Energy markets and climate change

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Innovations mechanisms on energy markets are discussed, in particular valorization of energy products which invokes decarbonization of energy recourses. The valorization, meaning higher value of energy products, is expressed as electrification and entry of modern renewable energy based on geothermal, wind and solar resources, entailing distributed energy systems with storage and auxiliary technologies. Consumption of electricity on grid grows along with manifold higher unit cost of electricity compared to fuels, and the distributed energy systems expands even faster though it is many times costlier than electricity on grid. The valorization can be explained by adding valuable attributes to functionalities of energy products such as consumer convenience, autonomy, flexibility silence, cleanness, and it contributes to communities' interest through local income and jobs. The decarbonization, meaning lower carbon or more electrons per resource mass, is expressed as lower energy-intensity of economies and substitution of coal and oil for gas and gas for renewable energy. Modern renewable energy grows faster than rival fossil fuels. It doubles every 3 to 4 years in several countries. The rivalry intensifies regarding the decreasing energy-intensity of economies in many countries, albeit slowly. Extrapolation of the annual average growth rates as trends for coming last twenty five years shows increase of income and slow increase of energy consumption along with emission reduction of carbon dioxide due to renewable energy by more than 50% compared to 2015. Trends on energy markets show that mitigation of climate change is possible.

Keywords: energy markets, consumption, value, income, carbon dioxide, trends

Highlights

1. Energy markets evolve due to innovation mechanism of valorization and decarbonization entailing tough rivalry between fossil fuels and renewable energy
2. Energy markets valorize due to electrification, renewable energy and distributed energy systems along with more energy deliveries and cheaper energy resources.
3. Energy markets decarbonize due to slowly decreasing energy intensity and fast, two digit growth rates of geothermal, wind and solar resources.
4. Extrapolation of trends on energy markets to 2040 show fast income growth, slower growth of energy consumption and decrease of carbon dioxide emission below 50% of 2015 level.
5. Trends on energy markets suggest sufficient emission reduction for mitigation of climate change if policies do not obstruct but foster the innovations mechanism

1. Introduction

Innovations mechanisms on energy markets are discussed, meaning processes of change in production and consumption of energy induced by markets demands rather than policies. This discussion relates to observations that uses of the materials and energy resources per product decreased when measured by the costs and mass of products across most countries and businesses[1] [2] [3] [4]. These observations are explained by allocations whereby cost-savings due to effective uses of these resources are transferred into value adding products, entailing income growth and lower environmental impacts if policies enable diversity of innovators through education, research and integer governance [5]. In energy consumption, this allocation is expressed as 0.6% to 2.2% annual growth of the national income per energy unit throughout last decades because heat, power, light, sound and other functionalities of energy serve virtually all activities [6]. Willingness to pay for energy is high [7]. Higher value products are generated; the value meaning sales price of a products mix multiplied by their volumes. The global value of energy markets grew during 1990 – 2010 by 4.4% annual average (from USD_{2000} 2 700 billion to USD_{2000} 6 400 billion) [8] along with 1.9% volume growth (from 102 billion MWh to 142 billion MWh) [9]; a hypothetical 1% cost reducing energy saving would cover all European Union expenditures on research and development into energy efficiency and renewable energy [10]. The fossil fuels prices in the same period decreased when corrected for inflation and fluctuations, except for the natural gas prices [11]. This paper underpins that the value increase on energy markets enables growth of income and renewable energy entailing far reaching emission reduction of carbon dioxide for mitigation of climate change.

An increasing value of energy products is observed throughout the last century. This innovation mechanism, herewith labelled as valorization, embraces the growing electricity consumption, followed

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[4] Wright, G., (1997), Towards a more historical approach to technological change', *The Economic Journal*, Vol. 107: 1560–1566.
[5] Krozer T, 2015, Theories and practices on innovating for sustainable development, Springer, Dordrecht-Heidelberg.
[6] WEC, Energy Efficiency: A Recipe for Success, 2010, World Energy Council, London, p. 13. It is incorrectly coined as energy-efficiency because the cost of energy do not decrease but the income per energy unit increases along with disparity across countries from 0.2 USD to by roughly factor 4 up to about USD 1 per kWh in the European Union.
[7] World Bank, The Welfare Impact of Rural Electrification: A Reassessment of Costs and Benefits, 2002, Appendix H, p.131-139, http://siteresources.worldbank.org/EXTRURELECT/Resources/appH.pdf, accessed 13-6-2017
[8] Enerdata, https://www.enerdata.net/publications/executive-briefing/world-energy-expenditures.html accessed 15-3-2017
[9] EIA https://www.eia.gov/totalenergy/data/annual/showtext.php?t=ptb0709 accessed 13-6-2017
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by entry of costly renewable energy and distributed energy systems. The energy prices increased along with energy consumption (contrary to intuition and mainstream views). Fuel is partially substituted for electricity though many times costlier because electricity enabled powerful machines, convenient mobility, brighter lights and other functional services entailing productivity and income despite higher prices [12], if not subsidized. The energy prices also increased when energy resources changed; it means biofuels growth is saturated and substituted for coal, then coal for oil, hydro and nuclear, followed by growth of natural gas and renewable energy, though all resources are still consumed [13]. The carbon-rich fossil fuels shift to more costly low-carbon renewable energy, in particular to the modern renewable geothermal, wind and solar energy. The energy prices increased again in the past decades when the modern renewable technologies for the electricity production are downscaled entailing small scale systems with energy storage for households and communities. Such distributed energy systems enabled individual mobility, peak shaving, enable linking local energy services, for instance heat and power,[14] as well as more local income and jobs in communities due to recovery of residual heat, energy exchange and development of local know-how[15].

The value increase on energy markets enables entry of costly energy technologies. When markets enlarge technologies become cheaper because mass production enables specialization [16], which generates a self-propelling dissemination of cheaper technologies as observed in solar power and other renewable energy resources [17]. Large investments are attracted to renewable energy, particularly the modern ones, despite prices far above fossil fuels. These investments, negligible during 1990s, grew fast during low fossil fuel prices in 2000s and reached USD 230 - 280 billion a year during high and low fossil fuel prices after the financial crisis in 2008[18]. Policies enhanced these in a few countries but generally obstructed because supported fossil fuels rather than renewable energy For example, the European Union that championed the renewable energy investments supported renewable energy with € 5.3 billion euro in 2001 compared to 23.9 billion euro for fossil fuels (respectively 0.045 and 0.024 eurocent per kWh) [19]. Only after 2008, renewable energy gained more support than fossil fuels due to feed-in tariffs which were cut down mid-2010s. The global support of energy consumption of USD 1 900 billion a year is by and large for fossil fuels [20], which is in addition to infrastructures, regulations and institutions dedicated to the fossil fuels production. The entry of modern renewable energy is due to attractive

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services which invoked policy support, not another way around. The services are, for instance, powerful resources due to higher ratio of hydrogen and electrons to carbon, individual sourcing and distribution of energy (e.g. on rooftop) and through participation in communities (e.g. windmill cooperatives), storage of electricity for virtual mobility (e.g. mobile phones) and transport (electric vehicles), as well as reduction of hazards, noise and pollution (e.g. greenhouse gasses).

