平成28年度JCMを活用した大規模削減案件形成可能性調査事業委託業務
（タイ王国のキャッサバ工場、パーム工場の廃液からのバイオガス精製・天然ガス自動車用燃料供給事業）

報告書（和文）

平成２９年２月

株式会社 日本総合研究所

目次

1. サマリー

本事業では、JCMの締結国であるタイ王国において、大阪ガス株式会社が保有するバイオガスの精製技術の導入によるGHG削減検討を実施した。

事業においては、タイ王国に所在するパーム油生産工場やキャッサバを原料とするタピオカ工場において生じる固形バイオマスやバイオマスを含む廃液の発酵から生産されるバイオガスを原料とする。生産されたバイオガスは大阪ガスが保有する精製技術を通じて、メタンの含有率を向上し、主に自動車燃料用途へ販売することを検討した。

調査にあたっては、タイ王国における関連する政策（エネルギー政策、ガス・電力政策、燃料への補助の見通し）動向の調査に加えて、事業パートナーとなるパーム・キャッサバ工場の選定、現地のEPC事業者の選定、NGVを保有する輸送会社の調査を通じて、事業体制の構築検討を行った。

このうち、導入先のパーム・キャッサバ工場に関しては、第1号案件としては、経営が安定しており、与信が高いことを前提に導入対象工場の選定を検討し、同工場における余剰バイオガスポテンシャル、近隣地におけるCNG価格（燃料ステーションにおける天然ガス価格）、JCMの適用可能性の評価を行い、2社への導入が有望であると考えられた。

また、現地サイトへのヒアリング調査、バイオガス発生量やバイオガス原料などのサイトの条件整理を通じて、導入する技術の仕様特定、事業性の試算、同サイトにおけるMRV方法論の特定を実施した。

結果、タイ王国における現下及び今後予想される市場環境下で、抽出した2社のサイトにおけるプロジェクトは、JCMスキームにおける設備補助を通じて事業性を確保できると考えられた。

また、CBG精製技術導入によるGHG排出削減量はバイオガスの大気放出回避、化石燃料代替により、サイト毎にそれぞれ19万t-CO2e/年、7.6万t-CO2e/年程度と試算され、大規模な削減量につながる可能性があることが確認された。

今後、2017年4月より大阪ガスが実施する精製技術の実証事業を通じて、技術の信頼性を確認し、サイトへの導入に向けた詳細協議を実施し、商用化を進めていくこととしている。

2. 事業の概要

2.1 調査事業の目的

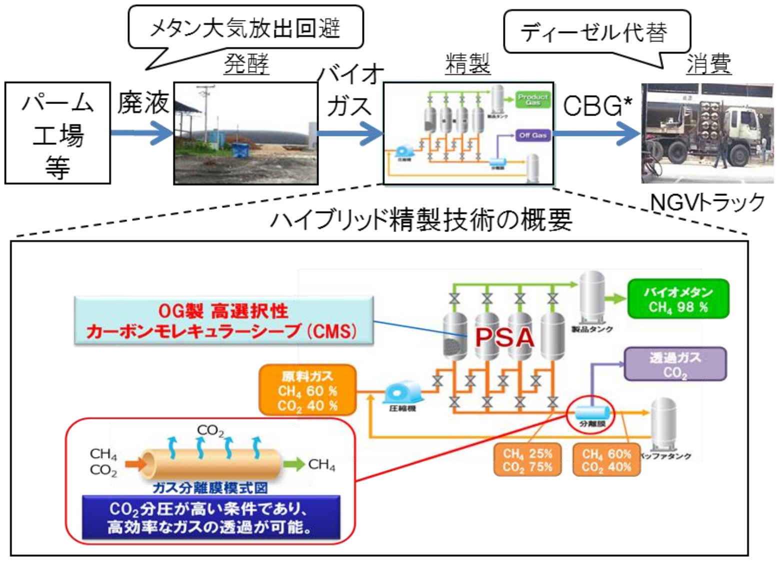
本調査事業においては、JCM の締結国であるタイ王国において、大阪ガス株式会社が開発したバイオガス精製技術の導入により、GHG 排出量の低減、CBG（Compressed Bio Gas）の生産・販売事業実施することを目的としている。

世界第 3 位のパーム油生産量・キャッサバ生産量を保有するタイ王国では、生産に伴って排出される工場廃液より発生するメタンが多く、同国の GHG 排出量の大きな部分を占めている。

他方、廃液の発酵を通じて発生するバイオガスは、主にメタン、二酸化炭素で構成されるものの、大阪ガスが開発する精製技術により、メタンを逃がすことなく（メタンの回収率 98%)、熱量を高めることが可能（メタンの含有比率 98%まで高めることが可能）であり、有価資源として活用可能である。

こうして精製されたバイオガスは、天然ガスの代替燃料として利用可能であることから、輸送部門における天然ガス利用量の多いタイ王国において、自動車用燃料としての販売を事業の収益として検討した。

図表 1　本プロジェクトにおけるフロー



出所：大阪ガス資料

GHG 削減量としては、大気放出されていたメタンの放出回避、天然ガス自動車（以下、「NGV」）、とりわけ NGV トラックにおける CBG 燃料の利用によるディーゼル、天然ガス等化石燃料の使用回避による二酸化炭素排出量の回避が可能であり、GHG 排出量削減の観点からは上記削減量の最大化を目指して、事業の構築可能性調査を実施した。

2.2 対象技術の概要

本事業において導入の対象とする技術は大阪ガスが開発したバイオガス精製システムである。同バイオガス精製システムは、PSA（Pressure swing adsorption）と分離膜を組み合わせたハイブリッド型バイオガス精製設備である。

一般的にはバイオガスの精製技術には PSA、膜分離、高圧吸水方式の 3 種類があり、それぞれに一長一短の特徴がある。

PSA は、吸着材に二酸化炭素を吸着させ除去する方式で、小型-中型システムに向く。高純度への精製に強く世界で 50 件以上の実績があるが、相対的にメタン回収率が低い。膜分離は、高分子膜を分離膜として使用し、メタンと二酸化炭素が膜を通り抜ける速さの違いで二酸化炭素を分離する方式で、小型システムに向く。高圧運転のため電力コストが高く、実績は欧州中心に 10 件程度である。高圧吸水方式は、高圧の水に二酸化炭素を吸収させ除去する方式で、大規模システムに向く。アジアを含む世界 50 件以上の実績があるが、循環水量が多いため電力コストが高くなる。

タイ王国向けのバイオガス精製技術開発に当たっては、標準的なパーム工場の廃水処理が可能な容量として、1,000Nm^3/h 程度のバイオガスに対応できる中型システムを検討した。大阪ガスは従前から技術蓄積がある PSA をベースに分離膜を組み合わせることでハイブリッド型バイオガス精製技術を開発し、PSA の弱点であるメタン回収率の向上を図った。なお PSA に搭載する吸着剤は大阪ガス独自の高機能剤である。

通常 PSA 単独でメタン精製を行った際のメタン回収率は 85%程度であるが、本システムではメタン濃度 98%の精製ガスを 98%のメタン回収率にて取り出せる仕様となっている。

本システムは、ガスを供給する圧縮機、PSA、ガス分離膜より構成され、PSA から排出されるオフガスを分離膜により原料バイオガスに近い濃度まで再濃縮し、PSA の入り口へとリサイクルするという特徴を持っている。PSA において高濃度への濃縮を行いながら、オフガス

のリサイクルにより回収率を補い、そのリサイクル時の濃縮には、中程度のメタン濃度条件において効率よく濃縮ができる分離膜を用いることで、全体として高効率なシステム構成となっている。

圧縮機によって 0.7 MPaG 程度まで昇圧された原料ガスは吸着塔へと導入され、内部の吸着材が原料ガス中より二酸化炭素を選択的に吸着させることで二酸化炭素を除去する。二酸化炭素が除去された高純度のメタンを含む製品ガス（以下、「バイオメタン」）は吸着塔上部より回収される。一定量の吸着を行った後、吸着塔内の吸着材の再生のため、吸着工程を別の吸着塔へと切り替え、吸着終了後の吸着塔内を減圧する脱着工程が行われる。この脱着工程の際に、脱着する二酸化炭素と共に吸着塔の空隙中に残存するメタンも吸着塔よりオフガスとして排出される。このオフガスをガス分離膜へと導入し、高濃度の二酸化炭素を含む透過ガスと、一部の二酸化炭素が除去されメタン濃度が上昇した非透過ガスへと分離を行う。透過ガスは系外へと排出し、非透過ガスは PSA の入口へとリサイクルをする。透過ガスとして系外へ排出されるメタンが殆ど無く、原料ガスとして導入されたメタンの大部分がバイオメタンとして回収できるため、本システムでは高いメタン回収率を達成できる。

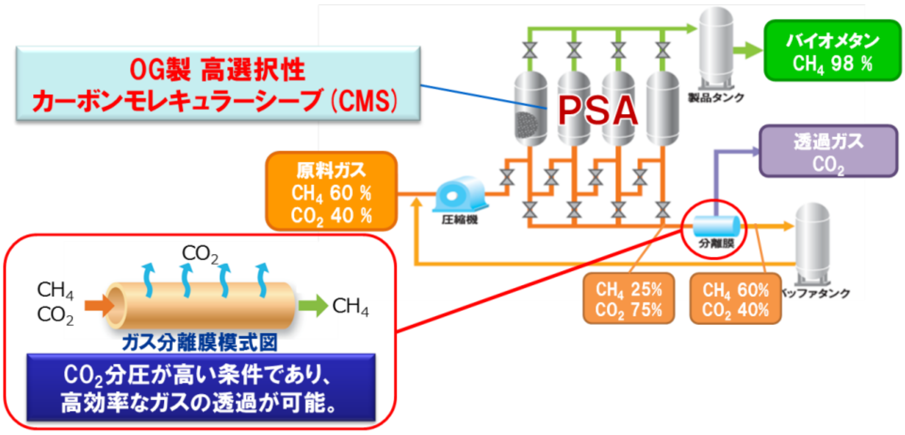
大阪ガスでは、2013 年からラボ試験を開始し、1 年半でシステム最適条件を確立し、次の 1 年半で紙屑・草木等から嫌気性発酵により生成されている実バイオガスによるフィールド試験を実施し、長期運転確認と制御システムを確立した。

現在すべてのベンチスケールテストを日本で完了し、商業化の前段階として、タイ王国のパーム工場で小規模設備（バイオガス流量 250Nm^3/h）によるパイロット実証試験を進めている。既に現地協力企業との調整を開始しており、2016 年 7 月頃から着工し 2017 年度から運転を開始する予定である。

なお、バイオガス精製技術の他に、大阪ガスの CBG 事業に関連するノウハウ・実績としては、天然ガスステーションの運営が挙げられる。これまでに日本国内で天然ガスステーションを 20 か所運営して

いる。また、神戸市東灘処理場で発生したバイオガスを精製し、NGVの燃料として利用する「こうべバイオガス」の設計、運用では技術支援を実施するなど、この分野に関してノウハウ・実績の蓄積がありCBG利用が初めてとなるパーム・キャッサバ工場（以下、「バイオマス工場」）へCBGの製造からNGVでの利用まで一貫したサービスを提供できる強みがある。

図表 2　ハイブリッド型バイオガス精製システム



出所：大阪ガス資料

2.3 事業展開の方針

大阪ガスは、ハイブリッド型バイオガス精製設備について、2016年度から自己負担にてパイロット実証に着手しており、2017年度には商業化を推進する計画である。パイロット実証と並行して、早期にCBG事業を立ち上げるために、2016年度は本事業を活用して、事業化案件の発掘に努めた。

2.4 調査実施内容

CBG 事業中期事業計画を実現するために、本調査では以下の調査を実施した。

- 対象国の基礎情報・動向

本技術の導入対象とするタイ王国の基礎情報・政策動向に関する調査を実施した。特にタイ王国のエネルギー需給、GHG 排出状況や GHG 排出削減の取り組み方針を中心に整理した。また、GHG 排出削減の取り組み方針のうち再生可能エネルギー目標、特にバイオガス由来エネルギーの生産・利用目標について調査を行い、本事業におけるバイオマス工場からの CBG 生産がタイ王国における政策目標に合致していることを確認した。

また、タイ政府は上記再エネ目標の達成のため、FIT の改正や CBG 製造に対する補助金を検討しており、こうした事業環境に影響する政策動向に関して調査を行った。

- 事業体制の構築

本技術を利用して 2021 年度末に累計約 101 万 t の GHG 排出量削減を達成するための、ステークホルダーの探索・事業検討に向けた協議を実施した。具体的には、プラント設計・建設を行う現地 EPC 事業者、バイオガスの供給源となるバイオマス工場オーナー、CBG の消費者となる NGV トラック保有者の探索を実施した。

・ EPC 事業者候補との協議

現在、タイ王国でバイオマス工場からのバイオガス生産プラント向けに EPC 事業を行っている 2 社を本事業におけるバイオガス生産プラント向けの EPC 事業者候補として選定した。両事業者は工場廃液より発生するバイオガスを利用した発電・工場熱供給プラントの EPC 及び運転・保守を実施しており、同分野の EPC に資する知見を豊富に保有する。

・ バイオマス工場オーナーの探索

本事業の導入対象となるバイオマス工場の探索を実施した。探索に当たっては、タイ王国全体におけるバイオマス工場の立地・分布把握のため、事前調査対象工場の精査、未確認工場の探索によってバイオマス工場をロングリスト化するとともに、生産規模（FFB 処理量）、バイオガスポテンシャル（発電等への利用有無）、所在地域、事業への関心などから本技術の事業パートナーの要件を充足するかスクリーニングを行い、案件候補探索および実導入に向けた協議を実施した。

・ トラック保有者の探索

製造した CBG の消費者となるトラック保有者の探索を実施した。多くのバイオマス工場においては、製品出荷のためのトラック保有が見込まれるものの、それだけで本プロジェクトで製造する CBG の量に見合う需要が得られるかが不透明であることから、バイオマス工場周辺地域の輸送会社を追加的な CBG 需要家候補として調査を進めることとした。

➢ 技術仕様の特定

本項目では、実導入を行うサイトを選定した後に、実導入に向けた技術仕様を検討した。具体的には、バイオガスの発生量、発生ガスにおけるメタン濃度、不純物の有無等をもとに、技術上必要となる精製規模・圧力などを検討した。

➢ 事業性試算

本項目においては、CBG 製造に必要な設備における導入費用を算出するとともに、マクロ経済動向（インフレ率、ユーテリティー単価動向等）、原料価格、精製費用（イニシャルコスト、人件費、電力コスト等）を算出した。これらのパラメータを基に本事業の事業性試算を実施した。

➢ 普及展開可能性の調査

本事業が今後タイ王国において普及する可能性の調査のため、本技術の普及を後押しする政策動向の調査、タイ王国の CBG 生産ポテンシャル、バイオマス工場のニーズ調査、他の CBG 製造技術保有者や小型バイオガス発電事業者との比較における本事業の競争優位性を調査した。

➢ MRV 方法論の特定

バイオマス工場からのバイオガス回収によるメタン放出回避及びトラックへの CBG 利用による自動車燃料代替のエネルギー削減の 2 つの活動において削減される GHG 排出量を特定、これら方法論を参考に MRV 方法論の特定を実施した。プロジェクト設計書(PDD)に関しては、策定した方法論とプロジェクト（現地調査にて特定された内容）に基づき作成を行った。

2.5　調査実施体制

本事業は、日本総合研究所が応募事業者、大阪ガスが共同応募事業者として調査コンソーシアムを結成して実施する。

また、現地の EPC 事業者に対し、バイオマス工場の調査、トラック保有事業者、事業性試算にかかる調査を一部委託し、事業の検討を行った。

株式会社 日本総合研究所	• **政策動向調査** • **事業性試算** • MRV**方法論の特定** • **普及可能性調査**
大阪ガス株式会社（JCMプロジェクト実現時参加企業）	• **事業体制の構築** • **技術仕様の特定**
外注 → **外注先（JCMプロジェクト実現時参加企業）** **・EPC事業者**	• **事業体制の構築** **-バイオマス工場の探索** **-トラック保有者の探索** **-事業性試算**

3. タイ王国の基礎情報・政策動向

3.1 タイ王国の基礎情報

図表 3 タイ王国の一般情報

面積	51 万 4,000km²（日本の約 1.4 倍）
人口	6,830 万人（2013 年）
首都	バンコク
民族	大多数がタイ族。その他　華人，マレー族等
言語	タイ語
宗教	仏教　94%，イスラム教　5%

出所：外務省ウェブサイト

タイ王国は日本の約 1.4 倍の国土を持つ一方、人口は日本の約半数の 6,830 万人である。文化面では、タイ語が公用語に話されており、また、仏教徒が全国民の約 94%を占める。

2016 年 10 月に前元首であるプミポン・アドゥンヤデート国王（ラマ 9 世）の死去に伴い、ワチラーロンコーン（ラーマ 10 世）氏が新たに着位した。プミポン前元首の在位年月は 70 年 4 カ月と長期に及び、過去に政治混乱に直接介入し事態を収拾したこともあり、国民から絶大な支持と尊敬を集めていた。そのため、プミポン氏死去に伴う国内経済への混乱が懸念されたが、政府の経済活動への影響を最小限に抑えたい意向もあり、現在のところ大きな混乱はみられていない。

一方、現在のプラユット政権になって以降、テロが定期的に発生しており、治安情勢については留意する必要がある。

図表 4　タイ王国の政治情報

政治体制	立憲君主制
元首	ワチラーロンコーン（ラーマ 10 世） （2016 年 12 月 1 日～）
議会	国家立法議会（220 名）
政府	首相名　プラユット・ジャンオーチャー （Mr. Prayuth Chan-o-cha） 外相名　ドーン・ポラマットウィナイ （Mr. Don Pramudwinai）

出所：外務省ウェブサイト

2014年5月、軍部を中心とする国家平和秩序維持評議会（NCPO）が全権を掌握したことによる政情混乱等もあり、2014年の成長率は0.9%であった。落ち着きを見せた2015年は2.8%、2016年については3.0～4.0%を見込んでいる。

図表 5　タイ王国の経済状況

主要産業	農業は就業者の約40%弱を占めるが，GDPでは12%にとどまる。一方，製造業の就業者は約15%だが，GDPの約34%，輸出額の90%弱を占める。
GDP	3,952億ドル(名目,2015年,国家経済社会開発庁(NESDB))
一人当たりGDP	5,878ドル（2015年，NESDB）
経済成長率	2.8%（2015年，NESDB）
消費者物価指数	-0.9（2015年，NESDB）
失業率	0.8%（2014年，NESDB）
総貿易額	（1）輸出　2,121億ドル（2015年，NESDB） （2）輸入　1,775億ドル（2015年，NESDB）
主要貿易品目	（1）輸出　コンピューター・同部品，自動車・同部品，機械器具，農作物，食料加工品 （2）輸入　機械器具，原油，電子部品
主要貿易相手国・地域（2015年）	（1）輸出　1.米国　2.中国　3.日本 （2）輸入　1.中国　2.日本　3.米国
通貨	バーツ（Baht）
為替レート	1円＝3.17THB（2016年平均）

出所：外務省ウェブサイト

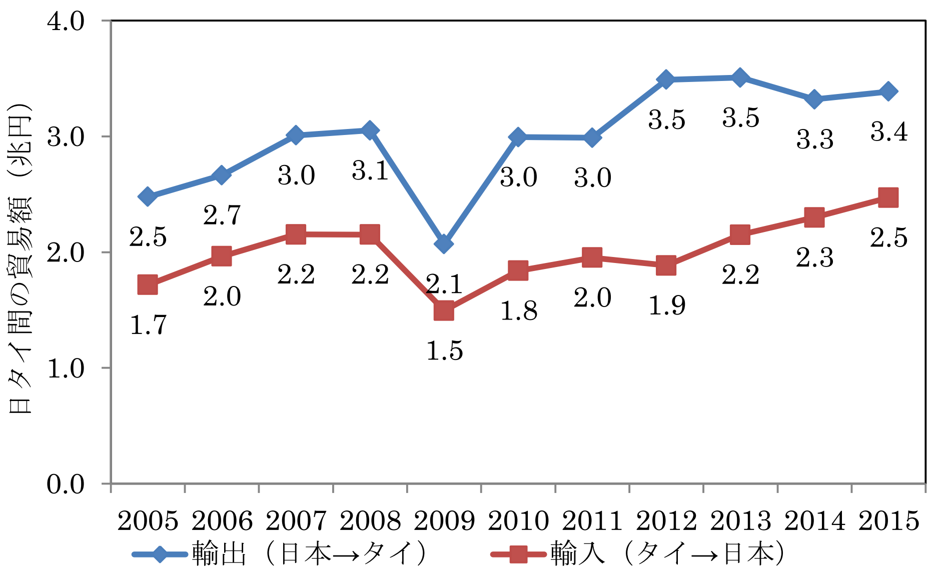
3.2　両国の関係

3.2.1 日本国との関係

日タイ両国は 600 年にわたる交流の歴史を持ち、伝統的に友好関係を維持している。近年は両国の皇室・王室間の親密な関係を基礎に、政治、経済、文化等幅広い面で緊密な関係を築いている。

2007 年に経済連携協定を発効するなど、両国の経済関係も良好である。2005 年以降、リーマンショックのあった 2009 年を除き、日タイ間の貿易額は順調に増加している。

図表 6　日本タイ間の輸出入額



出所：貿易統計（財務省）を基に日本総研作成

3.2.2 JCM 二国間文書への署名

2015 年 11 月 19 日、丸川環境大臣とスラサク・カーンジャナラット天然資源・環境大臣との間で、二国間クレジット制度（JCM）の構築について合意がなされ、両国は制度運用に係る二国間文書に署名を行った。これにより、タイ王国は 16 カ国目の JCM 署名国となった。

JCM 締結後、2 回の合同委員会を通じて、2 件の方法論が承認されている。

図表 7　日本タイ間で承認された方法論

セクトラルスコープ	方法論名	GHG 排出削減手法
エネルギー需要	Energy Saving by Introduction of Multi-stage Oil-Free Air Compressor	多段オイルフリー圧縮機の導入によるエネルギー使用量の削減
エネルギー需要	Installation of Solar PV System	ソーラーPV システムの導入及び運用により、ディーゼル燃料を使用したグリッド電力及び/または自家発電力を代替

出所：Joint Crediting Mechanism (JCM) web サイト「Approved methodologies」を基に日本総研作成

また、2010 年より環境省が支援する JCM 資金支援事業では、2015～2016 年（2016 年 7 月時点）の間に、既に 16 の案件が採択されている。

図表 8　環境省 JCM 資金支援事業におけるタイ案件一覧（2015～2016 年度）

年度	分野	事業者	案件名
2015	省エネ	(株)ファミリーマート	コンビニエンスストアにおける空調・冷蔵ショーケースの省エネ
2015	省エネ	東レ(株)	織物工場への省エネ型織機導入プロジェクト
2015	省エネ	ソニーセミコンダクタマニュファクチャリング(株)	半導体工場における省エネ型冷凍機・コンプレッサーの導入
2015	省エネ	パシフィックコンサルタンツ(株)	工場屋根を利用した太陽光発電システム導入プロジェクト
2015	省エネ	新日鉄住金エンジニアリング(株)	二輪車製造工場におけるオンサイトエネルギー供給のためのガスコージェネレーションシステムの導入
2015	省エネ	ソニーセミコンダクタマニュファクチャリング(株)	半導体工場における省エネ型空調システム及び冷凍機の導入
2016	省エネ	旭硝子（株）	苛性ソーダ製造プラントにおける高効率型イオン交換膜法電解槽の導入
2016	省エネ	（株）ファーストリテイリング	物販店舗へのＬＥＤ照明の導入

2016	省エネ	日本テピア（株）	牛乳工場における省エネ型冷水供給システムの導入
2016	省エネ	（株）エヌ・ティ・ティ・データ経営研究所	セメント工場への 12MW 廃熱回収発電システムの導入
2016	省エネ	（株）デンソー	自動車部品工場へのコージェネレーション設備の導入
2016	省エネ	協和発酵バイオ（株）	アミノ酸製造工場への省エネ型冷凍機及び自己蒸気機械圧縮型濃縮機の導入
2016	再エネ	シャープ（株）	エアコン部品製造工場群への 3.4MW 屋根置き太陽光発電システムの導入
2016	再エネ	（株）ファインテック	ペイント工場への屋根置き 1.5MW 太陽光発電および先進的ＥＭＳによる電力供給
2016	省エネ	兼松（株）	産業用冷蔵庫における省エネ冷却システムの導入

出所：新メカニズム情報プラットフォーム「JCM 支援事業・調査採択案件一覧」

3.3 本事業の関連省庁・機関の役割

本事業に関連する政策の動向に加えて、事業に関する規制・補助に関する情報収集のため、下記政府機関へのヒアリングを実施した。

3.3.1 Ministry of Energy, Energy Policy & Planning Office (EPPO)

電気事業を含むエネルギー部門を統括するエネルギー省（DOE）の傘下で、エネルギー政策と計画を担当している機関である。代替エネルギー促進による省エネルギー推進や短期的・長期的な石油不足解消策の提案、政府のエネルギーマネジメント計画の監督と評価などを行う[1]。

タイ王国国内におけるエネルギー（ディーゼル・CNG 等）小売価格の決定権限も保有しているため、今後のディーゼル・CNG 小売価格への補助の見込みに関するヒアリングを実施。政府・PTT における財政支出軽減のため、地方部における CNG 価格規制撤廃を議論するとの動向を得た。

3.3.2 Department of Energy Development and Efficiency (DEDE)

エネルギー省（DOE）の傘下で、エネルギーの効率化と省エネルギーに関する規制、エネルギー資源の調達、エネルギー価格の適正化を目的として、代替エネルギーの普及に関する技術移転を行う機関である[1]。

ヒアリングでは、2016 年に実施した CBG の設備補助に関して、今後の継続可能性等をヒアリングした。DEDE においては、AEDP で示された CBG 生産量の達成に向けて、CBG 設備補助などを実施。他方、政府側としても CBG 製造にかかる情報収集の段階であり、2016 年に措置した補助金が生産コストにいかに影響を及ぼすのかをモニタリ

[1] 一般社団法人海外電力調査会、海外諸国の電気事業　第 1 編（下巻）2014 年、81-82 ページ

ングしつつ、今後の補助措置について決定するとの情報を得た。

3.3.3 Department of Energy Business (DOEB)

エネルギー省（DOE）傘下で、エネルギー事業に関する規制について取り扱う機関である。バイオガス事業を行うにあたる法関連での規制を策定している。

ヒアリングを通じて、バイオガス精製事業における安全面からの規制は存在するものの、外資規制等本事業構築におけるクリティカルなリスクはないことを確認した。

3.3.4 Thailand Greenhouse Gas Management Organization (TGO)

気候変動対策に対する取組を管理する現地機関であり、JCM 登録におけるタイ政府側の事務処理を担う。バイオガスの有効利用事業の CDM への登録は実績があるものの、JCM 上ではまだないとの情報を得た。

3.3.5 National Innovation Agency (NIA)

タイ王国において新エネルギー・産業技術総合開発機構（NEDO）の役割を果たす機関である。規模は NEDO に比べると小さい。

NEDO と異なり支援対象に制約はないため、近年は EV、IoT についても範囲対象として扱っている。また、現在はスタートアップ企業の支援に注力している[2]。

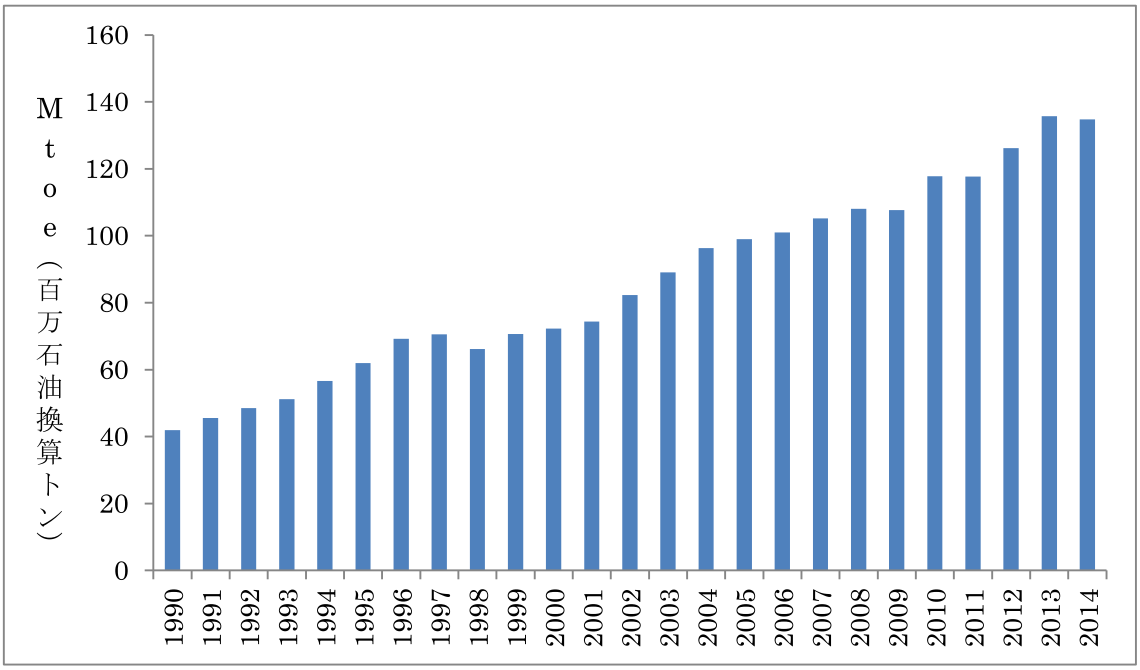
[2] 現地ヒアリング

3.4 エネルギーバランス（生産・輸出入・消費）及び推移

3.4.1 1次エネルギー需要の推移

タイ王国の1次エネルギー需要は高い経済成長率を背景に増加の一途を辿っている。

図表 9 タイ王国の一次エネルギー供給量の推移



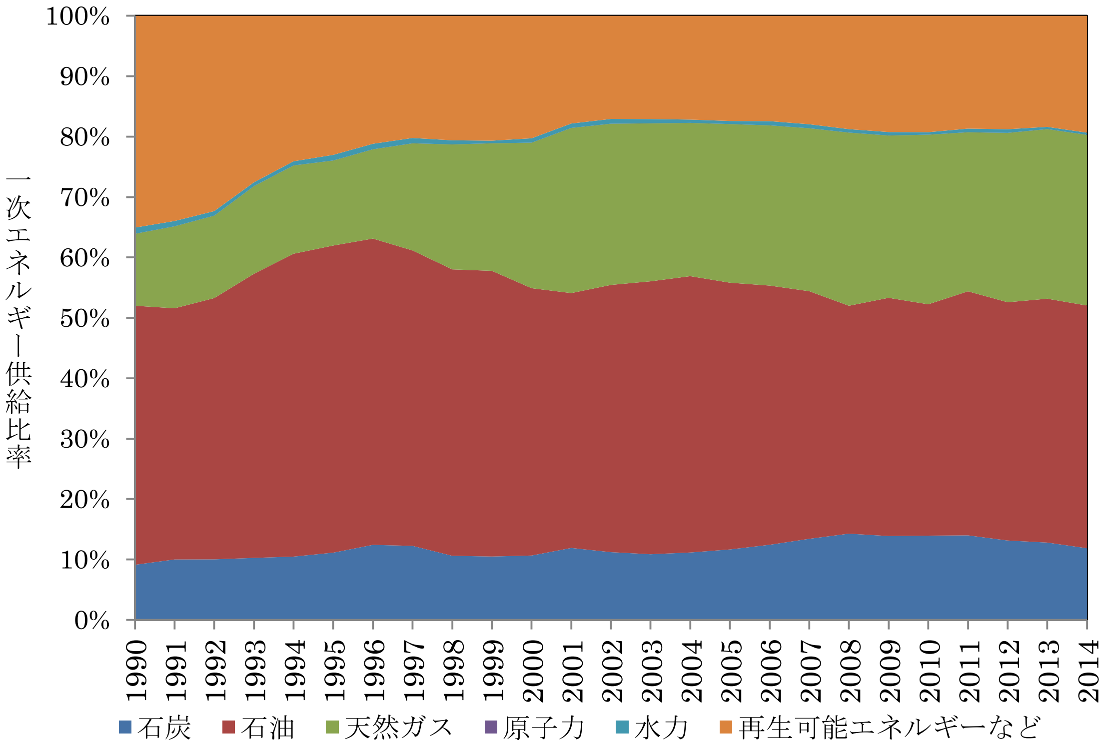
出所: OECD iLibrary

3.4.2 燃料別エネルギー消費の動向

エネルギー源として最も消費されているのは石油であり、次いで天然ガスである。タイ王国は化石燃料資源に恵まれており、天然ガスや石炭の自給率は従来非常に高く、特に天然ガスは全て国産で賄ってきた。しかしながら、上昇するエネルギー需要に対応するため、化石燃料の輸入が近年増加しており、100%であった天然ガスの自給率は2000 年を境に減少し、現在は 80%を割り込んでいる。また、石炭も大きく自給率を下げている。そのため、後述する通り、エネルギーの海外依存度の低減が課題となっており、タイ王国の政策は省エネやエネルギーセキュリティの向上に向けられている。

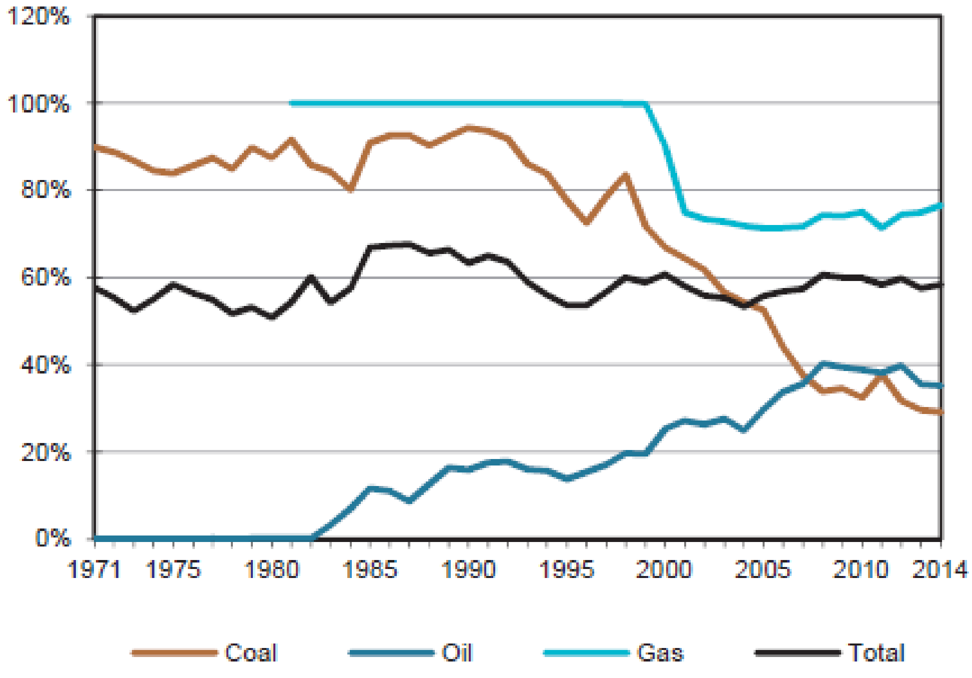
純国産エネルギーでありエネルギーセキュリティの向上に寄与すると考えられる再生可能エネルギーの導入状況を示す。再生可能エネルギーの大半がバイオマス由来であり、後述する再生可能エネルギーの長期計画においても、バイオマスにかける期待は極めて大きくなっている。

