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Metrics for driving political economy of energy and growth

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ABSTRACT: Energy metrics is *the development of a whole new theoretical framework for the conception and measurement of energy and economic performances, energy efficiency and productivity improvements with important political economy implications consistent with the best use of all natural and economic resources.* The purpose of this research is to present some vital energy indicators based on magnitude and scale of energy weakness, GDP per barrel that is an indicator of energy productivity and barrels per capita that is an indicator of energy efficiency. Energy metrics can support policy maker to monitor energy system of countries in order to design effective strategy and political economy focused to increase the competitive advantage of countries in modern economies.

KEYWORDS: Energy metrics, Energy productivity, Energy efficiency, Energy systems

JEL-CODES: L7, N7, Q4, O3, O52

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1. INTRODUCTION

The increasing demand for energy, soaring oil prices, uncertain energy supplies and fears of global warming have opened a hot debate about energy issues. In addition, the global economic downturn has triggered a world struggles to resume economic growth patterns considering multidimensional energy and economic challenges. In order to sustain the process of economic recovery, it is important to measure and monitor the energy performances, positioning and strategic behaviour of countries over time. The purpose of this paper is to determine and show new metrics concerning the energy weakness, energy productivity and efficiency that provide vital signals to policymakers to monitor the economic system of countries in order to set up effective policies that support the competitiveness of modern economies (Worrell *et al.,* 2003).

Next section introduces a theoretical framework which is the background to underpin the new energy metrics and discuss the results.

2. THEORETICAL FRAMEWORK

Economic growth of countries is also driven by energy forces and efficient energy systems (Marchetti, 1979; 1994). The term *National System of Energy* refers to the complex network of agents, policies, and institutions, concerning the process of search for, develop and use of energy resources and energy technologies with the aim of increasing the efficient use of them in order to support the competitive advantage and economic growth of countries. In fact, the fruitful interactions between economic and energy systems play a fundamental role in modern economies since transfer competitive advantages to firms and whole economic system, improving country's economic perspectives (Porter, 1990). As a matter of fact, efficient energy system generates cheaper goods and services that lead to higher wealth and well being of countries. Energy policy addresses factors, related to energy commodity, such as security of supply, environmental impact and costs that also lead to important industrial outcomes (Lund, 2009). Therefore, it is necessary to support energy strategy and policy of countries beyond their energy impact and more towards industrial impacts to increase the competitive advantage of countries and support a sustainable development (Omer, 2008). In turbulent scenarios, caused by global economic downturn, an important target for countries is the energy efficiency that may be defined as the ratio of useful outputs to energy inputs for a system (Sorrell, 2009). Sorrell (2009, p. 1459) recently has claimed that:

> «the measure of energy efficiency will depend upon how 'useful' is defined and how inputs and outputs are measured (Patterson, 1996).
>
> The options include:
>
> - *Thermodynamic measures*: the outputs are defined in terms of either heat content on the capacity to perform useful work;
> - *Physical measures*: where the outputs are defined in physical terms, such as vehicle kilometres or tonnes of steel;
> - *Economic measures*: where the outputs (and sometimes also the inputs) are defined in economic terms, such as value-added or Gross Domestic Product (GDP).
>
> When outputs are measured in physical terms, the term energy efficiency tends to be used, but when outputs are measured in economic terms it is more common to use the term 'energy productivity'. The inverse of both measures is termed 'energy intensity'. [...] Hence, the indicator that is furthest from a thermodynamic measure of energy efficiency is the ratio of GDP to total primary energy consumption within a national economy» (Sorrell, 2009).

In addition Sorrell (2009, p. 1460) argues that:

> «Although many studies demonstrate strong correlations between economic output and energy consumption, the extent to which the growth in economic output can be considered a cause of the increased energy consumption, or vice versa, remains unclear (Chontanawat *et al*., 2006). It seems likely that there is a synergistic relationship between the two, with each causing the other as part of a positive feedback mechanism (Ayres and Warr, 2005)».

Hence, it is important to measure and investigate the structure and process of energy systems because they are main determinants of economic growth.

In order to in-depth understand these relationships in turbulent markets caused by global economic downturn, it is necessary to analyze the weakness as well as the strength of countries' behaviour, to have information in order to support energy and industrial policy with joint effects for competitiveness and sustainable economic development of countries. Next section describes the methodology that measures and analyses the structure and performances of countries to support rational decisions of policymakers in energy settings.

3. DATA, SOURCES AND NEW ENERGY INDICATORS

In order to meet the increasing requirements of policy makers for energy monitoring, Eurostat[1] has developed a coherent and harmonised system of energy statistics. Annual data collection covers the 27 Member States of the EU, the candidate countries of Croatia and Turkey, and the European Economic Area countries of Iceland, Norway and Switzerland.

This research uses the data from Eurostat (2009; 2009a), which reports some key indicators relating to energy and economic systems from 1990s to the early years of the 21st century. The indicators considered are described in the table 1.

This paper determines and shows some indicators that provide vital information to policymakers to support economic and energy policies:

i. the Magnitude of Energy Weakness (MEW) whose results are presented in the Scale of Energy weakness (SEW);
ii. GDP per barrel that is an indicator of productivity concerning the input energy, and barrels per capita that is an indicator of energy efficiency.

These metrics can be the basis of a new energy metrics, described in the next section.

3.1. Energy metrics

As part of the economic policy certain explicit measures of energy have important implications for the measurement of economic performances, studies into country behaviour, analysis of international trade and so on. Energy metrics is *the development of a whole new theoretical framework for the conception and measurement of energy efficiency and productivity improvements with important political economy implications consistent with the best use of all natural and economic resources.*

Energy metrics can be underpinned in the general theory of measurement (Pfanzagl, 1968). The measurement of an empirical variable is a consistent assignment of numbers to the variable (Narens, 1981). Mathematicians and social scientists are interested in the representational measurement that is an attempt to understand the nature of empirical observations that can be usefully recoded in terms of familiar mathematical structures. The focus of measurement is not just on the numerical representation of any relational structures, but of ordered ones, that is, ones for which one of the relations is a weak order**,** denoted $\geq$, which has defining properties (Luce and Narens, 1985; 2008; Luce *et al.,* 1990):

(i) Transitivity
(ii) Completeness
(iii) Strong Monotonicity

Luce *et al.* (1990) add:

> «that the mapping from the weakly ordered structure via the isomorphism of the (mutually disjoint) equivalences classes to the ordered real numbers is called a homomorphism. Unlike an isomorphism, which is one to one, an homomorphism is many to one. A variable may have several scales, and how these scales relate to one another determines the scale type of the measurement process. The most important are the ordered scales for which there is a

[1] Eurostat is a Directorate-General of the European Commission located in Luxembourg. Its main responsibilities are to provide the European Union with statistical information at European level and to promote the harmonisation of statistical methods across the Member States of the European Union.

natural ordering of the empirical variable, which under measurement maps into the numerical ≥ relation of the real number system. Ordinal scales are ones for which the proper assignments consist of all strictly monotonic transformations of any single proper assignment where the resulting transformation has the same range as the given assignment» (see also Luce and Narens, 1985; 2008; Luce *et al*., 1990).

