# ការរៀបចំផែនការអភិវឌ្ឍន៍បញ្ចេញកាបូនតិច ឆ្ពោះទៅរកឆ្នាំ២០៥០ នៅប្រទេសកម្ពុជា

# A DESIGN OF LOW CARBON DEVELOPMENT PLAN TOWARDS 2050 IN CAMBODIA


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## PREFACE

This study provides a preliminary but comprehensive assessment of GHG emissions and reduction potentials through implementing some low carbon measures. The current study is mainly designed to conduct a quantitative estimation of GHG emissions reduction of the four policies and twelve strategies for low carbon development strategy towards 2050 proposed in 2013 through using quantitative tools, including the ExSS tool, the AFOLU-B model, and the ExSS/waste model. The projections are not prognostications, a range of possible future outcomes are also possible. The results of the present study are, however, expected to provide fundamental and useful insights for the Royal Government of Cambodia to formulate a concrete and tangible climate change mitigation policy and low carbon development plan in the future.

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Sincerely yours,

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# សេចក្តីសង្ខេប

ប្រទេសកម្ពុជាបាននិងកំពុងខិតខំយកចិត្តទុកដាក់អភិវឌ្ឍន៍សេដ្ឋកិច្ចរបស់ខ្លួនរហូតជាប់ចំណាត់ថ្នាក់ជាប្រទេសមានកំណើនសេដ្ឋកិច្ចលឿនបំផុត ក្នុងចំណោមបណ្តាប្រទេសកំពុងអភិវឌ្ឍន៍លើសកលលោក ពិសេសប្រទេសកម្ពុជារំពឹងថានឹងក្លាយជាប្រទេសមានចំណូលមធ្យមកំរិតខ្ពស់ក្នុងឆ្នាំ២០៣០ ហើយនឹងឈានឡើងទៅជាប្រទេសមានចំណូលខ្ពស់ក្នុងឆ្នាំ២០៥០។ ទន្ទឹមនឹងនោះដែរ ប្រទេសកម្ពុជាបាននឹងកំពុងទទួលរងនូវផលប៉ះពាល់យ៉ាងធ្ងន់ធ្ងរដោយសារការប្រែប្រួលអាកាសធាតុ ដែលប្រការនេះតម្រូវអោយចាត់វិធានការជាបន្ទាន់ និងប្រកបដោយភាពត្រឹមត្រូវ។ កម្ពុជាចង់អភិវឌ្ឍប្រទេសរបស់ខ្លួនប្រកបដោយភាពបៃតង បញ្ចេញកាបូនតិច ធន់នឹងអាកាសធាតុ ប្រកបដោយសមធម៌ ចីរភាព និងផ្អែកលើចំណេះដឹង។ម្យ៉ាងទៀត ដើម្បីឆ្លើយតបទៅនឹងតម្រូវការថាមពលអគ្គិសនីចេះតែកើនឡើងៗ រាជរដ្ឋាភិបាលបានកំណត់នូវគោលដៅអភិវឌ្ឍន៍វិស័យថាមពលសំខាន់ចំនួនពីររួមមាន៖ ត្រឹមឆ្នាំ២០២០ ប្រទេសកម្ពុជានឹងមានអគ្គិសនីប្រើប្រាស់គ្រប់ភូមិទាំងអស់ទូទាំងប្រទេស និង ត្រឹមឆ្នាំ២០៣០ ចំនួន៧០ភាគរយនៃលំនៅដ្ឋានសរុបនឹងមានអគ្គិសនីប្រើប្រាស់ដែលប្រភពថាមពលភាគច្រើនបានមកពីថាមពលវ៉ារីអគ្គិសនី។ ជាងនេះទៅទៀត រាជរដ្ឋាភិបាលបានប្តេជ្ញាចិត្តយ៉ាងមុតមាំដើម្បីរក្សាគម្របព្រៃអោយបាន៦០ភាគរយត្រឹមឆ្នាំ២០១៥។

តាមការព្យាករណ៍បង្ហាញថាបរិមាណការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់នៅកម្ពុជានឹងកើនឡើងពីចំនួន ៤.៨៤៧kt$CO_2$eq./year (គីឡូតោននៃសមមូលកាបូនក្នុងមួយឆ្នាំ) រហូតដល់ ២០.២៤៥ kt$CO_2$eq./year (កើនឡើង៤,២ ដង) និង ១២០.៥២៣kt$CO_2$eq./year (កើនឡើង២៤,៩ ដង) នៅឆ្នាំ 2030BaU និង 2050BaU រៀងៗខ្លួន។ ប៉ុន្តែ ការព្យាករណ៍ដដែលបង្ហាញថា ការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់នឹងថយចុះមកត្រឹម -១៧.៧៩៤kt$CO_2$eq./year និង៣៣.០៥៧kt$CO_2$eq./year នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួន តាមរយៈការអនុវត្តវិធានការអភិវឌ្ឍន៍បញ្ចេញកាបូនតិចមួយចំនួន។ ចំណែកឯ ការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់សំរាប់មនុស្សម្នាក់ៗនឹងកើនឡើងពី ០,៣៥ t$CO_2$eq./year នៅឆ្នាំ២០១០ រហូតដល់ ១,១០t$CO_2$eq./year និង ៥,៤៩t$CO_2$eq./year នៅឆ្នាំ 2030BaU និង 2050BaU រៀងៗខ្លួន ហើយបរិមាណនេះនឹងថយចុះមកត្រឹម -០,៩៧ t$CO_2$eq./year និង១,៥១t$CO_2$eq./year នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួន។ តាមការ

ព្យាករណ៍បង្ហាញថា វិស័យកសិកម្មបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់រហូតដល់ ៨២ភាគរយ ចំណែកឯវិស័យថាមពលបញ្ចេញចំនួន ១៣ភាគរយ ហើយវិស័យសំណល់បញ្ចេញចំនួនតែ ៥ភាគរយប៉ុណ្ណោះនៅឆ្នាំ២០១០។ ម្យ៉ាងទៀត វិស័យកសិកម្មនៅតែបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ច្រើនជាងគេរហូតដល់ ៦០ភាគរយ ចំណែកឯ វិស័យថាមពលបញ្ចេញចំនួន ៣២ភាគរយ ហើយវិស័យសំណល់បញ្ចេញចំនួនតែ៨ភាគរយប៉ុណ្ណោះនៅឆ្នាំ2030BaU។ ប៉ុន្តែ វិស័យថាមពលនឹងបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ច្រើនជាងគេរហូតដល់ ៥៣ភាគរយ ចំណែកឯ វិស័យកសិកម្មបញ្ចេញចំនួន ៣៨ភាគរយ ហើយវិស័យសំណល់បញ្ចេញតែ៩ភាគរយ ប៉ុណ្ណោះនៅឆ្នាំ2050BaU។ តាមការសិក្សាដដែលបង្ហាញថា វិស័យប្រែប្រួលការប្រើប្រាស់ដីនិងព្រៃឈើ (LULUCF) ដើរតួរនាទីយ៉ាងសំខាន់ក្នុងការរក្សានិងស្រូបយកឧស្ម័នកាបូន ហើយសមត្ថភាពស្រូបយកកាបូននេះនឹងកើនឡើងពី ២៧.០៨២kt$CO_2$eq./year ក្នុងឆ្នាំ២០១០រហូតដល់ចំនួនប្រហាក់ប្រហែលគ្នាមួយគឺ ៥២.៨២៦kt$CO_2$eq./year(កើនឡើងតិចជាង២ដង) ទាំងនៅឆ្នាំ2030BaU និង 2050BaU ហើយបរិមាណនេះនឹងកើនឡើងថែមទៀតរហូតដល់ចំនួនប្រហាក់ប្រហែលគ្នាមួយគឺ ៦១.៧១៥kt$CO_2$eq./year ទាំងនៅឆ្នាំ2030CM និង 2050CM (កើនឡើងលើសពី ២ដង)។ ក្នុងចំណោមការកាត់បន្ថយបរិមាណការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់សរុបចំនួនប្រហែល ៣៨.០៣៩kt$CO_2$eq./year និង ៨៧.៤៦២ kt$CO_2$eq./year នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួននោះ វិស័យកសិកម្ម ព្រៃឈើនិងការប្រើប្រាស់ដីផ្សេងៗទៀត (AFOLU) មានសក្តានុពលអាចកាត់បន្ថយឧស្ម័នផ្ទះកញ្ចក់ច្រើនជាងគេរហូតដល់ចំនួនប្រហែល ៦៤ភាគរយ បន្ទាប់មកគឺ វិស័យថាមពលអាចកាត់បន្ថយបានចំនួនប្រហែល ៣៤ភាគរយ និង វិស័យសំណល់អាចកាត់បន្ថយបានចំនួនតែ ២ភាគរយ ប៉ុណ្ណោះនៅឆ្នាំ2030CM ផ្ទុយទៅវិញ វិស័យថាមពលមានសក្តានុពលកាត់បន្ថយឧស្ម័នផ្ទះកញ្ចក់បានរហូតដល់ចំនួនប្រហែល ៥៩ភាគរយ បន្ទាប់មកគឺ វិស័យ AFOLU អាចកាត់បន្ថយបានចំនួនប្រហែល ៣៤ភាគរយ និងវិស័យសំណល់អាចកាត់បន្ថយបានចំនួនប្រហែល ៧ភាគរយ ប៉ុណ្ណោះនៅឆ្នាំ2050CM។

ដើម្បីសម្រេចបានគោលដៅកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ ការសិក្សានេះបានស្នើឡើងនូវគោលនយោបាយចំនួន០៤ និង យុទ្ធសាស្ត្រចំនួន១២ សម្រាប់ផែនការអភិវឌ្ឍន៍បញ្ចេញកាបូនតិចឆ្ពោះទៅរកឆ្នាំ២០៥០នៅប្រទេសកម្ពុជា។ គោលនយោបាយ និងយុទ្ធសាស្ត្រទាំងនេះអាចរួមចំណែកដោយផ្ទាល់ និង ដោយប្រយោលក្នុងការកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់។

គោលនយោបាយស្តីពី បរិស្ថានបៃតងមានសក្តានុ-ពលកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់បានច្រើនជាងគេ រហូតដល់ចំនួនប្រហែល៦៦,២៨ភាគរយ និង ៤០,៣៧ភាគរយ បន្ទាប់មកគឺគោលនយោបាយស្តីពី សុខដមនីយកម្មរវាងសេដ្ឋកិច្ចបៃតង សង្គម និងវប្បធម៌អាចកាត់បន្ថយបានចំនួនប្រហែល ២៩,៩៩ភាគរយ និង ៥៤,០២ភាគរយ នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួន។ គោលនយោបាយស្តីពី ភូមិបៃតង (Eco-village) អាចកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់បានចំនួនប្រហែល ៣,៧៣ភាគរយ និង ៥,៦១ភាគរយ នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួន ចំណែកឯគោលនយោបាយស្តីពី សេដ្ឋកិច្ចខៀវ (Blue Economy) រួមចំណែកដោយប្រយោលក្នុងការកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ទាំងនៅឆ្នាំ 2030CM និង 2050CM។ ជាងនេះទៅទៀត តាមការសិក្សាដដែលបង្ហាញថា យុទ្ធសាស្ត្រស្តីពី ការគ្រប់គ្រងកសិកម្មបៃតង និងការគ្រប់គ្រងព្រៃឈើប្រកបដោយចីរភាពអាចកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់បានចំនួនប្រហែល ៤០,៩៤ភាគរយ និង ២៣,៣៧ភាគរយ រៀងៗខ្លួននៅឆ្នាំ2030CM បន្ទាប់មកគឺយុទ្ធសាស្ត្រស្តីពី ការដឹកជញ្ជូនបៃតងអាចកាត់បន្ថយបានចំនួនប្រហែល ១៤,៩៥ភាគរយ និងយុទ្ធសាស្ត្រស្តីពី ថាមពលបៃតងអាចកាត់បន្ថយបានចំនួនប្រហែល ១១,២៥ភាគរយ។ ផ្ទុយទៅវិញ យុទ្ធសាស្ត្រស្តីពី ការដឹកជញ្ជូនបៃតង និងយុទ្ធសាស្ត្រស្តីពី ការគ្រប់គ្រងកសិកម្មបៃតងអាចកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់បានចំនួនប្រហែល ២៩,៤៥ភាគរយ និង ២៣,៥ភាគរយ រៀងៗខ្លួននៅ ឆ្នាំ2050CM បន្ទាប់មកគឺ យុទ្ធសាស្ត្រស្តីពី ថាមពលបៃតងអាចកាត់បន្ថយបានចំនួនប្រហែល ១៨,៩៣ភាគរយ និងយុទ្ធសាស្ត្រស្តីពី ការគ្រប់គ្រងព្រៃឈើប្រកបដោយចីរភាពអាចកាត់បន្ថយបានចំនួនប្រហែល ១០,១៦ភាគរយ។ ជាមួយគ្នានោះដែរ យុទ្ធសាស្ត្រស្តីពីការសាងសង់ហេដ្ឋារចនាសម្ព័ន្ធប្រកបដោយការបញ្ចេញកាបូនតិច អាចកាត់បន្ថយបានចំនួនប្រហែល ២,៨៥ភាគរយ និង ៤,១៤ភាគរយ ចំណែកឯ យុទ្ធសាស្ត្រស្តីពី ការគ្រប់គ្រងសំណល់ប្រកបដោយចីរភាពអាចកាត់បន្ថយបានចំនួនប្រហែល ១,៩៨ភាគរយ និង ៦,៧២ភាគរយ នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួន។ យុទ្ធសាស្ត្រស្តីពី បច្ចេកវិទ្យានិងវិនិយោគទុនបៃតងអាចកាត់បន្ថយបានចំនួនប្រហែល ៣,៧៩ភាគរយ និង ៥,៦៣ភាគរយ ចំណែកឯ យុទ្ធសាស្ត្រស្តីពី ការកសាងសំណង់អាគារបៃតងអាចកាត់បន្ថយបានចំនួនប្រហែល ០,៨៨ភាគរយ និង ១,៤៧ភាគរយ នៅឆ្នាំ 2030CM និង 2050CM រៀងៗខ្លួន។ ប៉ុន្តែ យុទ្ធសាស្ត្រស្តីពី៖ ជំនួញនាវាសមុទ្របៃតង និង

ការគ្រប់គ្រងតំបន់ឆ្នេរប្រកបដោយចីរភាព ការគ្រប់គ្រងទេសចរណ៍បៃតង អភិបាលកិច្ចល្អនិងការអភិវឌ្ឍធនធានមនុស្សបៃតង និង ការកៀរគរធនធានហិរញ្ញវត្ថុបៃតង អាចរួមចំណែកកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ដោយប្រយោលទាំងនៅឆ្នាំ 2030CM និង 2050CM។ ការអនុវត្តប្រកបដោយប្រសិទ្ធភាពនូវគោលនយោបាយទាំង០៤ និង យុទ្ធសាស្ត្រទាំ១២ ប្រទេសកម្ពុជានឹងរួមចំណែកមួយផ្នែកដ៏សំខាន់ជាមួយពិភពលោក ដើម្បីរក្សាកម្រិតសីតុណ្ហភាពមធ្យមមិនអោយកើនលើសពី២អង្សាសេនៃកម្រិតមុនបដិវត្តន៍ឧស្សាហ៍កម្មជឿនលឿន។ ជាមួយគ្នានោះដែរ ដើម្បីសម្រេចបានគោលដៅនេះ ប្រទេសកម្ពុជាត្រូវតែមានធនធានហិរញ្ញវត្ថុ និងសមត្ថភាពមនុស្សប្រកបដោយគុណភាពគ្រប់គ្រាន់។ ជារួម ប្រទេសកម្ពុជាត្រូវតែប្រកាន់យកនូវអភិក្រមអភិវឌ្ឍន៍ប្រកបដោយការបញ្ចេញកាបូនតិចដើម្បីត្រៀមរៀបចំយុទ្ធសាស្ត្ររយៈពេលមធ្យម និងវែង សម្រាប់អភិវឌ្ឍន៍សេដ្ឋកិច្ចសង្គមរបស់ខ្លួនប្រកបដោយប្រសិទ្ធភាព និង ដើម្បីកំណត់គោលដៅកាត់បន្ថយការបញ្ចេញឧស្ម័នផ្ទះកញ្ចក់ក្នុងរយៈពេលវែងផងដែរ។

# EXECUTIVE SUMMARY

Cambodia has made all of her utmost effort to develop the national economy to become one of the most rapid economic growth countries among the developing countries and is envisioned to reach the status of an upper-middle income country by 2030 and a high-income one by 2050. In the meantime, the country has experienced the adverse impacts of climate change, which requires to take urgent and appropriate actions. Cambodia is intended to develop her country towards a green, low-carbon, climate resilient, equitable, sustainable, and knowledge-based society. The Government has set the targets to electrify 100% of all villages by 2020 and 70% of all households by 2030 where the sources of the power supply derive largely from the hydropower. Additionally, the Government has a strong commitment to maintaining the forest cover of 60% by 2015.

Total GHG emissions in Cambodia are projected to increase to about 20,245 (4.2 times) and 120,523 kt$CO_2$eq./year (24.9 times) in 2030BaU and 2050BaU, respectively, from 4,847kt$CO_2$eq./year in 2010; however, they are projected to decrease to about -17,794 and 33,057 kt$CO_2$eq./year in 2030CM and 2050CM, respectively. Per capita GHG emissions are projected to increase from about 0.35t$CO_2$eq./year in 2010 to 1.10 and 5.49 t$CO_2$eq./year in 2030BaU and 2050BaU, respectively; and are expected to decrease to around -0.97 and 1.51 t$CO_2$eq./year in 2030CM and 2050CM, respectively. In 2010, the agriculture sector contributes the biggest share of GHG emissions of around 82%, followed by the energy sector (13%) and the waste sector of around 5%. The agriculture sector remains the biggest share of GHG emissions of around 60%, followed by the energy sector of around 32% and the waste sector of about 8% in 2030BaU. However, the energy sector becomes the largest emitter emitting about 53%, followed by the agriculture sector of around 38% and the waste sector of about 9% in 2050BaU. The LULUCF sector is the net carbon sink and the sink capacity is expected to increase from around 27,082kt$CO_2$eq./year in 2010 to be a similar of around 52,826kt$CO_2$eq./year (less than 2 times) in both 2030BaU and 2050BaU and is expected to further increase to be a similar of roughly 61,715kt$CO_2$eq./year in 2030CM and 2050CM (more than 2 times). Among the total GHG emissions reduction of around 38,039 and 87,462 kt$CO_2$eq./year in 2030CM and 2050CM, respectively; the AFOLU sector is projected to contribute the largest GHG emissions reduction potentials of about 64%, followed by the energy sector of roughly 34%, while the waste sector of about 2% in 2030CM; however, the energy sector is predicted to attribute the highest

GHG emissions reduction potentials of about 59%, followed by the AFOLU sector of around 34%, and the waste sector of around 7% in 2050CM.

In order to achieve GHG emissions reduction target, the present study proposes four policies and twelve strategies for low carbon development plan towards 2050 in Cambodia. They directly and indirectly contributes to reducing GHG emissions. The policy on green environment attributes the largest GHG emissions reduction of about 66.28% and 40.37%, followed by harmonization of green economy, society, and culture of about 29.99% and 54.02% in 2030CM and 2050CM, respectively. The policy on eco-village shares GHG emissions reduction of around 3.73% and 5.61% in 2030CM and 2050CM, respectively; while blue economy contributes indirectly to reducing GHG emissions in 2030CM and 2050CM. Besides, the strategies on green agriculture management and sustainable forest management attribute GHG emissions reduction of about 40.94% and 23.37%, respectively, in 2030CM, followed by green transportation of some 14.95% and green energy of about 11.25%. However, the strategies on green transportation and green agriculture management contribute around 29.45% and 23.5%, respectively, in 2050CM, followed by green energy of about 18.93% and sustainable forest management of roughly 10.16%. The strategy on low carbon infrastructure attributes about 2.85% and 4.14%, while sustainable waste management of about 1.98% and 6.72% in 2030CM and 2050CM, respectively. The strategy on green technology and investment shares roughly 3.79% and 5.63%, while green building of about 0.88% and 1.47% in 2030CM and 2050CM, respectively. The strategies on green merchant marine and sustainable coastal zone management, green tourism management, green good governance and human resource development, and green financial mobilization contribute indirectly to GHG emissions reduction in both 2030CM and 2050CM. The effective implementation of the four policies and twelve strategies, Cambodia is expected to partially contribute to the global efforts to holding the increase in the average temperature to well below 2 °C above pre-industrial levels. In doing so, Cambodia must ensure sufficient financial resources and qualified human capacity. In short, Cambodia must to move to a low-carbon paradigm to facilitate the effective medium- and long-term strategies for socioeconomic development and also to set GHG emissions reduction target in the long-run.

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## ABBREVIATIONS

| | |
|---|---|
| ADB | Asian Development Bank |
| AFOLU | Agriculture, Forestry and Other Land-Use |
| AFOLU-A | Agriculture, Forestry and Other Land-Use Activity Model |
| AFOLU-B | Agriculture, Forestry and Other Land-Use Bottom-up Model |
| AG | AGriculture |
| AGF | AGro-Forestry |
| ASEANs | Association of Southeast Asian Nations |
| BAU | Business as Usual |
| BOD | Biochemical Oxygen Demand |
| CM | CounterMeasure |
| CMDGs | Cambodia Millennium Development Goals |
| CCCSP | Cambodia Climate Change Strategic Plan |
| CFSP | Cambodia Fuelwood Saving Project |
| CDM | Clean Development Mechanism |
| CCTT | Climate Change Technical Team |
| $CO_2$ | Carbon Dioxide |
| CHP | Combined Heat and Power Plants |
| $CH_4$ | Methane |
| COD | Chemical Oxygen Demand |
| DNA | Designated National Authority |
| DOC | Degradable Organic Carbon |
| DDOC | Decomposable Degradable Organic Carbon |
| EAC | Electricity Authority of Cambodia |
| EIA | Environmental Impact Assessment |
| ExSS | Extended Snap Shot |
| ExSS/Waste | Extended Snapshot/Waste |
| EDC | Electricite Du Cambodge (Electricity of Cambodia) |
| EU | European Union |
| ESVG | Energy Service Demand Per Driving Force |
| ELCs | Economic Land Concessions |
| ESTD | Environmental Sustainable Transportation Development |
| FA | Forestry Administration |
| FTD | Freight Transportation Demand |

| | |
|---|---|
| FTG | Freight Transportation Generation |
| FTS | Freight Transportation Share (Modal share) |
| FTAD | Freight Transportation Average Distance |
| FTM | Freight Transportation Mode |
| FSDS | Financial Sector Development Strategy |
| GAMS | General Algebraic Modelling System |
| GDP | Gross Domestic Product |
| GG | Green Growth |
| GHG | Green House Gas |
| GMS | Greater Mekong Sub-region |
| GWP | Global Warming Potential |
| GCF | Green Climate Fund |
| HFO | Heavy Fuel Oil |
| HH | Household |
| IEA | International Energy Agency |
| IGES | Institute for Global Environmental Strategies |
| INC | Initial National Communication |
| INDCs | Intended Nationally Determined Contributions |
| IO Table | Input-Output Table |
| IPCC | Intergovernmental Panel on Climate Change |
| IPP | Independent Power Producers |
| IUCN | International Union for Conservation of Nature and Natural Resources |
| JICA | Japan International Cooperation Agency |
| LCS | Low Carbon Society |
| LCD | Low Carbon Development |
| LoCAR-Net | Low Carbon Research Network |
| LULUCF | Land Use, Land-Use Change and Forestry |
| LUCF | Land Use Change and Forestry |
| MFF | Mangroves for the Future |
| MAFF | Ministry of Agriculture, Forestry and Fisheries |
| MIME | Ministry of Industry, Mines, and Energy |
| MME | Ministry of Mines and Energy |
| MPWT | Ministry of Public Works and Transport |
| MoC | Ministry of Commerce |
| MoE | Ministry of Environment |

| | |
|---|---|
| MoH | Ministry of Health |
| MoI | Ministry of Interior |
| MoIH | Ministry of Industry and Handicraft |
| MoP | Ministry of Planning |
| MoT | Ministry of Tourism |
| MLMUPC | Ministry of Land Management Urban Planning and Construction |
| MoU | Memorandum of Understanding |
| NAPA | National Adaptation Programme of Action |
| NEEPSAP | National Energy Efficiency Policy, Strategy and Action Plan |
| NFP | National Forest Programme |
| NGL | Natural Gas Liquids |
| NBP | National Bio-digester Programme |
| NIES | National Institute for Environmental Studies |
| NIS | National Institute of Statistics |
| NGOs | Non-Governmental Organizations |
| NCCC | National Climate Change Committee |
| NCGG | National Committee for Green Growth |
| NSDP | National Strategic Development Plan |
| $N_2O$ | Nitrous Oxide |
| NPRD | National Programme to Rehabilitate and Develop Cambodia |
| NPRS | National Poverty Reduction Strategy |
| NTFP | Non-Timber Forest Product |
| OX | Oxidation Factor |
| PAs | Protected Areas |
| PD | Output by Industry |
| PFE | Permanent Forest Estate |
| POP | Population |
| PPP | Purchasing Power Parity |
| PASS.KM | PASSenger KiloMeter |
| PTD | Passenger Transportation Demand |
| PTG | Passenger Transportation Generation |
| PTS | Passenger Transportation Share (Modal share) |
| PTAD | Passenger Transportation Average Distance |
| PTM | Passenger Transportation Mode |
| RGC | Royal Government of Cambodia |

| | |
|---|---|
| REDD | Reduce Emission from Deforestation and Forest Degradation |
| RIL | Reduced Impact Logging |
| RFS | Reforestation-Fast Growing Species |
| SNEC | Supreme National Economic Council |
| SAGE | System for the Analysis of Global Energy Market |
| SMEs | Small and Medium Enterprises |
| SNC | Second National Communication |
| SOB | Strategic Objective |
| SSCA | State Secretariat of Civil Aviation of Cambodia |
| SEDP | Socio-Economic Development Plan |
| SW | Solid Waste |
| TPES | Total Primary Energy Supply |
| TFC | Total Final Consumption |
| TV | Television |
| TWG | Technical Working Group |
| UK | United Kingdom |
| UN | United Nations |
| UNEP | United Nations Environment Programme |
| UNDESA | United Nations Department of Economic and Social Affairs |
| USAID | United States Agency for International Development |
| USA | United States of America |
| U.S.EPA | United States Environmental Protection Agency |
| USD | United States Dollar |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNESCAP | Economic and Social Commission for Asia and the Pacific |
| UNWTO | United Nations World Tourism Organization |
| UYFC | Union of Youth Federations of Cambodia |
| VERs | Voluntary Emission Reductions |
| WB | World Bank |
| WW | Wastewater |

**UNIT:**

| | |
|---|---|
| GWh | Gigawatt Hour |
| Gg | Gigagram |
| $GtCO_2$ | Gigatonne of Carbon Dioxide |
| ha | Hectare |
| kgoe | Kilogram of Oil Equivalent |
| kWh | Kilowatt hour |
| $ktCO_2$ | Kilotonne of Carbon Dioxide |
| $ktCO_2$eq. | Kilotonne of Carbon Dioxide Equivalent |
| ktoe | Kilotonne of Oil Equivalent |
| KM | Kilometer |
| Mtoe | Megatonne of Oil Equivalent |
| MWh | Megawatt-hour |
| t | Tonne |

**CONVERSION:**

| | |
|---|---|
| GWh | $10^3$ MWh |
| MWh | $10^3$ KWh |
| Gg | $10^9$ Grams |
| Gg | $10^3$ t |
| Mtoe | $10^3$ ktoe |
| ktoe | $10^3$ toe |
| toe | $10^3$ Kgoe |
| $GtCO_2$ | $10^3$ $MtCO_2$ |
| $MtCO_2$ | $10^3$ $ktCO_2$ |
| $ktCO_2$ | $10^3$ $tCO_2$ |
| $tCO_2$ | $10^3$ $kgCO_2$ |
| $kgCO_2$ | $10^3$ $gCO_2$ |

## OBJECTIVES AND SCOPE OF THE STUDY

This study proposes seven major objectives as follows:

1) To design and propose appropriate low carbon development policies and strategies on energy, AFOLU, and waste sector for Cambodia;
2) To conduct a systematic and quantitative estimation of GHG emissions reduction of the proposed policies and strategies by using quantitative methodologies;
3) To quantify the socioeconomic parameters and to project $CO_2$ emissions as well as to identify the appropriate reduction measures towards 2050 from the energy sector by using the ExSS tool;
4) To estimate GHG emissions and mitigation potentials based on the assumed socioeconomic indicators and ongoing policies by using the AFOLU-B model;
5) To estimate GHG emissions and reduction potentials by using the ExSS/waste model;
6) To initiate, coordinate, and enhance communication and dialogue among policy-makers, researchers, academia, and the public on climate change mitigation and low-carbon development; and
7) To convince and encourage the translation of the proposed policies and strategies into the real implementation in Cambodia.

This study focuses on:

1) A design of the low carbon development plan in Cambodia, focused on energy, AFOLU, and waste policies;
2) GHG emissions from the energy sector cover residential, commercial, industrial, transportation, and power sectors; from the AFOLU sector include land use change, livestock population, harvested areas, fertilizer consumption, etc.; while from the waste sector consists organic and biodegradable substances for wastewater, and fossil carbon during waste incineration and decomposition of organic carbon in the disposal sites for solid waste;
3) Sources of GHG emissions include Carbon Dioxide ($CO_2$), Methane ($CH_4$), and Nitrous Oxide ($N_2O$). The energy sector considers only $CO_2$ emissions, while the AFOLU and waste sectors covers all sources of GHG emissions; and
4) Year 2010 is set as the base year, 2030 as the intermediate target year, and 2050 as the final target year for estimating GHG emissions and reductions.

## SCENARIOS OF THE STUDY

In order to estimate GHG emissions and reduction potentials, three quantitative models are applied including the Extended Snapshot (ExSS) tool, the ExSS/waste model, and the Agriculture, Forestry and Other Land-Use Bottom-up (AFOLU-B) model. GHG emissions are estimated with 2010 as the base year and the projection is based on two scenarios:

- 2030BaU and 2050BaU: Business As Usual (BaU) scenario without additional low-carbon measures besides the existing Government's policies, strategies, and plans in 2030 and 2050, and
- 2030CM and 2050CM: Countermeasure (CM) scenario with intensive low-carbon measures through adopting some more low carbon measures additional to the existing Government's ones in 2030 and 2050 to reduce GHG emissions.

## STRUCTURES OF THE REPORT

The overall framework of the report is structured with the overview of national status related to main national development indicators, climate change mitigation, and low carbon development, followed by the identification of main sectors of GHG emissions and the applied models. It comes after by the results of the estimation of GHG emissions and reduction potentials by sectors and lastly proposes low carbon development policies and strategies in order to achieve GHG emissions reduction target. Figure 0.1 shows the overall framework of the report. Moreover, the detail organization of this report covers seven parts as follows:

**Part 1** describes the overview of Cambodia's development status; climate change mitigation and low carbon development related national regulations, policies, and strategies; existing low carbon development framework and activities; all of which are the key indicators to convince this study. It indicates how and to what extend Cambodia is implementing climate change mitigation and low carbon development related policies, strategies, and activities and investigates sectors of the economy, which considered as the potential impacts of GHG emissions and reduction potentials. While, **Part 2** elaborates the Extended Snapshot tool (ExSS) used to quantify socioeconomic indicators and to estimate $CO_2$ emissions and reduction potentials in the energy sector. It describes some key socioeconomic parameters impacting energy demand and $CO_2$ emissions and reduction potentials under low carbon measures. Similarly, **Part 3** indicates the Agriculture, Forestry and Other Land Use Bottom-up model (AFOLU-B) used to estimate GHG emissions and mitigation potentials from the AFOLU sector based on the assumed socioeconomic indicators and on ongoing policies. It describes the results of GHG emissions and mitigation potentials through taking several constraints into account such as mitigation measures and costs. In addition, **Part 4** points out the ExSS/waste model used to estimate GHG emissions and reduction potentials in the waste sector. It describes the estimation of GHG emissions and reduction potentials from solid waste and wastewater thanks to increases in population and economic growths and waste management options. **Part 5** provides a summary of the total national GHG emissions and reduction potentials from the three main sectors. While, **Part 6** proposes low carbon development strategies and actions with quantitative GHG reductions in order to achieve GHG emissions reduction target as descried in the previous part. It also illustrates the role of a low carbon research network designed to facilitate, enhance, and expand communication, cooperation, and participation from different stakeholders as well as to bridge the gap between researchers and decision-makers. Finally, **Part 7** gives the conclusions and recommendation, which suggest the Government and other stakeholders to improve data recording, management, and accessibility as well as recommend more studies on climate change mitigation and low carbon development in Cambodia in order to provide good insights for the Government to design appropriate climate change mitigation policies and low carbon development plan in the future.

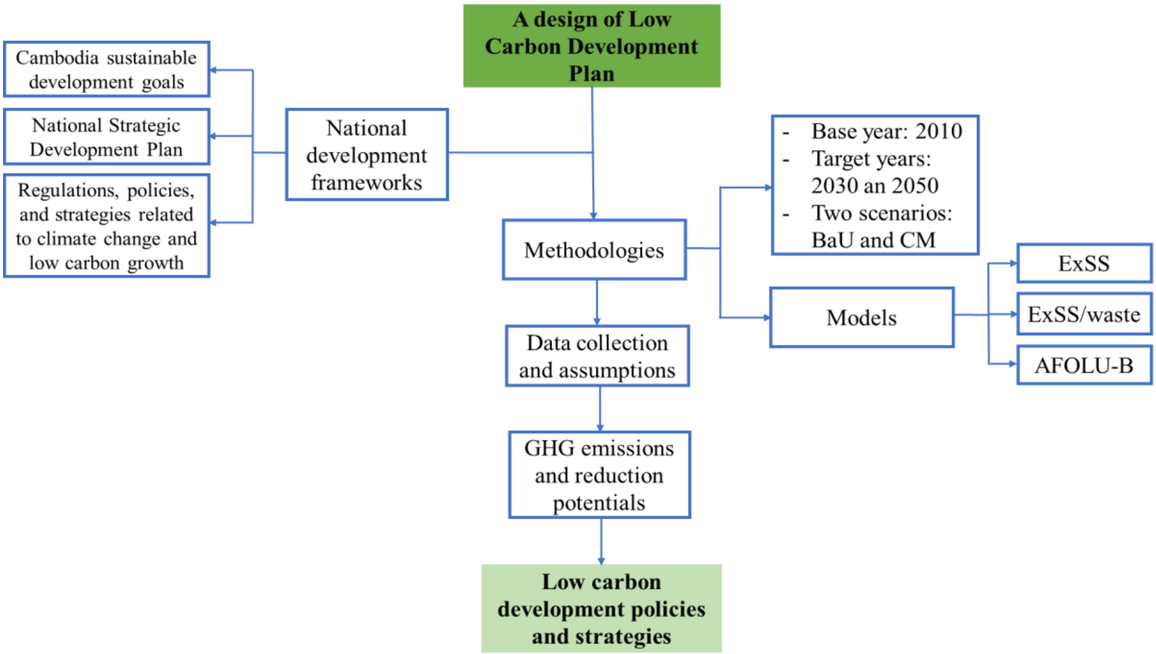


**Figure 0.1:** Overall framework of the report

## SUMMARY FOR POLICY MAKERS

International communities agreed to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change (Article 2 of the Paris Agreement). It requires each Party to prepare, communicate, and maintain successive nationally determined contributions through pursuing domestic mitigation measures in order to achieve emissions reduction target (Article 4). The present study provides a detail quantitative assessment of GHG emissions reduction of the four policies and twelve strategies for low carbon development strategy towards 2050 in Cambodia through using three quantitative models, including the ExSS tool (estimate $CO_2$ emissions and reductions from the energy sector), the AFOLU-B model (estimate GHG emissions and reductions from agriculture, forestry, and land use change), and the ExSS/waste model (estimate GHG emissions and reductions from the waste sector) proposed by a taskforce who are representatives of the Ministry of Environment and the Royal University of Agriculture of Cambodia and Kyoto University, Institute for Global Environmental Strategies, and National Institute for Environmental Studies of Japan in 2013. As the data used in this study based mainly on the Government's policies and strategies as well as the intensive discussion with relevant stakeholders, the assumptions are high quality enough to estimate and project GHG emissions and reduction potentials for Cambodia. GHG emissions are estimated with 2010 as the base year and the projections are based on two scenarios, including 2030BaU and 2050BaU (BaU scenario) with the existing Government's plans and 2030CM and 2050CM (CM scenario) with intensive low-carbon measures to reduce GHG emissions.

## 1. OVERVIEW OF CAMBODIA

### DEMOGRAPHY

Cambodian population was about 13.95 million in 2010-- about 19.5% were living in urban and 80.5% were living in rural areas. In that year, numbers of households were about 2.92 million -- about 0.55 million were in urban and 2.37 million were in rural areas. The population is projected to increase to about 18.39 million in 2030 and 21.96 million in 2050.

## ECONOMIC GROWTH AND DEVELOPMENT

Cambodia had experienced an average annual economic growth rate of around 7.0% from 1994 through to 2013, while per capita GDP had increased from about 216USD in 1992 to more than 1,000USD in 2013 and is expected to reach about 1,579USD in 2018. The Government set an economic development target to reach the status of an upper-middle income country by 2030 and a high-income level by 2050. The Government is encouraging a rapid transformation of the industrial structure to move from a labor-intensive and low productivity industry to a more broad-based, high-tech and high-skilled one. However, the Government still regards the stable and steady growth is largely attributed to the good performance of the agricultural sector.

## AGRICULTURE MANAGEMENT

The increased agricultural productivity improves farmers' incomes, enhances consumption of high quality nutritious food, and helps people escape from poverty. The Government set the target to export of at least one million ton of milled rice by 2015; however, this goal could not be reached due to some constraints such as primary farm production, post-harvest handling and processing, export logistics, and physical infrastructure. The intensification of rice cultivation is needed to increase agricultural output through increasing the efficient application of fertilizers. The Government has also to pay further attention to increase agriculture production by shifting from the extension of cultivated areas to intensive farming on the existing land and rehabilitating existing and constructing more irrigation networks.

## LIVESTOCK MANAGEMENT

Livestock is a key part of rural livelihoods and sources of incomes and food in Cambodia. The Government prepared National Strategic Planning Framework for Livestock (2015-2025) aiming to improve the livelihoods of small producers, household income, and food security and to provide a safe and sufficient supply of livestock products to the consumers as well as for export. This strategy is also expected to contribute to addressing the problems of transboundary and endemic animal diseases.

## LAND USE MANAGEMENT

Cambodia has faced strong and chronological land disputes due to limited land use planning. Land Law in 2001 was approved to establish a national system of land classification and land ownership rights and to set provisions on social and economic land concessions (ELCs). It was followed by the Sub-degree on ELCs in 2005 in order to grant private state land through a specific and long-term contract to use for agriculture and industrial development. Until 2013, around two million hectares of degraded forest land for ELCs were granted - around 1.3 million hectares within forest concession areas and around 0.7 million hectares within the PAs. The Government is implementing **“Old Policy-New Action”** framework and has allocated land to about 500,000 families.

## FOREST MANAGEMENT

Forest cover was about 57.1% of the total land area in 2010 decreased from around 73.0% in 1960, which remains below the target of maintaining the forest cover of 60.0% by 2015. Two main Government institutions manage forest resources including the MoE and the MAFF. The first manages the 23 PAs and the latter manages commercial and reproductive forests. The Law on Environmental Protection and Natural Resource Management was passed in late 1996 to govern environmental protection and natural resources management. While, the Forestry Law was passed in 2002 aiming to manage forest in a sustainable way in order to maximize the social, economic, and environmental benefits and cultural values and it is supported by NFP (2010 to 2029) in which REDD-plus scheme is defined as the main activity. Besides, Law on Protected Areas was passed in 2008 aiming primarily to manage and effectively implement the conservation of biological resources and the sustainable use of natural resources in protected areas

## ENERGY MANAGEMENT

Cambodia’s rapid economic growth has been accompanied by a steady increase in energy demand. In this regard, the Government adopted the “Law on Electricity” in 2000, which covered all activities related to the supply, provision of services and use of electricity, and other associated activities. The Government set two main energy development targets--the first is to achieve the 100% level of village electrification by 2020 and the second is to achieve 70.0% level of household electrification by 2030. According to power sector masterplan in 2014, the fuel mix of power generation comprises natural gas (40.0%), hydropower (35.0%), coal (15.0%), import (6.0%), oil (3.0%), and renewable energy (1.0%) in 2030. The Government is encouraging all ministries, public institutions, and the people to implement "*electricity saving measures*" to save budget and to ensure the effective and efficient use of electricity.

## TRANSPORTATION MANAGEMENT

The rapid economic development and urbanization presents tremendous challenges to the transportation systems. Many cities are enlarging capacity of road networks and many people have died and injured in road crashes, which cause severe social, economic, and health consequences. The Government prepared environmental sustainable transportation development strategy focusing on the establishment of transportation networks in line with land use planning; the introduction of modern public transportation systems; the development of efficient, comfortable, and safe transportation systems; and the establishment of efficient traffic control systems to reduce traffic accidents and congestion through effective traffic law enforcement.

## CLIMATE CHANGE POLICY

Climate change has become one of the greatest risks facing humanity and a high priority of global concern in the $21^{st}$ century. Among the total world GHG emissions of 49Gt$CO_2$eq./year in 2010, the energy sector contributed by about 35.0%, the AFOLU sector by 24.0%, industry by 21.0%, transportation by 14.0%, and buildings by 6.4%. The temperature in Cambodia has increased and this trend is predicted to continue with mean temperatures increase between 0.013$^{o}$C to 0.036$^{o}$C per year by 2099. Cambodia is regionally and globally insignificant with emissions per capita of about 0.23t$CO_2$/year in 2000. She has been working very closely and extensively with the world communities to address adverse impacts of climate change by ratifying the UNFCCC on 18 December 1995 and acceding to the Kyoto Protocol on 04 July 2002 and the NAPA was adopted in 2006. Climate change has been mainstreamed into the NSDPs aiming to build the capacity of the Government's institutions, to develop a strategy dealing with the anticipated impacts of climate change, and to strengthen disaster management capabilities and other development activities. The Government launched the first ever CCCSP (2014-2023) in 2013 to develop Cambodia towards a green, low-carbon, climate resilient, equitable, sustainable, and knowledge-based society. Besides, Cambodia prepared her Intended Nationally Determined Contribution (INDC) for submitting to the UNFCCC in compliance with the 'Lima Call for Action'.

### LOW CARBON DEVELOPMENT FRAMEWORK AND ACTIVITIES

The LCD refers to the development of an economy, which has a minimal output of GHG emissions into the atmosphere. It is a sustainable developed or developing society on the basis of close, reasonable and harmonious coordination of economic and social development and environmental protection. Cambodia has mainstreamed the LCD concept into relevant Government institutions, academia, and research institutes as well as other key stakeholders through workshops and trainings, etc. In order to initiate and enhance LCD as well as to bring together different relevant stakeholders, a series of workshops and training on LCD related topics have been organized in Cambodia and the targeted participants have been extended not only Cambodians but also Lao PDR and Myanmar, etc.

## 2. THE ENERGY SECTOR

### EXTENDED SNAPSHOT (EXSS) TOOL

The ExSS tool is a system of simultaneous equations, which can be used to quantify macro-socioeconomic indicators and environmental variables. It is primarily used to estimate energy consumption and $CO_2$ emissions in the energy sector. It is a designing tool of a future society rather than a projection or prediction of a likely future. The ExSS tool can project $CO_2$ emissions at present and in the future in a consistent way to assess the impact of low-carbon measures in Cambodia and it can show reduction potentials of each low-carbon measure and the decomposition of reduction factors.

## DATA QUANTIFICATION AND ASSUMPTIONS

### POPULATION GROWTH AND PROJECTIONS:

The total population of Cambodia was about 13.96 million in 2010 and is projected to reach about 18.39 million by 2030 and 21.96 million by 2050.

### NUMBERS OF HOUSEHOLDS AND AVERAGE PERSONS PER HOUSEHOLD:

The total number of households were about 3.0 million (0.6 million for urban and 2.4 million for rural) and are projected to increase about 4.2 million (1.2 million for urban and 3.0 million for rural) and 5.1 million (2.3 million for urban and 2.8 million for rural) in 2030 and 2050, respectively. The average persons per household in 2010 were 4.8 for both urban and rural and are expected to decrease to be a similar of 4.2 persons for urban and 4.5 persons for rural in 2030 and 2050, respectively.

### GDP GROWTH AND PROJECTIONS:

The average annual GDP growth rate is assumed to increase about 7.0% from 2010 through to 2050. As a result, the total GDP is projected to increase from 7,518 million USD (2000 constant price) or per capita GDP of 833USD (2010 current price) in 2010 to about 29,093 million USD (2000 constant price) in 2030 with per capita GDP of 2,448USD/year (2010 current price) and 112,582 million USD (2000 constant price) in 2050 with per capita GDP of 7,932USD/year (2010 current price).

### INDUSTRIAL STRUCTURE:

The detail information of industrial structures is collected from the IO table 2010. In the future, the share of products of the primary industry in private consumption is expected to decrease and substituted by the increase of goods and services of secondary and tertiary industries in both 2030 and 2050. The share of products of the primary industry in export is projected to decrease and substituted by the increase of the secondary industry, while the share of products of tertiary industry is assumed to remain the same. Meanwhile, the percentage distribution of the Government consumption and expenditure and gross fixed capital formation in both 2030 and 2050 is assumed to remain the same as in 2010.

**PASSENGER TRANSPORTATION DEMAND:**

The passenger transportation demand was about 53,829 million pass.km/year in 2010 and is projected to increase to around 276,819 million pass.km/year in 2030BaU (5 times) and 831,678 million pass.km/year in 2050BaU (15 times). Under low carbon measures, it is expected to decrease to roughly 223,155 million pass.km/year (4 times) in 2030CM and 711,406 million pass.km/year (13 times) in 2050CM.

**Table 1:** Passenger transportation demand [Million pass.km/year]

| Modes/years | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Motorbike | 8,562 | 22,560 | 9,024 | 67,360 | 31,089 | 2.63 | 1.05 | 7.87 | 3.63 |
| Tourist car | 17,073 | 101,544 | 56,523 | 378,983 | 299,184 | 5.95 | 3.31 | 22.20 | 17.52 |
| Bus | 14,988 | 49,283 | 51,387 | 183,935 | 166,215 | 3.29 | 3.43 | 12.27 | 11.09 |
| Train | 0 | 90,279 | 93,100 | 192,536 | 206,495 | 90,279 | 93,100 | - | - |
| Ship | 2 | 5 | 7 | 14 | 21 | 2.63 | 3.95 | 7.87 | 11.80 |
| Air | 32 | 171 | 171 | 765 | 765 | 5.27 | 5.27 | 23.60 | 23.60 |
| Walk | 4,646 | 4,325 | 4,978 | 2,695 | 3,061 | 0.93 | 1.07 | 0.58 | 0.66 |
| Bicycle | 8,526 | 8,651 | 7,965 | 5,390 | 4,576 | 1.01 | 0.93 | 0.63 | 0.54 |
| **Total** | **53,829** | **276,819** | **223,155** | **831,678** | **711,406** | **5.14** | **4.15** | **15.45** | **13.22** |

**FREIGHT TRANSPORTATION DEMAND:**

The freight transportation demand was about 18,562 million pass.km/year in 2010 and is projected to increase to around 116,048 million pass.km/year in 2030BaU (6 times) and 619,725 million pass.km/year in 2050BaU (33 times). Under low carbon measures, it is expected to decrease to roughly 103,975 million pass.km/year (5 times) in 2030CM and 557,766 million pass.km/year (30 times) in 2050CM.

**Table 2:** Freight transportation demand [Million ton.km/year]

| Modes/years | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Small cargo truck | 4,731 | 25,655 | 22,597 | 132,517 | 117,280 | 5.42 | 4.78 | 28.01 | 24.79 |
| Big cargo truck | 13,688 | 77,315 | 63,170 | 351,332 | 285,209 | 5.65 | 4.62 | 25.67 | 20.84 |
| Train | 0 | 11,277 | 15,506 | 121,341 | 133,475 | - | - | - | - |
| Ship | 143 | 1,801 | 2,702 | 14,535 | 21,802 | 12.55 | 18.83 | 101.32 | 151.98 |
| **Total** | **18,562** | **116,048** | **103,975** | **619,725** | **557,766** | **6.25** | **5.60** | **33.39** | **30.05** |

**POWER SUPPLY:**

The power supply in 2010 includes petroleum products (91.91%), coal (some 3.11%), hydropower (some 2.61%), biomass (some 2.01%), and renewable energy (less than

1.0%). It is expected to cover by natural gas (40.0%), hydropower (35.0%), coal (15.0%), import (6.0%), oil (3.0%), and renewable energy (1.0%) in both 2030BaU and 2050BaU. Under low-carbon measures, renewable energy (including, solar power, biogas/ biomass, and wind power) is assumed to increase its share to 5.0% with the reduction of oil and coal accordingly, while hydropower and natural gas are assumed to remain the same as those of the BaU levels.

**ENERGY DEMAND:**

Final energy demand is projected to increase to around 18,374 (5 times) and 66,932 ktoe/year (15 times) in 2030BaU and 2050BaU, respectively, from about 4,386ktoe/year in 2010. Under low-carbon measures, the Government can limit final energy demand to about 8,180 (2 times) and 27,691 ktoe/year (6 times) in 2030CM and 2050CM, respectively. Per capita energy consumption is projected to increase to around 999 and 3,047 kgoe/year in 2030BaU and 2050BaU, respectively, from around 314koe/year in 2010. It is expected to decrease to about 445 and 1,261 kgoe/year in 2030CM and 2050CM, respectively.

**Table 3:** Final energy demand by energy demand sectors [ktoe/year]

| Sectors/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 2,549 | 7,396 | 2,409 | 25,997 | 6,690 | 2.90 | 0.95 | 10.20 | 2.63 |
| Commercial | 172 | 1,107 | 672 | 3,086 | 1,560 | 6.45 | 3.91 | 17.98 | 9.09 |
| Industry | 1,021 | 6,100 | 3,453 | 20,868 | 11,497 | 7.55 | 5.43 | 20.43 | 11.26 |
| Passenger transportation | 321 | 2,005 | 879 | 7,006 | 3,027 | 6.24 | 2.74 | 21.81 | 9.42 |
| Freight transportation | 324 | 1,765 | 768 | 9,975 | 4,917 | 5.45 | 2.37 | 30.80 | 15.18 |
| **Total** | **4,386** | **18,374** | **8,180** | **66,932** | **27,691** | **4.56** | **2.34** | **15.26** | **6.31** |
| **Per capita (kgoe/person)** | **314** | **999** | **445** | **3,047** | **1,261** | **3.18** | **1.42** | **9.70** | **4.02** |

**$CO_2$ EMISSIONS AND REDUCTIONS POTENTIALS IN THE ENERGY SECTOR:**

$CO_2$ emissions from the energy sector are projected to increase to about 23,277 (about 6 times) and 91,325kt$CO_2$/year (22 times) in 2030BaU and 2050BaU, respectively, from around 4,221kt$CO_2$/year in 2010. Under low carbon measures, they are expected to decrease to approximately 10,451 (about 3 times) and 39,172 kt$CO_2$/year (9 times) in 2030CM and 2050CM, respectively. Per capita $CO_2$ emissions were about 0.30t$CO_2$/year in 2010 and are expected to increase to around 1.27t$CO_2$/year and 4.16t$CO_2$/year in 2030BaU and 2050BaU, respectively. Under low carbon measures, they are expected to decrease to about 0.57t$CO_2$/year and 1.78t$CO_2$/year in 2030CM and 2050CM, respectively. Per GDP $CO_2$ emissions were around 0.36kg$CO_2$/USD/year in 2010 and are expected to increase to be a similar of around 0.52kg$CO_2$/USD/year in both 2030BaU and 2050BaU. They are expected to decrease to about 0.23 and 0.22 kg$CO_2$/USD/year in 2030CM and 2050CM, respectively.

**Table 4:** $CO_2$ emissions and reduction potentials [kt$CO_2$/year]

| $CO_2$ emissions/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 830 | 2,414 | 918 | 9,889 | 2,034 | 2.91 | 1.11 | 11.91 | 2.45 |
| Commercial | 217 | 1,433 | 482 | 3,663 | 1,298 | 6.61 | 2.22 | 16.90 | 5.99 |
| Industrial | 1,173 | 7,536 | 3,926 | 23,691 | 11,136 | 6.42 | 3.35 | 20.19 | 9.49 |
| Passenger transportation | 996 | 6,374 | 2,743 | 22,276 | 9,431 | 6.40 | 2.75 | 22.36 | 9.47 |
| Freight transportation | 1,004 | 5,521 | 2,383 | 31,806 | 15,273 | 5.50 | 2.37 | 31.67 | 15.21 |
| Total emissions and reduction | 4,221 | 23,277 | 10,451 | 91,325 | 39,172 | 5.52 | 2.48 | 21.64 | 9.28 |
| Per capita emission (t$CO_2$/person) | 0.30 | 1.27 | 0.57 | 4.16 | 1.78 | 4.19 | 1.88 | 13.75 | 5.90 |
| Per GDP emission (kg$CO_2$/USD) | 0.36 | 0.52 | 0.23 | 0.52 | 0.22 | 1.43 | 0.64 | 1.45 | 0.62 |

## 3. THE AFOLU SECTOR

### AGRICULTURE, FORESTRY AND OTHER LAND-USE BOTTOM-UP (AFOLU-B) MODEL

The AFOLU-B model is a bottom-up type model designed to estimate GHG emissions and mitigation potentials in the AFOLU sector at a country or regional level, dealing with quantified mitigation measures. GHG emissions and mitigation potentials are calculated using a function of abatement costs, which are representative parameters representing willingness of GHG reductions under several constraints for mitigation costs and measures. The model illustrates a selection of GHG mitigation options (low carbon measures) based on minimizing net benefits. The AFOLU-B model consists of two modules: AGriculture Bottom-up (AG/Bottom-up) and Land Use, Land Use Change and Forestry Bottom-up (LULUCF/Bottom-up).

### DATA ASSUMPTIONS

**LAND USE:**

The cropland areas had increased from about 2,245 thousand ha in 2002 to 3,227 thousand ha in 2010 and they are expected to be extended to the maximum level of around 4,400 thousand ha by 2050. The grassland areas had increased from about

1,150 thousand ha in 2002 to 1,500 thousand ha in 2010 and they are assumed to decrease to roughly 700 thousand ha by 2050 since the country needs some grassland for animal habitat and feeding sources. Meanwhile, the forest land had decreased from around 11,104 thousand ha (61%) in 2002 to 10,364 thousand ha (57%) in 2010. It is expected that the forest land will cover around 60% of total land areas, which equal to roughly 10,862 thousand ha by 2050. The settlement areas were around 1,000 thousand ha in 2010 and are expected to cover around 1,573 thousand ha by 2050. The wetland areas were around 553 thousand ha in 2010 and are assumed to remain constant through to 2050, while the other land are subtracted from the total country land and the above-mentioned land use categories. Figure 1 shows the trends of land use change and projections.

As far as harvested cropland areas are concerned, the paddy rice production areas were around 2,777 thousand ha in 2010 and are expected to increase to some 5,357 thousand ha by 2050, the other coarse grain production areas were around 190 thousand ha in 2010 and are assumed to increase to approximately 288 thousand ha by 2050. Meanwhile, the vegetable, fruits and nut production areas were around 401 thousand ha in 2010 and are assumed to increase to approximately 763 thousand ha by 2050. The increase of these areas may come at the cost of forest areas. The oil crop production areas were around 139 thousand ha in 2010 and are assumed to increase to about 230 thousand ha by 2050. In addition, the sugar production areas were around 17 thousand ha in 2010 and are assumed to increase to about 29 thousand ha by 2050, while the other’s production areas were around 208 thousand ha in 2010 and are expected to increase to about 430 thousand ha by 2050. Figure 2 shows the trends of harvested land areas and projections.

Regarding crop yields, agricultural productivity in Cambodia remains low compared to the neighboring countries, such as Thailand and Vietnam. The rice yield was about 3 tons/ha in 2010 and is expected to increase to 5.3 tons/ha by 2050, while the other coarse grain yield was around about 3.6 tons/ha in 2010 and is assumed to increase to roughly 6.1 tons/ha by 2050. The Vegetable, fruits and nut yield was around 22.7 tons/ha and is assumed to remain the same through to 2050 as it is already high yield compared to other countries in the region. As for the oil crop yield, it was about 1.5 tons/ha in 2010 and is expected to increase to around 3.4 tons/ha by 2050, while the sugar yield was around 19.7 tons/ha in 2010 and is expected to increase to about 33.2 tons/ha by 2050. The other’s yield was about 1.1 tons/ha and is expected to increase to 2.9 tons/ha by 2050. Figure 3 shows trends of crop yields and projections.

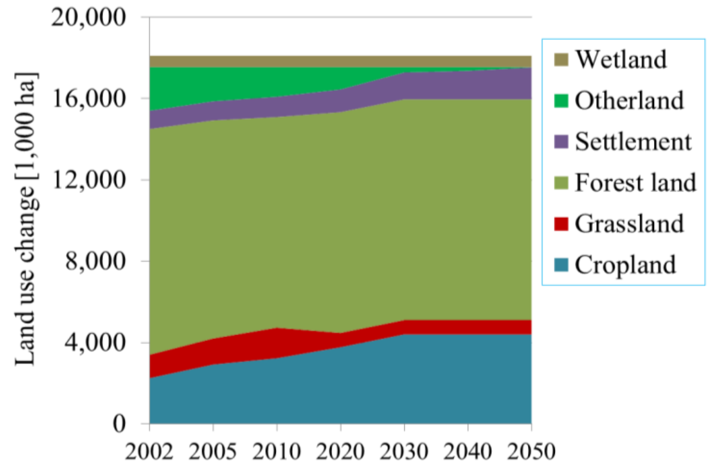


**Figure 1:** The trends of land use change and projections.

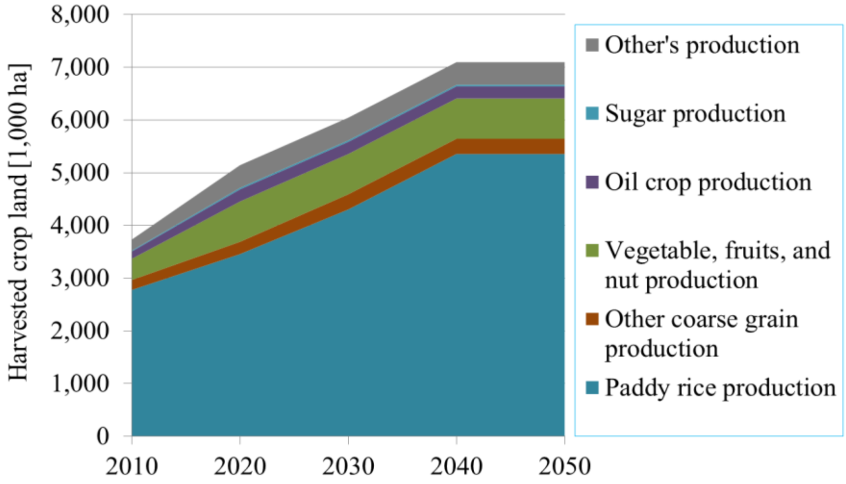


**Figure 2**: The trends of harvested land areas and projections.

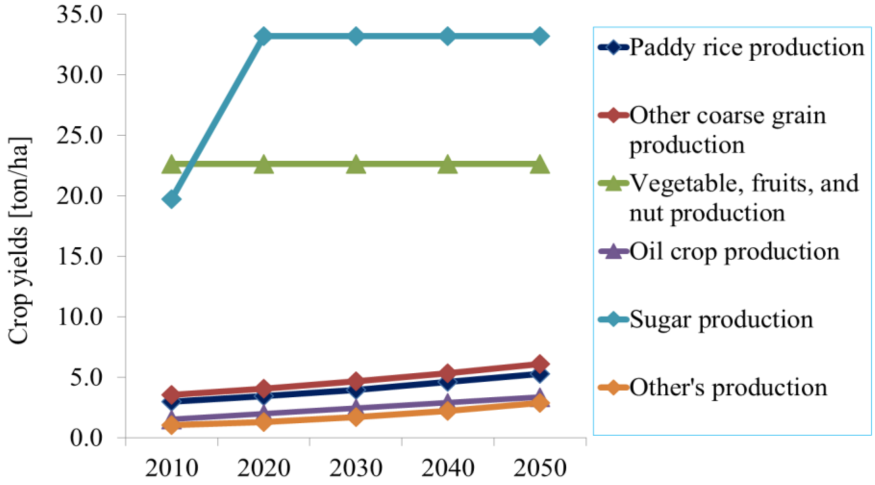


**Figure 3:** The trends of crop yields and projections.

**LIVESTOCK POPULATION:**

Livestock has a vital role in nutrition security as well as household incomes and livelihoods; however, livestock production in Cambodia is relatively a small scale. Dairy cattle population was really small, it was around 7 thousand heads in 2010 and is projected to increase to about 27 thousand heads by 2050. Numbers of meat cattle were around 3,547 thousand heads in 2010 and are projected to increase to about 9,915 thousand heads by 2050, while numbers of buffalo were relatively small, around 640 thousand heads in 2010 and are projected to increase to about 883 thousand heads by 2050. Meanwhile, numbers of pigs were around 3,047 thousand heads in 2010 and are projected to increase to about 9,915 thousand heads by 2050. Numbers of chickens were around 21,261 thousand heads in 2010 and are projected to increase to about 47,268 thousand heads by 2050, while numbers of ducks were around 4,050 thousand heads in 2010 and are projected to increase to about 9,003 thousand heads by 2050.

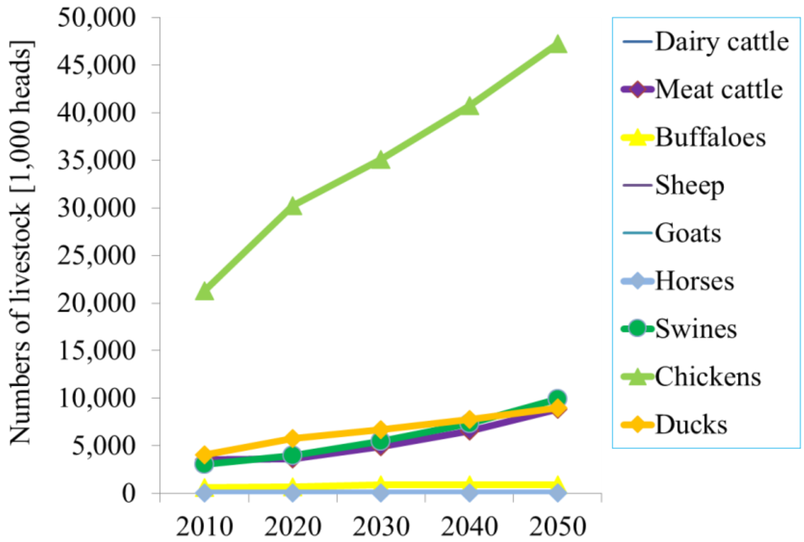


**Figure 4**: The trends of livestock population and projections.

**GHG EMISSIONS AND MITIGATION FROM THE AFOLU SECTOR**

The AFOLU sector in Cambodia was a net carbon sink with total carbon sink of around 940kt$CO_2$eq./year in 2010 and is expected to become a net emitter with total GHG emissions of about 13,982kt$CO_2$eq./year in 2050BaU. Per capita GHG emissions are projected to increase from a negative value of around -0.07t$CO_2$eq./year in 2010 to around 0.64t$CO_2$eq./year in 2050BaU. The LULUCF sector was a net sink with total carbon sink of around 27,082 kt$CO_2$eq./year in 2010 and the sink capacity is projected to increase to about 52,826 kt$CO_2$eq./year from 2020BaU through to 2050BaU.

In terms of mitigation potentials, the agriculture sector is plausible with the cost of less than 10USD/t$CO_2$eq., which generates GHG mitigation potentials of about 20,550kt$CO_2$eq./year in 2050CM. The rice cultivation (3C7) remains the biggest emissions reduction potential of around 77%, followed by enteric fermentation (3A1) (around 11%), while managed soil (3C4-3C6) contributes around 1.9%. Meanwhile, the LULUCF sector is suitable with the cost ranging from less than 50USD/t$CO_2$eq., and above and mitigation potentials of around 8,886kt$CO_2$eq./year in 2050CM are expected to reduce. The reduced impact logging (RIL) generates the largest mitigation potentials, followed by agro-forestry (AGF) and reforestation-fast growing species (RFS).

**Table 5:** GHG emissions and mitigation potentials in the AFOLU sector [kt$CO_2$eq./year]

| GHG emissions and reductions [kt$CO_2$eq./year] | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|
| The agriculture sector | | | | | |
| Enteric fermentation | 4,326 | 6,015 | 4,728 | 10,826 | 8,509 |
| Manure management | 606 | 993 | 721 | 1,568 | 1,081 |
| Rice cultivation | 17,090 | 26,479 | 13,695 | 32,961 | 17,059 |
| Managed soil | 4,120 | 10,574 | 9,348 | 21,454 | 19,609 |
| The LULUCF sector | | | | | |
| Changes in forest and other woody biomass stocks | -46,015 | -45,691 | -54,559 | -45,691 | -54,559 |
| Forest and grassland conversion | 18,933 | -7,135 | -7,156 | -7,135 | -7,156 |
| **Total** | **-940** | **-8,764** | **-33,224** | **13,982** | **-15,456** |

## 4. THE WASTE SECTOR

### EXTENDED SNAPSHOT (EXSS/WASTE) MODEL

The ExSS/Waste model describes waste-related activities and associated GHG emissions, which include generation and management of solid waste from residential, commercial, industrial, and construction sectors, and generation and management of residential and industrial wastewater. It is designed to estimate GHG emissions and reductions from fossil carbon during waste incineration, from decomposition of organic carbon in the disposed waste, and from the treatment of wastewater.

## DATA QUANTIFICATION AND ASSUMPTIONS

### SOLID WASTE GENERATION FACTORS:

Per capita solid waste generation in the residential sector was 0.3kg/(person.day) in 2010 and is expected to increase to 1.16 and 2.13 kg/(person.day) in 2030 and 2050, respectively. While, waste generation factors of industrial, commercial, and construction sectors are assumed to be similar to those of Vietnam in 2010 due to limited access to the information in Cambodia and they are assumed to remain the same for both 2030 and 2050.

