Setting baselines for the new market mechanism:

Examples from the power, cement and buildings sectors

Discussion paper

30 November 2012

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This paper was written for the German Federal Environment Agency (UBA) as part of the project titled “Design of the post-2012 climate regime: Sectoral approaches for greenhouse gas mitigation” (FKZ3710 41 134). This project is being carried out by Öko-Institut (coordination), Perspectives GmbH and the University of Zurich (IPZ).

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Summary

The establishment of a new market-based mechanism (NMBM) for the climate change regime post-2012 was decided upon in December 2011 during COP17 in Durban, with a view to defining its modalities and procedures during 2012. One of the crucial design elements to consider when establishing market-based mechanisms is the definition of a reference scenario or baseline for setting emission targets and calculating emission reductions. In this paper we consider approaches for setting baselines for a sectoral-level NMBM (sectoral crediting or sectoral trading). We define the baseline as the expected development of greenhouse gas (GHG) emissions under the assumption that no new mitigation measures would be taken, i.e. under a business-as-usual scenario.

We first review the literature on the different design components of baselines: scope or level of aggregation, reference data, dynamics and updating, metrics, conservativeness and stringency level. Then we present a set of evaluation criteria for assessing the appropriateness of different baseline designs for a NMBM: environmental integrity, transparency, flexibility and data requirements. We present and discuss possible sectoral baseline designs for three economic sectors: power, cement and buildings. The baselines are developed on the basis of aggregated historical sector-level emission trends, data on sector composition (e.g. fuels and technologies used, products, geographic specificities) and future demand projections. The selection of sectors allows the complexities of setting baselines in sectors with large-scale installations (power and cement) and in those with dispersed installations (buildings) to be considered. It also allows assessment different design possibilities for cases where sectors comprise heterogeneous technologies and installation types. Both absolute and indexed baselines are considered, and they are compared to potential emission targets for the sector. We rely both on extrapolations of historical emissions paths and more complex projections of emissions on the basis of regressions on important emission drivers to estimate baselines up to the year 2030. We also discuss more complex modelling tools that have been used, e.g. in the buildings sector.

The results show that data quality and the transparency of assumptions are crucial for setting a realistic baseline that leads to an environmentally credible sectoral target or emissions threshold. The coverage of the data (in terms of both scope and in time) is important, and the availability of disaggregated data not only on emission levels but also on emission drivers (types of technologies, plant vintages, fuels used, etc.) can improve the accuracy of the baseline, but needs to be weighed against costs, simplicity and transparency. Developers of sectoral baselines need to be transparent about data, methods and assumptions made in the projections, and should ideally show through sensitivity analyses that their projections are robust in terms of changes in some critical assumptions, and that they are realistic in terms of what a technology can (and should) achieve. At UNFCCC level, a fundamental decision needs to be taken about how much flexibility should be granted to baseline developers versus how much needs to be defined ex-ante through guidelines and default parameters.

1 Introduction

The establishment of a new market-based mechanism (NMBM) for the climate change regime post-2012 was decided upon in December 2011 during COP17 in Durban, with a view to defining its modalities and procedures during 2012. One of the crucial design elements to consider when establishing market-based mechanisms is the definition of a reference scenario or baseline on the basis of which emission reductions are calculated. Whereas for project-based mechanisms, emission reductions were historically calculated as the difference between the baseline and project emissions, for NMBMs their calculation will start from a level that is lower than the baseline in order to generate global emission reductions. We hence differentiate between the baseline emissions level and the emissions target or crediting threshold. This paper considers past experience in setting reference scenarios, from both the academic literature and existing market mechanisms, to draw lessons for the NMBM.

While the exact nature of the NMBM has not yet been defined, it is supposed to stimulate mitigation “across broad segments of the economy”, as agreed in Cancun in 2010. In this study, we thus focus on market-based mechanisms that seek to target a whole economic sector, such as sectoral trading or sectoral crediting.

Under sectoral trading, an emissions target is set for a specific sector within a country, and tradable emission allowances up to that target are issued and allocated to the sector’s installations ex ante. Installations need to implement measures to reduce greenhouse gas (GHG) emissions up to the level of their allocated allowances or else buy more allowances in the market[1]. Under sectoral crediting, a crediting threshold is set for a specific sector within a country. The government provides incentives to the activities within the sector to reduce emissions and meet the crediting threshold. The emission levels of the sector are then monitored during a crediting period. Emission credits corresponding to the amount of reductions achieved below the threshold are issued ex post. These credits can be traded in the international market and the revenue can be used for financing policies and measures or for rewarding those installations that contributed to the reductions. If the crediting threshold is not met, no penalty is applied.

Under both approaches – sectoral trading and sectoral crediting – a baseline needs to be defined upfront below which the allocation of allowances or the crediting threshold is set.

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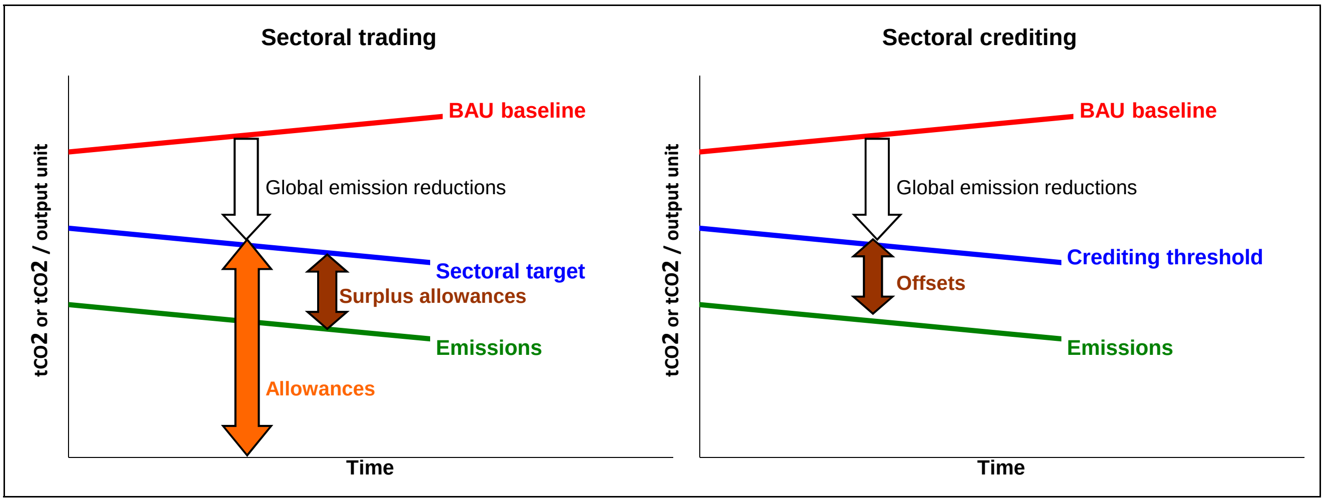
[1] In principle, sectoral trading does not need to rely on an intra-sectoral emissions trading scheme as depicted here. The allowances for the whole sector could be kept and managed by the government, which would implement applicable policies and measures to reach the sectoral target. In this case, if the target is not met, it would be up to the government to buy more allowances in the international market and to penalise those installations within the country which failed to contribute sufficiently to emission reductions. In this paper, however, we focus on sectoral trading as the design that more easily transfers responsibility and a carbon price signal to the private sector.

Definition:

A *baseline* is the expected development of GHG emissions over time under the assumption that from a certain point in time no new mitigation measures would be undertaken. It constitutes a reference scenario with respect to which the emission targets or the crediting thresholds are set. The baseline should predict business-as-usual (BAU) as accurately as possible. Approaches for determining the baseline could range from simply drawing a flat line from status quo emissions (if no other reliable information is available) to complex scenarios which take into account all covered activities, their estimated emission performance, their vintage and expected economic lifetime as well as projections of demand and socio-demographic indicators, etc.

See Figure 1 for a schematic representation of the relationship between BAU baseline, emissions target or threshold, actual performance, and credits or allowances obtained.

Figure 1: Baselines under the new market mechanism



Source: Adapted from Aasrud et al. (2010)

Thus, the way in which this baseline is set – and the way in which the stringency of the sectoral target or crediting threshold is defined – plays a crucial role for determining how many emission reductions are credited or allowances allocated. If the baseline predicts higher emission levels than those generated by the actual business-as-usual development, and the target/threshold is lenient, this may result in overallocation of allowances or crediting of reductions that are not “real”. Therefore, both baseline emission levels and stringency of the target or crediting threshold need to be considered when assessing the environmental integrity of the mechanism.

In this paper, we contribute to the discussion about how to set baselines for a sectoral NMBM by presenting and discussing possible sectoral baseline designs for three economic sectors: power, cement and buildings. We will first review the literature on the different design components of baselines. Then we will present a set of evaluation criteria for assessing the appropriateness of different baseline designs for the NMBM. And finally, we will assess different baseline designs for the three sectors, on the basis of available data on sector composition.[2] The selection of sectors allows the complexities of setting baselines in sectors with large-scale installations (power and cement) and in those with dispersed installations (buildings) to be considered. It will also allow assessment of different design possibilities for cases where sectors comprise heterogeneous technologies and installation types. Finally, lessons for new market-based mechanisms are drawn.

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[2] The objective of the case studies is to illustrate how sectoral baselines could be designed and what the challenges arising from such an exercise are. They should not be taken as proposals of real sectoral baselines in a specific country, but as examples of how baselines can be estimated and what considerations need to be taken into account. In order to make the case studies as close to reality as possible, they rely on real world datasets for specific countries. Where sufficient data is not available, plausible assumptions will be made and reported.

2 Overview of the literature on baseline setting

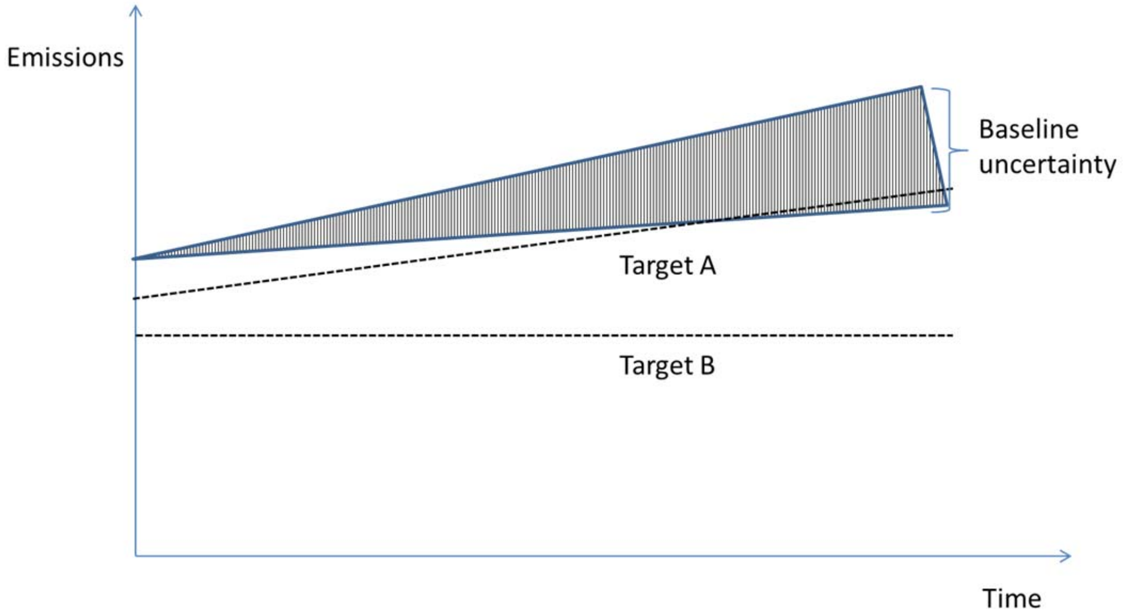
Substantive analysis on how to set baselines for emission reduction targets or for crediting systems has been available since the late 1990s when the discussions on how to implement the Kyoto Protocol and its flexibility mechanisms began. Drawing on the analysis made by Michaelowa (1998); Lazarus et al. (1999); Probase (2002); Broekhoff (2007); Schneider and Cames (2009); Hayashi et al. (2010); Prag and Clapp (2011); among others, we consider the following design elements of baseline setting:

- **Scope or level of aggregation**: Defines what categories of activities are covered by the emissions baseline. There are several dimensions in which the scope of a baseline can be defined:
    - **Process**: whether the baseline is differentiated by technology or process (e.g. a single baseline for the whole power sector, versus separate baselines for coal- or gas-fuelled power plants; or a baseline for direct emissions from fuel combustion in cement production, versus a baseline that also includes indirect emissions from electricity consumption).
    - **Product**: whether the baseline is differentiated according to the type or quality of product (e.g. primary/secondary aluminium as opposed to aluminium in general; or clinker versus cement).
    - **Time**: whether the baseline is based on the performance of installations of a specific vintage in a sector (e.g. average carbon intensity of all steel plants, versus average carbon intensity of all plants installed in the past 5 years).
    - **Space**: the geographic boundaries for which the baseline is applicable and from which data are drawn to establish the baseline (country, subnational region, group of countries, continent, whole world).
- **Reference data**: considers whether the baseline is set on the basis of the historical data within the scope defined above, or whether some kind of projection of future emission levels is performed. In the case of historical data, the baseline can further be based on a single time period (e.g. the 1990 base year for the Kyoto Protocol emission reduction commitments), or on the average emissions across several periods. If some kind of future projection is used, it can be a simple linear extrapolation of the emissions trend over several time periods, a projection based on expected changes in growth rates of the sector, or a more complex model that incorporates the effects of expected changes in other variables (economic and demographic variables, existing and expected policies, etc.). Data quality is also considered here.
- **Updating**: establishes whether the baseline is updated periodically once future information is available, how often this updating should take place, and which baseline parameters need to be updated.
- **Metrics**: whether the baseline should be set in absolute terms (total emission levels), in relative terms (emission levels indexed with respect to an indicator or a set of indicators such as economic size, or production output), or in terms of a technology penetration rate (share of a specific technology with respect to the whole output of a sector).

- **Stringency and conservativeness**: Operationalization of business as usual through an indicator can take many forms and it is often challenging to decide which indicator best represents business as usual. A conservative baseline setting approach, for example, uses a high percentile of the performance of all installations in a sector, instead of the sector average. Conservativeness helps to reduce the risks for environmental integrity arising from future uncertainty. But even if baselines are not conservative, targets / thresholds can be set in a stringent manner, i.e. significantly below the baseline. A stringent target or threshold contributes both to reducing the uncertainty problem and to the host country generating its own emission reduction contributions.

  Figure 2 schematically shows that baseline uncertainty increases over time. Target A, which would be stringent if the "true" baseline lies at the upper end of the uncertainty range, becomes lenient if the "true" baseline is at the lower end of the baseline range. Target B remains stringent under all circumstances.[3]

Figure 2: Baseline conservativeness compared to target/threshold stringency



Sectoral baselines are more comprehensive and potentially more complex than baselines for individual projects since they include all emissions of existing and future installations of the covered sectors. Determining such baselines is thus more similar to determining emission tar-

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[3] As explained above, in this study, we consider a baseline to be the projection of future emissions in a sector under a BAU scenario. This is different to some other conceptualizations in which the baseline itself is expected to be "stringent" or "ambitious". The rationale behind our treatment is that we propose that a BAU baseline can (and should) be established on the basis of technical-economic data, while the stringency level will have a political component related to the choice of policy measures and ambition level by a specific government. By separating the technical from the political component, decision-making can be made more transparent. However, the operationalization of the baseline may still be done in a conservative way to reduce uncertainties about the actual business-as-usual path. A conservative baseline would be placed on the lower bound of the uncertainty interval, a lenient one on the higher end.

gets for Annex I countries under the Kyoto Protocol than to baseline setting under the CDM. Experience from project-based approaches can provide important insights but needs to be complemented by knowledge of emission projections for sectors and/or countries.

2.1 Baseline scope

As outlined above, the scope of a baseline defines what activities it covers. If we consider the NMBM as potentially becoming a sectoral crediting or sectoral trading mechanism, then the natural scope for this market mechanism is the “sector”. However, there is no unique definition of what a sector is, as existing emission measurement systems (e.g. the IPCC classification for GHG inventories, or the EU ETS definition of covered sectors) frequently employ different definitions. Furthermore, while the widespread idea of a sector reflects the notion of an industry devoted to producing one type of product or service (e.g. cement, iron and steel, electricity, etc.), within these industries there are large differences in terms of production processes, product quality, age and size of installations that may make the installations not fully comparable (see e.g. Prag and Briner 2012).

Thus, for heterogeneous sectors there may be a need to establish separate baselines for different subgroups of products or installations and to determine an aggregate baseline that is, however, composed by multiple indexes that help to characterize the differences across subgroups (Schneider and Cames 2009). A similar approach would be required if implementing countries were intending to cover more than one sector or subgroup within their broad segment. A separate baseline would have to be established for each of the covered sectors or subgroups based on general and specific data and assumptions. Once the individual baselines are determined they can be combined to one aggregated baseline for the entire broad segment. This way it can be ensured that reliable and conservative baselines are determined while countries would still have the flexibility to optimize their reduction efforts among the sectors or subgroups covered under their broad segment once the NMBM is implemented.

As described by Hayashi et al. (2010), several dimensions can be used to define subgroups of installations that are covered by a baseline. The first two dimensions – **process** and **product** – consider disaggregation across technologies and product types or qualities. In general terms, the more disaggregated the baseline, the higher its accuracy in terms of representing the expected emissions level of a particular technology or product. However, the more disaggregated the baseline, the less it allows for broader mitigation options, and potentially also the more data-intensive it is. A fully disaggregated baseline would be akin to the project-type specific baselines used currently in the CDM.

Example:

A sectoral baseline for the transport sector could be defined as the level of emissions from transportation divided by the level of GDP in the country. Such a baseline would be relatively easy to estimate on the basis of data on overall consumption of transportation fuels and default emission factors. It would, however, be relatively imprecise in projecting future emissions because GDP is not the sole driver of transport emissions. But it would allow inclusion of the broadest possible range of mitigation measures, ranging from specific energy efficiency improvements, modal shift (e.g. from private to public transport, or from air to ground transport), to reductions in transport needs. A more disaggregated baseline, for example in terms of emissions per passenger-km or tonne-km in each transportation mode (road, railway, air, water), would more accurately reflect emission patterns in these subsectors, but would not incentivize emission reductions through modal changes and would be data-intensive (Schneider and Cames 2009).

Another critical aspect for a sectoral approach is whether to account for indirect emissions of electricity consumption in production processes. Considering these emissions allows for the inclusion of measures that reduce electricity consumption within the sector, but may lead to double counting if the broad segment covers the electricity sector as well.

The other two dimensions – **time** and **space** – may need to be taken into account for addressing further heterogeneity in a given sector. Determining the baseline for the entire sector will require a certain level of knowledge about the capacities, vintages and emission performances of the covered activities. In contrast to the CDM – where project-based baselines are mainly determined by the question what investors of new installations or retrofits would do in the absence of the CDM – baselines need to take into account all activities, i.e. existing ones of various vintages with or without a potential for retrofitting and projected new activities, under a sectoral approach. Recent capacity additions should, like the benchmark approach according to paragraph 48 (c) of the CDM's modalities and procedures, be used to reflect the emissions of new activities, but will require activity-specific data (Lazarus et al. 1999). However, the emission performance of new activities cannot be applied to project the business-as-usual emissions of an entire sector, particularly if the share of existing installations with high emission intensity is large. In most cases a more sophisticated approach would be required which takes into account closures of very inefficient activities as well as emission performances of retrofits in existing activities and of new installations based on a benchmark approach.

In terms of spatial differentiation, the "natural" scope level for a NMBM is a country's sector, though other options may in some cases be more appropriate. On the one hand, subnational differences may arise in terms of feedstocks or fuel types for products such as cement, or in terms of heating and air conditioning needs for buildings in different geographic environments. This may be reflected by either different baselines or different input values for certain parameters of the baseline according to regional characteristics. On the other hand, in neighbouring countries with small markets and similar economies it may make more sense to establish baselines that are applicable to a group of countries in order to reduce data collection costs and avoid competitiveness and leakage issues. Here again, the more aggregated the baseline, the lower are the data and transaction costs.