Considering this background of theory of measurement, it is defined the following measure of energy metrics, called Magnitude of Energy Weakness (MEW=ω).

$$\omega = \mathrm{Log}_{10}\left(\frac{\text{Total production primary energy}}{\text{Gross inland consumption primary energy}}\right)$$

ω is a metrics of energy empirical variables based on a weakly ordered structure and homomorphism property. ω is the basis of an ordered scale, called Scale of Energy Weakness (SEW) which indicates the magnitude and intensity of energy weakness of countries. Positive ω means low energy weakness, whereas negative ω means high energy weakness.

TABLE 1: DESCRIPTION OF THE VARIABLES FROM EUROSTAT DATABASE (2009)

Indicators	*Period*	*Description*
Total production of primary energy - (1 000 toe) [2]	1996-2007	Any kind of extraction of energy products from natural sources to a usable form is called primary production. Primary production takes place when the natural sources are exploited, for example in coal mines, crude oil fields, hydro power plants or fabrication of biofuels. Transformation of energy from one form to another, like electricity or heat generation in thermal power plants or coke production in coke ovens is not primary production.
Net imports of primary energy – (1 000 toe)	1996-2007	Net imports are calculated as imports minus exports. Imports represent all entries into the national territory excluding transit quantities (notably via gas and oil pipelines); electrical energy is an exception and its transit is always recorded under foreign trade. Exports similarly cover all quantities exported from the national territory.
Gross inland consumption of primary energy - (1 000 toe)	1996-2007	Gross inland consumption is defined as primary production plus imports, recovered products and stock change, less exports and fuel supply to maritime bunkers (for seagoing ships of all flags). It therefore reflects the energy necessary to satisfy inland consumption within the limits of national territory.
Gross domestic product at market prices - At current prices	1999-2007	GDP (gross domestic product) is an indicator for a nation's economic situation. It reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production. Expressing GDP in PPS (purchasing power standards) eliminates differences in price levels between countries, and calculations on a per head basis allows for the comparison of economies significantly different in absolute size.

Countries:
Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Turkey, The United Kingdom, EU (15 countries), EU (27 countries).

[2] Toe = tons-of-oil equivalent

The second vital indicator of energy metrics is the Gross Domestic Product (GDP) per barrel. The key variables are: the GDP in Purchasing Power Standards (PPS)[3] per countries and the Gross inland consumption of primary energy (1000 of tons-of-oil equivalent)[4]. The latter indicator is transformed in barrel of oil equivalent (boe) that is a unit of energy based on the energy released by burning one barrel (42 US gallons, ≅158.66 litres)[5]. The conversion factor, according to IEA/OECD[6], is 1 boe contains approximately 0.146 toe or 1 toe = 6.841 boe. After that, GDP per barrel (or boe) is calculated considering the GDP in Purchasing Power Standards (PPS) divided by Gross inland consumption of primary energy in boe (or barrel). i.e.

$$\text{GDP per barrel (or boe)} = \\ = \frac{\text{GDP in PPS}}{\text{Gross inland consumption of primary energy (boe)}} = A$$

In fact, GDP per boe (or barrel) is an indicator of the productivity of energy factor per country.

Remark: Higher values show higher capacity of countries to transform energy inputs in economic activity that generates wealth; in particular, countries should maximize this energy indicator.

Another vital indicator is:

$$\text{Barrels per capita} = \\ = \frac{\text{Gross inland consumption of primary energy (boe)}}{\text{Population}} = B$$

This index is an indicator of energy efficiency per country since indicates the consumption of barrels per capita.

Remark: Higher values of barrels per capita indicate that the consumption per capita of energy input (barrels) is higher, therefore the most energy efficiency countries are those with low values, i.e. lower consumption of barrels per capita. Countries should minimize this energy indicator.

The relationship between these two indicators of energy metrics is based on the *decomposition of GDP per capita in two effects* (Weber, 2009): energy productivity, measured by GDP per barrel, and energy efficiency, measured by consumption of barrels per capita, in other words:

$$\frac{\text{GDP in PPS}}{\text{Population}} = \\ = \frac{\text{GDP in PPS}}{\text{Gross Inland cons. (in boe)}} \cdot \frac{\text{Gross Inland cons.(in boe)}}{\text{Population}}$$

$$\frac{\text{GDP at current prices (or in PPS)}}{\text{Population}} = \\ = \text{energy productivity} \times \text{energy efficiency}$$

Remark: High performer country has high energy productivity (i.e. GDP per barrel) and high energy efficiency (i.e. lower consumption of barrels per capita).

In addition to individuate the strategic behaviour and positioning of countries, it is presented a strategic map with the origin (0;0) represented by EU-27 countries, *x*-axis is represented by GDP per barrel (cause), whereas

[3] Purchasing Power Standards (PPS), i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries.

[4] The tonne of oil equivalent (toe) is a unit of energy: the amount of energy released by burning one tonne of crude oil, approximately 42 GJ.

[5] The US Internal Revenue Service defines it as equal to 5.8×10^6 BTU. 5.8×10^6 $BTU_{59\ °F}$ equals 6.1178632×10^9 J or about 6.1 GJ.

[6] The International Energy Agency (IEA) is an intergovernmental organization located in Paris and established within the Organisation for Economic Co-operation and Development (OECD) in 1974, after the oil crisis. The IEA was initially dedicated to responding to physical disruptions in the supply of oil, as well as serving as an information source on statistics about the international oil market and other energy sectors. The IEA acts as a policy advisor to its 28 member countries, but also works with many countries outside of its membership, especially China, India and Russia. The Agency's mandate has broadened to focus on the "3Es" of sound energy policy: energy security, economic development, and environmental protection. The IEA has a broad role in promoting alternate energy sources (including renewable energy), rational energy policies, and multinational energy technology co-operation.

y-axis is represented by GDP per capita (effect). This map detects observed similarities or dissimilarities (distances) between countries based on key energy and economic indicators. In particular, this map assigns a specific location to countries in a space with two dimensions considering their behaviour measured by GDP per capita and GDP per barrel. As far as these energy indicators are concerned, they have to be considered in a general context of all energy variables in order to analyze the real energy behaviour and positioning of countries.

4. RESULTS

Table 2 shows the percentage of production of primary energy, renewable energy and net imports of primary energy per countries based on arithmetic mean over 1996-2007 period (in appendix the table 1A is in absolute values). The most virtuous countries are Norway, Denmark and the United Kingdom, that have positive values of net import (i.e. they export primary energy) and inland consumption is lesser than inner energy production (this is due to their richness of primary energy resources).