図表 10 エネルギー消費量内訳の推移



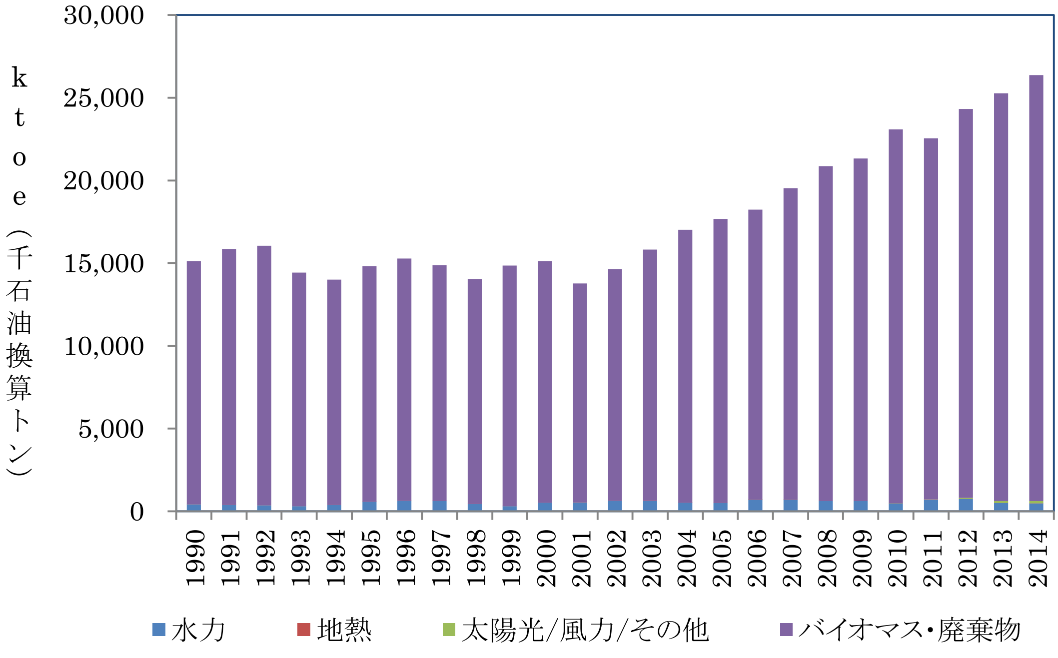
出所：OECD iLibrary

図表 11 化石燃料の自給率推移



出所：IEA World Energy Balances 2016

図表 12 再エネ由来 1 次エネルギー消費量の推移



出所：OECD iLibrary

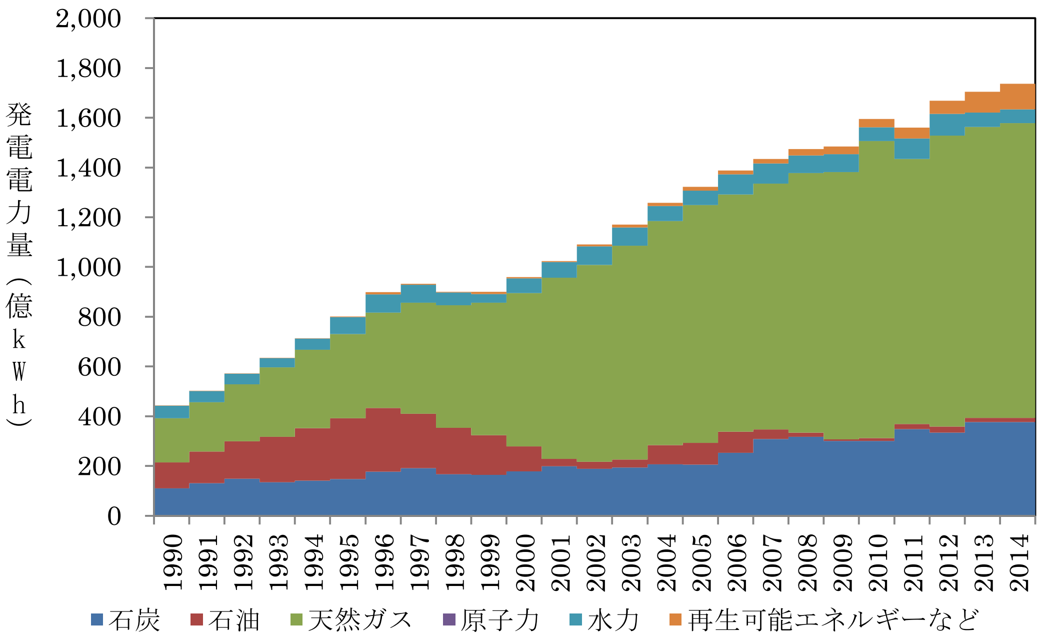
3.4.3 部門別エネルギー消費動向

3.4.3.1　電力

電力の需要も一次エネルギーと同様、拡大傾向にあり、それに合わせて発電能力の拡大が求められている。1990 年代前半から天然ガス専焼プラントが増加し、天然ガスによる発電量が急増している一方で、石油による発電量は大きく減少していることが見て取れる。また、2000 年頃から、水力を除く再生可能エネルギーの導入量が大きく伸びていることがわかる。

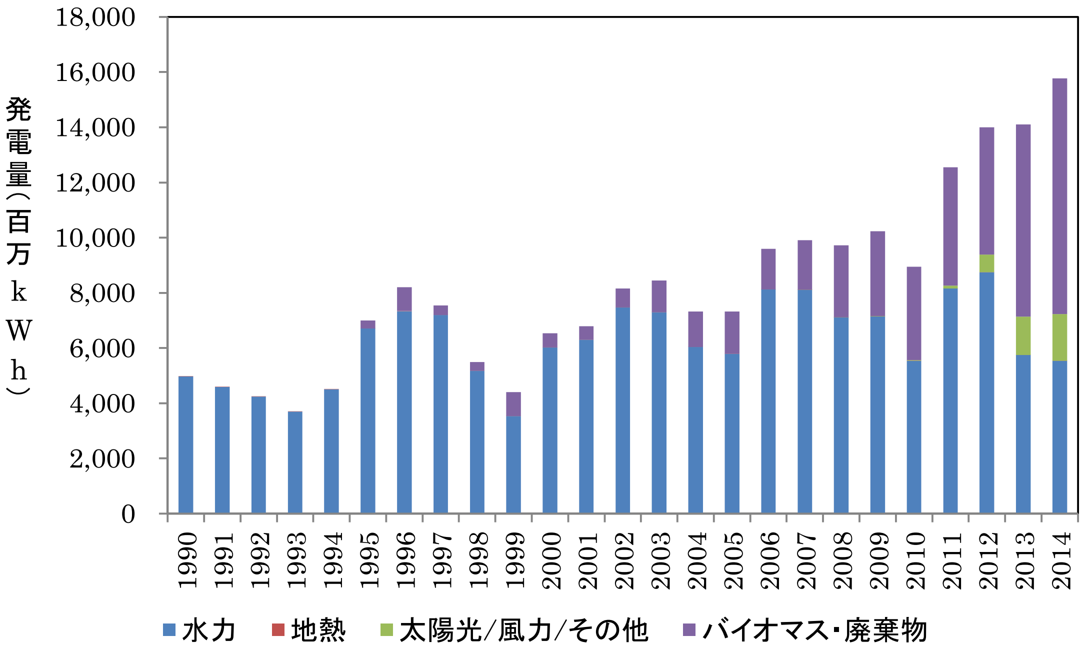
電力部門における再生可能エネルギーは従来、そのほとんどが水力由来であったが、近年水力以外の再生可能エネルギーの導入が進んでおり、2013 年には水力とその他再エネの発電量が逆転している。2010 年頃から太陽光や風力等が拡大していることも一因ではあるものの、導入拡大を牽引しているのはバイオマス発電であり、電力部門においてもバイオマスの存在が増している。

図表 13 発電量および内訳の推移



出所：OECD iLibrary

図表 14 再生可能エネルギー発電量の推移



出所：OECD iLibrary

3.4.3.2　熱

タイ王国では砂糖・製紙・精米・木材加工・パーム油等の産業を中心に再生可能エネルギーの熱利用が進んでいる。これらの産業において再生可能エネルギー利用が進む理由としては、事業に伴い排出される廃棄物が活用可能であるためであり、それら廃棄物がバイオマスや廃液由来のバイオガスとして使用されている。タイ政府は 2036 年までに熱部門に占める再生可能エネルギーの割合を 36.67%まで引き上げる目標を立てているが、目標達成に向けては上記に加えて熱電併給システムや太陽熱利用の拡大にも力を入れていくとしている。

図表 15 各産業の熱源

産業	各産業に用いられる熱源
砂糖	サトウキビの搾りかす99.96%、その他残物0.04%
製紙	黒液（廃液）62.37%、炭19.58%、薪6.23%
精米	もみ殻99.24%
木材加工	薪95.04%、おがくず4.91%
パーム油	パーム果房84.27%、その他残物8.96%

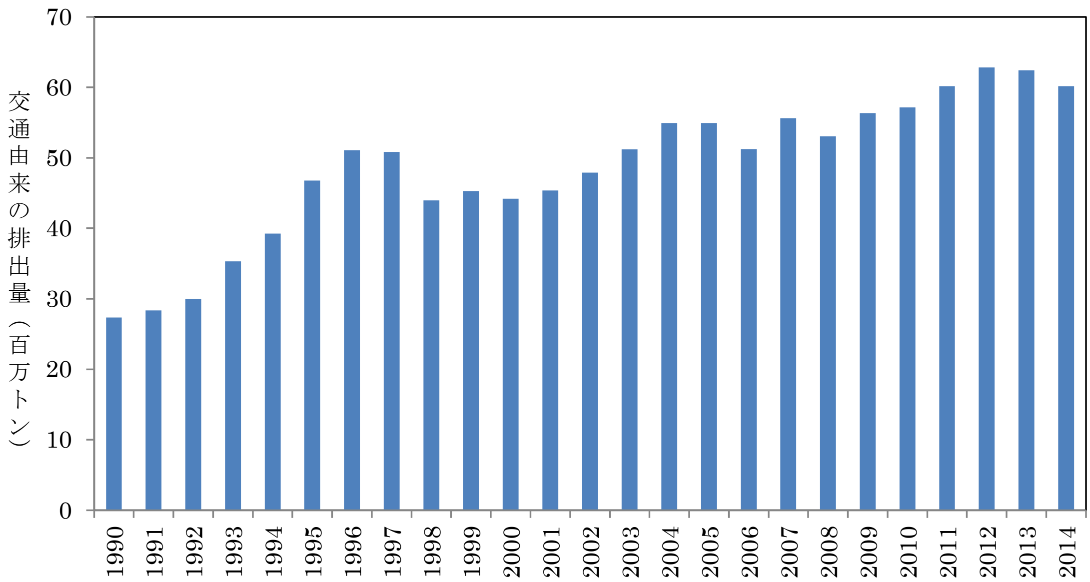
出所：タイ王国 代替エネルギー開発・効率化局「Alternative Energy Development Plan 2015」

3.4.3.3　燃料

交通における二酸化炭素の排出量は年々増加している。交通は産業と並びエネルギー消費の中で極めて大きな割合を占めていることから、燃料の自給率向上・低炭素化が全体に与える影響も大きいと考えられ、タイ王国のエネルギー政策において重要視されている。交通における燃料別の二酸化炭素排出割合をに示す。近年、石油に代わり天然ガス由来の二酸化炭素が生じ始めているが、これはガソリン価格の高騰に伴い、圧縮天然ガス（CNG）を燃料に用いる CNG 自動車が増加しているためであり、天然ガスの用途別消費量を見ても CNG 自動車向けが増えてきていることが分かる。

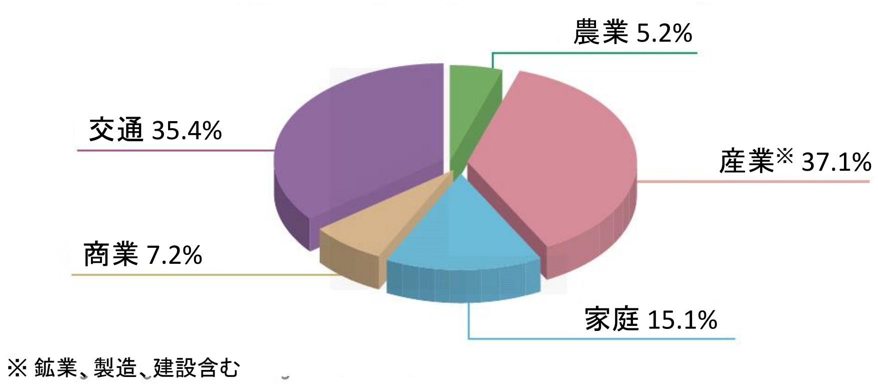
反面、前述の通り、タイ王国の天然ガスは枯渇に向かっており、輸入への依存度が高まっていることから、CNG 自動車の燃料は需給逼迫に伴う価格上昇リスクを抱えていることが、今後の普及拡大に向けての課題になると考えられる。

図表 16 交通由来の二酸化炭素排出量



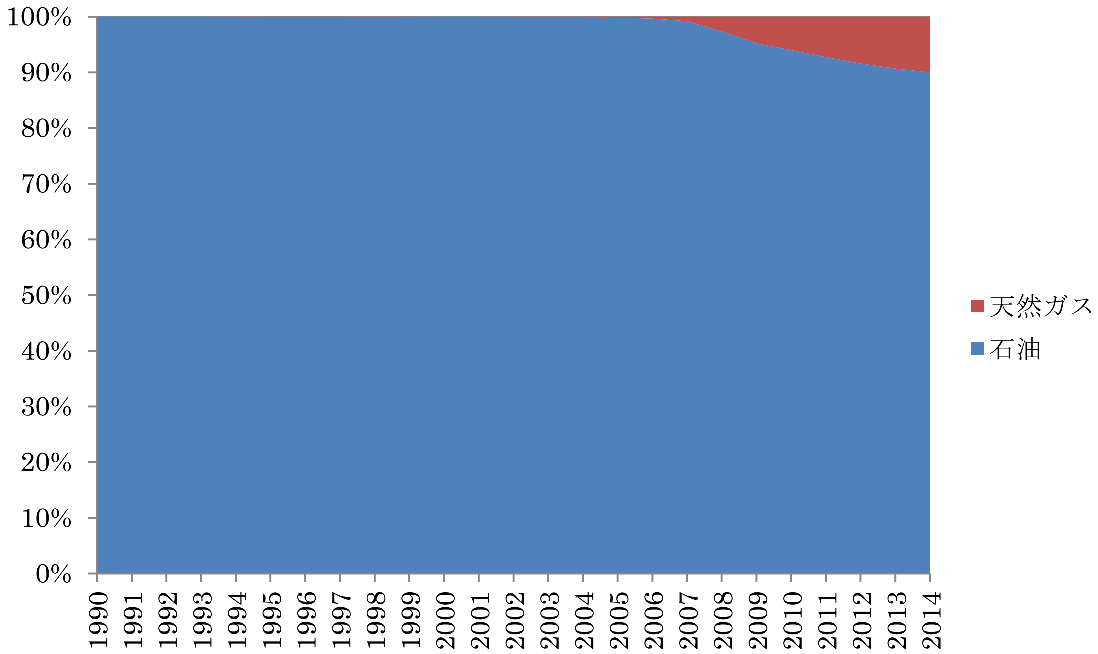
出所：OECD iLibrary

図表 17 各セクターのエネルギー消費割合（2014 年 Q1）



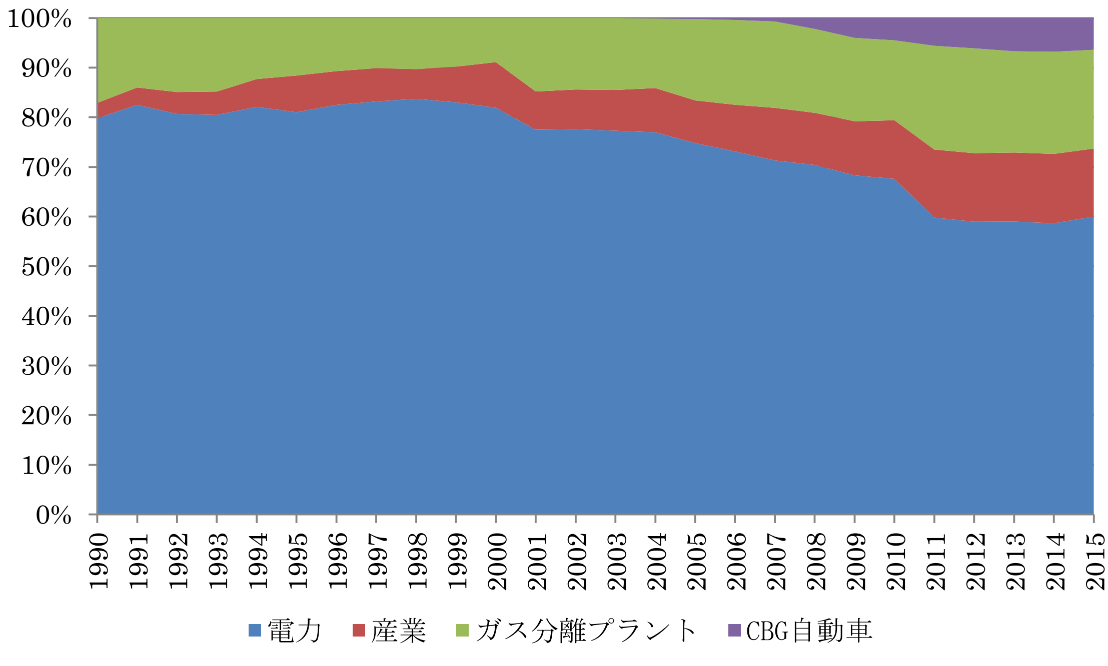
出所：タイ王国 代替エネルギー開発・効率化局「Energy in Thailand Q1/2014」

図表 18 交通燃料別二酸化炭素排出量の割合



出所：OECD iLibrary

図表 19 天然ガス消費量の用途別割合



出所：タイ王国 エネルギー政策企画事務局（EPPO）統計データベース

3.4.4 エネルギーバランスの推移まとめ

以上の通り、タイ王国は石炭や天然ガスに恵まれており 1990 年頃まで天然ガスの自給率は 100%、石炭の自給率も 90%を上回っていた。しかしながら経済成長を背景にそのような高い自給率を維持できなくなっており、特に化石燃料の中では比較的低炭素である天然ガスは発電や交通への利用が今後ますます上昇し、需給が逼迫すると見られている。

そのため、タイ王国政府は自給率の向上や低炭素社会の実現に向けて、省エネと共に再生可能エネルギーの拡大に力を入れている。農業国であるタイ王国はバイオマスの賦存量が大きく、再生可能エネルギーの大半がバイオマス由来であり、今後も再生可能エネルギー拡大を牽引するのはバイオマスになると見られている。

一方、消費の面から概観すると、産業と並んでエネルギー消費の大きな割合を交通が占めている。交通部門の燃料はガソリンの高騰から、天然ガスへと一部移行しつつある。比較的低炭素である天然ガスで走る CNG 自動車の普及は低炭素社会の実現に向けては歓迎されるものの、先に述べた通り天然ガスの需給逼迫を促進する材料になり兼ねないという懸念がある。

そうした背景の元、バイオマス由来の圧縮メタンガスである CBG の CNG 自動車への利用が注目され始めている。潤沢なバイオマス資源を天然ガス代替として用いる CBG は、再生可能エネルギーの拡大と天然ガスの需給緩和に繋がり、タイ王国が抱える 2 つの大きな課題を同時に解決すると見られている。

3.5 エネルギー目標及び政策

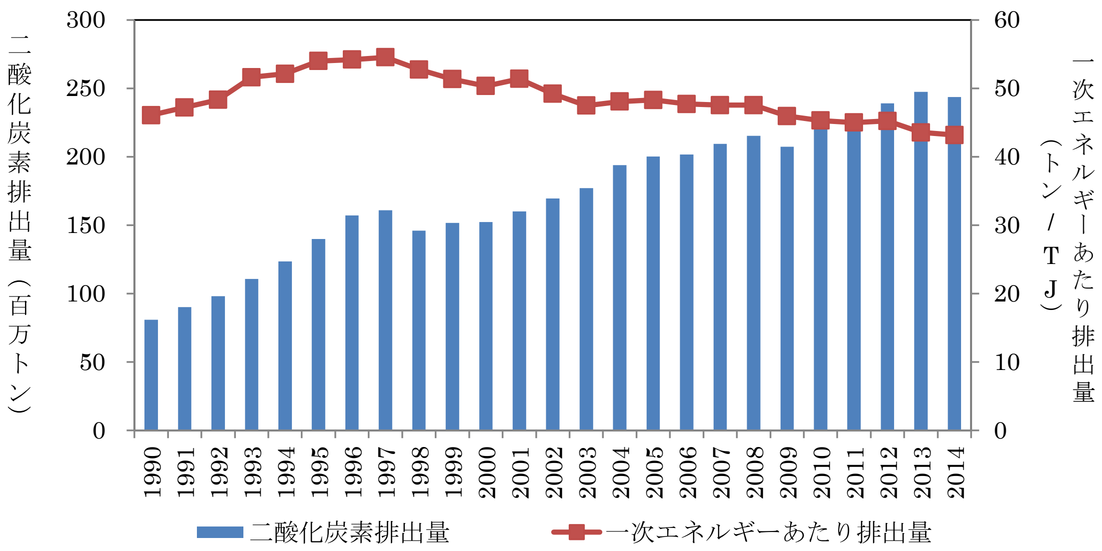
3.5.1 Alternative Energy Development Plan

3.5.1.1 背景

タイ王国は一次エネルギーあたりの二酸化炭素排出量は順調に低減させているものの、エネルギー消費量が拡大し続けていることから、二酸化炭素排出量の総量は逆に増加している。

増え続ける二酸化炭素排出量に歯止めをかけるため、タイ王国のエネルギー施策は二酸化炭素低減を強く意識したものとなっている。その代表的なものに、再生可能エネルギーの比率を 2036 年に 30%にすることを目標に策定された Alternative Energy Development Plan がある。

図表 20 二酸化炭素排出量の推移



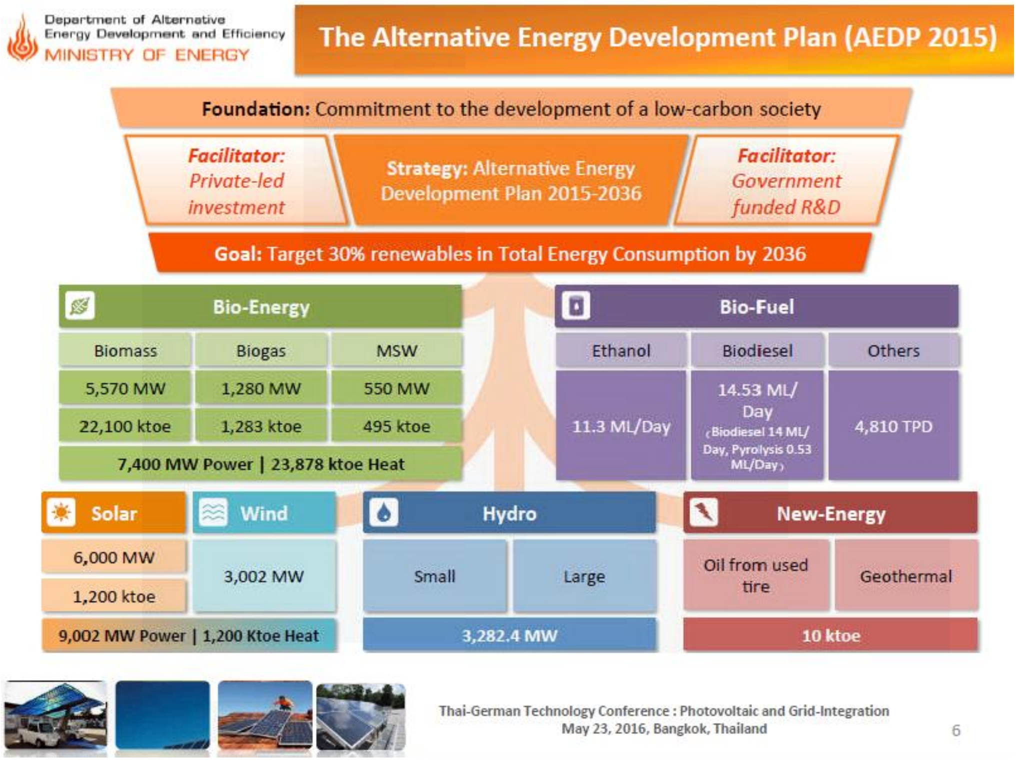
出所：OECD iLibrary

3.5.1.2 再生可能エネルギー導入目標

Alternative Energy Development Plan（代替エネルギー開発計画, 以下「AEDP」）は、タイ王国政府による再生可能エネルギー開発の長期計画であり、バイオエネルギー（電力・熱・燃料）や太陽光・風力・水力・その他新エネルギーに関する目標値やそれを実現するための施策の方向性が定められている。同計画において政府は再生可能エネルギー比率を 2036 年に 30%まで引き上げることを目標として掲げている。

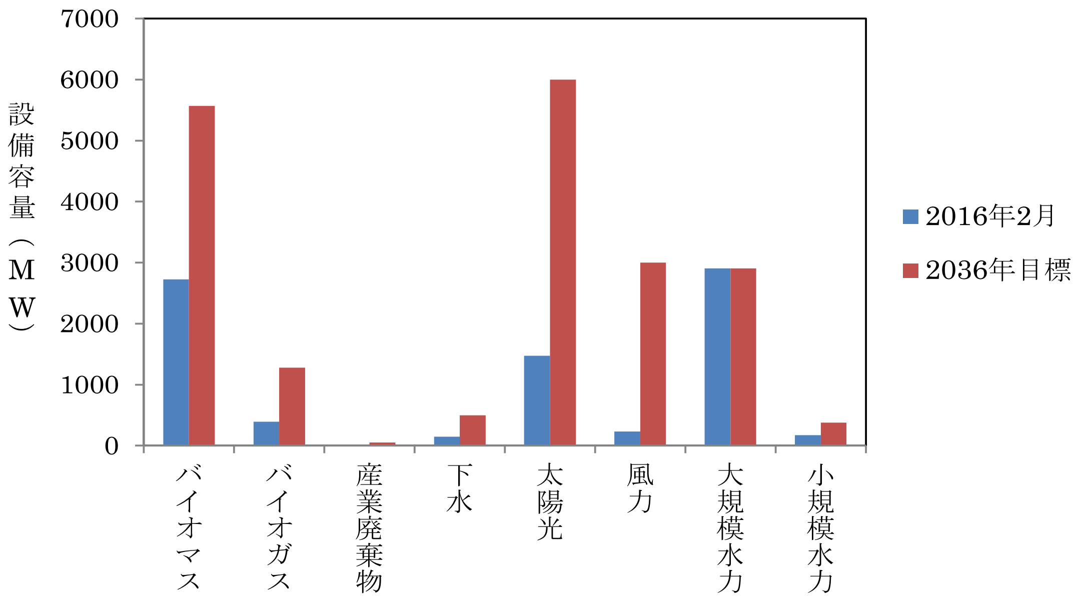
各再生可能エネルギーの導入状況と2036年導入目標を下記に示す。発電部門については現在大規模水力以外では最も導入量の多いバイオマス発電を引き続き拡大させる一方、太陽光と風力についても大幅に拡大させる計画としている。熱部門については太陽熱への期待はあるものの、現在の主流であるバイオガスとバイオマスが引き続き大部分を占めるという計画である。燃料部門ではバイオディーゼルが大きく伸びると共に、CNG の代替としての役割が期待される CBG を普及させる計画となっている。

図表 21 AEDP(Alternative Energy Development Plan)



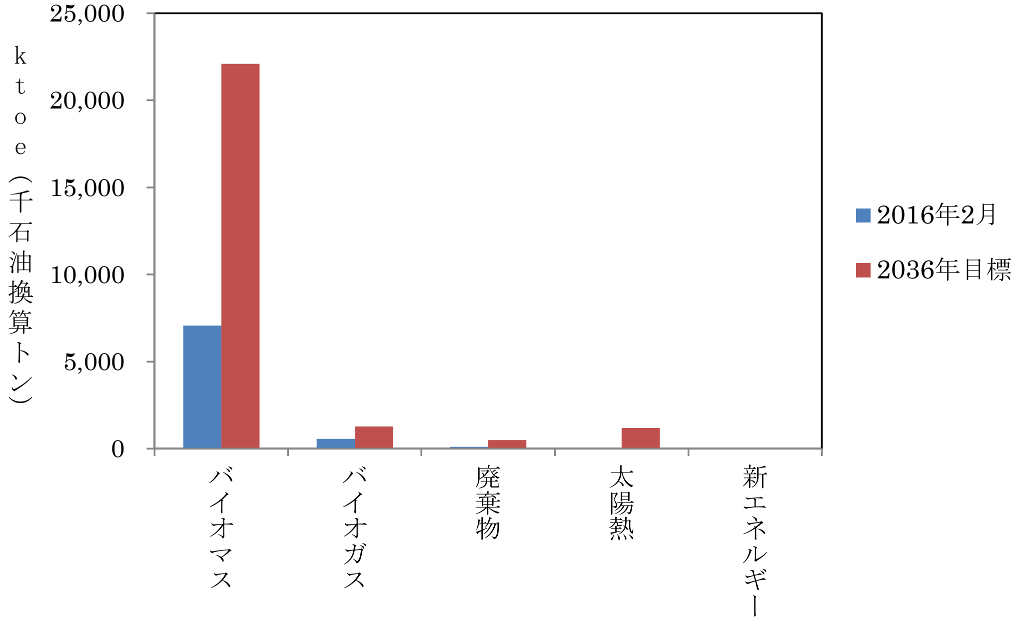
出所：タイ王国 代替エネルギー開発・効率化局「Solar Power Policy: Status Update 2016」

図表 22 再生可能エネルギー導入状況及び目標（電力）



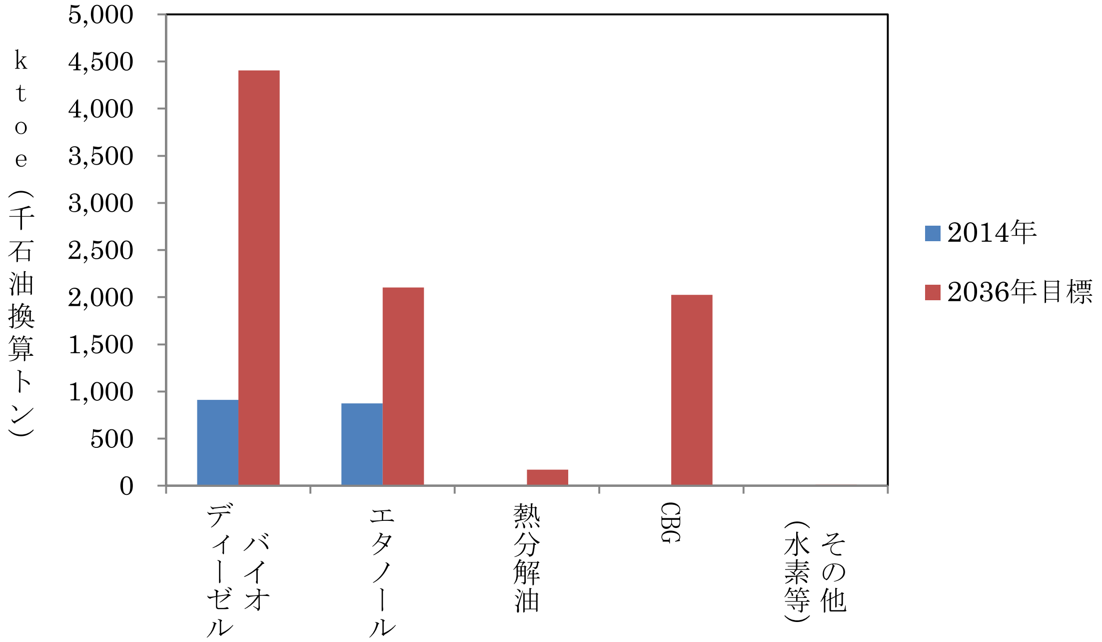
出所：タイ王国 代替エネルギー開発・効率化局「Solar Power Policy: Status Update 2016」

図表 23 再生可能エネルギーの導入状況及び目標（熱）



出所：タイ王国 代替エネルギー開発・効率化局「Solar Power Policy: Status Update 2016」

図表 24 再生可能エネルギーの導入状況及び目標（バイオ燃料）



出所：タイ王国 代替エネルギー開発・効率化局「Alternative Energy Development Plan 2015」

3.5.1.3　再生可能エネルギー拡大施策

タイ王国では、エネルギー政策企画事務局（EPPO）による固定価格買取制度や代替エネルギー開発・効率化局（DEDE）による ESCO ファンド、投資委員会（BOI）による税控除、EPPO や DEDE による補助金、DEDE による情報提供という形で再生可能エネルギーの導入を後押しする支援策が導入されている。

このうち、特に CBG と同じく原料にバイオガスを用いることから CBG への競合となり得るバイオガス発電にも関連する固定価格買取制度と CBG の補助制度を下表で整理する。

図表 25 タイ王国の再生可能エネルギー支援策

固定価格買取制度（EPPO）	コスト力の無い再生可能エネルギーの導入を促進するため、市場価格よりも高い価格で一定期間発電電力の買い取りを行う制度を導入。適用技術は、バイオマス・バイオガス・廃棄物・風力・水力・太陽光
ESCO ファンド（DEDE）	再生可能エネルギー事業への投資、設備リース等
投資委員会（BOI）	輸入関税控除、再生可能エネルギー販売や省エネ事業に伴う法人税を最大 8 年間控除
補助金（EPPO/DEDE）	再生可能エネルギー事業への各種補助金
情報提供（DEDE）	ワンストップサービスセンターの設立や、再エネ開発動向に関する情報の公開、風力・太陽光のリソースマップの公開。

出所：タイ王国 代替エネルギー開発・効率化局「Solar Power Policy: Status Update 2016」

3.5.2固定価格買取制度(FIT)の概要

3.5.2.1 従来の固定価格買取制度（～2015 年末迄）

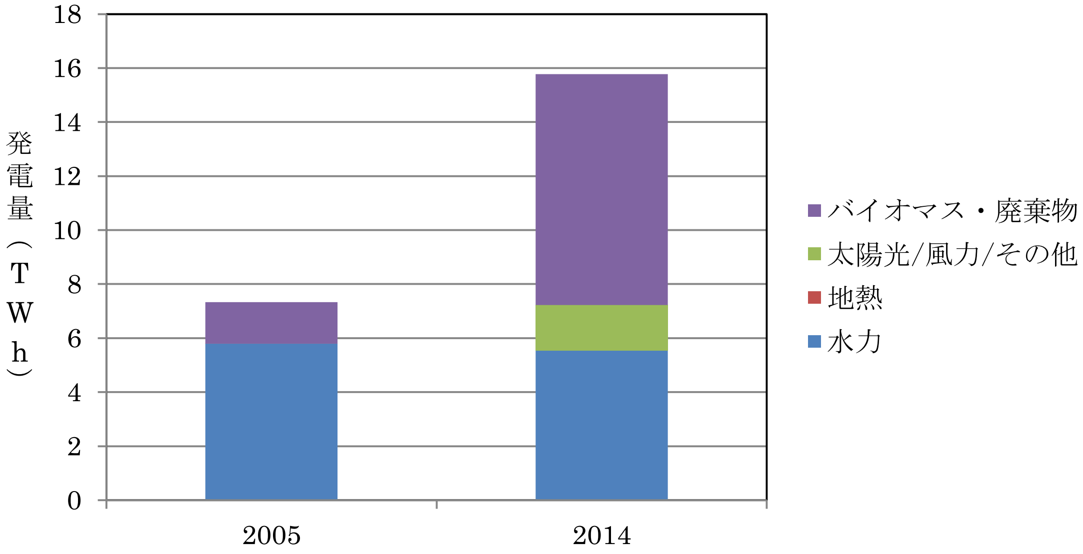
タイ王国は 2007 年に他の ASEAN 諸国に先駆けて再生可能エネルギーへの固定価格買取制度を導入した。同制度は通称 Adder と呼ばれ、民間事業者による再生可能エネルギー発電電力を国営電力事業者等が一定のプレミアムを加えた価格で買い取る制度として開始された。プレミアムの値を下記に示す。2007 年に太陽光に対して最も高額なプレミアム 8.0THB/kWh を設定して開始された Adder は、2009 年に小規模バイオマス等のプレミアムを引き上げる形で改訂された。固定価格買取制度導入前の 2005 年と 2014 年の再生可能エネルギー導入量を比較すると、設備容量ベースで 2 倍弱、発電量ベースで 2 倍強となっている。特に固定価格買取制度の対象であるバイオマス・バイオガス・廃棄物・太陽光・風力が大きく伸びており、再生可能エネルギーの普及に対する Adder の貢献が見て取れる。

