Global Green Growth Institute

Industry Greenhouse Gas Reduction to Support the Implementation of Thailand's Climate Change Master Plan

Final GHG Reduction Roadmap Report

The Global Green Growth Institute
19F Jeongdong Building, 21-15, Jeongdong-gil, Jung-gu, Seoul, Korea 100-784

Supported by:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

Global Green Growth Institute

Industry Greenhouse Gas Reduction to Support the Implementation of Thailand's Climate Change Master Plan

Final GHG Reduction Roadmap Report

This project is part of the International Climate Initiative. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supports this initiative on the basis of a decision adopted by the German Bundestag.

Foreword

Thailand is vulnerable to the impacts of climate change. Notwithstanding the rapid economic growth over the past three decades, which has lifted the country out of poverty, Thailand has increasingly seen the adverse impacts of development, including water shortage, droughts, floods, sea level rise, air pollution, and coastline erosion. Thailand is also faced with challenges of energy security, which is another important issue -that needs to be addressed, given that energyis the largest contributor to Thailand's greenhouse gas emissions (GHG). More emphasis needs to be placed on developing renewable energy and promoting energy efficiency in order to mitigate greenhouse gas emissions in the country.

The Royal Thai Government (RTG) has demonstrated the will to address such challenges. The overarching philosophy, called the King's Sufficiency Economy, bestowed by His Majesty King Bhumibol Adulyadej, stresses the middle path as an overriding principle for appropriate conduct by Thai people at all levels, from family, to community, to country. Under this philosophy, the Climate Change Master Plan was developed for the period of 2015 to 2050. The main thrust of the Plan aims to lead the country to a Low Carbon Society by 2050, byreducing GHG emissions within a sustainable growth framework.

In October 2015, Thailand announced that the country would reduce greenhouse gas emissions by 20-25% by 2030 in submission of the Intended Nationally Determined Contribution (INDC). In the letter, the Office of Natural Resources and Environment Policy and Planning (ONEP), the national focal point for climate negotiations, noted that the country is on track to achieve the 7% reduction in greenhouse gas target by 2020 what was pledged at the COP20 climate change conference in Lima. To meet Thailand's INDC target, different governing institutions are required to take collective action in a timely and decisive manner.

In support of the country's efforts to mitigate climate change, ONEP and the Global Green Growth Institute (GGGI) jointly launched a project *Industry GHG Reduction*. The project aims to provide technical assistance in the development of industrial sector GHG reduction strategies, complementing the Climate Change Master Plan. It also intends to enhance capacity within the RTG and the private sector in conducting GHG inventories, emissions projections, and economic impact assessments of mitigation measures.

This report, the *GHG Reduction Roadmap*, suggests a variety of action items for stakeholders per timeframe (short-, mid-, and long-term) to help effectively curb GHG emissions in the selected sub-sectors of focus. The report builds on two preceding reports: Emissions Projection Report, and Technical/Economic Analysis Report, which assessed the current level of GHG emissions in the selected sub-sectors, projected emissions until the year 2050, identified potential GHG reduction measures/technologies, and conducted technical/economic analyses of the suggested measures. The two reports are available upon request.

ONEP and GGGI appreciate the contribution and strong support from the International Climate Initiative (IKI), the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), to this initiative.

(Dr. Raweewan Bhuridej)
Secretary-General, ONEP

(Per Olof Bertilsson)
Assistant Director-General, GGGI

Thailand GHG Reduction Roadmap

Key Findings

- Implementation of the recommendations outlined in Thailand's GHG Reduction Roadmap would result in approximately 3-5 $MtCO_2e$ reduction across the three industrial sub-sectors of focus – palm oil, auto-parts and frozen seafood, leading to around THB 4,300 million or USD 123 million of savings. The implementation of similar activities across the manufacturing sector can lead to the reduction of 23-37 $MtCO_2e$, or 4-7% of the country's emission. This could potentially save THB 32,000 million for the Thai economy.
- The GHG reduction of the sub-sectors would be 31% compared to the BAU level in 2030. Various profitable measures can be adopted. Most of them are energy efficiency options such as improving management and operation practice, and replacing of low-cost measures. Adoption of these cost-effective options could result in the estimated GHG reduction of 3.05 $MtCO_2e$, equivalent to 7 million barrels of crude oil (2% of 2014 imported amount) or the amount sequestered by 78 million tree seedlings grown for 10 years.
- The Long-term Agreements (LTAs) are proposed as a policy framework to be established between the industrial sectors and the government. LTAs should be implemented in parallel with the on-going policies and measures. The LTA approach consists of three phased actions - short, medium, and long term - serves to increase sector involvement and awareness of climate change.

Three Sectors of Focus

Palm oil | Automotive parts | Frozen seafood

Long-term Agreements (LTAs)

Short-term

- Get the data 'right'
- Generate sector engagement and interest
- Implement low hanging fruit measures

Medium-term

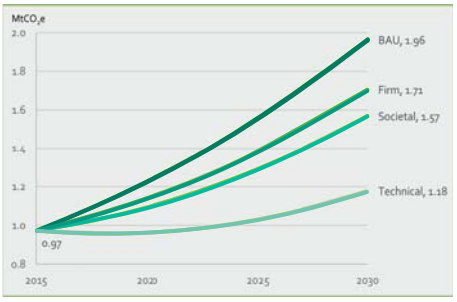
- Reach Long-Term Agreement with sub-sector for emission reduction
- Supporting mechanisms in place
- Begin implementing

Long-term

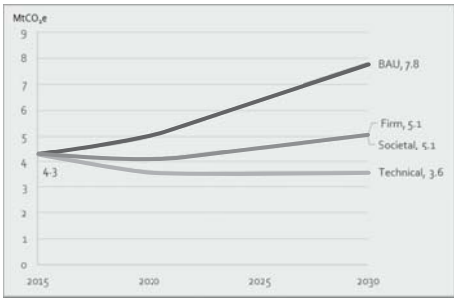
- Examine success of (voluntary) agreement
- Improve existing agreement or introduce mandatory approach

Roadmap Details

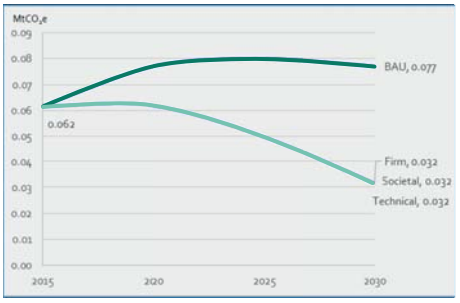
- Thailand's **palm oil** industry can technically achieve GHG reductions of 40% by 2030 compared with BAU forecasts if the identified GHG reduction measures are implemented. The economic potential from a societal perspective is 20% and 13% from a private perspective.
- Many cost-effective GHG abatement measures have been identified for the **automotive parts** industry, leading to a technical potential of 54% and an economic potential, both from a societal and private perspective, of 35% abatement in 2030. The key focus area in this sub-sector is the improvement of energy efficiency.
- The **frozen seafood** industry can employ a variety of measures to abate emissions, including improving the efficiency of current installations or shifting to newer, more efficient freezing techniques, leading to a technical abatement potential of 59%. The economic abatement potential is the same as the technical potential. Detailed activities for short-, medium-, and long-term for each sector to achieve GHG emission reduction are described in the roadmap.



Automotive parts



Palm oil



Frozen seafood

- Data availability and quality are the big challenges in developing the Roadmap. To address these challenges, it is recommended that the data collection and management processes be improved.
- Long-term Agreements (LTAs) is proposed as a policy framework to be established between the industrial sectors and the government to reduce GHG emissions. The LTAs serve to increase sector involvement and awareness of climate change. LTAs could be implemented in parallel with the on-going policies and measures initiated by relevant government agencies. LTAs could be developed into three time phases:
  - Short-term (2-3 years) - develop a foundation;
  - Medium-term (5 years) - establish long-term agreements, supporting actions and monitoring arrangement; and
  - Long-term (8 years) - implement and evaluate.
- In addition, the Roadmap recommends that:
  - Knowledge and understanding of GHG abatement measures and building operational capacity amongst government and private staff should be improved;
  - Financial support schemes should be evaluated and enhanced;
  - The outreach of energy efficiency programs should be extended;
  - Smart indicators to track the progress should be developed;
  - The government should provide a clear sign to industry of the country's commitment and how the industry performance could support this commitment; and
  - The Roadmap should be reviewed periodically.

About the project

- The Industry GHG Reduction to Support the Implementation of Thailand's Climate Change Master Plan ('Industry GHG Reduction') project aims to develop a practical and implementable GHG reduction target for Thai industry. The project is jointly implemented by the Global Green Growth Institute (GGGI) and Thailand's Office of Natural Resources and Environmental Policy & Planning (ONEP). It is funded by the German Federal Ministry for the Environment, Nature, Conservation, Building and Nuclear Safety.

Acknowledgements

The Global Green Growth Institute (GGGI) and the project team would like to express their gratitude to the Office of Natural Resources and Environmental Policy and Planning (ONEP) for their strong support to this project. This work should not have been possible without the sponsorship from the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. Special thanks goes to the members of the Project Steering Committee (PSC) who kindly provided guidance and advice during the course of the project. The PSC consisted of:

- Office of Natural Resources and Environmental Policy and Planning (ONEP)
- Department of Alternative Energy Development and Efficiency (DEDE)
- Energy Policy and Planning Office (EPPO)
- Department of Industrial Works (DIW)
- Office of the National Economic and Social Development Board (NESDB)
- The Federation of Thai Industries (FTI)
- Thailand Greenhouse Gas Management Organization (Public Organization) (TGO)
- Joint Graduate School for Energy and Environment (JGSEE)
- Good Governance for Social Development and the Environment Institute (GSEI)
- Prof. Dr. Chullapong Chullapodhi, King Mongkut's University of Technology Thonburi
- Assoc. Prof. Dr. Chat Chiemchaisri, Kasetsart University

We wish also to acknowledge with much appreciation the contribution of the many organizations that provided data and information, and helped us to understand better the Thai energy and climate change context:

- National Food Institute (NFI)
- Department of Alternative Energy, Development and Efficiency (DEDE)
- Thailand Greenhouse Gas Management Organization (Public Organization) (TGO)
- Office of the National Economic and Social Development Board (NESDB)
- Department of Industrial Works (DIW)
- Thai Autoparts Manufacturers Association (TAPMA)
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
- National Metal and Materials Technology Center (MTEC)
- Office of Industrial Economics (OIE)
- Provincial Electricity Authority (PEA)
- Palm Oil Industry Club (POIC)
- Electricity Generating Authority of Thailand (EGAT)
- Energy Policy and Planning Office (EPPO)
- Thai Frozen Foods Association (TFFA)

Executive Summary

This report is part of a project aimed to assist the implementation of the Thailand Climate Change Master Plan by developing a clear roadmap for reduction of greenhouse gas (GHG) emissions in three industrial sub-sectors of the Thai economy: the palm oil industry, the automotive parts industry and the frozen seafood industry. The sub-sector roadmaps are to be underpinned by:

1. An updated and improved GHG inventory for the selected sub-sectors.
2. A credible evidence base of actual and projected emissions, mitigation potential, abatement technologies, policy measures, and economic impact analysis for the selected sub-sectors.
3. An enhanced capacity for coordination and technical and economic analysis within the Government of Thailand and the private sector in relation to GHG inventories, emission projections, mitigation opportunities, and economic impact assessment of mitigation measures on the selected sub-sectors.

This report, the GHG Reduction Roadmap, builds on two other deliverables of this project:

- The Emissions Projection Report (EPR), aimed at developing GHG inventories for the selected sub-sectors and new business-as-usual projections to forecast GHG emissions up to the year 2050 which is consistent with Thailand's Climate Change Master Plan;
- The Technical and Economic Analysis Report (TEAR), aimed at assessing the potential for emission reduction in the selected sub-sectors, developing several GHG abatement scenarios, evaluating the barriers and enablers to implementations of emission abatement options and at assessing the wider socio-economic impacts of emission abatement.

The objectives of this GHG Reduction Roadmap report ('Roadmap') are:

- To bring together the findings of the previous reports to produce a roadmap report recommending emissions reduction pathways for the selected sub-sectors.
- To provide a credible and robust evidence base on which policymakers and other stakeholders can base their decisions to achieve cost-effective and appropriate emissions reductions in the selected industry sub-sectors.
- To enhance the capacity of policymakers and other stakeholders to act by recommending short-, medium- and long-term actions that will reduce the implementation barriers of emission abatement options and achieve reductions in GHG emissions while taking into account wider socio-economic impacts.

The Roadmap is developed for three industrial sub-sectors, selected in the Diagnostic Report, the first deliverable of this project, and further scoped in the Emissions Projection Report. The three sub-sectors are:

1. The palm oil industry, including palm oil mills, palm kernel oil mills and palm oil refineries, but excluding palm plantations and downstream activities;
2. The automotive parts industry, including the most energy intensive processes to manufacture automotive parts, but excluding the assembly of vehicles;
3. The frozen seafood industry, including all on-shore preparation, chilling, refrigeration and storage activities, but excluding all off-shore activities and transportation.

The scope is that only emissions that stem from manufacturing processes in the three sub-sectors are considered. Emissions that occur due to activities up or downstream in the value chain are not considered.

Direct emissions in manufacturing processes can be caused by the conversion of energy and treatment of waste (water) or come from the processes directly. Indirect emissions that are considered are only those arising from the generation of electricity. Therefore, a lifecycle approach was not needed.

Data situation in Thailand

A data map was created to outline the challenges related to the availability, quality, accessibility and sensitivity of GHG emissions and other emissions related data in Thailand. The data map outlines data on data needs and availability, data sources and the institutions collecting, compiling and analysing the data. The most important findings on data mapping are:

- **Information on data quality and availability as well as the data itself is dispersed. The data map created in this study shows that many organizations hold part of the information necessary to build GHG emission reduction roadmaps.** Differences in the level of data aggregation and scoping hinder combining and validating the data. Limited accessibility of data, e.g. for reasons of competitive sensitivity, further complicates the data acquisition process.
- **Detailed and recent data for industrial process and waste emissions is limited. If data are available, it is only at high levels of aggregation, i.e. with little or no sector breakdowns.** The GHG emission inventories therefore rely on several assumptions. This is far from an ideal starting point for emissions abatement, as it is unclear what exactly can be achieved. Furthermore, monitoring of progress and target achievement is cumbersome based on these data.
- **Consolidated, nation-wide data for long-term projections of emissions is also very limited.** Long-term projections had to be constructed based on trends; for instance, population growth and sector-specific trends. Economic forecasts only look one or two years into the future. Energy planning programs look further ahead, but lack the detail needed for the industrial roadmaps.

This study has three major recommendations to improve the data situation:

- **Improve the data collection and management processes** by appointing a single organization; for example, TGO would be an appropriate candidate, as it is centrally accountable. This organization should be in a strong position to establish an integrated data management system, capturing all relevant data associated with GHG emission inventories from various sources. Processes for data collection can be automated and simplified. Data access for third parties should be made quicker and easier, while still protecting sensitive data.
- **Create a "GHG Roadmap Guide" necessary for GHG inventories and projections.** The guide should address data needs and provide information on data availability, content, location and access/ request procedures and standard forms. The guides and forms should be available in hard and soft copy. Institutions with data related to GHG inventories, including DEDE and MTEC, can create simple additional guides to their databases. Other organizations with relevant data can create briefing notes detailing the data they collect that is specifically relevant to GHG inventories and roadmaps.
- **Improve data collection and consolidation of industrial process and waste emissions.** It may be possible to add additional reporting requirements to the energy reporting guidelines which inform the DEDE database under the Energy Conservation Promotion Act or the industrial reporting requirements of the Ministry of Industry. It is also recommended that further analysis is performed to improve the quality of the baseline emissions estimates and projections for each of the sub-sectors. Generally, sectoral organizations can play a role in collecting relevant sector data and work together with the central authority appointed to develop an integrated data management system.

Roadmap approach

The key lessons from the analyses in the EPR and TEAR which are important to the development of Roadmaps are:

- The understanding of industrial GHG emissions at a sub-sector level is limited. Information on data quality and availability as well as the data itself is dispersed. Consolidated, nation-wide datasets for long-term emission projections are also very limited.
- Over the last decade Thailand has shown an increased awareness of climate change, this theme is on the political agenda. Responsibility for the design, implementation and evaluation of climate change

policy frameworks are distributed among several ministries and government agencies. This fragmentation of accountability and ownership does not always lead to the most efficient and effective cooperation.

- Several laws and regulations exist that address GHG emissions, notably the Energy Conservation Promotion Act and the Energy Industry Act. Furthermore, a range of action plans have been developed, e.g. the Alternative Energy Development Plan, the Energy Efficiency Plan, the Strategic Plan on Climate Change and the Climate Change Master Plan. Several government agencies, such as DEDE, have been implementing relevant measures to directly and indirectly reduce GHG emissions.
- The barrier analysis conducted in the TEAR revealed a wide range of obstacles that hamper the adoption of emission reduction measures. An improved understanding of these barriers is needed to better inform policies and actions.

These key lessons are the starting point for the Roadmap study, which proposes an approach to policies and actions within this context.
The approach relies on two complementary solution pathways, but with the first as the leading framework for the Roadmaps proposed in this report:

1. **Establishing Long-term Agreements (LTAs)** between the Industrial (sub-)sectors and the Government with the aim of reducing GHG emissions. The LTAs can serve to increase sector involvement and awareness of the importance of climate change. Furthermore, they can support the improvement of GHG emissions data and target policies and actions to focus on industrial GHG abatement.
2. **Building further on the policies and actions already implemented by DEDE and other relevant government agencies,** which will either indirectly, or in parallel, support and accommodate the success of the LTAs.

Reaching an LTA is a proven approach for ensuring long-term commitments between the government and private sector. An LTA is most appropriate and effective when there is likely to be opposition against an obligatory approach. They can also reduce the costs and complexity to both Government and industry compared to the alternatives of a regulatory-led or mandatory approach. It is clear that there is currently neither the knowledge nor capacity in both industry and Government to effectively implement a more mandatory approach. The advantages of an LTA approach over other alternatives provide the key rationale for selecting it as a framework for the sectoral GHG emission reduction Roadmaps.

A program of LTAs can be used to further reinforce the existing programs and regulations in Thailand. DEDE already operates a number of voluntary agreements (VA) and has experience in this area. DEDE and other agencies also already carry out many other activities that can act as powerful supporting measures to the LTAs and which can also be adapted and improved under the umbrella of the LTA framework. The success factors identified above already provide clear insight into how best to structure and implement the LTAs and the supporting policies.

The LTA framework for emission reduction Roadmaps in Thailand

A Roadmap is based on taking actions over time to progress and build towards a goal or desired outcome. The overarching LTA framework is developed in this context, with short, medium and long-term phases to its implementation and for which at each stage there are (1) objectives; (2) key groups of policies and actions; and, (3) milestones and/or indicators to enable monitoring and measuring if the objectives are being achieved.

The objectives within the framework are split into phases below. Note that the proposed years and time periods below are only guidelines and could change with the starting period of roadmap implementation or the need for additional flexibility.

- **Short-term (2016-2017; 2 years): developing the foundations**
  - Getting the data right - to make an informed decision on goals it is crucial to understand where the sector currently stands, where it is going if no action is taken, and what is feasible considering the costs,

practicalities and barriers. While the EPR and TEAR provide a good start, there remain many data fidelity issues, which should be addressed in the short term.
    - Generate sector engagement – an LTA requires active participation, contribution, commitment and ownership by the sector. It is crucial therefore to engage them in the short-term.
    - Implement "low-hanging fruit", GHG reduction measures that are easy to implement – it does not make economic sense to wait to take mitigation measures that are cost effective, especially those with little or no investment costs, these can and should already be implemented in the short term. This will already help engage firms in the necessary cost-saving and emission reduction mindset.
- **Medium-term (2018-2022; 5 years): establishing the long-term agreements and supporting actions**
    - Reaching an LTA with the sector – will involve an in-depth dialogue to reach an agreement on targets and the roles and actions to be taken by both the sector and the government. This will also detail monitoring arrangements.
    - Supporting mechanisms put in place – effectively representing implementation of the agreement by the government where the objective is to develop and build upon their supporting actions, programs and incentives to enable the LTA to operate successfully.
    - Begin implementing – the sector should continue to implement GHG emission reduction measures, and move onto implementing measures that are no longer 'low-hanging fruit' but that in most cases are still cost effective and/or require only small capital investments or O&M costs.
- **Long-term (2023-2030; 8 years): Implementation and reflection**
    - Examine and evaluate success of LTA – this objective is to ensure that there is information available to evaluate if progress is satisfactory and that the LTA is having the desired impact on industry for GHG emissions reduction.
    - Improve existing agreement or introduce mandatory approach - continual improvement is desirable, if targets are achieved then the focus can turn to new objectives in future. If implementation is lagging remedial actions proposed, penalties applied and/or a stronger (i.e. mandatory) approach should be an objective.

The actions and milestones of each phase are elaborated in Chapter 2.

Roadmaps per sub-sector

Although roadmaps per sub-sector have been created, many of the recommended policies and actions are applicable to all sectors, although their impact, in terms of abatement potential will be different per sector.

Palm oil industry

The palm oil industry has the potential to reduce its own emissions in a variety of ways, six key measures were identified in this project. The technical potential of the identified measures would lead to a 40% reduction in GHG emissions compared with a BAU scenario by the year 2030. The economic potential from a societal perspective is 20% and 13% from a private perspective. The palm oil industry already predominantly uses biomass for its energy demand. Further integration of biogas capture has the dual benefits of both reducing methane emissions and providing fuel for grid connected electricity generation.

The data situation for the palm oil industry is the best of the three sub-sectors. This is due to the fact that data have been collected in the framework of Clean Development Mechanism (CDM) projects for the abatement of GHG emissions originating from the palm oil sector and other government's support schemes, mainly from the Ministry of Energy, to promote the use of biogas. Still many data are missing and sometimes sources contradict each other. There are some case studies on GHG abatement but they focus on a handful of mills. The Roadmap for the palm oil industry follows the overall Roadmap approach as elaborated above, i.e. based on a Long Term Agreement framework. The counterparties to the proposed LTA in this sector would be the Government and Thailand's Palm Oil Industry Club.

In the short term (2016-2017), the Government and the palm oil sector should investigate the feasibility of entering into a long-term agreement and what would be required for its implementation. In this phase, the data situation should be improved and a deeper investigation of the abatement potential should be conducted. The energy management and auditing approach, managed by DEDE, is a very appropriate tool for this. This first phase should also be used to create a sector wide understanding of abatement options. Low-hanging fruit measures can start to be implemented already by the sector, these are mostly related to cross-cutting technologies, like efficient motors, and improved operation and maintenance measures. DEDE already has policies and actions in place to support cross-cutting technologies, e.g. labeling and subsidies, which the industry can tap into.

The second phase (2018-2022) is needed for establishing the long-term agreement between the Government and the palm oil sector. Based on the improved data, an agreement should be reached on the ambition for GHG abatement, which could then be translated into a long-term target. Parties should also agree on the kind of support that is needed and the conditions to be met to make the agreement successful. A monitoring program should be established, based on measurable indicators, and it should be clear what would happen if parties do not comply with these arrangements. This phase also comprises further implementation of abatement measures such as energy efficiency measures and biogas recovery and use. The electrical utility, or Provincial Electricity Authority (PEA) in most cases, should be involved in aligning the requirements for tying any new palm oil fueled electricity generation to the grid. The third phase (2023-2030) is dedicated to the full implementation of the long-term agreements. Annual monitoring of the progress is required to be able to adjust and account for the resources spent so far. The LTA should be evaluated by both parties at this point, particularly the Government. If targets are being met and progress is satisfactory then there may still be some scope for further improvement and thoughts can already turn to future plans. If targets are missed then remediation, penalties and potential introduction of mandatory targets should be considered.

Automotive parts industry

Many cost-effective GHG abatement measures have been identified for the automotive parts industry, leading to a technical potential of 54% and an economic potential, both from a societal and private perspective, of 35% abatement in 2030. The key focus area in this sub-sector is the improvement of energy efficiency through the implementation of cross-cutting measures, like high-efficiency motors, variable speed drives and the avoidance of leakage in compressed air systems.

The automotive parts industry in Thailand is very heterogeneous, including many different brands of vehicles, more than 20,000 different products and a variety of manufacturing processes. Over the past decades the sector has grown to have a significant economic importance for Thailand. Although there are many smaller parts in manufacturing plants, the market is dominated by a few large foreign players. The challenges for an LTA in this sector are (1) how to capture the huge heterogeneity in processes under a single LTA and (2) dealing with the large differences in the size of the companies. The counterpart for the Government to set up a long-term agreement can be the Thai Autoparts Manufacturers Association (TAPMA).

In the short term (2016-2017), the Government and industry should investigate if entering into one long-term agreement is feasible. For this heterogeneous sector a one-size-fits-all approach might not work and that it might be better to have different LTAs for specific parts manufacture processes, i.e. seat manufacturers, auto glass manufacturers, etc. To achieve this, the data situation should be improved. This sector was already the subject of a project by GIZ aimed at greening the automotive industry. The data collected in the GIZ project, which only became available at the end of this Roadmap project, can provide a valuable source for deeper investigation of the abatement potential in the sector and to create sector-wide understanding of abatement options. Low-hanging fruit measures are mostly related to cross-cutting technologies, like efficient motors, and to improved operation and maintenance measures. DEDE already has measures in place to support cross-cutting technologies, e.g. labeling and subsidies.

The second phase (2018-2022) is needed for establishing one or more long-term agreements. Based on improved data, consensus should be reached on abatement ambitions, which can be translated into a long-term target. Parties should also agree on the type of support necessary and the conditions to be met for a successful agreement. The monitoring program should be set up, based on measurable indicators, and it should be clear what happens if parties do not comply with these arrangements. This phase also comprises a further roll out of energy efficiency measures.

The third phase (2023-2030) is dedicated to the full implementation of the long-term agreement(s). Annual monitoring of the progress is required to be able to adjust and account for the resources spent so far. The LTA should be evaluated by both parties at this point, particularly the Government. If targets are being met and progress is satisfactory then there may still be some scope for further improvement and thoughts can already turn to future plans. If targets are missed then remediation, penalties and potential introduction of mandatory targets should be considered.

Frozen seafood industry

The frozen seafood industry can employ a variety of different measures to abate emissions, including improving the efficiency of current installations or shifting to newer, more efficient freezing techniques, leading to a technical abatement potential of 59%. The economic abatement potential is the same as the technical potential, as almost all identified abatement options are related to improved energy management and require relatively inexpensive cross-cutting technologies. The largest abatement potential can be found in the use of new freezing techniques using NH_3 or CO_2 which are 2-20% more efficient than current techniques which use F-gases as the refrigerant.

The frozen seafood industry is the smallest of the three sub-sectors in terms of GHG emissions. The sector faces challenges with diseases and international trade and competition that threaten production and competitiveness. On the one hand, the relatively small size and concentration of firms in the frozen seafood sector make it a good candidate for a trial of the LTA approach. On the other hand, broadening the scope of an LTA to apply to the entire frozen food sector would increase the absolute emission abatement potential significantly. The counterpart for the Government to discuss an LTA with could be the Thai Frozen Food Association (TFFA).

In the short term (2016-2017), the Government and industry should investigate if entering a long-term agreement for this sector is feasible, or whether the scope should be broadened. In this phase the GHG emission data, including F-gases, should be improved. A further investigation on the cost-effectiveness of

emission abatement is recommended. Low-hanging fruit measures are mostly related to cross-cutting technologies, such as efficient motors, and to improved operation and maintenance measures. DEDE already has measures in place to support cross-cutting technologies, e.g. labeling and subsidies.

The second phase (2018-2022) is needed for establishing a long-term agreement. Based on the improved data, an agreement should be reached on the ambition for GHG abatement, which can be translated into a long-term target. Parties should also agree on the kind of support that is needed and the conditions to be met to make the agreement successful. The monitoring program should be set up, based on measurable indicators, and it should be clear what happens if parties do not comply with these arrangements. This phase also comprises a further roll out of energy efficiency measures.

The third phase (2023-2030) is dedicated to the full implementation of the long-term agreements. Annual monitoring of the progress is required to be able to adjust and account for the resources spent so far. The LTA should be evaluated by both parties at this point, particularly the Government. If targets are being met and progress is satisfactory then there may still be some scope for further improvement and focus can turn to future plans. If targets are missed then remediation, penalties and potential introduction of mandatory targets should be considered.

Further recommendations

Apart from the Roadmaps for the sub-sector, the study resulted in a number of recommendations to improve the implementation of GHG emission abatement measures.

Start with a pilot sector to test the LTA process in Thailand. While all studied sectors seem suitable for an LTA approach, there are differences. For example the palm oil sector seems to have the best data and can be clearly scoped. The automotive parts sector is very heterogeneous in terms of products and size of companies and is dominated by a few foreign automotive companies. The question here is whether a one-size-fits all approach would work. The frozen seafood sector is the smallest of the three in terms of absolute GHG emissions. For this sector it might be considered to increase the scope to include more industries, for instance the whole frozen food sector. Testing the approach in a single sector can help to evaluate its suitability and success, and to learn from the issues that are encountered, smoothing the process for expansion to other sectors. The LTA approach is flexible and can be tailored to any sector, therefore any industrial sector could be used as a pilot, not just one of the three studied sub-sectors. To aid in the success of the pilot project, attention should focus on the selection of a particular sector that the project will intervene. By choosing a sector which has relatively high absolute emissions, that is well organized and which already demonstrates awareness of climate change and commitments to GHG abatement, the outcomes are more likely to be positive. The pilot will also be instructive on the phasing of implementation of the LTA, providing guidance on likely timescales, where flexibilities and overlaps may occur and the extent to which deadlines are needed to maintain progress.

Within Government designate a single agency responsible for the LTAs. To have clear lines of communication with the sector and a single voice to industry, this agency should have, or be able to generate, the trust and cooperation of industry. The other agencies would play a supporting role. The agency designated to manage the LTA would also manage intra-governmental coordination between itself and the agency responsible for managing GHG inventory and projection data.

Improving knowledge and understanding of GHG abatement measures and building operational capacity amongst government and private staff are required to overcome the barriers that hamper uptake of the cost-effective measures. Cost-effective measures are not implemented due to market imperfections, such as imperfect information, as well as limited human capacity and vision or understanding at the management level. Current programs, such as the Energy Efficiency Plan (EEP), already address these and other barriers with a variety of policies and actions. In order to accelerate the capacity building measures in the private sector, the government can facilitate training for private companies. To ensure their buy-in, it is recommended that the knowledge and understanding on GHG abatement measures should be communicated through the lens of resource efficiency and competiveness enhancement. Government agencies should also be trained in understanding on climate change and (technical) knowledge of GHG abatement options.

Increase focus on technical education and training to build capacity in Thailand to develop and operate GHG emissions abatement projects. Important barriers to implementation include limited knowledge of abatement options and the skills or training to operate more efficient equipment and machinery. This should be addressed by placing more emphasis on sustainable technologies in educational programs. In the longer term, this would bring trained staff to the companies, awareness of the issue and abatement opportunities, which would contribute to reducing the abovementioned barriers.

Evaluate financial support schemes and make them more effective. Several financial support schemes are already available and being employed. These remain important to accelerate the adoption of many measures, particularly those which are not cost effective and/or require capital investment. It is encouraged that the Government regularly evaluates the effectiveness of these schemes and adjusts them accordingly.

Improved and enhanced financial support and access to finance are required to unlock the potential of measures with moderate abatement costs. According to the economic assessment, measures with moderate costs are still not attractive for companies. Currently, the Thai government has several financial incentive schemes - a government co-investing fund, soft loans, tax incentives and direct subsidies – to support the uptake of these measures. Assessing the effectiveness of these instruments would be beneficial to enhance the utilization of these measures. The use of other incentives and measures, i.e. market based instruments, can complement an LTA, for example sectors in the Netherlands subject to the EU emissions trading scheme (ETS) are also covered by LTAs, these complement and reinforce each other.

Improve the outreach of the current Energy Efficiency Program to accelerate the rate of energy efficiency improvement in industry. The program can run in parallel with, and be supportive to, the LTAs for specific sectors while also seeking to increase the scope of their coverage into new sectors. Various supports and schemes are in place, but the challenge is how to achieve industry outreach. A customer service unit was established with DEDE in 2002. This unit could be revived as part of the long-term agreements, with contact persons for each sector, providing solicited advice to the sector as well as carrying out pro-active outreach activities to make the sector familiar with the support programs of DEDE and other agencies.

Encourage the private sector to play a greater role in Thailand meeting its international commitments to reduce GHG emissions. The study recognizes the submission of the country's Intended Nationally Determined Contribution (INDC) to UNFCCC on October 1, 2015. The country aims to reduce its emissions by 20% from BAU by year 2030 and by 25% with international support. By this commitment the Thai government shows that it takes GHG abatement seriously. This facilitates communication to the private sector about the importance of climate change, raising awareness to the management of companies about this issue. Subsequent implementation of the INDC will require contributions from all sectors, and for the Government to articulate industries' contributions in greater detail in the future. This gives a clear signal that the private sector will need to contribute. Furthermore, it paves the way for more stringent enforcement, i.e. mandatory measures, if the rate of improvement under an LTA is too slow. This would be the proverbial 'stick' to go with the 'carrots' of improved incentives recommended previously.

Develop smart indicators to monitor progress towards targets and to enable steering of policy interventions. Currently, the overall target for energy efficiency is expressed in energy intensity, i.e. energy use per monetary unit (value added). As the relationship between energy and value added is weak at a product level and the decoupling of energy intensity and value added is an aspiration of the Thai economy, better indicators should be developed. Preferably, this indicator should be expressed in specific energy use or GHG emission per physical indicator, e.g. tonnes of product. It is noted that the study is aware of the on-going Ministry of Energy's initiative in developing a database for such indicators. These can also be used to track progress against broader national and international goals and indicators, such as INDCs or the UN Sustainable Development Goals.

It is recommended to review this study periodically. Since it is a long-term vision, important changes to circumstances may change over the timeframe of the study. It is impossible to predict the impacts of such events, for example new international commitments on emissions reduction, or dramatic technology shifts affecting the sub-sectors. This study and report should be treated as a living document and updated periodically to (re-)align the Roadmaps with new and developing situations as they occur.