The valorization can be comprehended within economic train of thoughts about negotiations between suppliers and customers in value chains of products[21] [22] [23]. When a suppliers in value chain compounds resources into its product because aims to deliver some valuable attributes to customers it also unintentionally adds qualities that may cause deficiencies. The valuable attributes are promoted for sales, which generate welfare. The deficiencies are rarely disclosed even if known to the suppliers because impede sales, which imposes costs on society that hidden in the gross income though indicated after correction for inflation in purchase prices parity albeit far from perfect. Having consumer technologies for recognition of the deficiencies and launching alternatives when sense of urgency to prevent threats is generated, the customers' preferences shift entailing welfare growth. This asymmetric information between suppliers and customers in value chains holds true on the energy markets. Attributes of fuels are often considered threats, for instance hazards of high temperature, large scale threatens local jobs, noise causes nuisance, whereas renewable energy is perceived as to contribute autonomy, flexibility, and reduce pollution. The perceptions persist though energy suppliers pinpoint at high costs caused by variability of resources and instability of networks and deficiencies are acknowledged, for instance large space use. Regarding the attributes and perceptions, the valorization based on modern renewable energy presumably continuous as a trend.

Trend, herewith, is interpreted as the annual average growth during a few decades. The growth rates of income, energy and electricity consumption and carbon dioxide emissions are assessed for the period of twenty five years during 1990 – 2015 in five years intervals and compared to the period of economic recession in high income countries during 2005 – 2015. Data for 2015 are extrapolated based on 2013 and 2014 because not available in the statistics as yet. The past trends are extrapolated to 2040 for illustration of consequences for the carbon dioxide emissions; the annual average growth rates are extrapolated without any change. This is with regard to arguments about mitigation of carbon dioxide due to emerging social initiatives in renewable energy[24], countered on the arguments that infrastructure and technologies are persistent[25], and renewable energy too costly and low performing[26]. Public

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statistical data is used because assumed unbiased; literature is briefly covered because reviewed in another paper [27].

The data cover eleven largest countries, including the European Union as one country, measured by their population. In descending order of income per capita in 2015 these countries are: United States, Japan, European Union, Russian Federation, Mexico, Brazil, China, Indonesia, Nigeria, India, and Pakistan. The assessment is scaled up on the global level based on their aggregated shares in 2015: 65% of the global population, 73% of the Gross Domestic Product in Purchasing Price Parity (GDP PPP), 62% of the energy production, 71% of the energy consumption, 75% of the electricity consumption, as well as 86% of coal, 62% oil, 62% gas, 81% nuclear, 68% biofuels, 65% hydropower, 80% modern renewable energy consumption and 73% of all carbon dioxide emission. The countries income refers to the Gross Domestic Product in Purchase Power Prices (GDP PPP). Energy is in ton oil equivalent (t.o.e.), equivalent of 11.630 kWh. Both are based on the International Energy Agency (IEA) data[28]. The IEA standards for conversion of coal, oil and gas into carbon dioxide emission are used: 3.80 ton CO_2 per ton coal, 2.52 ton CO_2 per t.o.e. and 2.20 CO_2 ton per t.o.e. gas [29]. The calculation with these conversions deviate from the statistical data in 2015: 1.2 % difference globally but below 10% in the countries except 13% for the Russian Federation and 12% for Nigeria; good reasons for the deviations are not found. Energy prices, costs and sales in the United States and European Union are based on the United States Energy Intelligence Agency (EIA)[30] respectively the European Statistical Bureau (Eurostat) [31]. All monetary data is deflated (2005 = 100) and Euro is converted into USD based the World Bank database. All regressions are Pearson correlations.

The valorization is introduced in section 2 and underpinned statistically in section 3. The decarbonization is introduced in section 4 and underpinned in section 5. The projection is shown in section 6. Conclusions are drawn in section 7. Appendix shows all necessary data for these calculations.

2. Valorization for decarbonization

The valorization on energy markets could invoke decarbonization through energy saving but the energy saving is slow. In production, 20% to 40% of potential energy saving is unused and expenditures on energy are inefficiently allocated. The potential is indicated by spread of energy consumption per product across similar industries; the spread is smaller in energy-intensive industries and larger in low-income countries [32] [33]. Low managerial interest is also pinpointed [34]. At households, cost-effective

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energy saving is unused though high willingness to save energy is stated; information campaigns help little and personal feed-back with financial incentives and collective actions are more effective [35]. Explanations are price distorting subsidies, high transaction costs compared to cost-savings, overstating of hidden costs, collision of interests in organizations, managerial focus on income generation, habitual behavior and so on but these are not satisfactory arguments for low sensitive of energy consumption to prices. The price elasticities of energy demands across countries, aggregation methods and economic fluctuations is usually above -0.4 (-0.35 to -0.20) in the short run and -0.7 (– 0.67 to - 0.45) in the long run, which means one unit price increase reduces less than 0.4 respectively 0.7 units energy volume[36]. Car purchasers do buy smaller cars when fuel prices increase and vice versa, but the travel mileage is not responsive to the prices (– 0.02 to – 0.04)[37]. Energy consumption is also income-inelastic. Consumers spend rarely more than 6% of income on energy across countries and periods; the income elasticity of energy demand is low negative but the cross elasticity of demand is high, meaning more use of costly energy services as income increases. These two factors combined provide a U-shaped energy consumption function of income: the low income groups are sensitive to the price increase because they spend relatively much on energy and high income are sensitive because they use relative much energy [38]. Energy supplies are also not responsive to prices because capacity development takes time but the price elasticity of supply increases to more than unity when new resources are found, for instance in case of shale gas. The long run price elasticities of supply vary from - 0.3 to + 0.5 [39].