### SOLID WASTE COMPOSITION:

The compositions of the residential and commercial solid waste in 2010 are referred to Fujiwara *et al.* (2012). The solid waste compositions in 2030 and 2050 are assumed to be similar to those of countries with upper middle income and high income status. Regarding the composition of industrial waste, it is named "Other" and is assumed to be the same as in the base year for 2030 and 2050. Meanwhile, the compositions of construction waste in 2010 are assumed to be similar to those of Vietnam except waste from wood, which is assumed to share only 2% compared to 5% in Vietnam. The compositions of construction waste in 2030 and 2050 are assumed to be same as in the base year.

### SOLID WASTE MANAGEMENT:

Waste management options by sectors by waste types in 2010 are collected from the department of pollution control of the Ministry of Environment. However, they are assumed with reference to several existing national regulations, policies, and strategies related to solid waste management and discussion with some national experts for 2030 and 2050 due to limited information.

### WASTEWATER GENERATION FACTORS:

Domestic wastewater generation factor in 2010 was 14.6kg BOD/(capita.year), which refers to IPCC 2006 guidelines and is assumed to remain the same for 2030 and 2050. Meanwhile, the wastewater generation factor in the industrial sector was 0.878 ton COD/million USD in 2010 and is assumed to remain the same for 2030 and 2050 due to limited information.

**WASTEWATER MANAGEMENT:**

Wastewater from the residential sector was 80% un-treated and 20% treated in 2010, while from the industrial sector was 60% un-treated and 40% treated. However, wastewater from the residential sector is expected to increase to 80% treated and 20% un-treated in 2030 and further increase to 100% treated in 2050. While, wastewater from the industrial sector is assumed to increase to 75% treated and 25% un-treated in 2030 and further increase to 100% treated in 2050.

**WASTE GENERATION**

Solid waste generation was around 2.92 million tons in 2010 and is expected to increase to roughly 10.07 million tons (about 4) and 11.69 million tons (about 12 times) in 2030BaU and 2050BaU, respectively. Meanwhile, wastewater generation was around 0.21$Mm^3$ in 2010 is expected to increase to 0.31$Mm^3$ (about 1.5) and 0.49$Mm^3$ (about 2.3 times) in 2030BaU and 2050BaU, respectively.

**GHG EMISSIONS AND REDUCTION POTENTIALS FROM THE WASTE SECTOR**

GHG emissions are projected to increase from around 1,566kt$CO_2$eq./year in 2010 to 5,731 and 15,216 kt$CO_2$eq./year in 2030BaU and 2050BaU, respectively. GHG emissions from the industrial sector contribute a similar share of more than 70% of total emissions in both 2030BaU and 2050BaU. However, under low carbon measures, GHG emissions are expected to reduce by approximately 13% and 39% in 2030CM and 2050CM, respectively.

**Table 6:** GHG emissions and reductions by sectors [kt$CO_2$eq./year]

| Sectors/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 262 | 951 | 826 | 2,326 | 1,535 | 3.63 | 3.15 | 8.88 | 5.86 |
| Commercial | 174 | 606 | 515 | 1,774 | 1,117 | 3.48 | 2.96 | 10.18 | 6.41 |
| Industrial | 1,127 | 4,160 | 3,627 | 11,082 | 6,661 | 3.69 | 3.22 | 9.84 | 5.91 |
| Construction | 3 | 14 | 12 | 34 | 28 | 4.59 | 3.92 | 11.10 | 9.02 |
| **Total** | **1,566** | **5,731** | **4,980** | **15,216** | **9,341** | **3.66** | **3.18** | **9.72** | **5.97** |

## 5. TOTAL NATIONAL GHG EMISSIONS AND REDUCTIONS

Total GHG emissions in Cambodia are projected to increase from roughly 4,847kt$CO_2$eq./year in 2010 to about 20,245 (4 times) and 120,523 kt$CO_2$eq./year (25 times) in 2030BaU and 2050BaU, respectively. In the base year, the agriculture sector contributes to the biggest share of around 82%, followed by the energy sector (13%), while the waste sector contributes around 5%. In 2030BaU, the agriculture sector remains the biggest share of GHG emissions of around 60%, followed by the energy sector (about 32%); however, the energy sector becomes the largest emitter emitting about 53%, followed by the agriculture sector (around 39%) in 2050BaU. The LULUCF sector is the net carbon sink and the sink capacity is expected to increase from around 27,082kt$CO_2$eq./year in 2010 to be a similar of around 52,826kt$CO_2$eq./year (about 2 times) in both 2030BaU and 2050BaU. It is noted that through implementing some low carbon measures, the total GHG emissions of around 38,039 and 87,462 kt$CO_2$eq./year are expected to reduce in 2030CM and 2050CM, respectively. In 2030CM, Cambodia becomes a net carbon sink, offsetting around 17,794kt$CO_2$eq./year in 2030CM; this is due to the potential carbon sink capacity in the LULUCF sector. However, Cambodia becomes a net carbon emitter, emitting about 33,057kt$CO_2$eq./year in 2050CM due to the tremendous increase of GHG emissions from the energy and waste sectors. Per capita GHG emissions are projected to increase from about 0.35t$CO_2$eq./year in 2010 to about 1.10 and 5.49 t$CO_2$eq./year in 2030BaU and 2050BaU, respectively; however, they are expected to decrease to around -0.97t$CO_2$eq./year in 2030CM and 1.51t$CO_2$eq./year in 2050CM.

**Table 7:** National GHG emissions and reductions by sectors [kt$CO_2$eq./year]

| GHG emissions and reductions | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|
| **The energy sector** | | | | | |
| Residential | 830 | 2,414 | 918 | 9,889 | 2,034 |
| Commercial | 217 | 1,433 | 482 | 3,663 | 1,298 |
| Industrial | 1,173 | 7,536 | 3,926 | 23,691 | 11,136 |
| Passenger transportation | 996 | 6,374 | 2,743 | 22,276 | 9,431 |
| Freight transportation | 1,004 | 5,521 | 2,383 | 31,806 | 15,273 |
| **Sub-total** | **4,221** | **23,277** | **10,451** | **91,325** | **39,172** |
| **The agricultural sector** | | | | | |
| Enteric fermentation | 4,326 | 6,015 | 4,728 | 10,826 | 8,509 |
| Manure management | 606 | 993 | 721 | 1,568 | 1,081 |
| Rice cultivation | 17,090 | 26,479 | 13,695 | 32,961 | 17,059 |
| Managed soil | 4,120 | 10,574 | 9,348 | 21,454 | 19,609 |
| **Sub-total** | **26,142** | **44,062** | **28,490** | **66,808** | **46,259** |
| **The LULUCF sector*** | | | | | |
| Changes in forest and other woody biomass stocks | -46,015 | -45,691 | -54,559 | -45,691 | -54,559 |
| Forest and grassland conversion | 18,933 | -7,135 | -7,156 | -7,135 | -7,156 |
| **Sub-total** | **-27,082** | **-52,826** | **-61,715** | **-52,826** | **-61,715** |
| **The waste sector** | | | | | |
| Residential | 262 | 951 | 826 | 2,326 | 1,535 |
| Commercial | 174 | 606 | 515 | 1,774 | 1,117 |
| Industrial | 1,127 | 4,160 | 3,627 | 11,082 | 6,661 |
| Construction | 3 | 14 | 12 | 34 | 28 |
| **Sub-total** | **1,566** | **5,731** | **4,980** | **15,216** | **9,341** |
| **Total** | **4,847** | **20,245** | **-17,794** | **120,523** | **33,057** |
| Per capita GHG emissions (t$CO_2$eq./person) | 0.35 | 1.10 | -0.97 | 5.49 | 1.51 |

## 6. LOW CARBON DEVELOPMENT PLAN IN CAMBODIA

### A DESIGN OF LOW CARBON DEVELOPMENT PLAN TOWARDS 2050

The LCD doesn’t only mean to reduce GHG emissions, but also to focus on a better energy efficiency improvement, which then may improve sustainable economic growth, energy security, and environmentally sound development. The RGC realizes that the LCD is very important approach to address not only the environmental distress of climate change, but also the social, economic, cultural, and political challenges. The current study proposes four policies and twelve strategies, coupled with a list of actions so as to reduce GHG emissions. Through implementing these policies and strategies, the total GHG emissions of around 38,039 (188%) and 87,462 ktCO$_2$eq./year (73%) are expected to reduce in 2030CM and 2050CM, respectively. The policy on green environment attributes the largest GHG emissions reduction of about 25,212 (66.28%) and 35,310 ktCO$_2$eq./year (40.37%) of total GHG emissions reduction in 2030CM and 2050CM, respectively. It follows by the policy on harmonization of green economy, society, and culture contributing about 11,409 (29.99%) and 47,246 ktCO$_2$eq./year (54.02%) in 2030CM and 2050CM, respectively. The policy on eco-village shares GHG emissions reduction of around 1,417 (3.73%) and 4,907 ktCO$_2$eq./year (5.61%), while the policy on blue economy contributes indirectly to reducing GHG emissions in 2030CM and 2050CM, respectively. Furthermore, the results yield that the strategies on green agriculture management and sustainable forest management attribute about 15,572 (40.94%) and 8,889ktCO$_2$eq./year (23.37%) of total GHG reductions in 2030CM, respectively, followed by green transportation of some 5,685ktCO$_2$eq./year (11.95%). However, the strategies on green transportation and green agriculture management contribute to around 25,761 (29.45%) and 20,550 ktCO$_2$eq./year (23.5%), respectively, followed by green energy of about 16,559ktCO$_2$eq./year (18.93%) in 2050CM. They are very strong causal relationship, the absence of anyone of them, the proposed low carbon development strategy cannot fully and effectively be achieved. In addition, the effective implementation of these policies and strategies doesn't only contribute to reducing GHG emissions but also ensuring sustainable economic growth, environmental sustainability, low carbon society, and green job creation. It can also provide fundamental and useful insights for the Government to formulate a concrete and feasible low carbon development plan and climate change mitigation policy in the future.

**Table 8:** Detail low carbon development policies and strategies, coupled with actions and quantitative GHG emissions reduction [kt$CO_2$eq./year]

| Four policies and twelve strategies | Actions | Quantitative GHG reductions | | | |
|---|---|---|---|---|---|
| | | 2030CM | Share (%) | 2050CM | Share (%) |
| **POLICY ON GREEN ENVIRONMENT** | | **25,212** | **66.28%** | **35,310** | **40.37%** |
| **Sustainable forest management** | | **8,889** | **23.37%** | **8,886** | **10.16%** |
| | Reductions of impact logging; | 8,866 | | 8,866 | |
| | Agro-forestry plantation; | 9 | | 9 | |
| | Reforestation of fast and slow growing species; | 8 | | 8 | |
| | Plant short and long rotation forest; and | 4 | | 1 | |
| | Natural forest regeneration enhancement. | 1 | | 1 | |
| **Strategy on sustainable waste management** | | **751** | **1.98%** | **5,874** | **6.72%** |
| | Install environmentally sound technology at landfill sites for methane recovery; | 196 | | 1,107 | |
| | Introduce 3Rs principles to minimize waste and reduce emissions; | 412 | | 3,814 | |
| | Introduce waste-to-energy technologies (incineration); | 29 | | 41 | |
| | Introduce biological treatment (composting); | 98 | | 106 | |
| | Waste separate and proper control of second hand goods import (indirect contribution); | | | | |
| | Promote self-governance and leadership to improve de-centralized coordination of waste management (indirect contribution); and | | | | |
| | Introduce and install wastewater treatment plants. | 17 | | 806 | |
| **Strategy on green agriculture management** | | **15,572** | **40.94%** | **20,550** | **23.50%** |
| | Midseason drainage; | 8,595 | | 10,699 | |
| | Off-season incorporation of rice straw; | 2,683 | | 3,339 | |
| | Replace urea with ammonium Sulfate; | 1,483 | | 1,846 | |
| | High efficiency fertilizer application; | 1,227 | | 1,814 | |
| | No-tillage; | 24 | | 48 | |
| | Replace roughage with concentrates; | 766 | | 1,379 | |
| | High genetic species; | 521 | | 938 | |
| | Daily spread of manure; and | 213 | | 381 | |
| | Construct dome digester. | 60 | | 106 | |
| **POLICY ON HARMONIZATION OF GREEN ECONOMY, SOCIETY, AND CULTURE** | | **11,409** | **29.99%** | **47,246** | **54.02%** |
| **Strategy on green transportation** | | **5,685** | **14.95%** | **25,761** | **29.45%** |
| | Use of public transport system; | 1,470 | | 2,897 | |
| | Introduce hybrid and biodiesel motorized vehicles; | 101 | | 1,110 | |
| | Low-emission and energy-efficient vehicles; and | 2,714 | | 15,373 | |
| | Eco-driving and vehicle technical inspection. | 1,400 | | 6,381 | |
| **Strategy on green energy** | | **4,281** | **11.25%** | **16,559** | **18.93%** |
| | Use of renewable energy; | 253 | | 1,284 | |
| | Reduce transmission losses and own uses; and | 560 | | 1,726 | |
| | Smart appliances and home automation (energy efficiency improvement and energy saving technology). | 3,467 | | 13,548 | |
| **Strategy on green tourism management (indirect contribution)** | | | | | |
| | Promote and implement clean city, clean resort, and good services; | | | | |
| | Promote tourist attraction through introducing cultural heritages and natural tourism (eco-tourism); | | | | |
| | Promote group tour with comfortable public transportation system; | | | | |
| | Promote green flag competition and green award for major tourism destination cities and provinces; and | | | | |
| | Introduce and encourage tourists to recycle waste, to minimize and manage waste, and to reduce emissions. | | | | |
| **Strategy on green good governance and human resource development (indirect contribution)** | | | | | |
| | Integrate green concept into academic curriculums; | | | | |
| | Introduce and improve green institutional management and arrangement; | | | | |
| | Implement green management initiatives and green jobs; | | | | |
| | Introduce and encourage green concept into local communities for natural resource management; and | | | | |
| | Enhance and increase human resource development considering youth and gender participation for low carbon society. | | | | |

| | | | | |
|---|---|---|---|---|
| **Strategy on green technologies and investment** | **1,443** | **3.79%** | **4,927** | **5.63%** |
| Green industries and industrial ecology; | 572 | | 1,440 | |
| Green technologies transfer (cleaner production); | 872 | | 3,486 | |
| Green business competition and green credit (indirect contribution); and | | | | |
| Encourage and incentivize the investment in effective environmental protection and natural resources management. | | | | |
| **Strategy on green financial mobilization (indirect contribution)** | | | | |
| Introduce green financial incentives; | | | | |
| Adopt green budget reform; | | | | |
| Introduce and implement feed-in-tariff approach for renewable energy investment; | | | | |
| Implement payment for environmental services based on polluter pays principle; | | | | |
| Conduct financial mobilization from development partners for green activities and development (*e.g.* climate change mitigation); and | | | | |
| Develop a sound market-based financial system to support resource mobilization, and effective financial resource allocation. | | | | |
| **POLICY ON BLUE ECONOMY** | | | | |
| **Strategy on green merchant marine and sustainable coastal zone management (indirect contribution)** | | | | |
| Introduce emissions standard in maritime transportation through inspection and maintenance system; | | | | |
| Promote integrated coastal zone management and mangrove plantation; | | | | |
| Develop and enforce the ballast water management to control marine invasive species; | | | | |
| Conduct proper oil resource exploration and exploitation and develop oilspill management regulation and policy; | | | | |
| Develop and implement sustainable development strategy for the sea of East Asia; | | | | |
| Promote marine biodiversity conservation and management, for instance, magrove forest, coral reefs and seagrass, etc.; | | | | |
| Conduct in-depth assessment of coastal erosion and develop its management strategy; and | | | | |
| Develop and implement land-based pollution management strategy. | | | | |
| **POLICY ON ECO-VILLAGE** | **1,417** | **3.73%** | **4,907** | **5.61%** |
| **Strategy on low carbon infrastructure** | **1,084** | **2.85%** | **3,618** | **4.14%** |
| Use the freight train for long-distance shipment; | 384 | | 427 | |
| Design comfortable and safe pavements; and | 700 | | 3,191 | |
| Design a standard road facility for different transport mode (indirect contribution). | | | | |
| **Strategy on green building** | **333** | **0.88%** | **1,289** | **1.47%** |
| Energy saving in households and institutions; | 155 | | 625 | |
| Green building designs and construction; and | 76 | | 268 | |
| Energy saving appliances in building designs. | 102 | | 396 | |
| **Total GHG reductions (kt$CO_2$eq./year)** | **38,039** | **100%** | **87,462** | **100%** |

**LOW CARBON RESEARCH NETWORK (LOCAR-NET)**

The establishment of LoCAR-Net is found very useful for the implementation of low carbon development polices and strategies in Cambodia. It can be used to facilitate and engage research communities and decision-makers with necessary knowledge to tackle internal and external challenges and to improve the capacity and understanding by using research-based evidence to influence policy making processes on the adverse impacts of climate change. It can be used to mobilize financial resources as well. In addition, through this network, various opportunities have been provided and are expected to engage different relevant stakeholders, including national and international agencies, local Governments, concerned Government/non-Government organizations, research institutes, and academia in order to enhance cooperation and dialogues among them.

## 7. CONCLUSIONS

The Government stressed that addressing economic and social development by taking climate change into account will assist the country in reducing vulnerability to potential climate risks, improving air quality, and mitigating GHG emissions. Cambodia has seen the LCD as one of the priority policy approaches not only to address the adverse impacts of climate change, but also to significantly contribute to the achievement of sustainable development goals, the NSDPs, and other Government's development policies and strategies. The total GHG emissions in Cambodia are projected to increase about 4 times and 25 times in 2030BaU and 2050BaU, respectively, from the base year. The effective implementation of the four polices and twelve strategies as well as associated actions, Cambodia is expected to become a net carbon sink, offsetting around 17,794kt$CO_2$eq./year in 2030CM and about 73% of total GHG emissions are expected to reduce in 2050CM.

## PART 1 OVERVIEW OF CAMBODIA SITUATION

### 1.1 Geography and demography of Cambodia


**Figure 1.1:** Map of Cambodia

Cambodia is an agricultural country, occupying 181,035km$^2$ and shares her 2,428km land border with Thailand to the northwest, Lao PDR to the northeast and Vietnam to the east and the south (see Figure 1.1). The country has the coastline of 435km along the Gulf of Thailand. It is influenced by the tropical monsoons with distinct rainy and dry seasons. The first extends from May to October, while the latter ranges from November to April. The average annual rainfall is about 1,400mm on the central plain and increases to as much as 3,800mm in the mountains and along the coast. The average annual temperature is about 27°C with the maximum mean temperature of about 28°C and the minimum mean temperature of about 22°C.

As far as the population is concerned, the Cambodian population was about 13.95 million in 2010, which was about 2.3% of the Southeast Asian population (NIS, 2012). At that time, about 19.5% and 80.5% of the total population of Cambodia were living in urban and rural areas, respectively (NIS, 2011). The population had increased to about 14.70 million in 2013 (RGC, 2014) and is projected to increase to about 18.39 million in 2030 (NIS, 2011) and about 21.96 million in 2050 (UN, 2011 and 2013). The total numbers of households had increased from about 2.16 million in 1998 to about 2.92 million -- about 0.55 million were urban and around 2.37 million were rural in 2010 (NIS, 2012). The Cambodian population dominated by Khmer (90.0%), Chinese and Vietnamese (5.0% of each), small numbers of Chams, Burmese and hill tribes. The predominant religion is Theravada Buddhism, virtually all Khmers are Buddhists (NIS, 2011).

## 1.2 Status of economic growth and development

After the full national reconciliation in 1999, the RGC set a **"Win-Win"** policy to unify all the national forces for socioeconomic rehabilitation and development where the priority policy was the **"War against Poverty"** (RGC, 2002). Furthermore, in order to sustain the socioeconomic growth and environmental sustainability, the Government has formulated the National Strategic Development Plan (NSDP), which focused on improving natural resources management, building peace, political and social stability, and promoting socioeconomic development (RGC, 2005, 2009 and 2014). The Royal Government of Cambodia (RGC) has made an utmost effort to rebuild the society, economy, and infrastructure and subsequently opened a market framework and the country is gradually advancing the economic development and social stability. The country has moved on the right tracks to restore and promote economic prosperity by moving from a night mare country to a rapid economic development one. As a result, Cambodia was ranked as one of the most rapid economic growth countries among the developing world (RGC, 2012).

Cambodia's economy relies on four main sectors: agriculture, industry, tourism, and construction. The highest contributor to the GDP was service (39.7%) with the tourism sector as the main contributor, followed by agriculture (29.6%) and industry, mainly contributed by the construction (23.9%) in 2010 (NIS, 2011). Although the industrial sector was smallest contributor for the GDP, it experienced the strongest average annual growth rate of around 13.6%, followed by agriculture (4.0%) and service (3.3%) during that year. The agricultural sector remains to be reckoned as one of the crucial parts for the national economy and this sector had sustained a strong annual growth of about 4.6% over the last decade (Vuthy *et al.*, 2014). Concerning the employment, the agricultural sector accounted for 54.2% of total workers, while industrial and service sectors provided 16.2% and 29.6%, respectively, in 2010 (NIS, 2012). It was observed that Cambodia had experienced an average annual economic growth rate of around 7.0% from 1994 through to 2013, while per capita GDP had quadrupled, increasing from 216USD in 1992 to more than 1,000USD in 2013 and is expected to reach roughly 1,579USD in 2018 (RGC, 2012 and 2014). Furthermore, several studies optimistically predicted that Cambodia's average annual GDP growth rate of around 7.0%, which will retain in years to come. For instance, JICA (2006) projected the average annual economic growth of around 7.0% through to 2020. And the Government recently set an economic development target to reach the status of an upper-middle income country by 2030 and a high-income level by 2050 (RGC, 2013).

The country must keep a strong and constant average annual economic growth rate of around 7.0% and this growth should be sustainable, inclusive, equitable and resilient to shocks through diversifying the economic base to achieve a more broad-based and competitive structure with low and manageable inflation, stable exchange rate, and steady growth in international reserves.

The Government reinstated that in any circumstances, the country still realizes that the stable and steady growth is largely attributed to the good performance of the agricultural sector coupled with other sectors. The Government, for instance, is increasing the value added in the agricultural sector, in particular through enhancing the value added of milled rice production and export as well as other high value agriculture products (RGC, 2013). Moreover, the country will promote the diversification of her secondary industrial base through encouraging investments in new high value added, more creative and competitive industries and expanding industrial development zones into the rural areas to boost economic growth, job creation, and incomes of people. The Government will also upgrade the diversification of manufacturing base and promote further development of Small and Medium Enterprises (SMEs). The Government is encouraging a rapid transformation of industrial structure to move from a labor-intensive and low productivity industry to a more broad-based, high-tech and high-skilled one (RGC, 2015). It is also giving priority to agro-processing industry and promoting other industries such as energy and heavy industries, water supplies, and green-based technology.

## 1.3 Agriculture and its policy

Most Cambodian households are depending on agriculture, livestock, fisheries, and Non-Timber Forest Product (NTFP) extraction for their livings. The increased agricultural productivity improves farmers' incomes, enhances consumption of high quality nutritious food, and helps people escape from poverty (Vuthy *et al*., 2014). The crop production growth over the last decade was driven largely by higher yields, which were attributable to the increased use of fertilizers, improved seeds, and available irrigation systems. It was indicated that a 1.0% increase in fertilizer use could increase wet season rice yield by 0.1% and dry season rice yield by 0.2% (Yu and Fan, 2009). However, the use of chemical fertilizer in Cambodia remains much lower than some Southeast Asian Nations (ASEANs) (Yu and Diao, 2011); thus, the intensification of rice cultivation is needed to increase agricultural output to meet the accelerating food demand by increasing the efficient application of fertilizers (Yu and Fan, 2009).

The Government shaped its policy toward enhancing rice production through developing a policy paper on the Promotion of Paddy Production and Rice Export with a vision to transform Cambodia into a **"rice basket"** and a key milled rice exporting country in the global market and set a target to export of at least one million ton of milled rice by 2015 (RGC, 2010). Therefore, there is a need to transform the traditional agricultural practice into a modern and diversified one in order to increase rice production. The Government has also improved other crop productions such as corn, cassava, mung bean, and soy bean, etc. for feeds and food processing. Livestock is also a key part of rural livelihoods and sources of incomes and food (RGC, 2013). Since the launch of the rice policy, milled rice exports have grown at a rapid pace, boasting a tenfold increase to 200,000 tons in 2012; however, this goal might not be reached due to constraints in the rice sector such as primary farm production, post-harvest handling and processing, export logistics, and physical infrastructure (Vuthy *et al*., 2014).

The Government has paid further attention to increase agriculture production by shifting from the extension of cultivated areas to intensive farming on the existing land (Jeremy and Rebeca, 2010). And it is expected to achieve through an integrated approach including the proper use of improved agricultural inputs, agricultural extension, research and development, construction and maintenance of the rural infrastructure, especially irrigation network, expansion of rural credit and microfinance, agricultural market development, organization of farmer communities, and better management of the agricultural land. The Government has put more focus on rehabilitating existing and constructing more irrigation networks to solve the water needs of the agricultural sector. In fact, the capacity of water reservoirs has been expanded and the ability to provide water for cultivation has increased (RGC, 2014).

## 1.4 Strategic planning framework for livestock management

Protein, minerals, and vitamins are essential for a healthy balanced diet and can be provided from milk, meat, and fish. Livestock is a key part of rural livelihoods and sources of incomes and food in Cambodia (RGC, 2013). The RGC has set a goal to ensure food security, increase incomes, create employment, and improve nutrition status for all people (RGC, 2014). On this, National Strategic Planning Framework for Livestock (2015-2025) was prepared with the objective to improve the livelihoods of small producers, household income, and food security and to provide a safe and sufficient supply of livestock products to the consumers as well as for export (RGC, 2015a). Besides, this strategy is developed to address the problems of transboundary and endemic animal diseases through progressive improvement of Government services, particularly the Department of Animal Production and Health and the provincial offices through to the district, commune, and village levels (RGC, 2015a).

## 1.5 Land use and its policy

The RGC holds about 14.5 million hectares (around 80% of the total land area) as **"state land"**, while around 3.6 million hectares (20%) are owned by private entities (USAID, 2011 and RGC, 2012). Cambodia has faced strong and chronological land disputes due to the lack of land use planning and the application of relevant policies and procedures is not sufficient for the effective land use management. Cambodia developed a Land Law in 2001, aiming to establish a national system of land classification and land ownership rights and to set provisions on social and economic land concessions (ELCs), which refers to a mechanism to grant private state land through a specific economic land concession contract to a concessionaire to use for agricultural and industrial-agricultural exploitation (RGC, 2005), indigenous land rights, land registration, and land dispute resolution. The law distinguished between the state land in the public domain, such as forests and protected areas (PAs), and the state land in the private domain, which is used to provide land for economic and social development (RGC, 2001). The law stipulated that the granting of concessions in several locations, jointly exceeding the 10 thousand hectares, for the same person(s) or different legal entities controlled by the same person(s) is prohibited.

The Sub-degree on ELCs was approved in 2005 with the objective to grant private state land through a specific and long-term ELC contract to use for agriculture and industrial development such as cultivation of food crops or industrial crops, raising animals and aquaculture, and construction such as plants or factories (RGC, 2005). The ELCs would help increase employment in the rural areas within the framework of intensification and diversification of livelihood opportunities and to generate state revenues through economic land use fees, taxation, and related services charges. It was reported that the RGC provided around two million hectares of degraded forest land for ELCs to some private companies to cultivate agro-industries; among them, the MAFF granted around 1.3 million hectares within forest concession areas (MAFF, 2013) and around 0.7 million hectares granted by the MoE within the PAs, which is named sustainable economic development zones (Mareth, 2014, an interview with Radio Free Asia).

The Government also declared that the land reform is a crucial tool to increase agricultural production by providing titles and security of land tenure to the poor. The land reform is vital to enhance social stability, development of an efficient land market, and environmental sustainability. The Government developed land policy in 2009 with the objective to strengthen land tenure security and land markets; to prevent or resolve land disputes; to manage land and natural resources in an equitable, sustainable and efficient manner; and to promote land distribution with equity. The RGC has issued more than 3 million land titles to Cambodian people, and granted social land concessions to 31,000 families of the poor, soldiers, and veterans (RGC, 2013). It has also provided the allocated land to about 500,000 families under the **"Old Policy-New Action"** framework (RGC, 2013).

## 1.6 Forestry and its policy

The RGC considers the ecologically, socially, and economically viable conservation and management of forest resources as a major pillar of public welfare directly contributing to environmental protection, poverty reduction, and socioeconomic development. Cambodia's forest has declined in recent decades due to logging, forest fires, land-grabbing (the contentious issue of large-scale land acquisitions, either buying or leasing), encroachment (unlawful entering, gradually and without permission, into the forest land), and intensified shifting cultivation. A logging concession system was introduced between 1994 and 1997 and the Government granted 36 forest concessions covering around 7 million hectares (70.0% of forest areas) (according to Cambodia's National Forest Progamme Background Document). Destructive, legal and illegal logging and over-capacity of processing facilities, combined with weak law enforcement and monitoring, jeopardized attempts toward sustainable forest management (ITTO, 2005). Besides, Mangroves have also been destroyed by urbanization and resort development or expansion of aquaculture, while the inundated forest around Tonle Sap Lake has been severely damaged by agricultural expansion and wood cutting for consumption. It was emphasized that the increasing population, high rates of internal migration, and rural poverty are the key factors. Forest resources accounted for, on average, 10-20% of household consumption and income sources for around one third of Cambodians (Turton, 2004). Forest resources have been extracted for firewood and charcoal, which are the main sources of energy for households and many SMEs such as palm sugar producers, noodle factories, and brick and tile industries.

To reverse the trend of forest degradation, a logging moratorium, which was a circulation issued by the Government to suspend granting forest concession to concession companies for timber export purpose, was introduced in 2002. Besides, an institutional reform was also initiated with a forest policy statement and a new forestry law. The Forestry Law was passed in 2002 stipulating that the Permanent Forest Estate (PFE) has to be managed in a sustainable way in order to maximize the social, economic, and environmental benefits and cultural values. Illegal logging and other human pressures on forest resources have noticeably decreased or stopped in many areas after the law came into force. In order to govern environmental protection and natural resources management, the Law on Environmental Protection and Natural Resource Management was enacted by the National Assembly in late 1996. Additionally, the Law on Protected Areas was passed in 2008, aiming to manage and effectively implement the conservation of biological resources and the sustainable use of natural resources in protected areas; to define the jurisdiction and responsibilities of the natural protection and conservation administration of the MoE in the management of protected areas; to determine standards and procedures for managing protected areas; to determine the responsibilities and participation of local communities, indigenous ethnic minorities, and the public; and to implement regional and international conventions, protocols, and agreements on the protection of biodiversity and ecosystem of protected areas.

As far as the forest management is concerned, there are two main Government institutions, which manage forest resources including the MoE and the MAFF. The first manages the 23 PAs, which were declared by the Royal Degree in 1993, while the latter manages commercial and reproductive forests. In 2010, forest cover was about 57.1% of the total land area decreased from around 73.0% in 1960 (RGC, 2011), which was below the target of maintaining the forest cover of 60.0% by 2015 (the target set for Cambodia Millennium Development Goals (CMDGs)). And to meet the determined target, the Government is implementing measures to reinforce the protection and management of forest resources, to decrease the pressure on forests by improving farming techniques, to reduce dependence on fuel-wood, and to engage in an active programme of forest rehabilitation and reforestation.

The RGC has issued a number of policies, orders, and proclamations in order to eliminate the forest anarchy and to move toward sustainable forest management and one approach for achieving a sustainable forestry sector was community forestry management (RGC, 2009). The Government has also embedded reform of the forestry sector into the NSDP and some other Government’s strategies. In this regard, the

Forestry Administration (FA) of the MAFF has a strong commitment to implementing the Forestry Law, relevant regulations, policy frameworks, and other related Government orders and more specifically the National Forest Programme (NFP) (2010 to 2029) (RGC, 2011). The main activity under the NFP is the implementation of REDD-plus scheme (reduce emissions from deforestation and forest degradation, forest conservation, sustainable forest management, and enhancement of carbon sinks) (Ty *et al*., 2011). In fact, two REDD-plus projects have been piloting, one in Oddar Meanchey province, which was awarded Dual Gold Validation by the Climate, Community and Biodiversity Standard and the Verified Carbon Standard, while the other in Keo Seima Protected Forests, Mondulkiri province, which was prepared Project Design Document (PDD) and submitted to a carbon standard for validation.

## 1.7 Energy and its policy

Cambodia's rapid economic growth was accompanied by a steady increase in energy demand, with peak demand rising by an annual average of over 20.0% between 2003 and 2008 (JICA, 2012). It was reported that only 29.7% of total households were connected with the national power grid in 2010, almost 100% of all households in the urban areas and around 12.3% of the rural households (MIME, 2010). It was indicated that the access to sustainable energy service was included in the CMDGs and the NSDP. It is seen as an important element to reduce fuel-wood dependency and poverty.

In 2010, the electricity sent-out by the Independent Power Producers (IPP), Electricity of Cambodia (EDC), and Consolidated Licensees comprised around 93.0% of diesel/HFO (heavy fuel oil), 3.0% of hydropower, 3.0% of coal, and 1.0% of biomass (EAC, 2010). Due to the increase of energy demand, energy imports were almost trebled from 2008 to 2010 and in 2011, 45.0% of total national electricity generation was imported from Lao PDR, Thailand, and Vietnam. It was investigated that per capita consumption of electricity had increased from around 15Kwhs/year in 1993 to 268Kwhs/year in 2013 (RGC, 2014).

In response to increasing energy needs, the Government adopted the "Law on Electricity" in 2000, which covered all activities related to the supply, provision of services and use of electricity, and other associated activities of the power sector. The law helps reform the current electricity sector, and was endorsed to boost private investors in the power sector in a fair, just, and efficient manner for the benefit of the Cambodian society. Besides, the RGC also specified the development of the energy sector in the NSDP with the prioritized aims of increasing electricity supply capacity and reducing tariff rates to an appropriate level, while strengthening institutional mechanism and management capacity. Hydropower is a cornerstone of Cambodia's energy policy with potential capacities of more than 10,000MW. The use of solar power was very low with total installed capacity between 1997 and 2002 of 205kW and reached over 300kW in 2004. The dependence on firewood had been reduced by 12.0% from 1998 to 2010 (from 90.4 % in 1998 to 79.5% in 2010); however, it remains far from the 52.0% target for 2015 (RGC, 2012).

Additionally, to meet the increasing energy demand, the Government set two main energy development targets--the first is to achieve the 100% level of village electrification (47.0% level as an intermediate target of household electrification) by 2020; and the second is to achieve 70.0% level of household electrification with grid quality electricity by 2030 (JICA, 2006). The Government has recently prepared a power sector masterplan indicating that the fuel mix of power generation in 2030 comprises natural gas (40.0%), hydropower (35.0%), coal (15.0%), import (6.0%), oil (3.0%), and renewable energy (1.0%) (MME, 2014). The Government also identified the best alternative options to introduce more constant, reliable, and affordable sources of energy and reiterated that the country has available capacity and facilities to build hydropower dams. Table 1.1 shows the detail list of power development plan.

It has been investigated that in order to reduce energy demand and $CO_2$ emissions in the future and simultaneously to provide reliable and affordable energy services to all of the end users in the most sustainable manner, the Government declared a circular on the "*implementation of electricity saving measures*" that required all Government ministries and public institutions to participate in a programme on "*electricity saving consumption*" in 2008 so as to save the national budget and to ensure the effective and efficient use of electricity. Moreover, the Government developed national policy, strategy and action plan (NEEPSAP) on energy efficiency in 2013, which covered five priority areas, including: *Energy efficiency in industry, Energy efficiency of end-user products, Energy efficiency in buildings, Energy efficiency of rural electricity generation and distribution, and Efficient use of biomass resources for residential and industrial purposes* (MME, 2013).

**Table 1.1:** Power development plan in Cambodia

| No. | Generation Expansion Plan | Fuel | MW | Year |
|---|---|---|---|---|
| 1 | Kamchay Hydro Power Plant | Hydro | 193.2 | 2011 |
| 2 | 200 MW Coal Power Plant (I) in Sihanouk Ville -Phase 1 | Coal | 100 | 2011 |
| 3 | Kirirom III Hydro power Plant | Hydro | 18 | 2012 |
| 4 | Atay Hydro Power Plant | Hydro | 110 | 2012 |
| 5 | 200 MW Coal Power Plant (I) in Sihanouk Ville -Phase 2 | Coal | 100 | 2012 |
| 6 | Tatay Hydro Power Plant | Hydro | 246 | 2013 |
| 7 | Lower Stung Rusey Chhrum Hydro Power Plant | Hydro | 338 | 2013 |
| 8 | 700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 1 | Coal | 100 | 2013 |
| 9 | 700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 2 | Coal | 100 | 2014 |
| 10 | 700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 3 | Coal | 100 | 2015 |
| 11 | 700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 4 | Coal | 100 | 2016 |
| 12 | Lower Sesan II + Lower Srepok II | Hydro | 400 | 2016 |
| 13 | Stung Chay Areng Hydro Power Plant | Hydro | 108 | 2017 |
| 14 | 700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 5 | Coal | 100 | 2017 |
| 15 | 700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 6 | Coal | 200 | 2018 |
| 16 | Steung Treng Power Plant | Hydro | 980 | 2018 |
| 17 | Sambor Hydro Power Plant | Hydro | 2600 | 2019 |
| 18 | Coal Power Plant (III) or Gas Power Plant | Coal/NG | 450 | 2020 |

## 1.8 Transportation and its policy

Cambodia's road infrastructure was almost completely destroyed after more than 20 years of civil strife and negligence; and it has recently been restored and built in order to accelerate the economic development and transportation demand. There are four main types of transportation mode, including road (80.0%), rail (1.0%), maritime (15.0%), and aviation (4.0%) (MPWT, 2013). It has been noted that the rapid urbanization presents tremendous challenges to the transportation systems; both the capital and urban areas are experiencing serious problems caused by inadequate transportation facilities and management system set against the rapid growth of population and socioeconomic development activities. Many cities are enlarging the capacity of road networks, but often at the expense of the safety of the vulnerable road users. Many people have died and injured in road crashes, which cause severe social, economic, and health consequences.

The rail transportation sector was almost entirely destroyed during the civil war of the 1970s, which urgently requires to renovate and construct. Once they are re-functioned, both of Cambodia's rail lines are expected to become part of the Greater Mekong Sub-region (GMS) southern economic corridor and to help Cambodia become more competitive by offering faster and less expensive transportation. It was indeed that the passenger train service was ceased to operate since 2009, while the freight one had gradually decreased after reaching about 557,000 tons in 2002 and only southern line remains in operation; however, it carried only cement with the cargo volume of roughly 3,000 tons (36,000 (tons.km)/year) in 2010 (MPWT, 2010 and 2012). The rail transportation mode is expected to grow by 7.0-12.0% per year by 2030, with a projected increase in locomotives (ADB, 2011).

Besides, the inland waterway also plays very important role for both passenger and freight demand. It has a total navigable length of around 1,750km of which only 580km are navigable all year round. The Mekong River accounts for about 30.0% of the total length of navigable inland waterways, Tonle Sap 15.0%, Tonle Bassac 5.0% and the remaining waterways 50.0%. The inland waterway has steadily declined in recent years as cargoes were switched to road transportation. However, it is expected to increase in the future due to the waterway improvements, including dredging to maintain the navigable length and providing safety markers. Regarding the air transportation mode, the State Secretariat of Civil Aviation of Cambodia (SSCA) undertook the operational management of Phnom Penh International Airport since 1995, Siem Reap International Airport since 2001, and Preah Sihanouk Airport since 2006. Since the Government policy to attract seven million foreign tourists annually by 2020 (MoT, 2012), Cambodia will improve international airports and rehabilitate the local ones located in several tourist destination provinces to support the eco-tourism.

At the time of the increasing traffic demand, the RGC does not ignore environmental stresses, and the strategy on Environmental Sustainable Transportation Development (ESTD) was formulated to ensure stable economic growth and environmental sustainability. The strategy focused on the establishment of transportation networks in accordance with land use planning; the introduction of modern public transportation systems to respond to future traffic demand; the development of efficient, comfortable, and safe transportation systems to reduce traffic congestion; and the establishment of efficient traffic control systems with the provision of traffic signals in urbanized areas to reduce traffic accidents and congestion through effective traffic law enforcement.

### 1.9 Waste generation and its management policy

The increasing population and economic development in tandem with the rapid urbanization and industrial development as well as limited national regulation for waste management are the main cause of waste generation and improper disposal, which cause increasing concerns for waste management in Cambodia. Indeed, waste disposal at landfill sites increased almost triple between 2004 and 2012 (DoPC, 2013). Similarly, wastewater generation has increased significantly over the past decade; however, the country doesn't have the exact figure at the moment. Most of wastewaters are discharged with treated and untreated or by natural purification process into receiving waters sources without complying with the environmental standards. There is no central wastewater treatment plant for domestic wastewater treatment, etc. In order to address the challenges of waste management, the RGC adopted the sub-decree No. 36 on solid waste management in April 1999, which is a fundamental regulation of solid waste management. It doesn't only apply to manage simple solid wastes and/or garbage properly, but also to manage hospital, industrial, and other hazardous wastes (RGC, 1999). The sub-decree requires the MoE to establish guidelines on disposal, collection, transportation, storage, recycling, minimizing, and dumping of household waste in provinces and cities in order to ensure the proper management of household waste. The authorities of the provinces and cities should establish waste management plans in their respective provinces and cities for short, medium, and long terms.

Besides, as a supplement to this sub-decree, the Ministry of Environment (MoE) and the Ministry of Interior (MoI) issued a joint Declaration (Prakas) No. 80 in 2003 (MoE/MoI, 2003) with the objectives to improve the responsibility of an authority and to engage institutions for efficient implementation of solid waste management in provinces and cities of Cambodia, in order to protect human health, environmental quality, aesthetics, and biodiversity. The declaration clearly states that disposal of waste in public areas, streets, and canals are illegal. In addition, local governments are required to provide sufficient waste bins, to arrange forbidden signs and educate the residents on proper waste management, to establish temporary waste stock, and to clean and dispose the generated solid waste in their administrative areas regularly. The MoE developed a national environmental guideline on solid waste management in order to ensure the protection of the public health, environment, and the conservation of bio-diversity to avoid pollution by solid waste. This guideline is intended to encourage/push to carry out the principle for the avoidance/reduction of waste amount, reuse, recycle, and disposal of solid waste in a proper technical and safe manner; to encourage/push for all citizens from different levels to understand and to be familiar with the importance of environmental and natural resources protection for the present and future generations; and to encourage/push for the establishment of a proper waste management plan in order to assure a sustainable environmental management, to protect natural assets and simultaneously to create jobs (MoE, 2006). Moreover, the

MoE proposed 3Rs (reduce, reuse, and recycle) strategy to ensure an efficient solid waste management system through increasing waste collection service, promoting waste separation for recycling, enhancing organic waste composting, and improving disposal sites (MoE, 2009). The strategy states that by 2015, the Government plans to compost about 20% of organic waste from all sectors and by 2020, the Government plans to increase composting of organic waste from households by around 40% and from business centers by about 50%, etc.

On top of that, the Government approved the Sub-degree on municipal solid waste management on 27th August 2015 with the objective to improve municipal solid waste management in an efficient, transparent, and accountable manner in order to ensure the protection of aesthetics, public health, and environment (RGC, 2015b). This Sub-degree is intended to enhance the responsibilities of ministries, institutions, specialized agencies, sub-national administrations, and other key stakeholders on municipal solid waste management; to decentralize municipal solid waste management powers to authorities of municipalities, cities, and districts; to take necessary actions to fortify an efficient and safe municipal solid waste management; and to raise public awareness and encourage the participation from the publics to prepare and implement municipal solid waste management actions. In addition, the Government issued an inter-ministerial (MoE/MoI) circulation to monitor the effective implementation of this Sub-degree (MoE/MoI, 2015). And, in order to mainstream and raise environmental awareness more widely, the MoE and the MoEYS prepared an inter-ministerial (MoE/MoEYS) declaration on the establishment of a working group for facilitating the cooperation between the twos in the framework of environmental education, training, research, and consultation (MoE/MoEYS, 2016).

Similarly, the RGC adopted the Sub-degree on water pollution control in 1999 with the main objective to regulate the water pollution control in order to prevent and reduce the water pollution of the public water areas so that the protection of human health and the conservation of bio-diversity should be ensured (RGC, 1999a). The MoE has encouraged the implementation of its surveillance on major pollution sources, *e.g.* factories and large enterprises, by encouraging the installation of liquid waste treatment plants at sources, air purification devices before emitting, and noise reduction equipment (RGC, 2014).

## 1.10 National climate change policy

Climate change has become one of the greatest risks facing humanity and a high priority of global concern in the 21st century. As the earth continues to heat up, the severity of climate change impacts on global socioeconomic development and environmental sustainability continue to intensify and amplify, prompting the need to seek urgent solutions. A recent assessment report discovered that warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. It went on to stress that the atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of GHGs have increased (IPCC, 2013). The report highlighted that among the total world GHG emissions of 49Gt$CO_2$eq./year in 2010, the energy sector contributed by about 35.0%, the AFOLU sector by 24.0%, industry by 21.0%, transportation by 14.0%, and buildings by 6.4% (IPCC, 2013). It was suggested that the anthropogenic GHG emissions from the AFOLU sector, which attributed mainly from deforestation and agricultural emissions from livestock, soil and nutrient management, had decreased from around 31.0% in 2004 to 24.0% in 2010 (IPCC, 2007 and Smith *et al*., 2014). Even so, the total amount of GHG emissions from this sector remained similar and the share to the world emissions had decreased largely due to increases in emissions in the energy sector.

It was also observed that Southeast Asia has faced increasing threats from climate change, with increasing loss of human lives and significant damage to economic development and natural resources. We have all observed the alarming trends of more frequent and intensified floods, droughts, saline intrusion, and extreme weather events, especially over the last decades. As for Cambodia, the temperature has increased and this trend is predicted to continue with mean temperatures increase between 0.013$^{o}$C to 0.036$^{o}$C per year by 2099 (MoE, 2013). In terms of GHG emissions, Cambodia is regionally and globally insignificant with per capita GHG emissions of about 0.23t$CO_2$/year in 2000 (MoE, 2013). The highest contributor was Land Use Change and Forestry (LUCF), which accounted for about 51.0%, followed by agriculture 45.0%, energy (4.0%), and waste (less than 1.0%). However, the country had changed from a net carbon sink in 1994 (MoE, 2002) to a net emitter in 2000 (MoE, 2013) and is expected to continue to increase in the future. Although Cambodia's GHG emissions are negligible, the participation of Cambodia as a member of the UNFCCC should be partially important to contribute to the global effort to achieving the GHG emissions reduction target (UNFCCC, 1992 and 1998)

Climate change mitigation is a human intervention to reduce the sources or enhance the sinks of GHGs emissions into the atmosphere. There is a need to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, and such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to the changing climate, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner (IPCC, 2014). Additionally, the Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities (Article 3 of the UNFCCC) (UNFCCC, 1992). On this, international communities agreed to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change (Article 2 of the Paris Agreement, UNFCCC, 2015).

Cambodia is aware that climate change is caused by intensive human industrial activities and past unsustainable economic development. As indicated previously, Cambodia has experienced a significant and steady economic growth; however, at the same time Cambodia has severely affected by the adverse impacts of climate change. The country has witnessed floods and droughts resulting in considerable economic losses, infrastructure damages and fatalities. The Government realized that addressing economic and social development by taking climate change into account will assist the country in reducing vulnerability to potential climate risks, improving air quality, and mitigating GHG emissions. In response, Cambodia has been working very closely and extensively with the world communities by ratifying the UNFCCC on 18 December 1995 and acceding to the Kyoto Protocol on 04 July 2002. In 2006, the Government adopted the National Adaptation Programme of Action (NAPA) covering 39 adaptation projects including agriculture development, water supply, irrigation, health care, fighting malaria, malaria education, agro-forestry development, and coastal zones (NAPA, 2006). Cambodia has established the National Climate Change Committee (NCCC) in 2006 as the policy and decision making body with the mandate to prepare, coordinate, and monitor the implementation of policies, strategies, legal instruments, plans and programmes to address climate change issues. The NCCC is chaired by the Minister of the Environment and honorary chair by the Prime Minister. Besides, a Climate Change Technical Team (CCTT) was established as an inter-ministerial body to provide technical support to the NCCC in fulfilling its mandate. Furthermore, the Government established National Council for Sustainable Development (NCSD) on 09 May 2015 with the primary mandate to prepare, coordinate, and monitor policies, strategic and action plans, legal instruments, and programmes related to sustainable development. The national council chaired by the Minister of Environment. Additionally, Cambodia prepared her Intended Nationally Determined Contribution (INDC) in compliance with the “Lima Call for Action” which then submitted to the UNFCCC in 2015 in order to indicate her contribution to the global effort to stabilising GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (RGC, 2015c). It is noted that the MoE has been appointed as the national focal point for the UNFCCC and its Kyoto Protocol, and the secretariat for the Cambodian Designated National Authority (DNA) for the Clean Development Mechanism (CDM). Ten CDM projects were approved, nine of which have been registered by the UN CDM Executive Board, and can reduce approximately two million tons of GHG emissions (MoE, 2013a). Cambodia has put a strong commitment on managing forests under the REDD-plus scheme (Ty *et al*., 2011).

The RGC has mainstreamed climate change into the National Strategic Development Plan (NSDP) Update (2009-2013), aiming to build the capacity of the Government’s institutions and to develop a strategy dealing with the anticipated impacts of climate change, and to strengthen disaster management capabilities and other development activities. In addition, some local organizations have implemented voluntary carbon standards as viable alternatives to the CDM. There are two Voluntary Emission Reductions (VERs) projects, including National Bio-digester Programme (NBP) and Fuel-wood Saving Project (CFSP). The first covered 10,000 family-sized bio-digesters with the expected annual emissions reduction of around 59kt$CO_2$ eq./year, while the latter has been working on the improvement of cook stoves that consume about 20.0% less charcoal than traditional ones, and could reduce GHG emissions by about 160kt$CO_2$eq./year over the period of 2003-2012 (RGC, 2013a). Precisely, Cambodia launched National Strategic Plan on Green Growth (NSPGG) (2013-2030) in March 2013, aiming to promote national economy with growth stability, reduction and prevention of environmental pollution, safe ecosystem, poverty reduction, and promotion of public health service, educational quality, natural resource management, sustainable land use, and water resource management to increase energy efficiency, ensure food safety, and glorify the national culture (NCGG, 2013). Besides, in November 2013, the country launched the first ever Climate Change Strategic Plan (CCSP) (2014-2023) in order to develop Cambodia towards a green, low-carbon, climate resilient, equitable, sustainable, and knowledge-based society (MoE, 2013a). It covers eight main strategic objectives (SOBs), including:

(1) SOB-1: Promote climate resilience through improving food, water, and energy security;
(2) SOB-2: Reduce sectoral, regional, gender vulnerability, and health risks to climate change impacts;
(3) SOB-3: Ensure climate resilience of critical ecosystems (Tonle Sap Lake, Mekong River, coastal ecosystems, and highlands, etc.), biodiversity, protected areas, and cultural heritage sites;
**(4) SOB-4: Promote low-carbon planning and technologies to support sustainable development;**
(5) SOB-5: Improve capacities, knowledge, and awareness for climate change responses;
(6) SOB-6: Promote adaptive social protection and participatory approaches in reducing loss and damage due to climate change;
(7) SOB-7: Strengthen institutions and coordination frameworks for national climate change responses; and
(8) SOB-8: Strengthen collaboration and active participation in regional and global climate change processes.

### 1.11 Low carbon development framework in Cambodia

The LCD or Low Carbon Society (LCS) is no longer a new concept for Cambodia. It has been introduced to this country since 10 January 2010 through the first LCD plan scoping meeting in Phnom Penh, Cambodia with the support from the Institute for Global Environmental Strategies (IGES), Kyoto University, and National Institute for Environmental Studies of Japan (Photo 1). Furthermore, IGES awarded a short-term LCS and climate change policy related training course to an officer of the MoE in the following year.

The LCD refers to the development of an economy, which has a minimal output of GHG emissions into the atmosphere. It is a sustainable developed or developing society on the basis of close, reasonable, and harmonious coordination of economic and social development and environmental protection (Skea and Nishioka, 2008). In Cambodia, the LCD means not only to reduce GHG emissions, but also to ensure better resource efficient consumption and energy efficiency as well as to improve economic growth. The LCD implementation will significantly contribute to the achievement of the CMDGs (recently so-called sustainable development goals) and other development plans and strategies of the country. It is considered as one of important economic development instruments for a sound socioeconomic development and environmental sustainability. The RGC has mainstreamed the LCD concept into relevant Government institutions, academia, and research institutes as well as other key stakeholders through workshops and trainings. It was obviously proposed in the SOB-4 of the CCCSP (2014-2023) that is "to promote low-carbon planning and technologies to support sustainable development". Politically, H.E. Dr. Mok Mareth, then Senior Minister, Minister of Environment of Cambodia was invited and honored to be a co-chair with H.E. Mr. Fumio Kishida, Minister for Foreign Affairs of Japan for the Second East Asia Low Carbon Growth Partnership Dialogue in Japan in May, 2013 (see Photo 2). The first also signed an MoU on the Low Emission and Climate Resilient Development with Ms. Rebecca Black, the United States Agency for International Development (USAID) Mission Director in June 2013, aiming to Enhance Capacity for Low Emissions Development Strategies (EC-LEDS) and to become an official EC-LEDS partner country with the United States (see Photo 3). Then, the Minister of Environment, H.E. Mr. Say Samal, also signed a Low Carbon Growth Partnership with H.E. Mr. Kumamaru Yuji, Ambassador Extraordinary and Plenipotentiary of Japan in April 2014, aiming to ensure the achievement of sustainable development and to address climate change (see Photo 4).

Cambodia is an energy poor country and uses little modern energy due to limited resources and energy technologies. The country needs to improve the energy consumption pattern by developing an energy system in an efficient and sustainable way to ensure sufficient energy distribution and simultaneously to reduce $CO_2$ emissions. The country also needs to improve the energy intensity status, promote end-use device efficiency, adopt some behavioral and consumption styles, and fuel switching from conventional to low-carbon energy. Cambodia requires developing a methodology for projecting the future scenario to achieve a sustainable and low carbon growth. A possible low carbon development framework can be seen in Figure 1.2: The shift from unsustainable development to a sustainable manner.

Renewable energy is considered as the best energy option to reduce $CO_2$ emissions. As for concrete low carbon measures, the Government considers hydropower as one of the main sources of energy supply, not only from the point of meeting the increasing energy demand, but also toward the LCD. Another important option for the LCD is an improvement of energy efficiency. On this, Cambodia developed national policy, strategy, and action plan on energy efficiency in 2013 to reduce energy demand and $CO_2$ emissions and at the same time to provide reliable and affordable energy services to all of the end users in the most sustainable manner (MME, 2013). The Government also established a national transportation implementation plan in 2012 to address the issues through implementing vehicle inspection, regulation of second hand vehicles, eco-driving, road management, and infrastructure improvement (MPWT, 2013). The Government has also encouraged the use of public transportation system such as buses and commuter trains, especially in some major cities, with a low-cost and efficient service (RGC, 2014). The country also sees technology development, transfer, and diffusion as a necessary prerequisite for a meaningful response to climate change as well as to promote low carbon social and economic development (RGC, 2013a).

**Photo 1:** The first low-carbon development plan scoping meeting in 2010

**Photo 2: H.E. Dr. Mok Mareth,** Former Senior Minister, Minister of Environment (right) and **H.E. Fumio Kishida**, Minister for Foreign Affairs during the Second East Asia Low Carbon Growth Partnership Dialogue

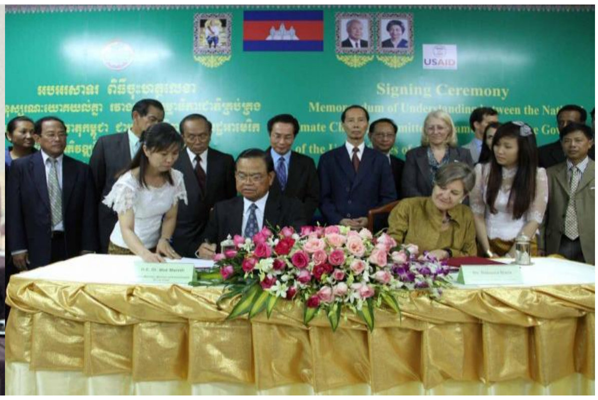


**Photo 3: H.E. Dr. Mok Mareth,** Former Senior Minister, Minister of Environment (left) and **Ms. Rebecca Black**, USAID Mission Director


**Photo 4: H.E. Mr. Say Samal**, Minister of Environment (right) and **H.E. Mr. Kumamaru Yuji**, Ambassador of Japan signed Low Carbon Growth Partnership

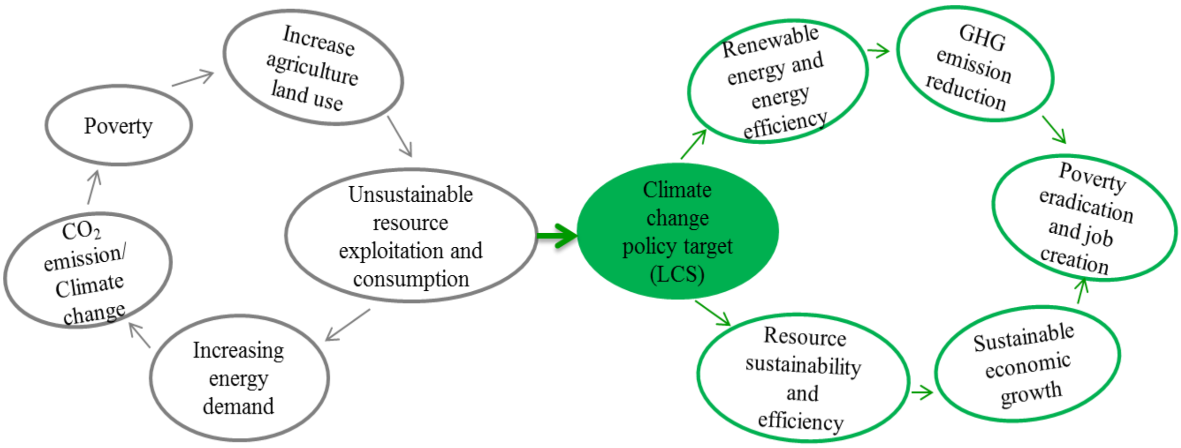


**Figure 1.2:** The shift from unsustainable development to a sustainable manner

### 1.12 Low carbon activities in Cambodia

The low carbon research network (LoCAR-Net) is a suitable and effective mechanism to bridge the gap between researchers and policy makers as well as other key stakeholders through dialogues. In this context, the establishment of the LoCAR-Net in Cambodia is considered playing very critical role to ensure the effective implementation of the LCD and climate change related activities. This network provides substantial advantages and important for data collection and discussion and helps distribute LCS and climate change related activities as well as to bring together different key stakeholders including decision-makers through trainings, workshops, and other climate change events. For instance, a series of workshops and training on LCD/LCS related topics have been organized in Cambodia and the targeted participants have been extended to not only Cambodians but also to Lao PDR and Myanmar, etc. See Photos 5-9: Subsequent workshops and training in Cambodia. Besides, in order to distribute LCS concept and activities, Japanese delegates led by Dr. Shuzo Nishioka, Secretary General of LoCAR-NET, IGES visited several universities and research institutes, including Royal University of Phnom Penh (RUPP) (Photo 10), Institute of Technology of Cambodia (ITC) (Photo 11), Royal University of Agriculture (RUA) (Photo 12), and Cambodian Agricultural Research and Development Institute (CARDI), etc. in 2010. On top of that, the same delegates paid a courtesy call on the leaders of the Ministry of Environment, including H.E. Dr. Mok Mareth, former Senior Minister, Minister of Environment on 23rd April 2013 in order to seek the support and enhance LCS activities in Cambodia (Photo 13). Besides, delegates from IGES and NIES of Japan visited H.E. Mr. Say Samal, Minister of Environment on 27th February 2015 in order to introduce LCS activities and seek for his cooperation and support as well (Photo 14). They both expressed their strong support and cooperation on this matter as well as encouraged the implementation of LCS related activities in the country in the future.

**Photo 5:** Workshop on a systematic and quantitative design of low carbon development plan for Cambodia on 22nd April 2013 co-chaired by **H.E. Mr. Chay Samith**, Delegate to the Government and Director General of General Administration for Nature Conservation and Protection (left) and **Dr. Dr. Shuzo Nishioka**, Secretary General of IGES (right)

**Photo 6:** Capacity-building workshop on low carbon development policies for Cambodia, Lao PDR, and Myanmar on 25-26 February 2014 co-chaired by **H.E. Mr. Sin Khandy**, Under Secretary of State of the MoE and **Dr. Shuzo Nishioka**, Secretary General of IGES

**Photo 7:** Workshop on the advancement and enhancement on low carbon development researches and policies among Cambodia, Lao PDR, and Myanmar on 26th February 2015 co-chaired by **H.E. Mr. Sao Sopheap**, Chief of the Cabinet and Adviser to the MoE and **Dr. Shuzo Nishioka**, Secretary General of IGES


**Photo 8:** Workshop on enhancing actions for a better response to climate change – towards COP21 and beyond on 21st September 2015 for Cambodia, Lao PDR, and Myanmar co-chaired by **H.E. Mr. Sao Sopheap**, Chief of the Cabinet and Adviser to the MoE (middle), **H.E. Dr. Tin Ponlok**, Secretary General of National Council for Sustainable Development of the MoE (right), and **Dr. Shuzo Nishioka**, Secretary General of IGES (left)


**Photo 9:** Capacity building training on low carbon planning on 22nd-23rd September 2015 co-chaired by **H.E. Dr. Tin Ponlok**, Secretary General of National Council for Sustainable Development of the MoE (middle), **Prof. Yuzuru Matsuoka**, Kyoto University (right), and **Dr. Shuzo Nishioka**, Secretary General of IGES (left)


**Photo 10:** Introduce low carbon activities to the RUPP, **Mr. Kok Sothea**, lecturer (white shirt) in 2010

**Photo 11:** Discuss with Japanese expert on biofuel project (black t-shirt) at ITC in 2010


**Photo 12:** Visit the rector (white shirt, fourth from the right) of the RUA in 2013

**Photo 13:** Visit **H.E. Dr. Mok Mareth**, former Senior Minister, Minister of Environment (fourth from the right) in 2013


**Photo 14:** Visit **H.E. Mr. Say Samal**, Minister of Environment (second from the right) to introduce LCS activities and seek for his further support in 2015

## PART 2 THE ENERGY SECTOR

### 2.1 Overview of the Extended Snapshot (ExSS) tool

The ExSS tool is a system of simultaneous equations. It is a designing tool of a future society rather than a projection or prediction of a likely future. Given a set of exogenous variables and parameters, solution is uniquely defined. Only $CO_2$ emissions from energy consumption are calculated, even though the ExSS tool can be used to estimate other GHG emissions and environmental loads such as air pollution, etc. For the future estimation, the assumption of export value is especially important if the target region is thought to (or, desired to) develop some particular industries, such as automotive manufacturing or sightseeing, etc.

The scenario for the LCD in this report is done in two stages: 1) Preparing and adjusting the tools for the Cambodian study to quantify projections, and 2) Identifying low-carbon measures based on the projected quantitative information for developing a future sustainable society. **"Scenarios"**, in this study, mean a plausible description of how the future may develop based on a coherent and internally consistent set of social, economic, and industrial assumptions about key driving forces and relationships. These characteristics well suit for the study of the LCD in Cambodia. The scenarios developed are valuable material for decision makers to design an LCD with several images of the future based on the different assumptions of socioeconomic indicators and the decision makers can select one of the scenarios, which is best suitable for socioeconomic development and for lowering $CO_2$ emissions in Cambodia.

To provide quantitative information on macro-socioeconomic and environmental variables, the Extended Snapshot (ExSS) tool, which has been applied to some Asian countries including Bangladesh (Tahsin *et al.*, 2012), Japan (Gomi *et al.*, 2009), Malaysia (Janice *et al.*, 2009 and Siong *et al.*, 2013), Thailand (Bundit *et al.*, 2010), and Vietnam (Nguyen, 2012) is applied. In order to estimate the activity of industrial, commercial, and residential sectors related to macro-socioeconomic framework, an input-output approach is applied, and adjustments of parameters are made to reflect the real economic structure of Cambodia. Using these sectoral activities coupled with energy device characteristics, energy consumption and $CO_2$ emissions are calculated. Based on the prescribed changes in population and numbers of households, gross domestic product (GDP), industrial structure, employment, passenger and freight transportation, and energy consumption, the ExSS tool can project $CO_2$ emissions at present and in the future in a consistent way to assess the impact of low-carbon measures in Cambodia.

The methodology of the ExSS tool is classified into seven steps (see Figure 2.1) as follows:

**(1) Setting framework:** framework of an LCD scenario including target area, base year, target year, environmental target, and the number of scenarios;

**(2) Assumptions of socioeconomic situations:** population, GDP, etc., before conducting more detailed quantitative projection, qualitative future images should be designed, including images of lifestyle, economy, and industry, land use, and so forth;

**(3) Quantification of socioeconomic assumptions:** to estimate a future snapshot of a society based on the future image of (2), values of exogenous variables and parameters are estimated. Using those inputs, the ExSS tool calculates socioeconomic indices of the target year such as composition of GDP, outputs by industries, transportation demand, and so forth (see Figure 2.2: The detail structure of the ExSS tool);

**(4) Collection of low-carbon measures:** to be implemented by the target year; for example, high energy-efficiency devices, public transportation, the use of renewable energy, and energy saving behaviors, and so on;

**(5) Setting the introduction of low-carbon measures by the target year:** technological parameters related to energy demand and $CO_2$ emissions, energy efficiency, and so on are listed;

**(6) Projection of $CO_2$ emissions by the target year:** based on socioeconomic indices and assumptions of measures introduced, $CO_2$ emissions are calculated; and

**(7) Proposal of strategies:** proposed strategy sets to introduce the measures introduced.

Additionally, the ExSS tool can show reduction potentials of each low-carbon measure and the decomposition of reduction factors. It can also identify measures, which have high reduction potentials and important.

