Influence of rising commodity prices on energy policy

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Abstract
During the past few years we have first witnessed a rapid increase in the prices of commodities and then later, as a consequence of the economic downturn, an even more drastic drop. Simultaneously with the commodity price increase, an increase in the investment costs of power plants was experienced. The rise in material costs was often stated as one of the reason for this increase. In this study the relationship between commodity costs and energy prices is studied. A bottom-up approach is used for estimating what kind of an impact increased commodity prices alone could be expected to have on the investment costs on the one hand, and how increased energy prices may affect commodity production costs on the other. The results indicate that although the commodity production costs usually have a fairly large energy component, even high increases in commodity prices, and therefore raw material costs of power plant investments, can not explain the recently experienced hikes in power plant investment costs; a doubling of the costs of the main raw material flows could explain an investment cost increase of some 5-10%, depending on the power plant type. This would seem to indicate that other contributing factors, such as bottle necks in the production of power plant components, may play an important role in the recent investment cost increase.

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1. Introduction

During past few years the world has experienced a rapid increase in the prices of most major tradable commodities, e.g. fuels, metals, agricultural commodities etc. This increase has coincided with fast economic growth and increased demand for these commodities. Although different commodity markets have different explaining factors, in one way or another, these price increases are linked to rapidly increasing demand and to a supply structure that is struggling to keep up with the demand (see Ferioli and Bruggink, 2008 for the background study. Also IMF, 2008a goes into detail concerning the reasons and consequences of the price increase). This all, however, came to a halt as the prices came crashing down following the financial crisis of 2008, therefore again showing the highly volatile and economic cycle dependent nature of the commodity prices.

In the energy sector the increased fuel prices have naturally had an impact on the variable costs of power plants using such fuels. However, it appears in parallel to the increase in commodity prices, also the specific investment costs of power plants have increased significantly (see, for example Cambridge Energy Research Associates, 2008 on capital cost development for power plants). Although it is clear that this increase can be caused by a number of things, including bottle necks in the production of the components for power plants, also increased material costs have been stated as one of the contributing elements, sometimes even the main one. However, even if is clear that an increase in steel price is likely to increase the construction costs of a power plant, it is less obvious how much such an increase can be expected to contribute to an increase in investment costs. In general, one could say that as long as there are now major capacity constraints, costs and prices should be related to each other. However, if such constraints do appear, this linkage is bound to be much less pronounced.

The aim of this study is to take a brief look on the major links between the commodities and energy. More specifically, we try to estimate how important energy prices are for commodity costs and vice versa, whether increased commodity prices can be expected to influence the specific investment cost of power plants significantly and if so, what impact this may have on the competitiveness of different technology options.

2. Commodity price developments and links to energy

There exists a bidirectional link between the prices and costs of energy and other commodities. Although there are clear differences between commodities, the production of them usually requires considerable amounts of energy, the applicable energy carriers and amounts of energy depending on the final product and the production process used. On the other hand, energy prices depend on a number of things, including the costs of the production facilities and the necessary infrastructure connected to these facilities. These facilities, in turn, need to be constructed and therefore material costs play a role on the investment costs of such facilities (oil production, gas pipelines, power plants etc). The variable costs of energy production are, however, less likely to be struck by increases in non-fuel commodity prices and therefore a non-fuel commodity price increase is unlikely to lead to an immediate increase in energy conversion costs[1].

In this section we take a brief look at the energy cost component of some chosen non-fuel commodities, mainly metals, and try to establish an approximation for the magnitude of this component. We furthermore summarize some existing sources for estimates on near future commodity price developments.

2.1 Approach and findings

In this following we will focus on estimating the energy component for a set of commodities that could be expected to contribute to the construction costs of a power plant. We approach the problem from a bottom-up perspective and use literature sources to estimate the quantity and quality of energy needed for producing a unit of commodity. Comparing the contribution of this energy cost to the total production cost, or the market price, of the commodity should give an indication on how sensitive the price of the said commodity is to a change in energy prices. For the main commodities to be studied, we have chosen steel, copper, aluminium and concrete. While some conversion technologies, such as photovoltaic (silicon), might be more reliant on the prices of some other materials, most of the large scale power plants being built today depend mainly on these materials.

We conclude this chapter by taking a quick look on literature that presents some projection made for the near future. Since the circumstances have changed extremely rapidly during the past 6 months and the basis of many of the projections done previously has changed, we will restrict this section to a couple of sources and not expand the section into a full literature survey. Nevertheless, the estimates made during these times of rapid change still show, if nothing else, at least the uncertainty concerning the movements of global economy and how that may impact the demand of the main commodities.

Steel

The main methods for steel production are basic oxygen steelmaking (BOS, or BOF from basic oxygen furnace) and the process based on electric arc furnace (EAF). While BOF is the most common process used for producing steel from iron ore, around 40% of the steel production is based on recycled steel, for which the electric arc furnace is the main technology. The quantity and quality of energy required for these different processes differ and therefore they're likely to be affected differently with increasing fuel and/or electricity prices.

