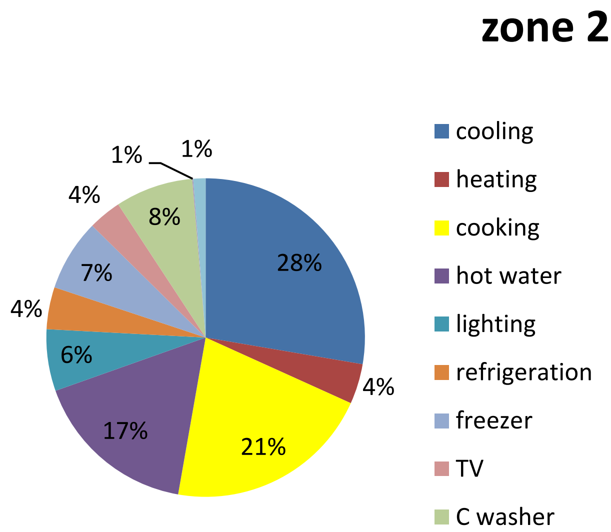
| | zone 1 | | zone 2 | | zone 3 | | zone 4 | | zone 5 | | zone 6 | | zone 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | € Tariffs | KWh | € Tariffs | KWh | € Tariffs | KWh | € Tariffs | KWh | € Tariffs | KWh | € Tariffs | KWh | € Tariffs | KWh |
| cooling | 605 | 2842 | 487 | 2289 | 400 | 1878 | 296 | 1389 | 142 | 667 | 58 | 271 | 21 | 98 |
| heating | 72 | 970 | 72 | 970 | 72 | 970 | 88 | 1186 | 108 | 1455 | 173 | 2339 | 164 | 2215 |
| cooking | 370 | 5000 | 370 | 5000 | 370 | 5000 | 370 | 5000 | 370 | 5000 | 370 | 5000 | 370 | 5000 |
| hot water | 296 | 4000 | 296 | 4000 | 296 | 4000 | 296 | 4000 | 296 | 4000 | 296 | 4000 | 296 | 4000 |
| lighting | 110 | 518 | 110 | 518 | 110 | 518 | 110 | 518 | 110 | 518 | 110 | 518 | 110 | 518 |
| refrigeration | 75 | 353 | 75 | 353 | 75 | 353 | 75 | 353 | 75 | 353 | 75 | 353 | 75 | 353 |
| freezer | 128 | 602 | 128 | 602 | 128 | 602 | 128 | 602 | 128 | 602 | 128 | 602 | 128 | 602 |
| TV | 59 | 278 | 59 | 278 | 59 | 278 | 59 | 278 | 59 | 278 | 59 | 278 | 59 | 278 |
| C washer | 139 | 653 | 139 | 653 | 139 | 653 | 139 | 653 | 139 | 653 | 139 | 653 | 139 | 653 |
| Microwaves | 2 | 8 | 2 | 8 | 2 | 8 | 2 | 8 | 2 | 8 | 2 | 8 | 2 | 8 |
| ironer | 22 | 103 | 22 | 103 | 22 | 103 | 22 | 103 | 22 | 103 | 22 | 103 | 22 | 103 |
| others | 17 | 80 | 17 | 80 | 17 | 80 | 17 | 80 | 17 | 80 | 17 | 80 | 17 | 80 |

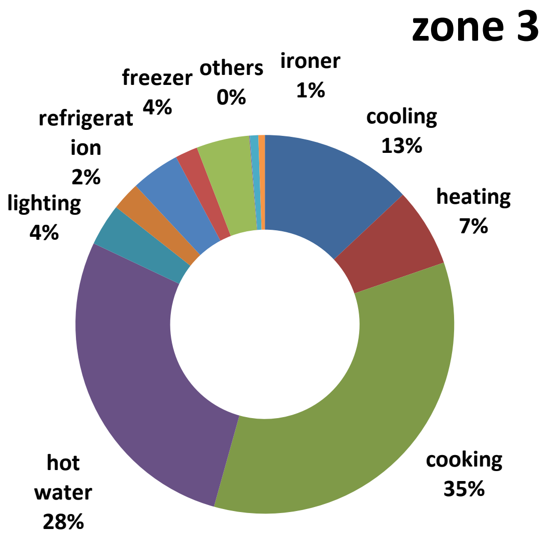
**Table III.12: House consumption for the 7 zones (2010)**

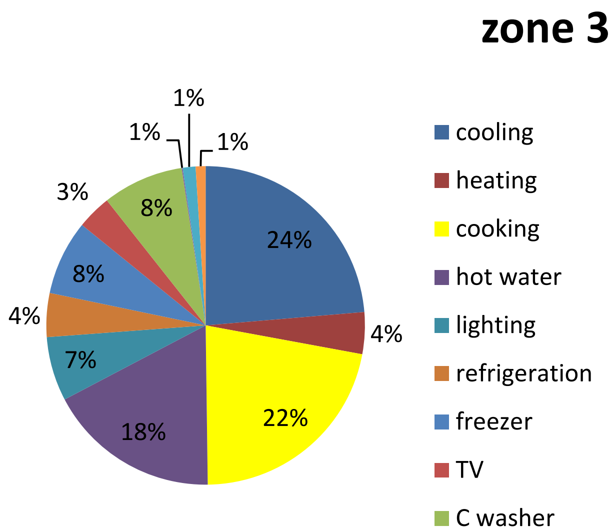


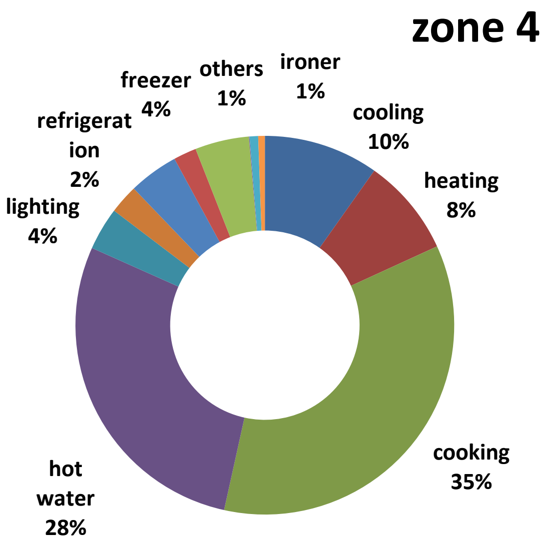



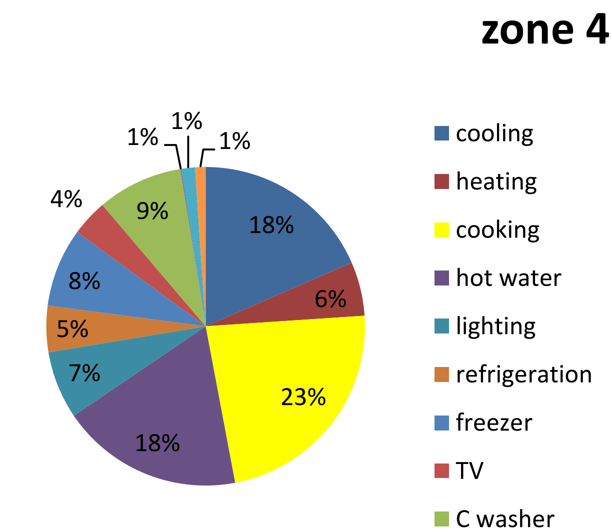

zone 2
freezer 4%
others 1%
ironer 1%
refrigeration 2%
lighting 3%
cooling 15%
heating 7%
hot water 27%
cooking 34%

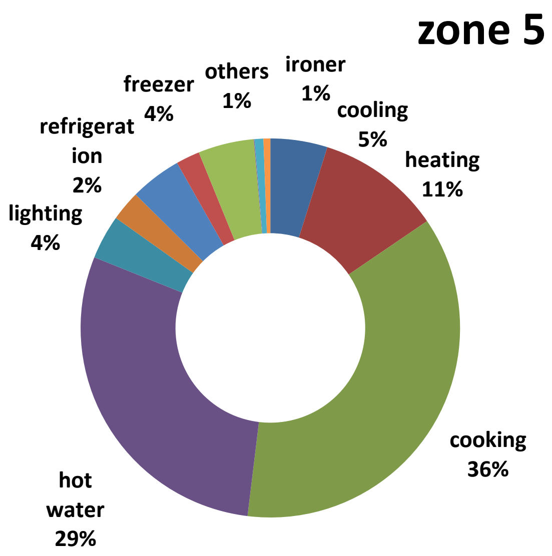

zone 2
1%
1%
4%
8%
28%
7%
4%
6%
4%
17%
21%
cooling
heating
cooking
hot water
lighting
refrigeration
freezer
TV
C washer

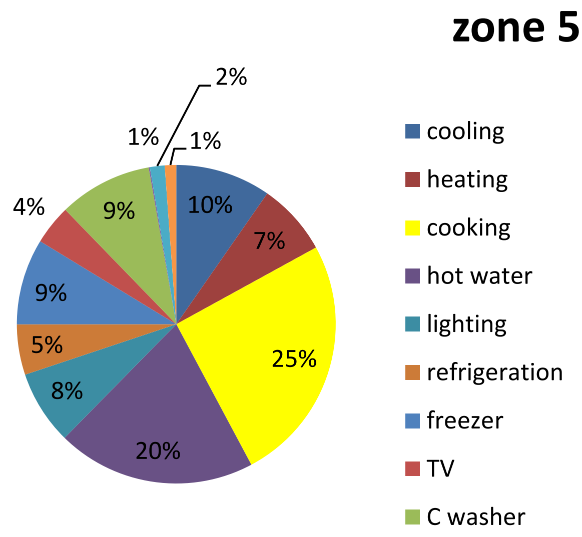

zone 3
freezer 4%
others 0%
ironer 1%
refrigeration 2%
lighting 4%
cooling 13%
heating 7%
hot water 28%
cooking 35%

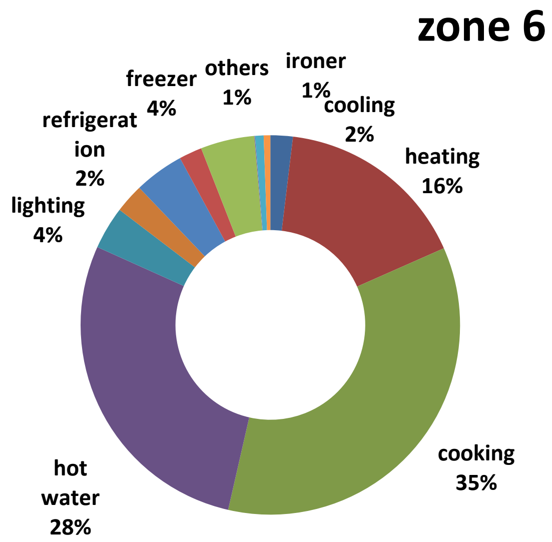

zone 3
1%
1%
1%
3%
8%
24%
8%
4%
4%
7%
18%
22%
cooling
heating
cooking
hot water
lighting
refrigeration
freezer
TV
C washer

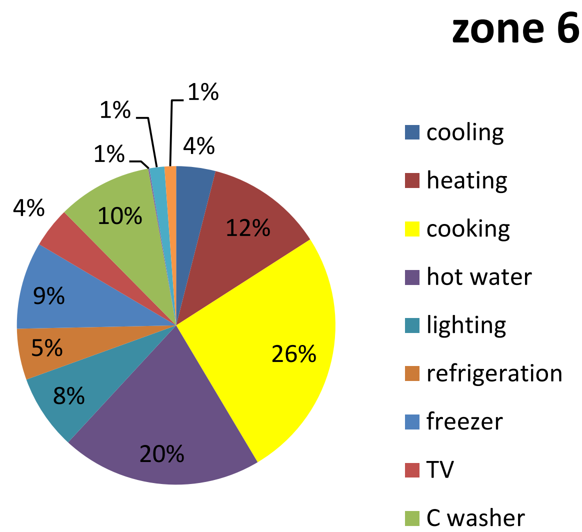

zone 4
freezer 4%
others 1%
ironer 1%
refrigeration 2%
lighting 4%
cooling 10%
heating 8%
hot water 28%
cooking 35%

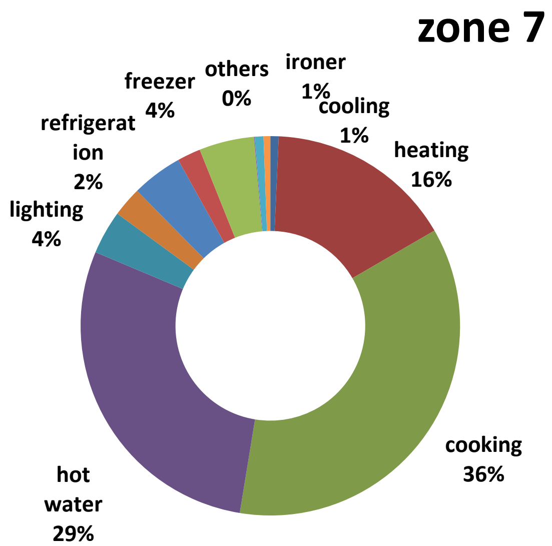

zone 4
1%
1%
1%
4%
9%
18%
8%
6%
5%
7%
23%
18%
cooling
heating
cooking
hot water
lighting
refrigeration
freezer
TV
C washer

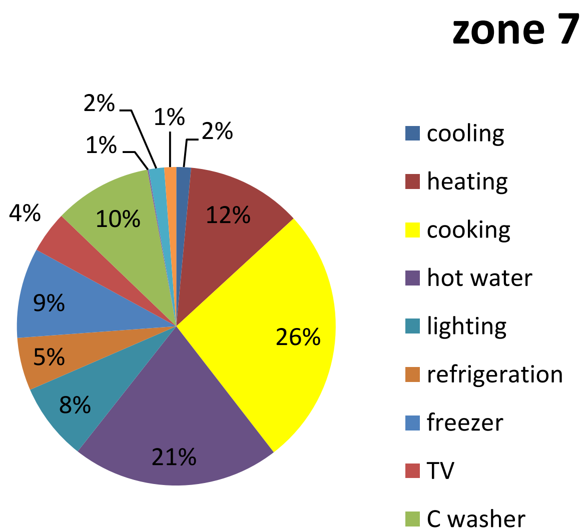

zone 5
freezer 4%
others 1%
ironer 1%
cooling 5%
refrigeration 2%
heating 11%
lighting 4%
cooking 36%
hot water 29%


zone 5
2%
1%
1%
4%
9%
10%
7%
9%
5%
25%
8%
20%
cooling
heating
cooking
hot water
lighting
refrigeration
freezer
TV
C washer


zone 6
freezer 4%
others 1%
ironer 1%
cooling 2%
refrigeration 2%
heating 16%
lighting 4%
cooking 35%
hot water 28%

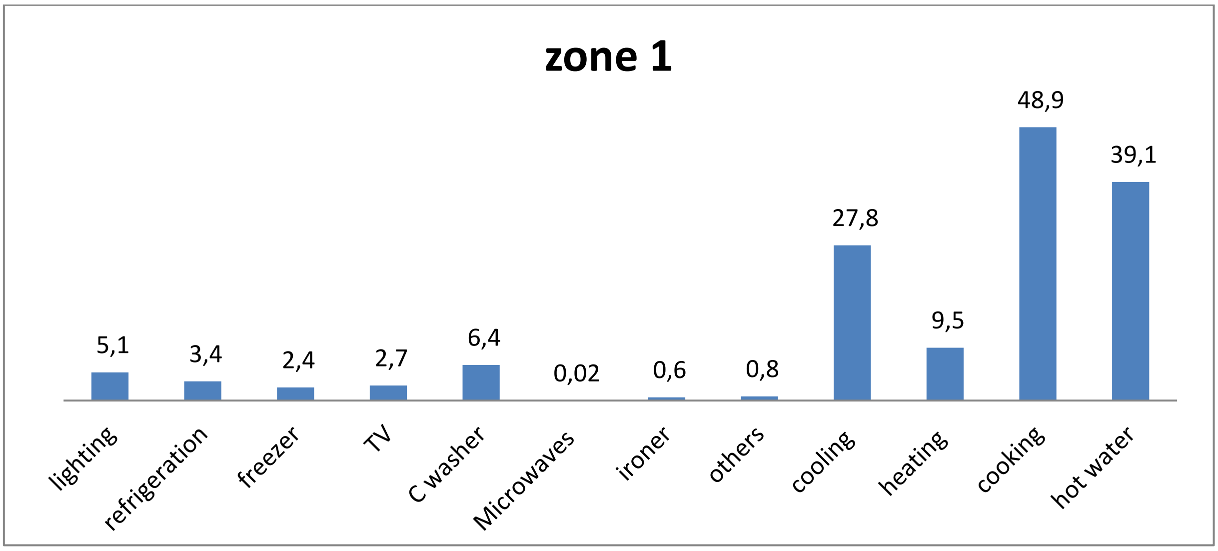

zone 6
1%
1%
1%
4%
4%
10%
12%
9%
5%
26%
8%
20%
cooling
heating
cooking
hot water
lighting
refrigeration
freezer
TV
C washer

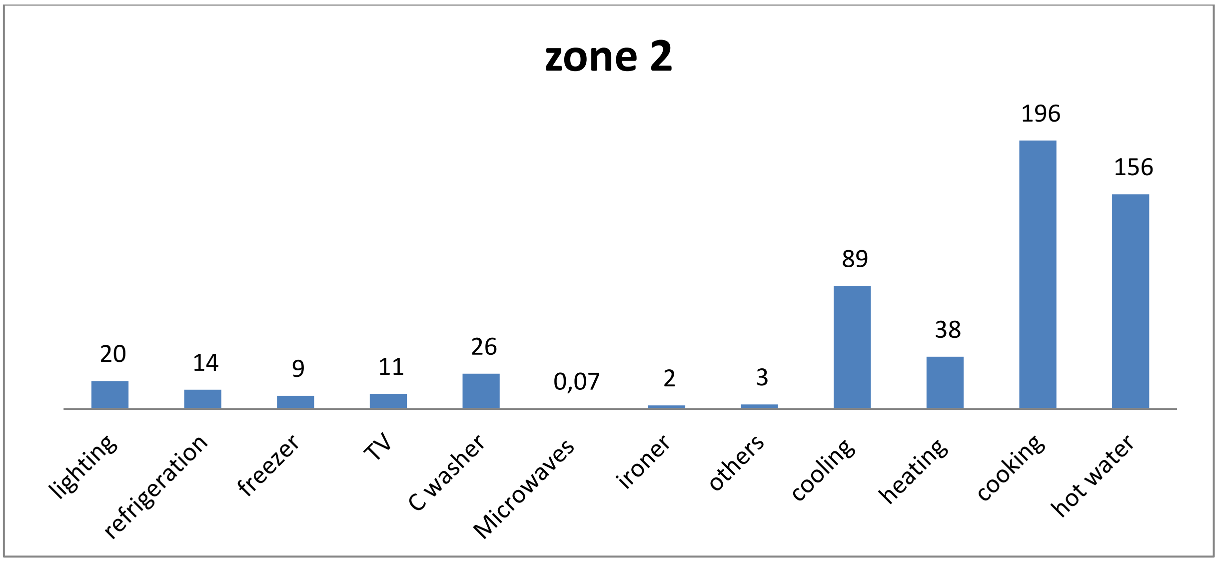

zone 7
freezer 4%
others 0%
ironer 1%
cooling 1%
refrigeration 2%
heating 16%
lighting 4%
cooking 36%
hot water 29%