Lazarus et al. (1999) discuss the essential trade-off between level of aggregation and types of mitigation measures incentivized. Aggregated baselines for entire sectors will be more efficient in terms of finding the least carbon intensive options throughout the whole sector. In heterogeneous sectors, this approach will provide the strongest mitigation incentives to subsectors that are, due to their specific characteristics, energy- or emissions-intensive. Lazarus et al. (2000) propose an hybrid approach to deal with this trade-off in the case of the electricity generation in the CDM: they propose a baseline composed of fuel-specific benchmarks that would be applicable for same-fuel efficiency improvement projects, and of a sector-wide benchmark that would be applicable to fuel switching projects or new installations. In the case of a sectoral NMBM, a similar effect could be achieved if sectors are disaggregated into existing and new installations.

As discussed by Murtishaw et al. (2006), spatial differentiation does not need to be set on the basis of administrative boundaries. For example, in the CDM different baselines are set for independent electricity grids within countries, which follows the delimiting lines of the transmission infrastructure. For land-use activities or buildings, spatial boundaries may follow biophysical characteristics, such as weather conditions or ecosystems. However, availability of aggregated data for determining sectoral baselines may often follow administrative boundaries.

2.2 Reference data

Ultimately, all baselines are based on historical data, which can either be used directly as the baseline – i.e. the past performance of existing facilities in the sector would be the reference for comparison – or can be used to project expected emission levels into the future. While projection-based baselines seek to more accurately reflect what activities would be displaced by the mitigation measures to be credited, they depend on many subjective and often intransparent assumptions, and are hence easier to manipulate (Michaelowa 1998; Lazarus et al. 1999).

In more detail, the following types of reference data can be used to set up a baseline:

- A single historical time period
- The average emissions level across several historical time periods
- A simple linear extrapolation of the emissions trend over several historical time periods
- A projection based on expected changes in growth rates of the sector
- A projection that incorporates the effects of expected changes in other variables (economic and demographic variables, existing and expected policies, etc.)
- In the absence of actual energy consumption or emissions data, nameplate parameters based on manufacturers' specifications or default factors applicable to certain geographical region(s) could be used (see Lazarus et al. 2000: 3-2).

Murtishaw et al. (2006) looked at the effect of different ways to use past reference data (without complex projections) on the baseline. They discussed that if emission levels remain stable historically, any past period could be used to establish an appropriate baseline. But if there is a downward or upward trend in past emissions, the more recent data periods should be used. If emission levels vary with no clear trend (they may depend on climatic or other external factors), an average over several years should be used to capture a representative level. Finally, if the historical emissions trend shows a clear break, it would be important to identify what caused that change in the trend and whether such change will be stable or not. If the break in the trend is due to, for example, a new policy or a technological breakthrough, the baseline should be established on the basis of the emissions data after the break point. In general, they recommend using longer time periods to minimize the effect of fluctuations.

On the basis of case studies of power sector installations in five developing countries, Lazarus et al. (1999) concluded that variations in the emissions intensity were unpredictable and unsystematic and could be affected by factors such as energy price shocks, new resource discoveries, technological advances and regulatory changes. They found that fuel choice was a better predictor of changes in emissions intensity than efficiency improvements. Thus they conclude that in the power sector, historical performance data are more reliable than projections as the latter are highly sensitive to the underlying assumptions. They found that projections made by different specialized bodies – or even by the same body but at different points in time – have high discrepancies with each other and can thus yield considerably different baselines. They therefore recommend that the baseline be based on historical data and be updated frequently to take account of the rapidly occurring changes in the sector's conditions, but that the frequency of updating needs to be balanced against certainty for investors. Larger groups of entities usually show lesser variance than individual installations. Therefore the conclusions of the analysis of individual installations cannot be directly transferred to the determination of sectoral baselines. Nevertheless, these conclusions illustrate the difficulties that need to be addressed when baselines are based on emission projections.

While the experience in using emission projections as the basis for setting emission reduction baselines is still limited (all Kyoto Protocol targets are based on historical emissions, EU ETS allocations are based on historical data or on benchmarks derived from existing installations), substantially more experience using models to predict future emission levels exists in Annex I national communications and in studies intending to estimate future abatement potentials. In their national communications to the UNFCCC, Annex I countries are supposed to report future emission projections for indicative purposes. Some of these projections include a business-as-usual scenario (BAU), a scenario that includes some mitigation measures, and a more ambitious scenario with more mitigation measures. These projections also rely on assumptions regarding economic growth, development of population and energy demand, etc. Similar projections also exist for some non-Annex I countries and have been prepared with a view to estimating future emission abatement potentials (see e.g. Cai et al. 2008 for the case of five economic sectors in China). Here again, comparisons have revealed that different projections for the same country vary substantially (Prag and Clapp 2011). If models are to be used for baselines of the NMBM, either the assumptions behind the baseline calculations need to be revealed very transparently by the proposers, or a central authority under the UNFCCC needs to define a set of standard assumptions that apply equally to all baseline calculations. Examples of such standard assumptions could be: whether mitigation policies should be considered as part of BAU and if so, which policies and up to what year, how to project GDP and population growth, etc.

2.3 Dynamics and updating

Baseline emission levels may be fixed over time or be dynamic and incorporate some type of updating as conditions change (Lazarus et al. 1999).

Fixed baselines would, for example, refer to the 20% best emissions of all steel plants in the country over the years of 2005-2010. Investors in the sector would have full information about how to account for their emissions. Baselines could include an autonomous emissions improvement factor (e.g. baseline emission levels decline at a rate of 1% emissions each year) and assumptions on the development of demand. In this case, while the baseline emission levels change every year, the investor still has full information.

Dynamic baselines, in contrast, would be based on new empirical data (e.g. baseline emission levels are calculated as the rolling 3-year average emissions level of all steel plants in the country, calculated each year anew). In this case, the baseline would more clearly reflect the evolution of the sector, but its calculation would be more data-intensive and investors would not know future baseline emission levels in advance.

In addition to the dynamics that can be introduced in the baseline calculation itself, even fixed baselines may need to be updated periodically (every certain number of years, e.g. for new monitoring periods) to reflect changes in economic, social, technological and environmental circumstances, as happens for projects with several crediting periods under the CDM. Such updates may cover the whole baseline or just specific parameters within it (Hayashi et al. 2010).

The frequency of updating or the need to establish dynamic baselines depends on the speed with which the sector evolves in response to technological, policy or other environmental changes, on the cost of the revisions to the baseline and on considerations of certainty for investors (Lazarus et al. 1999).

Updating of baselines may undermine the investment certainty if investors of GHG mitigation strategies expect that the established baseline may be made more lenient at some point in time. To address such concerns and in order to provide sufficient investment certainty, as a general rule, baselines should be established for a long period of time on the one hand – ideally until the GHG emissions of the respective sector or subgroup become zero – and on the other hand updating should only be used for strengthening the baseline (e.g. every five years)[4]. This may result in a reluctance to initially agree to ambitious baselines but may also provide a general investment climate that makes a later strengthening of baselines more likely because low GHG technologies are spread more widely and quicker.

2.4 Metrics

There is substantive discussion on whether the baselines of a NMBM should be established on the basis of absolute emissions levels or of emissions levels with respect to output (i.e. emissions intensity, relative emissions or indexed emissions). Other proposals suggest using alternative metrics such as the share of a specific technology with respect to the output of a sector (penetration rates). This discussion is summarized in Prag et al. (2011).

An absolute baseline implicitly or explicitly makes assumptions about the expected level of activity in the sector. So, if the growth of the sector's activity is highly subject to external shocks or to factors that are difficult to predict, such as economic growth, relative or indexed baselines are preferred. This is likely the case in developing countries, whose economies are growing at a

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[4] Investment uncertainty in this case is only reduced, though, if baseline updating is known ex-ante (i.e. during the time of the investment decision).

much faster pace than in Annex I countries. The absolute emission levels of relative or indexed baselines depend on the development of one single indicator or a set of indicators. The indicators, the data sources and the algorithm to calculate baseline emissions, all are determined ex ante while the absolute values of the baseline emissions are determined ex post.

However, relative or indexed emission thresholds are subject to the risk that they do not lead to a reduction of total emissions. This would be the case if the growth in output levels outweighs the reduction in relative emissions (Prag et al. 2011) which is frequently seen in rapidly growing developing countries with voluntary emission intensity pledges, e.g. China. To avoid restrictions to their economic development, developing countries may be reluctant to agree to ambitious absolute emission thresholds. If the underlying assumptions on economic development do not ultimately materialize, absolute emission thresholds may, on the other hand, result in substantial amounts of hot air, i.e. emission reductions are not result of mitigation efforts but of other factors (Schneider and Cames 2009).

Another metric that is being supported by stakeholders from developing countries is using technology-based standards to determine baseline emissions intensity. Such baselines would not directly be defined as emission levels, but derived from a predefined level of penetration of a desirable technology (e.g. X MW or Y % of renewable energy generating capacity). If defined as targets/thresholds, they would be substantially above the BAU course of action. This type of baseline and derived targets/threshold would reduce MRV costs, but the estimation of resulting emission reductions would need to be based on assumptions or estimations (again based on historical or similar data) for how the specific technology performs in terms of emissions (Lazarus et al. 1999; Prag et al. 2011). The uncertainty of such approaches is high.

2.5 Stringency level and conservativeness

As discussed above, there are two elements of stringency: choice of a conservative baseline among all possible baselines within the uncertainty range, and choice of a stringent target/threshold level with respect to the chosen baseline. This is expected to be a core area of political discussions in the UNFCCC, which needs to be informed by a thorough technical analysis. One example would be to set the baseline at the average or median emissions levels of the installations included within the sector boundaries defined above, which would reflect a representative performance of the sector, and would reward any activity that is even slightly better than the average. It would hence not incentivize substantial improvements over BAU. Better-than-average target or threshold levels (based e.g. on a pre-defined percentile of the best performing installations, or on the emissions level of a desirable technology) could be used to reward only activities that imply a significant improvement beyond the average level. However, the more ambitious the target or threshold, the fewer the installations that will effectively be incentivized to undertake a mitigation measure. Thus, the stringency level needs to be set at a level that “ensures a reasonable degree of environmental integrity while providing [...] sufficient incentives for investment” (Hayashi et al. 2010). As Broekhoff (2007) puts it, calibrating the stringency level is a matter of balancing “false positives” (too many non-additional measures are classified as additional because the threshold was set too lenient) and “false negatives” (too many measures that are actually additional are deemed to be non-additional, because the threshold was set too stringent). There is no technically correct way to calibrate the stringency level. Therefore, the calibration needs to be done according to the policy goals of the policy-makers.

In the end, however, it is likely that stringency levels will be a negotiated outcome between the host country representatives and a central authority or expert panel that assesses each proposed sectoral baseline. If host countries are left free to choose across design options regarding scope, reference data, dynamics and metrics, then a “standard” stringency level (such as the 20% best performance percentile established for the CDM under the Marrakesh Accords) cannot exist, and a desirable level needs to be established on a case by case basis.

3 Criteria for assessing baselines for the NMBM

In this study, we consider the following criteria for assessing the appropriateness of design options for baselines of new market-based mechanisms:

- **Environmental integrity**: it needs to be made clear that the conceptualization of environmental integrity is different under a sectoral market mechanism than under a project-based mechanism like the CDM. Under the CDM, demonstrating the additionality of a single mitigation measure in a single installation was the key for assessing whether "real" emission reductions are taking place. Under a sectoral NMBM, the additionality of individual measures is no longer as important, and does not need to be proven. But on aggregate, additionality is still important, as business-as-usual should by definition mean the sectoral production path with the highest profit level. As the emission reductions are to be credited for a whole sector, it is also no longer important to establish a clear causality link between an individual mitigation measure and the emission reductions achieved. As credits or allowances are issued only with respect to achievement of the overall emissions threshold or target, it is eventually a matter for the national government to decide how it rewards good performers and penalizes bad ones. From an international point of view it is crucial that the overall threshold constitutes a deviation from BAU (additionality at the sectoral level), and that the BAU emissions level for the sector is credibly defined. We will consider the following indicators of environmental integrity:
    - **Scale of real and additional emission reductions**: whether the threshold leads to emission reductions below BAU;
    - **Consideration of policies in baseline setting**: whether the baseline incorporates the effect of existing climate-friendly policies under the BAU scenario;
    - **Possibility of allocating reductions to own effort, supported activities and credited activities**: whether the baseline type allows for differentiating reductions that are due to own effort (e.g. existing or new policies), to international financial support (NAMAs) and to the NMBM.
- **Transparency**: whether all assumptions leading to the baseline can be clearly communicated and understood.
- **Flexibility**: whether the baseline-setting methodology provides the host country with flexibility in terms of design options that are most suitable for its own circumstances.
- **Data requirements**: whether the baseline setting methodology has data requirements that can be easily met by developing countries in a sectoral manner.

4 Assessing baselines for the NMBM: power sector

4.1 General characteristics of the sector

The power sector is one of the most important sectors globally. Global electricity generation was 11.8 PWh in 1990 and 21.4 PWh in 2010. Under current policies, global electricity generation may rise to 36.5 PWh in 2030. CO_2 emissions in the power sector were 7.5 Gt in 1990 and 12.5 Gt in 2010. CO_2 emissions are expected to rise to 14.7 Gt in 2030. The power sector is therefore of utmost importance for the mitigation of climate change. The main fuel consumption for power generation in 2010 stems from coal (46%), followed by natural gas (23%) and nuclear (15%). Renewables accounted for 10% of overall fuel consumption for electricity generation in 2010 (IEA 2012).

The highest contribution to the overall climate impact of electricity generation comes from CO_2 which is directly linked to the type and amount of fuel consumed by the power plants. Minor contributions stem from CH_4 and N_2O and are dependent on the type of fuel used as well as the combustion conditions of the respective technology.

The size of power plants ranges from small decentralised installations such as diesel generators or photovoltaics to large central power plants such as based on nuclear, coal, natural gas or hydro. Power plants can be classified according to a range of features. They may be based on renewable, fossil or other fuels (such as nuclear). Power plants may produce electricity only (e.g. condensing-type power plants or wind generators) or may co-produce heat for space heating or industrial process heat (so-called combined heat and power (CHP) plants). There is also a wide variety of technology types applied such as steam turbines, gas turbines, combined cycle power plants, different renewable technologies or a combination of different technologies. Power plants may be operated by central operators or independent power producers (IPP) and may serve both the overall supply of the area (e.g. power plants operated by electric utilities) or more specifically the electricity demand in a specific sector, e.g. in the industry (captive power plants). The heterogeneity of technologies as well as the number of installations and of operators depends on the specific circumstances in each country.

CO_2 emissions from electricity generation depend on the type of fuel used. In this regard, lignite has the highest specific CO_2 emissions (101 t CO_2/TJ), followed by hard coal (94.6 t CO_2/TJ[5]) and natural gas (56.1 t CO_2/TJ) (IPCC 2006). Renewable energy sources do not generate direct CO_2 emissions. The amount of CO_2 produced furthermore depends on the electric efficiency of the power plant, which may range from 30% (or less) for old inefficient power plants to 60% for new combined cycle natural gas-fired power plants. The resulting specific CO_2 emissions range from 0 g CO_2/kWh for renewables over 350 g CO_2/kWh for a state-of-the-art natural gas-fired combined cycle power plant to 1,200 g CO_2/kWh (or more) for an old lignite-fired power plant. Overall CO_2 emissions of the power sector finally depend on the overall electricity demand.

Against this background, several options are available to reduce greenhouse gas emissions from electricity generation. One option is the increase of the electric efficiency of power plants. On the one hand, new power plants have higher electric efficiencies than older plants. On the

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[5] Category “other bituminous coal” (IPCC 2006).

other hand, the electric efficiency may be increased retrospectively (e.g. by retrofitting or repowering) or by choosing a different plant configuration (e.g. combined cycle instead of single cycle). Another option relates to fuel switch, for instance from lignite to hard coal or from hard coal to natural gas. A further possibility is to build and operate power plants in cogeneration mode rather than in electricity-only mode[6]. Furthermore, the increased use of renewable electricity generation reduces greenhouse gas emissions in the power sector. Another option is the capture of CO_2 from the flue gas of the power plant and the disposal in storage sites underground, so-called carbon capture and storage (CCS). However, this option is still under research. There may also be different combinations of the options mentioned above, such as the shift from an old coal-fired power plant to a new high-efficiency combined cycle natural gas-fired power plant. Finally, the electricity demand directly affects greenhouse emissions in the power sector.

A potential baseline for the power sector therefore needs to deal explicitly with the following specific design elements with respect to its level of aggregation:

- **Process:** Depending on the data availability, different electricity generation technologies may be differentiated.
- **Product:** No differentiation needed due to a single homogeneous product (electricity)[7].
- **Time:** The baseline may consider the development of the power plant in the past (fuel types, electric efficiencies, etc.) as well as the autonomous improvement of efficiency in the future.
- **Space:** Generally all power plants in the sector under consideration should be included in the derivation of the baseline. The sector in this regard may, for instance, cover all power plants of a country or region. However, different regions (and even countries) may be connected by the same grid. Therefore, the delineation of the sectoral boundary may be set at all power plants serving a power grid or a set of connected grids operating in synchronous mode. The definition of the sectoral boundary also addresses specific geographical conditions, such as the availability of renewable or fossil resources in the area or grid, which should be considered for baseline setting[8].

In the following section, we present examples of how baselines for the power sector could be developed on the basis of publicly available bottom-up data for an advanced developing country.

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[6] It has to be noted, though, that the electric efficiency of CHP plants is usually lower than of the same power plant in condensing mode. However, since CHP plants also produce heat for space heating or industrial use, fuel consumption may be reduced in other sectors (e.g. by displacing the use of natural gas or light fuel oil to produce heat in boilers). However, this reduction effect would only be visible in the final consumption sectors.

[7] Cogeneration of electricity and heat constitutes a special case since it cannot be directly compared to electricity-only power plants. Extensive literature is available on this matter. However, this specific case is not further investigated as part of this case study. Furthermore, electricity generation may be differentiated with regard to load characteristics (base load, intermediate load, peak load). Different power plant types are dispatched to cover these load ranges. In this regard, specific CO_2 emissions also depend on the load range. However, since the whole power plant sector is considered, all kinds of load situations (off-peak, peak, etc.) are covered. For this reason, there is no differentiation according to load ranges for the derivation of sectoral baselines.

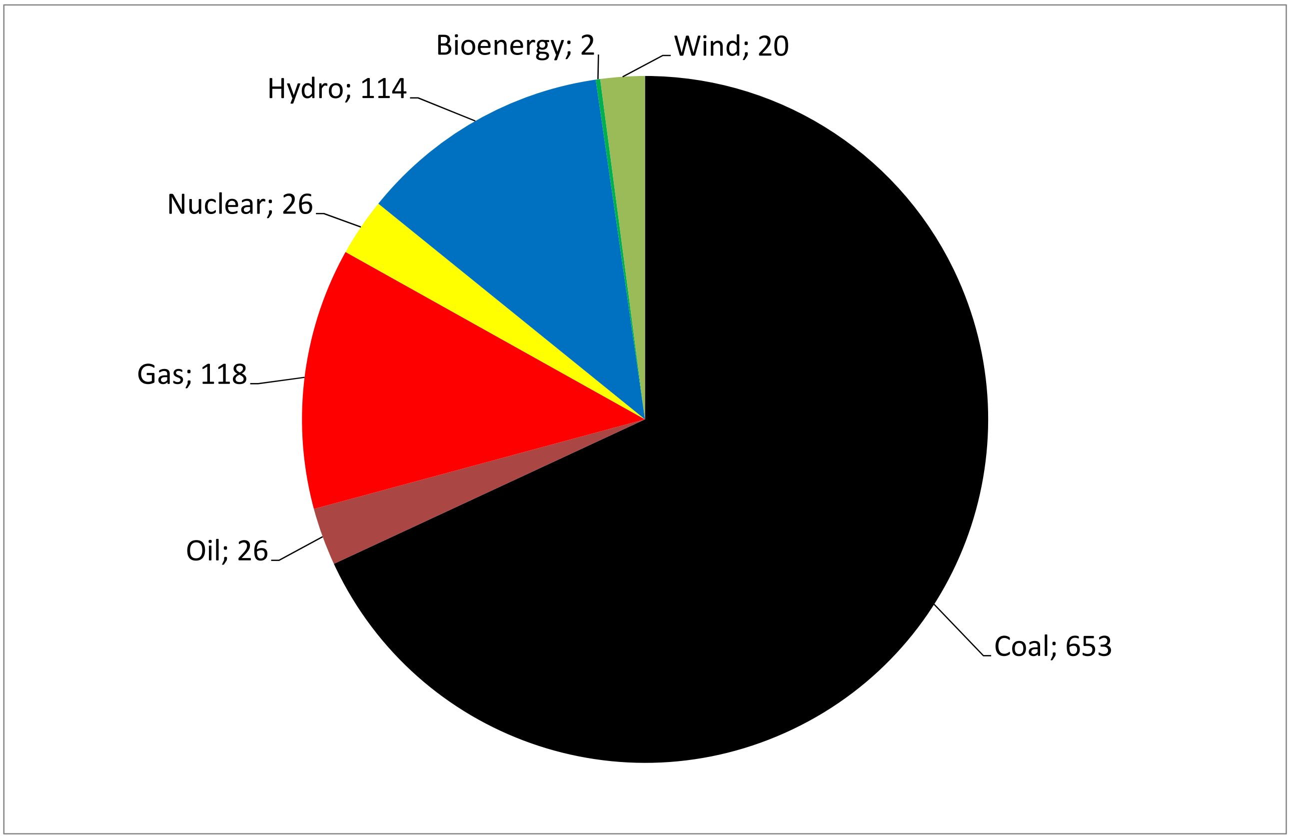
[8] For instance, in a grid without hydro resources, hydro power plants can be ruled out as potential power plant option for baseline setting.