Table of contents

Table of contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Description
AFOLU	Agriculture, Forestry, and Other Land Use
ASEAN	Association of Southeast Asian Nations
BAU	Business-as-usual
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
BUR	Biennial Update Report
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPC	Central Product Classification
CPKO	Crude Palm Kernel Oil
CPO	Crude Palm Oil
DEDE	Department of Alternative Energy Development and Efficiency
DIW	Department of Industrial Works
DNA-CDM	Designated National Authority for Clean Development Mechanism
EGAT	Electricity Generating Authority of Thailand
EMS	Early Mortality Syndrome
EPPO	Energy Policy and Planning Office
EU	European Union
F- gases	Fluorinated gases
FAO	Food and Agriculture Organization
FBT	Food, Beverage and Tobacco
FFB	Fresh Fruit Bunches
FM	Fabricated Metals
FTI	The Federation of Thai Industries
GDP	Gross Domestic Product
GEF	Global Environmental Fund
GGGI	Global Green Growth Institute
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSEI	Good Governance for Social Development and the Environment Institute
GTAP	Global Trade Analysis Project
GVA	Gross value added
GWh	Gigawatt-hour (thousand kWh)
HOSO	Head-on Shell -on
HSD	High Speed Diesel oil
HVAC	Heating, Ventilation, and Air Conditioning
IEA	International Energy Agency
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ISIC	International Standard Industrial Classification
IUU	Illegal, Unreported, and Unregulated
JGSEE	Joint Graduate School for Energy and Environment
KMUTT	King Mongkut's University of Technology Thonburi

List of Abbreviations

Abbreviation	Description
ktoe	Thousand tonnes of oil equivalent
KU	Kasetsart University
kWh	Kilowatt-hour
LTA	Long-Term Agreement
LCS	Low Carbon Society
MAC	Marginal Abatement Costs
MCA	Multi-criteria analysis
MJ	Million Joules
MNRE	Ministry of Natural Resources and Environment
$MtCO_2e$	Million tonnes of CO_2 equivalent
MTEC	National Metal and Materials Technology Center
N_2O	Nitrous oxide
NAMA	Nationally Appropriate Mitigation Actions
NC2	The Second National Communication
NC3	The Third National Communication
NESDB	Office of the National Economic and Social Development Board
NFI	National Food Institute
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compounds
OAE	Office of Agricultural Economics
OEM	Original Equipment Manufacturer
OIE	Office of Industrial Economics
ONEP	Office of The Natural Resources and Environmental Policy and Planning
PCD	Pollution Control Department
PDP	Power Development Plan
PEA	Provincial Electricity Authority
POME	Palm Oil Mill Effluent
PSC	Project Steering Committee
PTO	Peeled Tail-on
R&D	Research and Development
RBD PKO	Refined, Bleached, and Deodorized Palm Kernel Oil
RBD PO	Refined, Bleached, and Deodorized Palm Oil
REM	Replacement Equipment Manufacturer
RSPO	Roundtable on Sustainable Palm Oil
SEC	Specific Energy Consumption
SIIT	Sirindhorn International Institute of Technology
TAPMA	Thai Autoparts Manufacturers Association
TFFA	Thai Frozen Foods Association
TGO	Thailand Greenhouse Gas Management Organization (Public Organization)
THB	Thai Baht
TSIC	Thailand Standard Industrial Classification
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
WACC	Weighted Average Costs of Capital
WRI	World Resources Institute
WSD	White Spot Disease

To
provide credible
and robust evidence
to achieve cost-effective
and appropriate
emissions reductions in
the selected industry
sub-sectors

Automotive Parts

To
constitute a high
level investigation
into the GHG
emissions
of industry in
Thailand

To
enhance the
capacity of policymakers
and other stakeholders to
act by recommending short-,
medium- and long-term
actions while taking into
account wider
socio-economic
impact

Introduction

Palm Oil

Energy efficiency

Frozen Food

Lower carbon energy source

1. Introduction

1.1 Project Background and Objectives

Background

Recognizing the global climate change problem and its adverse impacts, Thailand is very committed to the global effort in reducing greenhouse gas (GHG) emissions. Low carbon society has become one of the country's key development objectives with the expected achievement by year 2050.

The country is committed to reducing its GHG emissions by 20% from BAU by year 2030 and by 25% with international support under the submitted Intended Nationally Determined Contribution (INDC) to United Nations Framework Convention on Climate Change (UNFCCC) on October 1, 2015. To achieve the commitment, the country has a number of high-level plans that address climate change mitigation, including a Strategic Plan on Climate Change and more recently the Climate Change Master Plan 2015-2050.

One of the key cross-cutting issues for implementation outlined in the Master Plan is the need for a robust database of sectoral GHG emissions and mitigation measures to facilitate scenario development and mitigation planning. The plan also outlines a number of short-term actions including: "to identify greenhouse gas emissions reduction targets and capacity of each sector by 2020". Therefore, an economic impact analysis for the reduction targets - assessing its potential effect on sectoral growth - is imperative for setting a reduction target that balances GHG mitigation and economic development.

The Overall Project

To this end, a project titled 'Industry GHG Reduction to Support the Implementation of Thailand's Climate Change Master Plan ('Industry GHG Reduction')' was initiated and is being managed and implemented by the Global Green Growth Institute (GGGI). This project aims

to assist the implementation of the Climate Change Master Plan by developing a practical and implementable roadmap for GHG reduction, in selected three industrial sub-sectors of the Thai economy. The Office of Natural Resources and Environmental Policy and Planning (ONEP), Ministry of Natural Resources and Environment (MNRE) is the key project counterpart. The project is supported by Germany's Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

The purpose of the project is to develop a GHG reduction roadmap for three industrial sub-sectors of the Thai economy. This roadmap shall be underpinned by:

1. An updated and improved GHG inventory for the selected sub-sectors which conforms to international standards for accurate emissions reporting.
2. A credible evidence base of actual and projected emissions, mitigation potential, abatement technologies, policy measures, and economic impact analysis for the selected sub-sectors. This will be accompanied by the identification and prioritization of comprehensive emissions mitigation policies, which have the support of businesses and government.
3. An enhanced capacity for coordination and technical and economic analysis within the Government of Thailand and the private a sector in relation to GHG inventories, emission projections, mitigation opportunities, and economic impact assessment of mitigation measures on the selected sub-sectors.

The project is divided into three major components:

- **Component 1: Sector Diagnostic**
  This first component aims to constitute a high level investigation into the GHG emissions of industry in Thailand. This diagnostic work provided the evidence on which the selection of the three industrial sub-sectors could be made.
- **Component 2: GHG Reduction Roadmap**
  The purpose of this component is to deliver GHG emission reduction roadmaps for the selected industrial sub-sectors in Thailand to support economically viable low-carbon industrial growth.
- **Component 3: Project Governance, Stakeholder Engagement and Capacity Building**
  This component supports the overall project process and management. It addresses governance for effective project management, buy-in and post-project ownership by the project ministry counterparts. It also ensures stakeholder inputs are gathered and the learning from the project is used to support capacity development in Thailand.

Component 1 resulted in the **GHG Diagnostic Report** and provided recommendations on the industrial sub-sectors to be the focus of this work. The selection was based on a pre-condition that the sector did not already have ongoing or existing similar work, to avoid duplication, which led to the exclusion of the petrochemical, iron and steel and cement sectors. Four criteria were then used to assess the remaining sectors for analysis:

- Abatement potential – considering both total potential and abatement costs for GHG emission reduction in the sectors.
- Economic importance – overall size and export success to prioritize for greatest impact.
- Readiness and sustainability – of firms in the sector, with a preference for sectors with more large firms, as an indicator for the ease to achieve more impact and the stability of the firm in the long term.
- Government priorities - to ensure that project outputs were relevant and of practical use to the Government

With the concurrence from the Project Steering Committee (PSC) in March 2015, the project would focus on the below selection of industrial sectors and sub-sectors which best reflect the objectives of the work and the criteria presented below:

Table 1-1: Sub-sector selection for this work

Industrial sector	Specific industrial saub-sector	Scope included in this report
Metal Products, Machinery and Equipment	Automotive Parts	Energy intensive parts manufacturing processes
Food, Beverages and Tobacco	Palm Oil	Refined palm oil, crude palm oil, oil palm meal (or cake)
	Frozen Food	Seafood

This report, the **GHG Reduction Roadmap**, is the final deliverable of Component 2. The GHG Reduction Roadmaps builds heavily on two other deliverables of Component 2:

- The **Emissions Projection Report (EPR),** aimed at developing the existing GHG inventory for the selected sub-sectors and the new business-and-usual projections to forecast GHG emissions up to 2050
- The **Technical and Economic Analysis Report (TEAR),** aimed at assessing the potential for emission abatement in the selected sub-sectors, at developing several abatement scenarios, at evaluating the barriers to implementations of emission abatement options and at assessing the wider socio-economic impacts of emission abatement.

Objectives

The objectives of this Roadmap are:

- To bring together the findings of the previous reports to produce the GHG reduction roadmap report recommending emissions reduction pathways for the industry selected sub-sectors;
- To provide a credible and robust evidence base on which policymakers and other stakeholders can base their decisions to achieve cost-effective and appropriate emissions reductions in the selected industry sub-sectors;
- To enhance the capacity of policymakers and other stakeholders to act by recommending short-, medium- and long-term actions for that will result in mitigation of implementation barriers of emission abatement options and reduction of GHG emissions while taking into account wider socio-economic impact.

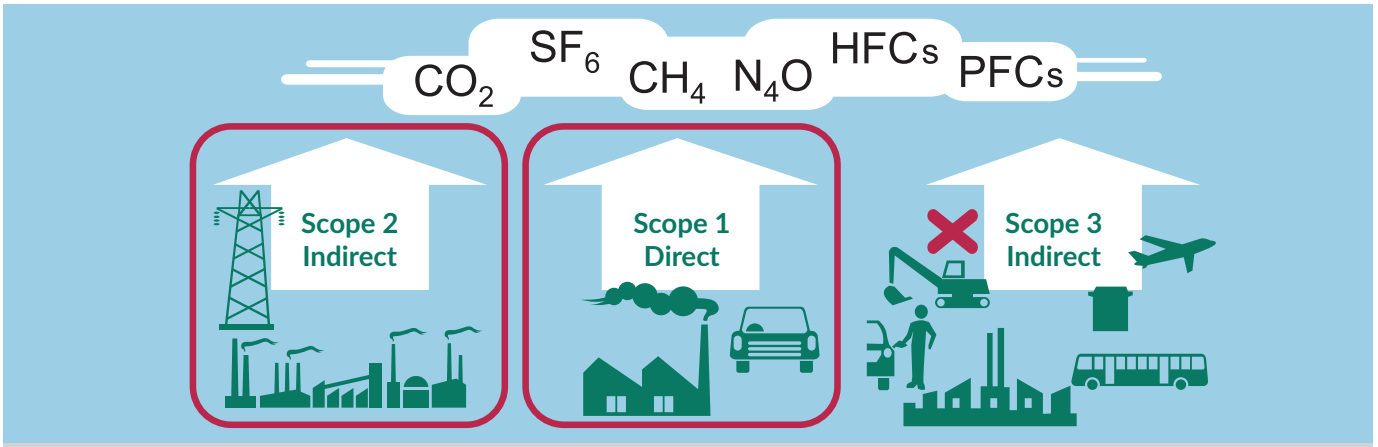
For details about data, assumptions and methodological choices, the reader is referred to the Emissions Projection Report and the Technical and Economic Analysis Report which are both available separately. Here only a few aspects will be highlighted which are deemed crucial for a good understanding of the Roadmap:

- Scoping of GHG emissions and activities;
- Types of emission abatement measures;
- Definition of abatement potentials.

Scoping of GHG Emissions and Activities

The scope of this Roadmap is on the three industrial sub-sectors as indicated in Table 1-1 above. The Roadmap is restricted to manufacturing processes only, as it is aimed at reducing industrial GHG emissions. Consequently, GHG emissions of upstream and downstream activities are excluded. For example, GHG emissions from plantation activities in the palm oil supply chain are not part of this Roadmap. Also transportation activities to bring produced goods to consumer down the value chain are excluded. Figure 1-1 below illustrates the scoping of emissions. This scoping will be further detailed in the sub-sector specific roadmaps

Figure 1-1: Scoping of activities and emissions



A second scoping decision relates to the GHG emissions included. In line with the focus on manufacturing processes, it was decided to consider only these emissions that can directly be controlled by the companies in the sector. More precisely:

- All direct emissions from sources that are owned and controlled by the company (scope 1 emissions);
- All indirect emissions from consumption of purchased electricity, heat or steam (scope 2 emissions).

GHG emissions cover all GHG as identified by Intergovernmental Panel on Climate Change (IPCC). For the sub-sectors under consideration the main GHG emitted are: Carbon Dioxide (CO_2), Methane (CH_4) and Hydrofluorocarbons (HFCs; F-gases).

Direct GHG emissions can stem from three sources:

- Combustion of fossil energy;
- Industrial processes, e.g. as a result of a chemical reaction;
- Waste (water) treatment

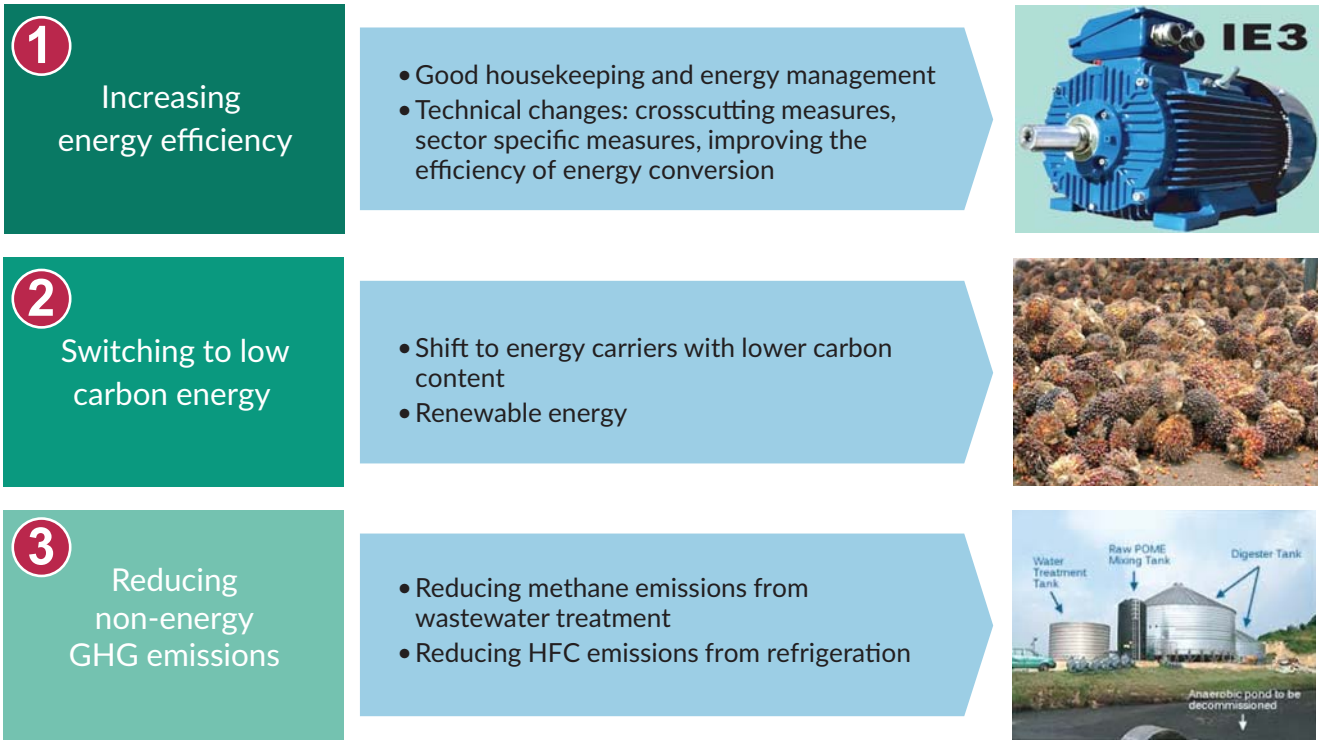
Emission Abatement Options

In this project the emission abatement options have been categorized into three categories (see Figure 1-2 below):

- **Increasing energy-efficiency** of both energy conversion and energy end-use processes. Included in this category are: good housekeeping and energy management, technical measures that can be applied across all industrial sectors (cross-cutting measures), technical measures that are sector specific, and improvement of the efficiency of energy conversion;
- **Switching to lower carbon energy source,** including a shift to fossil energy sources with a lower CO_2 - emission factor (e.g. from oil to natural gas) and a shift to renewable energy, e.g. biogas and solar energy.
- **Reducing non-energy GHG emissions** that are caused by industrial processes, e.g. by process reactions, waste (water) treatment and use of GHG for industrial purposes. Examples are the methane emissions in the wastewater treatment of palm oil mills and the emission of F-gases that are used as refrigerants in the frozen seafood industry.

It is worth noting that the Technical and Economic Analysis Report includes a detailed list of potential abatement options for each sub-sector of focus.

Figure 1-2: Categories of emission abatement options



Emission Abatement Potentials

Once a techno-economic analysis of the abatement measures is made and a business-as-usual scenario is developed, the potential for emission abatement can be assessed. Three different emission abatement potentials are distinguished in this study that reflect different perspectives:

1. **Technical potential:**
   which examines the technical abatement potential if cost is not an issue and all measures are implemented up to their maximum technical abatement potential.
2. **Economic or cost-effective potential (societal perspective):**
   assumes adoption of all measures that are cost effective from a societal perspective, using a lower discount rate (5%).
3. **Economic or cost-effective potential (firm perspective):**
   assumes adoption of all measures that are cost effective from a firm perspective, using a commercial discount rate (12%).

In the international literature, there is much debate about the discount rates to use for the economic potential. Textbox 1-1 summarizes this discussion and argues why in this study 5% and 12% are used.

Textbox 1-1: Discount rates

Discount rates are a common tool used to account for the risks and costs (and benefits) associated with an investment, taking into account that people generally have a (time) preference for benefits now, rather than in the future. Discount rates are the percentage by which the value of costs and benefits are reduced each year to enable fair comparison and analysis of an investment at a particular point in time. Therefore, discount rates have an important influence on the evaluation of costs and benefits of investments, with the influence becoming stronger each year into the future the impact occurs. As a result, discount rates are a significant area of debate, particularly for long-term problems such as climate change, due to the influence they can have on policy and economic decisions.[1]

This study has assumed discount rates of 5% for a societal perspective and 12% for the firm (private) perspective, this reflects the different costs (of capital and opportunity), preferences (time and risk) and needs (for returns) of both parties when making an investment and considering the issue of climate change. These rates are based upon a review of literature including the following:

- Societal discount rates: they are typically lower as a society must consider the needs not only of the current generation but all future generations, therefore future costs and benefits are not reduced as quickly as for firms. A review on behalf of the Asian Development Bank found social discount rates of 3-15% in use across the developed and developing world, tending towards the lower end, but with the values varying by the approach chosen. Further work[2] suggests that a social discount rate should fall in the range of 3.5-7%, while work for the US Federal Reserve Bank[3] suggests rates of 5-8% for developing countries, most of which are less developed than Thailand. On this basis the value of 5% was selected.
- Firm (private) discount rates: take into account the firms' preference for returns, which is shorter due to the requirements of owners or shareholders, and the cost of capital. The latter is often used, via a weighted average cost of capital (WACC), as a proxy for a private discount rate. Sources for WACC or private discount rates used in Thailand are limited. An online WACC calculator[4] estimates WACCs for industry in Thailand of between 11-12%, taking into account the impact of interest rates, taxes, inflation, country risks, risk free rates and market premiums. This is consistent with WACCs for Thailand estimated in 2004 of 11.71-12.55%[5]. These rates are consistent with analysis by Ecofys (2014) that suggests WACCs in the EU in the range of 4-8%, with a higher rate in Thailand reflecting the higher country risks and required returns. On this basis a rate of 12% was selected.

In the end, the impact of different discount rates on the results is relatively small as the evaluated measures typically have quite low capital costs and/or lifetimes and therefore future costs (and benefits) are less relevant to the overall calculations.

[1] For example in the EU, see http://www.eceee.org/all-news/columnists/Brook-Riley/battle-of-the-discount-rates

[2] Moore et al (2013) The choice of the social discount rate and the opportunity cost of public funds, Journal of Benefit-Cost Analysis, Vol 4, issue 3, pp401-409

[3] http://www.federalreserve.gov/econresdata/notes/feds-notes/2014/the-social-discount-rate-in-developing-countries-20141009.html

[4] www.waccexpert.com

[5] P. Sirasoontorn (2004) Privatisation, restructuring and regulation: electricity supply industry in Thailand

1.2 Report Structure

This report is structured as follows:

- **Chapter 2** describes the approach of this study to **develop a roadmap for industrial GHG emission abatement** introducing the **Long-term Agreement and supporting action framework** and how these link to the Marginal Abatement Cost (MAC) curves and barriers.
- **Chapter 3** maps the data needs for a **GHG emission inventory and projection.** Based on the findings in the EPR and TEAR, an assessment is given of the current availability and quality of the data. Finally, recommendations are given to improve the GHG emission inventories and projections for this and other, still to be developed, Roadmaps.
- **Chapters 4 to 6** present the **GHG abatement roadmaps** for each selected sub-sector. Each chapter starts with a summary of the sector and its abatement potential and costs presented as MAC-curves, the GHG inventory, projections and emission abatement scenarios. Next, policy and actions are discussed which will establish an LTA framework and the supporting actions to enable the uptake of the abatement measures. Finally, a framework for setting reduction targets is presented. As the reader might be interested in the roadmap of just one sector, these chapters are written as stand-alone sections. As a consequence of this choice, there is some text repetition, especially in the sections about policies and actions, since these are mostly applicable to the whole of industry rather than a specific sub-sector.
- **Chapter 7** draws **conclusions** and gives **recommendations** for implementing and improving this roadmap, and developing other roadmaps.
- Finally, **Annex A:** Data Map presents a concise overview of the specific data needs and availability of data for the construction of a GHG abatement roadmap.

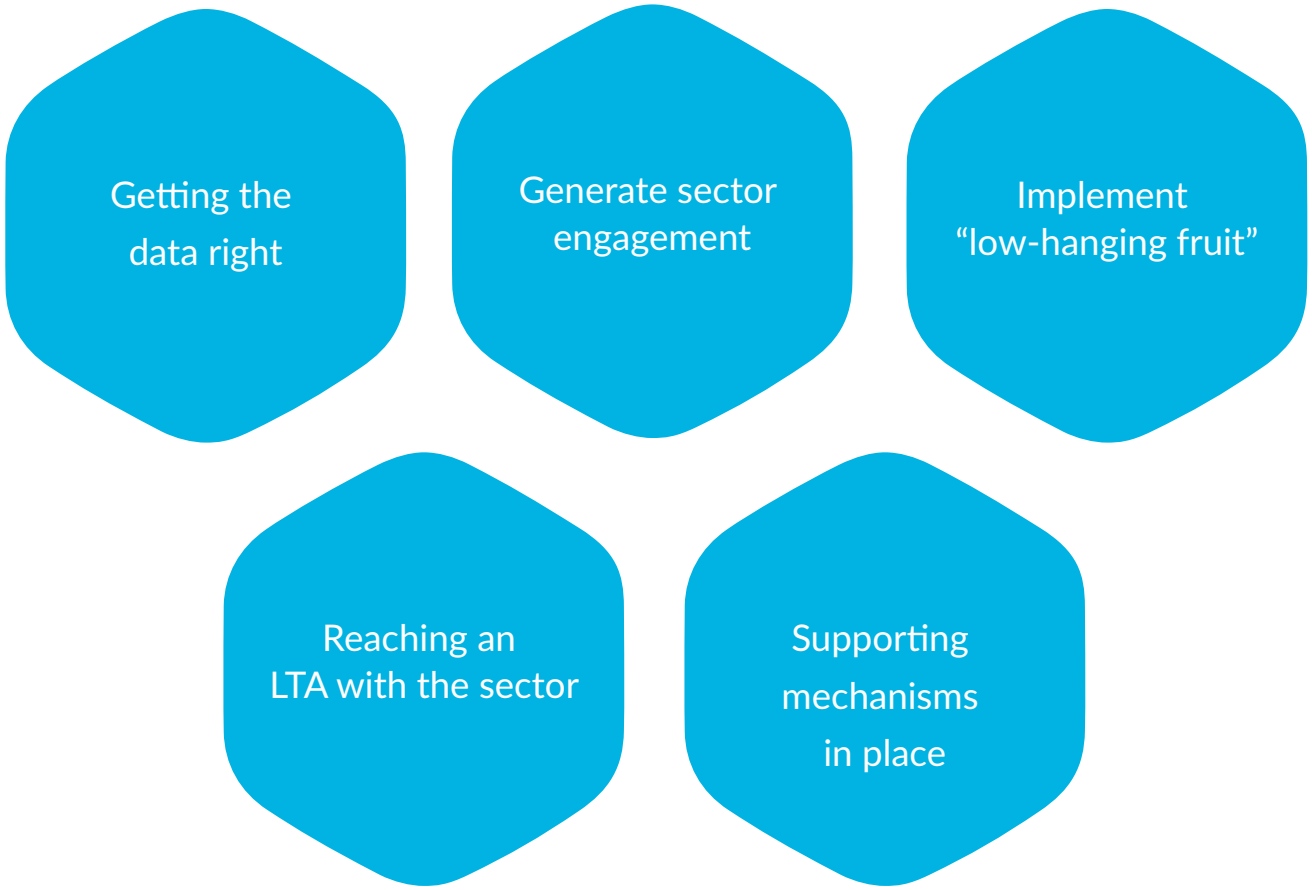
A mechanism to visualize future paths for GHG emission abatement and the required actions to achieve a certain level of GHG emission reduction at a future point in time

Long-term Agreement (LTA), established between Government and Industry to reduce GHG emissions, approach serves as the framework for the sectoral roadmaps

Voluntary Agreements

Negotiated agreements

Approach for Developing the Roadmaps


Getting the data right
Generate sector engagement
Implement “low-hanging fruit”
Reaching an LTA with the sector
Supporting mechanisms in place

2. Approach for Developing the Roadmaps

2.1 What are the Roadmaps?

A Roadmap, in the context of this study, is a mechanism to visualize future paths for GHG emission abatement and the required actions to achieve a certain level of GHG emission reduction at a future point in time. The future paths comprise GHG emissions projections and techno-economic analyses of technological abatement solutions. The summaries of these analyses are presented in the following sections, and the full method and details are available in the Emissions Projection Report (EPR) and Technical and Economic Analysis Report (TEAR). The required actions build on these future paths as well as on an analysis of the barriers that hamper uptake of these solutions and an understanding of the existing situation with regard to laws and regulations. Defining the required actions is the subject of this Roadmap report and this chapter will present a framework for doing so.

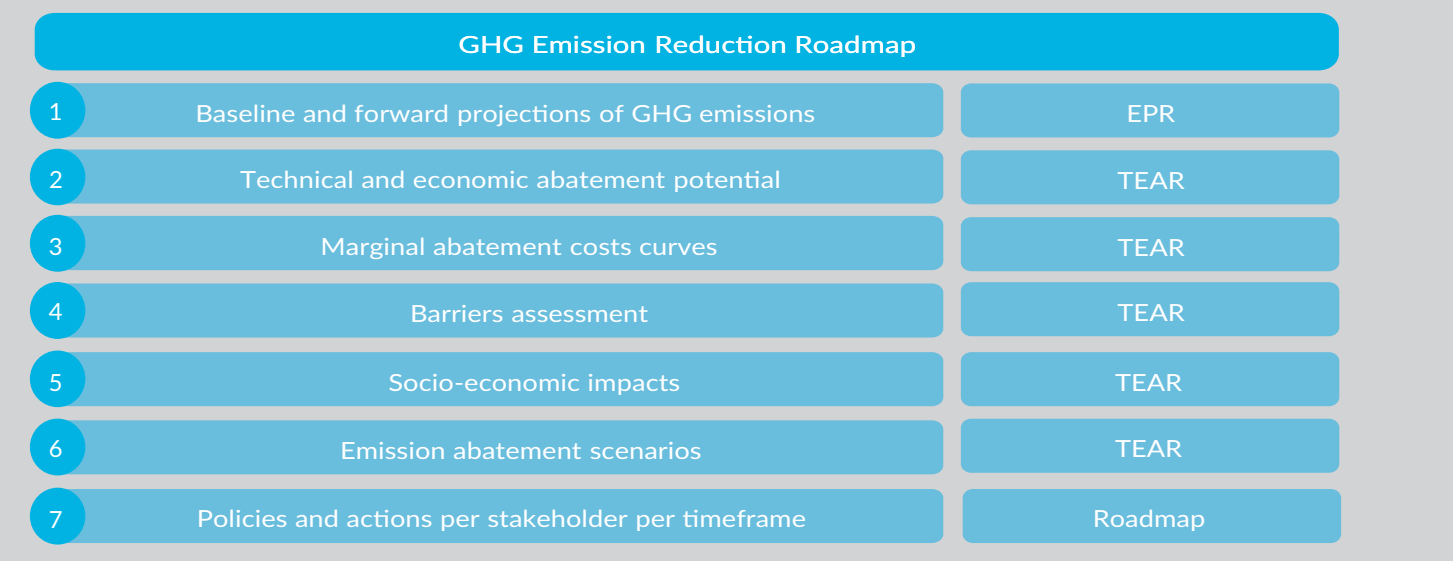
The steps that were followed to develop this Roadmap are illustrated in Figure 2-1 below, in summary:

1. Develop baseline GHG inventories and develop forward projections of emissions in a business-as-usual scenario (Emissions Projection Report)
2. Conduct the technical and economic analysis for the GHG emission abatement potentials (Technical and Economic Analysis Report)
3. Develop marginal abatement costs curves (MAC-curves) (Technical and Economic Analysis Report)
4. Evaluate barriers that hamper the implementation of abatement options and identify pathways to mitigate these barriers (Technical and Economic Analysis Report)
5. Evaluate the impacts of emission abatement on the Thai economy (GDP, labor) (Technical and Economic Analysis Report)
6. Develop technical and economic scenarios (both

from a private and societal perspective) for emission abatement per sub-sector (Technical and Economic Analysis Report)

7. Combine the scenarios with the barriers evaluation to come to a set of policies and actions to enable stakeholder to act (Roadmap Report).

Figure 2-1: Elements of the approach to develop a GHG Emission Reduction Roadmap. Per element the report is indicated that describes this step (EPR = Emissions Projection Report; TEAR = Technical and Economic Analysis Report; Roadmap = this report).



Key lessons for the Roadmap from the EPR and TEAR

The key lessons from the analyses in these reports which are important to the development of Roadmaps are:

- The understanding of industrial GHG emissions at a sub-sector level is limited. Information on data quality and availability as well as the data itself is dispersed. There is no consolidated, nation-wide dataset or long-term emission projections.
- Over the last decade Thailand has shown an increased awareness of climate change, this theme is on the political agenda. Responsibility for the design, implementation and evaluation of climate change policy frameworks are distributed among several ministries and government agencies. This fragmentation of accountability and ownership does not always lead to the most efficient and effective cooperation.
- Several laws and regulations exist that address GHG emissions, notably the Energy Conservation Promotion Act and the Energy Industry Act. Furthermore, a range of action plans have been developed, e.g. the Alternative Energy Development Plan, the Energy Efficiency Plan, the Strategic Plan on Climate Change and the Climate Change Master Plan. Several government agencies, such as DEDE, have been implementing relevant measures to directly and indirectly reduce GHG emissions.
- The barrier analysis conducted in the TEAR revealed a wide range of obstacles that hamper the adoption of emission reduction measures. An improved understanding of these barriers is needed to better inform policies and actions.

These key lessons are the starting point for the Roadmap study, which proposes an approach to policies and actions within this context. The approach relies on two complementary solution pathways, but with the first as the leading framework for the Roadmaps proposed in this report:

1. **Establishing Long-term Agreements (LTAs)** between the Industrial sectors and the Government with the aim of reducing GHG emissions. The LTAs can serve to increase sector involvement and awareness of the importance of climate change. Furthermore, they can support the improvement of GHG emissions data and target policies and actions to focus on industrial GHG abatement. These are examined further in the following section.
2. **Building further on the policies and actions already implemented by DEDE and others,** which will either indirectly, or in parallel, support and accommodate the success of the LTAs.

2.2 Long-term Agreements: A Framework for Policies and Actions

In this section, the Long-term Agreement (LTA) approach, which can serve as the framework for the sectoral roadmaps for GHG abatement, is described. This framework builds on establishing long-term agreements between Government and Industry to reduce GHG emissions. In the international literature these agreements are also referred to "voluntary agreements", or "negotiated agreements". In this study the more neutral term 'long-term agreements" is preferred.

Long-term agreements (LTA) for energy efficiency improvement and the reduction of GHG have been a popular policy instrument since the 1990's (Price, Lynn, 2005) (IPCC, 2015). LTAs are "essentially a contract between the government and industry, or negotiated targets with commitments and time schedules on the part of all participating parties" (International Energy Agency, 1995). See Textbox 2-1 for some examples of LTAs.

Textbox 2-1: Examples of Voluntary Agreements (IPCC, 2015)

- The Netherlands Voluntary Agreement on Energy Efficiency: A series of legally binding long-term agreements based on annual improvement targets and benchmarking covenants between 30 industrial sectors and the government with the objective to improve energy efficiency.
- Australia "Greenhouse Challenge Plus" program: An agreement between the government and an enterprise/industry association to reduce GHG emissions, accelerate the uptake of energy efficiency, integrate GHG issues into business decision making and provide consistent reporting. See http://www.greenhouse.gov.au/challenge.
- European Automobile Agreement: An agreement between the European Commission and European, Korean and Japanese car manufacturing associations to reduce average emissions from new cars to 140 gCO_2/km by 2008–2009. See http://ec.europa.eu/environment/CO2/CO2_agreements.htm.
- Canadian Automobile Agreement: An agreement between the Canadian government and representatives of the domestic automobile industry to a reduce emissions from cars and light-duty trucks by 5.3 $MtCO_2e$ by 2010. The agreement also contains provisions relating to research and development and interim reduction goals.
- Climate Leaders: An agreement between US companies and the government to develop GHG inventories, set corporate emission reduction targets and report emissions annually to the US EPA. See: http://www.epa.gov/climateleaders/.
- Keidaren Voluntary Action Plan: An agreement between the Japanese government and 34 industrial and energy-converting sectors to reduce GHG emissions. A third party evaluation committee reviews the results annually and makes recommendations for adjustments. See http://www.keidanren.or.jp

Three forms of LTAs can be distinguished, based on the impact of non-compliance: (Price, Lynn, 2005)

1. **Completely voluntary agreements:**
   Participation depends solely at the discretion of the private sector, and non-compliance will not have any impact. Although these kinds of programs have been applied frequently to create involvement of the private sector, the control on target achievement is weak. Compliance largely depends on public pressure.
2. **Agreements to avoid future regulation:**
   that use the threat of future regulations or energy/ greenhouse gas emissions taxes as a motivation for participation and compliance by industry. Participants that enter the agreement can also have several benefits tied to their participation, e.g. the ease of getting an environmental permit, and the promise of tax exemption. However, the success of the voluntary agreement will determine whether additional regulation is needed. If progress towards a target is too slow, the government may implement additional enforcing measures.
3. **Agreements to support existing regulation:**
   implemented in conjunction with an existing energy/ GHG emissions tax policy or with strict regulations. These programs are usually supportive to the existing policies. Participants to the voluntary agreements will be relieved from obligations coming from these existing policies, e.g. an energy taxation, as long as they comply.