The main energy flows for the blast oxygen steelmaking are some 0.7 tons of coking coal and 0.13 MWh of electricity per ton of crude steel produced. A process relying on recycled steel and

[1] However, it's quite possible, even likely, that when demand for commodities and energy both increase due to high economic growth, the prices also increase simultaneously.

electric arc furnace has a higher material cost, scrap steel being more expensive than iron ore, but no coal is required as an input. The amount of electricity required, however, is some three times BOF consumption, approximately 0.4 MWh per ton of crude steel[2]. Therefore, the energy component of the costs would be[3]

$$c_{energy} = c_{coal} \cdot Q_{coal} + c_{elec} \cdot Q_{elec} \tag{1}$$

Where the *c* refers to specific cost ($/ton of crude steel for total energy costs, $/ton for coking coal and $/MWh for electricity) and *Q* to the corresponding consumption of energy carriers needed for producing a ton of crude steel. For electric arc furnace, the Q_{coal} is 0 and therefore the energy component is a function of the electricity price alone. Figure 2.1 shows the cost of the energy component as a function of the coking coal and electricity price.

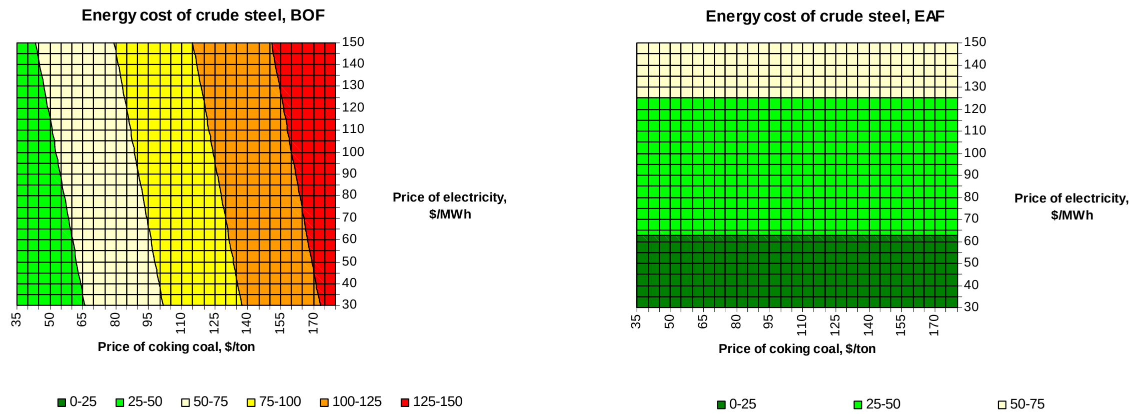

Figure 2.1 *Energy costs of crude steel production as a function of electricity and coking coal price*

As Figure 2.1 shows, the energy costs are generally higher when BOF and iron ore is used. However, a combination of very high electricity prices and low coking coal prices could of course change this. It's useful, however, to emphasize the fact that although oil and coal prices are often quite global, gas prices and electricity prices are much more local. Since commodities such as steel are globally traded, impacts of locally increased electricity prices may be more difficult to project on the prices of commodities, if there are no global reasons for the said increase.

As mentioned above, the price of electricity varies considerably based on the region where the electricity is being produced. The portfolio of production is quite different in different countries and while in some fuel price changes might have little to do with the electricity production costs (e.g. if the share of hydro and/or nuclear is high), in others the situation might be completely different (if gas and coal play a key role in the power sector). Furthermore, even if the power system would be based on non-fossils, in a liberalized market power plants providing the marginal production, and therefore determining the spot market price, might still be fossil fuel fired. Since there is such a wide variety of electricity systems and markets, we do not go further into details concerning the linkage between power market prices and increased fuel costs. However, it's important to keep in mind that no matter the region, if other energy costs increase, it is likely that so do the electricity generation costs.

In addition to the regional power production portfolio, also industry related tax decisions and other local policy decisions may play a key role in this. For example, according to EIA (EIA,

[2] Exact numbers taken from http://www.steelonthenet.com/steel_cost_bof.html and http://www.steelonthenet.com/steel_cost_eaf.html.

[3] Other, clearly smaller energy flows are not taken into account, nor are any energy costs related to the mining and transport of the materials.

2008a), the price of electricity for industry (including taxes) in Norway was some 43 $/MWh in 2006, while the neighboring Finland had some 85% higher prices, 70 $/MWh, despite the fact that both countries participate in the same liberalized electricity market. The price for the industry in the Netherlands was clearly higher, some 95 €/MWh, about 70% above the price in Finland. (Eurostat, 2006). These large differences emphasize the effect local conditions have on the energy costs and underline the competitive edge countries with low energy costs may have on the global commodity markets.

Coal, on the other hand, is traded internationally[4]. In the US, the coke coal price went from some 43 $/ton early 2001 to almost 180 $/ton at its peak in 2008. During the last months of the year coal spot price has dropped back to some 100 $/ton. (EIA, 2008b).

The range of energy costs depicted in Figure 2.1 go from 15 - 60 $/ton of crude steel for EAF and 30 - 150 $/ton of crude steel for BOF. Using the peak coal prices and electricity price of 120 $/MWh (close to the Dutch price early 2006), we get from equation 1 energy costs of 48 $/ton of crude steel for EAF and 140 $/ton of crude steel for the BOF. Since the peak steel prices were around 1000 $/ton, energy costs at the peak would be some 5% of the price for EAF and 14% for BOF.