The valorization has more impact on decarbonization when enables entry of renewable energy, in particular modern renewable energy. The initial high costs decreased entailing fast dissemination across many countries despite concerns about high costs, limited space, deficient infrastructure, obstructive energy-intensive industries, limited venture capital, R&D support, and variability of power and so on. By the end of 2000s when the fossil fuel prices were high price parity on grid is approached in a few countries [40]. Renewable energy acted as a backstop on energy prices which generated positive

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economic effects on the electricity markets [41] [42] and in economies at large [43]. Subsequent energy scenarios envisaged even faster growth in the European Union and on the global scale [44], which means that sceptic scholarly views in referred journals turned around into optimism. This optimism is often justified by scarcity of fossil fuels reserves compared to thousands times larger reserves of renewable energy resources [45]. However, the proven global reserves of fossil fuels enlarge in line with the energy consumption because explorations technologies improve, though it does not hold for coal with large proven reserves[46]. The valuable services are better explanations of the renewable energy growth.

When the distributed energy systems emerged during 2010s the value on energy markets increased again which attracted plenty of business in the European Union and United States [47]. Energy storage, necessary to overcome the variability of modern renewable energy, is particularly attractive. Batteries, herewith, are expected to grow fast in the next decades though their prices per kWh are higher than a few alternatives and they are many times higher than the electricity price on grid [48]. The storage capacity in the United States alone is expected to enlarge from 25MW in 2015 to 354 GW in 2030 with USD 228 billion market value that year at the price range of USD 170 to 1230 per kW [49], which implies manifold costlier power from batteries than grid. The attributes of distributed energy systems are considered sufficiently attractive to cover the costs[50]. It is speculated that low-income countries with high potential of modern renewable energy leapfrog to the distributed networks without central grid [51].

3. Valorization measured

The valorization on energy markets can be observed as the countries' income to energy consumption and as value of energy consumption in time. The former is estimated for eleven countries mentioned above and globally, the latter for the household and industrial energy consumption in United States and European Union.

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Table 1 shows the countries' population, income per capita in USD purchase power prices, energy consumption and share of electricity in it in 2015, as well as the growth rates 1990 – 2015 and 2005 - 2015. The population has grown during last twenty five years except in the Russian Federation. The income per capita have also grown in all countries, even accelerated in low income countries after the financial crisis in 2008, except in the United States whose income per capita decreased after the crisis. The valorization of energy consumption, indicated by higher income to consumption growth, is mixed across countries; it is high in lower income countries but lower in the high income ones though recession after the financial crisis blurs this division (correlations of the income to energy consumption growth across the countries are R^2 = 0.82 and R^2 = 0.43 during 1990 – 2015 respectively 2005 – 2015). China valorized its energy in income very fast because 9.1% annual average, India 4.8% and Indonesia 3.4% presumably because evolve to higher value knowledge-based economies. Brazil is an exception because used more energy to generate income. The electricity consumption, though costlier than fuels, grows in all countries, particularly fast in China and Indonesia. The electricity share in the energy consumption have grown in all countries during 1990 – 2015, but the growth slowed down during the recession (correlations of the income and electricity shares growth are R^2 = 0.69 and R^2 = 0.67 for the analyzed periods). The observations confirm valorization of energy consumption, in particularly use of electricity in it, which can be explained by attributes in functionalities of energy consumption though more studies are needed to assess causalities.

Table 1 Population, income and valorization across countries

	Population		Income in USD PPP			Valorization			Electricity		
	million	Grow	USD/ cap	Annual aver. growth		USD/ kWh	Annual aver. Growth		Share in all	Annual aver. Growth	
	2015	1990 - 2015	2015	1990- 2015	2005- 2015	2015	1990- 2015	2005- 2015	2015	1990- 2015	2005- 2015
World	7,335	1.3%	14,287	2.0%	2.4%	0.7	1.5%	1.7%	14%	1.0%	1.0%
Un. Stat.	321	1.0%	51,531	1.4%	-0.9%	0.6	1.8%	1.7%	16%	0.8%	0.6%
Japan	127	0.1%	34,929	0.8%	0.5%	0.9	1.0%	2.4%	19%	0.7%	0.8%
Euro. Un	509	0.3%	34,404	1.4%	0.7%	1.0	2.0%	2.7%	17%	1.1%	1.2%
Rus. Fed	145	-0.1%	22,352	1.9%	3.7%	0.4	1.7%	2.2%	12%	0.8%	0.9%
Mexico	122	1.4%	16,240	1.3%	1.0%	0.9	1.1%	2.1%	12%	2.4%	2.0%
Brazil	208	1.2%	14,728	1.5%	2.1%	0.8	-0.4%	-0.6%	15%	0.5%	0.0%
China	1,371	0.7%	13,124	9.1%	9.0%	0.5	4.5%	3.8%	16%	4.1%	3.5%
Indonesia	257	1.3%	10,207	3.4%	4.3%	1.0	1.4%	2.9%	8%	4.8%	4.1%
Nigeria	181	2.4%	5,755	2.8%	3.6%	0.7	2.4%	3.6%	2%	2.0%	1.1%
India	1,311	1.5%	5,630	4.8%	6.0%	0.7	2.2%	1.9%	11%	2.0%	2.0%
Pakistan	188	2.1%	4,632	1.8%	1.6%	0.8	1.0%	1.9%	8%	1.3%	0.2%

The prices of energy resources are compared to sales prices of electricity and the values of energy consumption are observed in the United States and European Union for the period 2005 – 2015; the value meaning prices times deliveries. All are real prices in USD_{2005}. The main energy resources are coal, oil and gas because the share of nuclear power and renewable energy in the total energy consumption was small. The main sales are due to electricity on grid because the distributed energy systems cover a small share in the total electricity consumption.

The purchases in the United States are estimated based on the international prices per fossil fuel multiplied by the resources consumption in it electricity mix [52]. Similarly, the sales to residential and industrial are energy deliveries multiplied by the sales prices. For the European Union, the purchase prices in the United States are used because the European data is not found, and the European mix of energy resources in electricity production. For the sales, the delivery prices to mid-size households and mid-size industries are used as presented in the statistics though these prices vary per delivery scale because taxes increase with the scale and suppliers provide price discounts to large purchasers. Table 2 shows results: the purchases, the purchase price, sales and value added. The valorization is indicated by the higher sales prices to the resource purchase prices.

