



[REPORT TASK I.3.1-I.3.4] ENERGY AND CO2 EMISSION SCENARIO ANALYSIS OF THE VIETNAM CEMENT INDUSTRY

EXECUTIVE SUMMARY

Objective

The purpose of this report I.3 is to identify and analyse the historical development of production, energy consumption, CO2 emission and efficiency of Vietnam's cement sector and to develop and discuss scenarios for future trends with the purpose to identify and quantify the energy and CO2 mitigation potential of the cement industry in Vietnam.

The next report of this project (report I.5) will discuss the operational and technical means, the regulatory framework, the gaps and barriers to implementation and solutions to overcome those barriers that will enable realizing the projected mitigation.

The quantification of long-term objectives and reference levels against which to measure and incentivize progress are policy issues that will be elaborated in the policy parts of this project, reports I.6 and I.7.

Database

The quantitative information for this analysis is largely sourced from the Vietnam cement sector energy and CO2 emission database developed for this project and the global cement industry "Getting the Numbers Right"

(GNR) database of the Cement Sustainability Initiative (CSI), along with other sources.

The second version of the Vietnam MRV database contains information from 35 out of 55 cement companies, from which 3 Joint Venture (JV) companies, 9 VICEM state owned and 23 private entities. Although this is only 64% of the number of installations they cover 69% of Vietnam's installed capacity and, with 41 million ton clinker, 42 million ton cement and 48 million ton cementitious production in 2013, they cover 71% of Vietnam's cement production in 2013.

This high coverage of production compares favourably with the coverage of the CSI Getting the Numbers Right database being about 78% for the Americas, 44% for Africa and 36% for Asia¹.

Based on the coverage of production (71%) and installed capacity (69%) one may expect that the database is representative for the performance of the whole Vietnam cement sector.

¹ <http://wbcsdcement.org/index.php/key-issues/climate-protection/gnr-database/geographic-coverage>

The data in the database and the sectoral consolidation methodologies are according to the CSI global cement industry standards as described in report I.2.2.

Methodology

The assessment of the historic and future trends is each done in three steps:

1. the assessment of clinker and cement installed capacity and actual production quantities;
2. the assessment of the industry's efficiency performance in terms of, among other, capacity utilisation, energy efficiency, fuel mix, clinker content in cement and CO₂ emission per ton product;
3. the combination of both leading to the assessment of absolute CO₂ emissions.

This systematic approach ultimately enables to conclude with a quantification of the medium and long-term energy and CO₂ mitigation potential.

Historic trends

Installed capacity and production volume

Vietnam's rapid economic growth and urbanization have led to increased demand for cement for the construction and infrastructure sectors. Until 2008-2009 Vietnam was a net importer of cement, but large-scale investment in new production capacity has led to rapid growth in the sector and excess domestic supply. Vietnam is one of the principal cement consumers in Southeast Asia, however since 2010 demand has fallen well below production capacity as high interest rates and inflation have slowed countries' construction (IFC, 2014). Production increased by an average annual rate of around 18% between 1995 and 2005 and 11% between 2005 and 2011. The recent economic downturn has led to a drop-off in production

growth, falling to around 6% in 2010-2011. (ADB, 2014)

Efficiency and performance

Capacity utilisation:

Annual clinker capacity utilisation varied very much between installations and with time, from as low as 15% to as high as 100% (excluding the first year of operation after start-up of a new installation). Especially the recently built, privately owned installations show high fluctuations, indicating operational as well as cement market difficulties. The sector average clinker capacity utilisation (CUF) varied around 80% from 2009 to 2012 and reached 85% only in 2013. In 2011-12 only about half of the clinker installations operated at or above the economical normal 80% CUF; in 2013 60% of the installations reached or exceeded 80% CUF. On the other hand 15% to 40% of the installations operated at the economically unsustainable level of less than 70% capacity utilisation. Cement capacity utilisation is better, ranging from 85% in 2009 to 100% in 2013.

This analysis of the sector capacity utilisation indicates that the sector should be prudent with expansion of the installed clinker capacity but that there is some room for increasing cement-grinding capacity.