If energy prices were for some reason very high at the same time as steel prices were low, would this share naturally be higher. For example, current steel prices are around 300 $/ton and since the electricity prices are not quite as affected as other prices, the shares can be quite different. Using the same electricity prices as above, but coal price of 100 $/ton, with the steel price of 300 $/ton the share of energy costs of the price is 16% for EAF and 28.5% for the BOF.

Figure 2.2 presents how the energy cost share of the steel price (y-axis in Figure 2.2) changes as a function of energy prices (shown as an index on the x-axis), steel price (the lines for steel prices of 300 $/ton and 1000 $/ton in Figure 2.2) and the process used for producing the steel (the dashed lines for EAF and solid lines for BOF in Figure 2.2).

The indexed energy prices shown on the x-axis of Figure 2.2 have been chosen such that that the index 2 corresponds to the peak energy prices for the needed energy carriers and the index 1 therefore to prices half of these (i.e. 120 $/MWh for electricity and 180 $/ton for coal during the peak (index value of 2) and 60 $/MWh for electricity and 90 $/ton for low energy prices, represented by the index value of 1).

[4] However, as with electricity, the local tax regime can cause the final price for the industry use to differ.

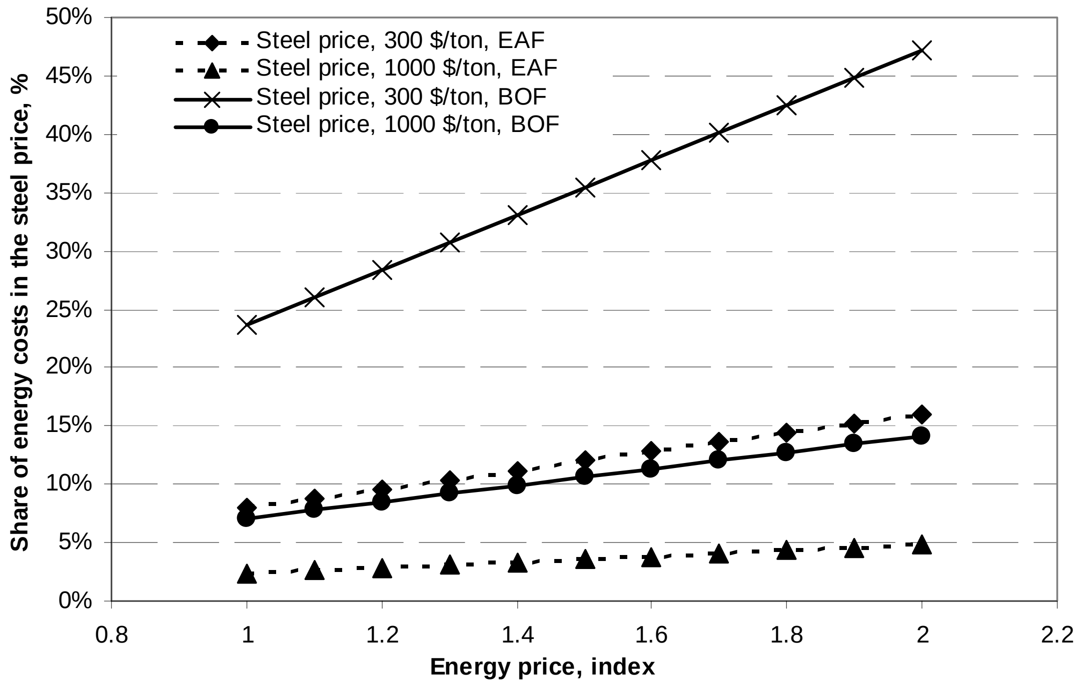

Figure 2.2 *Share of energy costs in the steel price*

Copper

Producing a ton of copper takes some 0.3 tons of fuel oil and approximately 1.65 MWh of electricity. Price of residual fuel oil was ~ 0.5 $/gal early 2000, 0.7 $/gal early 2005 and 1.8 $/gal early 2008. This would give a cost range of approximately 44 - 159 $/ton of copper. Using the electricity price of 120 $/MWh, the additional energy cost from electricity consumption would be 200 $/ton of copper. Using the peak values, these numbers would translate to total energy costs of 360 $ for a ton of copper. If the oil price is assumed to be half of what it was in early 2008, the total energy costs would be 280 $/ton. The copper price peaked at almost 8500 $/ton, but is currently closer to the level it has been on in the past, around 3500 $/ton. The energy costs would., with the above fuel prices, be a bit below 10% of the market price, whereas during the peak of copper prices the share would've been approximately half of this with the same energy costs (as is shown in Figure 2.3).

