Efficient but sufficient support of all RES technologies in times of volatile raw energy prices

Christian Panzer[1], Gustav Resch[1], Ric Hoefnagels[2], Martin Junginger[2]
[1]Energy Economics Group (EEG), Vienna University of Technology
Gusshausstrasse 25-29/373-2, A-1040 Vienna, Austria
Tel +43-1-58801-37360, Fax +43-1-58801-37397
Email panzer@eeg.tuwien.ac.at
Web http://eeg.tuwien.ac.at
[2] Dept. Science, Technology and Society Copernicus Institute, Utrecht University

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Abstract

Increasing penetrations of renewable energy sources (RES) require both effective and efficient support schemes in order to keep additional consumer expenditures at a moderate level. A necessary precondition for the design of efficient RES support options is a precise forecast tool of future investment costs of RES technologies. Recent market observations have shown that not only technological learning influences RES technology costs but much more also volatile raw material prices hold a significant impact. Hence, this paper discusses the multi-factor learning curve approach for incorporation of steel price impacts on wind energy technologies, in particular wind onshore, into energy models. First results show a high correlation of the historic development of primary energy prices, especially coal prices, to the steel price and in last consequence to wind onshore investment costs. However, the historic development of wind energy technology prices can not only be described by the impact of volatile steel prices, as other parameters as market structure or power influence the investment price strongly, as well. Based on this result a qualitative discussion addresses the potential adjustments of RES support options in order to guarantee efficient but sufficient support of RES technology installations for investors and the society.

Introduction and background

In a European context, significantly increasing the share of renewable energy sources (RES) of gross final energy demand up to 2020 in order to meet the target (Directive 2009/28/EC) of 20% RES by 2020 is currently high on the agenda of European policy makers. This implies effective and efficient policy support measures whereas especially efficiency is determined by the real generation costs of renewable energy technologies versus the eligible total level of income from selling the produced energy [1]. Thus, an important parameter for efficient RES support schemes is the incorporation of expected evolution of generation costs of RES technologies. In this respect, historic energy models have only considered a dynamic development of technology investment costs, respectively generation costs, by taking into account technological learning based on cumulative production [2, 3].

However, recent market observations have shown volatile investment costs of several energy technologies in general, and RES technologies in particular. At the same time energy and raw material prices showed a comparatively high level of fluctuations. Consequently, it is the aim of this paper to identify and elaborate on key parameters (besides those associated with the well-established concept of technological learning) that influence the evolution of investment cost for RES technologies. Therefore, the approach of determining the future development of overall RES investment costs is discussed in detail and derived results are depicted, serving as a basis for further research in this field.

In general, this paper focus exemplarily on wind onshore technology although it is only one among many which shows the discussed impact of energy and raw material prices on RES investment costs (see Yu et al, 2010 [4] for Photovoltaics). Besides energy and raw material prices, several other parameters, as market power and strategic pricing, have had important impacts on technology investment costs but are beyond the scope of this research. The key driver of raw material prices with respect to wind onshore investment costs in the recent past has been the steel price. Again, steam coal and coking coal prices have steadily been influencing the steel price development to certain extent. However, especially coking coal recently showed strong price increases due to mining capacity shortages which has not been reflected in the same extend in the steel price development.

Figure 1 depicts above mentioned relations between historic observations of the coal-, steel- and wind onshore investment costs. Thus, in 2001 the decreasing steel price was also noted in decreasing wind investment costs whereas an increasing steel price in 2005 has led to higher wind investment costs. However, in certain years as 2008, a strongly increasing steel price did not affect the wind investment costs similarly, mainly caused by two events. The increase in the steel price was driven by the strong global economic growth before the crises whereas wind investment costs have peaked in the years before due to a high demand on wind onshore technologies, caused by favorable RES support schemes, accompanied by manufacturing shortages. Hence, not every change of investment costs can solely be explained by volatile raw material prices but certainly there is an empirical evidence of a strong impact of raw material prices on RES technology investment costs.