Thermal energy efficiency:

92% of the total clinker production in the Vietnam cement sector is with the pre-heater with pre-calciner (PHPC) technology type, the other 8% with pre-heater kilns without pre-calciner (PH).

PHPC technology is the most energy efficient technology with which 3'300 MJ/ton clinker thermal energy efficiency should be feasible. The yearly average thermal energy consumption of PHPC kilns in Vietnam is about 3,620 MJ/ton clinker, trend increasing 0,5% per year from 3,570 MJ/ton clinker in 2009 to 3,660 MJ/ton clinker in 2013.

This is 7% more than the global average PHPC kiln efficiency (3'390 MJ/t cli) and 10% more than BATP achievable with PHPC technology.

Only 4 out of 33 PHPC kilns in Vietnam reach the global average efficiency of this technology and 25% of Vietnam clinker production in PHPC kilns is within the 10% most energy intensive globally (see figure 4).

This means: although the Vietnam cement sector has modern BAT PHPC installations, it does not reach the thermal efficiency achievable with this modern technology.

One could expect that the more recent installations have better thermal energy efficiency than the older ones. This hypothesis is though not confirmed by the facts in the database, quite the opposite: the more recent installations (i.e. younger than 6 years) consume more thermal energy per ton clinker than the older ones. Surprisingly, ten new installations commissioned since 2010 report energy consumption well above 4'000 MJ per ton clinker, i.e. 20% higher than what may be expected from modern pre-heater pre-calciner kilns and a level not exceeded by one of the ten old installations. This is because several recently built installations (as recently as between 2010 and 2013) are in existing cement plants replacing vertical shaft kilns with pre-heater without pre-calciner technology (PH), i.e. not-BAT technology. Hence, most PH kilns are small, with on average only 1'170 tpd clinker capacity and producing typically only about 300 kton cement per year.

However, similarly to the PHPC kilns, the yearly average thermal energy consumption of PH kilns in Vietnam is as much as 15% higher than what is globally achieved with this technology.

Not one of the more than 20 recently built installations reaches the thermal energy efficiency target defined by the Master Plan.

This may be a result of not implementing Best Available *Practice*. There is some evidence that the individual smaller and less experienced companies lack the technical and operational

knowledge and competence to efficiently run the installations. Individual small companies possibly lack the size to afford professional technical support departments and experts.

There is evidence that thermal energy efficiency can be improved mainly through improving operational management and practice and less so through capital investment.

Fuel mix and Alternative fuels:

The Vietnamese cement industry uses virtually exclusively coal, being the most CO₂ intensive fuel, as the source of thermal energy for the clinker kilns, with about 1% or less biomass and waste as alternative fuel. The rest of South East Asia and countries like Thailand and the Philippines sourced already about 13% from alternative fuels.

Clinker content in cement:

The sector average clinker content varied around 82% +- 1% from 2009 to 2013 without clear trend change as a function of time. This is 8 per cent point higher than the 75% global average and higher than most other regions in the world, equal only to the USA and similar to the 82% in countries like Thailand and the Philippines.

CO₂ emission per ton Clinker:

The combination of a relatively high thermal energy intensity with CO₂ intensive fuels leads to high CO₂ emission varying between 880 and 890 kg CO₂ per ton clinker.

The Vietnamese cement sector average CO₂ emission per ton clinker is about 5% higher than the South East Asian average (840). Interestingly, the 10% worst installations in South East Asia (excluding Vietnam) (870 kg CO₂/ton clinker), the Philippines (890) and India (855) still perform better than or equal to the Vietnamese average.

Similar to the energy trend-line there has been no improvement of specific CO₂ emission from 2009 to 2013. The 10% most CO₂ intensive clinker production causes up to 10 to 15% more CO₂ emission per ton clinker than the

average and 20% more than the best performing installation.

Since (with a very few exceptions) the Vietnamese cement sector does not yet use waste derived alternative fuels net CO₂ is equal to gross CO₂ emission².

