Analysis of energy system in Norway with focus on energy consumption prediction

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ANALYSIS OF ENERGY SYSTEM IN NORWAY WITH FOCUS ON ENERGY CONSUMPTION PREDICTION

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ABSTRACT: Today, the fossil fuels have dominant share of energy supply in order to respond to the high energy demand in the world. Norway is one of the countries with rich sources of fossil fuels and renewable energy sources. The current work is to investigate on the status of energy demand in Norway. First, energy and electricity consumption in various sectors, including industrial, residential are calculated. Then, energy demand in Norway is forecasted by using available tools. After that, the relationship between energy consumption in Norway with Basic economics parameters such as GDP, population and industry growth rate has determined by using linear regression model. Finally, the regression result shows a low correlation between variables.
KEY WORDS: Energy System, Energy modelling, Norway

1. INTRODUCTION

The global population continues to grow, and different countries develop rapidly. This fact causes an extensive increase in the energy demand, so providing this need has become a critical issue [1]. Considering the increasing rate of global energy consumption, energy demand is expected to increase about 65% by 2030 [2]. Because of limitations and environmental effects of fossil fuels, governments have implemented different strategies to reduce energy import dependency [3].

As an example, energy consumption is increasing highly in the Nordic countries (Denmark, Finland, Norway, Sweden and Island). These countries have tried to supply their energy need by utilization of more efficient and sustainable systems, as well as more affordable energy sources. This fact not only supplies energy demand, but also facilitate the transition to an environmentally sustainable society. Since the oil crisis in the early 1970s, Nordic countries have invested a lot to find alternative energy sources. As a result, replacing sources reduced the oil share from 70% in 1970 to 20% in 2012 [4].

In order to improve energy supply systems, different strategies have introduced as useful solutions. Two most efficient tools that can be used to improve existing and future energy systems are modeling and forecasting energy consumption. After that can conduct measures to achieve the goals Predicted of energy consumption and reduce dependence.

In this paper, the status of energy demand is investigated in one of the European countries, Norway. First, energy and electricity consumption are determined in different sectors, including industrial, residential, and etc. Then, energy demand in Norway is predicted by using available tools. After that, the relationship between energy consumption in Norway with Basic economic parameters such as GDP, population and industry growth rate has determined using linear regression model. Finally, considering results extracted in the previous part, energy policy investigates in this country.

2. LITERATURE REVIEW

2.1. Country situation

Norway is one of the Nordic countries located in Northern Europe and West Nordic Peninsula. This country has a cool and mountainous climate. According to 2016 statistics, Norway has 5.22 million people and growth rate of 0.2% (www.norway statistic.com, 2012).

Norway is one of the most significant energy producer and exporters among Europeans. This country is one of the largest oil and gas exporter in the world. Also, it has the second-largest reserves of natural gas in Europe, after Russia. (Miika Tommila, 2010).

In 2011, Norway produced 2311 TWh energy. In this statistic, crude oil, and natural gas were the largest parts with more than 90%. Norway is rich with both of petroleum and RE sources. Every year 120 135 TWh of RE is produced in this country. There is great potential for hydroelectric power and a large share of electricity is generated by this source. In the last decade, the share of produced electricity from RE that mainly is considered hydropower has accounted between 95 and 99 (Anne Therese Gullberg, 2014).

As of 1 January 2014, the total installed capacity in Norwegian hydropower plants was 30 960 MW, split between 1476 power plants. The ten largest hydropower plants together account for nearly one fifth of the production capacity. Table 1 shows the numbers and installed capacity of hydropower plants in various size categories as of 1 January 2014 (Kjersti Aarrestad, 2014).

Table 1. Operational hydropower stations by size and mean annual production. As of 01.01.2014. (www.nve.com)

MW	Number	Performance (MW)	Mean annual production (GWh/year)
<1 MW	554	175	0.8
1-10 MW	587	1989	8.3
10-100 MW	255	9523	43
Over 100	80	19273	79.5
Total	1476	30960	132

Norway generally has good wind resources, compared with other countries. The average annual wind speed 50 metres above ground in an exposed coastal area in Norway can be 7-9 m/s. At the start of 2014, Norway had 811 MW of installed wind power, provided by 356 turbines in 20 registered wind farms, see Figure 1 (Kjersti Aarrestad, 2014).