Moreover, linkages between the historic coal price and the historic steel price development (in Euro 2006 values) become obvious from Figure 1, since steam coal and coking coal are the main input parameters for steel-making processes, besides iron ore [5].

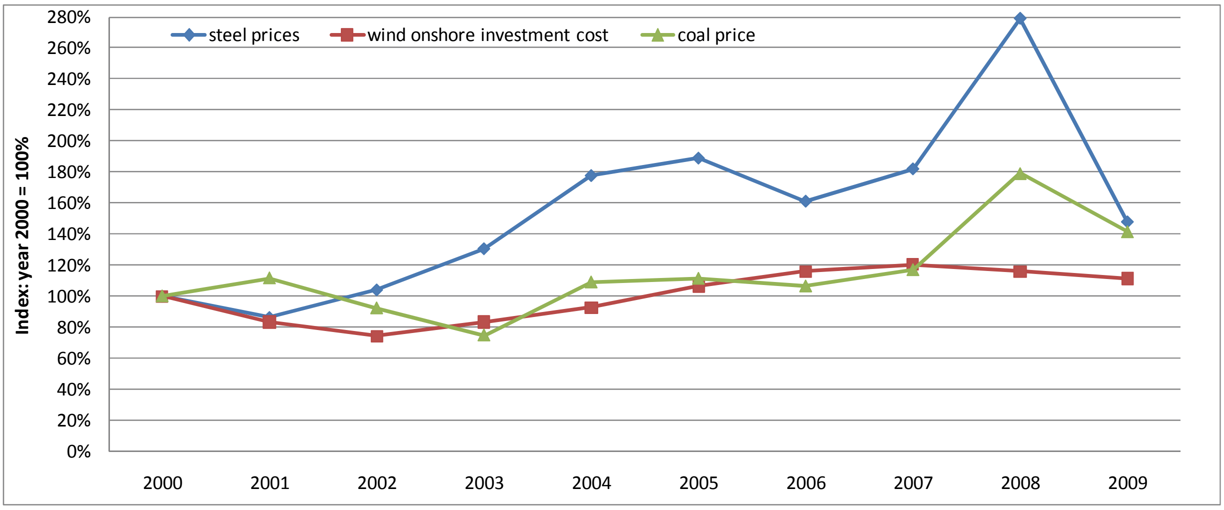

Figure 1 Relative, historic deployment of wind onshore investment costs (Source: EWEA, 2010), steel price (Source: Steel Business Briefing) and coal price development (Source: European Commission); Index year 2000 = 100%;

Methodology / practical implementation approach

The application of the simulation tool ***Green-X*** [6] allows deriving efficient and effective support schemes of RES technologies. The model ***Green-X*** has been developed by the Energy Economics Group (EEG) at Vienna University of Technology in the research project "***Green-X*** – Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market", a joint European research project funded within the 5th framework program of the European Commission, DG Research (Contract No. ENG2-CT-2002-00607). Initially focused on the electricity sector, this tool and its database on RES potentials and costs have been extended within follow-up activities to incorporate renewable energy technologies within all energy sectors. ***Green-X*** covers geographically the EU-27, and can easily be extended to other countries such as Turkey, Croatia or Norway. It allows to investigate the future deployment of RES as well as accompanying cost – comprising capital expenditures, additional generation cost (of RES compared to conventional options), consumer expenditures due to applied supporting policies, etc. – and benefits – i.e. contribution to supply security (avoidance of fossil fuels) and corresponding carbon emission avoidance. Thereby, results are derived at country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2020, accompanied by concise out-looks for the period beyond 2020 (up to 2030).

Besides the detailed RES technology representation, the core strength of the model is the in-depth energy policy representation. ***Green-X*** is fully suitable to investigate the impact of applying (combinations of) different energy policy instruments (e.g. quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, impact of emission trading on reference energy prices) at country- or at European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.