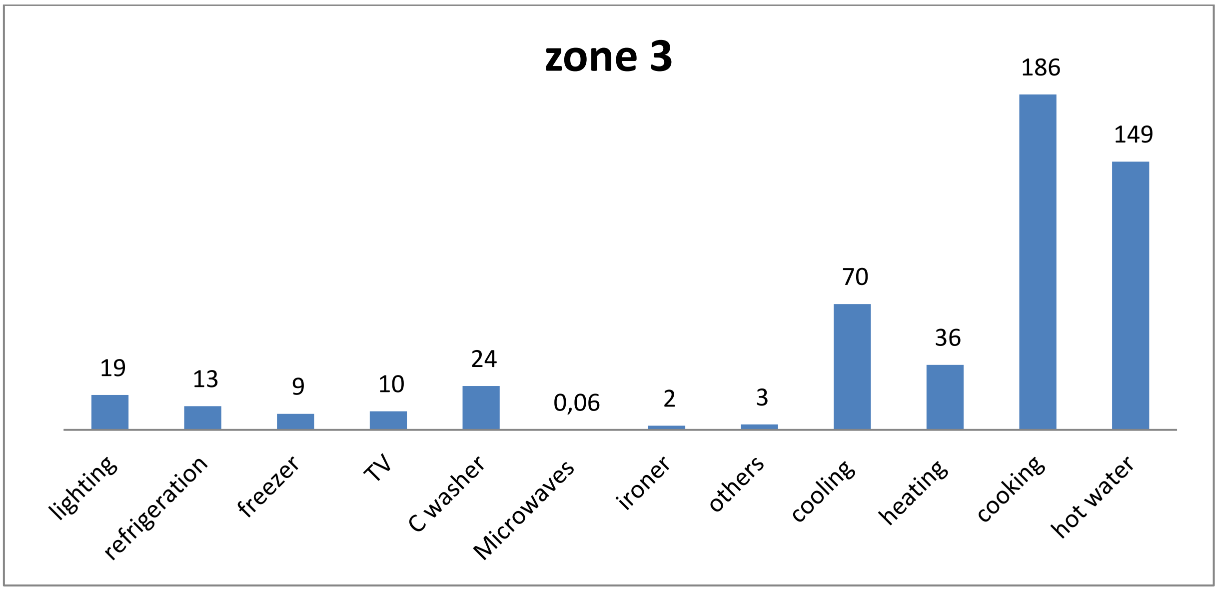

zone 7
2%
1%
1%
2%
4%
10%
12%
9%
5%
26%
8%
21%
cooling
heating
cooking
hot water
lighting
refrigeration
freezer
TV
C washer

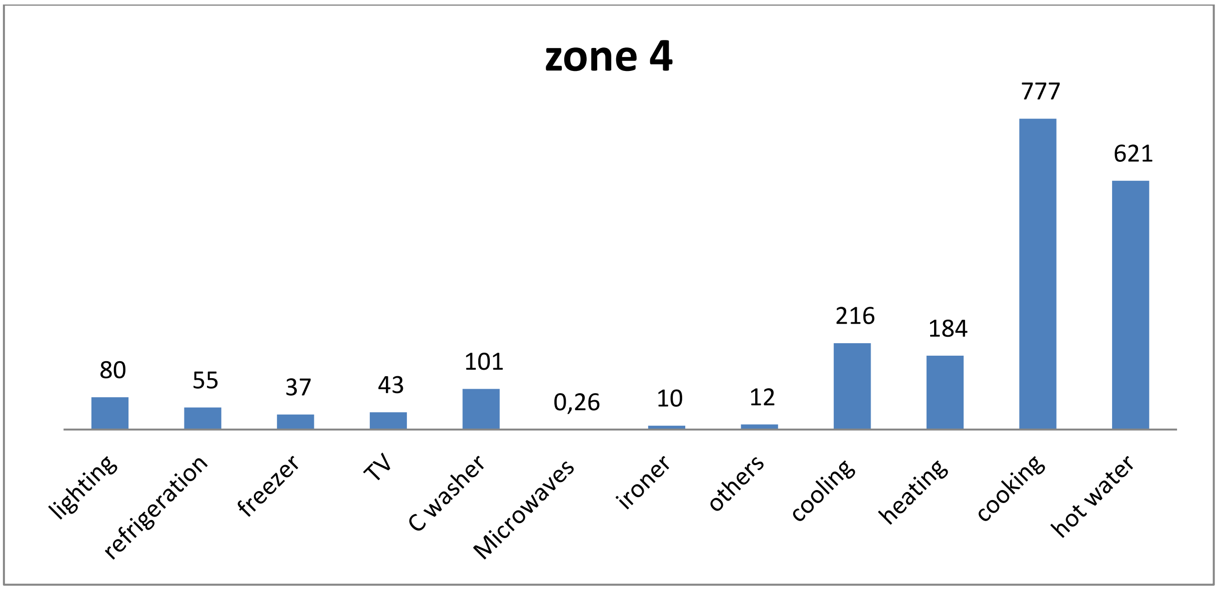
### III.7.Evaluation of consumption by zone:

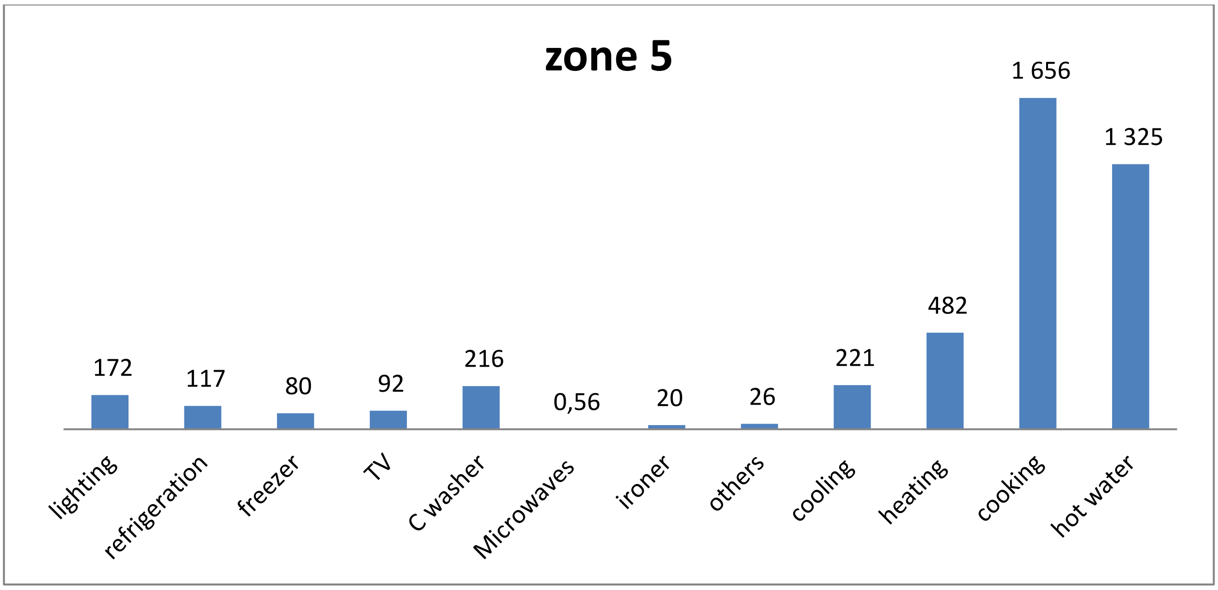
As it's shown in the figures below the consumption in the between zones, and that's because of the number of houses from zone to zone, the results are:

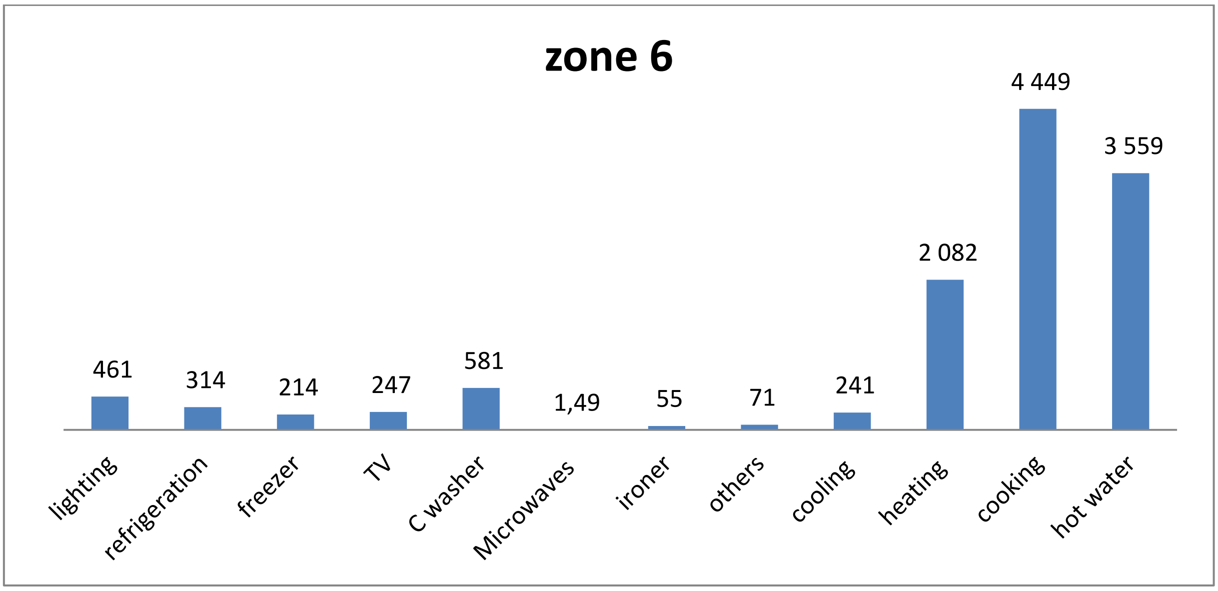



zone 3
19
13
9
10
24
0,06
2
3
70
36
186
149
lighting
refrigeration
freezer
TV
C washer
Microwaves
ironer
others
cooling
heating
cooking
hot water


zone 4
80
55
37
43
101
0,26
10
12
216
184
777
621
lighting
refrigeration
freezer
TV
C washer
Microwaves
ironer
others
cooling
heating
cooking
hot water


zone 5
172
117
80
92
216
0,56
20
26
221
482
1 656
1 325
lighting
refrigeration
freezer
TV
C washer
Microwaves
ironer
others
cooling
heating
cooking
hot water



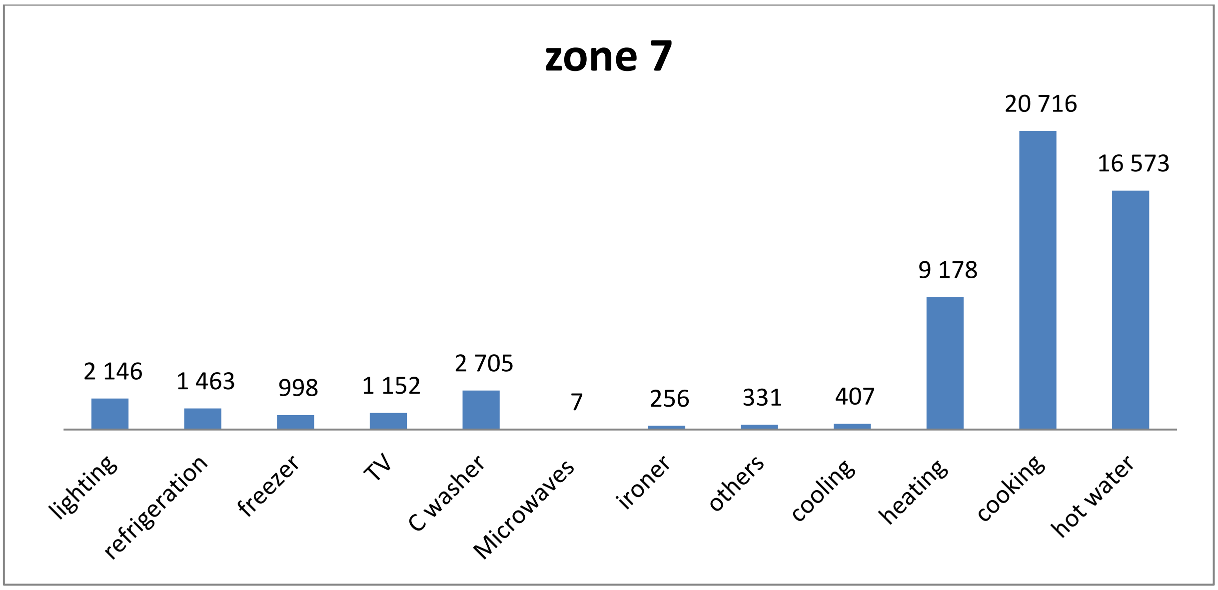




**Figure III.11 : Consumption of 7 zones**

| GWh | zone 1 | zone 2 | zone 3 | zone 4 | zone 5 | zone 6 | zone 7 |
|---|---|---|---|---|---|---|---|
| lighting | 5,1 | 20 | 19 | 80 | 172 | 461 | 2 146 |
| refrigeration | 3,4 | 14 | 13 | 55 | 117 | 314 | 1 463 |
| freezer | 2,4 | 9 | 9 | 37 | 80 | 214 | 998 |
| TV | 2,7 | 11 | 10 | 43 | 92 | 247 | 1 152 |
| C washer | 6,4 | 26 | 24 | 101 | 216 | 581 | 2 705 |
| Microwaves | 0,02 | 0,07 | 0,06 | 0,26 | 0,56 | 1,49 | 7 |
| ironer | 0,6 | 2 | 2 | 10 | 20 | 55 | 256 |
| others | 0,8 | 3 | 3 | 12 | 26 | 71 | 331 |
| cooling | 27,8 | 89 | 70 | 216 | 221 | 241 | 407 |
| heating | 9,5 | 38 | 36 | 184 | 482 | 2 082 | 9 178 |
| cooking | 48,9 | 196 | 186 | 777 | 1 656 | 4 449 | 20 716 |
| hot water | 39,1 | 156 | 149 | 621 | 1 325 | 3 559 | 16 573 |

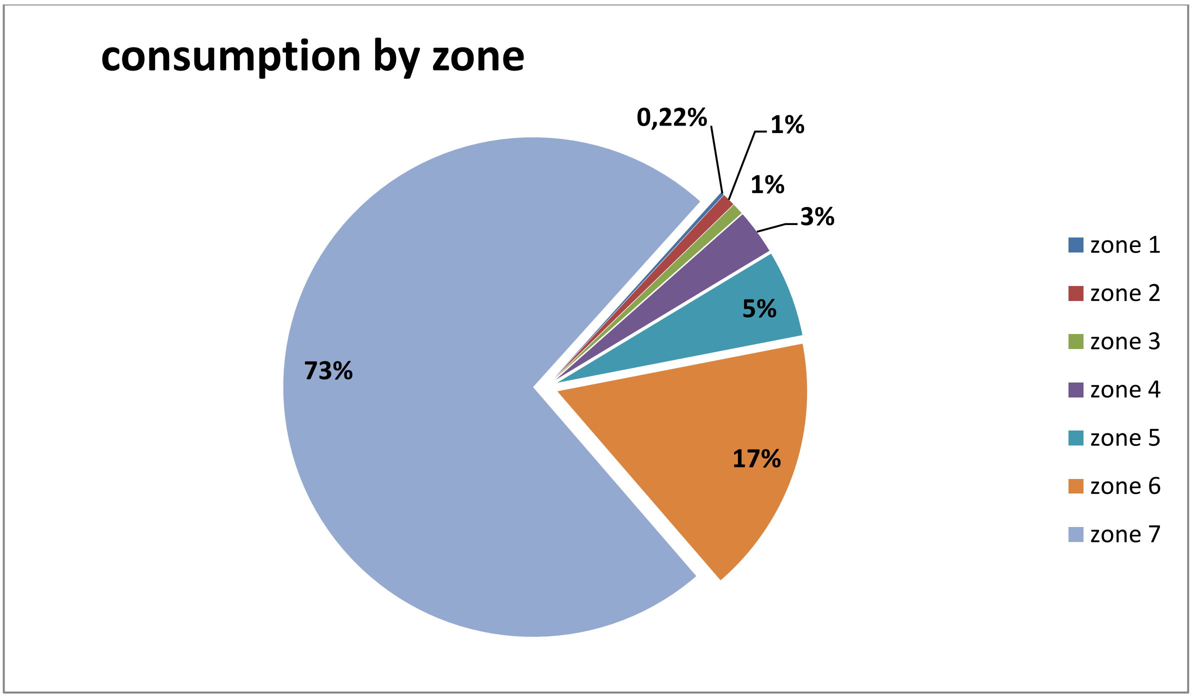



**Figure III.12: Repartition of energy consumption by zones**

## III.8.Evaluation of total end use:

| | | cost | |
|---|---|---|---|
| **appliance** | **kWh** | **EU Tariffs** | **Dz Tariffs** |
| lighting | 2 903 697 945 | 618 487 662 | 49 943 605 |
| refrigeration | 1 978 774 854 | 421 479 044 | 34 034 927 |
| TV | 1 558 355 268 | 331 929 672 | 26 803 711 |
| C washer | 3 660 453 201 | 779 676 532 | 62 959 795 |
| cooling | 1 271 762 604 | 270 885 435 | 21 874 317 |
| heating | 12 008 917 183 | 888 659 872 | 667 816 |
| cooking | 28 027 972 442 | 2 074 069 961 | 1 558 636 |
| hot water | 22 422 377 954 | 1 659 255 969 | 1 246 908 |
| Other elec appliances | 1 198 117 344 | 255 198 994 | 20 607 618 |
| | 75030428795 | 7299643140 | 219697332,8 |