TABLE 2: PERCENTAGE OF MAIN ITEMS OF GROSS INLAND CONSUMPTION OF PRIMARY ENERGY

	1996-2007 (%)				
Country	*Total production of primary energy – (1 000 toe) coal, oil, natural gas, nuclear*	*Primary production of renewable energy – (1 000 toe)*	*Net imports of primary energy – (1 000 toe)*	*Difference*	*Total Gross inland consumption of primary energy – (1 000 toe)*
Austria	8.68	21.61	68.68	1.03	100.00
Belgium	20.06	1.49	85.71	-7.25	100.00
Bulgaria	46.95	4.15	49.48	-0.57	100.00
Croatia	35.91	10.43	54.15	-0.49	100.00
Czech Republic	70.05	2.86	25.76	1.33	100.00
Denmark	115.28	11.46	-22.37	-4.37	100.00
Estonia	54.78	11.17	33.55	0.50	100.00
Finland	21.62	22.15	55.85	0.38	100.00
France	43.02	6.79	51.13	-0.94	100.00
Germany	34.94	3.82	60.76	0.48	100.00
Greece	30.00	5.09	76.44	-11.52	100.00
Hungary	39.27	3.09	57.70	-0.06	100.00
Iceland	0.00	71.38	29.90	-1.28	100.00
Ireland	12.59	1.90	86.60	-1.09	100.00
Italy	10.21	5.62	85.73	-1.56	100.00
Latvia	0.68	38.13	64.52	-3.33	100.00
Lithuania	38.99	7.93	54.27	-1.19	100.00
Luxembourg	0.00	1.49	98.51	0.00	100.00
The Netherlands	76.17	2.44	39.07	-17.68	100.00
Norway	796.31	44.04	-737.82	-2.53	100.00
Poland	82.01	4.43	12.76	0.80	100.00
Portugal	0.00	15.79	86.36	-2.15	100.00
Romania	60.48	10.76	27.69	1.07	100.00
Slovakia	27.44	3.59	67.86	1.12	100.00
Slovenia	36.79	10.10	52.79	0.31	100.00
Spain	18.36	6.25	81.00	-5.61	100.00
Sweden	35.89	27.70	39.38	-2.97	100.00
Switzerland	25.64	16.36	56.58	1.42	100.00
Turkey	19.85	13.20	67.61	-0.66	100.00
The United Kingdom	103.48	1.26	-4.30	-0.43	100.00
EU (27 countries)	46.17	6.07	49.75	-1.99	100.00
EU (15 countries)	43.44	6.12	52.85	-2.42	100.00

Note: The tonne of oil equivalent (toe) is a unit of energy: the amount of energy released by burning one tonne of crude oil, approximately 42 GJ

Table 3 shows the magnitude of energy weakness that is also represented in the figure 1.

The MEW of countries is described in table 3.

The MEW is the basis for an ordered scale presented in table 4. This well-designed scale of energy metrics can serve as a warning signal that the economic system can enter in a turbulent state with rather strong economic crisis in case of energy shocks. The magnitude MEW is the indicator guidelines for the scale of energy weakness (SEW) and countries should maximize the MEW that should tend to 0: i.e. close to energy independence.

TABLE 3: MAGNITUDE OF ENERGY WEAKNESS

Country	*1996-2007 period*	
	Total production of primary energy / Gross inland consumption of primary energy	*Magnitude of energy weakness (MEW)* ω
Norway	8.40	0.92
Denmark	1.27	0.10
The United Kingdom	1.05	0.02
Bulgaria	0.51	-0.29
France	0.50	-0.30
Lithuania	0.47	-0.33
Slovenia	0.47	-0.33
Croatia	0.46	-0.33
Finland	0.44	-0.36
Hungary	0.43	-0.37
Switzerland	0.42	-0.38
Germany	0.39	-0.41
Latvia	0.39	-0.41
Greece	0.35	-0.45
Turkey	0.33	-0.48
Slovakia	0.31	-0.50
Austria	0.30	-0.51
Spain	0.25	-0.61
Belgium	0.22	-0.67
Italy	0.16	-0.80
Portugal	0.16	-0.80
Ireland	0.14	-0.84
Luxembourg	0.01	-1.83
Czech Republic	0.73	-0.14
Estonia	0.68	-0.17
The Netherlands	0.79	-0.10
Poland	0.86	-0.06
Romania	0.71	-0.15
Sweden	0.64	-0.20
Iceland	0.71	-0.15
EU (27 countries)	0.52	-0.28
EU (15 countries)	0.50	-0.30