However, so far ***Green-X*** only incorporates dynamic costs developments based on cumulative production, whereas reference of cumulative production is laid on endogenous results for the EU27 countries and the IEA World Energy Outlook for the rest of the world. In the context of currently ongoing work, above mentioned, additional impact parameters as volatile energy and raw material prices are going to be implemented in the model according to the following approach:

In terms of raw energy prices the simulation tool ***Green-X*** refers to the European Commission published forecast scenarios until 2030 whereas wholesale energy prices are calculated endogenously in the model. Hence, dynamic investment cost changes of RES technologies based on volatile raw energy and material price will be derived from the exogenous crude oil, natural gas and coal price. In the case of onshore wind energy, a relation between the developments of coal respectively coke prices to the steel price has been derived using a regression approach based on empirical observations combined with scientific future expectations[1] [5]. Furthermore, the impact of the steel price on onshore wind investment costs is considered in a multi factor learning curve approach [7].

In this context, the multi factor learning curve has been implemented with only two factors, the impact of energy and raw material prices as well as technological learning based on cumulative production. Depending on the specific energy technology – in this paper wind onshore – the most important materials (steel price) is considered in the model, according to Eq(1).

$$c(x_t) = c(x_0) \cdot \left(\frac{x_t}{x_0} \right)^{-b} \cdot \left(\frac{CP_0}{CP_t} \right)^{LCP} \qquad \text{Eq(1)}$$

In Eq(1) the product of the first two terms represents a certain cost reduction based on technological learning with each doubling of cumulative installations ($\frac{xt}{x0}$) and the last term indicates the positive or negative impact (LCP) of raw material prices on RES technology costs, depending on the raw material price ($\frac{CP0}{CPt}$). In order to determine the impact factor (LCP) of steel prices on the wind onshore investment

[1] The currently high share of steam coal and coking coal in the steel-making process might decline over time according to a shift of the process (from BOF to EAF). Respectively the impact of increasing steel prices declines with higher coal and coke prices [8].

costs, a regression model was established and adjusted according to historic observations. Hence, the outcomes only reflect the impact of the steel price, but do not necessarily meet the real historic investment costs due to facts as strategic pricing, mentioned above. Consequently, the impact factor (LCP) holds a negative sign in every moment.

Results

First, an in depth discussion of the endogenous calculation of the steel price is given. Currently, two major steel-making processes are dominating the market, the Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF) whereas the BOF system still holds the higher share. Additionally, the BOF approach is much more energy intensive and depends strongly on coal and coke input and respectively prices but the EAF system, showing promising future market penetrations, uses high share of steel scrap and thus reduces the demand in coal and coke.

However, historic observations, see Figure 1, show a strong correlation between the coal price and the steel price development. In contrast, only a weak correlation between the coke and steel price development has been found, mainly due to strongly increased coke price in the last years caused by coke production shortages. Generally, looking at historic data from the year 2000, the relation between coal and steel price equals an exponential development, see Figure 2 but with an constant increase of the coal price, its impact is expected to decline caused by the above explained shift in the steel-making process. Using a regression line for historic data and adjusting it to future expectations according to scientific publications [5, 8], Figure 2 depicts the endogenously calculated relation between coal and steel prices applied in this research as well as the historic relation.