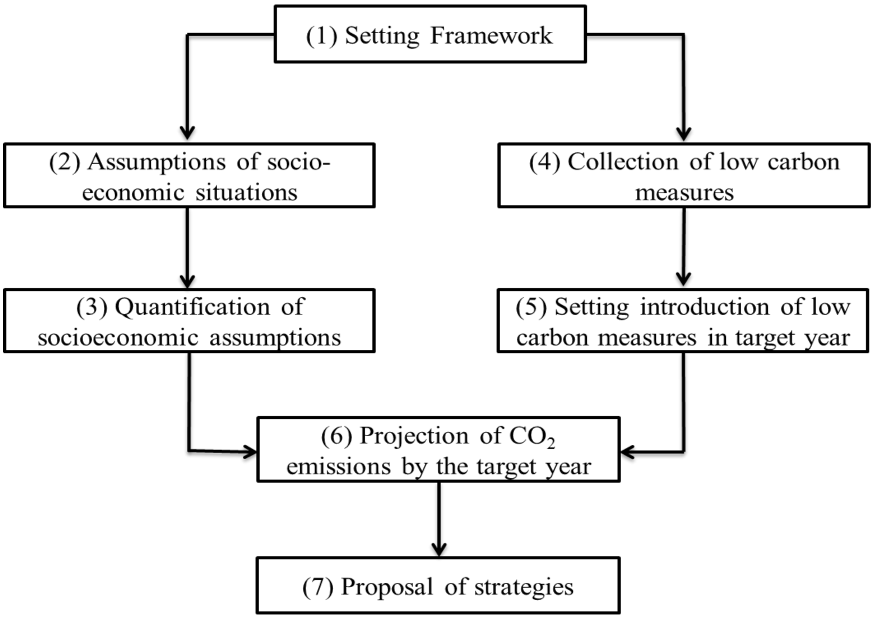


**Figure 2.1:** The procedure of the ExSS tool

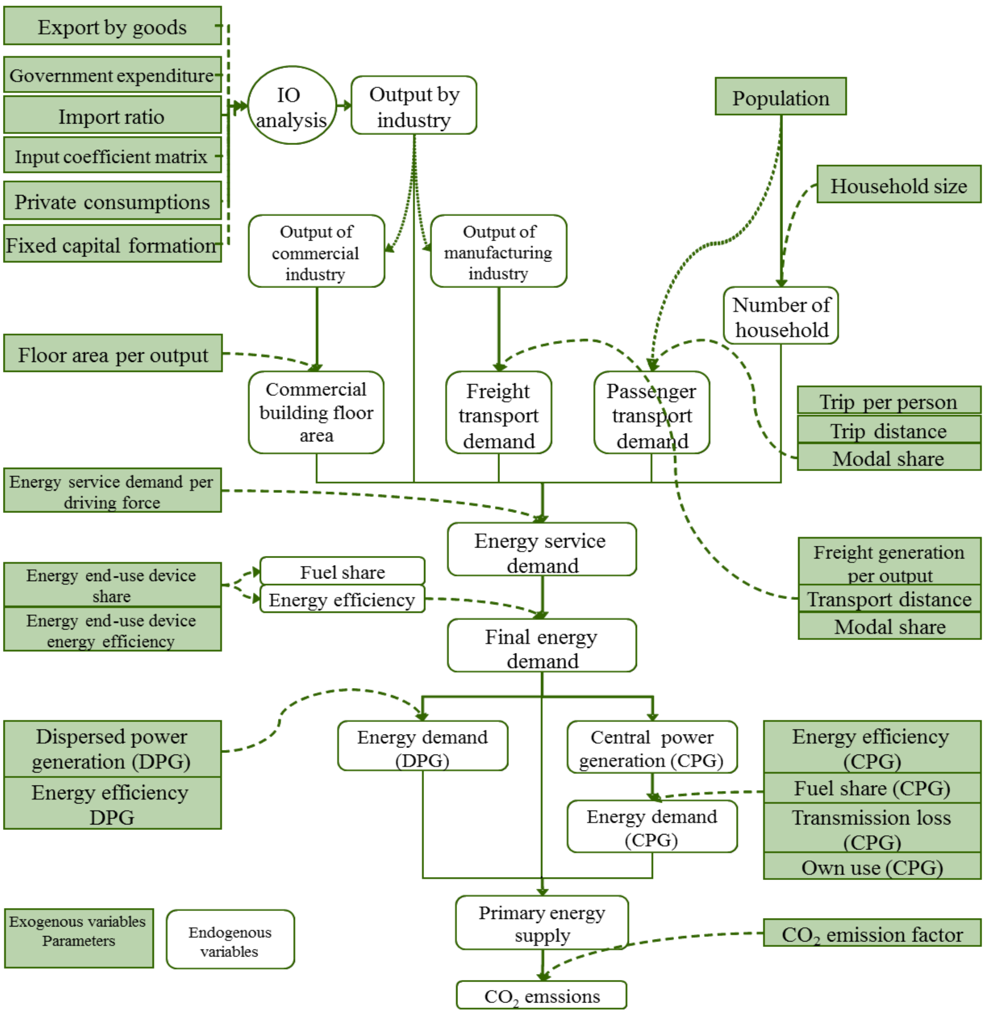


**Figure 2.2:** The structure of the ExSS tool

## 2.2 Data collection

Given the limited country information, additional calculations and assumptions are made to apply the model; for instance, estimation of the transportation demand and structural quantification of detailed energy demand, projections of demography and economy, and so on. The estimation and assumptions based mainly on available data, historical trends, and author's professional insights. Most of the data are mainly collected from the relevant Government documents and a series of discussions are made with key Government's officers and involved institutions to make the assumptions and estimation more reliable and acceptable to envision future development pathway of Cambodia. The procedures to acquire data assumptions are made in three steps.

First, relevant documents are collected and discussed with the involved persons to ensure the validity, reliability, and applicability of the collected information.

Second, a series of workshops are organized to disclose a preliminary estimation and to collect further comments and inputs from the participants to improve the assumptions and estimations.

Third, intensive interviews with relevant Government officers and experts are conducted. Table 2.1 shows lists of some collected documents and the interviewees, while Table 2.2 indicates a series of workshops held for collecting inputs and comments as well as for disclosing the adjusted results to estimate $CO_2$ emissions and reduction potentials in Cambodia.

**Table 2.1:** Lists of data collection and interviewees in Cambodia

| Sectors | Documents | Interviewees | Explanation |
|---|---|---|---|
| Demography | Statistical Year Book of Cambodia 2011; Cambodia Socioeconomic Survey 2010 of National Institute of Statistics of the Ministry of Planning (MoP) | H.E Mom Marady, Advisor to MoP | Discussed about demographic data and future population projection |
| Economy | Economic Statistics (main macroeconomic indicators) of Supreme National Economic Council (SNEC); IO table 2008 provided by Dr. Oum Sothea; Rectangular strategy phase III; National Strategic Development Plan (2014-2018) | H.E Ung Luyna, Head of Social Policy Devision, (SNEC); Dr. Oum Sothea, Economist of Economic Research Institute for ASEAN and East Asia in Indonesia | Discussed about the IO table and its validity; Government development strategy; long term economic development target (to be an upper middle-income level by 2030 and a high-income one by 2050), etc. |
| Energy | Energy balance table (1995-2010) provided by Mr. Heng Kun Leang; Analysis on Energy Saving Potential in East Asia by Mr. Lieng Vuthy; National Policy, Strategy and Action Plan on Energy Efficiency in Cambodia in 2013; Power Development Master Plan towards 2030 in 2014 of the Ministry of Mines and Energy (MME) | Mr. Hang Seiha, Vice Chief of Office of Energy Efficiency; Mr. Heang Bora, Deputy Director; Mr. Touch Sovanna, Director of Energy Technique Department, MME; Mr. Heng Kunleang, Director of Department of Energy Development, MME; Mr. Por Nimol, Deputy Director General, MME | Discussed about energy efficiency development plan; long term energy demand projection; power Development plan and master target. Clarified about the information used to construct energy balance table and the cooperation with International Energy Agency (IEA), etc. |
| Transportation | Data on vehicle fleet of Cambodia in 2009; Overview on Transportation Infrastructure Sectors; Annual Transportation Sector Report; National Implementation Plan on Environmental Improvement in Transportation Sector of the Ministry of Public Works and Transport (MPWT) | Mr. Bong Vuthy, Director of Inland Water Transport Department, MPWT; Mr. Chhreng Phollak, Director of Department of Planning, MPWT; Mr. Taing Peou, Chief of Office of Land Transport; Mr. Preab Chanvibol, Director of Land Transport Department, MPWT | Discussed about the registered vehicles; vehicle fleet data for the second national communication; transportation development strategy and action plan; and long term perspective, inland, air, and railway transportation sector, etc. |
| Cross sector | Draft Second National Communication; Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation; Cambodia Climate Change Strategic Plan (2014-2023) of the Ministry of Environement (MoE) | H.E Dr. Tin Ponlok, Secretary General of Green Growth, MoE; Mr. Sum Thy, Director of Climate Change Department, MoE | Discussed about the data used for the second national communication as some parts used for this study and technology improvement for energy and transportation, etc. |

**Table 2.2:** Lists of workshops in Cambodia

| Titles | Date | Venue | Participants |
|---|---|---|---|
| Workshop on a Systematic and Quantitative Design of Low Carbon Development Plan for Cambodia | 22-Apr-13 | Phnom Penh, Cambodia | Around 60 participants participated the workshop from line ministries, research institutes, academia, NGOs and Development Partners as well as research institutes and academia from Japan |
| Capacity Building Workshop on Low Carbon Development Policies for Cambodia, Lao RDR, and Myanmar | 25-26-Feb-14 | Phnom Penh, Cambodia | Around 70 participants from Institute for Global Environmental Strategies, National Institute for Environmental Studies, and Kyoto University, Japan; Representative of Research Institute from Myanmar; Representatives of Government agencies, research institutes and academia of Cambodia |
| The Advancement and Enhancement on Low Carbon Development Researches and Policies among Cambodia, Lao PDR, and Myanmar | 26-Feb-15 | Phnom Penh, Cambodia | Around 70 participants from Institute for Global Environmental Strategies, National Institute for Environmental Studies, and Kyoto University, Japan; Representative of Research Institute from Myanmar; Representatives of Government, research institutes and academia of Cambodia |

## 2.3 Collection of low-carbon measures

Low carbon measures considered feasible to be introduced by the target years are collected. They include high energy-efficiency devices, public transportation, the use of renewable energy, and energy saving behaviors, and so on. The selection of low carbon measures must be in line with national sustainable development objectives and provide highest development benefit to the people even if no concrete target of reduction exists (MoE, 2013 and 2013a; NCGG, 2013; and RGC, 2013). Furthermore, technical data are required to estimate their effect to reduce $CO_2$ emissions. The detail information of low carbon measures applied in this study is shown in Table 2.3, while detail low carbon measures with quantitative emissions reduction by sectors are shown in the Appendix 1.

**Table 2.3:** Lists of low carbon measures

| Sectors | Low carbon measures |
|---|---|
| Residential | Energy efficiency improvement of electrical and non-electrical equipment (eg. Cook stoves, lighting, refrigerators, hot water, heating, other equipment), fuel switch, and energy saving behavior |
| Commercial | Efficiency improvement in electric devices (eg. Lighting, refrigerators, hot water, heating, other equipment), insulation buildings (passive house), and energy saving behavior |
| Industrial | Energy efficiency improvement (eg. Steam boilors, furnaces, motors, and other equipment), fuel switch, and energy saving technology |
| Transportation | Fuel efficient vehicles, fuel switch (eg. Gasoline to natural gas, electric and biofuel), and modal shift (eg. Private cars and motorbikes to buses and trains), and eco-driving |
| Power | Reduction of transmission loss, fuel efficiency improvement (oil, coal and gas), and fuel switch from non-renewable to renewable energy (solar/wind) |

## 2.4 Data quantification and assumptions for the present and the future

The information on socioeconomic development and energy supply and demand in the base year (2010) is collected, while through to 2050 some available information is used to assume and project the future trends. The detailed list of the macro-socioeconomic indicators for the present and future are shown in Table 2.4.

**Table 2.4:** Macroeconomic indicators [Million USD at 2000 constant price]

| Indicator | 2010 | 2030 | 2050 | 2030/2010 | 2050/2010 |
|---|---|---|---|---|---|
| GDP | 7,518 | 29,093 | 112,582 | 3.87 | 14.97 |
| Primary industry (share %) | 30 | 22.68 | 19.03 | | |
| Secondary industry (share %) | 29 | 34.33 | 37.83 | | |
| Tertiary industry (share %) | 42 | 42.99 | 43.14 | | |
| GDP/Capita (USD at current price) | 833 | 2,448 | 7,932 | 2.94 | 3.24 |
| Gross outputs | 17,699 | 74,068 | 298,873 | 4.18 | 16.89 |
| Primary industry | 3,136 | 9,265 | 30,082 | 2.95 | 9.59 |
| Secondary industry | 8,910 | 42,155 | 180,851 | 4.73 | 20.30 |
| Tertiary industry | 5,653 | 22,649 | 87,940 | 4.01 | 15.56 |
| Private consumption | 6,169 | 23,871 | 92,372 | 3.87 | 14.97 |
| Government consumption | 654 | 2,530 | 9,790 | 3.87 | 14.97 |
| Gross fixed capital formation | 1,650 | 6,384 | 24,706 | 3.87 | 14.97 |
| Exports | 6,256 | 24,208 | 93,676 | 3.87 | 14.97 |
| Imports | 7,210 | 27,899 | 107,961 | 3.87 | 14.97 |

### 2.4.1 Population growth and projections

In 2010, the total population of Cambodia was about 13.96 million, which was about 2.3% of the Southeast Asian population (NIS, 2012). At that time, 19.5% and 80.5% of the total population were living in the urban and rural areas, respectively. The population is projected to reach about 18.39 million by 2030 (NIS, 2011) and about 21.96 million by 2050 (UN, 2013). The population in 2010 and projections by age group for the urban and rural areas are shown in Table 2.5.

**Table 2.5:** Classification by age group in 2010, 2030, and 2050 [1,000 persons]

| Age cohort | 2010 | | 2030 | | 2050 | |
|---|---|---|---|---|---|---|
| | Urban | Rural | Urban | Rural | Urban | Rural |
| a0014 | 658 | 3809 | 1,402 | 3,343 | 2,046 | 2,523 |
| a1564 | 1978 | 6875 | 3,657 | 8,720 | 6,678 | 8,236 |
| a65+ | 105 | 534 | 375 | 894 | 1,111 | 1,371 |
| Sub-total | 2741 | 11218 | 5,434 | 12,956 | 9,835 | 12,129 |
| **Total population** | **13,959** | | **18,391** | | **21,964** | |

### 2.4.2 Numbers of households and projections

Numbers of households in 2010 are collected from (NIS, 2011). The total numbers of households were about 3.0 million-- 0.6 million (about 20%) were in the urban areas and 2.4 million (about 80%) were in the rural ones (NIS, 2012). In this study, two types of households are classified: urban and rural. Urban household refers to any commune meeting the following criteria:

- Population density exceeds 200 per km²;
- Percentage of male employment in agriculture below 50.0%; and
- The total population of the commune should exceed 2,000.

There is no information about the population projection in the urban and rural areas through to 2050 in Cambodia; hence, we extrapolate by using the historical trend. NIS (2012) estimated the annual population growth rate between 1998 and 2010 of 2.1% in the urban areas and we assumes the trend will remain constant in the future. As a result, the share of the population in the urban areas is projected to increase to around 29.55% and 44.78% in 2030 and 2050, respectively. The assumed population in the urban areas in Cambodia in 2030 is similar to that of Vietnam in 2010 (31.0%), while the 2050 is similar to that of Thailand in 2030 (46.0%) (UNDESA, 2011).

### 2.4.3 Average persons per household and projections

The average persons per household in 2010 were 4.8 in which the urban and rural areas had very similar average numbers of 4.8 (NIS, 2012). Due to limited information, this study assumes that the average persons per household will decrease to 4.2 and 4.5 persons for urban and rural areas in 2030 and 2050, respectively, from 2010. The assumption is referred to the historical trends where the average persons per household in the urban decreased from 5.5 to 4.8, while the rural areas decreased from 5.1 to 4.8 between 1998 and 2010, respectively, (NIS, 2011 and 2012). It can be investigated that, in terms of decreasing rate, the urban areas decreased rather faster than the rural ones and this trend is expected to remain constant in the future as they want to move from the extended family (large number of people) to the nuclear one (smaller number of people) for a varieties of reasons such as family management, job competition, and economic development (MoP, 2013). Table 2.6 shows the historical and projected average persons per household by the urban and rural areas.

**Table 2.6:** The historical and projected average persons per household

| Year | Country | Urban | Rural |
|---|---|---|---|
| 1998 | 5.2 | 5.5 | 5.1 |
| 2008 | 4.7 | 5 | 4.6 |
| 2010 | 4.78 | 4.78 | 4.79 |
| 2030 (assumption) | 4.4 | 4.2 | 4.5 |
| 2050 (assumption) | 4.4 | 4.2 | 4.5 |

### 2.4.4 Macro economy

The macroeconomic data such as GDP, gross output of industry, and final demand sectors in 2010, 2030, and 2050 used in the present study is shown in Table 2.7.

**Table 2.7:** Macroeconomic indicators [Million USD at 2000 constant price]

| Indicator | 2010 | 2030 | 2050 | 2030/2010 | 2050/2010 |
|---|---|---|---|---|---|
| GDP | 7,518 | 29,093 | 112,582 | 3.87 | 14.97 |
| Primary industry (share %) | 30 | 22.68 | 19.03 | | |
| Secondary industry (share %) | 29 | 34.33 | 37.83 | | |
| Tertiary industry (share %) | 42 | 42.99 | 43.14 | | |
| GDP/Capita (USD at current price) | 833 | 2,448 | 7,932 | 2.94 | 3.24 |
| Gross outputs | 17,699 | 74,068 | 298,873 | 4.18 | 16.89 |
| Primary industry | 3,136 | 9,265 | 30,082 | 2.95 | 9.59 |
| Secondary industry | 8,910 | 42,155 | 180,851 | 4.73 | 20.30 |
| Tertiary industry | 5,653 | 22,649 | 87,940 | 4.01 | 15.56 |
| Private consumption | 6,169 | 23,871 | 92,372 | 3.87 | 14.97 |
| Government consumption | 654 | 2,530 | 9,790 | 3.87 | 14.97 |
| Gross fixed capital formation | 1,650 | 6,384 | 24,706 | 3.87 | 14.97 |
| Exports | 6,256 | 24,208 | 93,676 | 3.87 | 14.97 |
| Imports | 7,210 | 27,899 | 107,961 | 3.87 | 14.97 |

**GDP growth and projections**

Cambodia experienced the average annual GDP growth rate of 7.0% from 1994 to 2013 (RGC, 2014). Besides, a few studies optimistically predicted that Cambodia's GDP will grow around 7.0% in years to come. While, the RGC disclosed that the country will reach the status of an upper-middle income country by 2030 and a high-income level by 2050 (RGC, 2013). This commitment encourages the country to keep a strong and consistent average annual GDP growth rate of around 7.0%.

This study assumes the average annual GDP growth rate to be same as Government's projection, which is 7.0% from 2010 through to 2050. We expect that the assumed GDP growth rate will be plausible as the Government planned to develop human resources for labor markets, to improve infrastructure to facilitate trade, to expand and enhance industrial development, to increase value added from agriculture, and to strengthen governance and public institution to improve the investment climate. The government is encouraging a rapid transformation of industrial structure to move from a labor-intensive and low productivity industry to a more broad-based, high-tech and high-skilled one (RGC, 2015). In addition, the Government also planned to exploit oil resources from the seabed in the near future (RGC, 2013). In this regard, the GDP, which was around 7,518 million USD with per capita GDP of 539USD (2000 constant price) or 833USD (2010 current price) in 2010, is projected to increase to about 29,093 million USD in 2030 (3.87 times) with per capita GDP of 2,448USD/year (2010 current price), which is similar to that of the Philippines in 2013 (2,496USD/year) and is projected to increase to about 112,582 million USD (14.97 times) in 2050 with per capita GDP of 7,932USD/year (2010 current price), which is similar to that of Malaysia in 2008 (8,088USD/year) (IMF, 2014). The gross industrial outputs are projected to increase by 4.18 times and 16.89 times in 2030 and 2050, respectively.

**Industrial structure and projections**

Since the IO table in 2010 in Cambodia is not acquired, it is converted from the IO table in 2008, which was constructed by Sophal and Sothea (2011), by using an IO table conversion tool. The IO table in 2008 comprises 22 sectors (see Appendix 2: The IO Table 2008 [Million USD at 2000 constant price]) and is aggregated into a competitive import type of 10 sectors (see Appendix 3: The aggregated IO Table 2008 [Million USD at 2000 constant price]). **"Competitive import type"** means the value of supply for domestic demand is the combined sum of domestic and imported goods. The aggregation is done by GAMS programme (General Algebraic Modeling System). The aggregated sectors are shown in Table 2.8. In order to convert the IO table in 2008 to 2010, some economic data of the new IO table such as value added and final demand (gross domestic fixed capital formation, export, import, and private and Government consumption and expenditure) are required as controlled totals. The Procedure to convert the IO table from 2008 to 2010 is shown in Figure 2.3. A cross-entropy method, which is a methodology to minimize the distance between the two IO tables (to make IO 2010 close to IO 2008), under constraints of controlled totals (Foana et al., 2005), is used under input values and constraints. It is formulized as a nonlinear programming problem, which makes an objective function the minimum. The formulas of the constraints and the objective function of the method are shown in Appendix 4. As a result, the IO table in 2010 is obtained as shown in Appendix 5.

In terms of the contribution to the GDP, there is no doubt that the primary industry would decrease, while secondary industry and tertiary would increase when a country shifts from a low-income level to a middle- or high-income one. Since the Government of Cambodia has not projected any detail long-term economic structure, this study assumes to be based on the Government development policies and plans and other countries' experiences such as Thailand and Malaysia in which their economies are relying on the secondary and tertiary industry, while the primary industry contributes relatively smaller to the GDP (Bundit *et al.*, 2010 and Siong *et al.*, 2013). The RGC is planning to shift from a low income to an upper middle income and a high income level by 2030 and 2050, respectively; it is, therefore, the secondary and tertiary industry should grow substantially in the future. For instance, the Government stressed that it will promote the diversification of the secondary industry base through encouraging investments in new high value added, more creative and competitive industries, and expanding industrial development in the rural areas to boost economic growth, job creation, and incomes of the people (RGC, 2013). The Government will also upgrade the diversification of manufacturing base and promote further development of the SMEs. The Government is also giving priority to agro-processing industry and is promoting other industries such as energy and heavy industries, water supplies, and green-based technology (RGC, 2015).

Hence, this study assumes that the share of products of the primary industry in private consumption decreased, substituted by the increase of goods and services of secondary and tertiary industries in both 2030 and 2050. Similarly, the share of products of the primary industry in export is projected to decrease, substituted by the increase of the secondary industry, while the share of products of tertiary industry is assumed to remain the same. Meanwhile, the percentage distribution of the Government consumption and expenditure and gross fixed capital formation in both 2030 and 2050 is assumed to remain the same as that of the base year. Table 2.9 shows the percentage distribution of private consumption and expenditure and export in 2030 and 2050. As a result, the projected IO tables in 2030 and 2050 are obtained as shown in Appendix 6 and Appendix 7.

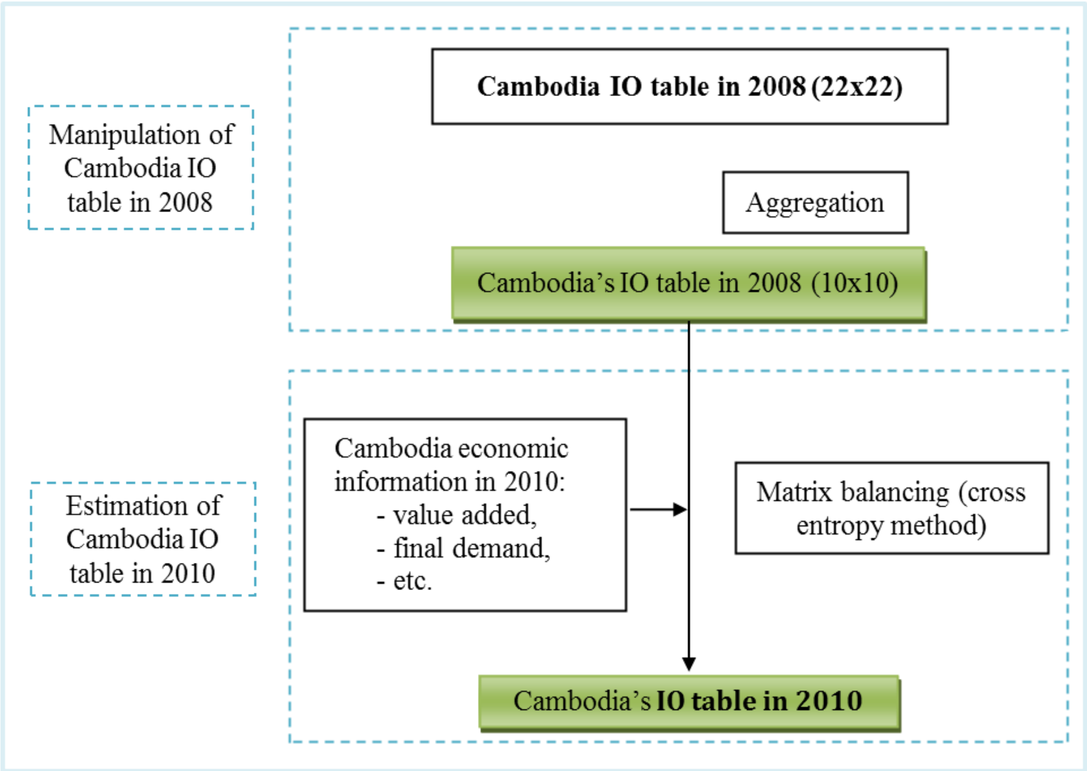


**Figure 2.3:** Procedure to convert the IO table from 2008 to 2010

**Source:** Tahsin (2013)

**Table 2.8:** The aggregated IO table

| 11-sector classification in aggregated IO table 2008 | | 22-sector classification in original table 2008 | |
|---|---|---|---|
| **Code** | **Sector** | **Code** | **Description** |
| 1 | Agriculture, fishery and forestry | 1 | Paddy |
| | | 2 | Other crops |
| | | 3 | Livestock |
| | | 4 | Forestry |
| | | 5 | Fishery |
| 2 | Mining and Quarrying | 6 | Mining |
| 3 | Manufacturing | 7 | Food, beverage & tobacco |
| | | 8 | Textile & garment |
| | | 9 | Wood, paper & publishing |
| | | 10 | Chemical, rubber & plastic |
| | | 11 | Non-metallic mineral |
| | | 12 | Basic metals |
| | | 13 | Other manufacturing |
| 4 | Electricity, gas & water | 14 | Electricity and water |
| 5 | Construction | 15 | Construction |
| 6 | Trade | 16 | Trade services |
| 7 | Transport | 18 | Transport and Communication |
| 8 | Finance | 19 | Finance |
| 9 | Government services | 21 | Public administration |
| 10 | Other private services | 17 | Hotels, restaurants |
| | | 20 | Real Estate and Business |
| | | 22 | Other services |

**Source:** Sophal and Sothea (2011)

**Table 2.9:** Percentage distribution of private consumption expenditure and export

| Industry | Share of private consumption and expenditure (%) | | | Share of export (%) | | |
|---|---|---|---|---|---|---|
| | 2010 | 2030 | 2050 | 2010 | 2030 | 2050 |
| Agriculture, forestry, & fishery | 22.91 | 11.46 | 6.55 | 6.78 | 3.39 | 1.56 |
| Mining | 0 | 0 | 0 | 0 | 0 | 0 |
| Manufacturing | 36.72 | 45.18 | 50.09 | 71.77 | 75.16 | 76.98 |
| Electricity, gas & water | 4.61 | 5.61 | 5.61 | 0 | 0 | 0 |
| Construction | 0 | 0 | 0 | 0 | 0 | 0 |
| Trade | 1.93 | 1.93 | 1.93 | 0 | 0 | 0 |
| Transport | 1.79 | 1.79 | 1.79 | 8.71 | 8.71 | 8.71 |
| Finance | 0.82 | 0.82 | 0.82 | 0 | 0 | 0 |
| Government services | 1.16 | 1.16 | 1.16 | 0.03 | 0.03 | 0.03 |
| Other private services | 30.06 | 32.06 | 32.06 | 12.71 | 12.71 | 12.71 |

**Final demand and its projection**

Final demand sectors including private and Government consumption and expenditure, gross domestic fixed capital formation, import, and export in 2010 are collected from NIS (2011). Since the Cambodia's economy is projected to increase significantly in the future, so is the final demand. This study assumes the average annual growth of final demand sectors to be the same as the GDP growth (7.0%) from 2010 through to 2050. Final demand sectors in 2010 and in the target years are shown in Table 2.10.

**Table 2.10:** Final demand sectors [Million USD at 2000 constant price]

| Final demand sectors/year | 2010 | 2030 | 2050 | 2030/2010 | 2050/2010 |
|---|---|---|---|---|---|
| Consumption expenditure | 6,822 | 26,401 | 102,163 | 3.87 | 14.97 |
| Private consumption | 6,169 | 23,871 | 92,372 | 3.87 | 14.97 |
| Government consumption | 654 | 2,530 | 9,790 | 3.87 | 14.97 |
| Gross fixed capital formation | 1,650 | 6,384 | 24,706 | 3.87 | 14.97 |
| Private fixed capital formation | 1,051 | 4,068 | 15,741 | 3.87 | 14.97 |
| Government fixed capital formation | 599 | 2,317 | 8,965 | 3.87 | 14.97 |
| Export | 6,256 | 24,208 | 93,676 | 3.87 | 14.97 |
| Import | 7,210 | 27,899 | 107,961 | 3.87 | 14.97 |
| **Total** | **7,518** | **29,093** | **112,582** | **3.87** | **14.97** |

### 2.4.5 Transportation demand

The transportation sector was reported to be the second-largest sector in terms of $CO_2$ emissions from fuel combustion in 2010 in the world, emitting about 6,756Mt$CO_2$ (22.3%) of total $CO_2$ emissions (IEA, 2012). This sector in Cambodia, however, contributed very little to the world's $CO_2$ emissions due to her limited transportation infrastructure and low economic development. Emissions from this sector are expected to increase considerably in the future because the Government has set plans to invest in transportation infrastructures and to improve trade facilitation through developing a multi-modal transportation network to ensure connectivity within the country and the whole region (RGC, 2013). In the current study, two types of transportation system (passenger and freight) are described.

**Passenger transportation**

The passenger transportation modes comprise land, railways, inland waterways and air. The land transportation modes include motorized vehicles (motorbike, tourist cars, and buses), bicycles and walk, while the railway transportation mode is train and the inland waterway transportation modes comprise ships and speedboats. Some of passenger demand data in 2010 are collected from MPWT (2009), NIS (2011), MPWT (2012), and MPWT (2010-2012), while others are assumed and estimated by professional judgement of the author in consultation with the national experts and relevant key stakeholders. The passenger transportation demand (Million pass.km/year) is estimated by the following formula.

$$PTD_{ptm} = Pop \cdot PTG \cdot PTS_{ptm} \cdot PTAD_{ptm} \cdot (365.25) \cdot (1/10^6) \quad (2.1)$$

***Where:***

$PTD_{ptm}$ : Passenger transportation demand (Million (pass.km)/year))
$Pop$ : Population (person)
$PTG$ : Trip generation per person per day (trip/(person.day))
$PTS_{ptm}$ : Modal share (%*100)
$PTAD_{ptm}$: Average trip distance by mode (passenger) (km/trip)
$ptm$ : Passenger transportation mode

Passenger transportation indicators and passenger demand in 2010 and in the target years used in this study are shown in Table 2.11 and Table 2.12, respectively. The procedures to acquire these data explain as follows.

**Table 2.11:** Passenger transportation indicators

| Modes (PTM) | Modal share ($PTS_{ptm}$) (%) | | | | | Average trip distance ($PTAD_{ptm}$) (km/trip) | | | | | Trip generation (PTG) (trip/(person.day)) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
| Motorbike | 8.4 | 16.79 | 11.20 | 33.59 | 25.84 | 10 | 10 | 6 | 10 | 6 | 2 | 2 | 2 | 2.5 | 2.5 |
| Tourist car | 2.45 | 7.34 | 4.89 | 18.35 | 17.35 | 68 | 103 | 86 | 103 | 86 | 2 | 2 | 2 | 2.5 | 2.5 |
| Bus | 1.79 | 4.47 | 6.71 | 11.18 | 14.54 | 82 | 82 | 57 | 82 | 57 | 2 | 2 | 2 | 2.5 | 2.5 |
| Train | 0.0 | 7.0 | 10.5 | 10.0 | 15.6 | 0 | 96 | 66 | 96 | 66 | 2 | 2 | 2 | 2.5 | 2.5 |
| Ship | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 36 | 36 | 36 | 36 | 36 | 2 | 2 | 2 | 2.5 | 2.5 |
| Air | 0.0 | 0.0 | 0.0 | 0.01 | 0.01 | 237 | 474 | 474 | 711 | 711 | 2 | 2 | 2 | 2.5 | 2.5 |
| Walk | 45.56 | 32.2 | 37.05 | 13.44 | 15.26 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2.5 | 2.5 |
| Bicycle | 41.81 | 32.2 | 29.64 | 13.44 | 11.41 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2.5 | 2.5 |

**Table 2.12:** Passenger transportation demand [Million pass.km/year]

| Modes/years | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Motorbike | 8,562 | 22,560 | 9,024 | 67,360 | 31,089 | 2.63 | 1.05 | 7.87 | 3.63 |
| Tourist car | 17,073 | 101,544 | 56,523 | 378,983 | 299,184 | 5.95 | 3.31 | 22.20 | 17.52 |
| Bus | 14,988 | 49,283 | 51,387 | 183,935 | 166,215 | 3.29 | 3.43 | 12.27 | 11.09 |
| Train | 0 | 90,279 | 93,100 | 192,536 | 206,495 | 90,279 | 93,100 | - | - |
| Ship | 2 | 5 | 7 | 14 | 21 | 2.63 | 3.95 | 7.87 | 11.80 |
| Air | 32 | 171 | 171 | 765 | 765 | 5.27 | 5.27 | 23.60 | 23.60 |
| Walk | 4,646 | 4,325 | 4,978 | 2,695 | 3,061 | 0.93 | 1.07 | 0.58 | 0.66 |
| Bicycle | 8,526 | 8,651 | 7,965 | 5,390 | 4,576 | 1.01 | 0.93 | 0.63 | 0.54 |
| **Total** | **53,829** | **276,819** | **223,155** | **831,678** | **711,406** | **5.14** | **4.15** | **15.45** | **13.22** |

**Trip generation (PTG) (trip/(person.day)):**

This study assumes the trip generations per person per day were 2 trips/ (person.day) in 2010 and are expected to remain the same in 2030. However, they are expected to increase to 2.5 trips/(person.day) in 2050 due to the projected increase of incomes of the people and more convenient transportation infrastructures and services. This assumption is similar to that of Thailand in 2030 (2.6 trips/(person.day)) (Bundit *et al.*, 2010). The trip generations are assumed to be the same in both BaU and CM.

**Model share ($PTS_{ptm}$) of passenger transportation modes (%/100):**

The information on the model share of each passenger transportation mode is collected and estimated from the transportation information of NIS (2011), MPWT (2012), and MPWT (2010-2012). Since there is no projected modal shares in Cambodia, this study uses some available information, extrapolates from historical trends, and refers to other countries' experiences. The share of motorized vehicles is assumed to be similar to the projected increase of numbers of motorized vehicles. It is observed that numbers of motorbikes had experienced an average annual growth of around 22.76% (9.54 times) between 2000 and 2010 and during that time the average annual population growth of around 2.45% (1.62 times) (NIS, 2011). The substantial increase of numbers of motorbikes was observed from 2005 through to 2009; however, it started decreasing from 2010 onward (MPWT, 2015). This trend brought the overall average annual growth rate down. Thus, we assumes that numbers of motorbikes will grow slower in the target years than the past, which is similar to the projected population growth. Similarly, it is observed that numbers of tourist cars had experienced an average annual growth of around 14.24% (2.90 times) between 2000 and 2010 and remains continue to increase (NIS, 2011 and MPWT, 2015). Hence, this study assumes that tourist cars will continue to grow in the target years due to the projected increase of incomes of the people and transportation infrastructure expansion. Meanwhile, numbers of buses are observed to experience an average annual growth of around 12.25% (2.52 times) between 2000 and 2010 and remains continue to increase (NIS, 2011 and MPWT, 2015). Thus, this study assumes that numbers of buses will increase in the target years as the Government is introducing public bus systems in Phnom Penh city and is planning to expand to some other major cities in the country (RGC, 2014).

As explained, this study assumes that the share of motorbike will increase about 2.0 times in 2030BaU from 2010 and is expected to retain the same growth in 2050BaU from 2030BaU. The share of tourist car is assumed to increase about 3.0 times in 2030BaU and is expected to decrease to around 2.5 times between 2030BaU and 2050BaU. Furthermore, the share of bus is assumed to increase about 2.50 times in 2030BaU from the base year and is expected to maintain the same growth in 2050BaU from 2030BaU. Additionally, the share of train, ship, and air is assumed to be mainly based on the transportation development plan. The Government is planning to improve all means of transportation and to expand some other means such as train and air; for instance, the Government is renovating the existing railways and will expand several more to connect other parts of the country. The Government is also planning to introduce commuter light trains in some major cities in the future (RGC, 2014). Moreover, ADB (2011) indicated that the railway sector, the smallest mode in 2010, is expected to grow annually between 7.0% and 12.0% through to 2030. The Government is also planning to renovate several more domestic airports, especially in the tourist destination provinces such as Rattanakiri, Stung Treng, Preah Vihear, and Koh Kong (MPWT, 2012). In fact, Cambodia just opened a new airline company “Cambodia

Bayon Airlines" to operate domestic flights at the end of December 2014 (extracted on 17 December 2014: http://www.phnompenhpost.com/business/bayon-air-welcomes-first-aircraft). Similarly, the Government is planning to improve inland waterway infrastructures to facilitate the ship navigation, especially along the Mekong River and Tonle Sap Lake. As indicated above, we assume the share of train is expected to contribute to about 7.0% and 10.0% in 2030BaU and 2050BaU, respectively. This sector experienced to contribute to about 20.0% of total passenger modes before 2005, during that time the road infrastructures were almost completely destroyed by the civil war (JICA, 2006a). However, road systems are currently playing more active role as the Government is renovating and constructing a country-wide (MPWT, 2015). However, it is noted that this assumption is still slightly lower than Thailand's projection in 2030 where the share of train is expected to contribute to around 12.0% (Bundit *et al*., 2010). The share of air is assumed to increase by about 2.0 times in 2030BaU from 2010 and retain the same growth in 2050BaU from 2030BaU. The share of ship is assumed to be double in 2030BaU from 2010 and will remain the same growth in 2050BaU from 2030BaU. The shares of bicycle and walk are assumed to decrease in both 2030BaU and 2050BaU.

Under low carbon measures, the shares of motorbike and car are assumed to decrease; conversely, the shares of bus, ship, and train are assumed to increase in both 2030CM and 2050CM as we expect that the Government will introduce more buses and trains as well as improve inland waterways. Meanwhile, the share of air is assumed to remain the same as those of the BaU. The share of walk is assumed to increase, while the share of bicycle is assumed to decrease.

**Average trip distance of passenger transportation modes ($PTAD_{ptm}$) (km/trip):**
The average trip distances of motorized vehicles are collected and estimated from MPWT (2009). The average trip distance of 36km/trip for ship (including passenger ship and speedboat) is assumed in 2010. The average trip distance of air is assumed to be in proportion to the distance from Phnom Penh to Siemreap airport, which is 237km/trip (MPWT, 2010 and 2012). No railway was operated in 2010 in Cambodia (MPWT, 2010). Concerning the average distances of walk and bicycle, this study assume the average trip distance of walk is 1 km/trip, while the average trip distance of bicycle is 2km/trip in 2010. These assumptions are referred to the real observation in which the passengers walk only for a short distance (around 1km), while a longer distance (around 2km) is for bicycle.

In the target years, we assume that the average trip distances of motorbike, bus, ship, bicycle, and walk are the same as in the base year in both 2030BaU and 2050BaU; however, for the tourist car is assumed to increase by 1.5 times in both 2030BaU and 2050BaU due to road renovation and expansion set by the Government and increased incomes of the people. This assumption is very similar to those of Vietnam and Bangladesh where they assumed the average trip distance of this mode increased due to road expansion and increased incomes (Nguyen, 2012 and Tahsin, 2013). The average trip distance of air is assumed to increase by 2.0 times in 2030BaU from 2010 and another 1.5 times in 2050BaU from 2030BaU because the Government is planning to expand several new domestic airports, which are far from the current ones to attract more tourists. The average trip distance of train in 2030BaU and 2050BaU is assumed to be similar to the past experiences, which was around 92km to 100km between 2002 and 2007 (MPWT, 2011). This study assumes 96km in 2030BaU and 2050BaU.

Under low carbon measures, the average trip distances of tourist car, air, ship, bicycle, and walk are assumed to be the same as those of the BaU in both 2030CM and 2050CM; however, for motorbike and tourist car are assumed to decrease to 6km and 86km in both 2030CM and 2050CM, respectively. The average trip distances of bus and train are assumed to decrease to around 57km and 66km in both 2030CM and 2050CM, respectively; due to compact city development and better land use design.

**Freight transportation**

The freight transportation modes comprise land, railways, and inland waterways, while the air is not included as it was too small in 2010 (MPWT, 2010 and 2012). Freight transportation information in 2010 such as numbers of freight, modal shares, and average trip distances is assumed and computed from the data of vehicle fleet of MPWT (2009), NIS (2011), MPWT (2012), and MPWT (2010 and 2012). The freight transportation demand (Million (ton.km)/year) is estimated by the following formula.

$$FTD_{ftm} = PD \cdot Ftg \cdot Fts_{ftm} \cdot Ftad_{ftm} \cdot (1/10^6) \quad (2.2)$$

***Where:***

$FTD_{ftm}$ : Freight transportation demand (Million ton.km/year)

$PD$ : Output of primary and secondary industry (Million USD)

$Ftg$ : Freight generation per industrial output (ton/USD)

$Fts_{ftm}$ : Modal share of freight transportation (%*100)

$Ftad_{ftm}$ : Average trip distance of freight transportation (km/trip)

Freight transportation indicators and freight demand in 2010 and in the target years used in this study are shown in Table 2.13 and Table 2.14, respectively. The procedures to acquire these data explain as follows.

**Table 2.13:** Freight transportation indicators

| Modes (FTM) | Modal share ($FTS_{ftm}$) (%) | | | | | Average distance ($FTAD_{ftm}$) (km/trip) | | | | | Freight generation (ton/USD) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
| Small cargo truck | 28.86 | 25.05 | 24.05 | 24.05 | 23.20 | 110 | 109 | 100 | 109 | 100 | 0.008 | 0.01 | 0.01 | 0.02 | 0.02 |
| Big cargo truck | 70.31 | 63.29 | 58.45 | 53.45 | 49.05 | 130 | 130 | 115 | 130 | 115 | 0.008 | 0.01 | 0.01 | 0.02 | 0.02 |
| Train | 0.00 | 10.00 | 15.00 | 20.00 | 24.00 | 12 | 120 | 110 | 120 | 110 | 0.008 | 0.01 | 0.01 | 0.02 | 0.02 |
| Ship | 0.83 | 1.67 | 2.50 | 2.50 | 3.75 | 115 | 115 | 115 | 115 | 115 | 0.008 | 0.01 | 0.01 | 0.02 | 0.02 |

**Table 2.14:** Freight transportation demand [Million ton.km/year]

| Modes/years | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Small cargo truck | 4,731 | 25,655 | 22,597 | 132,517 | 117,280 | 5.42 | 4.78 | 28.01 | 24.79 |
| Big cargo truck | 13,688 | 77,315 | 63,170 | 351,332 | 285,209 | 5.65 | 4.62 | 25.67 | 20.84 |
| Train | 0 | 11,277 | 15,506 | 121,341 | 133,475 | - | - | - | - |
| Ship | 143 | 1,801 | 2,702 | 14,535 | 21,802 | 12.55 | 18.83 | 101.32 | 151.98 |
| **Total** | **18,562** | **116,048** | **103,975** | **619,725** | **557,766** | **6.25** | **5.60** | **33.39** | **30.05** |

**Industrial output (PD):**

Industrial outputs are the total outputs of all industries of the IO table in 2010, 2030, and 2050.

**Freight transportation generation per industrial output ($FTG_{ftm}$) (ton/USD):**

This study assumes the same freight generation per output of all industries and only domestic transportation is considered. Freight transportation generation per output of industry is computed by dividing “the total numbers of freight (Million tons/year) by the total value of industrial outputs”. Freight generation per industrial output is expected to increase due to the projected increase of freight demand. This study assumes that the freight generation per industrial output will increase about 1.5 times and 2 times in 2030BaU and 2050BaU, respectively; compared to the base year and is assumed to remain the same in both 2030CM and 2050CM.

**Modal share ($FTS_{ftm}$) (%*100) of freight transportation modes:**

The data on the model shares of freight transportation modes in the base year are collected and estimated from the transportation information of NIS (2011) and MPWT (2010 and 2012). In the future, this study assumes that the shares of the small cargo and big cargo trucks will decrease in both 2030BaU and 2050BaU, substituted by the increase of the shares of train and ship. This is due to the fact that the Government is renovating the existing railways and also expanding several more rail lines in the future, which will mainly be used for the freight transportation purpose (MPWT, 2013). Meanwhile, ADB (2011) indicated that the train mode will grow significantly due to the increasing freight demand for economic development in the future.

As indicated, we assume that the share of train will increase to around 10.0% and 15.0% in 2030BaU and 2050BaU, respectively. This assumption referred to the historical experience between 2002 and 2007 in which the share of train was around 10.0% before it was almost completely destroyed by the civil war (JICA, 2006a). Besides, the Government will improve the inland waterways to facilitate the navigation for both small and big cargoes and oil tanker ships. Thus, the share of ship is assumed to increase twice in 2030BaU from 2010 and is expected to increase another 1.5 times in 2050BaU from 2030BaU. Under low carbon measures, the shares of train and ship are assumed to further increase, while the shares of other modes are assumed to further decrease in both 2030CM and 2050CM.

**Average trip distance of freight transportation modes ($FTAD_{ftm}$) (km/trip):**

The average trip distances of small cargo and big cargo trucks in 2010 are collected and estimated from the transportation information of MPWT (2009). The inland waterway is assumed to be in proportion to the average distance from one port to others, which is around 115km/trip (MPWT, 2012) due to limited information. The railway was 12 km/trip in 2010 (MPWT, 2011). In the future, this study assumes the average trip distances of small cargo, big cargo truck, and ship to be the same as those of the base year in both 2030BaU and 2050BaU. The average trip distance of train in 2030BaU and 2050BaU is assumed to be the same as that of 2011 and 2012, which was around 120km/trip (MPWT, 2013a). Under low carbon measures, the average trip distance of the small cargo truck is assumed to decrease to around 100km/trip, while the big cargo truck is assumed to decrease to around 115km/trip in 2030CM and 2050CM. Similarly, the average trip distance of train is assumed to decrease to around 110km/trip in 2030CM and 2050CM. However, the average trip distance of ship in 2030CM and 2050CM is assumed to be the same as those of the BaU levels.

### 2.4.6 Energy sector

The total volume of energy demand and supply in 2010 used in this study is taken from the energy balance table in 2010 of the International Energy Agency (IEA) (IEA, 2012) (see Appendix 8: Energy balance table in 2010 [ktoe/year]). The data used to construct this balance table was contributed by Energy Development Department of then Ministry of Industry, Mines and Energy (MIME) and other relevant institutions working in the energy sector in Cambodia ( a direct interview with Mr. Heng Kunleang, Director of Energy Development Department in 2012). In this table, energy consumption by agriculture, fishery, and forestry is recorded only up to 2009 and during that year, energy consumption in this sector was some 117ktoe/year, while in 2010 was not recorded due to lack of data, added he. We assume energy consumption by this sector to be in proportion to the incremental rate of the agricultural machines between 2009 and 2010, which increased about 1.06 times (Vuthy, 2013). Hence, energy consumption in this sector is computed to be some 123.95ktoe/year in 2010. Appendix 9 shows the detail of the adjusted energy balance table in 2010.

Energy supply and demand are expected to increase substantially in the target years due to increases of population, economy, outputs of industries, national grid, and reducing electricity tariffs (RGC, 2013). The industrial sector, which is identified as a key dynamic indicator for industrialization and modernization of Cambodia's economy, is a key sector consuming more electricity. Besides, residential and commercial sectors are also projected to consume large amount of electricity. The information of energy supply and demand used in this study in 2010 and in target years is shown in Table 2.15. The following sections explain the procedures to acquire these assumptions.

**Table 2.15:** Energy supply and demand in Cambodia [ktoe/year]

| Sector/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU/ 2010 | 2030CM/ 2010 | 2050BaU/ 2010 | 2050CM/ 2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 2,549 | 7,396 | 2,409 | 25,997 | 6,690 | 2.90 | 0.95 | 10.20 | 2.63 |
| Commercial | 172 | 1,107 | 672 | 3,086 | 1,560 | 6.45 | 3.91 | 17.98 | 9.09 |
| Industry | 1,021 | 6,100 | 3,453 | 20,868 | 11,497 | 5.97 | 3.38 | 20.43 | 11.26 |
| Passenger transportation | 321 | 2,005 | 879 | 7,006 | 3,027 | 6.24 | 2.74 | 21.81 | 9.42 |
| Freight transportation | 324 | 1,765 | 768 | 9,975 | 4,917 | 5.45 | 2.37 | 30.80 | 15.18 |
| **Total final energy demand** | **4,386** | **18,374** | **8,180** | **66,932** | **27,691** | **4.19** | **1.86** | **15.26** | **6.31** |
| Coal | 8 | 440 | 142 | 1,693 | 368 | 54.51 | 17.63 | 209.62 | 45.60 |
| Petroleum products | 1,351 | 6,210 | 2,905 | 24,464 | 11,429 | 4.60 | 2.15 | 18.11 | 8.46 |
| Natural gas | 0 | 970 | 374 | 3,729 | 968 | - | - | - | - |
| Hydropower | 2 | 390 | 170 | 1,501 | 440 | - | - | - | - |
| Solar/wind | 0 | 11 | 24 | 43 | 63 | - | - | - | - |
| Biofuels and waste | 3,109 | 11,241 | 4,854 | 38,918 | 15,173 | 3.62 | 1.56 | 12.52 | 4.88 |
| Import | 117 | 65 | 28 | 251 | 74 | 0.56 | 0.24 | 2.15 | 0.63 |
| **Total primary energy supply** | **4,587** | **19,327** | **8,499** | **70,598** | **28,515** | **4.21** | **1.85** | **15.39** | **6.22** |

**Power supply**

The information on the power supply in 2010 is collected and estimated from energy balance table in 2010. In that year, petroleum products shared about 91.91%, followed by coal (some 3.11%), hydropower (some 2.61%), biomass (some 2.01%), and renewable energy (solar and wind power) of less than 1.0%. Around sixty-five per cent of the total national energy supply was imported from Lao PDR, Thailand, and Vietnam (EAC, 2010) (Table 2.16). The RGC adopted the best alternative options for more constant, reliable, and affordable sources of energy so as to meet the pressing need of energy consumption. The Government has boosted and diversified energy supply sources to reduce reliance on fossil fuels for electricity generation. Furthermore, the expansion of the transmission line and distribution networks as well as a reduction in electricity losses to accommodate the electricity demand as a result of economic growth and a rise in numbers of households, businesses, and industries are also focused. The Government has also introduced and invested in other sources of energy originated from renewable sources such as biomass/biogas, wind, and solar power to respond to the need of the people where the national grid cannot be accessed (RGC, 2013).

The Government recently prepared a master plan for power supply towards 2030, which comprises natural gas (40.0%), hydropower (35.0%), coal (15.0%), import (6.0%), oil (3.0%), and renewable energy (1.0%) (MME, 2014). These values are used for the present study in 2030BaU and are assumed to be the same in 2050BaU due to limited information. Since there is no information on the projected fuel mix of power generation towards 2050, this study assumes it is the same as in 2030. Besides, to ensure the sufficient energy supply, the Government will also improve energy efficiency, especially from coal and oil in the future to be similar to those of some advanced countries such as Japan and France, etc. This study assumes energy efficiency of coal and oil will increase from 33.01% and 32.5% in 2010 to 38.0% in 2030BaU and 2050BaU, respectively, (Erik, 2011 and MME, 2014). Similarly, the efficiency of gas is assumed to be about 46.0% in both 2030BaU and 2050BaU, which is similar to that of the average efficiency of Australia, France, Japan, the Republic of Korea, and the United States in 2008 (Erik, 2011). The transmission loss and own use are also assumed to decrease in which the transmission loss is assumed to decrease from 12.23% in 2010 to 7.0% in both 2030BaU and 2050BaU. This assumption is referred to the historical experiences whereby the transmission loss had decreased from more than 14.0% in 2004 to 7.42% in 2012 and we expect it will continue to decrease in the future (EAC, 2012).

Under low-carbon measures, renewable energy (including, solar power, biogas/ biomass, and wind power) is assumed to increase its share to 5.0% with the reduction of oil and coal accordingly, while hydropower and natural gas are assumed to remain the same as those of the BaU levels. This study introduces the solar power as the main source of renewable energy because several studies yielded that Cambodia has very high potential for this source. JICA (2006a) figured out that Cambodia could generate the average annual solar irradiation of more than 5.10kWh/m$^2$/day, while Rogier (2011) indicated that the solar power is a good alternative energy option for Cambodia's people living in the rural areas where the national grid cannot be accessed. He went on to say that Cambodia developed a solar roadmap towards 2020 aiming at identifying areas and activities required to professionalize the solar market to be affordable, attractive and accessible and to enable as many as possible of 1.6 million households that are at present relying on car batteries and kerosene lamps. Moreover, the energy efficiency of coal and oil is assumed to increase to about 41.0% and 44.0% in 2030CM and 2050CM, respectively; which is similar to that of some advanced countries (Erik, 2011). The efficiency of natural gas is assumed to increase to around 52.0% in both 2030CM and 2050CM, which is similar to that of the UK and Ireland in 2008 (Erik, 2011). The transmission loss is assumed to further decrease to about 6.5% in both 2030CM and 2050CM. The results of the assumptions indicates that the total primary energy supply is projected to increase to around 19,327 (4.21 times) and 70,598 ktoe/year (15.39 times) in 2030BaU and 2050BaU, respectively, from about 4,587ktoe/year in 2010. Under low-carbon measures, it is expected to decrease to about 8,499 (1.85 times) and 28,515 ktoe/year (6.22 times) in 2030CM and 2050CM, respectively. Table 2.16 shows the share of the fuel mix of power generation, while Table 2.17 shows the power supply by fuel type (ktoe/year) used in this study.

**Table 2.16:** Projected fuel mix of power generation in Cambodia [%]

| Fuel/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|
| Coal | 1.3 | 15.0 | 12.0 | 15.0 | 12.0 |
| Petroleum products | 38.2 | 3.0 | 2.0 | 3.0 | 2.0 |
| Hydropower | 1.1 | 35.0 | 35.0 | 35.0 | 35.0 |
| Natural gas | 0.0 | 40.0 | 40.0 | 40.0 | 40.0 |
| Biofuels and waste | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Solar/wind | 0.1 | 1.0 | 5.0 | 1.0 | 5.0 |
| Import | 58.4 | 6.0 | 6.0 | 6.0 | 6.0 |
| **Total** | **100** | **100** | **100** | **100** | **100** |

**Table 2.17:** Power supply by fuel types [ktoe/year]

| Fuel/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|
| Coal | 3 | 152 | 53 | 583 | 138 |
| Petroleum products | 79 | 30 | 9 | 117 | 23 |
| Hydropower | 2 | 354 | 155 | 1,361 | 401 |
| Natural gas | 0 | 404 | 177 | 1,555 | 459 |
| Biofuels and waste | 2 | - | - | - | - |
| Solar/wind | 0 | 10 | 22 | 39 | 57 |
| Import | 117 | 61 | 27 | 233 | 69 |
| **Total** | **202** | **1,011** | **443** | **3,888** | **1,147** |

**Energy demand**

The energy demand of the energy demand sectors includes *residential, commercial, industrial, and transportation sector.* This study integrated energy consumption in Agriculture, fishery, and forestry into the industrial sector. Energy consumption of each energy demand sector is collected from the energy balance table in 2010; however, some adjustments are made to correspond to the real country situation. In the future, energy demand is expected to increase dramatically due to growths in population and incomes of the people and the heavily consuming electrical appliances such as refrigerators, air conditioners, rice cookers, TV sets, radios and washing machines, etc. will be used.

In response to the increasing energy needs, the RGC set two long-term energy development targets, first is to achieve the 100% level of village electrification by 2020 and second is to achieve 70.0% level of household electrification with grid quality electricity by 2030 (MME, 2013). According to Lieng (2013), energy demand is projected to increase annually by 4.7% between 2010 and 2035. He stressed that the strongest growth is the industrial sector at 5.4%; followed by the transportation sector at 4.6%, while the residential and commercial sectors are at 4.4%. Due to limited information, this study assumes that energy demand by sectors between 2010 and 2030 is the same as Lieng (2013); however, it is assumed to grow annually only by half between 2030BaU and 2050BaU. This assumption is similar to that of the draft SNC in which energy demand sectors are projected to grow slower between 2025 and 2050 compared to between 2008 and 2024. Energy demand by sectors in 2010 and the target years used in this study are shown in Table 2.18. It can be seen that final energy demand is projected to increase to around 18,374 (4.56 times) and 66,932 ktoe/year (15.26 times) in 2030BaU and 2050BaU, respectively, from about 4,386ktoe/year in

2010. Under low-carbon measures, the Government can limit final energy demand to about 8,180 (2.34 times) and 27,691 ktoe/year (6.31 times) in 2030CM and 2050CM, respectively. Per capita energy consumption is projected to increase to around 999 and 3,047 kgoe/year in 2030BaU and 2050BaU, respectively, from around 314koe/year in 2010. It is expected to decrease to about 445 and 1,261 kgoe/year in 2030CM and 2050CM, respectively. GDP per unit energy consumption is projected to be around 5.93 and 6.30 USD/kgoe in 2030BaU and 2050BaU, respectively, compared to around 6.42USD/kgoe in 2010 (GDP in PPP at 2005 constant price). The following sections explain the procedures to acquire these assumptions.

**Table 2.18:** Final energy demand by energy demand sectors [ktoe/year]

| Sectors/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 2,549 | 7,396 | 2,409 | 25,997 | 6,690 | 2.90 | 0.95 | 10.20 | 2.63 |
| Commercial | 172 | 1,107 | 672 | 3,086 | 1,560 | 6.45 | 3.91 | 17.98 | 9.09 |
| Industry | 1,021 | 6,100 | 3,453 | 20,868 | 11,497 | 7.55 | 5.43 | 20.43 | 11.26 |
| Passenger transportation | 321 | 2,005 | 879 | 7,006 | 3,027 | 6.24 | 2.74 | 21.81 | 9.42 |
| Freight transportation | 324 | 1,765 | 768 | 9,975 | 4,917 | 5.45 | 2.37 | 30.80 | 15.18 |
| **Total** | **4,386** | **18,374** | **8,180** | **66,932** | **27,691** | **4.56** | **2.34** | **15.26** | **6.31** |
| **Per capita (kgoe/person)** | **314** | **999** | **445** | **3,047** | **1,261** | **3.18** | **1.42** | **9.70** | **4.02** |

**Residential sector:**

Information of energy demand in the residential sector is collected from the energy balance table in 2010 in which the majority of energy consumption derived mainly from biofuels and waste. This study assumes 5.0% of energy consumption from petroleum products and biofuels and waste in this sector used in the commercial sector (the detail explanation can be found in the commercial sector). As a result, total energy demand in this sector decreases from around 2,673 to 2,549 ktoe/year in 2010.

Two types of households (urban and rural) are classified in the residential sector in this study and energy consumption is estimated by the household types accordingly. Energy service demand by energy service sectors in this sector includes cooling, heating, hot water, cooking, lighting, refrigerator, and other household appliances. Since the detail information on energy consumption by each household type is not fully acquired; it is estimated from the socioeconomic survey data of NIS (2012) in which the share of energy consumption in the urban was estimated around 20.39% (518ktoe/year), while in the rural was around 79.61% (2,022ktoe/year) in 2010. Besides, it was indicated that cooking and lighting were the main sources of energy consumption in 2010, while other energy service sectors such as cooling, heating, hot water, and refrigerator were commonly used in the urban areas (NIS, 2012). Since the detail information on energy consumption by each energy service sector is not fully acquired, the System for the Analysis of Global Energy Markets (SAGE) is used to split energy consumption by energy service sector (SAGE, 2003) (Appendix 10: Table used to split energy demand by energy service type in the residential sector [%]). However, some adjustments are made from the calculation by the SAGE to reflect the real country situation for both rural and urban households.

This study assumes that energy demand per household will increase due to the growths of per capita incomes and the improvement of energy access through urbanization and rural electrification as well as the diffusion of electric appliances to advance the living standards from 2010 through to 2050. It is obvious that when the incomes per household increase; more households are expected to equip with air conditioners and more electric appliances such as TV, refrigerator, washing machine, personal computer, etc. This will contribute to increasing energy demand accordingly.

Therefore, this study assumes that energy demand in this sector will grow annually by about 4.4% from 2010 through to 2030BaU and is expected to grow annually by only half from 2030BaU through to 2050BaU; that is 2.2%. However, under low carbon measures, energy savings are chosen. It was unveiled that about 20.0% of energy consumption can be reduced from 2010 through to 2035 by implementing some simple energy saving behaviors such as turning on air-conditioners at 25 $^{o}$C and off 30 minutes prior to leaving the office and plugging out all devises when stop usage, etc. (Lieng, 2013 and MME, 2013). Hence, this study assumes that energy consumption in this sector will decrease about 20.0% in 2030CM and 2050CM through introducing energy saving behaviors alone. This means that energy consumption in this sector decreases to 3.5% and 1.8% in 2030CM and 2050CM, respectively, from the BaU levels. Besides, other low carbon measures, which contribute significantly to reducing energy demand are also introduced. As a result, energy demand in the residential sector was around 2,549ktoe/year in 2010 and is expected to increase to around 7,396 and 25,997 ktoe/year in 2030BaU and 2050BaU, respectively; however, it is projected to decrease to about 2,409 and 6,690 ktoe/year in 2030CM and 2050CM, respectively. Table 2.19 shows final energy demand in the residential sector by energy service sectors (ktoe/year).

**Table 2.19:** Final energy demand in the residential sector by energy service sectors [ktoe/year]

| Residential energy services | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Cooling | 12 | 47 | 21 | 139 | 32 | 4.11 | 1.82 | 12.03 | 2.81 |
| Heating | 46 | 186 | 112 | 770 | 247 | 4.04 | 2.43 | 16.72 | 5.36 |
| Hot water | 46 | 273 | 234 | 874 | 682 | 5.89 | 5.03 | 18.83 | 14.68 |
| Kitchen | 2,337 | 6,588 | 1,909 | 22,890 | 5,419 | 2.82 | 0.82 | 9.80 | 2.32 |
| Lighting | 73 | 204 | 81 | 884 | 180 | 2.80 | 1.11 | 12.15 | 2.47 |
| Refrigerator | 11 | 31 | 18 | 140 | 36 | 2.76 | 1.58 | 12.66 | 3.27 |
| Other equipment | 24 | 66 | 35 | 299 | 95 | 2.77 | 1.45 | 12.49 | 3.95 |
| **Total** | **2,549** | **7,396** | **2,409** | **25,997** | **6,690** | **2.90** | **0.95** | **10.20** | **2.63** |

**Commercial sector:**

Information on energy demand in the commercial sector is collected from the energy balance table in 2010. It is observed that the main source of energy consumption in this sector derived solely from electricity; it doesn't reflect the real energy consumption in Cambodia at that time as this sector also covered a lot of hotels, guesthouses, and restaurants, which also consumed a lot of petroleum products and biofuels and waste for cooking food. Hence, some adjustments are made for the purpose of this study. According to NIS (2011), there were 440 hotels and 1,087 guesthouses in 2010 and most of the hotels served food service for clients, while some guesthouses also provided this service. Aside from that, there were a lot of restaurants, especially in the most tourist attractive cities such as Phnom Penh, Siemreap, and Sihanoukville (no detail information on numbers of restaurants). Those hotels, guesthouses, and restaurants mainly utilized petroleum products and biofuels and waste for cooking.

Therefore, this study assumes around 5.0% of petroleum products and biofuels and waste consumed in this sector, which is deducted from the residential one. As a result, energy consumption in this sector increased from 47 to 172 ktoe/year. Since the detail information on energy consumption by each industry is not fully grasped, this study assumes energy consumption to be in proportion to the intermediate input of each industry of the IO table. Furthermore, energy consumption by energy service sectors, such as cooling, heating, hot water, cooking, lighting, refrigerator, and other appliances are not acquired; hence we use the SAGE to split energy consumption by energy service sector (Appendix 11: Table used to split energy demand by energy service type in the commercial sector [%]).

Energy demand in the commercial sector is expected to grow at a high rate, in parallel with economic growth. JICA (2012) reported that electricity consumption in this sector dropped down to 31.7% in 2010 from 33.0% in 2009. It is, however, projected to increase in the future due to economic growth and increase of areas to be able to access to electricity. This study assumes that energy demand in this sector will grow annually by 4.4% from 2010 through to 2030BaU and is expected to grow annually by only half from 2030BaU through to 2050BaU; that is 2.2%. However, under low carbon measures, energy savings are chosen. It is obvious that about 20.0% of energy consumption can be reduced from 2010 through to 2035 by implementing some simple energy saving behaviors such as turning on air-conditioners at 25 $^oC$ and off 30 minutes prior to leaving the office and plugging out all devises when stop usage, etc. (Lieng, 2013 and MME, 2013). Hence, this study assumes that energy consumption in this sector will decrease about 20.0% in 2030CM and 2050CM through introducing energy saving behaviors alone. This means that energy consumption in this sector decreases to 3.5% and 1.8% in 2030CM and 2050CM, respectively, from the BaU levels. Besides, other low carbon measures, which contribute significantly to reducing energy demand are also introduced. As a result, energy demand in this sector is projected to increase to about 1,107 and 3,086 ktoe/year in 2030BaU and 2050BaU, respectively, from about 172ktoe/year in 2010 and is projected to decrease to around 672 and 1,560 ktoe/year in 2030CM and 2050CM. Table 2.20 shows final energy demand in the commercial sector by energy service sectors (ktoe/year).