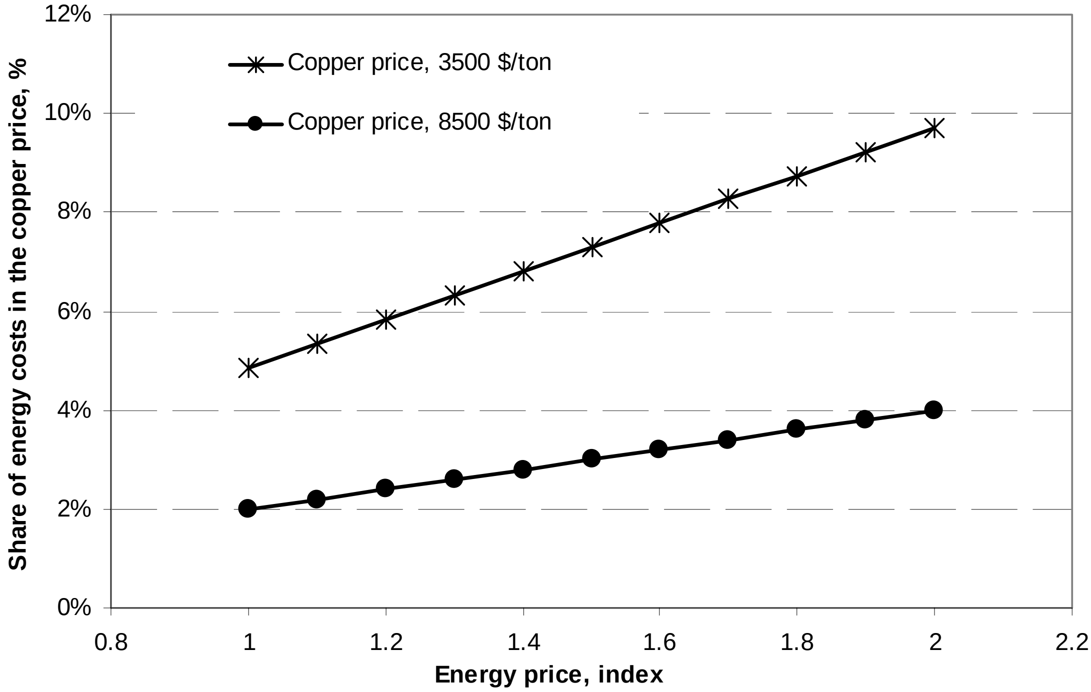

Figure 2.3 *Share of energy costs in the copper price*[5]

Aluminum

Production of aluminum requires a large amount of energy and since this energy is in the form of electricity, the impact of energy costs is high for the aluminum production costs. Producing a ton of aluminum takes some12 to 15 MWh of electricity, translating to a cost of 1440 to 1800 $/ton, if the electricity price of 120 $/MWh is used. Using the Norwegian cost of 43 $/MWh would lead to a range of 516 - 645 $/ton of aluminum.

Since 2006 and until very recently, the price of aluminum was around 2500 to 3000 $/ton. However, for years before that, and currently again, the price is considerably less, about 1500 $/ton. Looking at the energy costs calculated above, it seems clear that the combination of fairly high electricity costs and low aluminum prices can not be combined; using the electricity price of 120 $/MWh the energy costs would be higher than the current market price. Therefore aluminum production is often located in countries where cheap electricity is plentiful and cheap. During the high price peak for aluminum, energy costs calculated using the price of 120 $/MWh would've covered half of the market price, while even during the current lower prices the Norwegian 43 $/MWh would have a lower share than that. See Figure 2.4. for a summary (index 1 refers to electricity price of 60 $/MWh. Electricity consumption of 13.5 MWh/ton of aluminum is used for the calculations behind the figure).

[5] Energy price index 1 corresponds to half of the peak prices, i.e. 60 $/MWh for electricity and 0.9 $/gal for fuel oil.

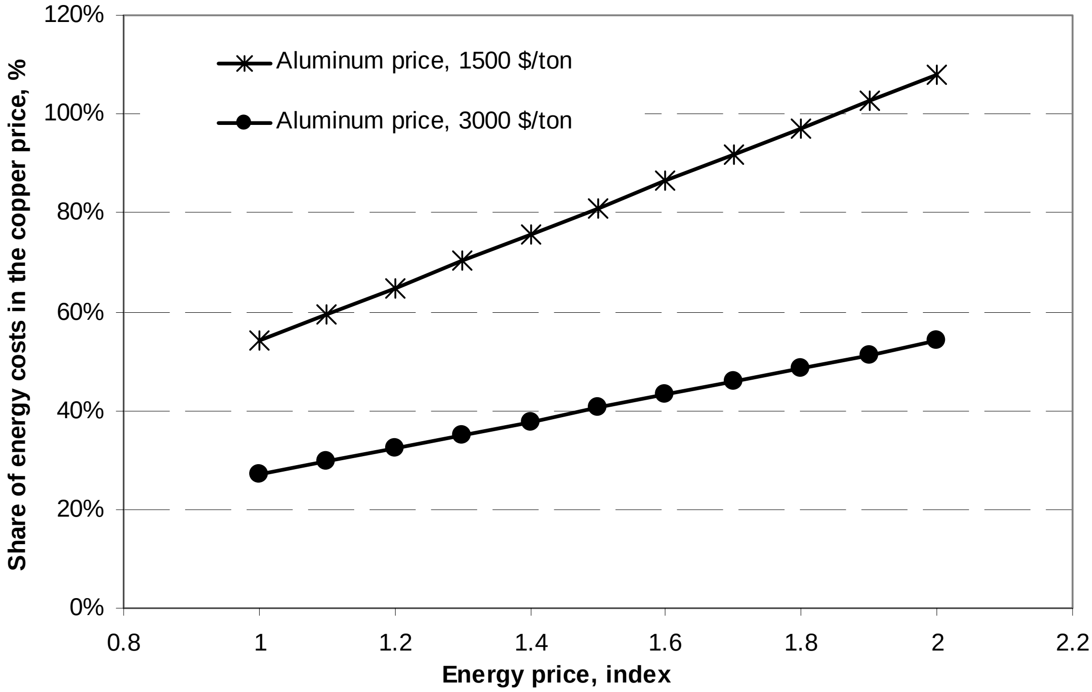

Figure 2.4 *Share of energy costs in the aluminum price*

Cement
Average specific energy consumption for cement production is around 4 to 5 GJ per ton of cement. The main fuels used are coal and gas, although other energy carriers are also required. According to Canadian data (on average) some 40% of the fuel used was coal, 20% gas, 10% electricity and 15% coke (rest waste fuels and little bit of heavy fuel oil).