4.2 Case study of sectoral baselines in the power sector

For the purpose of the case study, the choice of the country was guided by two principles. Firstly, the power sector should be sufficiently large in order to represent an important source of greenhouse gas emissions and thus of climate mitigation. Secondly, the public availability of detailed power plant data is crucial for baseline setting. Against this background, India was chosen as the example for the case study. However, the exercise may be carried out for other countries, too.

Electricity generation in India amounted to 960 TWh in 2010. The main part stems from coal (68%), followed by natural gas and hydro (each 12%). Minor shares come from oil, nuclear and wind (Figure 3). Overall installed electrical capacity amounted to 189 GW in 2010 with 53% coming from coal, 21% from hydro and 11% from natural gas-fired power plants. Overall CO_2 emissions from power generation amounted to 872 Mt in 2010 (IEA 2012).

Figure 3: Electricity generation in India (TWh), 2010



Source: IEA 2012

For the assessment of potential sectoral baselines in the power sector, two sources of data were assessed for suitability, the IEA GHG CO_2 Emissions Database and a database from the Central Electricity Authority of the Government of India.

The IEA GHG CO_2 Emissions Database (IEA 2008) contains emissions data from over 8,000 large point sources such as from the power sector, iron & steel, the chemical industry and several other industry branches. The quality of CO_2 emission estimates varies, ranging from “very high, confirmed by contact person" to "low (based on calculation with emission factors and capacity)".

In the case of India, all data are estimated based on the unit capacity of the power plant, assumed operating hours and a specific CO_2 emission factor depending on the type of fuel. There is no further differentiation of operating hours or CO_2 emission factors. Vintages of power plants (construction years) are not available. Emissions data are available for some years; however, there is no systematic time series of emissions.

Based on this dataset, it is not possible to derive an absolute CO_2 emission baseline since a systematic time series is not available. Also, since there is no information on vintages, efficiencies (and corresponding specific CO_2 emission factors) and operating hours for different years, it is not possible to derive an indexed baseline based on trends related to specific CO_2 emissions, fuel mix, etc.

The database by the Central Electricity Authority of the Government of India (Central Electricity Authority 2012a) provides data on Indian power plants including installed capacity, fuel as well as electricity generation, CO_2 emissions and resulting specific CO_2 emissions for five years (2006 to 2010[9]). The database covers installations with an installed capacity of at least 3 MW for hydro and 10 MW for other power plants. Both utilities and independent power producers (IPP) are covered. However, captive power plants[10] and non-conventional renewables such as wind, biomass, solar photovoltaic and hydro below 3 MW of installed capacity are not included. Data are available for the Northern, Eastern, Western and North-Eastern grids (NEWNE) as well as for the Southern Grid. The two grids are expected to be synchronously operated in the next few years. Also, the Southern Grid already has some connections to the Western and Eastern Grid. As part of this analysis, it is therefore assumed that by the time a new market-based mechanism is introduced, the whole of India is integrated in one grid. For this reason, all power plants included in the database (NEWNE grids and Southern Grid) are considered in the following analysis. The power plants usually include several units with a specific commissioning date each. In the analysis, each unit is considered separately, allowing for a more detailed differentiation according to vintages (construction years). It has to be noted, though, that for the individual units, only the construction year and the installed capacity are available in most cases whereas the yearly electricity generation and the corresponding CO_2 emissions are only available for all units of the same power plant together. For the analysis, electricity generation and CO_2 emissions are therefore distributed to individual units by considering the installed capacities of the unit. The dataset does not allow differentiation of operating hours or specific CO_2 emissions between the different units[11]. Some power plants run on two fuels (main fuel and auxiliary fuel, such as for start-up of the power plant). In the following, only the main fuel is considered for the classification. Furthermore, the dataset is corrected for abnormal operating conditions. On the one hand, the first year of operation of each newly-commissioned power plant is not con-

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[9] The respective fiscal years are considered.

[10] Captive power plants play an important role in India due to the instability of the grid, and produced 90 TWh in 2008, i.e. around 10% of the total electricity (Nag 2010, p. 199).

[11] This constitutes a significant data limitation. Power plants may comprise several units with different technologies and construction years. Therefore, in reality, operating hours and electric efficiencies (and ensuing specific CO_2 emissions) may differ significantly between the individual units of a power plant.

sidered in the analysis since fuel consumption and specific CO_2 emissions may be abnormally high due to initial testing of the power plant. On the other hand, the specific CO_2 emissions of a power plant in individual years are neglected that are at least 5% above the lowest value of all years. The underlying rationale is that the lowest specific CO_2 emissions are generally achievable by the power plant from a technical point of view and that significantly higher specific CO_2 emissions are therefore not plausible. An increase of 5% over the lowest value considers normal technical variations such as operation in part load or deterioration of plant efficiency over time due to tear and wear. Table 1 gives an overview of the net electricity generation and CO_2 emissions of the Indian power plants included in the database (after correction for abnormal values) for the years 2006 to 2010[12].

Table 1: Net electricity generation and CO_2 emissions of Indian power plants, 2006-2010

	Net generation (TWh)					CO_2 emissions (Mt)				
	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
Total	497	503	482	578	625	370	380	357	439	463
Nuclear	14	14	13	16	20	0	0	0	0	0
Lignite	18	20	18	21	20	25	29	25	30	29
Coal	310	322	304	367	386	324	336	314	378	398
Gas	43	27	33	62	67	20	13	15	28	29
Diesel	0	0	0	0	1	0	0	0	0	1
Oil	1	1	0	5	2	1	1	0	3	1
Naphtha	1	0	6	1	12	0	0	3	0	5
Hydro	110	117	108	106	115	0	0	0	0	0

Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

In the following, two different baselines are proposed: an absolute baseline based on the overall CO_2 emissions of the power sector (section 4.2.1) and an indexed baseline based on specific CO_2 emissions of the power sector and the fuel mix (section 4.2.2).

4.2.1 Absolute baseline

A baseline related to the development of overall CO_2 emissions of the sector over time can be derived in several ways. The future development may be projected as a trend extrapolation of historical CO_2 emissions with the possibility of using different reference periods (e.g. 2000-2010, 2005-2010, etc.). The development of overall emissions may also come from more sophisticated macro-economic modelling, taking into account the development of fuel prices, economic growth, the interactions between sectors, etc.

If it is assumed that the absolute CO_2 emissions of the Indian power sector follow between 2010 and 2030 the same trend as between 2006 and 2010, the absolute CO_2 emissions would more than double and grow from 463 Mt in 2010 to 940 Mt in 2030[13] (Figure 4).

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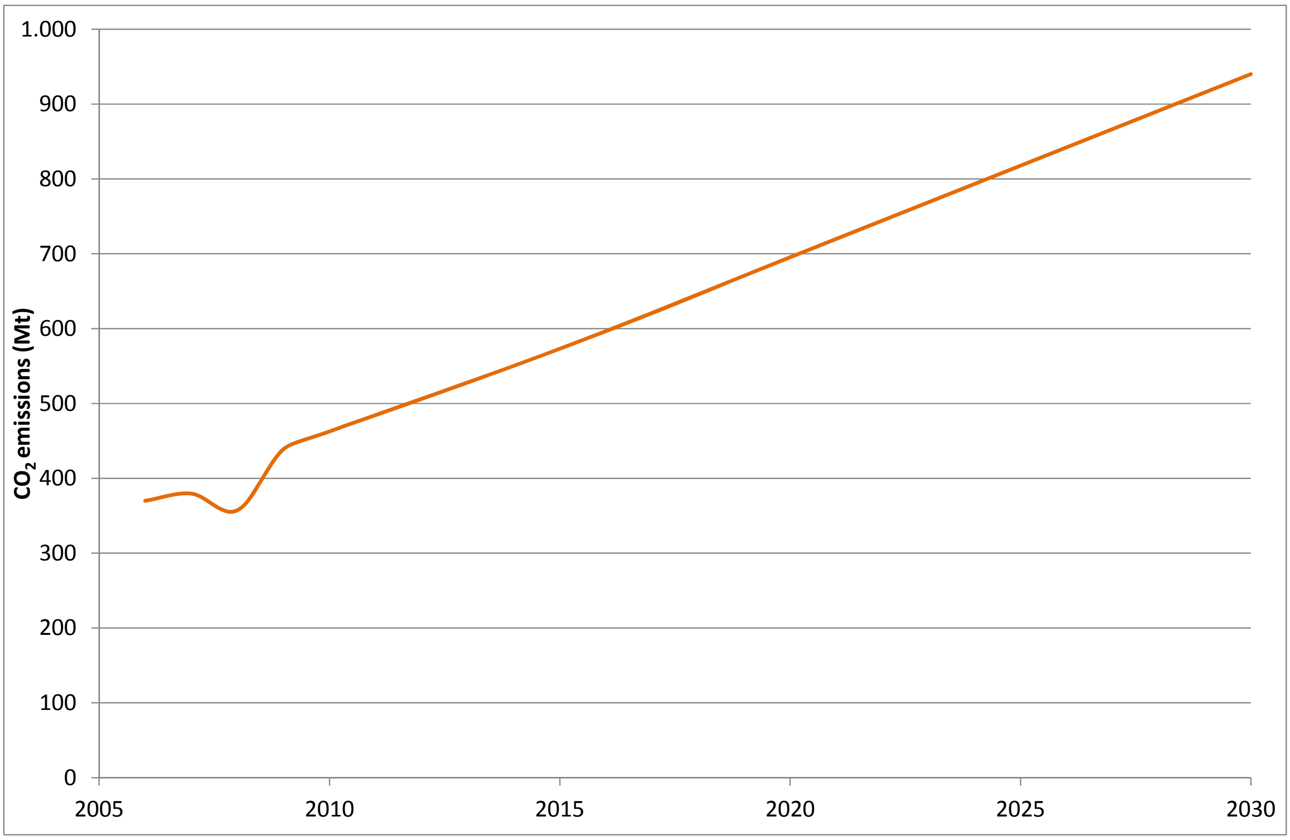
[12] Due to the restrictions related to coverage mentioned above, the overall electricity generation is less than reported by IEA (2012). Furthermore, variations between the years may be due to correction for outliers.

[13] It has to be noted that the coverage of power plants in the dataset may not be homogeneous over the years due to the correction for abnormal values (see above). Therefore, the estimated trend involves some uncertainty.

Figure 4: Overall CO_2 emissions in the absolute baseline



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

However, since the basis for such a trend projection which can be derived from the databases used for this analysis is quite short, this trend cannot be considered as a reasonable trend projection of the Indian power sector.

4.2.2 Indexed baseline based on specific CO_2 emissions of the power sector and the fuel mix

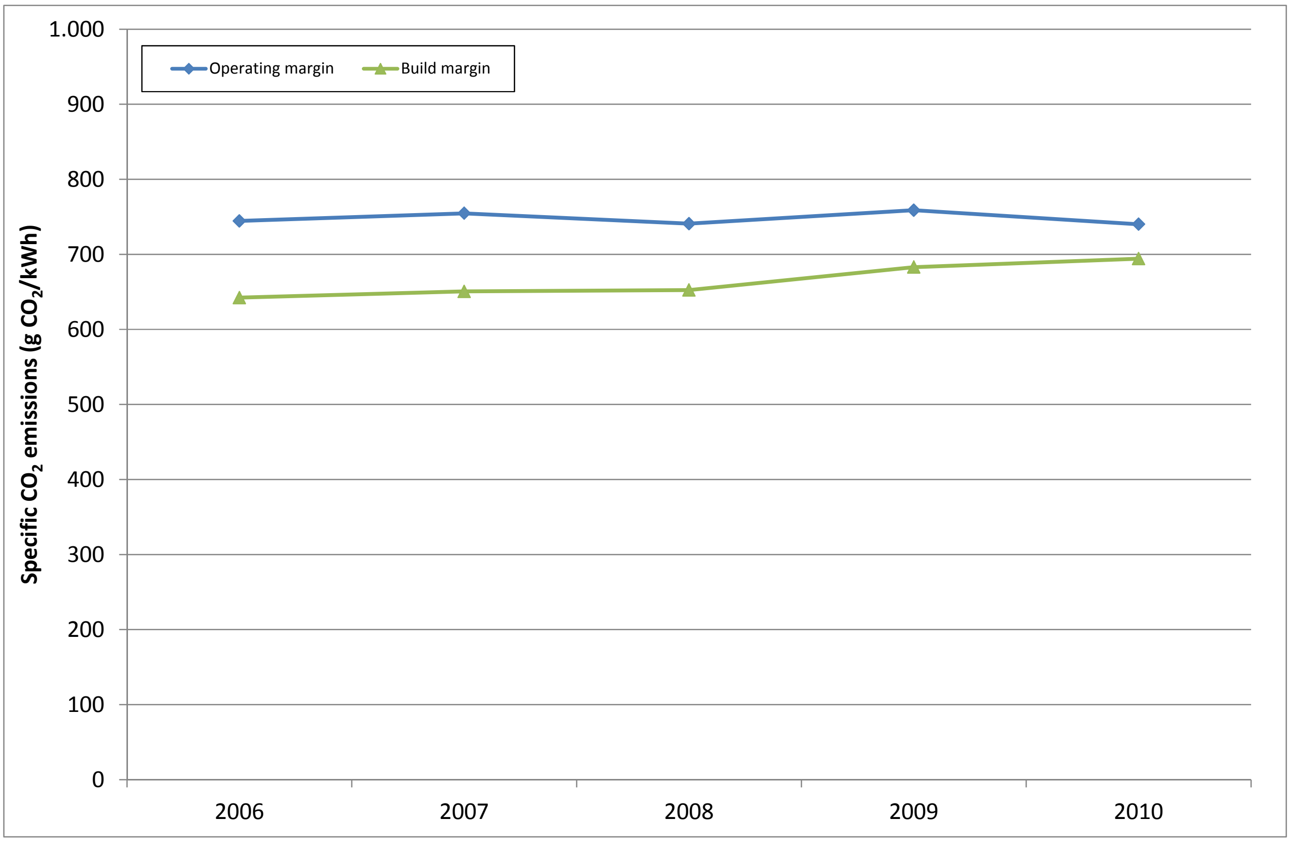
In order to derive an indexed baseline based on specific CO_2 emissions of the power sector and the fuel mix, an analysis has to be conducted related to the existing power plant fleet. In the following, the Indian power plant fleet is analysed with regard to specific CO_2 emissions of the power sector as a whole, with regard to specific CO_2 emissions of individual power plant types and with respect to the development of the fuel mix in the sector. Based on these analyses, a consolidated indexed baseline based on specific CO_2 emissions of the power sector and the fuel mix is derived.

Development of specific CO_2 emissions of the power sector as a whole

Specific CO_2 emissions of the power sector as a whole can be calculated in several ways. On the one hand, the analysis may be based on historical specific CO_2 emissions. This may consider different reference periods for the calculation (see section 4.2.1). On the other hand, it may consider only recently built power plants as a proxy of the most probable investments in the future.[14]

For the purpose of this case study, two types of specific CO_2 emission of the power sector as a whole are derived. For the operating margin, specific CO_2 emissions of all power plants from 2006 to 2010 are considered, including thermal, nuclear and hydro. For the build margin, specific CO_2 emissions of new power plants are calculated for the years 2006 to 2010 based on the power plants built in each respective year and four years prior to the year under consideration. For instance, the build margin of the year 2010 corresponds to the specific CO_2 emissions of all power plants commissioned in the years 2006 to 2010 (Figure 5).

Figure 5: Specific CO_2 emissions of the power sector according to the operating margin and the build margin, 2006-2010



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

Specific CO_2 emissions based on historical levels (operating margin) remain rather constant at approximately 750 g CO_2/kWh. This is due to the fact that the net electricity generation and CO_2 emissions grow in parallel between 2006 and 2010 and the fuel mix also remains rather constant (Table 1). The build margin, in contrast, features lower values for all years (642 to 694 g CO_2/kWh). This can be explained by the fact that new power plants are generally more efficient than incumbent ones. Also, capacity additions of hydro and natural gas-fired power plants

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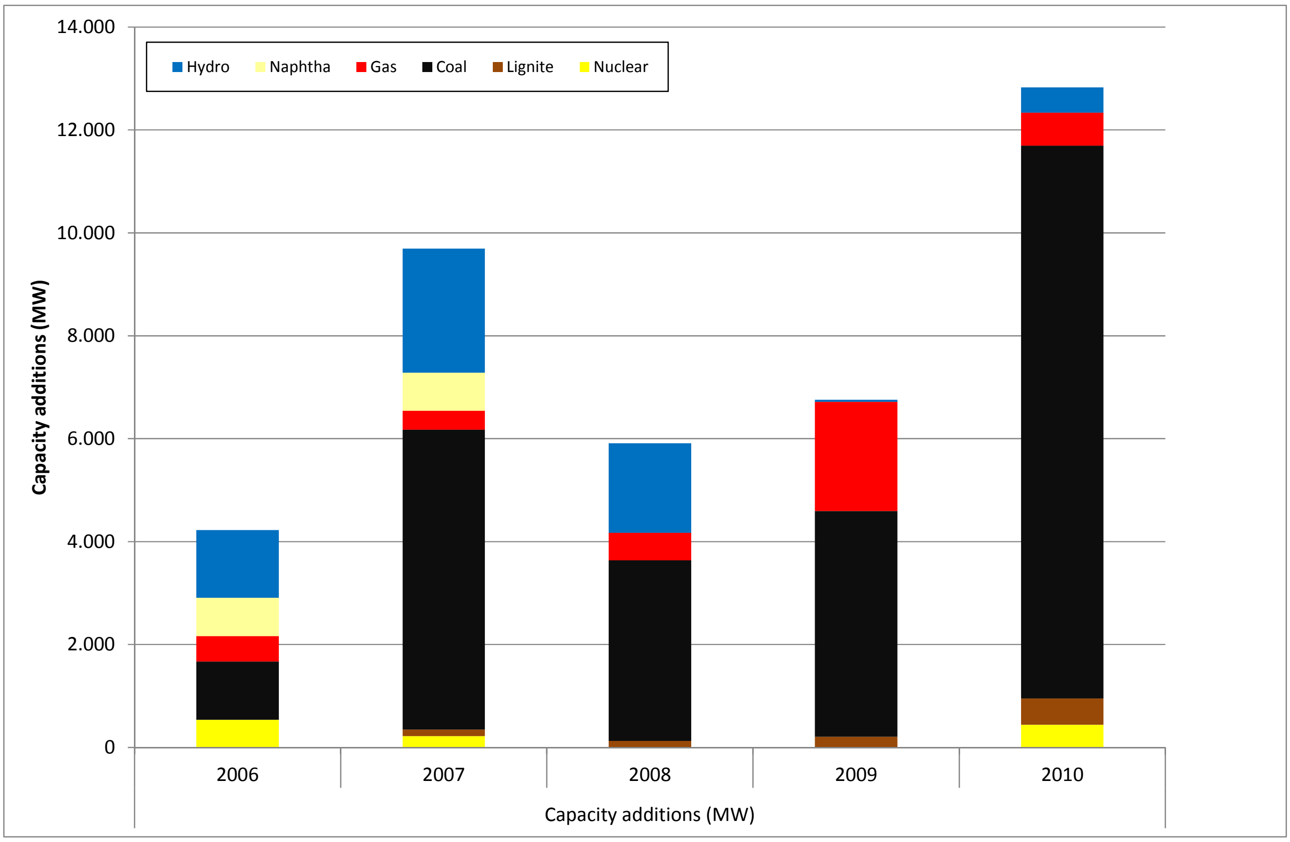
[14] Under the CDM, several approaches on how to derive a specific CO_2 emission factor for the power sector are discussed.

partly compensate for the higher specific CO_2 emissions of hard coal-fired power plants (Figure 6).