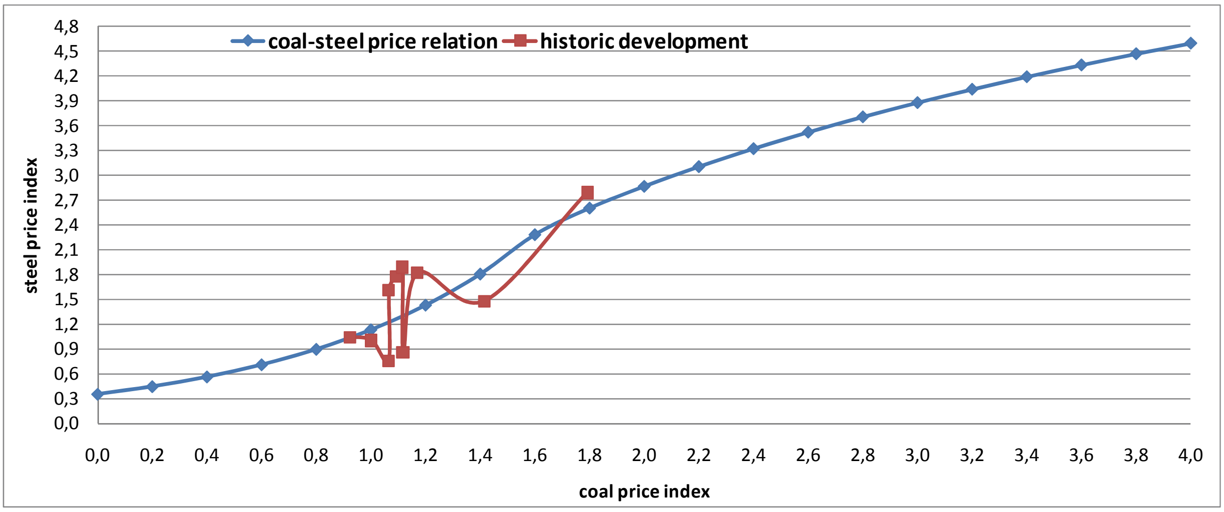

Figure 2 Relation between coal and steel price index according to historic observations and future expectations as well as historic records

Conducting sensitivity test of the identified approach, with two different sets of sources in different time periods resulted in a high match to the reported steel prices. Obviously, in certain time moments, a significant misinterpretation might occur, especially in times where coal and steel price have shown contrary changes caused by external effects as increasing demand or strategic pricing. Figure 3 depicts a significant mismatch in the year 2001 of the calculated steel price when the real steel prices decreased although coal price increased. This is in contrast to most other years where the price developments had the same sign.

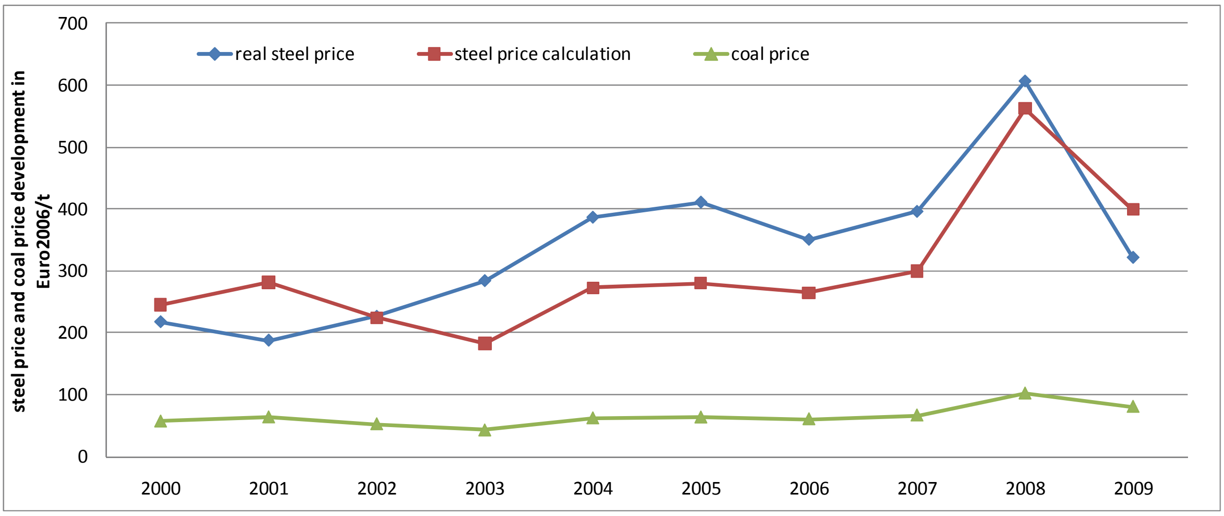

Figure 3 Historic development of steel price [9] and coal price [EC] in comparison to calculated steel price according to described approach