As electricity, also the price of gas is very location dependent. In the US, natural gas prices peaked at some 13.5 $/MMBTU, but has recently dropped to 5.5. $/MMBTU (12.8 $/GJ to 5.2 $/GJ). Prices in 2000 were still lower, around 4.23 $/MMBTU (4 $/GJ). Price for hard coal was around 33 $/ton in 2000, peaked at 165 $/ton and is currently around 100 $/ton (using the heating value of 35 MJ/kg, this range is approximately 1 $/GJ to 4.7 $/GJ, current price being bit below 3 $/GJ).

Assuming the price of 120 $/MWh for electricity and using the above fuel shares to calculate an average[6], we get an energy cost range of some 5 to 10 $/ton (~ 25 - 50% of the market price of 85 $/ton). Figure 2.5 below shows this for specific energy consumption of 4.5 MJ/ton of cement and, as before, energy prices reaching half of the peak prices receive the index value of one.

[6] For simplification, we have added coke to coal and the other fuels to coal and gas, based on the shares these two fuels have

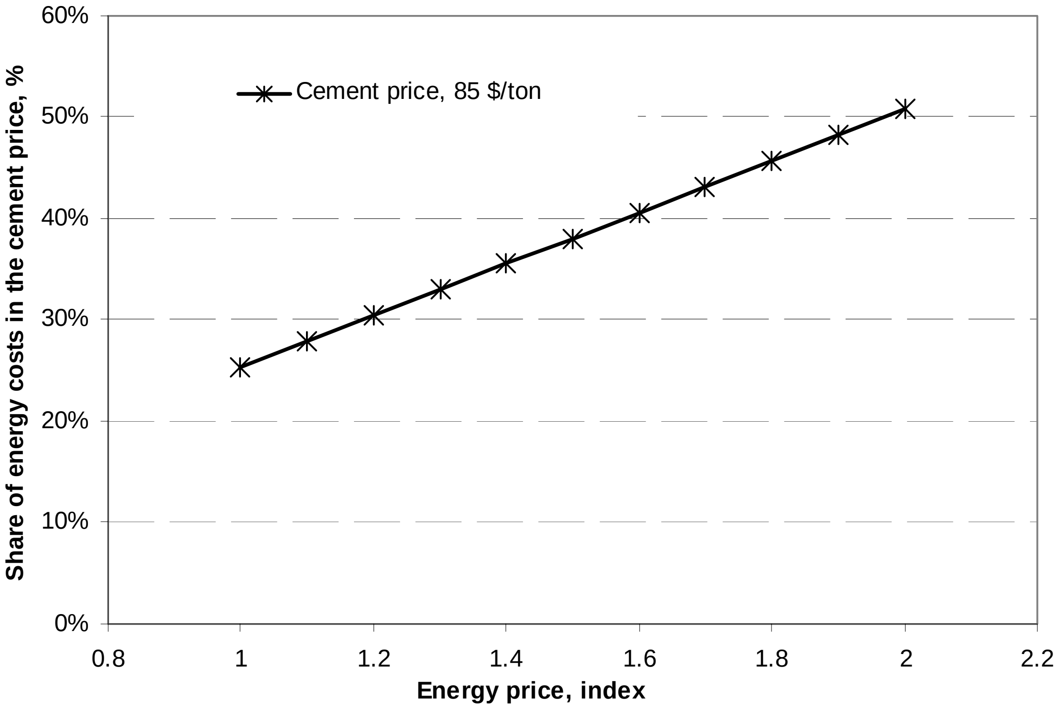

Figure 2.5 *Share of energy costs in the cement price*

Commodity price projections for the near future
Commodity prices have often been notoriously difficult to project - not only do the prices often follow (to an extent) general economic trends, the exact turning points of which are difficult to assess, but different commodities also have additional different drivers, the developments of which also need to be taken into account. In this section we summarize two short term projections, one from IMF and another from using market data.

In its World Economic Outlook IMF projects commodity prices for the next year. The most recent World Economic Outlook was published in October 2008 (IMF, 2008a). In this report IMF projected that metal prices would in 2009 (year over year) drop 8.2%, slightly more than the 6.2% projected for all nonfuel commodities[7]. Oil prices were expected to be 6.3% below the levels of 2008 in 2009. However, no more than a month later, in November, an update to the Outlook was published (IMF, 2008b), including new set of projections for a number of economic indicators. This update was produced, since the financial crisis had changed the basis according to which the forecast published merely a month before was based on.