Figure 6: Capacity additions in the Indian power sector, 2006-2010



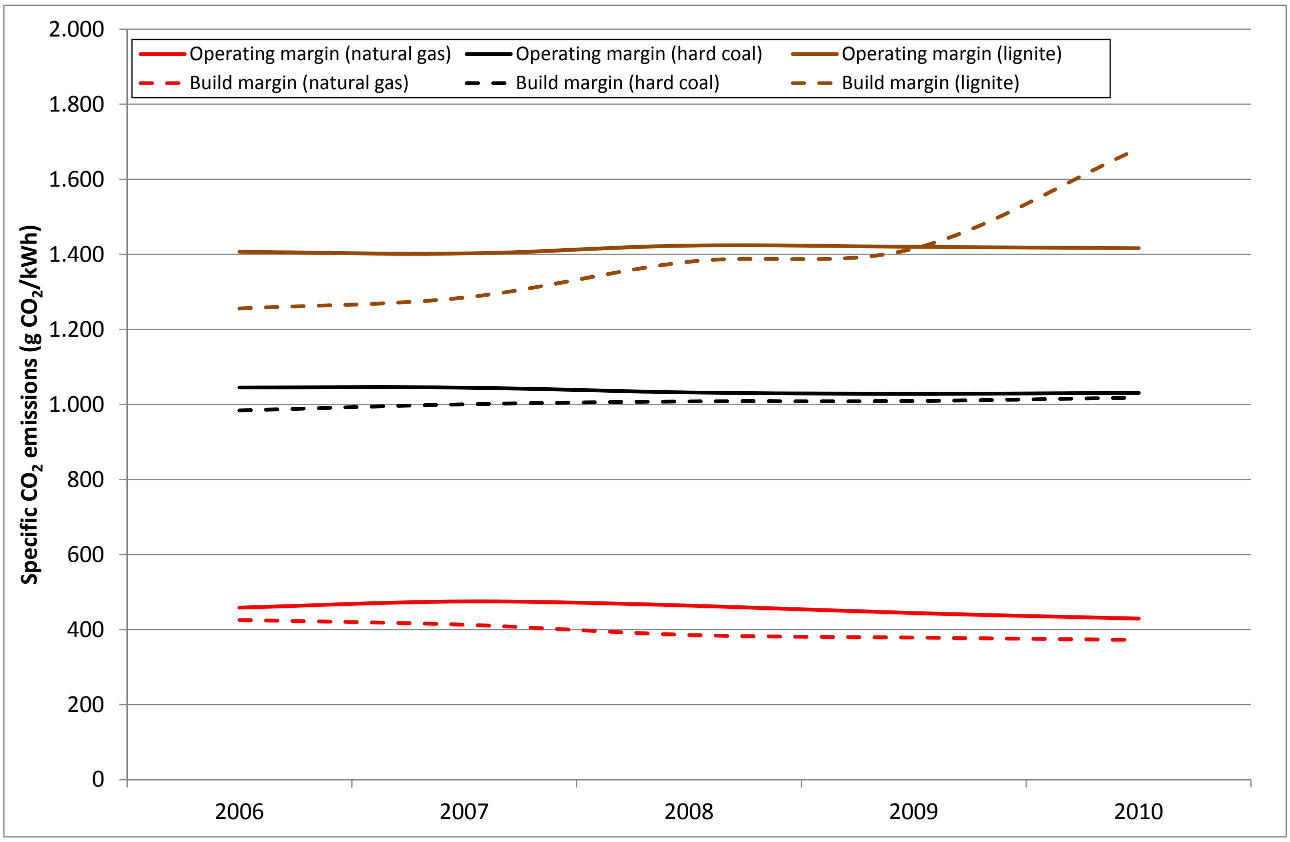
Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

The build margin is based on the years 2006 to 2010. However, the calculation may require updating since investment conditions, exploitation potential (e.g. hydro) and technical specifications (such as the electrical efficiency) may change over time and therefore cannot simply be assumed as ongoing in the future.

Development of specific CO_2 emissions of individual power plant types

For the purpose of this case study, two types of specific CO_2 emissions of individual power plant types (differentiated by fuel) are derived. The methodology generally follows the same rationale as for the specific CO_2 emissions of the power sector as a whole. For the operating margin, specific CO_2 emissions in the years 2006 to 2010 are considered. The build margin of new power plants is calculated for the years 2006 to 2010 based on the power plants built in the respective year and four years prior to the year under consideration (Figure 7).

Figure 7: Specific CO_2 emissions of power plant types (natural gas, hard coal and lignite) according to the operating margin and the build margin, 2006-2010



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

Generally, it can be expected for all power plant types that specific CO_2 emissions decrease over time as more efficient power plants are put online. This holds true both for the operating and the build margin. Also, the build margin is expected to have lower values than the operating margin due to more recent construction years and the correspondingly higher efficiencies of power plants. However, due to specific operating conditions (cycling, etc.), specific CO_2 emissions may also increase temporarily.

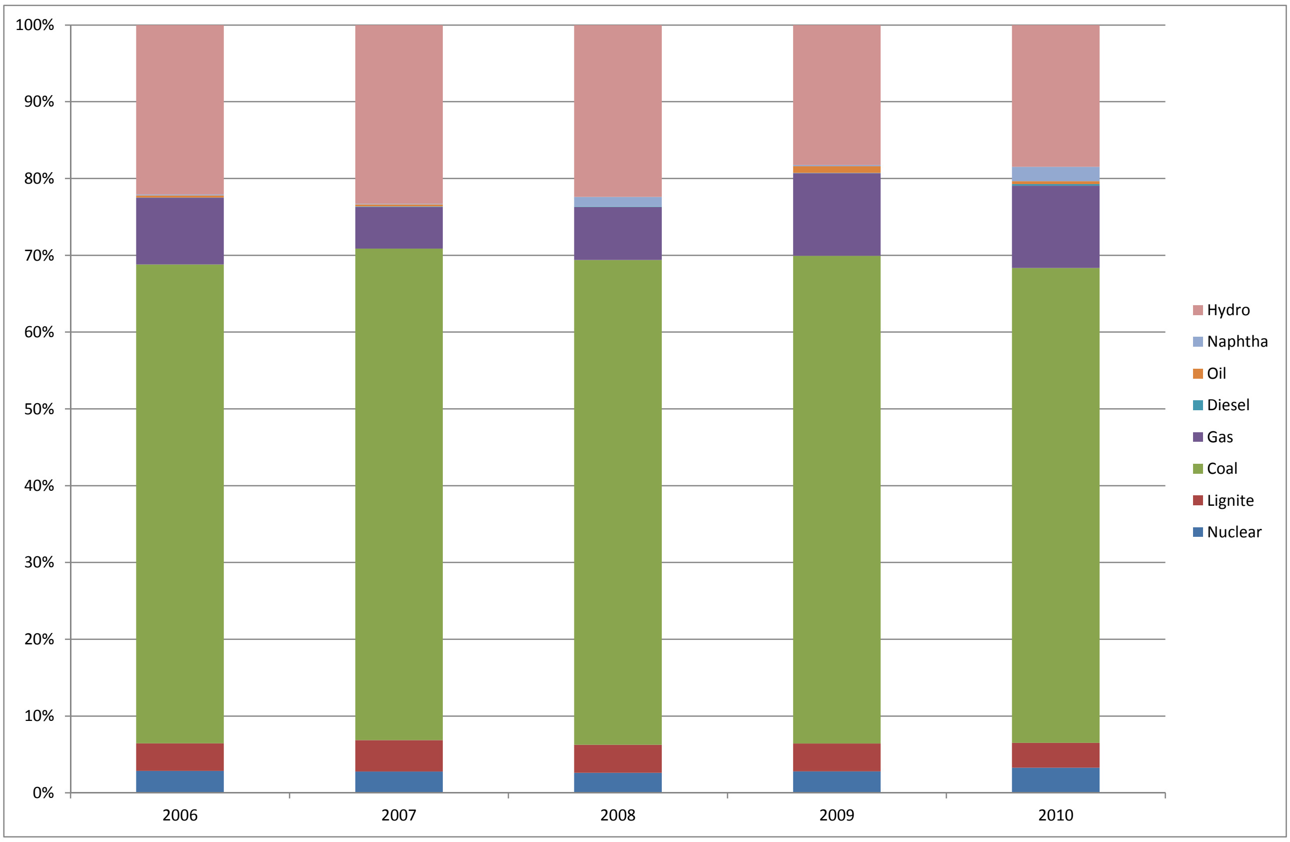
In Figure 7, the operating margin of lignite-fired power plants in the dataset is rather constant over time at around 1,410 g CO_2/kWh. The build margin of lignite-fired power plants shows a significant increase of specific CO_2 emissions between 2008 and 2010, which even goes beyond the specific CO_2 emissions of the operating margin in 2010. This is not plausible for the reasons mentioned above. Therefore, the lower build margin values of lignite for the years 2006 and 2007 are considered as the most realistic values (1,270 g CO_2/kWh).

Both the operating margin and the build margin of hard coal-fired and natural gas-fired power plants indicate a rather constant trend (approx. 1,040/1,000 g CO_2/kWh for hard coal-fired power plants and 450/400 g CO_2/kWh for natural gas-fired power plants). Values for the build margin lie below the ones for the operating margin, which is plausible for the above-mentioned reasons.

Development of the fuel mix

Similarly, to the trend in specific CO_2 emissions, the development of fuel mix in the power sector can be analysed (Figure 8). The development of the fuel mix between 2006 and 2010 shows a sensible increase of the share of gas-fired electricity generation (from 9% in 2006 to 11% in 2010) whereas the share of other fuels remains rather constant. Hydro features a decreasing trend (from 22% in 2006 to 18% in 2010), which may be due to variations in hydrological conditions.

Figure 8: Fuel mix (basis electricity generation), 2006-2010



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

Consolidated indexed baseline based on specific CO_2 emissions of the power sector and the fuel mix

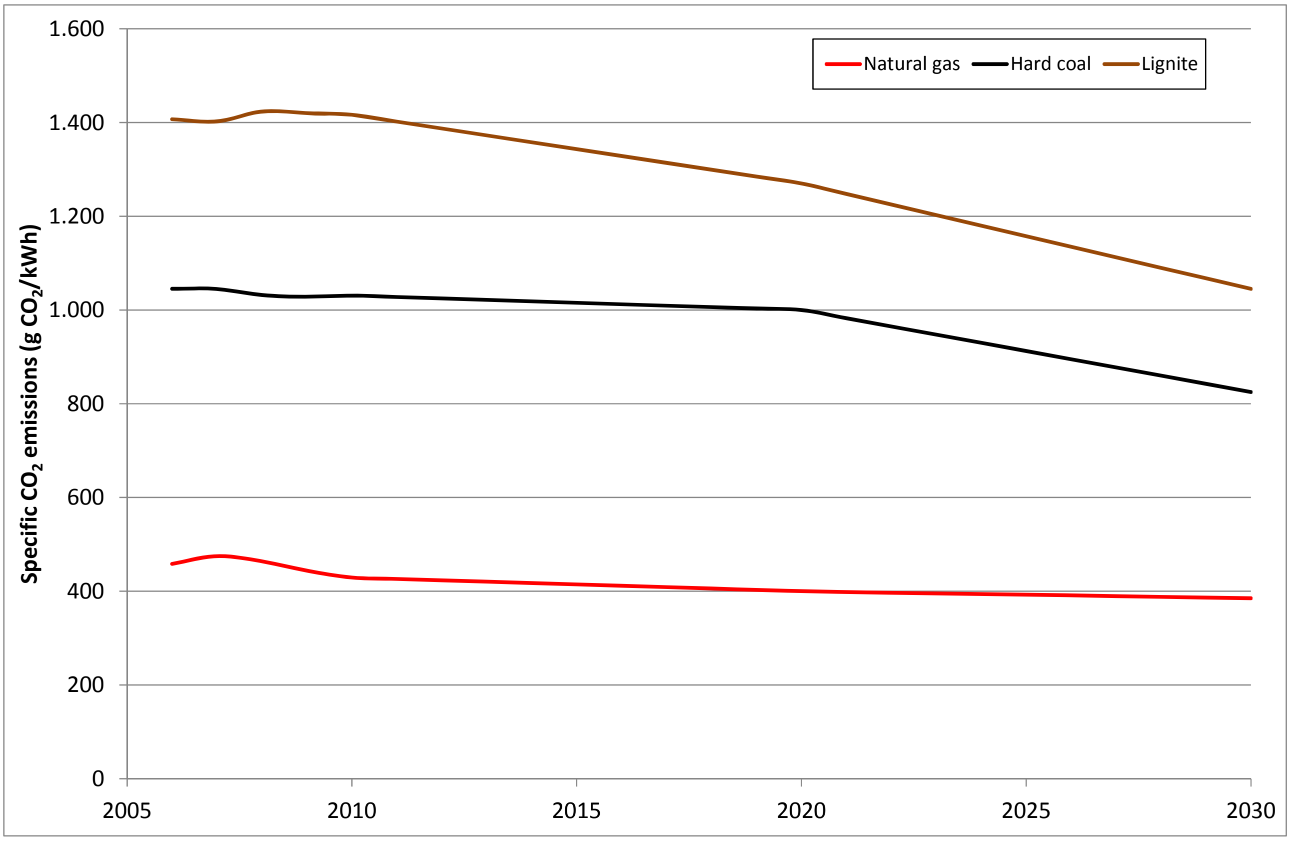
In reality, several aspects of the power sector may evolve simultaneously, specific CO_2 emissions of individual power plant types, fuel mix and overall electricity consumption. Different combinations thereof may be modelled. For the purpose of this case study, a combined indexed baseline based on specific CO_2 emissions of power plant types and the fuel mix is proposed. An absolute baseline is subsequently derived based on assumptions regarding the development of the electricity consumption.

Based on the analysis above, the following rationale for deriving the baseline is used:

Specific CO_2 emissions of individual power plant types (for all power plants of the same fuel) start at the operating margin of 2010: 1,416 g CO_2/kWh for lignite, 1,031 g CO_2/kWh for hard coal and 429 g CO_2/kWh for natural gas. It is assumed that the average efficiency of all power plants in the sector reaches the level of the build margin of the years 2006 to 2010 by 2020

(Figure 7). This is a conservative assumption since old power plants are gradually decommissioned and replaced by (more efficient) ones. In 2020, specific CO_2 emissions of all power plants therefore reach 1,270 g CO_2/kWh for lignite-fired power plants, 1,000 g CO_2/kWh for hard coal-fired power plants and 400 g CO2/kWh for natural gas-fired power plants. State-of-the-art power plants today feature specific CO_2 emissions of 950 g CO_2/kWh for lignite-fired power plants, 750 g CO_2/kWh for hard coal-fired power plants and 350 g CO_2/kWh for combined cycle natural gas-fired power plants. For 2030, it assumed that the share of state-of-the-art power plants has increased significantly, in a way that average specific CO_2 emissions in 2030 are only 10% above today's state-of-art power plants (1,045 g CO_2/kWh for lignite-fired power plants, 825 g CO_2/kWh for hard coal-fired power plants and 385 g CO_2/kWh for natural gas-fired power plants). This development can be considered as autonomous improvement of the power sector (Figure 9).

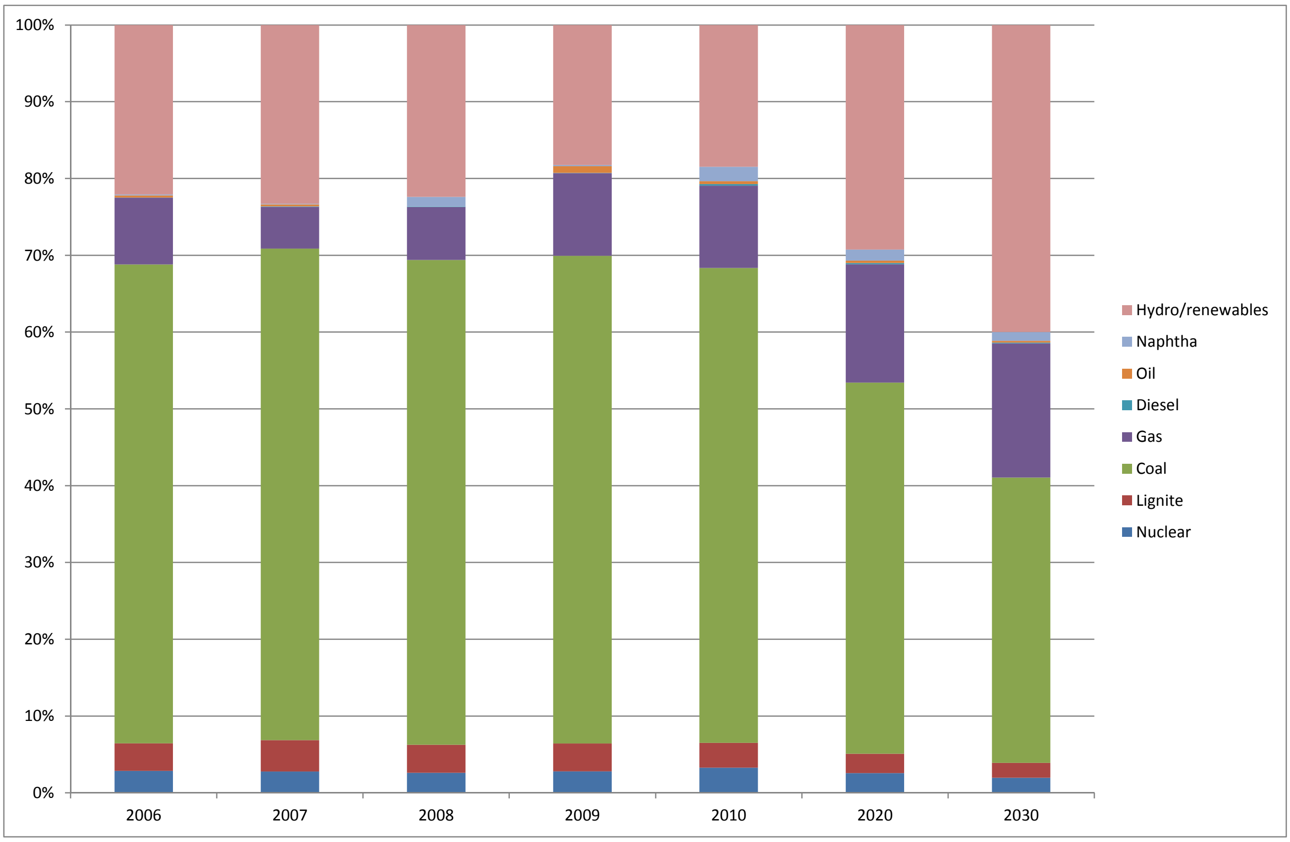
Figure 9: Historical and assumed projected specific CO_2 emissions of individual power plant types, 2006-2030



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

Fuel mix: The starting point of the development of the fuel mix is the fuel mix in 2010. It is assumed that the contribution of natural gas to the overall electricity mix continues to grow in the same manner as in 2006-2010 (Figure 8). Furthermore, it can be expected that due to significant cost decreases, renewable electricity generation, especially based on wind and PV, will grow substantially. An overall share of renewables of 40% in 2030 is assumed (starting from 18% hydro in 2010). The contribution of other fuels to the fossil electricity generation remains the same. Overall due to the increase in renewable electricity, natural gas is the only fossil fuel that shows a resulting increase of the generation share whereas all other fossil fuels have decreasing shares (Figure 10).

Figure 10: Historical and assumed projected fuel mix, 2006-2030



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

Figure 11 shows the development of the specific CO_2 emissions of the power sector resulting from the above-mentioned development of the specific CO_2 emissions of individual power plants and the fuel mix[15].