Next, based on the calculated steel price, its impact on future wind investment cost is analyzed. Therefore, the multi-factor learning curve approach is applied, by considering the dynamic change of the steel price compared to a start year. Figure 4 indicates the historic development as well as the model regression curve of the relation between the change in wind investment costs compared to the change in steel prices. In the recent past, most records have been done at negative $\log\left(\frac{CP0}{CPt}\right)$ (x-axis), since an almost constant increase of the steel price was noticed. Again, a plausible relation between steel costs and wind investment cost developments results in a negative sign for the logarithmic change of the steel price and in a positive sign for the change of wind investment costs, and vice versa. However, there have been certain years in the historic development which showed a different relation caused by other influences, as strategic pricing or high or low demand in one of the parameters. A detailed look at the regression curve points out, that increasing steel price only increases the wind investment costs to a certain extent, whereas decreasing steel prices have a higher impact on wind investment costs. This can be explained by varying steel alloys up to material substitutions in times of higher steel prices.

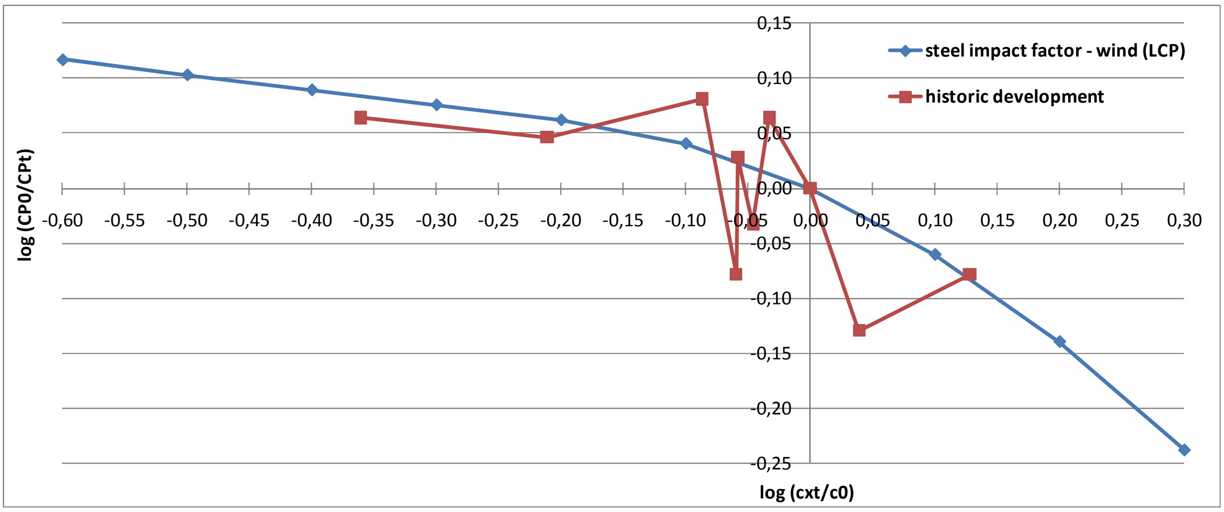

Figure 4 Historic relation between the wind investment costs and the steel price development as well as the mathematic regression used in the model for future development expectations

Finally, combining the two regression approaches and applying the two factor learning curve formula Eq(1), delivers estimates of the future development of wind investment costs. Figure 5 below depicts the result compared to the historic development on the one hand, and the future development only based on technological learning on the other hand. In both cases, a learning rate of seven percent (LR=7%) has been assumed as constant throughout the whole period. Additionally, steel prices have been considered as presented in Figure 3, derived from the approach depicted in Figure 2. With respect to historic observations, calculated wind investment costs do not totally match with real observation but show the same trend in significant magnitude. Again, it has to be noticed, that this approach does not aim to simulate the past, but solely allows forecast tools to incorporate the steel price influence. Hence, strong wind investment cost/price[2] increases between 2005 and 2008 were mainly caused by a high demand[3] of wind energy technologies and less available manufacturing capacities. However, the calculated wind onshore investment costs, illustrated in Figure 5, based on the two factor learning approach (2FLC) show high correlation to recently published future market expectations and form an adequate basis for models.