**Table III.13: Energy end use**

## III.8.1.Repartition of total end use:

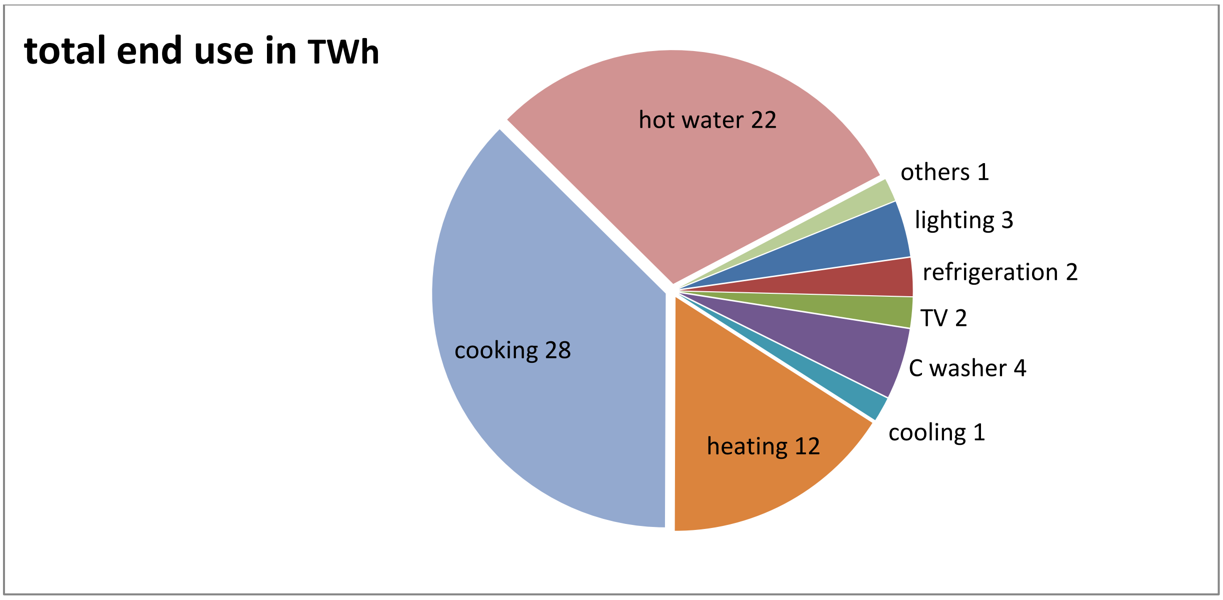



**Figure III.13: Total end use in TWh**

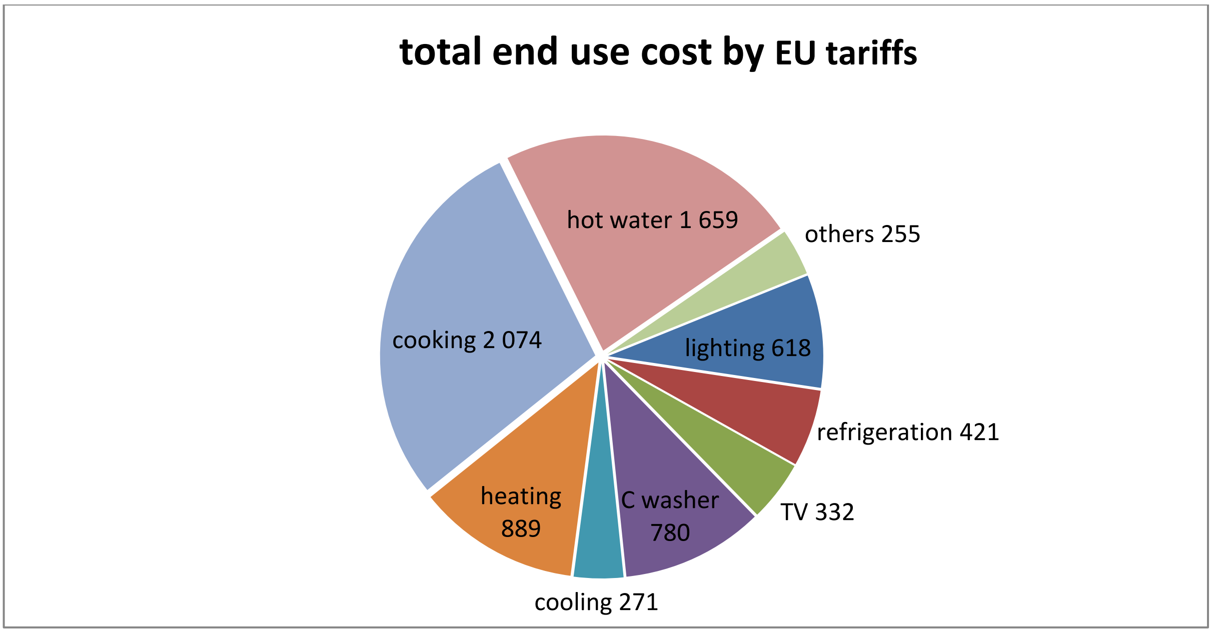



**Figure III.14: Total end use cost by EU tariffs**

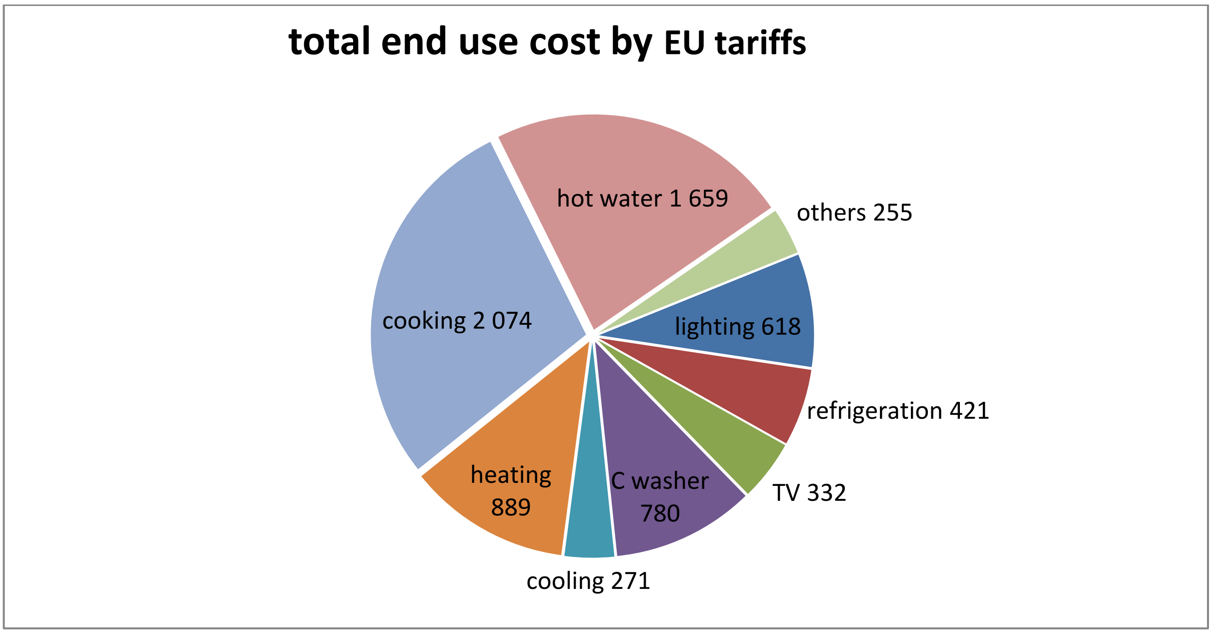



**Figure III.15: Total end use cost by EU tariffs**

### III.9.Conclusion:

- An analysis of annual energy consumption and cost usually accompanies the design heat load calculations and plays an important role in the selection of a heating or cooling system.
- as long as the data and statistics are rarely available about the consumption in the residential sector in Algeria, this study hopefully will give a closer look about this sector, and by dividing Algerian surface to 7 zones will give us a precise look, which will be a useful for further studies

## IV.1.Introduction:

## IV.2.Modeling Methodology

**IV.2.1.Energy projection**: also called outlook or forecasting, the projection is an iterative process that aims to prepare today for tomorrow. It is not to predict the future, but to develop scenarios based on available data. (Observatoire de l'Energie, 2005)
Also, forward is to explore what are the possible futures in embryo in the current situation, to assist in determining future proactive and identifying ways for implement. (François de Jouvenel, 2004)

**IV.2.2.Business-as-usual (BAU) scenario:** Its use for the Sustainable Energy Action Plan prepared by the government, used a local prospective outlook model for energy long term projection scenarios(Greet Janssens-Maenhout, 2012),BAU can only deliver development gains at an unaffordable, and probably unsustainable, price. Under a BAU scenario, which replicates historical trends and assumes, no fundamental changes in policy or external conditions to alter the trends. (Dr. Andrea M. Bassi, 2011)

**IV.2.3.Alternative scenario:** it's the scenario with the injection of some suggestions in the path according to specific assumptions; the suggestions suppose to show an improvement comparing with the BAU path.

**IV.2.4.Hypotheses:**

- Using 2008 populations by communes for determinate the number of houses, assuming that the percentage of population in each communes is the same as the percentage of houses
- Occupied houses
- Electrified houses rate is 98% in 2008 rising by AAGR of 0.5% per year.
- 80m² as the average surface of Algerian houses.
- Beginning from 2012, and realization of 2000000 house each year

**IV.2.5.projection model:**

These models implement a relationship between the studied magnitude and the time which is the only explanatory variable of evolution. Proper example of this model is provided by: The Law of doubling every ten years reflecting that whatever the context, the electricity consumption doubles every ten years.

The most common formulation is as follows:

$QE_t = QE_0 (1 + \alpha)^t$

Where $QE_t$ : represents the observed year t consumption

$QE_0$ : calculated consumption of the origin year t = 0,

α : the average annual growth rate observed over the studied period,

t : time expressed in year t compared to origin year t = o

The passage in decimal logarithms allows a graphical representation that overrides the straight line to exponential

$\log10QEt = \log10 QE0 + \log10 (1 + \alpha) t$

That we express:

$\log QEt = a + bt$

with $a = \log10 QE0$ ; $b = \log10 (1 + \alpha)$

Starting from the generic form log QE = a + bt which we answered in random precondition by adding a random residual ε.

the equation becomes:

$QEt = a + bt + \varepsilon t$

In this model, a and b may be approximated by the least squares method.

We seek $\hat{a}$ and $\hat{b}$ such that the sum of squared differences $\varepsilon_t$ is minimum:

$$\min \sum_{t=0}^{t=T-1} \varepsilon_t^2 = \min \sum_{t=0}^{t=T-1} [\log QE_t - (a + bt)]^2$$

The reference period is defined: T years, starting from the original year t = 0 to a final year t of the class T - 1.

$$\hat{b} = \frac{\sum_{t=0}^{t=T-1} (\log QE_t - \overline{\log QE})(t - \bar{t})}{\sum_{t=0}^{t=T-1} (t - \bar{t})^2}$$

$$\hat{a} = \overline{\log QE} - \hat{b}\,\bar{t}$$

Moderately a number of hypotheses about the random residuals ε (null average, constant standard deviation, no autocorrelation), we have:

$$\text{var}(\hat{b}) = \frac{\text{var}\varepsilon}{\sum_{t=0}^{t=T-1} (t - \bar{t})^2}$$

$$\text{var}(\hat{a}) = \text{var}\,\varepsilon\left[ (1/t) + \frac{\bar{t}^2}{\sum_{t=0}^{t=T-1} (t - \bar{t})^2} \right]$$

with $\text{var}\,\varepsilon = \sigma^2\,\varepsilon = \sum_{t=0}^{t=T-1} \varepsilon_t^2$

After performing the calculations on the past, the provisional estimate of consumption $QE_\theta$ of the year θ of the class T - 1 + n, becomes:

$$\log QE_\theta = \hat{a} + \hat{b}\,\theta$$

The effective realization of the year θ will be:

$\log QE_\theta = a + b\,\theta + \varepsilon_\theta$

The provision error $Z_\theta$ will be:

$Z_\theta = (a - \hat{a}) + (b - \hat{b})\,\theta + \varepsilon_\theta$

Taking into account the variance of the estimates of a and b and their covariance and assuming random residuals ε are not autocorrelated, the variance of the provision error is obtained from the expression:

$$\mathrm{Var}(Z_\theta) = \mathrm{var}\,\varepsilon\left[1 + 1/t + \frac{(\theta - t)^2}{\sum_{t=0}^{t=T-1} (t - \bar{t})^2}\right]$$

Under the above hypotheses, the provision error $Z_\theta$ follows a normal rule. We can also associate to the provision a confidence interval that delineates probability levels where effective realization of the year θ is situated in between them.

A confidence interval of 90% means that for example the realization has 9 chances out of 10 to be within bounds that define it. The bounds of a confidence interval are obtained from the formula:

$(\mathrm{Log}\,QE)_b = (\mathrm{Log}\,QE)_m \pm t^* \sqrt{\mathrm{var}\,Z\theta}$

$(\mathrm{Log}\,QE)_b$ is the log of the consumption, corresponding to the correct b;

$(\mathrm{Log}\,QE)_m$ represents the average log expected

t* the variable "t" student (n - 2) liberty degrees, to the limit of the chosen confidence.

**IV.3.Base year 2008:** Data from the base year are the actual data into the model prospectively. These structural data characteristics of the energy consumption (population, housing...). The year 2008 is the last general population census available in this time of commitment to energy forecasting.

**IV.4.Calibration Years (2010-2011):** After entering into the model data needed for its operation, the results may be far from reality. There needs to calibrate the model. Calibration aims to bring modeling observation.

2010, 2011, 2012 are the last years of regional energy data available at the time of commitment of prospective study.

**IV.5.Houses projections:**

The quinquennial program 2009-2014 provides:

- Realization of 2 million houses between 2010-2012 with average of 200000 houses per year but from 2010 to 2012 only 602717 houses realized (ONS).
- The self-construction of the order of 20 000 house per year.
- Realization of 200 000 house per year for the years 2018-2019-2020.
- The assumption as follows is will be followed between 2020-2040: it will continue in the same path by realization of 200 000 house per year plus self-construction of the order of 20 000 house per year.

as it's shown in figure IV.1 the houses number is the major effective factor in residential energy consumption (The World Bank, 2008), the houses number increased from 6.96 million in 2008 (ONS) to 7.09 million house (ONS) in 2010, and according to The quinquennial programs Algerian the houses number will be increasing to be 11.47 in 2030 and 13.67 in 2040.

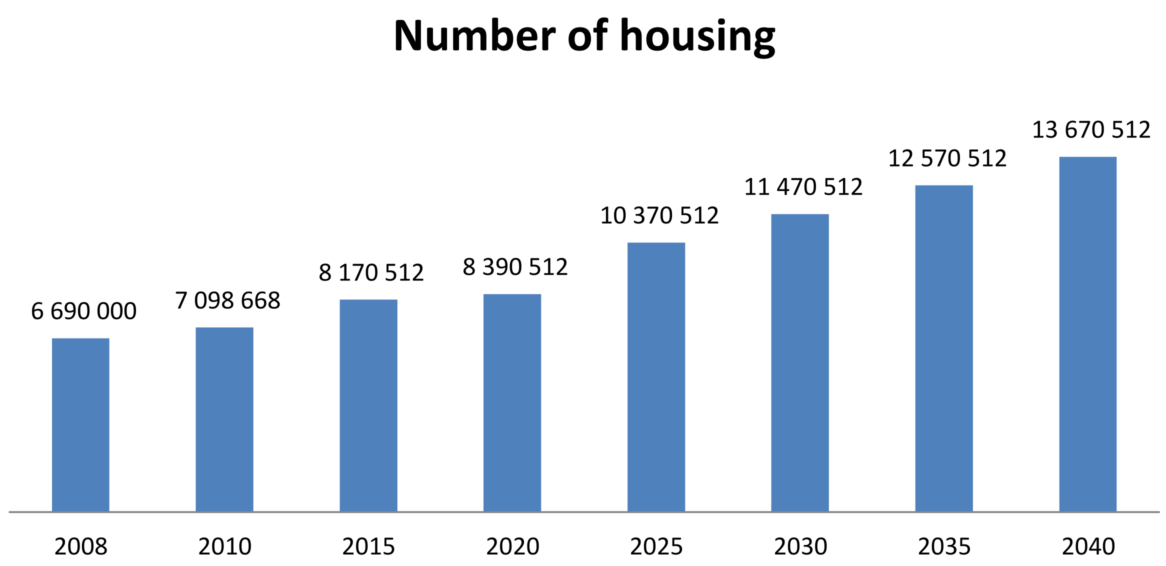



**Figure IV.1: Number of houses projection**

## IV.6.Occupied houses projection:

As it’s in the table the occupied houses rate have being increasing year after year, 97% in 2008 to 92.42 in 2040, with AAGR of 4.91% per year (MHUV) ministry of housing and urban development.

| year | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| Number of housing | 6 690 000 | 7 098 668 | 8 170 512 | 8 390 512 | 10 370 512 | 11 470 512 | 12 570 512 | 13 670 512 |
| Occupancy rate (%) | 79 | 79,78 | 80,56 | 81,76 | 83,79 | 88 | 90,18 | 92,42 |
| occupied houses | 5 285 100 | 5 663 221 | 6 050 840 | 6 680 127 | 7 767 620 | 10 094 031 | 11 336 620 | 12 634 679 |

**Table IV.1: The occupied houses**

As it’s shown in the figure below, the number of occupied houses has being rinsing from 5.2 million houses in 2008 to 2040.