Table 2 Trends in the electricity resources and sales in the United States and European Union

year	Purchase USD/kWh		Household sale prices USD/kWh		Industrial sales price USD/kWh		Deliveries households TWh		Deliveries industries TWh	
	US	EU	US	EU	US	EU	US	EU	US	EU
2005	0.015	0.010	0.095	0.17	0.06	0.08	1359	1588	1019	1132
2006	0.015	0.011	0.101	0.17	0.06	0.09	1352	1643	1011	1130
2007	0.015	0.011	0.100	0.20	0.06	0.11	1392	1649	1028	1141
2008	0.016	0.013	0.104	0.21	0.06	0.12	1381	1686	1010	1118
2009	0.016	0.010	0.106	0.21	0.06	0.12	1365	1690	917	965
2010	0.015	0.010	0.105	0.20	0.06	0.11	1446	1751	971	1027
2011	0.015	0.010	0.104	0.22	0.06	0.11	1423	1688	991	1035
2012	0.016	0.008	0.104	0.21	0.06	0.11	1375	1720	986	1011
2013	0.015	0.008	0.104	0.23	0.06	0.11	1395	1710	985	996
2014	0.016	0.010	0.105	0.23	0.06	0.10	1407	1650	998	992
2015	0.015	0.005	0.105	0.20	0.06	0.08	1404	1682	987	996

The valorization of energy fuels due to electricity production is substantial: sales to households are 7 times the purchase costs in the United States and 21 times in European Union and to industries they are respectively 4 and 11 times. The higher sales prices in the European Union compared to the United States are not solely related to higher taxes on the household energy consumption. The electricity production in the United States is also more cost-effective as the average purchase price in the United States was about 1.5 times higher than in the European Union but the average sales prices to households and industries were only 50% respectively 58% of the European Union prices. The purchase and sales prices changed during that period of time and the growth rates differ between the United States and the European Union. The purchase prices increased in the United States by 0.3% annual

[52] All is estimated in real USD per kWh. https://www.eia.gov/electricity/data.php#avgcost is used until 2012, then extrapolated and corrected based on the US Energy Information Administration, Short-Term Energy Outlook Real and Nominal Prices 2017 https://www.eia.gov/outlooks/steo/realprices/. These source show similar prices of coal but somewhat different for oil and gas

average and decreased by – 4.8% in the European Union; the latter is presumably mainly due to the lower gas prices during these years. The sales prices to households increased by 1.1% annual average in the United States and 2.0% in the European Union. The increases of electricity sales have compensated for hardly any increase of the deliveries to households in both countries and even decrease of the deliveries to industries. In result, the value added of the total electricity business increased in the United States and hardly changed in the European Union despite its lower efficiency.

The United States data on energy consumption during the period 2007 – 2015 show that the increasing sales prices of electricity evolved along with the decreasing prices of the renewable energy resources and that there are substantial differences between these resources. The solar power prices decreased by 48% annual average, the wind power by 8% of the wind power but nil decrease of the hydropower [53]. The growing disparity between these sales prices and purchase prices could partly be related to the emerging markets of distributed energy systems. In the United States statistics these systems are defined as an inventory of particular energy technologies: small scale photovoltaic, local electricity and heat grids, energy storage, electric vehicles, charging stations, demand management and measuring; sometimes also local biofuels, wind power and co-generation. Based on this the smart grid projects, distribution automation and smart metering has grown in that period of time from nil to about USD 3.3 billion a year. Although the sales value of the distributed energy systems is only about 0.8% of the total electricity sales in the United States its value growth is about 17% annual average, [54] which is nearly 7 times faster than the growth of all electricity sales. Similar data on the European Union is not found. The increasing sales prices in the European Union can partly related to the growing renewable energy consumption as indicated by the increasing correlations of that consumption with the enlarging share of renewable energy in electricity consumption across the countries (from $R^2 = 0.04$ in 2005 to $R^2 = 0.36$ in 2015). This correlation cannot be confirmed for the United States because data across the states cover only a few years during that period of time and the share of renewable energy was lower.

The observed increasing value function of energy consumption along with the decreasing costs of renewable energy has two major implications for the decarbonization. One is the price incentives for prudent energy consumption albeit not sensitive to the prices. More importantly, the value growth along with cheaper renewable energy enables faster substitution of fossil fuels entailing emission reduction of carbon dioxide.

4. Decarbonization measured

The decarbonization evolves due to changes of energy consumption per capita and carbon content in the energy mix of consumption. The result of these two factors is carbon dioxide emission (CO_2).

The decarbonization trends are shown in Table 3: energy consumption per capita, carbon content in CO_2 equivalents and CO_2 emissions based on calculations with use of the EIA conversion

[53] https://www.statista.com/statistics/289149/revenue-solar-power-industry-united-states

[54] https://www.statista.com/statistics/222082/projected-us-smart-grid-market-size-since-2009/

factors. The trend of energy consumption per capita hardly increases globally and decreases in all highest income countries; the economic recession had mixed effects on the countries' decrease. It is presumably caused by large differences in energy consumption between countries, for instance that consumption per capita is 14 times higher in the United States than in 11 times poorer Pakistan. That consumption is not solely related to income, for example the Chinese energy consumption increased nearly six times faster than the Pakistani one though it has three times higher income per capita. Some countries are energy intensive because host businesses that use much energy for low valued products, for instance Russian Federation and China, or consume wastefully as the United States. The carbon content in energy consumption has hardly decreased globally though it grows slower than the energy consumption globally and in all countries except Japan and Mexico; in Japan presumably because of closure of nuclear power and in Mexico because of more oil use. The carbon dioxide emissions are in line with the carbon content. The volume and composition of fossil fuels consumption have little influence on the global decarbonisation though there are difference between high income and lower income countries.