In this context, Figure 6 gives an overview of the relative development of coal and steel prices but, additionally, the corresponding dynamic development of wind onshore investment costs. Remarkable is the opening gap between the index of onshore wind investment costs at consideration of steel price impacts and without. In first years, volatile steel prices lead to a significant difference between wind investment costs only considering technological learning and those considering both influences. Additionally, in last later years, the gap stays constant, whereas the increasing steel price reduce significantly the improvements by technological learning, resulting in wind onshore investment costs of about 96% the price of 2000 in 2020, respectively 92.5% in 2030. Especially this effect becomes obvious, when comparing the years 2008 and 2015 in Figure 6 where an almost similar steel price level is expected, but resulting at different wind investment costs. Here, the effect of technological learning is almost totally compensated by the high steel price level in 2015. Hence, adjusting the technological learning rate by the effect of volatile steel price, the seven percent assumed learning rate (LR=7%), only equals the common technological learning approach at a learning rate of 1.7%.

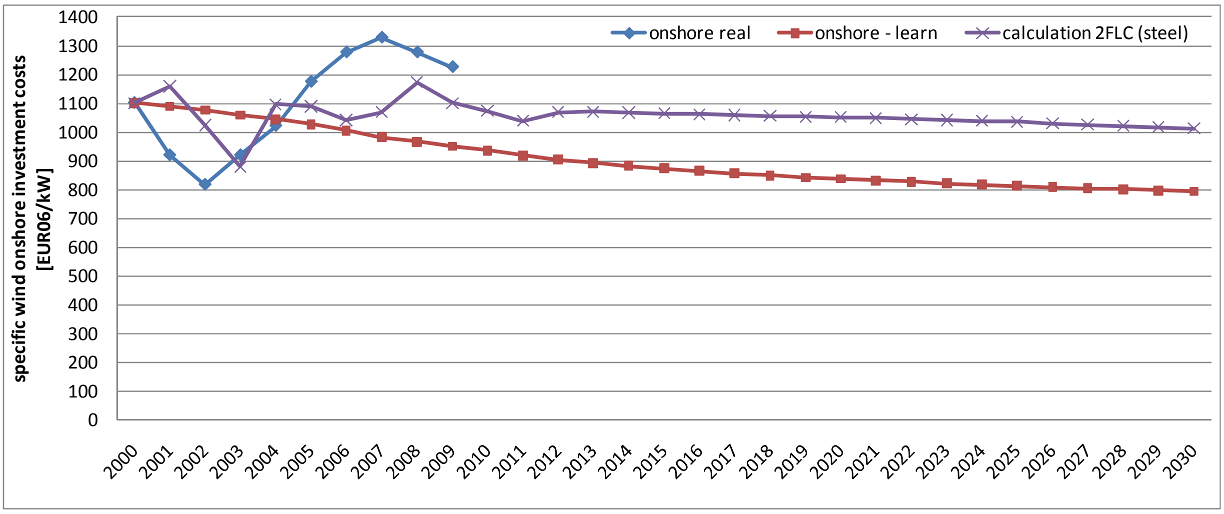

Figure 5 Specific wind onshore investment costs of real development (2000-2009) as well as future forecast based on technology learning (LR=7%) only and with consideration of steel price impact

[2] Historic observation of wind investments reflect the prices investors had to pay for the technology, whereas the calculated investment costs refer to real cost for the production of the technology regardless the market situation

[3] Favorable conditions for investors have been created in some of the EU27 Member States by implementing high support levels compared to generation costs, resulting in a high demand of wind energy technologies