All three forms have been used, with mixed success. The programmes with the greatest success have been those with substantial disincentives for non-participation and sanctions for non-compliance.

Success factors for voluntary agreements can be formulated as follows (IPCC, 2015):

- Ambitious and clearly defined targets and a baseline scenario;
- Third party participation in the design of the agreement;
- A description of the parties and their obligations;
- A defined relationship within the legal and regulatory framework;
- A robust system for monitoring, reporting and independent verification of results at the plant level;
- Commitments in terms of individual companies, rather than as sectoral commitments;
- References to sanctions or incentives in the case of non-compliance.

2.3 LTAs as a framework for GHG emissions reduction in Thai industry

Rationale for LTAs in Thailand

As presented in the previous section an LTA is a proven approach for entering a long-term commitment between government and private sectors. These are most appropriate and effective when there is likely to be opposition against an obligatory approach. They can also reduce the costs and complexity to both Government and industry compared to the alternatives of a regulatory-led or mandatory approach. It is clear that there is currently neither the knowledge nor capacity in both industry and Government to effectively implement a more mandatory approach. The advantages of an LTA approach over other alternatives provide the key rationale for selecting it as a framework for the sectoral GHG emission reduction Roadmaps.

A program of LTAs can be used to further reinforce the existing programs and regulations in Thailand. DEDE already operates a number of voluntary agreements (VA), especially in the area of energy efficiency, and has experience in this area. DEDE and other related agencies also already carry out many other activities that can act as powerful supporting measures to the LTAs and which can also be adapted and improved under the umbrella of the LTA framework. The success factors identified above already provide clear insight into how best to structure and implement the LTAs and the supporting policies.

The LTA Framework for GHG Emission Reduction Roadmaps in Thailand

A Roadmap is based on taking actions over time to progress and build towards a goal or desired outcome. The overarching LTA framework is developed in this context, with short, medium and long term phases to its implementation and for which at each stage there are (1) objectives; (2) key groups of policies and actions; and, (3) milestones and/or indicators to enable monitoring and measuring if the objectives are being achieved. This framework is presented in summary form in Figure 2-2 below.

Objectives

The objectives within the framework are split into phases below. The proposed years and time periods below are only guidelines and could change with the starting period of roadmap implementation or the need for additional flexibility.

- **Short-term (2016-2017): Developing the foundations**
  - Getting the data right – to make an informed decision on goals it is crucial to understand where the sector currently stands, where it is going if no action taken, and what is feasible considering the costs, practicalities and barriers. While the EPR and TEAR provide a good start there remain many data fidelity issues, these should be addressed in the short term. The following chapter directly addresses this issue.
  - Generate sector engagement – an LTA requires active participation, contribution, commitment and ownership by the sector. It is crucial to engage them in the short-term.
  - Implement "low-hanging fruit", measures that are easy to implement – it does not make economic sense to wait to take mitigation measures that are cost-effective, especially those with little or no investment costs, these can and should already be implemented in the short-term. This will already help engage firms in the cost-saving and emission reduction mind-set.
- **Medium-term (2018-2022): Establishing the long-term agreements and supporting actions**
  - Reaching an LTA with the sector – will involve an in-depth dialogue to reach an agreement on targets and agreement on the roles and actions to be taken by both the sector and the government. This will also detail monitoring arrangements.
  - Supporting mechanisms in place - these represent the implementation of the agreed actions by the government where they will typically develop and build upon their supporting measures, programs and incentives to enable the LTA to operate successfully.
  - Begin implementing – the sector should continue to implement GHG emission reduction measures, and move on to implementing those that are no longer 'low-hanging fruit' but that in most cases are still cost effective and/or require only small capital investments or O&M costs.
- **Long-term (2023-2030): Implementation and reflection**
  - Examine and evaluate success of LTA – this objective is to ensure that there is information available to evaluate if progress is satisfactory and that the LTA is having the desired impact on industry for GHG emissions reduction.
  - Improve existing agreement or introduce mandatory approach - continual improvement is desirable, if targets are achieved then thoughts can turn to new objectives in future. If implementation is lagging remedial actions proposed, penalties applied and/or a stronger (i.e. mandatory) approach should be an objective.

Figure 2-2: Overview of GHG emission reduction roadmap in a (voluntary) Long-term Agreement framework, with actions and milestone indicators

2030 Target: improvement of emissions on BAU, aligned with or exceeding INDC targets

These objectives all contribute to achieving the overarching objective for a reduction of industry GHG emissions compared to a Business-as-Usual (BAU) scenario, which should also align with other policy goals and commitments, such as those made in the Intended Nationally Determined Contributions (INDCs).

Actions

The actions are geared towards achieving the objectives, either directly as part of creating and implementing the LTAs or indirectly through their role in supporting the sectors in implementation.

In the first phase (short-term) the actions are focused around three key themes. The first set of actions aims to support the improved collection of data and seeks to achieve this by building on existing work from DEDE on energy management systems and audits. By extending and strengthening the enforcement of these requirements, more comprehensive data can be compiled. This should be supported by training and funding for compliance staff. Efforts need to be dedicated to compiling and analysing the data through a database or system, this will also require training and funding. As a result of these actions it will be possible to improve the sub-sector GHG footprint. The second set of actions is based around securing sector engagement in the LTA process, in the first instance this involves helping to create a sector working group on sustainable production and inviting this group to make a first roadmap proposal. From this a dialogue and feedback process can be established which can be a vehicle towards the eventual LTA. Part of this process can also involve establishing the type of government support needed. The third group of actions represents the implementation of the 'low-hanging fruit' measures by firms in the sector.

The second phase (medium-term) of actions is also based around three key themes. Firstly, the actions are taken to reach a final LTA between the government and the sector, and following this, to implement the agreed upon monitoring and reporting arrangements. Secondly, and most importantly, a group of actions are taken to ensure that the right support mechanisms are in place for firms to implement the LTA. This will involve reviewing, maintaining, adapting and creating new policies and instruments such as in the area of equipment labeling and performance standards, reputational and CSR mechanisms, educational and training programs (for both government and sectors), financial support and general climate, energy and industrial policies. The third group of actions is implementation of measures by firms in the sectors, which may include measures explicitly stated in the LTA.

The third phase (long-term) of actions reflects a decision point in the continuation of the LTA. It is necessary to bring together the ongoing monitoring data and to analyze this to check progress towards the agreed targets. The actions vary in response to the progress being made. If progress is lagging, remedial actions, penalties and alternative approaches all need to be on the table. If progress is satisfactory, actions can already be focused on future phases to the agreement.

At each of these stages, reference should be made to the success factors noted above so that these are accounted for in the specific design of the LTA as part of the Road map.

Milestones

A set of milestone indicators can be defined which will help to assess progress of the roadmap. The indicators correspond most closely to the overall objectives, although some link directly to the actions. These could form the basis of a monitoring program or progress review by responsible agencies.

In the first phase (short-term), the milestones are focused on data gathering and processing improvements, working towards the goal of an analysis report with an updated GHG footprint of the sector. The intention is that this becomes the starting point for discussion. The first phase also marks out milestones for stakeholder engagement, essentially bringing the key players in the sector into a dialogue towards a long-term agreement on emission reduction. Ideally this would already achieve a first submission on proposed ambitions by the sector itself, although this could also come later. Finally, the first phase would also look to measure progress on implementation of cost-effective measures. This measurement could be achieved in a variety of ways depending on the data available, from specific known implementation of a particular measure in a sector, to audited or per unit of production emission trends.

The second phase (medium-term)'s key milestone is the actual Long-term Agreement which should be agreed and start to be implemented in this phase. The process to do so could take some time.

Monitoring arrangements would be part of any agreement. The government will need to take an active role to support implementation, here indicators are geared to both specific policy reviews and programs, alongside more general monitoring of progress on climate issues. Finally a continuing measure of improvement in implementation remains important.

In the third phase (long-term), the key milestone is to complete an assessment of progress of the LTA. The agreement should result in the agreed targets being reached. This would then trigger a round of discussion for the following phase in the agreement. If targets are missed then the milestone will be the implementation of an alternative framework, which could be a revised LTA or a more mandatory approach.

The milestones and indicators developed for the roadmap of each sub-sector will clearly be influenced by the 'getting the data right' set of actions and in discussion with the sector.

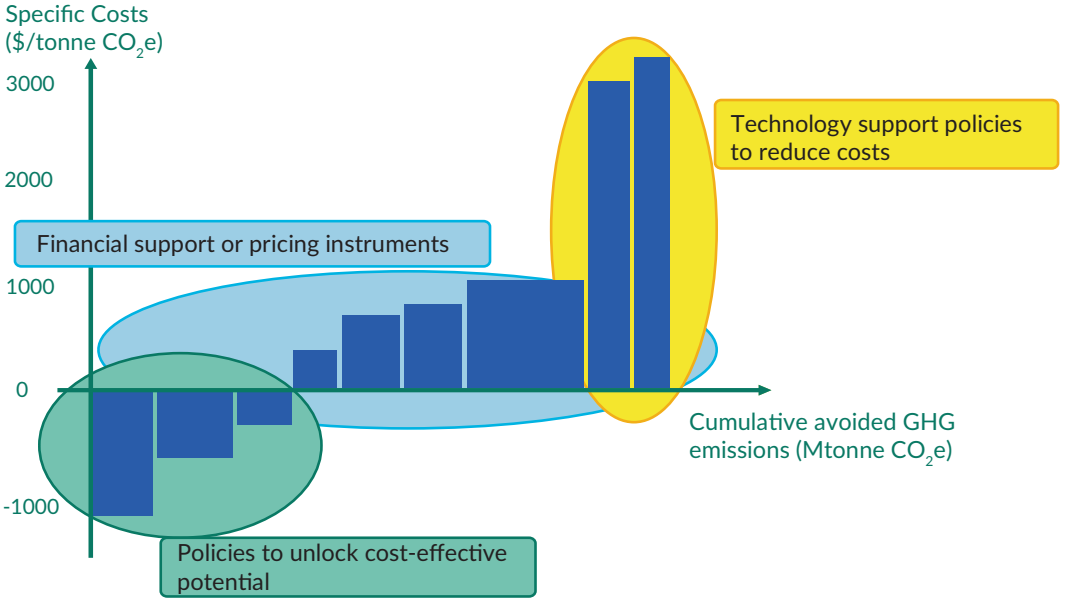
2.4 Linkage to Marginal Abatement Cost Curves and Barriers

The long-term agreements go hand in hand with policies and actions as noted above. To decide which specific policies and actions can be considered, the Marginal Abatement Cost (MAC) curves developed in the Technical and Economic Analysis Report (TEAR) can help to identify the specific policies and actions that could be taken, for example if one of the measures is for improved energy management systems then the actions associated with increasing compliance with DEDE audit requirements and training staff at firms and in government are both relevant.

As background, a schematic of a MAC-curve is depicted in Figure 2-3 below. The MAC-curve can be divided into three segments according to the specific abatement costs associated with the measure. Each segment comes with its own specific barriers that hamper uptake of the potential (see following section). Policy measures and actions should be aimed at tackling these barriers. The required approach varies with the cost and barrier type.

1. **The cost-effective potential – measures with specific abatement costs lower than 0 THB/tonne CO_2e (green area on MAC-curve schematic).**
   In an ideal market setting, the negative cost GHG reduction potential should be zero since it would be normal for all cost-effective measures to be completely taken. In reality, due to barriers, there are untapped cost-effective GHG reduction potentials, as also found in the sub-sectors analyzed in this study. On one hand this is due to market barriers and imperfections. On the other hand, uncertainty in the information and assumptions used in the study may be the cause.

Figure 2-3: Schematic MAC-curve illustrating three segments of policy interventions.



Uncertainty in the emission abatement potential can make policies less effective, hence should be reduced as much as possible. The abatement potentials determined for the sub-sectors in this study also show the uncertainty, due to lack of validated data, the disparity of the sectors and inherent constraints to the study. To minimize the uncertainty in the future it is important to get the data 'right' as noted above. Thus, case studies, further stakeholder interactions and improved energy auditing are recommended.

The TEAR assessed that market barriers that prevent unlocking this potential are mostly related to imperfect knowledge, as well as limited human capacity and vision or understanding by the management, see Figure 2-4 below. Taking away these barriers can be achieved by policies and actions such as training staff to operate equipment, raise awareness at management level, communication and stakeholder engagement, and aligning policies so that they strengthen each other.

2. **Abatement measures that have modest to high costs (blue area on MAC-curve schematic).** Barriers to utilizing this potential are mainly related to high operating costs, lack of financial (government) support, pressure of competitiveness and no incentive to go beyond compliance needs. These types of abatement measures can be promoted by e.g. financial support or pricing instruments and increasing awareness. A point of interest for policy design is to evaluate if the costs of a measure are significantly different when the discount rate is varied (see also textbox 1-1). It might be that measures have modest costs from a private perspective but are cost-effective from a societal perspective. In this case a subsidy can be considered, just to tilt the measure to being cost-effective from a private perspective. From a societal perspective this subsidy is cost-effective. Following this line of thought a subsidy will not be effective if there is no difference in cost effectiveness between the societal and private perspectives.

3. **Abatement measures with much higher costs (orange area on the MAC-curve).** Often measures in this range, necessary to attain deep emission reduction, also come with high uncertainties in costs and implementation potential. These measures are typically at the start of the development curve. Further research and development (R&D) should prove the economic feasibility of these measures, eventually resulting in cost reductions. Policies should aim to support R&D and pilot new technologies to gain experience and understand development needs. As the MAC-curves developed for the three sub-sectors hardly contain any of these expensive measures, the roadmap will not pay much attention to this category of measures.

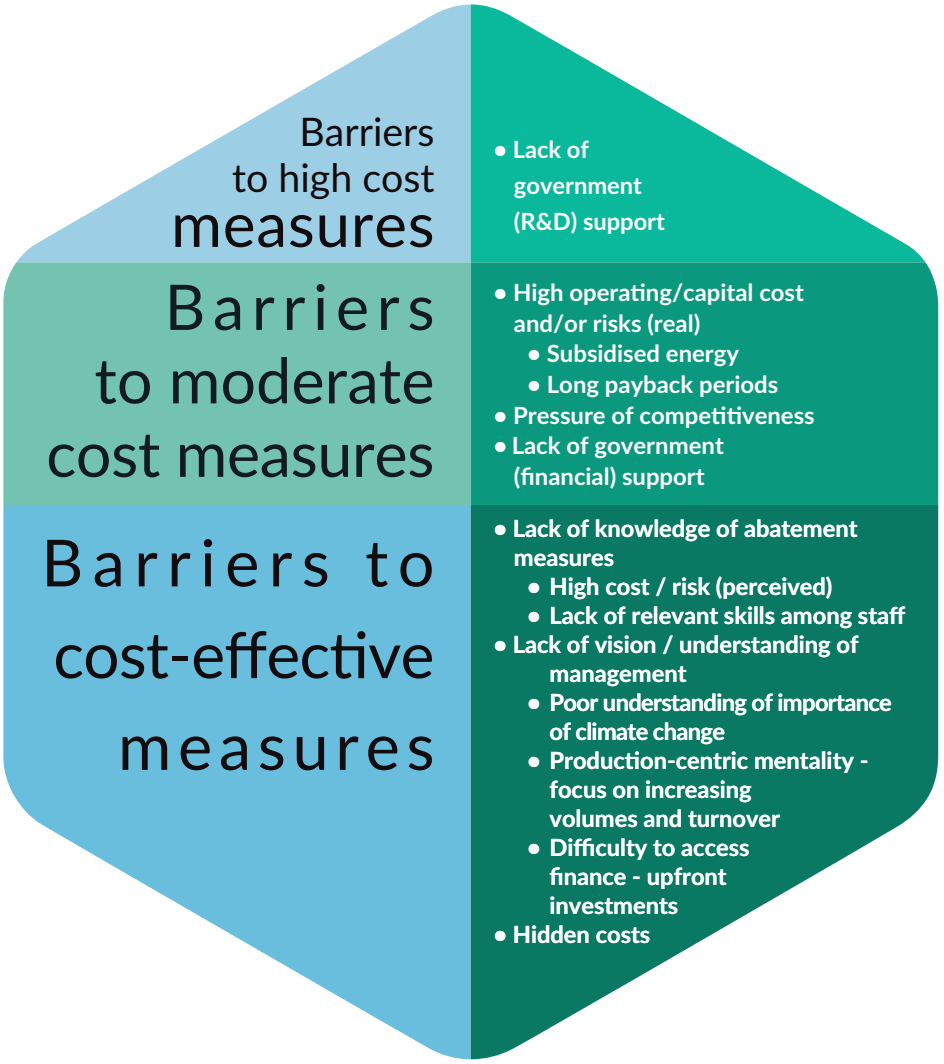
Addressing barriers

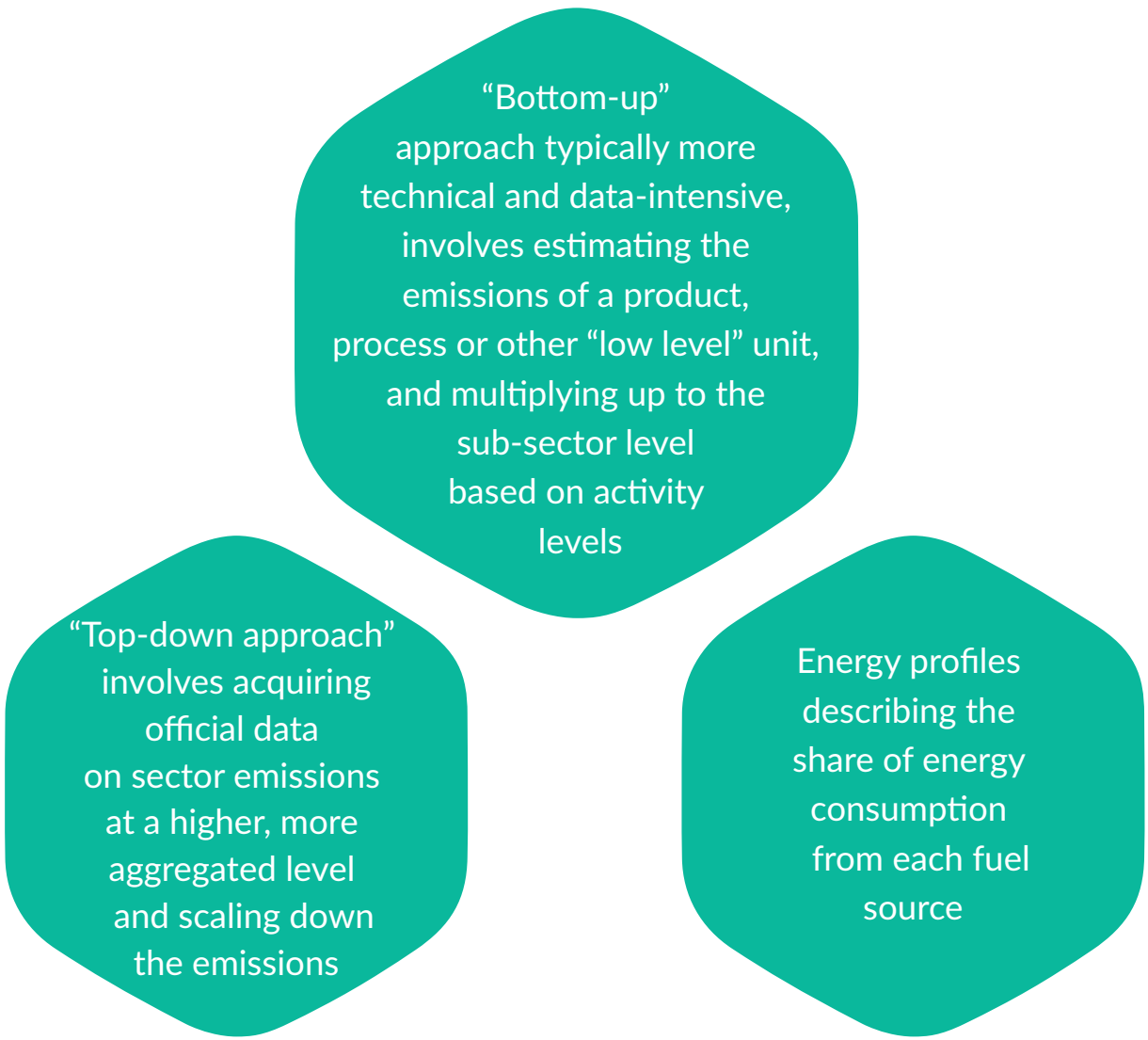
As noted above, barriers are an important factor in why GHG reduction measures are not implemented and are especially relevant for otherwise cost-effective measures. An analysis of barriers was carried out in the TEAR (Chapter 7) based on:

- A review of literature on barriers to GHG reduction and energy efficiency in Thailand, the Southeast Asian region and globally; and,
- A stakeholder workshop on barriers carried out as part of this project with relevant stakeholders from government, academia and industry.

Key barriers and their potential solutions were identified from the analysis, taking into account the weighting of the workshop staff towards government stakeholders. Figure 2-4 below presents a summary of the key barriers in the context of the cost categories identified above. The barriers stack upon each other, e.g. high cost measures would often also experience some or all of the barriers for moderate and cost-effective measures, whereas the cost-effective measures should rarely experience the moderate or high cost barriers as an issue. The policies and actions proposed per sub-sector are also based on this framework and aim to address one or more of the listed barriers to ease implementation of the relevant measures as part of the GHG emission reduction roadmaps.

Figure 2-4: Common barriers to the implementation of abatement measures, by cost of measure.





Developing GHG Emission Inventories and Projections

Delegate central responsibility to one organization to set up an integrated data management system

Create long-term sub-sector growth projections, especially economic and activity level growth

Create a "GHG and Roadmap Data Guide" necessary for GHG inventories and projections

3. Developing GHG Emission Inventories and Projections

3.1 Introduction

3.1.1 Rationale and Purpose

The development of a GHG reduction roadmap for the sub-sectors requires an overview of the complex data situation in Thailand with respect to GHG emissions and related data, with information on availability, quality, accessibility and sensitivity of data. However, such an overview was not available in a consolidated form, but instead information on data, and the data itself, was dispersed among many sources.

It was necessary to create the overview during the course of the project, adjusting the GHG inventory approach as information on data became available, sometimes after acquiring the data itself and analysing its contents. In order to systematically explore data avenues, the overview was structured as a map, by relating data needs to sources/institutions, and to availability, accessibility and quality. Such a "data-map" can also serve as a tool for future research and GHG inventory building.

The purpose of the data map is the following:

- To provide readers with a very good high-level understanding of the relevant data situation in Thailand;
- To provide insight in the methods adopted by the study team as a result of the data situation; and
- To facilitate the development of future roadmaps - in terms of sub-sector selection, locating data sources, selecting an approach based on likely quality and availability of data, and accessing the data via institutions.

More detailed information on specifics of the data (definition, source, quality, etc.) can be found in the Emissions Projection Report and Technical and Economic Analysis Report of this project. The data map itself is contained in Annex A to this report.

3.1.2 Contents of the Data Map

The data map presents a concise overview of data needs and availability of data for the construction of GHG inventories at the sub-sector level, as well as projections and measures in Roadmaps. Data sources and the roles of institutions in collecting, compiling and analysing the data are also described. The relevance of Thailand Standard Industrial Classification (TSIC) codes and classification systems is explained.

It also presents an overview of the methods and data used, as well as associated limitations, for the specific sub-sectors selected for this Roadmap: palm oil production, automotive parts, and frozen seafood industries. Lastly, challenges associated with the data in Thailand are discussed, and some of the strategies, assumptions and methods used to estimate energy and emissions when data was lacking or unavailable.

A strong understanding of the data situation in Thailand naturally leads to recommendations which could support building GHG inventories and roadmaps, with less effort and greater accuracy. Some recommendations are presented based on the data-map and lessons-learnt from this study. These have been divided into short-, medium- and long-term categories based on an estimate of their level of difficulty.

3.2 Data Needs and Availability

3.2.1 Approaches to Developing GHG Inventories and Data Categories

There is an extensive range of potentially useful types of data for estimating emissions from a sub-sector, making projections and Roadmaps. It is helpful to categorize these data needs into larger categories based on overall approaches – the “top-down approach” and the “bottom-up approach” – and with reference to three main sources of emissions (energy related, industrial process related, and waste related).

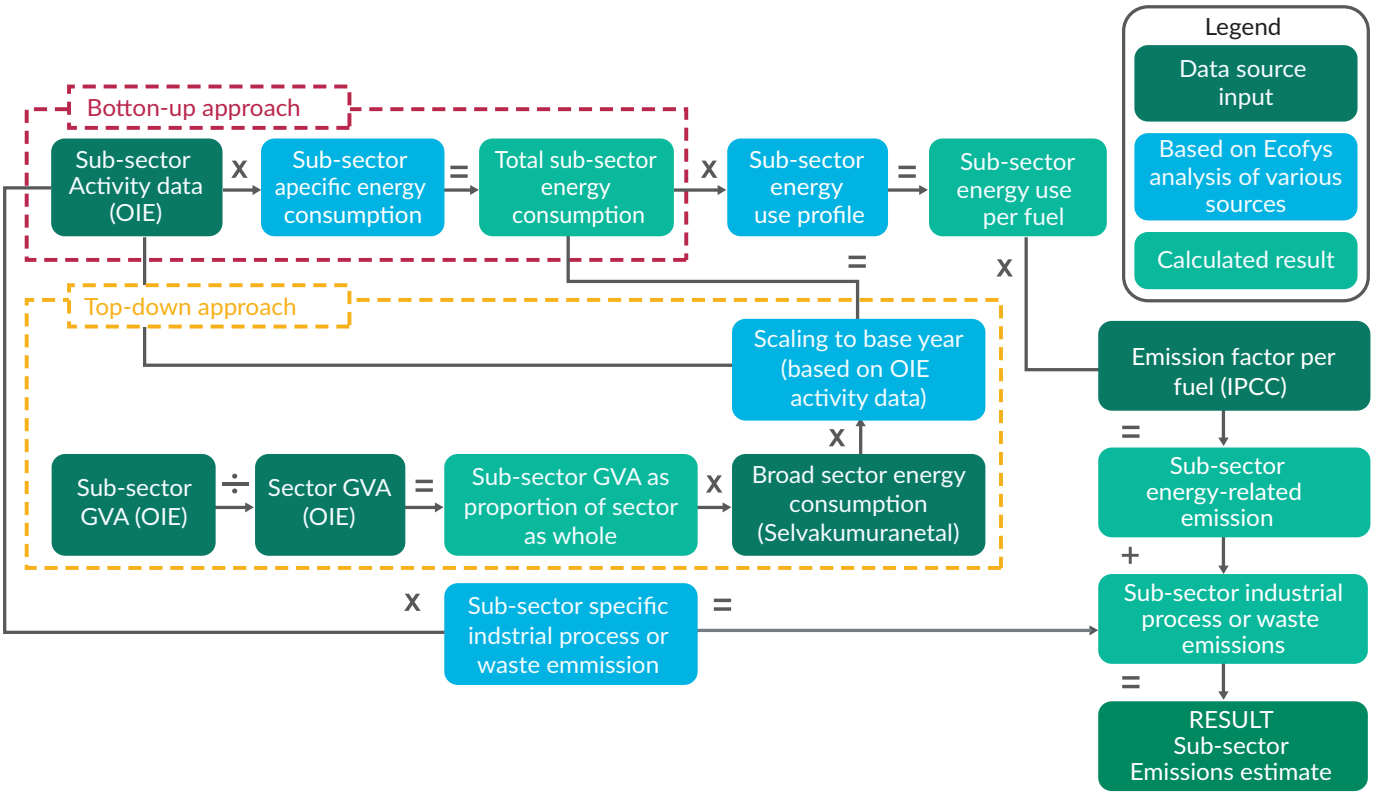
For both approaches, the main general categories of data needs can be related to calculations and steps. The bottom-up approach is typically more technical and data-intensive. It involves estimating the emissions of a product, process or other “low level” unit, and multiplying up to the sub-sector level based on activity levels. The top-down approach does the inverse. It involves acquiring official data on sector emissions at a higher, more aggregated level than the sub-sector in question, and scaling down the emissions. Using both approaches, results were compared in the Emissions Projection Report.

Although the approaches and associated general categories of data needs are similar for all sub-sectors, issues with data quality and availability, as well as the nature of the sub-sectors can determine the specific data used for each data category. For example, the relative importance of the main emission sources (energy, industrial process, waste) differs across sub-sectors. Furthermore, some sub-sectors may involve a large number of different processes, products, etc. and data may not be defined or disaggregated to the extent desirable.

For both the bottom-up and top-down approaches, once the emissions for a baseline year have been established, emissions need to be projected into the future over defined time periods. This can be done using existing projections, as well as trend/regression analysis based on recent historical data and growth assumptions, and supplemented with consultations and expert opinion.

In Figure 3-1 below, a flowchart is presented that illustrates the steps in both the bottom-up and the top-down approach to come to an inventory of GHG emissions.

Figure 3-1: Flowchart illustrating the development of GHG inventories using a bottom-up and a top-down approach



3.2.2 Top-down Approach

The top-down approach obtains available validated emissions or related data from national energy and economic statistics for an entire sector, which encompasses the economic sub-sector of interest. However, this data are typically at a higher level of classification than the sub-sector, and therefore aggregates the emissions of the sub-sector of interest with other sub-sectors.

The sub-sector share of the sector emissions must then be scaled down and estimated using the most appropriate indicator, e.g. added value or physical production can be used to estimate the share of the sector that the sub-sector occupies. An advantage of this approach is that it uses validated data and is relatively straightforward.

However, it works only well in sectors with homogeneous products, where a comparable correlation between activity and energy exists over all products. If the energy intensity varies too much, there is no good way to determine the share of emissions of a sub-sector. Furthermore, the more aggregated the sectors are, the less accurate will be the estimate of the sub-sector energy and emissions.

For this study, the lack of detailed and recent data for industrial process and waste emissions meant that it was not possible to use a top-down approach to accurately assist in estimates. Therefore the top-down approach was only employed to estimate energy-related emissions. Even for energy related emissions, the lack of detailed data required a number of assumptions.

With regards to validated sectoral data, EPPO and DEDE have the latest data on energy use from which emissions can be estimated. For this study data prepared by Selvakmuran et al (2014), based on EPPO and DEDE data, were used. These data provide information on 2010 energy use at the broad 2 digit TSIC industrial sector level, i.e. Food, beverages and tobacco, and Fabricated metal products.

The broad sector energy use was scaled to the sub-sectors proportional to the sub-sector share of total sector Gross Value Added (GVA), based on OIE data. Using GVA has the benefit of allowing this, and for it to be done consistently across sub-sectors, but it is far from an ideal approach as it does not directly reflect actual energy use of sub-sectors, which is a significant limitation of this approach. In any case, using this approach allowed an estimate of total energy use in the sub-sector in 2010 to be made. This was then scaled to the 2015 base year using the known production data of 2010 up to the second quarter of 2015, whereby the 2015 final production was estimated based on the average of second half (H2) production trends in the 2010-2014 period.

3.2.3 Bottom-up Approach

The bottom-up approach attempts to determine the emissions of each process step/unit of product (at a "low level" of production), and multiplies this by "activity levels" or other factors related to the total production for the entire sub-sector over time.

It builds on specific technical knowledge of a process or product and can include insights directly from the sector, such as footprint and energy audit data. However, it is also labor-intensive and often one plant differs significantly from another in lay-out and emission intensity. To cancel this variation out, the emission intensity of the processes should be based on several plants, although this might require primary data collection. For sectors that produce more than one product, this procedure has to be repeated for all products and trustworthy data on activity levels (e.g. national annual production) should be available.

The bottom-up approach was used for all three sources of emissions: energy, industrial process and waste. For the latter two emissions sources, top-down data on these is almost completely lacking. For the automotive parts sub-sector, only energy emissions were included, while for the palm oil sub-sector both energy and waste emissions were included. For the frozen food sub-sector, all three sources of emissions were considered. However, emissions from waste were not included due to data availability – this could merit further research, although their share of total emissions in the sub-sector is expected to be small.

For the three sub-sectors, the type of data and units used for the "low-level emissions" differed according to data availability and the nature of the sub-sectors. The chapter presenting the roadmaps for the sub-sectors give an account of the data used to do the bottom-up approach.

For the palm oil sub-sector, processes were identified to arrive at Specific Energy Consumption (SEC) per tonne of product. The fuel mix per tonne of product (and resulting energy profile) was also estimated based on processes, gate-to-gate data from National Metal and Materials Technology Center (MTEC), and case studies (on kernel production, methane emissions with and without capture, and share of installations with biogas capture from CDM studies). Estimating waste emissions used the same data sources, and focused on biogas capture. Based on a recent study (Kaewmai, 2012), biogas emissions were estimated per tonne of crude palm oil for installations with biogas capture and for those without. The percentage of plants assumed to have biogas capture was based on an estimate of higher capacity plants, roughly 70% of palm oil mills. Emissions from biomass were considered to be zero, based on the revised 1996 IPCC guidelines.

The automotive parts industry is particularly heterogeneous (a car contains 20,000 – 30,000 parts), and each part involves a wide range of materials and processes. Therefore, instead of dealing with individual parts, a single vehicle was used as the low-level product unit, for which the SEC was estimated based on a 2010 study on vehicle and component manufacturing. The fuel mix of producing one vehicle was estimated based on DEDE data, which identified four main processes and their energy intensities, and provided a breakdown of natural gas and diesel.

For frozen seafood, the specific energy consumption per tonne of product was estimated based on data relating to specific electricity and diesel consumption. These data were also used to calculate the fuel mix per product, and were based on a 2013 study (Piyawan & Yoncharoen, 2013), taking into account assumptions on boiling processes and assuming no use of natural gas. Emissions from industrial processes, specifically refrigerant emissions, were based on a GIZ study (GIZ, 2013) on the industrial refrigeration sector as a whole. Based on estimates of the share of frozen seafood and frozen fish in particular, the figure of specific emissions per tonne of seafood product was estimated. For waste (wastewater), no compelling evidence or data related to emissions could be found, although this

merits further investigation.

Activity levels for all three sub-sectors were based on OIE data from the first half (H1) of 2015, and added to an estimate for the second half (H2) on the basis of the 2010-2014 average split in production between H1 and H2 to taking into account seasonal variations.

3.2.4 Data Needs for a Top-down or Bottom-up Approach

Table 3-1 gives an overview of the data needs for the top-down approach as well as for the bottom-up approach. Although there are differences in data needs, both approaches also overlap in the need for particular data, namely energy profiles and fuel mix, emission factors, and projection data.