Table 3 Energy consumption per income and carbon dioxide emission in the consumption

	Energy consumption			C in energy consumption as CO_2 equivalents			CO_2 emission		
	kWh/ cap	Annual average growth		kg/kWh	Annual average growth		ton/ cap.	Annual average growth	
	2015	1990 - 2015	2005 - 2015	2015	1990 - 2015	2005-2015	2015	1990-2015	2005-2015
World	21,958	0.5%	0.6%	2.4	0.0%	0.0%	4.4%	0.5%	0.7%
United States	81,491	-0.3%	-2.5%	2.3	-0.3%	-0.5%	16.4%	-0.6%	-3.0%
Japan	39,286	-0.2%	-1.8%	2.7	0.5%	1.7%	9.0%	0.3%	-0.2%
European Un.	34,313	-0.6%	-2.0%	2.0	-0.8%	-1.0%	5.8%	-1.4%	-3.0%
Russian Fed.	55,558	-0.8%	0.5%	2.0	-0.8%	-1.2%	9.7%	-1.6%	-0.7%
Mexico	17,517	0.2%	-1.0%	2.3	0.3%	-0.2%	3.4%	0.6%	-1.2%
Brazil	17,452	1.9%	2.8%	1.6	0.8%	1.1%	2.4%	2.8%	3.9%
China	26,274	4.5%	5.0%	3.0	0.9%	0.1%	6.7%	5.4%	5.0%
Indonesia	10,550	2.0%	1.3%	2.0	1.6%	1.4%	1.8%	3.7%	2.7%
Nigeria	8,732	0.4%	0.0%	0.4	0.0%	-2.2%	0.3%	0.4%	-2.2%
India	7,762	2.6%	4.0%	2.5	1.5%	1.8%	1.7	4.1%	5.9%
Pakistan	5,628	0.8%	-0.3%	1.5	0.6%	-0.1%	0.7	1.4%	-0.3%

The decarbonization on the energy markets evolves due to the growing renewable energy, in particular the modern one. Table 4 shows shares of all renewable energy and modern renewable energy in all energy consumption as well as their annual average growth rates. The share of renewable energy is globally about 14% of all energy consumption which varies from 3% in the Russian Federation to about 80% in Nigeria. The biofuels and hydropower covered about 90% of all renewable energy in 2015, even 100% in Nigeria and Pakistan; lower income countries consume much renewable energy, in particular biofuels. The global growth of all renewable energy is slow because the biofuels increase is in line with the total energy consumption (both 1.8% annual average) and hydropower somewhat faster (2.5%). The energy consumption in China and India has grown even twice faster than all renewable energy. The decarbonization of the global energy consumption in the next few years is presumably slow because biofuels and hydropower have large scale but grow slowly. Modern renewable energy has only 1.4% share in the global energy consumption. Only geothermal energy in Indonesia (7% of all consumption) and wind power in the European Union (3% of all consumption) have significance in the energy mix whereas the share is nearly nil in Russian Federation, Nigeria and Pakistan. In the next decades, it can change because the global modern renewable energy grows fast, 7% a year though the growth varies across countries and periods. Fast growth of modern renewable energy is attained in China (37.2%), India (28.2%), Brazil (21.7%) and European Union (11.3%), but nil in Pakistan and Mexico. The income growth is correlated to growth of modern renewable energy (R^2 = 0.8). Moreover, economic recession in high income countries accelerated the global growth of modern renewable to 10.7%, as well as in Brazil (40.5%) and European Union (13.6%) along with minor slowdown in China (24.6%) and India (14.9%).

Table 4 Share renewable energy in all energy consumption and growth of renewable energy

	% all renewables	growth of all renewable energy		% modern renewables	growth of modern renewable energy	
		1990-2015	2000 -2015		1990-2015	2000-2015
World	14%	2.3%	3.1%	1.4%	6.9%	10.7%
United States	7%	1.9%	3.7%	1.4%	3.4%	10.0%
Japan	6%	2.2%	4.1%	1.4%	2.9%	4.2%
European Un.	15%	4.4%	5.4%	2.9%	11.3%	13.6%
Russian Fed.	3%	-0.8%	-0.6%	0.0%	9.0%	-9.1%
Mexico	9%	0.8%	0.0%	2.2%	0.1%	-3.9%
Brazil	38%	2.4%	2.5%	1.0%	21.7%	40.5%
China	12%	2.2%	4.2%	1.5%	37.2%	24.6%
Indonesia	34%	2.2%	2.2%	7.8%	9.3%	5.1%
Nigeria	80%	3.0%	2.8%	0.0%	0.0%	0.0%
India	24%	1.7%	2.1%	0.5%	28.2%	14.9%
Pakistan	40%	2.4%	1.8%	0.0%	0.0%	0.0%

During last decades, the energy consumption has grown slower than income but also the carbon content in the consumption is hardly decreased though renewable energy accrued a larger share on the global energy market. For the decades to come, modern renewable energy can become a dominant energy resource. The two-digit growth of modern renewable energy in China, Brazil, India, and European Union implies tough rivalry between fossil fuels and modern renewable energy.

5. Mitigation of climate change

Possibilities of mitigation climate change are assessed through extrapolation of the past growth rates on the assumption that renewable energy substitutes fossil fuels when it grows faster than the total energy consumption. It means that the biofuel, hydro and modern energy resources reduce consumption of coal, oil, gas or nuclear without preferences between them but in proportion to their share in the fossil fuels total in 2015. The totals of fossil fuels and renewable energy are aligned to the total energy consumption in every country, which implies that transfers of renewable energy across countries are assumed unfeasible. Table 5 shows indices of income, energy consumption, renewable energy and carbon dioxide emissions in the 2040 being 25 years after reference in 2015 (2015 = 100) based on trend from the past 25 years during 1990 – 2015 and 15 years during 2005 - 2015.

Table 5 Projection of income, energy consumption, renewable energy and carbon dioxide emission based on the growth rates during 1990-2015 and 2005-2015

2015 = 100	Income		Energy consumption		Modern renewable energy		Carbon dioxide emissions	
Past growth rates	1990-2015	2005-2015	1990-2015	2005-2015	1990-2015	2005-2015	1990-2015	2005-2015
Projection	2040	2040	2040	2040	2040	2040	2040	2040
World	378	310	150	196	81,803	17,774	44	57
United States	183	141	118	93	230	1,073	109	68
Japan	124	111	98	62	203	281	90	40
European Union	150	126	92	64	1,445	2,432	21	-
Russian Fed.	124	199	80	117	859	9	90	133
Mexico	195	178	149	107	102	37	151	99
Brazil	203	215	129	219	13,447	495,003	-	-
China	938	698	216	354	272,903	24,351	-	-
Indonesia	301	310	220	160	923	345	156	133
Nigeria	329	342	203	184	#DIV/0!	#DIV/0!	189	113
India	427	429	156	278	49,936	3,200	-	295
Pakistan	247	197	207	148	100	100	207	133

When trends are extrapolated 3 to 4 times larger income in 2040 can be expected, but the countries' income diverges, for instance the Chinese income can increase tenfold but the Japanese, European and Russian income growth stagnates. The energy consumption can increase 1.5 to 2 times along with the decrease in Japan, European Union and Russia Federation. The modern renewable energy enlarges hundreds of times in European Union, Brazil, China and India, but hardly in Russian Federation, Mexico, Nigeria and Pakistan. The global carbon dioxide emissions decrease by - 2.8% and – 1.9% annual average to 44% or 57% of the 2015 level. The European Union, Brazil, China and Indian become nearly fossil fuels free due to fast annual average growth of modern renewable energy during past 25 years. It can be questioned whether the growth rates of energy consumption and modern renewable energy can be sustained during the next decades because growth decreases as markets saturate. Technology diffusion is usually expressed as logistic function in time. This expression is approximated by the linear decrease of the growth rates of energy consumption and renewable energy from 100% in 2015 to nil in 2040. These extrapolations shows the growing global energy consumption by 0.3% annual average during next 25 years compared to 0.5% increase during past 25 years and the decreasing carbon dioxide emission by – 2.1% in the future compared to 1.9% increase in the past. The decreasing trend of carbon dioxide is a robust trend if policy interventions in favor of fossil fuels are prevented.