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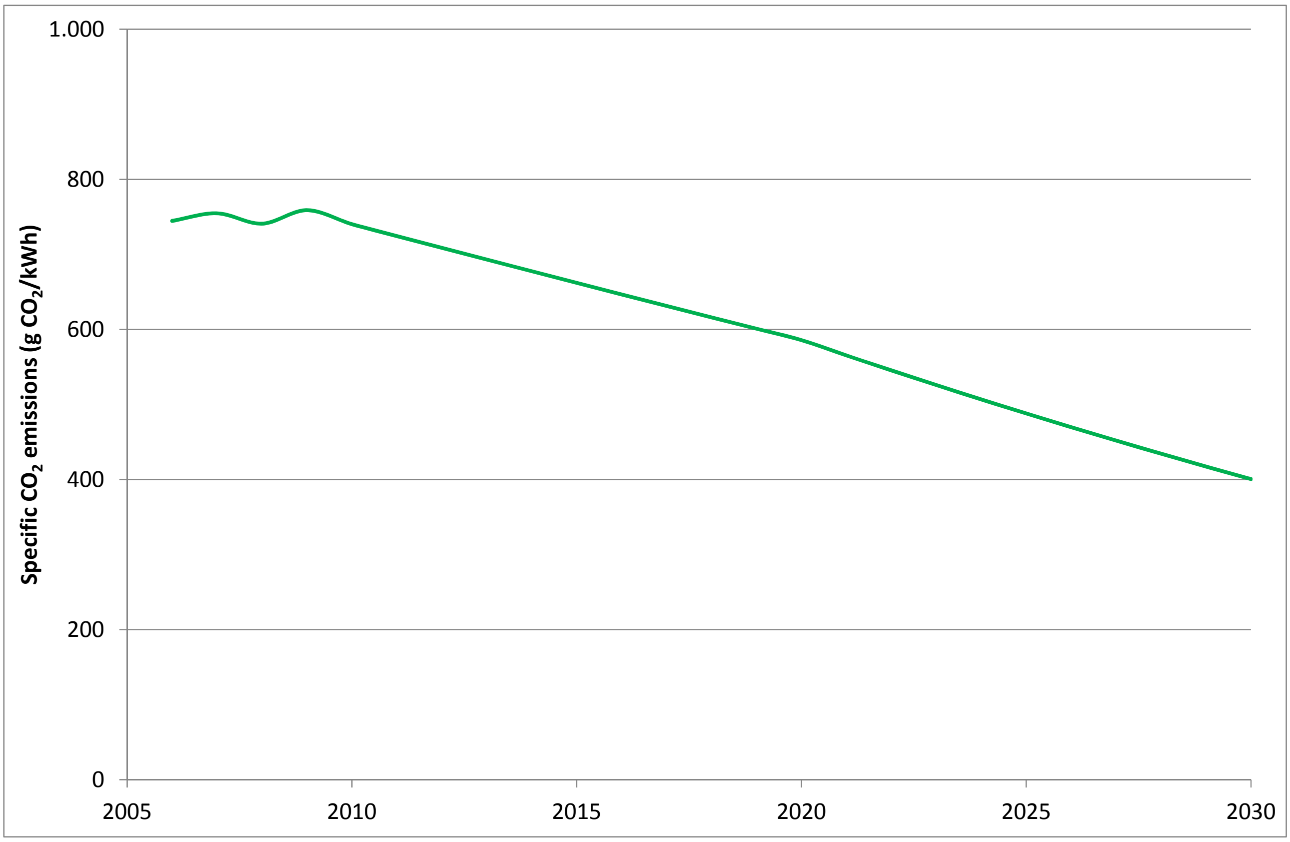
[15] For all other fuels (diesel, oil, naphtha), specific CO_2 emissions are assumed to remain constant at the level of 2010.

Figure 11: Indexed baseline of specific CO_2 emissions of the power sector based on specific CO_2 emissions of individual power plant types (natural gas, hard coal and lignite) as well as an assumed trend of the fuel mix, 2006-2030



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

The figure shows that the autonomous development of the power sector, i.e. the shift in the fuel mix (more natural gas-fired electricity generation, significant increase of renewables) and efficiency improvements of individual power plants, lead to significantly decreasing specific CO_2 emissions of the power sector from 740 g CO_2/kWh in 2010 to 401 g CO_2/kWh in 2030.

In order to assess the impact of the autonomous development of the power plant fleet on absolute CO_2 emissions, the development of the electricity generation up to 2030 needs to be estimated. The development of the electricity demand is dependent on a range of factors such as the development of economic growth, socio-economic development and the implementation of energy efficiency measures. Electricity generation has increased from 497 TWh in 2006 to 625 TWh in 2010[16], which corresponds to an annual growth of 5.9%. For this rough analysis it is assumed that this growth rate continues until 2020. Between 2020 and 2030, it is assumed that the annual growth of electricity generation can be limited to 3% due to an increased uptake of

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[16] It should be noted that electricity generation is derived from the CEA dataset. Please refer to the discussion of associated uncertainty due to changing coverage over time (footnote 12).

readily available efficiency measures. In such a scenario, electricity generation would increase from 625 TWh in 2010 to 1,490 TWh in 2030 (Table 2)[17].

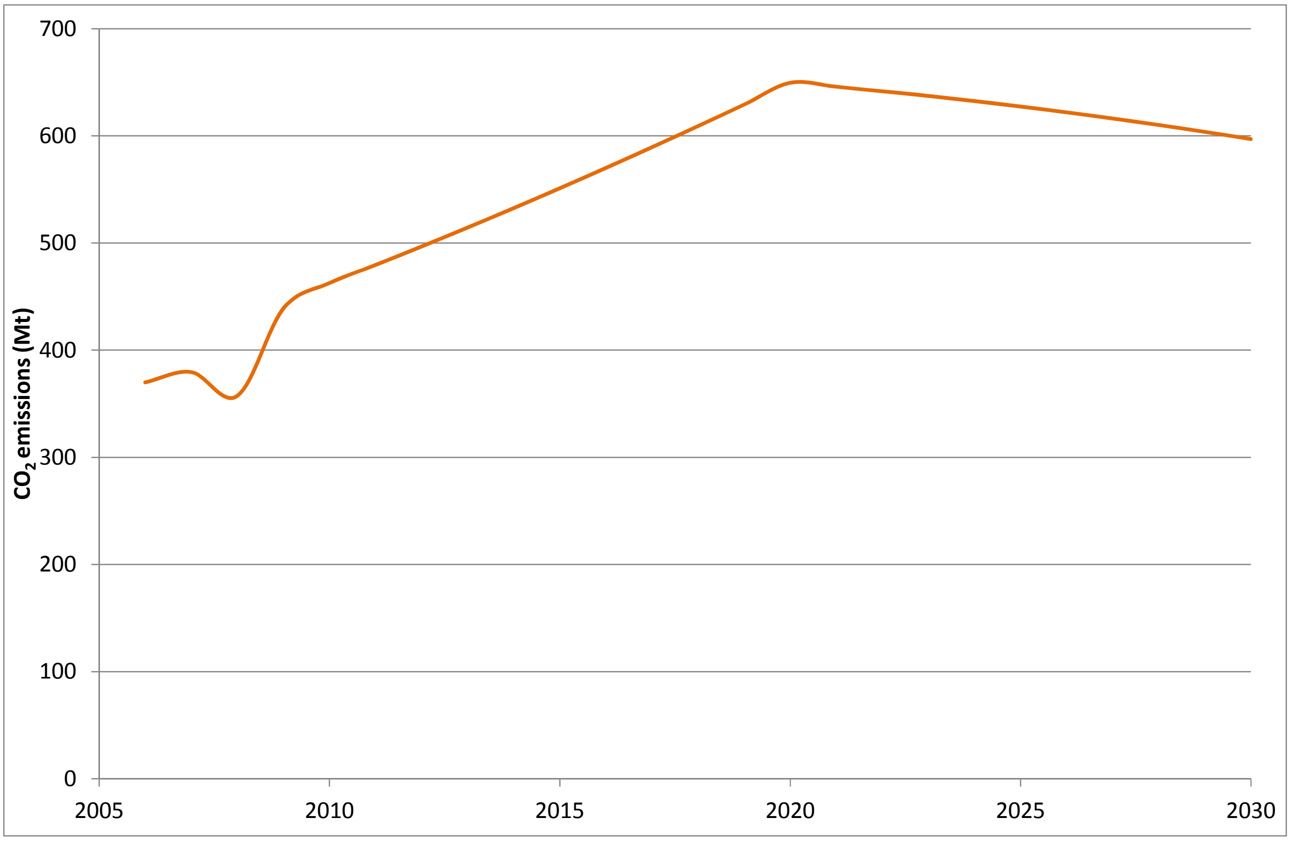
Table 2: Estimated development of the electricity generation of Indian power plants, 2006-2030

Net generation (TWh)								
2006	2007	2008	2009	2010	2015	2020	2025	2030
497	503	482	578	625	833	1.109	1.286	1.490

Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

On the basis of the indexed baseline of specific CO_2 emissions of the power sector (Figure 11) as well as on the development of the electricity generation (Table 2), absolute baseline CO_2 emissions can be calculated (Figure 12).

Figure 12: Absolute baseline CO_2 emissions based on an indexed baseline, 2006-2030



Source: Central Electricity Authority (2012a), calculations by Oeko-Institut

In such a scenario, absolute CO_2 emissions increase from 463 Mt CO_2 in 2010 to 650 Mt CO_2 in 2020. Although specific CO_2 emissions of individual power plants decrease and the share of renewables increases, the efficiency gains are more than outweighed by the significant growth of the electricity consumption. Only after 2020, absolute CO_2 emissions decrease (to 597 Mt CO_2

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[17] Different scenarios for the development of electricity demand are also available in Central Electricity Authority (2012b). However, forecasts reach until 2021/22 only.

in 2030) due to the increased uptake of energy efficiency measures and thus the limitation of growth of electricity consumption.

4.2.3 Result

This analysis demonstrates that a mere extrapolation of absolute CO_2 emissions (Figure 4) neglects important aspects of autonomous development of the power sector, namely the increased efficiency of individual power plants, fuel switch and the promotion of renewables. Also, potential (autonomous) abatement measures in other sectors (energy efficiency, expressed in yearly growth of electricity consumption) are not considered by a mere extrapolation of absolute CO_2 emissions. It can therefore be concluded that a plausible and conservative estimation of baseline emission needs to consider several key drivers at the same time. A purely technical analysis (based on benchmarks, etc.) does not lead to a robust baseline. The use of projection techniques (which allow considering a range of variables at the same time) should therefore be further explored.

5 Assessing baselines for the NMBM: cement sector

5.1 General characteristics of the sector

The cement industry is a crucial economic sector globally. Cement is produced practically in every country in the world, and is required to build the basic infrastructure needed for development. The world's total cement production reached 3.4 billion tonnes in 2011, with an average growth of 6.7% over the last 5 years (US Geological Survey 2012). The CO_2 emissions associated with cement production can be estimated at 2.72 $GtCO_2e$ in 2011.[18] In 2006, the sector's emissions represented 8% of global anthropogenic CO_2 emissions (Müller and Harnisch 2008).

Economic development has been recognized as the main driver of the cement industry. Per capita cement consumption tends to increase with income up to an income level of 15,000 USD/capita. After reaching this income level, cement consumption stabilizes (Müller and Harnisch 2008). As a result of such trend, most new production capacity needed in the next 10-20 years is expected to be installed in low- to middle-income countries. Already now, over half of global cement production takes place in China, and about of it occurs in just 12 developing countries (Lee et al. 2011).

Cement production involves several GHG (mainly CO_2) emission sources. About 50% of total emissions occur in the form of process (non-energy related) CO_2 emissions from limestone calcination; 40% occur through energy (coal) consumption in clinker production; the rest comprises mainly indirect emissions from electricity consumption (e.g. for grinding of raw material and clinker), and emissions from transportation. On average, 0.8 tCO_2 are emitted per tonne of cement (Lee et al. 2011). Such diversity of emission sources implies that, according to the IPCC guidelines for GHG inventories (IPCC 2006), cement sector emissions need to be accounted for in several IPCC sector definitions: process emissions are accounted within the IPCC 2 A 1 category (mineral industry – cement production); direct energy emissions are considered in the 1 A 2 f category (manufacturing industries and construction: non-metallic minerals); electricity emissions are included in the 1 A 1 a category (main activity electricity and heat production); transport emissions are considered within the 1 A 3 sector (transport). This already illustrates the challenges existing in defining "sectors" for a NMBM.

At the same time, the existence of all these emission sources gives place to several mitigation opportunities, such as the use of alternative raw materials for clinker production in kilns, the use of alternative kiln fuels, energy efficiency measures including waste heat recovery, an increased blending of clinker with cementitious materials, and, potentially, carbon capture and storage (Lee et al. 2011). With respect to fuel use, while similar fuels are generally used worldwide (usually coal), a mix with waste or biomass is possible, depending on their availability and on the applicable legal framework. In terms of energy efficiency, nowadays similar production technologies are applied worldwide in new plants, with a limited number of equipment manufacturers supplying the market (Hayashi et al. 2010). However, as production technology has become more efficient over time, plant vintage matters, and, particularly for existing installa-

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[18] Based on an estimated CO_2 intensity of 0.8 tCO_2e/t cement (Lee et al. 2011) and a production level of 3.4 Gt cement in 2011.

tions, technology types (e.g. wet versus dry kilns) are also relevant. While using alternative materials to produce clinker or to mix with it is a theoretically available option to reduce emissions, it strongly depends on local availability of appropriate materials.

A potential sectoral baseline for cement therefore needs to explicitly deal with following specific design elements with respect to its level of aggregation:

- **Process:** Consideration of two types of processes: dry and wet kilns (especially if the baseline is to be applied to retrofits of existing kilns, as new kilns usually apply the dry technology). If electricity emissions are included in the baseline, differentiation could be included in terms of plants with or without captive power plants.
- **Product:** Baselines could be set for clinker or for cement production. If set for cement, a potential market fragmentation could exist in terms of the blending ratio of clinker with alternative cementitious materials.
- **Time:** Consideration of autonomous efficiency improvements over time – estimates for the US put such autonomous improvement at between 0.5% and 1% per year, and relate them to an increased capacity of dry process kilns, energy efficiency improvements, and lower clinker to cement ratios (Worrell and Galitsky 2004).
- **Space:** Differentiation needed in terms of availability of alternative fuels, raw and blending materials, and of legal framework to allow the use of such materials. If electricity emissions are included in the baseline, differentiation could be needed in terms of the relevant electricity grids.

In the following section, we present an example about how a baseline for the cement sector could be developed on the basis of publicly available top-down (aggregated) data for an advanced developing country. As the particular local conditions existing in the case study will be fixed for this specific country, the analysis will not discuss the issues related to level of aggregation at length, but rather focus on the other design elements for sectoral baselines reviewed above: reference data, dynamics and updating, metrics and stringency level.

5.2 Case study of sectoral baselines in the cement sector

For the case study of the cement sector, we rely on the cement production and CO_2 emissions data that has been collected by the World Business Council for Sustainable Development (WBCSD)'s Cement Sustainability Initiative (CSI), which is publicly available on its website (CSI 2012). Due to confidentiality reasons, the publicly available data does not display production or emissions data per plant, nor vintage information of individual plants. Hence, only aggregated data (at the region level) is available for the years 1990, 2000, and 2005 onwards. This data will be used to illustrate how top-down, aggregated emission baselines for a whole sector up to the year 2030 could be established. For the case study, we have chosen to focus on the Indian cement sector because data for this country is reported separately by CSI, and has a relatively high coverage because complementary data from industry organisations is available, and because Indian cement production is, despite its already quite high energy efficiency, a large (and growing) contributor to GHG gases.

India is the second largest cement producer in the world, with a share of about 6% of global production (Parliament of India 2011). The industry comprises 154 large cement plants with an installed capacity of 230.8 million tonnes (Parliament of India 2011)[19] as well as over 365 mini plants with an installed capacity of about 11.1 million tonnes (Indian Brand Equity Foundation 2011). Cement production has grown at an average rate of over 8% over the last 5 years (Reserve Bank of India 2011), and emitted about 130 $mtCO_2e$ in the year 2007, which represented about 6.8% of India's greenhouse gas emissions[20] (Ministry of Environment and Forests 2010). Most of the country's cement production is consumed locally, with just a small percentage being exported (CMA 2010). There are no reports of cement or clinker being imported.

In terms of ***process***, the Indian cement industry hence comprises both new state-of-the-art plants using the efficient dry process technology, and smaller and inefficient wet process kilns. Production from the large plants accounts for about 97% of total production. While detailed statistics for small plants do not seem to be available, estimates show that production from small plants has not significantly grown in the last 15 years, remaining around 6 million tonnes per year.

With respect to ***products***, mainly three types of cement are produced. Portland Pozzolana Cement has a share of 67% of production, followed by Ordinary Portland Cement (25%) and Portland Slag Cement (8%). The present share of blended cement (75%) is expected to continue increasing in the future. Clinker substitutes for such blending are still available in large quantity: The Parliament of India (2011) estimates that currently 34 million tonnes of fly ash and 8 million tonnes of blast furnace slag are used as clinker substitutes per year. According to their estimations, 130 million tonnes of fly ash and 13 million tonnes of blast furnace slag are available each year. Another estimate cites a total of 161.5 million tonnes of these and other alternative cementitious materials per year (Pahuja 2008). However, due to increasing demand, also from competitive uses such as brick manufacturing, these originally free waste products have now become a priced commodity, which represents a cost barrier for a wider use(Parliament of India 2011). Technically, high blending levels are possible without affecting the performance of cement. In practice, some countries have achieved a clinker-to-cement ratio (CCR) of around 0.7, with Brazil reaching even 0.65 (in comparison, the current ratio in Indian large plants is about 0.77); some cement blends reach a CCR of 0.25 (Müller and Harnisch 2008; CMA 2010; Graus et al. 2011).

The CSI data covers 72 plants from 8 companies operating in India, which represents about 50% of current total production (see Table 3). The small number of plants and large coverage in terms of production suggests that the database only contains information from large production plants. In terms of process, the database includes only dry kilns, of which between 93% and 100% include a preheater and a precalciner, and 0-7% include only a preheater. In terms of fuel, mostly fossil fuels are used, but their share has decreased from about 100% in the years 1990 and 2000 to 97.9% in 2010, being replaced mostly by waste materials, but also by bio-

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[19] Other sources cite 139 large plants with a capacity of 234.3 million tonnes per year (Indian Brand Equity Foundation 2011). Large plants are those with an installed capacity above 1 million tonnes/year.

[20] Without considering indirect emissions from electricity use, and without counting LULUCF.

mass.[21] Similarly, the use of blending materials has increased from 13.6% in 1990 to 29.2% in 2010.

The data reports ***emissions*** from the calcination process and from fossil fuel combustion. Emissions from biomass and waste combustion are considered to be zero. Indirect emissions from electricity consumption are not included. While the CSI data includes an electricity consumption indicator (kWh per tonne of cement), finding an appropriate emissions factor for electricity consumption is problematic as an increasing number of plants has captive power production (probably based on co-generation or waste heat recovery). This is a significant drawback of the data, as some studies have pointed out that, while new cement plants usually incorporate state of the art clinker kilns, there is higher variation in the electricity-consuming equipment installed (e.g. grinding units). Thus, in new installations, there may be more scope for achieving efficiency gains from electricity consumption in grinding mills than from fuel combustion in clinker kilns (Ruth et al. 2000). In addition, 30% to 40% of total heat input in cement plants is released as waste heat. In India, the cement sector has an estimated potential of 400 MW electricity generation from co-generation, but so far only 13.5 MW are in operation and 71.5 MW under construction (frequently as part of CDM projects). Due to the imported technology, capital costs of co-generation are still higher than those of coal-fired power plants. In addition, state governments impose a duty on captive power generation and also demand a payment for grid power use even if the plants are self-reliant. This reduces the competitiveness of co-generation also in terms of operation costs (Parliament of India 2011).

Table 3: Cement statistics for India, CSI database and official statistics compared

Year	CSI database				CMA statistics [a]		CSI data coverage (production)	CSI data coverage (plants)
	Cement production (1000 tonnes)	Plants	Dry kilns with preheater and precalciner[b]	Clinker to cement ratio (t clinker / t cementitious)	Cement production (1000 tonnes)	Large plants		
1990	18'700	25	100.0%	0.864	48'900		38.2%	
2000	49'600	48	100.0%	0.852	100'110		49.5%	
2005	70'700	54	93.0%	0.778	147'810		47.8%	
2006	76'400	54	93.0%	0.749	161'640		47.3%	
2007	82'500	57	94.0%	0.728	174'310	136	47.3%	41.9%
2008	89'100	59	93.0%	0.713	187'610	145	47.5%	40.7%
2009	103'000	65	100.0%	0.715	206'940	156	49.8%	41.7%
2010	106'000	72	100.0%	0.711	215'560	161	49.2%	44.7%

[a] CMA data are based on financial years from 1 April to 31 March.