The November update does not include separate projections for metals, but only for nonfuel commodities as a single group. The price of this basket of commodities was now expected to go down 18.7% in 2009, almost three times as much as projected previously. Furthermore, if one assumes that the relationship between metal prices and prices of other nonfuel commodities remains in this forecast similar to that of the October one, metal prices can be assumed to go down even more than the 18.7%. For oil prices the change was even more dramatic; instead of the former 6.3% drop, the forecast now predicts a drop of almost 32% for 2009. This emphasizes the difficulty of making any projections that would not mainly rely on things progressing fairly continuously and without discrete events, which also the current financial crisis can be interpreted to be an example of.

Although commodity future prices are generally not considered to be very good predictors for future price movements (Chen et al, 2008), they do represent the view of the markets and there-

7 Calculated as an average based on world commodity export weights.

fore, in a certain way, "best available information" at the time. Using the data from The London Metal Exchange (data from end of December, 2008), prices for steel futures for 15 months are around 350 to 450 $/ton, depending on the region (current price at the same exchange 325 - 360 $.ton). For aluminum the price for 15 months is approximately 1630 $/ton (current price 1450 $/ton) and for copper 3000 $/ton (currently 2900 $/ton). These numbers would indicate that it is not expected that the price would significantly increase during the next 15 months, although a further price drop seems also unlikely.

Based on both of the projections summarized here, it does appear that clearly lower prices are expected for the near term than were experienced in the recent past. However, since the ongoing financial crisis has made all projections increasingly difficult, also these projections can potentially change even very quickly.

2.2 Conclusions

The energy cost component is significant for many commodities (5 - 15% of the market price, even more under unfavorable conditions concerning energy prices and commodity prices) and for some, like aluminum and concrete, it can even be considered to be dominating. Since many of the commodities require the use of fuels for which the prices are not global (e.g. electricity, natural gas), the exact numbers are highly dependent on the specific location of the production facilities. This importance of the local "energy environment" can be observed, for example, with aluminum, for which the production plants often can be found in locations with lower electricity costs.

However, although energy prices clearly have an impact on the commodity costs, increases in the commodity prices are not consequences of the increased energy costs alone. There also exists a link in the other direction; increased commodity costs imply higher construction costs for energy infrastructures. However, this linkage is much less clear, since power generation structures have long lifetimes and therefore higher investment costs don't necessarily show as higher electricity prices until much later. In the next chapter we try to assess, using simple LCA (**L**ife **C**ycle **A**ssessment) based material flows, the magnitude these increased commodity prices might have on specific investment costs of power plants.

Projections for near future commodity prices seem fairly cautious, generally expecting the prices to remain close to the current low levels also next year. The general uncertainty concerning the near future global economic situation means that the current projections might very easily change yet again.

3. Impact of commodity prices increase on investment costs of power plants and energy policy implications

In this section we turn our focus from determining how increased energy costs might affect commodity prices, to how the causality works in the other direction, i.e. what kind of impact increased commodity prices might have on power plant investment costs.

During the recent years, investment costs of power plants have been reported to have risen considerably. This increase has happened at the same time while commodity prices have also surged. Since building a power production facility of any kind requires large material inputs, it can be safely said that increased commodity prices lead to an increase of specific investment costs required to build a plant. However, since commodity prices are not the only possible explanation for increased investment costs (e.g. increased labor costs, bottle necks in production capacity of components and producers benefiting from this mismatch between supply and demand etc can also increase costs), it is unclear whether the increase in commodity prices explains most of the increase in the power plant investment costs, or is there (mainly) a correlation, not a causal relationship, between the developments of the two.

3.1 Approach and findings

Approach

Our starting point is the hypothesis that if a large proportion of the investment cost increase of a power plant increase is caused by increase in the material costs, comparing the raw material costs alone for a typical power plant should already show this. We use LCA based data (ECOINVENT, 2003) for a couple of illustrative power plants, together with the increased metal prices, and based on this define how much more the materials needed for the power plant cost and how much this alone would contribute to a specific cost increase of a power plant. That is, if the price for material now is p_t, the price used to be p_{t-1} and the quantity of the material required per unit of production capacity is q, then the material cost increase alone would increase the specific investment cost by:

$$q \cdot \left(p_t - p_{t-1}\right) \qquad (2)$$

If this is done for the main materials[8] required during the construction of the power plant and the cost increases derived do not explain the increases in investment costs, the conclusion should be that also other elements contribute significantly to the investment cost increase.

Results and conclusions

We will concentrate our focus here on a couple of different power plants; a gas combined cycle power plant, a hard coal fired power plant and a wind power plant[9]. The reference plants used for deriving the data are fairly large, 400 MW_e for the combined cycle plant, 2 MW_e for the wind power plant and a combination 460 MW_e for the coal power plant[10]. The main material requirements for four different power plants are shown in Figure 3.1 (ECOINVENT, 2003). In addition to what is shown here, materials such as rock wool, plastics, rubber, small amounts of

8 Since not all material flows, for example plastic, are included, the actual price increase would be higher than calculated here. However, the order of magnitude, our key focus, would not be different.

9 Data for a normal gas power plant is shown as well. For the following analysis, however, the combined cycle plant is chosen as a better representative of new gas fired power plant capacity.