**Table 2.20:** Final energy demand in the commercial sector by energy service sectors [ktoe/year]

| Commercial energy services | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Cooling | 6 | 27 | 19 | 104 | 69 | 4.39 | 3.17 | 17.12 | 11.41 |
| Heating | 14 | 335 | 277 | 654 | 546 | 24.34 | 20.10 | 47.50 | 39.70 |
| Hot water | 16 | 277 | 114 | 981 | 349 | 17.40 | 7.16 | 61.57 | 21.88 |
| Kitchen | 100 | 206 | 165 | 730 | 356 | 2.06 | 1.65 | 7.31 | 3.57 |
| Lighting | 16 | 137 | 36 | 281 | 73 | 8.35 | 2.20 | 17.14 | 4.48 |
| Refrigerator | 9 | 78 | 29 | 160 | 79 | 8.35 | 3.06 | 17.14 | 8.43 |
| Other equipment | 10 | 48 | 32 | 176 | 87 | 4.63 | 3.13 | 17.14 | 8.43 |
| **Total** | **172** | **1,107** | **672** | **3,086** | **1,560** | **6.45** | **3.91** | **17.98** | **9.09** |

**Industry:**

Among energy consuming industries, the garment sector is considered as the main driving force, followed by the fabrication of clay bricks, the rice mills for processing paddy into polished rice, the rubber production, and the food sector (MME, 2013). Information on energy consumption in this sector is collected from the energy balance table in 2010 and the data of “Other/non-specified industry and Non-energy use industry” are used. Energy consumption in Agriculture, fishery, and forestry was already assumed to be around 123.95ktoe/year in 2010; however, energy consumption by other industries is not grasped. This study assumes energy consumption by each industry to be in proportion to the intermediate input of each industry from the IO table. For the purpose of this study, some adjustments are made to reflect the real country situation; for instance, “mining and electricity and water” does not consume petroleum products and biofuels and waste and they are included into “manufacturing” accordingly. Since the detail information on energy service demand by energy service sector (such as direct heating, steam boiler, motor, and other equipment) is not grasped, we use the SAGE to split energy demand by energy service sector (Appendix 12).

The industrial sector showed a strong growth within the last several years. In addition, the Government just set an ambitious target to shift from a low income level to the middle income one by 2030 and a developed level by 2050; thus energy demand in this sector is expected to increase significantly and its share in total final energy demand is projected to be higher than other sectors.

This study assumes energy demand in this sector will grow annually by 5.4% from 2010 through to 2030BaU and is expected to grow annually by only half from 2030BaU through to 2050BaU; that is 2.7%. However, under low carbon measures, energy savings are chosen. It is obvious that about 20.0% of energy consumption can be reduced from 2010 through to 2035 by implementing some simple energy saving behaviors (Lieng, 2013 and MME, 2013). Hence, this study assumes that energy consumption in this sector will decrease about 20.0% in 2030CM and 2050CM through introducing energy saving behaviors alone. This means that energy consumption in this sector decreases to 4.3% and 2.2% in 2030CM and 2050CM, respectively, from the BaU levels. Besides, other low carbon measures, which contribute significantly to reducing energy demand are also introduced. As a result, energy demand in the industrial sector, which was about 1,021ktoe/year in 2010, is projected to spike to about 6,100 and 20,868 ktoe/year in 2030BaU and 2050BaU, respectively; and is expected to decrease to around 3,453 and 11,497 ktoe/year in 2030CM and 2050CM, respectively. Table 2.21 shows final energy demand in the industrial sector by energy service sectors (ktoe/year).

**Table 2.21:** Final energy demand in industry by energy service sectors [ktoe/year]

| Industrial energy services | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Direct heat | 43 | 292 | 123 | 877 | 361 | 6.77 | 2.85 | 20.35 | 8.38 |
| Steam boiler | 816 | 4,674 | 2,726 | 16,688 | 9,465 | 5.73 | 3.34 | 20.45 | 11.60 |
| Motor | 25 | 171 | 95 | 486 | 192 | 6.72 | 3.75 | 19.13 | 7.56 |
| Other energy service | 137 | 964 | 509 | 2,817 | 1,479 | 7.04 | 3.72 | 20.59 | 10.81 |
| **Total** | **1,021** | **6,100** | **3,453** | **20,868** | **11,497** | **5.97** | **3.38** | **20.43** | **11.26** |

**Transportation sector:**

Energy sectors of passenger and freight transportation are transportation modes. Total energy demand of the transportation sector is obtained from the energy balance table in 2010; however, it is not disaggregated energy consumption between passenger and freight mode. Total energy demand of the transportation sector is “non-energy use” in transportation. Since the balance table expresses the value of energy consumption only for road, rail, inland waterways, and air, etc., this study assumes energy consumption by service sectors to be in proportion to the average vehicle distance (vehicle.km/year) of each mode and fuel efficiency.

Energy demand in this sector is expected to increase substantially due to increase of transportation demand in the future. Energy demand in the passenger transportation sector is projected to increase to approximately 2,005 and 7,006 ktoe/year in 2030BaU and 2050BaU, respectively, from 321ktoe/year in 2010. Under low carbon measures, it is projected to decrease to roughly 879 and 3,027ktoe/year in 2030CM and 2050CM, respectively. Similarly, energy demand in the freight transportation sector is projected to increase to around 1,765 and 9,975ktoe/year in 2030BaU and 2050BaU, respectively, from 324ktoe/year in 2010. Under low carbon measures, it is expected to decrease to about 768 and 4,917ktoe/year in 2030CM and 2050CM, respectively. Table 2.22 shows final energy demand in the transportation sector by transportation modes.

**Table 2.22:** Energy service demand by each transportation mode [ktoe/year]

| Transportation sectors | | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Passenger transportation | Motorbike | 64 | 169 | 64 | 792 | 212 | 2.63 | 0.99 | 12.35 | 3.30 |
| | Tourist car | 185 | 1,098 | 387 | 4,189 | 1,676 | 5.95 | 2.09 | 22.69 | 9.08 |
| | Bus | 54 | 379 | 189 | 973 | 558 | 7.08 | 3.52 | 18.18 | 10.41 |
| | Train | 0 | 279 | 201 | 700 | 378 | - | - | - | - |
| | Ship | 13 | 48 | 21 | 258 | 139 | 3.73 | 1.66 | 20.23 | 10.90 |
| | Air | 6 | 32 | 18 | 93 | 64 | 5.27 | 2.94 | 15.02 | 10.41 |
| | **Sub-total** | 321 | 2,005 | 879 | 7,006 | 3,027 | 6.24 | 2.74 | 21.81 | 9.42 |
| Freight transportation | Small cargo truck | 82 | 445 | 178 | 2,209 | 696 | 5.42 | 2.17 | 26.94 | 8.49 |
| | Big cargo truck | 143 | 809 | 199 | 3,566 | 634 | 5.65 | 1.39 | 24.89 | 4.43 |
| | Train | 82 | 444 | 370 | 3,848 | 3,478 | 5.39 | 4.49 | 46.67 | 42.17 |
| | Ship | 16 | 66 | 20 | 352 | 109 | 4.13 | 1.25 | 21.86 | 6.80 |
| | **Sub-total** | 324 | 1,765 | 768 | 9,975 | 4,917 | 5.45 | 2.37 | 30.80 | 15.18 |
| **Grand total** | | **645** | **3,770** | **1,647** | **16,981** | **7,944** | **5.84** | **2.55** | **26.32** | **12.31** |

## 2.5 $CO_2$ emissions and reductions from the energy sector

### 2.5.1 $CO_2$ emissions and reduction potentials

The ExSS tool is used to estimate $CO_2$ emissions based on fuel inputs and domestic energy consumption; however, if the Government plans to export the electricity, $CO_2$ emissions will be calculated exogenously. $CO_2$ emissions in Cambodia are projected to increase to about 23,277 (about 5.52 times) and 91,325kt$CO_2$/year (21.64 times) in 2030BaU and 2050BaU, respectively, from around 4,221kt$CO_2$/year in 2010. Under low carbon measures, they are expected to decrease to approximately 10,451 (about 2.48 times) and 39,172 kt$CO_2$/year (9.28 times) in 2030CM and 2050CM, respectively. The results indicate that $CO_2$ emissions are expected to reduce by about 55.10% and 57.11% in 2030CM and 2050CM, respectively. Per capita $CO_2$ emissions were about 0.30t$CO_2$/year in 2010 and are expected to increase to around 1.27t$CO_2$/year and 4.16t$CO_2$/year in 2030BaU and 2050BaU, respectively. Under low carbon measures, they are expected to decrease to about 0.57t$CO_2$/year and 1.78t$CO_2$/year in 2030CM and 2050CM, respectively. Per GDP $CO_2$ emissions were around 0.36kg$CO_2$/USD/year in 2010 (or 0.48kg$CO_2$/USD/year in 2005 constant price) and are expected to increase to be similar of around 0.52kg$CO_2$/USD/year in both 2030BaU and 2050BaU. They are expected to decrease to about 0.23 and 0.22 kg$CO_2$/USD/year in 2030CM and 2050CM, respectively. $CO_2$ emissions and reduction potentials in the energy sector are shown in Table 2.23.

**Table 2.23:** $CO_2$ emissions and reduction potentials [kt$CO_2$/year]

| $CO_2$ emissions/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 830 | 2,414 | 918 | 9,889 | 2,034 | 2.91 | 1.11 | 11.91 | 2.45 |
| Commercial | 217 | 1,433 | 482 | 3,663 | 1,298 | 6.61 | 2.22 | 16.90 | 5.99 |
| Industrial | 1,173 | 7,536 | 3,926 | 23,691 | 11,136 | 6.42 | 3.35 | 20.19 | 9.49 |
| Passenger transportation | 996 | 6,374 | 2,743 | 22,276 | 9,431 | 6.40 | 2.75 | 22.36 | 9.47 |
| Freight transportation | 1,004 | 5,521 | 2,383 | 31,806 | 15,273 | 5.50 | 2.37 | 31.67 | 15.21 |
| Total emissions and reduction | 4,221 | 23,277 | 10,451 | 91,325 | 39,172 | 5.52 | 2.48 | 21.64 | 9.28 |
| Per capita emission (t$CO_2$/person) | 0.30 | 1.27 | 0.57 | 4.16 | 1.78 | 4.19 | 1.88 | 13.75 | 5.90 |
| Per GDP emission (kg$CO_2$/USD) | 0.36 | 0.52 | 0.23 | 0.52 | 0.22 | 1.43 | 0.64 | 1.45 | 0.62 |

### 2.5.2 $CO_2$ emissions and reductions by sectors

The results yield that the industrial sector, which shared the highest $CO_2$ emissions (27.79%) in 2010, remains the largest emissions, emitting about 7,536kt$CO_2$/year (about 32.37%), followed by the passenger transportation of about 6,374kt$CO_2$/year (about 27.38%) in 2030BaU. The freight transportation is projected to emit about

5,521kt$CO_2$/year (about 23.72%), while residential and commercial sectors are projected to emit about 2,414 and 918 kt$CO_2$/year (about 10.37% and 6.15%), respectively, in 2030BaU. However, the results show that the freight transportation accounts for the biggest $CO_2$ emissions, emitting about 31,806kt$CO_2$/year (about 34.83%), followed by the industrial sector of about 23,691kt$CO_2$/year (about 25.94%) in 2050BaU. The passenger transportation is projected to emit about 22,276kt$CO_2$/year (about 24.39%), while residential and commercial sectors are projected to emit about 9,889 and 3,663kt$CO_2$/year (about 10.83% and 4.01%), respectively, in 2050BaU.

Under low carbon measures, the results yield that around 8,714kt$CO_2$/year of total emissions reduction can be achieved by improving energy efficiency in 2030CM and 40,220kt$CO_2$/year in 2050CM, while about 1,793 and 3,248 kt$CO_2$/year in 2030CM and 2050CM, respectively, can be achieved by adopting a modal shift. Energy efficiency improvement in the power sector (reducing transmission loss and fuel switch to renewable energy) is projected to reduce $CO_2$ emissions by about 560 and 1,726 kt$CO_2$/year in 2030CM and 2050CM, respectively. The implementation of fuel switch is expected to reduce $CO_2$ emissions of around 204 and 2,207 kt$CO_2$/year in 2030CM and 2050CM, while energy saving behaviors are expected to reduce $CO_2$ emissions by approximately 1,555 and 4,751kt$CO_2$/year in 2030CM and 2050CM, respectively. $CO_2$ emission reductions by sectors and by each category of measures in 2030CM and 2050CM are shown in Figure 2.4.

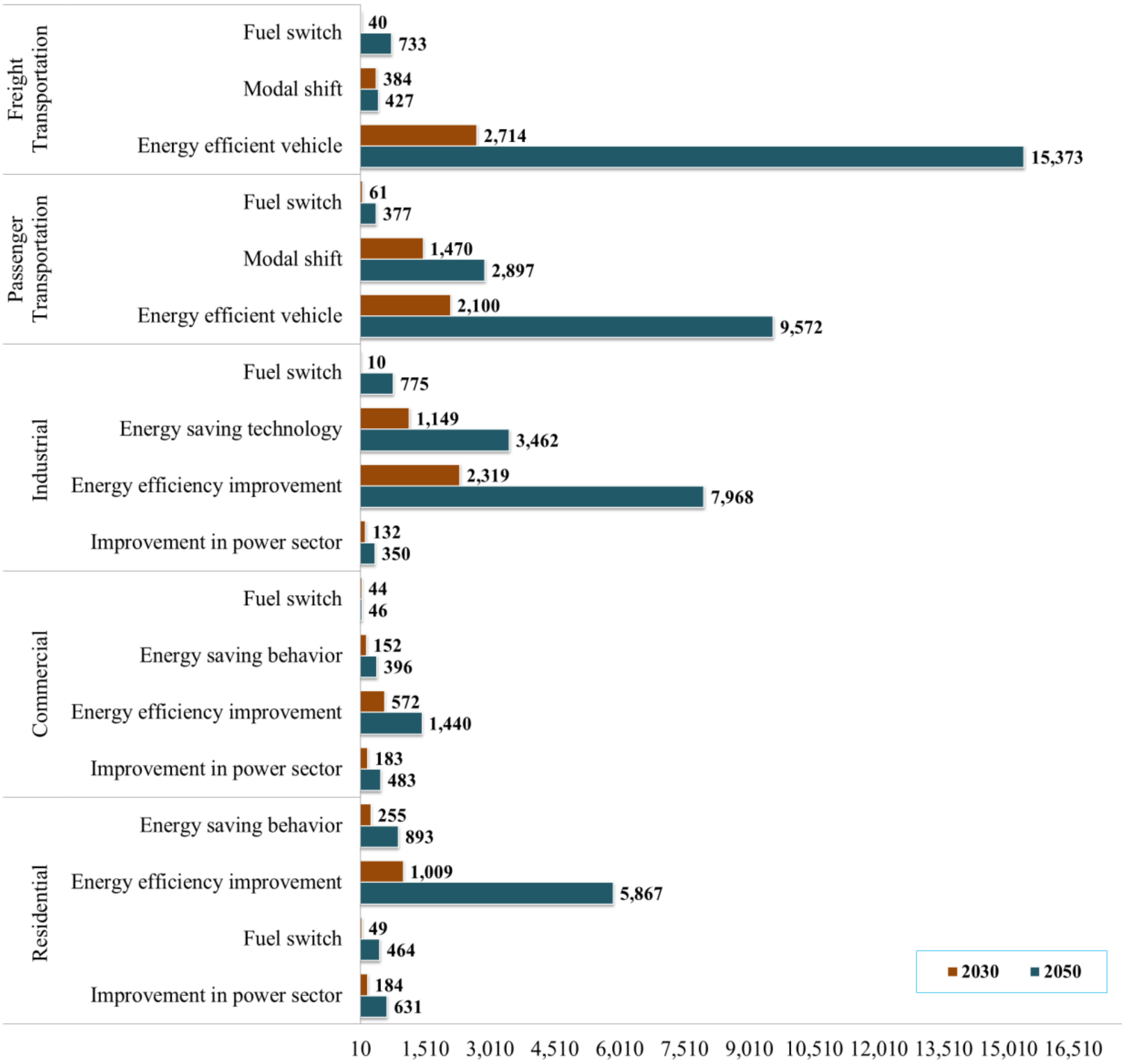


**Figure 2.4:** $CO_2$ emissions reductions by sectors, and by each category of measures [kt$CO_2$/year] in 2030CM and 2050CM

**Residential sector's emissions and reduction potentials**

Increasing energy demand in the residential sector depends on growths in population and incomes of the people, and increases of areas and population who can access to electricity. The results yield that $CO_2$ emissions in this sector are projected to increase to about 2,414 and 9,889 kt$CO_2$/year, which are about 2.91 times and 11.91 times in 2030BaU and 2050BaU, respectively, bigger than in 2010. However, $CO_2$ emissions reductions of around 1,313 and 7,224kt$CO_2$/year in 2030CM and 2050CM, respectively, can be achieved by adopting low carbon measures, *e.g.* energy efficiency improvement of electrical and non-electrical equipment, fuel switch, and energy saving behaviors.

Among them, efficient cooking system, energy efficient lighting, refrigerator, and cooling options are the potential options of emissions reduction. Figure 2.5 shows $CO_2$ emissions reduction by energy service sector in the residential sector ($ktCO_2$/year).

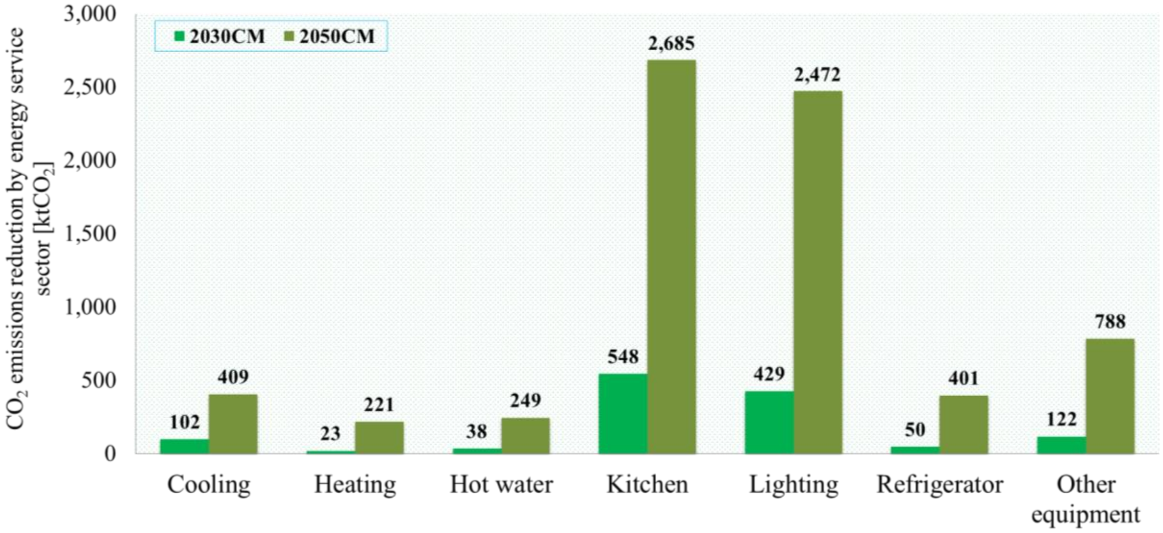


**Figure 2.5:** $CO_2$ emissions reduction by energy service sectors in the residential sector [$ktCO_2$/year]

**Commercial sector's emissions and reduction potentials**

Energy demand in the commercial sector is driven by the growth of the outputs of tertiary industry, which is projected to increase about 4.01 times and 15.56 times in 2030BaU and 2050BaU, respectively, larger than in 2010, while energy demand is projected to increase about 6.45 times and 17.98 times in 2030BaU and 2050BaU, respectively. The result yields that $CO_2$ emissions in this sector are expected to emit about 1,443 and 3,663 $ktCO_2$/year, which are about 6.61 times and 16.90 times in 2030BaU and 2050BaU, respectively, from 2010. However, under low carbon measures, improvement in energy efficiency (electric devices, insulation buildings), efficient improvement in the power sector, and energy saving behaviors are the potential options for $CO_2$ emissions reduction, and are expected to reduce $CO_2$ emissions by about 768 and 1,882 $ktCO_2$/year of total emissions reduction in 2030CM and 2050CM, respectively. Among them, lighting, other equipment, and refrigerator are the potential options of emissions reduction. Figure 2.6 shows $CO_2$ emissions reduction by energy service sector in the commercial sector ($ktCO_2$/year).

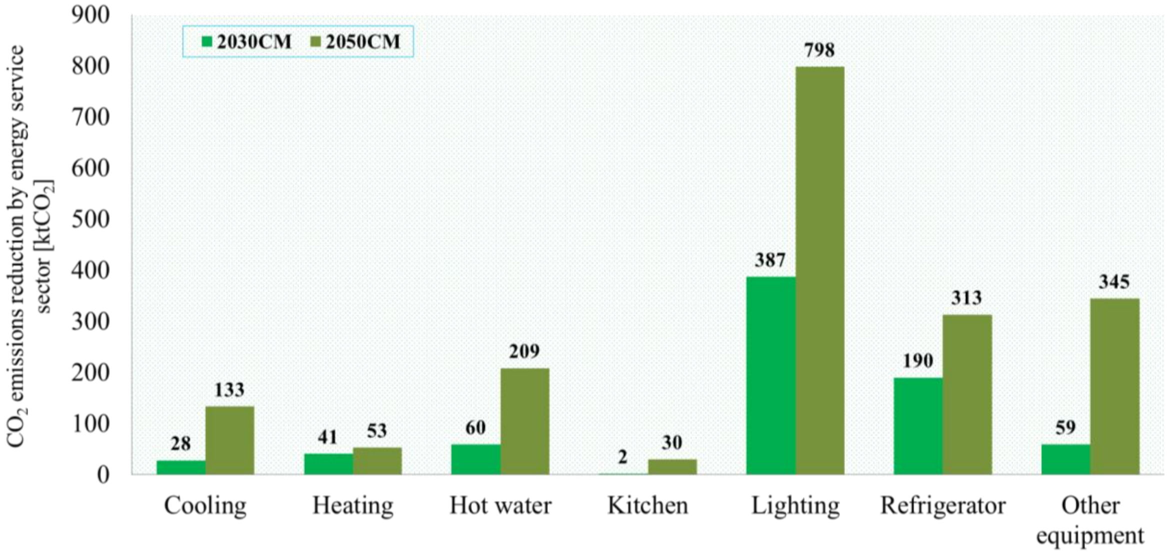


**Figure 2.6:** $CO_2$ emissions reduction by energy service sectors in the commercial sector [kt$CO_2$/year]

**Industrial sector's emissions and reduction potentials**

This study assumes the average annual GDP growth rate of 7.0% from 2010 through to 2050, while energy demand is projected to increase about 7.55 times and 20.43 times in 2030BaU and 2050BaU, respectively, larger than in 2010. Disregard of low-carbon measures, $CO_2$ emissions are expected to increase about 7,536 and 11,136kt$CO_2$/year, which are about 6.42 times and 20.19 times in 2030BaU and 2050BaU, respectively, larger than in 2010. However, by adopting some low-carbon measures such as energy efficiency improvement, fuel switch, and energy saving technologies, $CO_2$ emissions are expected to reduce by around 3,477 and 12,205 kt$CO_2$/year in 2030CM and 2050CM, respectively. Among them, steam boiler and other equipment are the potential options of emissions reduction. Figure 2.7 shows $CO_2$ emissions reduction by energy service sector in the industrial sector (kt$CO_2$/year).

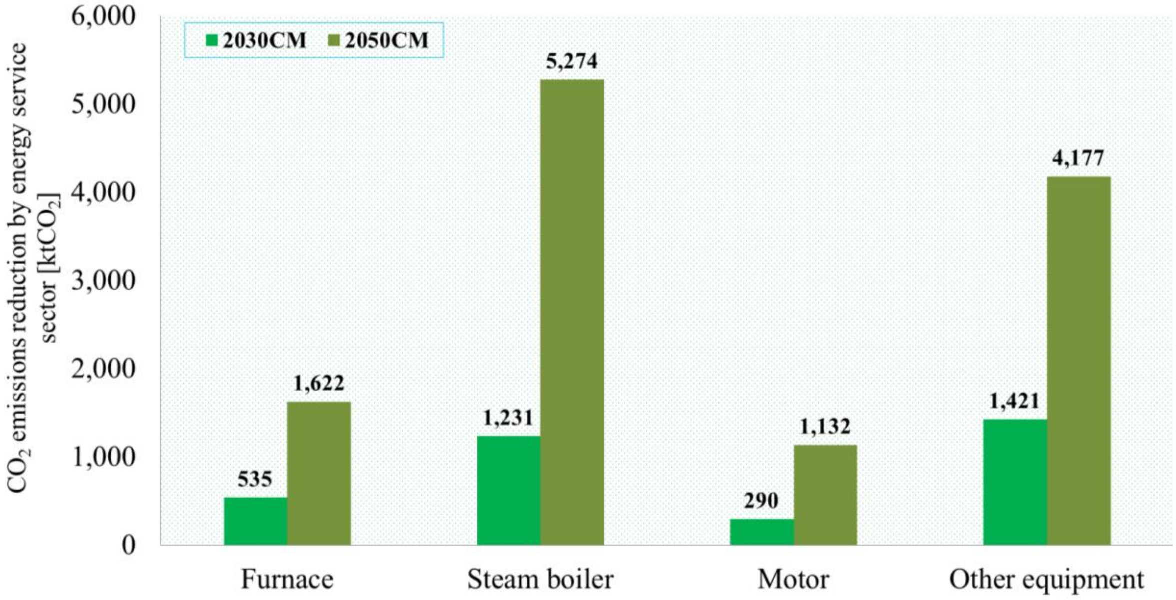


**Figure 2.7:** $CO_2$ emissions reduction by energy service sectors in the industrial sector [$ktCO_2$/year]

**Transportation sector's emissions and reduction potentials**

With the projected increase of transportation demand, energy demand in this sector is projected to increase about 11.69 times and 52.61 times in 2030BaU and 2050BaU, respectively, bigger than in 2010. The results yield that $CO_2$ emissions from the transportation sector are projected to increase from about 2000$ktCO_2$/year in 2010 to 11,895 and 54,082$ktCO_2$/year, which are about 11.90 times and 27.03 times in 2030BaU and 2050BaU, respectively, larger than in 2010. Among them, $CO_2$ emissions from the passenger transportation are projected to increase to about 6,374 and 22,276 $ktCO_2$/year, which are about 6.40 times and 22.36 times in 2030BaU and 2050BaU, respectively, compared to 2010, while $CO_2$ emissions from the freight transportation are projected to increase from around 1,004$ktCO_2$/year in 2010 to around 5,521 and 15,273 $ktCO_2$/year in 2030BaU and 2050BaU, respectively. By adopting low-carbon measures, *e.g.* improvement of energy efficiency, fuel switch, and modal shift; $CO_2$ emissions in this sector are expected to reduce by approximately 6,708 and 29,116 $ktCO_2$/year, which account for about 52.3% and 55.83% of total $CO_2$ emissions reduction in 2030CM and 2050CM, respectively. Among them, the passenger transportation is expected to reduce by about 3,574 and 12,658 $ktCO_2$/year in 2030CM and 2050CM, respectively, while the freight transportation is expected to reduce by about 3,134 and 16,458 $ktCO_2$/year in 2030CM and 2050CM, respectively.

**Power supply's emissions and reduction potentials**

In this study, the projected composition of fuel mix of power generation referred to the power development master plan of Cambodia in 2014, which fuel mix of power generation by 2030 and 2050 is dominated by natural gas and hydropower. Besides, some low-carbon measures such as reduction of transmission loss, energy efficiency improvement, and fuel switch from non-renewable to renewable energy (solar/wind) are introduced to reduce emissions. The results yield that $CO_2$ emissions in this sector are expected to reduce by about 560 and 1,726 kt$CO_2$/year of total $CO_2$ emissions reduction in 2030CM and 2050CM, respectively.

## 2.6 Discussion

This section will discuss some important results in the energy sector. Since the detailed information in Cambodia is not fully acquired, some assumptions are made based on the professional judgment of the authors and direct communication with the country's experts. Therefore, the trends of projections are not precise predictions, a range of possible future outcomes are possible.

### 2.6.1 Macro economy

This study projects that the GDP in Cambodia will increase significantly in the future (7% annually) and per capita GDP is also projected to increase accordingly. The results indicate that the projected per capita GDP in 2030 in Cambodia is similar to that of the Philippines in 2013; this implies that per capita GDP in Cambodia stays 17 years behind that of the Philippines. And per capita GDP in 2050 in Cambodia is similar to that of Malaysia in 2008; it means that this implies that per capita GDP in Cambodia stays 42 years behind that of Malaysia. Cambodia must, therefore, ensure and increase more GDP growth rate from today in order to reach a high income level where per capita GDP is the more than 12,476USD (UN, 2013) by 2050 (RGC, 2013). The results stressed that the projected per capita GDP of Cambodia in 2050 stays even far behind those of some of the advanced countries such as the Republic of Korea (20,756USD), Japan (42,783USD), and Sweden (49,183USD) in 2010 (IMF, 2014).

In the meantime, it is observed that in terms of the annual growth, there is no doubt that the primary industry would decrease, while the secondary industry would increase when a country shifts from a low-income level to a middle level or a high-income one. The RGC has set a long term economic development target by shifting from a low-income country to an upper middle-income and high-income level by 2030 and 2050 (RGC, 2013), respectively. It is, therefore, secondary industry is projected to grow substantially; however, Cambodia still counts the primary industry as a key contributor to her GDP growth. The results of this study suggest that the secondary industry in Cambodia contributed lower to the GDP than that of some other ASEANs, which experienced a similar GDP growth, while the tertiary industry illustrates a similar trend as that of other countries like Malaysia and Thailand. Figures 2.8, 2.9, and 2.10 show the correlation between per capita GDP growth in Purchasing Power Parity (PPP) at 2005 constant price (per capita GDP in PPP at 2005 constant price is used to compare with other countries' GDP) and value added (%) of the respective industries, which contribute to GDP growth between Cambodia and some other countries.

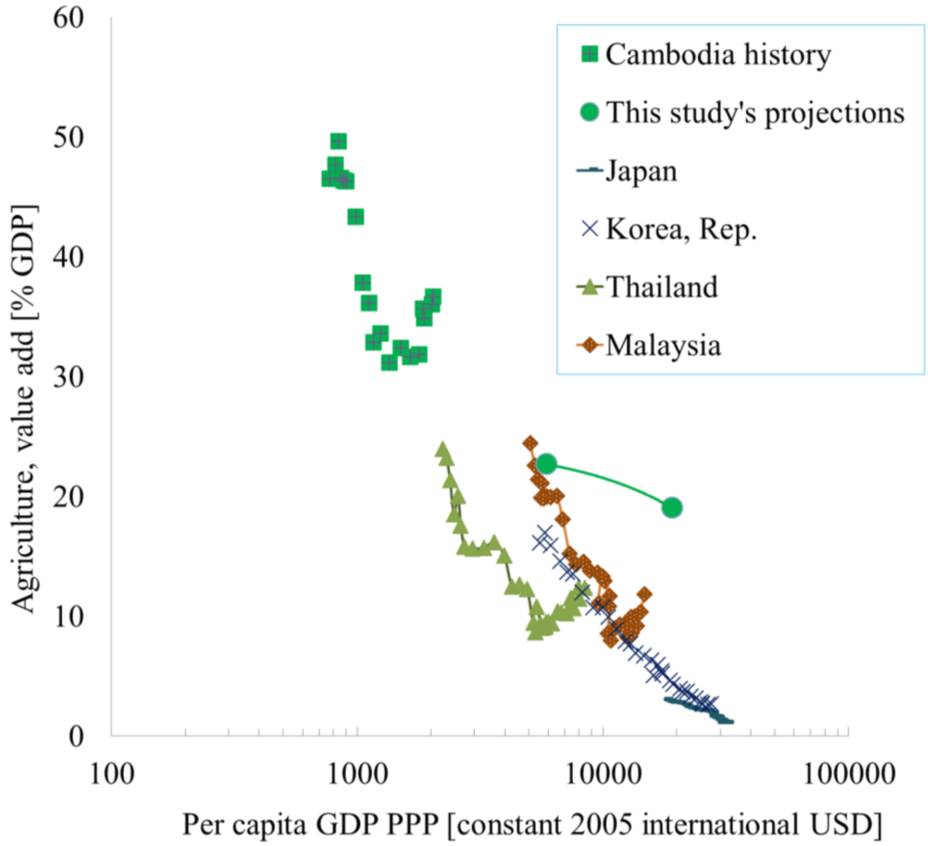


**Figure 2.8:** The correlation between primary industry contributions to the GDP and per capita [PPP at 2005 constant price] among Cambodia and other countries

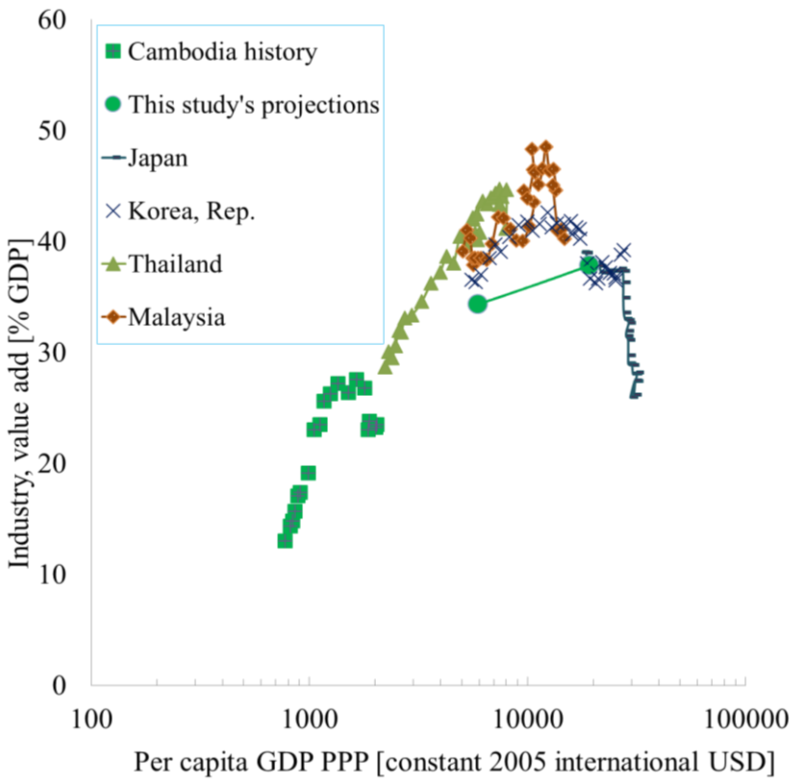


**Figure 2.9:** The correlation between secondary industry contributions to the GDP and per capita [PPP at 2005 constant price] among Cambodia and other countries

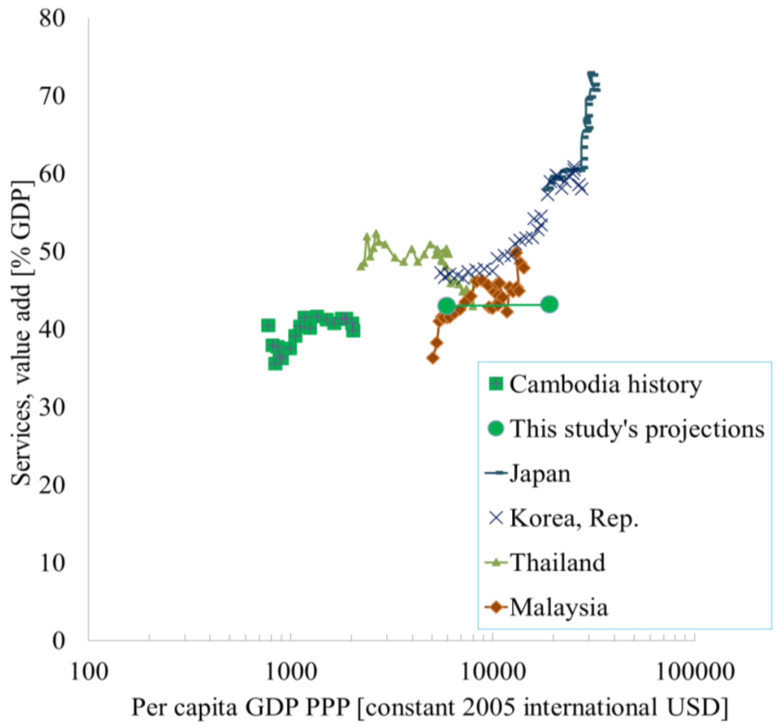


**Figure 2.10:** The correlation between tertiary industry contributions to the GDP and per capita [PPP at 2005 constant price] among Cambodia and other countries

### 2.6.2 Transportation demand

The results yields that passenger transportation demand in Cambodia is dominated by road in which numbers of motorbikes are largely dominated; however, transportation demand (Million pass.km/year) from this mode is smaller than other modes due to its short average trip distance. Total passenger transportation demand is projected to increase significantly in the target years; this is due to the projected increase of incomes, which make the people to use more motorized vehicles, especially private cars for travelling and going to work. It can be observed that the projected transportation demand is dramatically increased as most of passengers who are expected to use motorized vehicles mainly switch from walks and bicycles. The results suggest Cambodia could reduce private motorized vehicles, which lead to reduce transportation demand through introducing more public buses and trains, especially in the major cities. The projected per capita passenger demand (about 15,052km/person) in Cambodia in 2030 is higher than Vietnam's one (about 5,226km/person) in the same year (Nguyen, 2012) and it is even higher in 2050. This is because this study assumes the shares of walk and bicycle of around 64.39% and 26.88% in 2030BaU and 2050BaU, respectively, while it was assumed up to 93.0% in 2030BaU in Vietnam.

Similarly, the result yields that freight transportation demand is projected to increase significantly in the future; however, it remains lower than that of some ASEANs such as Malaysia, Thailand, and Vietnam in the same year in 2030 (Bundit *et al*., 2010; Nguyen, 2012; and Siong *et al*., 2013); and it is projected to increase further in Cambodia by 2050 (Table 2.24). Cambodia must put more effort to stimulate and expand her economic development, especially promoting industrial development policies and by doing so, the Government is expected to reach the economic development aspiration to be a high-income country by 2050 (RGC, 2013). Since Cambodia has very limited studies on the projection of transportation demand and the future trends of energy demand and $CO_2$ emissions, more studies are needed to better understand the possible future transportation scenarios so that the Government can develop an appropriate and effective infrastructure and traffic management plan to avoid traffic congestion, road accident, and air pollution as well as to mitigate $CO_2$ emissions accordingly.

**Table 2.24:** Comparative studies of projected freight transportation demand between Cambodia and some Asian countries [Million ton.km/year]

| Countries | Freight transportation demand [Million ton.km/year] | | Sources |
|---|---|---|---|
| | 2030 | 2050 | |
| Cambodia | 116,048 | 619,725 | This study |
| Malaysia | 214,000 | N/A | Siong *et al.* (2013) |
| Thailand | 589,859 | N/A | Bundit *et al.* (2010) |
| Vietnam | 235,212 | N/A | Nguyen (2012) |

### 2.6.3 Energy sector

It is observed that biomass was the main source of energy supply in 2010, accounting for about 72.8%, followed by oil (about 23.1%) and electricity (about 4.1%) (IEA, 2012). The residential sector was the highest biomass consumer (about 78.8%), followed by the industrial sector (about 21.2%); however, Cambodia stands the second after Myanmar (about 81.4%) in terms of biomass consumption in ASEANs in that year (IEA, 2013). Table 2.25 shows the comparisons of total final energy supply between Cambodia and some of ASEANs. It is noted that most of Cambodian households rely mainly on firewood; thus, it puts more pressures on forest resources (RGC, 2012). In order to address this concern, the Government has encouraged researchers and investors to invest and find appropriate alternative energy technologies in which some improved energy technologies have been recommended and two of them are introduced. First is the introduction of energy efficient cook stoves "Neang Kongrey stove and New Lao stove", which are more energy efficiency than "traditional three-stone one" (WB and MIME, 2009). These cook stoves use approximately 21.0% less fuel wood than a traditional Lao's one and 64.0% less than a three-stone one. Currently, about 40.0% of the urban households are using energy efficient cook stoves, while most of households in the rural areas are still using the traditional ones. It is expected that almost all households will be able to afford and change from traditional cook stoves to more efficient ones by 2030. Second is the introduction of "Bio-digester", which has been implemented since 2006, for producing methane gas for both cooking and lighting (MAFF, 2011). It also contributes to reduce deforestation, eliminate harmful indoor smoke from wood fires, reduce emissions, and improve sanitation. About 20,338 bio-digesters have been installed so far (MAFF, 2013).

It is obvious that energy is the most vital instrument of socioeconomic development, while population and economic growths are major driving forces to increase energy demand (Sahir and Qureshi, 2007). As the living standard rises and population continues to grow, energy use does the same (Aqeel and Butt, 2001; Fong *et al.*, 2007; Saidi and Hammami, 2015). Nguyen-Van (2008) suggested that energy consumption in the developing countries would rise more rapidly than expected, while Huang et al. (2008) echoed that economic growth in middle- and high-income countries leads to a higher energy consumption. The present study finds that energy demand in Cambodia is projected to increase about 4.6 and 15.3 times in 2030BaU and 2050BaU, respectively, due to the population growth and increased incomes of people. The results express similar casual relationships between energy demand and population and economic growths as previous studies. Moreover, per capita energy consumption (kgoe/year) is expected to increase about 3.2 and 9.7 times in 2030BaU and 2050BaU, respectively. The results show that the trends of per capita energy consumption (kgoe/year) and per capita GDP of Purchasing Power Parity (PPP) in Cambodia in 2030BaU and 2050BaU are very similar to those of the Republic of Korea, Malaysia, and Thailand, which experienced the same economic growth. The results suggest that the further improvement of energy efficiency and transmission loss in the supply side could provide more electricity generation with the same fuel input. Similarly, the improvement of energy efficiency, introduction of advanced technology devices, and smart energy consumption by the end users, the people can use more devices with the same or even lower energy consumption compared to the conventional devices. In this regard, it can be seen that the trends of per capita energy consumption and per capita GDP in Cambodia in 2030CM and 2050CM stay far below those of the Republic of Korea, Malaysia, and Thailand. Figure 2.11 shows the correlation between per capita energy consumption (kgoe) and per capita GDP of PPP at 2005 constant price both in CM and BaU cases. The results imply that Cambodia can maintain the same economic growth with lower energy demand if the country adopts a policy to move forward a transition to a low carbon development. Indeed, Cambodia could gain massive reductions of energy demand through implementing some low carbon measures. Around 55% and 59% of energy demand can be reduced in 2030CM and 2050CM, respectively, compared to the BaU levels by introducing advanced energy technologies, energy efficiency improvement, and energy saving behaviors, etc. The above analysis recommends that Cambodia should consider designing a low carbon energy plan in order to promote sustainable economic growth with lower energy consumption in the future. Moreover, the trends of the projected GDP per unit of energy consumption (per capita GDP of PPP at 2005 constant price) in Cambodia is also very similar to that of some Asian countries, which experienced the same economic growth (Figure 2.12).

In the meantime, it is observed that Cambodia has gradually shifted away from oil-based power supply to clean and renewable sources of the power supply. Hydropower is one of the highest shares of future fuel mix after natural gas. The Government strongly confirmed the country's available capacity and facilities to build hydropower dams as stated in the power development master plan. In general, hydropower helps Cambodia to access to electricity and to promote economic growth, job creation, and to reduce $CO_2$ emissions (MoE, 2013). Besides, Cambodia can earn additional benefits from selling carbon credit to some developed countries through implementing the CDM projects under the framework of carbon market mechanisms of the Kyoto Protocol (UNFCCC, 1998). Indeed, Cambodia has currently been registered four CDM projects from the hydropower with the total emissions reduction of around 1,812kt$CO_2$/year (IGES, 2015). However, hydropower dam construction has caused various concerns such as changing water flow regime, impacts on biodiversity, forestry, fisheries, agricultural land, the people living within and around the dam construction areas, and the indigenous culture (GIZ, 2014). Cambodia faced some challenges when the country invests in hydropower dams. One of the most controversial projects was the Lower Se San II with the installed capacity of about 400MW, constructed in 2013. This project impacted 797 families, houses, pagodas, schools, health centers, other private assets, and some parts of the land granted to five concession companies (RGC, 2013b). To solve the problem, the national assembly of Cambodia approved a law on the Government guarantee of payments to the Hydropower Lower Se San II in February 2013. This law was only used to solve problems on case by case basis. In short, hydropower construction provides significant opportunities such as electricity generation, economic development, green jobs creation, and GHG reductions in the long run when the EIA and Law enforcement are strictly and effectively enforced.

**Table 2.25:** Comparisons of total final energy supply in ASEANs in 2010

| Total final consumption | Share [%] of | | |
|---|---|---|---|
| | Biomass | Oil | Electricity |
| Cambodia | 72.8 | 23.1 | 4.1 |
| Indonesia | 34.0 | 38.1 | 8.1 |
| Myanmar | 81.4 | 8.0 | 4.2 |
| Malaysia | 4.0 | 56.8 | 22.0 |
| Philippines | 23.3 | 48.1 | 20.0 |
| Thailand | 17.0 | 44.9 | 15.2 |
| Vietnam | 28.5 | 33.8 | 15.4 |

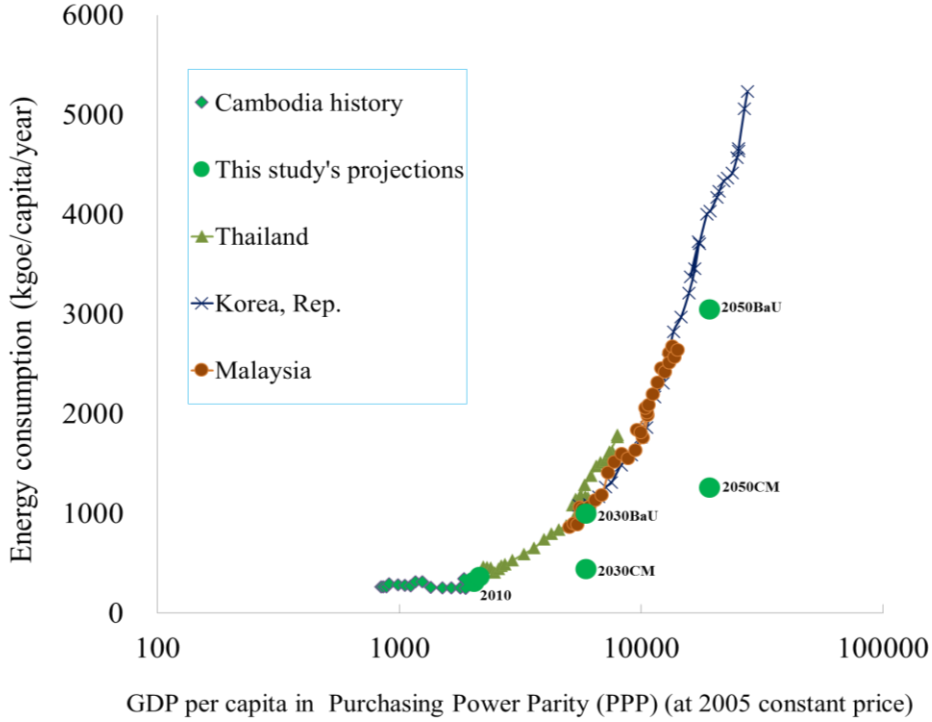


**Figure 2.11:** The correlation between energy use [kgoe] per capita and GDP per capita [PPP at 2005 constant price] among Cambodia and some Asian countries

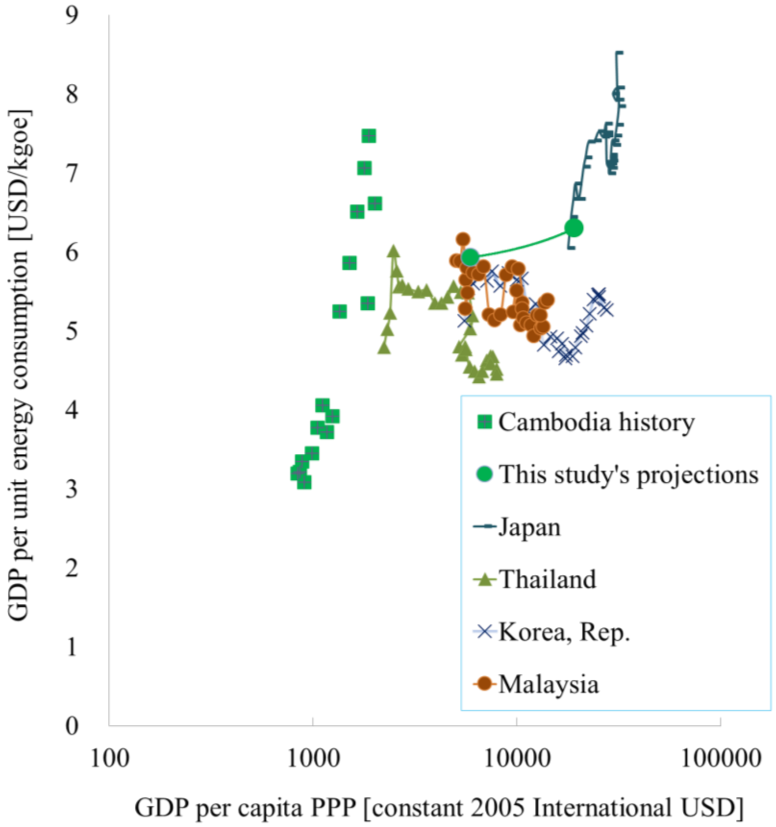


**Figure 2.12:** The correlation between GDP per unit of energy consumption and per capita GDP [PPP at 2005 constant price] among Cambodia and some Asian countries

### 2.6.4 $CO_2$ emissions

Several studies disclosed cohesive relationships between population and economic growths and energy demand and $CO_2$ emissions (Sahir and Qureshi, 2007; Fong *et al.*, 2007; Lean and Smith, 2009; Menyah and Rufael, 2010; Niu *et al.*, 2011; Arouri *et al.*, 2012). The results of the current study yield that $CO_2$ emissions are projected to increase about 5.52 and 21.64 times in 2030BaU and 2050BaU, respectively, due to growths in population (1.32 and 1.57 times), GDP (3.87 and 14.97 times), and energy demand (4.19 and 15.26 times). The analysis of key drivers lead to such a drastic change of $CO_2$ emissions between the base year (2010) and the target years (2030BaU and 2050BaU) is shown in Table 2.26. This analysis suggests that the population growth should not be the main driver of significant increase of $CO_2$ emissions. However, it can be investigated that the GDP grew considerably between 2030BaU and 2050BaU because of the Government's ambiguous target to move to an upper-middle income country and a high-income one in 2030 and 2050, respectively, (RGC, 2013). Besides, the sources of the power supply are unlikely the reason to attribute to higher emissions as they originate almost entirely from hydropower, which is considered as zero emissions (IPCC, 2006) and natural gas, which is considered as lower quantities of GHG emissions than coal or oil (EPA, 2015). According to the analysis in the table, it is explicitly implied that the considerable increases of $CO_2$ emissions should dominantly stimulate by a massive growth of the GDP.

The results also suggest that total $CO_2$ emissions in 2010 in this study be very similar to those of the Second National Communication (SNC) in the same year (MoE, 2013); however, the projected $CO_2$ emissions in 2030BaU and 2050BaU in this study are much larger than those of the SNC in the same years (Figure 2.13). It can be observed that the differences in $CO_2$ emissions are due mainly to the differences in assumptions of GDP growth, energy demand, and fuel mix of power generation. At the time of the SNC prepared, the Government did not formulate a concrete long-term economic development plan and the assumed GDP growth rate in the SNC (6.5%) was lower than the current Government's one (7%) (MoE, 2013). Besides, the fuel mix of power generation in this study includes natural gas (40.0%), hydropower (only 35.0%), and coal (15.0%) (MME, 2014); in contrast, the SNC were dominated largely by hydropower (up to 68.0%), while natural gas was very small (8.0%) (MoE, 2013). The results also suggest that per capita $CO_2$ emissions in Cambodia were lower than those of some other countries in the Association of South

East Asian Nations (ASEANs) in 2010 (IEA, 2013a) (Figure 2.14). Moreover, the projected per capita $CO_2$ emissions in 2030BaU and 2050BaU are still lower than those of some Asians in 2010 such as China (11.66t$CO_2$/year), Japan (8.89t$CO_2$/year), Republic of Korea (11.42t$CO_2$/year), Malaysia (6.46t$CO_2$/year), and Singapore (12.66t$CO_2$/year) (IEA, 2013).

The higher level of per GDP $CO_2$ emissions indicated a larger share of more energy intensive-economic activities, the use of less energy efficient technologies, and a larger share of coal in the energy mix (Oliver *et al*., 2013). He also stressed that China owned one of the largest shareholding of coal for power generation where her per capita $CO_2$ emissions were comparable to those in the EU and almost half of the USA; but her $CO_2$ emissions per GDP were almost double those of the EU and the USA, while Japan emitted less per GDP $CO_2$ emissions than other countries in the world (Oliver *et al*., 2013). The estimated $CO_2$ emissions per GDP in Cambodia in 2010 are higher than those of Singapore; they are, however, lower than those of some other countries in ASEANs (IEA, 2013a) (Figure 2.15). Moreover, the projected per GDP $CO_2$ emissions in Cambodia in 2030BaU and 2050BaU are larger than those of Japan (0.24kg/USD at 2005 constant price) and the Republic of Korea (0.55kg/USD at 2005 constant price) in 2010 (IEA, 2013). Moreover, the results argue that Cambodia could massively reduce $CO_2$ emissions through adopting some appropriate low carbon measures such as energy efficiency improvement, fuel switch, modal shift, etc. Besides, in order to analyse and examine factors that influence changes in the level of energy-related $CO_2$ emissions, a decomposition method is used. The detail decomposition analysis of $CO_2$ emissions reduction in this study is shown in Table 2.27 and Table 2.28 in 2030CM and 2050CM, respectively. The tables imply that energy efficiency equipment and vehicles contribute the largest $CO_2$ emissions reduction in both 2030CM (around 68%) and 2050CM (around 77%). Conversely, fuel switch attributes to the smallest $CO_2$ emissions reduction in 2030CM, while in 2050CM is renewable energy in power generation as the Government introduced small amount of renewable energy source. The projections suggest that Cambodia should consider renewable and clean energy as the main sources of the power supply for the economic development in order to avoid the perverse economic expense and environmental distress in the future. In doing so, the country must have sufficient financial and human resources. It can be observed that the results of this study are found to go in line with the Government policies and strategies to promote energy efficiency improvement (MME, 2013) and low carbon technology planning for sustainable development (MoE, 2013a). Besides, this study can estimate quantitative reductions of energy demand and $CO_2$ emissions, which are considered as very useful outcomes for the Government to formulate a comprehensive and concrete low carbon development policy in the future. In sum, the country needs to design a policy for low carbon development plan in order to reduce energy demand and $CO_2$ emissions, simultaneously ensuring economic growth and environmental sustainability.

**Table 2.26:** Key drivers for changes of $CO_2$ emissions in the energy sector

| Key drivers | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | Explanation |
|---|---|---|---|---|---|---|
| Population [1,000 persons] | 13,959 | 18,391 | | 21,964 | | The population growth is relatively slow, only 1.3 and 1.6 times in 2030 and 2050, respectively, (NIS, 2011 and UN, 2012). It would not be the main cause of the increase of $CO_2$ emissions. |
| GDP [Mil USD, at 2000 constant price] | 7,518 | 29,093 | | 112,582 | | The GDP growth is at a very high incremental rate, around 3.9 and 14.97 times in 2030 and 2050, respectively, (RGC, 2013). The GDP growth goes in line with energy demand and $CO_2$ emissions. Hence, the GDP growth is considered as the main contributor to accelerating $CO_2$ emissions in this study. |
| Power supply [fuel share %] | | | | | | |
| Coal | 1.30 | 15.0 | 12.0 | 15.0 | 12.0 | The fuel mix of power generation has changed drastically between 2010 and 2030 and 2050 (MME, 2014). The low $CO_2$ emissions in 2010 resulted mainly from the high rate of electricity import (around 60%) (EAC, 2010) as it is considered as zero emissions in the model. Besides, the future sources of the power supply dominated by renewable energy (hydropower, 35%) and low emissions sources (natural gas, 40%) (MME, 2014). Therefore, the change of sources of the power supply should not be the potential contributor for increasing $CO_2$ emissions. |
| Petroleum products | 38.21 | 3.0 | 2.0 | 3.0 | 2.0 | |
| Hydropower | 1.09 | 35.0 | 35.0 | 35.0 | 35.0 | |
| Natural gas | 0 | 40.0 | 40.0 | 40.0 | 40.0 | |
| Biofuels and waste | 0.84 | 0.0 | 0.0 | 0.0 | 0.0 | |
| Solar/wind | 0.15 | 1.0 | 5.0 | 1.0 | 5.0 | |
| Import | 58.43 | 6.0 | 6.0 | 6.0 | 6.0 | |
| Energy saving behaviour (%) | - | - | 20.0 | - | 20.0 | Energy saving behaviour can reduce energy consumption by 20% in 2030CM and 2050CM, which was referred to MME (2013). |
| Diffusion of energy effeciency equipment (%) | | - | 50 | - | 80 | The advanced energy efficiency equipment is expected to be diffused in Cambodia at around 50% in 2030CM and 80% in 2050CM due to the Government plan to improve technologies for low carbon planning and green growth development (MME, 2013; MoE, 2013a; and RGC, 2013b). |
| Transmission loss (%) | 12.23 | 7.0 | 6.50 | 7.00 | 6.50 | Transmission loss had decreased from 14.0% in 2004 to 7.42% (EAC, 2012) and the Government continue to improve the transmission loss in the future (MME, 2014 and RGC, 2013). Hence, this study assumed to decrease to 7% in both 2030BaU and 2050BU and further decrease to be similiar (6.5%) in 2030CM and 2050CM. |
| Energy demand (ktoe/year) | 4,386 | 18,374 | 8,180 | 66,932 | 27,691 | The energy demand increased around 4.19 and 15.26 times in 2030BaU and 2050BaU, which is proportionated to the GDP growth. |
| $CO_2$ emissions ($ktCO_2$/year) | 4,221 | 23,277 | 10,451 | 91,325 | 39,172 | The main drivers for the subtantial increases of $CO_2$ emissions in 2030 (5.5 times) and 2050 (21.6 times) are virtually certain to instigate mainly by the GDP growth and energy demand, followed by fuel mix of power generation. |
| Per capita emissions ($tCO_2$/person) | 0.30 | 1.27 | 0.57 | 4.16 | 1.78 | |

**Table 2.27:** Decomposition analysis for $CO_2$ emissions reduction in 2030CM

| Year | 2030BaU | 2030CM | Distribution of $CO_2$ emission reductions in 2030CM | | | | |
|---|---|---|---|---|---|---|---|
| Total $CO_2$ emissions ($ktCO_2$/year) | 23,277 | 10,451 | | | | | |
| | | | Renewable energy in power generation | Fuel switch | Energy efficiency equipment and vehicles | Modal shift | Improvement in energy intensity |
| Residential | | | 184 | 49 | 1,009 | 0 | 255 |
| Commercial | | | 183 | 44 | 572 | 0 | 152 |
| Industrial | | | 132 | 10 | 2,319 | 0 | 1,149 |
| Passenger transportation | | | 57 | 61 | 2,100 | 1,413 | 0 |
| Freight transportation | | | 4 | 40 | 2,714 | 379 | 0 |
| **Total reductions ($ktCO_2$/year)** | | **12,826** | **560** | **204** | **8,714** | **1,793** | **1,555** |
| Share of emission reductions | | | 4.4% | 1.6% | 67.9% | 14.0% | 12.1% |

**Table 2.28:** Decomposition analysis for $CO_2$ emissions reduction in 2050CM

| Year | 2050BaU | 2050CM | Distribution of $CO_2$ emission reductions in 2050CM | | | | |
|---|---|---|---|---|---|---|---|
| Total $CO_2$ emissions ($ktCO_2$/year) | 91,325 | 39,172 | | | | | |
| | | | Renewable energy in power generation | Fuel switch | Energy efficiency equipment and vehicles | Modal shift | Improvement in energy intensity |
| Residential | | | 631 | 464 | 5,867 | 0 | 893 |
| Commercial | | | 483 | 46 | 1,440 | 0 | 396 |
| Industrial | | | 350 | 775 | 7,968 | 0 | 3,462 |
| Passenger transportation | | | 187 | 189 | 9,572 | 2,897 | 0 |
| Freight transportation | | | 75 | 733 | 15,373 | 352 | 0 |
| **Total reductions ($ktCO_2$/year)** | | **52,153** | **1,726** | **2,207** | **40,220** | **3,248** | **4,751** |
| Share of emission reductions | | | 3% | 4% | 77% | 6% | 9% |

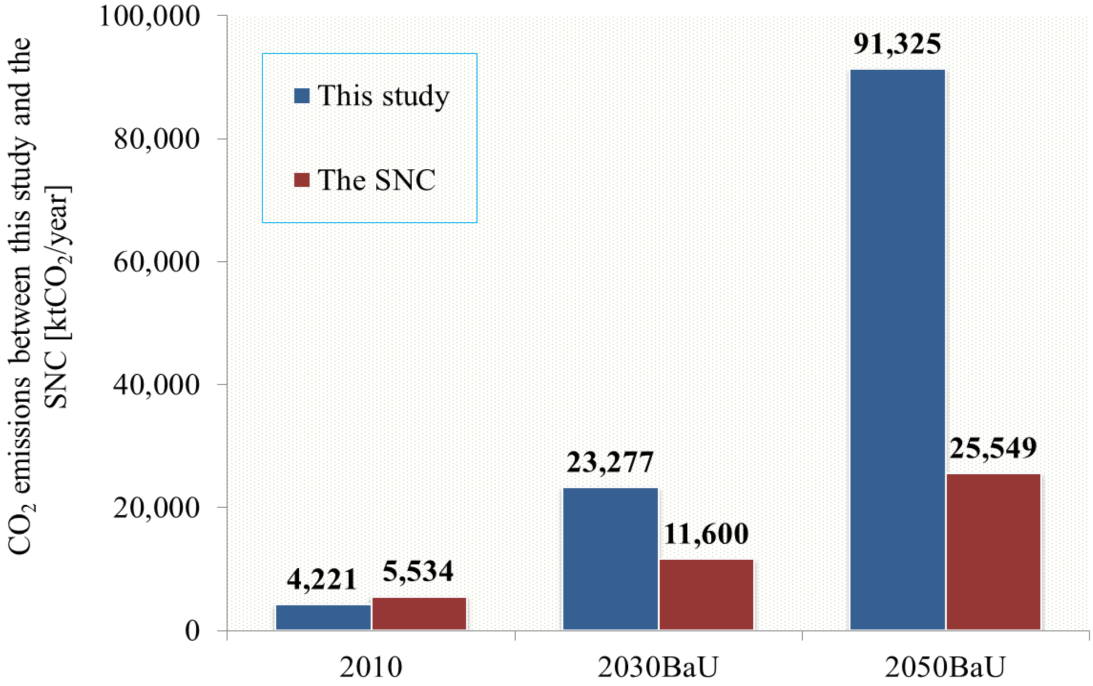


**Figure 2.13:** Comparisons of projected $CO_2$ emissions [$ktCO_2$/year] between this study and the Second National Communication (SNC)

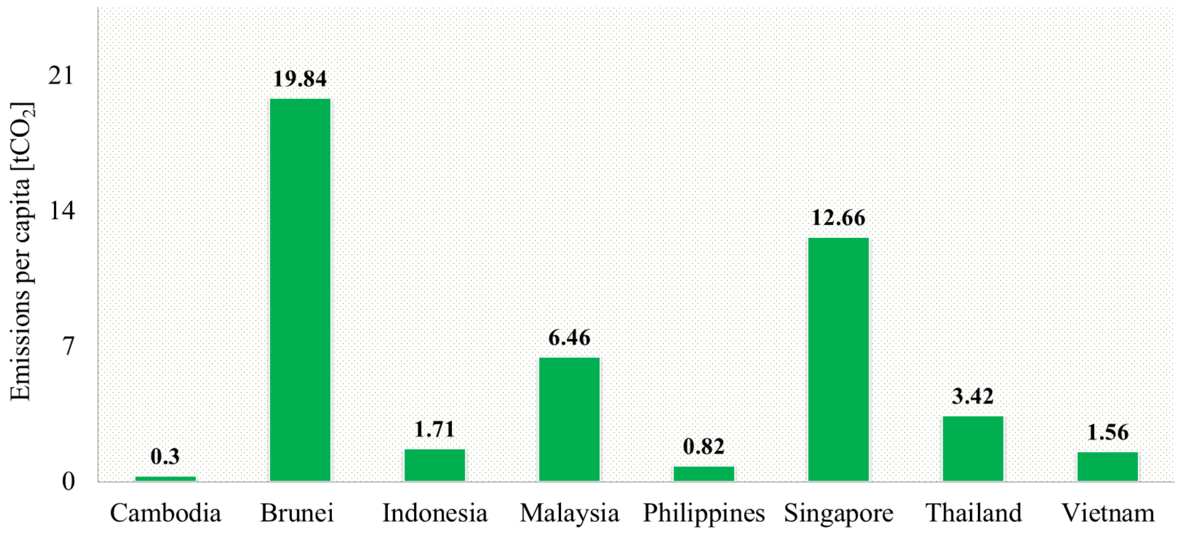


**Figure 2.14:** Comparisons of per capita $CO_2$ emissions [$tCO_2$/person] between Cambodia and ASEANs

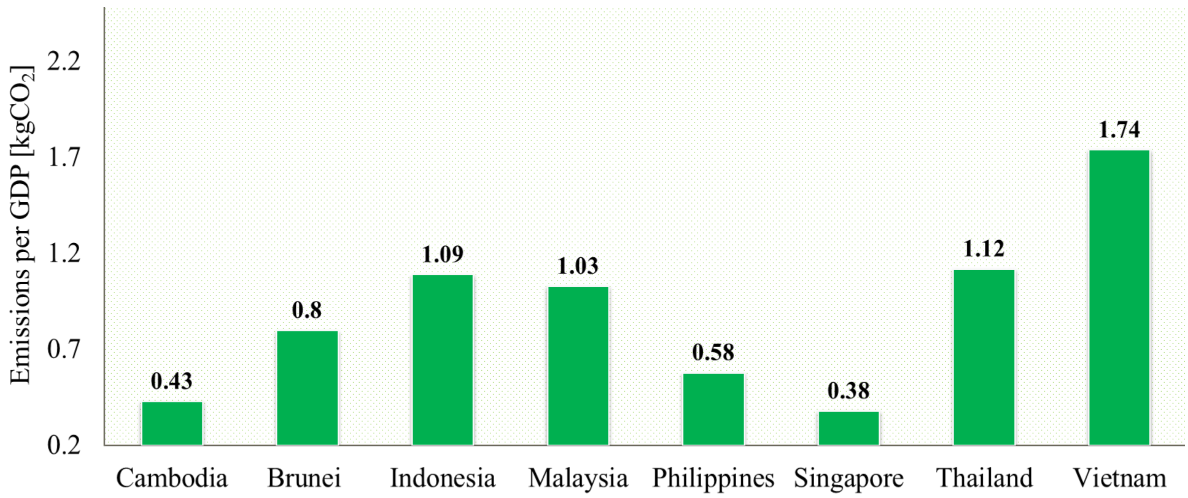


**Figure 2.15:** Comparisons of per GDP $CO_2$ emissions [$kgCO_2$/USD at 2005 constant price] between Cambodia and ASEANs

## PART 3 THE AFOLU SECTOR

### 3.1 Overview of Agriculture, Forestry and Other Land-Use Bottom-up (AFOLU-B) Model

The AFOLU-B model is a bottom-up type model to estimate GHG emissions and mitigation potentials in the AFOLU sector at a country or regional level, dealing with quantified mitigation measures (Hasegawa and Matsuoka, 2013) and has been applied to some Asian countries so far (Tahsin *et al*., 2014 and Nguyen *et al*., 2014). GHG emissions and mitigation potentials are calculated using a function of abatement costs, which are representative parameters representing willingness of GHG reductions under several constraints for mitigation costs and measures. Moreover, the calculation is also based on future assumptions of crop harvested areas, numbers of livestock and areas of land use change, etc.