[b] The remaining plants are dry kilns with a preheater only.

Sources: CMA (2010); CSI (2012). For year 2010: ACC Limited (2012); Ambuja Cements Ltd. (2012); CMA (2012).

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[21] While different types of fossil fuels have different carbon intensities, the CSI database does not report what types of fossil fuels are used in cement production in India. Data from the CMA show that besides coal, lignite and petroleum coke have been used since the early 1990s in shares ranging from 1 to 13% of total fuel consumption.

In addition, basic socioeconomic data (GDP, GDP per capita and population) and current industry statistics will be used for projecting future cement production levels. The historic socioeconomic data up to 2010 was obtained from the World Development Indicators (World Bank 2012), and future projections up to 2030 were gathered from the US Energy Information Administration's International Energy Outlook Reference Case projections (EIA 2011). Historic cement production levels were obtained, for the years 1981-1988, from the Reserve Bank of India (2011), and for the years 1989-2009 from the Cement Manufacturers' Association (CMA 2010).

The main factors influencing direct (non-electricity) emissions from the cement sector are fuel consumption and thermal efficiency in the clinker production process, and the blending ratio. Accordingly, the following types of baselines could be proposed:

- Indexed baseline based on CO_2 emissions per unit of cement production: This baseline would account for the effect of both the clinker production process and blending of clinker with other cementitious materials on emission levels.
- Indexed baseline based on CO_2 emissions per unit of clinker production: This baseline would incorporate only the effect of the clinker production process on emission levels.
- Absolute emissions baseline based on historical emissions and trends: This baseline would implicitly include also the size of the industry as a factor affecting emission levels.

These baselines will be compared with an hypothetical emissions goal for the cement sector in the year 2030 based on the CSI's Cement Technology Roadmap (WBCSD and IEA 2009): 0.426 tCO_2/t cement, which represents a 36% reduction with respect to the emissions intensity of Indian cement production in 2005 (as covered by the CSI database).

5.2.1 Indexed baseline based on emissions per unit of cement production

When emissions levels are indexed with respect to cement production, the thermal efficiency in the clinker production process, the amount of fossil fuels in the fuel mix, and the blending ratio of clinker with other materials (CCR) influence emission levels.[22] Hence, projections of future emission levels should ideally take these predictors into account. The slightly longer time series available for cement emissions than for power emissions allows us to display the effect of different types of projections into the future on the shape of the baseline. To illustrate the effect of using different projections and predictors on estimated future emission levels, we use the available historical data to generate four types of projections, as detailed in Table 4. Source:
Authors' own calculations based on CSI (2012) Ghosh and Chandrasekhar (2009)

Figure 13 presents the results of the different projections, and illustrates how different ways of estimating a baseline on the basis of historic data may yield very different results. In all the projections, the trend is towards lower emissions per unit of cement production. However, the longer the time period projected, the more divergent the results are, hence the higher the uncertainty of the projections. According to these projections, the direct CO_2 emissions from cement production in India in the year 2020 may be anywhere between 0.483 and 0.578 tCO_2/t cement. It is interesting to note that the most ambitious projections (in terms of less emissions

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[22] As described above, the CSI data does not report indirect emissions from electricity consumption, so that this emissions source will not be considered in our analysis.

per unit of cement) are obtained by using a simple linear extrapolation of the current trend. In the case of the Indian cement sector, energy efficiency is already among the highest in the world. Compared to the projections on the basis of realistic efficiency, fuel mix and blending achievements up to 2030, the simple linear projection of current trends would clearly require quite high blending or fuel shift percentages in the future, which may become challenging.

Table 4: Baselines based on projections of indexed emissions per unit of cement production: assumptions

Projection	Rationale and assumptions
Linear extrapolation of historical emissions on the basis of all the existing indexed emissions data	Continuation of historical emission trends.
Linear extrapolation of historical emissions on the basis of the indexed emissions data for the last 6 years	Continuation of historical emission trends, but using only the most recent data with a continuous time series. This would avoid potential bias due to missing data and due to longer term changes in the emission trends.
Linear projection from the last data point assuming an autonomous 1% annual improvement in emissions performance	Following historic improvements cited by the literature. This improvement factor would account for both energy efficiency improvements and changes in the fuel mix or blending proportions.

Projection	Rationale and assumptions
Linear regression with respect to projected fossil fuel consumption and clinker to cement ratio (CCR)	Relates cement emissions to its underlying causes: the use of fossil fuels in clinker production (influenced by energy efficiency improvements and by the use of biomass or waste as fuels) and the level of blending of clinker with other cementitious materials. Four scenarios about the future projection of fuel use and CCR are modelled: - In 2030, fuel consumption reaches best available technology (BAT) levels, but alternative fuels are not used. Fossil fuel consumption hence evolves linearly from current levels (3097 MJ/t clinker in 2010) to 2717 MJ/t clinker in 2030. An optimistic CCR of 0.57 is reached in 2030. - In 2030, fuel consumption reaches BAT levels, and 10% alternative fuels are used. Fossil fuel consumption evolves linearly from current levels to 2459 MJ/t clinker in 2030. An optimistic CCR of 0.57 is reached in 2030. - In 2030, fuel consumption reaches BAT levels, but alternative fuels are not used. Fossil fuel consumption evolves linearly from current levels to 2717 MJ/t clinker in 2030. A pessimistic CCR of 0.69 is reached in 2030. - In 2030, fuel consumption reaches BAT levels, and 10% alternative fuels are used. Fossil fuel consumption evolves linearly from current levels to 2459 MJ/t clinker in 2030. A pessimistic CCR of 0.69 is reached in 2030.[23]

Source: Authors' own calculations based on CSI (2012) Ghosh and Chandrasekhar (2009)

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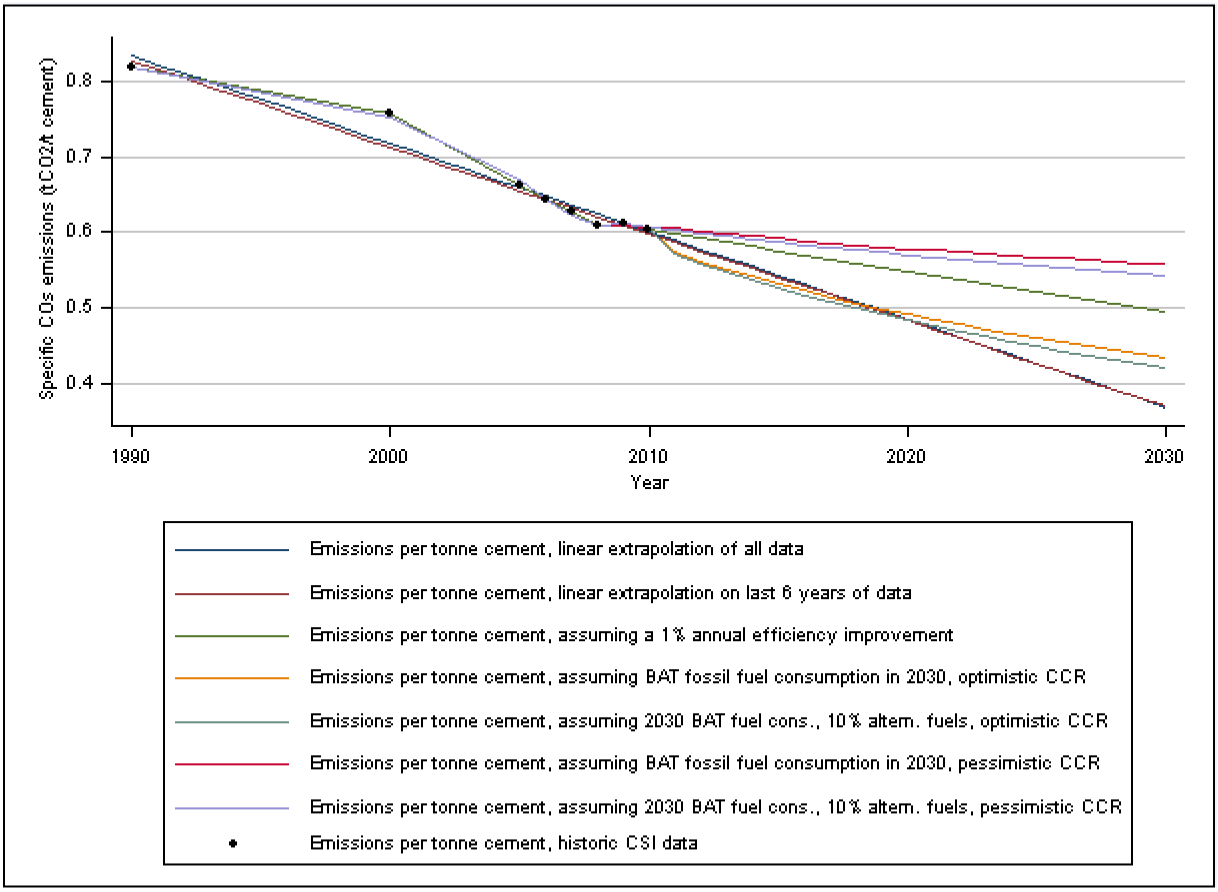
[23] BAT thermal energy consumption levels were obtained from Ghosh and Chandrasekhar (2009). Assuming BAT in 2030 means that existing old installations will be replaced or retrofitted to achieve the highest existing efficiency levels by 2030. With the rising costs of fuels, such an assumption is plausible even without policy intervention. The assumption on alternative fuels reaching 10% by 2030 is relatively pessimistic, if we consider that some European countries have already managed to source up to 47% of thermal energy from alternative fuels (Bischoff 2008), and individual plants up to 98% (WBCSD and IEA 2009). WBCSD and IEA (2009) expect that in developing countries, rates of substitution of 10-20% on average can be achieved by 2030. Different types of waste fuels are available in large quantities in India: Rajasekar (2008) cites a potential for heat substitution in clinker production of 47% from hazardous waste, municipal solid waste and tires in India. Trial runs in several cement plants with effluent treatment plant sludge, tar waste from petroleum industries, used tires, refinery sludge and paint sludge have had positive results (Bischoff 2008). However, there are regulatory barriers to the use of hazardous wastes for cement production, and the use of biomass as fuel is being adopted slowly (Kumar 2008). Other factors also influence the decision to adopt alternative fuels, such as the proximity of the fuel source to the plant, the sustainability of the supply, type of manufacturing process and compatibility of the fuel with it, and the infrastructural facilities needed to handle the alternative fuel (Pahuja 2008).

Figure 13: Baselines based on projections of indexed emissions per unit of cement production



Source: Authors' own calculations based on Ghosh and Chandrasekhar (2009); CSI (2012)

In order to be able to estimate total emission levels for an indexed baseline, the baseline needs to be related to total cement production levels. Usually, such activity data is monitored over time, so that the absolute emissions are not known in advance. In this case study, in order to illustrate the range of absolute emission levels that would be covered by the indexed baselines estimated above, we generate future cement production projections on the basis of historic industry data (CMA 2010; Reserve Bank of India 2011) and assuming different scenarios, as detailed in Table 5.

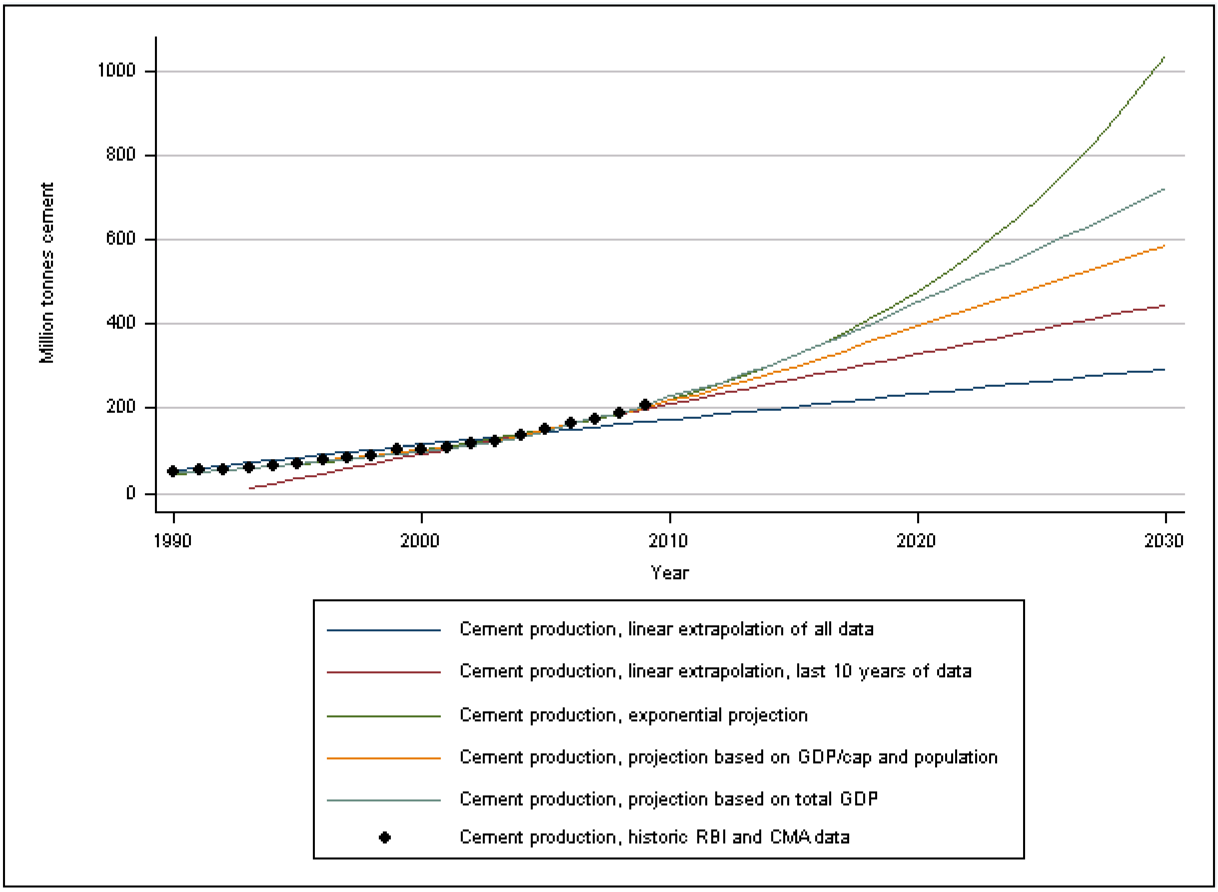
Table 5: Projections of cement production up to 2030: assumptions

Projection	Rationale and assumptions
Linear extrapolation of historical production data	Continuation of historical cement production trends.
Linear extrapolation of historical production data (only last 10 years)	Continuation of historical production trends, but using only the most recent data. This would avoid potential bias due to longer term changes in the underlying economic development trends.

Projection	Rationale and assumptions
Linear extrapolation of historical production data	Continuation of historical cement production trends.
Exponential projection of historical production data	The historical trend shows an exponential growth of cement production in India. An exponential projection is better suited to reflect this trend than a simple linear one as above.
Linear regression with respect to projected GDP per capita and population levels	Relates cement production to its underlying causes: economic and population growth. GDP per capita and population projections follow the reference case in EIA (2011). Different specifications for the regression were tested and the one with the best fit was used: $cement\_prod = \alpha + \beta_1\ GDPcap + \beta_2\ population + \beta_3\ population^2$
Linear regression with respect to projected total GDP	Relates cement production to its underlying causes: economic and population growth. Total GDP summarizes the effect of GDP per capita and population in a single variable. It is projected as in the reference case in EIA (2011). Different specifications for the regression were tested and the one with the best fit was used: $cement\_prod = \alpha + \beta_1\ GDP$

Source: Authors' own calculations based on CMA (2010); EIA (2011); Reserve Bank of India (2011); World Bank (2012)

Figure 14: Projections of Indian cement production up to 2030



Source: Authors' own calculations based on CMA (2010); EIA (2011); Reserve Bank of India (2011); World Bank (2012)

Figure 14 presents the results of the different cement production projections, and makes clear that the range of different results is even larger than in the case of indexed emissions. In the year 2020, cement production is projected to be anywhere between 234 and 478 million tonnes, up from 207 million tonnes reported for the year 2009. This uncertainty in production levels is implicitly included in baselines that are based on absolute emission levels, which supports the idea that indexed baselines are better suited for countries with uncertain future growth projections. It is likely that the highest projection displayed in Figure 14 (exponential projection) is not realistic, as it would imply reaching a production level of 698 kg cement per capita in 2030, which is much higher than current European consumption (450 kg/cap). IEA expects that current Indian annual consumption of cement (120 kg/cap) will raise to 450 kg/cap until 2050, to match current European consumption (Tam 2008).

Assuming that production levels in the year 2020 will be at the average between all the shown projections (378 million tonnes cement), total cement-related direct emissions in India will amount to 182.6 – 218.5 $mtCO_2$ in the year 2020.

5.2.2 Indexed baseline based on emissions per unit of clinker production

When emissions levels are indexed with respect to clinker production, only the thermal efficiency in the clinker production process and the amount of fossil fuels in the fuel mix influence emission levels. We generate the projections described in Table 6.

Table 6: Baselines based on projections of indexed emissions per unit of clinker production: assumptions

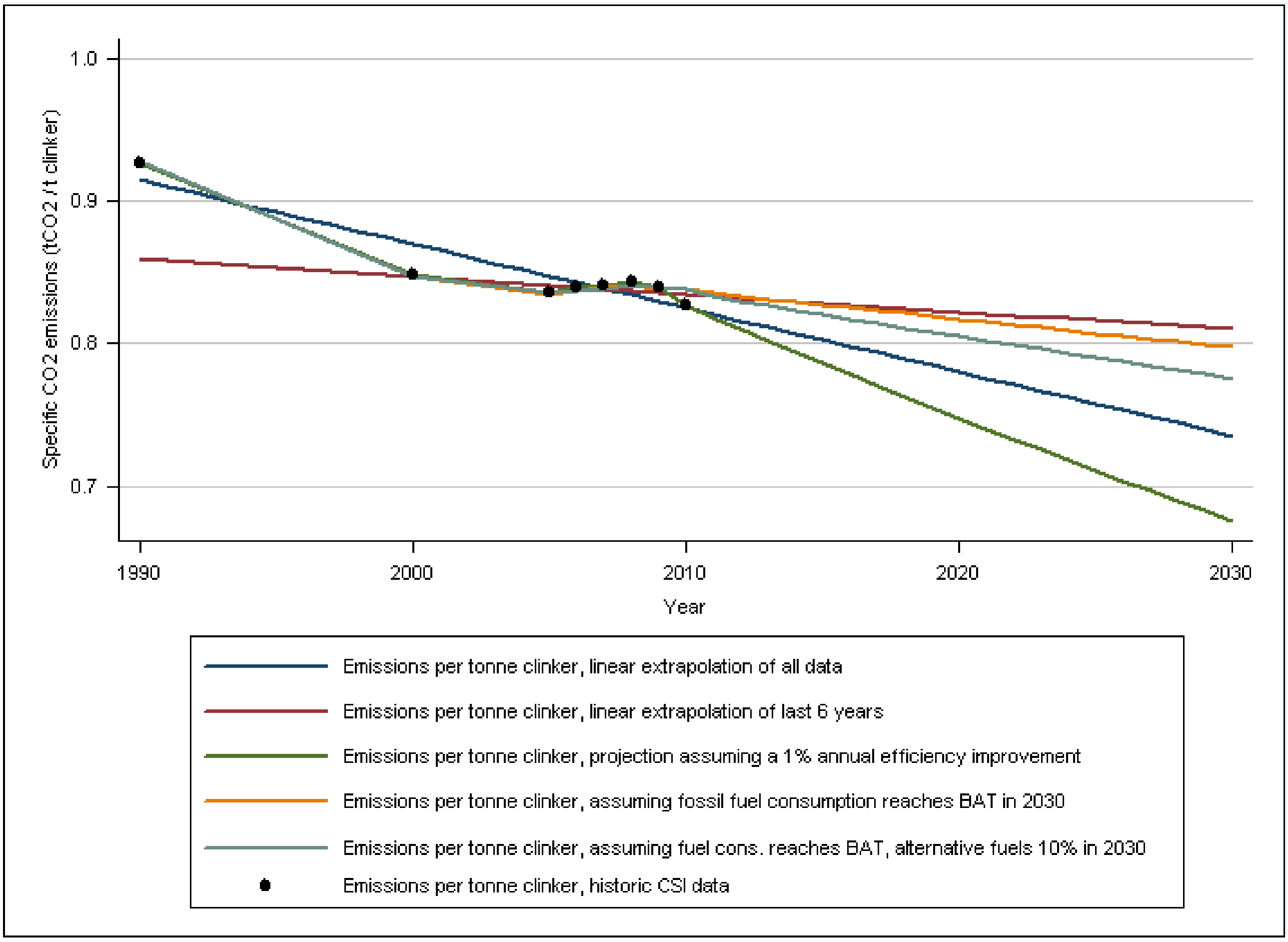
Projection	Rationale and assumptions
Linear extrapolation of historical emissions on the basis of all the existing indexed emissions data	Continuation of historical emission trends.
Linear extrapolation of historical emissions on the basis of the indexed emissions data for the last 6 years	Continuation of historical emission trends, but using only the most recent data with a continuous time series. This would avoid potential bias due to missing data and due to longer term changes in the emission trends.
Linear projection from the last data point assuming an autonomous 1% annual improvement in emissions performance	Following historic improvements cited by the literature. This improvement factor would account for energy efficiency improvements and changes in the fuel mix.
Linear regression with respect to projected fossil fuel consumption	Relates cement emissions to its underlying cause: the use of fossil fuels in clinker production (influenced by energy efficiency improvements and by the use of biomass or waste as fuels). The blending level does not play any role in this indicator. Two scenarios are modelled: - In 2030, fuel consumption reaches best available technology (BAT) levels, but alternative fuels are not used. Fossil fuel consumption hence evolves linearly from 3097 MJ/t clinker in 2010 to 2717 MJ/t clinker in 2030. - In 2030, fuel consumption reaches BAT levels, and 10% alternative fuels are used. Fossil fuel consumption evolves linearly from current levels to 2459 MJ/t clinker in 2030.