CO₂ emission per ton Cement:

The combination of these aspects – thermal energy consumption, fuel mix, CO₂ per ton clinker and clinker content in cement – results in a Vietnam cement sector average CO₂ emission per ton cement varying between 725 and 750 kg CO₂ per ton cement. Similar to the previous indicators there is a slight tendency for increasing CO₂ emission per ton cement, with on average about 0.5% increase per year.

This Vietnam cement sectoral average CO₂ emission per ton cement is about 15% higher than the global average and higher than in any region reported by the CSI Getting the Numbers Right database, which range between 590 and 730 kg gross CO₂ per ton cement or national averages in South East Asian countries like India (600 kg CO₂/ton cement), the Philippines (690) and Thailand (700).

The difference between the net CO₂ emission in Vietnam (725 to 750 kg CO₂ per ton cement) and the other regions is still larger: about 15 to 20% higher than the global and the regional averages ranging between 550 and 720 kg gross CO₂ per ton cement.

Electric power efficiency:

Interestingly, whereas the Vietnamese cement sector lags behind the industry in most regions worldwide on thermal energy consumption, alternative fuels, clinker content and direct CO₂ emission, the reported electric power efficiency is world-class.

The Vietnam cement sectoral average electric power consumption is around 59 kWh/ton clinker and 87 kWh/ton cement with little variation over 5-years, being 27% better than the worldwide and 12% better than the South East Asia averages. As such the Vietnam electric power efficiency is with the 2% best for clinker and 25% best for cement.

This is again an indication that the Vietnam cement sector is to a great extent equipped with Best Available Technology but does not yet sufficiently apply Best Available Practice for the technical aspects other than electric power.

Conclusion on historic performance:

This could lead to the conclusion that the improvement of energy and CO₂ efficiency in the Vietnamese cement industry should focus in the first place on operational management and practice (and this especially but not only for the many individual private companies) and less so on equipment investment, except for capacity expansions and investments for the pre-treatment of waste and the storage and feeding of alternative fuels.

If this were confirmed, then this may have a very significant impact on the mitigation cost as well as the policies, measures and type of support needed to achieve world class performance.

The resulting historic absolute CO₂ emission from the cement sector amounts to approx. 4.6 MtCO₂ in 1995 and 46.2 MtCO₂ in 2013 (applying the specific weighted average value of kg CO₂/ton cement (equivalent) for the years 2009-2013). In average 94% of the emission is direct emission (process and thermal energy related), and about 6% is indirect related to electricity consumption from the power grid.

Future trend scenario analysis

Installed capacity and production volume

² For the definition of gross and net CO₂ emission see sections 3.1.2 and 3.3.4 of report 1.2.2 on “Data set guidelines and calculation methodologies”

For the projection of future cement demand and production, the development of different driving factors, such as economic parameters, GDP and population, was analysed using sources including the Asian Development Bank, the UNDP study on Green Growth, the World Bank Low Carbon Development and the Vietnam's Cement Master Plan 2014.

In the "Business-as-Usual Master Plan" scenario, Vietnam's cement production would increase twofold over the next 15 years from approx. 59 million ton in 2013 to approx. 125 Mton in 2030 and increasing cement production capacity to 1'200 kg cement per capita per year.

Building 1'200 kg cement production capacity per capita per year would make Vietnam the 4th largest global cement producer only after China, Saudi Arabia and Qatar; with 1'000 kg per capita at par with Singapore and the UAE and with 800 kg cement per capita close to South Korea. These are all countries with a significantly different economy and mega-construction culture.

Building a cement production capacity of around 1'200 kg or even 1'000 cement per capita per year is likely to lead to significant systemic overcapacity in Vietnam, leading not only to unsustainable economic challenges for the industry and excess energy consumption and CO₂ emission.

Clinker production is an activity with high CO₂ emission and consumption of energy and natural resources per financial added value. Vietnam's cement production consumes 5 times more coal and emits 6 times more CO₂ per financial added value than the national economy.

Or vice versa: the financial added value of cement production of 0.56 USD/ton per ton coal is five times lower than the 3.2 USD added value per ton coal consumed by the Vietnam economy. The financial added value per ton CO₂ emitted by cement production, i.e. 0.08 USD/ton CO₂ is six times lower than

the 0.5 USD added value per ton CO₂ emitted by the Vietnam economy.