10 In the case of the coal power plant, material flows of a 100 MWe and 500 MWe power plant are considered and the actual numbers given are a combination of these two reference plants, with the weight of 90% given for the larger plant and 10% for the smaller one, reaching the average of 460 MWe.

other metals (e.g. nickel, chromium) are needed. However, since most of the other flows are modest and our focus in this study is on the main non-fuels, we will focus our cost analysis on concrete and the three metals shown in Figure 3.1.

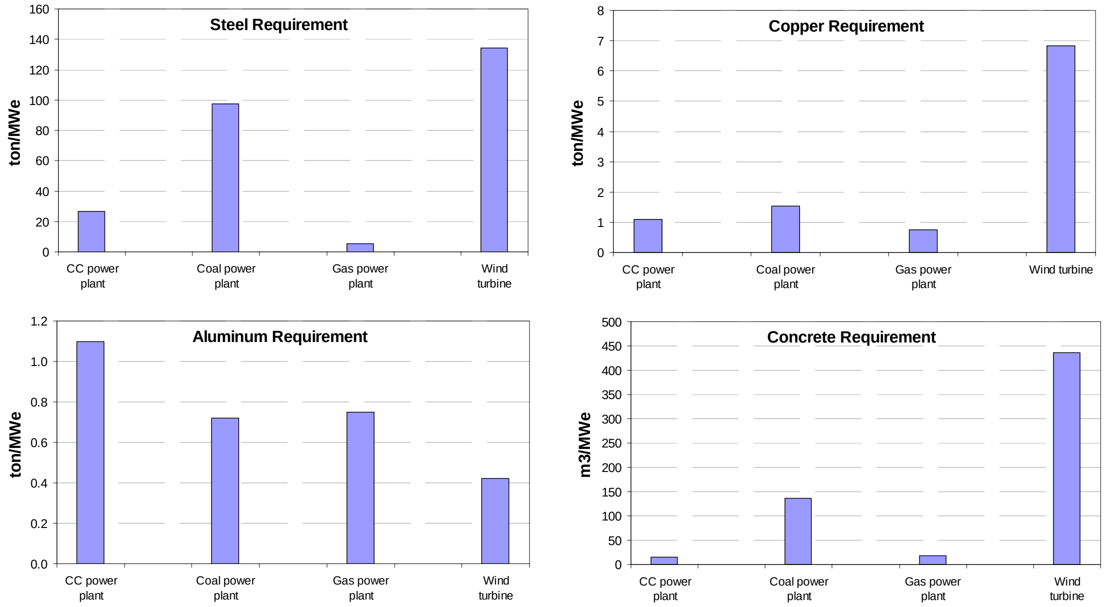

Figure 3.1 *Main material requirement of chosen power plants*

As Figure 3.1 shows, one can immediately conclude that the wind power plant is likely to be the most sensitive of the three to material cost changes; it has the highest steel, concrete and copper requirements per unit of output and these two metals are likely to impact the investment costs much more than aluminum.

Using the material flows shown in Figure 3.1 together with the on and off peak prices documented in previous section[11] (i.e. the prices at their peak in 2008 and the prices that are closer to long term values, either in the past or now after the prices have come down again), we calculate how much the specific investment cost of the three power plants would change, if only these costs were to be increased. The results are shown in Figure 3.2.

[11] For concrete we use value a low cost of 100 \$/ton and a peak cost of 140 \$/ton. Density of concrete is assumed to be 2400 kg/m^3.

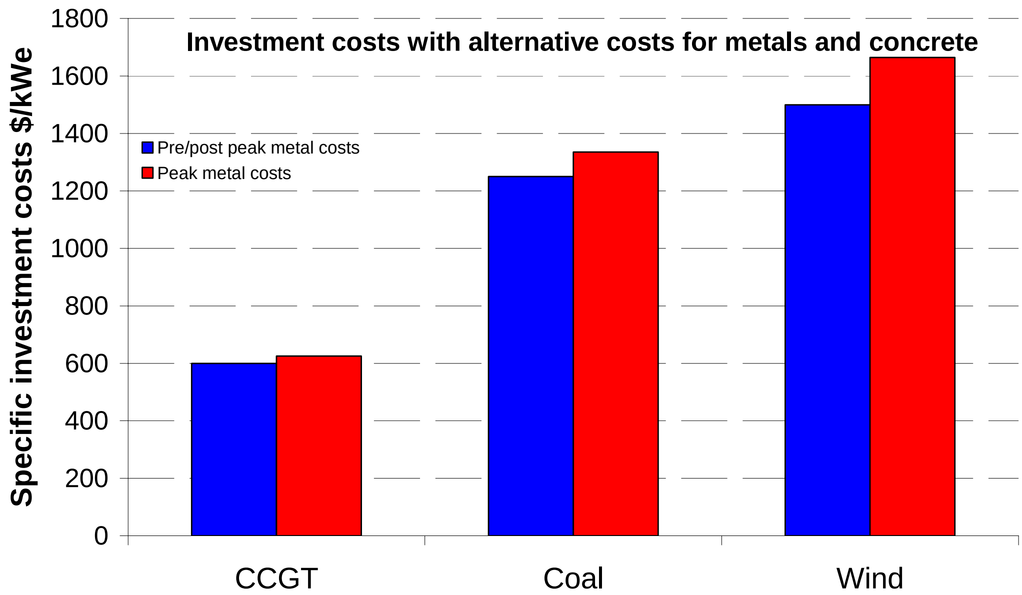

Figure 3.2 *Impact of material costs for specific investment cost of a power plant*

As Figure 3.2 shows, the cost increase that results from the increase in material cost alone can not explain very large increases in power plant investment costs. In the calculations made for Figure 3.2, the metal prices were at least doubled, almost tripled for steel, and still the steepest increase was the 10.9% for the wind power plant. Combined gas power plant and coal power plant had their prices increased by 4.3% and 6.8% respectively. For all the three power plants, steel is responsible for at least 50% of the investment cost increase. If all materials were included, the numbers would be slightly higher, but since most important flows are accounted for, the changes would be marginal.