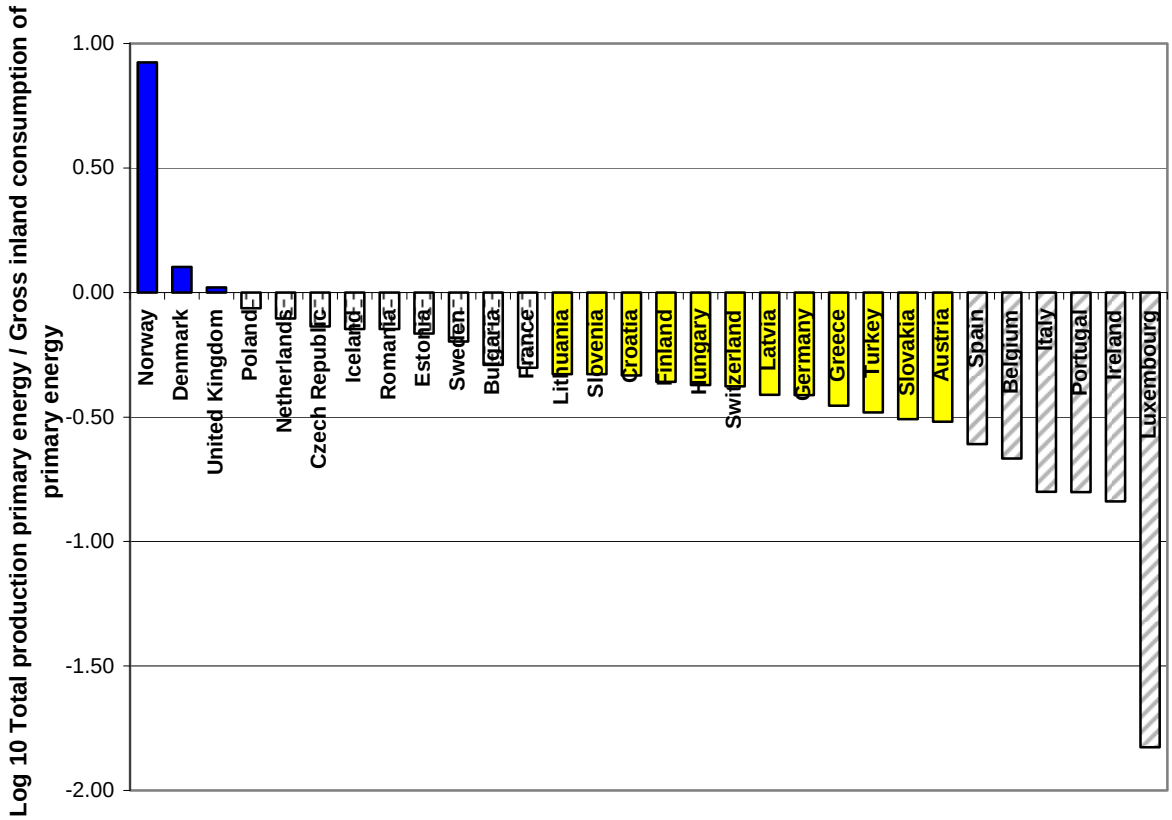


FIGURE 1: MAGNITUDE OF ENERGY WEAKNESS PER EUROPEAN COUNTRIES

TABLE 4: SCALE OF THE ENERGY WEAKNESSES

Degree of energy weakness	*Magnitude* ω	*Intensity of energy shock on economic system*	*Description*	*Location of some countries according to their magnitude* ω
1 the lowest energy weakness	[0.30; +∞[	Null	Countries rich of energy resources such that are exporter intensive. Possible energy shocks generate a feeble impact on economic system.	Norway
2	[0.00-0.30[	Quasi- Null	Countries abounding in energy resources such that satisfy all internal needs and export a part of their energy production. Possible energy shocks generate a lightest impact on economic system.	The United King-dom, Denmark
3	[−0.30; 0.00[	Moderate	Internal energy resources satisfy roughly half of internal needs, importing lesser than 50% of internal consumption. Possible energy shocks generate a moderate impact on economic system.	Poland, Czech Re-public, Romania, The Netherlands, etc.
4	[−0.60;−0.30[	Strong	Internal production of primary energy does not satisfy internal needs, such that the importation is between 50% -70% of internal consumption. Possible energy shocks generate a crisis on economic system.	France, Finland, Germany, Austria, etc.
5 the highest energy weakness	] −∞;−0.60 [	Very strong	Internal production of primary energy is largely insufficient for high internal needs, importing more than 70% of internal consumption. Possible energy shocks generate a strong crisis on economic system.	Italy, Spain, Bel-gium, etc.

TABLE 5: DECOMPOSITION OF GDP PER CAPITA IN ENERGY PRODUCTIVITY AND EFFICIENCY – ARITHMETIC MEAN OVER 1999-2007- VALUE IN PPS*

Country	*GDP per capita in Euros PPS*	*GDP per barrel in Euros-PPS*	*Energy consumption: barrels per capita in*
	Personal wealth	*Energy productivity*	*Energy efficiency*
Austria	26,838.27	987.71	27.15
Belgium	25,806.06	649.66	39.84
Bulgaria	6,839.07	403.94	16.79
Croatia	11,513.17	871.10	13.13
Cyprus	19,167.62	815.08	23.54
Czech Republic	15,619.46	534.62	29.09
Denmark	26,666.61	1,039.64	25.66
Estonia	11,676.93	427.72	26.99
Finland	24,420.12	525.05	46.46
France	23,854.30	801.76	29.75
Germany	24,725.90	859.96	28.76
Greece	19,203.35	1,020.49	18.73
Hungary	12,872.27	718.16	17.86
Ireland	29,834.75	1,153.68	25.92
Italy	23,279.40	1,092.76	21.30
Latvia	9,540.71	751.97	12.51
Lithuania	10,256.84	607.55	16.73
Luxembourg	53,444.32	837.99	63.57
Malta	16,811.60	1,090.64	15.43
The Netherlands	27,871.86	815.33	34.15
Norway	35,260.82	868.25	40.82
Poland	10,589.43	634.49	16.64
Portugal	16,286.60	960.66	16.96
Romania	6,924.13	566.58	12.11
Slovakia	12,125.81	511.85	23.69
Slovenia	17,889.23	748.47	23.81
Spain	21,516.37	975.43	22.00
Sweden	26,047.13	672.85	38.75
Switzerland	29,425.98	1,174.55	25.07
Turkey	8,282.27	1,016.76	8.09
The United Kingdom	25,544.77	970.34	26.39
EU (25 countries)	22,138.35	858.49	25.77
EU (27 countries)	21,204.42	847.15	25.01
Euro area (15 countries)	23,672.18	883.41	26.78

* *Note*: Basic figures are expressed in Purchasing Power Standards (PPS), i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries

This table 5 is based on the following equation:

$$\frac{\text{GDP}}{\text{Population}} = \frac{\text{GDP}}{\text{energy input}} \cdot \frac{\text{energy input}}{\text{Population}}$$

i.e.

$$\text{GDP per capita} = \text{energy productivity} \times \text{energy efficiency}$$

Table 6, instead, shows that the energy productivity is high in Switzerland, Ireland, Italy, Denmark, Greece and Turkey. In particular, Italy is the larger country with the higher energy productivity that is a staggering 1,093 Euros per barrel, other large countries such as Spain and the UK have lower GDP per barrel (roughly 975-988 Euros per barrel), Germany 860 Euros and France 802 Euros per barrel. The GDP per barrel is low in several countries of the East Europe such as Bulgaria,

Estonia, Romania, etc. In fact, Italy has the strongest capacity to transform energy input in economic activity as well as Italy has a higher energy efficiency that is an average consumption of 21.30 barrels per capita; this values is the best performance in comparison with other larger European countries such as Spain where the population consumes 22 barrels burned per capita, Germany 28.76 barrels per capita and France with 29.75 barrels burned per capita. Some Scandinavian countries have the lower energy efficiency, i.e. higher consumption of barrels per capita.