Table 3-1: Data needs for the top-down approach and the bottom-up approach

Top-down approach	Bottom-up approach
Validated Sectoral Data: Emissions or related data (e.g. energy consumption) are collected at the nearest sectoral level above the sub-sector of interest. For this study, the broad sector energy consumption data from EPPO and DEDE was used, as prepared by Selvakummaran et al.	**"Low-Level" Product and Process Emissions Data:** This includes Sub-sector Specific Energy Consumption; Life Cycle, Carbon Footprint; and other data to estimate emissions per product/process/component etc.
Sub-Sector Scaling Down Data: Information on the relative share of emissions from the sub-sector in relation to the validated higher-level emissions data. Activity data (physical production) can be used, as well as economic data such as Gross Value Added (GVA). To scale down the validated higher-level sectoral statistics, it is important to have a good understanding of the classification systems (TSIC in Thailand) and how the sub-sector relates to the validated data.	**Activity Levels:** This is for scaling up the "low-level" emissions to the entire sub-sector. Indicators preferably have a strong one-to-one relation with the "low-level" per-unit/process data, such as Specific Energy Consumption. Information on the size of the sub-sector may also inform estimates on the activity.
Energy Profiles and Fuel Mix: Sub-sector energy profiles describe the share of energy use for each fuel. They can be used in conjunction with the total energy use and the emissions factors of the fuels to arrive at total energy-related emissions. These sub-sector profiles can be constructed using a bottom-up analysis, in part by estimating the amount of each type of fuels used for products and processes.	
Emission Factors: Ideally emissions factors are country-specific, although default IPCC emissions factors can be used.	
Projection Data: Recent historical trends and projections are needed to construct emissions projections using trend/ regression analysis. This analysis is considered in conjunction with data and/or justifiable assumptions on activity levels and sub-sector growth, energy consumption, technological progress, and changes in energy profiles.	

3.2.5 Energy Profiles and Emissions Factors

The Energy Profiles of the sub-sectors, describing the share of energy consumption from each fuel source, were created using a bottom-up approach. These were then multiplied by total energy consumption and the emission factors from each fuel. For this study, the default emission factors from the IPCC revised 1996 guidelines were used. These emission factors are consistent with the 2nd National Communication and the upcoming the 3rd National Communication. It is possible to calculate country specific emission factors for fuels based on variations in the energy content of fuels compared to IPCC defaults. However, due to uncertainties related to assumptions on the carbon content and weight of local fuels, the estimated low impact on emission factors that such an adjustment would have[6], and for consistency with existing Thai inventories, it was decided to use the IPCC values. Nevertheless, developing robust country-specific emission factors by resolving the outstanding questions scientifically is recommended as a way to improve the emissions estimates in future.

[6] In a test calculation on this basis the emissions factors typically varied by less than +/- 5% from the IPCC value.

3.2.6 Projections

For both the top-down and bottom-up approaches, the same data was used to make emissions projections, based on projected activity level growth. Data needs include historical production trends from 2000-2014 (for linear regression projected to 2050), sector projections and known constraints such as land available for palm oil plantations, growth in global automotive vehicle demand, etc. (specific assumptions per sector are described in the Emissions Projection Report). The projection calculations also assumed that energy profiles (the mix of fuels used in a sub-sector), technology (e.g. energy efficiency of machinery), and emissions factors remain unchanged except for electricity. Emission factor projections for electricity are based on the latest Power Development Plans until 2036, and extrapolated until 2050.

In general, there was a lack of long-term growth projections of the sub-sectors of interest, including by the OIE. The growth projections therefore needed to rely to an extent on macroeconomic growth projections of 4% until 2030 and 2.5% thereafter, as economic growth slows as an economy becomes wealthier; and Thai population decline after the mid-2020's. This is based on a 2012 TGO and JGSEE study and other academic studies. The regression analysis was supplemented by this macroeconomic data as well as other information on the sectors – for example, a high growth rate of 8% for frozen seafood from 2016-2020 reflects an expected recovery of the shrimp production industry based on a solution to disease issues experienced from 2010.

To ensure the projections are the best-available-estimate, the project team worked and consulted closely with the Project Steering Committee and relevant stakeholders including the industry groups and received their concurrence on the study results.

3.3 Data Challenges and Recommendations

Based on the general categories of data needs listed above and in light of experience from this study, several main challenges associated with creating a roadmap due to the data situation in Thailand can be identified. Although the issues were identified during the investigation of the selected sub-sectors, they may be generally applicable. Recommendations addressing the points below are summarized in Table 3-2 below.

Firstly, information on data, and the data itself, is not currently consolidated in one easily accessible location, institution, or agency. A detailed overview and description of available data, its location as well as procedures to access the data should be available. The overview could build on the identified data needs and work done during this study, as described in the data map. It would allow researchers to select appropriate methodologies at the outset of studies. Furthermore, it would facilitate the selection and scoping of sectors. This would help to avoid or address data issues right from the definition of the project.

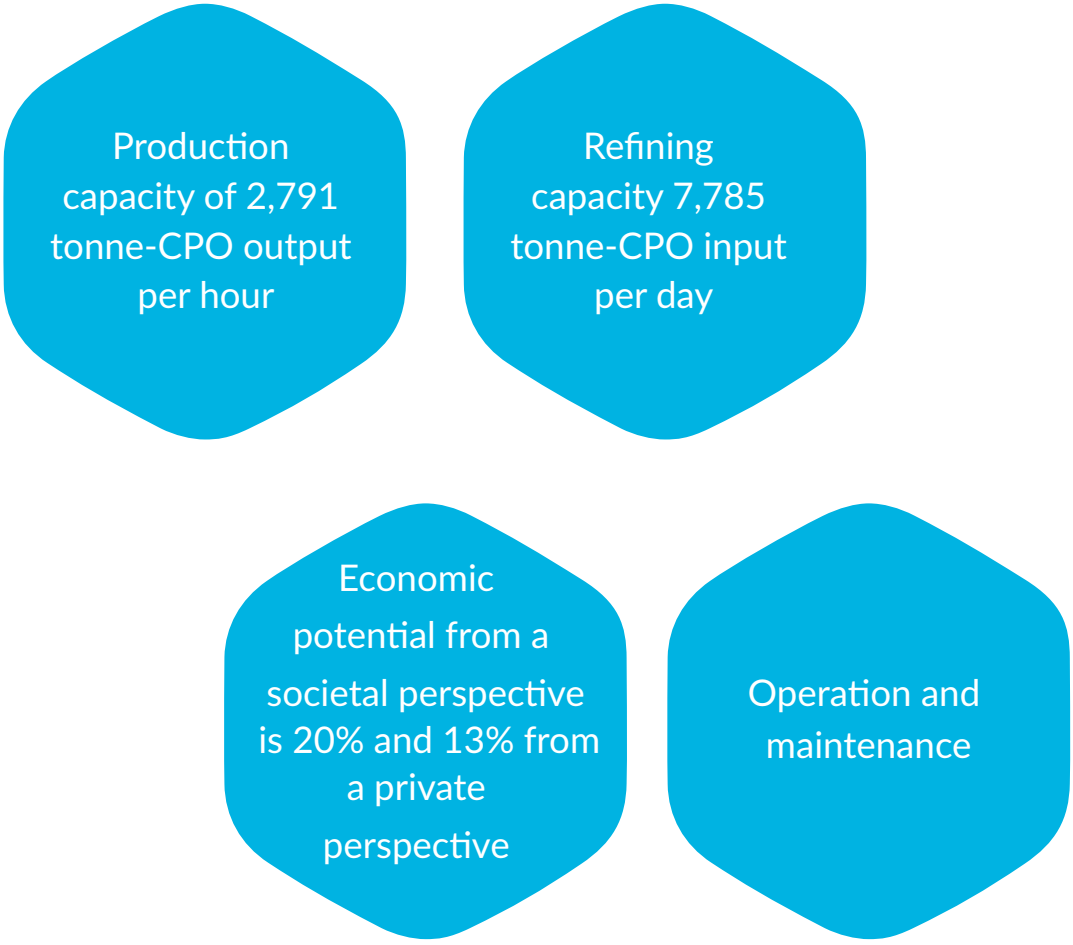
Such a detailed overview would also further identify data gaps, which may require actions for data consolidation and data collection over the medium or longer term. Similarly, guides to existing datasets should be easily available, with descriptions of their content and definitions.

While it is natural that data necessary for GHG inventories will be held by a number of different organizations, since the data needs are so varied in scope, some consolidation of data would be worthwhile. Such a dataset could contain essential information, while pointing to other datasets for more detail. Ideally, the data overview, guides and GHG specific dataset would be held by a body that would also develop information request procedures and facilitate the requests themselves. Formal procedures for data collection create long lead times, especially when an iterative process is need, which is normally the case as the first data received is often not an exact match with the needs.

Lastly, the data itself will need to be further developed over the longer term. For top-down analysis, in order to scale down sector emissions estimates, there needs to be more detailed sub-sectoral data below the 2 digit TSIC level. This was particularly the case for industrial process and waste emissions. This could involve additional data collection, including additions to the DEDE energy reporting and the Ministry of Industry's industrial reporting requirements on emissions for designated entities. Country-specific GHG emission factors of fuels are missing - this study relied on default IPCC emissions factors, but country-specific emission factors would result in more accurate inventories. There is also a lack of long-term projections on sub-sector level. These should ideally be developed by sub-sector experts, using a consistent and accepted methodology with clear assumptions, rather than by experts creating the GHG inventory.

Table 3-2: Recommendations to improve the data acquisition and management process

Challenge	Recommendation and Potential Agency
General data availability and quality	Delegate central responsibility to one organization to set up an integrated data management system, creating a consolidated database with data necessary for GHG inventories and roadmaps. Processes for data collection can be automated and simplified. Data access for third parties can made quicker and easier, while protecting sensitive data
Information on data availability and quality is dispersed, access to data is unclear.	Create a "GHG Roadmap Guide" necessary for GHG inventories and projections. The guide should address data needs and provide information on data availability, content, location and access/request procedures and standard forms. The guides and forms should be available in hard and soft copy. The same body responsible for the integrated data management can facilitate data requests. TGO can play a lead role, leading an interagency task force.
Some data definitions and scope are unclear	Institutions with data related to GHG inventories, including DEDE and MTEC, can create simple additional guides of their databases. Other organizations, including OIE and NESDB, can create briefing notes detailing their data specifically relevant to the development of GHG inventories and roadmaps—i.e. national and sectoral economic data.
There is a lack of detailed and recent data for industrial process and waste emissions.	Improve data collection and consolidation of industrial process and waste emissions. It may be possible to add reporting requirements to the energy reporting guidelines which inform the DEDE database or Ministry of Industry's reporting requirements.
There is a lack of detailed sub-sector energy and emissions data	Generally, sectoral organizations can play a role in collecting relevant sector data and work together with the central authority appointed to develop an integrated data management system. For the palm oil sub-sector, compile CDM project data and resume defunct monitoring activities with equipment already in place
There is a lack of country-specific emissions factors.	Develop robust country-specific emission factors by resolving the outstanding scientific questions to improve the emissions estimates in the future. Specifically, information on the carbon content and the weight of local fuels would be necessary to adjust default emissions factors.TGO can play a lead role, supported by JGSEE and other research institutions.
There is a lack of long-term projections at the sub-sector level.	Create long-term sub-sector growth projections, especially economic and activity level growth, using consistent methods and macro-economic assumptions across sub-sectors.OIE and sub-sector experts can play a lead role.



GHG Reduction Roadmap for the Palm Oil Industry

5.8%
of palm oil
production
exported in
2014

Technical
potential of
GHG reduction of
40% compared
to the BAU
in 2030

Efficient motors

Variable speed drives

Biogas recovery

4. GHG Reduction Roadmap for the Palm Oil Industry

This chapter, and the following two chapters, present a roadmap for GHG reduction in each sub-sector of focus. Each chapter presents an overview of the technical and economic abatement potential in the sub-sector and the different measures for emissions abatement. It then presents these potentials as translated into scenarios of emissions abatement, illustrating how sector emissions would evolve if a particular set of measures was fully implemented. Policies and actions that could be taken to achieve these potentials are then assessed. A concluding discussion on the scope of emissions reduction ambition is then presented, which could inform further actions and possible target setting discussions.

It should be noted that there are significant overlaps in the approach, measures, policies and actions between the sub-sectors. As each roadmap chapter is intended as a stand-alone section there may be similarities and repetition of text in Chapter 4 in Chapters 5 and 6

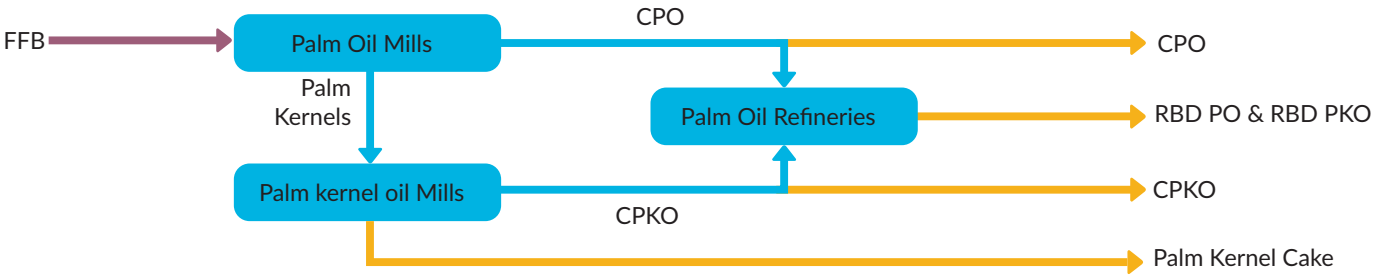
4.1 Technical-economic Emissions Abatement Potential

Sector overview

Crude palm oil (CPO) is extracted from fresh fruit bunches (FFB) from palm trees. The palm kernels are separated and sent to a palm kernel crushing mill where crude palm kernel oil (CPKO) is produced. Both CPKO and CPO can be further refined in palm oil refineries where different types of refined palm oil are produced. Refined palm oil is used in many products in the food and cosmetics value chains.

The scope of the analysis included palm oil mills, palm kernel oil mills and palm oil refineries (the blue parts of Figure 4-1 below). Upstream activities, mainly plantation of palm trees and transportation of FFB, and downstream activities, transportation and further processing of refined palm oil are excluded.

Figure 4-1: Scoping of the activities in the palm oil industry included in the analysis.



Within the supply chain, from plantation to the palm oil products, the largest share of GHG emissions are emitted at the plantations mainly due to the initial land use change (clearing existing vegetation) and the use of fertilizers. However, these emissions are not included in the scope of this study. Within the actual production process, the most GHG emissions are emitted during the waste treatment of the Palm Oil Mill Effluent (POME). When the POME is stored in open lagoons, rotting of the organic mass produces methane which has a large global warming potential. Other important sources of GHG emissions are related to electricity used in the refineries and fossil fuels used in the refineries to produce steam.

A large part of the energy demand in palm oil mills is typically met by using residues from the FFBs, such as fibers, as biomass fuel for boilers. Furthermore, palm kernel oil mills are often located near a palm oil mill, which allows them to also use this biomass fuel.

Key facts and figures of the Palm oil sub-sector in Thailand are provided in Table 4-1 below:

Table 4-1: Facts and figures of Palm oil industry in Thailand

Parameter	Value	Source
Number of companies	76 crushing mills 15 refineries Many small palm oil plantation owners	(Palm Oil Crushing Mill Association, 2011)
Production (2014)	1,294 ktonne	(OIE, 2015)
Production capacity Refining capacity	2,791 tonne-CPO output per hour 7,785 tonne-CPO input per day	(Palm Oil Crushing Mill Association, 2011)
Exports (2014)	5.8% of palm oil production	(OIE, 2015)
Labor (employment)	Variable based on the season. Harvesting takes place every 20 days. High harvesting season takes place from March-June	(Dallinger, 2011)
Added value/share in GDP (2014)	THB7 35,731 million / 0.4% of national GDP	(OIE, 2015; Bank of Thailand)
Price	FFB prices vary over the year and strongly relate to the volatile	(Dallinger, 2011)

Note: more comprehensive reviews of sub-sector characteristics are provided in the Emissions Projection and Technical and Economic Analysis Reports.

[7] Thai Baht

Emission abatement options

Table 4-2 below provides an overview of the emissions abatement options in the palm oil industry. For a detailed description of the options please refer to the Technical and Economic Analysis report. The number of the options relate the position in the MAC-curves in Figure 4-2 below, while the color shading of the cost columns illustrates the broad cost category of the measure, green (cost-effective), blue (modest cost), orange (high cost).

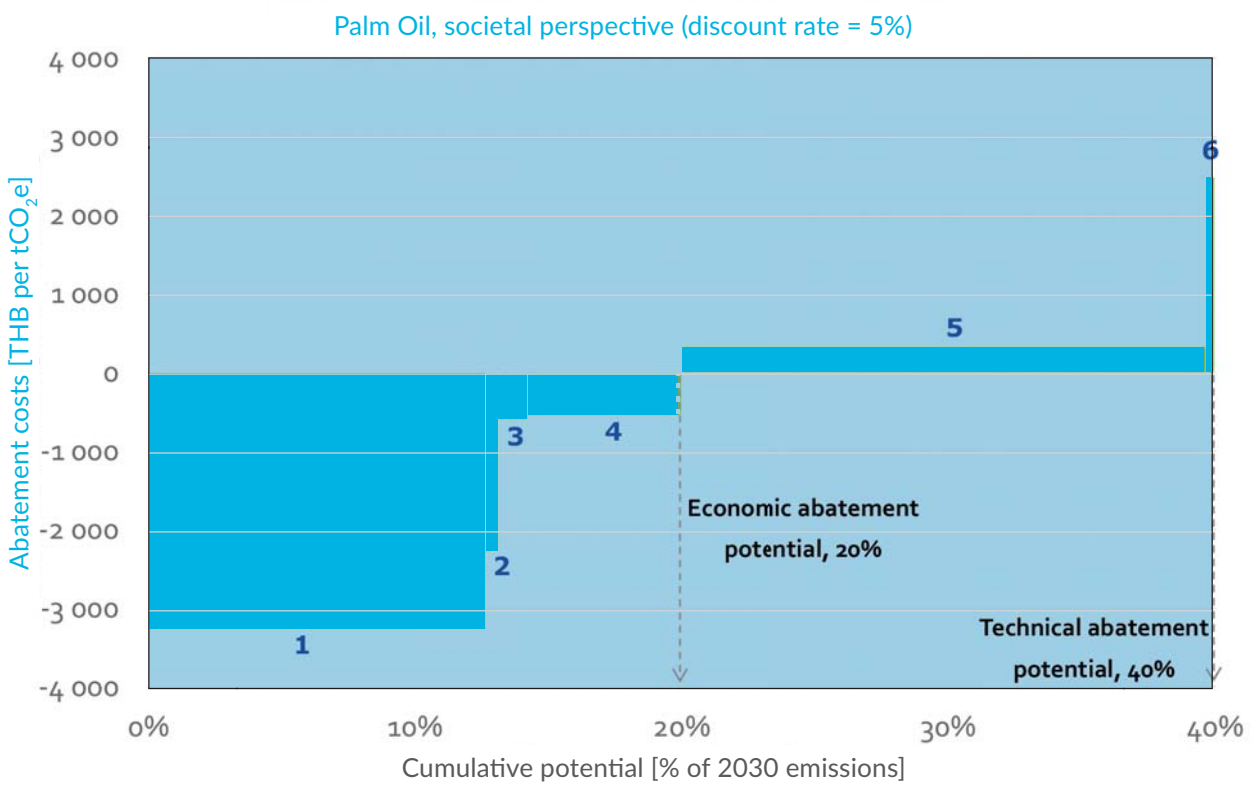
The largest abatement potential in this sector lies in improving and expanding the recovery of biogas in the wastewater treatment process. When not recovered, the biogas that consists largely of methane is emitted to the atmosphere. If the biogas is recovered, it can be used to generate electricity. Often the electricity production from biogas is more than is needed by the plant itself, making the facility a net electricity generator. The electricity can be fed into the grid. As the fuel source is biogas, the emission factor of this electricity is far less than of the grid, resulting in additional net emission areductions. The relatively high capital investment and maintenance costs of the measure means that it still has a positive cost, even taking into account revenue from electricity exports to the grid.

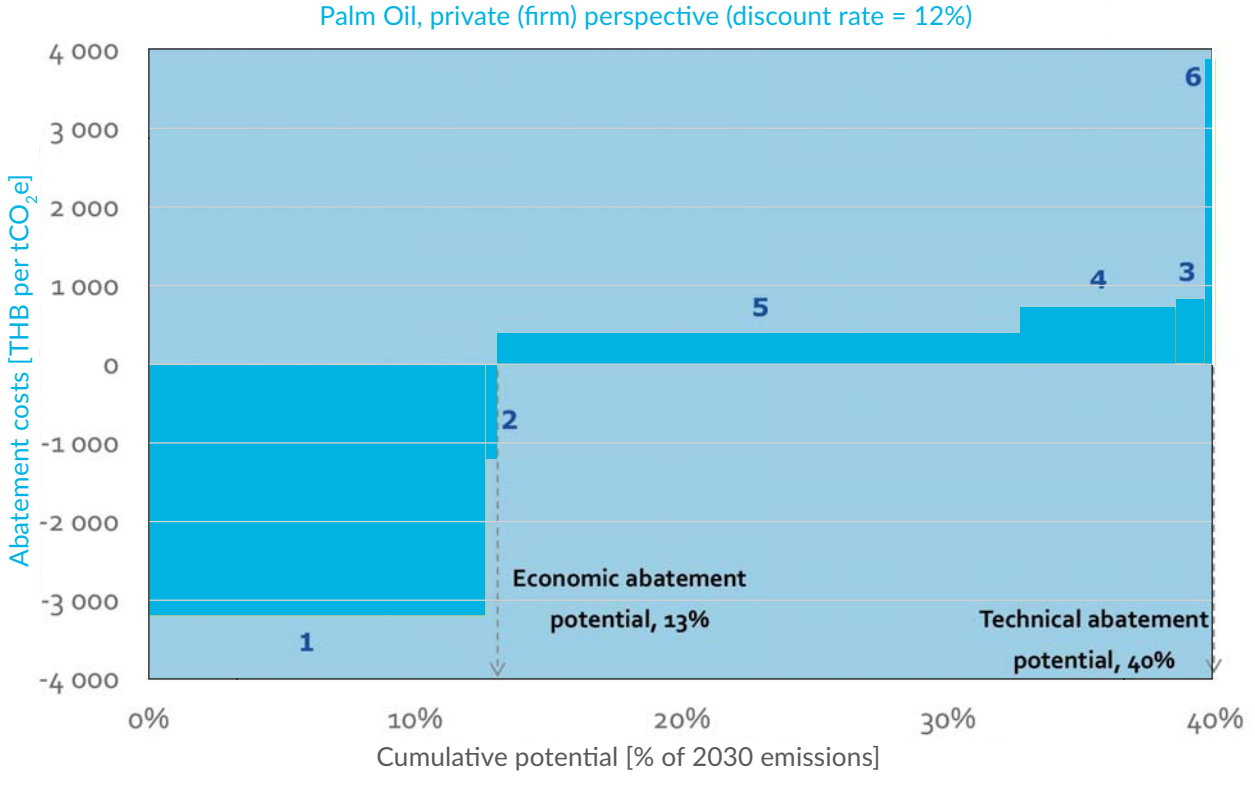
Table 4-2: Overview of emissions abatement measures and marginal abatement cost curves for the palm oil sub- sector

#	Category	Measure	Abateament cost with 5% discount rate (THB/tCO_2e)	Abatement cost with 12% discount rate (THB/tCO_2e)
1	Energy efficiency	Operation and maintenance	- 3,262	- 3,202
2	Energy efficiency	Efficient motors	- 2,272	- 1,207
3	Energy efficiency	Variable speed drives	- 590	830
4	Energy efficiency	Sector specific measures	- 539	718
5	Non-energy GHG emissions	Biogas recovery	336	388
6	Energy efficiency	Efficient lighting	2,493	3,882

Note: Green shading (cost-effective), blue shading (modest cost), orange shading (high cost)

Figure 4-2: MAC-curves for the palm oil sub-sector showing emissions abatement costs and potentials at societal and private discount rates.



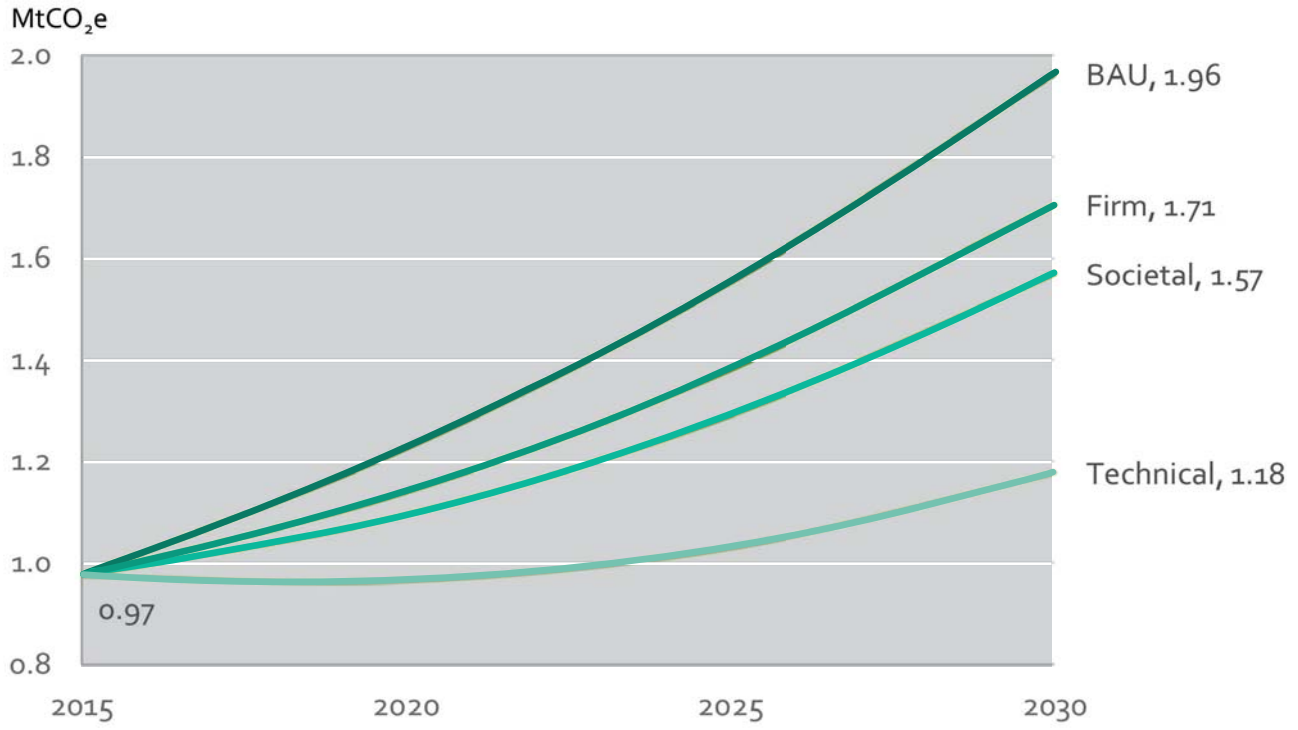


4.2 Emissions Projection and Abatement Scenarios

Business as usual scenario

Baseline palm oil sub-sector emissions are estimated at 0.97 $MtCO_2e$ in 2015, increasing to 1.96 $MtCO_2e$ in 2030 (+101%) and to 2.76 $MtCO_2e$ by 2050 (+183%), see Figure 4-3.

Figure 4 3: Emission projection for the palm oil sector



A bottom-up approach was used to estimate the emissions in the base year 2015 and is composed of estimates of energy-related and waste-related emissions.

For the energy-related emissions estimation, three key sources were used: a case study of twelve palm oil mills, a case study of five palm kernel crushing plants, and gate-to-gate energy data of Thai palm oil refineries (Vijaya S. , Ma, Choo, & Nik Meriam, 2008) (Vijaya & Choo, 2012) (MTEC, 2015). The average energy consumption of the different process steps in these case studies was used to calculate the average energy consumption per tonne crude palm oil (11.6 GJ/tonne CPO). Multiplying this by the palm oil production in 2015 as provided by the OIE, enabled us to estimate total energy consumption of the entire palm oil sub-sector (i.e. palm oil mills, palm kernel oil mills, and palm oil refineries) of 344 ktoe in 2015.

To estimate the energy-related emissions, the shares of different fuels used by the sub-sector were also retrieved from the case studies and multiplied by their respective emission factors. The biomass that is used as fuel was assumed to have zero net emissions. For the entire Thai palm oil sector, the resulting energy related emissions were estimated at 129 $ktCO_2e$ in 2015.

A similar process was applied to estimate the waste-related emissions of the sub-sector. The same sources as for the bottom-up estimation of energy related emissions were consulted to estimate these emissions. The amount of waste-related emissions is mainly influenced by the presence of a biogas capture installation. Based on plant data and feedback from the palm oil industry it was estimated that biogas recovery already covers 70% of palm oil production. For these installations waste-related emissions of 513 $kgCO_2e$ per tonne of crude palm oil

were estimated, while for the other 30% of installations emissions were estimated at 1,006 kgCO_2e per tonne (Kaewmai, 2012). As a result the waste-related emissions of the sub-sector were estimated at 845 ktCO_2e.

It is acknowledged that the baseline emission estimate relies on several assumptions and case studies. The emission estimate is therefore uncertain and should be treated as such.

The palm oil sub-sector is projected to grow its production at an annual rate of 4.9% between 2016 and 2030. This assumption is equal to the observed average annual production growth rate for the sub-sector for the period 2000-2014. Post 2030 the growth rate projection is lowered to 1.8% reflecting the wider economic trends and also the expectation of increasing resource (i.e. plantation land) constraints on production.

The technical abatement potential found in this study is 40% lower than the BAU emissions in 2030. This is the total potential for energy-related emissions, both direct and indirect, and process-related emissions. Most measures in the sector (grouped for simplicity) are primarily related to energy efficiency, although the measure with the largest potential is the expansion of biogas capture across the whole sector.

The energy efficiency measures, such as implementing better energy management and operations regimes, optimising technical cooling and pumping processes and using more efficient motors and drives, influence both the direct emissions from fuel use on-site and also the indirect emissions from electricity generation. In the case where sites become net energy generators through biogas capture and use, then (net) emissions can be reduced further when the plant exports electricity to the grid.

The technical abatement potential is based on the measures that could be identified in this study. It might be that measures are overlooked, or that new technologies will emerge that cannot be foreseen. The technical potential should therefore be seen as a minimum estimation of the actual technical potential.

The MAC-curve shows measures with both positive and negative abatement costs, but only a single measure - lighting replacement - with a high (>1,000 THB/tCO_2e) abatement cost was identified, where a high cost is driven by limited reduction potential relative to costs. In general there is not much literature or case study evidence on expensive measures, simply because they are not implemented or, for example solar PV, have very low potential and/or high costs in the sub-sector. Expensive measures also include innovative measures, which are still at the beginning of the development cycle. This study was not able to pinpoint innovations in palm oil milling or refining that would also result in emission reduction in the longer run. That is not to say that these are not conceivable. Therefore, it is still recommended to support R&D focused on making the production processes more efficient.

Economic potential – societal perspective

The economic (cost-effective) abatement potential from a societal perspective is 20% of the BAU emissions in 2030 (see also Figure 4-2).

Economic potential – firm perspective

If the discount rate is raised from 5% (societal rate) to 12% (private [firm] rate) to reflect the shorter time period and higher preferred rate of return demanded by private firms, then the economic abatement potential reduces to 13% (see also Figure 4-2). This is driven by measures with modest costs #3 (variable speed drives) and #4 (sector specific measures) that are no longer cost-effective, resulting in a shift in the order in the MAC-curve.

Sensitivity of economic abatement potential

Taking the data and calculation uncertainties into account it is useful also to look at measures with costs relatively close to 0 THB/tCO_2e, as this gives an indication of the sensitivity of the abatement potential to different costs. The range of measures with costs relatively close to zero per tCO_2e is quite large in this sub-sector if we include measures #3, 4 & 5. These represent around 25% of the total abatement potential. The sensitivity of the abatement potential is therefore relatively high and warrants further investigation and better data on costs to assure that any targets can be set at a reasonable level.

4.3 Policies and Actions

The previous sub-section has demonstrated that significant emissions abatement potential has been identified in the palm oil sub-sector, albeit with

uncertainties into the cost-effective potential.
The identified abatement measures have a range of costs with measures that can be classified as either cost-effective, having modest costs or having high costs. This sub-section outlines key policies and actions that could be taken within the LTA framework and which address the barriers identified in the palm oil sub-sector, with a focus on the barriers grouped under a lack of knowledge of measures, a lack of understanding/vision and financial support.

Policies and actions to unlock abatement potential

Table 4-3 gives an overview of policies and actions aimed at unlocking the abatement potential in the palm oil sub-sector.

Long-term agreement

There are multiple actions that can contribute directly towards the development, agreement and implementation of an LTA.

To get the data right it is important and proposed to:

- Encourage greater cooperation and compliance from the sector in GHG relevant data gathering – the Thailand energy management program already provides a good entry point for this. Although the data in the sector is already quite well developed and there is audit data, academic work and other studies to draw upon this can still be improved further and enable remaining data gaps or uncertainties to be addressed.
- Once the data is gathered, it will be necessary to aggregate and analyze this effectively - by implementing a central database, possibly managed by TGO, the data can be used to improve the quality of the GHG footprint of the sub-sector and provide a basis for performance-based monitoring going forward, which will be an important part of the LTA implementation. This data can also be used in the longer term to support future policy through sector performance benchmarking.
- Improve the training and funding of government staff at the relevant agencies, as getting the data right can only be successful if the technical understanding and resources are available. This helps to address the key knowledge barriers that exist.

To engage the sector it is important and proposed to:

- Engage directly with the sub-sector, most effectively through the most relevant sector association or biggest firms, in this case the Palm Oil Industry Club offer a useful entry point. Disseminating the findings of this work can help to initiate a discussion.
- Taking this further, a working group on sustainable production in the sector should be set up, this would become the main counterpart in discussions and also fulfil other roles relevant to data and implementation. The working group should be encouraged to propose its own emissions reduction roadmap and to make a needs assessment of what is required to achieve it. This can form the starting point for the negotiation of the LTA for the sector.