The average cement export sales price was 0.88 Mio VND per ton cement, being only 69% of the domestic sales price. It is not uncommon that in an oversupplied market the export price covers the variable cost but not the total (fixed, variable plus capital cost) production cost. Building an excess capacity for export when the export sales price does not cover the total cost is economically unsustainable.

The Vietnamese cement export displaces cement produced locally or regionally with a lower CO₂ emission (740 kg CO₂/ton cement from Vietnam, versus 680 for the Asian destination countries, 620 kg in Peru and 600 kg in Chile). Adding on this the sea transport emissions that range from about 40 kg transport CO₂/ton cement to the Philippines, 100 to Bangladesh and Sri Lanka, 180 to Australia and almost 400 kg transport CO₂/ton cement to Chile and Peru makes that the Vietnamese export causes 15 to 90% more CO₂ emission per ton cement than the local or regional production.

Thus, building excess capacity, especially including 10% capacity for export, is from an economic, environmental, energy and CO₂ emission point of view not at all an attractive value proposition for the Vietnamese economy.

Hence, besides the Master Plan-based Business-as-Usual production scenario we also propose two other production volume scenario's. In one scenario additional capacity expansion is capped when the sector capacity reaches 800 kg cement per capita per year, being 150 kg or 23% more than today's 650 kg cement per capita capacity and in another scenario capacity is maintained at today's level (i.e. 650 kg/capita). The expansion of clinker and cement capacity should be coordinated in such a way to enable further reduction of clinker content in cement while reaching for both products a normal, economically

sustainable capacity utilisation between 80% and 85%.

Energy and CO₂ intensity scenarios

Apart from the three mentioned production scenarios, the study also investigates six different performance improvement scenarios: National Business-as-Usual, National Business-as-Usual with policy measure, National Benchmark scenario, International Business-as-Usual Progress, International Benchmark scenario and Best Available Technology and Practice (BATP)

Error! Reference source not found. summarizes the prognoses of gross CO₂ emission per ton cement of the six scenarios. With the Vietnam cement average emission equalling 740 kg CO₂/ton cement, the scenarios range from a maximum of 800 kg CO₂/ton cement to a minimum of 545 kg CO₂/ton cement, with the majority of scenarios ranging between 660 and 550 kg CO₂/ton cement by 2030. This is an improvement potential ranging from 12% to 27% compared to 2013 level.

In summary:

1. The simple linear extrapolation of the Vietnam 2009 – 2013 Business-as-Usual trend is not a viable scenario. The stable to slightly increasing trend of the key KPIs and the continued absence of alternative fuels would lead to a steady increase of CO₂ emission per ton clinker and per ton cement. On the other hand, the steady improvement of electric energy efficiency per ton cement will hit a technical limit soon.
2. Existing policy measures in the first place aim at quite ambitious energy efficiency targets for new installations. In practice these are however rarely achieved for thermal energy. Effectively implementing these targets would improve the sector average thermal energy efficiency but leave it still almost 10%

above the South East Asian average achieved in 2013.

Current Vietnam policy measures don't have an objective for the two other important CO₂ mitigation drivers: alternative fuels and clinker content reduction in cement.

The implementation of the Waste Heat Recovery policy could recover part of the currently wasted energy, but it is an expensive option and it would be advisable to prioritize energy efficiency improvement over waste heat recovery because waste heat to electric power conversion efficiency is low. Waste heat recovery does not decrease direct CO₂ emission.

Existing policy measures have a relatively small effect on long-term CO₂ emission mitigation.