TABLE 6: GDP PER BARREL (BOE) OF SOME COUNTRIES OVER TIME

Country	*GDP (PPS) per barrel*										
	1999	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*Arithmetic mean 1999-2007*	*St. Dev.*
Ireland	895.9	964.9	986.8	1,058.9	1,130.8	1,151.2	1,299.2	1,394.8	1,500.4	**1,153.7**	*205.8*
Italy	1,014.5	1,071.5	1,117.6	1,098.8	1,054.1	1,063.4	1,078.1	1,136.3	1,200.6	**1,092.8**	*54.0*
Spain	845.7	882.8	907.6	949.8	949.7	964.6	1,006.1	1,099.8	1,172.7	**975.4**	*104.2*
The United Kingdom	785.6	841.9	879.7	944.0	950.7	1,005.6	1,035.7	1,099.2	1,190.7	**970.3**	*127.8*
EU (15 countries)	777.8	825.7	839.5	872.7	864.6	891.2	928.8	981.3	1,046.5	**892.0**	*82.5*
Norway	628.8	789.8	779.9	864.8	792.3	843.2	829.9	1,181.5	1,104.0	**868.2**	*170.6*
Germany	766.1	792.1	786.0	822.7	836.6	867.2	912.7	944.1	1,012.0	**860.0**	*82.0*
EU (27 countries)	733.2	780.1	794.4	826.7	819.5	849.8	885.8	935.0	999.8	**847.2**	*82.1*
France	704.4	752.0	766.0	799.8	772.8	788.0	826.0	872.4	935.1	**801.8**	*68.6*
Sweden	573.3	653.8	608.0	633.5	659.4	674.8	690.8	756.9	805.1	**672.8**	*71.7*
Romania	411.3	438.4	488.2	498.1	512.5	591.4	633.4	702.0	823.8	**566.6**	*134.1*

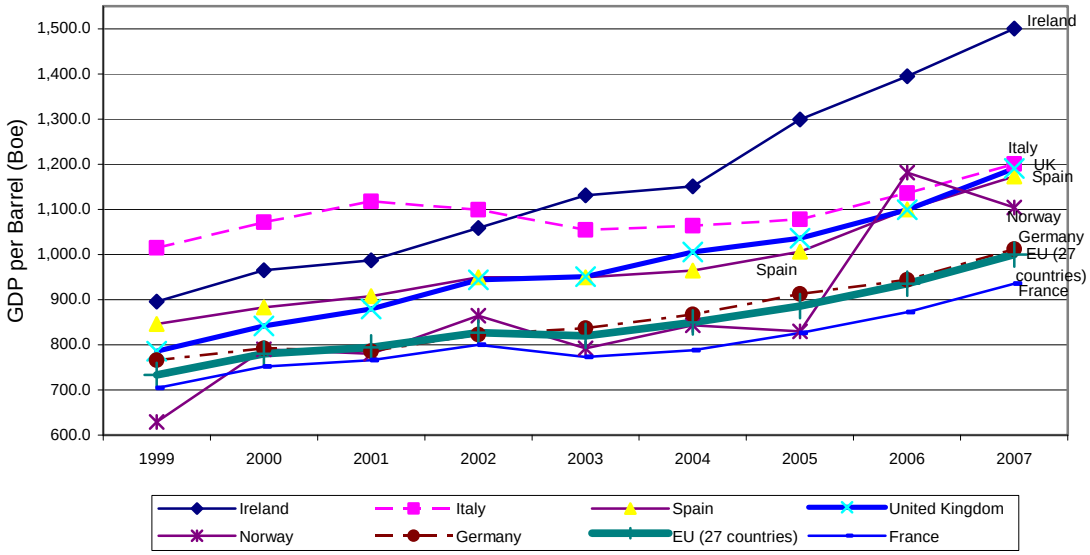


FIGURE 3: TRENDS OF ENERGY PRODUCTIVITY OF SOME COUNTRIES – GDP (PPS PER BOE)

Arithmetic mean in table 6 shows how the highest GDP per barrel is present in Ireland and Italy; in particular Italy is a large country that has an high energy performance (with low standard deviation that confirms the low variability and stability trend of this main energy indicator) in comparison with Spain, Germany and France.

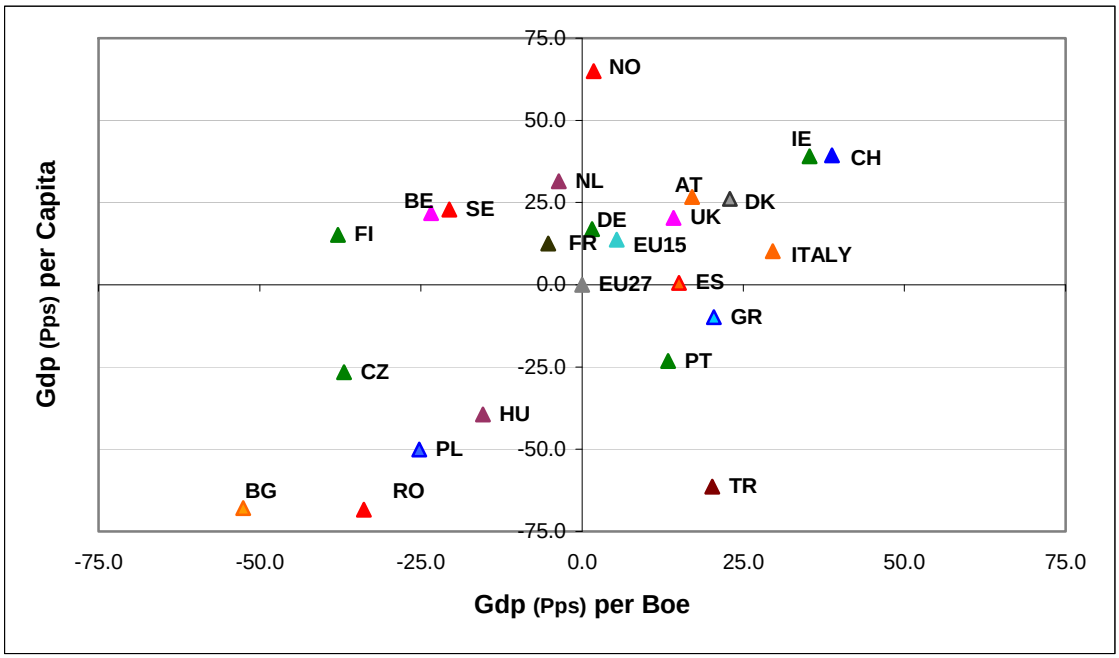
Figure 3 and table 6 also show the trends over time and confirm the higher energy productivity of Ireland and Italy, although since 2004 and 2005, The UK and Spain[7] have been recovering their positioning. The France instead has a lower performance of GDP per barrel, below the trend of EU-27 countries. These values are expressed in Purchasing Power Standards (PPS), i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries. In appendix, table 2A shows the growth rate of GDP per barrel and per capita among countries. These indicators are energy guide-posts for countries in order to find and go through the modern paths of sustainable economic growth.

Main findings are in the figure 4 where the origin (0;0) is EU-27 countries and the positioning of countries, which indicates the strategic behaviour of European countries, is measured by the distance in GDP per barrel and GDP per capita from EU-27 Countries. This map shows four main strategic behaviours of countries:

- North-East corner is the area of the most energy and economic dynamic countries in comparison with EU-27 countries, such as Switzerland, Italy, Denmark, Austria, Germany and so on.
- South-West corner is the area of countries with the lowest economic and energy performances in comparison with EU-27 countries. These counties, mainly of East Europe, are Romania, Hungary, Bulgaria, Poland, Czech Republic, and so on.
- South-East Corner is the area of countries that have a good energy productivity measured by GDP per barrel and low GDP per capita in comparison to EU-27 countries (e.g. Greece, Portugal and Turkey).
- North-West corner has the countries with a good GDP per capita in comparison with EU-27 and lower energy productivity than average position of EU-27 Countries (Finland, Belgium and Sweden).