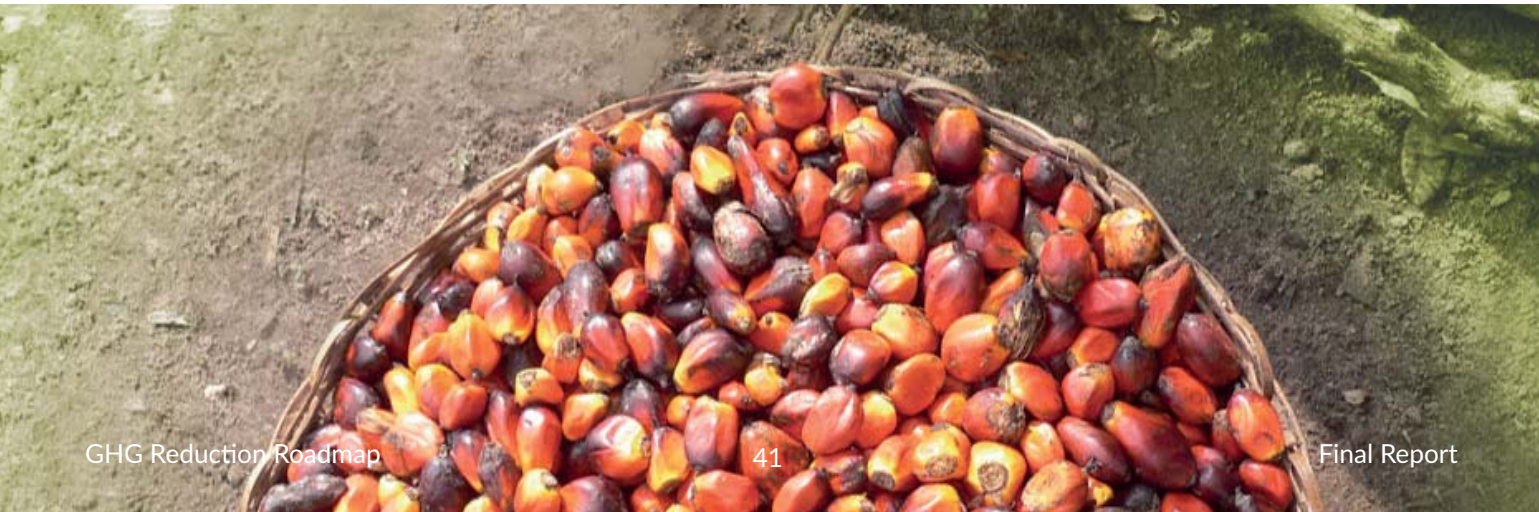


Table 4-3: Policy and actions for the palm oil industry

Solution pathway	Addresses objective(s)	Actions per LTA framework phase			Addresses barriers
		Phase I (Short Term)	Phase II (Medium Term)	Phase III (Long Term)	
LTA	Generating sector engagement and interest LTA	Create sub-sector working group on sustainable production, starting point with the Palm Oil Association. Invite the sector to develop their own low carbon roadmap and needs assessment which identifies the possibilities and constraints of GHG emission abatement. G P F I A	Sub-sector and government negotiate and reach LTA for GHG reduction in the sector. G P F I A	Monitor LTA, take action as appropriate. Benchmarking of specific energy consumption in the sector. International benchmarking of sector to guide policy and support competitiveness. G P F I A	Firms lack of knowledge Firms lack of vision/understanding
LTA	Getting the data right Implementation by firms	Encourage greater adoption of (and compliance with) Thailand EM Programme to improve understanding of energy use and reduction options. Implement no regret EM system processes (see MACC measure #1). G P F I A	Evaluate and improve energy management system. Replace equipment with more energy efficient equipment when replacement is needed. G P F I A	Best practice energy management system, energy use key criteria in business decisions. G P F I A	Firms lack of knowledge (imperfect information) Firms lack of vision/understanding (energy only compliance issue, production-centric focus)
LTA	Getting the data right	Aggregate data and collect these in central database, combine with other data sources to produce improved sector GHG footprint and start performance-based monitoring. G P F I A	Continue performance-based monitoring. G P F I A	Continue performance-based monitoring. G P F I A	Firms lack of knowledge (imperfect information) Firms lack of vision/understanding (poor management understanding)
LTA	Getting the data right	Improve training and funding for relevant govt. staff, subjects to include technical measures, impacts, global GHG context. G P F I A	Continue training of staff G P F I A	Continue training of staff G P F I A	Lack of knowledge (lack of relevant skills among staff)
LTA	Implementation	Through sector network share knowledge, focus on dissemination of best practice in POME treatment, biogas recovery and heating processes. Government consider re-introducing customer support service for industry. G P F I A	Continue to share relevant knowledge. Implement customer support service. G P F I A	Continue to share relevant knowledge G P F I A	Firms lack of knowledge (perceived high costs/risks)
LTA	Implementation	Implement any simple, low capital cost equipment measures G P F I A	Implement cost-effective, but more capital intensive measures (see MACC measures #2) and biogas capture (#5) and other measures (#3 & 4) with govt. support. G P F I A	Implement other measures (see MACC measure #6). G P F I A	Firms lack of knowledge (perceived high costs/risks)
Supporting measure	Supporting mechanisms from govt.	Review the energy efficiency labelling, MEPS, HEPS requirements for equipment/appliances crucial for sector, i.e. motors and VSDs. G P F I A	Modify requirements to support energy efficiency improvement in sector. G P F I A	Review standards periodically and increase minimum requirements, revise label grades to provide continuing incentives. G P F I A	Firms lack of knowledge
Supporting measure	Supporting mechanisms from govt.	 G P F I A	Accredit training providers to set up training courses for staff of companies to learn how to improve management of processes, and to implement and operate sustainable technologies. G P F I A	Introduce relevant modules and information to technical and vocational education to train students on sustainable technologies. Sectors should contribute to these. G P F I A	Firms lack of knowledge (lack of relevant skills among staff) Firms lack of vision/understanding
Supporting measure	Supporting mechanisms from govt.	Encourage firms to participate in Thailand Energy Awards scheme G P F I A	Consider creation of sector category within Thailand Energy Awards scheme. Evaluate overlap and potential for linkage with international industry schemes, i.e. through RSPO. G P F I A	Evaluate success of awards in stimulating competition in sector, how firms compare internationally. Use to promote industry internationally. G P F I A	Firms lack of vision/understanding (lack of prestige)
Supporting measure	Supporting mechanisms from govt.	Increase visibility of climate change in national policy discourse. Communicate need for increased climate commitments in future, discussion on national targets and role of industry. G P F I A	Ensure sector targets are in line with policy commitments, i.e. INDC, RE, EE strategies. G P F I A	Ensure sector targets are in line with policy commitments, i.e. INDC, RE, EE strategies. G P F I A	Firms lack of vision/understanding (poor understanding of importance of climate change)
Supporting measure	Supporting mechanisms from govt.	Develop integrated approach to climate change in general and designate responsible agency for sector engagement. Evaluate need for improved grid infrastructure (with PEA, EGAT) to facilitate electricity export. G P F I A	Evaluate current set of financial support schemes (revolving fund, soft loans, ESCO fund, tax incentives, direct subsidies) on effectiveness for this sector. Revise as appropriate. Offer specific incentives to firms participating in the LTA. G P F I A	Evaluate and assess need to further incentivise investments in abatement measures by e.g. implementing a carbon pricing scheme, emission trading or carbon/energy tax; and/or energy price (subsidy) reform. G P F I A	High operating/capital costs and/or risks Lack of government (financial) support
Supporting measure	Supporting mechanisms from govt.	 G P F I A	Attract national and international financing from e.g. development banks to support implementation of sustainable technologies. G P F I A	Attract national and international financing from e.g. development banks to support implementation of sustainable technologies. G P F I A	High operating/capital costs and/or risks Lack of government (financial) support
Supporting measure	Supporting mechanisms from govt.	 G P F I A	Set up targeted R&D programmes aimed at technologies specific for Thai industry, for example improved biogas capture, wastewater treatment and biomass energy systems. G P F I A	Fund deployment and pilot programmes of these technologies. G P F I A	High operating/capital costs and/or risks Lack of government (R&D) support

Key: G=Government, P=Private sector, F=Financial sector, I=International community, A=Academia education

To implement the LTA, it is important and proposed to:

- Build on the sector engagement to actually negotiate and agree an LTA, which includes targets, defines actions for both the sector and government and which also agrees the monitoring arrangements going forward.
- It is important also that there are review and decision moments/timeframe built into the LTA process so that if progress is unsatisfactory appropriate action can be taken by the Government in the longer term.
- Encourage knowledge sharing in the sub-sector through the working group and consider a revived customer support service to disseminate knowledge. These actions are important as companies are not always aware of the existence of specific measures, or even if they are aware of measures, they only have a limited understanding of the costs and benefits. This action can help to address this issue. In the case of the palm oil sub-sector it is important that best practice in dealing with Palm Oil Mill Effluent (POME), biogas capture and heating and cooling processes is shared as these are key emissions sources. The information can become very specific; for example, sharing knowledge on sub-sector specific energy efficiency and abatement measures, such as optimising cooling tower and pump operation, increasing boiler feed water temperature using process heat recovery from plate heat exchangers (Pinch method) at bleaching plants and improving condensate collection methods at fractionation plants in palm oil refineries (all part of measure #4).
- Implementation of energy management systems operations and maintenance measures (measure #1) is a low-hanging fruit action for firms in the sector, which can be continually developed over time. The actions on training and data proposed above can improve the pressure and incentives for firms to do this.
- Implementation of measures in the Palm oil sector is influenced by the fact that most have significant capital investments attached, which may limit what can be achieved in the short term. In the medium term these more capital intensive measures can be addressed, particularly efficient motors (#2) which is cost-effective. Other measures which are capital intensive (#3, 4 & 5) are on the borderline of being cost-effective and with the right policy incentives should also be achievable in this timeframe. Particularly relevant is to improve the incentives for biogas capture (#5) as this has the largest individual abatement potential. The least attractive measure from a marginal abatement cost perspective, efficient lighting (#6) can also be implemented in the medium-long term with relatively low capital costs.

Supporting measures and actions

It is crucial that the government and its agencies provide support to the success of the LTA through its broader policies and actions and also through specific actions. A considerable part of the policy framework and supporting instruments are already in place and effective, although there also remains scope for improvement and innovation. The following actions were identified and proposed:

- Improve the information connected to equipment which the sub-sector purchases to incentivize more efficient choices can mitigate the information deficit in decision making. Energy efficiency policies like the current MEPS, HEPS and Green Labels, should be reviewed and their requirements enhanced to improve the efficiency of the appliances that industry use and provide easy-to-understand guidance on the energy efficiency. Relevant for the palm oil sector is that these schemes are expanded to include relevant equipment, particularly motors, variable speed drives and boilers. In the longer term more stringent minimum mandatory requirements for these could be implemented.
- Supporting capacity building is also important here, the government can act to improve the training and education situation, either directly or through the accreditation of qualified trainers in the appropriate areas of energy management, energy efficiency and GHG emission reduction strategies.
- The Thailand Energy Awards scheme can be a useful vehicle to address management reluctance to act on GHG emission reduction, by attracting prestige and good publicity this can provide a strong incentive to firms. Examining how this could be implemented at a sector level within the framework of the LTA could be important, this could include recognising significant achievements in energy efficiency or emissions abatement, i.e. best performer, most improved, most innovative. Given the international nature of the palm oil product consumer market it can also be useful to encourage the sector to engage with relevant organizations in this area such as the Roundtable on Sustainable Palm Oil (RSPO) which

can also provide certification and awards. This will further improve the reputation and profile of the sector and the incentives to management.

- Ensuring higher visibility and coherence of government policy on climate change will also help. The commitments in the INDC are an important step, this can also help to engage with industry on the discussion of what their role and contribution should be. Furthermore it remains important to encourage and convince industry of the seriousness and urgency of the problem and how efforts will most likely need to intensify over time, as will the contribution that industry will need to make.
- Measures in the Palm oil sector tend to require significant investments. Therefore, access to finance can be a barrier for firms to adopt measures, which is a particular barrier for implementing biogas capture systems (#5) and the sector specific efficiency measures (#4) which need large one-off investments. Given that these measures are not typically cost-effective from the firm perspective but account for around 20% of the 40% total abatement potential it is important that the government ensures that financial support is available and known to firms. The existing policies and schemes (e.g. revolving fund, ESCOs, direct subsidies) and their applicability to sub-sector should be reviewed. It could also be considered, subject to being non-discriminatory, to directly link particular financial incentives or benefits, i.e. lower interest rates, tax exemptions/reductions; to participation in the LTA.
- In the long term wider policy reform particularly in the area of energy and/or carbon prices can provide a significant boost to the business case for energy efficiency measures, increasing the value of energy savings and reducing cost exposure to carbon prices, incentivising firms to invest.
- In addition to financial support there is in some cases an additional infrastructure barrier to implementing biogas capture. Where the physical and regulatory infrastructure enabling firms to export electricity to the grid is not as strong as it could be. The revenue stream from electricity exports is an important part of the investment consideration, especially following the decline in the market for carbon credits from Clean Development Mechanism (CDM), which helped make the business case for many previous biogas capture projects. The overall problem needs to be better understood through further research before appropriate actions can be taken by the sub-sector and energy companies.
- Finally, for the most important emissions sources in the sub-sector the Government should support research, development and deployment programs. These should develop and demonstrate new technologies in the industry in Thailand, helping to create best practice cases and to reduce costs.

4.4 Scope for GHG Emission Reduction Ambitions

Setting an ambition level for sector emissions abatement is a complex discussion. The results of this work can be suggestive of appropriate and/or realistic ambition levels for the sub-sector, but the MAC-curve and scenario projections also contain some (sometimes significant) assumptions and uncertainties. They cannot accommodate some of the very specific and practical issues that may limit abatement potential.

Setting an ambition level also needs to take into account the economic effects on the sector itself and the wider socio-economic impacts for the economy. These impacts were assessed and, in summary, for the palm oil sector they suggest:

- The impact of implementing cost-effective abatement measures will be positive for the sub-sector GVA, exports and employment.
- Implementing non-cost effective measures will create some negative impact on sub-sector outcomes, but these are likely to be very low, i.e. -1% or less, even if the full technical potential was implemented. The impact on exports could be greater, up to -6% at full technical potential, but it should also be noted that palm oil exports are also very low, with only 6% of production being exported.
- These results are mirrored at the wider national economy level, cost-effective emissions abatement is expected to also result in positive overall socio-economic impacts and implementing more costly measures will have minimal (negative) impacts on the wider economy, i.e. -0.01% impacts on output, imports and exports.

The Technical and Economic Analysis Report contains the more detailed modeling assessment of the impact of emissions abatement on the palm oil sector.

The societal and firm perspective scenarios elaborated two different cost-effective potentials, 20% and 13% respectively, which already introduces an important element into any discussion of emissions abatement ambitions. While society requires a sufficiently high ambition level, it should remain sensitive to the needs of industry (firms) otherwise the negative socio-economic impacts flagged above, although small, may occur. In addition, taking the various information into account we suggest that:

- Incentivising the achievement of cost-effective abatement should bring both emissions and economic benefits for the sub-sector and wider economy and is to be recommended.
- This suggests potential for 13-20% emissions reduction in 2030 compared to 2015, yet this range may not be a realistic target due to:
  - The difficulties in achieving the full potential for each measure. There can be real practical reasons why an assessed potential may not be possible, for example the costs are assessed at the average level and will not apply to all firms in the same way. Some cost-effective measures may not be cost-effective for part of the sub-sector;
  - Uncertainties underlying the calculations and the future. While best identified sources were used it is impossible to predict the precise situation and costs in 2030. The previous analysis highlights that there is significant abatement potential, up to 25% of the 40% that could change from cost-effective to not, and vice-versa with relatively small changes in costs and assumptions. Further research into costs and potential would help to clarify the situation and realistic cost-effective emission reduction potential.
- Any target setting should be the outcome of a political or negotiation process between the various stakeholders – we propose the LTA framework for this purpose – any target should also align with the national target of 20% emissions reductions (or 25% with international support), as stated in the Thailand INDC commitment. Based on the MAC-curve analysis achieving this level of reduction would be very likely to require financial support to the sector to incentivize implementation of measures such as biogas capture.
- This work can already be used as a basic to begin a focused discussion with the palm oil sub-sector towards an LTA, starting to address the questions of what is achievable and the continuing and additional policies and actions needed.
- Even if an LTA is not possible, the suggested supporting policies and actions will incentivize emissions abatement in the sector and should be pursued, particularly those that remove barriers to the adoption of cost-effective measures and address the issue of POME treatment (MAC-curve measure #5).
- Revisiting this roadmap periodically is important to ensure it remains relevant to the sub-sector, indeed as part of the LTA framework the Palm oil sub-sector could take ownership and further develop this roadmap.

GHG Reduction Roadmap for the Automotive Parts Industry


Size boilers to suit production demands
Insulation and temperature control rinsing tanks
Run equipment at maximum efficiency and as continuously as possible
Heat exchangers
Improve storage logistics
Key focus area in this sub-sector is the improvement of energy efficiency
Efficient motors
Improve efficiency drying processes
Management air systems and boilers
Variable speed drives (VSD)
Efficient lighting

5. GHG Reduction Roadmap for the Automotive Parts Industry

5.1 Technical-economic Emissions Abatement Potential

Sector overview

The automotive parts industry in Thailand is very heterogeneous. It includes many different brands of vehicles and therefore also components of various types. A car consists of about 20,000 – 30,000 parts. The industry contains both very large and small manufacturers to serve both domestic and foreign markets.

The manufacturing of these parts requires many different materials and a wide set of skills and processes. The main raw materials used for automotive parts include steel, plastics, cast iron, glass, aluminium and rubber. Important processes for automotive part manufacturing are forging, extrusion, moulding, casting, welding, gluing and machining.

Not all automotive parts used on Thai assembly lines are manufactured in Thailand. Some foreign manufactured automotive parts are also imported and used by Thai part manufacturers and Original Equipment Manufacturers (OEMs). Thai produced parts and fully assembled vehicles are also exported. Automotive parts that are not directly manufactured for use in assembly are used for the Replacement Equipment Market (REM) and the aftermarket as spare parts to replace original parts.

The automotive industry contributes significantly to the Thai economy, in terms of value added and employment. It is also important for technology development in the automotive industry as well as supply chain related industries. Thailand has been the automotive hub of ASEAN (Association of Southeast Asian Nations), with the largest automotive production among Southeast Asian countries, and ranking ninth globally in 2013 (Thailand Automotive Institute and Office of Industrial Economics, 2014).

The Thai automotive industry has been growing rapidly in recent years. The production of vehicles in Thailand has grown from around 425,000 vehicles in 2000 to 1.75 million in 2014, an increase of 320% or 10.8% annually (Thailand Automotive Institute , 2012). The export value of automotive parts has been growing at a comparable rate, and in 2013 contributed an export value of approximately USD 12.3 billion (Bank of Thailand, 2015).

The Local Content Requirement regulation (which forces automotive assemblers to use a certain percentage of locally sourced components in their vehicles) has transformed the automotive industry in Thailand and resulted in many new individual car part suppliers and direct expansion of in-house production of large manufacturers (Techakanont, 2011). This regulation was effective from 1975 to 1999. With this regulation manufacturers were obliged to use a certain percentage of local suppliers.

In Table 5-1 the main facts and figures about the Thai automotive parts industry are presented.

Table 5-1: Facts and figures about the automotive parts industry in Thailand.

Parameter	Value	Source
Number of companies in 2010	Assemblers: 21 companies 1st tier: 690 companies 2nd + 3rd tier: 1,700 manufacturers	(Thailand Automotive Institute and Office of Industrial Economics, 2014)
Production in 2014	1.77 million cars[8]	(Thailand Automotive Institute and Office of Industrial Economics, 2014)
Production capacity 2013	2.75 million cars per year	(Thailand Automotive Institute and Office of Industrial Economics, 2014)
Exports 2013	1.33 million domestic sales 1.12 million vehicles exported (value is 4.3% of GDP) Vehicle parts and accessories: THB 378,500 million (USD 12.3 billion)	(Thailand Automotive Institute and Office of Industrial Economics, 2014) (Bank of Thailand, 2015)
Labor (employment) 2012	>500,000 direct jobs	(Thailand Automotive Institute, 2012)
Added value/share in GDP 2012	10% of GDP	(Thailand Automotive Institute, 2012)

Note: more comprehensive reviews of sub-sector characteristics are provided in the Emissions Projection and Technical and Economic Analysis Reports.

The sector faces several challenges in the coming years:

- Difficulties in maintaining or increasing added value. The sector has a large share of low added value suppliers. More complex parts are often imported. The low added value parts segment faces strong competition from other countries in the region and a poor investment climate.
- Increasing labor costs as the country becomes wealthier and increasing competition among ASEAN countries. Competition can be especially relevant to Indonesia, which has a larger domestic market than Thailand, lower labor costs and is starting from a relatively low production base. There is a risk that investors may relocate their production from Thailand to Indonesia (Thailand Automotive Institute , 2012).

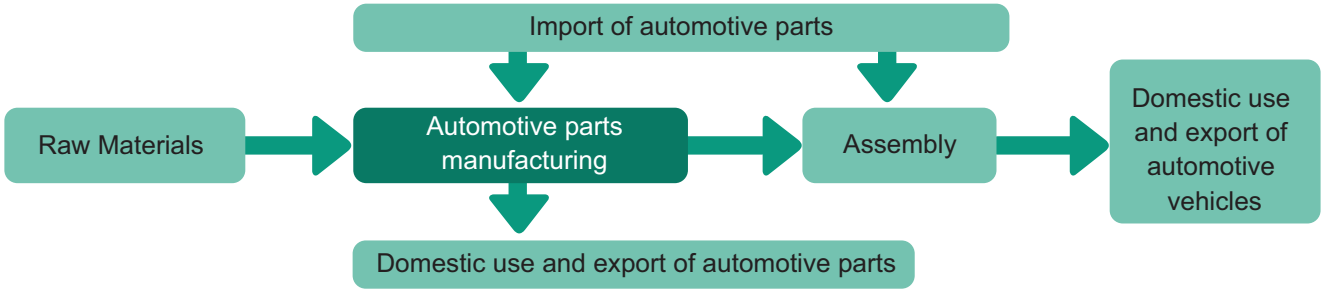
The main opportunities for the sectors can be found in the following areas:

- Global demand for vehicles is projected to grow from about 1 billion vehicles now to 2.5 billion in 2050, and a large part of this growth will be in South-East Asia (International Transport Forum, 2011). Thailand is very well placed to benefit from this growing demand.
- The fuel economy of vehicles and the share of electric vehicles will increase. This means that a market will emerge for producing new automotive parts.
- Further development of the ASEAN agreement towards a single market will liberalize trade in goods and services.

The focus of this roadmap for the automotive parts industry is on part suppliers and not on vehicle assemblers or raw material suppliers, see Figure 5-1. Furthermore, motorcycle parts are outside the scope in order to keep the sector relatively homogeneous whilst including the bulk of energy consumption and emissions.

[8] Including: Car under 1,800 cc, Car 1,800-2,400 cc, Car 2,400 cc and Off - road pass vehicle, Truck 1t 2W space cab.

Figure 5-1: Scoping of the activities in the automotive parts industry included in the analysis



Emission abatement options

Table 5-2 below gives an overview of the options to abate the emissions in the automotive parts industry. The detailed description of the options is provided in the Technical and Economic Analysis report. The number of the options relate the position in the MAC-curve, given in Figure 5-2 below, while the color shading of the cost columns illustrates the broad cost category of the measure, green (cost-effective), blue (modest cost), orange (high cost).

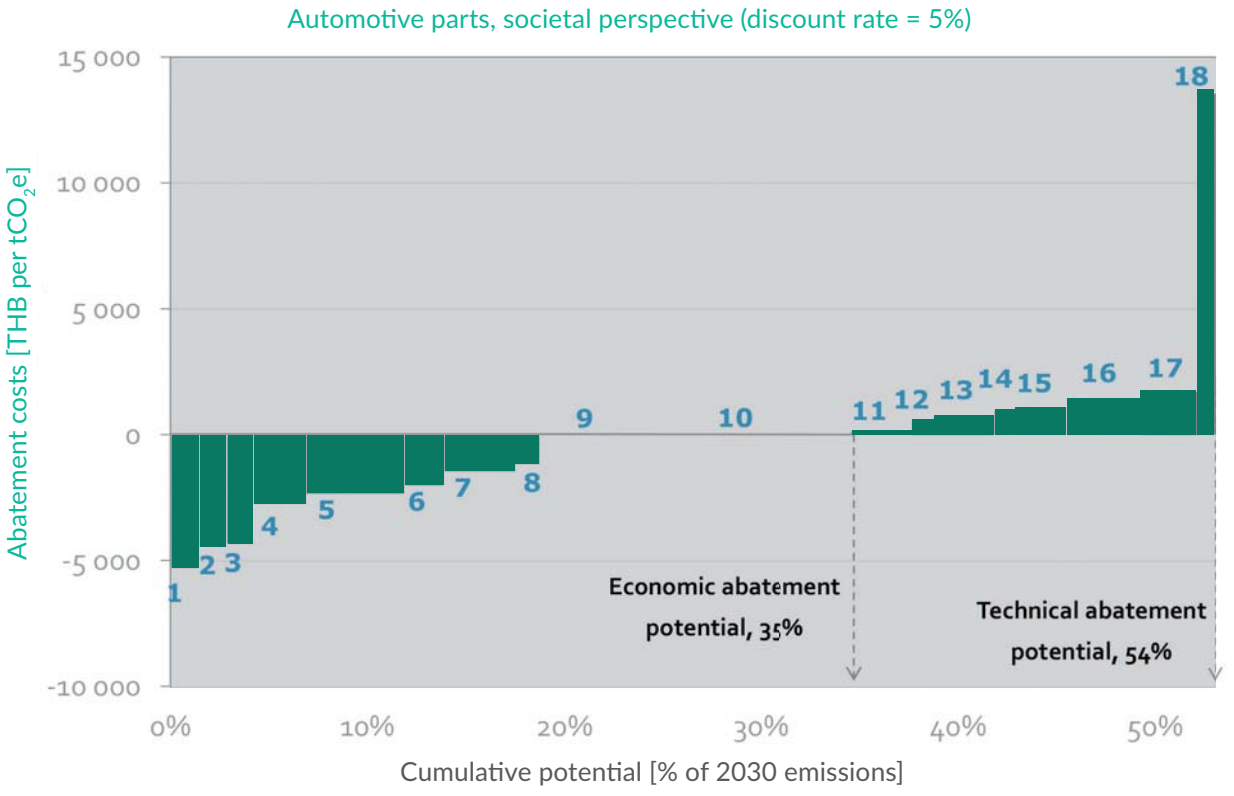
Many cost-effective abatement measures have been identified for the automotive parts industry, leading to a technical potential of 54% and an economic potential, both from a societal and private perspective, of 35% reduction in 2030. The key focus area in this sector is the improvement of energy efficiency by the implementation of cross-cutting measures, like high efficiency motors (#4), variable speed drives (#7) and the avoidance of leakage in compressed air systems (#11 and 17). Management and organization measures are among the most effective in terms of emissions reduction, for example the single largest potentials arising from ensuring equipment is managed to run at maximum efficiency as continuously as possible (#10) and from managing air systems and boilers (#5). While capital investment decisions in boilers (#1) and heat exchangers (#3 & 15) can also have significant potential.

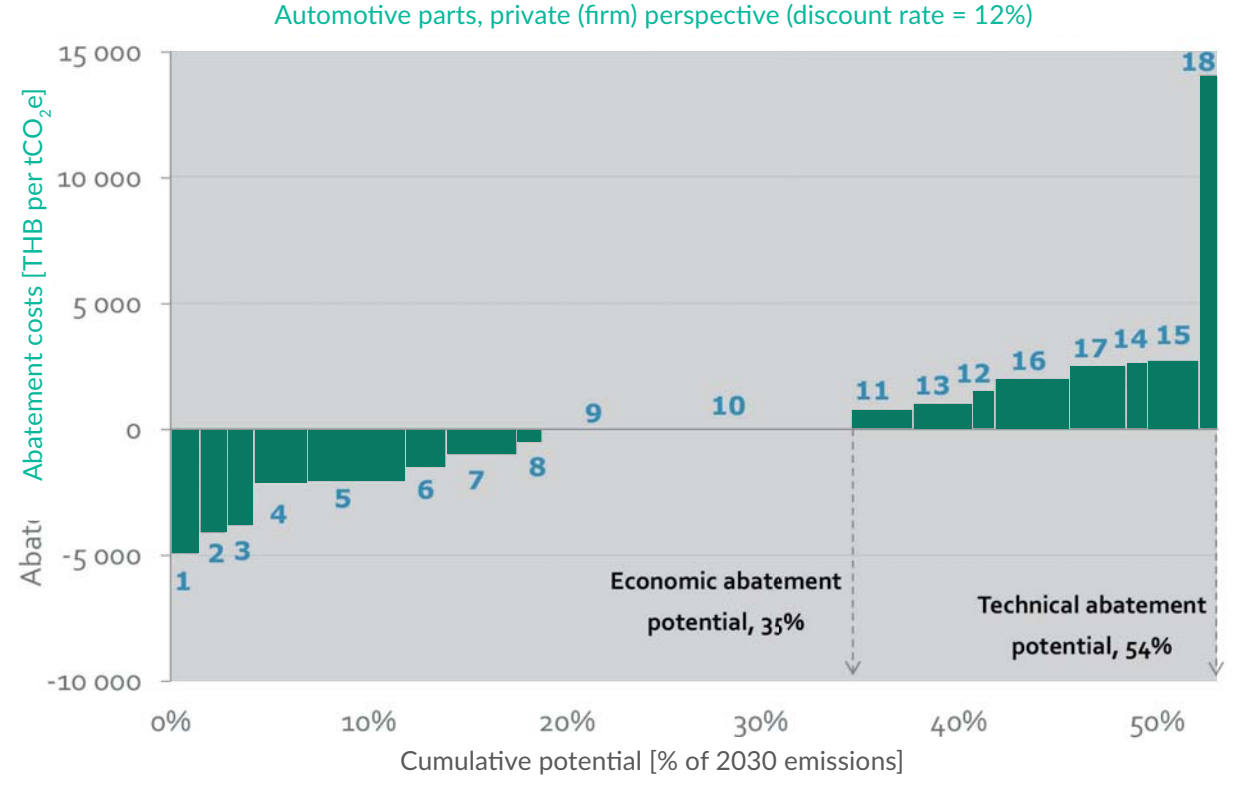
Table 5-2: Overview of the abatement measures in the automotive parts industry.

#	Category	Measure	Abatement cost with 5% discount rate (THB/tCO_2e)	Abatement cost with 12% discount rate (THB/tCO_2e)
1	Energy Efficiency	Size boilers to suit production demands	- 5,299	- 4,973
2	Energy Efficiency	Insulation and temperature control rinsing tanks	- 4,459	- 4,139
3	Energy Efficiency	Heat exchangers	- 4,339	- 3,849
4	Energy Efficiency	Efficient motors	- 2,753	- 2,153
5	Energy Efficiency	Management air systems and boilers	- 2,329	- 2,083
6	Energy Efficiency	Efficient lighting	- 2,032	- 1,525
7	Energy Efficiency	Variable speed drives (VSD)	- 1,439	- 1,031
8	Energy Efficiency	Improve efficiency drying processes	- 1,184	- 545
9	Energy Efficiency	Improve storage logistics	0	0
10	Energy Efficiency	Run equipment at maximum efficiency and as continuously as possible	0	0
11	Energy Efficiency	Reducing supply pressure of compressed air	187	799
12	Energy Efficiency	Fit shut off dampers to retain heat after ovens are switched off.	579	1,537
13	Energy Efficiency	Maintain filters (e.g. mist eliminators or bag house filters)	731	1,039
14	Energy Efficiency	Heat recovery system to capture blow down heat.	1,015	2,647
15	Energy Efficiency	Heat exchangers on furnaces and boiler exhausts	1,119	2,752
16	Energy Efficiency	More efficient spraying processes	1,456	2,025
17	Energy Efficiency	Improved efficiency of compressed air systems.	1,713	2,528
18	Energy Efficiency	Improved boiler maintenance.	13,587	14,068

Note: Green shading (cost-effective), blue shading (modest cost), orange shading (high cost)

Figure 5 2: MAC-curves for the automotive parts industry.



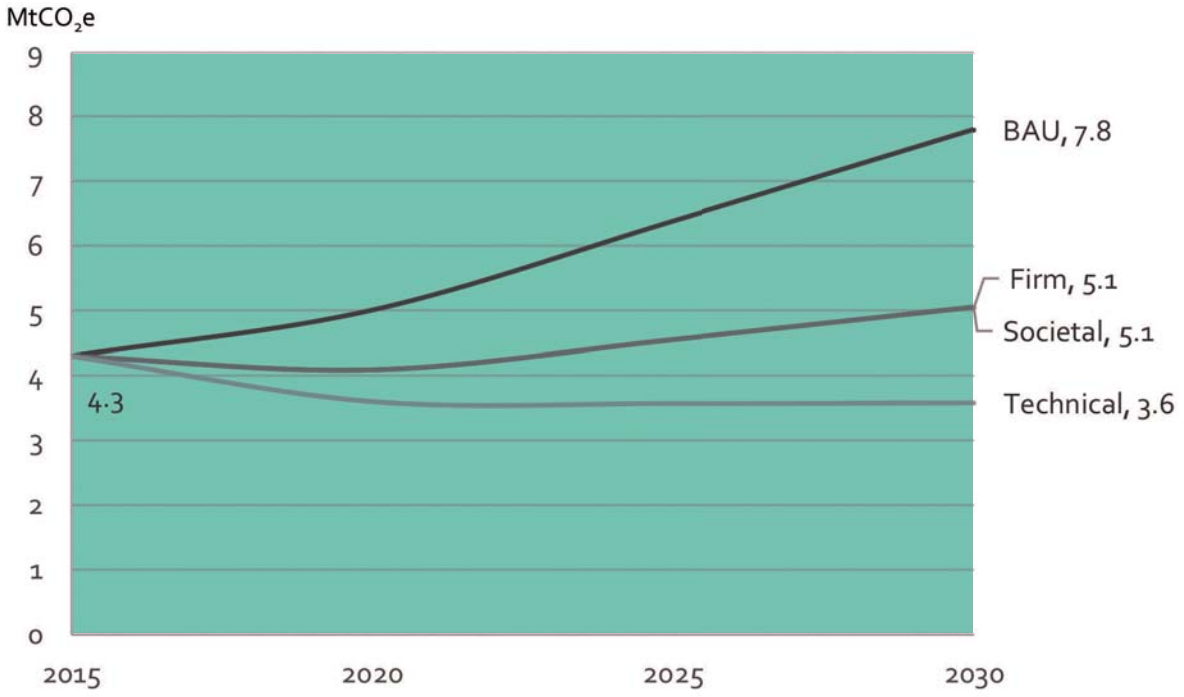


5.2 Emissions Projection and Abatement Scenarios

Business-as-usual scenario

Baseline automotive parts sub-sector emissions are estimated at 4.3 $MtCO_2e$ in 2015, increasing to 7.8 $MtCO_2e$ in 2030 (+81%) and to 11.0 $MtCO_2e$ by 2050 (+159%), see Figure 5-3. A bottom-up approach was used to estimate the emissions in the base year 2015. Due to the heterogeneity of the sector it was not possible to scope down the approach to a few well-defined products. Furthermore, the activities in this sectorv sit in diverse economic sectors, which complicates using national statistics to a large extent.