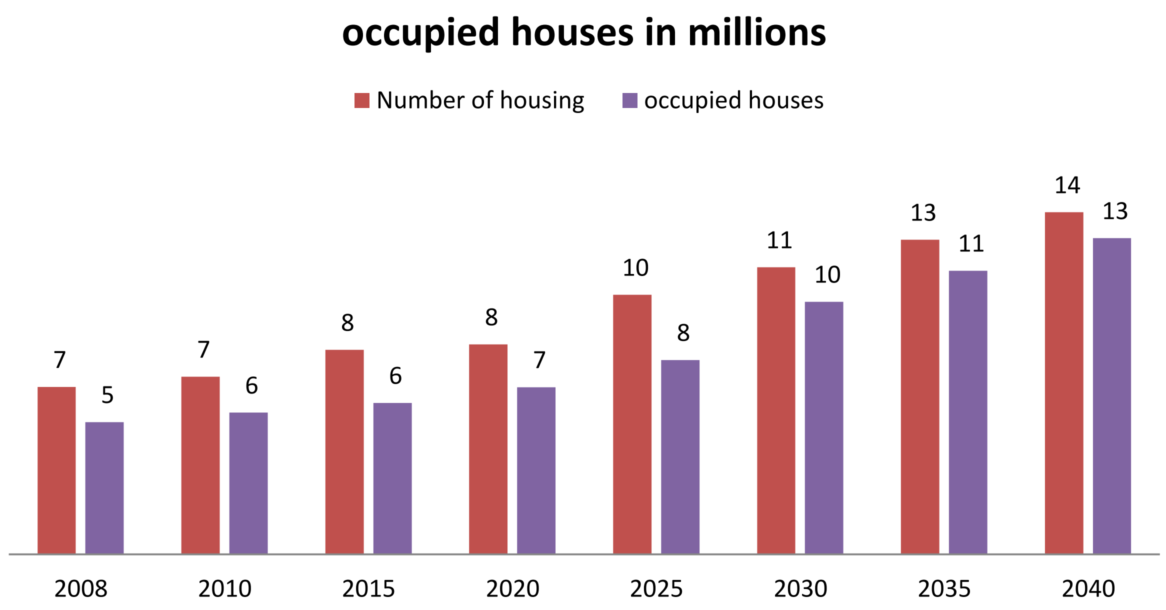



**Figure IV.2: Occupied houses projection (2008-2040)**

## IV.7.Electrification and gas penetration projection:

Assumption: the gas will be considered 100% over time, because the households which aren't supplied with natural gas uses the butane as alternative.

The Table IV.2 Shows the Electrification rate which has being increasing 98 %2008 during the years to reach 100% begins from 2012 (APRUE).

| year | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| Electrification rate | 0,98 | 0,99 | 1 | 1 | 1 | 1 | 1 | 1 |
| gas supplied rate | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| electificated gas supplied houses | 5179398 | 5606588 | 6050840 | 6680127 | 7767620 | 10094031 | 11336620 | 12634679 |
| gas supplied houses | 5285100 | 5663221 | 6050840 | 6680127 | 7767620 | 10094031 | 11336620 | 12634679 |

**Table IV.2: Electrification and gas penetration projection (APRUE)**

## IV.8.Electrical appliance efficiency projection:

According to (APRUE), and as it's shown in Table IV.3 below, the decline of the specific energy consumption of the electrical appliances means that the efficiency have been developed, in those resent years from 2005 to 2010 as it appears in the table below, and that's because of the new high efficiency appliance (higher than the old appliance) witch penetrated the Algerian markets this years.

| KWH | lighting | refrigeration | freezer | TV | C washer | Microwaves | ironer | fan |
|---|---|---|---|---|---|---|---|---|
| AAGR (%) | 0,57 | 2,9 | 1,32 | -0,63 | -0,6 | -5 | -0,95 | -2,7 |

**Table IV.3: Electrical appliance efficiency development (2005-2010) (APRUE)**

In this study it assumed that the development in the efficiency of electrical appliances will be continued in the same path tell 2015, and then it will be decline by the half from 2015 to 2030 then in third tell 2040, because it's impossible for the efficiency of electrical appliance to be 100%.The cooling and other gas appliances efficiency will be considered constant.

| KWH | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| lighting | 524 | 518 | 503 | 496 | 489 | 482 | 478 | 473 |
| refrigeration | 372 | 353 | 306 | 285 | 265 | 247 | 235 | 224 |
| freezer | 493 | 478 | 448 | 434 | 420 | 406 | 397 | 389 |
| TV | 278 | 278 | 377 | 383 | 390 | 396 | 400 | 404 |
| C washer | 660 | 653 | 634 | 624 | 615 | 606 | 600 | 594 |
| Microwaves | 10 | 8,4 | 7 | 6 | 5 | 5 | 4 | 4 |
| ironer | 103 | 103 | 98 | 96 | 94 | 91 | 90 | 89 |

**Table IV.4: Electrical appliances specific consumption projection (author)**

## IV.9.Total consumption projection:

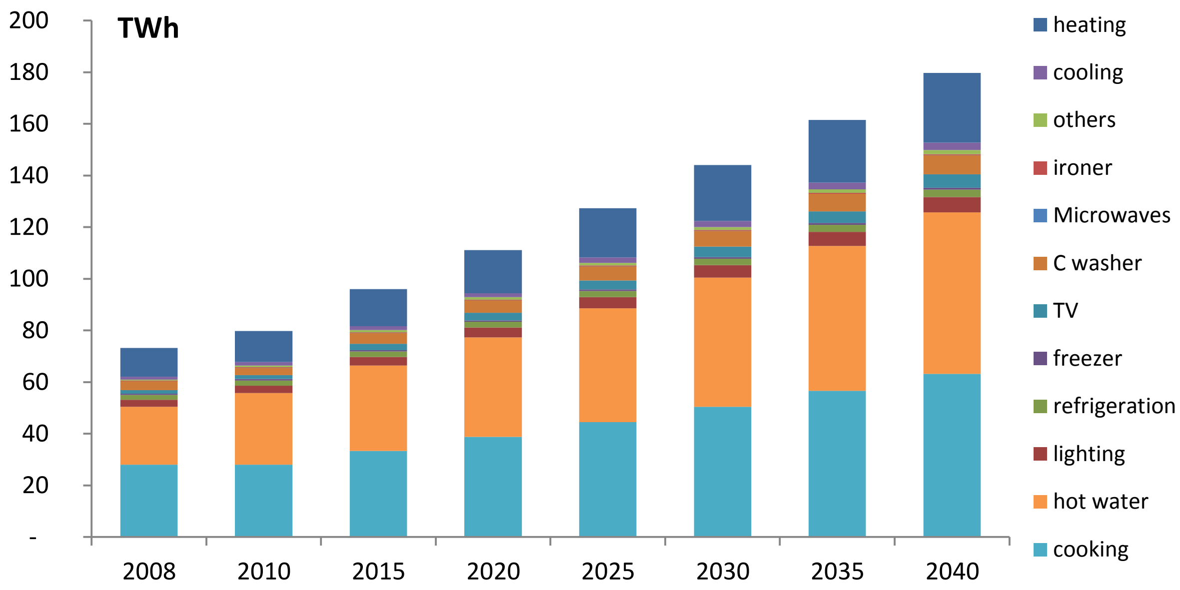



**Figure IV.3: Total consumption projection in kWh**

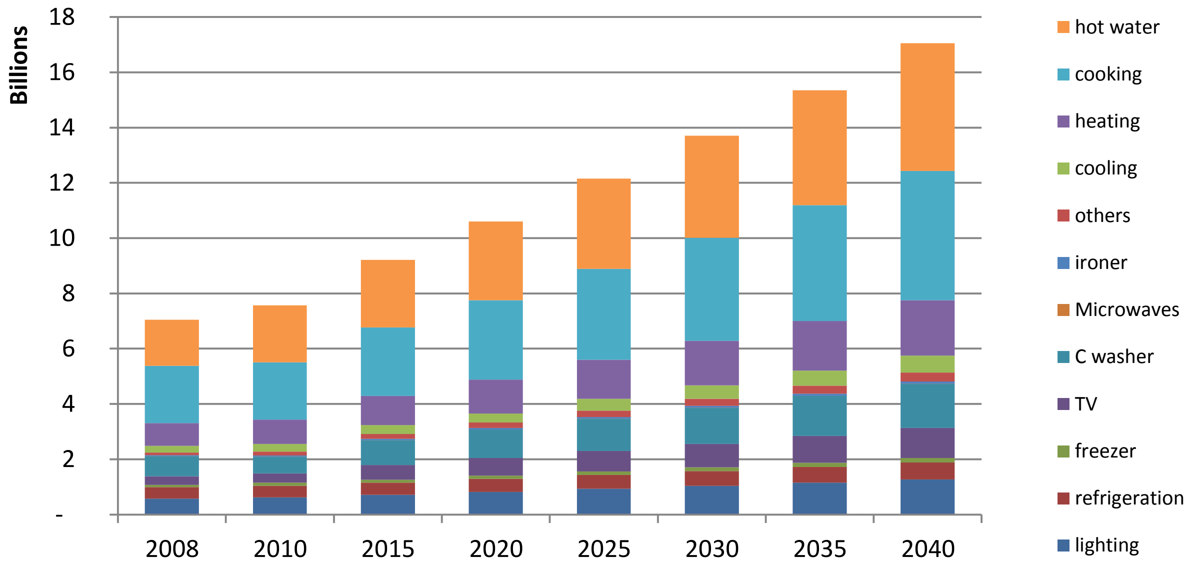



**Figure IV.4: Total consumption projection in EU prices**

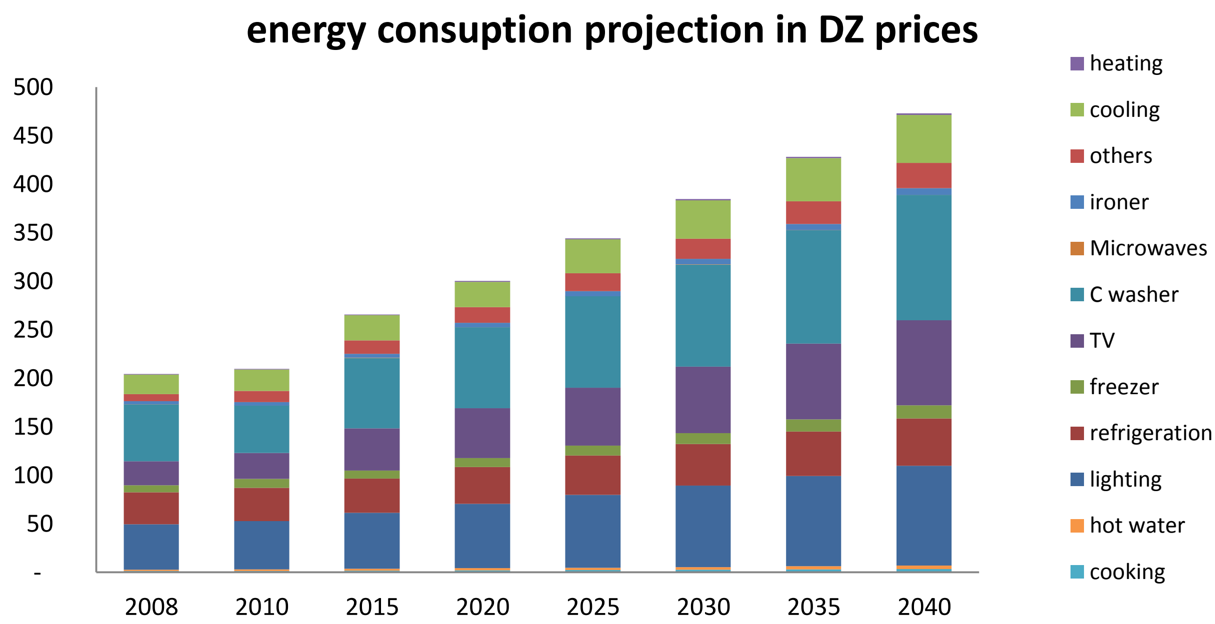



**Figure IV.5: Total consumption projection in DZ prices**

## IV.10.Alternative scenarios:

### IV.10.1.Lighting:

According to The quinquennial program, the number of the new houses between 2004 and 2005 was 440000, which means 440000 houses used LBC lamps witch leaded to consumption of 64 GWh, years further that consumption will increased by the increase of the new houses number, to reach 867 GWh in the end of 2040, when the number of houses used LBC lamps will be 5.94 million houses.

| | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| **new houses** | | | 440 000 | 1 540 000 | 2 640 000 | 3 740 000 | 4 840 000 | 5 940 000 |
| **new houses lighting (GWh)** | - | - | 64 | 225 | 385 | 546 | 707 | 867 |
| **Old houses lighting (GWh)** | 2 714 | 2 904 | 3 151 | 3 107 | 3 063 | 3 019 | 2 991 | 2 963 |
| **total lighting (GWh)** | 2 714 | 2 904 | 3 215 | 3 331 | 3 448 | 3 566 | 3 698 | 3 830 |
| **cost in EU prices (million €)** | 578 | 618 | 685 | 710 | 734 | 759 | 788 | 816 |
| **Cost DZ prices(million €)** | 47 | 50 | 55 | 57 | 59 | 61 | 64 | 66 |

**Table IV.5 Lighting projection in (GWh, EU prices cost, DZ prices cost)**

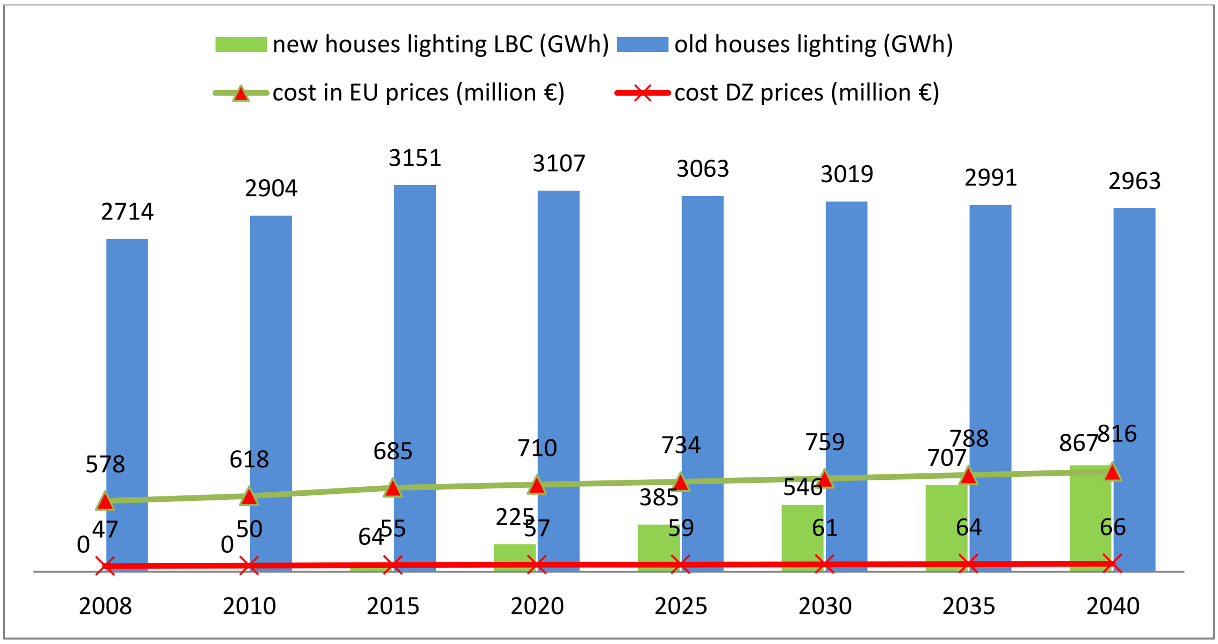



**Figure IV.6: Lighting projection in (GWh, EU prices cost, DZ prices cost)**

## IV.10.2.Cooling:

### IV.10.2.1.Principal:

Absorptive refrigeration uses a source of heat to provide the energy needed to drive the cooling process.

The absorption cooling cycle can be described in three phases:

1. Evaporation: A liquid refrigerant evaporates in a low partial pressure environment, thus extracting heat from its surroundings – the refrigerator.
2. Absorption: The gaseous refrigerant is absorbed – dissolved into another liquid - reducing its partial pressure in the evaporator and allowing more liquid to evaporate.

3. Regeneration: The refrigerant-laden liquid is heated, causing the refrigerant to evaporate out. It is then condensed through a heat exchanger to replenish the supply of liquid refrigerant in the evaporator.

(http://en.wikipedia.org/wiki/Absorption_refrigerator)

**IV.10.2.2.Types:**

Absorption chillers are generally classified as director indirect-fired, and as single, double or triple-effect. Indirect-fired units, the heat source can be gas or some other fuel that is burned in the unit. Indirect-fired units use steam or some other transfer fluid that brings in heat from a separate source, such as a boiler or heat recovered from an industrial process. Hybrid systems, which are relatively common with absorption chillers, combine gas systems and electric systems for load optimization and flexibility.

- **Single Effect:** The single-effect "cycle" refers to the transfer of fluids through the four major components of the refrigeration machine - evaporator, absorber, generator and condenser, as shown in the Pressure-Temperature diagram in Figure IV.7.

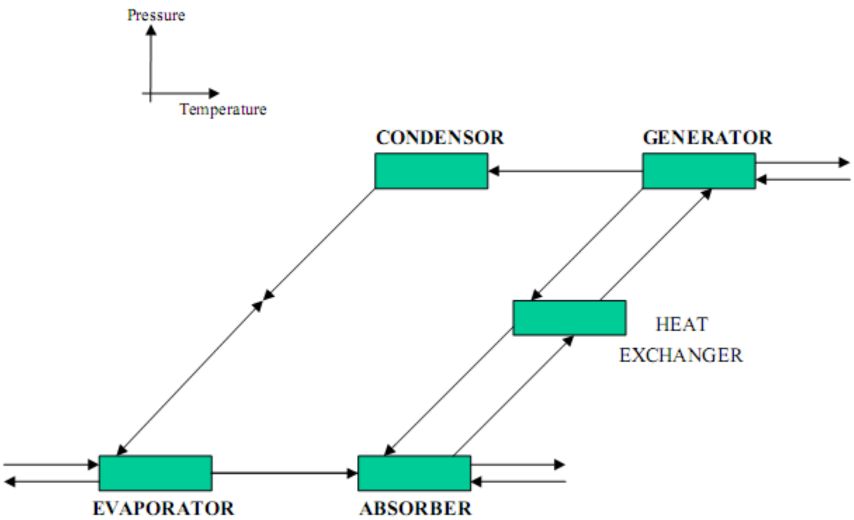



**Figure IV.7: Single-Effect Absorption Refrigeration Cycle**

Single-effect LiBr/H2O absorption chillers use low-pressure steam or hot water as the heat source. The water is able to evaporate and extract heat in the evaporator because the system is under a partial vacuum. The thermal efficiency of single-effect absorption systems is low. Although the technology is sound, the low efficiency has inhibited the cost competitiveness of single-effect systems. Most new single-effect machines are installed in applications where waste heat is readily available.

- **Double Effect:** The desire for higher efficiencies in absorption chillers led to the development of double-effect LiBr/H2O systems. The double-effect chiller differs from the single-effect in that there are two condensers and two generators to allow for more refrigerant boil-off from the absorbent solution. Figure IV.7 shows the double effect absorption cycle on a Pressure-Temperature diagram.

  The higher temperature generator uses the externally-supplied steam to boil the refrigerant from the weak absorbent. The refrigerant vapor from the high temperature generator is condensed and the heat produced is used to provide heat to the low temperature generator.