The model illustrates selections of production countermeasures of the agricultural commodities and mitigation measures by producers (i.e. farmers) based on economic rationality. The model illustrates a selection of GHG mitigation options (low carbon measures) based on minimizing net benefits. Since the selection depends not only on evaluation methodologies of cost and mitigation, but also among countermeasures, the dependency is considered in the model. For example, for reducing fertilizer, which is one of low carbon measures for croplands, the balance among decrease in output of the crop due to fertilizer reduction, decrease in GHG emissions cost and an increase in revenue due to saving fertilizer is considered in the model. Another example, the improvement of livestock productivity, the balance among the increase in mitigation costs, increase in output of livestock products and decrease in GHG emissions cost is also taken into account in the model. The AFOLU-B model consists of two modules: AGriculture Bottom-up (AG/Bottom-up) and Land Use, Land Use Change and Forestry Bottom-up (LULUCF/Bottom-up).

#### 3.1.1 AG/Bottom-up module

The AG/Bottom-up module calculates GHG emissions and mitigation potentials in agricultural production; energy consumption of agricultural machines; and combination of production and mitigation measures under several abatement costs. (See more detail in Hasegawa and Matsuoka, 2013). This module is based on the assumption that producers produce commodities to supply the amount of productions given exogenously. The term of applying countermeasure application term is divided into several periods and the producers select ways of producing commodities and combinations of mitigation measures in order to maximize their net profits. The profit is defined by “benefit – cost + benefit by bioenergy sales”. Production is calculated as a “multiplication of productivity (i.e. crop production per unit area or carcass weight) and quantity of activity (area of cropland or numbers of livestock)”. Yields are defined as the production of commodities per unit activity; for example, crop production per unit area harvested and carcass weight of livestock. It can be observed that yields may change due to the application of countermeasures. For example, yields may decrease by fertilizer reduction and carcass weight of livestock may increase by improving feed systems. The model considers impacts of climate conditions on crop yields. Figure 3.1 shows the structure of the AG/Bottom-up module. The AFOLU-B model takes into account emissions from fossil fuel directly consumed in the agricultural sector (*e.g.* energy for agricultural machinery, pumps, seeders, milking machines, tractors, combine harvesters, manure spreaders, fertilizer distributions, and so on). However, basically, GHG emissions from energy consumption are categorized into different IPCC guideline from the AFOLU sector.

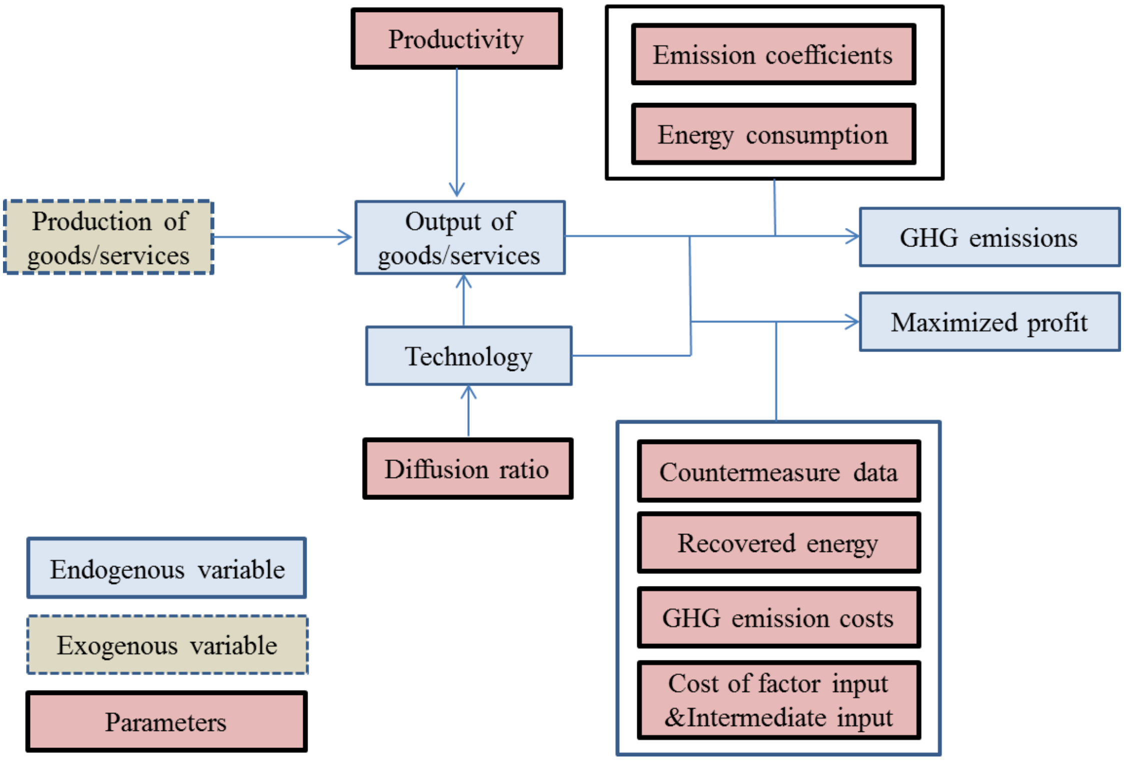


**Figure 3.1:** The structure of AG/Bottom-up module

### 3.1.2 LULUCF/Bottom-up module

The LULUCF/Bottom-up module calculates GHG emissions from carbon stock changes in biomass and soils on the land and those from fire, natural disturbance and peat lands and mitigation by specific countermeasures. Since Cambodia does not have peat land, we exclude it for this study. The module does not capture emissions from wood harvesting as it is assumed that wood harvesting is not too a large factor to make great impacts on change in land use and change in emissions and sink coefficients. Assumption of the future land use change is given exogenously. Also, the module calculates GHG emissions and sink caused by historical land use change. GHG emissions reduction is calculated based on schemes assumed for mitigation measures selection. The schemes can be set as conditions of allowable minimum reduction or total maximum cost in a certain application period. The module does not cover benefit from activity (i.e. improved land use and wood production). The module calculates total mitigation impacts in an assumed period since mitigation impacts of some countermeasures last for the long term after the application.

Figure 3.2 shows the structure of the LULUCF/Bottom-up module.

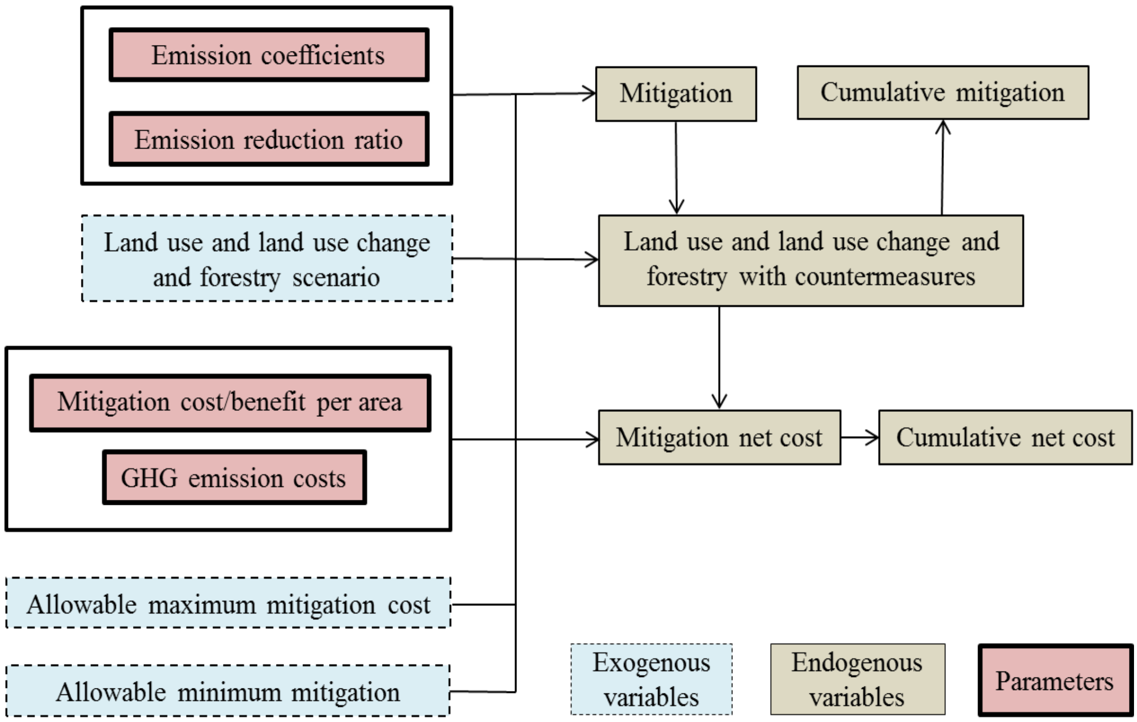


**Figure 3.2:** The structure of the LULUCF/Bottom-up module

## 3.2 Input and output of the AFOLU-B model

The data input to the AFOLU-B model includes: i) list of countermeasures; ii) characteristics of countermeasures such as cost, reduction effect, life time, diffusion ratio, energy consumption and recovery; iii) scenarios of crop production, numbers of livestock and areas of land use, land use change and forestry; iv) scenarios of fertilizer input, price of commodity and energy, and production technologies; and vi) future assumption on policy such as allowable abatement costs for GHG reduction, energy cost, subsidy and so on. Based on the information, countermeasures to be applied to reduce GHG emissions are evaluated.

The module considers only additional cost, which is caused by the installation of mitigation measures. The additional cost is defined to be a difference from a cost in the BaU case. The cost includes i) wage for additional mitigation measures, ii) cost for additional intermediate inputs, iii) surcharges of GHG emissions, etc. They are described in annual costs. The detail framework of the Input and Output of the AFOLU-B model is shown in Figure 3.3. Sources of GHG emissions in the AFOLU-B model are defined in the IPCC guideline (IPCC, 2006). Emission/sink sources taken into account in the study are enteric fermentation (3A1, this code represents categories of emission and sinks in IPCC (2006)), manure management (3A2) of livestock, LULUCF (3B), managed soils (3C4-3C6), and rice cultivation (3C7). The target GHGs are carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). The LULUCF sector is considered as a source of both emissions and sink of carbon. The detail information on the emission sources and target GHG emissions is shown in Table 3.1.

The management of livestock manure causes both $CH_4$ and $N_2O$ emissions. $CH_4$ is produced by the anaerobic decomposition of livestock manure, while $N_2O$ is produced through the nitrification and denitrification of the inorganic nitrogen derived from livestock manure and urine. Normal digestive process in animals can produce $CH_4$. The microbial fermentation process in animal's digestive system ferment food consumed by the animal is referred to as enteric fermentation and produces $CH_4$ as a by-product. Decomposition of organic material process in anaerobic condition in paddy fields can produce both $CH_4$ and $N_2O$. Anaerobic decomposition of soil organic matter by methanogenic bacteria generates $CH_4$.

GHG emission coefficients are listed in the 2006 IPCC guideline (IPCC, 2006). The IPCC guideline defines that GHG emissions are calculated by "multiplying quantity of activity and at least one coefficient". For the LULUCF sector, GHG emissions are calculated by “multiplying land area and carbon stock change per unit area (emissions coefficients)”. To consider GHG emissions and mitigation potentials caused by land use change in the past, the coefficients for the land with the conversion are assumed to change over time due to time-varying emission and sink through biomass growth. For example, quantity of emissions and mitigation potentials due to forest growth is different depending on the time from plantations. In contrast, the coefficients stay constant for the remaining land.

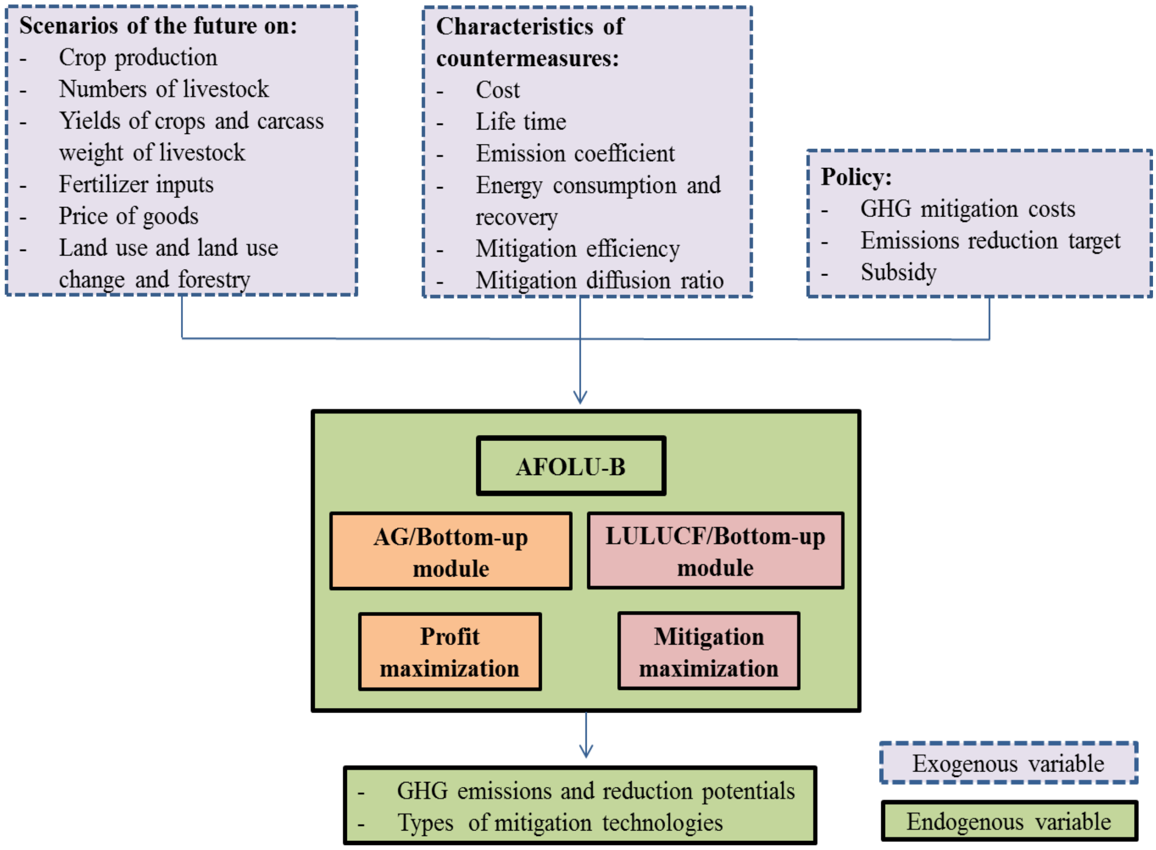


**Figure 3.3:** Input and Output of the AFOLU-B model

**Table 3.1:** Emission sources and target GHG emissions in the AFOLU sector

| Emission sources | Classification | Gases | IPCC categories[1] |
|---|---|---|---|
| Enteric fermentaion | Dairy cattle, Other cattle, Buffalo, Sheep, Goats, Horses, Mules, Asses, Swine | $CH_4$ | 3A1 |
| Manure management | Dairy cattle, Other cattle, Buffalo, Sheep, Goats, Horses, Mules, Asses, Swine, Chickens, Ducks | $CH_4$, $NO_2$ | 3A2 |
| Aggregate sources and Non-$CO_2$ emission sources on land | Emissions from Biomass Burning[2] | $CO_2$, $CH_4$, $NO_2$ | 3C1 |
| | Liming[2] | $CO_2$ | 3C2 |
| | Urea Application[2] | $CO_2$ | 3C3 |
| | Direct $N_2O$ emission from managed soil | $NO_2$ | 3C4 |
| | Indirect $N_2O$ emission from managed soil | $N_2O$ | 3C5 |
| | Indirect $N_2O$ emission from manure management | $N_2O$ | 3C6 |
| Rice cultivations | Wetland and upland rice | $CH_4$ | 3C7 |
| Land use, land use change and forestry (LULUCF) | Cropland, forestland, settlement, grassland, wetland and other land | $CO_2$ | 3B |

Note: [1] Emission categories of IPCC (2006); [2] Grey color is not estimated in this study

### 3.3 Framework of the scenarios

Two scenarios are assumed:

- Business As Usual (BaU) scenario without applying mitigation measures and
- Countermeasure (CM) scenario with the application of mitigation measures to reduce GHG emissions.

The GHG mitigation is defined to be a difference of emissions between the two scenarios. In the CM case, we assume several alternative mitigation costs: less than 0, 10, 20, 50, and 100USD/t$CO_2$eq. to estimate financial feasibility of the measures and no cost consideration case. Countermeasures are assumed to be applied after 2015.

### 3.4 Mitigation measures

The information on mitigation measures is collected from various international and domestic literatures, including the SNC (MoE, 2013). Table 3.2 shows the types of countermeasures, reduction amount, cost, lifetime, maximum expanding area per year, and target area in the LULUCF sector used in this study. Then, GHG emissions reduction potentials are calculated within the model based on the assumption that the annual effect will last for a certain times after introducing the measures (*i.e.* planting the intact forests and reforestation). To reflect a characteristic of land-based mitigation measures in terms of mitigation cost and effects lasting over years, information of reduction effects, costs, and areas used for the mitigation measures implemented in the year are considered in the next year. Table 3.3 presents types of countermeasures and cost for the agricultural sector used in this study. Technology is defined as a combination of agricultural production technology (main technology) and GHG mitigation technologies (additional technology).

Characteristics of the measures including cost, mitigation effects, agricultural productivity, and emission coefficient are calculated based on the combinations of the two technologies. Parameters representing the characteristics of a technology are provided by multiplying the parameters of the characteristics of the main technologies and adjustment factors of additional technologies. For example, an emission coefficient of main technology (*e.g.* 50t$CO_2$eq./ha) is adjusted by using a parameter of additional technology (*e.g.* 0.8 for 20% reduction technology). Therefore, countermeasures selection depends not only on cost and mitigation potentials, but also on combinations of the technologies. Mitigation amount of each technology is calculated from mitigation amount per unit area or animal where countermeasure is applied. The costs reported in the literatures are exchanged into costs in Cambodia using wage from (NIS, 2012) based on the idea that the labor cost dominates the agricultural mitigation measures. See (Hasegawa and Matsuoka, 2013) for more details.

**Table 3.2:** Lists of countermeasures for the LULUCF sector

| Countermeasures | CODE | Cost [USD (ha・yr)]* | Mitigation effect of $CO_2$ reduction [t$CO_2$(ha・yr)] | Maximum expanding area per year [1000 ha/year] | Target area [1000 ha] | Period of cost required [year] | Effective period of measure [year] |
|---|---|---|---|---|---|---|---|
| Plantation-short rotation | PSR | 47.25 | 13.57 | 0.22 | 2.19 | 10.0 | 10.0 |
| Plantation-long rotation | PLR | 58.47 | 18.90 | 0.06 | 2.19 | 35.0 | 35.0 |
| Reforestation-fast growing species | RFS | 39.75 | 30.86 | 0.18 | 2.19 | 12.0 | 12.0 |
| Reforestation-slow growing species | RSS | 52.50 | 30.80 | 0.06 | 2.19 | 35.0 | 35.0 |
| Reduced Impact Logging | RIL | 31.14 | 5.13 | 862.40 | 10,348.80 | 12.0 | 12.0 |
| Enhanced natural regeneration | ENR | 10.75 | 7.33 | 0.15 | 2.19 | 15.0 | 15.0 |
| Agro-forestry | AGF | 7.97 | 43.45 | 0.22 | 2.19 | 10.0 | 10.0 |

*The cost represents that of in base year.

**Table 3.3:** Lists of countermeasures for the agriculture sector

| Emission sources | Countermeasures | CODE | Cost [USD/(ha・yr)] or [USD/ (head・yr)] | Mitigation [$tCO_2eq$/(ha・yr)] or [$tCO_2eq$/ (head・yr)] | Change in productivity from baseline level [%] | Maximum application ratio [%] | Explanation | Reference |
|---|---|---|---|---|---|---|---|---|
| Enteric fermentation (3A1) | Improvement of genetic merit of dairy cows | HGM | 0.35 | 0.32 | 10.00 | 100 | It escalated with the import of Holstein genetic material for use on native dairy breeds. | Bates (1998) |
| | Replacement of roughage with concentrated feed | RRC | -0.05 | 0.45 | 10.00 | 100 | Replace roughage that contains high portions of structural carbohydrates with concentrates to improve propionate generation in rumen. | Graus et al. (2004), Shibata et al. (2010) |
| Manure management (3A2) | Anaerobic Digestion by centralised plant | ADC | 0.04 | 0.33 | 0.00 | 100 | Capture and use of manure $CH_4$ through anaerobic digesters. | Bates (2001) |
| | Daily spread of manure | DSM | 0.00 | 0.33 | 0.00 | 100 | Manure is routinely removed from a confinement facility and is applied to cropland within 24 hours of excretion. | Bates (1998), IPCC (2006) |
| | Dome digester for cooking fuel and light | CFL | -0.14 | 0.62 | 0.00 | 100 | A small-scale unheated digesters generate biogas used by households for cooking and lighting | USEPA(2006) |
| | Covered anaerobic digesters | CAD | 0.52 | 0.65 | 0.00 | 100 | $CH_4$ is captured by covering lagoon where manure is stored and piping the gas out to a flare or used on-farm. | USEPA (1999, 2003), Bates (1998, 2001), IPCC(2007) |
| | Aerobic decomposition | AD | 0.30 | 0.59 | 0.00 | 100 | The biological oxidation of manure collected as a liquid with either forced or natural aeration can reduce $CH_4$ emissions from current levels. | Bates (1998), IPCC (2006) |
| Rice cultivation (3C7) | Replace urea with ammonium sulphate | RAS | 0.23 | 0.31 | 0.00 | 100 | Ammonium sulfate additions to soil can elevate reduction potential, which suppresses $CH_4$ production. | USEPA (2006), Graus et al. (2004) |
| | Midseason drainage | MD | 0.00 | 1.15 | 0.00 | 32 | Rice fields are dried three times within a growing period. Not applied on rain-fed areas. | USEPA (2006) |
| | Off-season incorporation of rice straw | OIR | 0.23 | 0.87 | 0.00 | 100 | Shifting straw amendment from in-season to off-season can reduce availability of dissolved organic carbon and methanogens. | USEPA (2006) |
| Managed soils (3C4-3C6) | High efficiency fertilizer application | HEF | 0.03 | 0.00 | -10.00 | 100 | Apply nitrogen fertilizer is divided into three smaller increments during crop uptake period to reduce nitrogen availability for leaching, nitrification, denitrification and volatilization. | USEPA (2006), Hendriks et al. (1998), Amann et al. (2005) |
| | Tillage and residue management | TRM | 0.35 | 0.00 | 0.00 | 100 | Conversion fertilizational tillage to no till where soils are disturbed and less and more crop residue is retained. Avoiding the burning of residues also avoids emissions. | USEPA (2006), IPCC (2007), Smith et al. (2007) |
| | Slow-release fertilizer | SRF | 8.21 | 0.03 | 0.00 | 100 | Coated or tablet fertilizer releases nitrogen slowly over a 30-day period and increase fertilizer-use efficiency. | USEPA (2006), Akiyama et al. (2010) |

## 3.5 Data collection

In order to apply the model, specific information of Cambodia is needed such as land use classifications, livestock population, crop yields, fertilizer consumption, etc. Given the limited country information, additional calculations and assumptions are made based on available data, historical trend, and professional insights as well as discussions with national experts. The data estimations and assumptions are primarily based the relevant Government documents. The procedures to acquire the information are made in three steps.

First, relevant documents such as forest cover and management, agriculture production and management, livestock requirement and projection, and fertilizer consumption, etc. are collected from relevant institutions and subsequent discussions are made with key persons from respective institutions (Table 3.4) to ensure the validity, reliability, and applicability of the collected information.

Second, a workshop on the “Advancement and Enhancement on Low Carbon Development Researches and Policies among Cambodia, Lao PDR, and Myanmar” was organized on 26 February 2015 in Cambodia, aiming to disclose the preliminary estimation of GHG emissions and reductions from the AFOLU sector and to collect further comments and inputs in order to improve the estimations. The workshop was attended by around 70 participants who are the representatives of Japan, Myanmar, and Cambodia.

Third, intensive interviews with relevant Government officials and experts are conducted in order to clarify assumptions and estimations as indicated in Table 3.4.

**Table 3.4:** Lists of collected documents and interviewees for the AFOLU sector

| Sectors | Documents | Interviewees | Explanation |
|---|---|---|---|
| Settlement | Land reform in Cambodia | Dr. Meng Bundarith, Director of Dept. of Land Management of the Ministry of Land Management, Urban Planning and Construction in 2014 | Cambodia has not developed the detail plan on land use classification and the information provided by Forestry Administration, MAFF. |
| Forest cover and Grassland | Strategy for Natural Rubber Development in Cambodia (2011-2020); National Forest Pogramme (NFP) (2010-2029) | H.E Chea Sam Ang, Deputy Director General of Forestry Administration (FA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF) in 2013 | Discussed about the forest cover target as set by the Government to maintain 60% by 2015 and the future plan to manage forests. The NFP is a very important document for the government to follow. The NFP doesn't only mean to ensure the sustainable forest management but also to enhance carbon sequestration and stock capacity. |
| | Forest Cover 2010 in Cambodia | Mr. Leng Chivin, Deputy Director of Forestry and Community Forestry and Country Focal Point of National REL/MRV Development Systems of FA, MAFF in 2013 and 2015 | Discussed about the land use classifications since Cambodia has not develop detail land classifications as recommended by IPCC. The country will prepare such an information in the near future. |
| Crop production | Annual Report of the Agricultural Sector (2010-2013); Strategy for Agriculture and Water (2010-2013) | Mr. Am Phirum, Deputy Director of Dept. of Agronomy, MAFF in 2013 | Discussed about the validity and reliability of the information on cropland and production and the long term crop management and improvement. |
| Livestock population | The Strategic Planning Framework for Livestock (2015-2024) | Ms. Ok Savin, Deputy Director of Dept. of Animal Health and Animal Production, MAFF in 2015 | Discussed about the methodology for livestock demand estimation and projection and the future prospective to manage livestock. |
| Wetland | - | Mr. Kong Kimsreng, Programme Officer of the International Union for Conservation of Nature in 2014 | Discussed about the wetland situation in Cambodia and how the country defined the wetland area. |
| Fertilizer | Annual Report on Fertilizer Import and Export | Mr. Chhup Thavith, Officer of Dept. of Planning and Statistics, MAFF | Discussed the informaton on import and export of fertilizer and the reliability of the data. |

## 3.6 Data assumptions for the present and the future

### 3.6.1 Land use and its change

The land use classification in this study follows the IPCC guideline 2006 in which six categories are classified, including cropland (potential cultivated land), grassland, forestland, settlement, wetland, and other land (IPCC, 2006). This study chooses 2010 as the base year and the target years are 2030 and 2050 to project land use change and to estimate GHG emissions and mitigation potentials. The information on land use in Cambodia is not reported every year; it is available in 1965, 1996/97, 2002, and 2010; however, the year 2002 is sorted out as the reference year for estimating land use change as the information from that time is considered as more reliable and acceptable after the country pertained full peace in 1999. Table 3.5 shows historical and projected land use change in Cambodia, while the detail description to acquire this information explains as follows.

**Table 3.5:** Historical and projected land use change in Cambodia [1,000 ha]

| Land use categories/year | 2002 | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|
| Cropland | 2,245.28 | 2,915.59 | 3,227.20 | 3,768.25 | 4,400.0 | 4,400.0 | 4,400.0 |
| Grassland | 1,150.00 | 1,281.25 | 1,500.0 | 700.0 | 700.0 | 700.0 | 700.0 |
| Forest land | 11,104.29 | 10,730.0 | 10,363.79 | 10,862.10 | 10,862.10 | 10,862.10 | 10,862.10 |
| Settlement | 904.01 | 919.34 | 1,000.0 | 1,161.33 | 1,322.66 | 1,448.06 | 1,573.47 |
| Wetland | 552.63 | 552.63 | 552.63 | 552.63 | 552.63 | 552.63 | 552.63 |
| Other land | 2,147.29 | 1,704.69 | 1,459.88 | 1,059.19 | 266.11 | 140.70 | 15.30 |
| **Total** | **18103.5** | **18103.5** | **18,103.50** | **18,103.50** | **18,103.50** | **18,103.50** | **18,103.50** |

**Cropland:**

The cropland areas in 2002 and 2010 were 2,245 and 3,227 thousand ha, respectively, (NIS, 2011). The projection of the cropland areas from 2010 through to 2050 is collected from MoE (2013). This study assumes that the potential cropland areas will be able to extend to the maximum level of around 4,400 thousand ha by 2030 (MoE, 2013) and is assumed to remain constant until 2050. The expansion of cropland areas results from the increasing food demand due to the increase of the population, the availability of irrigation systems, and agricultural technologies in the country. The Government will renovate and construct new irrigation systems in the country-wide to ensure sufficient water supply for farmers to cultivate agricultural crops and will also introduce new and high agricultural technologies (RGC, 2013).

**Grassland:**

The grassland areas in 2002 and 2010 were around 1,150 and 1,500 thousand ha, respectively, (FAO, 2002 and 2010). Since there is no information on the projection of the grassland areas towards 2050, the assumption is made based on the historical experience. It is reported that the grassland areas had decreased by around 80 thousand ha annually from 1992 through to 1996 (MoE, 2013) and the trend is expected to remain constant as the country needs to expand more agriculture land to increase crop production (Phirum, 2013); however, the country needs some grassland for animal habitat and feeding sources. Therefore, this study assumes that the grassland will continue to decrease until 2020 and will remain constant through to 2050.

**Forest land:**

The forest land in 2002 and 2010 were around 11,104 and 10,364 thousand ha, respectively, (RGC, 2011). Forest cover from 2010 through to 2050 is assumed to be the same as the Government's target of maintaining the forest cover by 60.0% (RGC, 2011). The country has not yet set any plan to change the status of forest cover (Sam Ang, 2013). In order to ensure the target to be achieved, the Government formulated National Forest Programme (NFP) (2010-2029), which serves as an appropriate mechanism and provides a transparent and participatory process for planning, implementing, monitoring, evaluating, and coordinating all forest related activities and also to ensure sustainable forest management in the long run.

**Settlement:**

The settlement areas in 2010 were around 1,000 thousand ha (Sovan, 2010) and is calculated backward to 2002. The result of around 996.02 thousand ha is obtained for 2002. The projection of the settlement areas towards 2050 is not available at the time of the study; therefore, this study assumes that it will increase in proportion to the population growth, which is around 1.14% per year (UN, 2011 and 2013). As a result, the settlement areas are expected to cover around 1,573 thousand ha by 2050.

**Wetland:**

The information on wetland areas in 2002 and 2010 is not fully acquired. In order to assume this data, some interviews are made. According to Kim Sreng, Country Officer for International Union for Conservation of Nature and Natural Resources (IUCN), the total volume of wetland areas is quite large; and it includes flooded forests, rice field, and settlement (floating houses) (Kim Sreng, 2014). However, Bun Heng (2002) and FAO (2010a) reported that the net wetland areas were around 84 thousand ha in 1996-1997. Due to limited information, this study assumes the wetland areas to be the same as in 1996-1997. For the current study, the inland water is merged with wetland areas. Besides, this study assumes the wetland areas in 2050 to be the same as that of in 2010.

**Other land:**

Other land areas include bare soil, rock, and all unmanaged land areas that do not fall into any of the above-mentioned categories. It allows the total of identified land areas to match the national areas, where data are available. Other land areas are subtracted from the total country land and the above-mentioned land use categories.

**Harvested cropland areas**

This study classifies the harvested cropland areas into six main categories as shown in Table 3.6 to make it more precise and easy to estimate. The information of the harvested cropland in 2010 is collected from NIS (2011), FAO (2010), and MAFF (2011). Since the detail information on projection towards 2050 is not fully acquired, some assumptions based on other countries' experiences, relevant documents, and discussions with key experts are made for the present study. The harvested cropland areas in 2010 and in the future in a10-year interval are shown in Table 3.7, while the detailed procedure to acquire the future assumptions explains as follows.

**Table 3.6:** The cropland classification and aggregation

| Crop types | Composition |
|---|---|
| Paddy rice production | Rice |
| Other coarse grain production | Maize |
| Vegetable, fruits, and nut production | Cassava, Sweet potatos, Vegetables, Mung bean, Roots and tubers, Bananas, Mangoes, Mangosteens, Guavas, Oranges, Lemons and Limes, Pineapples, Fruit, etc. |
| Oil crop production | Peanuts, Soybeans, Sesame, Coconuts, Oilseeds, etc. |
| Sugar production | Sugar cane |
| Other's production | Rubber, Tobacco, Jute, Coffee, Green pepper, and Chillies and Peppers, etc. |

**Table 3.7:** The harvested cropland areas in Cambodia [1,000 ha]

| Cropland types/year | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Paddy rice production | 2,777.30 | 3,457.08 | 4,303.25 | 5,356.52 | 5,356.52 |
| Other coarse grain production | 189.50 | 233.72 | 288.27 | 288.27 | 288.27 |
| Vegetable, fruits, and nut production | 400.75 | 763.29 | 763.29 | 763.29 | 763.29 |
| Oil crop production | 139.33 | 230.34 | 230.34 | 230.34 | 230.34 |
| Sugar production | 17.10 | 28.50 | 28.50 | 28.50 | 28.50 |
| Other's production | 207.63 | 429.93 | 429.93 | 429.93 | 429.93 |
| **Total** | **3,731.61** | **5,015.61** | **5,916.32** | **6,969.60** | **6,969.60** |

**Paddy rice production:** The harvested paddy rice land areas through to 2050 are extrapolated from the historical trend because there is no information available at the time of the study. It is observed that the harvested rice land areas had increased notably between 1980 and 2013 due to the increase of food demand and export orientation in order to nurture the economic development; and this trend is expected to remain constant in the future due to increasing population growth, available agriculture technologies, and irrigation systems (with only around 32% in 2010 (RGC, 2012a)) as well as agriculture extension activities to the farmers (MAFF, 2011; NIS, 2011; and RGC, 2013). The Government will also increase cultivation times for some provinces where the irrigation systems are annually available so as to achieve the target for rice export (RGC, 2010). The harvested rice areas are, therefore, assumed to increase until 2040 and are expected to remain constant until 2050.

**Other coarse grain production:** It refers to the harvested maize land areas. It is observed to increase about 2 times between 1980 and 2010 with the average annual growth rate of around 2.12%. The trend is observed to decrease between 1990 and 2005 and to start gradually increasing from 2005 to 2010 (NIS, 2011 and MAFF, 2011). This study assumes that the maize harvested area will continue to grow a similar trend from 2010 through to 2030 and is assumed to remain constant through to 2050.

**Vegetable, fruits and nut production:** The land use under this category had significantly increased between 1980 and 2013 (NIS, 2011 and MAFF, 2013), especially the land for cassava and mango as they are the main industrial crops for export (TWG-AG, 2010). This study assumes that the land for these crops will continue to increase until 2020 and is assumed to remain constant through to 2050 since the increase of these areas may come at the cost of forest areas.

**Oil crop production:** The harvested oil crop land areas had increased from 1980 to 2005 and decreased afterward (NIS, 2011). Therefore, this study assumes the land areas in 2050 to be similar to 2005's one, which is around 230 thousand ha.

**Sugar production:** The harvested sugar cane plantation areas had increased from around 2 thousand ha in 1980 to 17 and 29 thousand ha in 2010 and 2013 (MAFF, 2013), respectively. However, the expansion of these areas came at the expense of forest land areas, which are contrary to the Government's target to manage forest resources in a sustainable manner. Therefore, this study assumes the harvested sugar land areas in 2050 to be the same as in 2013's one.

**Other's production:** Rubber plantations are regarded as the main driver in this category. It is indicated that the Government plans to increase rubber plantation areas to around 400 thousand ha by 2020 (DGR, 2011). And the recent report disclosed that the rubber plantation areas have recently approached the target (MAFF, 2013). In the meantime, it is also observed that the expansion of the rubber plantation may come at the cost of forest land areas. Thus, this study assumes that the total harvested land areas of this category will increase to around 430 thousand ha (400 thousand ha for rubber plantation, while another 30 thousand ha for other production plantations) in 2020 and is assumed to remain constant through to 2050.

**Crop yields**

Although the total population is comparatively small, agricultural production for domestic consumption will have to increase in line with population growth to maintain self-sufficiency and food security. Agricultural productivity in Cambodia remains low compared to the neighboring countries, such as Thailand and Vietnam. Several factors account for the poor productivity such as poor agricultural technology, limited access agricultural extension, poor soil quality, and poor infrastructure (Vuthy *et al*., 2014). The crop yields are expected to increase considerably in the future. Due to limited information, the current study projects crop yields through to 2050 based on the historical experience and the world agriculture projection towards 2030 and 2050 (Alexandratos and Bruinsma, 2012) as well as other related documents. The classifications and assumptions of crop yields in 2010 and in the future used in this study are shown in Table 3.8. The detail procedure to acquire these assumptions explains as follows.

**Table 3.8:** Crop yield information and projections in Cambodia [ton/ha]

| Crop yields/year | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Paddy rice production | 3.00 | 3.46 | 3.99 | 4.61 | 5.32 |
| Other coarse grain production | 3.58 | 4.09 | 4.67 | 5.33 | 6.09 |
| Vegetable, fruits, and nut production | 22.65 | 22.65 | 22.65 | 22.65 | 22.65 |
| Oil crop production | 1.53 | 1.99 | 2.45 | 2.92 | 3.38 |
| Sugar production | 19.72 | 33.23 | 33.23 | 33.23 | 33.23 |
| Other's production | 1.04 | 1.34 | 1.73 | 2.24 | 2.90 |

**Paddy rice production:** The rice yield in 2010 was about 3 tons/ha NIS (2011) and MAFF (2011), which is lower than Lao PDR (3.5 tons/ha) and Vietnam (4.9 tons/ha) (TWG-AG, 2010) due to limited irrigation system and low fertilizer usage, etc. The country must improve the rice productivity and crop intensity in order to achieve the Government's target to export at least one million tons of milled rice by 2015 (RGC, 2010). The SNC assumed that the rice yield in 2050 will increase to be similar to that of Vietnam (MoE, 2013). However, it is noted that after rice export policy was raised, the yield had notably increased from about 2.5 to 3.1 tons/ha in 2005 and 2012, respectively, (NIS, 2011 and ACI, 2014) and is projected to increase to around 3.3 tons/ha by 2018 (RGC, 2014). It is indicated that the country has a potential opportunity to increase rice production per unit activity. The Government also declared to reduce poverty and promote economic growth through rehabilitating the existing and constructing more irrigation networks for crop intensification. The country will also increase fertilizer consumption to improve crop productivity and will shift from extensive to intensive cultivation in the future. Therefore, we expect that the rice yield in 2050 will reach that of the world's average, which is around 5.3 tons/ha (the average annual growth of around 1.44% from 2010) (Alexandratos and Bruinsma, 2012).

**Other coarse grain production:** It refers to "maize" in this study and the biggest production area for this crop is Battambang province, followed by Banteay Meanchey, Kandal, Pailin and Kampong Cham. Maize products has increased mainly due to yield improvements through introducing quality seeds and some additional plantations. The maize yield in 2010 was about 3.6 tons/ha (TWG-AG, 2010) and increased to around 4.4 tons/ha in 2012 (ACI, 2014). The yield is expected to increase significantly due to available technologies and increasing food demand for both people and animals. This study assumes that the yield is expected to increase to be similar to that of the world's average in 2050, which is about 6.1 tons/ha (with the average annual growth rate of around 1.34% from 2010) (Alexandratos and Bruinsma, 2012).

**Vegetable, fruits and nut production:** The main driver in this category is “cassava”, which is the second largest cash crop in Cambodia by volume and main production areas are Kampong Cham, Battambang, Banteay Meanchey, and Pailin provinces. Cassava is mainly harvested in the dry season as drying is dependent upon the sun. This causes an oversupply in the dry season and under supply in the rainy season. This product is mainly produced for exporting to Thailand and Vietnam. The cassava yield in 2010 was around 22.7 tons/ha (TWG-AG, 2010), the highest yield in the region and it is assumed to remain the same though to 2050.

**Oil crop production:** The main driver in this category is “soybean”, which is the important source of food. Main production areas are Battambang and Kampong Cham provinces. The soybean yield in 2010 was about 1.5 tons/ha (TWG-AG, 2010) and increased to 1.7 tons/ha in 2012 (ACI, 2014). The soybean yield had increased from 1.2 to 1.5 tons/ha in 2002 and 2010, respectively, which increased about 0.05 ton/year (NIS, 2011 and ACI, 2014). Due to the limited country information, this study assumes that the yield through to 2050 will increase to be in proportion to the historical growth. Hence, the yield is projected to increase to around 3.4 tons/ha by 2050, which is similar to that of the world’s average (3.2 tons/ha) (Alexandratos and Bruinsma, 2012).

**Sugar production:** It refers to “sugar cane” and the yield in 2010 was 19.7 tons/ha (MAFF, 2011) and increased to about 33.2 tons/ha in 2012 (ACI, 2014), which was very high yield in Cambodia. Due to the limited country information, this study assumes the yield in 2050 to be the same as that of 2012.

**Other’s production:** The dominant sector in this category is “rubber tree”, a kind of economic production, which does not only provide multiple benefits for farmers, the national economy, but also for the society as a whole; particularly, it can generate incomes to improve livelihoods and creates jobs of the people living in the rural areas, and it also contributes to mitigating GHG emissions, which is considered as the main cause of global warming and climate change (GDR, 2011). There are three kinds of rubber plantations in Cambodia, including industrial plantations (land areas of over 200ha and manage by the State company or authorities and employ State labor forces);

agro-industrial plantations (manage by companies, associations or communities with land areas over 200ha); and small and medium sized family plantations (manage by households or private planters with the land areas ranging from 5 to 200 ha) (GDR, 2011). The rubber plantation area is mainly located in Kampong Cham province and most of the rubber production are exported to China. The rubber yield in 2010 was about 1.1 tons/ha (ACI, 2014) and is projected to increase to 1.7 tons/ha in 2018 (RGC, 2014). Although the rubber tree is the main economic production for national economy and incomes of the rural people, the Government has not set a clear target to increase the yield in the future. The yield had slightly increased from 0.9 to 1.1 tons/ha between 2002 and 2012, respectively, (the average annual growth of around 2.6%) (ACI, 2014). This growth rate is used to project the yield through to 2050.

### 3.6.2 Livestock population and projections

Protein, minerals and vitamins are essential for a healthy balanced diet and can be provided from milk, meat, and fish. In response to the country development and the increasing food demand, the Government has set a goal to ensure food security, increase incomes, create employment, and improve nutrition status for all people (RGC, 2014). The Government developed a national strategic planning framework for livestock (2015-2025) (RGC, 2015a) with the objective to improve the livelihoods of small producers, household incomes, and food security and provide a safe and sufficient supply of livestock products to the people and for export. Besides, this strategy also indicates the Government’s direction to improve animal health and increase both quantity and quality of feeding sources to respond to the required amount of livestock (RGC, 2015a).

It is observed that livestock has a vital role in nutrition security as well as household incomes and livelihoods; also, fish is regarded as another primary source of food, nutrition, and income of millions of Cambodians. Livestock production in Cambodia is mainly a small scale. The population of cattle has increased about 20.0%, while buffalo has gradually declined over the last ten years (RGC, 2015a). It is observed that the population of pigs had increased until 2006 but has declined since then and Cambodia currently does not produce enough pig meat for domestic consumption. Cambodia has, so far, exported very small amount of beef; however, the country has a high potential to export to the neighboring countries in the future such as Vietnam, etc. (RGC, 2015a). Since the detail information on numbers of livestock requirement and population in 2050 is not acquired, this study projects by using some available information, historical trends, and discussions with national experts. Table 3.9 shows the livestock population in a 10-year interval from 2010 to 2050 and the detail procedure to acquire these assumptions explains as follow.

**Table 3.9:** Livestock population and projection in Cambodia [1,000 heads]

| Types of livestock/year | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Dairy cattle | 7 | 13 | 27 | 27 | 27 |
| Meat cattle | 3,547 | 3,643 | 4,895 | 6,579 | 8,842 |
| Buffalo | 640 | 657 | 883 | 883 | 883 |
| Sheep | 5 | 5 | 5 | 5 | 5 |
| Goats | 35 | 35 | 35 | 35 | 35 |
| Horses | 24 | 24 | 24 | 24 | 24 |
| Pigs | 3,047 | 4,000 | 5,490 | 7,378 | 9,915 |
| Chickens | 21,261 | 30,240 | 35,095 | 40,729 | 47,268 |
| Ducks | 4,050 | 5,760 | 6,685 | 7,758 | 9,003 |

**Dairy cattle population:** The detail information on the number of dairy cattle in 2010 in Cambodia is not fully acquired; however, a national strategic planning framework for livestock (2015-2025) indicates that milk consumption in Cambodia is expected to increase from around 108 thousand tons in 2010 to around 191 thousand tons in 2020 and 75% of which are imported (RGC, 2015a). This report also illustrates that around 50 thousand dairy cattle are needed in order to produce around 191 thousand tons of milk production (RGC, 2015a). It is explicitly suggested that one dairy cattle could produce around 3.8 tons of milk production per year. Based on this information, numbers of dairy cattle of around 7 thousand heads is obtained in 2010. Besides, Cambodia is expected to be able to accommodate around 27 thousand dairy cattle, which can produce approximately 103 thousand tons of milk production in 2020 (RGC, 2015a); however, numbers of dairy cattle as of 2014 was not significant and only Phnom Penh City and Kandal Province are raising dairy cattle with the cooperation and support from Japan (MAFF, 2015). Hence, it is a very low possibility to increase numbers of dairy cattle to achieve the target by 2020. Therefore, this study assumes that numbers of dairy cattle will reach around 27 thousand heads by 2030 and is assumed to remain constant through to 2050.

**Meat cattle and buffalo population:** The information on numbers of cattle and buffalo in 2010 was collected from NIS (2011 and 2012) and MAFF (2011). RGC

(2015) projected numbers of cattle and buffalo through to 2020. Since there is no detail information through to 2050, we assume the annual growth rate of numbers of cattle to be the same as a projection by RGC (2014), which grows annually by 3.0% from 2010. However, numbers of buffalo are assumed to increase through to 2030 and are expected to remain constant through to 2050 as buffalo meat is not preferred by Cambodians.

**Sheep, goat and horse population:** The information on numbers of horses, goats, and sheep in 2010 was collected from NIS (2011 and 2012) and MAFF (2011). And through to 2050, they are assumed to be the same as those of 2010 because most of Cambodians do not eat those animals' meat.

**Pig population:** The information on numbers of pigs in 2010 was collected from NIS (2011 and 2012) and MAFF (2011). RGC (2015) projected numbers of pig requirement through to 2020. Since there is no information through to 2050, this study assumes the annual growth rate through to that year to be the same as a projection by RGC (2014), which grows annually by 3.0% from 2010.

**Poultry population:** The information on numbers of chickens and ducks in 2010 was collected from NIS (2011 and 2012) and MAFF (2011). RGC (2015) projected the poultry requirement through to 2020. It is indicated that the poultry requirement will grow lower than those of cattle and pigs. Hence, this study assumes that numbers of poultry will grow annually by around 1.5% through to 2050 from 2010. The share of numbers of ducks in 2050 is assumed to be similar to that of 2010, which is around 16% of the total poultry (NIS, 2011).

### 3.6.3 Fertilizer consumption

Cambodia has abundance of fertile (fertile land, which is capable of producing crops and other vegetables) agricultural land, accounting for about 4 million ha in 2012 of which around 3 million ha is under rice crop production (MAFF, 2013). The country has a low fertilizer usage rate; the amount of ammonia applied in paddy cultivation is about one third that of Lao PDR and Thailand, and 15% that of Vietnam (TWG-AG, 2010). It is emphasized that fertilizer is very important to increase crop productivity in Cambodia. Since the majority of the poor depend largely on farming for their livelihoods, increasing crop productivity is a key to improve the incomes of farmers (Yu and Fan, 2009).

Nitrogen fertilizer per unit harvested area by crop is estimated by using the cross-entropy methodology (Golan *et al*., 1996) using total fertilizer consumption (214 thousand tons in 2010, Department of Planning and Statistics of the MAFF) and fertilizer input per harvested area by crop in the same year (Vuthy *et al.*, 2014). It is observed that fertilizer supply in Cambodia has increased rapidly over the last few years, especially since the launch of the rice export policy in 2010. Hence, this study assumes that fertilizer consumption will increase in proportion to the projected increase of crop yields in the future.

## 3.7 GHG emissions and mitigation potentials from the AFOLU sector

The emission sources used in this study followed the IPCC guideline (IPCC, 2006). Table 3.10 shows GHG emissions and mitigation potentials in the AFOLU sector (kt$CO_2$eq./year) and Table 3.11 indicates GHG emissions in the BaU case from the AFOLU sector (kt$CO_2$eq./year) in a 10-year interval from 2010 through to 2050, while Table 3.12 presents GHG emissions reduction (kt$CO_2$eq./year) in a 10-year interval, applied from 2020 through to 2050 in the AFOLU sector in different costs.

**Table 3.10:** GHG emissions and mitigation potentials in the AFOLU sector [kt$CO_2$eq./year]

| GHG emissions and reductions [kt$CO_2$eq./year] | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|
| The agriculture sector | | | | | |
| Enteric fermentation | 4,326 | 6,015 | 4,728 | 10,826 | 8,509 |
| Manure management | 606 | 993 | 721 | 1,568 | 1,081 |
| Rice cultivation | 17,090 | 26,479 | 13,695 | 32,961 | 17,059 |
| Managed soil | 4,120 | 10,574 | 9,348 | 21,454 | 19,609 |
| The LULUCF sector | | | | | |
| Changes in forest and other woody biomass stocks | -46,015 | -45,691 | -54,559 | -45,691 | -54,559 |
| Forest and grassland conversion | 18,933 | -7,135 | -7,156 | -7,135 | -7,156 |
| **Total** | **-940** | **-8,764** | **-33,224** | **13,982** | **-15,456** |
| Per capita GHG emission (t$CO_2$eq./year) | -0.07 | -0.48 | -1.81 | 0.64 | -0.70 |

**Table 3.11:** GHG emissions in agricultural and LULUCF sectors in the BaU case

| Emission sources [ktCO$_2$eq./year] | CODE* | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| The agricultural sector | | | | | | |
| Enteric fermentation | 3A1 | 4,326 | 4,470 | 6,015 | 8,068 | 10,826 |
| Manure management | 3A2 | 606 | 794 | 993 | 1,244 | 1,568 |
| Rice cultivation | 3C7 | 17,090 | 21,273 | 26,479 | 32,961 | 32,961 |
| Managed soil | 3C4-3C6 | 4,120 | 6,899 | 10,574 | 16,515 | 21,454 |
| Sub-total | | 26,142 | 33,436 | 44,062 | 58,788 | 66,808 |
| The LULUCF sector** | | | | | | |
| Changes in forest and other woody biomass stocks | 5A | -46,015 | -45,691 | -45,691 | -45,691 | -45,691 |
| Forest and grassland conversion | 5B | 18,933 | -7,135 | -7,135 | -7,135 | -7,135 |
| Sub-total | | -27,082 | -52,826 | -52,826 | -52,826 | -52,826 |
| **Total** | | -940 | -19,390 | -8,764 | 5,962 | 13,982 |

*The code of the IPCC guideline 2006, while ** (-) means carbon sink capacity

**Table 3.12:** Mitigation potentials in agricultural [with cost of the less than 10USD/tCO$_2$eq.] and LULUCF [with the cost of less than 50USD/tCO$_2$eq.] sectors

| Mitigation measures [ktCO$_2$eq./year] | CODE* | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| The agricultural sector | | | | | |
| Daily spread of manure | DSM | 157 | 213 | 285 | 381 |
| Dome digester and biogas is used as energy | CFL | 45 | 60 | 79 | 106 |
| High genetic merit | HGM | 387 | 521 | 699 | 938 |
| Replacement of roughage with concentrates | RRC | 568 | 766 | 1,028 | 1,379 |
| Replace urea with ammonium sulphate | RAS | 1,191 | 1,483 | 1,846 | 1,846 |
| Midseason drainage in rice paddy | MD | 6,905 | 8,595 | 10,699 | 10,699 |
| Off-season incorporation of rice straw | OIR | 2,155 | 2,683 | 3,339 | 3,339 |
| Convert fertilizational tillage to no-tillage | CFT | 22 | 24 | 26 | 17 |
| High efficiency fertilizer application | HEF | 956 | 1,227 | 1,594 | 1,814 |
| Tillage and residue management | TRM | 0 | 0 | 2 | 31 |
| Slow-release fertilizer | SRF | 0 | 0 | 0 | 0 |
| Sub-total | | 12,386 | 15,572 | 19,597 | 20,550 |
| The LULUCF sector | | | | | |
| Plantation-short rotation | PSR | 3 | 3 | 3 | 0 |
| Plantation-long rotation | PLR | 1 | 1 | 1 | 1 |
| Reforestation-fast growing species | RFS | 6 | 6 | 6 | 6 |
| Reforestation-slow growing species | RSS | 2 | 2 | 2 | 2 |
| Enhanced natural regeneration | ENR | 1 | 1 | 1 | 1 |
| Agro-forestry | AGF | 9 | 9 | 9 | 9 |
| Reduced impact logging | RIL | 8,866 | 8,866 | 8,866 | 8,866 |
| Sub-total | | 8,889 | 8,889 | 8,889 | 8,886 |
| **Total** | | **21,275** | **24,461** | **28,485** | **29,435** |

* The code used in the AFOLU-B model

### 3.7.1 GHG emissions from the AFOLU sector

The results yield that the AFOLU sector was a net sink with total carbon sink of around 940kt$CO_2$eq./year in 2010 and is projected to increase to roughly 8,764 kt$CO_2$eq./year in 2030BaU; however, it is expected to become a net emitter with total GHG emissions of about 13,982kt$CO_2$eq./year in 2050BaU. The results indicate that per capita GHG emissions are projected to increase from a negative value of roughly -0.07t$CO_2$eq./year in 2010 and -0.48t$CO_2$eq./year in 2030BaU to 0.64t$CO_2$eq./year in 2050BaU. GHG emissions from the agricultural sector are projected to increase about 3 times in 2050BaU compared to 2010. Among them, rice cultivation (3C7) is the largest contributor, contributing about 65% of total GHG emissions in 2010 and is projected to increase about 2 times in 2050BaU; followed by enteric fermentation (3A1), which contributes about 17% in 2010 and is expected to increase around 3 times in 2050BaU. Meanwhile, managed soil (3C4-3C6) contributes about 16% in 2010 and is projected to increase around 5 times, which is the highest incremental rate among other sources. Manure management (3A2) contributes about 2% in 2010 and is expected to increase 2 times in 2050BaU.

The results yield that The LULUCF sector is a net carbon sink and the sink capacity is expected to increase from around 27,082kt$CO_2$eq./year in 2010 to be a similar of around 52,826kt$CO_2$eq./year in 2030BaU and 2050BaU. The sink capacity is expected to future increase to be a similar of around 61,715kt$CO_2$eq./year in 2030CM and 2050CM. In the base year, change in forest and other woody biomass stocks (5A) contributes about 72%, while the rest attributes by forest and grassland conversion (5B). Carbon sinks from 2020 through to 2050 in 5B show carbon uptake along with the growth of planted forest in 2015 in response to the Government's target to ensure forest cover by 60% by 2015. The results yield that the sink capacity increases significantly from 2010 through to 2020CM and is expected to remain constant from 2020CM through to 2050CM.

### 3.7.2 Mitigation potentials in the agricultural sector in different costs

In general, the higher costs the larger GHG reduction potentials. Table 3.13 shows GHG mitigation potentials of the agricultural sector in different costs in 2050CM. The results illustrate that the cost of less than 0USD/t$CO_2$eq. generates GHG emissions mitigation potentials of around 5,959kt$CO_2$eq./year. The rice cultivation (3C7) is the largest contributor, followed by enteric fermentation (3A1), while managed soil (3C4-3C6) cannot be applied under this cost. The cost of less than 10USD/t$CO_2$eq. generates GHG emissions reduction potentials of about 20,550kt$CO_2$eq./year. The rice cultivation (3C7) remains the biggest GHG emissions reduction potentials of around 77%, followed by enteric fermentation (3A1) (around 11%), while managed soil (3C4-3C6) contributes around 1.9%. The manure management (3A2) contributes the smallest share of around 2%. The cost ranging over 10USD/t$CO_{2eq.}$ does not cause a great increase in GHG emissions reduction potentials. This indicates that the implementation of countermeasures in the agricultural sector is relatively low cost and most of the effects are applied with the cost of less than 10USD/t$CO_2$eq. The maximum mitigation potentials without considering economic constraints (technical potential) are expected to reduce GHG emissions by about 22,651kt$CO_2$eq./year in 2050CM, which means about 1.5 times higher than the cost of less than 10USD/t$CO_2$eq.

**Table 3.13:** GHG mitigation potentials in the agricultural sector in different costs [USD/t$CO_2$eq.] in 2050CM

| Mitigation potential [kt$CO_2$eq./year] | CODE | 0 | 10 | 20 | 50 | 100 | Max.* |
|---|---|---|---|---|---|---|---|
| Enteric fermentation | 3A1 | 302 | 1,043 | 943 | 980 | 980 | 974 |
| Manure management | 3A2 | 0 | 381 | 581 | 547 | 547 | 556 |
| Rice cultivation | 3C7 | 5,657 | 17,263 | 17,263 | 17,248 | 17,248 | 17,248 |
| Managed soil | 3C4-3C6 | 0 | 1,845 | 2,647 | 3,877 | 3,877 | 3,872 |
| **Total** | | 5,959 | 20,532 | 21,434 | 22,651 | 22,651 | 22,651 |

*Max. represents technological potential without considering economic constraints.

### 3.7.3 Mitigation potentials in the LULUCF sector in different costs

Table 3.14 shows GHG mitigation potentials in different costs in the LULUCF sector. This table indicates that the reduced impact logging dominates other mitigation measures because limited land areas used for forest plantation due to increases in cropland and settlement expansion. The results yield that the cost of less than 0USD/t$CO_2$eq. generates GHG mitigation potentials of 0kt$CO_2$eq./year. It implies that mitigation measures cannot be applied under this cost. Meanwhile, the cost of less than 10USD/t$CO_2$eq. generates GHG mitigation potentials of around 9kt$CO_2$eq./year and can be applied only with agro-forestry (AGF). The cost of less than 20USD/t$CO_2$eq. generates GHG mitigation potentials of about 15kt$CO_2$eq./year, while the cost ranging from less than 50USD/t$CO_2$eq. and above contributes to the same GHG mitigation potentials of some 8,886kt$CO_2$eq./year. The results suggest that the cost of less than 50USD/t$CO_2$eq. is the most cost effective GHG mitigation potentials in Cambodia in which reduced impact logging (RIL) generates the largest GHG mitigation potentials, followed by agro-forestry (AGF) and reforestation-fast growing species (RFS). The maximum GHG mitigation potentials at the cost without considering economic constraints (technical potential) are expected to mitigate GHG emissions by about 8,889kt$CO_2$eq./year in 2050.

**Table 3.14:** GHG mitigation potentials [kt$CO_2$eq./year] in the LULUCF sector in different costs in 2050CM

| Mitigation measures [USD/t$CO_2$eq.] | Code | 0 | 10 | 20 | 50 | 100 | Max.* |
|---|---|---|---|---|---|---|---|
| Plantation-short rotation | PSR | 0 | 0 | 0 | 0 | 3 | 3 |
| Plantation-long rotation | PLR | 0 | 0 | 0 | 1 | 1 | 1 |
| Reforestation-fast growing species | RFS | 0 | 0 | 6 | 6 | 6 | 6 |
| Reforestation-slow growing species | RSS | 0 | 0 | 0 | 2 | 2 | 2 |
| Enhanced natural regeneration | ENR | 0 | 0 | 0 | 1 | 1 | 1 |
| Agro-forestry | AGF | 0 | 9 | 9 | 9 | 9 | 9 |
| Reduced impact logging | RIL | 0 | 0 | 0 | 8,866 | 8,866 | 8,866 |
| **Total** | | **0** | **9** | **15** | **8,886** | **8,889** | **8,889** |

* Represents technological potentials without considering economic constraints.

### 3.8 Discussion

The results obviously explain that the agricultural sector is a net emitter and the cumulative GHG emissions are projected to increase considerably from 2010 through to 2050BaU. In contrast, the LULUCF sector is projected to be a net carbon sink from 2010 through to 2050BaU and will continue to increase in CM cases. The analysis of main drivers leads to the increase of GHG emissions and carbon sequestration in the AFOLU sector is shown in Table 3.15. It can be observed from the table that the growths in agriculture crop production, land expansion, and livestock demand (MoE, 2013 and RGC, 2013 and 2015) result largely from the population growth (NIS, 2011 and UN, 2012) and the Government's plan to export some agricultural products (RGC, 2013) and meat (cattle) (RGC, 2015a). These drives are extremely certain to stimulate considerable increases of GHG emissions from the agricultural sector. However, it can be noted that the Government has the target to increase forest cover by 60% in 2015 (RGC, 2011), which is used to estimate GHG emissions in the LULUCF sector for the present study. The increase of forest cover is very important to mitigate global warming and to balance forest ecosystem (RGC, 2010a).

Moreover, the results of GHG emissions in the agricultural sector in 2010 of this study are very similar to those of the SNC's ones (MoE, 2013); however, they are larger than projections in those of the Initial National Communication (INC) (MoE, 2002) and the United States Environmental Protection Agency (U.S.EPA) (EPA, 2012), respectively. Comparisons of GHG emissions by sources in the agriculture sector in Cambodia from different studies are shown in Figure 3.4. Meanwhile, the LULUCF sector, both GHG emissions and sink capacity in this study are slightly lower than those of the SNC's ones in 2010 (Figure 3.5). This results from differences in assumptions and limited access to information in the SNC (MoE, 2013). In addition, both GHG emissions and sink capacity in the current study are almost half those of the INC because under the INC the forest exploitation was assumed at a higher rate (MoE, 2002) since the Government granted very large forest concessions to the international forest logging companies (RGC, 2010a and Turton, 2004) and there was no concrete plan for forest management during that time (MoE, 2002). All the logged forests would regrow after forest exploitation; this led to increase of the biomass growths, which are the sources of both carbon stock and sequestration.

Besides, it is noted that GHG emissions in the agricultural sector in 2020 and 2030 between the current study and the SNC are very similar; however, they are greatly larger than in the U.S.EPA (EPA, 2012) in the same years (Table 3.16). This is due mainly to the limited access to the country information under the U.S.EPA (EPA, 2012) and most of the information used were collected from the FAOSTAT database (EPA, 2012) in which it is observed that some information under the FAOSTAT are different from national reports for year 2010 (MAFF, 2011 and NIS, 2011). GHG emissions in the agricultural sector in 2050 in this study are almost double those of the SNC; this is thanks to the limited access to information and different assumptions in the SNC (MoE, 2013). The results also yield that the most effective mitigation measures in the agricultural sector can be applied with the cost of less than 10USD/t$CO_2$eq.; however, it cannot be applied under the LULUCF sector in which the most plausible mitigation measures are applied with the cost of less than 50USD/t$CO_2$eq.The results suggest that the mitigation potentials in the AFOLU sector would be much higher than that of the energy sector. For instance, the BaU emissions are projected to be about 20,800kt$CO_2$/year in the energy sector in 2045 under the SNC (MoE, 2013) and around 13,982kt$CO_2$eq./year in the AFOLU sector in 2050 for this study. From the BaU emissions, around 5,400kt$CO_2$eq./year (about 26%) of energy-induced $CO_2$ emissions under the SNC (MoE, 2013) and around 29,438kt$CO_2$eq./year (about 200% due to increase of carbon sequestration) of the

AFOLU sector of this study can be mitigated at maximum. It is clear that the application of mitigation measures in the AFOLU sector has a greater potential to reduce GHG emissions at this cost level in Cambodia. Furthermore, this study suggests that the land limitation to apply mitigation measures in the LULUCF sector be one of the main challenges to increase mitigation potentials since increase of land areas for forest plantations would decrease other land areas (*e.g.* cropland and settlement), while the SNC did not take the land limitation into account. In order to improve the future analysis, additional studies are needed, especially by combining the AFOLU-B model with the AFOLU Activity model (AFOLU-A) (Gomi and Misumi, 2013) in order to assess mitigation potentials under different assumptions; for instance, improving crop intensity and productivity can reduce the demand for cropland areas, building more compact cities can reduce the demand for settlement areas, and improving feeding sources and alternative healthy diet can reduce meat demand from livestock, etc. Thus, Cambodia has more lands to increase forest plantations. The AFOLU-A model is a top-down model formulated to estimate amounts of human activities in the AFOLU sector based on population and socioeconomic indicators (Gomi and Misumi, 2013).