Figure 5-3: Emission projection for the automotive sector



The bottom-up estimate relies on a decomposition of the specific energy consumption to produce a vehicle into the most energy-intensive processes for parts manufacture and assembly. For this, a 2010 study on energy consumption of vehicle and component manufacturing is used (Sullivan, Burnham, & Wang, 2010). This study provides a bottom-up estimation of specific energy consumption of about 34 Gigajoules (GJ) for a generic 1,532 kg vehicle. Thai vehicle production in 2015 is estimated at 1.75 million vehicles. Multiplying the energy consumption per car by the number of cars produced results in a total automotive energy consumption of nearly 2,000 ktoe. Considering that about 81% of vehicle manufacturing energy consumption is allocated to automotive parts manufacturing (Sullivan, Burnham, & Wang, 2010), and assuming a share of Thai parts in vehicles of 50% and a ratio of domestic use/export of Thai produced parts of 0.5 (to account for energy use associated with the export of Thailand produced parts), the Thai automotive parts energy consumption in 2010 is estimated to be 1,158 ktoe. By using the average fuel mix of the sector and the associated GHG emissions factors, the resulting GHG emissions in the base year 2015 are estimated at 4.3 $MtCO_2e$.

It is acknowledged that this baseline emission estimate relies on several assumptions, for example the share of Thailand produced automotive parts in Thailand produced vehicles and the share of Thai produced parts sent for export, which could not be soundly validated. The emission estimate is therefore uncertain and should be treated as such.

The automotive parts sector is projected to grow its production at an annual rate of 5.2% between 2016 and 2030. This rate is equal to the observed average annual production growth rate for the sub-sector for the period 2005-2014, the years 2000-2004 were excluded as these included exceptionally high production growth rates not anticipated to be repeated in future. Post 2030 the growth rate projection is lowered to 2.4% reflecting the wider economic trends.

Technical abatement potential

The technical abatement potential found in this study is 54% lower than the BAU emissions in 2030. This is the total potential for energy-related emissions, both direct and indirect. In this case indirect emissions are caused by the power sector. By improving the electricity efficiency of the operations, less electricity has to be generated. Effectively, this will reduce the peak load in electricity demand. The avoided emissions are therefore calculated with the emission factor of the marginal unit and not with the average emission factor of the grid.

The technical abatement potential is based on the measures that could be identified in this study. It might be that measures are overlooked, or that new technologies will emerge that cannot be foreseen. The technical potential should therefore be seen as a minimum.

The MAC-curve shows that one of the identified measures (#18) has particularly high abatement costs, but most measures are either cost-effective or can be regarded to have relatively modest costs. In general there is not much literature or case study evidence on expensive measures, simply because they are not implemented or, for example solar PV, have very low potential and/or high costs in the sub-sector. Expensive measures also include innovative measures that are still at the beginning of the development cycle. This study was not able to pinpoint innovations in the automotive parts sub-sector that would also result in emission reduction in the longer run. That is not to say that these are not conceivable. Therefore, it is still recommended to support R&D focused on making the production processes more efficient and to identify new measures.

Economic potential – societal perspective

The economic (cost-effective) abatement potential from a societal perspective is 35% of the BAU emissions in 2030 (see also Figure 5-2).

Economic potential – firm perspective

If the discount rate is raised from 5% (societal rate) to 12% (private [firm] rate) to reflect the shorter time period and higher preferred rate of return demanded by private firms, there is no change in the economic abatement potential (see Figure 5-2), which remains at 35%. The marginal abatement costs are affected by the change, with all measures affected to some extent, reflected by a 'raising' of the MAC-curve. The change is most clearly reflected in a change in the order of the measures, for example measures #13, 16 and 17 become relatively more attractive in this perspective, while measures #12, 14 & 15 relatively less so.

Sensitivity of economic abatement potential

Taking the data and calculation uncertainties into account it is useful also to look at measures with costs relatively close to 0 THB/tCO_2e, as this gives an indication of the sensitivity of the abatement potential to different costs. The measures with costs relatively close to zero per tCO_2e in the automotive parts sector, for example measures #8, 9, 10 and 11, represent around 20% of the total abatement potential. The sensitivity of the economic abatement potential is therefore relatively high and warrants further investigation and better data on costs to assure that any targets can be set at a reasonable level.

5.3 Policies and Actions

The previous sub-section has demonstrated that significant emissions abatement potential has been identified in the automotive parts sub-sector, albeit with uncertainties into the cost-effective potential. The identified abatement measures have a range of costs with measures that can be classified as either cost effective, and those which have modest or high costs. This sub-section outlines key policies and actions that could be taken within the LTA framework and which address the barriers identified in the automotive parts sub-sector, with a focus on the barriers grouped under a lack of knowledge of measures, a lack of understanding/ vision and financial support.

Policies and Actions to Unlock Abatement Potential

Table 5-3 gives an overview of policies and actions aimed at unlocking the abatement potential in the automotive parts sub-sector.

Long-term agreement

There are multiple actions that can contribute directly towards the development, agreement and implementation of an LTA.

To get the data right it is important and proposed to:

- Encourage greater cooperation and compliance from the sector in GHG relevant data gathering the Thailand energy management program already provides a good entry point for this. The GIZ study (see textbox 5.1) already provides some useful context and background data for the sector but there remain many gaps and room for uncertainties, for example on the assumptions identified in section 5.2, to be addressed.
- Once the data is gathered, it will be necessary to aggregate and analyze this effectively – by implementing a central database, possibly managed by TGO, the data can be used to improve the quality of the GHG footprint of the sub-sector and provide a basis for perfomance-based monitoring going forward, which will be an important part of the LTA implementation. This data can also be used in the longer term to support future policy through sector performance benchmarking.
- Improve the training and funding of government staff at the relevant agencies, as getting the data right can only be successful if the technical understanding and resources are available. This helps to address the key knowledge barriers that exist.

Textbox 5.1: GIZ - Greening Supply Chains in the Thai Auto and Automotive Parts Industries

The project Greening Supply Chains in the Thai Auto and Automotive Parts Industries was funded by European Union and implemented by consortium partners consisting of German International Cooperation (GIZ), Thailand Automotive Institute (TAI), SME Bank, The Federation of Thai Industries (FTI) and Center for Sustainable Consumption and Production (CSCP). The overall objective of project is to improve sustainable production of SMEs in the Thai auto and automotive parts supply chains. The four main work packages are implemented as per following;

WP1: improve productivity and environmental performance,
WP2: improve access to financial services to SMEs,
WP3: strengthen sustainable consumption and production (SCP) related services and networks and,
WP4: disseminate good practices and policy recommendations

The project has successfully produced results in term of increasing productivity, environmental and energy management performance with active participation of 500 Thai SMEs as well as stakeholder such as big car maker, tier 1 company, association, Ministry of Industry, Ministry of Energy and service providers. To ensure the continuation and exit strategy of the action, therefore project best practices and lesson learned shall be transferred and encourage this industry more widely adopt sustainable production practice in improving their business performance.

To engage the sector, it is important and proposed to:

- Engage directly with the sub-sector, given the high number of firms in the sub-sector this should be most effectively achieved through the most relevant sector association(s), in this case the Thai Autoparts Manufacturers Association (TAPMA) offer a useful entry point. Disseminating the findings of this work can help to initiate a discussion. This is a crucial point to also evaluate how best to engage with the sub-sector given the heterogeneous nature of the products and processes which are included. It is likely to be more feasible to sub-divide the sector into key products/processes and agree separate LTAs with each.
- Taking this further working group(s) on sustainable production for each agreed sub-sector should be encouraged, this would become the main counterpart in discussions and also fulfil other roles relevant to data and implementation. The working group(s) should be encouraged to propose their own emissions reduction roadmap and to make a needs assessment of what is required to achieve it. This can form the starting point for the negotiation of the LTA(s) with the sector(s).

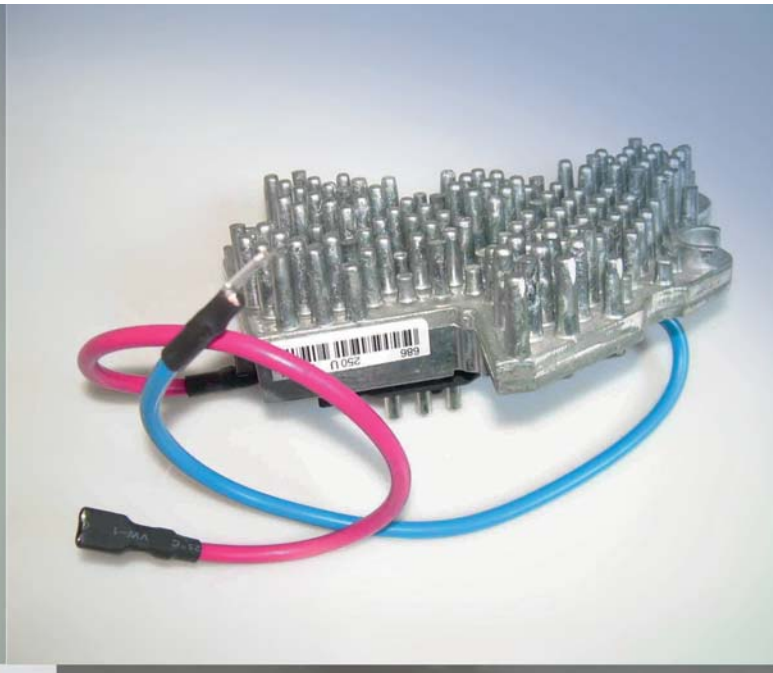


Table 5-3: Policy and actions for the automotive parts industry

Solution pathway	Addresses objective(s)	Actions per LTA framework phase			Addresses barriers
		Phase I (Short Term)	Phase II (Medium Term)	Phase III (Long Term)	
LTA	Generating sector engagement and interest LTA	Create sub-sector working group on sustainable production, starting point with the Thai Automotive Parts Manufacturing Association (TAPMA). Evaluate with sub-sector if multiple LTAs per main process groups are better than single LTA. Invite the sector(s) to develop their own low carbon roadmap and needs assessment (building on GIZ work) which identifies the possibilities and constraints of GHG emission abatement.	Sub-sector(s) and government negotiate and reach LTAs for GHG reduction in the sector(s).	Monitor LTA, take action as appropriate. Benchmarking of specific energy consumption in the sector. International benchmarking of sector to guide policy and support competitiveness.	Firms lack of knowledge Firms lack of vision/understanding
		G P F I A	G P F I A	G P F I A	
LTA	Getting the data right Implementation by firms	Encourage greater adoption of (and compliance with) Thailand EM Programme to improve understanding of energy use and reduction options. Implement no regret EM system processes (i.e. MACC measure #5).	Evaluate and improve energy management system. Replace equipment with more energy efficient equipment when replacement is needed.	Best practice energy management system, energy use key criteria in business decisions.	Firms lack of knowledge (imperfect information) Firms lack of vision/understanding (energy only compliance issue,
		G P F I A	G P F I A	G P F I A	
LTA	Getting the data right	Aggregate data and collect these in central database, combine with other data sources to produce improved sector GHG footprint and start performance-based monitoring.	Continue performance-based monitoring.	Continue performance-based monitoring.	Firms lack of knowledge (imperfect information) Firms lack of vision/understanding (poor management
		G P F I A	G P F I A	G P F I A	
LTA	Getting the data right	Improve training and funding for relevant govt. staff, subjects to include technical measures, impacts, global GHG context.	Continue training of staff	Continue training of staff	Lack of knowledge (lack of relevant skills among staff)
		G P F I A	G P F I A	G P F I A	
LTA	Implementation	Through sector network share knowledge, focus on dissemination of best practice in energy efficient processes especially storage logistics (#9) and maximum efficiency of equipment (#10). Use GIZ work and audits as a basis. Government consider re-introducing customer support service for industry.	Continue to share relevant knowledge. Implement customer support service.	Continue to share relevant knowledge	Firms lack of knowledge (perceived high costs/risks)
		G P F I A	G P F I A	G P F I A	
LTA	Implementation	Implement simple, low capital cost equipment measures (#1, 2, 4, 5, 6 & 8)	Implement cost-effective, but more capital intensive measures (see MACC measures #3, 7, 9, 10).	Implement other measures (see MACC measure #11, 12, 13, 14, 15, 16 & 17)	Firms lack of knowledge (perceived high costs/risks)
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.	Review the energy efficiency labelling, MEPS, HEPS requirements for equipment/appliances crucial for sector, i.e. motors and VSDs, lighting, boilers, compressed air systems, dryers.	Modify requirements to support energy efficiency improvement in sector.	Review standards periodically and increase minimum requirements, revise label grades to provide continuing incentives.	Firms lack of knowledge
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.		Accredit training providers to set up training courses for staff of companies to learn how to improve management of processes, and to implement and operate sustainable technologies.	Introduce relevant modules and information to technical and vocational education to train students on sustainable technologies. Sectors should contribute to these.	Firms lack of knowledge (lack of relevant skills among staff) Firms lack of vision/understanding
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.	Encourage firms to participate in Thailand Energy Awards scheme	Consider creation of sector category within Thailand Energy Awards scheme.	Evaluate success of awards in stimulating competition in sector, how firms compare internationally. Use to promote industry internationally.	Firms lack of vision/understanding (lack of prestige)
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.	Increase visibility of climate change in national policy discourse. Communicate need for increased climate commitments in future, discussion on national targets and role of industry.	Ensure sector targets are in line with policy commitments, i.e. INDC, RE, EE strategies.	Ensure sector targets are in line with policy commitments, i.e. INDC, RE, EE strategies.	Firms lack of vision/understanding (poor understanding of importance of climate change)
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.	Develop integrated approach to climate change in general and designate responsible agency for sector engagement.	Evaluate current set of financial support schemes (revolving fund, soft loans, ESCO fund, tax incentives, direct subsidies) on effectiveness for this sector. Revise as appropriate. Offer specific incentives to firms participating in the LTA.	Evaluate and assess need to further incentivise investments in abatement measures by e.g. implementing a carbon pricing scheme, emission trading or carbon/energy tax; and/or energy price (subsidy) reform.	High operating/capital costs and/or risks Lack of government (financial) support
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.		Attract national and international financing from e.g. development banks to support implementation of sustainable technologies.	Attract national and international financing from e.g. development banks to support implementation of sustainable technologies.	High operating/capital costs and/or risks Lack of government (financial) support
		G P F I A	G P F I A	G P F I A	
Supporting measure	Supporting mechanisms from govt.		Set up targeted R&D programmes aimed at improving technologies and processes specific for Thai industry, i.e. (#18).	Fund deployment and pilot programmes of these technologies.	High operating/capital costs and/or risks Lack of government (R&D) support
		G P F I A	G P F I A	G P F I A	

Key: G=Government, P=Private sector, F=Financial sector, I=International community, A=Academia education

To implement the LTAs it is important and proposed to:

- Build on the sector engagement to actually negotiate and agree LTAs, which include targets, define actions for both the sectors and government and which also agree the monitoring arrangements going forward.
- It is important also that there are review and decision moments/timeframes built into the LTA process so that if progress is unsatisfactory appropriate action can be taken by the Government in the longer term.
- Encourage knowledge sharing in the sub-sector through the working group and consider a revived customer support service to disseminate knowledge. These actions are important as companies are not always aware of the existence of specific measures, or if they are aware of measures only have a limited understanding of the costs and benefits. This action can help to address this issue. In the case of the automotive parts sub-sector(s) there are a range of important energy efficiency measures where best practice should be shared, such as with heat exchangers, boilers, compressed air systems, motors and drives. The information can become very specific; for example, sharing knowledge on sub-sector specific energy efficiency and abatement measures, example advanced drying technologies (#8) or the potential for heat exchangers in recovering waste heat (#3). The GIZ study (see textbox 5-1) can also be instructive in this area.
- There are a range of relatively low-hanging fruit measures that can be taken within the sector, including measures #1, 2, 4, 5, 6 and 8, which already provide significant emissions reduction potential and many of which can be continually developed over time. The actions on training and data proposed above can improve the pressure and incentives for firms to do this.
- Implementation of other measures that are cost effective, but have moderate capital costs (#3 & 7) or are borderline cost-effective (#9 & 10), can be done in the medium term. In the long term, there remains significant abatement potential through measures with modest abatement costs (#11, 12, 13, 14, 15, 16 & 17). Both these sets of measures are important in the automotive parts sub-sector where 19% of the 54% technical abatement potential has a net marginal abatement cost.

Supporting measures and actions

It is crucial that the government and its agencies provide support to the success of the LTAs through its broader policies and actions and also through specific actions. A considerable part of the policy framework and supporting instruments are already in place and effective, although there also remains scope for improvement and innovation. The following actions were identified and proposed:

- Improve the information connected to equipment which the sub-sector purchases to incentivize more efficient choices can mitigate the information deficit in decision making. Energy efficiency policies like the current MEPS, HEPS and Green Labels, should be reviewed and their requirements enhanced to improve the efficiency of the appliances that industry use and provide easy to understand guidance on the energy efficiency. Relevant for the automotive parts sector is that these schemes are expanded to include relevant equipment, particularly motors, variable speed drives, air compression systems, dryers and boilers. In the longer term more stringent minimum mandatory requirements for these could be implemented.
- Supporting capacity building is also important here, the government can act to improve the training and education situation, either directly or through the accreditation of qualified trainers in the appropriate areas of energy management, energy efficiency and GHG emission reduction strategies. The GIZ program in the automotive sector (see textbox 5-1), already indicates how trained energy auditors can contribute to improved energy efficiency performance, continuing and expanding these activities in the sector can also help to address this barrier.
- The Thailand Energy Awards scheme can be a useful vehicle to address management reluctance to act on GHG emission reduction, by attracting prestige and good publicity this can provide a strong incentive to firms. Examining how this could be implemented at a sector level within the framework of the LTA could be important, this could for example include recognising significant achievements in energy efficiency or emissions abatement, i.e. best performer, most improved, most innovative.
- Ensuring higher visibility and coherence of government policy on climate change will also help. The commitments in the INDC are an important step, this can also help to engage with industry on the discussion of what their role and contribution should be. Furthermore it remains important to encourage and convince industry of the seriousness and urgency of the problem and how efforts will most likely need to intensify over time, as will the contribution that industry will need to make.

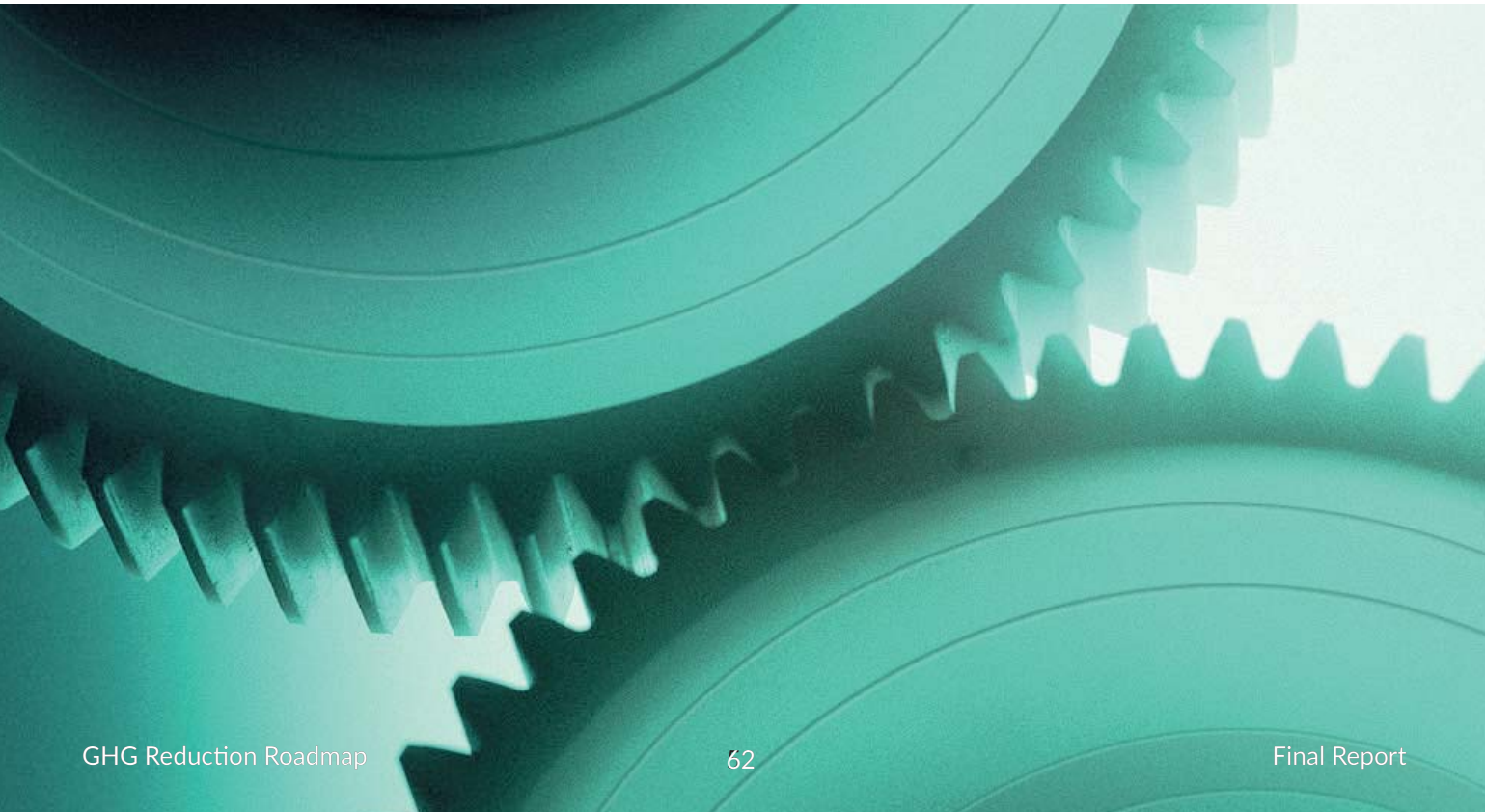
- Measures in the automotive parts sector tend to only have moderate capital cost requirements, even so access to finance can remain a barrier for firms to adopt measures. This issue is particularly important for measures that are not cost effective from the firm perspective but where if the government ensures that financial support is available and known to firms then firms could adopt these measures. The existing policies and schemes (e.g. revolving fund,ESCOs, direct subsidies) and their applicability to sub-sector should be reviewed. It could also be considered, subject to being non-discriminatory, to directly link particular financial incentives or benefits, i.e. lower interest rates, tax exemptions/reductions; to participation in the LTA.
- In the long term wider policy reform particularly in the area of energy and/or carbon prices can provide a significant boost to the business case for energy efficiency measures, increasing the value of energy savings and reducing cost exposure to carbon prices, incentivising firms to invest.
- Finally, for the most important emissions sources in the sub-sector, i.e. heat, compressed air and drying processes, the Government should support research, development and deployment programs. These should develop and demonstrate new technologies in the industry in Thailand, helping to create best practice cases and to reduce costs.

5.4 Scope for GHG Emission Reduction Ambitions

Setting an ambition level for sector emissions abatement is a complex discussion. The results of this work can be suggestive of appropriate and/or realistic ambition levels for the sub-sector, but the MAC-curve and scenario projections also contain some (sometimes significant) assumptions and uncertainties. They cannot accommodate some of the very specific and practical issues that may limit abatement potential, which are particularly relevant to a sector as heterogeneous as the automotive sector.

Setting an ambition level also needs to take into account the economic effects on the sector itself and the wider socio-economic impacts for the economy. These impacts were assessed as part of this work, in summary, for the automotive parts sector they suggest:

- The impact of implementing cost-effective abatement measures will be positive for the sub-sector GVA, exports and employment
- Implementing non-cost effective measures will create some negative impact on sub-sector outcomes, but these are likely to be very low, =i.e. -0.05% or less, even if the full technical potential was implemented.
- These results are mirrored at the wider national economy level, cost-effective emissions abatement is expected to also result in positive overall socio-economic impacts and implementing more

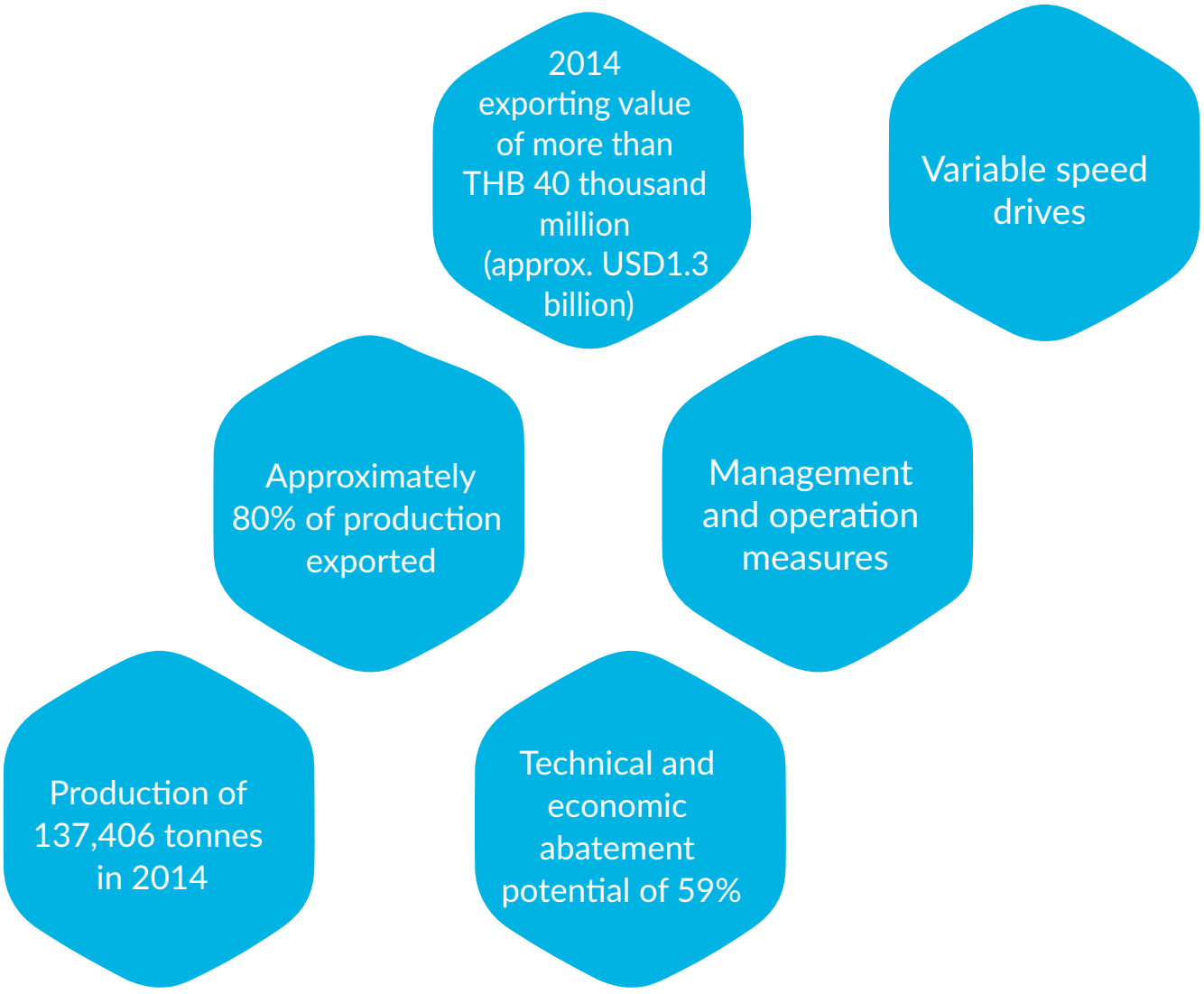


costly measures will have minimal (negative) impacts on the wider economy.

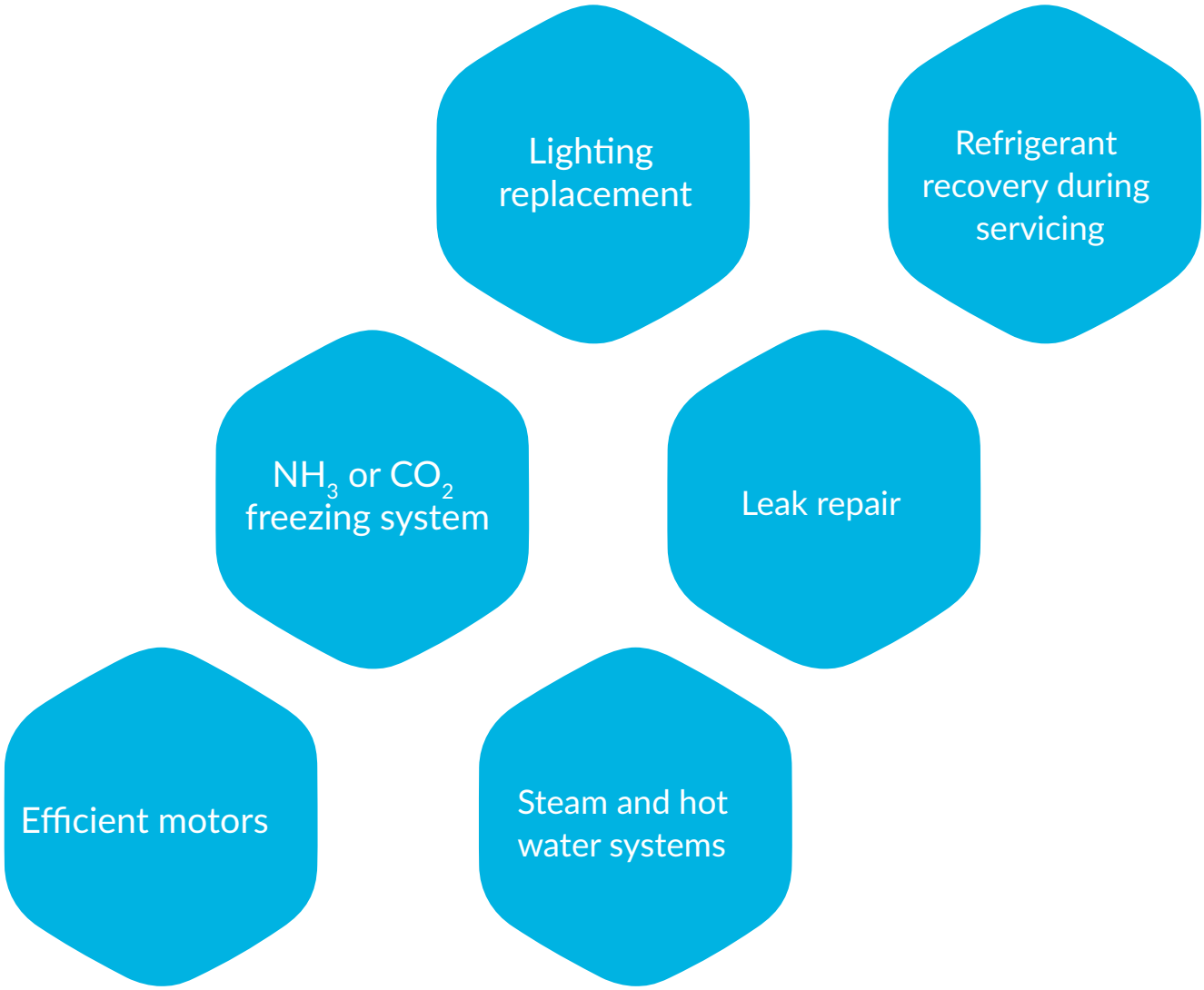
The Technical and Economic Analysis Report contains the more detailed modeling assessment of the impact of emissions abatement on the automotive parts sector.

The societal and firm perspective scenarios elaborated identical emission abatement potential of 35%, compared to the full technical potential of 54%, as the measures are not significantly affected by discount rate changes. Taking the various information into account we suggest that:

- Incentivising the achievement of cost-effective abatement should bring both emissions and economic benefits for the sub-sector and wider economy and is to be recommended.
- This suggests potential for up to 35% emissions reduction in the sub-sector, yet this range may not be a realistic target due to:
  - The difficulties in achieving the full potential for each measure, there can be real practical reasons why an assessed potential may not be possible. For example, while the costs are assessed at the average level, these will not be applied to all firms in the same way, and some cost-effective measures may not be cost-effective for part of the sub-sector;
  - The sensitivity analysis suggesting that up to 20% of the abatement potential is close to the cost-effective limit, and relatively small changes in assumptions could lead to higher or lower cost-effective potential. Further research into costs and potential would help to clarify the situation and realistic cost-effective emission reduction potential.
- Any target setting should be the outcome of a political or negotiation process between the various stakeholders – we propose the LTA framework for this purpose – any target should also align with the national target of 20% emissions reductions (or 25% with international support), as stated in the Thailand INDC commitment. Based on the MAC-curve analysis the sector can cost-effectively achieve more than the INDC targets.
- This work can already be used as a basic to begin a focused discussion with the automotive parts sub-sector towards an overarching LTA (or product/process specific LTAs) and contribute to starting to address the questions of what is achievable and the continuing and additional policies and actions needed.
- Even if an LTA is not possible, the suggested supporting policies and actions will incentivize emissions abatement in the sector and should be pursued, particularly those that remove barriers to the adoption of cost-effective measures.
- Revisiting this roadmap periodically is important to ensure it remains relevant to the sub-sector, indeed as part of the LTA framework the automotive parts sub-sector could take ownership and further develop this roadmap.



GHG Reduction Roadmap for the Frozen Seafood Industry


Lighting replacement
Refrigerant recovery during servicing
NH_3 or CO_2 freezing system
Leak repair
Efficient motors
Steam and hot water systems

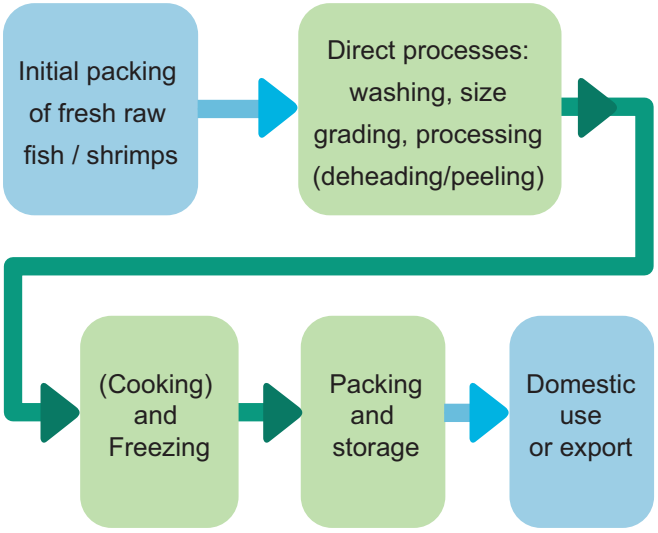
6. GHG Reduction Roadmap for the Frozen Seafood Industry

6.1 Technical-economic Emissions Abatement Potential

Sector overview

Frozen seafood is an important export product for Thailand and is part of the frozen food sector. The majority of frozen seafood consists of fish, shrimp and squid production, therefore the focus of the analysis and the roadmap is on these three products. Although fish, shrimp and squid processing has some differences, these processes have a lot of equipment and technology in common. Raw fish, shrimp and squid are transported to the processing factory, often from fisheries in Myanmar or Indonesia, or from farms in Thailand. In general the following processes in the factory can be distinguished: washing, size grading, processing (deheading/peeling), cooking (if any), freezing, packing and storing. The production process is indicated in Figure 6-1, with the green areas indicating the scope of the analysis.