図表 26 Adder プレミアム価格改定履歴（単位：THB/kWh）

種類	規模	2007-08 Adder	2009 Adder	ディーゼル置換の場合	南部特定地域の場合	買取期間	2015.12.31
太陽光		8.00		1.50	1.50	10 年	廃止。新固定価格買取制度に移行
風力	50kW 未満	3.50	4.50				
	50KW 以上		3.50				
バイオマス	1MW 未満	0.30	0.50	1.00	1.00	7 年	
	1MW 以上		0.30				
バイオガス	1MW 未満	0.30	0.50				
	1MW 以上		0.30				
廃棄物	埋立地	2.50	2.50				
	熱処理		3.50				
小水力	50-20kW	0.40	0.80				
	50kW 未満	0.80	1.50				

出所：IEA ホームページ Policies and Measures (Thailand)

図表 27 固定価格買取制度導入前後の再エネ導入量の比較



出所：OECD iLibrary

3.5.2.2 新固定価格買取制度

2014 年 12 月、2007 年から続いてきた Adder に変えて新しい固定価格買取制度を導入することが、国家エネルギー政策委員会（以下 NEPC）に承認された。この新固定価格買取制度はタイ王国の限られた系統容量を加味して、まずは 10MW 未満の発電プロジェクト（Very Small Power Producer, 以下「VSPP」）に適用されることとなった。

旧制度では 7-10 年だった買取期間が廃棄物（埋立地ガス）を除いて 20 年（太陽光は 25 年）に伸びていることと、技術や規模に応じて単価が大きく異なる点が、旧制度との主な違いとなっている。

新制度における買取価格（FIT 価格）は、下表に示す 4 つの要素の足し算で構成されている。また、新固定価格買取制度において、2017 年に導入される再生可能エネルギーに適用される買取価格を下記に示す。

プロジェクトの選出は従来の申し込み順から入札制度へと変更される。従い、固定価格は上限値としての役割を果たすこととなり、事業者はその範囲内でプロジェクトに応募することとなる。プロジェクトのロケーションや規模については、エネルギー省がタイ発電公社・首都圏配電公社・地方配電公社の 3 社と共同で決定する後述する通り、現在、タイ王国の送電網は急増する再生可能エネルギーに整備が追いついていない状況だが、入札制度に移行することにより、効果的な系統整備を行うことが可能となり、結果としてより多くの再生可能エネルギーが系統接続可能になると見られている。

図表 28 買取価格の構成要素

FIT（固定）	ベースとなる買取期間を通じて普遍の価格
FIT（変動）	バイオマス・バイオガス・廃棄物など、原料が必要な技術に限定して適用され、原料コストの変動に応じて毎年見直される価格。
FIT プレミアム 1	バイオマス・バイオガス・廃棄物に対して買取期間の最初の 8 年間支払われるプレミアム価格
FIT プレミアム 2	南部特定地域に対して買取期間に渡って支払われるプレミアム価格
FIT 価格	上記 4 要素の合計

出所：IEA ホームページ Policies and Measures (Thailand)

図表 29 各再生可能エネルギーの買取価格（太陽光以外、単位：THB/kWh）

種類	規模	FIT（固定）	FIT(変動)	FIT（小計）	FIT プレミアム 1	FIT プレミアム 2	買取期間
廃棄物（焼却）	1MW 未満	3.13	3.21	6.34	0.70	0.50	20 年
	1-3MW	2.61	3.21	5.82			
	3MW 以上	2.39	2.69	5.08			
廃棄物（埋立地）		5.60	-	5.60	-		10 年
バイオマス	1MW 未満	3.13	2.21	5.34	0.50		20 年
	1-3MW	2.61	2.21	4.82	0.40		
	3MW 以上	2.39	1.85	4.24	0.30		
バイオガス（廃液）		3.76	-	3.76	0.50		
バイオガス（作物）		2.79	2.55	5.34			
水力		4.90	-	4.90	-		
風力		6.06	-	6.06	-		

出所：タイ王国 代替エネルギー開発・効率化局「AEDP2015-2036 プレゼンテーション資料」

図表 30 太陽光発電の買取価格（単位：THB/kWh）

種類	FIT（固定）	FIT(変動)	FIT（小計）	FIT プレミアム 1	FIT プレミアム 2	買取期間
メガソーラー（90MW 未満）	5.66	-	5.66	-	0.50	25 年
家庭用（10kW 未満）	6.85		6.85			
商業（10-250kW）	6.40		6.40			
商業（250-1,000kW）	6.01		6.01			
公共・農業（5MW 未満）	5.66		5.66			

出所：タイ王国 代替エネルギー開発・効率化局「AEDP2015-2036 プレゼンテーション資料」

3.5.3　省エネ・再エネ補助制度の概要・見通し

タイ王国における省エネルギー・再生可能エネルギーに関連する主な補助制度は以下の 3 つである。また、2016 年には DEDE より CBG 製造設備に対する補助が措置されたが、継続性は不透明である。

- 省エネルギープログラム(ENECON Program)
  - 1992 年に制定された「Energy Conservation Program Act, 1992」に従って、省エネおよび新・再生可能エネルギーの導入も推進されている。省エネ・再生可能エネルギー導入プロジェクト促進のための財政支援として「省エネルギー推進基金（Energy Conservation Promotion　Fund : ENECON Fund)」が 1995 年に設けられ、省エネルギープログラム（ENECON Program）として承認され実行される。

- ESCO 基金（Energy Conservation Promotion Fund）
  - ESCO 基金は、民間部門及び投資家による共同投資プログラムとして、「エネルギーの節約及び促進基金（Energy Conservation Promotion Fund, ENCON Fund）」の下に 2008 年に設立された。設立当初の基金規模は 1,500 万米ドルであり、長期的には 1 億～2 億米ドル規模に拡大する計画である。

- 回転基金(Revolving Fund)
  - 政府は、Adder と並行して、各種の経済補助施策を実施している。エネルギー分野を対象とした回転基金はその一つであり、政府と金融部門との協力により、エネルギー効率の改善や再生可能エネルギーの促進等に関する民間投資の促進を目的としている。

- CBG 設備補助
  - DEDE が CBG 製造設備への補助金として 2016 年に措置。AEDP2015 に示された目標に向けて、今後とも補助を実施し、導入を促進していく見込みであるものの、どの形態におけるどの程度の補助率が有効か、政府機関としても探っている段階であり、今後の補助可能性は不透明である。[3]

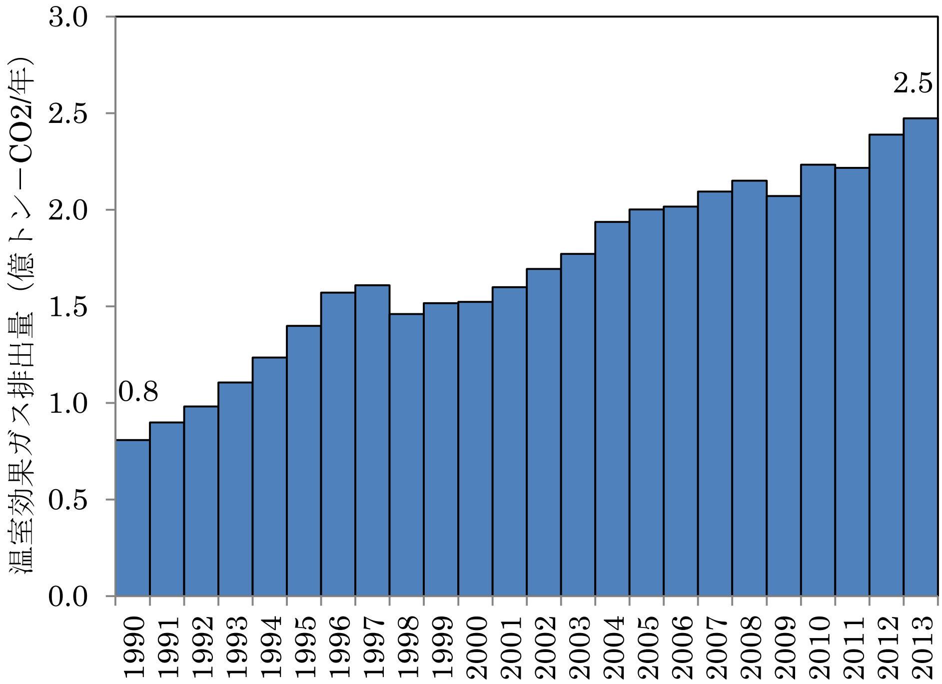
[3] DEDE 関係者への現地ヒアリング

3.6　GHG 排出動向

3.6.1GHG 排出量

タイ王国における二酸化炭素排出量は年々増加している。2013 年の二酸化炭素排出量は 2.5（億 t-CO_2/年）であり、1990 年と比較して 30%増加した。

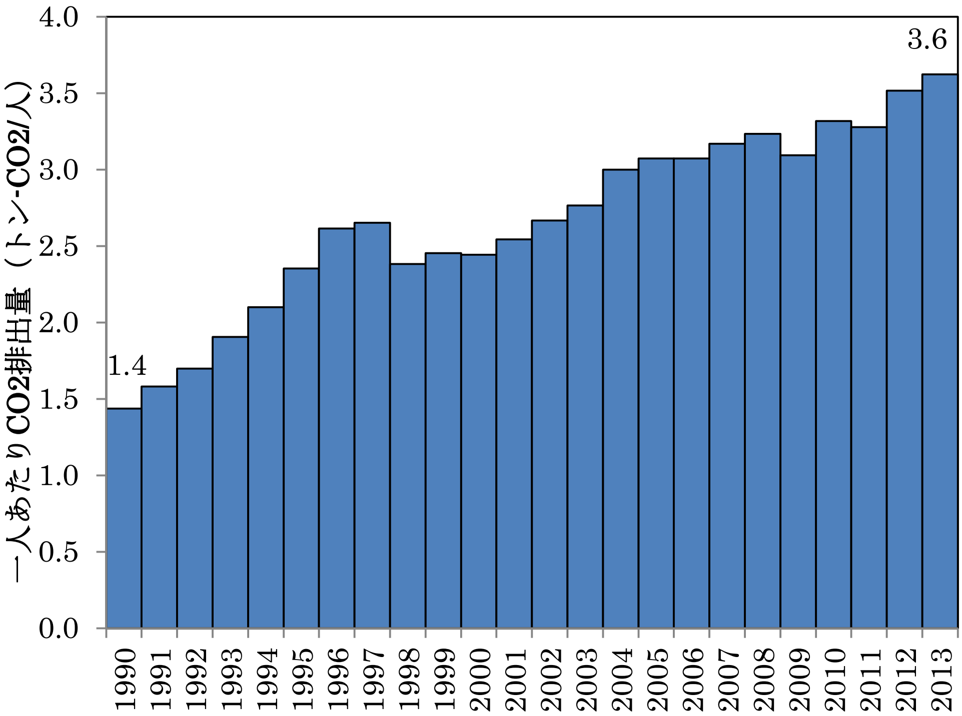
図表 31　タイ王国における二酸化炭素排出量の推移



IEA（International Energy Agency, 国際エネルギー機関）, CO_2 Emissions from Fuel Combustion 2015（燃料燃焼による CO_2 排出）データベースを基に日本総研作成

下図には一人あたり二酸化炭素排出量の推移を示した。総排出量と同様に 1990 年から 2013 年にかけて単調に増加していることから、生活水準の向上などを背景に、二酸化炭素排出量は増加している。

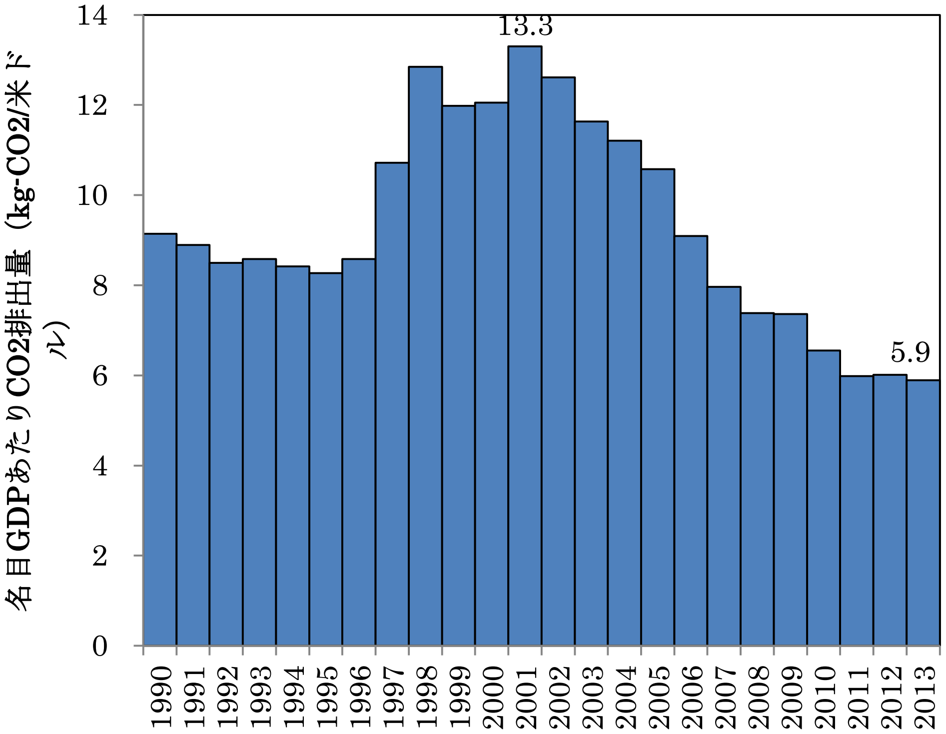
図表 32　一人あたり二酸化炭素排出量の推移



出所：温室効果ガス：IEA（International Energy Agency, 国際エネルギー機関）, CO_2 Emissions from Fuel Combustion 2015（燃料燃焼による CO_2 排出）データベース。人口：International Monetary Fund（国際通貨基金）, World Economic Outlook Database（世界経済概況）データベースを基に日本総研作成

一方、名目 GDP あたりの二酸化炭素排出量の推移を見ると、2001 年の 13.3（kg-CO_2/米ドル）をピークに減少している。

図表 33　名目 GDP あたりの二酸化炭素排出量の推移



出所：温室効果ガス：IEA（International Energy Agency, 国際エネルギー機関）, CO_2 Emissions from Fuel Combustion 2015（燃料燃焼による CO_2 排出）データベース。名目 GDP：International Monetary Fund（国際通貨基金）, World Economic Outlook Database（世界経済概況）データベースを基に日本総研作成

3.6.2 約束草案（INDC）

2015 年 10 月 1 日に約束草案を UNFCCC に提出しており、GHG 排出量の削減目標は、2005 年比で 2030 年に自主努力で BAU 比 20%削減、国際援助活用の場合には 25%削減と設定している。対象ガスは、CO_2・CH_4・N_2O・HFCs・PFCs・SF_6である。

タイ政府は気候変動の緩和策として市場メカニズム(Market-Based Mechanisms)の役割の重要性を認識しており、日本と締結済みの JCM(Joint Crediting Mechanisms)を初めとした国際的なメカニズムと国内の独自のメカニズムを推進している。

約束草案はタイ国内の次の国家経済社会開発プランや気候変動マスタープランと連動している。

- National Economic and Social Development Plants
- Climate Change Master Plan B.E.2558-2593 (2015-2050)
- Power Development Plan B.E.2558-2579 (2015-2036)
- Thailand Smart Grid Development Master Plan B.E. 2558-2579 (2015-2036)
- Alternative Energy Development Plan B.E. 2558-2579 (2013-2030)
- Environmentally Sustainable Transport System Plan B.E. 2556-2573 (2013-2030)
- National Industrial Development Master Plan B.E. 2555-2574 (2012-2031)
- Waste Management Roadmap

3.6.3 National Master Plan on Climate Change 2013‐2050

National Master Plan on Climate Change 2013‐2050 は、持続可能な国家開発の計画に即しながら、気候変動への対応と低炭素成長を目的に制定されたマスタープランである。長期的な課題に対応する計画であり、気候変動の適応策分野と緩和策分野とそれにかかる横断的な課題を戦略の主軸としている。短期・中期・長期的な目標のロードマップを設定し、政策手段の設立を重点としている。

図表 34 戦略の分野一覧

適応策分野	緩和策分野	横断的な課題
水源管理 農業・食糧保全 観光 公衆衛生 天然資源管理 住居、人間の安全保障	発電 交通 建築 産業 廃棄物管理 農業 森林 都市管理	データベース、R&D、技術開発 政策手段の制定 意識啓発、キャパシティビルディング 国際協力の向上

出所：タイ王国・天然資源・環境省「プレゼン資料 Thailand's Climate Change Policies (http://www-gio.nies.go.jp/wgia/wg12/pdf/0_3_ONEP_N.pdf)」、日本環境省「タイ王国 気候変動政策．（2015 年 12 月 24 日）」

図表 35 短期・中期・長期的な目標

	適応策	緩和策
短期目標（2016）	鍵となる社会経済、環境的視点を盛り込んだ一貫的な気候変動リスクマップの作成 生物多様性保全地区拡大のためにマングローブ林を年間	国内の NAMA、MRV システムの開発 低炭素開発を促進させるための経済・法制度の統合 GHG インベントリシステム、

	5,000rai 以上拡大 海岸線地域の保全計画強化 経済全体に関する気候変動適応能力指数を開発	緩和レジストリシステム、自主的な排出量取引制度など 気候変動データベースシステムの強化 国家気候変動戦略の作成、適応・緩和両方に対する行動計画の作成
中期目標（2020）	農業部門において効果的な予測、早期警報システムを作成、全土の脆弱な地域に対する自然災害管理を制定 気候変動によって影響を受けた農作物に対する保障制度を設立 気候変動による影響からの復興に対する国家適応基金メカニズムの設立 生物多様性保護地区の拡大	森林面積を 40%増加 2020年までにGHG排出量を約 7%～20%削減（NAMA） 全エネルギー消費における再生可能エネルギーの割合を 25%に増加 一人あたりに対する森林面積を 10 ㎡に増加 スマートグリッド技術を導入し、エネルギー効率を向上
長期目標（2030）	灌漑地区の拡大 灌漑未整備地域の水源管理 自然災害リスクの高い地域における自然災害への対処能力の育成 作物保障制度への農業従事者の増加 気候変動の影響を受けやすい作物生産量を減少	公共交通の量を増加 エネルギー係数を BAU 値よりも 25%以上向上 陸上輸送による排出量の削減 農業廃棄物の野焼き削減 農業生産工程管理や有機農業の割合を増加 政府、地方自治体両方で低炭素開発計画を増加

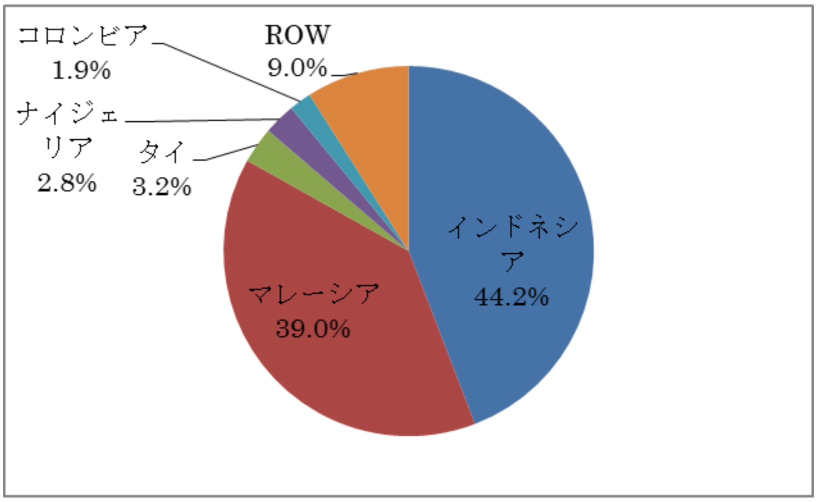
出所：タイ王国・天然資源・環境省「プレゼン資料 Thailand's Climate Change Policies (http://www-gio.nies.go.jp/wgia/wg12/pdf/0_3_ONEP_N.pdf)」、日本環境省「タイ王国　気候変動政策．（2015 年 12 月 24 日）」

4. 事業を取り巻く環境

4.1 パーム/キャッサバ産業の動向

世界のパーム油生産量は 2013 年実績で約 6,000 万 t である。そのうちタイ王国の生産量は約 3.6%で、インドネシア、マレーシアに次いで世界第 3 位のパーム油生産国である。

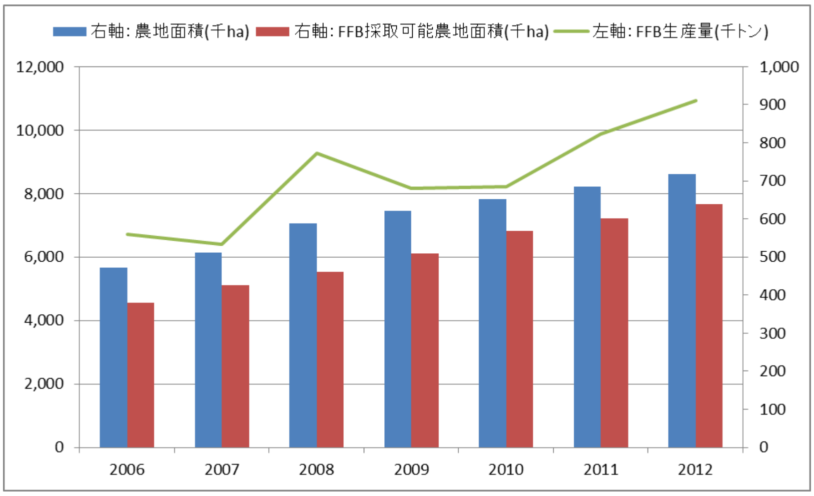
図表 36 各国別パーム生産量のシェア



生産したパーム油は約 97%をタイ国内で消費し、そのうち約 50%は食品向けに、約 40%はバイオディーゼル向けに、利用されている。

また、タイ王国におけるパーム生産量は世界全体の需要量の拡大に応じて、拡大してきており、2006 年には約 7 百万 t であったところ、2012 年には約 11 百万 t に達している。

図表 37 タイ王国におけるパーム生産量の推移



出所：各種資料を基に日本総研作成

世界のキャッサバ生産量の 2014 年実績は約 2 億 7 千万 t で、タイ王国はナイジェリアに次いで世界第 2 位のキャッサバ生産国である。生産量シェアは 1989 年の 16%をピークに昨今では 11%前後で推移している。キャッサバを原料とする加工品には、チップ（およびチップを粉砕加工したペレット）、澱粉（および澱粉を加工した加工澱粉）、エタノールがある。2015 年度のタイ王国の生産シェアは澱粉 55%、チップ 40%、エタノール 5%であり、澱粉生産が過半数を占めている。

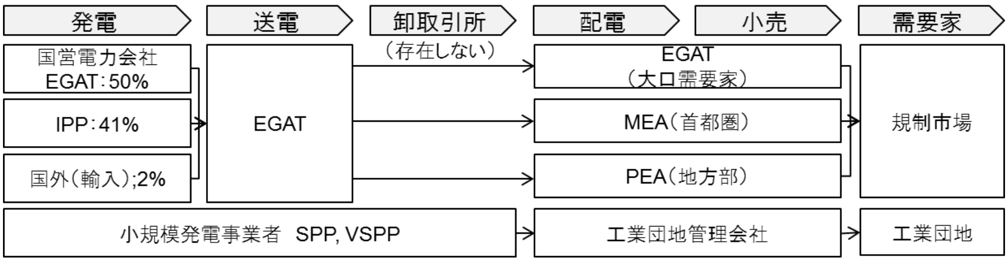
4.2　エネルギーセクターの動向

4.2.1電力セクターの構造

タイ王国の電力セクターは従来、国営電力会社である EGAT が発電・送電・小売部門を独占していたものの、電力自由化により、発電部門を中心に規制緩和が進められ、独立系発電事業者（IPP）の参入が認められるようになった。

また、前述した通り、タイ王国においては、再生可能エネルギーの導入が促進されており、固定買取価格制度（Feed in Tariff）を通じた再エネ発電への民間資本の導入が進められている。

図表 38 タイ王国における電力セクターの構造



出所：各種資料を基に日本総研作成

4.2.1.1　送配電系統

送配電設備の整備は国営電力企業である EGAT を中心に進められている。もっとも近年の再生可能エネルギーの普及を通じて、分散型の電源構成が進んでいることもあり、系統の増強が発電事業者側の送配電ニーズに追いついておらず、系統連系申請時に連系を拒否されるとの事例が発生している。

タイ王国においては、FIT 制度の導入もありパーム・キャッサバ工場から発生するバイオガスを燃料とするバイオガス発電が進められているものの、特に南部地域において系統が脆弱であることから、売電が許可されなかったとの事例がサイトオーナー、EPC 事業者から聞

かれた。

本事業においては、バイオガス発電は競合する技術（原料であるバイオガス発電を取り合う関係にある技術）であることから、こうした系統連系面での制約は事業推進の上でのポジティブな要素となり得ると考えられる。

4.2.2 天然ガスセクターの構造

前述の通り、タイ王国における天然ガスは産業・商業・家庭部門に加えて、交通部門で多く消費されている。

タイ王国における NGV の台数は 42 万台、CNG 充填所数は 488 箇所であり、日本における NGV の台数(4 万 3 千台)より多く、また世界台 10 位の NGV 普及国（台数ベース）となっている。

タイ王国におけるガスの輸送・配給については国営企業であるタイ石油公社（以下、「PTT」）が独占してきており、また、小売りも民間事業者の参入が認められているものの、実質的には PTT の独占市場である。

インフラは需要の高まりに応じて、拡大してきており、海上ガス田より生産されるガス田からのパイプライン輸送、タイ=ミャンマー間の国境間パイプラインによるガス輸入、PTT による Map Ta Phut LNG 受入基地が整備されている。

他方、国内におけるガスインフラの整備は未発達であり、バンコク周辺部においてはガスパイプラインの整備が進められる一方、北部地域、中部地域においては、ガスパイプラインが存在しない。

これら地域においては、もっとも近接するガス加工設備（Mother Station（以下、「MS」）より、ローリー輸送により、ガスパイプライ

ンが存在しない地域におけるステーション（Daughter Station（以下、「DS」）へ運搬される。

これに伴い、タイ国内における CNG の販売原価は地域により大きく異なっている。

4.2.3 燃料価格への補助、推移・見通し

タイ王国においては、地方部における CNG 販売は、バンコク周辺部における価格より高い価格での販売が認められているものの、輸送費の上限によるプライスキャップがかけられているため、MS から DS までの輸送費を全て価格に転嫁するまでには至っておらず、販売によって生じるコストは国営ガス事業者である PTT が負担している。

後述するとおり、こうした不均衡を是正するため、2016 年 7 月より輸送費のプライスキャップの緩和が実施されており、今後地方部における CNG 価格は長期的に上昇するものと見込まれる。

本事業においては、バイオガスより精製した CBG を CNG 代替として販売することから、サイト近隣地における CNG 価格は CBG の販売価格設定の上で極めて重要である。前述したとおり、タイ王国においては長期的に補助撤廃による CNG 価格の上昇が見られることから、事業への追い風になると期待できる。

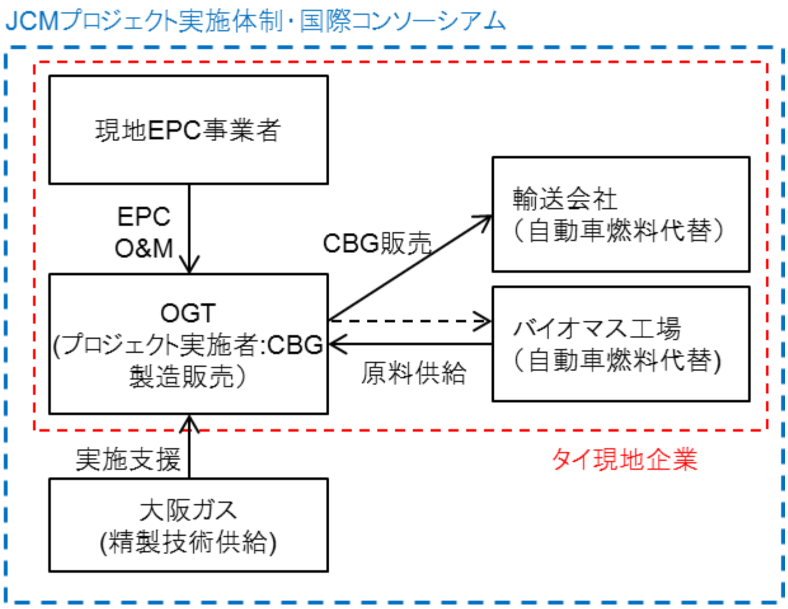
5. 事業体制の構築

5.1 想定される事業体制

大阪ガスは 2013 年 10 月に OSAKA GAS(THAILAND) CO.,LTD.（以下、「OGT」）を設立し、タイ王国の産業用市場でエネルギーサービス事業を展開している。また、2015 年 9 月に PTT との共同出資により、産業用顧客向けの燃料転換エネルギーサービス事業を行う OGP Energy Solutions Co.,LTD を設立した。こうした大阪ガスのタイ王国における事業基盤拡大の一環として、本事業は大阪ガスが開発したメタン回収率の高いバイオガス精製技術をタイ王国のバイオマス工場に導入して CBG を製造し、それを NGV トラック用燃料として使用するものである。

本プロジェクトは OGT が製造事業者となりバイオマス工場から原料となるバイオマス原料を購入し CBG を製造する。販売先となる CBG 消費者は、バイオマス工場や輸送会社を対象とし、EPC 事業者を含めた国際コンソーシアムを構築する。

図表 39　想定される事業体制



出所：大阪ガス作成

事業体制を構築するにあたり、バイオガスポテンシャル、CBG 消費ポテンシャルは当然のことながら、原料供給の継続性が事業の重要な要素となることから、バイオマス工場の与信も候補地選定基準に加え検討した。

5.2 体制構築における条件

5.2.1 バイオマス工場

まずは各種情報源を基に、60 件にのぼるバイオガスポテンシャルのある工場のロングリストを作成した。

その上で､原料供給の継続性は事業を維持するための重要な要因であるため､継続企業としての信頼性を測る目安の一つとして企業与信を評価することとして、ロングリストを元に、以前から OGT と取引のある 2 社に企業与信の評価を依頼し、候補案件の絞り込みを行った。また、事前に本プロジェクトへの関心表明レターをもらい興味を示していたバイオマス工場においても企業与信により選別を行った。その結果、候補案件を 12 件選定した。その内訳は、キャッサバ工場 5 件、パーム工場 3 件、エタノール工場 3 件、食品工場 1 件である（以下、これらの工場を総称して「バイオマス工場等」という）。

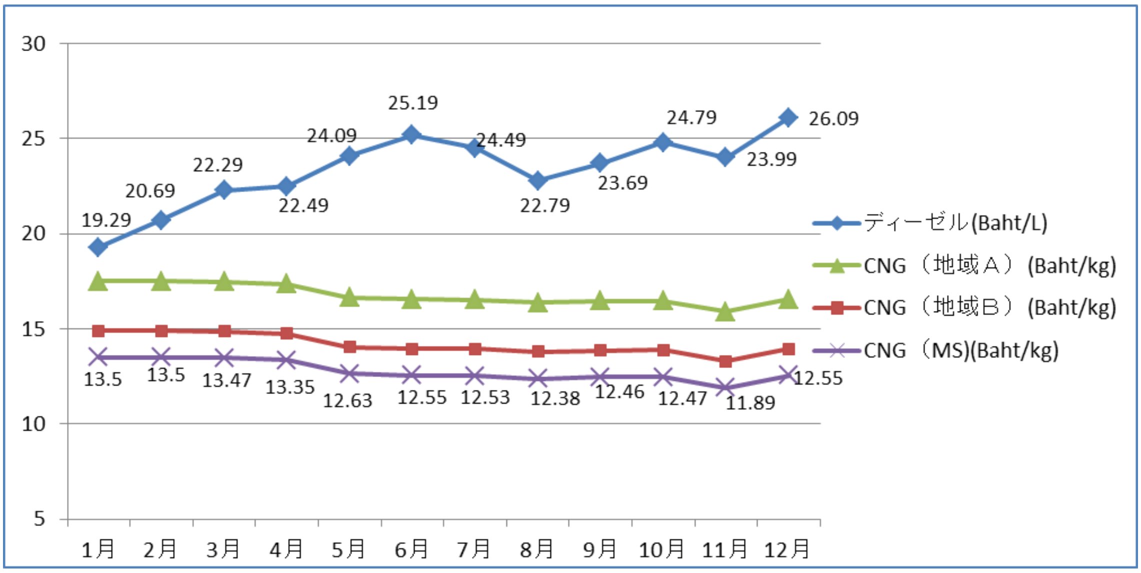
5.2.2 CBG 消費ポテンシャル

CBG の利用は、バイオマス工場等が所有している車両及び工場に出入りしている製品輸送用トラックを対象とした。製品輸送用トラックはバイオマス工場等やその関連会社が所有していることが理想的であるが、第三者へ輸送業務を委託しているケースも考えられるため、その場合は輸送会社も CBG 利用先の候補対象と考えた。Thai Truck Center の公開情報と電話ヒアリングにより NGV トラックを 50 台以上所有している輸送会社を 8 社選定し、CBG 利用先の候補とした。

5.2.3 工場周辺地における CNG 価格

タイ王国における CNG 価格は 2017 年 7 月から政府統制価格から天然ガス連動価格へ変更され、天然ガス価格を毎月 16 日に反映させるシステムとなっている。また、MS より 50km 以上離れた DS では輸送費を加算した販売価格となり、従来輸送費の上限が 1.84THB/kg であったものが 4.0THB/kg まで緩和された。調査した 2 つの地域における CNG 価格は、MS の価格より 1.4THB/kg 、4.0THB/kg の輸送費を加算した小売価格であった。MS からの距離が遠いほど CNG 価格が高く、ディーゼル価格に比べると CNG 価格は安定していることがわかる。

図表 40 工場周辺における CNG 価格の推移（2016 年）



出所：大阪ガス作成

5.3 実施内容・結果

5.3.1 バイオマス工場等の選定

バイオマス工場等の選定は以下の手順で実施した。

- ドアノック訪問を実施し、JCM 事業の FS 候補地として協力を依頼。
- 協力の承諾を得た後、バイオガスポテンシャル、設備設置場所、CBG 消費ポテンシャルについて現場調査を実施。
- 収集したデータを元に FS を実施。

まずは選定した 12 件の候補へ訪問を要請し、このうち 7 件のバイオマス工場等から FS 協力の承諾を得、現場調査を実施した。

次に、FS を実施するにあたり、現場調査で得られた情報を基にバイオガス原料の GHG 削減効果を検討した。その結果、既に有効利用されているバイオガスの用途変更や家畜の飼料として利用されているキャッサバパルプを対象から除外し、EFB、廃水を原料とする A 社の 2 工場（既存工場及び新設予定工場）と、フレアガスを利用できる B 社を FS 候補案件として選定した。