**Table 3.15:** Key drivers for changes of GHG emissions and carbon sequestration in the AFOLU sector in Cambodia

| Key drivers | 2010 | 2030 | 2050 | Explanation |
|---|---|---|---|---|
| Population [1,000 persons] | 13,959 | 18,391 | 21,964 | The population was projected to increase about 1.3 and 1.6 times in 2030 and 2050, respectively, (NIS, 2011and UN, 2012). The population growth led to the increase of food demand and land expansion, which are the main drivers for GHG emissions. |
| Crop land [1,000 ha] | 3,227 | 4,400 | 4,400 | Crop land areas are expected to increase about 1.4 times in both 2030 and 2050 (MoE, 2013) because the Government needs to increase rice production for domestic comsumption and export target of at least one million ton of milled rice by 2015 (RGC, 2010). |
| Livestock requirement [1,000 heads] | | | | |
| Meat cattle | 3,547 | 4,895 | 8,842 | The meat cattle is projected to increase about 1.4 and 2.5 times in 2030 and 2050, respectively, compared to 2010 and the increase of meat demand thanks to the population growth and export oriented (RGC, 2014 and 2015). |
| Pigs | 3,047 | 5,490 | 9,915 | The pig requirement is projected to increase about 1.8 and 3.3 times in 2030 and 2050, respectively, compared to 2010 and the increase of number of pigs thanks to the population growth (RGC, 2014 and 2015). |
| Chickens | 21,261 | 35,095 | 47,268 | The chicken requirement is projected to increase about 1.7 and 2.2 times in 2030 and 2050, respectively, compared to 2010 and the increase of number of chickens thanks to the population growth (RGC, 2014 and 2015). |
| Forest land [1,000 ha] | 10,364 | 10,862 | 10,862 | Forest cover increased from around 57% in 2010 to around 60% in 2030 and 2050 due to the Government's commitment to increasing forest cover to respond to the CMDGs (RGC, 2011) |
| Harvested land areas [1,000 ha] | 3,732 | 5,916 | 6,970 | Harvested land areas are projected to increase about 1.6 and 1.9 times in 2030 and 2050, respectively, (MoE, 2013) due to the available irrigation systems and advanced agriculture technologies and the Government also needs to increase crop production for domestic comsumption and for export (RGC, 2013). The expansion of harvested land areas would increase fertilizer demand |
| GHG emissions [$ktCO_2$eq./year] | | | | |
| The agricultural sector | 26,142 | 44,062 | 66,808 | GHG emissions from the agriculture sector are projected to increase about 1.7 and 2.6 times in 2030 and 2050, respectively; this would result from the population growth, which caused the increase of the demand for meat and crop production as well as land expansion. |
| The LULUCF sector | -27,082 | -52,826 | -52,826 | The LULUCF sector is a net carbon sink and sink capacity is expected to increase about 2 times in both 2030 and 2050 due to the increase of forest cover set by the Government. |

**Table 3.16:** Comparisons of GHG emissions projections in the agricultural sector in Cambodia between this study, the SNC, and the U.S.EPA [ktCO$_2$eq./year]

| Emission sources [ktCO$_2$eq./year] | CODE | This study | | | | The SNC | | | | The U.S.EPA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2020 | 2030 | 2050 | 2010 | 2020 | 2030 | 2050 | 2010 | 2020 | 2030 |
| Enteric fermentation | 3A1 | 4,326 | 4,470 | 6,015 | 10,826 | 5,836 | 6,882 | 7,927 | 10,018 | 4,407 | 5,267 | 6,248 |
| Manure management | 3A2 | 606 | 794 | 993 | 1,568 | - | - | - | - | 2,122 | 2,533 | 3,005 |
| Rice cultivation | 3C7 | 17,090 | 21,273 | 26,479 | 32,961 | 17,940 | 19,620 | 21,178 | 22,625 | 3,753 | 3,629 | 3,243 |
| Managed soil | 3C4-3C6 | 4,120 | 6,899 | 10,574 | 21,454 | 3,552 | 4,206 | 4,888 | 6,305 | 1,836 | 2,320 | 3,069 |
| Others* | | | | | | | | | | 7,312 | 7,312 | 7,312 |
| **Total** | | **26,142** | **33,436** | **44,062** | **66,808** | **27,328** | **30,708** | **33,993** | **38,948** | **19,430** | **21,061** | **22,878** |

* GHG emissions from the agriculture sector additional to the above four categories and are used by the U.S.EPA (2012)

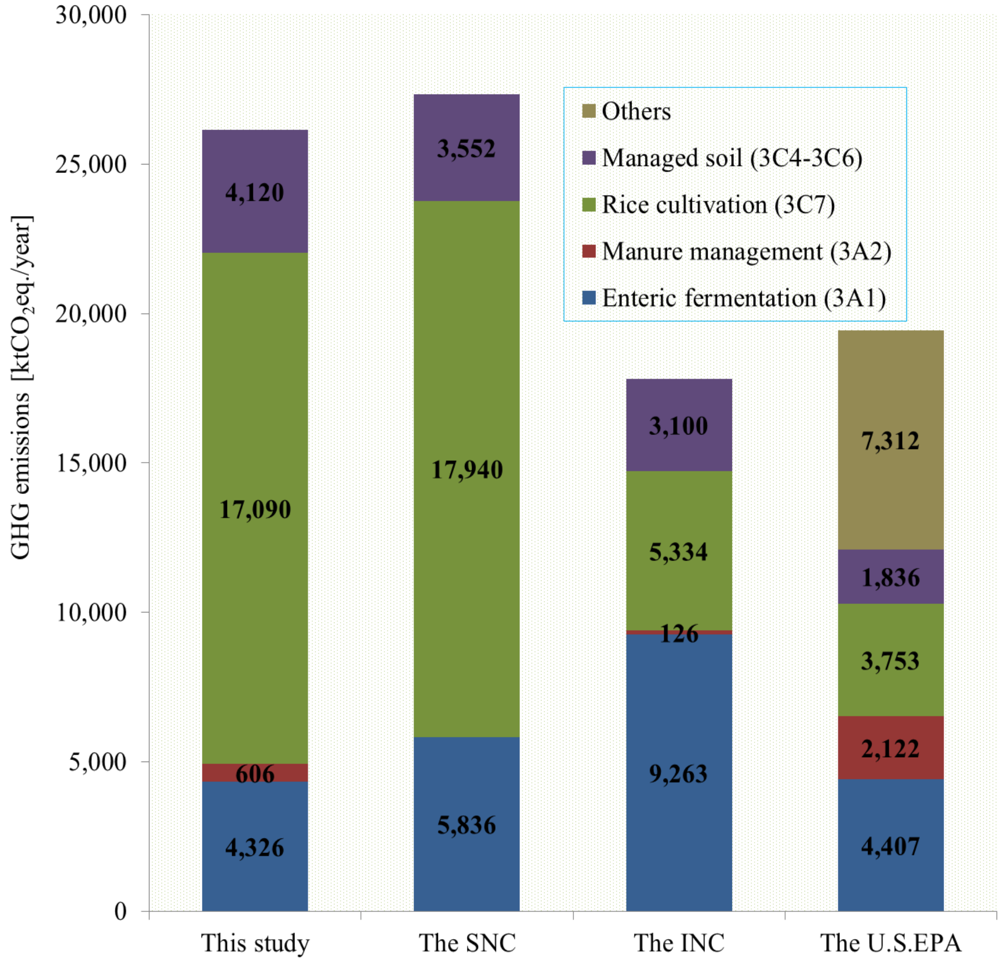


**Figure 3.4:** Comparisons of GHG emissions in the agricultural sector between this study, the SNC, and the U.S. EPA in 2010

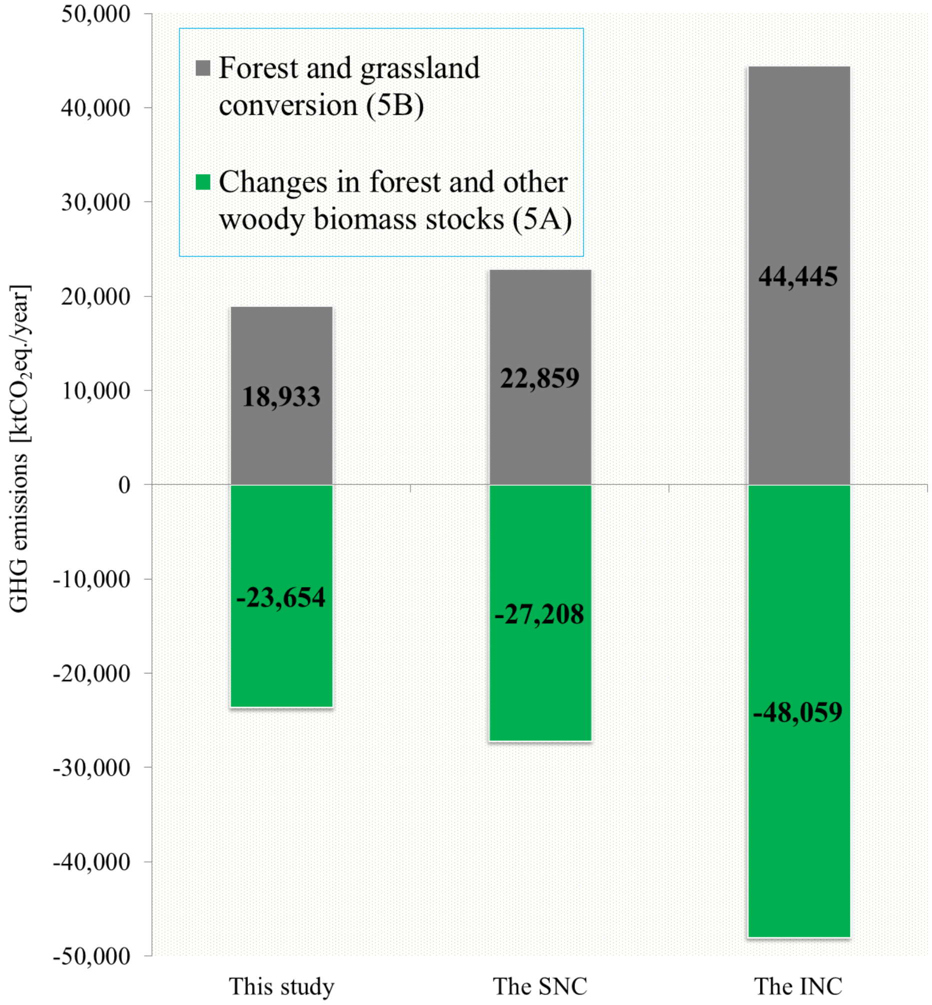


**Figure 3.5:** Comparisons of GHG emissions in the LULUCF sector between this study, the INC, and the SNC in 2010

# PART 4 THE WASTE SECTOR

## 4.1 Overview of the Extended Snapshot (ExSS/Waste) Model

The ExSS/Waste model describes waste-related activities and associated GHG emissions and mitigation potentials (Figure 4.1). These include generation and management of solid waste from residential, commercial, industrial, and construction sectors, and generation and management of residential and industrial wastewater. According to IPCC (2006a), domestic wastewater is defined as used water from households (residential), commercial or service establishments, whereas industrial wastewater is defined as coming only from industrial sources. The main sources of GHG emissions from wastewater are organic and biodegradable substances. The model estimates GHG emissions from fossil carbon during waste incineration, from decomposition of organic carbon in the disposed waste, and from the treatment of wastewater. Since the methodology is on a per person basis for wastewater-treatment GHG emissions, emissions from commercial wastewater are included as part of domestic wastewater. The method for GHG emissions from disposal sites applies a first-order decay method to incorporate the delayed decomposition of organic wastes after disposal. Coverage of the model corresponds to the waste sector in the 2006 IPCC Guidelines (IPCC, 2006a). It does not consider energy consumption and GHG emissions from energy use in the waste management process. They are included in the energy sector in the ExSS/Energy. GHG emissions from agricultural activities such as manure management and on-site burning of agricultural residues are handled in the agriculture and land use sector.

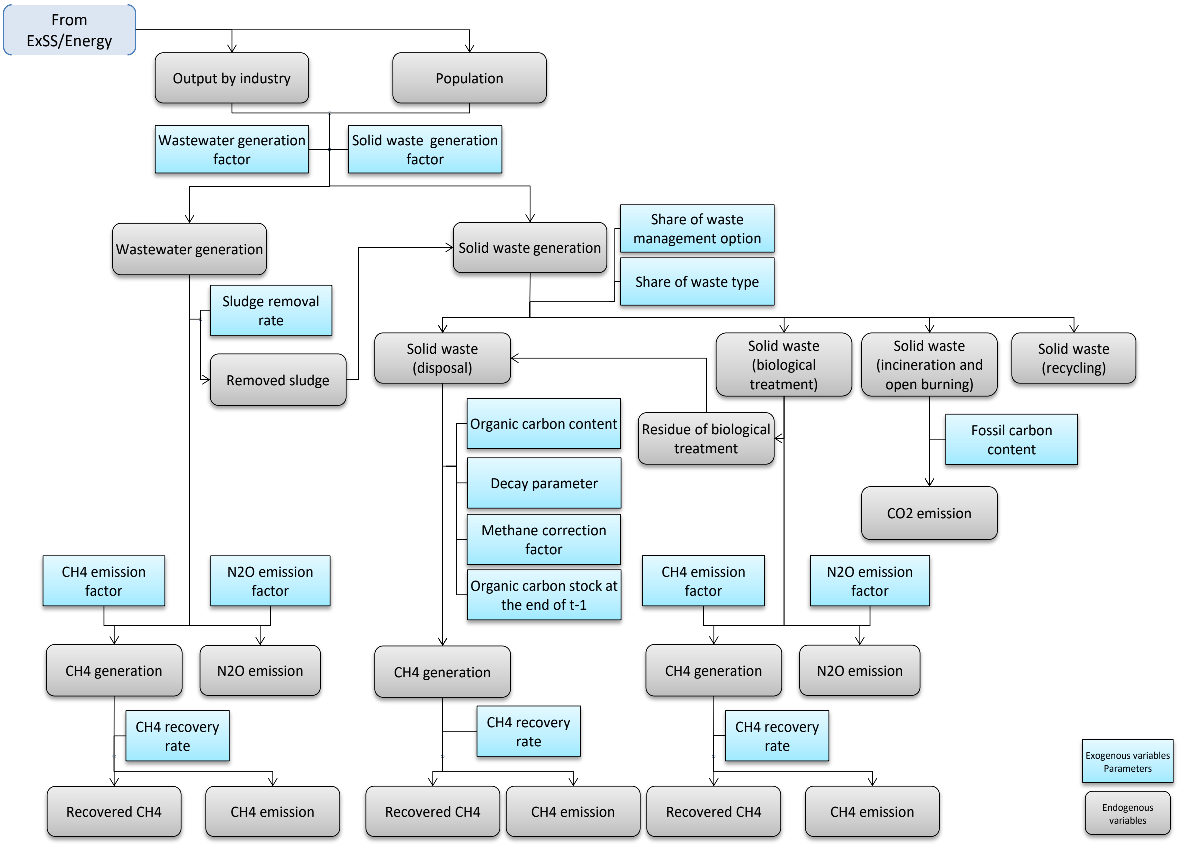


**Figure 4.1:** Structure and function of the ExSS/Waste

## 4.2 Formula to estimate waste generation

$$WM_{s,i,t,g} = WGT_{t,s} \times WGf_{t,i,s} \times WMf_{s,i,t,g} \text{ (ton/year)} \quad (4.1)$$

$$RW_{t,i} = \sum_s WM_{s,i,t,\mathrm{recycle}} \quad \text{(ton/year)} \quad (4.2)$$

$$IW_{t,i,i\_o} = \sum_s WM_{s,i,t,i\_o} \text{ (ton/year)} \quad (4.3)$$

$$DW_{t,i} = \sum_s WM_{s,i,t,\mathrm{deposit}} \text{ (ton/year)} \quad (4.4)$$

$$BW_{t,i,bio} = \sum_s WM_{s,i,t,\mathrm{bio}} \text{ (ton/year)} \quad (4.5)$$

$$WW_{t,wws} = \sum_s WM_{s,ww,t,wws} \text{ (m}^3\text{/year)} \quad (4.6)$$

$WGT_{t,s}$: Total waste generation by sector $s$ in year $t$

$WGf_{t,i,s}$: Fraction of waste type $i$

$WM_{s,i,t,g}$: Volume of waste by management option

$WMf_{s,i,t,g}$: Fraction of waste management option

$RW_{t,i}$: Recycled waste

$IW_{t,i,\ i\_o}$: Incinerated waste

$DW_{t,i}$: Deposited waste

$BW_{t,i,bio}$: Solid waste with biological treatment

$WW_t$: Wastewater

$t$: Year ($t \in T$, $T = \{t0, t0{+}1, t0{+}2, \ldots, t_{end}\}$, $t0$: base year, $t_{end}$: target year)

$i$: Waste type ($i \in I$, $I = \{paper, textile, food,,,\}$)

$s$: Sector ($s \in S$, $S = \{residential, commercial, industrial, construction\}$)

$g$: Waste management option ($g \in G$, $G = \{recycle, incinerate, deposit,..\}$)

$i\_o$: Incineration and open burning ($i\_o \in G$, $i\_o = \{incinerate, open\ burning\}$)

$bio$: Biological treatment ($bi \in G$, $bio = \{composting, anaerobic\ digestion\}$)

$ww$: Waste water ($ww \in I$ )

$wws$: Options for waste water treatment ($wws \in G$)

## 4.3 Formula to estimate GHG emissions and reduction potentials

### 4.3.1 GHG generation from incineration and open burning

$$GHGg_{t,gas,incineration} = \sum_{i\_o}\sum_{i}(IW_{t,i,i\_o} \times dm_i \times CF_i \times FCf_i \times OF_{i,i\_o} \times 44/12 \times GWP_{gas}) \ (\text{tCO}_2\text{eq./year}) \quad (4.7)$$

$GHGg_{t,gas,g}$: GHG generation by management option $g$ by $gas$

$CF_i$: Total carbon content in dry matter

$FCf_i$: Fraction of fossil carbon in total carbon

$GWP_{gas}$: Global warming potential

$dm_i$: Dry matter content in waste type $i$

$OF_{i,i\_o}$: Oxidation factor of fossil carbon

$gas$: Greenhouse gases ($gas \in GHG$, $GHG = \{CO_2, CH_4, N_2O\}$)

44/12: Conversion rate from carbon (C) to $CO_2$

### 4.3.2 GHG generation from the waste deposal site

$$DDOCmd_{t,i} = DW_{t,i} \times DOCf_i \times MCF \quad (4.8)$$

$$DDOCmrem_{t,i} = DDOCmd_{t,i} \times e^{-k_i} \quad (4.9)$$

$$DDOCmdec_{t,i} = DDOCmd_{t,i} \times (1- e^{-k_i}) \quad (4.10)$$

$$DDOCma_{t,i} = DDOCmrem_{t,i} + DDOCma_{t-1,i} \times e^{-k_i} \quad (4.11)$$

$$DDOCmdecomp_{t,i} = DDOCmdec_{t,i} + DDOCma_{t-1,i} \times (1- e^{-k_i}) \quad (4.12)$$

$$GHGg_{t,CH4,deposit} = \sum_i DDOCmdecomp_{t,i} \times F \times 16/12 \text{ (tCO}_2\text{eq/year)} \quad (4.13)$$

| | |
|---|---|
| $DDOCmd_{t,i}$: | Mass of decomposable degradable organic carbon (DDOC) in deposited waste in year *t* |
| $DDOCmrem_{t,i}$: | Mass of DDOC deposited in year t and undecomposed amount at the end of the year *t* |
| $DDOCmdec_{t,i}$: | Mass of DDOC deposited and decomposed in year *t* |
| $DDOCma_{t,i}$: | Total mass of DDOC left undecomposed at end of year *t* |
| $DDOCmdecomp_{t,i}$: | Total mass of DDOC decomposed in year *t* |
| $DOCf_i$: | Fraction of degradable organic carbon (DOC) in waste type *i* |
| $F$: | Fraction of $CH_4$ by volume in generated GHG from disposal sites |
| $k_i$: | Rate of reaction constant of waste type *i* |
| $MCF$: | Methane correction factor |
| $GHGg_{t,CH4,g}$: | Generated $CH_4$ ($CH_4 \in GHG$) |
| 16/12: | Conversion rate from C to $CH_4$ |

### 4.3.3 GHG generation from biological treatment

$$GHGg_{t,gas,bio} = \sum_i (BW_{t,i,bio} \times EFB_{bio,gas}) \text{ (tCO}_2\text{eq/year)} \quad (4.14)$$

$EFB_{bio,gas}$ : Emission factor of biological treatment

### 4.3.4 GHG generations from wastewater treatment

$$GHGg_{t,CH4,wws} = WW_{t,wws} \times EFW_{s,wws,CH4} \times MCF_{wws} \text{ (tCO}_2\text{eq./year)} \quad (4.15)$$

$$GHGg_{t,others,wws} = WW_{t,wws} \times EFW_{s,wws,others} \quad (4.16)$$

$EFW_{s,wws,gas}$: Emission factor of GHG *gas* by wastewater treatment *wws*

$MCF_{wws}$: Methane correction factor for *wws*

*Others*: GHG except $CH_4$ ($others \in gas$)

### 4.3.5 GHG emissions and methane recovery

$$GHGem_{t,CH4,deposit} = GHGg_{t,CH4,deposit} \times (1 - OX_{deposit}) \times (1 - Rf_{t,deposit}) \times GWP_{CH4} \text{ (tCO}_2\text{eq./year)} \quad (4.17)$$

$$GHGem_{t,CH4,wws} = GHGg_{t,CH4,wws} \times (1 - Rf_{t,wws}) \times GWP_{CH4} \text{ (tCO}_2\text{eq./year)} \quad (4.18)$$

$$GHGem_{t,others,g} = GHGg_{t,others,g} \times GWP_{others} \text{ (tCO}_2\text{eq./year)} \quad (4.19)$$

$$CH_4r_{t,g} = CH_4g_{t,g} \times (1 - OX_g) \times Rf_{t,g} \text{ (tCO}_2\text{eq./year)} \quad (4.20)$$

$$GHG_{t,gas} = \sum_g GHGsg_{t,gas,g} \text{ (tCO}_2\text{eq./year)} \quad (4.21)$$

$CH_4r_{t,g}$: Volume of $CH_4$ recovered

$CH_4g_{t,g}$: Volume of $CH_4$ generated

$GHGem_{t,gas,g}$: GHG emissions in $CO_2$ equivalent

$OX_g$: Oxidation factor of $CH_4$ generated by management option *g*

$Rf_{t,g}$: Fraction of recovered in $CH_4$ generated

## 4.4 Data quantification and assumptions for the present and the future

Cambodia has very limited information on waste generation indicators, hence some assumptions are made for the purpose of the present study. The information on the main waste generation indicators for the present and the future used in this study is shown in Table 4.1, while the detail methodologies to acquire these assumptions are explained as follows.

**Table 4.1:** Main waste generation indicators

| Indicators | 2010 | 2030 | 2050 | References |
|---|---|---|---|---|
| Population (persons) | **13,959,000** | **18,391,000** | **21,964,000** | Statistical year book of Cambodia 2011 |
| Urban | 2,741,000 | 5,434,000 | 9,835,000 | (NIS, 2011) and Mao (2015) |
| Rural | 11,218,000 | 12,957,000 | 12,129,000 | |
| Outputs of industry (million USD at 2000 constant price) | **28,334** | **119,549** | **486,468** | Sophal and Sothea (2011) and Mao (2015) |
| Commercial sector | 6,472 | 25,845 | 100,322 | |
| Industrial sector | 10,635 | 45,480 | 187,596 | |
| Agriculture, fishery & forestry | 3,136 | 9,265 | 30,082 | |
| Mining | 125 | 558 | 2,338 | |
| Manufacturing | 7,374 | 35,657 | 155,176 | |
| Construction sector | 592 | 2,743 | 10,955 | |
| Generation factor | | | | |
| Residential sector (kg/(person.day)) | 0.3 | 0.6 | 1.3 | Hoornweg and Bhada-Tata (2012) |
| Commercial sector (ton/(million USD.year)) | 69 | 69 | 69 | Hoa and Matsuoka (in press) |
| Industrial sector (ton/(million USD.year)) | 64.8 | 64.8 | 64.8 | |
| Construction sector (ton/million USD.year)) | 431.8 | 431.8 | 431.8 | |
| Waste generation (ton/year) | **2,919,392** | **10,074,706** | **34,142,096** | |
| Residential sector | 1,528,511 | 4,161,883 | 10,341,749 | Estimated by multiplying waste generation per capita and population in the year |
| Commercial sector | 446,424 | 1,782,835 | 6,920,399 | Estimated by multiplying waste generation factor in the commercial sector and output of the commercial sector in monetary units |
| Industrial sector | 688,802 | 2,945,617 | 12,149,988 | Estimated by multiplying waste generation factor in the industrial sector and output of the industrial sector in monetary units |
| Construction sector | 255,656 | 1,184,371 | 4,729,959 | Estimated by multiplying waste generation factor in the construction sector and output of the construction sector in monetary units |

## 4.5 Solid waste sector

This study estimates solid waste generation from four sectors, namely residential, commercial, industrial, and construction sectors. The residential and commercial waste is generally defined as waste collected by municipalities or other local authorities, which include household waste, garden (yard) and park waste, market waste and commercial/institutional waste. While, the industrial and construction waste is generated by manufacturing or industrial processes/technologies such as construction, fabrication, light and heavy manufacturing, refineries, chemical plants, demolition plants, and power plants.

### 4.5.1 Solid waste generation factors

Since it is necessary to develop a time-series projection for estimating GHG emissions from solid waste disposal, the time period is extended from 2000 to 2050. The waste generation factor from the residential sector (ton/(person.year)) is estimated by population multiplied by waste generation per capita and days of a year. The population in 2010 is collected from NIS (2012), while those of 2030 and 2050 are collected from UN (2013). Waste generation per capita in the residential sector was

0.3kg/(person.day) in 2010 (DoPC, 2010). In the future, the waste generation per capita is assumed to increase due to the population growth and increased incomes of the people. For instance, the Government recently set an economic development target to reach the status of an upper-middle income country by 2030 and a high-income level by 2050 (RGC, 2013); therefore, waste generation per capita in 2030 and 2050 is assumed to be similar to those of countries with upper middle income status of 1.16kg/(person.day) and high income status of 2.13kg/(person.day), which are collected from "What a Waste" (Hoornweg and Bhada-Tata, 2012). Waste generation factors in 2010 of industrial, commercial, and construction wastes are assumed to be similar to those of Vietnam (Hoa and Matsuoka, in press) thanks to the limited access to the information in Cambodia and they are assumed to be the same as in 2010 for both 2030 and 2050. Solid waste generation factors used in this study are shown in Table 4.2.

**Table 4.2:** Solid waste generation factors

| Sector | | Residential | Commercial | Industry | Construction |
|---|---|---|---|---|---|
| Type of waste | Unit | ton/(person.year) | ton/(million USD.year) | | |
| Solid waste | 2000 | 0.08 | 68.982 | 64.767 | 431.78 |
| | 2010 | 0.11 | 68.982 | 64.767 | 431.78 |
| | 2030 | 0.423 | 68.982 | 64.767 | 431.78 |
| | 2050 | 0.777 | 68.982 | 64.767 | 431.78 |

### 4.5.2 Solid waste composition

The detail information on solid waste composition in Cambodia is not available; hence, several assumptions are made for the purpose of this study. This study does not clarify composition of wastewater; however, composition of solid waste is defined in different sectors as below:

**Composition of Residential and Commercial Waste**

Composition of residential and commercial solid waste has some common characteristics such as high rate of organic composition; high contain of soil, sand and fragment of brick, stone; and high moisture content, low specific heat energy (Nguyen, 2014). Socio-economic conditions that enable to increase in standards of living will influence the composition of the generated waste. The major types of the residential and commercial solid waste are food waste, paper, textile, plastic, metal, rubber, glass and others. In this study, composition of the residential and commercial solid waste in 2010 is referred to Fujiwara *et al.* (2012), who estimated solid waste composition in Phnom Penh municipality; and it is assumed to be the same in the country-wide. Due to limited information, solid waste composition in 2030 and 2050 is assumed to be similar to those of countries with upper middle income and high income status, which are collected from "What a Waste" (Hoornweg and Bhada-Tata, 2012) since Cambodia will reach similar economic development status in those years. Table 4.3 shows the solid waste composition in the residential and commercial sectors in Cambodia.

**Table 4.3:** Residential and commercial solid waste composition [%]

| Waste types | 2010 | 2030 | 2050 |
|---|---|---|---|
| Paper | 4.60% | 14.00% | 31.00% |
| Textile | 0.80% | 2.00% | 5.00% |
| Food | 66.30% | 54.00% | 28.00% |
| Wood | 0.60% | 0.60% | 0.60% |
| Garden | 0.20% | 0.20% | 0.20% |
| Rubber | 0.40% | 0.40% | 0.40% |
| Plastic | 9.80% | 11.00% | 11.00% |
| Metal | 2.00% | 3.00% | 6.00% |
| Glass | 3.00% | 5.00% | 7.00% |
| Other | 12.50% | 9.80% | 10.90% |

**Composition of Industrial Waste**

Since there are various industries in Cambodia but information is limited, only one type of waste composition, namely "Other", is assumed for the industrial sector in this study. It is assumed to be the same as those of the base year for 2030 and 2050.

**Composition of Construction Waste**

Construction waste consists of wood, brick, concrete, asphalt pavement, glass, metal, drywall, and asphalt shingles generated during the construction, remodeling, or demolition of structures. Since there is no information of construction waste's composition at the time of the study, we assume that it is similar to that of Vietnam (Hoa and Matsuoka, in press) except waste from wood, which is assumed to be 2% (based on the discussion with national experts) compared to 5% in Vietnam. Furthermore, it is assumed to be the same as that of the base year for 2030 and 2050. The composition of construction waste used in this study is shown in Table 4.4.

**Table 4.4:** Composition of construction waste [%]

| Waste types | 2010 | 2030 | 2050 |
|---|---|---|---|
| Brick | 1.16% | 1.16% | 1.16% |
| Concrete | 65.83% | 65.83% | 65.83% |
| Metal | 0.83% | 0.83% | 0.83% |
| Soil and sand | 26.93% | 26.93% | 26.93% |
| Wood | 2.0% | 2.0% | 2.0% |
| Others | 3.25% | 3.25% | 3.25% |

### 4.5.3 Fraction of degradable organic carbon (DOC)

Cambodia has not developed her own DOC in 2010; therefore, the DOC content used in this study follows the 2006 IPCC guidelines as indicated in Table 4.5 and they are assumed to be the same as those of the base year for 2030 and 2050.

**Table 4.5:** Fraction of DOC-weight fraction [%]

| Solid waste component | DOC content in % of wet waste (IPCC, 2006) | | This study |
|---|---|---|---|
| | Range | Default | |
| Food waste | 8-20 | 15 | 15 |
| Garden | 18-22 | 20 | 20 |
| Paper | 36-45 | 40 | 40 |
| Wood and straw | 39-46 | 43 | 43 |
| Textiles | 20-40 | 24 | 24 |
| Disposable nappies | 18-32 | 24 | 24 |
| Sewage sludge | 4-5 | 5 | 5 |
| Industrial waste | 0-54 | 15 | 54 |

### 4.5.4 Methane generation rate

Cambodia has not developed her own Methane generation rate in 2010; therefore, this study uses the default value of the 2006 IPCC guidelines as indicated in Table 4.6 and they are assumed to be the same as those of the base year for 2030 and 2050.

**Table 4.6:** Methane generation rate constant (k): year-1 (moist and tropical country)

| Solid waste component | Methane generation rate constant (k) – year-1 | | This study |
|---|---|---|---|
| | Range | Default | |
| Food waste | 17–70 | 40 | 40 |
| Garden | 15–20 | 17 | 17 |
| Paper | 6–8.5 | 7 | 7 |
| Wood and straw | 3–5 | 3.5 | 3.5 |
| Textiles | 6–8.5 | 7 | 7 |
| Disposable nappies | 15–20 | 17 | 17 |
| Sewage sludge | 17–70 | 40 | 40 |
| Industrial waste | 15–20 | 17 | 20 |

### 4.5.5 Dry matter content of waste composition

Cambodia has not developed her own Dry matter content in 2010; therefore, this study uses the default value of the 2006 IPCC guidelines as indicated in Table 4.7 and they are assumed to be the same as those of the base year for 2030 and 2050.

**Table 4.7:** Dry matter content, total carbon content and fossil carbon fraction of different waste type

| Solid waste component | Dry matter content in % of wet weight | Total carbon content in % of dry waste | Fossil carbon fraction in % of total carbon |
|---|---|---|---|
| Paper | 90 | 46 | 1 |
| Textiles | 80 | 30 | 20 |
| Food waste | 40 | 38 | 0 |
| Wood | 85 | 50 | 0 |
| Garden | 40 | 49 | 0 |
| Nappies | 40 | 60 | 10 |
| Rubber | 84 | 47 | 20 |
| Plastics | 100 | 75 | 100 |
| Metal | 100 | 0 | 0 |
| Glass | 100 | 0 | 0 |
| Soil | 0 | 0 | 0 |
| Brick | 0 | 0 | 0 |
| Concrete | 0 | 0 | 0 |
| Other | 0 | 0 | 0 |
| Industrial | 100 | 50 | 90 |

### 4.5.6 Other parameters

There are some other parameters required to estimate GHG emissions from the waste sector in this study as explained below:

- Fraction of methane by volume in generated landfill gas: according to IPCC (2006a) – Chapter 3 (Solid waste disposal), most waste in solid waste diposal site generates a gas with approximately 50 percent $CH_4$. Only material including substantial amounts of fat or oil can generate gas with substantially more than 50 percent $CH_4$. The use of the IPCC default value for the fraction of $CH_4$ in landfill gas (0.5) is therefore encouraged.
- Oxidation factor of generated methane: the oxidation factor (OX) reflects the amount of $CH_4$ from solid waste diposal site that is oxidised in the soil or other material covering the waste. In Cambodia, most of solid waste (SW)

disposal sites are unmanaged and uncategorized; therefore, oxidation factor of generated methane for SW disposal site is assumed as 0 in this study (see Table 4.8).

**Table 4.8:** Oxidation factor of generated methane for SW disposal site

| Type of Site | Oxidation factor of generated methane for SW disposal site | |
|---|---|---|
| | Default values | This study |
| Managed (but not covered), unmanaged, and uncategorized SW disposal site | 0 | 0 |
| Managed covered with CH4 oxidizing material (soil, compost) | 0.1 | |

### 4.5.7 Solid waste management

The composition of waste management in different sectors in 2010 is collected from the Government's report (DoPC, 2010). The country has not developed a long-term plan for waste management options in different sectors; thus, this study assumes the composition of waste management to be based on available information and discussion with national experts. It is noted that several regulations, policies, and strategies related to solid waste management in Cambodia have been prepared; however, specific waste management options in 2030 and 2050 have not been set. It is investigated that the Government has prepared a National Strategy on 3R (reduce, reuse, and recycle) for waste management in general (MoE, 2009) as shown in Table 4.9. For the purpose of this study, some assumptions are made based on this strategy as well as the discussion with Government officers (Mr. Sina, Deputy Director and Mr. Sothun, Vice Chief of Solid Waste Management Office, Department of Pollution Control in 2014 and 2015). The compositions of waste management options by sectors by waste types in the base year and in BaU and CM cases used in this study are shown in Table 4.10.

**Table 4.9:** Solid waste management options in Cambodia (3Rs strategy)

| Management options | 2015 | | | 2020 | | |
|---|---|---|---|---|---|---|
| | Residential | Commercial | Industrial | Residential | Commercial | Industrial |
| Collection | 50% | 50% | 70% | 60% | 60% | 70-80% |
| Recycling | 10-20% | 30-40% | 50% | 50% | 70% | 80% |
| Composting | 20% | 20% | NA | 40% | 50% | NA |
| Dumpsite | 30% | 30% | NA | 40% | 40% | NA |

NA: Not available

**Table 4.10:** Compositions of waste management in BaU and CM cases

| Sector | Waste type | Management options | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|---|---|
| Residential and commercial | Paper, textile, nappies, plastic, etc. | Recycling | 0.01 | 0.1 | 0.3 | 0.3 | 0.7 |
| | | Incineration | 0 | 0.01 | 0.05 | 0.04 | 0.1 |
| | | Composting | 0 | 0 | 0 | 0 | 0 |
| | | Disposal | 0.99 | 0.89 | 0.65 | 0.66 | 0.2 |
| | Food, garden, wood, etc. | Recycling | 0.01 | 0.1 | 0.1 | 0.3 | 0.2 |
| | | Incineration | 0 | 0.01 | 0.05 | 0.04 | 0.1 |
| | | Composting | 0 | 0.1 | 0.3 | 0.4 | 0.5 |
| | | Disposal | 0.99 | 0.79 | 0.55 | 0.26 | 0.2 |
| | Others (metal, glass, brick, concrete, etc.) | Recycling | 0.01 | 0.1 | 0.3 | 0.3 | 0.7 |
| | | Incineration | 0 | 0 | 0 | 0 | 0 |
| | | Composting | 0 | 0 | 0 | 0 | 0 |
| | | Disposal | 0.99 | 0.9 | 0.7 | 0.7 | 0.3 |
| Industrial | Others | Recycling | 0.1 | 0.2 | 0.3 | 0.5 | 0.7 |
| | | Incineration | 0 | 0.01 | 0.05 | 0.04 | 0.1 |
| | | Composting | 0 | 0 | 0 | 0 | 0 |
| | | Disposal | 0.9 | 0.79 | 0.65 | 0.46 | 0.2 |
| Construction | Wood, brick, soil, concrete, etc. | Recycling | 0.1 | 0.2 | 0.3 | 0.5 | 0.7 |
| | | Incineration | 0 | 0 | 0 | 0 | 0 |
| | | Composting | 0 | 0 | 0 | 0 | 0 |
| | | Disposal | 0.9 | 0.8 | 0.7 | 0.5 | 0.3 |

## 4.6 Wastewater sector

Wastewater is categorized into two types: domestic and industrial wastewater. According to IPCC (2006a), domestic wastewater is defined as used water from households (residential), commercial or service establishments, whereas industrial wastewater is defined as coming only from industrial sources.

### 4.6.1 Wastewater generation factors

The activity data used to calculate emissions from domestic wastewater treatment includes population and degradable organic component (DOC) or biochemical oxygen demand (BOD), while those for the industrial wastewater treatment includes industrial production and chemical oxygen demand (COD). For domestic wastewater, generation factor in 2010 follows the default value of BOD per capita (14.6kg BOD/(capita.year)), which refers to Table 6-5 of 2006 IPCC guidelines–page 6.23 (IPCC, 2006a); and it is assumed to the same for 2030 and 2050 due to limited information. Meanwhile, domestic wastewater is estimated by multiplying population and generation factor. For the industrial wastewater, only main industries that produce large volumes of organic wastewater, with the largest potential for GHG emissions are considered, value of

COD differs from different industries. Industrial wastewater generation indicators and total organic degradable material in 2010 in Cambodia are shown in Table 4.11. Industrial wastewater is estimated by multiplying wastewater generation factor in the industrial sector and outputs of the industrial sector (Million USD). The wastewater generation factor in the industrial sector is estimated as following formula. The result of 0.878 ton COD/million USD is obtained and it is assumed to be the same for 2030 and 2050 due to limited information.

$$\text{Generation factor} = \frac{\text{Total COD/year}}{\text{Outputs of industries}} = \frac{6{,}564.43}{10{,}635} = 0.878 \text{ ton/million USD} \tag{4.22}$$

**Table 4.11:** Industrial wastewater generation indicators and total organic degradable material in 2010

| Unit | Industrial production | Waste water generated | Total waste water | COD | Total organic degradable material in |
|---|---|---|---|---|---|
| | ton/year | $m^3/t$ | $m^3/year$ | $kgCOD/m^3$ | kgCOD/year |
| Beer & Malt | 159,285[(1)] | 10.00[(3)] | 1,592,850 | 3.50[(3)] | 5,574,975 |
| Fish processing | 35,000[(1)] | 21.50[(3)] | 752,500 | 1.20[(3)] | 903,000 |
| Starch production | 961[(2)] | 9.00[(4)] | 8,645 | 10.00[(3)] | 86,455 |
| **Total** | **195,246** | **12.06** | **2,353,995** | | **6,564,430** |

**Sources:** [(1)] FAO (2015), [(2)] RGC (2013c), [(3)] Hoa and Matsuoka (in press), [(4)] IPCC (2006a)

### 4.6.2 Wastewater management

The information on wastewater management in 2010 is collected from DoPC (2010). Cambodia has very limited wastewater treatment system, especially in the residential sector. And the concrete wastewater management plan has not been in place. However, the country has gradually improved and installed wastewater treatment plants, notably in the industrial sector (RGC, 2014) and it is expected to increase significantly in the future in both industrial and residential sectors. The information on the assumptions of the share of wastewater management options used in this study is shown in Table 4.12. Besides, the Government has not also been installed the $CH_4$ recovery system in both solid waste disposal sites and wastewater treatment plants; however, they are under feasibility studies (an interview with Mr. Vuthy, Vice Chief Office of Department of Pollution Control in 2015). Therefore, we expect that $CH_4$ collecting system will be increased its share to 1% and 5% in 2030BaU and 2050BaU, respectively. Moreover, it is expected to further increase to 5% and 20% in 2030CM and 2050CM, respectively.

**Table 4.12:** Share of wastewater management [%]

| Sector | Management option | 2010 | 2030BaU | 2050BaU | 2030CM | 2050CM |
|---|---|---|---|---|---|---|
| Residential waste water | Non-treated | 0.8 | 0.2 | 0 | 0.2 | 0 |
| | Treated | 0.2 | 0.8 | 1 | 0.8 | 1 |
| Industrial waste water | Non-treated | 0.6 | 0.25 | 0 | 0.25 | 0 |
| | Treated | 0.4 | 0.75 | 1 | 0.75 | 1 |

### 4.7 Waste generation and projections

The results of the assumptions indicate that solid waste generation was around 2.92 Million tons in 2010; among solid waste generation sources, the residential sector contributes the highest share of around 52%, while the construction sector contributes the smallest one of around 9%. In the base year, most of solid waste generation are dumped into disposal sites (about 99%), and no regulation or standard has been established to control methane gas at the landfills released by the decay of solid waste in these disposal sites. The results yield that solid waste generation is expected to increase about 3.5 and 11.7 times in 2030BaU and 2050BaU, respectively, from the base year. The construction sector increases relatively higher (18.5 times), followed by the industrial sector (17.6 times).

The results of the assumptions indicate that wastewater generation was around 0.21 $Mm^3$ in 2010 in which the residential sector shares around 96% of the total wastewater generation. The results also yield that wastewater generation increases about 1.5 and 2.3 times in 2030BaU and 2050BaU, respectively, from the base year. In the BaU scenario, waste management options introduced are followed the existing Government plans, strategies, and policies related to waste management. Cambodia has very limited policies and strategies for waste management in general, and methane recovery and incineration in particular. In the CM scenario, some countermeasures such as composting, reuse, recycling, and incineration are introduced in order to reduce waste disposal at the landfill sites. The detail results of the assumptions of solid waste generation by management options in both BaU and CM scenarios from 2010 through to 2050 are shown in Appendix 13. The results of the assumptions of waste generation and projections are shown in Table 4.13.

**Table 4.13:** Waste generation and projections in Cambodia

| Solid waste generation (Million ton/year) | 2010 | 2030 | 2050 | 2030 /2010 | 2050 /2010 |
|---|---|---|---|---|---|
| Residential sector | 1.53 | 4.16 | 10.34 | 2.72 | 6.77 |
| Commercial sector | 0.45 | 1.78 | 6.92 | 3.99 | 15.50 |
| Industrial sector | 0.69 | 2.95 | 12.15 | 4.28 | 17.64 |
| Construction sector | 0.26 | 1.18 | 4.73 | 4.63 | 18.50 |
| **Total** | **2.92** | **10.07** | **34.14** | **3.45** | **11.69** |
| Waste water generation ($Mm^3$/year) | | | | | |
| Residential sector | 0.20 | 0.27 | 0.32 | 1.32 | 1.57 |
| Industrial sector | 0.01 | 0.04 | 0.17 | 4.28 | 17.64 |
| **Total** | **0.21** | **0.31** | **0.49** | **1.45** | **2.29** |

## 4.8 GHG emissions and reduction potentials from the waste sector

The results yield that GHG emissions will increase from around 1,566kt$CO_2$eq./year in 2010 to 5,731 and 15,216 kt$CO_2$eq./year in 2030BaU and 2050BaU, respectively. GHG emissions from the industrial sector contribute a similar share of more than 70% of total emissions in both 2030BaU and 2050BaU. Table 4.14 shows GHG emissions and reduction potentials by sectors in Cambodia (kt$CO_2$eq./year). The results indicate that GHG emissions from the residential sector increases about 3.6 and 8.9 times, while the commercial sector increases about 3.5 and 10.2 times in 2030BaU and 2050BaU, respectively. Similarly, GHG emissions from the industrial sector increases about 3.7 and 9.8 times, while the construction sector increases about 4.6 and 11.1 times in 2030BaU and 2050BaU, respectively.

However, under low carbon measures with the expected implementation of better waste management and increase of methane recovery, GHG emissions are expected to reduce by approximately 13% and 39% in 2030CM and 2050CM, respectively. Figure 4.2 shows GHG emissions and reduction potentials in BaU and CM scenarios in Cambodia. Meanwhile, the detail information of GHG emissions and reductions in both BaU and CM scenarios from 2010 through to 2050 are shown in Appendix 14.

**Table 4.14:** GHG emissions and reductions by sectors [kt$CO_2$eq./year]

| Sectors/year | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM | 2030BaU /2010 | 2030CM /2010 | 2050BaU /2010 | 2050CM /2010 |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 262 | 951 | 826 | 2,326 | 1,535 | 3.63 | 3.15 | 8.88 | 5.86 |
| Commercial | 174 | 606 | 515 | 1,774 | 1,117 | 3.48 | 2.96 | 10.18 | 6.41 |
| Industrial | 1,127 | 4,160 | 3,627 | 11,082 | 6,661 | 3.69 | 3.22 | 9.84 | 5.91 |
| Construction | 3 | 14 | 12 | 34 | 28 | 4.59 | 3.92 | 11.10 | 9.02 |
| **Total** | **1,566** | **5,731** | **4,980** | **15,216** | **9,341** | **3.66** | **3.18** | **9.72** | **5.97** |

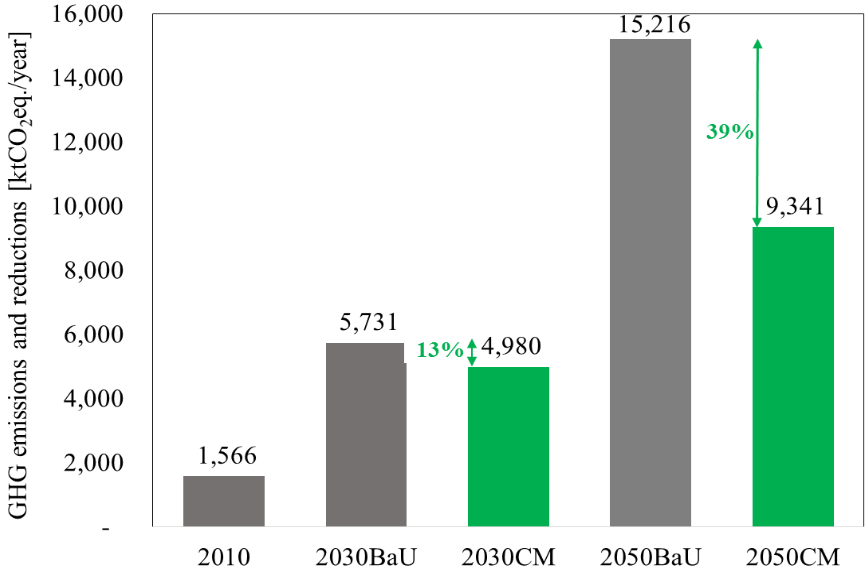


**Figure 4.2:** GHG emissions and reductions in BaU and CM scenarios in Cambodia

### 4.8.1 GHG emissions from the solid waste sector

The results yield that among GHG emissions by management options, disposal sites attribute the largest emissions and $CH_4$ is the main source of emissions. $CH_4$ emissions from the industrial sector is accounted for the largest amount of around 77% compared to other wastes and is projected to increase about 3.0 and 4.1 times in 2030BaU and 2050BaU, respectively. $CH_4$ emissions from the residential sector is expected to increase about 3.3 and 4.5 times, while the commercial sector will increase about 2.4 and 3.8 times in 2030BaU and 2050BaU, respectively. Table 4.15 shows $CH_4$ emissions ($ktCO_2$eq./year) from disposal sites in Cambodia.

**Table 4.15:** $CH_4$ emissions from disposal sites in Cambodia [$ktCO_2$eq./year]

| Sectors/year | 2010 | 2030BaU | 2050BaU | 2030BaU /2010 | 2050BaU /2010 |
|---|---|---|---|---|---|
| Residential | 170 | 560 | 760 | 3.29 | 4.47 |
| Commercial | 170 | 410 | 640 | 2.41 | 3.76 |
| Industrial | 1,110 | 3,360 | 4,540 | 3.03 | 4.09 |
| Construction | 0 | 10 | 10 | - | - |
| **Total** | **1,460** | **4,330** | **5,950** | **2.97** | **4.08** |

### 4.8.2 GHG emissions from the wastewater sector

The results yield that through the wastewater treatment process, $CH_4$ emissions from the residential sector (83% in 2030BaU and 67% in 2050BaU) are larger than those of the industrial sector (17% in 2030BaU and 32% in 2050BaU). However, the results show that the share of $CH_4$ emissions from the industrial sector will increase in 2050BaU, while the residential sector will decrease. This is due mainly to the expected increase of the industrial sector for economic development; thus, waste generation and GHG emissions will increase proportionally. Table 4.16 shows $CH_4$ emissions ($ktCO_2$eq./year) from the wastewater sector in Cambodia

**Table 4.16:** $CH_4$ emissions from the wastewater sector in Cambodia [$ktCO_2$eq./year]

| Sectors/year | 2010 | 2030BaU | 2050BaU | 2030BaU /2010 | 2050BaU /2010 |
|---|---|---|---|---|---|
| Residential | 0.30 | 1.90 | 2.90 | 6.33 | 9.67 |
| Industrial | 0.10 | 0.40 | 1.40 | 4.00 | 14.00 |
| **Total** | **0.40** | **2.30** | **4.30** | **5.75** | **10.75** |

## 4.9 Discussion

### 4.9.1 GHG emissions and reductions and environmental benefits

The results of this study suggest that GHG emissions from the waste sector in Cambodia would increase significantly in 2030BaU (about 3.7 times) and 2050BaU (9.7 times) compared to 1,566$ktCO_2$eq./year in the base year. The results illustrate that $CH_4$ emissions from disposal sites of the residential sector (560$ktCO_2$eq./year) in 2030BaU in this study is very similar to those of the estimation by Environmental Protection Agency of United States of America (U.S.EPA) (500$ktCO_2$eq./year) in the same year (EPA, 2012). Table 4.17 shows comparisons of the projection of $CH_4$ emissions from disposal sites between this study and the U.S.EPA. Similarly, CH4 emissions from the wastewater sector of this study in 2030BaU is slightly bigger than those of the assessment by the U.S.EPA (EPA, 2012). This is due to the fact that the estimation under the U.S.EPA has limited access to available country information, for instance, population and other related parameters was referred to U.S. Census database (EPA, 2012), while this study projects based on the information of the existing Government's policies and strategies related to waste generation. Table 4.18 shows comparisons of the projections of $CH_4$ emissions from the wastewater treatment between this study and the U.S.EPA. Furthermore, it can be observed from the results that Cambodia can reduce GHG emissions from the waste sector through applying some appropriate low carbon measures through reducing amount of waste generation (reuse, reduce, and recycle, etc.), improving the efficiency of waste collection, expanding methane avoidance (renewable energy to replace fossil fuel), and composting, etc. In general, waste recycling is classified as the highest priority to reduce large amount of disposal wastes, which represent a potential for reducing GHG emissions. Indeed, the results of the present study show that waste recycling accounts for about 77% of total GHG emissions reduction in 2050 in Cambodia.

Additionally, waste offers a significant source of renewable energy. Through methane recovery, which accounts for about 22% of total GHG emissions reduction in 2050 in Cambodia, energy generated from methane combustion can displace other fossil fuels either as a process energy resource or as electricity. Besides, through biological treatment, organic wastes (food, wood, and garden waste) can be recovered and transformed into organic fertilizers. These processes can reduce GHG emissions by sequestering carbon in soils and adding soil nutrients. The organic waste in Cambodia is the largest component of waste ranging from 30-70% of total residential and commercial waste (about 66% in 2010). In this regard, when the organic component of waste is collected separately, it can contribute to reducing GHG emissions and improving soil quality. Figure 4.3 shows contribution of GHG emission reductions by different waste generation sectors in Cambodia.

It is argued that there is a need to consider the environmental, economic, and social aspects for waste management in order to reduce waste generation and GHG emissions. The assessment does not only concentrate on the amount of GHG reduction, but also other conditions such as possible implementation of each waste generation reduction option, direct and environmental costs, availability of land, etc. The selected integrated systems of waste management should contribute to both economic and environmental sustainability. Hence, additional studies are encouraged to assess the cost-benefit analysis of waste management options and GHG emission reduction potentials. The sound and strong policies and regulations of waste management are very important drivers to reduce waste generation and GHG emissions for Cambodia.

**Table 4.17:** Comparisons of $CH_4$ emissions from the disposal sites between this study and the U.S.EPA.

| Sectors/year | 2010 | 2030BaU | 2050BaU | 2030 (EPA, 2012) |
|---|---|---|---|---|
| Residential | 170 | 560 | 760 | 500 |
| Commercial | 170 | 410 | 640 | |
| Industrial | 1,110 | 3,360 | 4,540 | |
| Construction | 0 | 10 | 10 | |
| **Total** | **1,460** | **4,330** | **5,950** | |

**Table 4.18:** Comparisons of projected $CH_4$ emissions from the waste water treatment between this study and the U.S.EPA.

| Sectors/year | 2010 | 2030BaU | 2050BaU | 2030 (EPA, 2012) |
|---|---|---|---|---|
| Residential | 0.30 | 1.90 | 2.90 | 0.0 |
| Industrial | 0.10 | 0.40 | 1.40 | |
| **Total** | **0.40** | **2.30** | **4.30** | |

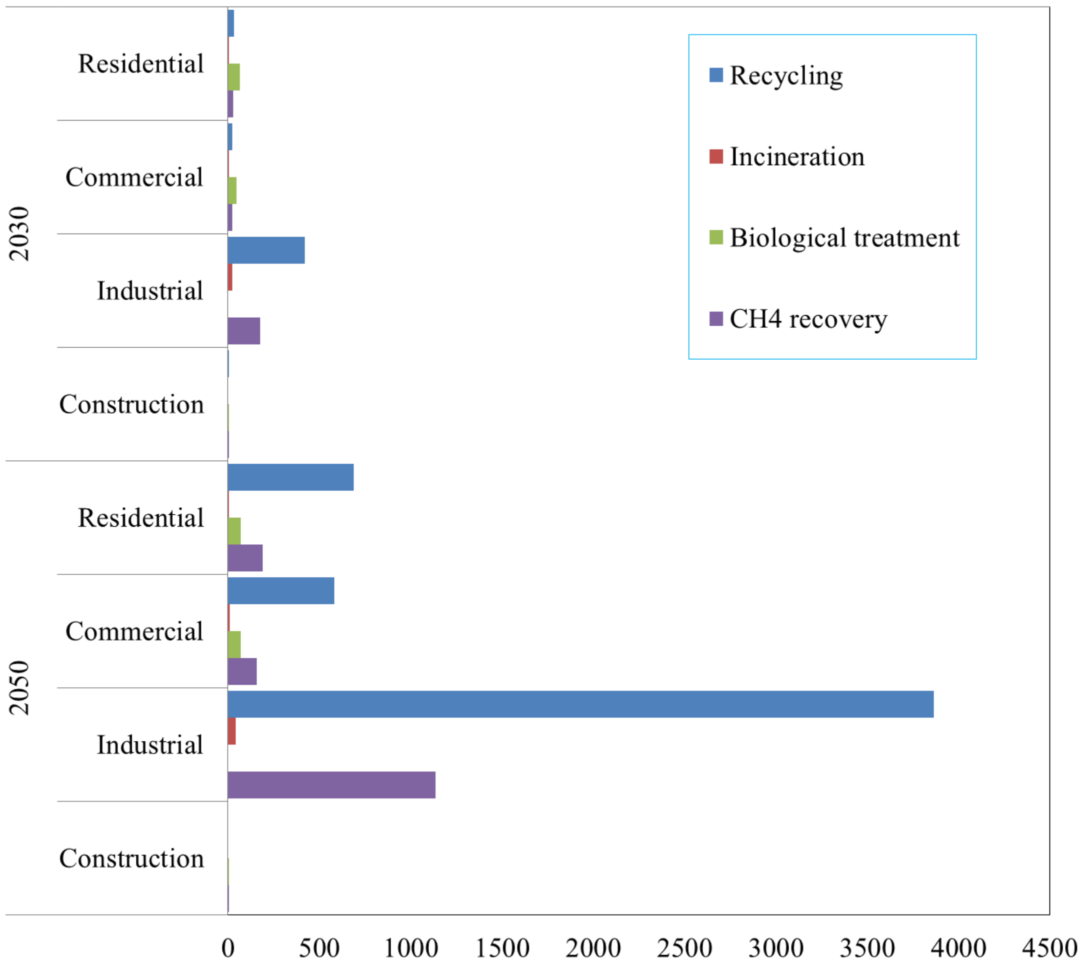


**Figure 4.3:** Contribution of GHG emissions reduction through applying some low carbon measures by sectors in Cambodia

### 4.9.2 Comparisons of waste generation and GHG emissions between Cambodia and some other Asian countries

As indicated in the results, waste generation and GHG emissions in Cambodia are expected to increase drastically in the future resulting from population growth, increased incomes of the people, and modern lifestyle. However, the projected per capita waste generation and GHG emissions in 2025 in Cambodia remain lower than those of some other countries in the region (see Table 4.19). The Table shows that Japan has the highest waste generation rate, followed by Singapore, Malaysia and Indonesia, accordingly. Meanwhile, Cambodia, Philippines, Thailand and Vietnam have similar generation rates between 0.52 and 0.64 kg/(capita.day).

Furthermore, since the organic fraction in waste shares more than 55% in Cambodia, Vietnam, Indonesia, and Malaysia, GHG emissions in these countries are also larger than those of other countries, which have lower organic fraction. In fact, Vietnam, Indonesia and Malaysia have the highest organic fraction (more than 60%), their GHG emissions are very high at 62,900, 73,300 and 61,000 kt$CO_2$eq./year, respectively, in 2025. It can be observed that Cambodia's per capita GHG remains lower than those of some other countries in the region in the same year (2025); however, GHG emissions without applying sound waste management are similar to those of Japan and almost double those of Singapore. This result clues that by taking account of low carbon measures, Cambodia can reduce quite large amount of GHG emissions (13% in 2030CM and 39% in 2050CM compared to those of the BaU levels).

**Table 4.19:** Comparisons of waste generation and GHG emissions in Cambodia and other Asian countries in 2025

| Countries | GDP per capita | | Population | | Waste generation rates (kg/(capita.day)) | | Organic fraction in waste[e] (%) | GHG emissions ($MtCO_2$eq./year) |
|---|---|---|---|---|---|---|---|---|
| | 2010[a] | 2025[a] | Urban[b] (% ) | Total[c] (million) | Generation rates (kg/(capita.day)) | Waste generation amount (ton/year) | | |
| Cambodia | 774 | 1,862 | 29.6 | 17.2 | 0.62[g] | 3,884,666 | 55 | 4,300[g] |
| Vietnam | 1,299 | 2,882 | 39.0 | 93.4 | 0.61[d] | 20,799,963 | 60 | 62,900[d] |
| Philippines | 1,998 | 3,261 | 74.3 | 107.7 | 0.52[b] | 20,435,766 | 41 | 12,900[h] |
| Indonesia | 2,913 | 5,765 | 60.7 | 253.6 | 0.76[b] | 70,351,414 | 62 | 73,300[h] |
| Thailand | 4,780 | 7,911 | 39.1 | 67.7 | 0.64[b] | 15,824,064 | 48 | 10,600[h] |
| Malaysia | 8,755 | 14,354 | 72.7 | 30.1 | 0.81[b] | 8,890,196 | 62 | 61,000[f] |
| Singapore | 45,995 | 62,473 | 100.0 | 5.6 | 1.10[b] | 2,236,355 | 44 | 2,100[h] |
| Japan | 43,049 | 50,102 | 100.0 | 127.1 | 1.70[e] | 78,865,550 | 26 | 4,300[h] |

[a] Projected Gross Domestic Product Per Capita (GDP per cap) for Baseline Countries/Regions (in 2005 dollars) 2000-2030 in 2014: ERS International Macroeconomic Data Set. www.ers.usda.gov/datafiles/.../ProjectedRealPerCapitaGDPValues.xls

[b] Nguyen and Schnitzer (2009)

[c] UN (2011 and 2013)

[d] Hoa and matsuoka (in press)

[e] Hoornweg and Bhada-Tata (2012)

[f] Siong *et. al.* (2013)

[g] This study

[h] EPA (2012)

## PART 5 TOTAL NATIONAL GHG EMISSIONS AND REDUCTIONS

It is witnessed that climate change risks and threats to Cambodia's economy, livelihoods, and ecosystem functions require to call for the need for integrated approaches to design a climate change policy aligning to the sustainable economic development agenda (MoE, 2013a). Although the country gives the priority to the climate change adaptation, some mitigation activities have been implemented. The country is also designed to balance between adaptation and mitigation. For instance, the Government is promoting the society toward a green, low carbon and climate resilient economy (MoE, 2013a and NCGG, 2013).

In order to estimate GHG emissions and reduction potentials in Cambodia, this study applies three quantitative models including the ExSS tool, the AFOLU-B model, and the ExSS/waste model. The results yield that total GHG emissions in Cambodia are projected to increase to about 20,245 (4.2 times) and 120,523 kt$CO_2$eq./year (24.9 times) in 2030BaU and 2050BaU, respectively, compared to those of 2010. However, they are projected to decrease to -17,794 and 33,057 kt$CO_2$eq./year in 2030CM and 2050CM, respectively. In the base year, the agriculture sector contributed to the biggest share of GHG emissions of around 82%, followed by the energy sector (13%), while the waste sector contributes the smallest emissions of around 5%. The results express that the agriculture sector remains the biggest share of GHG emissions of around 60%, followed by the energy sector of around 32%, while the waste sector attributes about 8% in 2030BaU. However, the energy sector becomes the largest emitter emitting about 53%, followed by the agriculture sector of around 38%, while the waste sector remains the smallest emissions of about 9% in 2050BaU. The results yield that the LULUCF sector is the net carbon sink and the sink capacity is expected to increase from around 27,082kt$CO_2$eq./year in 2010 to be a similar of around 52,826kt$CO_2$eq./year (about 2 times) in both 2030BaU and 2050BaU. The sink capacity in the LULUCF sector is expected to further increase to be a similar of roughly 61,715kt$CO_2$eq./year in 2030CM and 2050CM. The results indicate that per capita GHG emissions are projected to increase from about 0.35t$CO_2$eq./year in 2010 to about 1.10 and 5.49 t$CO_2$eq./year in 2030BaU and 2050BaU, respectively. Under low carbon measures, per capita GHG emissions are projected to decrease to a negative value of around -0.97t$CO_2$eq./year in 2030CM and to 1.51t$CO_2$eq./year in 2050CM. Table 5.1 shows detail GHG emissions and reductions by sectors (kt$CO_2$eq./year), while Figure 5.1

illustrates the contribution of GHG emissions and reduction potentials ($ktCO_2eq./year$).

The results illustrate that total GHG emissions of around 38,039 and 87,462 $ktCO_2eq./year$ are expected to reduce in 2030CM and 2050CM, respectively, through implementing some low carbon measures. Table 5.2 shows detail GHG reductions by sectors and by measures in 2030CM and 2050CM. The results also yield that the AFOLU sector is projected to contribute to the largest GHG reduction potentials of about 24,461$ktCO_2eq./year$ (64%), followed the energy sector of approximately 12,826$ktCO_2eq./year$ (34%), while the waste sector attributes about 2% in 2030CM; however, the energy sector is predicted to attribute to the highest reduction potentials of about 52,153$ktCO_2eq./year$ (59%), followed by the AFOLU sector of around 29,435$ktCO_2eq./year$ (34%), while the waste sector remains the smallest share of around 7% in 2050CM.

The results indicate that Cambodia becomes a net carbon sink, offsetting around 17,794$ktCO_2eq./year$ in 2030CM; this is because the LULUCF sector is already a net carbon sink in 2030BaU and the sink capacity will continue to increase in 2030CM. However, the results show that Cambodia becomes a net carbon emitter, emitting about 33,057$ktCO_2eq./year$ in 2050CM due to the tremendous increase of GHG emissions from the energy and waste sectors in 2050BaU. The results indicate that around 73% of GHG emissions are expected to reduce in 2050CM.

Besides, in order to analyse and examine factors that influence changes in the level of energy-related $CO_2$ emissions, a decomposition method is used (Shyamal and Rabindra, 2004; and Sheinbaum-Pardo *et al.*, 2012). Thus, this study uses a decomposition analysis to assess and quantify GHG emissions reduction by each low carbon measures. The detail decomposition analysis is shown in Table 5.3 and Table 5.4 in 2030CM and 2050CM, respectively. Table 5.3 suggests that non-energy related GHG reductions contributed the highest share of around 66% of total GHG emissions reduction, followed by energy efficiency equipment and vehicles (around 23%) in 2030CM, while fuel switch contributes the smallest share of about 0.5%. Conversely, energy efficiency equipment and vehicles attribute to the highest share of GHG emissions reduction of about 46%, followed by non-energy related GHG reductions of around 40% in 2050CM, while renewable energy in power generation shares the smallest GHG emissions reduction of around 2%.

The results of this study obviously argue that Cambodia has a big window of opportunity to reduce GHG emissions if the country shifts to a low carbon paradigm through introducing some low carbon measures, etc. Therefore, an adoption of a policy to design a low carbon development plan plays a critical role to achieve GHG emissions reduction target, simultaneously ensuring sustainable economic growth and environmental sustainability as well as promoting a society to be more resilient to the impacts of climate change.