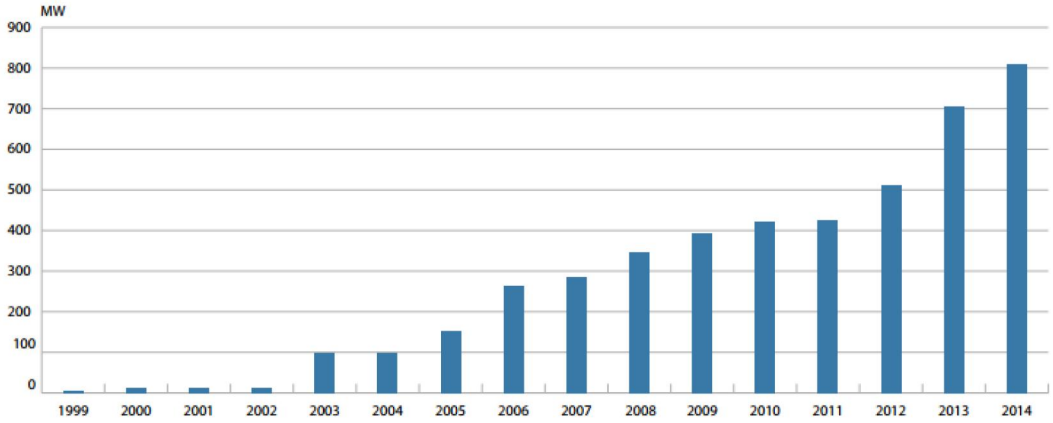

Figure 1. Installed peak wind power capacity. 1999 to 2014. (www.norway statistic.com, 2012)

According to the organization for Economic Co-operation and Development (OECD) statistics, Norway is one of the richest countries in the world. In fact, it has the second place among OECD countries in terms of GDP per capita (after Luxembourg). One of the main reasons is that the petroleum sector is the spine of the Norwegian economy. For instance in 2009, this sector produced 22% of GDP, 47% of exports, and also 27% of this its government revenue (Miika Tommila, 2010). Nevertheless there is no fossil fuel dependency on imports in any sector of this country.

Nordic countries consume more energy, their carbon dioxide emissions is compared with the EU average of 8 tons and the US average of 19 tons are 5 tons per year. The reason for this is that most part of electricity in these countries supplied by nuclear and hydroelectric power plants, cogeneration from combined heat and power, and the wind turbines (Irandoust, 2016). Fig 2 shows time plot of RE generation in terms of thousand tons in the Nordic countries from 1975 to 2012.

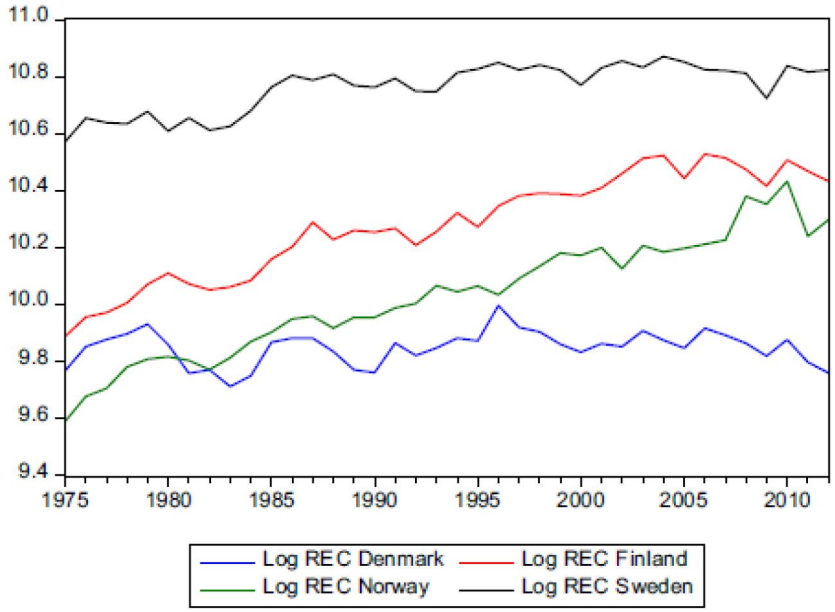

Figure 2. RE consumption in the Nordic countries (1975–2012) (Irandoust, 2016)

The international energy agency (IEA) encouraged Norway to utilize its high hydropower capacity, to balance differences in demand and supply, as the largest in Europe after Russia. More hydropower resources, not only enhance flexibility in the electricity market integration in Europe but also puts Norway in a favorable strategic position (Miika Tommila, 2010).

2.2. Energy balance analysis

According to Sankey curve, in 2013 total primary energy

supply (TPES) in Norway was 32706 ktoe, 4.8% biomass, 0.7% geothermal, the wind and, solar, 33.3% hydropower, 17.3% natural gas, 41.5% crude oil and 2.3% coal (www.iea.org). As it is illustrated in figure 3, crude oil, hydropower and natural gas were the largest energy supplies in Norwey.