5.3.2 需要家（CNG 車両保有事業者）の選定

FS 候補のバイオマス工場等として選定した上記 2 社のうち、A 社は輸送トラックを持たず、第三者へ輸送業務を委託している。また B 社は輸送業務の大半を第三者に委託し自社所有車両が少ないため、自家消費だけでは製造した CBG を消費しきれない。そこで両社が委託している輸送会社や事前調査でリストアップした輸送会社を需要家候補として検討した。

B 社へヒアリングした結果、主な輸送業務の委託先は事前調査でも候補リストに挙げていた輸送会社であり、NGV トラックを多数保有する有望な候補である。そこで、ドアノック訪問を実施し FS への協力を打

診した結果、CBG がディーゼルに対して価格優位性があれば興味があるということで、FS への協力の承諾を得ることができ、需要家対象として選定した。

その他の輸送事業者には今後ドアノック訪問を実施し､事業体制の構築を進めていく予定である。

5.3.3 EPC 事業者の選定

本プロジェクトに必要な設備は、発酵槽、精製設備、燃料ステーションから構成される。大阪ガスは精製設備に関する技術はあるが、発酵槽については知見がない。そこで既に発酵槽に関する知見があり、バイオガス発電事業の EPC 実績のあるエンジニアリング会社 2 社を選定した。両社とも CBG 事業に協力的であり、顧客も多く持っており EPC 事業者の候補となり得ると判断した。

精製設備については現在大阪ガスが実施するパイロット実証試験における設備の EPC 事業者、ステーション設備については、タイ王国で NGV ステーションの EPC 実績のある 3 社を対象とし候補地毎に選定することとした。

6. 事業性の検討

6.1 A社における事業性検討

6.1.1 A社の概要

A社は40年以上の操業実績を持つタイ王国の最大手のパーム事業者である。2014年の売り上げは約170億円である。

A社は現在国内に3工場を所有している。また、2017年に新工場を建てる計画があり、完成すると4つのパーム搾取工場を所有することになる。この4工場の中から、立地条件やバイオガスポテンシャルを勘案し、2工場(以下「a工場」、「b工場」)を候補地として選定した。

6.1.2 a工場における設備仕様

A社ではEFBの5%を肥料として利用しているが、残りは自社のプランテーションへ廃棄しており、有効活用の方法を模索しているため、CBGの原料として活用できるかどうかを検討することとした。発生するEFBからどれだけのバイオガスを製造することができるかを試算した結果、2,000m^3/hの容量を検討することとした。

CBGの消費ポテンシャルとして、A社は車両を保有していないため、近隣地域で輸送事業を営む企業をCBG消費ポテンシャルの対象と想定することとした。本報告時点では候補企業にドアノック訪問をできていないが、事前調査では、候補の1社はNGVを数十台保有することが判明し、魅力あるCBG価格を提示できれば有望なパートナーになると期待される。

以上の現場調査と検討を踏まえ、a工場の設備仕様を決定した。

図表 41 a 工場の設備仕様

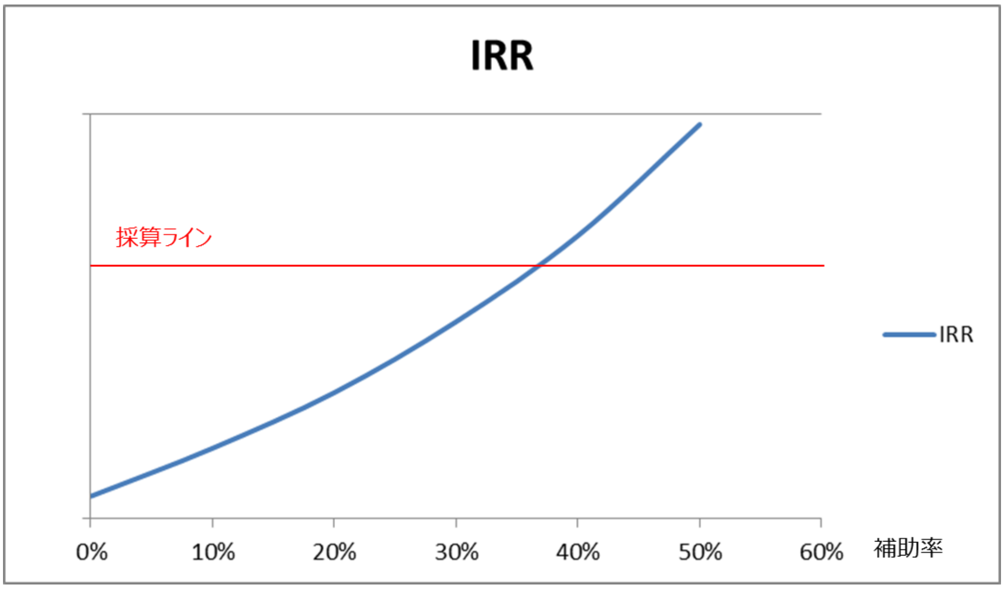
	発酵槽	精製設備	ステーション設備
設備容量	定格 48,000Nm³/d-BG	原料 2,000Nm³/h-BG 製品 1,025kg/h-CBG	Storage 12ton/d Dispenser 2 基-2 ノズル

6.1.3 a 工場の事業性評価、感度分析（JCM 補助率 vs IRR）

以上の検討を基に、10 年 IRR を試算した結果を図表 42 に示す。バイオガスの購入価格と CBG 販売価格はバイオマス工場等、輸送事業者との協議により決まる条件であるが、本 FS で試算した条件であれば実現の可能性は高いと考えている。このケースでは補助率 40%以上で事業を実現できるレベルとなる。

また、EFB のバイオガス化には通常の発酵槽より設備投資が必要であるため事業実現のためには規模を大きくし、スケールメリットを追求する必要がある。幸い a 工場には原料となる EFB が十分に存在することから、CBG の販売先の確保が課題と考える。今後、輸送会社のみならず DS への販売も含め、CBG 販売先の検討を行う。

図表 42 IRR 分析



6.1.4 b 工場における設備仕様

b 工場における A 社の課題は、水質基準を遵守するために POME にカバードラグーンを設置しなければならないにもかかわらず、売電ができないためバイオガスの利用用途がないことである。

試算では POME から 12,000Nm^3/d のバイオガスが生成できることから、精製設備は、500m^3/h の容量を検討することとした。CBG の消費ポテンシャルについては前述の a 工場と同様の状況を想定している。以上の調査を踏まえ、b 工場の設備仕様を決定した。

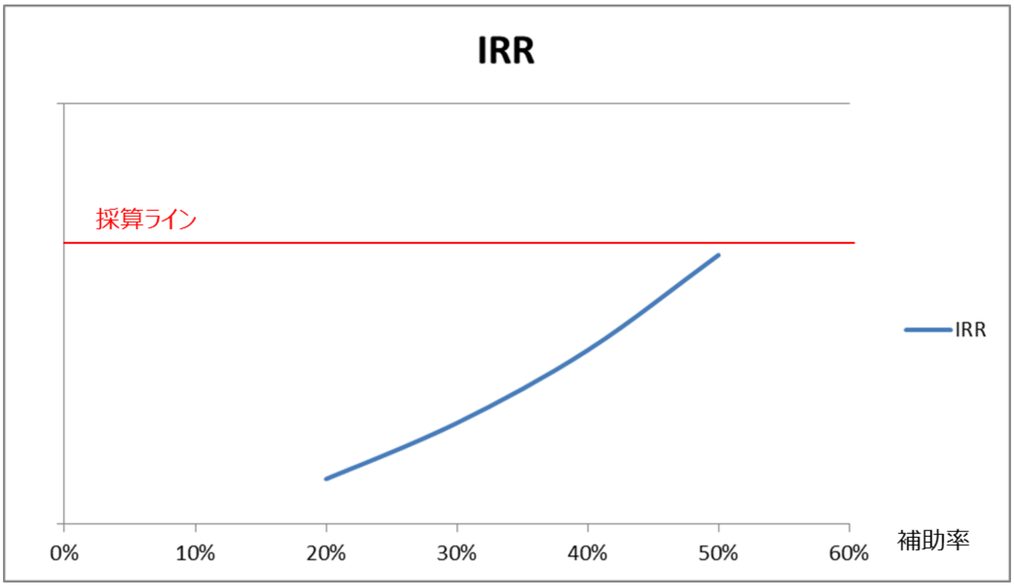
図表 43 b 工場の設備仕様

	発酵槽	精製設備	ステーション設備
設備容量	定格 15,000Nm^3/d-BG	原料 500Nm^3/h-BG 製品 292kg/h-CBG	Storage 7ton/d Dispenser 1 基-2 ノズル

6.1.5 b 工場の事業性評価、感度分析（JCM 補助率 vs IRR）

以上の検討を基に、10 年 IRR を試算した結果を図表 44 に示す。バイオガスの購入価格と CBG 販売価格はバイオマス工場等、輸送事業者との協議により決まる条件であるが、本 FS で試算した条件であれば実現の可能性は高いと考えている。このケースでは補助率 50%以上で事業を実現できるレベルとなる。

図表 44 IRR 分析



6.2 B 社における事業性検討

6.2.1 設備仕様

B 社は 20 年以上の操業実績を持つ加工澱粉製造会社で年間売上 110 億円規模の会社である。キャッサバを原料とする生産工場を営む。

B 社では、工場廃水は水質管理のため Upflow anaerobic sludge blanket reactor(以下、「UASB」）とカバードラグーン（以下、「CL」）によって処理されている。UASB から発生するバイオガスは、臭気の問題からそのまま大気放散できず、全てフレアしている。CL のバイオガスは発電設備とボイラ設備の燃料として利用している。

また、UASB のラインは後段にフレア設備しかないため、廃水は CL 側に優先供給し、余りを UASB に回す運用を行っている。2015 年のフレアガス量の実績から、精製設備は、常時安定稼働できる水準として、750m³/h の容量を検討することとした。

精製設備の設置候補場所は既存発酵槽に隣接する場所で、工場の奥の入り込んだ場所にあったため、給油のためにトラックが往来することが難しいと判断し、ステーションは工場入口付近を設置場所として検討した。このため、バイオガス搬送用の配管を約 500m 敷設する計画とした。

CBG の消費ポテンシャルとして、自社保有のトラックも若干数あるものの、製造する CBG 量に見合う消費を見込めないと推察される。一方、製品輸送の大半を輸送事業者へ委託している。そのうちの 1 社は、前述のとおり NGV トラックを保有している大手の輸送会社で、ドアノック訪問をした結果、魅力ある CBG 価格を提示できれば有望な買い手になり得ることがわかった。

以上の現場調査を踏まえ、B 社の設備仕様を決定した。

図表 45 B 社の設備仕様

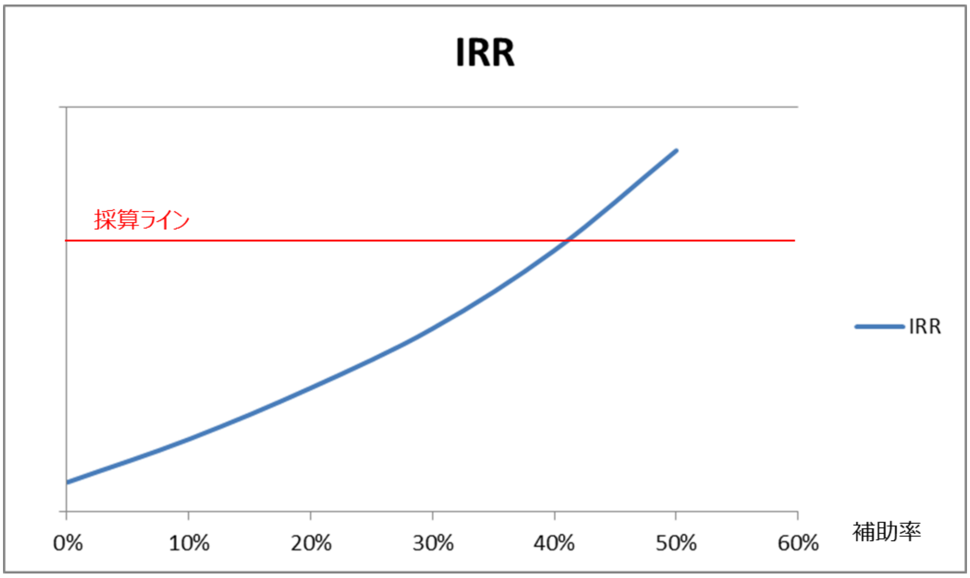
	発酵槽設備	精製設備	ステーション設備
設備容量	定格 40,000Nm³/d-BG	原料 750Nm³/h-BG 製品 404kg/h-CBG	Storage 7ton/d Dispenser 1 基-2 ノズル

6.2.2 事業性評価、感度分析（JCM 補助率 vs IRR）

以上の検討を基に、10 年 IRR を試算した結果を図表 46 に示す。バイオガスの購入価格と CBG 販売価格はバイオマス工場等、輸送事業者との協議により決まる条件であるが、本 FS で試算した条件であれば実現の可能性は高いと考えている。このケースでは補助率 40%以上で事業を実現できるレベルとなる。

また、B 社の余剰ガスをより多く調達でき、かつ、それに見合う CBG 需要を見込めれば、スケールアップが可能となり、事業性も向上する。今後はそうした検討を深めて、事業性を高める検討をしていきたい。

図表 46 IRR 分析



6.3 実証サイトにおける事業化検討

6.3.1 パイロット実証協力企業の概要

大阪ガスがパイロット実証試験を実施するサイトとして選定したC社は操業15年のパーム油事業者で2014年の売り上げは約10億円である。パーム農園は所有しておらず、FFBはすべて外部から購入している。工場では2017年に規模拡大の計画があるが、発電会社から売電量の増設は認められないため、増加するバイオガスはフレアせざるを得ない状況である。

大阪ガスは2014年頃からタイ王国で精製設備のパイロット実証サイトを探索していた。C社は将来的に発電機の増設が難しいこと、既にNGVトラックを所有していたこと、CBGは将来有望な再生可能エネルギーのひとつと考えていたことから大阪ガスの提案に協力的であった。こうした背景のもと実証試験の条件についてC社と合意が得られた結果、C社をパイロット実証サイトに選定した。

6.3.2 パイロット実証の概要

パイロット実証では、大阪ガスは原料バイオガス、ユーティリティを提供してもらいCBGを製造し、C社へ供給する。C社は自社のNGVトラックの燃料としてCBGを利用する。大阪ガスは試験期間中、システムのパフォーマンス、分離膜の耐久性、コンプレッサーの耐久性、製品のメタン濃度変化への対応等の確認を行い商業化へ向けたデータを収集する。

設備規模については、試験に最低限必要な規模として、250m^3/hを選定した。現在、パイロット設備を建設中で2017年3月末に完成予定である。順調に行けば、2017年4月から1年間実証試験を行う予定である。

6.3.3 C 社における設備仕様

実証試験終了後、C 社で CBG 事業を実施するケースで設備仕様を決定した。

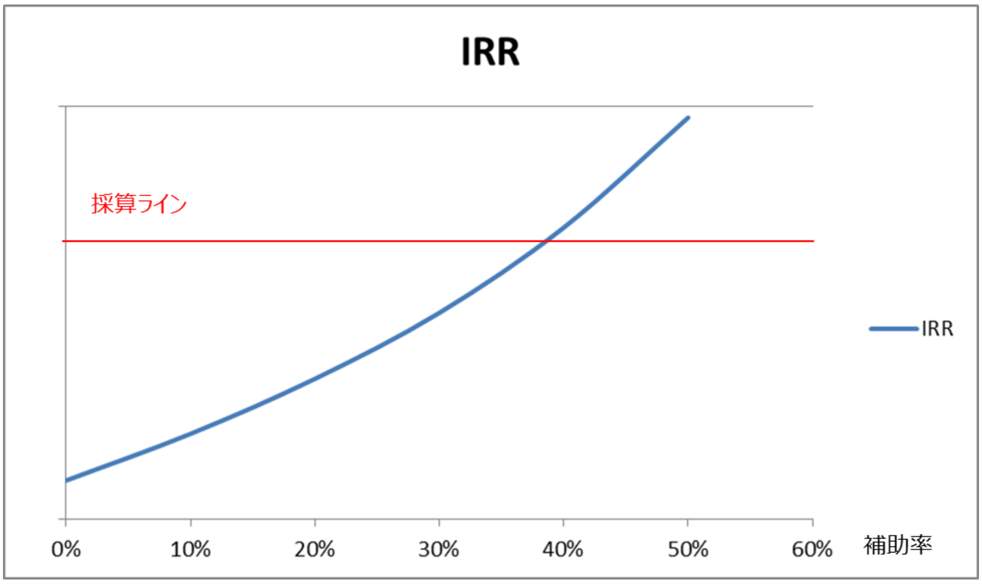
図表 47 C 社の設備仕様

	発酵槽	精製設備	ステーション設備
設備容量	C 社の既存設備	原料 250Nm³/h-BG 製品 146kg/h-CBG	C 社の既存設備

6.3.4 C 社の事業性評価、感度分析（JCM 補助率 vs IRR）

以上の検討を基に、10 年 IRR を試算した結果を図表 48 に示す。バイオガスの購入価格と CBG 販売価格はバイオマス工場との協議により決まる条件であるが、本 FS で試算した条件であれば実現の可能性は高いと考えている。このケースでは補助率 40%以上で事業を実現できるレベルとなる。

図表 48 IRR 分析



7. 普及展開可能性の分析

7.1 分析における基本的な考え方

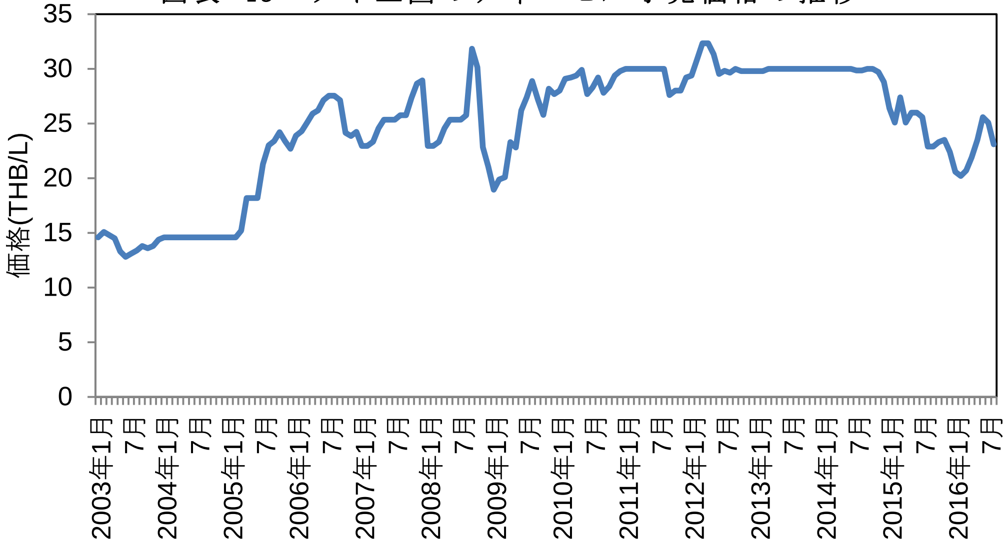
前章では CBG 事業における事業性を試算し、タイ王国において同事業が十分に事業性を有する蓋然性が高いことを示した。この章では、ディーゼルや CNG 等の自動車燃料の価格動向を整理し CBG のそれら燃料に対する競争力を分析すると共に、CBG と同じくバイオマスを材料とし、競合技術となるバイオガス発電や農作物残渣の有機利用の調査を行い、CBG を事業として実施する十分なインセンティブが事業者に存在するかを検討し、タイ王国における CBG 事業の普及展開可能性を分析する。加えて、7.3.2 にて競合他社の分析を実施した。

7.2 代替燃料の動向

7.2.1 ディーゼル価格の見通し

タイ国内のディーゼル小売価格の推移を示す。近年のディーゼル小売価格は下落傾向であり、30THB/L を超えない範囲で推移してきた。これは 2011 年 1 月以降価格に対して 30THB/L のプライスキャップがかけられているためである。

図表 49 タイ王国のディーゼル小売価格の推移



出所：タイ王国・エネルギー政策・計画室（EPPO）統計を基に日本総研作成

タイ王国のディーゼル小売価格は、主に燃料価格、物品税、石油基金拠出金の 3 つで構成される。各項目は下記の方法に基づき決定している。

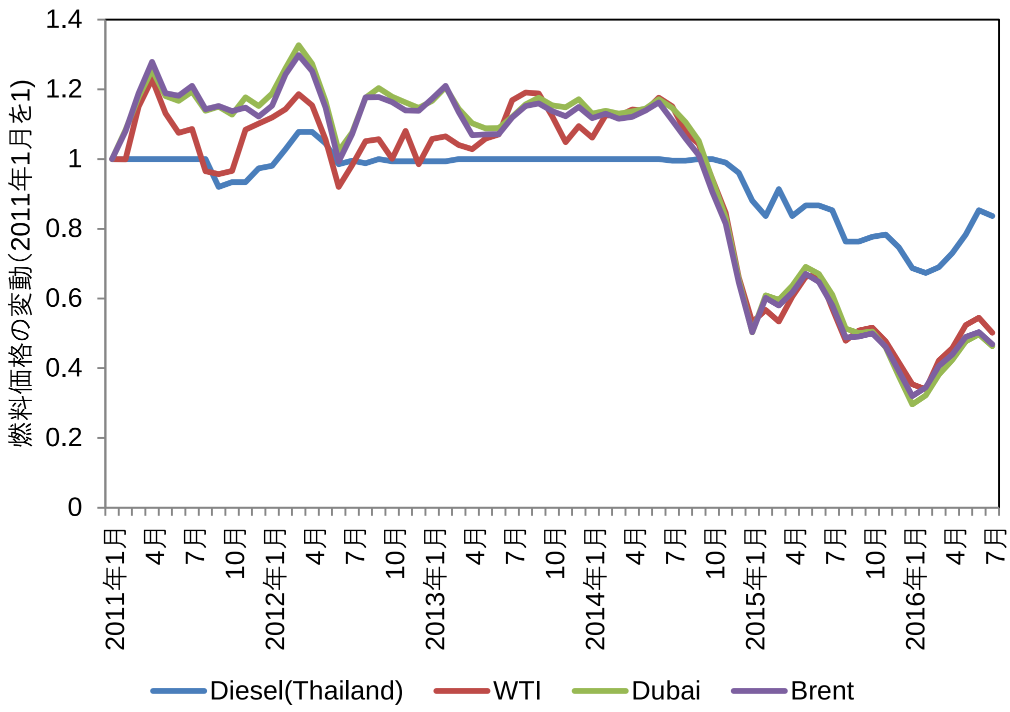
- 燃料価格：国際燃料価格の変動に基づき、PTT が決定
- 物品税：タイ王国・財務省によって設定
- 石油基金拠出金：燃料価格が高騰した際に補填することを目的として設立された基金。再エネへの投資などへも利用。燃料価格や物品税による変動を調整し、価格ボラティリティを小さくしている。

図表 50 タイ王国のディーゼル小売価格の構成要素

① 小売価格 ＝ ② 燃料価格 ＋ ③ 物品税 ＋ ④ 石油基金拠出金

下表には、直近5年間のタイ王国ディーゼル小売価格と主要な国際原油価格（WTI・Dubai・Brent）の価格変動の推移を示している。各価格とも2011年1月時点の価格を1として計算した。国際原油価格が2011年1月時点との価格と比較して最大70%下落したのに対して、タイ王国ディーゼル価格の下落幅は30%に留まった。また、総じて、国際原油価格の変動に比べタイ王国ディーゼル価格の変動が小さいことが見て取れる。

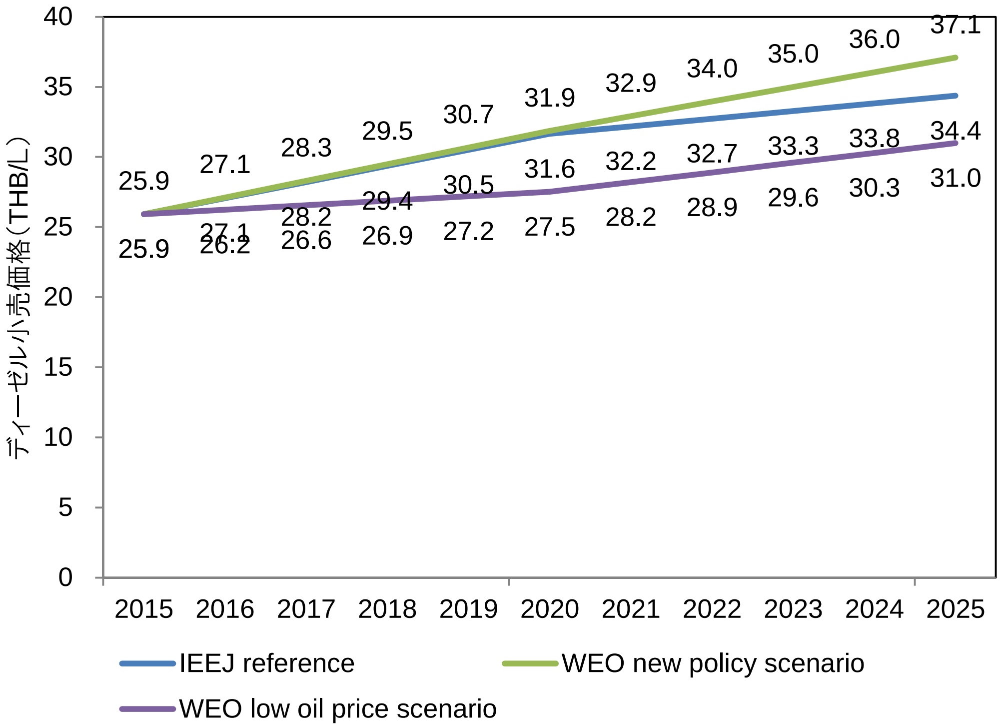
図表 51　タイ王国ディーゼル価格と国際原油価格の推移の比較（2011年1月の価格を基準"i"と設定）



出所：タイ王国・エネルギー政策・計画室（EPPO）統計
IMF（国際通貨基金）、Primary Commodity Pricesを基に日本総研作成

一方で、石油基金拠出金は、燃料価格以外への投資増加による政府の財政難の懸念から、将来的には廃止される方向で検討されている[4]。また、同様の理由によりプライスキャップについても廃止されるとの報道もある。したがって、今後のタイ王国ディーゼル価格は国際原油価格の変動にしたがって動いていくと推察される。下表には将来のタイ王国ディーゼル価格の推移を示した。それぞれの結果は各調査機関の公表した国際原油価格に連動するよう推計した。いずれの場合においても、2025 年にはプライスキャップとなっている 30THB/L を超える見込みである。

図表 52　将来のタイ王国ディーゼル価格の見通し



*将来価格の推計を行った。なお、燃料価格には国際燃料価格に輸送コスト 9.5THB/L（2016 年 8 月実績値）を加算している。物品税及び石油基金拠出金についてもそれぞれ 5.65THB/L、0.14THB/L（2016 年 8 月の実績値）として試算した。

出所：各調査機関報告書（下記参照）を参考に日本総研推計

[4] EPPO 関係者への現地ヒアリングより

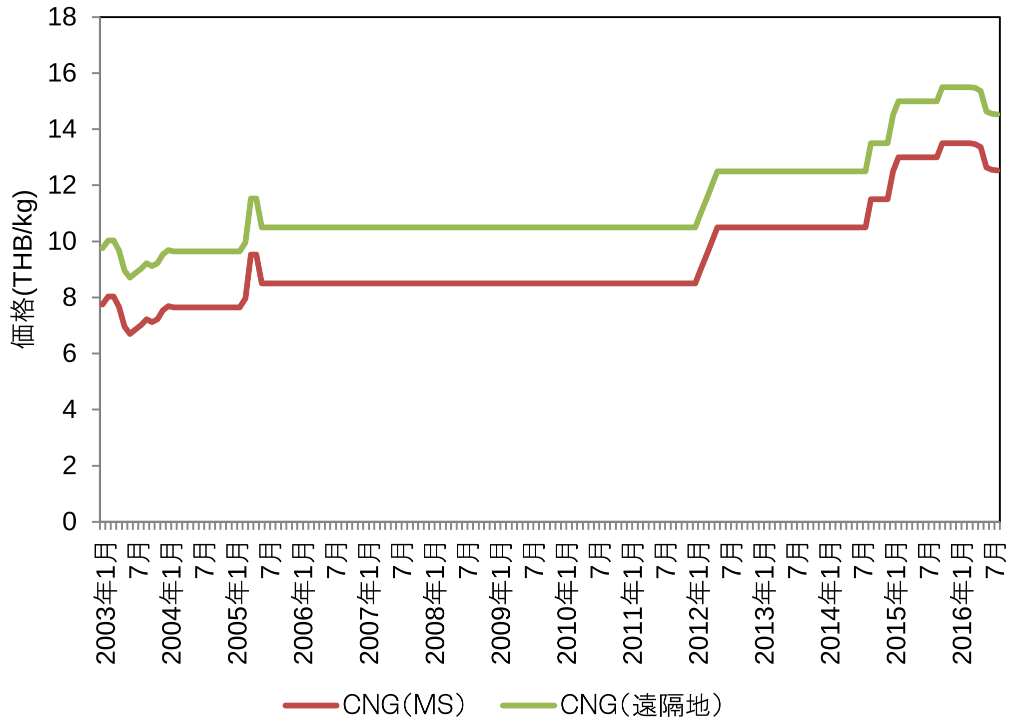
図表 53 各調査結果の諸元

ケース名	調査機関名	報告書名	ケース概要
IEEJ reference	日本エネルギー経済研究所	アジア/世界エネルギーアウトルック 2015	過去の趨勢および現在までのエネルギー・環境政策等にしたがって推移するケース
WEO new policy scenario	International Energy Agency（国際エネルギー機関）	World Energy Outlook 2015	過去の趨勢および現在までのエネルギー・環境政策等にしたがって推移するケース
WEO low oil price scenario			原油価格の低価格傾向が長引くことを想定したケース

7.2.2 CNG価格の見通し

タイ王国のCNG価格の推移を示す。2015年ごろまで価格の変動がないのは、政府の統制価格によって取引がされていたためである[5]。

図表 54　タイ王国のCNG価格の推移



出所：タイ王国・エネルギー政策・計画室（EPPO）統計を基に日本総研作成

現在のCNG価格は、製造価格、輸送コスト、運用コスト、税金によって構成されている。ただし、小売価格については15.84THB/kgのプライスキャップがかけられていた。

2016年7月、CNG価格のプライスキャップが撤廃され、小売価格については政府統制価格から市場連動制となった。なお、バンコクから半径50km以遠の地域については、1kmあたり0.015THB/kgの輸送コストが生じるシステムとなっており、最大4THB/kgまで上乗せ可能な価格

[5] EPPO関係者への現地ヒアリングより

方式に変更した。政府統制価格から市場連動制へと移行したことにより将来的に CNG 価格についても国際原油価格の上昇に伴い、CNG 価格も上昇していく見通しである。

7.3 競合技術の動向

7.3.1 広義の競合

7.3.1.1 バイオガス発電

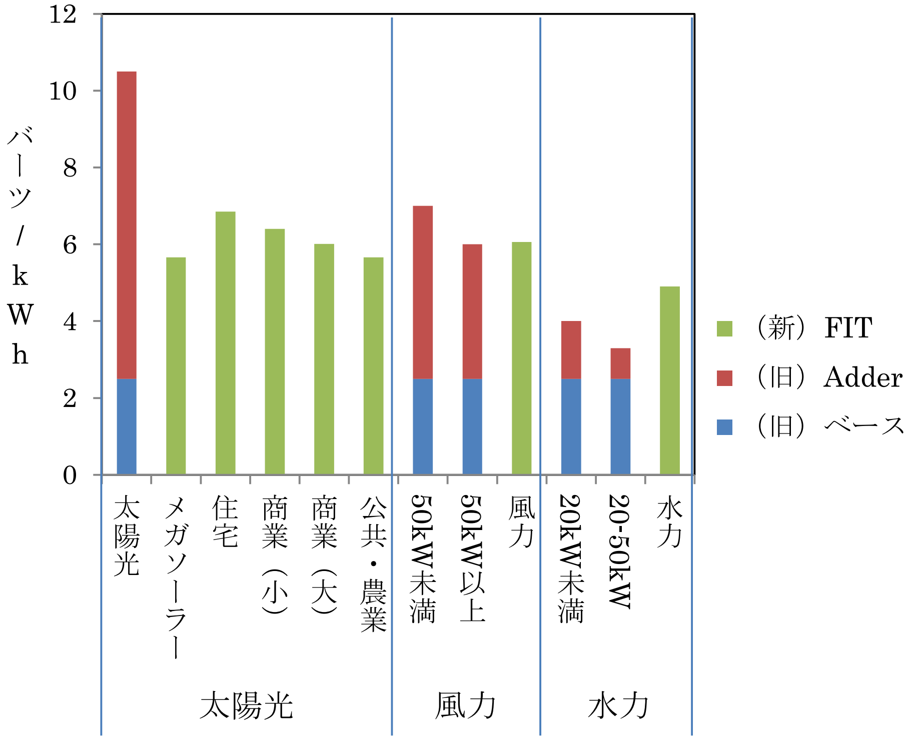
3.5.2 で示した通り、2016 年にタイ王国の固定価格買取制度が改定され、バイオマス・バイオガス・廃棄物に対して比較的優位な制度に変更されている。ベース単価 2.5THB/kWh（出所：IEA, 2.0-2.5THB/kWh の上方値）と Adder を用いて計算した旧制度における買取価格と、新制度における買取価格を比較したものを

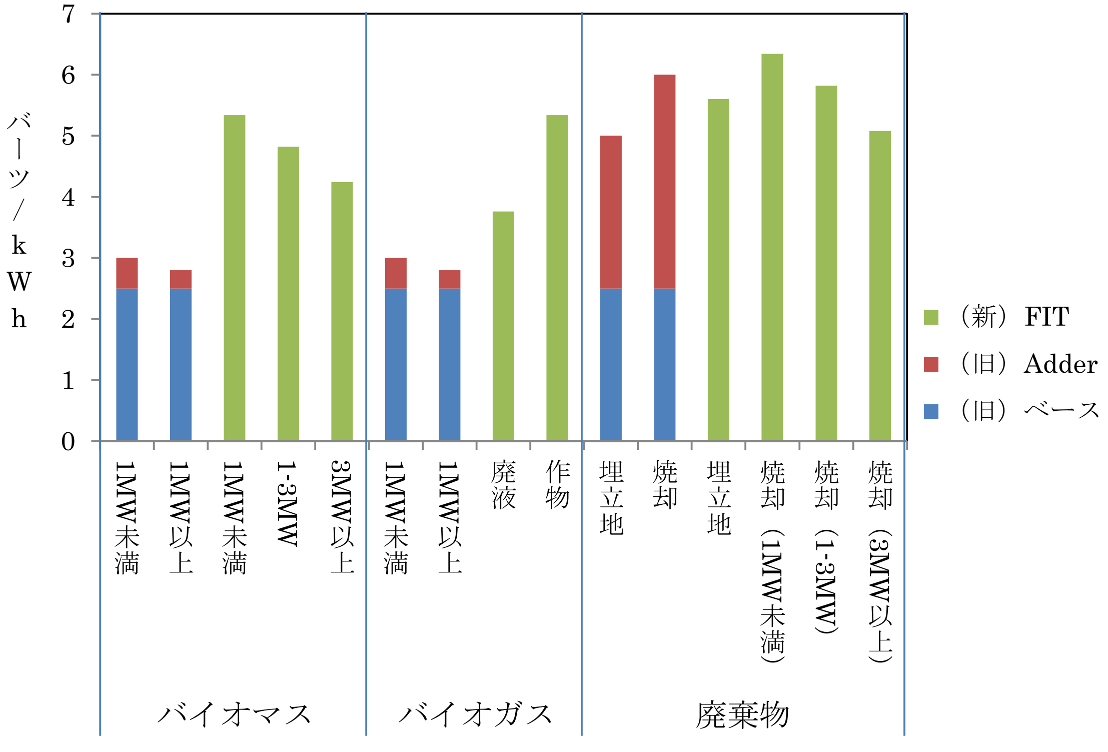
図表 55 に示す。青と赤で構成される積み上げ棒グラフが旧制度の買取価格（青：ベース、赤：Adder）であり、緑の棒グラフが新制度のものである。尚、新制度の買取価格のうち毎年見直される変動部分（FIT(変)）については、2017 年運転開始の再生可能エネルギー電源の買取価格に適用される値を用いた。