Extrapolations of the past trend on energy markets indicate sufficient reduction of carbon dioxide to mitigate climate change along with higher income and lower energy consumption. This is attained due to value adding energy products based on modern renewable energy if this trend is not obstructed by policies aiming to protect interests in fossil fuels. Climate change can be mitigated if policies foster the innovations mechanisms on energy markets.

6. Conclusions

The innovations mechanism of valorization on energy markets and its consequences for the emission reduction of carbon dioxide are assessed statistically for the periods 1990 – 2015 and 2005 – 2015; the latter with regard to economic recession in high income countries. Value on energy markets increases faster than energy consumption. This valorization enables market entry of costly modern renewable technologies based on geothermal, wind and solar resources entailing fast cost-reducing technological change when scale in the renewable energy consumption is generated, referred to as decarbonization on energy markets.

The valorization is explained by compounding of valuable attributes in the value chains of energy products because aiming at more powerful, flexible and cleaner services because aiming to fulfil growing demands of individuals and communities for convenience, mobility, autonomy, respectively local jobs, stable income, pollution reduction and so on. When functionalities of energy products are enriched with valuable attributes income growth is generated, given energy consumption. The electricity consumption is an expression of that valorization. The costs of electricity consumption in the United States and European Union are more than dozen times higher than the energy resources and they increase along with lower costs of energy resources. The value of electricity services increased when renewable energy is introduced on grid entailing two-digit growth of modern renewable energy based on geothermal, wind and solar resources in China, Brazil, India and the European Union. The value of electricity services manifold when distributed energy systems with storage are introduced.

If past trend are extrapolated to 2040 without changes the global income increases four to five times along twice higher global energy consumption, which reflects the valorization mechanism. The carbon dioxide emissions, however, decrease to 42% or 57% of the 2015 emissions, which enables to mitigate climate change and a number of countries become fossil free. This reflects the decarbonization mechanism due to modern renewable energy. Energy markets face tough rivalry between the fossil fuel resources and renewable energy ones, whereby the renewable presumably gain because they generate higher value on energy markets. The innovation mechanisms of valorization of energy products entailing decarbonization of energy resources enable sustainable development towards higher income, prudent energy consumption and low level of carbon dioxide emission.

Appendix.

	Statistics and Extrapolated 2013-14		Annual average growth		*Extrapolated trend*	
World	1990	2015	1990-2015	2005-2015	*2020*	*2040*
Population mln	5,278	*7,335*	1.3%	1.2%	7,738	9,666
GDP bln USD 2010	37,741	*74,776*	2.8%	2.6%	88,457	219,699
GDP PPP bln USD	45,735	*104,746*	3.4%	3.6%	129,899	395,645
Energy prod. Mtoe	8,809	*14,009*	1.9%	1.9%	15,601	26,178
Energy cons. Mtoe	8,772	*13,849*	1.8%	1.8%	14,863	20,760
Electric cons. TWh	10,912	*22,360*	2.9%	2.9%	27,872	92,415
CO2 Mt	20,502	*32,633*	1.9%	1.9%	34,024	14,304
coal	2220	*3,940*	2.3%	2.8%	4,219	964
all liquids	3233	*4,356*	1.2%	0.8%	4,479	2,667
gas	1663	*2,897*	2.2%	2.1%	2,929	2,282
nuclear	525	*675*	1.1%	-0.7%	667	418
biofuels	909	*1,435*	1.8%	2.4%	1,590	2,516
hydro	184	*343*	2.5%	3.1%	442	1,724
geoth, solar wind	37	*193*	6.9%	10.7%	488	157,880
total and balance	8771	13839	1.8%	1.8%	14,880	188,384
fossil fuels	7,116	11,193	1.8%	1.8%	12,440	6,008
renewable	1,130	1,971	2.3%	3.1%	2,562	187,448

United States	1990	*2015*	1990-2015	2005-2015	2020	2040
Population mln	250	*321*	1.0%	2.3%	338	414
GDP bln USD 2010	9,064	*16,540*	2.4%	1.4%	18,660	30,229
GDP PPP bln USD	9,064	*16,538*	2.4%	1.4%	18,657	30,222
Energy prod. Mtoe	1,652	*2,146*	1.1%	2.8%	2,263	2,798
Energy cons. Mtoe	1,915	*2,249*	0.7%	-0.3%	2,323	2,645
Electric cons. TWh	2,923	*4,164*	1.4%	0.3%	4,471	5,942
CO2 Mt	4,802	*5,249*	0.4%	-0.8%	5,196	5,735
coal	460	*432*	-0.2%	-2.5%	445	491
all liquids	756	*792*	0.2%	-1.2%	816	900
gas	438	*642*	1.6%	2.4%	661	730
nuclear	159	*218*	1.3%	0.3%	225	248
biofuels	62	*107*	2.2%	3.5%	119	185
hydro	23	*21*	-0.3%	-0.9%	21	19
geoth, solar wind	14	*31*	3.4%	10.0%	37	71
total and balance	1912	2243	0.6%	-0.2%	2,323	2,645
fossil fuels	1,654	1,866	0.5%	-0.5%	2,146	2,369