The strategic positioning of this map provides main information to policymakers to design and plan efficient and efficacious energy and economic policies in order to support the perspective of growth of countries and European Union. In fact, the map shows the weak and strong countries by the distance of their main energy and economic performances from a fixed point represented, in this case, by EU-27 countries.

[7] However, Spain has been increasing its economic performances but with high negative externalities: Spain is a country with the highest index of greenhouse gas emissions (in CO_2 equivalents) which is 140.35 (arithmetic mean over 1999-2006 period) *vs.* 109.19 Italy, 98.04 of France and 82.76 of Germany. Appendix B shows these trends by the index of sustainable GDP per barrel which is corrected with greenhouse gas emissions.



Note: **EU27: EU (27 countries)=(0.0)**, BE: Belgium, BG: Bulgaria, CZ: Czech Republic, DK: Denmark, DE: Germany, IE: Ireland, GR: Greece, ES: Spain, FR: France, IT: Italy, HU: Hungary, NL: The Netherlands, AT: Austria, PL: Poland, PT: Portugal, RO: Romania, FI: Finland, SE: Sweden, UK: The United Kingdom, TR: Turkey, NO: Norway, CH: Switzerland, EU15: EU (15 countries)

Note: GDP per capita in PPS and GDP per boe are arithmetic means over 1999-2007

FIGURE 4**:** ENERGY AND ECONOMIC STRATEGIC BEHAVIOUR OF COUNTRIES

5. LESSONS LEARNED AND ECONOMIC POLICY IMPLICATIONS

This paper provides vital results to support the modern economic growth patterns of countries. In particular, the paper has analyzed the structure of energy system of European countries showing the production of primary energy, renewable energy and net imports. This paper determines also main indicators of energy, and the first one is the magnitude of energy weakness (MEW) whose values are ordered in the scale of energy weaknesses (SEW) that provides vital warning signals about the energy system of countries. In fact, this scale shows that the strongest countries are Norway, Denmark and the UK, whereas the weakest countries are Spain, Italy, Portugal, Sweden, etc. A well-designed scale can serve as a warning signal that the economic system can enter in a turbulent state with rather strong economic crisis in case of energy shocks.

This paper shows also other two critical indicators of energy based on the decomposition of GDP per capita in two effects, GDP per barrel and barrels per capita: the first one is an indicator of energy productivity, the second one is an indicator of energy efficiency. In fact, higher values of GDP per barrels show higher capacity of countries to transform energy inputs in economic activity that generates wealth, whereas, higher values of barrels (burned) per capita indicate that the consumption per capita of energy input (barrels) is higher, therefore the most energy efficiency countries are those with low values, i.e. low consumption of barrels per capita. This decomposition shows the high performance of Italy both for energy productivity and for energy efficiency. The other countries have lower energy performances.

In addition, the strategic behaviour and positioning of countries, is presented in a strategic map with the *x*-axis represented by GDP per barrel (cause), whereas *y*-axis is

represented by GDP per capita (effect). This map detects observed similarities or dissimilarities (distances) between countries based on key energy and economic indicators. This map assigns a specific location to countries in a space with two dimensions in comparison with EU-27 which is the origin (0;0). The higher interaction of energy and economic performance is in the North-East area where are located countries such as Norway, Italy, Denmark, Germany, the UK, and so on. Other areas have countries with a lesser energy and/or economic performance.

This analysis shows that the European energy market is based on an heterogeneity of situations that need rational and prudent decisions aimed at supporting future patterns of economic growth. A systemic analysis of energy system of countries should be driven by these energy indicators in order to design effective energy policy. The future challenge for policy makers is how to ensure that such findings are integrated in national economic policies, in order to maximize the positive long run impact on steadier economic growth patterns. This approach is a necessary but not sufficient condition since there are other factors that can affect the economic and energy systems of countries such as entrepreneurship, path dependence in the production of goods and service, culture, social environments and their rules.

This paper presents energy indicators important to build an efficient European system of energy that supports future sustainable economic growth paths. In all, this comprehensive analysis of the strategic behaviour of countries can provide vital information in order to drive the success of future energy policy for countries. The results of this paper are important for policymakers and politicians, since in the future they have to focus much more on encouraging an effective energy policy, based on maximization of energy productivity and efficiency, as well as minimization of energy weakness in order to improve the industrial organization and therefore national wealth and wellbeing. These vital goals of countries can be achieved monitoring the economic and energy signals provided by these driving energy indicators that represent the guide-posts for going through fruitful trajectories based on synergic interaction between energy and economic systems. Although this paper does not provide exhaustive metrics and analysis about all the contending variables that affect energy system of European countries, the results can provide the basic driving information for rational decisions aimed at improving the performance of countries. No doubt that further research is needed to strengthen this important research field for future economic growth of the World.

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APPENDIX A

TABLE 1A: GROSS INLAND CONSUMPTION OF PRIMARY ENERGY
(1000 TOE= TONS-OF-OIL EQUIVALENT)

Country	*Arithmetic mean 1996-2007*				
	Gross inland consumption of primary energy	*Total production of primary energy coal, oil, natural gas, nuclear*	*Primary production of renewable energy*	*Net imports of primary energy*	*Difference*
Austria	31,416.92	2,728.42	6,788.83	21,575.58	324.08
Belgium	60,022.17	12,038.50	893.00	51,442.25	-4,351.58
Bulgaria	19,855.42	9,322.08	823.08	9,823.58	-113.33
Croatia	8,341.50	2,995.17	870.08	4,517.17	-40.92
Czech Republic	43,233.75	30,287.33	1,235.25	11,134.92	576.25
Denmark	20,534.58	23,671.92	2,353.08	-4,592.58	-897.83
Estonia	5,426.83	2,972.83	605.92	1,820.83	27.25
Finland	34,673.00	7,497.42	7,678.92	19,365.25	131.42
France	264,913.25	113,963.08	17,996.25	135,449.58	-2,495.67
Germany	346,829.83	121,187.67	13,245.08	210,717.67	1,679.42
Greece	29,131.75	8,738.58	1,481.50	22,267.58	-3,355.92
Hungary	26,339.08	10,344.50	812.58	15,198.25	-16.25
Iceland	3,233.82	0.00	2,308.45	966.90	-41.54
Ireland	14,379.42	1,810.25	273.67	12,452.00	-156.50
Italy	175,992.75	17,965.42	9,894.50	150,886.42	-2,753.58
Latvia	4,311.17	29.50	1,643.83	2,781.50	-143.67
Lithuania	8,635.50	3,367.00	685.00	4,686.33	-102.83
Luxembourg	3,984.08	0.00	59.33	3,924.92	-0.17
The Netherlands	79,553.58	60,594.75	1,937.42	31,084.58	-14,063.17
Norway	26,503.92	211,053.92	11,671.25	-195,551.42	-669.83
Poland	95,078.08	77,971.92	4,211.00	12,135.67	759.50
Portugal	24,761.92	0.00	3,910.42	21,384.17	-532.67
Romania	40,375.33	24,419.50	4,345.50	11,180.25	430.08
Slovakia	18,415.50	5,052.33	661.17	12,495.92	206.08
Slovenia	6,821.25	2,509.58	689.17	3,601.08	21.42
Spain	127,746.75	23,447.92	7,989.75	103,474.75	-7,165.67
Sweden	50,762.42	18,221.08	14,059.25	19,989.00	-1,506.92
Switzerland	26,515.42	6,797.67	4,338.33	15,002.33	377.08
Turkey	79,180.83	15,719.92	10,448.75	53,537.42	-525.25
The United Kingdom	229,148.75	237,113.08	2,877.67	-9,848.50	-993.50
EU (27 countries)	1,765,626.83	815,254.00	107,198.25	878,390.08	-35,215.50
EU (15 countries)	1,493,850.83	648,976.75	91,439.08	789,572.67	-36,137.67

