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COAL'S ROLE IN THE WORLD ENERGETIC SYSTEM

Theoretical Article

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Abstract

The world energy needs are on the rise, and they come from developing economies, especially the emerging ones such as China or India with high demographic and economic growth rates. These countries future demand for energy will shape the world's energetic system. They will require considerable quantities of energy to fuel their demanding economies. The last decade has shown that the world's energetic needs are being reoriented from West to East. Coal represents an available, secure and competitive energetic resource which can help the growing need for energy. However it is not that flexible as gas or renewables and it has also a greater impact upon environment due to its greenhouse gas emissions in the context of climate change. For these reasons coal is being less used for the energetic needs of the developed economies. Will the current attributes of coal be sufficient to maintain coal's place in the world energetic mix?

1.Introduction – aspects regarding coal

From a technical perspective coal represents a sedimentary rock which contains mainly carbon, hydrocarbon and minerals (Bradely Jr., Fulmer, 2004:22). It has been generated over a period of millions of years due to the massive accumulation of dead plants. Due to the climatic variations that have taken place over the geological periods swampy forests were buried bellow water level and covered further with mud and sand generating thus peat. In this trapped environment and in the absence of air, the anoxic decomposition of the matter was facilitated. In the presence of increasing temperature and pressure peat was converted to coal and in some instances coal to diamond. The most important deposits of coal were generated in the carboniferous period, about 360-286 millions years ago (Armaroli, Balzani, 2011).

Initially for thousand of years the global energetic system was dominated by biomass, which was available and in the case of wood only necessitated the cutting down of trees and the combustion of wood. However due to population growth and the need for agricultural land a shortage of wood became felt in European countries such as Great Britain where as early as the thirteenth century wood was replaced by coal in urban areas. It was however prohibited in London in 1306 due to its smoke and detrimental health effects. But its availability and the rising population of Britain which nearly doubled in the period of 1530-1650 coupled also with rising wood prices led to the acceptance of coal in spite of its externalities. The economics aspects of coal namely its price and availability being found also at the surface were decisive. Coal became also adopted in the iron industry, by turning it into coke, replacing thus charcoal. In order to continue the exploitation coal, it was necessary to be extracted from the underground as surface reserves were depleted. Thanks to the steam engine, invented in 1712 by Thomas Newcomen and latter improved by James Watt, coal could be exploited from the mines, used for powering locomotives, ships, mills and the factories of the Industrial Revolution. Its energy density 3 times higher than that of wood played an important role in this transition. At the end of the eighteen century, with the emerging of electricity market, coal found a new role firstly with the help of the steam engine and latter with steam tubines which were more efficient. This opened its ascension in the world energetic mix, wood being still dominant that time, coal reaching a 50% share in the primary energy supply. Thereafter oil and natural gas entered the scene and limited coal's ascension. It was not until 1964, that oil overruns coal in the world energy mix (WEF, 2013).

However coal represents currently a key player in our energetic system, this is due to its current share in global energy mix but also to its characteristics which make him an attractive resource for countries with a growing demand for energy. As we can observe in Figure 1, coal holds the second position in the world total primary energy supply after oil, with a share of 28.8% this being the equivalent of over 3700Mtoe of energy supply.

2. Coal's role in the energetic system

Looking back at the beginning of this century we can observe that coal alone represented 45% of the primary energy demand growth in the period 2001-2011. This is due to the growing demand for electricity that has occurred over the past decade in China, India and other non-OECD countries. In this area total power output almost doubled, being met in a significant share, 60%, by coal. In the power sector, due to these evolutions in 2011 China surpassed the United States in electricity production, becoming the first producer in the world, 80% of its electricity being of coal origin (IEA, 2012).

But what are the reasons behind the place detained by coal in the world's energetic mix? Firstly it is an abundant resource with a varied distribution around the world. Due to these characteristics, coal can enhance the energetic security of a country through its availability and stability of price (IEA, 2012a).

Regarding the availability of the resource we can mention that from the perspective of the economically recoverable fossil resources, 64% are represented by coal while oil amounts to 19% and gas to 17% (IEA, 2012a). If we refer to the reserves of coal, these are estimated to be at 1000 billion tones, which will be sufficient for 132.5 years of production at current levels. Being an economic function, coal's proved reserves have been on an ascending trend during the start despite the production output that has been on an ascending trend. This aspect can be observed in Table 1, where with the exception of 2005, the global estimates for reserves have been growing.