Figure 6-1: Production process of frozen seafood. In green the processing steps from a seafood processing factory. Blue arrows indicate transport outside of the factory



The most energy intensive process, although wide variations can be found, is the freezing of the raw or cooked processed seafood. Freezing requires electricity, resulting in indirect emissions of GHG. Furthermore, refrigerants are used which have per weight a very high global warming potential, these can be leaked to the atmosphere during filling, operation and disposal. Other energy intensive processes are cold storage and ice making. In the frozen seafood sector a considerable amount of wastewater is discharged, depending on the type of fish and the type of processing. Treating this wastewater may result in emissions, but these emissions are not thought to be significant (AIT, 2007) and could not be quantified in this work. This may be a useful area for future research.

Key facts and figures of the frozen seafood sub-sector in Thailand are provided in Table 6-1 below:

Table 6-1: Facts and figures of the frozen seafood industry in Thailand

Parameter	Value	Source
Number of companies	49	(OIE, 2015)
Production in 2014	137,406 tonnes of which: 71,471 tonnes of frozen fish 40,673 tonnes of frozen shrimp 25,262 tonnes of frozen squid	IE, 2015)
Production capacity	760,991 tonnes	
Total frozen seafood exports in 2014	~80% of production	(OIE, 2015)
Labor (employment)	N/A	
Export value in 2014	THB 41,856 million (approx. USD 1.3 billion)	(OIE, 2015)

Note: more comprehensive reviews of sub-sector characteristics are provided in the Emissions Projection and Technical and Economic Analysis Reports.

Emission abatement options

Table 6-2 below provides an overview of the emissions abatement options in the frozen seafood industry. For a detailed description of the options please refer to the Technical and Economic Analysis Report. The number of the options corresponds to the position in the MAC-curves in Figure 6-2 below.

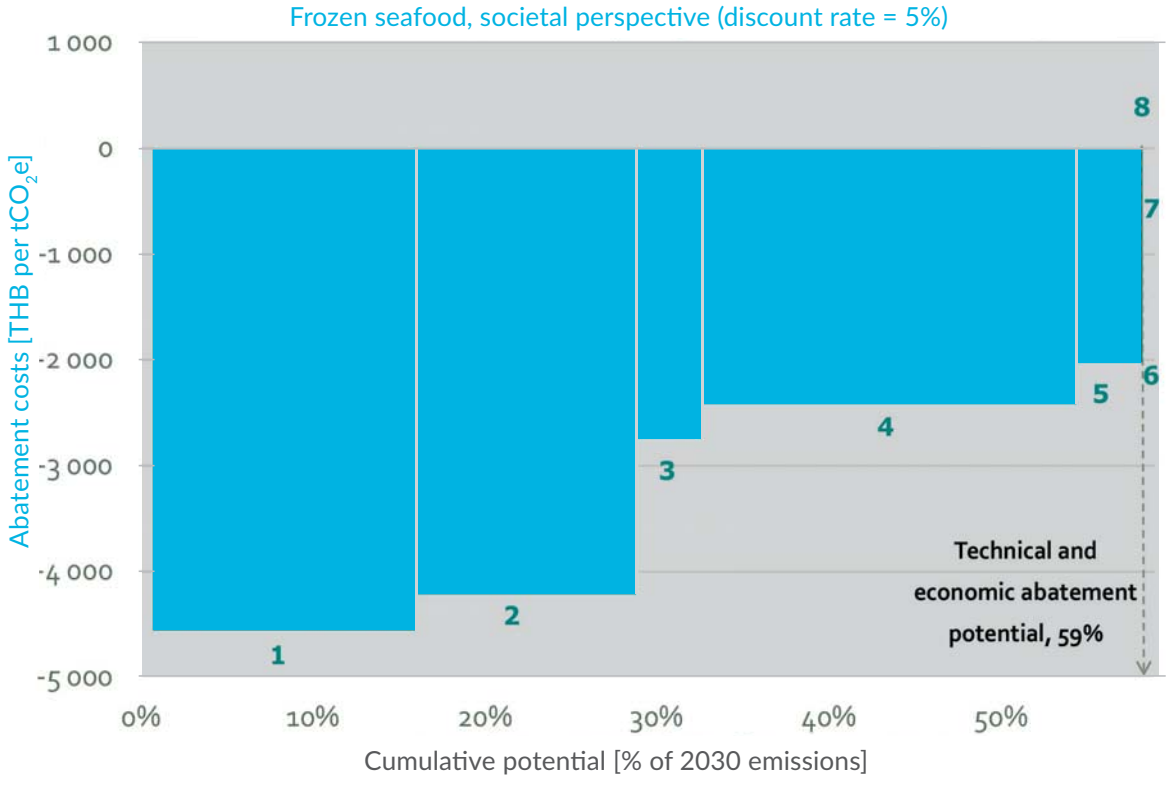
Emissions abatement in the frozen seafood sector is assessed to be highly cost-effective, with almost all measures of being cost-effective. The largest abatement potential in this sector can be found in switching to NH_3 or CO_2 freezing systems (#4), the introduction of better energy management and operational measures (#1) and the use of variable speed drives (#2). Other more generic energy efficiency measures can also have an impact. Process emissions from refrigerant leakage were assessed to be very low in total, accordingly the abatement potential for these measures (#7 & 8) is also very low.

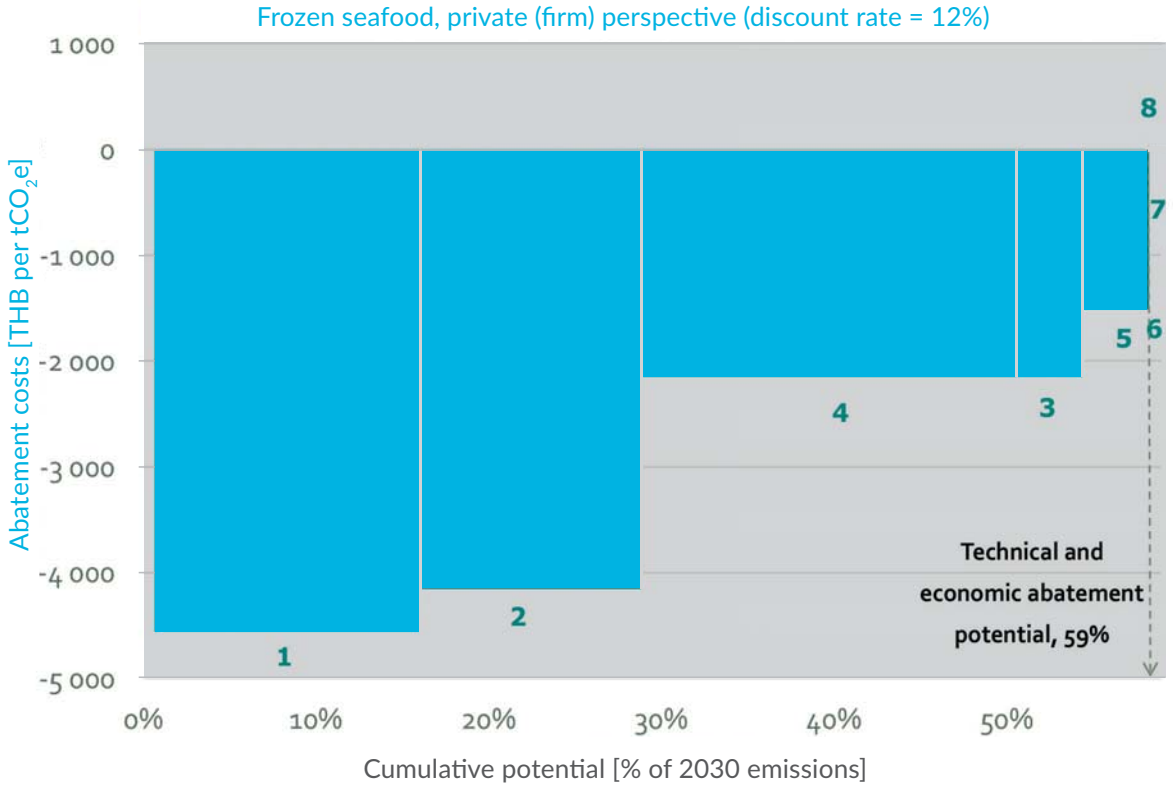
Table 6-2: Overview of emissions abatement measures and marginal abatement cost curves for the frozen seafood sub-sector.

#	Category	Measure	Abatement cost with 5% discount rate (THB/tCO_2e)	Abatement cost with 12% discount rate (THB/tCO_2e)
1	Energy Efficiency	Management and operation measures	- 4,564	- 4,564
2	Energy Efficiency	VSDs	- 4,223	- 4,162
3	Energy Efficiency	Efficient motors	- 2,753	- 2,153
4	Energy Efficiency Non-energy GHG emissions	NH3 or CO2 freezing system	- 2,425	- 2,155
5	Energy efficiency	Lighting replacement	- 2,032	- 1,525
6	Energy efficiency	Steam and hot water systems	- 1,096	- 1,096
7	Non-energy GHG emissions	Leak repair	- 56	- 51
8	Non-energy GHG emissions	Refrigerant recovery during servicing	257	343

Note: Green shading (cost-effective), blue shading (modest cost), orange shading (high cost)

Figure 6-2: MAC-curves for the frozen seafood industry



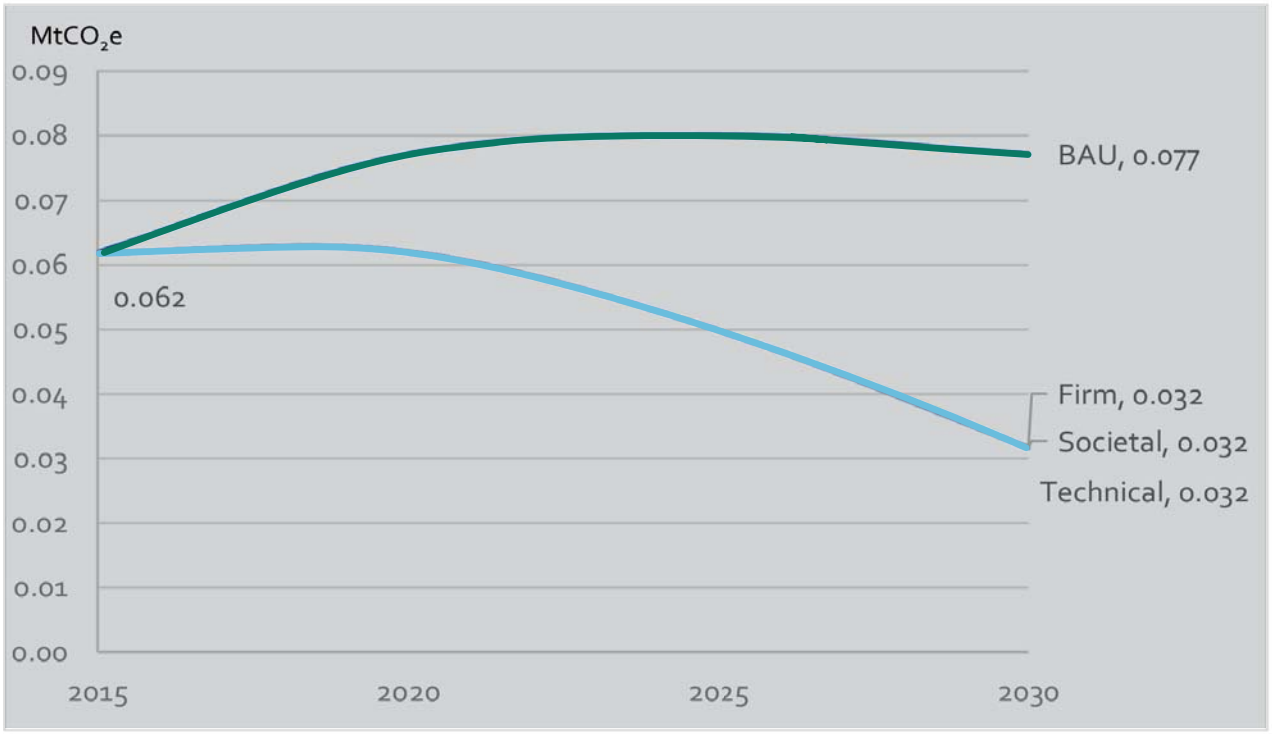


6.2 Emissions Projection and Abatement Scenarios

Business-as-usual scenario

Baseline frozen seafood sub-sector emissions are estimated at 0.062 $MtCO_2e$ in 2015, increasing to 0.077 $MtCO_2e$ in 2030 (+25%), but then declining to 0.068 $MtCO_2e$ by 2050 (still an increase of +9% on 2015), see Figure 6-3. Emissions are projected to decline after 2030 as growth of the sector slows and also due to an assumption of continued decline in the emissions factor of electricity over the same period.

Figure 6-3: Emission projection for the frozen seafood sector



A bottom-up approach was used to estimate the emissions in the base year 2015 and is composed of estimates of energy-related and process emissions.

For the bottom-up estimation, Thai specific data was used for energy consumption per tonne product (Piyawan & Yoncharoen, 2013). The specific electricity and diesel consumption per tonne product was then summed to calculate the total specific energy consumption of 3.8 GJ/tonne per product. The specific energy consumption per tonne was subsequently multiplied by the frozen seafood production in Thailand which resulted in a total frozen seafood sector energy consumption of 12 ktoe.

To estimate the sector's energy related emissions, the fuel mix is first calculated from the specific electricity and diesel consumption. Electricity accounts for 91% of the energy supply, and the remaining 9% is supplied by diesel. Multiplying the sector's energy consumption with the respective emission factors results in an emissions estimate of 61.4 $ktCO_2e$

The process emissions from the frozen seafood industry arise from leakage of the refrigerant gases in the cooling systems. The only data found on such emissions was an estimation of refrigerant emissions from industrial refrigeration for 2010 (GIZ, 2013). This source estimated 4,473 tCO_2e total emissions from the industrial refrigeration sector. Assuming that frozen seafood accounts for 15% of this total, this sector emitted 671 tCO_2e in 2010. With the production of frozen fish in Thailand in 2010 of 196 kt, that is a specific emission of 3.42 $kgCO_2e$ per tonne product.

Using this intensity, the refrigerant emissions for 2015 were calculated. The total refrigerant emissions from the frozen seafood sector in 2015 are estimated at 0.56 $ktCO_2e$. This is very low. Therefore, the impact of the assumption stated above (i.e. a 15% share of frozen fish in industrial refrigerant emissions) is very limited.

It is acknowledged that the baseline emission estimate relies on several assumptions and limited case studies. The emission estimate is therefore uncertain and should be treated as such.

The frozen seafood sub-sector is projected to grow its production at an annual rate of 8% between 2015 and 2020 as the sub-sector sees production recover towards peaks achieved prior to recent disease outbreaks, particularly in the shrimp industry, which have contributed to a significant recent decline in production. Following this recovery period sub-sector growth is projected to return to long-run trends with growth of 1.1% between 2021 and 2030 and post 2030 the growth rate projection is lowered further to 0.6% reflecting the wider economic and population trends in Thailand and increasing competition for feedstocks and their sustainability.

Technical abatement potential

The technical abatement potential found in this study is 59% lower than the BAU emissions in 2030. This is the aggregated potential of the potential reductions in energy-related emissions, both direct and indirect, and process-related emissions. Emissions abatement in the sector is primarily indirect as its main emissions arise from electricity use. The key measures in the sector are related to energy efficiency, although three measures to address the (very low total) process emissions were also identified.

The energy efficiency measures such as: switching to NH_3 or CO_2 freezing systems (measure #4), implementing better energy management and operations regimes (#1) and using more efficient motors and drives (#2 & 3); influence the indirect emissions from electricity generation.

The technical abatement potential is based on the measures that could be identified in this study. It might be that measures are overlooked, or that new technologies will emerge that cannot be foreseen. The technical potential should therefore be seen as a minimum estimation of the actual technical potential.
The MAC-curve (see Figure 6-2) shows that the measures are almost exclusively those with negative abatement costs regardless of the perspective. Only a single measure – refrigerant recovery during servicing (#8) - has a positive, although still very low, abatement cost. In general there is not much literature or case study evidence on expensive measures, simply because they are not implemented or, for example solar PV, have very low potential and/or high costs for the sub-sector. Expensive measures can also include innovative measures that are still at the beginning of the development cycle. This study was not able to pinpoint innovations in frozen seafood production that would also result in emission reduction in the longer run. That is not to say that these are not conceivable. Therefore, it is still recommended to support R&D focused on making the production processes more efficient and to identify new measures.

Economic potential – societal perspective

The economic (cost-effective) abatement potential from a societal perspective is 58.9% of the BAU emissions in 2030 (see Figure 6-2).

Economic potential – firm perspective

If the discount rate is raised from 5% (societal rate) to 12% (private [firm] rate) to reflect the shorter time period and higher preferred rate of return demanded by private firms, there is no change in the economic abatement potential (see Figure 6-2), as almost all measures are very cost-effective.

Sensitivity of economic abatement potential

Taking the data and calculation uncertainties into account it is useful also to look at measures with costs relatively close to 0 THB/tCO_2e, as this gives an indication of the sensitivity of the abatement potential to different costs. There are two measures (#7 & 8) in the frozen seafood sector with costs relatively close to zero per tCO_2e but these have a combined abatement potential of only 0.4% of emissions. Therefore the sensitivity of the abatement potential is understood to be relatively low. Major adjustments to the potential are unlikely to occur apart from the identification and addition of new measures, as noted above emissions from wastewater is one area warranting further investigation, and which could change the emissions baseline and abatement potential.

6.3 Policies and Actions

The previous sub-section has demonstrated that relatively significant emissions abatement potential has been identified in the frozen seafood sub-sector, indeed the highest potential of the three sub-sectors for which analysis was carried out. The identified abatement measures are assessed in all but one case to be cost-effective. This sub-section outlines key policies and actions that could be taken within the LTA framework and which address the barriers identified in the frozen seafood sub-sector, with a focus on the barriers grouped under a lack of knowledge of measures and a lack of understanding/vision.

Policies and Actions to Unlock Abatement Potential

Table 6-3 gives an overview of policies and actions aimed at unlocking the abatement potential in the frozen seafood sub-sector.

Long term agreement

There are multiple actions that can contribute directly towards the development, agreement and implementation of an LTA.

To get the data right it is important and proposed to:

- Encourage greater cooperation and compliance from the sector in GHG relevant data gathering – the Thailand energy management program already provides a good entry point for this. This should also serve to help fill any data gaps or address uncertainties, such as those relating to wastewater emissions.
- Once the data is gathered to aggregate and analyze this effectively – by implementing a central database, possibly managed by TGO, the data can be used to improve the quality of the GHG footprint of the sub-sector and provide a basis for performance-based monitoring going forward that will be an important part of the LTA implementation. This data can also be used in the longer term to support future policy through sector performance benchmarking.
- Improve the training and funding of government staff at the relevant agencies, as this can only be successful if the technical understanding and resources are available. This helps to address the key knowledge barriers that exist.

Table 6-3: Policy and actions for the frozen seafood industry

Solution pathway	Addresses objective(s)	Actions per LTA framework phase			Addresses barriers
		Phase I (Short Term)	Phase II (Medium Term)	Phase III (Long Term)	
LTA	Generating sector engagement and interest LTA	Evaluate need to extend sub-sector to consider wider Frozen Food sector. Create (sub-)sector working group on sustainable production, starting point with Thai Frozen Food Association. Invite the sector to develop their own low carbon roadmap and needs assessment which identifies the possibilities and constraints of GHG emission abatement. G P F I A	Sub-sector and government negotiate and reach LTA for GHG reduction in the sector. G P F I A	Monitor LTA, take action as appropriate. Benchmarking of specific energy consumption in the sector. International benchmarking of sector to guide policy and support competitiveness. G P F I A	Firms lack of knowledge Firms lack of vision/understanding
LTA	Getting the data right Implementation by firms	Encourage greater adoption of (and compliance with) Thailand EM Programme to improve understanding of energy use and reduction options. Implement no regret EM system processes (see MACC measure #1). G P F I A	Evaluate and improve energy management system. Replace equipment with more energy efficient equipment when replacement is needed. G P F I A	Best practice energy management system, energy use key criteria in business decisions. G P F I A	Firms lack of knowledge (imperfect information) Firms lack of vision/understanding (energy only compliance issue, production-centric focus)
LTA	Getting the data right	Aggregate data and collect these in central database, combine with other data sources to produce improved sector GHG footprint and start performance-based monitoring. Improve data on refrigerant emissions and wastewater treatment processes and emissions. G P F I A	Continue performance-based monitoring. Analyse refrigerant and wastewater data to decide if further action is needed. G P F I A	G P F I A	Firms lack of knowledge (imperfect information) Firms lack of vision/understanding (poor management understanding)
LTA	Getting the data right	Improve training and funding for relevant govt. staff, subjects to include technical measures, impacts, global GHG context. G P F I A	Continue training of staff G P F I A	Continue training of staff G P F I A	Lack of knowledge (lack of relevant skills among staff)
LTA	Implementation	Through sector network share knowledge, focus on dissemination of best practice in cooling processes. Government consider re-introducing customer service support for industry. G P F I A	Continue to share relevant knowledge. Implement customer support service. G P F I A	Continue to share relevant knowledge G P F I A	Firms lack of knowledge (perceived high costs/risks)
LTA	Implementation	Implement no regret, low capital cost equipment measures (see MACC measures #5 & 7) G P F I A	Implement cost-effective, but more capital intensive measures (see MACC measures #2, 3, 4 & 6) G P F I A	Implement other measures (see MACC measure #8). G P F I A	Firms lack of knowledge (perceived high costs/risks)
Supporting measure	Supporting mechanisms from govt.	Review the energy efficiency labelling, MEPS, HEPS requirements for equipment/appliances crucial for sector, i.e. refrigeration units and motors. G P F I A	Modify requirements to support energy efficiency improvement in sector. G P F I A	Review standards periodically and increase minimum requirements, revise label grades to provide continuing incentives. G P F I A	Firms lack of knowledge
Supporting measure	Supporting mechanisms from govt.	G P F I A	Accredit training providers to set up training courses for staff of companies to learn how to improve management of processes, and to implement and operate sustainable technologies. G P F I A	Introduce relevant modules and information to technical and vocational education to train students on sustainable technologies. Sectors should contribute to these. G P F I A	Firms lack of knowledge (lack of relevant skills among staff) Firms lack of vision/understanding
Supporting measure	Supporting mechanisms from govt.	Encourage firms to participate in Thailand Energy Awards scheme G P F I A	Consider creation of sector category within Thailand Energy Awards scheme. G P F I A	Evaluate success of awards in stimulating competition in sector, how firms compare internationally. Use to promote industry internationally. G P F I A	Firms lack of vision/understanding (lack of prestige)
Supporting measure	Supporting mechanisms from govt.	Increase visibility of climate change in national policy discourse. Communicate need for increased climate commitments in future, discussion on national targets and role of industry. G P F I A	Ensure sector targets are in line with policy commitments, i.e. INDC, RE, EE strategies. G P F I A	Ensure sector targets are in line with policy commitments, i.e. INDC, RE, EE strategies. G P F I A	Firms lack of vision/understanding (poor understanding of importance of climate change)
Supporting measure	Supporting mechanisms from govt.	Develop integrated approach to climate change in general and designate responsible agency for sector engagement. G P F I A	Evaluate current set of financial support schemes (revolving fund, soft loans, ESCO fund, tax incentives, direct subsidies) on effectiveness for this sector. Revise as appropriate. Offer specific incentives to firms participating in the LTA. G P F I A	Evaluate and assess need to further incentivise investments in abatement measures by e.g. implementing a carbon pricing scheme, emission trading or carbon/energy tax; and/or energy price (subsidy) reform. G P F I A	High operating/capital costs and/or risks Lack of government (financial) support
Supporting measure	Supporting mechanisms from govt.	G P F I A	Attract national and international financing from e.g. development banks to support implementation of sustainable technologies. G P F I A	Attract national and international financing from e.g. development banks to support implementation of sustainable technologies. G P F I A	High operating/capital costs and/or risks Lack of government (financial) support
Supporting measure	Supporting mechanisms from govt.	G P F I A	Set up targeted R&D programmes aimed at technologies specific for Thai industry, for example improved freezing systems and storage. G P F I A	Fund deployment and pilot programmes of these technologies. G P F I A	High operating/capital costs and/or risks Lack of government (R&D) support

Key: G=Government, P=Private sector, F=Financial sector, I=International community, A=Academia education

To engage the sector it is important and proposed to:

- Engage directly with the sub-sector, most effectively through the most relevant sector association or biggest firms, in this case the Thai Frozen Food Association offer a useful entry point. Disseminating the findings of this work can help to initiate a discussion. At this stage it is important to evaluate if the frozen seafood sector is too narrow, and if expanding the scope to the entire frozen food sector is beneficial.
- Taking this further a working group on sustainable production in the sector should be encouraged, this would become the main counterpart in discussions and also fulfil other roles relevant to data and implementation. The working group should be encouraged to propose its own emissions reduction roadmap and to make a needs assessment of what is required to achieve it. This can form the starting point for the negotiation of the LTA for the sector.

To implement the LTA it is important and proposed to:

- Build on the sector engagement to actually negotiate and agree an LTA, which includes targets and defines actions for both the sector and government and which also agrees the monitoring arrangements going forward.
- It is important also that there are review and decision moments/timeframes built into the LTA process so that if progress is unsatisfactory appropriate action can be taken by the Government.
- Encourage knowledge sharing in the sub-sector through the working group and consider a revived customer support service to disseminate knowledge. These actions are important as companies are not always aware of the existence of specific measures, or if they are aware of measures only have a limited under standing of the costs and benefits. This is particularly an issue in the frozen seafood sub-sector the abatement costs are assessed to be cost-effective and to actually deliver benefits to the sector. This action can help to address this issue. In the case of the frozen seafood sub-sector it is important that best practice and case studies of firms that have adopted NH_3 or CO_2 systems (measure #4), or that have adopted management and operation measures are involved. The information can also be very specific. For example sharing knowledge on sub-sector specific energyefficiency measures such as: keeping condensers clean and replacing corroded ones, shading the condensers, freezing at night instead of during the day, removing anything that obstructs condenser airflow and raising the evaporation temperature by optimizing various freezing tunnels (all part of measure #1);
- Implementation of energy management systems (measure #1) is a low-hanging fruit action for firms in the sector, which can be continually developed over time. The actions on training and data proposed above can improve the pressure and incentives for firms to do this.
- Implementation of low capital cost measures (#5 & 7) should be prioritized in the short term, while more capital intensive measures which remain cost effective (#2, 3, 4 & 6) should be implemented in the medium term.

Supporting measures and actions

It is crucial that the government and its agencies provide support to the success of the LTA through its broader policies and actions and also through specific actions. A considerable part of the policy framework and supporting instruments are already in place and effective, although there also remains scope for improvement and innovation. The following actions were identified and proposed:

- Improve the information connected to equipment which the sub-sector purchases to ncentivize more efficient choices can mitigate the information deficit in decision making. Energy efficiency policies for refrigeration and freezing units, like the current MEPS, HEPS and Green Labels, should be reviewed and their requirements enhanced to improve the efficiency of the appliances that industry use and provide easy to understand guidance on the energy efficiency. These schemes can also be expanded to include other relevant equipment, particularly motors, variable speed drives and lighting, and in the longer term more stringent minimum requirements could be implemented.
- Supporting capacity building is also important here, where the government can act to improve the training and education situation, either directly or through the accreditation of qualified trainers in the appropriate areas of energy management, energy efficiency and GHG emission reduction strategies.
- The Thailand Energy Awards scheme can be a useful vehicle to address management reluctance to act on GHG emission reduction, by attracting prestige and good publicity this can provide a strong incentive to firms. Examining how this could be implemented

at a sector level within the framework of the LTA could be important, this could include recognising significant achievements in energy efficiency or emissions abatement, i.e. best performer, most improved, most innovative.

- Ensuring higher visibility and coherence of government policy on climate change will also help. The commitments in the INDC are an important step, this can also help to engage with industry on the discussion of what their role and contribution should be. Furthermore it remains important to encourage and convince industry of the seriousness and urgency of the problem and how efforts will most likely need to intensify over time, as will the contribution that industry will need to make.
- While measures in the frozen seafood sector are cost effective in the long term, they can require significant upfront investments, and access to finance can be a barrier for firms to adopt measures, which is a particular barrier for switching the refrigerant system (#4), a large one-off investment. The government can help to address this finance issue by reviewing the existing policies and schemes (e.g. revolving fund, ESCOs, direct subsidies) and their applicability to sub-sector. It could be considered, subject to being non-discriminatory, to directly link particular financial incentives or benefits, i.e. lower interest rates, tax exemptions/ reductions; to participation in the LTA.
- In the long term wider policy reform particularly in the area of energy and/or carbon prices can provide a significant boost to the business case for energy efficiency measures, increasing the value of energy savings and reducing cost exposure to carbon prices, incentivising firms to invest.
- Finally, for the most important emissions sources in the sub-sector, particularly refrigerant switching, the Government should support research, development and deployment programs. These should develop and demonstrate new technologies in the industry in Thailand, helping to create best practice cases and to reduce costs.

6.4 Scope for GHG Emission Reduction Ambitions

Setting an ambition level for sector emissions abatement is a complex discussion. The results of this work can be suggestive of appropriate and/or realistic ambition levels for the sub-sector, but the MAC-curve and scenario projections also contain some (sometimes significant) assumptions and uncertainties. They cannot accommodate some of the very specific and practical issues that may limit abatement potential.

The Technical and Economic Analysis Report contains the more detailed modeling assessment of the impact of emissions abatement on the frozen seafood sector.

The societal and firm perspective scenarios elaborated emission abatement potential almost identical to the full technical potential of 59% as all but one measure remains cost-effective even if the discount rate changes. Taking the various information into account we suggest that:

- Incentivising the achievement of cost-effective abatement should bring both emissions and economic benefits for the sub-sector and wider economy and is to be recommended.
- This suggests potential for up to 59% emissions reduction in the sub-sector, yet this range may not be a realistic target due to:
  - The difficulties in achieving the full potential for each measure, there can be real practical reasons why an assessed potential may not be possible. For example, while the costs are assessed at the average level, these will not be applied to all firms in the same way, and some cost-effective measures may not be cost-effective for part of the sub-sector.
  - The scale of the change for firms to switch their refrigeration systems to NH_3 or CO_2, as this is something that would need to occur at one time, from new, as the entire system would need to change.
  - While a sensitivity analysis suggested that uncertainty in the abatement potential is low and the best-identified sources were used, it remains impossible to predict the precise situation and costs in 2030, this should be kept in mind.
- Any target setting should be the outcome of a political or negotiation process between the various stakeholders – we propose the LTA framework for this purpose – any target should also align with the national target of 20% emissions reductions (or 25% with international support), as stated in the Thailand INDC commitment. Based on the MAC-curve analysis the sector can achieve far more and do so cost-effectively.
- This work can already be used as a basic to begin a focused discussion with the frozen seafood (or frozen food) sub-sector towards an LTA, starting to address the questions of what is achievable and the continuing and additional policies and actions needed.
- Even if an LTA is not possible the suggested supporting policies and actions will incentivize emissions abatement in the sector and should be pursued, particularly those that remove barriers to the adoption of cost-effective measures.
- Revisiting this roadmap periodically is important to ensure it remains relevant to the sub-sector, indeed as part of the LTA framework the frozen seafood sub-sector could take ownership and further develop this roadmap.

Improvement of the data is required to be able to set realistic abatement targets for all sub-sectors.

Although there are differences between the sectors, in cross-cutting energy efficiency improvement measures can be conceived in all sectors.

Cost-effective measures are not implemented due to market imperfections, as well as limited human capacity and vision or understanding at management level.

Over the last decade, Thailand has shown an increased awareness of climate change issues.

Conclusions and Recommendations

Improving knowledge and understanding of abatement measures and building operational capacity amongst government and private staff

Unlocking the potential of measures with moderate abatement costs

Evaluating and enhancing the financial support schemes

Encouraging the private sector to play a greater role in Thailand meeting its international commitments

7. Conclusions and Recommendations

This Roadmap sets out short-, mid- and long-term actions for policy makers and other stakeholders to reduce the emissions of greenhouse gas emissions in three industrial sectors in Thailand: the palm oil industry, the automotive parts industry and the frozen seafood industry.

This Roadmap builds upon two reports:

- The **Emissions Projection Report**, which estimated GHG inventories for the selected sub-sectors and to developed new business-as-usual projections to forecast GHG emissions up to 2050.
- The **Technical and Economic Analysis Report,** which assessed the potential for emission abatement in the selected sub-sectors, analyzed abatement measures in each sub-sector, evaluated the barriers to implementation of the identified emission abatement options and assessed the wider socio-economic impacts of emissions abatement scenarios.

For detailed conclusions and recommendations about these subjects, the reader is referred to the above reports. Here the focus is on the conclusions needed for building the roadmap.

7.1 Conclusions

The Emissions Projection Report and the Technical and Economic Analysis Report lead to a number of conclusions that form the basis for the Roadmap Approach.

1. The status of the data needed for making GHG inventories, projections and estimating abatement potential needs further enhancement.

Improvement of the data is required to be able to set realistic abatement targets for all sub-sectors. The data status can be further qualified.

- Information on data quality and availability as well as the data itself is dispersed. This hampers the creation of a good overview of, and access to,

the data. The data map created in this study shows that many organizations hold part of the information necessary to build GHG emission reduction roadmaps. Differences in the level of data aggregation and scoping hinder the combination and validation of data. Limited accessibility of data, e.g. for reasons of competitive sensitivity, further complicate the data acquisition process.

- Detailed and recent data for industrial process and waste emissions is limited. If data is available it is only at higher levels of aggregation. The GHG emission inventories therefore rely on several assumptions. This is not an ideal starting situation for emission abatement, as it is unclear what exactly can be achieved. Furthermore, monitoring of progress and target achievement is cumber some based on this data.
- Consolidated, nation-wide view on long-term projections of emissions are also very limited. Long-term projections had to be constructed based on trends in, for instance, population growth and sector-specific trends. Economic forecasts only look one or two years into the future. Energy planning programs look further ahead, but lack the detail needed for the industrial roadmaps.