Note: The tonne of oil equivalent (toe) is a unit of energy: the amount of energy released by burning one tonne of crude oil, approximately 42 GJ.

TABLE 2A: RATES OF GROWTH OF DRIVING ENERGY INDICATORS
(VALUE IN PPS)

Country	*Energy productivity GDP (PPS) per barrel*	*Energy productivity growth rate Basis is1999*	*Energy productivity growth rate by year*	*GI (barrels) growth rate Basis is1999*	*GI (barrels) growth rate by year*	*GDP growth rate Basis is1999*	*GDP growth rate by year*
	Arithmetic mean 1999-2007						
EU (27 countries)	847.15	36.36	3.98	5.56	0.69	43.94	4.67
EU (25 countries)	858.49	35.53	3.90	5.42	0.67	42.88	4.57
EU (15 countries)	892.04	34.54	3.81	4.89	0.61	41.12	4.41
Euro area	883.62	31.59	3.52	10.00	1.21	44.75	4.75
Euro area (16 countries)	877.81	31.74	3.53	6.83	0.84	40.74	4.38
Euro area (15 countries)	883.40	31.36	3.50	6.88	0.84	40.40	4.35
Belgium	649.66	48.56	5.18	-6.07	-0.74	39.54	4.29
Bulgaria	403.94	62.12	6.30	11.84	1.45	81.32	7.74
Czech Republic	534.62	34.82	3.87	20.02	2.35	61.81	6.21
Denmark	1039.63	28.81	3.38	2.16	0.33	31.59	3.53
Germany	859.95	32.10	3.57	-0.37	-0.03	31.62	3.50
Estonia	427.72	80.49	7.84	20.92	2.53	118.25	10.26
Ireland	1153.67	67.47	6.71	15.56	1.88	93.54	8.63
Greece	1020.48	32.22	3.57	24.64	2.81	64.80	6.46
Spain	975.42	38.66	4.21	23.99	2.74	71.93	7.02
France	801.83	32.75	3.66	5.60	0.69	40.17	4.35
Italy	1092.76	18.35	2.19	6.82	0.84	26.41	3.00
Cyprus	815.08	38.29	4.31	19.93	2.40	65.85	6.56
Latvia	751.96	77.66	7.58	20.36	2.43	113.84	10.00
Lithuania	607.54	77.35	7.68	15.92	2.15	105.59	9.44
Luxembourg	837.99	29.45	3.39	34.97	3.87	74.72	7.28
Hungary	718.06	51.89	5.46	6.01	0.77	61.02	6.17
Malta	1090.63	28.40	3.70	10.64	1.52	42.07	4.56
The Netherlands	815.33	29.78	3.39	11.62	1.41	44.86	4.79
Austria	987.70	18.91	2.30	15.46	1.85	37.28	4.07
Poland	634.49	47.32	5.01	4.49	0.58	53.93	5.56
Portugal	960.66	35.90	3.97	4.37	0.59	41.85	4.49
Romania	566.58	100.28	9.19	8.59	1.07	117.48	10.26
Slovenia	748.47	38.00	4.14	14.12	1.68	57.49	5.86
Slovakia	511.85	78.36	7.62	3.92	0.55	85.34	8.04
Finland	525.04	25.88	3.10	14.42	1.82	44.03	4.71
Sweden	672.85	40.43	4.50	0.25	0.10	40.79	4.41
The United Kingdom	970.34	51.56	5.36	-3.52	-0.43	46.23	4.88
Croatia	871.10	46.49	4.93	17.33	2.05	71.87	7.02
Turkey	1016.76	23.03	2.76	42.52	4.67	75.33	7.53
Iceland	327.85	-8.28	-1.02	41.25	5.24	34.48	3.82
Norway	868.25	75.57	8.44	3.50	1.15	81.72	7.97
Switzerland	1174.55	33.56	3.79	3.10	0.43	37.69	4.11

Note: GI is the Gross inland consumption of primary energy.

APPENDIX B

TABLE 1B: INDEX OF SUSTAINABLE GDP PER BARREL (BOE) CORRECTED WITH GREENHOUSE GAS EMISSIONS*

Country	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Arithmetic mean 1999-2006*	*Dev. St.*
The United Kingdom	9.14	9.76	10.15	11.23	11.20	11.87	12.27	13.09	11.09	*1.34*
Germany	9.25	9.58	9.35	9.97	10.01	10.40	11.20	11.58	10.17	*0.85*
Romania	8.50	8.79	9.44	9.24	9.09	10.36	11.60	12.47	9.94	*1.42*
Italy	9.59	10.02	10.35	10.16	9.49	9.51	9.64	10.34	9.89	*0.37*
EU (27 countries)	8.08	8.58	8.64	9.07	8.81	9.12	9.58	10.13	9.00	*0.63*
EU (15 countries)	8.09	8.56	8.60	9.00	8.77	9.02	9.47	10.09	8.95	*0.61*
Ireland	7.40	7.78	7.76	8.55	9.16	9.32	10.27	11.11	8.92	*1.31*
France	7.09	7.63	7.75	8.22	7.89	8.05	8.39	9.09	8.01	*0.59*
Norway	5.80	7.34	7.08	8.04	7.28	7.65	7.66	10.97	7.73	*1.47*
Sweden	5.93	6.91	6.36	6.54	6.73	6.99	7.45	8.31	6.90	*0.73*
Spain	6.61	6.64	6.82	6.84	6.71	6.56	6.61	7.36	6.77	*0.26*

* Greenhouse gas emissions - Index of greenhouse gas emissions - In CO_2 equivalents (Actual base year = 100)[8].