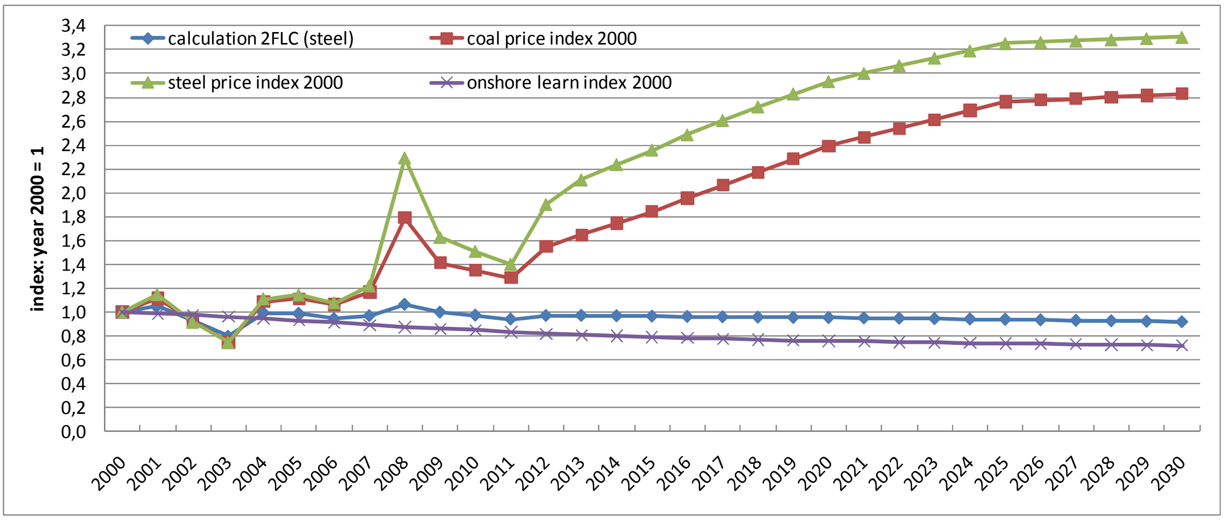

Figure 6 Indexes of coal and steel price (endogenous calculation) development for the period 2000-2030 as well as corresponding development of wind onshore investment costs, at technological learning (LR=7%) only, and with steel price consideration

Outline and conclusion

The conducted research has shown that volatile raw material prices have a significant impact on RES investment costs. However, raw material prices are not the only parameters which influence investment costs, since market power or strategic pricing play an important role as well. In order to derive precise future forecasts on RES investment costs, the impact of raw material prices will be included in the simulation tool ***Green-X***, but other parameters are beyond the scope of the model and have to be neglected. In order to enable endogenously linked raw material prices to primary energy prices, regression curves have been derived between historic coal and steel price developments, showing high correlation. Based on these results, the two factor learning curve approach is identified as the most suitable approximation in order to allow energy models to take raw material impacts on RES technology investment costs into account. Several sensitivity analysis of the approach, have shown appropriate correlations between historic observations on the hand and future expectations on the other hand.

In a next step, these results will be implemented in the simulation model ***Green-X*** allowing modeling the impact of adjusted investment costs on consumer expenditures. Furthermore this allows to shape RES support schemes according to varying market prices and thus, resulting in more effective and efficient RES support options. In this context, for efficient and effective RES support schemes, not only a too high levels of support result in a low efficiency of the overall support scheme, but also insufficient levels of support schemes are dangerous since only limited installations of RES will be realized due to the missing incentive for investors. Therefore, it is the task to bridge the path between too high financial incentives and consequently increased consumer expenditures and too low incentives with only moderate additional RES installations. Consequently, support schemes of RES technologies can be reshaped by taking into account, besides the technological learning effects, also the influence of raw material prices. On the one hand, empirical evidence of this linkage between market prices of RES technologies and RES support schemes is given by the adjustment of the renewable energy law in Germany in 2009, increasing the level of support for wind according to increased technology prices. On the other hand, the Spanish government reduced the tariffs for Photovoltaics recently due to the decreased investment prices of Photovoltaic modules.

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