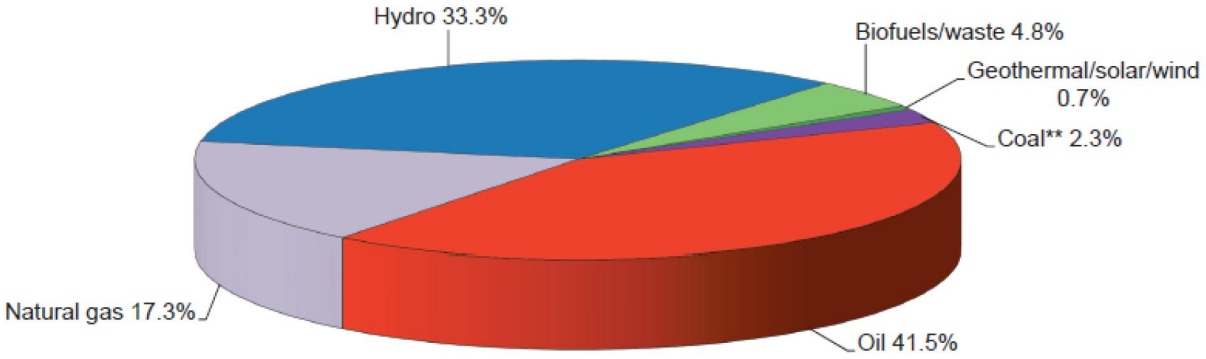

Figure 3. The share of TPES in 2013 (www.iea.org)

The results indicated trend of TPES has increased from 1971 to 2013 for all sources, but it was decreased in 2010 and 2011 because of the world recession. According to figure 4 as a renewable resource between all energy reserves, hydropower has increased much higher. It shows the great potential of Norway to use this renewable resource.

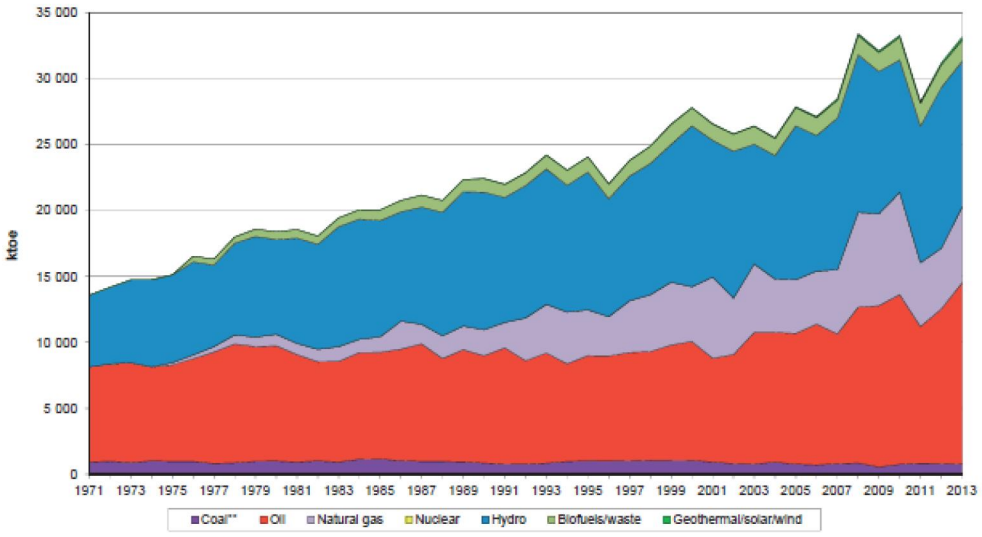

Figure 4. TPES in Norway (www.iea.org).

According to the Norwegian energy balance statistics, the maximum part of energy production is related to crude oil, natural gas, and hydropower, respectively. The most part of the crude oil and natural gas production is exported and only a small amount of it is stored. That's why oil production owns the biggest share of imports. Although the biggest share of natural gas and crude oil are exported every year, in recent years the total export has a downward trend. For instance, in 2013 their export was reduced by 7% over the previous year. Energy resource production trends are shown in figure 5. The hydropower production has enhanced, however, it declined for crude oil as a fossil fuel (www.iea.org).