Similarly the production of coal was on an ascending trend during this period, we can see that at global level the output has grown with about 60%, while for China it has more than doubled during this interval. In this moment, China represents 45% of the world production of coal (IEA, 2013a).

For hard coal only if we refer to resources, which represents coal that may be located in a deposit for which mining feasibility is yet unknown from an economic point of view, the stock is estimated to be at over 17 trillion tones, which is about 17 times the level of proved reserves (IEA, 2013a). This aspect alone highlights the fact that coal will be available in the future to supply the energetic needs of countries with growing demand such as China or India.

From the geographical perspective, coal is remarkable for a wide distribution. This is in

contrast with the gas and oil reserves for which almost half are located in just three countries: Russia, Iran and Qatar (IEA, 2012). If we take a look at the proved reserves overview from 2011 in Figure 2 we can observe that neither of the political regions analyzed hold more than 30% of the recoverable reserves.

This varied distribution across all continents and regions of coal reserves confers an enhanced stability regarding availability and price of this resource because it provides a variation of producers at world level. This improves the prospects of countries in assuring their energetic security either by exploiting the resource within their own borders or acquiring it through international trade. However if we refer to trading coal internationally we must point out that coal represents a voluminous fuel that raises difficulties in transporting it over considerable distances. Shipping coal over see can represent in the end 70% of the total cost of coal, aspect for which coal is predominantly used in the vicinity of its production site, 60% of production being used within a 50 km range of the extraction point. This is because electricity is more easily to distribute to the consumers through the network and also it reduces the impact upon environment (Armaroli, Balzani, 2011). We can observe that in this aspect, in contrast with oil mainly but also gas that can be traded oversees by liquefaction, coal is a less flexible resource raising difficulties in its transportation. This is one of the reasons for which oil and gas have known over time an important evolution in the global energy mix because of their flexibility in transport.

If we take a look at the production figures for coal over the last 2 decades we can observe in Figure 3, the fact that at the global level the production has been on a constant rise, growing with about 68%, but the growth occurs mainly from the non-OECD area (144%) in contrast with OECD countries which knew a descending trend being now with about 10% as in 1990. As we can observe at the beginning of the analyzed period the production levels of the two areas were close but they have followed opposing trends. For the non OECD we also mention the fact that production has been growing despite the economic crisis and reduced demand for energy.

The most important exponent in production growth of the non OECD area is represented by China. From 1990 its coal production doubled achieving a level of 3.549.061 thousand tones, which is about 45% of the global production level. Similarly another major emerging economy, India, grew its production level with over 160% reaching 595.011 thousand tones. On the other side, in the developed economies group, from the leading countries in this area, only the United States has maintained a similar level of production of almost 1 million thousand tones (but as we are going to see further on also for exporting reasons), while other major producers such as Germany (-55%), Poland (- 33%) or the United Kingdom (-82%) decreased their productions levels. From the OECD countries only Australia, which is a major exporting country, has known an important ascension in its production levels more than doubling it to over 400.000 thousand tones (IEA, 2013a). We can conclude in this aspect, that coal production is evolving predominantly in the developing economies in contrast with the developed economies.

Similarly this divergent trend between OECD vs. non OECD can be also observed in the consumption patterns. From Figure 4 we can see that during the analyzed period consumption in non OECD area have more than doubled reaching 5.5 million thousand tones, while in the OECD area it decreased with 6% to a little over 2 million thousand tones. At this point non OECD area represents over 70% of the global coal consumption

At the level of exponent countries we can observe similar trends, in Figure 5, emerging economies raising their coal consumption while developed ones like the United States or Germany having a decreasing trend overall the analyzed period. This general trend both in production and consumption leads us to the conclusion that coal has become a resource predominantly attractive for developing economies with high demographic and economic growth rates which need at their disposal growing and reliable quantities of energy. On the contrary, the developed economies are searching for new sources of energy mainly from environmental reasons, climate change being the most important aspect.