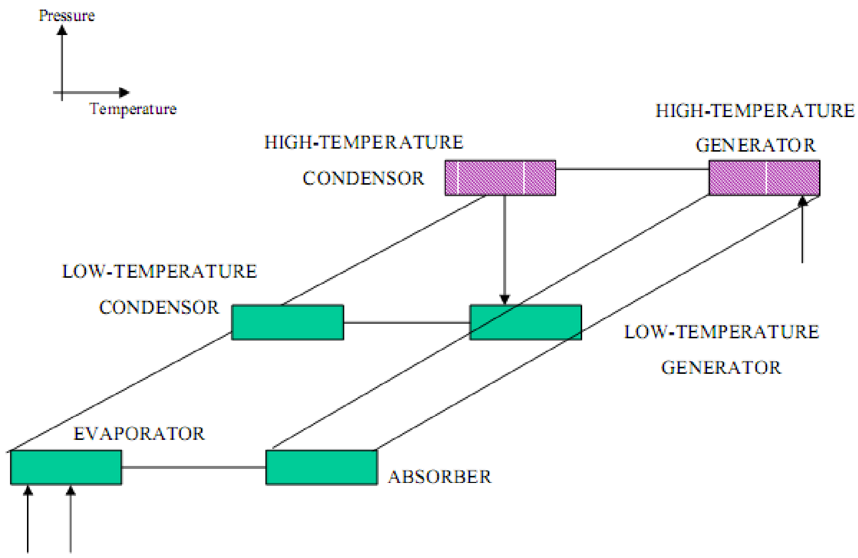



**Figure IV.8: Double-Effect Absorption Refrigeration Cycle**

These systems use gas-fired combustors or high pressure steam as the heat source. Double-effect absorption chillers are used for air-conditioning and process cooling in regions where the cost of electricity is high relative to natural gas. Double-effect absorption chillers are also used in applications where high pressure steam, such as district heating, is readily available. Although the double-effect machines are more efficient than single-effect machines, they have a higher initial manufacturing cost. There are special materials considerations, because of increased corrosion rates (higher operating temperatures than single-effect machines), larger heat exchanger surface areas, and more complicated control systems.

- **Triple Effect:** The triple-effect cycles are the next logical improvement over the double-effect. Triple-effect absorption chillers are under development, as the next step in the evolution of absorption technology. Figure IV.9 shows the triple effect absorption cycle on a Pressure-Temperature diagram. The refrigerant vapor from the high and medium temperature generators is condensed and the heat is used to provide heat to the next lower temperature generator. The refrigerant from all three condensers flows to an evaporator where it absorbs more heat.

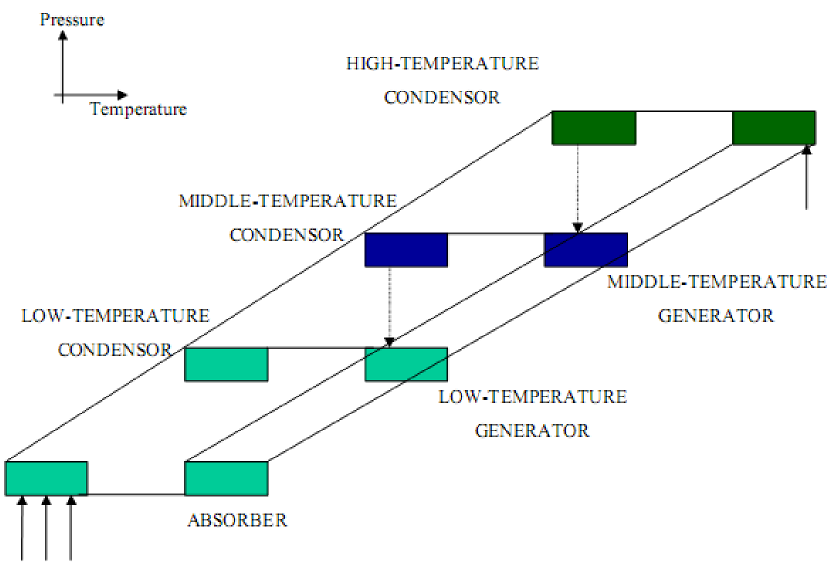



**Figure IV.9: Triple-Effect Absorption Cycle**

Two different triple-effect absorption chiller cycles are capable of substantial performance improvements over equivalent double-effect cycles. One uses two condensers and two absorbers to achieve the triple effect. A second, the double condenser coupled (DCC) triple-effect, uses three condensers as well as a third condenser sub cooler.

Triple-effect systems offer the possibility of thermal efficiencies equal to those of electrical chillers. The cost, however, will be higher, so system cost-effectiveness will need to be evaluated on a case-by-case basis. The higher efficiency levels would open wider markets for absorption chillers.

## IV.10.2.3.Thermodynamic analysis of solar absorption refrigeration system:

To evaluate the performance of the absorption cycle shown above Figure IV.10 the following hypotheses are adopted:

- In the points1, 2, 3 and 7, the refrigerant is in its pure state.
- There is no change in pressure in the tubing unless the expander and in level of the solution pump.
- In the points 4and 8, the solution is the saturated state.
- Expanders are adiabatic.
- There is no heat losing the various components.

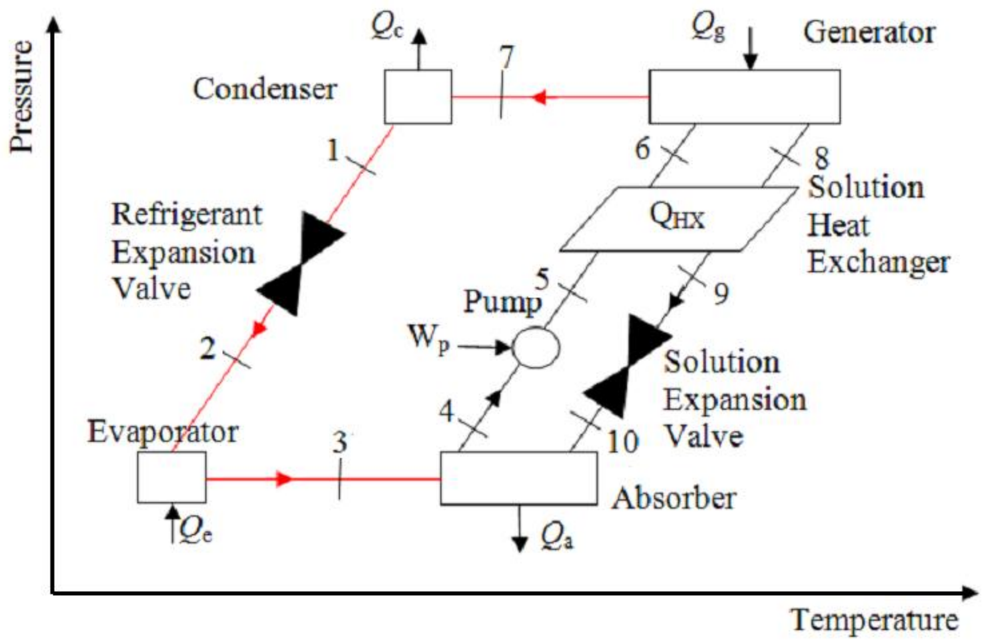



**Figure IV.11: Basic single-effect H2O-LiBr absorption chiller model**

The mass and energy conservation is determined at each component of the cycle.

➤ **<u>generator:</u>**

$\dot{m}_6 = \dot{m}_7 + \dot{m}_8$(Abdulateef and Sopian, 2008)

$\dot{m}_6 X_6 = \dot{m}_7 + \dot{m}_8 X_8$(Abdulateef and Sopian, 2008)

$Qg = \dot{m}_7 h_7 + \dot{m}_8 h_8 - \dot{m}_6 h_6$(Mittal et al., 2005)

$h_7$: Enthalpy of the super heated refrigerant evaporates the temperature of the generator (T7) and at high pressure (hp)

$h_6$: Enthalpy of the strong liquid solution at the temperature (T6) and at high pressure (hp)

$h_8$: Enthalpy of the weak liquid solution at the temperature of the generator (Tg) and high pressure (hp).

- **condenser:**

$\dot{m}_7 = \dot{m}_1$

$Qc = \dot{m}_7(h_1 - h_7)$

h1: the enthalpy of saturated liquid of refrigerant at the temperature (Tc) and the high pressure (hp).

- **evaporator:**

$\dot{m}_7 = \dot{m}_2 = \dot{m}_1 = \dot{m}_3$

$Q_e = \dot{m}_1(h_3 - h_2)$

Where:

$h_3$: Enthalpy of the saturated refrigerant at the temperature (Te) and the low pressure (lp).

$h_2$: Liquid enthalpy at the temperature (T2) and low pressure (lp).

- **absorber:**

$\dot{m}_{10} = \dot{m}_3 + \dot{m}_4$

$\dot{m}_{10}X_{10} + \dot{m}_3 = \dot{m}_4X_4$

$Qa = \dot{m}_4h_4 - \dot{m}_3h_3 - \dot{m}_{10}h_{10}$

Where:

$h_4$: Enthalpy of the liquid solution at the absorber temperature (T4) and low pressure (lp) and strong concentration ($X_s$).

$h_{10}$: Enthalpy of the liquid solution at the temperature (T10) and low pressure (Pb) and weak consultation ($X_w$).

- **Solution Pump:**

$\dot{m}_4 = \dot{m}_5 = \dot{m}_6$

$W_p = \dot{m}_6(h_5 - h_4) = v_6(P_5 - P_4)$

$h_5$: Enthalpy of the liquid solution at temperature ($T_5$) and high pressure (hp) and strong concentration ($X_s$).

$v_6$: Specific volume of the strong refrigerant solution.

- **Exchanger solution:**

$\dot{m}_6 = \dot{m}_5$

$\dot{m}_8 = \dot{m}_9$

$T_9 = T_5\, Eff + T_8\ (1 - Eff)$

$$h_6 = h_5 + \frac{\dot{m}_8}{\dot{m}_5}(h_8 - h_9)$$

$h_9$: Enthalpy of the liquid solution at temperature ($T_9$) to high pressure(hp) and weak coordination ($X_w$).

We can establish the following two mass balances of the absorber:

$\dot{m}_{10} + \dot{m}_3 = \dot{m}_4 \Leftrightarrow \dot{m}_1 + \dot{m}_8 = \dot{m}_6$ (global balance)

$\dot{m}_{10}X_{10} = \dot{m}_4X_4 \Leftrightarrow \dot{m}_{10}X_{10} = \dot{m}_6X_4$(balance sheet of LiBr)

Therefore:

$$\dot{m}_8 = \dot{m}_1 \frac{X_4}{X_{10} - X_4}$$

$$\dot{m}_6 = \dot{m}_1 \frac{X_{10}}{X_{10} - X_4}$$

- **The specific solution flow (FR):**

The specific solution flow is the ratio of the mass flow of the rich solution (ma) delivered by the pump and steam (mf) adsorbed by generator: (MuhsinKilic, 2004)

$$\text{FR} = \frac{\dot{m}_6}{\dot{m}_1} = \frac{X_{10}}{X_{10} - X_4} = \frac{X_w}{X_w - X_s}$$

- **Coefficient of Performance:**

$$COP = \frac{Q_e}{Q_g - W_p} = \frac{\dot{m}_1(h_3 - h_2)}{\dot{m}_1 h_7 + \dot{m}_8 h_8 - \dot{m}_4(\ h_6\ + h_4 - h_5)}$$

So:

$$COP = \frac{(h_3 - h_2)}{h_7 + (FR - 1)h_8 - FR(\ h_6\ + h_4 - h_5)}$$

- **system efficiency ($\boldsymbol{\eta}$):**

$$\eta = \frac{COP}{COP_c} = \frac{\dfrac{\dot{m}_1(h_3 - h_2)}{\dot{m}_1 h_7 + \dot{m}_8 h_8 - \dot{m}_4(\ h_6\ + h_4 - h_5)}}{(\dfrac{T_g - T_a}{T_g})(\dfrac{T_e}{T_c - T_e})}$$

## Numerical application:

## Charts utilized:

- **Equilibrium Chart:** (sydneyhvac.net)

The properties of an aqueous lithium bromide solution, including vapor pressure, temperature, and the mass fraction at equilibrium, may be illustrated on an equilibrium chart based on the Dühring plot, as shown in Figure IV.12 The ordinate of the equilibrium chart is the saturated vapor pressure of water in log-scale millimeters of mercury absolute (mm Hg abs) and the corresponding saturated temperature (°F). The scale is plotted on an inclined line. The abscissa of the chart is the temperature of the solution (°F). Mass fraction or concentration lines are inclined lines and are not parallel to each other.

At the bottom of the concentration lines, there is a crystallization line or saturation line. If the temperature of a solution of constant mass fraction of LiBr drops below this line—or if the mass fraction of LiBr of a solution of constant temperature is higher than the saturated condition—the part of LiBr salt exceeding the saturated condition tends to form solid crystals.

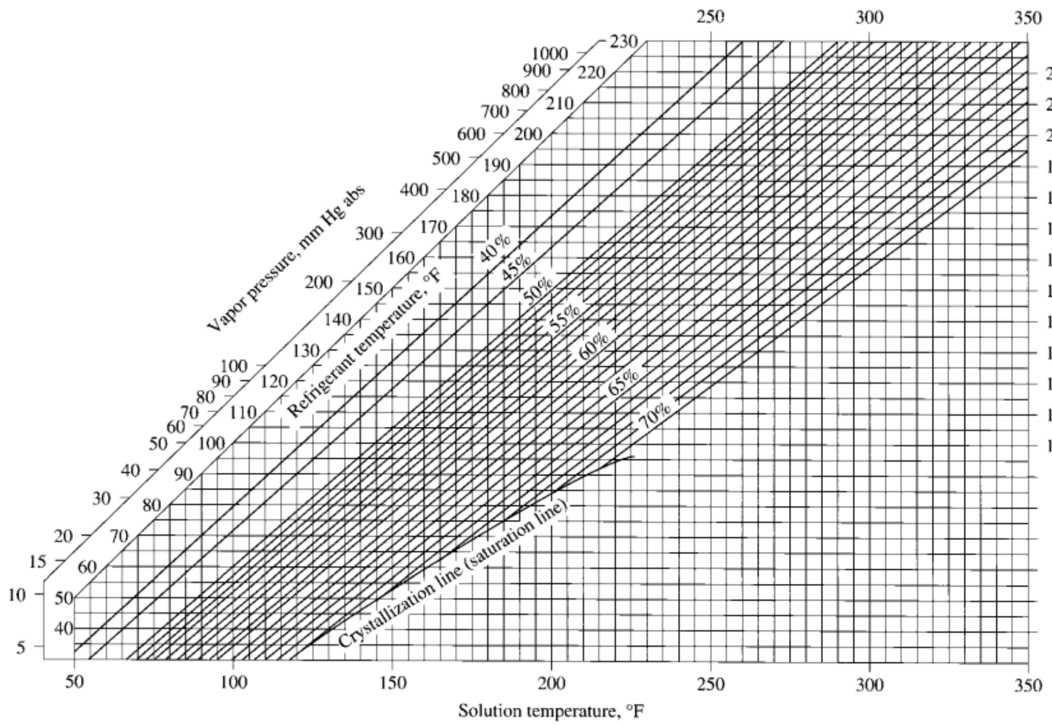



**Figure IV.12 Equilibrium chart for aqueous lithium-bromide (LiBr) solution.**

- **<u>Enthalpy-Concentration Diagram:</u>**

When water is mixed with anhydrous lithium bromide at the same temperature to form a solution adiabatically, there is a significant increase in the temperature of the solution. If the mixing processes to be an isothermal process, i.e., if the temperature of the process is to be kept constant, then heat must be removed from the solution. Such a heat transfer per unit mass of solution is called the integral heat of the solution $\Delta h_i$, or heat of absorption, in Btu/ lb (kJ /kg). Based on the common rule of thermodynamics, $\Delta h_i$ is negative.

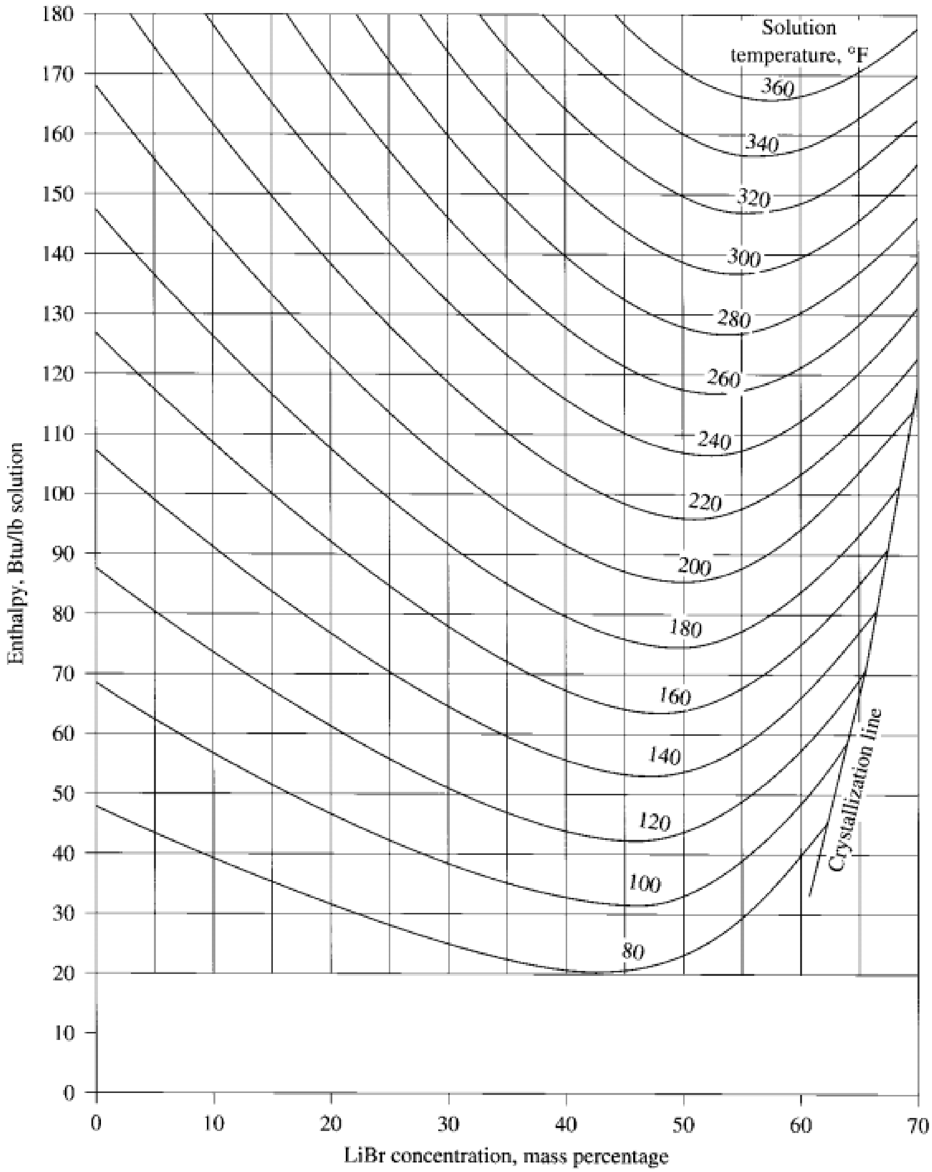



**Figure IV.13: Enthalpy-concentration diagrams for aqueous LiBr solution.** (ASHRAE Handbook, 1989)

**Assumptions:**

- Refrigeration capacity $Q_0$: we assumed it to be 5,720 kW (LG air conditioner KS-H1865NA3)
- generator temperature: $t_g$ =80 C°
- evaporator temperature:$t_e$ = 20 C°
- condenser temperature: $t_c$ = 40 C°
- ambient temperature: $t_0$ = 45 C°