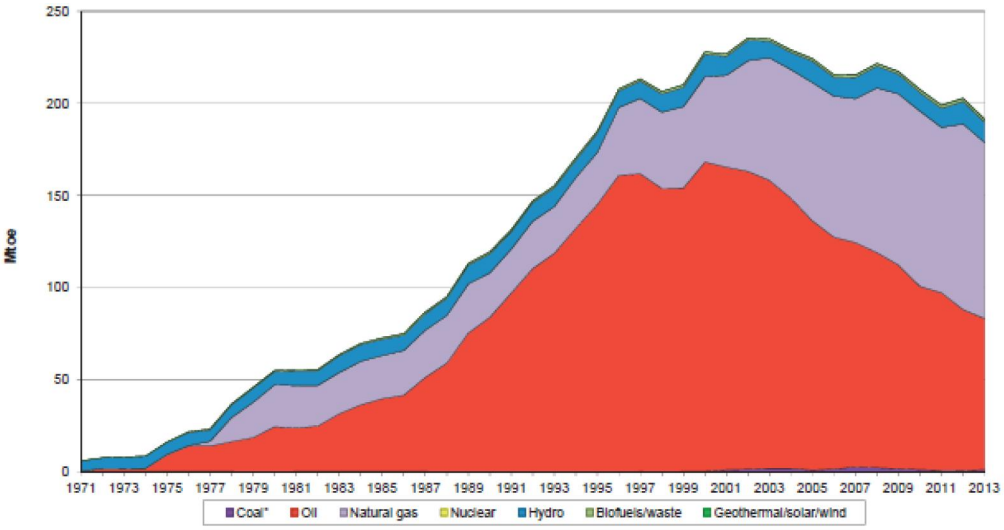

Figure 5. Energy production in Norway (www.iea.org).

Based on the Norway energy balance reported by IEA, in 2013 the total final consumption was 20435 Ktoe. Which decreased 0.16% over the previous year. The share of production electricity and production oil in total final consumption were 46% and 40%, respectively. In the year the industrial sector with 5785 Ktoe and 28%, the transport sector 4780 Ktoe and 23.39% and the household sector with 3938 Ktoe and 19.2% had the highest rate of energy demand (www.iea.org).

2.3. Energy demand in the residential sector

In 2013 electricity had very high amount 3187 Ktoe and 80% and after that respectively biomass, oil products, heat and natural gas had the most demand in the residential sector. As the share of natural gas was 4 Ktoe, and it had only 0.1% of energy consumed in the residential sector. Recently, energy consumption has decreased in this sector because of high efficiency in the country's energy system. Fig 6 shows energy consumption, by Norwegian households. The statistics show energy used in the residential sector in 2013 declined by 5% compared with last year that. It is recognizable that oil product and natural gas consumption in this sector has a decreasing trend (www.iea.org).

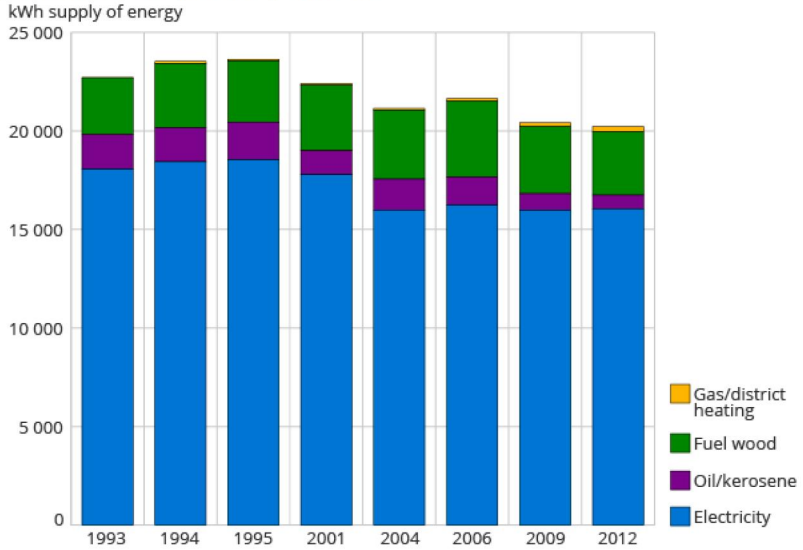

Figure 6. Energy consumption, by household (www.norway statistic.com, 2012).

Energy consumption per household has had a declining trend since 1990s, both in total per household. Energy consumption in the household sector is compared in 2009 with 2012 in the figure 7. The Result shows that average energy consumption per household in 2012 was 20 230 kWh, including approximately 16 000 kWh of electricity and 3 200 kWh of fuel wood. The oil consumption has dropped with 700 kWh in this year so, this accounted half of the oil consumption level in 2006. Despite the fact that it was warmer in 2009 than in 2012, the average energy consumption in 2012 was lower than in 2009. (www.norway statistic.com, 2012).