太陽光の買取価格が大きく減少、風力がやや減少している一方で、水力・廃棄物の買取価格がやや上昇、バイオマス・バイオガスが大きく上昇していることが見て取れる。そのため、従来よりもバイオガス発電の事業性は向上する可能性が高い（ただし、3.5.2 で記載したとおり、同金額は上限値であり、各社の入札動向によっては旧制度の買取価格よりも下がる可能性は存在する）。

一方、前述した通り、現在、再エネ普及に系統整備が追いついておらず、系統が脆弱な地域においては再エネの系統接続が制限されている。入札制度への移行に伴い、計画的な再エネ導入と系統整備が実施されていくものと考えられるが、同計画から外れた地域の農園事業者は将来的にもバイオマスを発電用途に使用できず、別の有効活用の方法を検討すると考えられる。

図表 55 買取価格の比較（旧制度・新制度）





出所：IEA・タイ王国 代替エネルギー開発・効率化局

7.3.1.2 農作物残渣の有機利用

一般に化学肥料の価格は原油価格と強い相関がある。事実、タイ王国で原油価格が高騰した 2008 年には、それに合わせて化学肥料の価格も高騰している。前述の通り、タイ王国の化石燃料の海外依存は高まっており今後も原油価格高騰リスクは存在すると考えられる。そうしたリスクをヘッジするため、また、健康意識の高まりに伴い、化学肥料に変えて農作物残渣を肥料として使用することへの関心が高まりを見せている。

ただし、し尿や POME 等を肥料として用いる場合は、発酵後のものを用いるため、CBG 事業やバイオガス発電事業とは直接的には競合せず、むしろ付帯事業として位置づけられる可能性がある。

7.3.2 狭義の競合

7.3.2.1 CBG 製造技術の競合事業者

タイ王国で CBG を製造し継続した事業を実施している事業者はない。大学等の小規模な実験を除けば、UAC Global Public Company Limited（以下、UAC）が CBG 実証事業を実施した事例がある。UAC は豚のし尿とネピアグラスを材料に 2003 年から年間 1,100t 程度（ディーゼル 220 万 t 相当）の CBG を製造できる設備を建設し、PTT の DS に販売するモデルで実証事業を実施した。同事業では 3t/日の生産を目論んでいたが、技術的課題により実際は 1/3 程度しか CBG を生産できていない。このように CBG 製造事業は事業的にも技術的にもまだまだ実証段階のレベルである。

CBG がタイ王国において事業として花開いていない理由としては、UAC の事例にも見られる通り、現時点では、信頼性のある技術が普及してないことが挙げられる。

また、従来、買取価格と期間の固定されたバイオガス発電を実施する方が、安定して長期的収益が見込めたことも一因といえる。しかしながら、特にタイ王国の南部地域の系統は脆弱であり、バイオガス発電の系統接続が不可能な地域は今後も一定数存在すると見られる。6 で分析した通り、今後 CBG が投資回収可能な事業となっていく中で、農園の廃棄物を有効活用する方法として CBG が候補となる機会は極めて多くなると考えられる。一方で、従来投資回収ができない事業として見做されていた CBG 技術を保有する現地企業は、前述の通り極めて少ない。そのため、実証を通じて十分なノウハウを身に着けることで、他の競合事業者を寄せ付けず、タイ王国の CBG 黎明期におけるリーディングカンパニーへと一気に駆け上がっていくことも十分可能であると考えられる。

8. MRV方法論・PDDの特定

8.1 MRV方法論案

本プロジェクトは、バイオマス工場の廃棄物(廃液や加工残渣)を原料として、カバードラグーン方式にて嫌気性消化し、バイオガスを回収・精製して純度を高めて、自動車用燃料として利用する。次の 2 つの活動により GHG 排出削減を実現するものである。

- バイオマス工場の廃棄物(廃液や加工残渣)を原料としてバイオガス回収することによるメタン排出回避
- トラックへの Bio-CNG 利用による化石燃料代替のエネルギー削減

本プロジェクトの 2 つの活動に合致する CDM 方法論を参考に、MRV 方法論の策定を行った。参考とする CDM 方法論は次の 3 つである。

AMS-III.H: Methane recovery in wastewater treatment (Version 18.0) （以下、「廃液のメタン排出回避 CDM 方法論」とする。）
AMS-III.E: Avoidance of methane production from decay of biomass through controlled combustion, gasification or mechanical/ thermal treatment (Version 17.0) （以下、「加工残渣のメタン排出回避 CDM 方法論」とする。）
AMS-III.AQ.: Introduction of Bio-CNG in transportation applications (Version 2.0) （以下、「輸送機器関連 CDM 方法論」とする。）

廃液のメタン排出回避 CDM 方法論は、有機性排水のメタン回収を行うプロジェクトに適用するものである。プロジェクトサイトでは、現状ではバイオマス工場からの廃液はカバードラグーン形式にて嫌気性処理を行った上でエネルギー利用しているが、一部は余剰ガスとしてフレア処理を行っている。フレア処理は臭気対策のために自主的かつ追加的に行っている活動である。そのため、リファレンスは余剰ガスを大気放

出しているものとして設定する。

加工残渣のメタン排出回避 CDM 方法論は、工場からの加工残渣を廃液に混合させ、メタン回収を行うプロジェクトに適用するものである。プロジェクトサイトでは、現状ではバイオマス工場からの加工残渣はプランテーションに野積みで廃棄されている。そのため、リファレンスは埋立処分場からメタンを大気放出しているものとして設定する。

図表 56　加工残渣の廃棄状況

出所：A 社プランテーションにて日本総研撮影

輸送機器関連 CDM 方法論は、生物起源のバイオガスを精製し昇圧することにより Bio-CNG（Biogenic Compressed Natural Gas）を製造し、輸送機器にて燃料として利用するプロジェクトに適用するものである。生物起源のバイオガスは、バイオマス専用のプランテーション、排水処理、肥料管理やバイオマス残渣からのバイオマスを嫌気性処理によるメタン発酵をして得られるガスである。本プロジェクトは、バイオマス工場からの廃棄物(廃液・加工残渣)を原材料としてバイオガスを精製し、昇圧した CBG を輸送機器の燃料とするものである。

本プロジェクトは、これら 3 つの CDM 方法論を基に、JCM の考え方に則りながら、適格性要件とリファレンスシナリオの設定を行った。適格性要件はプロジェクトに導入する技術と原料となる廃棄物の前提

条件を元に設定した。技術仕様として、大阪ガスが有するCBG製造に不可欠なバイオガス精製技術であるPressure Swing Adsorption(以下、PSA とする。)とガス分離膜を組み合わせたハイブリッド型二酸化炭素除去システムを用いることとした。PSA 単独でメタン精製を行った際のメタン回収率は 85%程度であるが、本システムではメタン濃度98%の精製ガスをメタン回収率98%にて取り出せる仕様となっている。本システムは、ガスを供給する圧縮機、PSA 及びガス分離膜より構成され、PSA から排出されるオフガスを分離膜により原料バイオガスに近い濃度まで再濃縮し、PSA の入り口へとリサイクルするという特徴を持っている。PSA において高濃度への濃縮を行いながら、オフガスのリサイクルにより回収率を補い、そのリサイクル時の濃縮には、中程度のメタン濃度条件において効率よく濃縮ができる分離膜を用いることで、全体として高効率なシステム構成となっている。通常、オフガスは大気放出するが、本システムではリサイクルすることで高効率化を図るため、その技術も適格性要件として設定した。また、輸送機器利用時の安全性を担保するたに、精製された Bio-CNG は NGV への燃料利用に適合するための国際又はタイ王国の品質基準を満たす計画があることも設定する。

リファレンスシナリオは、次の 2 つを排出源とする。

- バイオマス工場の廃棄物(廃液や加工残渣)から大気放出されるメタン排出
- NGV の化石燃料利用による二酸化炭素排出

BaU は、バイオマス工場からの廃棄物(廃液や加工残渣)は嫌気性処理を行い、利用されないメタンが大気放出されると設定する。リファレンスも同様の状況とするが、純削減の実現を担保するために、メタンの大気放出量の算定の際に、廃液からのメタン量は Bio-CNG としての使用量を用い、加工残渣からのメタン量は FOD モデル(2006 年 IPCC ガイドライン)を用いて埋立処分を行った際のメタン量の算定を行う。そのため、BaU 排出量よりもリファレンス排出量が低くなる設定を行った。

MRV 方法論案は、タイ政府と日本政府で締結している JCM Proposed Methodology Form ver01.0.を用いて作成し、次項以降に示す。スプレッドシート JCM_TH_F_PMS_ver01.0 を用いて作成し、別添 1 とする。

JCM Proposed Methodology Form

Cover sheet of the Proposed Methodology Form

Form for submitting the proposed methodology

Host Country	Kingdom of Thailand
Name of the methodology proponents submitting this form	Osaka Gas Co., Ltd.
Sectoral scope(s) to which the Proposed Methodology applies	7. Transport 13. Waste Handling and Disposal
Title of the proposed methodology, and version number	Refining Bio-CNG from organic waste at Biomass Plant for using as fuels of NGV in Thailand, ver1.0.
List of documents to be attached to this form (please check):	☐The attached draft JCM-PDD: ☐Additional information
Date of completion	17/02/2017

History of the proposed methodology

Version	Date	Contents revised
1.0	17/02/2017	First edition

A. Title of the methodology

Refining Bio-CNG from organic waste at Biomass Plant for using as fuels of NGV in Thailand, ver1.0.

B. Terms and definitions

Terms	Definitions
Organic waste	Liquefied and solid waste that contains degradable organic matter. This may include, for example, waste water and processing residue from Biomass plant.
Bio-gas	Gases generated from anaerobic digesters.
Bio-CNG	Biogenic Compressed Natural Gas purified from Bio-gas.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	● The project is to capture CH_4 from anaerobic digestion system with organic waste (e.g. waste water and processing residues) at Biomass Plant and purify to Bio-CNG (Compressed Natural Gas), which are used for NGV (Natural Gas Vehicle) in Thailand. It is to achieve GHG emission reduction through the following 2 activities. 1) Avoiding CH_4 emissions by recovering biogas

	using organic waste at Biomass Plant. 2) Reducing consumption of fossil fuel by using Bio-CNG for vehicle.
Calculation of reference emissions	● Reference emissions are GHG emissions from releasing CH4 to the atmosphere from organic waste (e.g. waste water and processing residues) at Biomass plant, and consuming fossil fuel for vehicles. ● Reference emissions are calculated with volume of Bio-gas putting into upgrading system and consumption of Bio-CNG (for estimating consumption of fossil fuel) by vehicles.
Calculation of project emissions	● Project emissions are calculated with project activity and CO_2 emission factor (default value). ● Project activities are the following; ➢ Upgrading process: Electricity consumption by bio-gas upgrading system.
Monitoring parameters	● (In case of waste water and processing residues) Amount of processing residue putting into anaerobic digestion system [t/p] ● (In case of waste water and processing residues) Electricity consumption by anaerobic digestion system during the period p [MWh/p] ● Electricity consumption by Bio-gas upgrading system during the period p [MWh/p] ● Electricity consumption by refueling station during the period p [MWh/p] ● Bio-CNG consumption by transport application (j) during the period p [t/p]

D. Eligibility criteria

This methodology is applicable to projects that satisfy all of the following criteria.

Criterion 1	The project is to capture CH_4 from anaerobic digestion system with organic waste (e.g. waste water and processing residues) at Biomass Plant and purify to Bio-CNG (Compressed Natural Gas), which are used for NGV (Natural Gas Vehicle) in Thailand.
Criterion 2	Organic waste from Biomass Plant is not used for Energy or Materials. (e.g. Waste water is discharged into river, captured CH_4 is released into atmosphere, and process residue is landfilled or left in the field.)
Criterion 3	The technology of purifying to Bio-CNG is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.
Criterion 4	The off-gas discharged from PSA is recycled.
Criterion 5	Plant to apply the international or national qualification standard of Bio-CNG for using NCV is prepared.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Methane emissions from decay of organic waste	CH_4
Fossil fuel consumption by Natural Gas Vehicle	CO_2
Project emissions	
Emission sources	GHG types

Electricity consumption by anaerobic digestion system	CO_2
Electricity consumption by upgrading system for Bio-CNG	CO_2
Electricity consumption by refueling station for Bio-CNG	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Reference emissions consist of two types of emission sources:

1) Methane emissions from decay of organic waste
2) Fossil fuel consumption by Natural Gas Vehicle

1) Calculation of reference emissions from decay of organic waste

- In case of using waste water for raw material

Waste water from a Biomass Plant is typically discharged into river and anaerobically digested which leads to methane emissions to the atmosphere. The reference emissions from decay of waste water are calculated using volume of CH_4 consisted of Bio-CNG.

- In case of using waste water and processing residues for raw material

Waste water from a Biomass Plant is typically discharged into river, and organic waste from a Biomass Plant is typically landfilled at SWDSs and anaerobically digested which leads to methane emissions to the atmosphere. The reference emissions from decay of organic waste are calculated using volume of CH_4 consisted of Bio-CNG and the FOD model adopted in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

2) Fossil fuel consumption by Natural Gas Vehicle

Bio-CNG replaces the fossil fuel which is used for NGV. The reference emissions from fossil fuel consumption are calculated by multiplying the amount of Bio-BNG supplied to NGV, NCV of Bio-CNG and CO_2 emission factor of the reference fossil fuel.

This methodology ensures a net emission reduction by following reasons:
The avoidance of CH_4 from decay of organic waste is calculated with Bio-CNG consumption by transport application and set the default DOC value conservatively in line with 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Default DOC value of 8%, which is the lower value of the range 8-20% for food waste, is applied and FOD model adopted in the 2006 IPCC Guidelines. Food waste, which has the lowest DOC value among organic waste types, is assumed to represent the organic waste from Biomass Plant. The reference emissions are underestimated by using conservatively-set Bio-CNG consumption, since reference emissions are lower than the BaU emissions.

F.2. Calculation of reference emissions

$$RE_p = RE_{CH4,p} + RE_{trans,p}$$

(EQ1)

RE_p	: Reference emissions during the period p [tCO_2e/p]
$RE_{CH4,p}$	: Reference emissions from decay of organic waste during the period p [tCO_2e/p]
$RE_{trans,fuel,p}$	: Reference emissions from fossil fuel consumption by transport applications during the period p [tCO_2e/p]

$$RE_{CH4,p} = RE_{CH4,ww,p} + RE_{CH4,residue,p}$$

(EQ2)

$RE_{CH4,p}$	: Reference emissions from CH_4 into atmosphere during the period p [tCO_2e/p]
$RE_{CH4,ww,p}$	: Reference emissions from CH_4 of waste water into atmosphere during the period p [tCO_2e/p]
$RE_{CH4,residue,p}$	: Reference emissions from CH_4 of processing residue into atmosphere during the period p [tCO_2e/p]

- In case of using waste water for raw material

$$RE_{CH4,ww,p} = FC_{Bio-CNG,j,p} \times R_{CH4,Bio-CNG} \times GWP_{CH4}$$

(EQ2-1)

$RE_{CH4,ww,p}$	: Reference emissions from CH_4 of waste water into atmosphere during the period p [tCO_2e/p]
$FC_{Bio-CNG,j,p}$	: Bio-CNG consumption by transport application (j) during the period p [t/p]
$R_{CH4,Bio-CNG}$	: Rate of CH_4 content of Bio-CNG by volume [-]
GWP_{CH4}	: Global Warming Potential for CH_4:25

- In case of using waste water and processing residues for raw material

$$RE_{CH4,ww,p} = \left[FC_{Bio-CNG,j,p} \times R_{CH4,Bio-CNG} - \left(W_{residue,p} \times R_{CH4,residue}\right)\right] \times GWP_{CH4}$$

(EQ2-2)

$RE_{CH4,ww,p}$: Reference emissions from decay of waste water during the period p [tCO_2e/p

$FC_{Bio-CNG,j,p}$: Bio-CNG consumption by transport application (j) during the period p [t/p]

$R_{CH4,Bio-CNG}$: Rate of CH_4 content of Bio-CNG by volume [-]

$W_{residue,p}$: Weight of processing residue putting into anaerobic digestion system during the period p [t/p]

$R_{CH4,residue}$: Rate of CH_4 gasification from processing residue [-]

GWP_{CH4} : Global Warming Potential for CH_4:25

$$RE_{CH4,residue,p} = \sum_{m=p\_start}^{p\_end} \left\{ (1-f) \times GWP_{CH4} \times (1-OX) \times \frac{16}{12} \times F \times DOC_f \times MCF \times \sum_{x=1}^{m-13} W_{residue,p} \times DOC \times e^{-\frac{k}{12}(m-13-x)} \times \left(1-e^{-\frac{k}{12}}\right) \right\}$$

(EQ2-3)

$RE_{CH4,residue,p}$: Reference emissions from decay of processing residue during the period p [tCO_2e/p]

f : Fraction of methane captured at the SWDS and flared, combusted or used in another manner that prevents the emissions of methane to the atmosphere

GWP_{CH4} : Global Warming Potential for CH_4:25

OX : Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)

16/12 : Molecular weight ratio of methane and carbon

F : Fraction of methane in the SWDS gas [volume fraction]

DOC_f : Fraction of degradable organic carbon (DOC) that

	decomposes under specific conditions occurring in the SWDS [weight fraction]
MCF	: Methane Correction Factor
$W_{residue,p}$	: Weight of processing residue putting into anaerobic digestion system [t/p]
DOC	: Fraction of degradable organic carbon (by weight) [weight fraction]
k	: Decay rate [1/year]
x	: Months in the time period in which waste is disposed at the SWDS, extending from the first month in the time period (x=1) to month m (x=m)
m	: The Nth month from the first disposal at the SWDS, extending from the first month of the period p (m=p_start) to the last month of the period p (m=p_end)
p_start	: The Nth month from the first disposal, which is the first month of the period p. If that month is smaller than 14 and p_end is larger than 13, p_start is set at 14 because CH_4 generation can be accounted only after 13 months have passed since the first disposal at the SWDS.
p_end	: The Nth month from the first disposal, which is the last month of the period p. If p_end is smaller than 14, CH4 generation cannot be accounted.

$$RE_{trans,p} = FC_{Bio-CNG,j,p} \times NCV_{CNG} \times EF_{CNG}$$

(EQ3)

$RE_{trans,p}$	: Reference emissions from fossil fuel consumption by transport applications during the period p [tCO_2e/p]

$FC_{Bio-CNG,j,p}$: Bio-CNG consumption by transport application (j) during the period p [t/p]

NCV_{CNG} : Net calorific value of CNG [GJ/t]

EF_{CNG} : CO_2 emission factor of CNG [tCO_2e/GJ]

G. Calculation of project emissions

$$PE_p = PE_{ww\_elec,p} + PE_{upgrading\_elec,p} + PE_{refueling\_elec,p}$$

(EQ4)

PE_p : Project emissions during the period p [tCO_2e/p]

$PE_{ww\_elec,p}$: Project emissions from electricity consumption by wastewater treatment during the period [tCO_2e/p]

$PE_{upgrading\_elec,p}$: Project emissions from electricity consumption by Bio-gas upgrading system during the period [tCO_2e/p]

$PE_{refueling\_elec,p}$: Project emissions from electricity consumption by refueling station during the period [tCO_2e/p]

$$PE_{ww\_elec,p} = EC_{ww,p} \times \left[\left(W_{residue,p} \times R_{CH4,residue}\right) \div FC_{Bio-CNG,j,p}\right] \times EF_{grid}$$

(EQ5)

$PE_{ww\_elec,p}$	: Project emissions from electricity consumption by wastewater treatment during the period [tCO_2e/p]
$EC_{ww,p}$	: Electricity consumption by anaerobic digestion system during the period p [MWh/p]
$FC_{Bio-CNG,j,p}$	: Bio-CNG consumption by transport application (j) during the period p [t/p]
$W_{residue,p}$	: Weight of processing residue putting into anaerobic digestion system [t/p]
$R_{CH4,residue}$	: Rate of CH_4 gasification from processing residue [-]
EF_{grid}	: CO_2 emission factor of grid electricity [tCO_2e/MWh]

$$PE_{upgrading\_elec,p} = EC_{upgrading,p} \times EF_{grid}$$

(EQ6)

$PE_{upgrading\_elec,p}$	: Project emissions from electricity consumption by upgrading system during the period [tCO_2e/p]
$EC_{upgrading,p}$	: Electricity consumption by upgrading system during the period p [MWh]
EF_{grid}	: CO_2 emission factor of grid electricity [tCO_2e/MWh]

$$PE_{refueling\_elec,p} = EC_{refueling,p} \times EF_{grid}$$

(EQ7)

$PE_{refueling\_elec,p}$	: Project emissions from electricity consumption by refueling station during the period [tCO_2e/p]
$EC_{refueling,p}$	: Electricity consumption by refueling station during the period p [MWh]
EF_{grid}	: CO_2 emission factor of grid electricity [tCO_2e/MWh]

H. Calculation of emissions reductions

$$ER_p = RE_p - PE_p$$

(EQ7)

ER_p	:	Emission reductions during the period p [tCO_2e/p]
RE_p	:	Reference emissions during the period p [tCO_2e/p]
PE_p	:	Project emissions during the period p [tCO_2e/p]

I. Data and parameters fixed *ex ante*

The source of each data and parameter fixed *ex ante* is listed as below.

<table>
<tr><th>Parameter</th><th>Description of data</th><th>Source</th></tr>
<tr><td>$R_{CH4,residue}$</td><td>Rate of CH_4 gasification from processing residue [-]</td><td>Default value in the methodology</td></tr>
<tr><td>f</td><td>Fraction of methane captured at the SWDS and flared, combusted or used in another manner that prevents the emissions of methane to the atmosphere
f=0</td><td>Default value in the methodology</td></tr>
<tr><td>OX</td><td>Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
Value of either 0.1 or 0 is applied to OX depending on the type of SWDS.
<table><tr><th>Type of SWDS</th><th>Values</th></tr><tr><td>Managed[1], unmanaged and uncategorised SWDS</td><td>0</td></tr></table></td><td>IPCC default values provided table 3.2 of Vol.3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.</td></tr>
</table>

<table>
<tr>
<td></td>
<td><table><tr><td>Managed covered with CH_4 oxidising material[2]</td><td>0.1</td></tr></table>[1] Managed but not covered with aerated material
[2] Examples: soil, compost</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Fraction of methane in the SWDS gas [volume fraction]
F=0.5</td>
<td>IPCC default values provided in “FRACTION OF CH4 IN GENERATED LANDFILL GAS (F)” of Ch.3 Vol.5 of 2006 IPCC Guidelines for National GHG Inventories.</td>
</tr>
<tr>
<td>DOC_f</td>
<td>Fraction of degradable organic carbon (DOC) that decomposes under specific conditions occurring in the SWDS [weight fraction]
DOC_f=0.5</td>
<td>IPCC default values provided table 2.4 and 2.5 of Vol.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.</td>
</tr>
<tr>
<td>MCF</td>
<td>Methane correction factor<table><tr><th>Type of SWDS</th><th>Value</th></tr><tr><td>Anaerobic managed SWDS</td><td>1.0</td></tr><tr><td>Semi-aerobic managed SWDS</td><td>0.5</td></tr><tr><td>Unmanaged SWDS-deep</td><td>0.8</td></tr><tr><td>Unmanaged-shallow SWDS or stockpiles that are considered SWDS</td><td>0.4</td></tr></table></td>
<td>IPCC default values provided table 3.1 of Vol.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.</td>
</tr>
</table>

	In Thailand, Type of SWDSs is Anaerobic managed SWDS.	
DOC	Fraction of degradable organic carbon (by weight) [weight fraction] DOC =0.08 Lower value of the range 8-20% for food waste set in IPCC 2006 Guidelines for National Greenhouse Gas Inventories is applied.	IPCC default values provided table 2.4 and 2.5 of Vol.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
k	Decay rate [1/year] k=0.4	IPCC default values provided table 3.3 of Vol.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
NCV_{CNG}	Net calorific value of CNG [GJ/t]	IPCC default values provided in table 3.2.1 of Ch.1 Vol.2 of 2006 IPCC Guidelines for National GHG Inventories.
EF_{CNG}	CO_2 emission factor of CNG [tCO_2e/GJ]	IPCC default values provided in table 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines for National GHG Inventories.
EF_{grid}	CO_2 emission factor of grid electricity [tCO_2e/MWh]	Updates on Grid Electricity Emission Factors, National Committee on Clean

		Development Mechanism, Thailand unless otherwise instructed by the Joint Committee.
GWP_{CH4}	Global Warming Potential for CH4 GWP_{CH4}=25	2006 IPCC Guidelines for National Greenhouse Gas Inventories

8.2 PDD及び候補サイトにおける見込み排出削減量

プロジェクト対象候補サイトとして、事業与信およびBio-CBG製造と消費のポテンシャルが高い2つのサイトにおけるPDD(Project Design Document)の作成と二酸化炭素排出削減見込み量の試算を行った。

8.2.1 サイトA（A社）

A社・a工場では、工場から排出されるEFBのうち95%を利用し廃液に混合して嫌気性処理によりバイオガスを精製できることが確認できた。この結果、精製設備は、常時安定稼働できる水準として、2,000Nm^3/hの容量を検討することとした。2,000Nm^3/h機を選定した場合には、Bio-CNGは約8,118t/年の生産量が見込める。

おおよその二酸化炭素排出削減量を試算するために、EFBの埋立処理におけるメタン回避量は考慮せずに、Bio-gasの使用量の大気放出におけるメタン回避量をリファレンス排出量とした。リファレンス排出量はメタン回避分172,507t-CO_2/yと車両における化石燃料利用分22,953 t-CO_2/y、各設備での電力使用量によるプロジェクト排出量は3,253 t-CO2/y、その差分として二酸化炭素排出削減量は192,207 t-CO_2/yと試算された。

図表 57 a工場の設備仕様

	発酵槽	精製設備	ステーション設備
設備容量	定格 48,000Nm^3/d-BG	原料 2,000Nm^3/h-BG 製品 1,025kg/h-CBG	Storage 12ton/d Dispenser 2基-2ノズル

図表 58　a工場の二酸化炭素排出削減量試算におけるモニタリング項目と数値

モニタリング項目	数値	根拠
Bio-CNG 量[t/y]	8,118	大阪ガス試算値
CNG 単位発熱量[GJ/t]	50.4	IPCC2006 TABLE 1.2
CNG 排出係数[t-CO_2/GJ]	0.0561	IPCC2006 TABLE 3.2.1
電力排出係数(*)[t-CO_2/MWh]	0.5477	Thailand Greenhouse Gas Management Organization 「The Study of emission factor for an electricity system in Thailand 2009_Table 10 Calculated Combined Margin Emission Factor」

*:「General project」の BM（ビルト・マージン）の数値を利用。OM（オペレーティング・マージン）0.6147 と CM（コンバインド・マージン）0.5812 と比較し、最も数値が低い BM（ビルト・マージン）0.5477 の数値を用いることで、JCM の考え方である保守性の担保を確保。

図表 59　a工場の二酸化炭素排出削減量の試算結果

二酸化炭素排出削減量 [t-CO_2/y]	リファレンス排出量 [t-CO_2/y]	プロジェクト排出量 [t-CO_2/y]
192,207	195,460	3,253

JCM Project Design Document Form

A. Project description

A.1. Title of the JCM project

Refining Bio-CNG from organic waste at Biomass Plant for using as fuels of NGV in Thailand.

A.2. General description of project and applied technologies and/or measures

The proposed JCM project aims to achieve GHG emission reduction by capturing CH_4 from anaerobic digestion system with organic waste (e.g. waste water and processing residues) at Biomass Plant and purify to Bio-CNG (Compressed Natural Gas), which are used for NGV (Natural Gas Vehicle) in Thailand. It is to achieve GHG emission reduction through the following 2 activities. 1） Avoiding CH_4 emissions by recovering biogas using organic waste at Biomass Plant. 2） Reducing consumption of fossil fuel by using Bio-CNG for vehicle. The key technology of purifying to Bio-CNG is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.

A.3. Location of project, including coordinates

Country	Kingdom of Thailand
Region/State/Province etc.:	TBD
City/Town/Community etc:	TBD
Latitude, longitude	TBD

A.4. Name of project participants

The Kingdom of Thailand	Participant A
Japan	Osaka Gas Co., Ltd.

A.5. Duration

Starting date of project operation	2018
Expected operational lifetime of project	10 years

A.6. Contribution from Japan

The state-of-the-art technology of purifying to Bio-CNG which has been

developed by the Japanese project participant is introduced in the proposed project. The Japanese project participant transfers the technology through training to the Thailand project participants. The Japanese side provides financial support to the project.

B. Application of an approved methodology(ies)

B.1. Selection of methodology(ies)

Selected approved methodology No.	Proposed methodology : Refining Bio-CNG from organic waste at Biomass Plant for using as fuels of NGV in Thailand.
Version number	Ver. 01.0
Selected approved methodology No.	N/A
Version number	N/A
Selected approved methodology No.	N/A
Version number	N/A

B.2. Explanation of how the project meets eligibility criteria of the approved methodology

Eligibility criteria	Descriptions specified in the methodology	Project information
Criterion 1	The project is to capture CH_4 from anaerobic digestion system with organic waste (e.g. waste water and processing residues) at Biomass Plant	The project participant plan to capture CH_4 from anaerobic digestion system with organic waste at Biomass Plant and purify to Bio-CNG (Compressed Natural Gas), which are used for

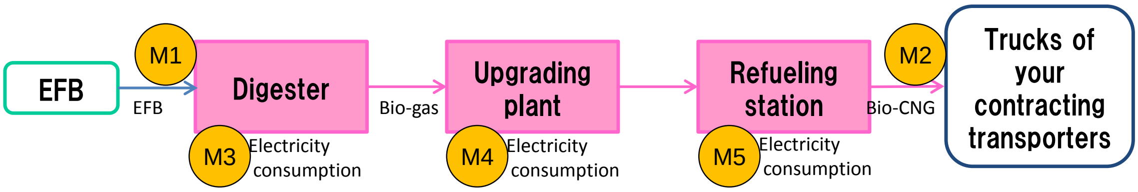
	and purify to Bio-CNG (Compressed Natural Gas), which are used for NGV (Natural Gas Vehicle) in Thailand.	NGV (Natural Gas Vehicle) in Thailand.
Criterion 2	Organic waste from Biomass Plant is not used for Energy or Materials. (e.g. Waste water is discharged into river, captured CH_4 is released into atmosphere, and process residue is landfilled or left in the field.)	Organic waste from Biomass Plant is not used for Energy or Materials.
Criterion 3	The technology of purifying to Bio-CNG is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.	The project participant plan to apply the technology of purifying to Bio-CNG which is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.
Criterion 4	The off-gas discharged from PSA is recycled.	The project participant plan to reuse the off-gas discharged from PSA.
Criterion 5	Plant to apply the international or national qualification standard of Bio-CNG for using NCV is prepared.	The project participant plan to apply the international qualification standard of Bio-CNG for using NCV

C. Calculation of emission reductions

C.1. All emission sources and their associated greenhouse gases relevant to the JCM project

Reference emissions	
Emission sources	GHG type
Methane emissions from decay of organic waste	CH_4
Fossil fuel consumption by Natural Gas Vehicle	CO_2
Project emissions	
Emission sources	GHG type
Electricity consumption by anaerobic digestion system	CO_2
Electricity consumption by upgrading system for Bio-CNG	CO_2
Electricity consumption by refueling station for Bio-CNG	CO_2

C.2. Figure of all emission sources and monitoring points relevant to the JCM project



M1: Weight of processing residue putting into anaerobic digestion system

M2: Bio-CNG consumption by transport applications

M3: Electricity consumption by anaerobic digestion system

M4: Electricity consumption by upgrading system

M5: Electricity consumption by refueling station

C.3. Estimated emissions reductions in each year

Year	Estimated Reference	Estimated Project	Estimated Emission

	emissions (tCO_{2e})	Emissions (tCO_{2e})	Reductions (tCO_{2e})
2018	172,507	3,253	169,254
2019	172,507	3,253	169,254
2020	172,507	3,253	169,254
Total (tCO_{2e})	517,521	9,759	507,762

D. Environmental impact assessment

Legal requirement of environmental impact assessment for the proposed project	To be confirmed later

E. Local stakeholder consultation

E.1. Solicitation of comments from local stakeholders

Project participants plan to implement the local stakeholder consultation at the start of the demonstration project.

E.2. Summary of comments received and their consideration

Stakeholders	Comments received	Consideration of comments received
TBD	TBD	TBD

F. References

Reference lists to support descriptions in the PDD, if any.

Annex

Revision history of PDD		
Version	Date	Contents revised
01.0	17/02/2017	First Edition

8.2.2 サイトB（B社）

B社では、2015年のフレアガス量の実績から、精製設備は、常時安定稼働できる水準として、750Nm^3/h の容量を検討することとした。750Nm^3/h 機を選定した場合には、Bio-CNG は約 3,200t/年の生産量が見込める。

CO_2 排出削減量を試算するために、Bio-gas の使用量の大気放出におけるメタン回避量をリファレンス排出量とした。リファレンス排出量はメタン回避分 68,000t-CO_2/y と車両における化石燃料利用分 9,047 t-CO_2/y、各設備での電力使用量によるプロジェクト排出量は 954 t-CO_2/y、その差分として二酸化炭素排出削減量は 76,093 t-CO_2/y と試算された。

図表 60　B社の設備仕様

	発酵槽設備	精製設備	ステーション設備
設備容量	定格 40,000Nm^3/d-BG	原料 750Nm^3/h-BG 製品　404kg/h-CBG	Storage 7ton/d Dispenser 1 基-2 ノズル

図表 61　B 社の二酸化炭素排出削減量試算におけるモニタリング項目と数値

モニタリング項目	数値	根拠
Bio-CNG 量[t/y]	3,200	大阪ガス試算値
CNG 単位発熱量[GJ/t]	50.4	IPCC2006 TABLE 1.2
CNG 排出係数[$t\text{-}CO_2$/GJ]	0.0561	IPCC2006 TABLE 3.2.1
電力排出係数(*)[$t\text{-}CO_2$/MWh]	0.5477	Thailand Greenhouse Gas Management Organization「The Study of emission factor for an electricity system in Thailand 2009_Table 10 Calculated Combined Margin Emission Factor」

*:「General project」の BM（ビルト・マージン）の数値を利用。OM（オペレーティング・マージン）0.6147 と CM（コンバインド・マージン）0.5812 と比較し、最も数値が低い BM（ビルト・マージン）0.5477 の数値を用いることで、JCM の考え方である保守性の担保を確保。

図表 62　B 社の二酸化炭素排出削減量の試算結果

二酸化炭素排出削減量 [$t\text{-}CO_2$/y]	リファレンス排出量 [$t\text{-}CO_2$/y]	プロジェクト排出量 [$t\text{-}CO_2$/y]
76,093	77,047	954

JCM Project Design Document Form

A. Project description

A.1. Title of the JCM project

Refining Bio-CNG from organic waste at Biomass Plant for using as fuels of NGV in Thailand.