**Table 5.1:** Total GHG emissions and reductions by sectors [kt$CO_2$eq./year]

| GHG emissions and reductions | 2010 | 2030BaU | 2030CM | 2050BaU | 2050CM |
|---|---|---|---|---|---|
| **The energy sector** | | | | | |
| Residential | 830 | 2,414 | 918 | 9,889 | 2,034 |
| Commercial | 217 | 1,433 | 482 | 3,663 | 1,298 |
| Industrial | 1,173 | 7,536 | 3,926 | 23,691 | 11,136 |
| Passenger transportation | 996 | 6,374 | 2,743 | 22,276 | 9,431 |
| Freight transportation | 1,004 | 5,521 | 2,383 | 31,806 | 15,273 |
| **Sub-total** | **4,221** | **23,277** | **10,451** | **91,325** | **39,172** |
| **The agricultural sector** | | | | | |
| Enteric fermentation | 4,326 | 6,015 | 4,728 | 10,826 | 8,509 |
| Manure management | 606 | 993 | 721 | 1,568 | 1,081 |
| Rice cultivation | 17,090 | 26,479 | 13,695 | 32,961 | 17,059 |
| Managed soil | 4,120 | 10,574 | 9,348 | 21,454 | 19,609 |
| **Sub-total** | **26,142** | **44,062** | **28,490** | **66,808** | **46,259** |
| **The LULUCF sector*** | | | | | |
| Changes in forest and other woody biomass stocks | -46,015 | -45,691 | -54,559 | -45,691 | -54,559 |
| Forest and grassland conversion | 18,933 | -7,135 | -7,156 | -7,135 | -7,156 |
| **Sub-total** | **-27,082** | **-52,826** | **-61,715** | **-52,826** | **-61,715** |
| **The waste sector** | | | | | |
| Residential | 262 | 951 | 826 | 2,326 | 1,535 |
| Commercial | 174 | 606 | 515 | 1,774 | 1,117 |
| Industrial | 1,127 | 4,160 | 3,627 | 11,082 | 6,661 |
| Construction | 3 | 14 | 12 | 34 | 28 |
| **Sub-total** | **1,566** | **5,731** | **4,980** | **15,216** | **9,341** |
| **Total** | **4,847** | **20,245** | **-17,794** | **120,523** | **33,057** |
| Per capita GHG emissions (t$CO_2$eq./person) | 0.35 | 1.10 | -0.97 | 5.49 | 1.51 |

**Table 5.2:** Quantitative GHG emissions reduction by sectors and measures [kt$CO_2$eq./year]

| GHG emissions reduction [kt$CO_2$eq./year] | 2030CM | 2050CM |
|---|---|---|
| **The energy sector** | | |
| Residential | 1,497 | 7,855 |
| Commercial | 951 | 2,365 |
| Industrial | 3,610 | 12,554 |
| Passenger transportation | 3,631 | 12,845 |
| Freight transportation | 3,138 | 16,533 |
| **Sub-total** | **12,826** | **52,153** |
| **The agricultural sector** | | |
| Daily spread of manure | 213 | 381 |
| Dome digester and biogas is used as energy | 60 | 106 |
| High genetic merit | 521 | 938 |
| Replacement of roughage with concentrates | 766 | 1,379 |
| Replace urea with ammonium sulphate | 1,483 | 1,846 |
| Midseason drainage in rice paddy | 8,595 | 10,699 |
| Off-season incorporation of rice straw | 2,683 | 3,339 |
| Convert fertilizational tillage to no-tillage | 24 | 17 |
| High efficiency fertilizer application | 1,227 | 1,814 |
| Tillage and residue management | 0 | 31 |
| Slow-release fertilizer | 0 | 0 |
| **Sub-total** | **15,572** | **20,550** |
| **The LULUCF sector** | | |
| Plantation-short rotation | 3 | 0 |
| Plantation-long rotation | 1 | 1 |
| Reforestation-fast growing species | 6 | 6 |
| Reforestation-slow growing species | 2 | 2 |
| Enhanced natural regeneration | 1 | 1 |
| Agro-forestry | 9 | 9 |
| Reduced impact logging | 8,866 | 8,866 |
| **Sub-total** | **8,889** | **8,886** |
| **The waste sector** | | |
| Residential | 126 | 791 |
| Commercial | 91 | 657 |
| Industrial | 532 | 4,420 |
| Construction | 2 | 6 |
| **Sub-total** | **751** | **5,874** |
| **Total** | **38,039** | **87,462** |

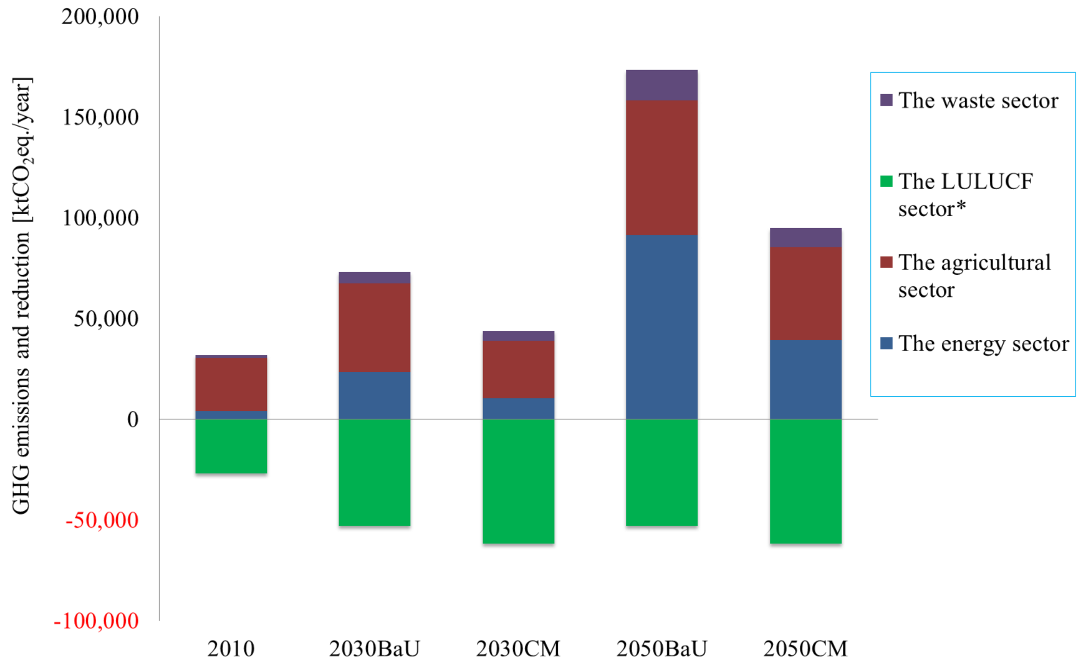


**Figure 5.1:** Contribution of GHG emissions and reductions ($ktCO_2eq./year$)

**Table 5.3:** Decomposition analysis for GHG emissions reduction in 2030CM

| Year | 2030BaU | 2030CM | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total GHG emissions ($ktCO_2eq./year$) | 20,245 | -17,794 | Distribution of GHG emission reductions in 2030CM | | | | | |
| | | | Renewable energy in power generation | Fuel switch | Energy efficiency equipment and vehicles | Modal shift | Improvement in energy intensity | Non-energy related GHG reductions |
| AFOLU | | | | | | | | 24,461 |
| Waste | | | | | | | | 751 |
| Residential | | | 184 | 49 | 1,009 | 0 | 255 | |
| Commercial | | | 183 | 44 | 572 | 0 | 152 | |
| Industrial | | | 132 | 10 | 2,319 | 0 | 1,149 | |
| Passenger transportation | | | 57 | 61 | 2,100 | 1,413 | 0 | |
| Freight transportation | | | 4 | 40 | 2,714 | 379 | 0 | |
| **Total GHG reduction ($ktCO_2eq./year$)** | | **38,039** | **560** | **204** | **8,714** | **1,793** | **1,555** | **25,212** |
| **Share** | | | **1.5%** | **0.5%** | **22.9%** | **4.7%** | **4.1%** | **66%** |

**Table 5.4:** Decomposition analysis for GHG emissions reduction in 2050CM

| Year | 2050BaU | 2050CM | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total GHG emissions ($ktCO_2eq./year$) | 120,523 | 33,060 | Distribution of GHG emission reductions in 2050CM | | | | | |
| | | | Renewable energy in power generation | Fuel switch | Energy efficiency equipment and vehicles | Modal shift | Improvement in energy intensity | Non-energy related GHG reductions |
| AFOLU | | | | | | | | 29,435 |
| Waste | | | | | | | | 5,874 |
| Residential | | | 631 | 464 | 5,867 | 0 | 893 | |
| Commercial | | | 483 | 46 | 1,440 | 0 | 396 | |
| Industrial | | | 350 | 775 | 7,968 | 0 | 3,462 | |
| Passenger transportation | | | 187 | 189 | 9,572 | 2,897 | 0 | |
| Freight transportation | | | 75 | 733 | 15,373 | 352 | 0 | |
| **Total GHG reductions ($ktCO_2eq./year$)** | | **87,462** | **1,726** | **2,207** | **40,220** | **3,248** | **4,751** | **35,310** |
| **Share** | | | **2%** | **3%** | **46%** | **4%** | **5%** | **40%** |

# PART 6 LOW CARBON DEVELOPMENT PLAN IN CAMBODIA

## 6.1 A design of low carbon development plan towards 2050 in Cambodia

The concept of the LCD doesn't only mean to reduce GHG emissions, but also to focus on a better energy efficiency improvement, which then may improve sustainable economic growth, energy security, and environmentally sound development. This concept could become a key driver to enable Cambodia to develop her economy in a low carbon manner and to achieve the sustainable development goals. The source of the power supply from renewable energy is considered as one of the best energy options to reduce $CO_2$ emissions in the energy sector. Japan has counted renewable energy as an alternative energy source after the nuclear disaster in 2011; and hydroelectricity is counted as the main source of energy supply (Oliver *et al.*, 2013). Likewise Japan, Cambodia has adopted hydropower as one of the major sources of the power supply in order to meet the increasing energy demand and to reduce GHG emissions (MME, 2014). Besides, the country developed national policy, strategy, and action plan on energy efficiency in 2013, aiming to introduce energy efficiency and energy saving technologies so as to reduce energy demand and $CO_2$ emissions and to provide reliable and affordable energy services in the most efficient and sustainable manner (MME, 2013). The Government also established a national transportation implementation plan in 2012 to address the issues through implementing vehicle inspection, regulation of second hand vehicles, eco-driving, road management, and infrastructure improvement (MPWT, 2013). On top of that, there are numbers of regulations, policies, and strategies have been formulated to ensure sustainable natural resources management, protection, and consumption on the one hand and to contribute to reducing GHG emissions on the other hand. For instance, the Government is promoting and implementing national forest programme (2010-2029) (RGC, 2010a) in order to increase forest cover by 60% by 2015, which, in turn, contributes significantly to reducing sources of GHG emissions and enhancing carbon stock and sequestration. The country also formulated sustainable agriculture and livestock management strategies, aiming to increase and improve agriculture and livestock production as well as to reduce GHG emissions (MAFF, 2013 and RGC, 2015a). Moreover, the country passed the sub-degree on municipal waste management (RGC, 2015b) and 3Rs strategy in order to reduce waste generation at sources and disposal at the landfill sites (MoE, 2009) in particular and to reduce GHG emissions in general.

The RGC realizes that the LCD is very important policy approach to address not only the environmental distress of climate change, but also the social, economic, cultural, and political challenges (MoE, 2013a). We need to develop the country on the basis of a close, reasonable, harmonious coordination of inclusive economic and social development, environmental sustainability, and cultural conservation as well as to make Cambodia a more liveable country to all her residents (RGC, 2009 and 2013b). Therefore, the formulation of a policy to design a low carbon development plan is regarded as one of the most important policy approaches to direct and encourage Cambodia to achieve the sustainable development objectives.

In May 2013, a taskforce who are representatives of the Ministry of Environment and the Royal University of Agriculture of Cambodia and Kyoto University, Institute for Global Environmental Strategies, and National Institute for Environmental Studies of Japan proposed qualitatively four policies (green environment; harmonization of green economy, society, and culture; blue economy; and eco-village) and twelve strategies (green energy, green technologies and investment, green building, green transportation, low carbon infrastructure, sustainable forest management, green agriculture management, sustainable waste management, green merchant marine and sustainable coastal zone management, green tourism management, green good governance and human resource development, and green financial mobilization), coupled with a list of actions for low carbon development strategy towards 2050 in Cambodia. It is available via “http://2050.nies.go.jp/report/file/lcs_asia/Cambodia.pdf.” It is noted that some actions are updated and added in response to the current situation. These policies, strategies, and actions were selected through intensive and subsequent discussion with key relevant stakeholders and fully supported by the leader of the Ministry of Environment of Cambodia. The current study is mainly designed to conduct a quantitative estimation of GHG emissions reduction of the proposed policies and strategies by using quantitative models such as ExSS tool, AFOLU-B model, and ExSS/waste model. They can directly and indirectly contribute to reducing GHG emissions; and they are very strong causal relationship. The absence of anyone of them, the proposed low carbon development strategy cannot fully and effectively be achieved. The effective implementation of these policies and strategies doesn’t only contribute to reducing

GHG emissions but also ensuring sustainable economic growth, environmental sustainability, low carbon society, and green job creation.

The results illustrate that total GHG emissions of around 38,039 (188%) and 87,462 kt$CO_2$eq./year (73%) are expected to reduce in 2030CM and 2050CM, respectively, from those of the BaU levels through implementing the four policies and twelve strategies, coupled with a list of actions. The policy on green environment attributes the largest GHG emissions reduction of about 25,212 (66.28%) and 35,310 kt$CO_2$eq./year (40.37%) of total GHG emissions reduction in 2030CM and 2050CM, respectively. It follows by the policy on harmonization of green economy, society, and culture contributing about 11,409 (29.99%) and 47,246 kt$CO_2$eq./year (54.02%) in 2030CM and 2050CM, respectively. The policy on eco-village shares GHG emissions reduction of around 1,417 (3.73%) and 4,907 kt$CO_2$eq./year (5.61%), while the policy on blue economy contributes indirectly to reducing GHG emissions in 2030CM and 2050CM, respectively. Furthermore, the results yield that the strategies on green agriculture management and sustainable forest management attribute about 15,572 (40.94%) and 8,889 kt$CO_2$eq./year (23.37%) of total GHG reductions in 2030CM, respectively, followed by green transportation of some 5,685kt$CO_2$eq./year (14.95%). However, the strategies on green transportation and green agriculture management contribute to around 25,761 (29.45%) and 20,550 kt$CO_2$eq./year (23.5%), respectively, followed by green energy of about 16,559kt$CO_2$eq./year (18.93%) in 2050CM. The results of the present study are expected to provide fundamental and useful insights for the Government to formulate a concrete and feasible climate change mitigation policy and low carbon development plan in the future. The detail low carbon development policies and strategies, coupled with a list of actions with quantitative GHG emissions reduction are shown in Table 6.1.

**Table 6.1:** Quantitative GHG emissions reduction by each policy and strategy, coupled with actions [$ktCO_2$eq./year]

| Four policies and twelve strategies | Actions | Quantitative GHG reductions | | | |
|---|---|---|---|---|---|
| | | 2030CM | Share (%) | 2050CM | Share (%) |
| **POLICY ON GREEN ENVIRONMENT** | | **25,212** | **66.28%** | **35,310** | **40.37%** |
| **Sustainable forest management** | | **8,889** | **23.37%** | **8,886** | **10.16%** |
| | Reductions of impact logging; | 8,866 | | 8,866 | |
| | Agro-forestry plantation; | 9 | | 9 | |
| | Reforestation of fast and slow growing species; | 8 | | 8 | |
| | Plant short and long rotation forest; and | 4 | | 1 | |
| | Natural forest regeneration enhancement. | 1 | | 1 | |
| **Strategy on sustainable waste management** | | **751** | **1.98%** | **5,874** | **6.72%** |
| | Install environmentally sound technology at landfill sites for methane recovery; | 196 | | 1,107 | |
| | Introduce 3Rs principles to minimize waste and reduce emissions; | 412 | | 3,814 | |
| | Introduce waste-to-energy technologies (incineration); | 29 | | 41 | |
| | Introduce biological treatment (composting); | 98 | | 106 | |
| | Waste separate and proper control of second hand goods import (indirect contribution); | | | | |
| | Promote self-governance and leadership to improve de-centralized coordination of waste management (indirect contribution); and | | | | |
| | Introduce and install wastewater treatment plants. | 17 | | 806 | |
| **Strategy on green agriculture management** | | **15,572** | **40.94%** | **20,550** | **23.50%** |
| | Midseason drainage; | 8,595 | | 10,699 | |
| | Off-season incorporation of rice straw; | 2,683 | | 3,339 | |
| | Replace urea with ammonium Sulfate; | 1,483 | | 1,846 | |
| | High efficiency fertilizer application; | 1,227 | | 1,814 | |
| | No-tillage; | 24 | | 48 | |
| | Replace roughage with concentrates; | 766 | | 1,379 | |
| | High genetic species; | 521 | | 938 | |
| | Daily spread of manure; and | 213 | | 381 | |
| | Construct dome digester. | 60 | | 106 | |
| **POLICY ON HARMONIZATION OF GREEN ECONOMY, SOCIETY, AND CULTURE** | | **11,409** | **29.99%** | **47,246** | **54.02%** |
| **Strategy on green transportation** | | **5,685** | **14.95%** | **25,761** | **29.45%** |
| | Use of public transport system; | 1,470 | | 2,897 | |
| | Introduce hybrid and biodiesel motorized vehicles; | 101 | | 1,110 | |
| | Low-emission and energy-efficient vehicles; and | 2,714 | | 15,373 | |
| | Eco-driving and vehicle technical inspection. | 1,400 | | 6,381 | |
| **Strategy on green energy** | | **4,281** | **11.25%** | **16,559** | **18.93%** |
| | Use of renewable energy; | 253 | | 1,284 | |
| | Reduce transmission losses and own uses; and | 560 | | 1,726 | |
| | Smart appliances and home automation (energy efficiency improvement and energy saving technology). | 3,467 | | 13,548 | |
| **Strategy on green tourism management (indirect contribution)** | | | | | |
| | Promote and implement clean city, clean resort, and good services; | | | | |
| | Promote tourist attraction through introducing cultural heritages and natural tourism (eco-tourism); | | | | |
| | Promote group tour with comfortable public transportation system; | | | | |
| | Promote green flag competition and green award for major tourism destination cities and provinces; and | | | | |
| | Introduce and encourage tourists to recycle waste, to minimize and manage waste, and to reduce emissions. | | | | |
| **Strategy on green good governance and human resource development (indirect contribution)** | | | | | |
| | Integrate green concept into academic curriculums; | | | | |
| | Introduce and improve green institutional management and arrangement; | | | | |
| | Implement green management initiatives and green jobs; | | | | |
| | Introduce and encourage green concept into local communities for natural resource management; and | | | | |
| | Enhance and increase human resource development considering youth and gender participation for low carbon society. | | | | |

| | | | | |
|---|---|---|---|---|
| **Strategy on green technologies and investment** | **1,443** | **3.79%** | **4,927** | **5.63%** |
| Green industries and industrial ecology; | 572 | | 1,440 | |
| Green technologies transfer (cleaner production); | 872 | | 3,486 | |
| Green business competition and green credit (indirect contribution); and | | | | |
| Encourage and incentivize the investment in effective environmental protection and natural resources management. | | | | |
| **Strategy on green financial mobilization (indirect contribution)** | | | | |
| Introduce green financial incentives; | | | | |
| Adopt green budget reform; | | | | |
| Introduce and implement feed-in-tariff approach for renewable energy investment; | | | | |
| Implement payment for environmental services based on polluter pays principle; | | | | |
| Conduct financial mobilization from development partners for green activities and development (*e.g.* climate change mitigation); and | | | | |
| Develop a sound market-based financial system to support resource mobilization, and effective financial resource allocation. | | | | |
| **POLICY ON BLUE ECONOMY** | | | | |
| **Strategy on green merchant marine and sustainable coastal zone management (indirect contribution)** | | | | |
| Introduce emissions standard in maritime transportation through inspection and maintenance system; | | | | |
| Promote integrated coastal zone management and mangrove plantation; | | | | |
| Develop and enforce the ballast water management to control marine invasive species; | | | | |
| Conduct proper oil resource exploration and exploitation and develop oilspill management regulation and policy; | | | | |
| Develop and implement sustainable development strategy for the sea of East Asia; | | | | |
| Promote marine biodiversity conservation and management, for instance, magrove forest, coral reefs and seagrass, etc.; | | | | |
| Conduct in-depth assessment of coastal erosion and develop its management strategy; and | | | | |
| Develop and implement land-based pollution management strategy. | | | | |
| **POLICY ON ECO-VILLAGE** | **1,417** | **3.73%** | **4,907** | **5.61%** |
| **Strategy on low carbon infrastructure** | **1,084** | **2.85%** | **3,618** | **4.14%** |
| Use the freight train for long-distance shipment; | 384 | | 427 | |
| Design comfortable and safe pavements; and | 700 | | 3,191 | |
| Design a standard road facility for different transport mode (indirect contribution). | | | | |
| **Strategy on green building** | **333** | **0.88%** | **1,289** | **1.47%** |
| Energy saving in households and institutions; | 155 | | 625 | |
| Green building designs and construction; and | 76 | | 268 | |
| Energy saving appliances in building designs. | 102 | | 396 | |
| **Total GHG reductions (kt$CO_2$eq./year)** | **38,039** | **100%** | **87,462** | **100%** |

Comprehensive and subsequent descriptions of both qualitative and quantitative assessment of GHG emissions reduction by each policy and strategy, coupled with action are as follows.

### 6.1.1 Policy on green environment

This policy covers three strategies, including sustainable forest management, sustainable waste management, and green agriculture management. The effective implementation of this policy, total GHG emissions of around 25,212 (66.28%) and 35,310 kt$CO_2$eq./year (40.37%) are expected to reduce in 2030CM and 2050CM, respectively. They include:

**STRATEGY ON SUSTAINABLE FOREST MANAGEMENT**

Forests provide significant resources, functions, and services such as wood and forest by-products, recreational opportunities, wildlife habitat, water and soil conservation, a filter for pollutants, producing oxygen, and absorbing $CO_2$ emissions (RGC, 2010a). The Government has made significant efforts to maintain forest cover of 60% by 2015 (RGC, 2011) and the national forest programme (2010-2029) was developed in which the REDD-plus schemes have been implemented (RGC, 2010a). This study is expected that the introduction of the strategy on sustainable forest management can help not only increase forest cover, but also reduce GHG emissions and balance forest ecosystem. The effective implementation of this strategy, similar GHG emissions of about 8,889kt$CO_2$eq./year or about 23.37% and 10.16% are expected to reduce in 2030CM and 2050CM, respectively, and the mitigation measures can be applied with the cost of less than 50USD/t$CO_2$eq. Detail low carbon actions, coupled with quantitative GHG emissions reduction are shown in Table 6.2.

**Table 6.2:** Strategy on sustainable forest management and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Effectively implement forest logging management and improvement | 8,866 | 8,866 |
| 2) | Encourage the application of agro-forestry, which can also provide agriculture products for household consumption | 9 | 9 |
| 3) | Promote reforestation of fast and slow growing species, including commercial plantation | 8 | 8 |
| 4) | Promote forest plantation of short and long rotation | 4 | 1 |
| 5) | Effective law enforcement to avoid illegal forest land encroachment in order to enhance natural regeneration | 1 | 1 |
| **Total GHG emissions reduction** | | **8,889** | **8,886** |

**Photo 15:** Tree plantation during the Arbor Day (Source: Mr. Kosal)

**Photo 16:** Forest regeneration measurement

**STRATEGY ON GREEN AGRICULTURE MANAGEMENT**

The agricultural sector plays a vital role in Cambodia, where around 80% of Cambodians are relying on (MAFF, 2011). The stable and steady growth of Cambodia's economy is largely attributed to the continued good performance of this sector (RGC, 2013) and the Government is promoting to export of at least one million ton of milled rice by 2015 (RGC, 2010). Besides, so as to provide sufficient and safe food supply, ensure food security, and improve incomes of the people, Cambodia developed national strategic planning framework for livestock (2015-2025) (RGC, 2015). The implementation of this strategic planning framework will also increase meat productivity and improve the livelihood condition of the rural communities. The introduction of the strategy on green agriculture management is expected not only to help increase the agriculture products, but also to reduce GHG emissions and improve soil quality. The results of this study indicate that the effective implementation of this strategy, GHG emissions of around 15,572 and 20,550 kt$CO_2$eq./year or approximately 40.94% and 23.50% are expected to reduce in 2030CM and 2050CM, respectively. The detail low carbon actions, coupled with quantitative GHG emissions reduction are shown in Table 6.3.

**Table 6.3:** Strategy on green agriculture management and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Implement midseason drainage in rice paddy, which involves the removal of surface floodwater from the rice crop for about seven days toward the end of tilling. It aerates the soil and shifts drainage time from vegetative period to reproductive one and helps reduce $CH_4$ production and emission (ClimateTech Wiki, n.d.) | 8,595 | 10,699 |
| 2) | Introduce off-season incorporation of rice straw, which is the application of rice straw in the fallow period, would significantly reduce $CH_4$ emissions. On this, rice straw is best applied to dry soil in the off-season and emits even less $CH_4$ if composted (Richards and Sander, 2014) | 2,683 | 3,339 |
| 3) | Encourage the replacement of urea with ammonium Sulfate to suppress $CH_4$ production | 1,483 | 1,846 |
| 4) | Promote the high efficiency fertilizer application, which is required to apply nitrogen fertilizer in three smaller increments during crop uptake period to better match nitrogen application with crop demand and to reduce nitrogen availability for leaching, nitrification, denitrification | 1,227 | 1,814 |
| 5) | Introduce the conversion from tillage to no-tillage, which is applied where soils are disturbed and less and more crop residue is retained. Soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion | 24 | 48 |
| 6) | Introduce the replacement of roughage with concentrates, which is the most promising and cost-effective way to reduce $CH_4$ emissions from cattle, is to enhance productivity by improving feed quality. $CH_4$ production with high-concentrate feed is lower than that with high-roughage feed. Feeding starchy crop waste is also an effective way to reduce $CH_4$ emissions from ruminants (Shibata and Terada, 2009) | 766 | 1,379 |
| 7) | Introduce high genetic species, which involves with the improvement of the genetic merit of dairy cows through the import of Holstein genetic material for use on native dairy breeds. It increases average yield in a dairy herd | 521 | 938 |
| 8) | Encourage the daily spread of manure where the manure is routinely removed from a confinement facility and is applied to crop land or pasture within 24 hours of excretion | 213 | 381 |
| 9) | Introduce and encourage the construction of dome digester (bio-digester) and biogas to use as energy sources, which generate biogas for cooking and lighting, while the effluence can be used as organic fertilizer for vegetable and other agriculture crops | 60 | 106 |
| **Total GHG emissions reduction** | | **15,572** | **20,550** |

**Photo 17:** Methane gas generated from bio-digester (Source: Mr. Chanvibol)

**Photo 18:** Rice cultivation

**STRATEGY ON SUSTAINABLE WASTE MANAGEMENT**

Increases in population and economic growths, rapid urbanization and industrial development, and limited national regulations, policies, and strategies for waste management are the major causes of waste generation in Cambodia. Several national regulations, polices, and strategies have been developed to address waste management challenges; however, none of them address GHG emissions and reductions. In order to reduce GHG emissions, this study proposes a strategy on sustainable waste management. The results show that the effective implementation of this strategy, GHG emissions of around 751 and 5,874 kt$CO_2$eq./year or about 1.98% and 6.72% are expected to reduce in 2030CM and 2050CM, respectively. This strategy will also contribute to ensuring effective and sound waste management as well as to providing economic benefit through waste composting and recycling, etc. The detail low carbon actions, coupled with quantitative GHG emissions reduction are shown in Table 6.4.

**Table 6.4:** Strategy on sustainable waste management and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Develop environmentally sound technology landfill sites through waste management strategy/plan, waste collection, and segregation | 196 | 1,107 |
| 2) | Minimize waste and by-products and maximum use of renewable resources by implementing 3Rs principle | 412 | 3,814 |
| 3) | Introduce waste-to-energy technologies (incineration) | 29 | 41 |
| 4) | Introduce biological treatment (composting) | 98 | 106 |
| 5) | Apply environmentally sound waste management through allocation of waste deposal/storage and proper control of second hand goods import | | |
| 6) | Promote local level self-governance and leadership to improve de-centralized coordination of waste management and segregation | | |
| 7) | Introduce and install waste water treatment plants | 17 | 806 |
| **Total GHG emissions reduction** | | **751** | **5,874** |

**Photo 19:** Making compost from organic waste (Source: Mr. Bol)

**Photo 20:** Wastewater treatment pond (Source: MoE)

### 6.1.2 Policy on harmonization of green economy, society, and culture

This policy consists six strategies, including green transportation, green energy, green tourism management, green good governance and human resource development, green technologies and investment, and green financial mobilization. The effective implementation of this policy, total GHG emissions of around 11,409 (29.99%) and 47,246 kt$CO_2$eq./year (54.02%) are expected to reduce in 2030CM and 2050CM, respectively. They include:

**STRATEGY ON GREEN TRANSPORTATION**

Cambodia is facing many challenges in the transportation sector, such as traffic jam, limited public transportation, and traffic violation, etc. (MPWT, 2013). The Government is managing to solve such a difficult situation through enforcing road safety related regulations, constructing sky bridges, and introducing public buses and trains, etc. The Government established a national transportation implementation plan for vehicle inspection, regulation of second hand vehicles, eco-driving, road management, and infrastructure improvement (MPWT, 2013). The Government has also encouraged the use of public transportation system such as buses and trains, especially in urban areas (RGC, 2014). This study expects that the implementation of the strategy on green transportation does not only help address traffic concerns, but also mitigate GHG emissions. This strategy is expected to reduce GHG emissions by around 5,685 and 25,761 kt$CO_2$eq./year or about 14.95% and 29.45% of total GHG emissions reduction in 2030CM and 2050CM, respectively. A package of low carbon actions, coupled with quantitative GHG emissions reduction is shown in Table 6.5.

**Table 6.5:** Strategy on green transportation and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Promote public transportation system (energy efficient urban mass transportation) in major cities by intensive urban mass transit facilities | 1,470 | 2,897 |
| 2) | Introduce hybrid and biodiesel motorized vehicles | 101 | 1,110 |
| 3) | Introduce low-emission and energy-efficient vehicles | 2,714 | 15,373 |
| 4) | Promote eco-driving to save energy and motorized vehicle technical inspection | 1,400 | 6,381 |
| **Total GHG emissions reduction** | | **5,685** | **25,761** |

**Photo 21:** Introduce public buses in Phnom Penh city


**Photo 22:** Introduce solar electric buses in Phnom Penh city

## STRATEGY ON GREEN ENERGY

The increases in population and economic growths result in increasing energy demand in Cambodia. In response, the Government adopted the best alternative options for more constant, reliable, and affordable sources of energy by shifting from the biomass-based energy supply to more advanced one. Besides, the Government developed national policy, strategy, and action plan on energy efficiency to reduce energy demand and $CO_2$ emissions and at the same time to provide reliable and affordable energy services to all of the end users in the most sustainable manner (MME, 2013). In the present study, the strategy on green energy focuses on energy efficiency improvement in residential, commercial, and industrial sector; fuel switch; and reduction of transmission losses and own uses in the power sector. The effective implementation of this strategy, about 4,281 and 16,559 kt$CO_2$eq./year or about 11.25% and 18.93% of total GHG emissions reduction in 2030CM and 2050CM, respectively, are projected to reduce. The detail low carbon actions, coupled with quantitative emissions reduction are shown in Table 6.6.

**Table 6.6:** Strategy on green energy and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Encourage the use of renewable energy through the construction of hydropower plants and installation of solar, wind, mini-hydro, tidal, and biogas/biomass, and so forth | 253 | 1,284 |
| 2) | Improve the quality of electricity distribution lines through reducing transmission losses and own uses | 560 | 1,726 |
| 3) | Promote the use of smart appliances and home automation systems including energy-saving and energy efficient appliances, power control devices, and electricity appliance maintenance | 3,467 | 13,548 |
| **Total GHG emissions reduction** | | **4,281** | **16,559** |

**Photo 23:** Hydropower construction for power generation (Source: MoE)

**Photo 24:** National grid improvement to avoid transmission loss

## STRATEGY ON GREEN TOURISM MANAGEMENT (INDIRECT CONTRIBUTION)

The tourism sector represents about 5% of world GDP and contributes to about 8% of total employment in 2010 (UNEP, 2011). This sector is identified as one of the priority sectors for socio-economic development, job creation, revenue generation, the improvement of people's livelihood, and poverty alleviation of Cambodia. Numbers of tourists to visit Cambodia have increased dramatically from around 466 thousand in 2000 to more than 4.5 million in 2014. (MoT, 2015). It is projected that Cambodia will receive about 7 million international tourists together with approximately 8 to 10 million domestic tourists by 2020 (MoT, 2012). The annual tourism revenue for national economy will soar up to around 5 billion dollars and create around 800 thousand jobs.

There are different assessments of consumptions in the tourism sector globally but limited to Cambodia. Peeters *et al.*, (2010) released that energy use in hotels range between 0.6 to 6 kgoe/(person.night). Meanwhile, water consumption varies between

100 and 2,000L/(person.night) (Gossling, 2005). Every international tourist in Europe generates solid waste of at least 1kg/(person.day), and up to 2 kg/(person.day) for the U.S.A (UNEP, 2003). While, CalRecovery and UNEP (2005) investigated that waste generation varies for different countries, *e.g.* Austria (1.18 kg/(person.day)), Mexico (0.68 kg/(person.day)), and India (0.4 kg/(person.day)).

Besides, it is assessed that the tourism sector is estimated to create about 5% of total GHG emissions, primarily from tourist transportation (75%) and accommodation (21%) in 2005. A globally-averaged tourist journey is estimated to generate about 0.25t$CO_2$ (UNWTO and UNEP, 2008). In order to reduce consumptions in the tourism sector, it is advised to invest in energy-efficient design and equipment to lower electrical consumption and reduce $CO_2$ emissions (Six Senses, 2009); water-saving technologies, grey water reuse, and rainwater collection and management (Fortuny *et al.*, 2008), and improved waste management (Hamele and Eckardt, 2006).

For Cambodia, there is no assessment of consumptions in the tourism sector. In order to attract tourists and address environmental concerns, the Government is planning to implement the measures leading to greenness, cleanliness, and sanitation as well as encourage the implementation of sound solid and liquid waste management. The Government will also restore and construct more infrastructures for transportation facilitation and reduce traffic congestion. Besides, the Government obviously indicates that the sustainable development of tourism plays a crucial role to maintain, protect, and conserve cultural and natural resources, as well as to mitigate climate change. In order to contribute to achieving GHG emissions reduction target, this study proposes green tourism management strategy. The implementation of this strategy doesn't only indirectly attribute to reduce GHG emissions but also create green jobs and local communities' livelihoods.

Green tourism in this study refers to tourism activities that can be maintained, or sustained social, economic, cultural, and environmental development and management. It is encouraged to use more renewable energy and energy efficiency equipment; consume less water; minimize waste generation; conserve biodiversity, cultural heritage and traditional values; generate local incomes; and integrate local communities with a view to improving livelihoods and reducing poverty. The quantitative GHG emissions reduction through implementing this strategy is not precisely assessed; however, the effective implementation of this strategy plays a critical role to meet the emissions reduction target for this study. Therefore, a number of low carbon actions under this strategy are proposed as follows.

1) Promote and implement clean city, clean resort and good services;
2) Promote tourist attraction through introducing cultural heritages and natural tourism (eco-tourism)- Cambodia-Kingdom of Wonder;
3) Promote group tour with comfortable public transportation;
4) Promote and advise tourists to save electricity and water consumption and to minimize waste generation;
5) Encourage tourists to recycle waste and to reduce emissions;
6) Encourage the hotel and guest owners to use renewable energy (solar power) to generate electricity; and
7) Promote green flag competition and green award.

**Photo 25:** Angkorwat temple (cultural tourism) (Source: Ms. Vanna)

**Photo 26:** Water birds at Tonle Sap great lake (ecotourism) (Source: Mr. Kimsreng)

## STRATEGY ON GREEN GOOD GOVERNANCE AND HUMAN RESOURCE DEVELOPMENT (INDIRECT CONTRIBUTION)

The Government regards good governance as the core of achieving social justice and sustainable and equitable socio-economic development. Some key reform programmes have firmly been declared and implemented including public financial management reform, land reform, and forestry and fisheries reform so as to strengthen the capacity, efficiency, and quality of public services to raise public confidence and to respond to the needs and aspirations of the people and business communities (RGC, 2013). Besides, the Government counts the development of high quality and capable human resources with high standards of work ethics as an important instrument to support economic growth and competitiveness of the country. Human resource development, especially for the youth, will target capacity building without gender discrimination. In addition, the Government considers youths as the pillars and backbone of the nation and as potential successors to preserve the past achievements and to achieve socio-economic development in the future. They are encouraged to participate in the development so that they will have positive image and avail themselves of opportunities to make use of their talents in the decision making process and in the development of the family, community, and country (UYFC, 2016). For instance, over past several years, youths play very active and prominent role in the society under the leadership of the president of union of youth federations of Cambodia (UYFC). They have voluntarily joined various environmental and natural resources management activities such as forest plantations, waste collection at the public areas, traffic control management, and climate change related trainings and campaigns, etc.

In this study, green good governance and human resource management refer to governance, management, and leadership of both institution and legal entity to promote green investment and green jobs creation, green economic management, green environment and natural resources management, green education and vocational training, and green technology management, etc. (NCGG, 2013). This concept is expected to be integrated into Government's institutional and human capacity development at all levels, academia, private sectors, and other related stakeholders in order to ensure transparency of management, leadership, responsibility, accountability, and effectiveness. The quantitative GHG emissions reduction through implementing this strategy is not precisely assessed in this study; however, it plays very important role to contribute to achieving the emissions reduction target. A number of low carbon actions under this strategy include:

1) Integrate green concept into curriculum from primary education to universities as well as vocational training;
2) Introduce and improve the green institutional management and arrangement;
3) Implement green management initiatives, intellectual capital, and green jobs;
4) Introduce and encourage green concept into local communities to seek their participation for environmental protection and natural resource management;
5) Increase human resources development throughout the country considering youth and gender participation for low carbon society; and
6) Engage youths in natural resources management and environmental sanitation.

**Photo 27: H.E. Hun Many,** President of UYFC participated a campaign: No plastic bag waste in Cambodia (Source: MoE)

**Photo 28:** Waste collection campaign in Phnom Penh city (Source: MoE)

**STRATEGY ON GREEN TECHNOLOGY AND INVESTMENT**

Technology innovation is considered as an important tool to reduce GHG emissions. It is clearly stated under the Paris agreement that Parties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce GHG emissions (Article 10 of Paris agreement). It is suggested financial support shall be provided to developing country Parties for strengthening cooperative action on technology development and transfer.

The Government pointed out its commitment to improving business climate through enhanced regulatory framework, promotion of innovation and technology, and increased access to finance. It is intended to prepare science and technology policy to increase research and development capability to respond to the needs of national development. The Government will enhance knowledge and human resource capacity in science and technology, especially in the priority sectors of development. The Government is promoting green technology and investment through encouraging investors to invest capital in green agriculture, industry, transportation, energy, and construction, etc. (NCGG, 2013). The implementation of the strategy on green technology and investment is expected to reduce GHG emissions by around 1,443 and 4,927 kt$CO_2$eq./year or around 3.79% and 5.63% of total GHG reductions in 2030CM and 2050CM, respectively. A package of low carbon actions, coupled with quantitative emissions reduction is shown in Table 6.7.

**Table 6.7:** Strategy on green technology and investment and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Promote green industries and industrial ecology | 572 | 1,440 |
| 2) | Implement transfer of green technologies such as cleaner production, sustainable product innovation, renewable energy utilization | 872 | 3,486 |
| 3) | Promote green business competition and green credit (indirect contribution) | | |
| **Total GHG emissions reduction** | | **1,443** | **4,927** |


**Photo 29:** Biomass gasification for electricity generation of a rice-mill company (Source: MME)

**Photo 30: H.E. Say Samal**, Minister of Environment visited electric motorbikes in Malaysia (white shirt, no tie)

## STRATEGY ON GREEN FINANCIAL MOBILIZATION (INDIRECT CONTRIBUTION)

The Government of Cambodia succeeded in maintaining macroeconomic stability and as a consequence, the economy managed to achieve high economic growth of more than 7% after the near stagnation of 2009. Cambodia has developed the financial sector to be more broad-based, diversified, deepened, sound and effective, based on market principles to support sustainable economic growth and poverty reduction (RGC, 2013). For instance, financial sector development strategy 2011-2020 (FSDS) is designed to respond to changing conditions in the economic, social, and political situation; to financial industry developments; and to the changes and challenges that result from Cambodia's increasing integration into the regional and global markets (MEF, 2012). The country has made a gradual progress in integrating climate change into budgeting through the development of a climate change financing framework. An assessment released that Cambodia will require about 1.27 billion USD up to 2018 to address climate change. The same report estimated that in 2012, expenditure on climate related policies and actions represented about 6.5% of public expenditure, or 1.31% of national GDP. There is a plan to increase the ratio of climate expenditure on GDP from an estimated 1.39% in 2015 to 1.5% in 2018 (INDCs, 2015).

As far as the financial support is concerned, developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention (Article 9 of Paris agreement). As a member of the UNFCCC, Cambodia has received continuous financial support from development partners and donor countries to build climate change institution and human capacity and to implement some climate change related projects and activities. Cambodia has made progress for direct access to the Green Climate Fund (GCF), which may become the principal vehicle for climate finance in the future. However, Cambodia has not developed any concrete financial policy or strategy to address a specific climate change mitigation, let alone the green financial mobilization. Therefore, there is a need to take this policy into account in the future.

Green financial mobilization refers to the investment in renewable energy and clean energy technologies, low carbon infrastructures, sustainable agriculture, sustainable natural resources management (forestry), and sound waste management, etc. For the purpose of the current study, the quantitative GHG emissions reduction through implementing green financial mobilization strategy is not precisely assessed; however, it plays a vital role to contribute to achieving emissions reduction target. Moreover, the amount of money required for implementing this strategy in order to achieve the GHG emissions reduction target is not assessed as well. Under this strategy, a number of low carbon actions are proposed including:

1) Green financial incentives including green tax and subsidy;
2) Adoption of green budget reform, especially for the investment in low carbon related projects;
3) Introduce and implement feed-in-tariff approach for renewable energy investment;
4) Implement payment for environmental services (PES) based on polluter pays principle to promote the internalization of environmental costs;
5) Conduct fund mobilization from development partners for green development;

and

6) Develop a sound market-based financial system to support resource mobilization, effective financial resource allocation.

### 6.1.3 Policy on blue economy

This policy covers only the strategy on green merchant marine and sustainable coastal zone management. The implementation of this policy is expected to indirectly contribute to reducing GHG emissions. The detail explanation of this strategy is as follow.

**STRATEGY ON GREEN MERCHANT MARINE AND SUSTAINABLE COASTAL ZONE MANAGEMENT (INDIRECT CONTRIBUTION)**

The seas of Cambodia are part of the Gulf of Thailand, which can provide ship navigation navigated millions tonnes of containerized cargo per year. The Cambodia coastline of 435km long is rich in mangrove forests, coral reefs, seagrass beds and other coastal ecosystems, which provide significant goods and services. The coastline is a beautiful tourist area with white sand and fresh air, which was ranked as the Most Beautiful Bays of the World in 2011. Apart from marine ecosystems, there are oil resources and other important minerals under the sea. The Cambodia coastal zones have been impacted by various activities such as expansion of cities, cultivation of forestlands, cutting of mangrove forest for businesses, dredging of sand, and mining, etc. (RGC, 2012b). Besides, it is severely affected by climate change leading to sea-level rise, increased seawater temperature, and acidification. In response, the Government has established several major institutions and coordinating bodies in order to protect and conserve the coastal and marine resources. Moreover, many regulatory frameworks, policies, strategies, plans, and guidelines related to coastal zone development and management have been developed including Law on environmental protection and natural resources management in 1996, Law on protected areas in 2008, national policy on coastal development and management, national strategic plan for land based pollution management (2006-2010), national policy and guideline on the use of dispersants in 2008, sustainable development strategy for the seas of East Asia (SDS-SEA) in Cambodia in 2013, etc. Recently, the Government adopted national strategy and action plan for coastal zone management (2014-2016) under the mangroves for the future initiative (MFF) in order to promote healthy coastal ecosystems through a partnership-based, people-focused, policy-relevant and investment-orientated approach, which builds and applies knowledge, empowers communities and other stakeholders, enhances governance, secures livelihoods, and increases resilience to natural hazards and climate change (MoE, 2013b). However, it can be observed that there is no regulation, policy or strategy dealing directly with merchant marine and sustainable coastal zone management to address climate change. Therefore, this study proposes a strategy on green merchant marine and sustainable coastal zone management in order to contribute to reducing GHG emissions, ensuring effective management and conservation of the coastal zones, and improving livelihoods of the people. It is noted that GHG emissions and reductions from the maritime transportation sector are excluded in this study, while GHG reductions through mangrove forest conservation and plantations are considered in the sustainable forest management strategy. The implementation of this strategy is expected to indirectly contribute to reducing GHG emissions in this study; however, without this strategy, GHG emissions reduction target cannot be achieved. A number of low carbon actions are proposed under this strategy as follows:

1) Introduce emission standard in maritime transportation through inspection and maintenance system;
2) Promote integrated coastal zone management and mangrove plantation;
3) Conduct proper oil resource exploration and exploitation and develop oil spill management regulation and policy;
4) Develop and enforce the ballast water management to control marine invasive species;
5) Enhance the implementation of sustainable development strategy for the seas of East Asia in Cambodia;
6) Promote marine biodiversity conservation and management, for instance, mangrove forest, coral reefs, and seagrass, etc.;
7) Conduct in-depth assessment of coastal erosion and develop its management strategy; and
8) Develop and implement land-based pollution management strategy.

**Photo 31:** Mangrove forest plantation (Source: MoE)

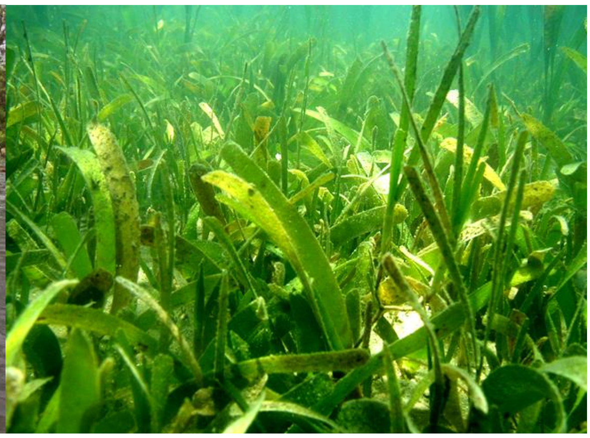

**Photo 32:** Sea-grasses along the coastal water (Source: MoE)

### 6.1.4 Policy on eco-village

This policy covers two strategies such as low carbon infrastructure and green building. The effective implementation of this policy, total GHG emissions of around 1,417 (3.73%) and 4,907 $ktCO_2eq.$/year (5.61%) are expected to reduce in 2030CM and 2050CM, respectively. They include:

**STRATEGY ON LOW CARBON INFRASTRUCTURE**

Infrastructure development and modernization is a key factor for supporting economic growth, enhancing economic efficiency as well as strengthening competitiveness and promoting Cambodia's economic diversification, especially for reducing poverty incidence (RGC, 2013). The Government is placing a great effort to develop urban infrastructures to facilitate traffic congestion and road accident concerns, especially the Phnom Penh city. The strategy on low carbon infrastructure in this study focuses on modal shift and compact city design and planning for major cities. The effective implementation of this strategy, GHG emissions are expected to reduce by about 1,084 and 3,618 $ktCO_2eq.$/year or about 2.85% and 4.14% of total GHG emissions reduction in 2030CM and 2050CM, respectively. The detail actions, coupled with quantitative GHG emissions reduction are shown Table 6.8.

**Table 6.8:** Strategy on low carbon infrastructure and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions | |
|---|---|---|---|
| | | 2030CM | 2050CM |
| 1) | Use freight train for long-distance shipment | 384 | 427 |
| 2) | Design comfortable and safe pavements to produce a walkable city | 700 | 3,191 |
| 3) | Design a standard road facility to differentiate between vehicle, motorist, cyclist, and walking lanes to avoid accidents and traffic congestion (indirect contribution) | | |
| **Total GHG emissions reduction** | | **1,084** | **3,618** |

**Photo 33:** Sky-bridge construction to reduce traffic congestion and road accident (Source: MoE)

**Photo 34:** Road design for cars, motorbikes, and walk, etc.

**STRATEGY ON GREEN BUILDING**

The building sector is the single largest contributor to global GHG emissions, with approximately one-third of global energy end use taking place within buildings (UNEP, 2011). However, it is argued that there are significant opportunities to improve energy-efficiency in buildings, which has the greatest potential to reduce global GHG emissions. The introduction of green buildings can contribute significantly to health, livability, and productivity improvements. As for Cambodia, green building is a new concept (NCGG, 2013). It is referred to the implementation of renewable energy, energy saving behaviour and energy efficiency improvement, water saving, and environmental beauty (NCGG, 2013). The implementation of the strategy on green building is expected to reduce GHG emissions of around 333 and 1,289 kt$CO_2$eq./year or about 0.88% and 1.47% in 2030CM and 2050CM, respectively. The detail low carbon actions and quantitative GHG emissions reduction are shown in Table 6.9.

**Table 6.9:** Strategy on green building and quantitative GHG emissions reduction by each action [kt$CO_2$eq./year]

| No. | Actions | Quantitative GHG reductions 2030CM | Quantitative GHG reductions 2050CM |
|---|---|---|---|
| 1) | Promote green industries and industrial ecology | 572 | 1,440 |
| 2) | Implement transfer of green technologies such as cleaner production, sustainable product innovation, renewable energy utilization | 872 | 3,486 |
| 3) | Promote green business competition and green credit (indirect contribution) | | |
| 4) | Encourage and incentivize the investment in effective environmental protection and natural resources management. | | |
| **Total GHG emissions reduction** | | **1,443** | **4,927** |

**Photo 35:** Energy efficiency building design of the Ministry of Environment (Source: MoE)


**Photo 36: H.E. Say Samal**, Minister of Environment encourages people to save energy (Source: MoE)

## 6.2 Low carbon research network (LoCAR-Net) in Cambodia

The establishment of LoCAR-Net is found very useful for both this study and the implementation of low carbon development policies and strategies in Cambodia. It can be used to facilitate and engage research communities and decision-makers with necessary knowledge to tackle internal and external challenges and to improve the capacity and understanding by using research-based evidence to influence policy making processes on the adverse impacts of climate change as well as to mobilize financial resources. It has facilitated not only data collection, but also distributed LCD related information through trainings, workshops, and other climate change events. In addition, through this network, various opportunities have been provided and are expected to engage different relevant stakeholders, including national and international agencies, local Governments, Government/non-Government organizations, research institutes, and academia in order to enhance cooperation and dialogues among them. For instance, through this study, several workshops and trainings were organized in order to disclose some findings, share other countries' experiences on LCS related activities, and enhance and expand research network among them. Between 70 to 100 participants who came from different national and international agencies, research institutes, NGOs, and academia participated each workshop and training. For the purpose of this study, we propose LoCAR-NET in Cambodia so as to maintain, enhance, and expand the collaboration and cooperation among different key stakeholders as well as to encourage the implementation of the proposed four policies and twelve strategies, coupled with a list of actions in the future (the detail proposal on LoCAR-NET in Cambodia is shown in Appendix 15).

## PART 7 CONCLUSIONS

Cambodia has made all of her utmost effort to develop the national economy to be recognized as one of the most rapid economic growth countries among the developing world. The country is expected to move out of the least developed country status in the coming years and is envisioned to reach the status of an upper-middle income country by 2030 and a high-income level by 2050 (RGC, 2013). At the time of enjoying the economic growth, Cambodia has faced a lot of challenges of climate change, which require to take urgent actions. The Government stressed that addressing economic and social development by taking climate change into account will assist the country in reducing vulnerability to potential climate risks, improving air quality, and mitigating GHG emissions (MoE, 2013a). Cambodia has seen the LCD as one of the priority policy approaches not only to address the adverse impacts of climate change, but also to significantly contribute to the achievement of sustainable development goals and other Government's development policies and strategies. The LCD in Cambodia means to reduce GHG emissions on the one hand and to improve economic productivity, energy security, and environmentally sound development on the other hand.

The present study yields that total GHG emissions in Cambodia are projected to increase to about 20,245 (4.2 times) and 120,523 kt$CO_2$eq./year (24.9 times) in 2030BaU and 2050BaU, respectively, compared to 4,847kt$CO_2$eq./year in 2010. However, total GHG emissions of around 38,039 and 87,462 kt$CO_2$eq./year are expected to reduce in 2030CM and 2050CM, respectively, through implementing some low carbon measures. Per capita GHG emissions are projected to increase from about 0.35t$CO_2$eq./year in 2010 to about 1.10 and 5.49 t$CO_2$eq./year in 2030BaU and 2050BaU, respectively; and are projected to decrease to a negative value of around -0.97t$CO_2$eq./year in 2030CM and to 1.51t$CO_2$eq./year in 2050CM. However, the projections are not prognostications, a range of possible future outcomes are also possible. In order to make the projections high quality enough, the country must improve data recording, management, accessibility, and more precise predictions. Hence, additional researches are encouraged in order to provide a wide range of alternative options for decision makers to make a better design of low carbon development plan and climate change mitigation policy in Cambodia.

In order to achieve GHG reductions target, this study proposes four policies and twelve strategies, coupled with a list of actions for the low carbon development plan towards 2050. They are expected to contribute directly and indirectly to reducing GHG emissions. The effective implementation of these policies and strategies, Cambodia will become a net carbon sink, offsetting around 17,794kt$CO_2$eq./year in 2030CM and about 73% of total GHG emissions are expected to reduce in 2050CM. The policy on green environment attributes about 66.28% and 40.37% of total GHG emissions reduction in 2030CM and 2050CM, respectively. The policy on harmonization of green economy, society, and culture contributes about 29.99% and 54.02% of the total GHG emissions reduction in 2030CM and 2050CM, respectively. The policy on eco-village shares GHG emissions reduction of around 3.73% and 5.61%, while the policy on blue economy contributes indirectly to reducing GHG emissions in 2030CM and 2050CM, respectively. Furthermore, the results yield that the strategies on green agriculture management and sustainable forest management attribute to about 41% and 23% of total GHG reductions in 2030CM, respectively, followed by green transportation of some 15%. However, the strategies on green transportation and green agriculture management contribute to around 29% and 23%, respectively, followed by green energy of about 19% in 2050CM.

It is suggested that in order to effectively implement these policies and strategies, Cambodia must ensure sufficient financial resources, especially from development partners and donor countries and enough qualified human capacity. The participation and cooperation from Government's institutions and different stakeholders are a must. Additionally, the LoCAR-Net is expected to be a useful tool to ensure and enhance the effective implementation of the proposed policies and strategies and to mobilize financial resources; it will also help bridge the gap between researchers and decision-makers. In short, Cambodia must to move to a low-carbon paradigm to facilitate the effective medium- and long-term strategies for socioeconomic development and also to set GHG emissions reduction target in the long-run. Therefore, the results of this study are expected to provide fundamental and useful insights for the Government to formulate a concrete and feasible low carbon development plan and climate change mitigation policy in the future.

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# APPENDICES

## **Appendix 1:** Lists of countermeasures and quantitative $CO_2$ emissions reduction

| Sector | Energy saving measures | 2030CM | | | 2050CM | | |
|---|---|---|---|---|---|---|---|
| | | Identified implementing intensity | | Emissions reduction ($ktCO_2$) | Identified implementing intensity | | Emissions reduction ($ktCO_2$) |
| Residential | Energy Efficiency Equipment | | | | | | |
| | Air conditioner | Diffusion ratio | 50% | 80 | Diffusion ratio | 80% | 356 |
| | Heating | Diffusion ratio | 50% | 25 | Diffusion ratio | 80% | 183 |
| | Hot water | Diffusion ratio | 100% | 14 | Diffusion ratio | 100% | 58 |
| | Cook stove | Diffusion ratio | 50% | 419 | Diffusion ratio | 80% | 2,095 |
| | Lighting | Diffusion ratio | 50% | 347 | Diffusion ratio | 80% | 2,167 |
| | Refrigerator | Diffusion ratio | 50% | 35 | Diffusion ratio | 80% | 345 |
| | Other equipment | Diffusion ratio | 50% | 89 | Diffusion ratio | 80% | 663 |
| | Energy saving measures | Reduction ratio of energy service demand (20%) | | 255 | Reduction ratio of energy service demand (20%) | | 893 |
| | Fuel switch | Diffusion ratio | 50% | 49 | Diffusion ratio | 80% | 464 |
| | **Sub-Total** | | | **1,313** | | | **7,224** |
| Commercial | Energy Efficiency Equipment | | | | | | |
| | Air conditioner | Diffusion ratio | 50% | 13 | Diffusion ratio | 80% | 78 |
| | Heating | Diffusion ratio | 50% | 2 | Diffusion ratio | 80% | 2 |
| | Hot water | Diffusion ratio | 50% | 33 | Diffusion ratio | 80% | 161 |
| | Cook stoves | Diffusion ratio | 50% | 0 | Diffusion ratio | 80% | 16 |
| | Lighting | Diffusion ratio | 50% | 333 | Diffusion ratio | 80% | 686 |
| | Refrigerator | Diffusion ratio | 50% | 156 | Diffusion ratio | 80% | 237 |
| | Other equipment | Diffusion ratio | 50% | 34 | Diffusion ratio | 80% | 261 |
| | Energy saving measures | Reduction ratio of energy service demand (20%) | | 152 | Reduction ratio of energy service demand (20%) | | 396 |
| | Fuel switch | | | 44 | | | 46 |
| | **Sub-Total** | | | **768** | | | **1,882** |
| Industrial | Energy Efficiency Equipment | | | | | | |
| | Furnace | Diffusion rate | 50% | 402 | Diffusion rate | 80% | 1,234 |
| | Steam boiler | Diffusion rate | 50% | 774 | Diffusion rate | 80% | 3,037 |
| | Motor | Diffusion rate | 50% | 187 | Diffusion rate | 80% | 871 |
| | Other equipment | Diffusion rate | 50% | 956 | Diffusion rate | 80% | 2,825 |
| | Energy saving measures | | | 1,149 | | | 3,462 |
| | Fuel switch | | | 10 | | | 775 |
| | **Sub-Total** | | | **3,477** | | | **12,205** |
| Passenger transportation | Efficiency improvement | | | | | | |
| | Modal shift | | | | | | |
| | Bus | Share of bus = 6.71% (from base year = 1.79%) | | | Share of bus = 14.54% (from base year = 1.79%) | | |
| | Train | Share of train = 10.50% (from base year = 0% ) | | | Share of train = 15.60% (from base year = 0%) | | |
| | **Sub-Total** | | | **3,574** | | | **12,658** |
| Freight transportation | Effeciency improvement | | | | | | |
| | Modal shift | | | | | | |
| | Motorized vehicle to train | Share of train = 15.00% (from base year = 0.02%) | | | Share of train = 24.00% (from base year = 0.02%) | | |
| | **Sub-Total** | | | **3,134** | | | **16,458** |
| Power | Efficiency improvement | | | | | | |
| | Coal | 41.00% (from base year = 33.01% | | | 41.00% ( from base year = 33.01% | | |
| | Oil | 44.00% (from base year = 32.50%) | | | 44.00% ( from base year = 32.50%) | | |
| | Gas | 52.00% | | | 52.00% | | |
| | Fuel switch | Solar power = 5% (from the base year = 0.2%) | | | Solar power = 5% (from the base year = 0.2%) | | |
| | Transmission loss | 6.50% ( from base year = 12.23%) | | | 6.50% ( from base year = 12.23%) | | |
| | **Sub-Total** | | | **560** | | | **1,726** |
| | **Grand Total** | | | **12,826** | | | **52,153** |

## **Appendix 2:** The IO Table 2008 [Million USD at 2000 constant price]

| Description | Paddy | Other Crops | Livestock | Forestry | Fishery | Mining | Food, beverage & tabacco | Textile & garment | Wood, paper & publishin | Chemical, rubber & plastic | Non metallic mineral | Basic metals | Other manufacturing | Electricity & water | Construction | Trade | Hotel & restaurants | Transport & communication | Finance | Real estate & business | Public administration | Other services | Total intermediate consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paddy | 59.59 | 2.62 | 2.86 | 0.00 | 0.00 | 0.00 | 813.80 | 0.00 | 0.39 | 0.00 | 0.00 | 0.00 | 0.76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.89 | 0.55 | 0.81 | 885.28 |
| Other Crops | 0.00 | 2.16 | 0.00 | 0.00 | 0.00 | 0.00 | 25.72 | 9.36 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.00 | 0.22 | 37.72 |
| Livestock | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 80.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 80.73 |
| Forestry | 0.89 | 2.18 | 1.97 | 0.38 | 0.70 | 1.55 | 11.98 | 1.08 | 101.93 | 15.36 | 29.74 | 0.67 | 3.08 | 0.00 | 32.26 | 0.23 | 0.09 | 0.13 | 0.01 | 16.51 | 0.90 | 4.07 | 225.71 |
| Fishery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 47.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 47.28 |
| Mining | 0.48 | 0.02 | 0.00 | 0.00 | 0.01 | 1.02 | 0.16 | 0.04 | 0.12 | 2.76 | 8.61 | 4.92 | 0.39 | 0.60 | 31.93 | 0.03 | 0.12 | 0.01 | 0.00 | 0.79 | 0.16 | 0.01 | 52.17 |
| Food, beverage & tabacco | 2.69 | 0.48 | 53.14 | 0.00 | 3.59 | 0.00 | 413.67 | 0.01 | 0.00 | 0.46 | 2.72 | 0.00 | 0.11 | 0.01 | 0.01 | 42.49 | 8.56 | 23.74 | 1.83 | 53.35 | 22.83 | 105.91 | 735.60 |
| Textile & garment | 7.41 | 6.53 | 0.02 | 0.01 | 0.24 | 0.28 | 4.22 | 2,199.95 | 3.13 | 41.93 | 0.60 | 0.76 | 17.69 | 22.70 | 3.94 | 26.97 | 17.58 | 15.07 | 12.13 | 40.64 | 6.57 | 32.55 | 2,460.91 |
| Wood, paper & publishing | 0.18 | 0.01 | 0.00 | 0.00 | 0.00 | 0.05 | 2.72 | 3.86 | 3.16 | 1.19 | 0.65 | 0.18 | 0.41 | 3.12 | 0.22 | 0.81 | 2.21 | 0.45 | 3.70 | 11.08 | 6.90 | 4.37 | 45.28 |
| Chemical, rubber & plastic | 144.01 | 19.32 | 0.26 | 0.02 | 10.30 | 1.34 | 12.22 | 19.06 | 2.32 | 35.59 | 2.26 | 5.18 | 2.17 | 67.70 | 3.89 | 2.02 | 152.33 | 1.13 | 1.23 | 15.91 | 7.30 | 8.97 | 514.51 |
| Non metallic mineral | 6.88 | 0.49 | 0.03 | 0.01 | 0.09 | 0.09 | 5.45 | 0.38 | 0.20 | 1.92 | 4.04 | 0.98 | 1.39 | 2.33 | 158.22 | 0.64 | 1.18 | 0.36 | 0.22 | 8.45 | 1.37 | 8.67 | 203.40 |
| Basic metals | 11.69 | 2.44 | 0.06 | 0.01 | 0.07 | 1.81 | 10.50 | 2.47 | 0.92 | 1.59 | 2.80 | 73.30 | 32.01 | 17.22 | 70.20 | 0.67 | 3.27 | 0.37 | 0.14 | 8.87 | 1.25 | 16.71 | 258.38 |
| Other manufacturing | 50.54 | 7.16 | 0.27 | 0.04 | 4.37 | 19.69 | 26.61 | 53.80 | 9.23 | 11.55 | 6.44 | 5.41 | 208.35 | 163.48 | 88.19 | 19.58 | 369.40 | 10.94 | 36.00 | 97.13 | 185.19 | 51.42 | 1,424.77 |
| Electricity & water | 4.49 | 0.12 | 0.02 | 0.00 | 0.03 | 0.29 | 7.93 | 23.09 | 1.02 | 6.01 | 1.41 | 4.42 | 32.88 | 36.54 | 0.55 | 22.49 | 4.78 | 12.57 | 4.99 | 7.63 | 11.22 | 13.22 | 195.70 |
| Construction | 9.99 | 0.74 | 0.09 | 0.00 | 0.01 | 0.49 | 1.79 | 1.84 | 0.66 | 0.92 | 0.56 | 0.29 | 0.27 | 18.83 | 5.07 | 2.07 | 2.73 | 1.16 | 4.67 | 7.60 | 10.66 | 66.07 | 136.51 |
| Trade | 245.33 | 12.24 | 1.13 | 0.02 | 2.54 | 1.35 | 58.53 | 81.17 | 7.55 | 30.90 | 3.56 | 7.35 | 12.59 | 8.60 | 17.66 | 3.45 | 13.21 | 1.93 | 5.77 | 38.03 | 11.82 | 85.21 | 649.94 |
| Hotel & restaurants | 27.16 | 9.90 | 0.07 | 0.06 | 1.05 | 6.26 | 23.41 | 37.36 | 4.66 | 7.73 | 7.76 | 4.77 | 2.47 | 11.43 | 11.05 | 15.16 | 53.83 | 8.47 | 13.28 | 18.90 | 18.76 | 9.68 | 293.23 |
| Transport & Communication | 0.11 | 0.13 | 0.01 | 0.00 | 0.03 | 0.01 | 0.64 | 0.89 | 0.08 | 0.34 | 0.04 | 0.08 | 0.14 | 0.09 | 0.19 | 0.04 | 0.14 | 0.02 | 0.06 | 0.41 | 0.13 | 0.93 | 4.52 |
| Finance | 15.09 | 3.60 | 0.05 | 0.00 | 0.38 | 0.27 | 4.58 | 6.84 | 1.00 | 3.26 | 0.56 | 1.08 | 1.15 | 13.58 | 2.96 | 14.72 | 10.20 | 8.23 | 6.76 | 10.81 | 1.66 | 50.54 | 157.31 |
| Real estate & business | 56.18 | 11.90 | 0.01 | 0.00 | 0.46 | 1.42 | 4.19 | 5.54 | 0.36 | 1.74 | 0.37 | 0.42 | 0.61 | 6.32 | 4.29 | 9.24 | 18.06 | 5.16 | 10.16 | 9.95 | 11.16 | 5.44 | 163.00 |
| Public administration | 0.17 | 0.01 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.14 | 0.01 | 0.06 | 0.01 | 0.01 | 0.01 | 0.74 | 0.14 | 0.09 | 0.14 | 0.05 | 0.16 | 0.65 | 2.51 | 0.10 | 5.04 |
| Other services | 16.26 | 4.30 | 0.01 | 0.00 | 0.15 | 0.18 | 2.42 | 9.34 | 0.33 | 1.83 | 0.35 | 0.48 | 0.77 | 6.54 | 2.95 | 6.23 | 8.97 | 3.48 | 15.10 | 16.09 | 101.39 | 36.65 | 233.82 |
| Domestic goods | 440.02 | 48.55 | 58.05 | 0.46 | 9.00 | 14.35 | 1,467.58 | 381.27 | 116.70 | 75.48 | 56.78 | 53.77 | 90.90 | 133.62 | 212.35 | 120.45 | 133.26 | 67.31 | 62.29 | 189.00 | 204.93 | 382.85 | |
| Imported goods | 204.46 | 35.04 | 1.78 | 0.08 | 13.55 | 20.11 | 80.80 | 2,045.93 | 15.69 | 84.61 | 13.68 | 53.76 | 209.21 | 225.19 | 210.02 | 42.87 | 489.96 | 23.96 | 49.31 | 163.25 | 177.21 | 103.83 | |
| Total goods | 659.14 | 86.34 | 60.01 | 0.56 | 24.04 | 36.13 | 1,558.58 | 2,456.22 | 137.13 | 165.16 | 72.48 | 110.28 | 317.26 | 379.83 | 433.71 | 166.93 | 666.80 | 93.28 | 116.21 | 366.88 | 402.31 | 501.55 | |
| Labour | 308.57 | 345.46 | 198.94 | 14.81 | 218.35 | 7.22 | 61.37 | 301.11 | 7.57 | 11.11 | 4.58 | 3.27 | 22.85 | 6.50 | 140.01 | 204.52 | 51.36 | 114.29 | 9.95 | 52.83 | 155.43 | 128.45 | |
| Capital | 23.27 | 13.01 | 11.42 | 180.83 | 176.82 | 12.94 | 102.29 | 619.81 | 57.38 | 27.86 | 17.50 | 8.31 | 70.76 | 28.57 | 276.94 | 397.94 | 443.53 | 222.37 | 65.39 | 78.83 | 212.19 | 580.28 | |
| Land | 169.54 | 94.80 | 83.19 | 27.78 | 172.44 | 3.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Tax on domestic Products | 3.13 | 0.35 | 0.21 | 8.78 | 1.91 | 0.49 | 18.45 | 30.10 | 3.25 | 7.86 | 0.81 | 0.22 | 3.49 | 1.25 | 10.94 | 12.02 | 6.82 | 6.72 | 3.55 | 4.15 | 0.00 | 23.20 | |
| Total cost | 1,163.64 | 539.97 | 353.78 | 232.75 | 593.57 | 60.00 | 1,740.69 | 3,407.25 | 205.33 | 211.98 | 95.37 | 122.08 | 414.36 | 416.15 | 861.59 | 781.39 | 1,168.50 | 436.65 | 195.10 | 502.69 | 769.93 | 1,233.48 | |