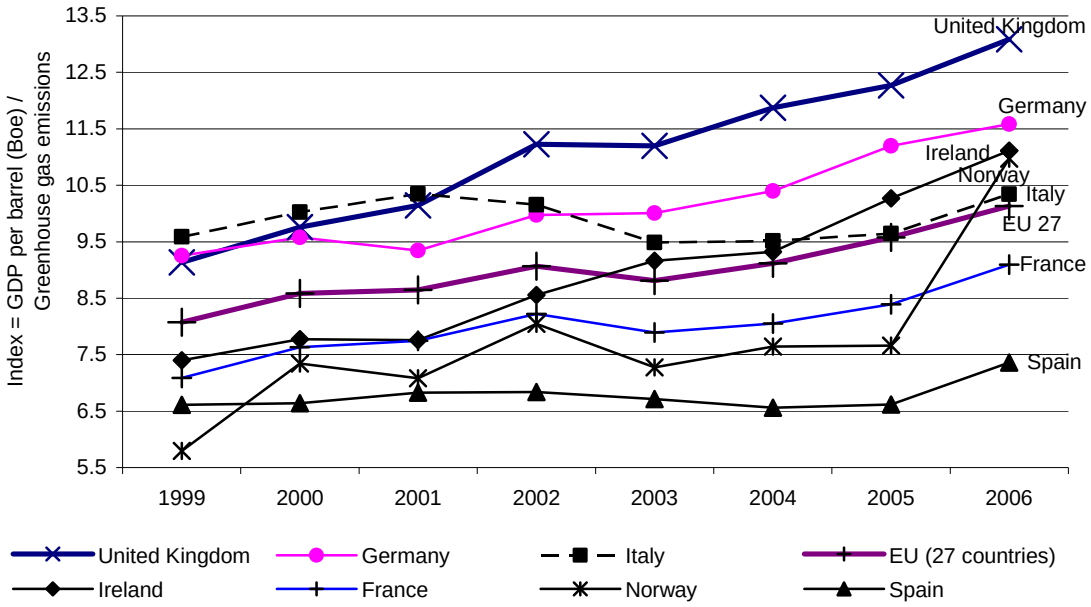

FIGURE 1B**:** TRENDS OF SUSTAINABLE GDP PER BARREL

[8] Under the Kyoto Protocol, the EU has agreed to an 8% reduction in its greenhouse gas emissions by 2008-2012, compared to the Kyoto base year. The reductions for each of the EU-15 countries have been agreed under the so-called EU Burden Sharing Agreement (Council Decision 2002/358/EC), which allows some countries to increase emissions, provided these are offset by reductions in other Member States. Eight of the ten new Member States have chosen other reduction targets and other base years, as allowed under the Kyoto Protocol. These and the 'Burden sharing' targets for 2008-2012 are shown in the table as figures for 2010 (no target for Cyprus and Malta). Emissions of the 6 greenhouse gases covered by the Protocol are weighted by their global warming potentials (GWPs) and aggregated to give total emissions in CO_2 equivalents. The total emissions are presented as indices, with the base year = 100 (EU-27, Euro area 15, Cyprus and Malta base year = 1990). In general, the base year is 1990 for the non-fluorinated gases (CO2, CH4 and N_2O), and 1995 for the fluorinated gases (HFC, PFC and SF_6). Data exclude emissions and removals due to land use change and forestry.

TABLE 2B: GDP PER BARREL, INDEX OF SUSTAINABLE GDP PER BARREL AND GREENHOUSE GAS EMISSIONS

GDP per barrel (boe)		*Index = GDP per barrel (boe) corrected with Greenhouse gas emissions*		*Greenhouse gas emissions - Index of greenhouse gas emissions and targets - In CO_2 equivalents (Actual base year = 100)*	
Country	*Arithmetic mean 1999-2006*	*Country*	*Arithmetic mean 1999-2006*	*Country*	*Arithmetic mean 1999-2006*
Switzerland	1,147.17	Latvia	17.21	Turkey	168.79
Ireland	1,110.34	Lithuania	13.52	Cyprus	153.69
Italy	1,079.28	Switzerland	11.50	Portugal	140.39
Malta	1,073.54	United Kingdom	11.09	Spain	140.35
Denmark	1,024.27	Denmark	10.29	Malta	135.21
Greece	1,003.80	Hungary	10.25	Ireland	124.39
Turkey	1,002.44	Germany	10.17	Greece	122.15
Austria	972.54	Romania	9.94	Iceland	111.36
Spain	950.76	Italy	9.89	Austria	111.31
United Kingdom	942.79	Croatia	9.59	Italy	109.19
Portugal	939.20	Luxembourg	9.33	Norway	108.61
EU (15 countries)	872.73	Estonia	9.32	Finland	107.13
Euro area	865.63	EU (27 countries)	9.00	Euro area (15 countries)	100.98
Euro area (15 countries)	865.39	Poland	8.99	Euro area	100.60
Croatia	848.11	EU (15 countries)	8.95	The Netherlands	100.43
Germany	840.95	Ireland	8.92	Denmark	99.95
EU (25 countries)	839.59	EU (25 countries)	8.91	Switzerland	99.74
Norway	838.78	Austria	8.76	Belgium	98.71
EU (27 countries)	828.07	Euro area	8.60	France	98.04
Luxembourg	817.35	Euro area (15 countries)	8.57	EU (15 countries)	97.51
The Netherlands	801.88	Greece	8.21	Slovenia	97.29
Cyprus	798.14	France	8.01	Sweden	95.28
France	785.25	The Netherlands	7.99	EU (25 countries)	94.16
Slovenia	730.43	Malta	7.96	EU (27 countries)	91.98
Latvia	720.16	Norway	7.73	Luxembourg	88.60
Hungary	701.95	Slovenia	7.50	Croatia	88.33
Sweden	656.32	Bulgaria	7.44	United Kingdom	85.14
Belgium	631.41	Slovakia	7.06	Germany	82.76
Poland	618.76	Czech Republic	6.92	Czech Republic	75.11
Lithuania	583.62	Sweden	6.90	Poland	68.86
Romania	534.43	Spain	6.77	Slovakia	68.70
Czech Republic	520.01	Portugal	6.69	Hungary	68.49
Finland	516.62	Belgium	6.41	Romania	53.54
Slovakia	484.80	Turkey	5.95	Bulgaria	52.43
Estonia	412.39	Cyprus	5.18	Estonia	44.16
Bulgaria	390.27	Finland	4.85	Lithuania	42.98
Iceland	327.85	Iceland	2.95	Latvia	41.73

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