A.2. General description of project and applied technologies and/or measures

The proposed JCM project aims to achieve GHG emission reduction by capturing CH_4 from anaerobic digestion system with organic waste (e.g. waste water and processing residues) at Biomass Plant and purify to Bio-CNG (Compressed Natural Gas), which are used for NGV (Natural Gas Vehicle) in Thailand. It is to achieve GHG emission reduction through the following 2 activities. 1） Avoiding CH_4 emissions by recovering biogas using organic waste at Biomass Plant. 2） Reducing consumption of fossil fuel by using Bio-CNG for vehicle. The key technology of purifying to Bio-CNG is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.

A.3. Location of project, including coordinates

Country	Kingdom of Thailand
Region/State/Province etc.:	TBD
City/Town/Community etc:	TBD
Latitude, longitude	TBD

A.4. Name of project participants

The Kingdom of Thailand	Participant B
Japan	Osaka Gas Co., Ltd.

A.5. Duration

Starting date of project operation	2018
Expected operational lifetime of project	10 years

A.6. Contribution from Japan

The state-of-the-art technology of purifying to Bio-CNG which has been developed by the Japanese project participant is introduced in the

proposed project. The Japanese project participant transfers the technology through training to the Thailand project participants. The Japanese side provides financial support to the project.

B. Application of an approved methodology(ies)

B.1. Selection of methodology(ies)

Selected approved methodology No.	Proposed methodology : Refining Bio-CNG from organic waste at Biomass Plant for using as fuels of NGV in Thailand.
Version number	Ver. 01.0
Selected approved methodology No.	N/A
Version number	N/A
Selected approved methodology No.	N/A
Version number	N/A

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Eligibility criteria	Descriptions specified in the methodology	Project information
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	(Compressed Natural Gas), which are used for NGV (Natural Gas Vehicle) in Thailand.	Thailand.
Criterion 2	Organic waste from Biomass Plant is not used for Energy or Materials. (e.g. Waste water is discharged into river, captured CH_4 is released into atmosphere, and process residue is landfilled or left in the field.)	Organic waste from Biomass Plant is not used for Energy or Materials.
Criterion 3	The technology of purifying to Bio-CNG is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.	The project participant plan to apply the technology of purifying to Bio-CNG which is Hybrid type CO_2 removal system combining Pressure Swing Adsorption and Gas Separation Membrane.
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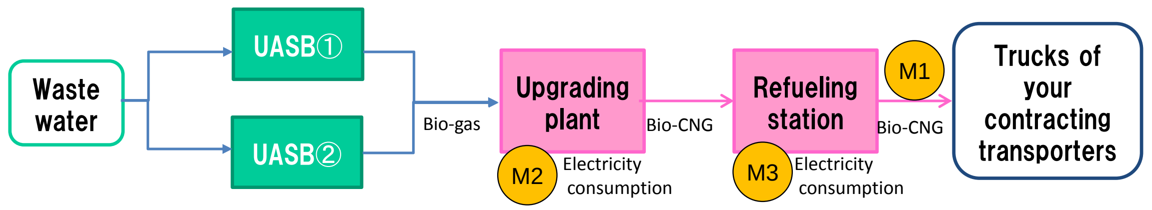
Criterion 5	Plant to apply the international or national qualification standard of Bio-CNG for using NCV is prepared.	The project participant plan to apply the international qualification standard of Bio-CNG for using NCV

C. Calculation of emission reductions

C.1. All emission sources and their associated greenhouse gases relevant to the JCM project

Reference emissions	
Emission sources	GHG type
Methane emissions from decay of organic waste	CH_4
Fossil fuel consumption by Natural Gas Vehicle	CO_2
Project emissions	
Emission sources	GHG type
Electricity consumption by anaerobic digestion system	CO_2
Electricity consumption by upgrading system for Bio-CNG	CO_2
Electricity consumption by refueling station for Bio-CNG	CO_2

C.2. Figure of all emission sources and monitoring points relevant to the JCM project



M1: Bio-CNG consumption by transport applications

M2: Electricity consumption by upgrading system

M3: Electricity consumption by refueling station

C.3. Estimated emissions reductions in each year

Year	Estimated Reference emissions (tCO_{2e})	Estimated Project Emissions (tCO_{2e})	Estimated Emission Reductions (tCO_{2e})
2018	77,047	954	76,093
2019	77,047	954	76,093
2020	77,047	954	76,093

Total (tCO_{2e})	231,141	2,862	228,279

D. Environmental impact assessment	
Legal requirement of environmental impact assessment for the proposed project	To be confirmed later

E. Local stakeholder consultation

E.1. Solicitation of comments from local stakeholders

Project participants plan to implement the local stakeholder consultation at the start of the demonstration project.

E.2. Summary of comments received and their consideration

Stakeholders	Comments received	Consideration of comments received
TBD	TBD	TBD

F. References

Reference lists to support descriptions in the PDD, if any.

Annex

Revision history of PDD		
Version	Date	Contents revised
01.0	17/02/2017	First Edition

以上

別添資料 1

Joint Crediting Mechanism Proposed Methodology Spreadsheet Form (input sheet) [Attachment to Proposed Methodology Form]

JCM_TH_F_PMS_ver01.0

Joint Crediting Mechanism Proposed Methodology Spreadsheet Form (input sheet) [Attachment to Proposed Methodology Form]

Table 1: Parameters to be monitored *ex post*

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Monitoring point No.	Parameters	Description of data	Estimated Values	Units	Monitoring option	Source of data	Measurement methods and procedures	Monitoring frequency	Other comments
1	$FC_{Bio\text{-}CNG,j,p}$	Bio-CNG consumption by transport application (j) during the period p		t/p	Option C	monitored data	Measured by gas flow meter certified in line with international/national standards.	Continuously	N/A
2	$R_{CH4,Bio\text{-}CNG}$	Bio-CNG consumption by transport application (j) during the period p		t/p	Option C	monitored data	Measured by gas flow meter certified in line with international/national standards.	Continuously	N/A
3	$W_{residue,p}$	Weight of processing residue putting into anaerobic digestion system during the period p		t	Option C	monitored data	Measured in wet basis by mesurement equipments certified in line with international/national standards.	Continuously and aggregated monthly	Input on "PMS(input)(2)" sheet
-	p_start	The N[th] month from the first disposal, which is the first month of the period *p*	13	-	Option C	monitored data	Count the number of the month (N[th] month) from the first disposal, which is the first month of the period *p*. If that month is smaller than 14 and *p_end* is larger than 13, *p_start* is set at 14.	-	N/A
-	p_end	The N[th] month from the first disposal, which is the last month of the period *p*	0	-	Option C	monitored data	Count the number of the month (N[th] month) from the first disposal, which is the last month of the period *p*.	-	N/A
4	$EC_{ww,p}$	Electricity consumption by anaerobic digestion system during the period p	0	MWh/p	Option C	monitored data	Measured by electricity meter certified in line with international/national standards.	Continuously	N/A
5	$EC_{upgrading,p}$	Electricity consumption by upgrading system during the period p	0	MWh/p	Option C	monitored data	Measured by electricity meter certified in line with international/national standards.	Continuously	N/A
6	$EC_{refueling,p}$	Electricity consumption by refueling station during the period p	0	MWh/p	Option C	monitored data	Measured by electricity meter certified in line with international/national standards.	Continuously	N/A

Table 2: Project-specific parameters to be fixed *ex ante*

(a)	(b)	(c)	(d)	(e)	(f)
Parameters	Description of data	Estimated Values	Units	Source of data	Other comments
$R_{CH4,Bio\text{-}CNG}$	Rate of CH4 content of Bio-CNG by volume	0.85	-	The specifications of system for quotation or the factory acceptance test data by manufacturer.	N/A
GWP_{CH4}	Global Warming Potential for CH4	25	-	2006 IPCC Guidelines for National Greenhouse Gas Inventories	N/A
$R_{CH4,residue}$	Rate of CH4 gasification from processing residue		-	The specifications of system for quotation or the factory acceptance test data by manufacturer.	N/A
MCF	Methane correction factor	1.0	-	Select from the default values	N/A
OX	Oxidation factor	0.1	-	Select from the default values	N/A
NCV_{CNG}	Net calorific value of CNG	50.40	GJ/t	IPCC default values provided in table 3.2.1 of Ch.1 Vol.2 of 2006 IPCC Guidelines for National GHG Inventories.	N/A
EF_{CNG}	CO2 emission factor of CNG	0.0561	tCO_2/GJ	IPCC default values provided in table 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines for National GHG Inventories.	N/A
EF_{elec}	CO_2 emissions factor of the electricity consumed	0.5477	tCO_2/MWh	Thailand Greenhouse Gas Management Organization [The Study of emission factor for an electricity system in Thailand 2009_Table 10 Calculated Combined Margin Emission Factor]	N/A

Table3: *Ex-ante* estimation of CO_2 emission reductions

CO_2 emission reductions	Units
#DIV/0!	tCO_2/p

[Monitoring option]

Option A	Based on public data which is measured by entities other than the project participants (Data used: publicly recognized data such as statistical data and specifications)
Option B	Based on the amount of transaction which is measured directly using measuring equipments (Data used: commercial evidence such as invoices)
Option C	Based on the actual measurement using measuring equipments (Data used: measured values)

JCM Proposed Methodology Spreadsheet Form (input sheet)

[Attachment to Proposed Methodology Form]

Table 1: Parameters to be monitored *ex post*

(a)	Monitoring point No.	-
(b)	Parameters	$W_{residue,p}$
(c)	Description of data	Weight of processing residue putting into anaerobic digestion system during the period p
(e)	Units	t
(f)	Monitoring option	Option C
(g)	Source of data	monitored data
(h)	Measurement methods and procedures	Measured in wet basis by mesurement equipments certified in line with international/national standards.
(i)	Monitoring frequency	Continuously and aggregated monthly
(j)	Other comments	Input on "PMS(input) (2)" sheet
(d)	Estimated Values	
	Month 1	
	Month 2	
	Month 3	
	Month 4	
	Month 5	
	Month 6	
	Month 7	
	Month 8	
	Month 9	
	Month 10	
	Month 11	
	Month 12	
	Month 13	
	Month 14	
	Month 15	
	Month 16	
	Month 17	
	Month 18	
	Month 19	
	Month 20	
	Month 21	
	Month 22	
	Month 23	
	Month 24	
	Month 25	
	Month 26	
	Month 27	
	Month 28	
	Month 29	
	Month 30	
	Month 31	
	Month 32	
	Month 33	
	Month 34	
	Month 35	
	Month 36	
	Month 37	
	Month 38	
	Month 39	
	Month 40	
	Month 41	
	Month 42	
	Month 43	
	Month 44	
	Month 45	
	Month 46	
	Month 47	
	Month 48	
	Month 49	
	Month 50	
	Month 51	
	Month 52	
	Month 53	
	Month 54	
	Month 55	
	Month 56	
	Month 57	
	Month 58	
	Month 59	
	Month 60	

Joint Crediting Mechanism Proposed Methodology Spreadsheet Form (Calculation Process Sheet)

[Attachment to Proposed Methodology Form]

1. Calculations for emission reductions	Fuel type	Value	Units	Parameter
Emission reductions during the period *p*	N.A.	#DIV/0!	tCO_2/p	ER_p
2. Selected default values, etc.				
Methane correction factor	N.A.	1.0		MCF
3. Calculations for reference emissions				
Reference emissions during the period *p*	N.A.	0.0	tCO_2/p	RE_p
EQ1_Reference emissions during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,p}$
Reference emissions from decay of organic waste during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,ww,p}$
Reference emissions from fossil fuel consumption by transport applications during the period p	Natural Gas	0.0	tCO_2/p	$RE_{trans,fuel,p}$
EQ2_Reference emissions from decay of organic waste during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,p}$
Reference emissions from CH4 of waste water into atmosphere during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,ww,p}$
Reference emissions from CH4 of processing residue into atmosphere during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,residue,p}$
EQ2-1_Reference emissions from CH4 of waste water into atmosphere during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,ww,p}$
Bio-CNG consumption by transport application (j) during the period p	N.A.	0.0	t/p	$FC_{Bio\text{-}CNG,j,p}$
Rate of CH4 content of Bio-CNG by volume	N.A.	0.85	-	$R_{CH4,Bio\text{-}CNG}$
Global Warming Potential for CH4	N.A.	25	-	GWP_{CH4}
EQ2-2_Reference emissions from CH4 of waste water into atmosphere during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,ww,p}$
Bio-CNG consumption by transport application (j) during the period p	N.A.	0.0	t/p	$FC_{Bio\text{-}CNG,j,p}$
Rate of CH4 content of Bio-CNG by volume	N.A.	0.85	-	$R_{CH4,Bio\text{-}CNG}$
Weight of processing residue putting into anaerobic digestion system during the period p	N.A.	0.0	t/p	$W_{residue,p}$
Rate of CH4 gasification from processing residue	N.A.	0.0	-	$R_{CH4,residue}$
Global Warming Potential for CH4	N.A.	25.0	-	GWP_{CH4}
EQ2-3_Reference emissions from decay of processing residue during the period p	N.A.	0.0	tCO_2/p	$RE_{CH4,residue,p}$
EQ3_Reference emissions from fossil fuel consumption by transport applications during the period p	Natural Gas	0.0	tCO_2/p	$RE_{trans,fuel,p}$
Bio-CNG consumption by transport application (j) during the period p	N.A.	0.0	t/p	$FC_{Bio\text{-}CNG,j,p}$
Net calorific value of CNG	CNG	50.4	GJ/t	NCV_{CNG}
CO2 emission factor of CNG	CNG	0.1	tCO_2/GJ	EF_{CNG}
4. Calculations of the project emissions				
Project emissions during the period *p*	N.A.	#DIV/0!	tCO_2/p	PE_p
EQ4_Reference emissions during the period p	N.A.	#DIV/0!	tCO_2/p	PE_p
Project emissions from electricity consumption by wastewater treatment during the period	electricity	#DIV/0!	tCO_2/p	$PE_{ww\_elec,p}$
Project emissions from electricity consumption by Bio-gas upgrading system during the period	electricity	0.0	tCO_2/p	$PE_{upgrading\_elec,p}$
Project emissions from electricity consumption by refueling station during the period	electricity	0.0	tCO_2/p	$PE_{refueling\_elec,p}$
EQ5_Project emissions from electricity consumption by wastewater treatment during the period	N.A.	#DIV/0!	tCO_2/p	$PE_{ww\_elec,p}$
Electricity consumption by anaerobic digestion system during the period p	electricity	0.0	tCO_2/p	$EC_{ww,p}$
Weight of processing residue putting into anaerobic digestion system	N.A.	0.0	t/p	$W_{residue,p}$
Rate of CH4 gasification from processing residue	N.A.	0.0	-	$R_{CH4,residue}$
Bio-CNG consumption by transport application (j) during the period p	N.A.	0.0	t/p	$FC_{Bio\text{-}CNG,j,p}$
CO2 emission factor of grid electricity	electricity	0.5477	tCO_2/MWh	EF_{elec}
EQ6_Project emissions from electricity consumption by Bio-gas upgrading system during the period	N.A.	0.0	tCO_2/p	$PE_{upgrading\_elec,p}$
Electricity consumption by upgrading system during the period p	electricity	0.0	tCO_2/p	$EC_{upgrading,p}$
CO2 emission factor of grid electricity	electricity	0.5477	tCO_2/MWh	EF_{elec}
EQ7_Project emissions from electricity consumption by refueling station during the period	N.A.	0.0	tCO_2/p	$PE_{refueling\_elec,p}$
Electricity consumption by refueling station during the period p	electricity	0.0	tCO_2/p	$EC_{refueling,p}$
CO2 emission factor of grid electricity	electricity	0.0000	tCO_2/MWh	EF_{elec}

[List of Default Values]

Fraction of methane captured at the SWDS and flared, combusted or used in another manner that prevents the emissions of methane to the atmosphere	0	f
Global Warming Potential of methane	25	GWP_{CH4}
Oxidation factor		
Managed, unmanaged and uncategorised SWDS	0	OX
Managed covered with CH_4 oxidising material	0.1	OX
Fraction of methane in the SWDS gas	0.5	F
Fraction of degradable organic carbon that decomposes under specific conditions occurring in the SWDS	0.5	DOC_f
Methane correction factor		
Anaerobic managed SWDS	1.0	MCF
Semi-aerobic managed SWDS	0.5	MCF
Unmanaged SWDS-deep	0.8	MCF
Unmanaged-shallow SWDS or stockpiles that are considered SWDS	0.4	MCF
Fraction of degradable organic carbon (by weight)	8%	DOC
Decay rate (1/year)	0.4	k
Net calorific value of the biogas (GJ/t)	50.4	NCV_{BG}

JCM Proposed Methodology Spreadsheet Form (Calculation Process Sheet) **[Attachment to Proposed Methodology Form]**

	m	$\Sigma W_{residue,p} \times DOC \times e^{-k(m-13-x)/12} \times (1-e^{-k/12})$
	The N^{th} month from the first disposal at the SWDS, extending from the first month of the period *p* (*m*=*p_start*) to the last month of the period *p* (*m*=*p_end*)	Decayed degradable organic carbon in month *m*
Month 1	0	0.00
Month 2	0	0.00
Month 3	0	0.00
Month 4	0	0.00
Month 5	0	0.00
Month 6	0	0.00
Month 7	0	0.00
Month 8	0	0.00
Month 9	0	0.00
Month 10	0	0.00
Month 11	0	0.00
Month 12	0	0.00
Month 13	0	0.00
Month 14	0	0.00
Month 15	0	0.00
Month 16	0	0.00
Month 17	0	0.00
Month 18	0	0.00
Month 19	0	0.00
Month 20	0	0.00
Month 21	0	0.00
Month 22	0	0.00
Month 23	0	0.00
Month 24	0	0.00
Month 25	0	0.00
Month 26	0	0.00
Month 27	0	0.00
Month 28	0	0.00
Month 29	0	0.00
Month 30	0	0.00
Month 31	0	0.00
Month 32	0	0.00
Month 33	0	0.00
Month 34	0	0.00
Month 35	0	0.00
Month 36	0	0.00
Month 37	0	0.00
Month 38	0	0.00
Month 39	0	0.00
Month 40	0	0.00
Month 41	0	0.00
Month 42	0	0.00
Month 43	0	0.00
Month 44	0	0.00
Month 45	0	0.00
Month 46	0	0.00
Month 47	0	0.00
Month 48	0	0.00
Month 49	0	0.00
Month 50	0	0.00
Month 51	0	0.00
Month 52	0	0.00
Month 53	0	0.00
Month 54	0	0.00
Month 55	0	0.00
Month 56	0	0.00
Month 57	0	0.00
Month 58	0	0.00
Month 59	0	0.00
Month 60	0	0.00

$e^{-k(m-13-x)/12} \times (1-e^{-k/12})$

Month *m*

Month *x*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Month 1														0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Month 2															0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Month 3																0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Month 4																	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Month 5																		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Month 6																			0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Month 7																				0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
Month 8																					0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Month 9																						0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Month 10																							0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
Month 11																								0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Month 12																									0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 13																										0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 14																											0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 15																												0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 16																													0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 17																														0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 18																															0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 19																																0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 20																																	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Month 21																																		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Month 22																																			0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Month 23																																				0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
Month 24																																					0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
Month 25																																						0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
Month 26																																							0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
Month 27																																								0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Month 28																																									0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Month 29																																										0.03	0.03	0.03	0.03	0.03	0.03	0.03
Month 30																																											0.03	0.03	0.03	0.03	0.03	0.03
Month 31																																												0.03	0.03	0.03	0.03	0.03
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参考資料
参考とした CDM 方法論

① AMS-III.H: Methane recovery in wastewater treatment (Version 18.0)

② AMS-III.E: Avoidance of methane production from decay of biomass through controlled combustion, gasification or mechanical/ thermal treatment (Version 17.0)

③ AMS-III.AQ.: Introduction of Bio-CNG in transportation applications (Version 2.0)

Small-scale Methodology

AMS-III.H: Methane recovery in wastewater treatment

Version 18.0

Sectoral scope(s): 13

1. Introduction

The following table describes the key elements of the methodology:

Table 1. Methodology key elements

Typical project(s)	Recovery of biogas resulting from anaerobic decay of organic matter in wastewaters through introduction of an anaerobic treatment system for wastewater and/or sludge treatment with biogas recovery
Type of GHG emissions mitigation action	GHG destruction. Destruction of methane emissions

2. Scope, applicability, and entry into force

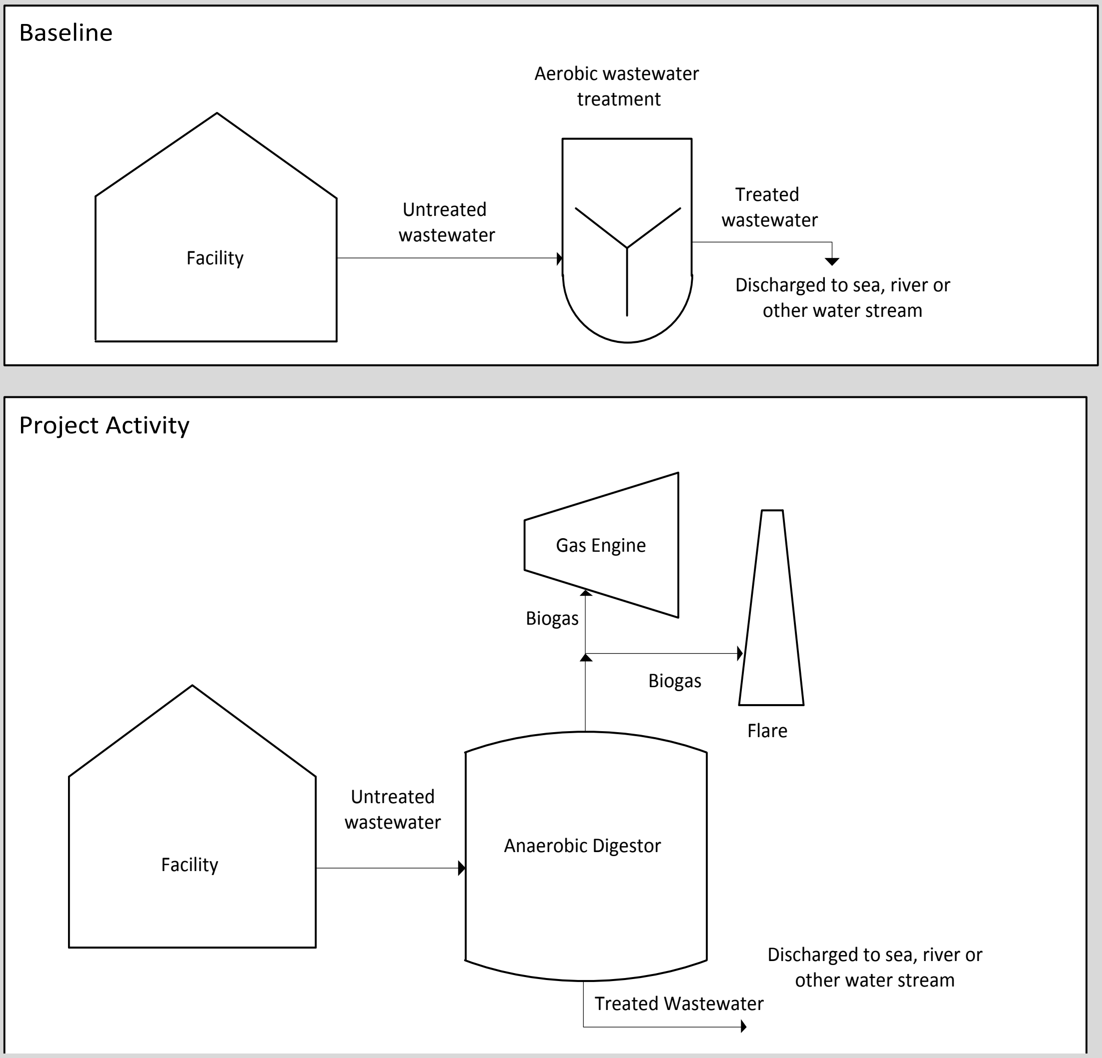
2.1. Scope

This methodology comprises measures that recover biogas from biogenic organic matter in wastewater by means of one, or a combination, of the following options:

Substitution of aerobic wastewater or sludge treatment systems with anaerobic systems with biogas recovery and combustion;

Figure 1. Non-binding best practice example 1: Application of paragraph 2 (a)

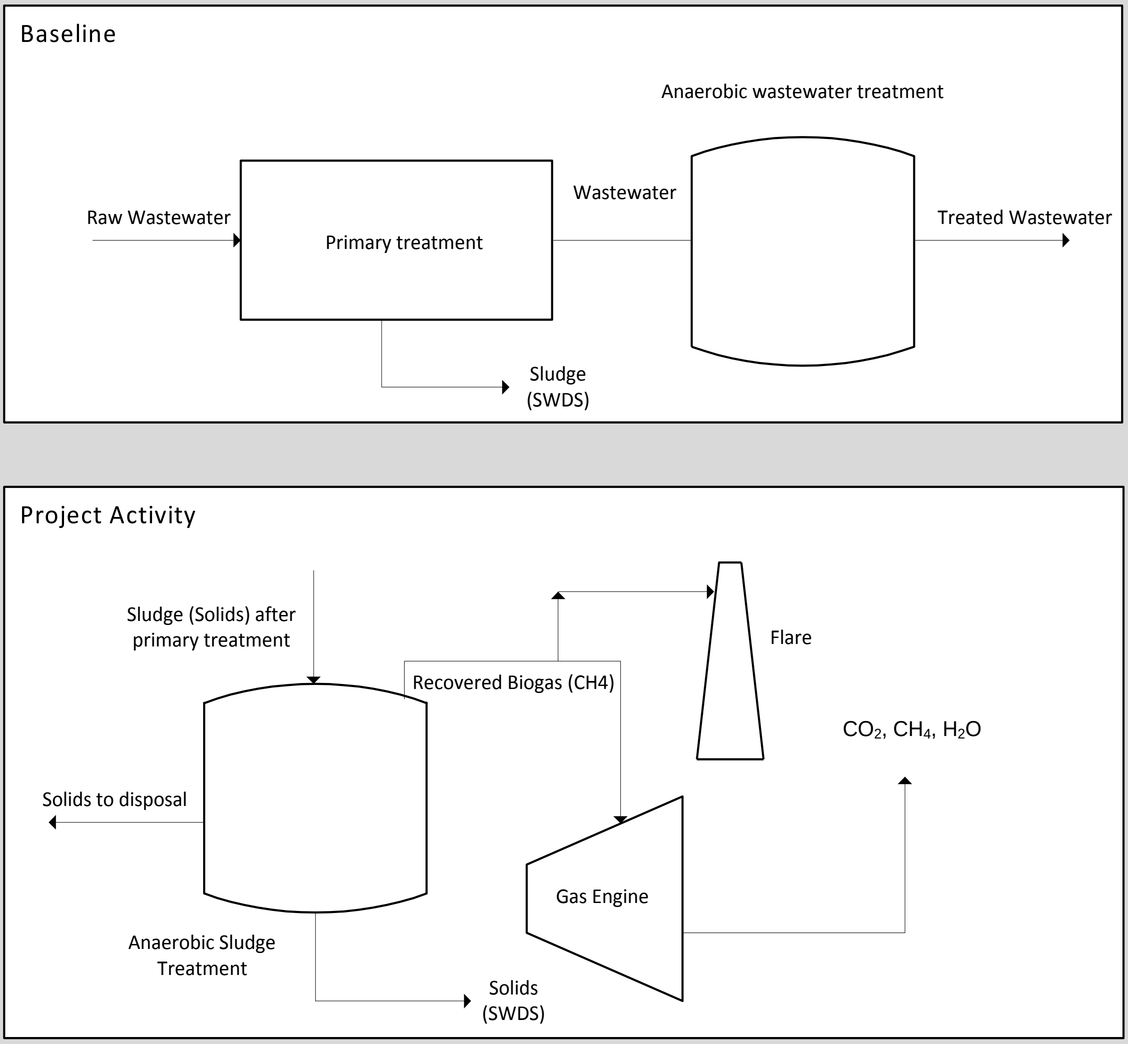
In absence of the project activity, the wastewater is treated aerobically. The project activity aims to recover biogas using anaerobic digester and utilize it for electricity generation using a gas engine.



Introduction of anaerobic sludge treatment system with biogas recovery and combustion to a wastewater treatment plant without sludge treatment;

Figure 2. Non-binding best practice example 2: Application of paragraph 2 (b)

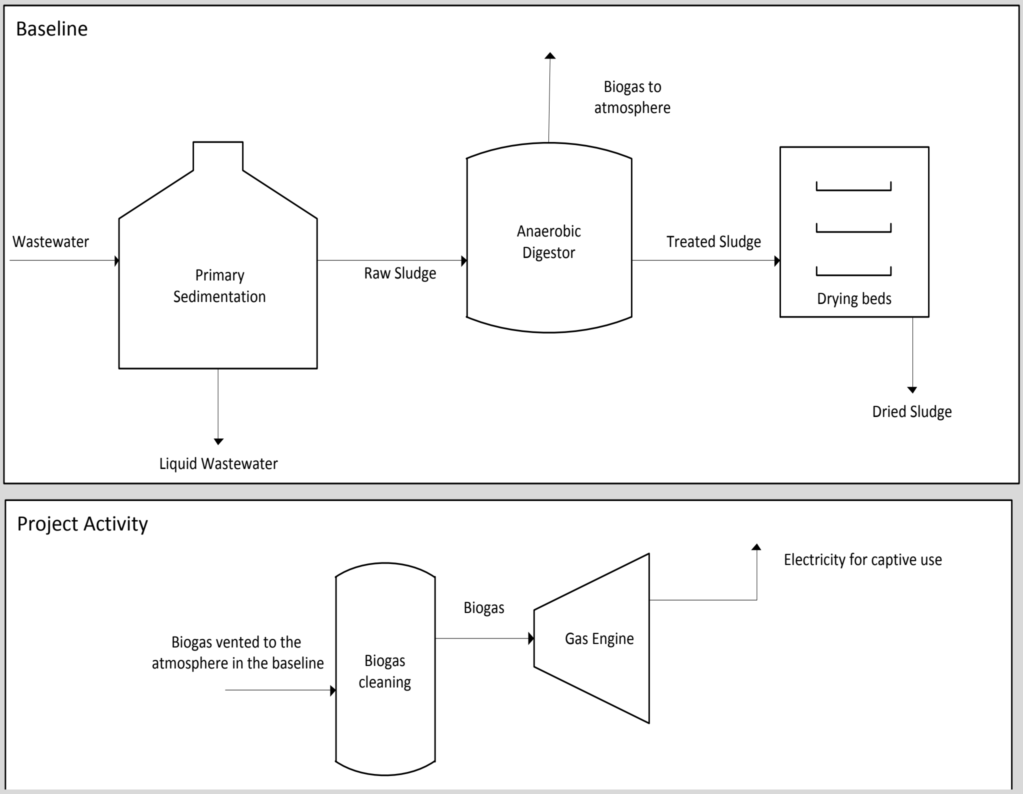
In absence of the project activity, wastewater is treated (aerobically or anaerobically) without sludge treatment (e.g. the sludge is disposed anaerobically in a solid waste disposal site without methane recovery). The project activity aims to treat the sludge in anaerobic digester to recover biogas and to flare it or utilize it to generate electricity using gas engines.



Introduction of biogas recovery and combustion to a sludge treatment system;

Figure 3. Non-binding best practice example 3: Application of paragraph 2 (c)

In absence of the project activity, the biogas generated in the anaerobic digester is vented. The project activity aims to capture and use the biogas for electricity generation using a gas engine. The project involves the installation of gas cleaning facility, gas engines and eventually an enclosed flaring system to burn the excess biogas. The electricity will be used for captive use, replacing electricity from the grid.



Introduction of biogas recovery and combustion to an anaerobic wastewater treatment system such as anaerobic reactor, lagoon, septic tank or an on-site industrial plant;[6]

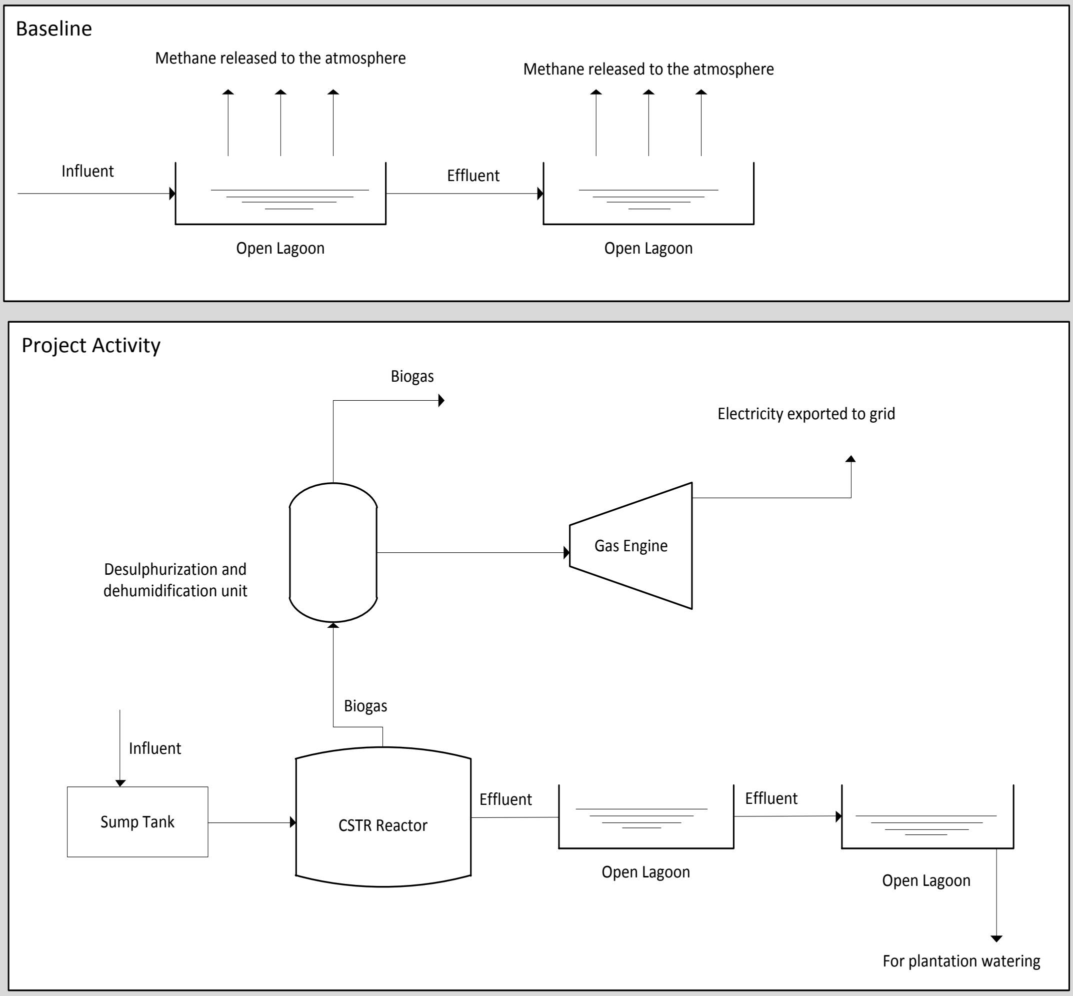
Introduction of anaerobic wastewater treatment with biogas recovery and combustion, with or without anaerobic sludge treatment, to an untreated wastewater stream;

6 Other technologies in Table 6.3 of Chapter 6: Wastewater Treatment and Discharge of 2006 IPCC Guidelines for National Greenhouse Gas Inventories are included.

Introduction of a sequential stage of wastewater treatment with biogas recovery and combustion, with or without sludge treatment, to an anaerobic wastewater treatment system without biogas recovery (e.g. introduction of treatment in an anaerobic reactor with biogas recovery as a sequential treatment step for the wastewater that is presently being treated in an anaerobic lagoon without methane recovery).

Figure 4. Non-binding best practice example 4: Application of paragraph 2 (f)

In absence of the project activity, the wastewater would have been treated in anaerobic open lagoons. The project activity involves the installation of a new stage in the wastewater system (for example CSTR reactor in the figure below); the wastewater is treated sequentially in a sump tank, then treated in the biogas reactor with methane recovery and it's utilization for electricity generation, without sludge separation, and finally treated by the existing series of anaerobic open lagoons.