3. The Vietnamese benchmarking scenarios also lead to fairly unambitious mitigation scenarios, certainly with respect to alternative fuels and clinker substitution because even today's 10% or 20% best performers in Vietnam are still relatively modest compared to regional and global benchmarks. The Vietnam benchmarking scenarios would result in a CO₂ per ton clinker and per ton cement level by 2030 comparable to today's performance in the rest of South East Asia.
4. Vietnam achieving today's performance level in the rest of South East Asia would already be a significant improvement: i.e. 9% better gross CO₂ emission per ton cement and 11% better thermal energy efficiency. On the other hand, the Vietnam cement sector is already 20% better than the rest of South East Asia in terms of electric power efficiency. Also reaching today's SEA performance on alternative fuels and

- clinker substitution would be a significant improvement.
5. If on top of reaching today's South East Asia's performance level Vietnam would also follow the SEA improvement trend, then Vietnam would be on a fast track to reaching *Best Available Technology and Practice* level by 2030. This level is also about 15% better (in terms of CO₂ per ton cement) than today's 20% best performing installations in South East Asia. This is a quite ambitious scenario.
 6. The last scenario is that the Vietnam cement sector would reach *Best Available Technology and Practice* level by 2030 with a linear progress from 2015 to 2030. In this scenario Vietnam would reach South East Asia's sector average 2013 performance by 2020. This should be a realistic scenario.
4. Ensuring that new installations effectively operate at current best practice energy efficiency and fuel mix.
 5. The quantity of wasted heat may be decreased considerably by improving the thermal energy efficiency to the level that is achievable with the modern equipment that has been built recently in Vietnam. The potential for waste heat recovery will then be reduced proportionally. Energy efficiency improvement should have priority over waste heat recovery because the waste heat to electric power conversion efficiency is low.
 6. Considering the world-class electric energy efficiency of the Vietnam cement sector, the potential to further improve electric power efficiency is limited.

In conclusion, the main levers to achieve this improvement include:

1. Improvement of operational management and practice to improve thermal energy efficiency, mainly with the existing equipment and less so with new equipment. Such improvement is especially needed in the recent and privately owned installations.
2. Substantial increase of the contribution of alternative fuels, both biomass and fossil waste derived fuels. This will require investment in waste collection, management, handling, storage and feeding infrastructure, waste operational management and practice. For all this to become possible it is indispensable that adequate waste management legislation is developed and implemented;
3. Further lowering the content of clinker in cement;

Conclusion

There is considerable potential to mitigate absolute CO₂ emission from the Vietnam cement sector through a combination of mastering capacity expansion and implementing *Best Available Technology and Practice*.

The continuation of the clinker and cement production capacity expansion as currently planned in the Vietnam cement Master Plan 1488, combined with the current sector performance trend of energy and CO₂ intensity would cause cement sector absolute CO₂ emissions to more than double from approx. 46 MtCO₂ in 2013 to approx. 104 MtCO₂ in 2030. The implementation of existing policy measures would help to reduce the GHG emissions by around 10% in 2030 (

Figure 2).

Four policies and actions will enable to drastically curb this trend and limit the growth of absolute CO₂ emissions to just about 9% above 2013 level to approx. 50 million ton CO₂ per year by 2030 or even approximately 6

Mton or 13% *below* 2013 level to 40 MtCO₂ in 2030.

These four areas are:

1. Limit the growth of clinker and cement production capacity to the real need of Vietnam and refrain from an economically and environmentally unsustainable clinker and cement export strategy. This would enable approx. 36 to 49 Mt CO₂ or 35 to 47% mitigation of absolute CO₂ emission to between 68 and 55 million ton CO₂ per year by 2030.
2. Effectively implement *Best Available Technology and Practice* across the industry will enable a further 15 - 28 million ton reduction to 50 - 40 million ton CO₂ emitted per year by 2030.
 - 2.1. Implementing *Best Available Practice* in all installations, but especially and with priority in all recently built and privately owned clinker installations. Considering that most of those recent installations seem to have been built with *Best Available Technology* it can be expected that this improvement will require few new equipment. Investment in technical competence and expertise, in a technical centre, may be necessary.
 - 2.2. Reducing the clinker content in cement. This may require investment in slag granulation installations at steel plants, pozzolanic material mining, fly ash beneficiation and cement grinding capacity.
 - 2.3. Increasing the contribution from biomass and alternative fossil

waste derived fuels. This will require investment in waste collection, management, handling, storage and feeding infrastructure and equipment and waste operational management and practice. For all this to become possible it is indispensable that adequate waste management legislation is developed and implemented