If we analyze the OECD economies, in the case of the US we can see that although the production remained fairly stable for the end of the period, consumption decreased. On an Mtoe equivalent, total consumption decreased with over 15% in the period 2010-2012e, due to the development of unconventional gas sector in the United States. In the period 2005-2010, shale gas production grew with over 45%, the unconventional sector representing 60% of the total US gas production (IEA, 2012c). From an economic point of view, this development led to the creation of 1.7 million jobs and 237 billion $ contribution to the GDP. Also the knowledge and technology that is now available for the American companies in drilling and extracting unconventional gas represents an aspect that must not be overlooked as it can represent an opportunity for developing the sector in other parts of the world (IHS, 2012). Regarding price, we can mention that gas spot price due to these developments decreased from 13$/MBtu in 2008 to 5 $/MBtu in 2010 (WEC, 2010). As we can observe due to the development of the

unconventional gas sector in the United States coal use is being replaced by gas, as gas is more maneuverable than coal being transportable at great distances from the place of production to the consumption centre by liquefaction (LNG) or pipeline. Also its impact upon the environment is lower and gas plants can adapt better as backup source to intermittency of the renewables energy sources such as wind or solar. The construction period is about 2 years which represents half of the period needed to build a coal plant (IEA, 2010) From this point of view we conclude that gas is more flexible fuel than coal and in the presence of gas resources at an attractive price, gas will substitute coal, such as in the case of the United States.

Coal's price is another aspect that must not be overlooked when we refer to this fuel. Attractive and stable prices have led to ascending trend in coal's use at global level. If we refer to the power sector taking into consideration the costs from electricity generation we can observe in Table 2, that coal despite the assumed 30$/tonne CO_2 carbon tax in the OECD countries maintains itself as an attractive option for electricity generation. In Germany and the United States a 5% discount rate coal is a more attractive option than gas despite the higher taxation of CO_2. For the higher 10% discount rate for certain gas technologies options can become more attractive than coal options. However in the absence of carbon taxation, coal becomes one of the cheapest options to produce electricity its cost being close to that of nuclear. In China the world leading coal consumer, where carbon costs are not taken into account, only large Hydro outperforms in terms of cost coal plants. We can also observe as a general trend for all 3 selected countries that new renewable energies such as wind or solar are generally more expansive than the traditional forms of generating electricity (IEA, 2010). We can conclude that at cost level coal remains an attractive option for generating electricity and despite the efforts for developed countries to replace coal with energy sources with a lower impact upon the environment such as gas or renewable forms, coal will remain an important option in countries such as China where important resources are available and at attractive cost of generating electricity.

Coal's main drawback is represented by high emissions rate in contrast with other forms of electricity generation, as we can observe in Figure 5, this aspect raising concerns at the global level regarding climate change mitigation. In contrast with the other fossil fuels we can see that coal emission rates are closer to that of oil but oil tends represent a specialized resource in the transportation sector being less used in the power sector (IEA, 2012). Regarding gas, on a median level coal's emissions rate per GWh is 78% higher and in the case of lignite it is over 100% (WNA, 2011).

Due to this high emissions rate, global coal-fired plant fleet is responsible yearly for more 8.5 Gt of CO_2 emissions, which is about one quarter of the world's anthropogenic carbon emissions (IEA, 2012a).

CO_2 emissions represent a current challenge to the world energetic system. Several countries are implementing measures in order to limit these emissions. For example in relation with coal plants, in the United States the Environmental Protection Agency (EPA) requires new fossil-fuelled units with a net capacity of over 25MW must meet an emission standard of 455 kg CO_2/MW hr, target that is not currently achieved by current coal plants (IEA 2013b).

One of the possible solutions to coal's high GHG emission rate is the adoption of carbon capture and storage technologies (CCS) for coal plants around the world. These technologies would reduce the carbon emission rate but for the moment they are not commercially viable and they would also affect the competitiveness of coal in relation with other energetic resources.

3. Conclusions

We can conclude regarding coal that it is an available, secure and competitive energetic resource. It has a wide geographical availability and its reserves will be available for many years to come. Also due to its distribution and varied number of producers coal presents a relative stabile price which makes it available for different countries in meeting their energetic needs. Availability and competitiveness represent the main attributes of coal through which it can contribute to the energy security of a country. However coal is not that flexible in contrast with gas and oil because it is not easily transportable due to its volume. This is why it is transformed into electricity and transported to the point where it is needed. Also by doing so the impact upon environment is limited.

As we have seen during the past decade coal has represented an important resource in assuring the global energy needs that have been in ascending trend especially due to the emerging energetic needs of developing economies such as China or India. In the area of developed economies coal is being replaced by gas or renewable energies due to environmental considerations, its main disadvantage being its high carbon emissions. Also these energies are more flexible than coal and can better adapt to each other, especially if it is the case of supporting renewable development policies. While research and development efforts are made in the case of renewables for reducing their costs in the case of coal there is the need for making this fuel cleaner regarding its emissions.