From the Equilibrium chart for aqueous lithium-bromide (LiBr) solution:

$$\begin{cases} t_c = 40\ C^\circ \\ t_g = 80\ C^\circ \end{cases} X_s = 58\ \%$$

$$\begin{cases} t_c = 20\ C^\circ \\ t_0 = 45\ C^\circ \end{cases} X_w = 51\ \%$$

From the enthalpy-concentration diagram for aqueous LiBr solution:

$$\begin{cases} t_g = 80\ C^\circ \\ X_s = 58\ \% \end{cases} h_8 = 182.6\ \ kj/kg$$

$$\begin{cases} t_0 = 45\ C^\circ \\ X_w = 51\ \% \end{cases} h_4 = 95.65\ kj/kg$$

$$\begin{cases} t_0 = 67\ C^\circ \\ X_w = 51\ \% \end{cases} h_6 = 119.56\ kj/kg$$

Since the state of the refrigerant the leaves the generator and the evaporator is superheated, then $h_7$and $h_{10}$can be calculated using the equation that is expressed below:

$h_{7,10} = 2501 + 1{,}88\ t\ (t - t_{ref})$ (Mittal et al., 2005)

As known, $t_{ref}$ of water is zero so:

$h_7 = 2501 + 1{,}88\ (80)$

$h_7 = 2651.4\ \ kj/kg$

And

$h_{10} = 2501 + 1{,}88\ (20)$

$h_{10} = 2538.6\ \ kj/kg$

The enthalpy of the refrigerant that leaves the condenser is calculated using the equation below.

$$h_{1,2} = 4.19\ (t - t_{ref})$$

$h_1 = h_2 = \ 4.19\ (40)$

$h_1 = h_2 = 167.6\ kj/kg$

Then, the mass flow rate of the refrigerant is calculated.

$$\dot{m}_7 = \frac{Q_0}{h_{10} - h_2}$$

$$\dot{m}_7 = \frac{5.720}{2538.6 - 167.6}$$

$$\dot{m}_7 = 0.00241 \ kg/s$$

Then, the mass flow rate of the strong solution and the weak solution can be calculated by calculating the circulation first.

$$\text{FR} = \frac{X_w}{X_s - X_w}$$

$$\text{FR} = \frac{51}{58 - 51}$$

$$\text{FR} = 7.285$$

$$\dot{m}_8 = FR\ \dot{m}_7$$

$$\dot{m}_8 = 7.285 \times 0.00241$$

$$\dot{m}_8 = 0.01757\ kg/s$$

$$\dot{m}_6 = (FR + 1)\ \dot{m}_7$$

$$\dot{m}_6 = 8.285 \times 0.00241$$

$$\dot{m}_6 = 0.0199\ kg/s$$

Now, heat transfer for generator will be calculated:

$$Qg = \dot{m}_7 h_7 + \dot{m}_8 h_8 - \dot{m}_6 h_6$$

$$Qg = (0.00241)2651.4 + (0.01757)182.6 - (0.0199)\ 119.56$$

$$Qg = 7.2084\ \text{kW}$$

Finally, COP can be calculated with negligence of work ($W_p \approx 0$):

$$COP = \frac{Q_0}{Q_g - W_p}$$

$$COP = \frac{5.720}{7.2084}$$

$$COP = 0.793$$

## IV.10.2.4.Efficiencies:

Efficiencies of absorption chillers are described in terms of coefficient of performance (COP), which is defined as the refrigeration effect, divided by the net heat input.

Single-effect absorption chillers have COPs of approximately 0.6 to 0.8 out of an ideal 1.0. Since the COPs are less than one, the single-effect chillers are normally used in applications that recover waste heat such as waste steam from power plants or boilers.

Double-effect absorption chillers have COPs of approximately 1.0 out of an ideal 2.0. While not yet commercially available, prototype triple effect absorption chillers have calculated COPs from 1.4 to 1.6. (Southern California Gas Company, 1998)

## IV.10.2.5.Advantages: (http://www.sustainable-buildings.org/wiki/index.php/Absorption_Chillers)

- Elimination of the use of CFC and HCFC refrigerants
- Quiet, vibration-free operation
- Lower pressure systems with no large rotating components
- High reliability
- Low maintenance

## IV.10.2.6.Inconvenient:

- The low thermal efficiency of single-effect absorption systems has made them non-competitive with readily available free waste heat.
- Absorption systems also require greater pump energy than electric chillers.
- Absorption chillers require larger cooling tower capacity than electric chillers, due to the larger volume of water.

## IV.11.Compression absorption chiller vers mechanical compression air conditioner:

| Q0 kWh | Absorption | | | | | | | | | Mechanical Compression | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COP = 0,793 | | | COP = 1 | | | COP = 1,5 | | | COP = 2,71 | | |
| | Q0 kWh | EU Cost (€) | DZ Cost (€) | Q0 kWh | EU Cost (€) | DZ Cost (€) | Q0 kWh | EU Cost (€) | DZ Cost (€) | Q0 kWh | EU Cost (€) | DZ Cost (€) |
| **1** | 1,3 | 0,1 | 0,00007 | 1 | 0,07 | 0,0001 | 0,7 | 0,05 | 0,00004 | 0,4 | 0,08 | 0,004 |
| **5** | 6,3 | 0,5 | 0,00035 | 5 | 0,37 | 0,0003 | 3,3 | 0,25 | 0,00019 | 1,8 | 0,39 | 0,018 |
| **10** | 12,6 | 0,9 | 0,00070 | 10 | 0,74 | 0,0006 | 6,7 | 0,49 | 0,00037 | 3,7 | 0,79 | 0,036 |
| **15** | 18,9 | 1,4 | 0,00105 | 15 | 1,11 | 0,0008 | 10 | 0,74 | 0,00056 | 5,5 | 1,18 | 0,054 |

**Table IV.6. Absorption chiller vers mechanical compression in kWh & cost**

| ratio (Mechanical Compression/Absorption) | | | | | |
|---|---|---|---|---|---|
| COP = 0,793 | | COP = 1 | | COP = 1,5 | |
| EU Cost (€) | DZ Cost (€) | EU Cost (€) | DZ Cost (€) | EU Cost (€) | DZ Cost (%) |
| 0,842 | 51,041 | 1,062 | 64,365 | 1,593 | 96,547 |

**Table IV.7. Ratio of absorption chiller vers mechanical compression**

## IV.12.Projection of cooling with Absorption chiller with (cop = 1.5)

| | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| Ele comprsion (GWh) | 1 175 | 1 272 | 1 212 | 456 | - | - | - | - |
| abs COP (1,5) (GWh) | - | - | 546 | 1 917 | 3 650 | 4 137 | 4 647 | 5 179 |
| ele com cost in euro price (million €) | 250 | 271 | 258 | 97 | - | - | - | - |
| abs cost in euro price (million €) | - | - | 40 | 142 | 270 | 306 | 344 | 383 |
| total cost in euro prices (million €) | 250 | 271 | 299 | 239 | 270 | 306 | 344 | 383 |
| ele com cost in dz prics (million €) | 20 | 22 | 21 | 8 | - | - | - | - |
| abs cost in dz prics (million €) | - | - | 0,030 | 0,107 | 0,203 | 0,230 | 0,258 | 0,288 |
| total cost in dz price (million €) | 20,211 | 21,874 | 20,884 | 7,956 | 0,203 | 0,230 | 0,258 | 0,288 |

**Table IV.8. Projection of cooling with Absorption chiller with (cop = 1.5)**

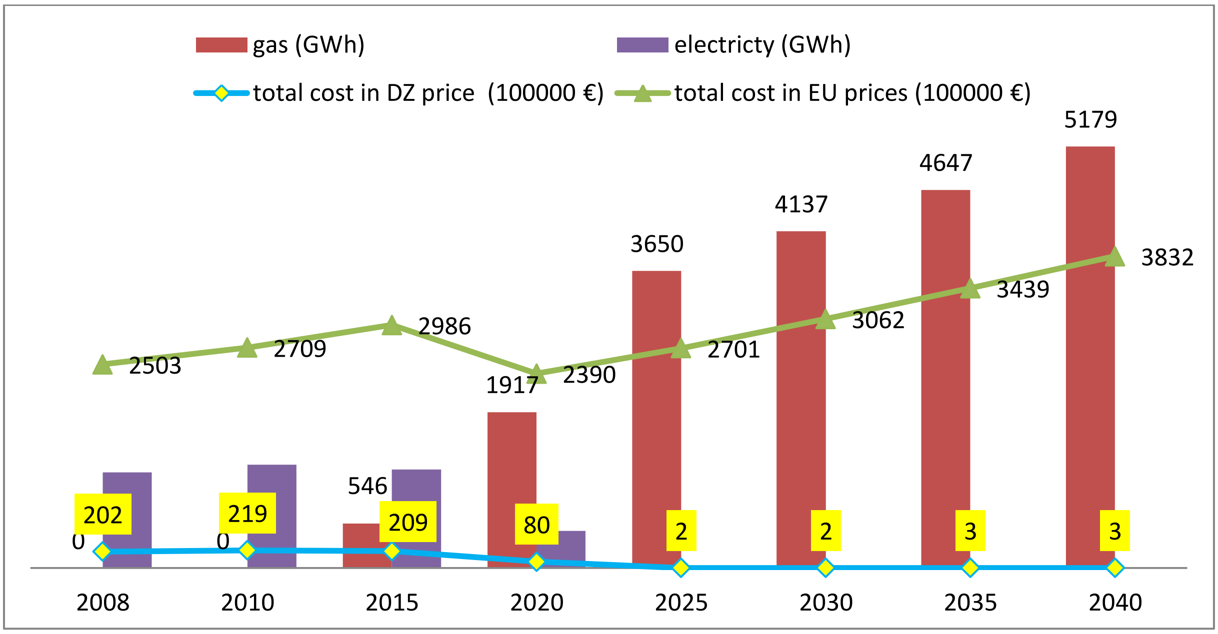



**Figure IV.14: Energy consumption and cost projection**

## IV.13.Total energy consumption:

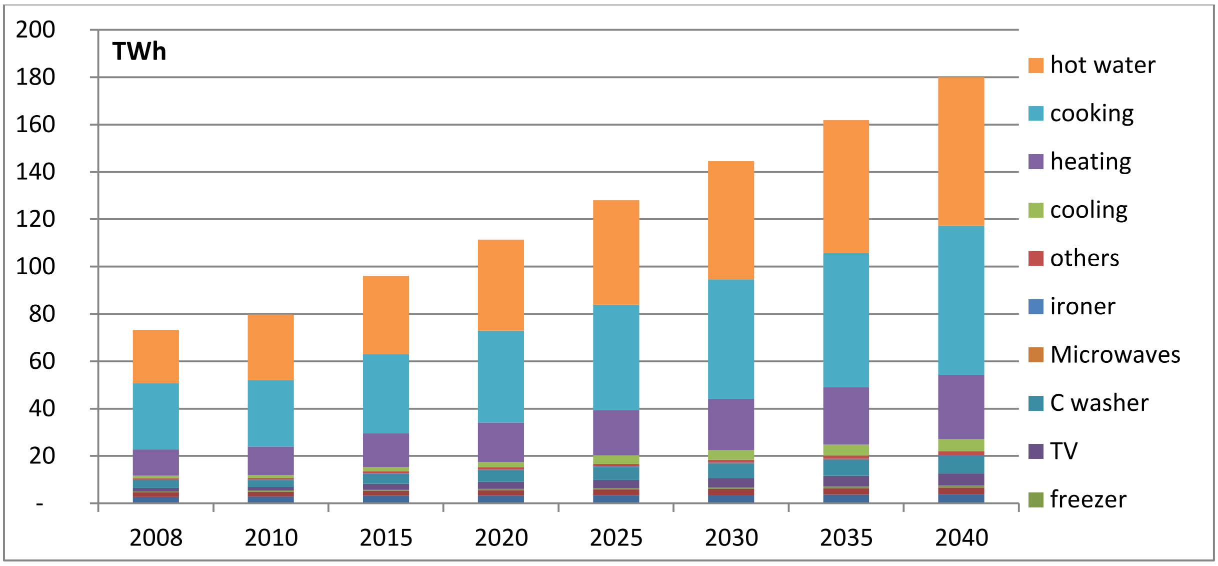



**Figure IV.15: Total Energy consumption in TWh**

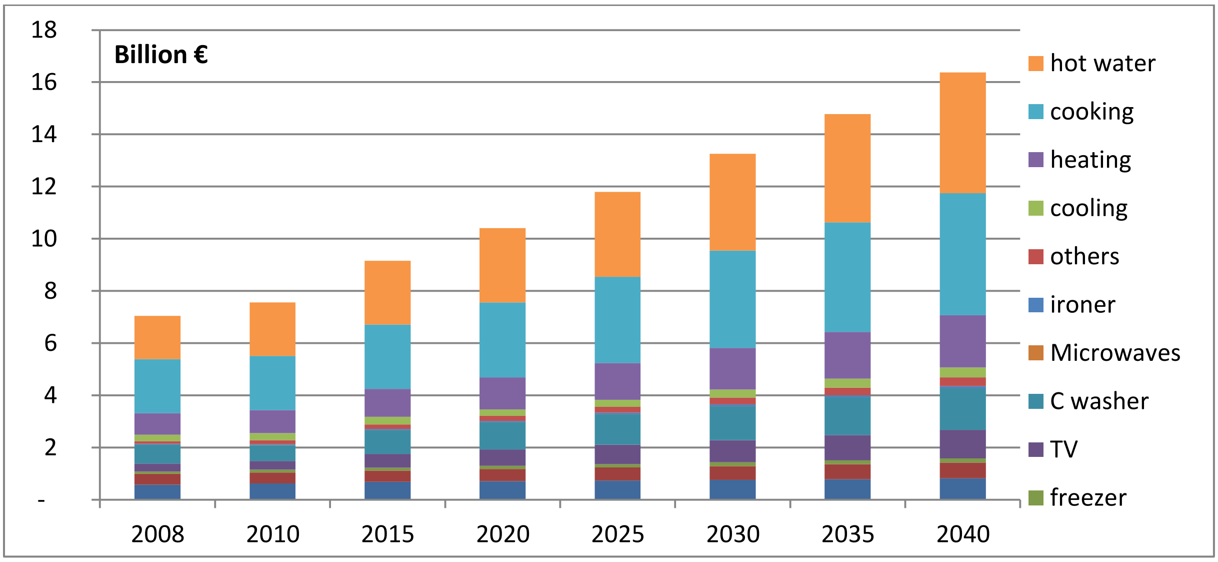



**Figure IV.16: Total Energy consumption in EU prices**

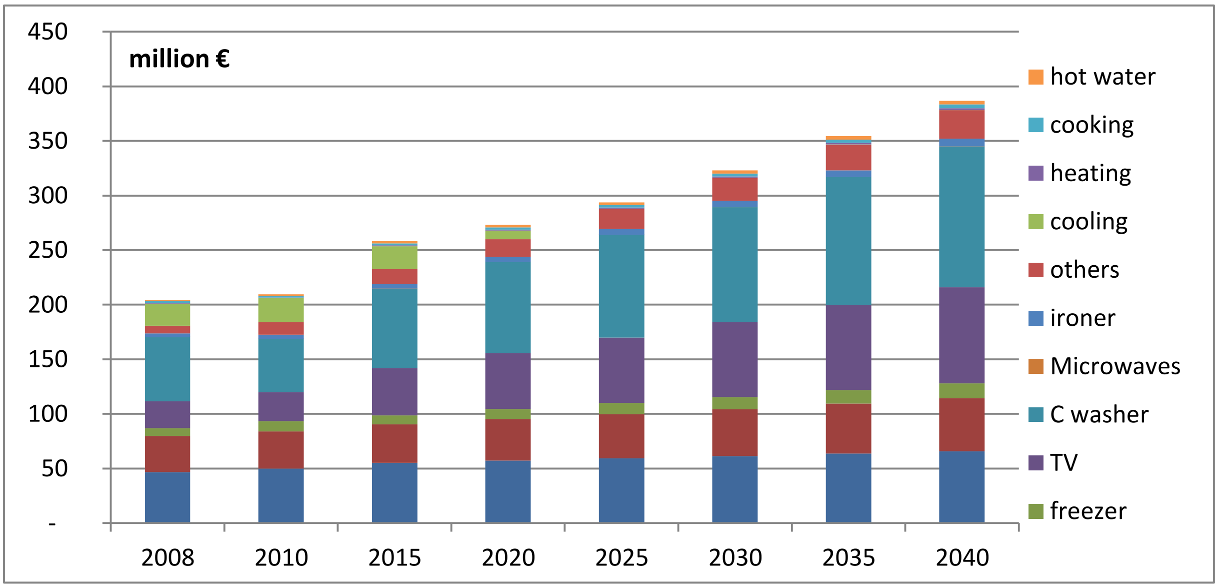



**Figure IV.17: Total Energy consumption in DZ prices**

## IV.14.Alternative scenario 2:

### IV.14.1.Cooling: absorption chiller with (cop = 1):

| | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| Ele comprsion (GWh) | 1 175 | 1 272 | 1 212 | 456 | 0 | 0 | 0 | 0 |
| abs COP (1) (GWh) | 0 | 0 | 821 | 2 886 | 5 495 | 6 229 | 6 996 | 7 797 |
| ele com cost in euro price (million €) | 250 | 271 | 258 | 97 | - | - | - | - |
| abs cost in euro price (million €) | - | - | 61 | 214 | 407 | 461 | 518 | 577 |
| total cost in euro prices (million €) | 250 | 271 | 319 | 311 | 407 | 461 | 518 | 577 |
| ele com cost in dz prics (million €) | 20 | 22 | 21 | 8 | - | - | - | - |
| abs cost in dz prics (million €) | - | - | 0,046 | 0,160 | 0,306 | 0,346 | 0,389 | 0,434 |
| total cost in dz price (million €) | 20,211 | 21,874 | 20,900 | 8,010 | 0,306 | 0,346 | 0,389 | 0,434 |