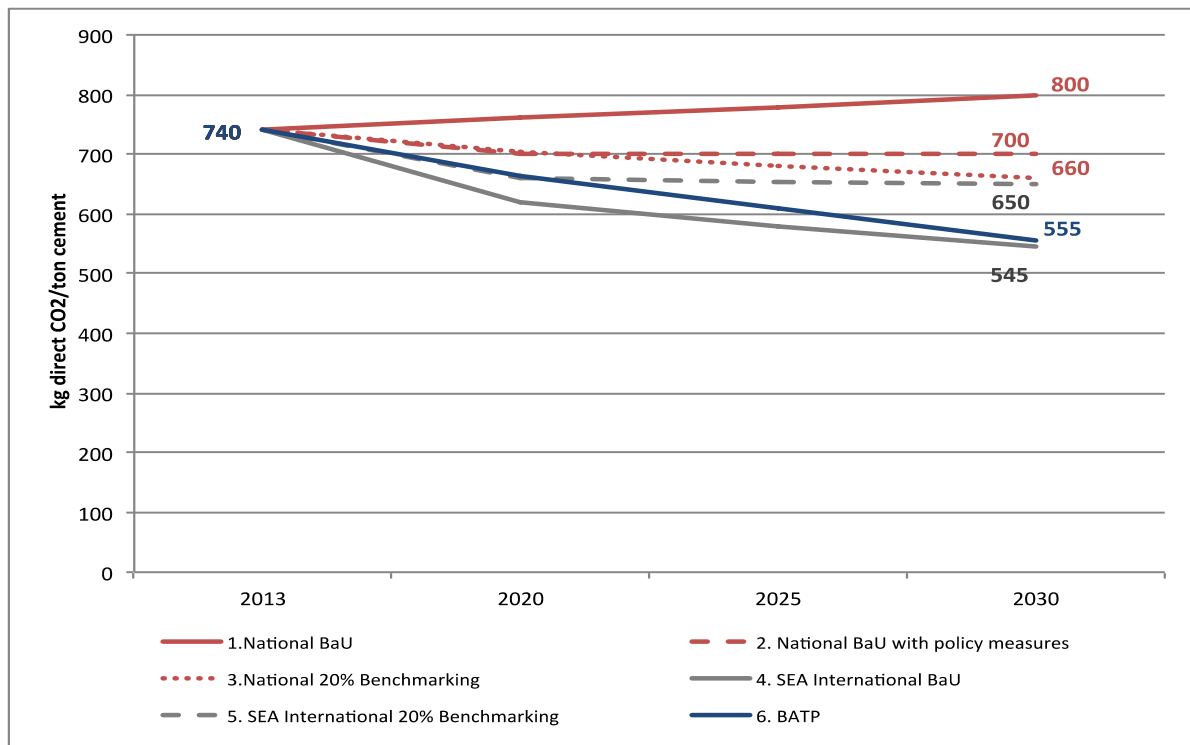
The potential to mitigate indirect CO₂ emission through improvement of electric energy efficiency, waste heat recovery and own captive power generation is very small compared to the mentioned four priority actions. The indirect CO₂ mitigation through WHR would be around 0,35 Mton in 2030, or about 0.5 to 1% of the mitigation potential through the four other levers.

All these energy and CO₂ mitigation actions are feasible with existing technologies and practices. It is likely that they can be implemented at long-term low if not negative cost.

This summary overview of the scenario analysis by no means implies a proposal for a NAMA “reference or baseline scenario”. The scenario with the unabridged extrapolation of current practice and capacity expansion is rather a “worst case” but not viable scenario against which several viable scenarios can be measured. Before proposing NAMA reference or baseline scenarios report I.5 will elaborate on the technical and practical means for those mitigation actions and the barriers, opportunities and challenges for implementation in Vietnam. Report I.6 will then elaborate on NAMA baseline and target scenarios as well as policy and economic incentives to realize this important potential.