In 2014, the total domestic energy consumption excluding the industries and consumption of raw materials with 209 TWh decreased by 4 % compared to the previous year. In this regard, energy consumption by households and services was 9 % lower than the year before, which is widely related to the high temperatures in 2014. Since a large proportion of the energy consumption in these groups is associated with heating, the high temperature in 2014 was the main reason for this decline. Almost 80 % of the energy consumption in these groups is related to electricity, and the electricity consumption met 8 % fall in 2014 (www.norway statistic.com, 2012).

Average energy consumption per household, total and per m2 dwelling area. Two last years. kWh

	Total energy consumption (kWh)	Total energy consumption (kWh)	Change in per cent
	2009	2012	
All energ commodities	20 415	20 230	-0.9
Electrisity	15 977	16 044	0.4
Oil and kerosene	845	698	-17.4
Wood, coal and coke	3 407	3 204	-6.0
	Specific energy consumption (kWh per m2 dwelling area)	Specific energy consumption (kWh per m2 dwelling area)	Change in per cent
All energ commodities	181	185	2.2
Electrisity	146	149	2.1
Oil and kerosene	7	6	-14.3
Wood, coal and coke	27	27	0.0

Figure 7. Total and per m2 average energy consumption of dwelling areas in 2009 and 2012 (www.norway statistic.com, 2012).

2.4. Energy demand in the industrial sector

In 2013, energy demand in the industrial sector was mostly related to the electricity with the amount of 3739 Ktoe (64.5%). Other resources using in this sector were oil products, coal, biomass, natural gas and heat. Actually, one of the most important sources of energy, crude oil, is not consumed in this sector. Norway energy balance result shows total energy consumption had a rising trend in the industrial part. It has increased 0.3% compared to the previous year which made GDP improvement and Industrial growth rate (www.iea.org). Oil products and natural gas have declined respectively 7% and 3 % in the manufacturing industries, while there was a rise about 5% in consumption of electricity in 2014. Consumption in other energy-intensive manufacturing industries rose in 2014 by 4 % compared to the previous year (www.norway statistic.com, 2012).

2.5. Energy consumption comparison in residential and industrial sectors

The household sector is faced with a slowly ascending trend however curve is almost linear and climb. However, energy consumption faced a sudden increase in 2010 because of high electricity demand, it came back to its normal trend again. Household consumption decrease in 2011 could be due to the global warming and lower heating needs (www.iea.org).

The industrial sector has shown more severe fluctuations than residential. Figure 8 illustrates that the lowest industrial consumption was in 2009. As discussed above, electricity use had the greatest impact on total energy consumption in this sector.

According to the graph trend of energy consumption is almost horizontal between 2010 and 2013 and energy consumption associated with recession.

Figure 8. Energy consumption by industry and residential (www.iea.org).

2.6. Energy demand in the transport sector

Statistics in 2013 showed a demand for oil products with a value of 4489 Ktoe and 93.3% was the highest, while natural gas with103 Ktoe and 2% had the lowest value in the transport sector. However oil products have increased in recent years, natural gas use have had a decreasing trend (www.iea.org).

In 2014 total energy consumption estimated around 65 GWh for transport purposes felt by 2% in comparison with the

previous year. Nevertheless, Electricity consumption for electric vehicles had an increasing trend. The use of biofuels for transport purposes has improved in value around 1.5 TWh in both 2013 and 2014. Total consumption of biofuels accounted for no more than 5 % of net domestic energy consumption in this year, but is important for meeting the commitments in the RE Directive (www.norway statistic.com, 2012).

2.7. Electricity

As it is discussed before, this large and mountainous country supplies almost all of its electricity from hydropower resources. This fact strongly distinguishes Norway from other members of IEA. Two-thirds of production electricity is provided by RE sources in northern Europe, which one of this reason is the large capacity of hydropower in Norway (Irandoust, 2016).According to fig 9 hydropower resources have the largest proportion in generating electricity, during the past 40 years.