For the moment there is no global agreement regarding the reductions of greenhouse gases from the energy sources, but developed actors such us the European Unions are pursuing measures in this direction and taking unilateral actions. Given the vast reserves of coal available worldwide and especially in China it is difficult to believe that this fossil resource will not play an important role assuring world's energy needs with or without the global agreement. For the time the United States with its shale gas sector development is an example of how the dispatch of coal can occur in the presence of a developed resource. It is questionable if this example can be replicated in other parts of the world. The European Union is aiming for similar measures of dispatching coal by renewables and gas as a transitional fuel in achieving its climate and energetic objectives at the same time. At the global level it is to be seen what will matter most climate related objectives or energy security and competitiveness objectives given the growing need for energy.

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Tables and figures

Table 1: World reserves and production of coal 2003-2013, Gt. Reserves data for 2003-2005 are from World Energy Council, while other from BGR. Source: IEA, 2013a.

Year	Global reserves	China's reserves	Global production	China's production
2003	984.5	114.5	4.92	1.54
2005	909.1	114.5	5.67	2.08
2007	934.9	133.2	6.33	2.48
2009	989.9	192	6.74	2.73
2011	1000.5	191.6	7.21	3.14
2013	1037.6	191.6	7.83	3.55

Table 2: Levelised costs of electricity with 5% and 10% discount rate for different energy sources. Selected countries: United States, Germany, China. Source: IEA/NEA OECD 2010.

Country	Energy Source	Technology	Net capacity Mwe	Fuel Costs USD/MWh	Carbon Costs USD/MWh	LCOE 5% USD/MWh	LCOE 10% USD/MWh
United States	Coal	Black PPC	600	19.60	26.40	72.49	87.85
United States	Coal	Black IGCC	550	19.63	24.40	74.87	92.61
United States	Coal	Black IGCC w/CC (S)	380	24.15	2.61	68.04	93.92
Germany	Coal	Black PCC	800	28.17	22.04	79.26	94.10
Germany	Coal	Black PCC w/CC (S)	740	34.56	3.25	85.28	109.61
Germany	Coal	Brown PCC	1050	11.27	26.12	70.29	87.41
Germany	Coal	Brown PCC w/CC (S)	970	13.70	3.81	68.06	94.60
China	Coal	Black USC PCC	932	23.06	0.00	29.99	34.17
China	Coal	Black SC	1119	23.06	0.00	29.42	33.26
China	Coal	Black SC	559	23.06	0.00	30.16	34.43
United States	Gas	CCGT	400	49.27	14.74	76.56	82.76
United States	Gas	AGT	230	66.52	14.74	91.48	95.08
United States	Gas	CCGT w/CC (S)	400	67.01	1.47	91.90	104.19
Germany	Gas	CCGT	800	58.57	10.08	85.23	92.81
Germany	Gas	Gas Turbine	150	92.48	15.92	118.77	122.61
China	Gas	CCGT	1358	28.14	0.00	35.81	39.01
China	Gas	CCGT	1358	28.14	0.00	36.44	39.91
United States	Nuclear	Advanced Gen III+	1350	9.33	0.00	48.73	77.39
Germany	Nuclear	PWR	1600	9.33	0.00	49.97	82.64
China	Nuclear	CPR-1000	1000	9.33	0.00	29.99	44.00
China	Nuclear	AP-1000	1250	9.33	0.00	36.31	54.61
United States	Renewables	Onshore wind	150	0.00	0.00	48.39	70.47
United States	Renewables	Offshore wind	300	0.00	0.00	101.02	146.44
United States	Renewables	Solar PV	5	0.00	0.00	215.45	332.78
Germany	Renewables	Onshore wind	3	0.00	0.00	105.81	142.96
Germany	Renewables	Offshore wind	300	0.00	0.00	137.94	186.76
Germany	Renewables	Solar PV (Open Space)	0.5	0.00	0.00	304.59	439.77
Germany	Renewables	Solar PV (Roof)	0.002	0.00	0.00	352.31	508.71
China	Renewables	Onshore wind	200	0.00	0.00	50.95	72.01
China	Renewables	Onshore wind	50	0.00	0.00	64.18	90.70
China	Renewables	Large Hydro	18134	0.00	0.00	29.09	51.50
China	Renewables	Large Hydro	6277	0.00	0.00	16.87	33.57
China	Renewables	Solar PV	20	0.00	0.00	122.86	186.54
China	Renewables	Solar PV	10	0.00	0.00	186.33	282.92

Figure 1: World total primary energy supply 2011, Mtoe. Category *Other* includes geothermal, solar, wind, heat etc. Source: IEA, 2012.