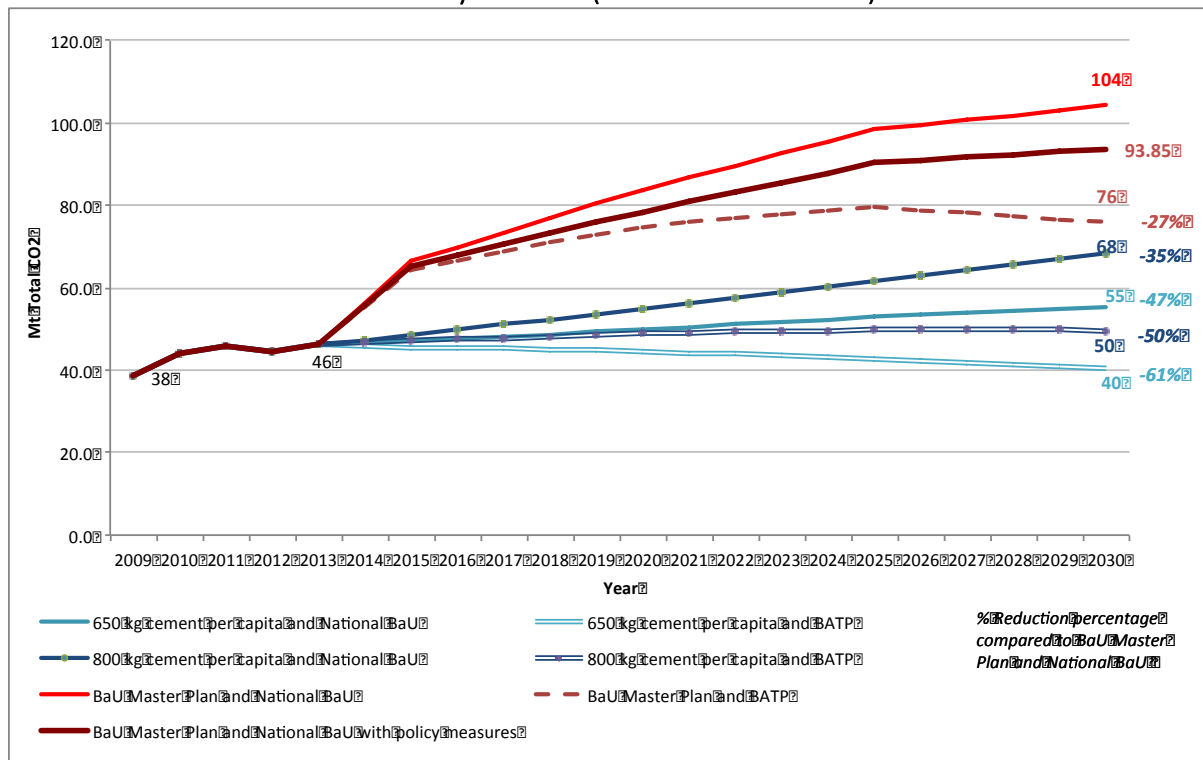
Annexes

Figure 1: Development of specific direct CO₂ emissions under the different scenarios



Note: Note x-axis is not true to scale

Figure 2: Absolute cement sector CO₂ emission according to the three production scenarios and three CO₂ intensity scenarios (National BaU and BATP)



The report was developed under the framework of the Nordic Partnership Initiative Pilot Programme for Supporting Up-scaled Climate Change Mitigation Action in Vietnam's Cement Sector.

The Nordic Partnership Initiative (NPI) established in December 2011 to support climate change mitigation efforts in developing countries and funded by Denmark, Finland, Iceland, Norway and Sweden. The budget of the NPI Programme in Vietnam is €1.6 million, and it is financed by Nordic Development Fund (NDF) and the Ministry of Construction of Vietnam. The implementation of the Vietnam cement sector Pilot Programme started in March 2014, by a consortium led by NIRAS A/S (Denmark) in collaboration with Perspectives GmbH, South Pole Group, VNEEC JSC and NIRAS Vietnam.

For more information on the project and the full report, please contact:

Mrs. Luu Linh Huong
Department of Science, Technology and Environment
Ministry of Construction of Vietnam
ndfc34@moc.gov.vn