**Table IV.9: Projection of cooling with Absorption chiller with (cop = 1.5)**

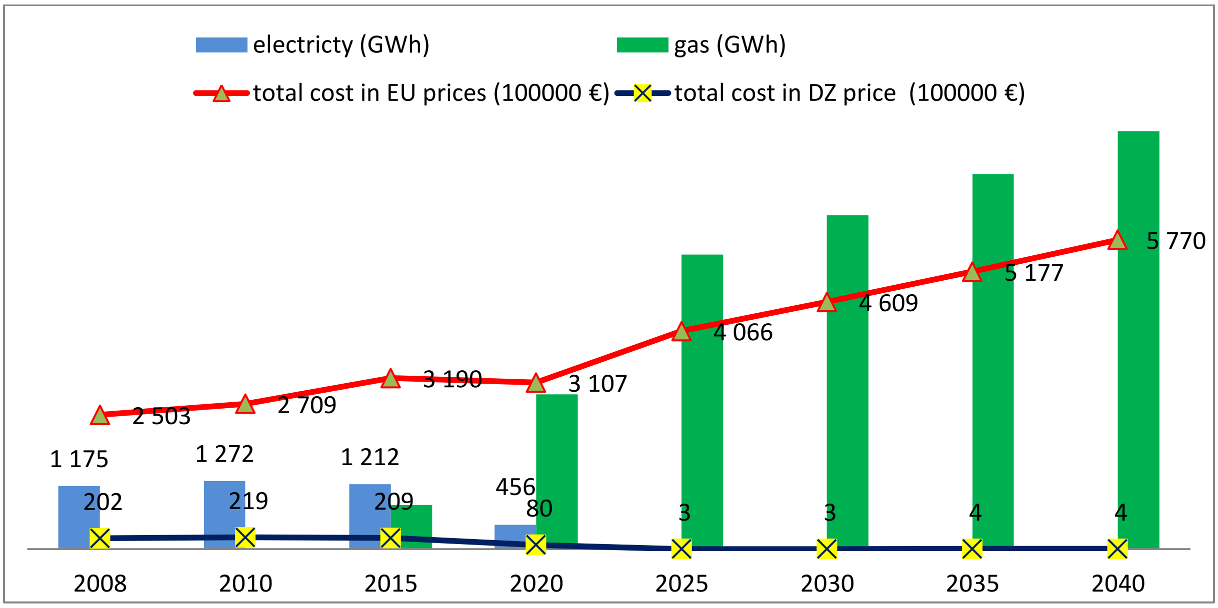



**Figure IV.18: energy consumption and cost projection**

## IV.14.2.Total energy consumption:

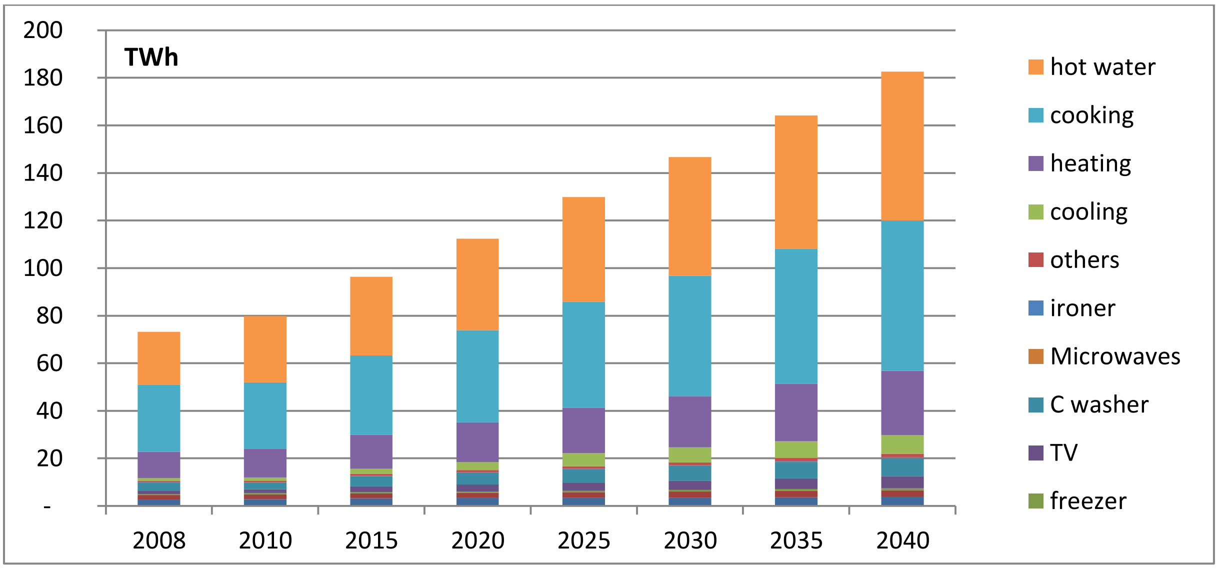



**Figure IV.19: Total energy consumption in TWh by Alternative scenario 1**

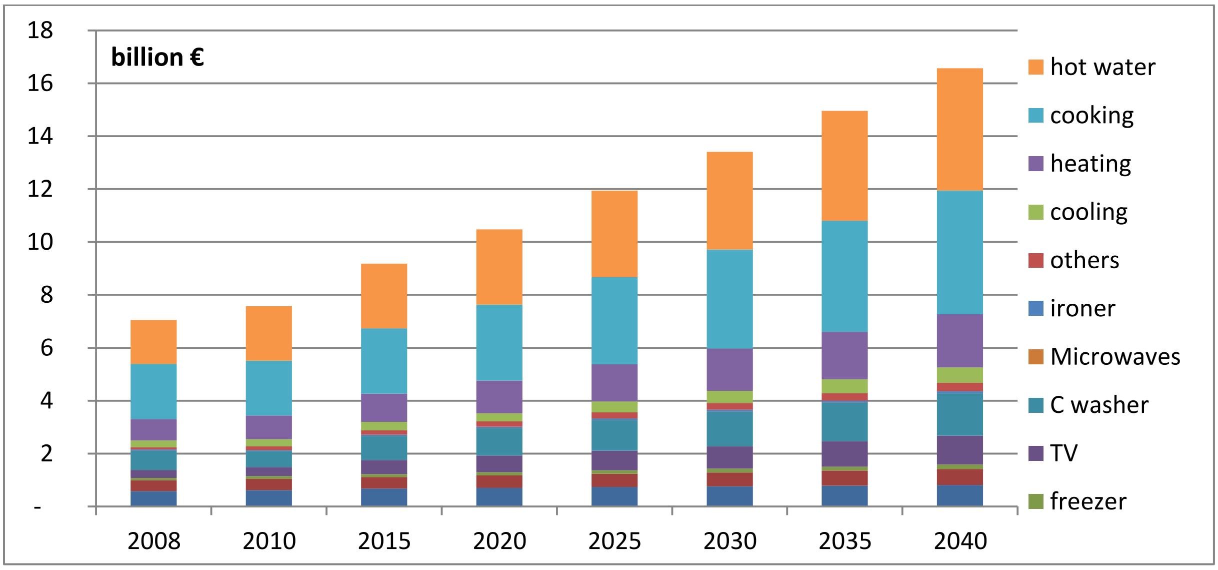



**Figure IV.20: Total energy consumption in EU prices Alternative scenario 1**

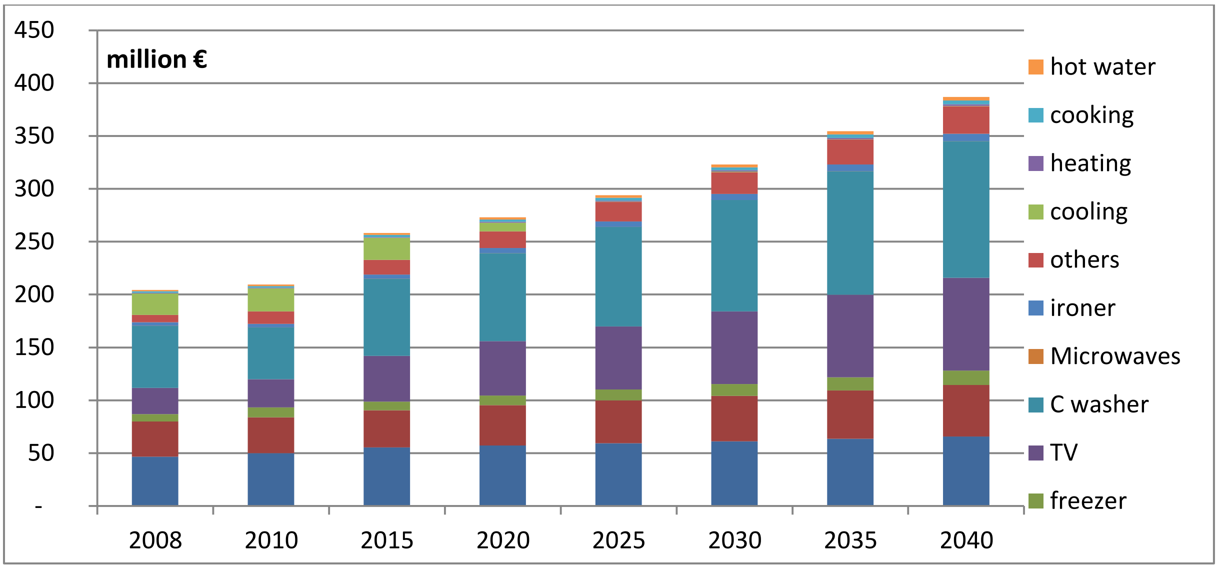



**Figure IV.21: Total energy consumption in DZ prices Alternative scenario 1**

## IV.15.Comparison:

### IV.15.1.Lighting

| | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| Alternative lighting (GWh) | 2 714 | 2 904 | 3 215 | 3 331 | 3 448 | 3 566 | 3 698 | 3 830 |
| cost in euro prices 1000000 € | 578 | 618 | 685 | 710 | 734 | 759 | 788 | 816 |
| cost dz prices 1000000 € | 47 | 50 | 55 | 57 | 59 | 61 | 64 | 66 |
| BAS lighting (GWh) | 2 714 | 2 904 | 3 363 | 3 856 | 4 358 | 4 870 | 5 418 | 5 981 |
| cost in euro prices 1000000 € | 578 | 618 | 716 | 821 | 928 | 1 037 | 1 154 | 1 274 |
| cost dz prices 1000000 € | 47 | 50 | 58 | 66 | 75 | 84 | 93 | 103 |
| energy gain (GWh) | - | - | 148 | 524 | 910 | 1 304 | 1 720 | 2 151 |
| gain in euro prices 1000000 € | - | - | 32 | 112 | 194 | 278 | 366 | 458 |
| gain dz prices 1000000 € | - | - | 3 | 9 | 16 | 22 | 30 | 37 |