Source: Authors' own calculations based on Ghosh and Chandrasekhar (2009); CSI (2012)

In Figure 15 we see the results of the projections on emissions per tonne of clinker produced. Here again we have a trend towards lower emission intensities, but quite a large divergence between the different results. According to the results, business-as-usual direct CO_2 emissions per tonne of clinker production will be between 0.748 and 0.822 tCO_2/t clinker in the year 2020.

To estimate future absolute emission levels on the basis of this set of indexed baselines, we project clinker production levels into the future by using the projections of cement production presented above and assuming an optimistic and a pessimistic evolution of the clinker-to-cement ratio as presented in Table 4. In the optimistic case, CCR would reach 0.61 in 2020 and 0.57 in 2030; in the pessimistic one, it would reach 0.70 in 2020 and 0.69 in 2030. Under these assumptions, clinker production would range from 143.2 to 333.6 million tonnes in 2020, with an average production level of 247.2 million tonnes. Assuming this average production level, total clinker-related direct emissions in India will amount to 184.9 – 203.4 $mtCO_2$ in the year 2020.

Figure 15: Baselines based on projections of indexed emissions per unit of clinker production



Source: Authors' own calculations based on Ghosh and Chandrasekhar (2009); CSI (2012)

5.2.3 Absolute emissions baseline based on historical emissions and trends

So far, we have projected future emission baselines on the basis of indexed emissions, which are independent of the production level. In the climate regime, however, emission targets have usually been expressed in absolute terms. In this section we therefore illustrate how absolute emissions baselines could be estimated on the basis of historical data and projections. To avoid distortions caused by the changing coverage of the CSI database over time, the CSI data on absolute emissions have been scaled so that they represent a coverage of 100%. The projected baselines and their assumptions are explained in Table 7.

Figure 16 shows the results of the projections. It is interesting to see that the absolute level of emissions is largely determined by the assumptions about future cement production levels, and much less by assumptions about how the industry's technology (fossil fuel use and blending ratio) will evolve.

The projections of absolute emissions lead to an estimated emissions from total cement production in India of 131.4 to 253.6 $mtCO_2$ in the year 2020.

Table 7: Baselines based on projections of absolute emissions up to 2030: assumptions

Projection	Rationale and assumptions
Linear extrapolation of historical absolute emissions data	Continuation of historical emissions trends.
Linear extrapolation of historical absolute emissions data (only last 6 years)	Continuation of historical emissions trends, but using only the most recent data. This would avoid potential bias due to missing data and longer term changes in the emission trends.
Linear regression with respect to projected cement production levels, fossil fuel consumption and CCR	Relates the absolute emissions to its underlying causes: the size of the industry, the use of fossil fuels in clinker production, and the amount of clinker replaced by substitutes. Different scenarios are created: - High cement production, high fossil fuel use and CCR: Assumes the exponential projection of cement production from Table 5 and Figure 14, fossil fuel consumption reaching BAT in 2030, CCR reaching 0.69 in 2030. - High cement production, low fossil fuel use and CCR: Assumes the exponential projection of cement production from Table 5 and Figure 14, fuel consumption reaching BAT in 2030 with 10% alternative fuels, CCR reaching 0.57 in 2030.[24] - Low cement production, high fossil fuel use and CCR: Assumes the linear projection of cement production from Table 5 and Figure 14, fossil fuel consumption reaching BAT in 2030, CCR reaching 0.69 in 2030. - Low cement production, low fossil fuel use and CCR: Assumes the linear projection of cement production from Table 5 and Figure 14, fuel consumption reaching BAT in 2030 with 10% alternative fuels, CCR reaching 0.57 in 2030.

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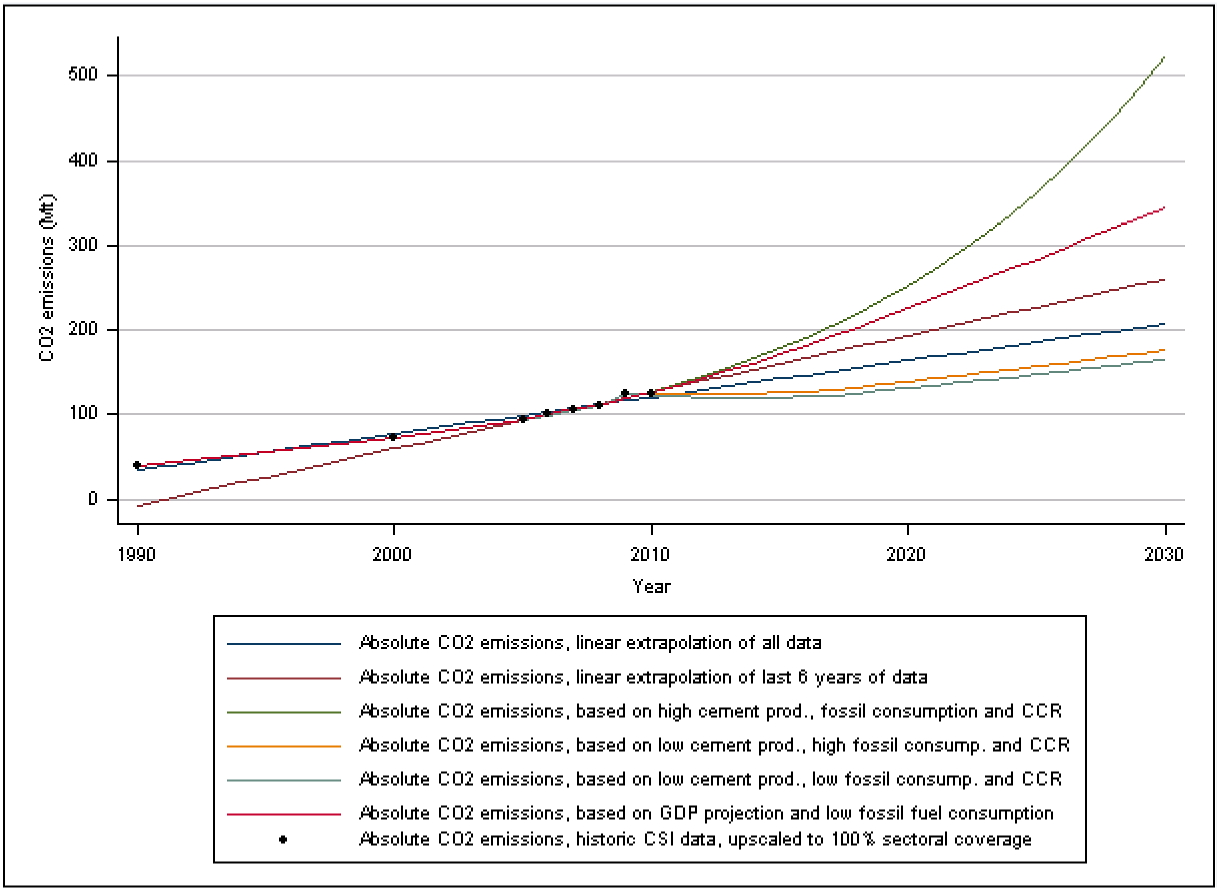
[24] Both high cement production scenarios had very similar results in terms of projected absolute emission levels. Hence, only one of them is shown in Figure 16.

Projection	Rationale and assumptions
Linear regression with respect to projected total GDP and fossil fuel consumption	Relates cement production to its underlying causes: economic and population growth. Total GDP summarizes the effect of GDP per capita and population in a single variable. Two scenarios are modelled: - High fuel consumption: assumes fossil fuel consumption reaching BAT in 2030. GDP projection follows the reference case in EIA (2011). - Low fuel consumption: assumes fuel consumption reaching BAT in 2030 and 10% substitution with alternative fuels. GDP projection follows the reference case in EIA (2011).[25]

Source: Authors' own calculations based on Ghosh and Chandrasekhar (2009); CMA (2010); EIA (2011); Reserve Bank of India (2011); CSI (2012); World Bank (2012)

Figure 16: Baselines based on projections of absolute emissions



Source: Authors' own calculations based on Ghosh and Chandrasekhar (2009); CMA (2010); EIA (2011); Reserve Bank of India (2011); CSI (2012); World Bank (2012)

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[25] Both scenarios had very similar results in terms of projected absolute emission levels. Hence, only one of them is shown in Figure 16.

5.2.4 Comparison to hypothetical emissions goal

The WBCSD and IEA have proposed a technology roadmap for the cement industry with emission reduction goals up to 2050 (WBCSD and IEA 2009). We take their 2050 goal under a low cement demand scenario as an appropriate hypothetical target for the Indian cement industry in 2030, because the Indian cement industry has already begun a transition towards higher efficiency and stronger use of clinker substitutes, with current thermal efficiency of 3.1 GJ/t clinker, and clinker-to-cement ratio of 71% (as reported by the CSI database). Such a good performance can be explained partly because the CSI database does not cover the part of the industry that is less efficient; in addition, the large-scale Indian cement plants are already among the most efficient in the world.

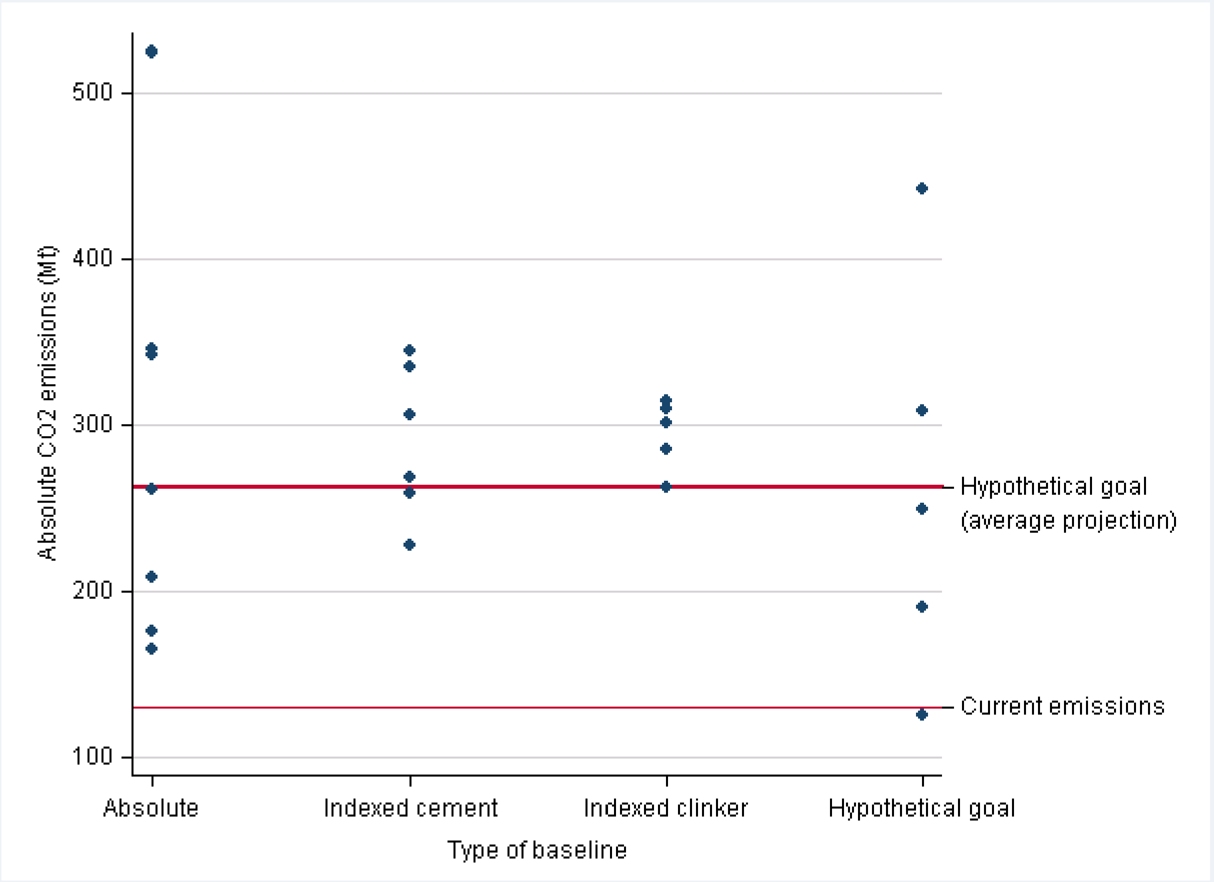
The WBCSD-IEA target implies reaching an emissions intensity of 0.426 tCO_2/t cement, which is to be achieved through a combination of BAT in terms of thermal energy efficiency (3.2 GJ/t clinker), a share of alternative fuels of 37%, a clinker-to-cement ratio of 71%, and a number of carbon capture and storage (CCS) plants in commercial operation. Compared to the current performance of the Indian cement industry covered by the CSI database, such a hypothetical goal means a substantial change in the fuel mix used, and probably also some application of CCS.

Such a goal implies a reduction in emissions intensity of about 36% with respect to the performance of India's cement production in 2005 (as covered by the CSI database). We assume it can be achieved by 2030.

Our projections based on indexed emissions from cement production indicate that in 2030, BAU emissions should be in the range between 0.368 and 0.557 tCO_2/t cement. The comparison indicates that the hypothetical target is in line with the lowest end of the BAU projections we have made previously.

Figure 17 shows how this hypothetical goal compares to all our estimated baseline emissions in 2030 in absolute emission terms. The dots represent the estimated level of emissions under the different assumptions for each baseline type. Besides the three types of baselines we have estimated, we also show what ranges of absolute emissions would be achieved with the hypothetical emissions intensity goal if different projections of future cement production are used. The horizontal lines show both the current Indian cement emissions (as of year 2007), and the emissions under the hypothetical goal for an average cement production projection. The comparison between the indexed baselines and the average hypothetical goal (red line) shows that the hypothetical goal lies at the lower end of our indexed BAU baseline projections. As discussed above, some of these projections may be unrealistic: the lowest "indexed cement" projection assumes a linear trend in reduction of emissions intensity in an industry that is already quite efficient; the second-to-lowest assumes reaching BAT in fuel consumption by 2030, 10% of alternative fuel use and an optimistic clinker-to-cement ratio of 57%. While stronger ambition might still be possible, the hypothetical goal already makes sure that emission reductions are achieved below the most credible BAU scenarios presented. The graph also illustrates that the uncertainty of future projections is large, especially when projections of cement production levels are included (as has been done in the absolute type of baseline and in the hypothetical goal spread to the right). Finally, it also shows that Indian BAU total emissions from the cement sector are expected to grow significantly due to the expected growth in the sector, even if positive trends in energy efficiency, changes in the fuel mix and cement blending are considered.

Figure 17: Comparison of estimated baselines with political emissions goal in the year 2030



Source: Authors' own calculations based on Ghosh and Chandrasekhar (2009); CMA (2010); EIA (2011); Reserve Bank of India (2011); CSI (2012); World Bank (2012)

6 Assessing baselines for the NMBM: buildings sector

6.1 General characteristics of the sector

About 30 to 40% of global primary energy is used in residential, commercial and institutional buildings. According to the 4th IPCC report (Levine et al. 2007), direct greenhouse gas emissions from the buildings sector amounted to about 5 Gt CO_2eq in the year 2004; of this total, 3 Gt were CO_2 emissions. If indirect emissions from electricity use are included, CO_2 emissions reached 8.6 Gt/year, which represents almost one quarter of total global CO_2 emissions. The sector's CO_2 emissions, including indirect emissions from electricity, grew by about 2% per year globally between 1971 and 2004. Halocarbons (CFCs, HCFCs and HFCs) represent more than 15% of total GHG emissions from buildings, and are caused mainly from the use of refrigerators, air conditioners and insulation.

Levine et al. (2007) estimate an emissions reduction potential of about 3 $GtCO_2$ in developing countries by 2030. The main drivers of emissions growth in these countries will be the high demographic growth, urbanization trends and economic development. Using a bottom-up engineering-economics model of energy consumption from appliances and lighting in residential and commercial buildings up to 2030, McNeil et al. (2008) find that, if current best energy efficiency practices were adopted globally, cumulative CO_2 emissions from 2010 to 2030 could be reduced by 21.3 Gt. Regionally, Centrally Planned Asia (China, Cambodia, Laos, North Korea, Mongolia and Vietnam) has the highest mitigation potential, followed by the rest of Asia. In the residential sector, refrigeration and lighting have the greatest potential for emission reductions, while in the commercial sector most reductions can be achieved in space cooling and lighting.

However, this high mitigation potential from the buildings sector has so far not been tackled by the CDM despite approval of several baseline methodologies in the last years. Only projects and programmes to replace traditional incandescent lighting by energy-saving bulbs have been meaningfully included. In addition, a few recent projects aim at introducing efficient cooking stoves in poor countries. The sectoral approach for a NMBM could allow for moving from such single-measure projects to whole-building ones. Minimising energy consumption in a building requires that the building as a whole is optimised by addressing as many as possible of its components at the same time: building form, orientation, envelope, glazing, mechanical and electrical systems, and appliances. Such system-thinking can lead to positive synergies in reducing energy consumption and thus emissions (Hayashi et al. 2010).

Setting meaningful emission baselines for the buildings sector represents a critical challenge, due to the high complexity of the sector. First, the buildings sector can be decomposed into two large sub-sectors: (i) residential and (ii) commercial / institutional buildings. Energy consumption patterns differ largely among them, so that baselines need to be distinguished between these types of buildings.

But further disaggregation is also possible. Within residential buildings, one can differentiate between single-family and multi-family buildings. Within commercial buildings, a study about energy use in commercial and institutional buildings in Canada in the year 2000 distinguished between following types of uses (Natural Resources Canada 2003):

- Commercial and institutional accommodation
- Entertainment and recreation
- Office
- Food retails
- Non-food retails
- Food service
- Non-food service
- Shopping malls
- Warehouse / wholesale
- Administration
- Education
- Health care
- Public assembly.

The study shows that buildings devoted to these different types of activities have very different energy intensity levels (defined as energy consumption per unit of floor space). Due to the interrelations between this and other factors influencing energy consumption, it is however very difficult to establish any clear causal relationship (Natural Resources Canada 2003). A problem for setting baselines is that no universal classification by types of activities exists, which makes any comparison extremely difficult (Perez-Lombard et al. 2008). Comparing data from the US, Spain and the UK, Perez-Lombard et al. (2008) find that office and retail buildings are the most energy-intensive buildings among non-residential ones, followed by hotels and restaurants, hospitals and schools. Air conditioning is the main energy consumer, followed by lighting and appliances. Agreeing with the Canadian study, they also find that building type is a critical factor determining energy intensity and how energy use is distributed. A potential classification of building types may be based on the one used by the approved CDM methodology for whole-building efficiency projects (AM 0091)[26], which provides a list of building types based on information from several building codes and building efficiency programmes worldwide (for the background of the methodological approach see Hayashi et al. 2010).