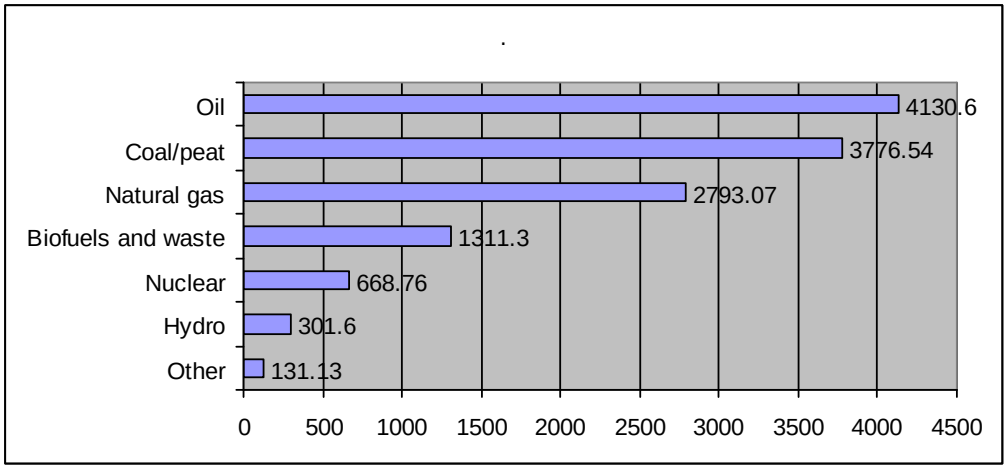

Figure 2: Coal proved recoverable reserves across political regions and selected countries, Mt. Source: IEA, 2013a after BGR.

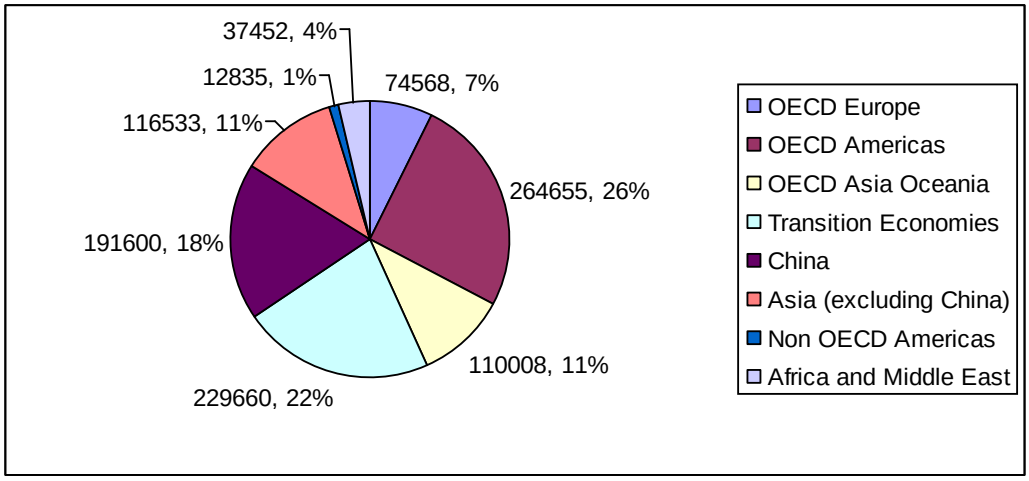

Figure 3: World coal production 1990-2012e, OECD, non OECD, thousand tones. Data for 2012 represents an estimation Source: IEA, 2013a