2. **In all sub-sectors there is a considerable potential for emissions abatement.** Although there are differences between the sectors in data quality and sector-specific measures, in all sectors cross-cutting energy efficiency improvement measures can be conceived.
   - The palm oil industry has the potential to reduce its own emissions by supplying electricity, generated by using recovered biogas, to the grid. The technical potential of the identified measures would lead to a 40% reduction in GHG emissions compared with a BAU scenario by the year 2030. The economic potential from a societal perspective is 20% and from a private perspective it is 13%. The palm oil industry already predominantly uses biomass for its energy demand. Further integration of biogas capture has the dual benefits of both reducing methane emissions and providing fuel for grid connected electricity generation.
   - Many cost effective abatement measures have been identified for the automotive parts industry, leading to a technical potential of 54% and an economic potential, both from a societal and private perspective, of 35% abatement in 2030. The key focus area in this sub-sector is the improvement of energy efficiency by the implementation of cross-cutting measures, like high-efficiency motors, variable speed drives and the avoidance of leakage in compressed air systems.
   - The frozen seafood industry can improve the efficiency of current installations or shift to newer, more efficient freezing techniques, leading to a technical potential of 59%. The economic potential is the same as the technical potential, as almost all identified abatement options are related to improved energy management and require relatively inexpensive cross-cutting technologies. The largest abatement potential can be found in the use of new freezing techniques using NH_3 or CO_2 which are 2-20% more efficient than current techniques which use F-gases as the refrigerant.

3. **Thailand has laws and regulations in place that address GHG emissions and there is a range of action plans**. Cost-effective measures are not implemented due to market imperfections, such as imperfect information, as well as limited human capacity and vision or understanding at management level. Current programs, like the Energy Efficiency Plan (EEP), already address these and other barriers with a variety of policies and actions. In order to accelerate the capacity building measures in the private sectors, the government can facilitate training for private companies. Government agencies should also be trained in understanding on climate change and (technical) knowledge on abatement options.

4. **Over the last decade, Thailand has shown an increased awareness of climate change issues.** Recently, the country submitted the Intended Nationally Determined Contribution (INDC) to UNFCCC (October 1, 2015). The country aims to reduce its emissions by 20% from BAU by year 2030 and by 25% with international support.

7.2 Recommendations

These key lessons are the starting point for the Roadmap study, which proposes an approach to policies and actions within this context. The approach relies on two complementary solution pathways, but with the first as the leading framework for the Roadmaps proposed in this report:

1. **Establishing long-term agreements (LTAs)** between the Industrial sectors and the Government with the aim to reduce GHG

emissions. The LTAs can serve to increase sector involvement and awareness of the importance of climate change. Furthermore, they can be supportive in improving the data situation and target policies and actions to industrial GHG abatement.

2. **Building further on the policies and actions already implemented by DEDE and others,** which will either indirectly, or in parallel, support and accommodate the success of the LTAs.

A Roadmap is based on taking actions over time to progress and build towards a goal or desired outcome. The overarching LTA framework is developed in this context, with short, medium and long-term phases:

- Short-term (2016-2017): Developing the foundations
  - Getting the data right – to make an appropriate decision on goals it is crucial to understand where the sector currently stands, where it is going if no action is taken, and what is feasible considering the costs, practicalities and barriers. While the EPR and TEAR provide a good start there remain many data issues, these should be addressed in the short term.
  - Generate sector engagement – an LTA requires active participation, contribution, commitment and ownership by the sector. It is crucial therefore to engage them in the short-term.
  - Implement "low-hanging fruit", measures that are easy to implement – it does not make economic sense to wait to take mitigation measures that are cost effective, especially those with little or no investment costs attached, these can and should already be implemented in the short term. This will already help engage firms in the necessary cost-saving and emission reduction mindset.
- Medium-term (2018- 2022): Establishing the long-term agreements and supporting actions
  - Reaching an LTA with the sector – will involve an in-depth dialogue and discussion with the sector to reach an agreement on targets and the roles and actions to be taken by both the sector and the government. This will also detail monitoring arrangements.
  - Supporting mechanisms put in place – effectively representing implementation of the agreement by the government where the objective is to develop and build upon their supporting actions, programs and incentives to enable the LTA to operate successfully.
  - Begin implementing – the sector should continue to implement GHG emission reduction measures, and move onto implementing measures that are no longer 'low-hanging fruit' but that in most cases are still cost effective and / or require only small capital investments or O&M costs.
- Long-term (2023-2030): Implementation and reflection
  - Examine and evaluate success of LTA – this objective is to ensure that there is information available to evaluate if progress is satisfactory and that the LTA is having the desired impact on industry for GHG emissions reduction.
  - Improve existing agreement or introduce mandatory approach - continual improvement is desirable, if targets are achieved then thoughts can turn to new objectives in future. If imple mentation is lagging remedial actions proposed, penalties applied and/or a stronger (i.e. mandatory) approach should be an objective

Start with a pilot sector to test the LTA process in Thailand. While all studied sectors seem suitable for an LTA approach, there are differences. For example the palm oil sector seems to have the best data and can be clearly scoped. The automotive part sector is very heterogeneous in terms of products and size of companies and is dominated by a few foreign automotive companies. The question here is whether a one-size-fits-all approach would work. The frozen seafood sector is the smallest of the three in terms of absolute GHG emissions. For this sector it might be considered to increase the scope to include more industries, for instance the whole frozen food sector. Testing the approach in a single sector can help to evaluate its suitability and success, and to learn from the issues that are encountered, smoothing the process for expansion to other sectors.

The LTA approach is flexible and can be tailored to any sector, therefore any industrial sector could be used as a pilot, not just one of the three studied sub-sectors. To aid in the success of the pilot project, attention should focus on the selection of a particular sector that the project will intervene. By choosing a sector which has relatively high absolute emissions, that is well organized and which already demonstrates awareness of climate change and commitments to GHG abatement, the outcomes are more likely to be positive. The pilot will also be instructive

on the phasing of implementation of the LTA, providing guidance on likely timescales, where flexibilities and overlaps may occur and the extent to which deadlines are needed to maintain progress. Apart from the Roadmaps per sub-sector, the study results in a number of more general recommendations:

Within Government designate a single agency responsible for the LTAs. To have clear lines of communication with the sector and a single voice to industry. This agency should have, or be able to generate, the trust and cooperation of industry. The other agencies would play a supporting role. The agency designated to manage the LTA would also manage intra-governmental coordination between itself and the agency responsible for managing GHG inventory and projection data.

Improving knowledge and understanding of abatement measures and building operational capacity amongst government and private staff are required to overcome the barriers that hamper uptake of the cost-effective measures. Cost-effective measures are not implemented due to market imperfections, such as imperfect information, lack of capacity and lack of vision or understanding at management level. Current programs, such as the Energy Efficiency Plan (EEP), already address these and other barriers with a variety of policies and actions. In order to accelerate the capacity building measures in the private sector, the government can facilitate training for private companies. Government agencies should also be trained in understanding on climate change and (technical) knowledge of abatement options.

Increase focus on technical education and training to build capacity in Thailand to develop and operate emissions abatement projects. Important barriers to implementation include the lack of knowledge about abatement options and lack of skills or training to operate more efficient equipment and machinery. This should be addressed by placing more emphasis on sustainable technologies in educational programs. In the longer term, this would bring trained staff to the companies, awareness of the issue and abatement opportunities, which would contribute to reducing the abovementioned barriers.

Evaluate financial support schemes and make them more effective. Several financial support schemes are already available and being employed. These remain important to accelerate the adoption of many measures, particularly those which are not cost effective and/or require capital investment. It is encouraged that the Government regularly evaluates the effectiveness of these schemes and adjusts them accordingly.

Improved and enhanced financial support and access to finance are required to unlock the potential of measures with moderate abatement costs. According to the economic assessment, measures with moderate costs are still not attractive for companies. Currently, the Thai government has a few financial incentive schemes – a government co-investing fund, soft loans, tax incentives and direct subsidies – to support the uptake of these measures. Assessing the effectiveness of these instruments would be beneficial to encourage further implementation of these abatement measures. The use of other incentives and measures, i.e. market based instruments, can complement an LTA; for example, sectors in the Netherlands subject to the EU emissions trading scheme (ETS) are also covered by LTAs, and these complement and reinforce each other.

Improve the outreach of the current Energy Efficiency Program to accelerate the rate of energy efficiency improvement in industry. The program can run in parallel with, and be supportive to, the LTAs for specific sectors while also seeking to increase the scope of their coverage into new sectors. Various supports and schemes are in place, but the challenge is how to achieve the outreach to industry. A customer service unit was established with DEDE in 2002. This unit could be revived as part of the long-term agreements, with contact persons for each sector, providing solicited advice to the sector as well as carrying out pro-active outreach activities to make the sector familiar with the support programs of DEDE and other agencies.

Encourage the private sector to play a greater role in Thailand meeting its international commitments to reduce GHG emissions. The study recognizes the submission of the country's Intended Nationally Determined Contribution (INDC) to UNFCCC on October 1, 2015. The country aims to reduce its emissions by 20% from BAU by year 2030 and by 25% with international support. By this commitment the Thai government shows that it takes GHG abatement seriously. This facilitates communication to the private sector about the importance of climate change, raising awareness to the management of companies about this issue. Subsequent implementation of the INDC will require contributions from all sectors, and for the Government to articulate industries' contributions in greater detail in the future. This gives a clear signal that the private sector will need to contribute. Furthermore, it paves the way to more stringent enforcement, i.e. mandatory measures, if the rate of improvement under an LTA is too slow. This would be the proverbial 'stick' to go with the 'carrots' of improved incentives recommended previously.

Develop smart indicators to monitor progress towards targets and to enable steering of policy interventions. Currently, the target for energy efficiency is expressed in energy intensity, i.e. energy use per monetary unit (value added). As the relationship between energy and value added is weak at a product level and the decoupling of energy intensity and value added is an aspiration of the Thai economy, better indicators should be developed. Preferably, this indicator should be expressed in specific energy use or GHG emission per physical indicator, e.g. tonnes of product. It is noted that the study is aware of the on-going Ministry of Energy's initiative in developing a database for such indicators. These can also be used to track progress against broader national and international goals and indicators, such as INDCs or the UN Sustainable Development Goals.

It is recommended to review this study periodically. Since it is a long-term vision, important changes to circumstances may change over the timeframe of the study. It is impossible to predict the impacts of such events, for example new international commitments on emissions reduction, or dramatic technology shifts affecting the sub-sectors. This study and report should be treated as a living document and updated periodically to (re-)align the Roadmaps with new and developing situations as they occur.

References

AIT. (2007). *Seafood Processing.* Pathumthani, Thailand: Asian Institute of Technology.

APMA. (2005). *Best practice benchmarking in energy efficiency: Canadian Automotive Parts Industry.* Toronto: Automotive Parts Manufacturers' Association.

Bank of Thailand. (2015). *EC_XT_008_S2 : Total Value and Quantity of Exports Classified by Product Group.*

Bundit et al. (2015). *Thailand NAMA Roadmap INDC and Peak CO_2 scenarios in 2050.*

Dallinger, J. (2011). Oil palm development in Thailand: economic, social and environmental considerations. *Forestpeoples.* Retrieved from http://www.forestpeoples.org/sites/fpp/files/publication/2011/11/chapter-1-oil-palm-development-thailand-economic-social-and-environmental-considerations.pdf

DEDE. (2010). *Training Manual for Energy Conservation in Fabricated Metal Product, Machinery and Equipment Industries.* Bangkok: DEDE.

DEDE. (2013). *Thailand energy efficiency situation 2013.*

EPPO. (2012). *Summary of Thailand Power Development Plan 2012-2030 (PDP2010: Revision 3).*

FAOSTAT. (2013). Oil, palm Production. Rome, Italy. Retrieved October 17, 2013, from http://faostat.fao.org

FAOSTAT. (2015). Oil, Palm Production and Number of mills. Retrieved from http://faostat3.fao.org/

GIZ. (2012). *Akzente, Political participation.* The GIZ Magazine, Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH, Germany. Retrieved from https://www.giz.de/en/downloads/giz2012-en-akzente01-complete.pdf

GIZ. (2013). *Data collection support for establishing an inventory of consumption and emission of F-gases (CFC, HCFC, HFCs, PFCs, and SF_6) in Thailand.* Bangkok: GIZ.

IEA. (2015). *International Energy Agency.* Retrieved from FAQs: Transport: http://www.iea.org/aboutus/faqs/transport/

IFC. (2010). *Energy efficiency in aquatic product processing sector.* International Finance Corporation, World Bank Group.

Infolliance. (2009). *Case study: plant wide energy audit identifies numerous energy cost cutting measures at Felda Oil Products.* Retrieved from Infolliance web site: http://www.infolliance.com/pdf/case_study/Case%20Study%20Palm%20Oil%20Refinery%20new.pdf

International Energy Agency. (1995). *Voluntary Approaches for Mitigating Greenhouse Gas Emissions.* Paris: IEA/OECD.

International Transport Forum. (2011). *Transport Outlook - Meeting the Needs of 9 Billion Pepole.* Paris: OECD/ITF.

IPCC. (2015, 11 11). *4th Assessment Report 2007.* Retrieved from https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch13s13-2-1-4.html

Kaewmai, R. (2012). *Calculation of Greenhouse Gas Emissions: A Case Study of Crude Palm Oil Production in Thailand.* Sonkla: Prince of Sonkla University. Retrieved from http://kb.psu.ac.th/psukb/bitstream/2010/9092/1/361680.pdf

MTEC. (2015, August 5). Gate-to-gate palm oil data. Thailand.

OIE. (2015, 07 24). *Industrial Indices.* Retrieved from Office of Industrial Economics website: http://www.oie.go.th/en/acadeic/index

Palm Oil Crushing Mill Association. (2011). *Future of the Thai Palm Oil industry.* Bankok. Retrieved from http://fic.nfi.or.th/food/upload/pdf/12_411.pdf

Piyawan, P., & Yoncharoen, W. (2013). Energy Management in Frozen Food Process. *The 14th TSAE National Conference and the 6th TSAE International Conference.*

Price, Lynn;. (2005). Voluntary Agreements for Energy Efficiency or GHG Emissions Reduction. *2005 ACEEE Summer Study on Energy Efficiency in Industry* (pp. 5-114 - 5-125). Washington: ACEEE.

RSPO. (2014, 05 02). *Sustainable palm oil conversation and debate Country Profile: Thailand.* (N. Hawa, Ed.) Retrieved from betterpalmoildebate.org: http://betterpalmoildebate.org/features/post.php?s=2014-02-05-country-profile-thailand

Sea Minh Hai. (2009, 12 28). *Shrimp Species and Main Proccessing Types.* Retrieved from Sea Minh Hai: http://www.seaminhhai.com/?q=node/12

SEA-LAC Trade Center. (2014, March). *Thailand Food Processing Industry.* Southeast Asia and Latin America Trade Center, University of the Thai Chamber of Commerce. Retrieved from http://www.indianembassy.in.th/pdf/Final%20Report%20Market%20Survey%20Thailand%20Food%20Processing%20Industry%20March%202014.pdf

Selvakkumuran et al. (2014). *Low carbon society scenario 2050 in Thai industrial sector.*

SIIT et al. (2010). *Low-Carbon Society Vision 2030 Thailand.*

Sullivan, J., Burnham, A., & Wang, M. (2010). *Energy-Consumption and Carbon-Emission Analysis of Vehicle and Component*

Manufacturing. Argonne, IL: Argonne National Laboratory.

Techakanont, K. (2011). Thailand Automotive Parts Industry. In K. Techakanont, & M. Kagami (Ed.), *Intermediate Goods Trade in East Asia: Economic Deepening Through FTAs/EPAs* (BRC Research Report No.5 ed.). Bankok, Thailand: Bankok Research Center, IDE-JETRO. Retrieved from http://www.ide.go.jp/English/Publish/Download/Brc/pdf/05_chapter6.pdf

TGO & JGSEE. (2012). *Final report on Projection of Greenhouse Gas Emission and Mitigation and their scenario studies using economic models.*

Thai Frozen Foods Association. (2013). *Thailand Seafood Industry Overview, The situation of Thai Shrimps in 2012 and its trend in 2013.* Retrieved from Thai Frozen Foods Association: http://www.thai-frozen.or.th/thailand_seafood_02_en.php

Thailand Automotive Institute . (2012). *Masterplan for Automotive Industry 2012-2016.* Ministry of Industry.

Thailand Automotive Institute and Office of Industrial Economics. (2014). *Vehicle Information Program.* Bankok: Thailand Automotive Institute and Office of Industrial Economics.

Thepkun et al. (2013). *Assessment of GHG Mitigation measures on energy, environmental and economic aspects in Thailand towards 2050 using AIM/CGE model.*

Thomas, A., & Phaovisaid, D. (2005). *Investment review: focus on the seafood industry.* Bankok: Board of Investment Thailand. Retrieved from http://www.boi.go.th/tir/issue/200508_18_8/5.htm

Transparency Market Research. (2013). *Frozen Food Market - Global Industry Analysis, Size, Share, Growth, Trends & Forecast 2013 - 2019.* Research and Markets. Retrieved from http://www.researchandmarkets.com/research/hcn62f/frozen_food

Vijaya, S., & Choo, Y. (2012). Greenhouse Gas Emissions for the Production of Crude Palm Kernel Oil - A gate-to-gate case study. *Journal of Oil Palm Research,* 1511-1517.

Vijaya, S., Ma, A., & Choo, Y. (2010). Capturing Biogas: A Means to Reduce Green House Gas Emissions for the Production of Crude Palm Oil. *American Journal of Geoscience,* 1, 1-6. Retrieved from http://thescipub.com/PDF/ajgsp.2010.1.6.pdf

Vijaya, S., Ma, A., Choo, Y., & Nik Meriam, N. (2008). Life Cycle Inventory of the Production of Crude Palm Oil - a gate to gate case study of 12 palm oil mills. *Journal of Oil Palm Research,* 484-494. Retrieved from http://www.palmoilworld.org/PDFs/Environment/7-joprv20june-vijaya_Env.pdf

Annex A: Data Map

The data map presents a concise overview of data needs and availability of data for the construction of a GHG abatement roadmap. The data map contains three tables:

1. Data needs and availability
2. Institutions
3. Data sources used in the Roadmap

Table A-0-1: Data needs and availability

Relevant Inventory Approach and Task	Data Need Category	Overview of Data Availability and Issues	Relevant Institutions and Main Data Sources
Bottom-up Approach	Low-Level Sub-Sector Emissions: Specific Energy Consumption (SEC)	• The DEDE database contains information on SEC. However, data definitions were unclear. For the automotive parts analysis, a 2010 study with information on the SEC of component manufacturing per vehicle was used.	DEDE, US and Canadian studies (for automotive parts).
Bottom-up Approach	Low-Level Sub-Sector Emissions: Carbon footprints	• TGO also has carbon footprint data from other sub-sectors, for both products as well as organizations, and is currently adopting a new online reporting platform. For food, the National Food Institute (NFI) works with the Thai Greenhouse Gas Management Organization (TGO) to develop a carbon footprints product database. MTEC is also contributing to carbon footprints.	TGO, NFI, others
Bottom-up Approach	Low-level Sub-Sector Emissions: Other product level energy and emissions data, Life Cycle Analysis (LCA)	• MTEC has LCA data on sectors, including: Gate to gate information on Palm Oil production Fresh Fruit Bunches and Crude Palm Oil, Palm Oil refineries), frozen foods, automotive parts. Due to data sensitivity, the team was unable to obtain reports from MTEC on frozen food and automotive parts. • The Department of Industrial Works (DIW) prepares product level energy and emissions data. It has compiles data at a factory level on energy, industrial process pollution, waste and wastewater, among others.	MTEC, DIW
Bottom-up (also relevant to top down)	Activity Levels: Production Data, other	• Activity Data can be used for both the bottom-up and the top-down approaches. For the bottom up approach, it is used in conjunction with sub-sectoral energy and emissions data (per unit/component/process, etc.) to arrive at sub-sector estimates. They are also used to create energy profiles relevant to both bottom-up and top-down calculations of sub-sector emissions. • Sources: The OIE has a production volume dataset for products from 2000-2015 in relevant units (vehicles, tonnes, etc.) and a value added production index. • For the automotive parts analysis, volume of activity was estimated using Office of Industrial Economics (OIE) data and by regression and trend analysis inputting recent production. • For the palm oil and frozen fish sectors, the Office of Agricultural Economics (OAE) has data an agricultural outputs which can be used as activity data. • The NESDB has studies on economics sub-sectors, including the automative and the food industry.	OIE, OAE, NESDB
Bottom-up and Top Down Approach	Sub-sector Fuel Mix for Energy Use Profile	• The energy use profile describes the share of energy use from each fuel type and energy source in the sub-sector. It is used to estimate the total use of each fuel type and energy source based on activity levels, and then to calculate total emissions using fuel emission factors. • Gate-to-gate information from MTEC, DEDE data and reports, case studies.	MTEC, DEaDE, case studies

Relevant Inventory Approach and Task	Data Need Category	Overview of Data Availability and Issues	Relevant Institutions and Main Data Sources
Bottom-up Approach	Energy Emission Factors: including per fuel/energy carrier and other sources	Emissions factors are used to estimate the emissions from a specific source, including processes, fuels, equipment, and other. If sub-sector energy use profile is known, fuel emission factors can be used to calculate the entire sub-sector energy emissions. • The IPCC has emissions factors per fuel. EPPO has information on the emission factors of energy carriers (fuels) and their use in sectors, and produces estimates of emissions on this basis. Sectors, however, are not very disaggregated. • For this study, IPCC revised 1996 guidelines were used, consistent with the 2nd National Communication, and with the 3rd National Communication currently being prepared. • Country specific emissions factors for fuels were not used	IPCC, EPPO (PDPs)
Top Down Approach	Validated Sectoral Emissions: Including Energy Consumption Statistics	Provide emissions related data at the broader industrial sector level encompassing the sub-sector of interest. • DEDE and EPPO have sectoral data at the 2 digit TSIC level, and institutions and researchers have consolidated and/or analyzed the data from these and other sources. Based on these sources, this study used data prepared by Selvakkumuran et al based on these sources, resulting in sector energy consumption data. At the 2 digit TSIC level, this data is a more aggregated level than the selected sub-sectors. For instance, it covers "Food Beverages and Tobacco", which encompasses both frozen foods and palm oil.	DEDE, EPPO, studies (Selvakkumuran et al, 2014; Bundit et al, 2015; SIIT et al, 2010; TGO & JGSEE, 2012; WR)I
Top Down Approach	Scaling Down Data: Including Gross Value Added (GVA)	• For the selected sub-sectors, there is generally a lack of detailed data related to energy and emissions. OIE has Gross Value Added economic data which was used for this study.	OIE
Bottom-up and Top-Down Approaches	Data for Projections: recent historical activity level growth, supported by GDP projections and other economic, productivity, technology and consumption information.	Activity level growth and information on the change in other statistics (emission factors, technological changes) is needed to estimate the change in emisisons over time. GDP and other economic projections can help to model future growth, consumption and emissions in the particular sub-sector of interest. • The OIE has some information on sub-sector growth and historical production trends, but does not have long term growth projections for the sub-sectors in this study. TGO & JGSEE have data on wider Thai economic growth for the projection periods, as does the IMF (World Economic Outlook). These can be used to adjust the regression analysis based on historical production trends. Other data can also supplement the regressions analysis, such as vehicle demand projections from the IEA. The Power Development Plans have information on projected emission factors for electricity until 2036 and projections of power demand. For this study, data was not sought on technology improvements, change in fuel emissions factors, or changes in the energy profiles of sectors.	OIE, NESDB, TGO & JGSEE, PDPs,IMF, IEA, World Economic Outlook

Table A-0-2: Overview of institutions that have data relevant for creating a GHG abatement roadmap

Institution Relevance	Relevance to GHG Inventories
Office of Agricultural Economics (OAE) Office of the National Economic and Social Development Board (NESDB)	The OAE contributes to projects that assist preparation of GHG inventories, and produces data on agricultural outputs that can be relevant as activity indicators in the palm oil and frozen fish sectors. The NESDB provides macroeconomic data including national Input/Output (I/O) tables. However data is typically aggregated at a level that is less useful for the sub-sectors. They also have the following data of relevance: • Sectoral and Projection Data (short-term projections). • Information on the economic outlook of Thailand for the coming decade and longer (GDP, estimate for 2020- 2030, and if possible up to 2050). These are used for the development of plans, such as The Eleventh National Economic and Social Development Plan (2012-2016). • Information on the relative share of each sector in the economy. • Data related to the preparation of the Industrial Master Plan, with data collected from the Board of Investment, Ministry of Industry, and Ministries.· • Studies on economics sub-sectors, including the automotive and the food industry.
Office of Industrial Economics (OIE)	The OIE provides detailed data and indicators for industry, including at product-specific levels. These data are especially relevant for production, trade and other economic data for the relevant sub-sectors, especially automotive parts.The OIE also has data on Thailand industry growth for sectors, which can be used for energy and emissions projections.The specific OIE datasets used for this study were: • Production index (value added weight); which provides an index of the weight of the sector in total value added indexed to the year 2000 and through which trends in value added can be tracked. • Production (volume): which provides volumes of production of products from 2000-2015 H1 in the relevant unit, i.e. tonnes, vehicles.
Thailand Greenhouse Gas Management Organization (TGO)	Two separate work streams of TGO are calculating or consolidating 1.) Product Footprints, and 2.) Organizational Footprints. TGO consolidates data for products and organizations (on a voluntary basis) to calculate the footprint of products and organizations. There are about 80 mostly energy intensive companies for which a carbon footprint has been calculated with 25 more in development, with data provided on a voluntary basis. There are about 25 more companies for which this work is currently being undertaken. Energy use related to emissions is based on energy data from Ministry of Energy • Detailed data has been collected for cement and iron/steel, based on TIER 1 data (energy related emissions) For the Frozen Food sector data is available from 2000 – 2010 -> frozen food available. •White Paper on reductions per sector has information on both product as well as organization product footprints. However it is difficult to share reduction options due to confidentiality.
Department of Industrial Works (DIW)	The DIW compiles industrial data at factory level with a focus on energy, industrial process pollution, waste and wastewater. • Data is prepared for product and factory level energy and emissions data. These can be relevant for each sub-sector.
Provincial Electricity Authority (PEA)	PEA is responsible for the generation, distribution and sales of electricity in all of Thailand, except for the Bangkok area.
Electricity Generating Authority of Thailand (EGAT)	EGAT is the country's major power producer and the only transmission operator. It is also responsible for developing the Power Development Plan (PDP).
EPPO Energy Policy and Planning Office (EPPO)	EPPO is responsible for formulation and administration of government energy policies. EPPO produces detailed publications on energy demand and supply and also routinely estimates emissions on the basis of the emissions factors of the energy carriers. However sector disaggregation is limited.
ONEP	ONEP is the national focal point for UNFCCC. ONEP is responsible for developing the national GHG inventories, national climate change policies and plans, and national GHG reduction targets (i.e. NAMA and INDC). At the time of preparation of the report, ONEP just submitted the country's INDC to UNFCCC and is currently working on the 3rd National Communication.
National Metal and Materials Technology Center (MTEC)	The National Metal and Materials Technology Center (MTEC) produces product carbon footprints with TGO and also maintains a life cycle inventory database with Gate-to Gate information. Official requests for data must be made, and data is not always provided due to sensitivity and confidentiality, and there may be differences in approaches with IPCC based GHG inventories.
Joint Graduate School for Energy and Environment (JGSEE)	JGSEE is an autonomous graduate school instituted under the jurisdiction of the Council of the King Mongkut's University of Technology Thonburi. JGSEE have worked previously with TGO and the Ministry of Energy and have contributed to GHG emissions calculations.

Institution Relevance	Relevance to GHG Inventories
DEDE Department of Alternative Energy Development and Efficiency (DEDE)	DEDE maintains an energy database which has data on: • Final energy consumption per sub-sector 2009-2013, for example: Food and Beverages, Fabricated Metal Manufacturing; Thai Manufacturing. This is further broken down into the specific energy carriers and fuels used by the sub-sectors. • DEDE creates reports from this data, other data, and analysis, including DEDE (2013) Thailand Energy Efficiency Situation 2013.
Good Governance for Social Development and the Environment Institute (GSEI)	• Research point and forum for sustainable development and production
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	• LCA study on Thailand Palm Oil industry • Profit Environmental Management (PREMA) Automobile parts documents • Master plan of the Thai Automotive Institute • Handbook analysing 300 cases, including identification on the 7 sub-processes identified • Comparative Assessment (Excel Sheet), containing figures of energy reduction, barriers and drivers, for 288 company cases. • PREMA Trainers and Consultants contacts, Reports from companies if available including material flow charts showing losses • Study on "Data collection support for establishing an inventory of consumption and emission of F-gases (CFC, HCFC, HFCs, PFCs and SF6) in Thailand"
Palm Oil Association Thai Frozen Foods Association (TFFA)	• Sectoral data • Energy consumption • Economic growth of sector • Sectoral data • Energy consumption • Economic growth of sector
Thai Auto Parts Manufacturing Association (TAPMA)	• Sectoral data • Energy consumption • Economic growth of sector
The Federation of Thai Industries (FTI)	• Sectoral data • Economic growth of sector
NFI	NFI is an organization under the Ministry of Industry, and works jointly with TGO in developing the carbon footprint for products database. NFI is involved in carbon footprint calculations. NFI has calculated the carbon footprints of over 2000 products manufactured by more than 277 companies/110 food products.

Table A-0-3: Overview of the data acquired

Data Name	File Type	Data Source	Sub-Sector	Relevance to Study
GHG Emissions for Frozen food (NMVOC)	Report	TGO	Frozen Food	GHG inventory per sub-sector. TGO has only direct emissions, "NMVOC" which are directly emitted from the manufacturing process according to IPCC methodology.
Economic growth projection by sector (contains the PDP rev.3)	Report	NESDB	Frozen Food Palm Oil Automobile parts	Economic long term growth projection by sector and sub-sector that contains the PDP rev.3 report
Clean technology for Frozen seafood	Report	Department of Industrial works	Frozen Food	Overview of sub-sector clean technologies
TAPMA directory	Report	TAPMA	Automobile parts	Scoping of the companies in sub-sector
Comparative Assessment in Automotive part	Excel	GIZ	Automotive parts	Energy use/measure in Automotive part sector. Comparative Assessment in Automotive part include Energy use/Measure in Automotive part sector
PREMA Automobile parts documents	Report	GIZ	Automotive parts	Overview of sub-sector Overview of Automotive part in Thailand
Master plan of Thai Automotive Institute	Report	GIZ	Automotive parts	Policy and Measure. Policy and Plan in Automotive part industry
Handbook analyzing 300 cases, including identification on the 7 sub-processes identified	Report	GIZ	Automotive parts	Overview of sub-sector. Overview of Automotive part in Thailand
Climate Public Expenditure review	Report	UNDP	General	A review of the financial scheme for Climate change activities in Thailand.
PREMA Trainers and Consultants contacts, Reports from companies if available including material flow charts showing losses	Report	GIZ	Automotive parts	Overview of sub-sector
Gate-to-gate information in the national database relating to Palm Oil production, including Fresh Fruit Bunches and Crude Palm Oil Data and Palm Oil refineries	Report	MTEC	Palm oil	GHG inventory of sub-sector
Gate-to-gate information on frozen foods	Report - not available	MTEC	Frozen food	GHG inventory of sub-sector
Gate-to-gate information on Automotive Parts	Report - not available	MTEC	Automotive parts	GHG inventory of sub-sector
Best practice guide waste to energy in palm oil industry	Report	GIZ/DEDE	Palm Oil	Understand the process of Palm oil mill. GHG inventory and Measure in Palm oil sector
Benchmarking implementation for eco-efficiency improvement in Thailand palm oil industry	Report	GIZ/DEDE	Palm Oil	Understand the process of Palm oil mill. GHG inventory and Measure in Palm oil sector
GHG Emissions of palm oil mills in Thailand	Report	GIZ/DEDE	Palm Oil	GHG inventory
Frozen seafood production of Thailand	Report	OIE	Frozen Food	GHG inventory Frozen seafood production of Thailand in year 2000 - 2015. May be use for calculate inventory and estimate growth
Thailand Energy Statistics 2013	PDF	DEDE	General	Energy statistic. Statistic energy use in Thailand. May be use for forcast growth
Presentation on Thailand's Policy on Energy Efficiency	Ppt	DEDE	General	Energy policy. Overview about energy policy and plan in Thailand
Energy Management System Report Guidelines	Report	DEDE	Frozen Food Palm Oil Automotive parts Web download	Measure
Specific Energy Consumption (Electricity Consumption for the Whole Country (Classified by TSIC).xls)	Report	DEDE	Frozen Food Palm Oil Automotive parts	energy consumption in sub-sector

Data Name	File Type	Data Source	Sub-Sector	Relevance to Study
Examples measures in energy audit report (Energy Audit Report)	Report	DEDE	Frozen Food Palm Oil Automotive parts	Measure
Carbon footprint for frozen food product	Report	National Food institute	Frozen Food	GHG inventory. Not available data due to confidentiality issues.
Life cycle assessment for automotive parts	Report	Electrical and Electronics institute	Automobile parts	GHG inventory. Not available data due to confidentiality issues.
Electricity consumption in sub-sector	Report	PEA	All sector	GHG inventory
Electricity consumption in sub-sector (classify by TSIC) Expand this title....	Report	EPPO	All sector	GHG inventory
Frozen seafood Market 2006-2014	PDF	FFA	Frozen Food	Data projection
Green Industry Manual	PDF	OIE	All sector	Policy and Measure
F-gas inventory - Report from GIZ focus on F-gas inventory in Thailand	Report	GIZ	Frozen Food	GHG inventory
20Yr EE Plan - Measure for energy efficiency in Thailand (Eng)	PDF	DEDE	All sector	Policy and Measure
CO2 Emission_PDP2015 - Translated PDP2015 focus on CO2 emission	Word	EPPO	All sector	Power Development Plan
PDP2015.pdf - Official full text Power Development Plan 2015 (Thai)	PDF	EPPO	All sector	Power Development Plan

About GGGI

The Global Green Growth Institute (GGGI) is an international organization dedicated to supporting and promoting strong, inclusive, and sustainable economic growth in developing countries and emerging economies. GGGI partners with developing countries and emerging economies to achieve their green growth aspirations through an integrated service and delivery model that starts with macro-economic assessment, moves to sectoral policy analyses, develops frameworks for appropriate financial resources, and culminates in the on-the-ground-implementation of a green growth plan. GGGI's global knowledge products and services inform our work to ensure best practices and create an attractive environment for green investments. GGGI has 27 programs in 19 countries, helping integrate green growth into regional or national economic goals.

Global
Green Growth
Institute

Follow our activities
on Facebook and Twitter

www.gggi.org