**Appendix 2.1** [Continued]

| Description | Households | Investment | Government | Exports | Total demand | Imports CIF | Tax on imported products | Domestic demand |
|---|---|---|---|---|---|---|---|---|
| Paddy | 23.12 | 31.58 | 33.05 | 193.99 | 1,167.03 | 3.01 | 0.37 | 1,163.64 |
| Other Crops | 553.67 | 0.00 | 0.00 | 7.06 | 598.45 | 57.64 | 0.84 | 539.97 |
| Livestock | 260.71 | 0.00 | 0.00 | 12.52 | 353.95 | 0.18 | 0.00 | 353.78 |
| Forestry | 7.03 | 0.01 | 0.00 | 0.00 | 232.75 | 0.00 | 0.00 | 232.75 |
| Fishery | 438.39 | 0.00 | 0.00 | 107.95 | 593.61 | 0.05 | 0.00 | 593.57 |
| Mining | 0.00 | 7.83 | 0.00 | 0.00 | 60.00 | 0.00 | 0.00 | 60.00 |
| Food, Beverage & Tabacco | 1,133.04 | 0.00 | 43.88 | 67.21 | 1,979.73 | 222.06 | 16.98 | 1,740.69 |
| Textile & Garment | 182.43 | 228.66 | 14.18 | 2,890.63 | 5,776.81 | 2,320.69 | 48.87 | 3,407.25 |
| Wood, Paper & Publishing | 130.36 | 0.00 | 0.00 | 62.11 | 237.74 | 31.97 | 0.44 | 205.33 |
| Chemical, Rubber & Plastic | 313.91 | 0.43 | 0.00 | 179.60 | 1,008.44 | 686.59 | 109.07 | 212.78 |
| Non Metallic Mineral | 4.13 | 4.10 | 0.00 | 0.00 | 211.64 | 114.70 | 1.57 | 95.37 |
| Basic Metals | 0.00 | 23.71 | 0.02 | 0.00 | 282.11 | 147.56 | 12.47 | 122.08 |
| Other Manufacturing | 270.07 | 580.70 | 0.01 | 166.61 | 2,442.17 | 1,811.01 | 216.77 | 414.38 |
| Electricity & Water | 241.86 | 0.00 | 0.00 | 0.00 | 437.56 | 21.12 | 0.29 | 416.15 |
| Construction | 0.00 | 745.35 | 0.00 | 0.00 | 881.86 | 19.99 | 0.27 | 861.60 |
| Trade | 105.65 | 27.38 | 0.00 | 0.00 | 782.98 | 2.05 | 0.05 | 780.88 |
| Hotel & Restaurants | 565.11 | 5.21 | 0.01 | 470.11 | 1,333.67 | 160.05 | 5.12 | 1,168.50 |
| Transport & Communication | 88.59 | 13.74 | 0.00 | 364.51 | 471.37 | 34.55 | 0.45 | 436.36 |
| Finance | 41.20 | 0.02 | 0.70 | 0.00 | 199.24 | 4.08 | 0.06 | 195.10 |
| Real Estate & Business | 214.04 | 8.00 | 164.89 | 16.11 | 566.05 | 62.50 | 0.86 | 502.69 |
| Public Administration | 483.71 | 0.00 | 280.12 | 12.05 | 780.92 | 10.84 | 0.15 | 769.93 |
| Other Services | 837.50 | 0.01 | 75.70 | 92.46 | 1,239.49 | 5.91 | 0.08 | 1,233.49 |

**SOURCE: Sophal and Sothea (2011)**

**Appendix 3:** The aggregated IO Table 2008 [Million USD at 2000 constant price]

| Description | Agriculture, fishery & forestry | Mining | Manufacturing | Electricity & water | Construction | Trade | Transport & Communication | Finance | Government services | Other services | Total intermediate Consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 73.35 | 1.55 | 1,141.94 | 0 | 32.26 | 0.23 | 0.13 | 0.01 | 1.45 | 25.77 | 1,276.69 |
| Mining | 0.51 | 1.02 | 17.00 | 0.60 | 31.93 | 0.03 | 0.01 | 0 | 0.16 | 0.92 | 52.18 |
| Manufacturing | 332.36 | 23.26 | 3,235.56 | 276.56 | 324.67 | 93.18 | 52.06 | 55.25 | 231.41 | 1,018.56 | 5,642.87 |
| Electricity & water | 4.66 | 0.29 | 76.76 | 36.54 | 0.55 | 22.49 | 12.57 | 4.99 | 11.22 | 25.63 | 195.70 |
| Construction | 10.83 | 0.49 | 6.33 | 18.83 | 5.07 | 2.07 | 1.16 | 4.67 | 10.66 | 76.40 | 136.51 |
| Trade | 261.26 | 1.35 | 201.65 | 8.60 | 17.66 | 3.45 | 1.93 | 5.77 | 11.82 | 136.45 | 649.94 |
| Transport & communication | 0.28 | 0.01 | 2.21 | 0.09 | 0.19 | 0.04 | 0.02 | 0.06 | 0.13 | 1.48 | 4.51 |
| Finance | 19.12 | 0.27 | 18.47 | 13.58 | 2.96 | 14.72 | 8.23 | 6.76 | 1.66 | 71.55 | 157.32 |
| Government services | 0.18 | 0.02 | 0.27 | 0.74 | 0.14 | 0.09 | 0.05 | 0.16 | 2.51 | 0.89 | 5.05 |
| Other Services | 127.51 | 7.86 | 116.91 | 24.29 | 18.29 | 30.63 | 17.11 | 38.54 | 131.31 | 177.57 | 690.02 |
| Total intermediate inputs | 830.06 | 36.12 | 4,817.10 | 379.83 | 433.72 | 166.93 | 93.27 | 116.21 | 402.33 | 1,535.22 | 8,810.79 |
| Labor | 1,086.13 | 7.22 | 411.86 | 6.50 | 140.01 | 204.52 | 114.29 | 9.95 | 155.43 | 232.65 | 2,368.56 |
| Capital | 953.10 | 16.16 | 903.91 | 28.57 | 276.94 | 397.94 | 222.37 | 65.39 | 212.19 | 1,102.64 | 4,179.21 |
| Tax on domestic products | 14.38 | 0.49 | 64.18 | 1.25 | 10.94 | 12.02 | 6.72 | 3.55 | 0 | 34.17 | 147.70 |
| Value added | 2,053.61 | 23.87 | 1,379.95 | 36.32 | 427.89 | 614.48 | 343.38 | 78.89 | 367.62 | 1,369.46 | 6,695.47 |
| Total input | 2,883.67 | 59.99 | 6,197.05 | 416.15 | 861.61 | 781.41 | 436.65 | 195.10 | 769.95 | 2,904.68 | 15,506.26 |

**Appendix 3.1** [Continued]

| Description | Private consumption | Government consumption | Investment | Export | Import | Total final demand | Total output |
|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 1,282.92 | 33.05 | 31.59 | 321.52 | 62.09 | 1,731.17 | 2,883.68 |
| Mining | 0 | 0 | 7.83 | 0 | 0 | 7.83 | 60.01 |
| Manufacturing | 2,033.94 | 58.09 | 837.60 | 3,366.16 | 5,740.75 | 12,036.54 | 6,197.91 |
| Electricity & water | 241.86 | 0 | 0 | 0 | 21.41 | 263.27 | 416.15 |
| Construction | 0 | 0 | 745.35 | 0 | 20.26 | 765.61 | 861.60 |
| Trade | 105.65 | 0 | 27.38 | 0 | 2.10 | 135.13 | 780.87 |
| Transport & communication | 88.59 | 0 | 13.74 | 364.51 | 35.00 | 501.84 | 436.35 |
| Finance | 41.20 | 0.70 | 0.02 | 0 | 4.14 | 46.06 | 195.10 |
| Government services | 483.71 | 280.12 | 0 | 12.05 | 10.99 | 786.87 | 769.94 |
| Other services | 1,616.65 | 240.60 | 13.22 | 578.68 | 234.52 | 2,683.67 | 2,904.65 |
| Total intermediate inputs | 5,894.52 | 612.56 | 1,676.73 | 4,642.92 | 6,131.26 | 18,957.99 | 15,506.26 |

**Appendix 4:** Formula of the constraints and objective function used to adjust the IO Tables

**Constraints:**

*The sum total of a row and the sum total of a column (demand and supply) are in agreement.*

$$\sum_i x_{i,k} = \sum_j x_{k,j} \times n_{k,j} \tag{1}$$

$x_{i,j}$ : IO table (estimated),

$n_{k,j}$ : A matrix which is -1 in the columns of imports and 1 in others,

$i$ : Row elements of IO table,

$j$ : Column elements of IO table,

$k$ : Industry $(k \in i)$.

*The maximum of import (import does not exceed domestic demand)*

$$IM_k < \sum_l x_{k,l} + \sum_{df} x_{k,df} \tag{2}$$

$IM_k$ : Imports of goods k,

$df$ : Domestic final demand sectors $(df \in j)$,

$l$ : Industrial sector $(l \in i)$.

*The maximum of exports (exports do not exceed domestic product)*

$$EX_k < \sum_j x_{k,j} \tag{3}$$

$EX_k$: Exports of goods $k$

**Objective function:**

*The sum total of deviation from the distribution of the column element of the IO table in 2008, deviation from the distribution of the final demand item of the table, and deviation from an input value shall be made into the minimum. An objective function is shown below.* $\omega_1 \sim \omega_4$ *is the weight of each term.*

$$\min \ \omega_1 \sum_i \sum_j p_{i,j} \ln \frac{p_{i,j}}{q_{i,j}} + \omega_2 \sum_f u_f \ln \frac{u_f}{v_f} + \omega_3 \sum_l \varepsilon_l^{\ 2} + \omega_4 \sum_f \varepsilon_f^{\ 2} \tag{4}$$

*The contents of each term are explained below.*

*The cross-entropy of the percentage distribution in the column of each element in each column.*

$$\sum_i \sum_j p_{i,j} \ln \frac{p_{i,j}}{q_{i,j}} \tag{5}$$

$$p_{i,j} = \frac{x_{i,j}}{\sum_i x_{i,j}} \tag{6}$$

$$q_{i,j} = \frac{z_{i,j}}{\sum_i z_{i,j}} \tag{7}$$

$p_{i,j}$ : Percentage distribution of the column element of the estimated IO table,
$q_{i,j}$ : Percentage distribution of the column element of IO table in 2008,
$z_{i,j}$ : IO table in 2008.

*The cross-entropy of the percentage distribution of each final demand sector to the whole final demand sector*

$$\sum_f u_f \ln \frac{u_f}{v_f} \tag{8}$$

$$u_f = \frac{\sum_i x_{i,f}}{\sum_i \sum_f x_{i,f}} \tag{9}$$

$$v_f = \frac{\sum_i z_{i,f}}{\sum_i \sum_f z_{i,f}} \tag{10}$$

$u_{i,j}$ : Percentage distribution of final demand sector of the estimated IO table,
$v_{i,j}$ : Percentage distribution of final demand sector of the IO table in 2008.

*The rate of change from an initial value (statistic)*

$\varepsilon$ is raised to the power of two because it may become a negative value.

$$\sum_l \varepsilon_l^{\ 2} \tag{11}$$

$$\sum_f \varepsilon_f^{\ 2} \tag{12}$$

$$\sum_{av} x_{av,l} = d_l (1+\varepsilon_l) \tag{13}$$

$$\sum_j x_{f,j} = d_f (1+\varepsilon_f) \tag{14}$$

$d_l$ : The statistic of value added,
$\varepsilon_l$ : The rate of change of an estimated value of the input value,
$d_f$ : The statistic of final demand sectors,
$\varepsilon_f$ : The rate of change of an estimated value from the input value,
$av$ : Value added sectors $(av \in i)$.

**Appendix 5:** The aggregated IO Table 2010 [Million USD at 2000 constant price]

| Description | Agriculture, fishery & forestry | Mining | Manufacturing | Electricity & water | Construction | Trade | Transport & communication | Finance | Government services | Other services | Total intermediate consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 71.65 | 3.21 | 1,168.25 | 0 | 29.83 | 0.26 | 0.19 | 0.02 | 0.38 | 27.76 | 1,301.54 |
| Mining | 0.93 | 2.16 | 75.71 | 0.94 | 34.76 | 0.04 | 0.02 | 0 | 0.04 | 2.00 | 116.60 |
| Manufacturing | 343.08 | 48.22 | 3,769.01 | 390.97 | 304.57 | 106.19 | 75.52 | 104.39 | 61.08 | 1,167.25 | 6,370.30 |
| Electricity & water | 6.32 | 0.61 | 169.69 | 54.38 | 0.55 | 27.76 | 19.29 | 9.74 | 3.01 | 39.84 | 331.20 |
| Construction | 8.09 | 1.00 | 3.45 | 25.04 | 4.37 | 2.15 | 1.57 | 8.49 | 2.76 | 60.97 | 117.89 |
| Trade | 286.07 | 2.81 | 269.82 | 12.29 | 16.82 | 4.00 | 2.83 | 10.98 | 3.13 | 167.04 | 775.79 |
| Transport & communication | 0.51 | 0.02 | 9.84 | 0.14 | 0.21 | 0.05 | 0.03 | 0.12 | 0.04 | 3.21 | 14.17 |
| Finance | 33.17 | 0.57 | 72.93 | 21.18 | 3.18 | 19.53 | 13.29 | 13.58 | 0.45 | 146.61 | 324.50 |
| Government services | 0 | 0.03 | 0 | 0.15 | 0.01 | 0.01 | 0.01 | 0.09 | 0.34 | 0.01 | 0.65 |
| Other services | 152.88 | 16.39 | 193.63 | 35.32 | 17.84 | 36.47 | 25.60 | 74.12 | 35.00 | 240.61 | 827.87 |
| Total intermediate inputs | 902.70 | 75.02 | 5,732.33 | 540.43 | 412.15 | 196.46 | 138.36 | 221.53 | 106.24 | 1,855.30 | 10,180.50 |
| Labor | 1,181.17 | 15.00 | 490.11 | 9.25 | 133.05 | 240.70 | 169.54 | 18.97 | 41.04 | 281.15 | 2,579.93 |
| Capital | 1,036.50 | 33.56 | 1,075.65 | 40.65 | 263.17 | 468.34 | 329.86 | 124.65 | 56.03 | 1,332.53 | 4,760.94 |
| Tax on domestic products | 15.64 | 1.02 | 76.37 | 1.78 | 10.40 | 14.15 | 9.97 | 6.77 | 0 | 41.29 | 177.38 |
| Value added | 2,233.31 | 49.58 | 1,642.13 | 51.68 | 406.61 | 723.18 | 509.36 | 150.38 | 97.08 | 1,654.98 | 7,518.30 |
| Total input | 3,136.01 | 124.60 | 7,374.46 | 592.10 | 818.76 | 919.64 | 647.72 | 371.91 | 203.32 | 3,510.27 | 17,698.80 |

**Appendix 5.1** [Continued]

| Description | Private consumption | Government consumption | Investment | Export | Import | Total final demand | Total output |
|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 1,413.36 | 38.59 | 31.21 | 424.13 | 72.83 | 1,834.47 | 3,136.01 |
| Mining | 0 | 0 | 8.00 | 0 | 0 | 8.00 | 124.60 |
| Manufacturing | 2,265.21 | 67.91 | 830.02 | 4,489.58 | 6,648.57 | 1,004.17 | 7,374.46 |
| Electricity & water | 284.19 | 0 | 0 | 0 | 23.29 | 260.90 | 592.10 |
| Construction | 0 | 0 | 726.15 | 0 | 25.27 | 700.87 | 818.76 |
| Trade | 119.04 | 0 | 27.22 | 0 | 2.40 | 143.85 | 919.64 |
| Transport & communication | 110.37 | 0 | 14.03 | 544.71 | 35.56 | 633.55 | 647.72 |
| Finance | 50.82 | 0.83 | 0.02 | 0 | 4.26 | 47.41 | 371.91 |
| Government services | 71.38 | 264.33 | 0 | 2.07 | 135.11 | 202.67 | 203.32 |
| Other services | 1,854.27 | 282.15 | 13.20 | 795.20 | 262.42 | 2,682.41 | 3,510.27 |
| Total intermediate inputs | 6,168.64 | 653.81 | 1,649.85 | 6,255.69 | 7,209.69 | 7,518.30 | 17,698.80 |

**Appendix 6:** The aggregated IO Table 2030 [Million USD at 2000 constant price]

| Description | Agriculture, fishery & forestry | Mining | Manufacturing | Electricity & water | Construction | Trade | Transport & communication | Finance | Government services | Other services | Total intermediate consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 211.68 | 14.36 | 5,648.74 | 0 | 116.46 | 1.01 | 0.72 | 0.08 | 1.48 | 112.47 | 6,106.99 |
| Mining | 2.75 | 9.69 | 366.05 | 4.38 | 135.71 | 0.16 | 0.06 | 0 | 0.17 | 8.09 | 527.06 |
| Manufacturing | 1,013.62 | 215.96 | 18,224.01 | 1,811.23 | 1,189.05 | 415.92 | 293.09 | 428.22 | 236.41 | 4,728.59 | 28,556.10 |
| Electricity & water | 18.66 | 2.72 | 820.49 | 251.94 | 2.16 | 108.74 | 74.86 | 39.95 | 11.67 | 161.41 | 1,492.60 |
| Construction | 23.90 | 4.49 | 16.67 | 116.02 | 17.06 | 8.40 | 6.11 | 34.83 | 10.66 | 246.98 | 485.14 |
| Trade | 845.16 | 12.56 | 1,304.65 | 56.95 | 65.68 | 15.67 | 11.00 | 45.03 | 12.12 | 676.67 | 3,045.50 |
| Transport & communication | 1.51 | 0.09 | 47.56 | 0.66 | 0.81 | 0.21 | 0.13 | 0.50 | 0.14 | 13.00 | 64.60 |
| Finance | 98.00 | 2.56 | 352.65 | 98.10 | 12.41 | 76.51 | 51.58 | 55.72 | 1.75 | 593.92 | 1,343.20 |
| Government services | 0.01 | 0.12 | 0.02 | 0.70 | 0.04 | 0.02 | 0.03 | 0.37 | 1.32 | 0.04 | 2.66 |
| Other services | 451.66 | 73.41 | 936.27 | 163.64 | 69.65 | 142.86 | 99.35 | 304.06 | 135.45 | 974.71 | 3,351.06 |
| Total intermediate inputs | 2,666.96 | 335.97 | 27,717.10 | 2,503.60 | 1,609.03 | 769.49 | 536.94 | 908.76 | 411.17 | 7,515.88 | 44,974.90 |
| Labor | 3,489.70 | 67.16 | 2,369.80 | 42.84 | 519.41 | 942.77 | 657.95 | 77.81 | 158.84 | 1,138.97 | 9,465.26 |
| Capital | 3,062.28 | 150.31 | 5,201.00 | 188.32 | 1,027.40 | 1,834.38 | 1,280.15 | 511.35 | 216.85 | 5,398.12 | 18,870.17 |
| Tax on domestic products | 46.20 | 4.56 | 369.29 | 8.24 | 40.59 | 55.41 | 38.69 | 27.76 | 0 | 167.28 | 758.01 |
| Value added | 6,598.19 | 222.03 | 7,940.09 | 239.40 | 1,587.40 | 2,832.56 | 1,976.79 | 616.92 | 375.70 | 6,704.38 | 29,093.44 |
| Total input | 9,265.15 | 558.00 | 35,657.19 | 2,743.00 | 3,196.43 | 3,602.05 | 2,513.73 | 1,525.68 | 786.86 | 14,220.26 | 74,068.35 |

**Appendix 6.1** [Continued]

| Description | Private consumption | Government consumption | Investment | Export | Import | Total final demand | Total output |
|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 2,734.64 | 149.34 | 120.79 | 820.62 | 667.23 | 3,158.16 | 9,265.15 |
| Mining | 0 | 0 | 30.94 | 0 | 0 | 30.94 | 558.00 |
| Manufacturing | 10,784.18 | 262.79 | 3,211.92 | 18,193.90 | 25,351.70 | 7,101.09 | 35,657.19 |
| Electricity & water | 1,338.44 | 0 | 0 | 0 | 88.04 | 1,250.40 | 2,743.00 |
| Construction | 0 | 0 | 2,809.97 | 0 | 98.67 | 2,711.30 | 3,196.43 |
| Trade | 460.63 | 0 | 105.32 | 0 | 9.40 | 556.55 | 3,602.05 |
| Transport & communication | 427.10 | 0 | 54.29 | 2,107.84 | 140.10 | 2,449.13 | 2,513.73 |
| Finance | 196.65 | 3.20 | 0.08 | 0 | 17.46 | 182.47 | 1,525.68 |
| Government services | 276.22 | 1,022.86 | 0 | 8.01 | 522.88 | 784.21 | 786.86 |
| Other services | 7,652.86 | 1,091.84 | 51.10 | 3,077.17 | 1,003.77 | 10,869.20 | 14,220.26 |
| Total intermediate inputs | 23,870.71 | 2,530.03 | 6,384.41 | 24,207.54 | 27,899.24 | 29,093.44 | 74,068.35 |

**Appendix 7:** The aggregated IO Table 2050 [Million USD at 2000 constant price]

| Description | Agriculture, fishery & forestry | Mining | Manufacturing | Electricity & water | Construction | Trade | Transport & communication | Finance | Government services | Other services | Total intermediate consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 687.28 | 60.17 | 24,582.66 | 0 | 451.10 | 3.94 | 2.80 | 0.30 | 5.71 | 435.46 | 26,229.44 |
| Mining | 8.93 | 40.59 | 1,593.02 | 17.48 | 525.69 | 0.62 | 0.25 | 0 | 0.66 | 31.31 | 2,218.54 |
| Manufacturing | 3,290.96 | 904.96 | 79,308.80 | 7,233.42 | 4,605.88 | 1,623.29 | 1,136.10 | 1,693.43 | 914.85 | 18,308.78 | 119,020.48 |
| Electricity & water | 60.59 | 11.41 | 3,570.68 | 1,006.15 | 8.38 | 424.39 | 290.19 | 157.97 | 45.15 | 624.98 | 6,199.88 |
| Construction | 77.61 | 18.82 | 72.54 | 463.33 | 66.10 | 32.80 | 23.68 | 137.75 | 41.27 | 956.29 | 1,890.19 |
| Trade | 2,744.02 | 52.65 | 5,677.69 | 227.45 | 254.42 | 61.15 | 42.63 | 178.09 | 46.91 | 2,620.01 | 11,905.02 |
| Transport & communication | 4.90 | 0.40 | 206.96 | 2.62 | 3.13 | 0.82 | 0.49 | 1.97 | 0.53 | 50.35 | 272.18 |
| Finance | 318.17 | 10.72 | 1,534.71 | 391.76 | 48.09 | 298.61 | 199.93 | 220.35 | 6.79 | 2,299.61 | 5,328.74 |
| Government services | 0.02 | 0.52 | 0.07 | 2.78 | 0.14 | 0.08 | 0.13 | 1.45 | 5.10 | 0.17 | 10.44 |
| Other services | 1,466.42 | 307.63 | 4,074.53 | 653.51 | 269.81 | 557.55 | 385.11 | 1,202.42 | 524.18 | 3,774.00 | 13,215.17 |
| Total intermediate inputs | 8,658.92 | 1,407.87 | 120,621.65 | 9,998.51 | 6,232.73 | 3,003.25 | 2,081.32 | 3,593.74 | 1,591.14 | 29,100.95 | 186,290.09 |
| Labor | 11,330.16 | 281.42 | 10,313.10 | 171.10 | 2,012.00 | 3,679.53 | 2,550.38 | 307.70 | 614.70 | 4,410.01 | 35,670.10 |
| Capital | 9,942.44 | 629.88 | 22,634.18 | 752.07 | 3,979.74 | 7,159.36 | 4,962.19 | 2,022.16 | 839.17 | 20,901.16 | 73,822.33 |
| Tax on domestic products | 150.01 | 19.10 | 1,607.09 | 32.90 | 157.21 | 216.25 | 149.96 | 109.78 | 0 | 647.71 | 3,090.01 |
| Value added | 21,422.61 | 930.40 | 34,554.37 | 956.07 | 6,148.95 | 11,055.14 | 7,662.53 | 2,439.64 | 1,453.87 | 25,958.88 | 112,582.45 |
| Total input | 30,081.53 | 2,338.27 | 155,176.02 | 10,954.59 | 12,381.67 | 14,058.38 | 9,743.85 | 6,033.38 | 3,045.01 | 55,059.83 | 298,872.53 |

**Appendix 7.1** [Continued]

| Description | Private consumption | Government consumption | Investment | Export | Import | Total final demand | Total output |
|---|---|---|---|---|---|---|---|
| Agriculture, fishery & forestry | 6,046.96 | 577.90 | 467.40 | 1,465.63 | 4,705.81 | 3,852.09 | 30,081.53 |
| Mining | 0 | 0 | 119.73 | 0 | 0 | 119.73 | 2,338.27 |
| Manufacturing | 46,266.60 | 1,016.91 | 12,429.14 | 72,114.54 | 95,671.65 | 36,155.54 | 155,176.02 |
| Electricity & water | 5,179.32 | 0 | 0 | 0 | 424.62 | 4,754.70 | 10,954.59 |
| Construction | 0 | 0 | 10,873.69 | 0 | 382.21 | 10,491.48 | 12,381.67 |
| Trade | 1,782.49 | 0 | 407.55 | 0 | 36.68 | 2,153.37 | 14,058.38 |
| Transport & communication | 1,652.73 | 0 | 210.09 | 8,156.68 | 547.83 | 9,471.67 | 9,743.85 |
| Finance | 760.97 | 12.39 | 0.30 | 0 | 69.03 | 704.63 | 6,033.38 |
| Government services | 1,068.88 | 3,958.15 | 0.000 | 30.99 | 2,023.45 | 3,034.57 | 3,045.01 |
| Other services | 29,614.15 | 4,225.07 | 197.72 | 11,907.69 | 4,099.97 | 41,844.67 | 55,059.83 |
| Total intermediate inputs | 92,372.11 | 9,790.42 | 24,705.63 | 93,675.53 | 107,961.25 | 112,582.45 | 298,872.53 |

**Appendix 8:** Energy balance table in 2010 [ktoe/year]

| SUPPLY AND CONSUMPTION | Coal & peat | Crude oil | Oil products | Natural Gas | Nuclear | Hydro | Geotherm. solar etc. | Biofuels & waste | Electricity | Heat | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | - | - | - | - | - | 2 | 0 | 3619 | - | - | 3621 |
| Imports | 16 | - | 1304 | - | - | - | - | - | 117 | - | 1437 |
| Exports | - | - | - | - | - | - | - | - | - | - | - |
| Intl. marine bunkers | - | - | - | - | - | - | - | - | - | - | - |
| Intl. aviation bunkers | - | - | -26 | - | - | - | - | - | - | - | -26 |
| Stock changes | -8 | - | - | - | - | - | - | - | - | - | -8 |
| **TPES** | **8** | **-** | **1278** | **-** | **-** | **2** | **0** | **3619** | **117** | **-** | **5024** |
| Electricity and CHP plants | -8 | - | -242 | - | - | -2 | -0 | -7 | 85 | - | -174 |
| Oil refineries | - | - | - | - | - | - | - | - | - | - | - |
| Other transformation* | -0 | - | -51 | - | - | - | - | -509 | -27 | - | -588 |
| **TFC** | **-** | **-** | **985** | **-** | **-** | **-** | **-** | **3102** | **175** | **-** | **4262** |
| **INDUSTRY** | **-** | **-** | **205** | **-** | **-** | **-** | **-** | **657** | **33** | **-** | **894** |
| Iron and steel | - | - | - | - | - | - | - | - | - | - | - |
| Chemical and petrochemical | - | - | - | - | - | - | - | - | - | - | - |
| Non-metallic minerals | - | - | - | - | - | - | - | - | - | - | - |
| Other/non-specified | - | - | 205 | - | - | - | - | 657 | 33 | - | 894 |
| **TRANSPORT** | **-** | **-** | **630** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **630** |
| Domestic aviation | - | - | 6 | - | - | - | - | - | - | - | 6 |
| Road | - | - | 513 | - | - | - | - | - | - | - | 513 |
| Other/non-specified | - | - | 111 | - | - | - | - | - | - | - | 111 |
| **OTHER** | **-** | **-** | **131** | **-** | **-** | **-** | **-** | **2445** | **143** | **-** | **2719** |
| Residential | - | - | 131 | - | - | - | - | 2445 | 89 | - | 2665 |
| Comm. and public services | - | - | - | - | - | - | - | - | 47 | - | 47 |
| Agriculture/forestry | - | - | - | - | - | - | - | - | - | - | - |
| Other/non-specified | - | - | - | - | - | - | - | - | 7 | - | 7 |
| **NON-ENERGY USE** | **-** | **-** | **19** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **19** |
| **Electricity and Heat Output** | | | | | | | | | | | |
| Electricity generated - GWh | 31 | - | 914 | - | - | 26 | 3 | 20 | - | - | 994 |
| Heat generated - TJ | - | - | - | - | - | - | - | - | - | - | - |

* Includes transfers, statistical differences, energy industry own use, and losses.

**Source:** IEA (2012)

**Appendix 9:** The adjusted energy balance table in 2010 [ktoe/year]

| Supply and consumption | Coal & peat | Crude Oil | Oil products | Natural gas | Nuclear | Hydro | Geotherm, Solar, etc. | Biofuels & waste | Electricity | Heat | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | **0** | **0** | **0** | **0** | **0** | **2.24** | **0** | **3,618.61** | **0** | **0** | **3,621.10** |
| Imports | **16.15** | **0** | **1,427.70** | **0** | **0** | **0** | **0** | **0** | **116.70** | **0** | **1,560.55** |
| Exports | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| International marine bunkers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| International aviation bunkers | 0 | 0 | -25.69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -25.69 |
| Stock changes | -7.67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -7.67 |
| **Total primary energy supply** | **8.48** | **0** | **1,402.02** | **0** | **0** | **2.24** | **0** | **3,618.61** | **116.70** | **0** | **5,148.04** |
| Statistical differences | -0.40 | 0 | -51.33 | 0 | 0 | 0 | 0 | -2.08 | 0.17 | 0 | -53.63 |
| Main activity producer electricity plants | **-8.08** | **0** | **-241.85** | **0** | **0** | **-2.24** | **-0.26** | **-6.88** | **85.48** | **0** | **-173.81** |
| Oil refineries | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Non-specified transformation processes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -507.35 | 0 | 0 | -507.35 |
| **Energy industry own use** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **-2.49** | **0** | **-2.49** |
| **Losses** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **-24.60** | **0** | **-24.60** |
| **Total final consumption** | **0** | **0** | **1,108.84** | **0** | **0** | **0** | **0** | **3,102.30** | **175.27** | **0** | **4,386.42** |
| **Industry** | 0 | 0 | 204.52 | 0 | 0 | 0 | 0 | 657.18 | 32.59 | 0 | 894.30 |
| Iron and steel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chemical and petrochemical | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Non-metallic minerals | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Non-specified (industry)** | **0** | **0** | **204.52** | **0** | **0** | **0** | **0** | **657.18** | **32.59** | **0** | **894.30** |
| **Transport** | **0** | **0** | **630.37** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **630.37** |
| **Road** | 0 | 0 | 512.88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 512.88 |
| World aviation bunkers | - | - | - | - | - | - | - | - | - | - | - |
| Domestic aviation | 0 | 0 | 6.16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.16 |
| **Rail** | 0 | 0 | 82.47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 82.47 |
| Pipeline transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| World marine bunkers | - | - | - | - | - | - | - | - | - | - | - |
| Domestic Navigation | 0 | 0 | 28.86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28.86 |
| Non-specified (transport) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Other** | **0** | **0** | **255.32** | **0** | **0** | **0** | **0** | **2,445.13** | **142.67** | **0** | **2,843.12** |
| **Residential** | **0** | **0** | **131.36** | **0** | **0** | **0** | **0** | **2,445.13** | **88.75** | **0** | **2,665.24** |
| **Commerce and public services** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **46.78** | 0 | **46.78** |
| **Agriculture/forestry** | 0 | 0 | **123.95** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **123.95** |
| Fishing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Non-specified (other) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **7.14** | 0 | **7.14** |
| Non-energy use | 0 | 0 | **18.64** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **18.64** |
| Non-energy use industry /transformation/energy | 0 | 0 | 2.94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.94 |
| Non-energy use in transport | 0 | 0 | 14.71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14.71 |
| **Non-energy use in other** | 0 | 0 | 0.98 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.98 |
| **Electricity output in GWh** | **31.00** | **0** | **914.00** | **0** | **0** | **26.00** | **3.00** | **20.00** | **0** | **0** | **994.00** |
| Electric output-main activity producer electric plants | 31.00 | 0 | 914.00 | 0 | 0 | 26.00 | 3 | 20.00 | 0 | 0 | 994.00 |
| Heat output in TJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Appendix 10:** Table used to split energy demand by energy service type in the residential sector [%]

| **Residential** | | Space heating | Space cooling | Hot water heating | Refrigerators and freezers | Cloth dryer | Cooking | Cloth washers | Dish washers | Other energy uses | Miscellaneous electric energy | Lighting | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RH1 | RC1 | RHW | RRF | RCD | RK1 | RCW | RDW | ROT | REA | RL1 | |
| Natural gas | RESNGA | 10 | | 35 | | | 40 | | | 15 | | | 100 |
| Diesel | RESDST | 20 | | 50 | | | 0 | | | 30 | | | 100 |
| Heavy fuel oil | RESHFO | 100 | | 0 | | | 0 | | | | | | 100 |
| Kerosene | RESKER | 15 | | 30 | | | 40 | | | | | 15 | 100 |
| Coal | RESCOA | 50 | | 40 | | | 10 | | | | | 0 | 100 |
| LPG | RESLPG | 25 | | 40 | | | 35 | | | | | 0 | 100 |
| Biofuels | RESBIO | 20 | | 30 | | | 50 | | | | | 0 | 100 |
| Electiricity | RESELC | 2 | 8 | 8 | 10 | 1 | 5 | 3 | 1 | | 20 | 42 | 100 |
| Heat | RESHET | 100 | | | | | | | | | | | 100 |
| Geothermal | RESGEO | 100 | | | | | | | | | | | 100 |
| Solar | RESSOL | | | 100 | | | | | | | | | 100 |

**Appendix 11:** Table used to split energy demand by energy service type in the commercial sector [%]

| **Commercial** | | Space heating | Space cooling | Hot water heating | Lighting | Cooking | Refrigerators and freezers | Electric Equipment | Other Energy Use | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CH1 | CC1 | CHW | CLA | CCK | CRF | COE | COT | |
| Natural gas | COMNGA | 15 | | 40 | | 40 | | | 5 | 100 |
| Diesel | COMDST | 50 | | 50 | | 0 | | | | 100 |
| Heavy fuel oil | COMHFO | 70 | | 30 | | 0 | | | | 100 |
| Kerosene | COMKER | 50 | | 40 | | 10 | | | | 100 |
| Coal | COMCOA | 60 | | 30 | | 10 | | | | 100 |
| LPG | COMLPG | 60 | | 35 | | 5 | | | | 100 |
| Biofuels | COMBIO | 30 | | 30 | | 40 | | | | 100 |
| Electiricity | COMELC | 3 | 13 | 6 | 35 | 1 | 20 | 22 | | 100 |
| Heat | COMHET | 100 | | | | | | | | 100 |
| Geothermal | COMGEO | 100 | | | | | | | | 100 |
| Solar | COMSOL | | | 100 | | | | | | 100 |

**Appendix 12:** Table used to split energy demand by energy service type in the industrial sector

**Appendix 12.1:** Iron and Steel Industry [%]

| **Industry** | **Iron and Steel** | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | | Boilers | Boilers | Process Heat | Machine Drive | chemical | Others | |
| | | ISIS | ISIS | IPIS | IMIS | IEIS | IOIS | |
| Electricity | INDELC | | | 29 | | | 2 | 100 |
| Natural Gas | INDNGA | 7 | | 82 | 69 | | 11 | 100 |
| LPG | INDLPG | 3 | | 95 | | | 2 | 100 |
| NGL | INDNGL | | | 0 | | | | 100 |
| Coal | INDCOA | | | 100 | | | | 100 |
| Ovencoke | INDCOK | | | 0 | | | | 100 |
| Coke Oven Gas | INDCOG | 18 | | 82 | | | | 100 |
| Blast Furnace Gas | INDBFG | 6 | | 92 | | | 2 | 100 |
| Oxygen Steel Furnace Gas | INDOXY | | | 100 | | | | 100 |
| Heavy Fuel Oil | INDHFO | 18 | | 82 | | | | 100 |
| Refined Petroleum Products | INDOIL | 6 | | 84 | | | 2 | 100 |
| Ethane | INDETH | | | | 8 | | | 100 |
| Naphta | INDNAP | | | | | | | 100 |
| Petroleum Coke | INDPTC | | | | | | | 100 |
| Biofuels | INDBIO | 100 | | | | | | 100 |
| Geothermal | INDGEO | 100 | | | | | | 100 |
| Heat | INDHET | | | 100 | | | | 100 |

**Appendix 12.2:** Non-Ferrous Metal Industry [%]

| **Industry** | **Non Ferrous metals** | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | | Boilers | Boilers | Process Heat | Machine Drive | chemical | Others | |
| | | ISNF | ISNF | IPNF | IMNF | IENF | IONF | |
| Electricity | INDELC | | | 47 | | 15 | 3 | 100 |
| Natural Gas | INDNGA | 11 | | 86 | 35 | | 3 | 100 |
| LPG | INDLPG | | | 100 | | | | 100 |
| NGL | INDNGL | | | | | | 100 | 100 |
| Coal | INDCOA | 38 | | 62 | | | | 100 |
| Ovencoke | INDCOK | | | 100 | | | | 100 |
| Coke Oven Gas | INDCOG | | | 100 | | | | 100 |
| Blast Furnace Gas | INDBFG | | | 100 | | | | 100 |
| Oxygen Steel Furnace Gas | INDOXY | | | 100 | | | | 100 |
| Heavy Fuel Oil | INDHFO | 25 | | 74 | | | | 100 |
| Refined Petroleum Products | INDOIL | 25 | | 59 | 1 | | 11 | 100 |
| Ethane | INDETH | | | | 5 | | | 100 |
| Naphta | INDNAP | | | | | | | 100 |
| Petroleum Coke | INDPTC | | | | | | 100 | 100 |
| Biofuels | INDBIO | 100 | | | | | | 100 |
| Geothermal | INDGEO | 100 | | | | | | 100 |
| Heat | INDHET | | | 55 | | | 45 | 100 |

## **Appendix 12.3:** Chemical Industry [%]

| **Industry** | **Chemicals** | | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| | | Boilers | Boilers | Process Heat | Machine Drive | Electro-chemical | Feed-stocks | Others | |
| | | ISCH | ISCH | IPCH | IMCH | IECH | IFCH | IOCH | |
| Electricity | INDELC | 0 | | 5 | 81 | 10 | | 4 | 100 |
| Natural Gas | INDNGA | 8 | | 13 | 0 | | 78 | 0 | 100 |
| LPG | INDLPG | 0 | | 0 | 0 | | 100 | 0 | 100 |
| NGL | INDNGL | 0 | | 0 | 0 | | 100 | 0 | 100 |
| Coal | INDCOA | 100 | | 0 | 0 | | 0 | 0 | 100 |
| Ovencoke | INDCOK | 0 | | 0 | 0 | | 0 | 100 | 100 |
| Coke Oven Gas | INDCOG | 0 | | 100 | 0 | | 0 | 0 | 100 |
| Blast Furnace Gas | INDBFG | 0 | | 100 | 0 | | 0 | 0 | 100 |
| Oxygen Steel Furnace Gas | INDOXY | 0 | | 100 | 0 | | 0 | 0 | 100 |
| Heavy Fuel Oil | INDHFO | 69 | | 5 | 0 | | 26 | 0 | 100 |
| Refined Petroleum Products | INDOIL | 50 | | 30 | 3 | | 17 | 0 | 100 |
| Ethane | INDETH | 0 | | 0 | 0 | | 100 | 0 | 100 |
| Naphta | INDNAP | 0 | | 0 | 0 | | 100 | 0 | 100 |
| Petroleum Coke | INDPTC | 0 | | 0 | 0 | | | 100 | 100 |
| Biofuels | INDBIO | 100 | | 0 | 0 | | | 0 | 100 |
| Geothermal | INDGEO | 100 | | 0 | 0 | | | 0 | 100 |
| Heat | INDHET | 0 | | 73 | 9 | | | 18 | 100 |

## **Appendix 12.4:** Pulp and Paper Industry [%]

| **Industry** | **Pulp and paper** | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | | Boilers | Boilers | Process Heat | Machine Drive | Electro-chemical | Others | |
| | | ISLP | ISLP | IPLP | IMLP | IELP | IOLP | |
| Electricity | INDELC | 0 | | 0 | 95 | 0 | 5 | 100 |
| Natural Gas | INDNGA | 80 | | 19 | | | 1 | 100 |
| LPG | INDLPG | 23 | | 69 | | | 7 | 100 |
| NGL | INDNGL | 0 | | 0 | | | 0 | 100 |
| Coal | INDCOA | 89 | | 1 | | | 10 | 100 |
| Ovencoke | INDCOK | 0 | | 0 | | | 0 | 100 |
| Coke Oven Gas | INDCOG | 0 | | 0 | | | 0 | 0 |
| Blast Furnace Gas | INDBFG | 100 | | 0 | | | 0 | 100 |
| Oxygen Steel Furnace Gas | INDOXY | 100 | | 0 | | | 0 | 100 |
| Heavy Fuel Oil | INDHFO | 90 | | 10 | 0 | | 0 | 100 |
| Refined Petroleum Products | INDOIL | 29 | | 15 | | | 56 | 100 |
| Ethane | INDETH | 0 | | 0 | | | 0 | 100 |
| Naphta | INDNAP | 0 | | 0 | | | 0 | 100 |
| Petroleum Coke | INDPTC | 0 | | 0 | | | 100 | 100 |
| Biofuels | INDBIO | 40 | | 60 | | | 0 | 100 |
| Geothermal | INDGEO | 100 | | 0 | | | 0 | 100 |
| Heat | INDHET | | | 100 | | | 0 | 100 |

**Appendix 12.5:** Non-Metal Mineral Industry [%]

| Industry | Non metal minerals | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Boilers | Boilers | Process Heat | Machine Drive | Electro-chemical | Others | |
| | | ISNM | ISNM | IPNM | IMNM | IENM | IONM | |
| Electricity | INDELC | 0 | | 6 | 88 | 0 | 6 | 100 |
| Natural Gas | INDNGA | 13 | | 82 | 0 | | 5 | 100 |
| LPG | INDLPG | 4 | | 88 | 0 | | 8 | 100 |
| NGL | INDNGL | 0 | | 0 | 0 | | 100 | 100 |
| Coal | INDCOA | 0 | | 100 | 0 | | 0 | 100 |
| Ovencoke | INDCOK | 0 | | 0 | 0 | | 0 | 100 |
| Coke Oven Gas | INDCOG | 0 | | 100 | 0 | | 0 | 100 |
| Blast Furnace Gas | INDBFG | 0 | | 100 | 0 | | 0 | 100 |
| Oxygen Steel Furnace Gas | INDOXY | 0 | | 100 | 0 | | 0 | 100 |
| Heavy Fuel Oil | INDHFO | 13 | | 84 | 2 | | 0 | 100 |
| Refined Petroleum Products | INDOIL | 35 | | 47 | 7 | | 11 | 100 |
| Ethane | INDETH | 0 | | | | | 0 | 100 |
| Naphta | INDNAP | 0 | | | | | 0 | 100 |
| Petroleum Coke | INDPTC | 0 | | | | | 100 | 100 |
| Biofuels | INDBIO | 100 | | | | | | 100 |
| Geothermal | INDGEO | 100 | | | | | | 100 |
| Heat | INDHET | 100 | | | | | | 100 |

**Appendix 12.6:** Other Industries [%]

| Industry | Other industries | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Boilers | Boilers | Process Heat | Machine Drive | Electro-chemical | Others | |
| | | ISOI | ISOI | IPOI | IMOI | IEOI | IOOI | |
| Electricity | INDELC | 0 | | 9 | 78 | 3 | 10 | 100 |
| Natural Gas | INDNGA | 49 | | 38 | 0 | | 13 | 100 |
| LPG | INDLPG | 6 | | 65 | 0 | | 29 | 100 |
| NGL | INDNGL | 0 | | 0 | | | 0 | 100 |
| Coal | INDCOA | 41 | | 49 | | | 10 | 100 |
| Ovencoke | INDCOK | 0 | | 0 | | | 100 | 100 |
| Coke Oven Gas | INDCOG | 0 | | 0 | | | 0 | 0 |
| Blast Furnace Gas | INDBFG | 100 | | 0 | | | 0 | 100 |
| Oxygen Steel Furnace Gas | INDOXY | 100 | | 0 | | | 0 | 100 |
| Heavy Fuel Oil | INDHFO | 70 | | 29 | 0 | | 1 | 100 |
| Refined Petroleum Products | INDOIL | 47 | | 13 | 0 | | 40 | 100 |
| Ethane | INDETH | 0 | | 0 | | | 0 | 100 |
| Naphta | INDNAP | 0 | | 0 | | | 0 | 100 |
| Petroleum Coke | INDPTC | 100 | | 0 | | | 0 | 100 |
| Biofuels | INDBIO | 100 | | 0 | | | 0 | 100 |
| Geothermal | INDGEO | 100 | | 0 | | | 0 | 100 |
| Heat | INDHET | | | 63 | 0 | | 36 | 100 |

**Appendix 13:** Waste generation and projections from 2010 through to 2050

| Solid waste generation (Million ton) | BaU scenario | | | | CM scenario | | | |
|---|---|---|---|---|---|---|---|---|
| | Disposal | Recycling | Composting | Incineration | Disposal | Recycling | Composting | Incineration |
| 2010 | 2.152 | 0.022 | 0.026 | 0.006 | 2.144 | 0.022 | 0.008 | 0.030 |
| 2011 | 2.284 | 0.039 | 0.030 | 0.007 | 2.255 | 0.049 | 0.020 | 0.036 |
| 2012 | 2.425 | 0.059 | 0.035 | 0.008 | 2.370 | 0.080 | 0.034 | 0.042 |
| 2013 | 2.572 | 0.082 | 0.041 | 0.010 | 2.490 | 0.115 | 0.050 | 0.049 |
| 2014 | 2.728 | 0.108 | 0.047 | 0.011 | 2.614 | 0.155 | 0.068 | 0.056 |
| 2015 | 2.893 | 0.137 | 0.054 | 0.013 | 2.742 | 0.200 | 0.088 | 0.064 |
| 2016 | 3.066 | 0.169 | 0.061 | 0.015 | 2.876 | 0.250 | 0.111 | 0.073 |
| 2017 | 3.249 | 0.205 | 0.069 | 0.017 | 3.013 | 0.307 | 0.136 | 0.083 |
| 2018 | 3.442 | 0.246 | 0.078 | 0.019 | 3.156 | 0.370 | 0.164 | 0.094 |
| 2019 | 3.645 | 0.291 | 0.088 | 0.021 | 3.303 | 0.441 | 0.195 | 0.107 |
| 2020 | 3.860 | 0.342 | 0.098 | 0.024 | 3.456 | 0.519 | 0.229 | 0.120 |
| 2021 | 4.088 | 0.398 | 0.108 | 0.027 | 3.614 | 0.610 | 0.262 | 0.135 |
| 2022 | 4.328 | 0.461 | 0.118 | 0.030 | 3.778 | 0.712 | 0.297 | 0.151 |
| 2023 | 4.582 | 0.530 | 0.129 | 0.034 | 3.948 | 0.825 | 0.335 | 0.169 |
| 2024 | 4.851 | 0.607 | 0.141 | 0.038 | 4.123 | 0.952 | 0.375 | 0.188 |
| 2025 | 5.135 | 0.692 | 0.153 | 0.042 | 4.303 | 1.093 | 0.418 | 0.209 |
| 2026 | 5.434 | 0.786 | 0.166 | 0.047 | 4.489 | 1.250 | 0.463 | 0.233 |
| 2027 | 5.751 | 0.890 | 0.180 | 0.052 | 4.680 | 1.424 | 0.512 | 0.258 |
| 2028 | 6.086 | 1.004 | 0.194 | 0.057 | 4.876 | 1.617 | 0.563 | 0.286 |
| 2029 | 6.439 | 1.131 | 0.209 | 0.063 | 5.078 | 1.832 | 0.617 | 0.317 |
| 2030 | 6.813 | 1.270 | 0.225 | 0.070 | 5.284 | 2.069 | 0.674 | 0.350 |
| 2031 | 7.150 | 1.475 | 0.271 | 0.086 | 5.484 | 2.374 | 0.730 | 0.394 |
| 2032 | 7.498 | 1.702 | 0.320 | 0.105 | 5.682 | 2.713 | 0.787 | 0.442 |
| 2033 | 7.859 | 1.953 | 0.372 | 0.125 | 5.877 | 3.089 | 0.847 | 0.496 |
| 2034 | 8.232 | 2.231 | 0.428 | 0.148 | 6.069 | 3.506 | 0.910 | 0.554 |
| 2035 | 8.617 | 2.539 | 0.487 | 0.173 | 6.255 | 3.968 | 0.975 | 0.617 |
| 2036 | 9.016 | 2.877 | 0.550 | 0.201 | 6.435 | 4.479 | 1.042 | 0.687 |
| 2037 | 9.428 | 3.251 | 0.616 | 0.232 | 6.607 | 5.044 | 1.112 | 0.763 |
| 2038 | 9.853 | 3.662 | 0.685 | 0.266 | 6.769 | 5.667 | 1.184 | 0.847 |
| 2039 | 10.292 | 4.114 | 0.758 | 0.304 | 6.918 | 6.354 | 1.258 | 0.937 |
| 2040 | 10.746 | 4.610 | 0.833 | 0.345 | 7.054 | 7.112 | 1.334 | 1.036 |
| 2041 | 11.214 | 5.156 | 0.912 | 0.391 | 7.172 | 7.945 | 1.411 | 1.144 |
| 2042 | 11.697 | 5.754 | 0.993 | 0.442 | 7.271 | 8.862 | 1.490 | 1.262 |
| 2043 | 12.194 | 6.409 | 1.077 | 0.497 | 7.347 | 9.870 | 1.570 | 1.390 |
| 2044 | 12.707 | 7.127 | 1.164 | 0.558 | 7.397 | 10.977 | 1.652 | 1.530 |
| 2045 | 13.235 | 7.913 | 1.252 | 0.624 | 7.417 | 12.192 | 1.734 | 1.681 |
| 2046 | 13.778 | 8.773 | 1.342 | 0.697 | 7.403 | 13.525 | 1.816 | 1.846 |
| 2047 | 14.336 | 9.713 | 1.433 | 0.777 | 7.350 | 14.987 | 1.898 | 2.025 |
| 2048 | 14.909 | 10.741 | 1.525 | 0.865 | 7.254 | 16.588 | 1.979 | 2.220 |
| 2049 | 15.498 | 11.863 | 1.618 | 0.960 | 7.108 | 18.341 | 2.059 | 2.432 |
| 2050 | 16.102 | 13.089 | 1.710 | 1.065 | 6.906 | 20.260 | 2.137 | 2.662 |

**Appendix 14:** GHG emissions and reductions by management options from 2010 to 2050

| GHG emissions | BaU scenario | | | | CM scenario | | | |
|---|---|---|---|---|---|---|---|---|
| ($ktCO_2$eq./year) | Residential | Commercial | Industry | Construction | Residential | Commercial | Industry | Construction |
| 2010 | 262 | 174 | 1,127 | 3 | 260 | 173 | 1,142 | 3.012 |
| 2011 | 315 | 187 | 1,220 | 3 | 313 | 186 | 1,234 | 3.375 |
| 2012 | 359 | 201 | 1,316 | 4 | 356 | 198 | 1,326 | 3.746 |
| 2013 | 397 | 215 | 1,414 | 4 | 391 | 211 | 1,418 | 4.124 |
| 2014 | 430 | 229 | 1,516 | 5 | 422 | 224 | 1,512 | 4.511 |
| 2015 | 462 | 244 | 1,622 | 5 | 451 | 237 | 1,608 | 4.907 |
| 2016 | 492 | 261 | 1,733 | 5 | 477 | 251 | 1,707 | 5.312 |
| 2017 | 521 | 278 | 1,850 | 6 | 503 | 266 | 1,810 | 5.726 |
| 2018 | 551 | 296 | 1,973 | 6 | 528 | 281 | 1,916 | 6.150 |
| 2019 | 581 | 315 | 2,102 | 7 | 553 | 297 | 2,026 | 6.584 |
| 2020 | 611 | 335 | 2,239 | 7 | 578 | 314 | 2,141 | 7.028 |
| 2021 | 641 | 356 | 2,384 | 8 | 602 | 330 | 2,261 | 7.483 |
| 2022 | 670 | 377 | 2,538 | 9 | 624 | 347 | 2,387 | 7.947 |
| 2023 | 700 | 399 | 2,701 | 9 | 647 | 364 | 2,518 | 8.423 |
| 2024 | 731 | 423 | 2,873 | 10 | 670 | 382 | 2,656 | 8.908 |
| 2025 | 763 | 448 | 3,057 | 10 | 694 | 401 | 2,800 | 9.404 |
| 2026 | 797 | 475 | 3,252 | 11 | 719 | 421 | 2,951 | 9.910 |
| 2027 | 832 | 504 | 3,459 | 12 | 744 | 443 | 3,108 | 10.427 |
| 2028 | 870 | 536 | 3,678 | 13 | 770 | 465 | 3,274 | 10.952 |
| 2029 | 910 | 570 | 3,912 | 13 | 798 | 490 | 3,446 | 11.487 |
| 2030 | 951 | 606 | 4,160 | 14 | 826 | 515 | 3,627 | 12.031 |
| 2031 | 1,000 | 644 | 4,411 | 15 | 857 | 539 | 3,792 | 12.516 |
| 2032 | 1,050 | 682 | 4,668 | 16 | 891 | 563 | 3,955 | 13.025 |
| 2033 | 1,102 | 720 | 4,931 | 17 | 927 | 589 | 4,118 | 13.560 |
| 2034 | 1,156 | 760 | 5,202 | 18 | 964 | 616 | 4,280 | 14.121 |
| 2035 | 1,211 | 801 | 5,482 | 19 | 1,002 | 643 | 4,442 | 14.709 |
| 2036 | 1,269 | 844 | 5,771 | 20 | 1,041 | 672 | 4,604 | 15.326 |
| 2037 | 1,329 | 889 | 6,070 | 21 | 1,081 | 702 | 4,765 | 15.972 |
| 2038 | 1,390 | 936 | 6,381 | 22 | 1,120 | 732 | 4,927 | 16.648 |
| 2039 | 1,454 | 987 | 6,702 | 23 | 1,160 | 763 | 5,088 | 17.357 |
| 2040 | 1,520 | 1,040 | 7,036 | 24 | 1,199 | 794 | 5,248 | 18.098 |
| 2041 | 1,589 | 1,096 | 7,382 | 25 | 1,238 | 826 | 5,407 | 18.875 |
| 2042 | 1,659 | 1,155 | 7,740 | 26 | 1,277 | 859 | 5,565 | 19.687 |
| 2043 | 1,733 | 1,218 | 8,112 | 27 | 1,314 | 892 | 5,720 | 20.536 |
| 2044 | 1,809 | 1,284 | 8,496 | 28 | 1,351 | 925 | 5,871 | 21.425 |
| 2045 | 1,888 | 1,355 | 8,894 | 29 | 1,386 | 958 | 6,019 | 22.355 |
| 2046 | 1,969 | 1,429 | 9,305 | 30 | 1,420 | 991 | 6,162 | 23.327 |
| 2047 | 2,054 | 1,508 | 9,730 | 31 | 1,452 | 1,024 | 6,299 | 24.344 |
| 2048 | 2,141 | 1,591 | 10,167 | 32 | 1,482 | 1,056 | 6,429 | 25.408 |
| 2049 | 2,232 | 1,680 | 10,618 | 33 | 1,510 | 1,087 | 6,550 | 26.522 |
| 2050 | 2,326 | 1,774 | 11,082 | 34 | 1,535 | 1,117 | 6,661 | 27.687 |

**Appendix 15:** Low carbon research network (LoCAR-Net) in Cambodia

**A PROPOSAL FOR LOW-CARBON RESEARCH NETWORK (LOCAR-NET) IN CAMBODIA**

**1. What does Low-Carbon Development (LCD) mean?**

LCD is a concept that refers to the development of an economy which has a minimal output of GHG emissions into the atmosphere. It is a sustainable developed or developing society on the basis of close, reasonable and harmonious coordination of economic and social development and environmental protection. To achieve a low carbon society, Skea and Nishioka (2008) suggested that a country should:

- take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within a society are met;
- make an equitable contribution toward the global effort to stabilize the atmospheric concentration of $CO_2$ and other GHGs at a level that will avoid dangerous climate change, through deep cuts in global emissions;
- demonstrate a high level of energy efficiency and use low-carbon energy sources and production technologies; and
- adopt patterns of consumption and behaviour that are consistent with low levels of GHG emissions.

**2. Why does Cambodia need LCD?**

The concept of an LCD is considered as the important economic development tool for Cambodia as it is compatible with the principles of sustainable development. Cambodia should address the development needs of all groups within the society, make a voluntary contribution toward the global effort to stabilize the atmospheric concentration of $CO_2$ and other GHG emissions at a level that would avoid dangerous climate change impacts, demonstrate a high level of energy efficiency and use low-carbon energy sources and production, and adopt patterns of consumption and behavior that are consistent with low levels of GHG emissions.

**3. Why does Cambodia need LoCAR-Net?**

The LoCAR-Net is a suitable and effective strategy to bridge the dialogues between researchers and policy makers and other stakeholders. It helps facilitate to access to the latest information on LCD in the world. As such, the establishment of the LoCAR-Net in Cambodia found very important to ensure the effective implementation of the LCD and it is used to facilitate a research network with the necessary knowledge to tackle internal and external challenges and to improve the capacity on using research-based evidence to influence policy making processes in response to the adverse impacts of climate change.

## 4. Opportunity for LoCAR-Net in Cambodia

Cambodia has set up various Government ministries/institutions, national committees and inter-ministerial working groups to ensure overall coordination and cooperation among the different policies and measures at all levels and to ensure the effective implementation among them. The NCCC was established in 2006 with the mandate to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programmes of the Government to address climate change related issues and it is assisted by the CCTT. It is realized that climate change becomes important and attracts the interest of the relevant key stakeholders. Based on this, the establishment of the LoCAR-Net in Cambodia should be possible in the future.

## 5. A proposal for LoCAR-Net in Cambodia

In order to establish the LoCAR-Net, we need to engage among national agencies, local Governments and concerned Government/non-Government organizations, research institutes and academia as well as other key stakeholders. We should build confidence, strengthen capacity, and engender a stronger sense of ownership among them. Figure 1 illustrates some key stakeholders involving with the LoCAR-Net in Cambodia. The MoE is considered as a key coordinator; however, we need to get the active participation and cooperation from other line ministries that are the member of the NCCC, relatively.

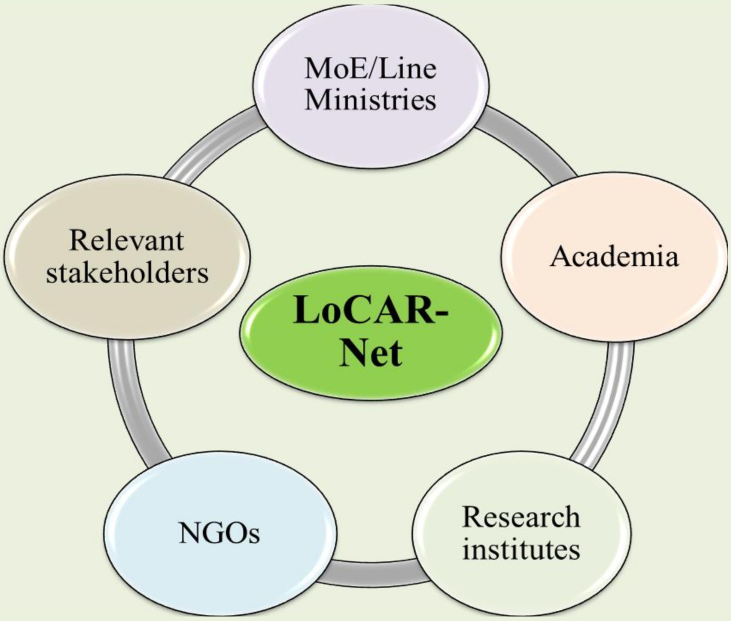


**Figure 1:** LoCAR-Net framework in Cambodia

The following proposed activities are needed to ensure the effective implementation of the LoCAR-Net in Cambodia.

***Government's ministries***

- Develop concrete national strategy and policy on the LCD;
- Cooperate with the international communities for the LCD research work;
- Build human capacity through nominating for the LCD trainings and workshops;
- Establish research institute under the relevant ministries;
- Encourage researchers for the LCD research activities;
- Mobilize resources for the LCD strategies implementation and research activities;
- Encourage the participation from academia, NGOs, research institutes and stakeholders for the LCD research;
- Mainstream the LCD concept into respective policies, strategies and action plans; and
- Translate the LCD strategies and actions into a concrete implementation.

***Academia***

- Encourage public universities and private universities; for example, Royal University of Agriculture, Royal University of Phnom Penh, Institute of Technology of Cambodia and other private universities, etc. to engage with the LoCAR-Net;
- Participate with international universities for the LCD training and research activities;
- Encourage researchers to conduct the LCD research activities;
- Share the research findings on the LCD related matters with other researchers and decision makers;
- Mainstream LCD concept into study calendar;
- Convince the decision makers to believe on the research findings with clear explanation and references so that they can use for economic development;
- Demonstrate the research findings via implementing a pilot project; and
- Be willing to work with international communities on the LCD.

***Other stakeholders***

- Share information and data from their respective offices and institutions for the purpose of the LCD research;
- Cooperate with the Government agencies to ensure effective LCD implementation; and
- Be willing to work with other stakeholders and international communities.

***Research institutes***

- Mainstream the LCD subject into research plan;
- Participate with international universities and institutions for the LCD trainings (*e.g.* NIES in Japan) and workshops;
- Encourage researchers to conduct the LCD research;
- Mobilize and allocate budget for the LCD research activities;
- Share the research findings with decision makers and other stakeholders;
- Convince the decision makers to believe on the research findings with clear explanation and references so that they can use for economic development;
- Demonstrate the research findings via implementing a pilot project; and
- Be willing to work with other international communities on the LCD.

***Non-Governmental Organizations (NGOs)***

- Mainstream the LCD concept into their respective strategies and action plans;
- Encourage researchers for the LCD research;
- Allocate budget for the LCD research activities;
- Share the research findings with decision makers and other stakeholders;
- Demonstrate the research findings via implementing a pilot project; and
- Be willing to work with international communities on the LCD.

Contributed institutions are:

The Ministry of Environment, Cambodia

Kyoto University, Japan

Institute for Global Environmental Strategies, Japan

National Institute for Environmental Studies, Japan

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