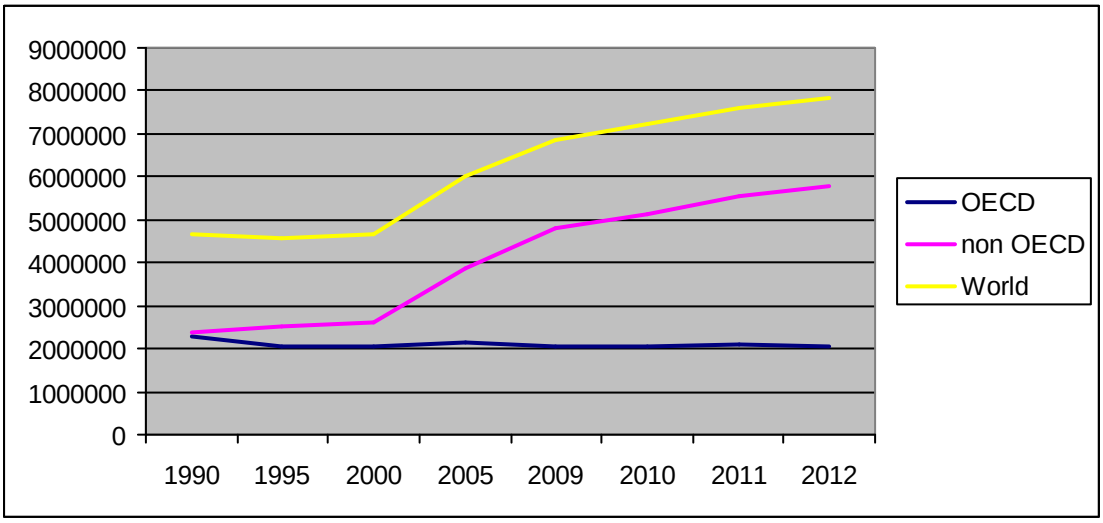

Figure 4: World coal consumption, OECD, non OECD 1990-2012e, thousand tones. Data for 2012 represents an estimation Source: IEA, 2013a

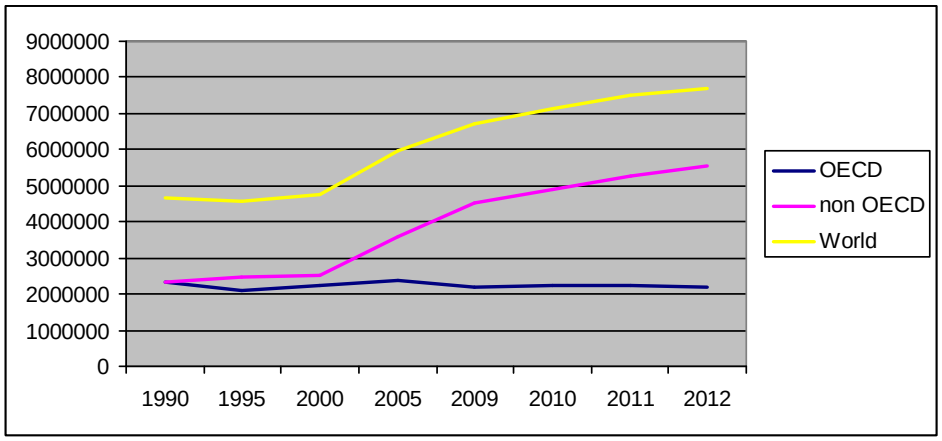

Figure 4: Coal consumption in selected countires 1990-2012e, thousand tones. Data for 2012 represents an estimation Source: IEA, 2013a.

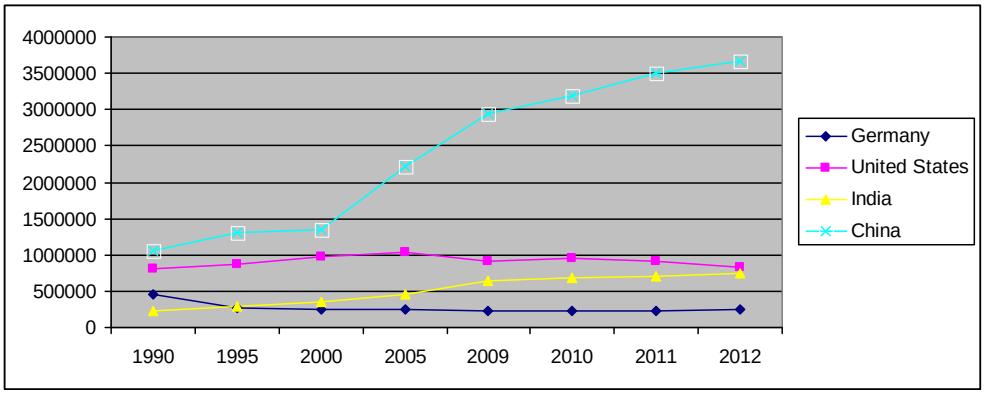

Figure 5: GHG Lifecycle Intensity in CO_2 equivalent for various forms of electricity generation, tones CO_2e/GWh. Source WNA, 2011.