The results presented in Figure 3.2 indicate that the increased specific investment costs experienced recently follow not only from increased material costs, but also other contributing effects must happen simultaneously. Such effects, for example labor costs and bottle necks in production capacity for power plant components, may be also related to high economic growth, as also increased commodity prices often are.

The results here also seem to imply that due to the fairly long lead times, increased nonfuel commodity prices do not, as such, lead to increased energy prices (i.e. if commodity prices remain at very high levels for very long, costs for resource extraction, transmission etc may increase, when new capacity is built and old capacity is retired). It is of course quite likely that high energy prices coincide with high commodity prices, since both often emerge during periods of high economic growth, but if the economic growth is the true underlying force that creates the price hikes, then there would be no direct, immediate causal relationship that would cause energy prices to increase as a result of high commodity prices.

In the other direction, however, the causal link is clearer, since high energy prices do have a very direct impact on some commodity prices (see previous section). Even in this case, though, for most commodities the major share of the costs come from elsewhere, therefore softening the impact of high energy prices alone on the total costs (similar conclusion was reached in Manders and Veenendaal, 2008). Furthermore, since many of the main energy carriers are traded globally, the competitive position of a regional industry should not change too dramatically. Regionally asymmetric factors naturally could change this (e.g. if energy prices increase only in certain places or if stringent emission quotas are implemented only in certain geographical areas.

Fuel prices naturally do have a big impact on the competitiveness of energy conversion technologies, both new and existing. Using the range of fuel prices from previous sections and the range of investment costs shown in Figure 3.2[12], the total production costs ($/MWh) for the coal power plant would be 36 to 72 $/MWh, 42 to 106 $/MWh for the gas plant and 55 to 61 $/MWh for the wind power plant[13]. Concerning the economic performance of the power plants against each other, the wind power plant is the cheapest option with high fuel prices and coal power plant with low ones. If prices are in between, gas power plant is the cheapest. Panel a) of Figure 3.3 summarizes the levelized production costs.

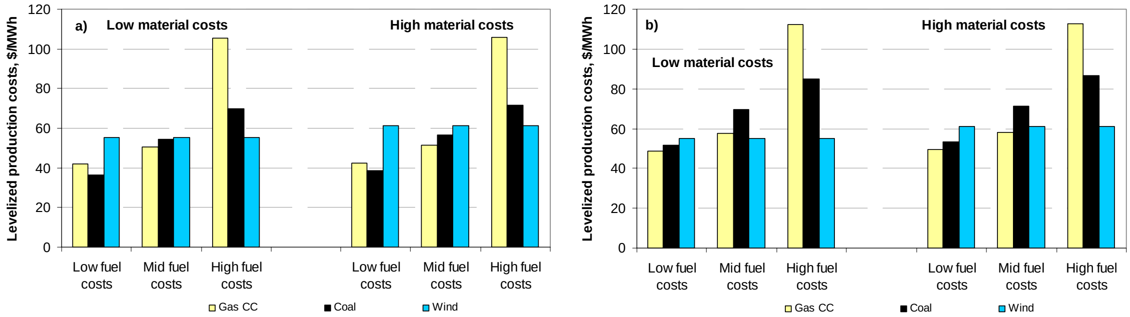

Figure 3.3 *Levelized electricity production costs as a function of fuel and material costs, without (panel a) and with (panel b) emission costs*

The numbers in Figure 3.3, panel a), would, however, change, if a cost was also assigned to the emissions that are being emitted. If we assume carbon content of coal to be about 300 kg/MWh and that of gas some 170 kg/MWh, we get carbon emissions of 0.75 tCO_2/MWh_e for coal and 0.34 tCO_2/MWh_e for gas. Using an emission price of 20 $\$/tCO_2$, this would translate to an additional cost of 15 $\$/MWh_e$ for coal and 6.8 $\$/MWh_e$ for gas, making wind clearly more competitive.

Since it seems that commodity prices do not have a big impact on the investment costs of power plants, it also appears that there should not be a major impact on the competitiveness of different power production technologies or on energy policy as a whole. High commodity prices do seem to coincide with increased investment costs, but based on the analysis done here, the other contributing factors seem to play a bigger role and therefore have a larger influence also from the energy policy perspective; for example, if the bottle necks in the production capacity of power plants is the main cause for the increased investment costs, any measures made to remove these bottle necks would have a more relevant energy policy impact than actions directed at commodity prices themselves.

[12] Economic lifetime of 25 years and a discount rate of 10% is assumed. Efficiency is 50% for gas and 40%for coal.
[13] Most of the cost range comes from fuel price differences, as the small range given for the wind power plant already implies.

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