2.2. Applicability

In cases where baseline system is anaerobic lagoon the methodology is applicable if:

The lagoons are ponds with a depth greater than two meters, without aeration. The value for depth is obtained from engineering design documents, or through direct measurement, or by dividing the surface area by the total volume. If the lagoon filling level varies seasonally, the average of the highest and lowest levels may be taken;

Ambient temperature above 15°C, at least during part of the year, on a monthly average basis;

The minimum interval between two consecutive sludge removal events shall be 30 days.

The recovered biogas from the above measures may also be utilised for the following applications instead of combustion/flaring:

Thermal or mechanical,[7] electrical energy generation directly;

Thermal or mechanical, electrical energy generation after bottling of upgraded biogas, in this case additional guidance provided in the appendix shall be followed; or

Thermal or mechanical, electrical energy generation after upgrading and distribution, in this case additional guidance provided in the appendix shall be followed:

Upgrading and injection of biogas into a natural gas distribution grid with no significant transmission constraints;

Upgrading and transportation of biogas via a dedicated piped network to a group of end users; or

Upgrading and transportation of biogas (e.g. by trucks) to distribution points for end users;

Hydrogen production;

Use as fuel in transportation applications after upgrading.

If the recovered biogas is used for project activities covered under paragraph 4(a), that component of the project activity can use a corresponding methodology under Type I.

For project activities covered under paragraph 4(b), if bottles with upgraded biogas are sold outside the project boundary, the end-use of the biogas shall be ensured via a contract between the bottled biogas vendor and the end-user. No emission reductions may be claimed from the displacement of fuels from the end use of bottled biogas in such situations. If, however, the end use of the bottled biogas is included in the project boundary and is monitored during the crediting period CO_2 emissions avoided by the displacement of fossil fuel can be claimed under the corresponding Type I methodology, e.g. "AMS-I.C.: Thermal energy production with or without electricity".

For project activities covered under paragraph 4(c)(i), emission reductions from the displacement of the use of natural gas are eligible under this methodology, provided the geographical extent of the natural gas distribution grid is within the host country boundaries.

[7] For example combusted in a prime mover such as an engine coupled to a machine such as grinding machine.

For project activities covered under paragraph 4(c)(ii), emission reductions for the displacement of the use of fuels can be claimed following the provision in the corresponding Type I methodology, e.g. AMS-I.C.

In particular, for the case of paragraph 4(b) and (c)(iii), the physical leakage during storage and transportation of upgraded biogas, as well as the emissions from fossil fuel consumed by vehicles for transporting biogas shall be considered. Relevant procedures in paragraph 18 of the appendix of “AMS-III.H.: Methane recovery in wastewater treatment” shall be followed in this regard.

For project activities covered under paragraph 4(b) and (c), this methodology is applicable if the upgraded methane content of the biogas is in accordance with relevant national regulations (where these exist) or, in the absence of national regulations, a minimum of 96 per cent (by volume).

If the recovered is utilized for the production of hydrogen (project activities covered under paragraph 3(d)), that component of the project activity shall use the corresponding methodology “AMS-III.O.: Hydrogen production using methane extracted from biogas”.

If the recovered biogas is used for project activities covered under paragraph 4(e), that component of the project activity shall use corresponding methodology “AMS-III.AQ.: Introduction of Bio-CNG in transportation applications”.

New facilities (Greenfield projects) and project activities involving a change of equipment resulting in a capacity addition of the wastewater or sludge treatment system compared to the designed capacity of the baseline treatment system are only eligible to apply this methodology if they comply with the relevant requirements in the “General guidelines for SSC CDM methodologies”. In addition the requirements for demonstrating the remaining lifetime of the equipment replaced, as described in the general guidelines shall be followed.

Box 1. Non-binding best practice example 5: Application of “General guidelines to SSC CDM methodologies” as per paragraph 13

New facilities (Greenfield projects) and project activities involving capacity addition should follow step-wise approach (step 1 to step 4) in accordance with the “General guidelines to SSC CDM methodologies”.

In regard to the application of Step 1 under paragraph 19 of “General guidelines to SSC CDM methodologies”, EB 61 Annex 21 (i.e. Identify the various alternatives available to the project proponent that deliver comparable levels of service), practices carried out in the industry or similar industry should also be considered.

For a project activity involving capacity addition, e.g. because the industrial process increases its production capacity, the continuation of the current practice can be an available alternative if it is demonstrated that it is able to attend the increasing quantity of wastewater from the production facility and/or the difference of the quality of the inflowing wastewater. For example, if the existing practice is the use of anaerobic lagoons, it needs to be demonstrated that there is enough land area available in the neighboring terrains, adequate to be used for increasing the size or to build new lagoons such as to attend the increased capacity for wastewater treatment plant using the same technology.

The location of the wastewater treatment plant as well as the source generating the wastewater shall be uniquely defined and described in the PDD.

Measures are limited to those that result in aggregate emissions reductions of less than or equal to 60 kt CO_2 equivalent annually from all Type III components of the project activity.

2.3. Entry into force

The date of entry into force is the date of the publication of the EB 86 meeting report on 16 October 2015.

3. Normative references

Project participants shall apply the “General guidelines for SSC CDM methodologies and information on additionality (attachment A to Appendix B) provided at <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html> mutatis mutandis.

This methodology also refers to the latest approved versions of the following approved methodologies and methodological tools:

“AMS-I.C.: Thermal energy production with or without electricity”;

“AMS-III.H.: Methane recovery in wastewater treatment”;

“AMS-III.O.: Hydrogen production using methane extracted from biogas”;

“AMS-III.AQ.: Introduction of Bio-CNG in transportation applications”;

“AM0053: Biogenic methane injection to a natural gas distribution grid”;

“Project emissions from flaring”;

“Tool to calculate baseline, project and/or leakage emissions from electricity consumption”;

“Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”;

“Emissions from solid waste disposal sites”.

4. Definitions

The definitions contained in the Glossary of CDM terms shall apply.

5. Baseline methodology

5.1. Project boundary

The project boundary is the physical, geographical site where the wastewater and sludge treatment takes place, in the baseline and project situations. It covers all facilities affected by the project activity including sites where processing, transportation and application or disposal of waste products as well as biogas takes place.

Implementation of the project activity at a wastewater and/or sludge treatment system will affect certain sections of the treatment systems while others may remain unaffected. The treatment systems not affected by the project activity, i.e. sections operating in the project scenario under the same operational conditions as in the baseline scenario (e.g. wastewater inflow and COD content, temperature, retention time, etc.), shall be described in the PDD, but emissions from those sections do not have to be accounted for in the baseline and project emission calculations (since the same emissions would occur in both baseline and project scenarios).[8] The assessment and identification of the systems affected by the project activity will be undertaken ex ante, and the PDD shall justify the exclusion of sections or components of the system. The treatment systems (lagoons, reactors, digesters, etc.) that will be covered and/or equipped with biogas recovery by the project activity, but continue to operate with the same quality of feed inflow, volume (retention time), and temperature (heating) as in the baseline scenario, may be considered as not affected i.e. the methane generation potential[9] remains unaltered.

5.2. Additionality

The following project activities are deemed additional if it is demonstrated that:

The existing treatment system is an anaerobic lagoon and waste water discharged meets the host country legislation; and

There is no regulation in the host country, applicable to the project site that requires the management of biogas from domestic, industrial and agricultural sites.

This additionality condition does not apply to Greenfield project activities.

Furthermore, for project activities applying this methodology in combination with a Type I methodology, that has an energy component whose installed capacity is less than 5 MW, this procedure for additionality demonstration also applies to that component.

The above simplified additionality demonstration is valid for three years from the date of entry into force of Version 17.0 of AMS-III.H. on the date of the publication of the EB 81 meeting report on 28 November 2014; the CDM Executive Board may reassess the validity of the simplified additionality demonstration and extend or update it if needed. Any update does not affect the projects that request registration as a CDM project activity or a programme of activities by 28 November 2017 (i.e. three years from the date of entry into force) and apply the simplified additionality demonstration contained in Version 17.0 of AMS-III.H.

5.3. Baseline

Wastewater and sludge treatment systems equipped with a biogas recovery facility in the baseline shall be excluded from the baseline emission calculations.

Baseline emissions for the systems affected by the project activity may consist of:

Emissions on account of electricity or fossil fuel used ($BE_{power,y}$);

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[8] As per EB 22, annex 2 “Guidance regarding methodological issues” section E.

[9] The covering of lagoons and the installation of biogas recovery equipment may result in changes in the operational conditions (such as temperature, COD removal, etc.) of an anaerobic treatment system. These changes are considered small and hence not accounted for under this methodology.

Methane emissions from baseline wastewater treatment systems ($BE_{ww,treatment,y}$);

Methane emissions from baseline sludge treatment systems ($BE_{s,treatment,y}$);

Methane emissions on account of inefficiencies in the baseline wastewater treatment systems and presence of degradable organic carbon in the treated wastewater discharged into river/lake/sea ($BE_{ww,discharge,y}$);

Methane emissions from the decay of the final sludge generated by the baseline treatment systems ($BE_{s,final,y}$).

$$BE_y = \{BE_{power,y} + BE_{ww,treatment,y} + BE_{s,treatment,y} + BE_{ww,discharge,y} + BE_{s,final,y}\} \quad \text{Equation (1)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2e)
$BE_{power,y}$	=	Baseline emissions from electricity or fuel consumption in year *y* (t CO_2e)
$BE_{ww,treatment,y}$	=	Baseline emissions of the wastewater treatment systems affected by the project activity in year *y* (t CO_2e)
$BE_{s,treatment,y}$	=	Baseline emissions of the sludge treatment systems affected by the project activity in year *y* (t CO_2e)
$BE_{ww,discharge,y}$	=	Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake in year y (t CO_2e). The value of this term is zero for the case 1(b)
$BE_{s,final,y}$	=	Baseline methane emissions from anaerobic decay of the final sludge produced in year *y* (t CO_2e). If the sludge is controlled combusted, disposed in a landfill with biogas recovery, or used for soil application in the baseline scenario, this term shall be neglected

Baseline emissions from electricity and fossil fuel consumption ($BE_{power,y}$) are determined as per the procedures described in the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption” and “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”, respectively. The energy consumption shall include all equipment/devices in the baseline wastewater and sludge treatment facility. If recovered biogas in the baseline is used to power auxiliary equipment it should be taken into account accordingly, using zero as its emission factor.

Methane emissions from the baseline wastewater treatment systems affected by the project ($BE_{ww,treatment,y}$) are determined using the COD removal efficiency of the baseline plant:

$$BE_{ww,treatment,y} = \sum_i \left(Q_{ww,i,y} \times COD_{inflow,i,y} \times \eta_{COD,BL,i} \times MCF_{ww,treatment,BL,i}\right) \times B_{o,ww} \times UF_{BL} \times GWP_{CH4}$$ Equation (2)

Where:

$Q_{ww,i,y}$	=	Volume of wastewater treated in baseline wastewater treatment system i in year y (m^3). For ex ante estimation, forecasted wastewater generation volume or the designed capacity of the wastewater treatment facility can be used. However, the ex post emissions reduction calculation shall be based on the actual monitored volume of treated wastewater
$COD_{inflow,i,y}$	=	Chemical oxygen demand of the wastewater inflow to the baseline treatment system *i* in year *y* (t/m^3). Average value may be used through sampling with the confidence/precision level 90/10
$\eta_{COD,BL,i}$	=	COD removal efficiency of the baseline treatment system *i*, determined as per the paragraphs 38, 39 or 40 below
$MCF_{ww,treatment,BL,i}$	=	Methane correction factor for baseline wastewater treatment systems *i* (MCF values as per Table 2 below)
i	=	Index for baseline wastewater treatment system
$B_{o,ww}$	=	Methane producing capacity of the wastewater (IPCC value of 0.25 kg CH_4/kg COD)[10]
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)[11]
GWP_{CH4}	=	Global Warming Potential for methane

If the baseline treatment system is different from the treatment system in the project scenario, the monitored values of the COD inflow during crediting period will be used to calculate the baseline emissions ex post.

The Methane Correction Factor (*MCF*) shall be determined based on the following table:

[10] Project activities may use the default value of 0.6 kg CH_4/kg BOD, if the parameter $BOD_{5,20}$ is used to determine the organic content of the wastewater. In this case, baseline and project emissions calculations shall use BOD instead of COD in the equations, and the monitoring of the project activity shall be based in direct measurements of $BOD_{5,20}$, i.e. the estimation of BOD values based on COD measurements is not allowed.

[11] Reference: FCCC/SBSTA/2003/10/Add.2, page 25.

Table 2. IPCC default values[12] for Methane Correction Factor (*MCF*)

Type of wastewater treatment and discharge pathway or system	***MCF* value**
Discharge of wastewater to sea, river or lake	0.1
Land application	0.1
Aerobic treatment, well managed	0.0
Aerobic treatment, poorly managed or overloaded	0.3
Anaerobic digester for sludge without methane recovery	0.8
Anaerobic reactor without methane recovery	0.8
Anaerobic shallow lagoon (depth less than 2 metres)	0.2
Anaerobic deep lagoon (depth more than 2 metres)	0.8
Septic system	0.5
Land application [13]	0.1

Methane emissions from the baseline sludge treatment systems affected by the project activity are determined using the methane generation potential of the sludge treatment systems:

$$BE_{treatment,s,y} = \sum_{j} S_{j,BL,y} \times MCF_{s,treatment,BL,j} \times DOC_s \times UF_{BL} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$$ Equation (3)

Where:

$S_{j,BL,y}$	=	Amount of dry matter in the sludge that would have been treated by the sludge treatment system *j* in the baseline scenario (t). For ex ante estimation, forecasted sludge generation volume or the designed capacity of the sludge treatment facility can be used. However, the ex post emissions reduction calculation shall be based on the actual monitored volume of treated sludge
j	=	Index for baseline sludge treatment system

[12] Default values from chapter 6 of volume 5. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[13] Please refer SSC_664, "Clarification on methane correction factors for treated water used for irrigation under AMS-III.H ver. 16".

DOC_s	=	Degradable organic content of the untreated sludge generated in the year *y* (fraction, dry basis). Default values of 0.5 for domestic sludge and 0.257 for industrial sludge[14] shall be used
$MCF_{s,treatment,BL,j}$	=	Methane correction factor for the baseline sludge treatment system *j* (*MCF* values as per Table 2 above)
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)
DOC_F	=	Fraction of DOC dissimilated to biogas (IPCC default value of 0.5)
F	=	Fraction of CH_4 in biogas (IPCC default of 0.5)

If the sludge is composted, the following equation shall be applied:

$$BE_{s,treatment,y} = \sum_j S_{j,BL,y} \times EF_{composting} \times GWP_{CH4} \quad \text{Equation (4)}$$

Where:

$EF_{composting}$	=	Emission factor for composting organic waste (t CH_4/t waste treated). Emission factors can be based on facility/site-specific measurements, country specific values or IPCC default values (Table 4.1, chapter 4, Volume 5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories). IPCC default value is 0.01 t CH_4/ t sludge treated on a dry weight basis

If the baseline wastewater treatment system is different from the treatment system in the project scenario, the sludge generation rate (amount of sludge generated per unit of COD removed) in the baseline may differ significantly from that of the project scenario. For example, it is known that the amount of sludge generated in aerobic wastewater systems is larger than in anaerobic systems, for the same COD removal efficiency. Therefore, for these cases, the monitored values of the amount of sludge generated during the crediting period will be used to estimate the amount of sludge generated in the baseline, as follows:

$$S_{j,BL,y} = S_{l,PJ,y} \times \frac{SGR_{BL}}{SGR_{PJ}} \quad \text{Equation (5)}$$

Where:

$S_{l,PJ,y}$	=	Amount of dry matter in the sludge treated by the sludge treatment system *i* in year *y* in the project scenario (t)
SGR_{BL}	=	Sludge generation ratio of the wastewater treatment plant in the baseline scenario (tonne of dry matter in sludge/t COD removed). This ratio will be determined as per paragraphs 38, 39 or 40 below

[14] The IPCC default values of 0.05 for domestic sludge (wet basis, considering a default dry matter content of 10 per cent) or 0.09 for industrial sludge (wet basis, assuming dry matter content of 35 per cent), were corrected for dry basis.

SGR_{PJ}	=	Sludge generation ratio of the wastewater treatment plant in the project scenario (tonne of dry matter in sludge/t COD removed). Calculated using the monitored values of COD removal (i.e. $COD_{inflow,i}$ minus $COD_{outflow,i}$) and sludge generation in the project scenario

Methane emissions from degradable organic carbon in treated wastewater discharged in e.g. a river, sea or lake in the baseline situation are determined as follows:

$$BE_{ww,discharge,y} = Q_{ww,y} \times GWP_{CH4} \times B_{o,ww} \times UF_{BL} \times COD_{ww,discharge,BL,y} \times MCF_{ww,BL,discharge} \quad \text{Equation (6)}$$

Where:

$Q_{ww,y}$	=	Volume of treated wastewater discharged in year y (m^3)
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)
$COD_{ww,discharge,BL,y}$	=	Chemical oxygen demand of the treated wastewater discharged into sea, river or lake in the baseline situation in the year y (t/m^3). If the baseline scenario is the discharge of untreated wastewater, the COD of untreated wastewater shall be used
$MCF_{ww,BL,discharge}$	=	Methane correction factor based on discharge pathway in the baseline situation (e.g. into sea, river or lake) of the wastewater (fraction) (MCF values as per Table 2 above)

To determine $COD_{ww,discharge,BL,y}$: if the baseline treatment system(s) is different from the treatment system(s) in the project scenario, the monitored values of the COD inflow during crediting period will be used to calculate the baseline emissions ex post. The outflow COD of the baseline systems will be estimated using the removal efficiency of the baseline treatment systems, estimated as per paragraphs 38, 39 or 40 below.

Methane emissions from anaerobic decay of the final sludge produced are determined as follows:

$$BE_{s,final,y} = S_{final,BL,y} \times DOC_s \times UF_{BL} \times MCF_{s,BL,final} \times DOC_F \times F \times 16/12 \times GWP_{CH4} \quad \text{Equation (7)}$$

Where:

$S_{final,BL,y}$	=	Amount of dry matter in the final sludge generated by the baseline wastewater treatment systems in the year *y* (t). If the baseline wastewater treatment system is different from the project system, it will be estimated using the monitored amount of dry matter in the final sludge generated by the project activity ($S_{final,PJ,y}$) corrected for the sludge generation ratios of the project and baseline systems as per equation (5) above
$MCF_{s,BL,final}$	=	Methane correction factor of the disposal site that receives the final sludge in the baseline situation, estimated as per the procedures described in the methodological tool “Emissions from solid waste disposal sites”
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)

In determining baseline emissions using equation (1), historical records of at least one year prior to the project implementation shall be used. This shall include for example the COD removal efficiency of the wastewater treatment systems, the amount of dry matter in sludge, power and electricity consumption per m^3 of wastewater treated the amount of final sludge generated per tonne of COD removed, and all other parameters required for determination of baseline emissions.

For wastewater treatment plant that has been operating for at least three years and if one year of historical data is not available, the following procedures shall be followed:

All the available data in determining the required parameters (COD removal efficiency, specific energy consumption and specific sludge production) shall be used to determine the baseline emissions in year *y*;

An ex ante measurement campaign shall be implemented to determine the required parameters (COD removal efficiency, specific energy consumption and specific sludge production). The measurement campaign shall be implemented in the baseline wastewater systems for at least 10 days. The measurements should be undertaken during a period that is representative for the typical operation conditions of the systems and ambient conditions of the site (temperature, etc). Average values from the measurement campaign shall be used and the result shall be multiplied by 0.89 to account for the uncertainty range (30 per cent to 50 per cent). The parameters from the measurement campaign are used to calculate the baseline emission in year *y*;

The baseline emissions in year *y* is taken as the minimum between the result of (a) and (b).

Box 2. Non-binding best practice example 6: Ex-ante measurement campaign for existing facilities as per paragraph 39 (a) and (b)

The project activity involves the installation of a UASB digester in a palm oil industry to recover and utilize biogas. In the pre-project scenario, the wastewater was being treated in an existing anaerobic open lagoon system.

Partial historical COD data for the treatment system is available; therefore, an ex-ante measurement campaign has been carried out to determine the required parameters (CODinflow,y, CODoutflow,y, ηCOD,BL and Qww,y) to calculate the baseline emissions in year y. The average value of the baseline emissions obtained through measurement campaign was lower than the historical value, therefore, the minimum value was taken up for ex-ante calculation (see paragraph of 39 (c)).

The average baseline emissions value measured is thereafter multiplied by 0.89 to account for the uncertainty in accordance with the methodology paragraph 39 (b). During the 10-days COD-measurement campaign, the inflow and the outflow COD content of the open lagoon was measured. The efficiency was estimated as the quotient between the removal capacity and the inflow.

Table 1: Average value of the 10 days COD -measurement campaign may be demonstrated as follows:

	COD content before open lagoon	COD content after open lagoon	COD content before released to the river	Water temp. before covered lagoon	Air Tempe-rature	Amount of wastewater per ton of product
Unit	(mg/L)	(mg/L)	(mg/L)	(°C)	(°C)	(m^3/t)
Average 10 days	9558	3239	117	27.7	26.3	26.26

External data obtained from other wastewater treatment plants or registered PDDs are not allowed.

In the case of Greenfield and capacity addition projects, or existing plant without three year operating history, the following procedures shall be used to determine the baseline emissions:

For existing plant without three year operating history, procedures in paragraph 39 shall be followed;

For Greenfield and capacity addition projects, one of the following procedures shall be used:

Value obtained from a measurement campaign in a comparable existing wastewater treatment plant i.e. having similar environmental and technological circumstances for example treating similar type of wastewater. Average values from the measurement campaign shall be used and the result shall be multiplied by 0.89 to account for the uncertainty range (30 per cent to 50 per cent) associated with this approach. The treatment plant and wastewater source can be considered as similar as the baseline plant, whereby the measurement campaign can be implemented when following conditions can be fulfilled:

The two sources of wastewater (wastewater treated in the selected plant and from the project activity) are of the same type, e.g. either domestic or industrial wastewater;

The selected plant and the baseline plants employ the same treatment technology (e.g. anaerobic lagoons or activated sludge), and the hydraulic retention times in their biological and physical treatment systems do not vary by more than 20 per cent; and

For project activity treating industrial wastewater, both industries have the same raw material and final products, and apply the same industrial technology. Alternatively, different industrial wastewaters may be considered as similar if the following requirements are fulfilled:

The ratio COD/BOD (related to the proportion of biodegradable organic matter) does not differ by more than 20 per cent; and

The ratio total COD/soluble COD (related to the proportion of suspended organic matter, and therefore to the sludge generation capacity) does not differ by more than 20 per cent.

Value provided by the manufacturer/designer of a Greenfield wastewater treatment plant using the same technology, demonstrated to be conservative, e.g. average values from the top 20 per cent plants with lowest emission rate per tonne COD removed among the plants installed in the last five years designed for the same country/region to treat the same type of wastewaters as the project activity.

Box 3. Non-binding best practice example 7: Ex-ante measurement campaign for greenfield projects as per paragraph 40 (b) (i)

This is a greenfield project which aims to build and operate a biogas plant that will process Palm Oil Mill Effluent (POME) from a new palm oil mill. The recovered biogas will be used to generate electricity in two units of 609 kWe biogas engines for the mill's own consumption.
The project activity only claims emission reductions from baseline emissions of the wastewater treatment system affected by the project activity. Other values such as electricity consumption, sludge generation etc. are not included in the baseline calculation and no emission reductions are claimed for the potential emissions that could be reduced.
Since this is a greenfield project, the estimation of COD values shall be based on paragraph 40 (b) of the methodology

The estimated COD values for the conventional open lagoon wastewater treatment system are obtained from a measurement campaign for a similar registered CDM project with all the baseline data clearly depicted in the PDD. The average values from the measurement campaign are multiplied by 0.89 to account for the uncertainty. The treatment plant and wastewater source is considered as similar as the baseline plant based on the following facts:

a) POME is the type of wastewater treated in the selected CDM project and from the proposed project activity. So both of the plants are treating same type of wastewater.
b) The selected CDM project and the baseline plants employ the same treatment technology, which is comprised of a cooling/ acidification pond, anaerobic lagoons, aerobic lagoons. The hydraulic retention time for the selected plant in the CDM project is about 90 days, and the baseline plant of the proposed project activity is 106 days. The difference is no more than 20%.
c) The baseline plant of the selected CDM project and the proposed project activity are treating POME. Both of the mills process raw FFBs and produce crude palm oil.

5.4. Project emissions

Project emissions consists of:

CO_2 emissions from electricity and fuel used by the project facilities ($PE_{power,y}$);

Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in the project scenario ($PE_{ww,treatment,y}$);

Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation ($PE_{s,treatment,y}$);

Methane emissions on account of inefficiency of the project activity wastewater treatment systems and presence of degradable organic carbon in treated wastewater ($PE_{ww,dischargey}$);

Methane emissions from the decay of the final sludge generated by the project activity treatment systems ($PE_{s,final,y}$);

Methane fugitive emissions due to inefficiencies in capture systems ($PE_{fugitive,y}$);

Methane emissions due to incomplete flaring ($PE_{flaring,y}$);

Methane emissions from biomass stored under anaerobic conditions which would not have occurred in the baseline situation ($PE_{biomass,y}$).[15]

$$PE_y = \begin{Bmatrix} PE_{power,y} + PE_{ww,treatment,y} + PE_{s,treatment,y} + PE_{ww,discharge,y} + PE_{s,final,y} + \\ PE_{fugitive,y} + PE_{biomass,y} + PE_{flaring,y} \end{Bmatrix}$$ Equation (8)

Where:

PE_y	Project activity emissions in the year y (t CO_2e)
$PE_{power,y}$	Emissions from electricity or fuel consumption in the year *y* (t CO_2e). These emissions shall be calculated as per paragraph 28, for the situation of the project scenario, using energy consumption data of all equipment/devices used in the project activity wastewater and sludge treatment systems and systems for biogas recovery and flaring/gainful use
$PE_{ww,treatment,y}$	Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery, in year *y* (t CO_2e). These emissions shall be calculated as per equation (2) in paragraph 29 using an uncertainty factor of 1.12 and data applicable to the project situation ($MCF_{ww,treatment,PJ,k}$ and $\eta_{,PJ,k,y}$) and with the following changed definition of parameters:
$MCF_{ww,treatment,PJ,k}$	Methane correction factor for project wastewater treatment system *k* (*MCF* values as per Table 2 above)
$\eta_{,PJ,k,y}$	Chemical oxygen demand removal efficiency of the project wastewater treatment system *k* in year *y* (t/m^3), measured based on inflow COD and outflow COD in system *k*
$PE_{s,treatment,y}$	Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery, in year *y* (t CO_2e). These emissions shall be calculated as per equations (3) and (4) in paragraphs 32 and 33, using an uncertainty factor of 1.12 and data applicable to the project situation ($S_{l,PJ,y}$, $MCF_{s,treatment,l}$) and with the following changed definition of parameters:
$S_{l,PJ,y}$	Amount of dry matter in the sludge treated by the sludge treatment system *l* in the project scenario in year *y* (t)
$MCF_{s,treatment,l}$	Methane correction factor for the project sludge treatment system l (*MCF* values as per Table 2 above)

15 For instance in the baseline situation Palm Kernel Shells (PKS) are used as fuel in a boiler. In the project situation PKS is replaced by biogas captured at a wastewater treatment system. The PKS will no longer be used as fuel in the boiler, but sold on the market. Before it is sold it is likely it will be stored for a period of time (few months or longer) on site which might lead to methane emissions from anaerobic decay.

$PE_{ww,discharge,y}$	Methane emissions from degradable organic carbon in treated wastewater in year *y* (tCO_2e). These emissions shall be calculated as per equation (6) in paragraph 35, using an uncertainty factor of 1.12 and data applicable to the project conditions ($COD_{ww,discharge,PJ,y}$, $MCF_{ww,PJ,discharge}$) and with the following changed definition of parameters:
$COD_{ww,discharge,PJ,y}$	Chemical oxygen demand of the treated wastewater discharged into the sea, river or lake in the project scenario in year *y* (t/m^3)
$MCF_{ww,PJ,discharge}$	Methane correction factor based on the discharge pathway of the wastewater in the project scenario (e.g. into sea, river or lake) (*MCF* values as per Table 2)
$PE_{s,final,y}$	Methane emissions from anaerobic decay of the final sludge produced in year *y* ($t\ CO_2e$). These emissions shall be calculated as per equation (7) in paragraph 37, using an uncertainty factor of 1.12 and data applicable to the project conditions ($MCF_{s,PJ,final}$, $S_{final,PJ,y}$). If the sludge is controlled combusted, disposed in a landfill with biogas recovery, or used for soil application in aerobic conditions in the project activity, this term shall be neglected, and the sludge treatment and/or use and/or final disposal shall be monitored during the crediting period with the following revised definition of the parameters:
$MCF_{s,PJ,final}$	Methane correction factor of the disposal site that receives the final sludge in the project situation, estimated as per the procedures described in the methodological tool "Emissions from solid waste disposal sites"
$S_{final,PJ,y}$	Amount of dry matter in final sludge generated by the project wastewater treatment systems in the year *y* (t)
$PE_{fugitive,y}$	Methane emissions from biogas release in capture systems in year *y*, calculated as per paragraph 42 ($t\ CO_2e$)
$PE_{flaring,y}$	Methane emissions due to incomplete flaring in year *y* ($t\ CO_2e$). For ex ante estimation, baseline emission calculation for wastewater and/or sludge treatment (i.e. equation (2) and/or equation (3)) can be used but without the consideration of GWP for CH_4. However, the ex post emission reduction shall be calculated as per methodological tool "Project emissions from flaring"
$PE_{biomass,y}$	Methane emissions from biomass stored under anaerobic conditions. If storage of biomass under anaerobic conditions takes place in the project and does not occur in the baseline , methane emissions due to anaerobic decay of this biomass shall be considered and be determined as per the procedure in the methodological tool "Emissions from solid waste disposal sites" ($t\ CO_2e$)

Project activity emissions from methane release in capture systems are determined as follows:

Based on the methane emission potential of wastewater and/or sludge:

$$PE_{fugitive,y} = PE_{fugitive,ww,y} + PE_{fugitive,s,y} \quad \text{Equation (9)}$$

Where:

$PE_{fugitive,ww,y}$	=	Fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment systems in the year y (t CO2e)
$PE_{fugitive,s,y}$	=	Fugitive emissions through capture inefficiencies in the anaerobic sludge treatment systems in the year *y* (t CO_2e)

$$PE_{fugitive,ww,y} = (1 - CFE_{ww}) \times MEP_{ww,treatment,y} \times GWP_{CH4} \qquad \text{Equation (10)}$$

Where:

CFE_{ww}	=	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems (a default value of 0.9 shall be used)
$MEP_{ww,treatment,y}$	=	Methane emission potential of wastewater treatment systems equipped with biogas recovery system in year *y* (t)

$$MEP_{ww,treatment,y} = Q_{ww,y} \times B_{o,ww} \times UF_{PJ} \times \sum_{k} COD_{removed,PJ,k,y} \times MCF_{ww,treatment,PJ,k} \qquad \text{Equation (11)}$$

Where:

$COD_{removed,PJ,k,y}$	=	The chemical oxygen demand removed[16] by the treatment system *k* of the project activity equipped with biogas recovery in the year *y* (t/m^3)
$MCF_{ww,treatment,PJ,k}$	=	Methane correction factor for the project wastewater treatment system *k* equipped with biogas recovery equipment (*MCF* values as per Table 2 above)
UF_{PJ}	=	Model correction factor to account for model uncertainties (1.12)

$$PE_{fugitive,s,y} = (1 - CFE_{s}) \times MEP_{s,treatment,y} \times GWP_{CH4} \qquad \text{Equation (12)}$$

Where:

CFE_{s}	=	Capture efficiency of the biogas recovery equipment in the sludge treatment systems (a default value of 0.9 shall be used)

[16] Difference between the inflow COD and the outflow COD.

$MEP_{s,treatment,y}$	=	Methane emission potential of the sludge treatment systems equipped with a biogas recovery system in year *y* (t)

$$MEP_{s,treatment,y} = \sum_{l}\left(S_{l,PJ,y} \times MCF_{s,treatment,PJ,l}\right) \times DOC_s \times UF_{PJ} \times DOC_F \times F \times 16/12$$ Equation (13)

Where:

$S_{l,PJ,y}$	=	Amount of sludge treated in the project sludge treatment system l equipped with a biogas recovery system (on a dry basis) in year *y* (t)
$MCF_{s,treatment,PJ,l}$	=	Methane correction factor for the sludge treatment system equipped with biogas recovery equipment (MCF values as per Table 2 above)
UF_{PJ}	=	Model correction factor to account for model uncertainties (1.12)

Optionally a default value of 0.05 m^3 biogas leaked/m^3 biogas produced may be used as an alternative to calculations per equation (9) to (13).

5.5. Leakage

If the technology is using equipment transferred from another activity, leakage effects at the site of the other activity are to be considered and estimated (LE_y).

5.6. Emission reduction

For all scenarios in paragraph 2, emission reductions shall be estimated ex ante in the PDD using the equations provided in the baseline, project and leakage emissions sections above. Emission reductions shall be estimated ex ante as follows:

$$ER_{y,ex\ ante} = BE_{y,ex\ ante} - \left(PE_{y,ex\ ante} + LE_{y,ex\ ante}\right)$$ Equation (14)

Where:

$ER_{y,ex\ ante}$	=	Ex ante emission reduction in year *y* (t CO_2e)
$LE_{y,ex\ ante}$	=	Ex ante leakage emissions in year *y* (t CO_2e)
$PE_{y,ex\ ante}$	=	Ex ante project emissions in year *y* calculated as paragraph 41 (t CO_2e)
$BE_{y,ex\ ante}$	=	Ex ante baseline emissions in year *y* calculated as per paragraph 27 (t CO_2e)

Ex post emission reductions shall be determined for case 2(a) and 2(e) as per paragraph 48. For cases 2(b), 2(c), 2(d) and 2(f), ex post emission reductions shall be based on the lowest value of the following, as per paragraph 46:

The amount of biogas recovered and fuelled or flared (MD_y) during the crediting period, that is monitored ex post;

Ex post calculated baseline, project and leakage emissions based on actual monitored data for the project activity.

For cases 2(b), 2(c), 2(d) and 2(f): it is possible that the project activity involves wastewater and sludge treatment systems with higher methane conversion factors (*MCF*) or with higher efficiency than the treatment systems used in the baseline situation. Therefore the emission reductions achieved by the project activity is limited to the ex post calculated baseline emissions minus project emissions using the actual monitored data for the project activity. The emission reductions achieved in any year are the lowest value of the following:

$$ER_{y,ex\,post} = min\left(\left(BE_{y,ex\,post} - PE_{y,ex\,post} - LE_{y,ex\,post}\right), \left(MD_y - PE_{power,y} - PE_{biomass,y} - LE_{y,ex\,post}\right)\right) \quad \text{Equation (15)}$$

Where:

$ER_{y,ex\,post}$	=	Emission reductions achieved by the project activity based on monitored values for year *y* (t CO_2e)
$BE_{y,ex\,post}$	=	Baseline emissions calculated as per paragraph 27 using ex post monitored values
$PE_{y,ex\,post}$	=	Project emissions calculated as per paragraph 41 using ex post monitored values
MD_y	=	Methane captured and destroyed/gainfully used by the project activity in the year *y* (t CO_2e)

In the case of flaring/combustion MD_y will be measured using the conditions of the flaring process:

$$MD_y = BG_{burnt,y} \times w_{CH4,y} \times D_{CH4} \times FE \times GWP_{CH4} \quad \text{Equation (16)}$$

Where:

$BG_{burnt,y}$	=	Biogas[17] flared/combusted in year *y* (m^3)
$w_{CH4,y}$	=	Methane content[13] of the biogas in the year *y* (volume fraction)
D_{CH4}	=	Density of methane at the temperature and pressure of the biogas in the year *y* (t/m^3)

[17] Biogas volume and methane content measurements shall be on the same basis (wet or dry).