**Table IV.10. Lighting comparison**

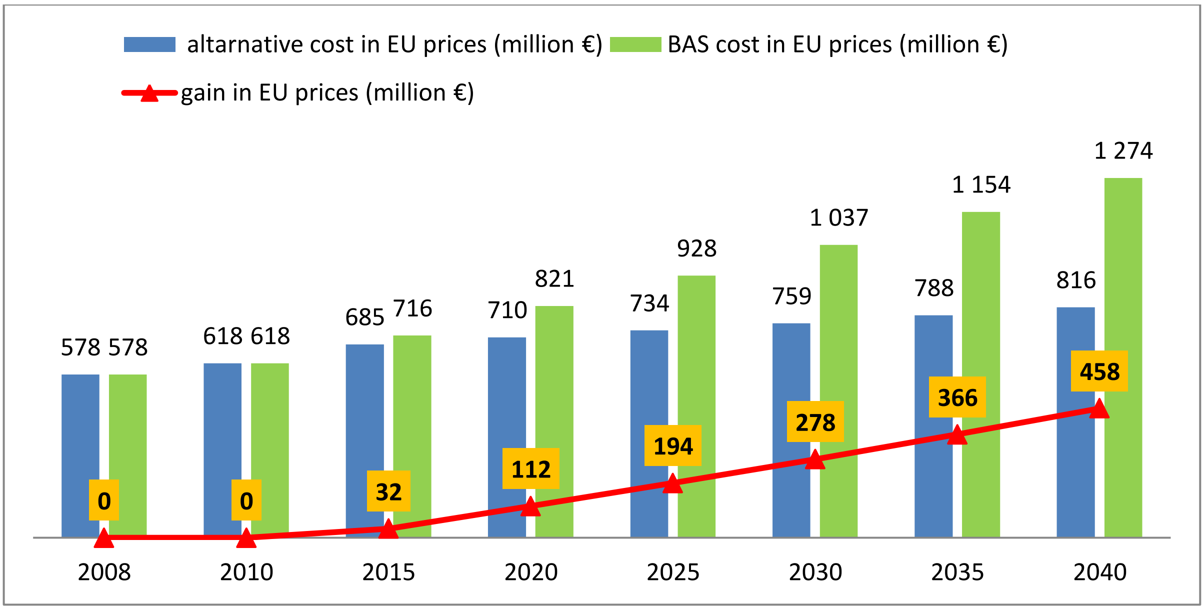



**Figure IV.22: Energy gain in EU prices**

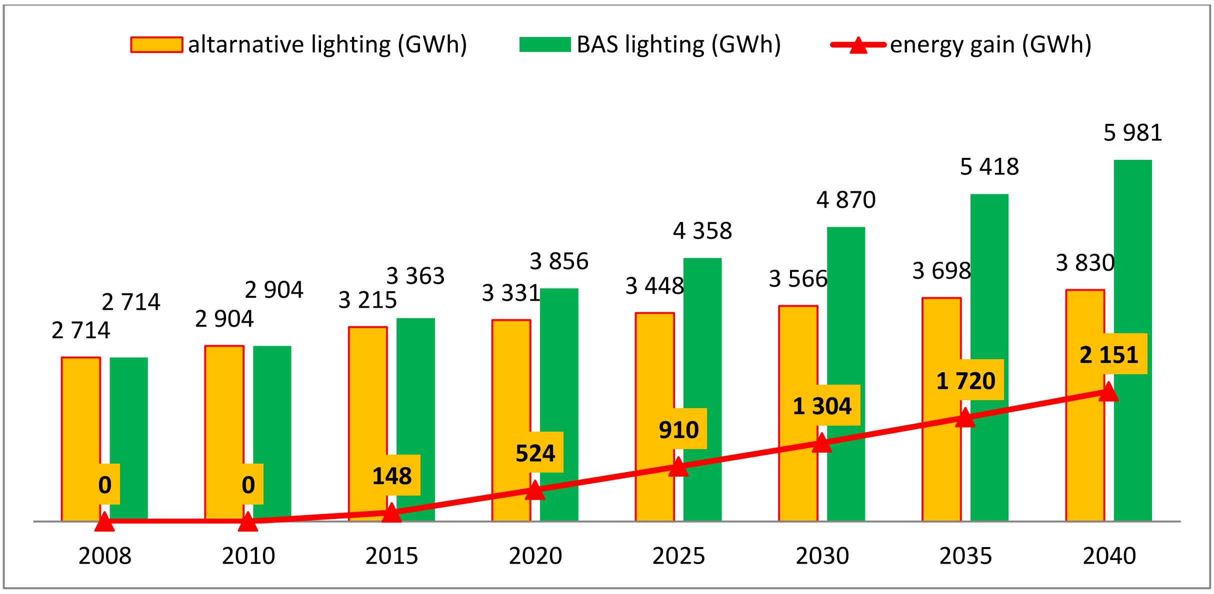



**Figure IV.23: Energy gain in EU prices in GWh**

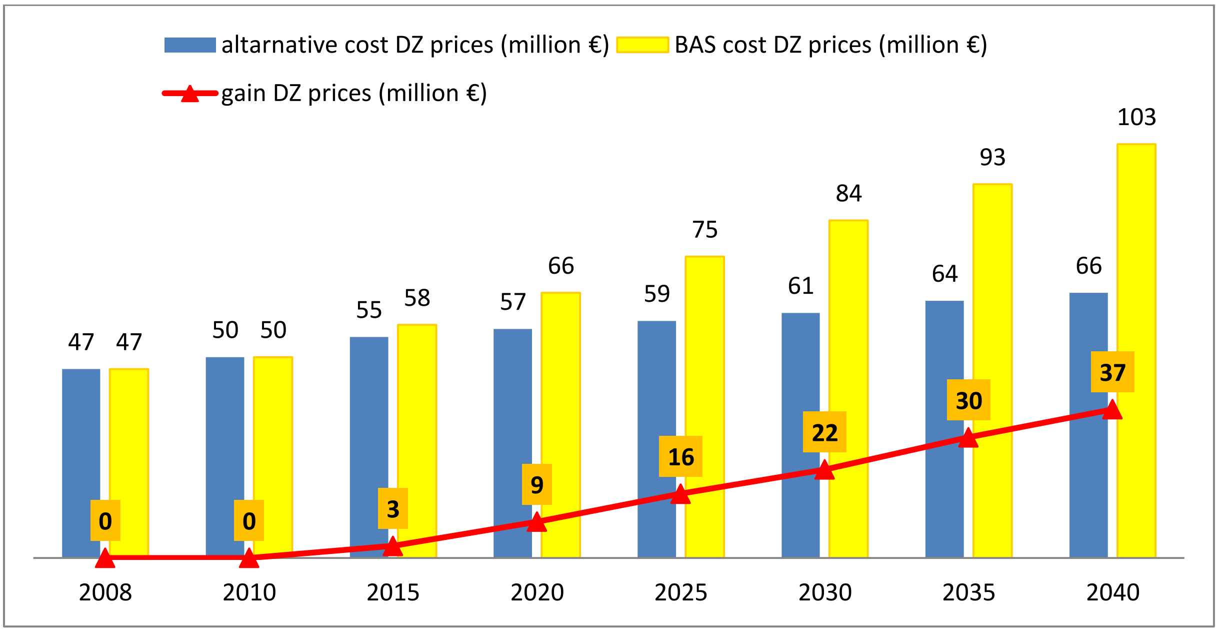



**Figure IV.24: Energy gain in EU prices in GWh**

## IV.15.2.Cooling:

__Mechanical comparison chillers VS absorption chiller:__

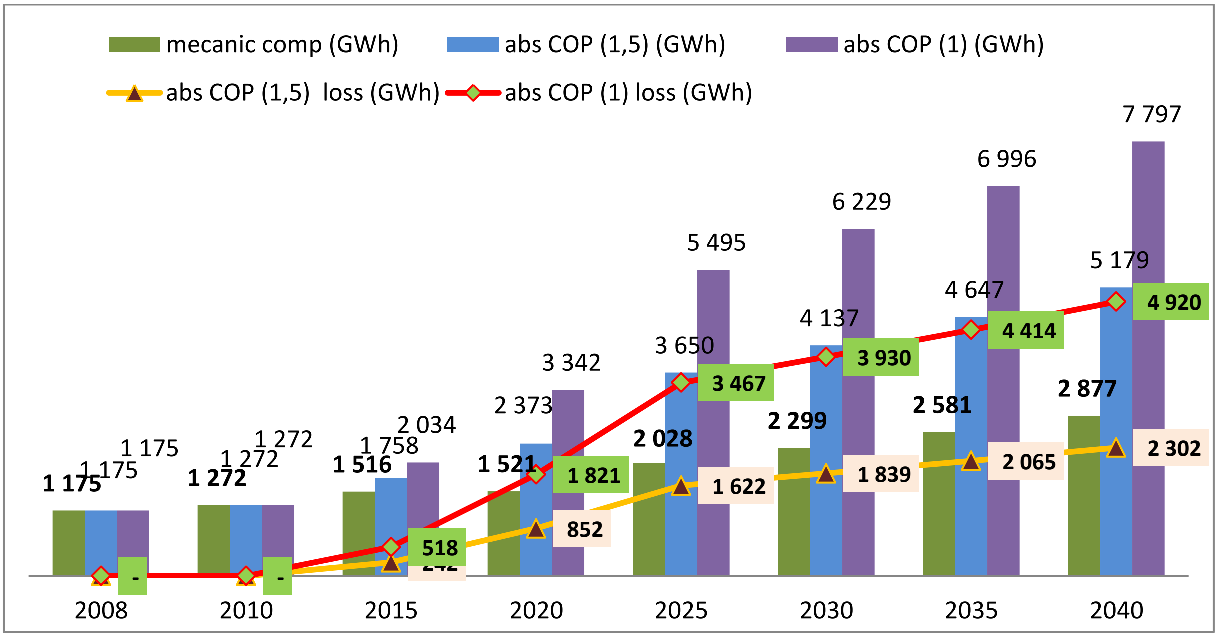



**Figure IV.25: Energy loss**

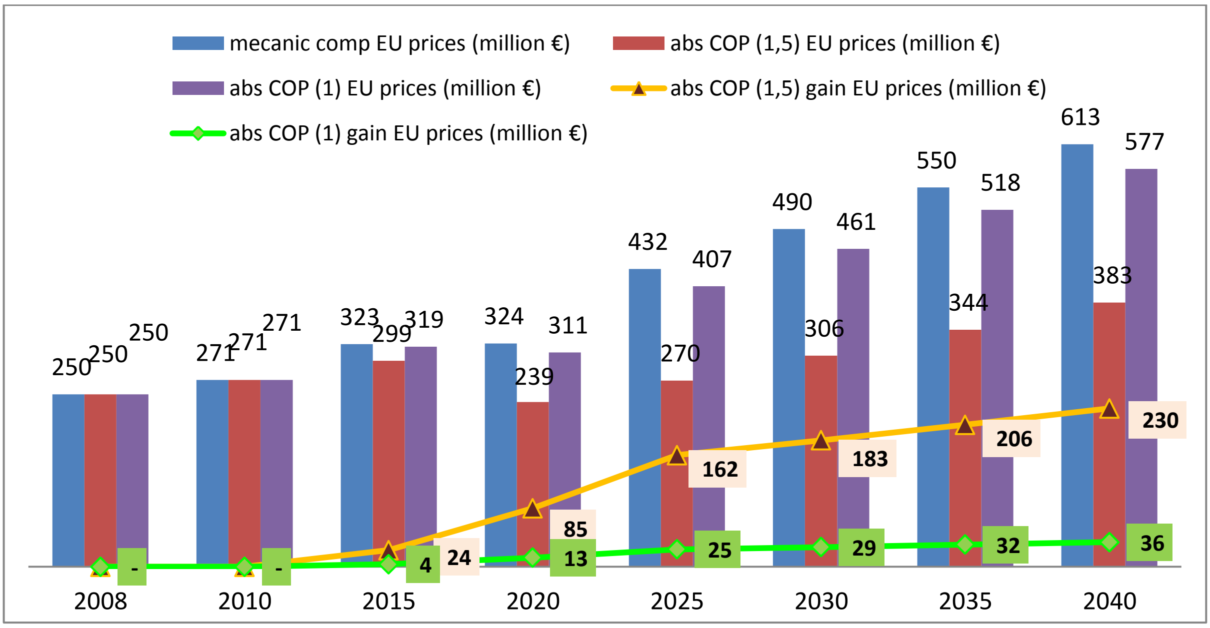



**Figure IV.26: Cost gain in EU prices**

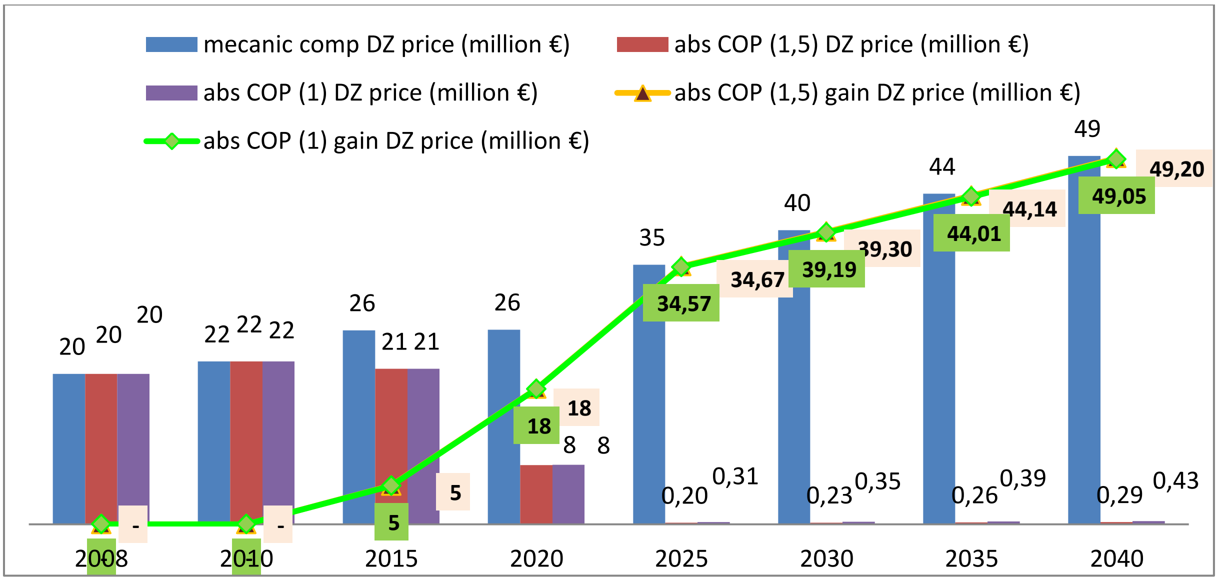



**Figure IV.27: Cost gain in DZ prices**

## IV.15.3. Total comparison:

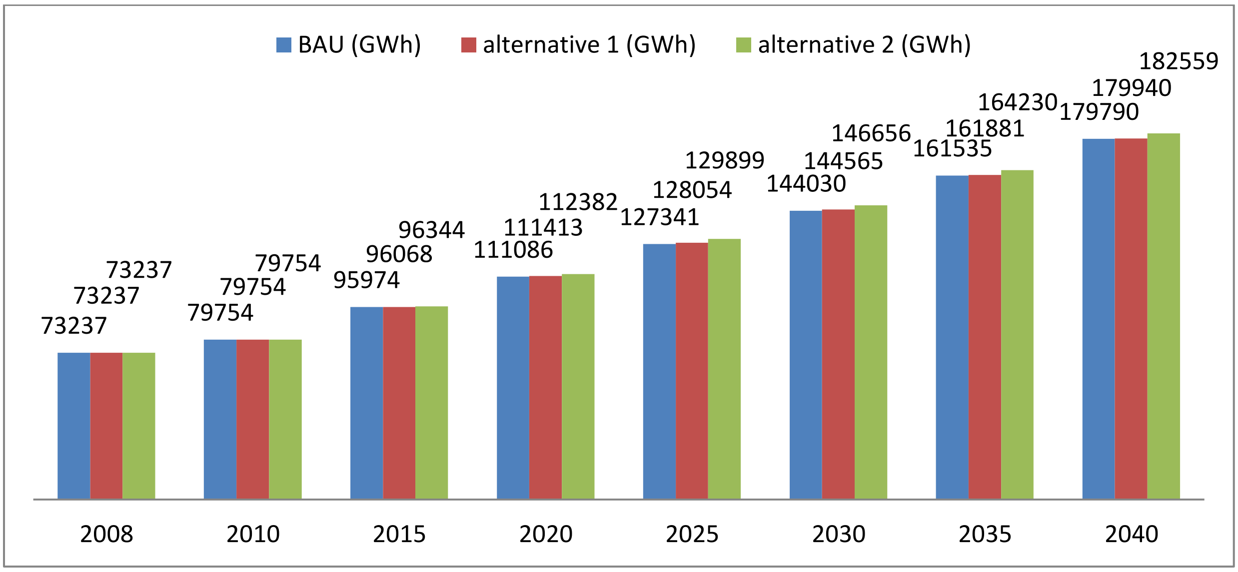



**Figure IV.28: Scenarios comparison in EU prices**

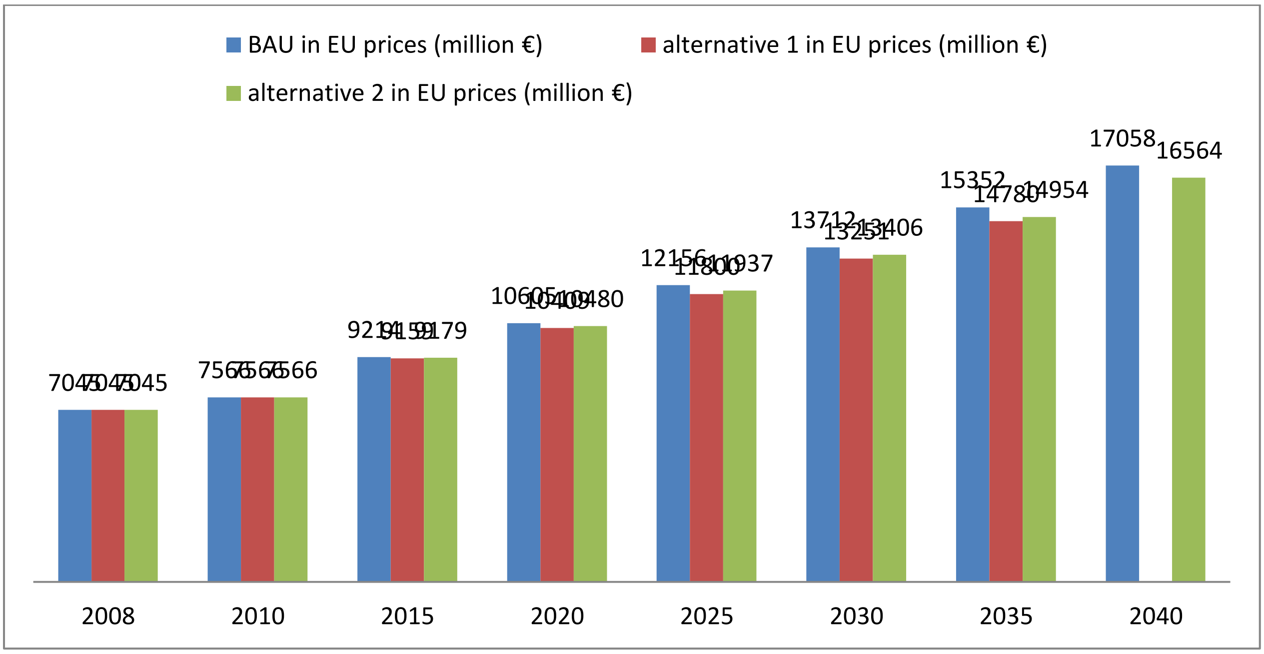



**Figure IV.29: Scenarios comparison in EU prices**

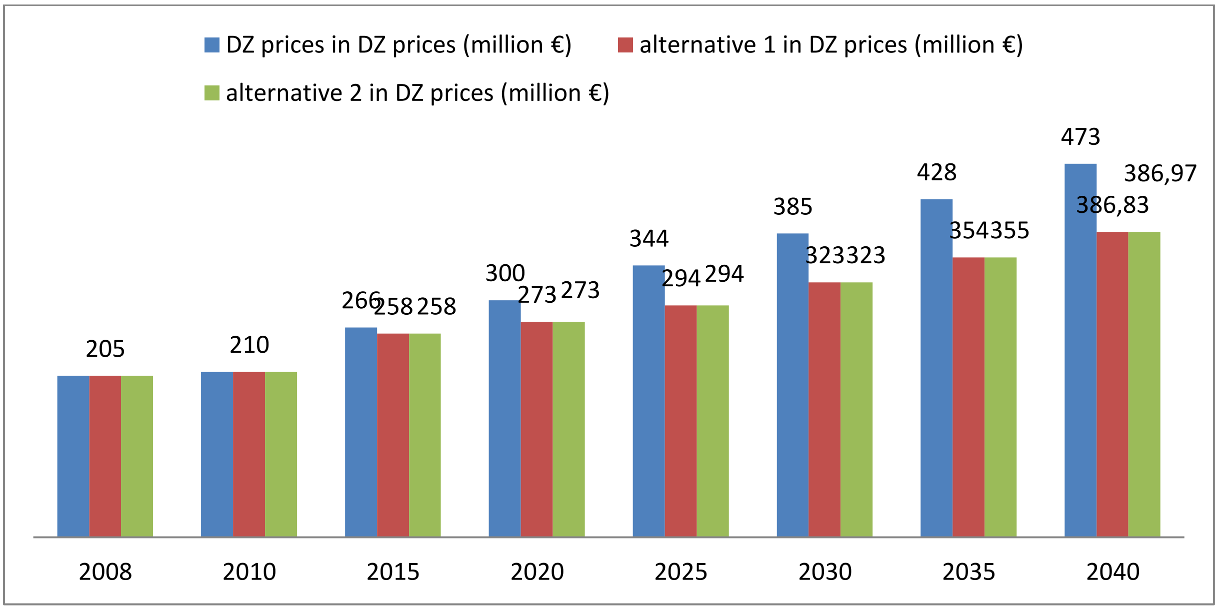



**Figure IV.30: Scenarios comparison in DZ tariffs**

| | | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|---|
| Mechanic comp | EU prices (1000000 €) | 250 | 271 | 323 | 324 | 432 | 490 | 550 | 613 |
| | DZ price (1000000 €) | 20 211 200 | 21 874 317 | 26 067 388 | 26 163 577 | 34 877 525 | 39 534 575 | 44 401 334 | 49 485 350 |
| abs COP (1,5) | EU prices (1000000 €) | 250 | 271 | 299 | 239 | 270 | 306 | 344 | 383 |
| | DZ price (1000000 €) | 20,211 | 21,874 | 20,884 | 7,956 | 0,203 | 0,230 | 0,258 | 0,288 |
| abs COP (1) | EU prices (1000000 €) | 271 | 293 | 320 | 247 | 270 | 306 | 344 | 384 |
| | DZ prices (1000000 €) | 290,712 | 314,634 | 340,392 | 254,943 | 270,504 | 306,623 | 344,369 | 383,800 |

**Table.IV.11. cooling Scenarios comparison**

**Gain in euro prices:**

| | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|---|
| Ele comprsion (GWh) | 1 175 | 1 272 | 1 212 | 456 | - | - | - | - |
| COP (1,5) | - | - | 546 | 1 917 | 3 650 | 4 137 | 4 647 | 5 179 |
| ele com cost in euro price (1000000 €) | 250 | 271 | 258 | 97 | - | - | - | - |
| abs cost in euro price (1000000 €) | - | - | 40 | 142 | 270 | 306 | 344 | 383 |
| total cost in euro prices (1000000 €) | 1 425 | 1 543 | 2 057 | 2 612 | 3 920 | 4 444 | 4 991 | 5 562 |
| ele com cost in dz prics (1000000 €) | 20 | 22 | 21 | 8 | - | - | - | - |
| abs cost in dz prics (1000000 €) | - | - | 0,030 | 0,107 | 0,203 | 0,230 | 0,258 | 0,288 |
| total cost in dz price (1000000 €) | 20,211 | 21,874 | 20,884 | 7,956 | 0,203 | 0,230 | 0,258 | 0,288 |

**Table.IV.12. cooling gain comparison**

## General conclusion:

The results of this study appears the big difference in heating and cooling consumption of houses in different zones, in cooling 2841 kwh for a house in zone 1 kWh while it's just 241 kWh in zone 7, and it's the reverse about heating 969 kWh about a house in zone 1 and 2215 kWh in house in zone 7 kWh.

The zone 7 is the large consumer of energy in Algeria, it's represent 73% of the total energy consumed, while the zone 1 is only represent 1%, and that's mainly because of on the number of houses in the zones, it's 4.1 million house in zone 7 and 9770 house in zone 1.

That's let us conclude that we have not to treat the housing in Algeria in the same way but we have to deal with the housing according to the nature of the climatic zone it located in.

The results shows the cooking and the heating and hot water are the major energy consumer in the residential sector in Algeria and that's because of the total end use in Algeria, and that's can be justified by the high calorific value of gas comparing with electricity. But when we analyses it by the cost in EU tariffs, the reparation will change a bit

According to the results the gain we get from injecting LBC is 148 GWh in 2015 and increased to be 2150 GWh in 2040, while the absorption chiller gain is 24 million € in 2015 and 203 million € in 2040 with the cop of 1.5 and with cop of 1 the gain was 4 million € in 2015 and 36 million €.

The residential sector have a lot factors that influence it's consumption like the kind of appliances and the efficiency of the appliances of using an absorption chiller in one of many solution, so if reduce some of all the factors we will be massage gain.

During studying this subject, I noticed an insufficient data about this kind of subjects in Algeria, so the residential sector needs more attention from the researchers. As long as the data and statistics are rarely available about the consumption in the residential sector in Algeria, this study hopefully will give a closer look about this sector.