Beyond the purpose of the buildings, many other factors influence their emissions levels. Natural Resources Canada (2003) finds that energy intensity also varies regionally, by year of construction, building size, and type of owner. UNEP (2007) in addition emphasizes the role of climate differences and of income levels for both energy intensity and distribution across different uses and/or energy carriers. With respect to climate, the number of heating and cooling degree days can be useful in estimating how much energy is needed for different uses such as heating, air conditioning, refrigerators and other appliances. In terms of income levels, a clear transition can be observed from, for example, the high use of biomass for cooking and heating in poor households, to the use of other fuels and finally to electricity as income rises. In addi-

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[26] http://cdm.unfccc.int/UserManagement/FileStorage/8RIP2VC674KZTUJEDLAWQXBNYFM3OG

tion, the preferences and culture of the users also influence energy use, as do the design and orientation of buildings.

Hence, buildings emissions are generated by different fuel types and uses, which in turn depend on the factors mentioned above: building types, climate zones and level of economic development. According to UNEP (2007) in rural areas of Sub-Saharan Africa between 90 and 100% of household energy consumption is used for cooking. In developed countries, on average, most residential energy is used for space heating, and then for water heating and domestic appliances. The main emission sources can be classified into electricity use (indirect emissions), use of fossil fuels (e.g. for heating or cooking), external supply of chilled or hot water (indirect emissions), refrigerant leakage, and use of unsustainable biomass (for cooking).

While these different fuel types and uses can be regarded independently from each other to establish emission baselines, it is also known that they interact with each other. For example, savings in lighting can lead to reductions in energy use for ventilation and cooling, due to the reduced heat produced by the lighting equipment. It has been estimated that for every three watts of lighting energy reduction about one watt of air-cooling energy can be saved (UNEP 2007).

6.2 Considerations for setting baselines

Baselines for the buildings sector need to deal with all the elements discussed above within their level of aggregation:

- **Process:** Depending on the data availability, baselines can be established on the basis of a whole building approach (e.g. with indicators such as energy consumption or emissions per square meter of building area) or can be differentiated across individual uses (heating, cooling, lighting, cooking, other appliances, etc.).
- **Product:** Baselines need to be differentiated between commercial and residential buildings, and within these categories between different sub-types of buildings. The size of the building may also have an effect on energy efficiency and emissions.
- **Time:** Baselines can consider the different technological standards existing in new versus existing buildings.
- **Space:** Baselines need to be set up for buildings within regions with similar climatic and socio-economic conditions. Differences may exist between urban and rural areas, and in large countries between different regions.

Beyond the complexity of the buildings sector, the lack of sufficient and consistent information is also a barrier for setting baselines (Perez-Lombard et al. 2008). Developed countries nowadays regularly perform comprehensive surveys on the energy consumption of residential and commercial buildings, e.g. by Natural Resources Canada or by the Energy Information Agency in the US. Such studies can be a useful reference for developing countries wishing to start tackling energy efficiency and emissions in this sector.

Opportunities to tackle emissions in the buildings sector hence range from energy efficiency measures (for heating through insulation and multi-glazed windows, for air conditioners and electric appliances, and for lighting), to fuel switch (e.g. in heating systems), use of renewable energy (centralized or decentralized at the building level), replacement of refrigerants and behavioural changes. How many of these opportunities can be grasped by a baseline depends, as in the case of power and cement, on its scope. A whole-building approach (e.g. as used in the CDM Methodology AM 0091) can be used to tackle as many emission reduction measures as possible per building unit. Such an approach allows estimation of an indexed emissions baseline in terms of tCO_2e per m^2 of residential building area, and accounting for synergies across different energy uses as described above. Its drawback is, however, the extensive data requirements. Data on energy consumption and refrigerant leakage need to be available per building unit, data on floor area and socio-economic status of occupants (income level or property price) can be collected for a representative sample (Castro et al. 2011). Wehner et al. (2010) use a simplification of the whole building approach, differentiated according to climatic zone in calculating a baseline for the Mexican residential sector.

Another approach to tackle emissions in the buildings sector could be to focus at individual measures, as has been done so far in the CDM. At a sectoral level, the task could be simplified if monitoring would be done at the supply side. For example, for energy efficient appliances, baselines could be set on the basis of how many refrigerators with a certain energy efficiency level are sold in the country. In this way, the rate of penetration of specific technologies could be used as a baseline metric. Measures such as labelling and setting energy efficiency standards could then be introduced and their impact could be measured by looking at the change in purchase patterns ex post. The actual emission reductions could be estimated by surveying a sample of users in terms of hours and patterns of use, lifetime of equipment, etc. and by taking into account the relevant grid emissions factor and typical energy consumption levels of the appliance.

A more complex but also comprehensive possibility is the modelling approach adopted by McNeil et al (2008) in their study of energy efficiency potentials in the buildings sector. On the basis of global macro-regions and macroeconomic data and projections (income levels, percentage of urbanization, percentage of electrification), this study forecasts how major appliances will diffuse in the residential sector, how floor space of commercial buildings will grow and how different equipment will penetrate the sector per region up to 2030. The model is based on the notion that the level of energy services demanded by households and businesses depends on economic growth. As growth projections are uncertain, this is the component of the model that is most uncertain, too. The growth projections are used to forecast levels of activity for the different components analysed on the basis of econometric techniques: diffusion of certain type of appliances in households (i.e. how many of these appliances are used per household), and floor space of commercial buildings. To estimate energy consumption, the model relies on estimations of the typical annual energy consumption of appliances in each region, which depend on what types of appliances are used (e.g. what size of refrigerator), the average energy efficiency of the appliances used, and on use patterns (driven by climate – heating and cooling degree days). Finally, the model can also estimate energy saving potentials by modelling scenarios of future diffusion of efficient appliances. Such an approach would allow generating baselines in terms of energy consumption per type of appliance per household.

As in other sectors, baselines for the building sector would ideally need to take into account the existence of policies that already affect emission levels. This is, for example, carried out by Wehner et al. (2010) in their baseline for a NAMA in the Mexican residential building sector. Even though developing countries frequently have enacted policies to regulate energy consumption in buildings (building codes, but also economic incentives such as tax rebates and financial support for retrofitting measures), enforcement and compliance are often insufficient. The lack of financial and human resources leads to weak monitoring mechanisms. Price distorting subsidies for energy prevent changes in energy consumption patterns. Information barriers and lack of capital prevent investments in energy efficiency. Richerzhagen et al. (2008), for example, provide a detailed account of the challenges in China to enforce the energy efficiency policies supported at high political levels. Hence, not only the existence but also the real application of such policies needs to be taken into account in baselines.

7 Qualitative discussion of illustrative baselines

In order to evaluate the suitability of the proposed options for setting the baseline and potential sectoral targets outlined in chapters 4, 5 and 6, the different approaches should be evaluated against the different design elements and corresponding evaluation criteria described in chapters 2 and 3.

With regard to the baseline ***scope***, all power plants in the electricity system (or in a specific grid like the NEWNE grids or Southern Grid) or all cement plants in a country should ideally be included in the sector. However, in practice, databases usually cover only a part of all installations in the system. In the power plants database used for this analysis, captive power plants that cover 10% of electricity production are not included, nor are certain renewables and small units (section 4.2). In the cement case study, only 50% of the sector is covered by the CSI database, and notably small and inefficient plants are not included. In addition, the coverage of the database has changed over time (section 5.2). For the purpose of baseline setting and subsequent monitoring, it should be ensured that the coverage is consistent throughout the time series. For instance, if the coverage of power plant operators varies over time or if the cut-off criteria for inclusion of power plants is modified (e.g. 5 MW in one year and 20 MW in another year), artefacts of emission reductions or increases may occur which do not reflect the real development. This effect may jeopardise the environmental integrity of the system.

In this report, we have started from the idea that the NMBM will be based on specific economic sectors, such as electricity or cement. But the UNFCCC definition refers to “broad segments of the economy”, which could well mean a segment that includes several (unrelated) economic sectors, e.g. electricity and heavy industry. In this case, individual baselines should be established for each of the economic sectors included (electricity, cement, steel, etc.) while they can then be aggregated to one overall baseline. Basing the emissions threshold (or target) on this overall baseline is advisable because it allows for flexibility (and cost reduction) in terms of how to reach the emissions goal. But by first establishing individual baselines for each of the sectors more transparency about real trends in emissions and hence about the environmental implications of the baseline (and the threshold or target) can be achieved.

The ***product*** to be evaluated can be homogeneous or not within a sector. In the power sector, due to the homogeneity of electricity, there is no issue of definition. However, in some cases, power plants may co-produce heat (combined heat and power (CHP) plants) which may be used to reduce fuel consumption in other sectors (reducing fuel consumption of boilers). In this case, the product heat should be considered, too, and the scope of the analysis may need to cover final consumption sectors, too. However, this is methodologically challenging which is demonstrated by several studies on the evaluation of CHP. In the case of cement, baselines can be based on clinker or on cement production, and could be further disaggregated if different types of cement have different properties affecting its final use.

For the buildings case, we have seen that baseline scope will need to be more narrowly defined than at the whole sector level. Sub-sectoral approaches will be more able to reflect the differences in energy service consumption between urban and rural areas, residential and commercial buildings, and regions with different climates. In addition, separate baselines can be established for different appliances or other equipment or uses, or a whole building approach can be used.

With regard to further differentiation, the dataset should include information on vintages, capacities, fuel types, other raw materials, technology and energy efficiencies at the most disaggregated level possible. This allows a more sophisticated evaluation of power and industrial sectors over time. Aggregated data (e.g. as mentioned above, specific CO_2 emissions are not available for individual power plants, but only for the power plant as a whole) may reduce significantly the validity of the calculated baseline.

With regard to the ***reference data*** used, several lessons can be learned. Firstly, the analysis shows that different approaches of using reference data for establishing the baseline show similar results, within ranges of uncertainty, if projections of activity levels are left constant. However, sectoral targets are very much dependent on the type of data and assumptions used for the calculation. In addition, if potential variation in projected activity levels is incorporated into the baseline (as we did in the case of absolute emissions from the cement sector, see Figure 16), very high uncertainty is the result. Thus, if a high emissions projection is chosen, the credited reductions may not be “real”. Furthermore, some of the projections, even if they have a very good statistical fit, may not be realistic, as in the case of projected Indian cement production levels up to 2030. One way to deal with such uncertainty is to be transparent about the assumptions of the projections and the methods used, and to show different projections, as we have done above, so that a conservative estimate of future emissions can be chosen among the several projections. It is also important to be clear about the implications of the projections, e.g. in terms of projected per capita demand or needs of blending materials, or expected gains in energy efficiency (are they realistic?). An approach to take this into account is to incorporate caps in the projections, as is the case for the power case study. In order to reduce uncertainty of projections, frequent updates of the activity levels underpinning the baseline could also be considered.

Secondly, the projections that we have estimated are based merely on historic data on production levels, emission levels, and some drivers of emissions (in the case of cement, fuel mix, fuel consumption and clinker to cement ratio), and on some future projections of other drivers (GDP and population). No consideration of the effect of past policies or of technological costs and financial viability of the projected emissions paths has been included in the estimations. This means that the idea of financial (or policy) additionality, very important in the CDM context, has been left out of our consideration of baselines for the NMBM.

Thirdly, our projections are based on a limited dataset (the Central Electricity Authority includes 5 years, the CSI database 8 years). This, of course, leads to substantial uncertainty in projections for much longer timescales. It also makes it statistically difficult to include many emission drivers as predictors for future emissions. Having longer historic time series would hence be very helpful for improving the reliability of future projections, and in recognising potential changes in observed trends and their causes. Nevertheless, if sufficient reliable data is not available, it can also be gathered in a pre-implementation phase. In this regard the situation of many developing countries is not that much different to the situation of many developed countries before they started to implement market-based GHG mitigation policies. Availability of reliable data may be a difficulty in the domestic implementation of the NMBM but should not prevent any such implementation. If required, implementing countries would need to establish a data gathering and compilation phase before the proposal for the implementation of the NMBM can be submitted.

Fourthly, the inclusion of the appropriate emission drivers in the projections is important, also in relation to the scope of the baseline. As we have seen for the case of cement, for a baseline that is indexed on clinker production, mainly the energy consumption and fuel type determine emission levels in our case study. For a baseline indexed on cement production, the blending percentage comes in addition (and also indirect, electricity-related emissions, but this data was not available). In other countries with a more diverse industry, other factors may need to be taken into account such as type of technology. For cement, emission levels are very different between the dry and the wet process, and between different kiln designs and sizes. In India, however, at least among the plants covered by the CSI, only the dry process is used. The many small plants that very likely have higher emission levels are outside of the scope of the baselines that we have estimated, as they are not covered by the CSI data. In a real-world situation they would need to be included. In all cases, a balance needs to be found between inclusion of potential emission drivers in the modelled scenarios and transparency of the assumptions and projections. The more drivers are included, the more data needs to be projected into the future and the more assumptions need to be made for calculating these projections. This may leave room for manipulating assumptions to reach more favourable baselines. Again, being transparent about assumptions and displaying several projections with different assumptions is necessary to demonstrate the reliability of a baseline. One option would be to agree ex-ante on certain standard parameters to be used in projections, e.g. future demographic and economic growth or the type of sensitivity analysis that should be conducted.

In terms of ***dynamics and updating***, the baselines we have illustrated have relied exclusively on historic data or projections based on historic data. As discussed above in the literature review, the reliability of the baseline can be improved substantially if it is related to parameters that are monitored in real time, or if it is updated periodically on the basis of such monitored parameters. For example, an indexed baseline could be set on the basis of historic trends in energy efficiency improvements, but on a yearly measured fuel mix and blending percentage. The difficulty in this case would be to disentangle the effect of changes that are taking place because of BAU developments, and changes that are a result of policies oriented to reducing GHGs. In the case of the Indian power sector, the analysis showed that estimated specific CO_2 emissions of some power plant types are expected to increase. Technologically this is unlikely to be persistent; it could be linked to start-up problems of new plants, as well as incentives to over-report fuel use. In the longer term, the autonomous improvement of power plants should prevail, which leads to decreasing specific CO_2 emissions over time. Therefore updating of data for baseline setting may be required. Alternatively, this could be addressed by setting a stringent sectoral target, which outweighs the uncertainty related to baseline setting.

Concerning ***metrics***, the environmental effectiveness of baseline options and sectoral targets depends on the methodology and assumptions. Absolute baselines may be increasing (as in this analysis) or decreasing. Similarly, (politically negotiated) absolute sectoral targets may be more or less ambitious. The advantage of using absolute values is that all kinds of measures can be considered at the same time: efficiency improvements, fuel switch and demand reduction. Indexed baselines or sectoral targets do not necessary lead to decreasing overall emissions, especially if specific emissions are expected to increase. In the case of applying benchmark values for individual power plants, overall emissions also may increase due to the overall increasing trend of electricity generation or cement production. Overall emission reductions are then only achievable if there is a dedicated sectoral target leading for a far-reaching decarbonisation of the sector, either by (politically) specifying decreasing specific CO_2 emissions or an increase of emission-free fuels in the overall fuel mix. In addition, a target in terms of energy consumption per unit of GDP can act in combination with the sectoral indexed baseline (and target or threshold) to address the demand side.

8 Conclusions and recommendations for baselines of a sectoral NMBM

The case studies of sectoral baselines in the power, cement and buildings sectors provide several lessons that need to be considered when discussing baseline setting and the modalities and procedures for a NMBM.

In its conception, a sectoral-level NMBM is more similar to international emissions trading than to the CDM, and the development of baseline-setting methodologies for the NMBM needs to take this into account. Sectoral baselines need to include all emissions of existing and projected new installations of the covered sector(s); ideally, they need to take into account the drivers of emissions in order to generate realistic projections about how the sector will develop into the future. Developments at the sector level include not only adding new, state-of-the-art installations, but also retrofitting or decommissioning old ones. This kind of logic is very different to the CDM-like approach of determining what investors of individual new installations would most likely do in the absence of the CDM. It is more similar to emissions trading – where baseline setting has been difficult, politically contested and too lenient in most cases, or to the projections of future emissions included in national communications. This sectoral logic for baseline determination has important implications in terms of the data requirements and assumptions for projecting future trends.

In terms of **data quality,** the coverage of the data needs to be as comprehensive as possible, so that possibly a whole sector can be considered in the baseline. The coverage needs to remain consistent over time to avoid potential biases in the future emission projections. In sectors as complex as the buildings sector, where data collection at the building level is very costly, a NMBM could be started at the sub-sectoral level, e.g. by focusing on specific types of appliances and by monitoring their consumption at the supply side (e.g. retailers). Ideally, GHG emissions data is needed, but if it is not available, activity data or penetration rates of a technology and an emissions factor can also be used. Data should also be available on vintages, capacities, fuel types, other raw materials and energy efficiencies at the most disaggregated level as possible, to allow for a more sophisticated evaluation of the drivers of emissions over time. Aggregated data may be used for setting sectoral baselines, but may reduce its validity if the sector is heterogeneous. The longer the time series of available historical data, the more accurate the projections will be, and the more emission drivers may be considered for setting the baseline. However, if appropriate data is initially not available, it may be gathered in a pre-implementation phase. Moreover, a tiered approach may be considered where uncertainty discounts are relaxed as soon as more reliable data becomes available.

In heterogeneous sectors with many products or technology types (and vintages), or in broad segments that include several economic sectors, it is advisable to establish a baseline for each of the products or sectors, and then aggregate it into an overall baseline. This ensures that the baselines are reliable and conservative by promoting transparency into the data and assumptions, but it also provides flexibility in how to reach the envisaged emission reductions.

Another important lesson for ensuring the environmental integrity of sectoral baselines and targets is the **transparency of assumptions**. As shown above, many different approaches may be used to project expected emission levels into the future, from simple linear projections of historical emissions levels, to regressions on the basis of drivers of emissions, to more complex models of a whole economy. While, ideally, information on all potential drivers of emissions can thus be used for setting the baseline, this should be weighed against the cost of collecting all these data and the simplicity and transparency of the baseline. Different types of projections may yield similar results (within levels of uncertainty), especially if projected activity levels are left constant. However, if absolute baselines are used, potential variation in projected activity levels is incorporated into the baseline, so that very high uncertainty may result. Thus, transparency about the assumptions of the projections and the methods used is necessary, and if possible, different projections (e.g. by relying on different projection methodologies as done above, or by slightly varying some of the critical assumptions) should be shown so that the sensitivity of the baseline to these assumptions can be assessed. Then, a conservative estimate of future emission levels can be chosen among the several projections.

A decision needs to be taken at UNFCCC level about whether it is advisable to let developers of baselines choose what types of projections and assumptions they use (provided these are communicated clearly and can be replicated) or whether it is necessary to develop ex-ante guidelines and agreements about the methods (e.g. extrapolations, regressions, modelling, sensitivity analysis), the metrics (absolute, indexed baselines, or baselines based on technology penetration rates) and specific parameters (e.g. IPCC default emission factors, a centralised source of future demographic and economic growth) to be used for the projections.

Important is also to make sure that the projections are **realistic** in terms of what is achievable with the existing technology, but that they keep the incentive towards reducing emissions. With a given technology, a declining trend in relative emission levels may not be possible to continue ad infinitum because the efficiency limit of the technology will be reached at some point. This may need to be taken into account in the projections, e.g. by incorporating caps. At the same time, however, an incentive to invest in research and development of zero-emission technologies needs to be maintained because for a transition to a carbon free economy all emission rates will eventually need to reach zero. In addition, if the existing (historical) data shows unrealistic patterns (e.g. as seen above, increasing specific CO_2 emissions of power plants over time), this may point towards unreliable data, or towards missing emission drivers that still need to be taken into account. In principle, having an indexed baseline (a projection of specific emissions per unit of output) that increases over time should not be allowed as it goes against the goal of reducing emissions and against the expectations that technologies improve over time. To keep long-term incentives for technological change and to provide investment certainty, baselines should be valid as long as possible, but this increases uncertainty regarding the realism of the baseline. A realistic baseline would require frequent updates (e.g. every 5 years); updates should only be allowed when they lead to strengthening the baseline, not to relaxing it.

Overall, determining baselines for a sectoral NMBM implies a different way of thinking that departs from the CDM; it requires better and broader data and agreement on guidance about critical assumptions and minimum transparency requirements. This will be challenging; however, the experience already gathered – from existing emissions trading schemes, from projections of future emissions in national communications, and from industry efforts to collect sectoral data – will make the determination of sectoral baselines possible.

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