renewable	99	159	1.9%	3.7%	177	276

Appendix continue

	Statistics and Extrapolated 2013-14		Annual average growth		*Extrapolated trend*	
Japan	1990	*2015*	1990-2015	2005-2015	2020	2040
Population mln	124	*127*	0.1%	-0.1%	128	130
GDP bln USD 2010	4,553	*5,641*	0.9%	0.4%	5,888	6,990
GDP PPP bln USD	3,580	*4,436*	0.9%	0.4%	4,631	5,498
Energy prod. Mtoe	75	*26*	-3.5%	-11.6%	22	11
Energy cons. Mtoe	439	*429*	-0.1%	-1.9%	427	421
Electric cons. TWh	841	*972*	0.6%	-1.1%	1,001	1,128
CO2 Mt	1,041	*1,148*	0.4%	-0.3%	1,117	1,035
coal	76	*115*	1.7%	0.4%	113	105
all liquids	251	*182*	-1.3%	-2.8%	179	166
gas	44	*110*	3.7%	4.5%	108	100
nuclear	53	-	-18.6%	-50.5%	-	-
biofuels	4	*11*	4.2%	8.3%	14	31
hydro	7	*7*	0.0%	0.0%	7	7
geoth, solar wind	3	*6*	2.9%	4.2%	7	12
total and balance	438	431	0.0%	-1.8%	427	421
fossil fuels	371	407	0.4%	-0.4%	400	371
renewable	14	24	2.2%	4.1%	27	50

European Union	1990	*2015*	1990-2015	2005-2015	2020	*2040*
Population mln	478	*509*	0.3%	0.3%	515	542
GDP bln USD 2010	11,880	*17,658*	1.6%	0.9%	19,117	26,265
GDP PPP bln USD	11,706	*17,511*	1.6%	0.9%	18,983	26,213
Energy prod. Mtoe	951	*756*	-0.9%	-1.8%	722	602
Energy cons. Mtoe	1,645	*1,502*	-0.4%	-1.8%	1,476	1,375
Electric cons. TWh	2,465	*2,932*	0.7%	-0.6%	3,037	3,495
CO2 Mt	4,024	*2,972*	-1.2%	-2.7%	2,673	617
coal	455	*250*	-2.4%	-2.4%	232	54
all liquids	606	*506*	-0.7%	-2.3%	470	108
gas	297	*299*	0.1%	-3.8%	277	64
nuclear	207	*227*	0.4%	-1.3%	211	49
biofuels	47	*143*	4.6%	4.8%	179	437
hydro	25	*32*	1.0%	1.7%	34	41
geoth, solar wind	3	*43*	11.3%	13.6%	73	622
total and balance	1640	1500	-0.3%	-1.8%	1,476	1,375

fossil fuels	1,358	1,055	-1.0%	-2.8%	1,190	275
renewable	75	218	4.4%	5.4%	286	1,100

Appendix continue

	Statistics		Annual average growth		*Extrapolated trend*	
Russian Federation	1990	*2015*	1990-2015	2005-2015	2020	*2040*
Population mln	148	*145*	-0.1%	0.1%	144	142
GDP bln USD 2010	1,414	*1,688*	0.9%	2.8%	1,761	2,087
GDP PPP bln USD	2,715	*3,241*	0.9%	2.8%	3,381	4,006
Energy prod. Mtoe	1,293	*1,272*	0.0%	0.6%	1,271	1,268
Energy cons. Mtoe	879	*693*	-0.9%	0.6%	662	552
Electric cons. TWh	990	*962*	-0.1%	1.5%	958	943
CO2 Mt	2,163	*1,401*	-1.7%	-0.6%	1,513	1,256
coal	191	*100*	-2.5%	-1.2%	96	79
all liquids	264	*173*	-1.5%	3.0%	165	137
gas	367	*349*	-0.2%	0.0%	334	277
nuclear	31	*49*	1.9%	2.3%	47	39
biofuels	12	*7*	-2.1%	0.0%	6	4
hydro	14	*14*	0.0%	-0.7%	14	14
geoth, solar wind	0.02	*0*	9.0%	-9.1%	0	1
total and balance	879	692	-0.9%	0.6%	662	552
fossil fuels	822	622	-1.1%	0.5%	642	533
renewable	26	21	-0.8%	-0.6%	20	19

Mexico	1990	*2015*	1990-2015	2005-2015	2020	*2040*
Population mln	87	*122*	1.4%	1.3%	131	171
GDP bln USD 2010	618	*1,203*	2.7%	2.3%	1,375	2,347
GDP PPP bln USD	1,018	*1,981*	2.7%	2.3%	2,264	3,864
Energy prod. Mtoe	195	*200*	0.1%	-2.5%	201	207
Energy cons. Mtoe	124	*184*	1.6%	0.3%	199	274
Electric cons. TWh	99	*265*	4.0%	2.3%	323	712
CO2 Mt	257	*414*	1.9%	0.1%	452	625
coal	4	*13*	4.9%	0.8%	14	20
all liquids	80	*93*	0.7%	-0.7%	102	141
gas	23	*58*	3.8%	2.3%	64	88
nuclear	1	*1*	0.7%	-9.9%	1	2
biofuels	8	*9*	0.5%	0.0%	9	10
hydro	2	*4*	3.0%	7.2%	5	8
geoth, solar wind	4	*4*	0.1%	-3.9%	4	4
total and balance	122	182	1.7%	0.2%	199	274

fossil fuels	107	164	1.8%	0.4%	181	251
renewable	14	17	0.8%	0.0%	18	23

Appendix continue

	Statistics		Annual average growth		*Extrapolated trend*	
Brazil	1990	*2015*	1990-2015	2005-2015	2020	*2040*
Population mln	150	*208*	1.2%	0.8%	221	283
GDP bln USD 2010	1,190	*2,414*	2.9%	3.1%	2,780	4,894
GDP PPP bln USD	1,510	*3,064*	2.9%	3.1%	3,529	6,212
Energy prod. Mtoe	104	*281*	3.6%	2.7%	336	688
Energy cons. Mtoe	140	*312*	3.0%	3.2%	328	402
Electric cons. TWh	218	*546*	3.5%	3.2%	649	1,294
CO2 Mt	184	*501*	3.7%	3.8%	483	0
coal	10	*18*	2.4%	3.3%	18	0
all liquids	59	*130*	3.2%	4.1%	131	0
gas	3	*38*	11.0%	8.4%	38	0
nuclear	0.5	*4*	8.8%	3.0%	4	0
biofuels	48	*85*	2.3%	3.1%	95	152
hydro	18	*30*	2.1%	0.4%	33	50
geoth, solar wind	0	*3*	21.7%	40.5%	8	403
total and balance	139	308	3.3%	3.8%	328	606
fossil fuels	72	186	3.9%	4.7%	191	-
renewable	66	118	2.4%	2.5%	137	606