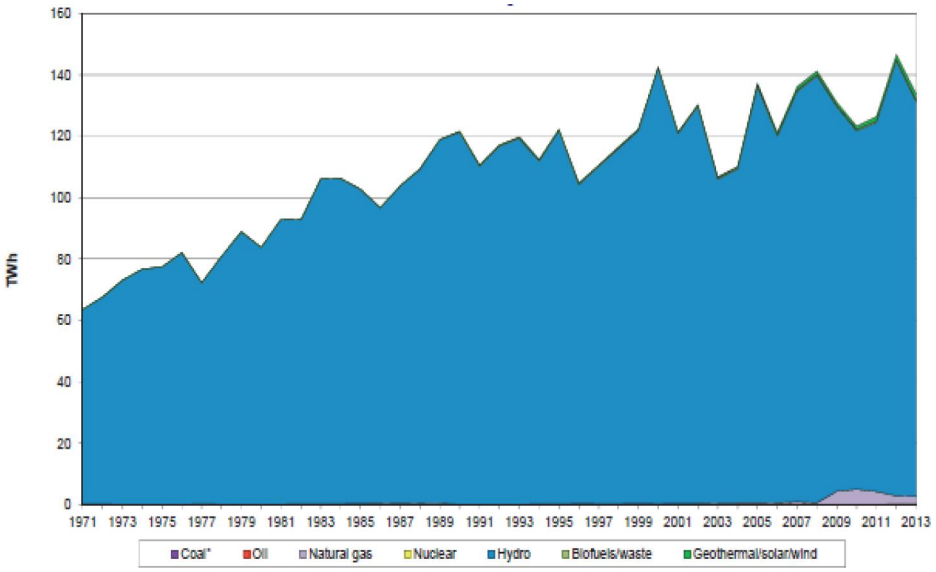

Figure 9. Electricity production by fuel (www.iea.org).

Figure 10 shows electricity use per capita in 2008. As it is illustrated in this figure, Norway was higher than other IEA members and it has the second place in the world. In this year, average use per capita was more than 23 MWh in Norway, while the IEA and the world average were only 9 and 2.5 MWh, respectively. It shows the great electricity production in Norway and their ability to export the exceed production (Miika Tommila, 2010).

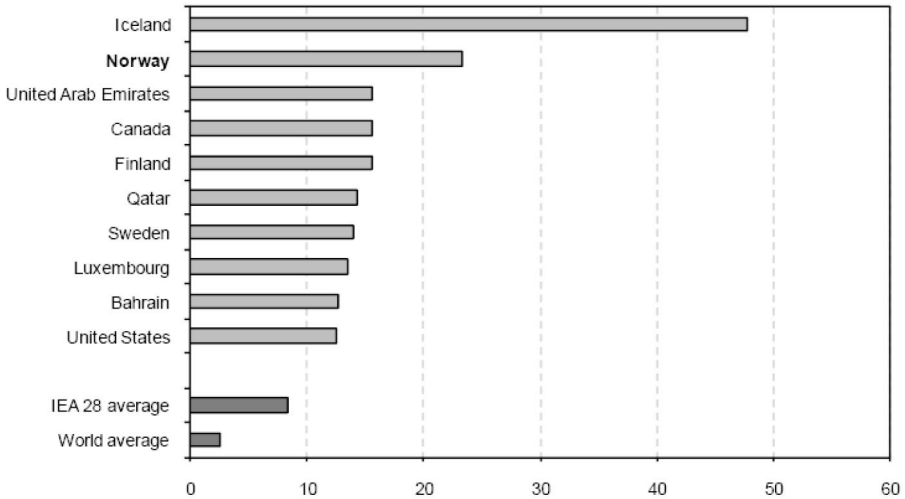

Figure 10. Electricity consumption per capita by countries, 2008 Sources (Energy Balances of OECD Countries, IEA/OECD Paris, 2010, and Energy Balances of non-OECD Countries, IEA/OECD Paris, 2010.© OECD/IEA, 2011).

Figure 11 shows the total final consumption of electricity in Norway in the last 10 years, Although, in these years, final consumption of electricity has had a lot of fluctuations, but it has been associated with a gentle upward trend. In 2013 total final electricity consumption was 9397 Ktoe (about 46% of total final consumption) and it has reduced 1.29% compared to 2012 (www.iea.org).

Indeed, electricity consumption ratio is very high, since this energy source often replaces oil and gas in deferent sectors like industry and residential (Miika Tommila, 2010). Also, Norway uses electricity in the heating of space and water to a much greater rate than the other Nordic countries, which have more developed district heating systems though underground water pipes (Irandoust, 2016). As a result, the supply of electricity in this country has a vital role.

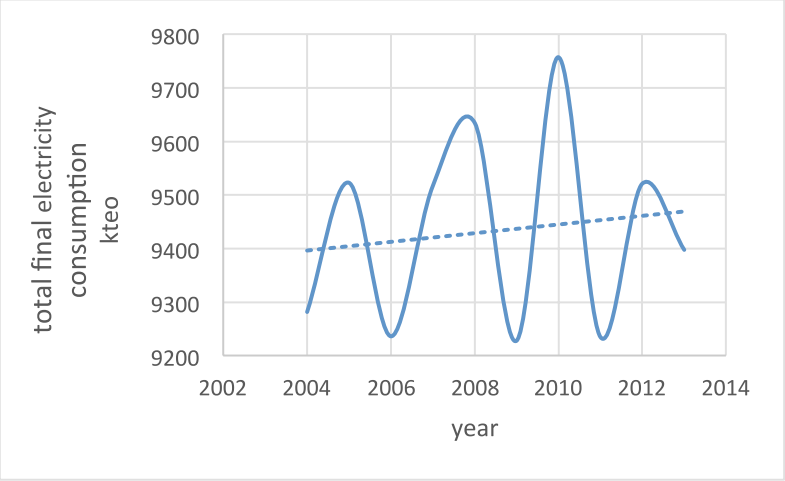

Figure 11. Total final electricity consumption (www.iea.org).