China	1990	*2015*	1990-2015	2005-2015	2020	2040
Population mln	1,135	*1,371*	0.7%	0.4%	1,421	1,639
GDP bln USD 2010	824	*8,788*	9.4%	8.1%	13,750	82,393
GDP PPP bln USD	1,686	*17,982*	9.4%	8.1%	28,135	168,615
Energy prod. Mtoe	881	*2,625*	4.4%	4.2%	3,255	7,696
Energy cons. Mtoe	871	*3,097*	5.1%	5.2%	3,612	6,681
Electric cons. TWh	580	*5,592*	9.1%	8.3%	8,661	49,831
CO2 Mt	2,076	*9,194*	6.1%	5.3%	10,234	0
coal	578	*2,002*	5.2%	5.3%	2,206	0
all liquids	119	*524*	6.3%	5.6%	577	0
gas	13	*168*	10.9%	15.7%	185	0
nuclear	0	*39*	11.2%	10.9%	43	0
biofuels	200	*218*	0.3%	0.7%	222	238
hydro	11	*102*	9.4%	11.6%	160	957
geoth, solar wind	0.03	*45*	37.2%	24.6%	219	122,806
total and balance	921	3098	5.0%	5.5%	3,612	124,002

fossil fuels	710	2,694	5.5%	5.6%	3,011	-
renewable	211	365	2.2%	4.2%	600	124,002

Appendix continue

	Statistics		Annual average growth		*Extrapolated trend*	
Indonesia	1990	*2015*	1990-2015	2005-2015	*2020*	*2040*
Population mln	181	*257*	1.3%	1.1%	274	356
GDP bln USD 2010	300	*987*	4.5%	4.6%	1,230	2,971
GDP PPP bln USD	796	*2,621*	4.5%	4.6%	3,267	7,891
Energy prod. Mtoe	168	*454*	4.1%	5.1%	556	1,251
Energy cons. Mtoe	99	*233*	3.2%	1.9%	273	512
Electric cons. TWh	29	*219*	8.0%	5.6%	321	1,484
CO2 Mt	134	*472*	4.5%	2.3%	507	738
coal	3	*43*	11.3%	6.9%	51	74
all liquids	33	*73*	3.3%	1.2%	87	126
gas	16	*36*	3.4%	2.3%	43	62
nuclear	0	-	0.0%	0.0%	-	-
biofuels	43	*59*	1.3%	1.5%	63	81
hydro	0.5	*1*	2.9%	0.0%	1	2
geoth, solar wind	2	*18*	9.3%	5.1%	28	166
total and balance	98	230	3.5%	2.5%	273	512
fossil fuels	52	152	4.4%	2.7%	181	263
renewable	46	78	2.2%	2.2%	92	249

Nigeria	1990	*2015*	1990-2015	2005-2015	2020	2040
Population mln	96	*181*	2.4%	2.1%	204	326
GDP bln USD 2010	131	*479*	4.9%	5.1%	608	1,577
GDP PPP bln USD	284	*1,040*	4.9%	5.0%	1,320	3,426
Energy prod. Mtoe	146	*265*	2.3%	0.9%	296	464
Energy cons. Mtoe	66	*136*	2.9%	2.5%	157	276
Electric cons. TWh	8	*26*	4.6%	2.9%	33	81
CO2 Mt	28	*58*	3.3%	1.0%	70	110
coal	0.04	*0*	1.9%	20.6%	0	0
all liquids	11	*12*	0.4%	-0.8%	13	20
gas	3	*16*	7.0%	6.1%	17	27
nuclear	0	-	0.0%	0.0%	-	-
biofuels	52	*109*	3.0%	2.9%	126	229
hydro	0.4	*1*	1.3%	-6.5%	1	1
geoth, solar wind	0	-	0.0%	0.0%	-	-

total and balance	66	138	3.0%	2.7%	157	276
fossil fuels	14	28	2.9%	2.5%	30	47
renewable	52	110	3.0%	2.8%	127	229

Appendix continue

	Statistics		Annual average growth		*Extrapolated trend*	
India	1990	*2015*	1990-2015	2005-2015	2020	2040
Population mln	871	*1,311*	1.5%	1.1%	1,416	1,926
GDP bln USD 2010	481	*2,346*	6.0%	6.0%	3,136	10,006
GDP PPP bln USD	1,512	*7,371*	6.0%	6.0%	9,852	31,446
Energy prod. Mtoe	280	*560*	2.5%	2.7%	635	1,050
Energy cons. Mtoe	306	*874*	3.8%	4.2%	956	1,365
Electric cons. TWh	238	*1,105*	5.8%	6.2%	1,467	4,561
CO2 Mt	530	*2,188*	5.1%	5.6%	2,350	0
coal	93	*416*	6.2%	8.5%	454	0
all liquids	61	*192*	4.7%	4.5%	209	0
gas	11	*42*	5.7%	3.1%	46	0
nuclear	2	*9*	6.4%	8.5%	10	0
biofuels	133	*196*	1.6%	2.0%	212	289
hydro	6	*10*	2.1%	1.1%	11	17
geoth, solar wind	0.01	*4*	28.2%	14.9%	14	1,997
total and balance	306	869	4.3%	5.4%	956	2,303
fossil fuels	165	650	5.6%	6.7%	719	-
renewable	139	210	1.7%	2.1%	237	2,303

Pakistan	1990	*2015*	1990-2015	2005-2015	2020	2040
Population mln	108	*188*	2.1%	1.8%	209	317
GDP bln USD 2010	80	*215*	3.7%	2.8%	258	530
GDP PPP bln USD	322	*870*	3.7%	2.8%	1,042	2,148
Energy prod. Mtoe	34	*68*	2.8%	1.1%	78	136
Energy cons. Mtoe	43	*91*	3.0%	1.6%	105	189
Electric cons. TWh	30	*87*	4.4%	2.1%	108	254
CO2 Mt	56	*139*	3.6%	1.4%	154	288
coal	2	*3*	1.9%	-2.8%	4	7
all liquids	10	*25*	3.8%	3.9%	29	55
gas	10	*26*	4.0%	0.0%	31	57
nuclear	0.1	*1*	10.6%	0.0%	1	2
biofuels	19	*33*	2.2%	2.0%	37	57
hydro	1	*3*	5.3%	0.0%	4	11
geoth, solar wind	0	*0*	0.0%	0.0%	0	0
total and balance	42	91	3.1%	1.6%	105	189

fossil fuels	22	54	3.7%	1.4%	65	120
renewable	20	36	2.4%	1.8%	41	68