2.8. Electricity price

The average electricity price in the first quarter of 2016 for households and service industry excluding taxes and grid rent were respectively 28.7 and 27.3 NOK per kWh (NOK = 0.108171 EUR). Therefore prices are 8.3% and 6.2% lower than the past year, respectively. In 2015 electricity consumption rose around 1%, however, 4 % declining in the electricity price contributed to NOK 400 million decrease in the total energy costs (www.norway statistic.com, 2012).

3. DEMAND FORECASTING IN NORWAY

In this section, energy consumption is forecasted by using prediction models including regression and trend line equation.

3.1. Regression Model

The relationship between a dependent variable with independent variables is expressed in the form of multivariate linear regression model or complex. In this part, energy consumption in 2014 is forecasted by using Regression Model thus total energy consumption in Norway in the last 10 years is consumed as the dependent variable and GDP, population and industrial growth rates are considered as independent variables to forecast energy consumption in 2014.Table 2 shows the extracted information to predict.

Table 2. GDP, population, and industrial growth rates (www.data.world-bank.org), (www.indexmundi.com).

year	total consumption	GDP at market prices (current US$) Norway	Population	Industrial growth rate
2004	20488	2.64357E+11	4591910	5.2
2005	20453	3.08722E+11	4623291	-0.5
2006	20406	3.45425E+11	4660677	1.8
2007	20872	4.00884E+11	4709153	0.1
2008	20963	4.61947E+11	4768212	-0.2
2009	20031	3.86384E+11	4828726	-2.9
2010	21351	4.28525E+11	4889252	0.3
2011	20426	4.98157E+11	4953088	-4.3
2012	20468	5.09705E+11	5018573	6.5
2013	20435	5.22349E+11	5079623	-3

Table 3. Information extracted from the regression

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.940152883							
R Square	0.883887444							
Adjusted R Square	0.825831166							
Standard Error	372.9238368							
Observations	10							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	3	6351982.872	2117328	15.2247	0.003271661			
Residual	6	834433.1281	139072					
Total	9	7186416						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	48662.98936	13188.5965	3.68978	0.01021	16391.65629	80934.32242	16391.65629	80934.32242
GDP	-2.02194E-10	6.36057E-09	-0.03179	0.97567	-1.5766E-08	1.53616E-08	-1.5766E-08	1.53616E-08
population growth	-0.00431212	0.00268814	-1.60413	0.15981	-0.010889762	0.002265522	-0.010889762	0.002265522
Industrial production growth	105.2563298	19.21076538	5.47903	0.00154	58.2492803	152.2633793	58.2492803	152.2633793

Table 3 shows information extracted from the regression. regarding this table, and calculated correlation coefficient, it is concluded that among total energy consumption in the last 10 years and GDP, population, and industry growth rate there is no correlation in Norway (R Square = 0.19). Due to this,

below results can be extracted:

1. The effect of oil exports on Norway's GDP: As mentioned, oil exports as the backbone of Norway's economy has a significant impact on GDP growing.

2.The effect of downturn on energy consumption (2010 to 2011)

In 2011 industry growth rate fell because of the downturn in European countries whereby the energy consumption reduced.

3.The effect of efficiency energy system: (2011 to 2012) in 2012, energy consumption is reduced under the influence the country's energy system efficiency.

Base on table 2 line equation has shown in equation (1):

$$Y = -2.021X_1 - 0.0043X_2 + 105.25X_3 \quad (1)$$

X_1: GDP

X_2: Papulation

X_3: Industrial growth rate

3.2. Trend line equation

Using derived trend line equation from the previous stage help to forecast three economic parameters GDP, population and industrial growth rate by 2020. First, trend line equation of GDP calculated for the past 10 years by 2013, which is shown in equation (2). Then, by using this equation values are projected by 2020, obtained results are shown in Table 4.

$$Y = 3E+10X + 3E+11 \quad (2)$$

Table 4. Predicted GDP by 2020

year	GDP at market prices (current US$) Norway
2014	6.072E+13
2015	6.075E+13
2016	6.078E+13
2017	6.081E+13
2018	6.084E+13
2019	6.087E+13
2020	6.09E+13

The calculated trend line equation of population for the past 10 years by 2013 is shown in equation (3). By utilizing this equation values are projected by 2020, results obtained are shown in Table 5.

$$Y = 55874X + 5E+06 \quad (3)$$

Table 5. Projected population by 2020

year	Population
2014	112530236.6
2015	112586110.6
2016	112641984.6
2017	112697858.7
2018	112755736.6
2019	112811611.6
2020	112867486.6

The calculated trend line equation of Industrial growth rate for the past 10 years by 2013 is shown in equation (4). Using this equation values are predicted by 2020, obtained results are shown in Table 6.

$$Y = -0.3479X + 2.2133 \quad (4)$$

Table 6. Predicted Industrial growth rate by 2020

year	Industrial growth rate
2014	-698.4573
2015	-698.8052
2016	-699.1531
2017	-699.501
2018	-699.8489
2019	-700.1968
2020	-700.5447

By having predicted amounts of the three basic economic parameters by 2020 can adopt the best policy to provide country's energy demand until this year.

Finally total consumption by 2020 based on previous results is shown in table 7:

Table 7. Predicted total consumption by 2020

year	Total consumption
2014	-1.22715E+14
2015	-1.22776E+14
2016	-1.22836E+14
2017	-1.22897E+14
2018	-1.22958E+14
2019	-1.23018E+14
2020	-1.23079E+14

4. THE FUTURE OF ENERGY IN NORWAY

EU member states have agreed on the 20-20-20 target by 2020. So they agreed on a 20% decline in greenhouse gas (GHG) emissions, 20% of RE in the energy mix and a 20% increase in energy efficiency (12. European Commission,2014b. ⟨http://ec.europa.eu/energy/efficiency/eed/eed_en. htm⟩ (accessed 22.04.14)). The RES directive states the 2020 Target for 20% RE sources in the energy consumption mix "increased use of energy from RE sources, together with energy savings and increased energy efficiency, organize measures needed to reduce greenhouse gas emissions and accordance with the Kyoto Protocol (13. European Parliament, 2009. Directive 2009/28/EC of the European Parliament and of the counsil of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/ 77/EC and 2003/30/EC, 2009). However, bilateral cooperation among member states can also help the achievement of objectives. Norway is engaged in increasing the share of RE sources 67.5% by 2020 (Blindheim, 2015) .Norway and Sweden have obligated to an electricity "green" certificate market, which was starting in 2012. Accordingly, this target increases the RE electricity production in Norway and Sweden by a total of 26.4 TWh before 2021, and the consumer's certificate commitment is shared equally (rtifikater, 2011). Table 8 indicates the details of the Norwegian and

Swedish RE sources operational programs.

		2005 (base year)		2011[d]		2020		2011– 2020 (changes)	
		Consumption, TWh[a, b]	Renewables share, %[a]	Consumption, TWh[b]	Renewables share, %	Consumption, TWh[b]	Renewables share,%	Consumption, TWh[b, e]	Renewables share,%
Norway	Heating and cooling	51	33.3	51	37.2	50	43.2	- 1	6.0
	Electricity	125	97.0	126	103.3	127	113.6	1	10.3
	Transport	47	1.2	52	4.6	57	10.0	5	5.4
	Gross final[c]	*230*	*60.1*	*240*	*62.6*	*250*	*67.5*	*10*	*4.9*

Table 8. Key figures in Norwegian Operational programs for increased RE shares (Direktiv, 2009).

5. CONCLUSION

Norway is one of the Nordic countries that is counted an important exporter oil and natural gas to European countries. Nevertheless dependence on imports of fossil resources in any of the parts of the country. This country is also very rich in term of RE sources, particularly hydropower. More than 90 % of its electricity is supplied by this source. In this country energy consumption has a rising trend in the industrial sector therefore, this reason increases the rate of GDP, however, it has a decreasing trend in the residential sector. Since electricity is allocated a large proportion of energy demand in the industrial and residential, as a result the supply of electricity in this country has a vital role. Norway intends to predict energy consumption in future years provides energy demand, as well as by replacing fossil fuels with clean energy optimizes energy system and reduces GHG emissions. In this paper, researchers investigate the status of energy demand in one of the European countries, Norway. First, energy and electricity consumption in various sectors, including industrial, residential, ... are calculated. Then, energy demand in Norway is forecasted by using available tools. After that, the relationship between energy consumption in Norway with Basic economics parameters such as GDP, population and industry growth rate has determined by using linear regression model. Finally, the regression result shows a low correlation between variables. Future studies can investigate other economic, political and technological variables on energy consumption, also take act using other forecasting models in this country.

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