FE	=	Flare efficiency in year *y* (fraction). If the biogas is combusted for gainful purposes, e.g. fed to an engine, an efficiency of 100 per cent may be applied

For the cases 2 (a) and (e) the emission reduction achieved by the project activity (ex post) will be the difference between the baseline emissions and the sum of the project emissions and leakage.

$$ER_y = BE_{y,ex\ post} - \left(PE_{y,ex\ post} + LE_{y,ex\ post}\right) \quad \text{Equation (17)}$$

The historical records of electricity and fuel consumption, the COD content of untreated and treated wastewater, and the quantity of sludge produced by the replaced units will be used for the baseline calculation.

In case (a), if the volumetric flow and the characteristic properties (e.g. COD) of the inflow and outflow of the wastewater are equivalent in the project and the baseline scenarios (i.e. the project and baseline systems have the same efficiency for COD removal for wastewater treatment), then the higher energy consumption and sludge generation in the baseline scenario are the only significant differences contributing to emissions reductions in the project case. In this case, the emission reductions can be calculated as the difference between the historical energy consumption of the replaced unit and the recorded energy consumption of the new system, plus the difference in emissions from sludge treatment and/or disposal. Project emissions from fugitive emissions and incomplete flaring ($PE_{fugitive,y}$, $PE_{flaring,y}$) shall also be considered in the calculation of the emission reductions, however the emissions from the wastewater outflow and sludge ($PE_{ww,discharge,y}$, $PE_{s,final,y}$) may be disregarded, if they are equivalent in the baseline and project scenarios.

6. Monitoring methodology

Relevant parameters shall be monitored as indicated in the tables below. The applicable requirements specified in the "General guidelines for SSC CDM Methodologies" (e.g. calibration requirements, sampling requirements) are also an integral part of the monitoring guidelines specified below and therefore shall be referred by the project participants.

6.1. Parameters for monitoring during the crediting period

Data / Parameter table 1.

Data / Parameter:	$Q_{ww,i,y}$
Data unit:	m³/month
Description:	The flow of wastewater
Measurement procedures (if any):	Measurements are undertaken using flow meters
Monitoring frequency:	Monitored continuously (at least hourly measurements are undertaken, if less, confidence/precision level of 90/10 shall be attained)
Any comment:	-

Data / Parameter table 2.

Data / Parameter:	$COD_{ww,untreated,y}$, $COD_{ww,treated,y}$, $COD_{ww,discharge,PJ,y}$
Data unit:	t COD/m³

Description:	The chemical oxygen demand of the wastewater before and after the treatment system affected by the project activity
Measurement procedures (if any):	Measure the COD according to national or international standards. COD is measured through representative sampling
Monitoring frequency:	Samples and measurements shall ensure a 90/10 confidence/precision level
Any comment:	-
Data / Parameter:	-

Data / Parameter table 3.

Data / Parameter:	$S_{l,PJ,y}$, $S_{final,PJ,y}$
Data unit:	t
Description:	Amount of dry matter in the sludge
Measurement procedures (if any):	Measure the total quantity of sludge on a wet basis. The volume (m^3) and density or direct weighing may be used to determine the sludge amount (wet basis). Representative samples are taken to determine the moisture content to calculate the total sludge amount on dry basis. If the methane emissions from anaerobic decay of the final sludge are to be neglected because the sludge is controlled combusted, disposed of in a landfill with methane recovery, or used for soil application, then the end-use of the final sludge will be monitored during the crediting period. If the baseline emissions include the anaerobic decay of final sludge generated by the baseline treatment systems in a landfill without methane recovery, the baseline disposal site shall be clearly defined, and verified by the DOE
Monitoring frequency:	Monitoring of 100 per cent of the sludge amount through continuous or batch measurements and moisture content through representative sampling to ensure the 90/10 confidence/precision level
Any comment:	-

Data / Parameter table 4.

Data / Parameter:	$BG_{burnt,y}$
Data unit:	m^3
Description:	Biogas volume in year *y*
Measurement procedures (if any):	In all cases, the amount of biogas recovered, fuelled, flared or otherwise utilized (e.g. injected into a natural gas distribution grid or distributed via a dedicated piped network) shall be monitored ex post, using continuous flow meters. If the biogas streams flared and fuelled (or utilized) are monitored separately, the two fractions can be added together to determine the total biogas recovered, without the need to monitor the recovered biogas before the separation. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place
Monitoring frequency:	Monitored continuously (at least hourly measurements are undertaken, if less, confidence/precision level of 90/10 shall be attained)
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	$w_{CH4,y}$
Data unit:	%

Description:	Methane content in biogas in the year *y*
Measurement procedures (if any):	The fraction of methane in the gas should be measured with a continuous analyser or, alternatively, with periodical measurements at a 90/10 confidence/precision level. It shall be measured using equipment that can directly measure methane content in the biogas - the estimation of methane content of biogas based on measurement of other constituents of biogas such as CO_2 is not permitted. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place
Monitoring frequency:	-
Any comment:	-

Data / Parameter table 6.

Data / Parameter:	***T***
Data unit:	^{o}C
Description:	Temperature of the biogas
Measurement procedures (if any):	The temperature of the gas is required to determine the density of the methane combusted. If the biogas flow meter employed measures flow, pressure and temperature and displays or outputs the normalised flow of biogas, then there is no need for separate monitoring of pressure and temperature of the biogas
Monitoring frequency:	Shall be measured at the same time when methane content in biogas ($w_{CH4,y}$) is measured
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	***P***
Data unit:	Pa
Description:	Pressure of the biogas
Measurement procedures (if any):	The pressure of the gas is required to determine the density of the methane combusted. If the biogas flow meter employed measures flow, pressure and temperature and displays or outputs the normalised flow of biogas, then there is no need for separate monitoring of pressure and temperature of the biogas
Monitoring frequency:	Shall be measured at the same time when methane content in biogas ($w_{CH4,y}$) is measured
Any comment:	-

Data / Parameter table 8.

Data / Parameter:	**-**
Data unit:	%
Description:	The flare efficiency
Measurement procedures (if any):	As per the methodological tool "Project emissions from flaring". Regular maintenance shall be carried out to ensure optimal operation of flares
Monitoring frequency:	-
Any comment:	-

Data / Parameter table 9.

Data / Parameter:	**-**
Data unit:	-

Description:	Parameters related to emissions from electricity and/or fuel consumption in year *y*
Measurement procedures (if any):	As per the procedure in the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption” and/or “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”. Alternatively it shall be assumed that all relevant electrical equipment operate at full rated capacity, plus 10 per cent to account for distribution losses, for 8760 hours per annum
Monitoring frequency:	-
Any comment:	-

Data / Parameter table 10.

Data / Parameter:	**-**
Data unit:	t CO_2e
Description:	Parameters related to methane emissions from biomass stored under anaerobic conditions which does not occur in the baseline situation
Measurement procedures (if any):	As per the latest version of the methodological tool “Emissions from solid waste disposal sites”
Monitoring frequency:	-
Any comment:	-

7. Project activity under a programme of activities

The following conditions apply for use of this methodology in a project activity under a programme of activities:

In case the project activity involves the replacement of equipment, and the leakage effect of the use of the replaced equipment in another activity is neglected, because the replaced equipment is scrapped, an independent monitoring of scrapping of replaced equipment needs to be implemented. The monitoring should include a check if the number of project activity equipment distributed by the project and the number of scrapped equipment correspond with each other. For this purpose scrapped equipment should be stored until such correspondence has been checked. The scrapping of replaced equipment should be documented and independently verified.

Appendix. Provisions for upgradation and distribution of biogas

Project boundary

In case of project activities covered under paragraph 4(b) and 4 (c),[1] if the project activity involves bottling of biogas the project boundary includes the upgrade and compression installations, the dedicated piped network/natural gas distribution grid for distribution of biogas from the wastewater treatment plant to the end user sites and all the facilities and devices connected directly to it.

Baseline

In case of project activities covered under paragraph 4(c)(i) the baseline emissions for upgraded biogas injection ($BE_{injection,y}$) are determined as follows:

$$BE_{injection,y} = E_{ug,y} \times CEF_{NG} \quad \text{Equation (1)}$$

Where:

$BE_{injection,y}$	=	Baseline emissions for injection of upgraded biogas into a natural gas distribution grid in year *y* (t CO_2e)
$E_{ug,y}$	=	Energy delivered from the upgraded biogas in the project activity to the natural gas distribution grid in year *y* (TJ)
CEF_{NG}	=	Carbon emission factor of natural gas (t CO_2e/TJ); (Accurate and reliable local or national data may be used where available, otherwise appropriate IPCC default values shall be used)

The energy delivered from the upgraded biogas in the project activity to the natural gas distribution grid in year *y* ($E_{ug,y}$) is calculated as follows:

$$E_{ug,y} = Q_{ug,y} \times NCV_{ug,y} \quad \text{Equation (2)}$$

[1] These are references to the section “Scope, applicability, and entry into force” in the methodology including upgrading of biogas before distribution to the quality of natural gas for use as fuel or for bottling or for injection into a natural gas distribution system. The eligible biogas upgrading technologies covered in this appendix include: (1) Pressure Swing Adsorption; (2) Absorption with/without water circulation; (3) Absorption with water, with or without water recirculation (with or without recovery of methane emissions from discharge). For those technologies, please refer to annex 1 of the approved methodology “AM0053: Biogenic methane injection to a natural gas distribution grid”/Version 04.0 regarding the description of these technologies project proponent may submit a request for revision to include more technology options.

Where:

$Q_{ug,y}$	=	Quantity of upgraded biogas displacing the use of natural gas in the natural gas distribution grid in year *y* (kg or m^3)
$NCV_{ug,y}$	=	Net calorific value of the upgraded biogas in year *y* (TJ/kg or TJ/m^3)

The quantity of upgraded biogas displacing the use of natural gas in the natural gas distribution grid in year *y* is calculated as follows:

$$Q_{ug,y} = \min(Q_{ug,in,y}, Q_{cap,CH4,y}) \quad \text{Equation (3)}$$

Where:

$Q_{ug,in,y}$	=	Quantity of upgraded biogas injected into the natural gas distribution grid in year *y* (kg or m^3)
$Q_{cap,CH4,y}$	=	Quantity of methane captured at the wastewater treatment source facility(ies) in year *y* (kg or m^3)

The quantity of methane captured at the waste water treatment source facility(ies) is calculated as follows:

$$Q_{cap,CH4,y} = w_{CH4,ww} \times Q_{cap,biogas,y} \quad \text{Equation (4)}$$

Where:

$w_{CH4,ww}$	=	Methane fraction of biogas as monitored at the outlet of the wastewater treatment source facility(ies) (kg or m^3 CH_4/kg or m^3 of biogas)
$Q_{cap,biogas,y}$	=	Monitored amount of biogas captured at the source facility(ies) in year *y* (kg or m^3)

Project activity emission

In case of project activities covered under paragraph 4(b) and 4(c) the following project emissions related to the upgrading and compression of the biogas ($PE_{process,y}$) shall be included:

CO_2 emissions from electricity and fuel used by the upgrading facilities (t CO_2e);

Methane emissions from the discharge of the upgrading equipment (t CO_2e);

Fugitive methane emissions from leaks in compression equipment (t CO_2e);

Emissions on account of vent gases from upgrading equipment (t CO_2e).

$$PE_{process,y} = PE_{power,upgrade,y} + PE_{ww,upgrade,y} + PE_{CH4,equip,y} + PE_{ventgas,y}$$ Equation (5)

Where:

$PE_{process,y}$	=	Project emissions related to the upgrading and compression of the biogas in year *y* (t CO_2e)
$PE_{power,upgrade,y}$	=	CO_2 emissions from electricity and fuel used by the upgrading facilities (t CO_2e), as per paragraph 19 of AMS-III.H.
$PE_{ww,upgrade,y}$	=	Emissions from methane contained in any waste water discharge of upgrading installation in year *y* (t CO_2e)
$PE_{CH4,equip,y}$	=	Emissions from compressor leaks in year *y* (t CO_2e)
$PE_{ventgas,y}$	=	Emissions from venting gases retained in upgrading equipment in year *y* (t CO_2e)

Project activity emissions from methane contained in waste water discharge of upgrading installation are determined as follows:

$$PE_{ww,upgrade,y} = Q_{ww,upgrade,y} \times [CH_4]_{ww,upgrade,y} \times GWP_{CH4}$$ Equation (6)

Where:

$Q_{ww,upgrade,y}$	=	Volume of wastewater discharge from upgrading installation in year *y*
$[CH_4]_{ww,upgrade,y}$	=	Dissolved methane contained in the wastewater discharge in year *y*

Project activity emissions from compressor leaks are determined as follows:

$$PE_{CH4,equip,y} = GWP_{CH4} \times (\frac{1}{1000}) \times \sum_{equipment} w_{CH4,stream,y} \times EF_{equipment} \times T_{equipment,y}$$ Equation (7)

Where:

$w_{CH4,stream,y}$	=	Average methane weight fraction of the gas (kg-CH_4/kg) in year *y*
$T_{equipment,y}$	=	Operation time of the equipment in hours in year *y* (in absence of detailed information, it can be assumed that the equipment is used continuously, as a conservative approach)
$EF_{equipment}$	=	Leakage rate for fugitive emissions from the compression technology as per specification from the compressor manufacturer in kg/hour/compressor. If no default value from the technology provider is available, the approach below shall be used

Fugitive methane emissions occurring during the recovery and processing of gas may in some projects be small, but should be estimated as a conservative approach. Emission factors may be taken from the 1995 Protocol for Equipment Leak Emission Estimates, published by EPA.[2]

Emissions should be determined for all relevant activities and all equipment used for the upgrading of biogas (such as valves, pump seals, connectors, flanges, open-ended lines, etc.).

The following data needs to be obtained:

The number of each type of component in a unit (valve, connector, etc.);

The methane concentration of the stream;

The time period each component is in service.

The EPA approach is based on average emission factors for Total Organic Compounds (TOC) in a stream and has been revised to estimate methane emissions. Methane emissions are calculated for each single piece of equipment by multiplying the methane concentration with the appropriate emission factor from the table below.

Table. Methane emission factors for equipment[3]

Equipment type	Emission factor (kg/hour/source) for methane
Valves	4.5E-0.3
Pump seals	2.4E-0.3
Others[4]	8.8E-0.3
Connectors	2.0E-0.4
Flangs	3.9E-0.4
Open ended lines	2.0E-0.3

Project activity emissions from venting gases retained in upgrading equipment do not have to be considered if vent gases ($PE_{vent\ gas,y}$) are channeled to storage bags. In case vent gases are flared, emissions due to the incomplete or inefficient combustion of the gases will be calculated using the methodological tool “Project emissions from flaring”, as follows:

$$PE_{ventgas,y} = \sum_{h=1}^{8760} TM_{RG,h} \times (1 - \eta_{flare,h}) \times \frac{GWP_{CH4}}{1000}$$ Equation (8)

2 Please refer to the document US EPA-453/R-95-017 at: <http://www.epa.gov/ttn/chief/efdocs/equiplks.pdf>, accessed on 23/10/2007.

3 Please refer to the document US EPA-453/R-95-017 Table 2.4, page 2-15, accessed on 23/10/2007.

4 The emission factor for “other” equipment type was derived from compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, relief valves and vents. This “other” equipment type should be applied for any equipment type other than connectors, flanges, open-ended lines, pumps or valves.

Where:

$TM_{RG,h}$	=	Mass flow rate of methane in the residual gas in hour *h* (kg/h)
$\eta_{flare,h}$	=	Flare efficiency in hour *h*

In case vent gases are not flared the methodological tool "Project emissions from flaring" will be used, without considering measurements and calculations for the flare efficiency, which will be assumed to be zero. In this case, emissions due to the vent gases will be:

$$PE_{y,ventgas} = \sum_{h=1}^{8760} TM_{RG,h} * \frac{GWP_{CH4}}{1000}$$ Equation (9)

Alternatively, in case vent gases are directly vented to the atmosphere, it may also be calculated by conservatively calculating the mass of the gases vented based on the volume, pressure and temperature of gas retained in upgrading equipment. This mass should be multiplied with the frequency with which it is vented and assuming that the vented gas is pure methane.

In order to account for emissions that occur when the upgrade facility is shut down due to maintenance, repair work or emergencies one of the alternatives proposed above should be used to calculate and include emissions from flaring or venting.

In case of project activities covered under paragraph 4(c)(ii) emissions due to physical leakage of upgraded biogas from the dedicated piped network ($PE_{leakage,pipeline,y}$) shall be determined as follows:

$$PE_{leakage,pipeline,y} = Q_{methane,pipeline,y} \times LR_{pipeline} \times GWP_{CH4}$$ Equation (10)

Where:

$PE_{leakage,pipeline,y}$	=	Emissions due to physical leakage from the dedicated piped network in year *y* (t CO_2e)
$Q_{methane,pipeline,y}$	=	Total quantity of methane transported in the dedicated piped network in year *y* (m^3)
$LR_{pipeline}$	=	Physical leakage rate from the dedicated piped network (if no project-specific values can be identified a conservative default value of 0.0125 Gg per 10^6 m^3 of utility sales shall be applied[5])

[5] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, chapter 4, Table 4.2.5 provides default values for fugitive emissions from gas operations in developing countries. The default values provided for fugitive emissions for the distribution of natural gas to end users range from 1.1 E-3 to 2.5 E-3 Gg per 10^6 m^3 of utility sales. The uncertainty in this value is -20 per cent to 500 per cent. A conservative value of 2.5 E-3 * 500% = 0.0125 Gg per 10^6 m^3 of utility sales shall be taken.

Leakage emissions

In case of project activities covered under paragraph 4(b) and the users of the bottles filled with upgraded biogas are not included in the project boundary then the following leakage emissions shall be included and calculated as follows:

Emissions due to physical leakage of biogas from the bottles during storage, transport etc. until final end use (t CO_2e);

Emissions due to fossil fuel use for transportation of bottles; biogas filled bottles to the end users and the return of empty bottles to the filling site (t CO_2e).

$$LE_{bottling,y} = LE_{leakage,bb,y} + LE_{trans,y}$$ Equation (11)

Where:

$LE_{bottling,y}$	=	Leakage emissions project activities involving bottling of biogas in year *y* (t CO_2e)
$LE_{leakage,bb,y}$	=	Emissions due to physical leakage from biogas bottles in year *y* (t CO_2e)
$LE_{trans,y}$	=	Emissions due to fossil fuel use for transportation of bottles; biogas filled bottles to the end users and the return of empty bottles to the filling site in year *y* (t CO_2e)

Leakage emissions due to physical leakage from biogas bottles are determined as follows:

$$LE_{leakage,bb,y} = Q_{methane,bb,y} \times LR_{bb} \times GWP_{CH4}$$ Equation (12)

Where:

$Q_{methane,bb,y}$	=	Total quantity of methane bottled in year *y* (m^3)
LR_{bb}	=	Physical leakage rate from biogas bottles (if no project-specific values can be identified a default value of 1.25 per cent shall be applied)[6]

Leakage emissions due to fossil fuel use for transportation of bottles (biogas filled bottles to the end users and the return of empty bottles to the filling site) are determined as below. If some of the locations of the end-users are unknown a conservative approach assuming transport emissions of 250 km, shall be used.

[6] Victor (1989) Leaking Methane from Natural Gas Vehicles: Implication for Transportation Policy in the Greenhouse Era, in Climatic Change 20: 113-141, 1992 and American Gas Association (1986), 'Lost and Unaccounted for Gas', Planning and Analysis issues, issue brief 1986-28, p. 3.

$$PE_{trans,y} = \left(\frac{Q_{bb,y}}{CT_{bb,y}} \right) \times DAF_{bb} \times EF_{CO2}$$ Equation (13)

Where:

$Q_{bb,y}$	=	Total freight volume of upgraded biogas in bottles transported in year *y* (m^3)
$CT_{bb,y}$	=	Average truck freight volume capacity for the transportation of bottles with upgraded biogas (m^3/truck)
DAF_{bb}	=	Aggregated average distance for bottle transportation; biogas filled bottles to the end users and the return of empty bottles to the filling site (km/truck)
EF_{CO2}	=	CO_2 emission factor from fuel use due to transportation (t CO_2/km)

Monitoring methodology

The project proponents shall maintain a biogas (or methane) balance based on:

Continuous measurement of the amount of biogas captured at the wastewater treatment system;

Continuous measurement of the amount of biogas used for various purposes in the project activity: e.g. heat, electricity, flare, hydrogen production, injection into natural gas distribution grid, etc. The difference is considered as loss due to physical leakage and deducted from the emission reductions.

In case of project activities covered under paragraph 4(c) the quantity of biogas, temperature, pressure and concentration of methane in the biogas injected into the natural gas grid/distributed via the dedicated piped network shall be measured continuously using certified equipment. The net calorific value (NCV) shall be measured directly from the gas stream using an online Heating Value Meter or calculated based on the measured methane content using the NCV of methane. This measurement must be in mass or volume basis and the project participants shall ensure that units of the measurements of the amount of biogas injected and of the net calorific value are consistent. The methane content of the injected or transported biogas shall always be in accordance with national regulations or, in absence of national regulations, 96 per cent (by volume) or higher. Biogas injected or transported with inferior methane content shall be excluded from the emission reduction calculations.

In case of project activities covered under paragraph 4(b) and 4(c), the following parameters shall be monitored and recorded:

The volume of discharge into the desorption pond from the upgrading installation ($Q_{ww,upgrade,y}$), monitored continuously;

The methane content ($[CH_4]_{ww,upgrade,y}$) of the discharge water from the upgrade facility, samples are taken at least every six months during normal operation of the facility;

The annual operation time of the compressor and each piece of equipment in the biogas upgrading and compression installations in hours ($T_{equipment,y}$). In case this information is not available it shall be assumed that the upgrading installation and compressor is used continuously;

The quantity, pressure and composition of the bottled biogas, biogas injected into a natural grid or transported via a dedicated piped network; monitored continuously using flow meters and regularly calibrated methane monitors. The pressure of the biogas shall be regulated and monitored using a regularly calibrated pressure gauge. The methane content of the biogas shall always be in accordance with national regulations or, in absence of national regulations, 96 per cent (by volume) or higher in order to ensure that biogas could readily be used as a fuel, inferior methane content shall be excluded from the emission reduction calculations;

In case vent gases are calculated using the methodological tool “Project emissions from flaring”, the monitoring criteria contained in this tool shall be used. In case this tool is not used and the alternative approach in paragraph 13 of this appendix is used, then temperature and pressure of gas retained in upgrading equipment shall be measured continuously and their values before the venting process are used, together with the volume capacity of the installation, to estimate the amount of methane released during the venting process;

During the periods when the biogas upgrading facility is closed due to scheduled maintenance or repair of equipment or during exigencies, project participants should ensure that the captured biogas is flared at the site of its capture using an (emergency) flare. Appropriate monitoring procedures should be established to monitor this emergency flare;

In case of project activities covered under paragraph 4(b) the number and volume of biogas bottles produced and transported, the average truck capacity ($CT_{bb,y}$) and the average aggregated distance for transporting the bottled biogas (DAF_{bb}).

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Document information

Version	*Date*	*Description*
18.0	16 October 2015	EB 86, Annex 16 Revision to include non-binding best practice examples.
17.0	28 November 2014	EB 81, Annex 34 Revision to standardize the requirements on additionality in the methodology in line with other waste sector methodology such as AMS-III.D. It includes provisions for automatic additionality.
16.0	26 November 2010	EB 58, Annex 22 To include additional guidelines pertaining to transport of biogas (e.g. by trucks) and biogas application for transportation; To clarify the conditions under which the measurement campaign can be used for baseline emissions determination.
15.0	30 July 2010	EB 55 Annex 34 To clarify the criteria to be satisfied for the baseline lagoon treatments systems under the methodology; To include the monitoring table with the required frequency of

Version	*Date*	*Description*
		measurements and options for collection and recording of data.
14.0	26 March 2010	EB 53, Annex 17 To include additional clarification on the monitoring requirements of biogas.
13.0	17 July 2009	EB 48, Annex 21 To include additional eligible technologies for upgrading biogas for bottling or feeding to natural gas distribution grid. Include an option to use the calculated net calorific value (NCV) of biogas based on methane content measurement instead of directly monitoring NCV using a NCV meter.
12.0	28 May 2009	EB 47, Annex 26 To include additional guidance on use of methane generation potential based on Biochemical Oxygen Demand ($BOD_{5,20}$).
11.0	25 March 2009	EB 46, Annex 22 To clarify the methods for determination of baseline for Greenfield projects; To specify minimum requirements concerning sludge removal interval in the baseline anaerobic lagoon; Further guidance on measuring equipment for biogas pressure, temperature and flow rate.
10.0	26 September 2008	EB 42, Annex 17 Additional guidance on baseline determination and project emission calculations; Restructured, provisions related to methane correction factor and related uncertainties were revised.
09.0	14 March 2008	EB 38, Annex 10 Expand applicability to include pipeline transport of the recovered and upgraded biogas; Additional guidance on sequential treatment of wastewater in anaerobic lagoons.
08.0	30 November 2007	EB 36, Annex 24 Expand applicability to bottling of recovered biogas; Additional guidance on emissions from dissolved methane in the treated wastewater; Guidance on use of IPCC default factors for the degradable organic content of sludge.
07.0	19 October 2007	EB 35, Annex 29 Expand the applicability to allow recovered biogas to be used for hydrogen production.
06.0	27 July 2007	EB 33, Annex 35 Additional leakage guidance to allow for application under a programme of activities (PoA).
05.0	04 May 2007	EB 31, Annex 27 To exclude scope 15 from the methodology

Version	*Date*	*Description*
04.0	15 December 2006	EB 28, Annex 26 Broaden the applicability to include sequential stage of anaerobic wastewater treatment; Additional guidance based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories on the following: (a) Methane correction factor (*MCF*) determined by wastewater discharge pathways or type of treatment; (b) Default values for sludge treatment, particularly for degradable organic carbon (DOC) and methane correction factor (*MCF*).
03.0	21 July 2006	EB 25, Annex 28 Clarify the inclusion of methane emission factor in the equation for baseline calculations.
02.0	10 May 2006	EB 24, paragraph 64 of the report The Board at its twenty-fourth meeting noted that Type III project activities might be able to achieve significant emission reductions, without exceeding the direct emissions limits i.e. 15 kilo tonnes CO_2e applicable at the time. As an interim solution, the Board agreed to include the following text in all Type III categories: “This category is applicable for project activities resulting in annual emission reductions lower than 25,000 tonnes CO_2e. If the emission reduction of a project activity exceeds the reference value of 25,000 tonnes CO_2e in any year of the crediting period, the annual emission reduction for that particular year is capped at 25,000 tonnes CO_2e.”
01.0	24 February 2006	EB 23, Annex 23 Initial adoption.

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AMS-III.E

Small-scale Methodology

Avoidance of methane production from decay of biomass through controlled combustion, gasification or mechanical/thermal treatment

Version 17.0

Sectoral scope(s): 13

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1. Introduction

The following table describes the key elements of the methodology:

Table 3. Methodology key elements

Typical projects	Decay of the wastes that would have been let to decay or are already deposited in a waste disposal site is prevented through controlled combustion; or gasification to produce syngas/producer gas; or mechanical/thermal treatment to produce refuse-derived fuel (RDF) or stabilized biomass (SB).
Type of GHG emissions mitigation action	Greenhouse gas (GHG) emission avoidance. Avoidance of methane emissions due to prevention of anaerobic decay of biomass in waste. Use of biomass in waste as energy source.

2. Scope, applicability, and entry into force

2.1. Scope

2. This project category comprises measures that avoid the production of methane from biomass or other organic matter that:

(a) Would have otherwise been left to decay under clearly anaerobic conditions throughout the crediting period in a solid waste disposal site without methane recovery, or

(b) Is already deposited in a waste disposal site without methane recovery.

3. Due to the project activity, decay of the wastes of type referred to in paragraph 1(a) and/or 1(b) above is prevented through one of the following measures:

(a) Controlled combustion;

(b) Gasification to produce syngas/producer gas;

(a) Mechanical/thermal treatment to produce refuse-derived fuel (RDF) or stabilized biomass (SB).[1] An example of a mechanical/thermal treatment process is the pelletization of wood particles.[2]

4. The produced RDF/SB shall be used for combustion either on site or off-site.

5. In the case of stockpiles of wastes baseline emission calculations as described in the methodological tool “Emissions from solid waste disposal sites” shall be adjusted. Stockpiles can be characterised as waste disposal sites that consist of wastes of a homogenous nature with similar origin (e.g. rice husk, empty fruit bunches of oil palm, sawmill waste, etc.). Paragraph 22 provides specific instructions for the calculation of baseline emissions where the baseline is stockpiling of the waste.

6. Measures are limited to those that result in emission reductions of less than or equal to 60 kt CO_2 equivalent annually.

7. Where in the baseline usually there is a reduction in the amount of waste through regular open burning or removal for other applications, the use of the methodological tool “Emissions from solid waste disposal sites” shall be adjusted to take account of this burning or removal in order to estimate correctly the baseline emission.

2.2. Applicability

8. The project activity does not recover or combust methane unlike AMS-III.G. Nevertheless, the location and characteristics of the disposal site in the baseline condition shall be known, in such a way as to allow the estimation of its methane emissions.

9. If the project activity involves combustion, gasification or mechanical/thermal treatment of partially decayed waste mined (i.e. removed) from a solid waste disposal site in addition to freshly generated waste the project participants shall demonstrate that there is adequate capacity of the combustion, gasification or mechanical/thermal treatment facility to treat the newly generated wastes in addition to the partially decayed wastes removed from the disposal site. Alternately justifications for combusting, gasifying or mechanically/thermally treating the partially decayed wastes instead of the newly generated wastes shall be provided.

10. If the combustion facility, the produced syngas, producer gas or RDF/SB is used for heat and electricity generation within the project boundary, that component of the project activity may use a corresponding methodology under Type I project activities.

[1] The thermal treatment process (dehydration) shall occur under controlled conditions (up to 300 Celsius) and shall generate a stabilized biomass that would be used as fuel or raw material in other industrial processes. Stabilized biomass (SB) is defined as biomass adequately treated to prevent further degradation in the environment. Examples of SB are: pellets, briquettes and torrefied wood chips.

[2] Pelletization is defined as the compression of wood particles into modules of solid fuel. The process includes thermal and mechanical pre-treatment of the raw material (e.g. saw dust). Pellets have moisture content of maximal 12 per cent.

11. In case of RDF/SB production, project proponents shall provide evidence that no GHG emissions occur, other than biogenic CO_2, due to chemical reactions during the thermal treatment process for example limiting the temperature of thermal treatment to prevent the occurrence of pyrolysis and/or the stack gas analysis.[3]

12. In case of gasification, the process shall ensure that all the syngas produced, which may contain non-CO_2 GHG, will be combusted and not released unburned to the atmosphere. Measures to avoid physical leakage of the syngas between the gasification and combustion sites shall also be adopted.

13. In case of RDF/SB processing, the produced RDF/SB should not be stored in such a manner as resulting in high moisture and low aeration favouring anaerobic decay. Project participants shall provide documentation showing that further handling and storage of the produced RDF/SB does not result in anaerobic conditions and do not lead to further absorption of moisture.

14. In case of RDF/SB processing, local regulations do not constrain the establishment of RDF/SB production plants/thermal treatment plants nor the use of RDF/SB as fuel or raw material.

15. During the mechanical/thermal treatment to produce RDF/SB no chemical or other additives shall be used.

16. In case residual waste from controlled combustion, gasification or mechanical/thermal is stored under anaerobic conditions and/or delivered to a landfill emissions from the residual waste shall to be taken into account using the first order decay model (FOD) described in AMS-III.G.

2.3. Entry into force

17. The date of entry into force is the date of the publication of the EB 81 meeting report on 28 November 2014.

3. Normative references

18. Project participants must take into account the “General guidelines for SSC clean development mechanism methodologies”, “Guidelines on the demonstration of additionality of small-scale project activities” at <http://cdm.unfccc.int/Reference/Guidclarif/index.html#meth> mutatis mutandis.

19. This methodology also refers to the latest approved versions of the following approved methodologies and tool:

(a) “AMS-III.G.: Landfill methane recovery”;

(b) “AMS-III.H.: Methane recovery in wastewater treatment”;

(c) “Emissions from solid waste disposal sites;

(d) “Project and leakage emissions from transportation of freight”.

[3] See also footnote 1.

4. Definitions

20. The definitions contained in the Glossary of CDM terms shall apply.

5. Baseline methodology

5.1. Project boundary

21. The project boundary are the physical, geographical sites:

(a) Where the solid waste would have been disposed or is already deposited and the avoided methane emission occurs in absence of the proposed project activity;

(b) Where the treatment of biomass through controlled combustion, gasification or mechanical/thermal treatment takes place;

(c) Where the final residues of the combustion process will be deposited (this parcel is only relevant to controlled combustion activities);

(d) And in the itineraries between them, where the transportation of wastes and combustion residues and/or residues of gasification and mechanical/thermal treatment process occurs.

5.2. Project emissions

22. Project emissions consist of:

(a) CO_2 emissions related to the gasification and combustion of the non-biomass carbon content of the waste (plastics, rubber and fossil derived carbon) or RDF/SB and auxiliary fossil fuels used in the combustion, gasification or mechanical/thermal treatment facility;

(b) Incremental CO_2 emissions due to:

(i) Incremental distances between the collection points to the project site as compared to the baseline disposal site;

(ii) Transportation of combustion residues and final waste from controlled burning to disposal site;

(iii) Transportation of RDF/SB from the mechanical/thermal treatment facility to the storage site within the project boundary;

(iv) Transportation of RDF/SB to the sites of the end users (if some of the sites are unknown a conservative approach assuming transport emissions for a specific distance, for example a default of 250 km, shall be used);

(c) CO_2 emissions related to the fossil fuel and/or electricity consumed by the project activity facilities, including the equipment for air pollution control required by regulations. In case the project activity consumes grid-based electricity, the grid emission factor (t CO_2e/MWh) should be used, or it should be assumed that diesel generators would have provided a similar amount of electricity, calculated as described in category I.D.

$$PE_y = PE_{y,comb} + PE_{y,transp} + PE_{y,power}$$ Equation (18)

Where:

PE_y	=	Project activity direct emissions in the year *y* (t CO_2e)
$PE_{y,comb}$	=	Emissions through combustion and gasification of non-biomass carbon of waste and RDF/SB in the year *y* (t CO_2e)
$PE_{y,transp}$	=	Emissions through incremental transportation in the year *y* (t CO_2e)
$PE_{y,power}$	=	Emissions through electricity or diesel consumption in the year *y* (t CO_2e)

23. The expected annual quantity (tonnes) and composition of the waste combusted, gasified or mechanically/thermally treated by the project activity during the crediting period shall be described in the project design document, including the biomass and non-biomass carbon content of the combusted or gasified waste and RDF/SB ($Q_{biomass}$ and $Q_{non\text{-}biomass}$).

24. The expected consumption of auxiliary fuel for the incineration, gasification, mechanical/thermal treatment process (Q_{fuel}) should also be reported in the project design document. CO_2 emissions from the combustion of the non-biomass (i.e. fossil) carbon content of the wastes and RDF/SB and from the auxiliary fossil fuel consumed will be estimated assuming the complete oxidation of carbon to CO_2 in the combustion.

$$PE_{y,comb} = Q_{y,non-biomass} \times 44/12 + Q_{y,fuel} \times EF_{y,fuel}$$ Equation (19)

Where:

$Q_{y,non-biomass}$	=	Non-biomass carbon of the waste and RDF/SB combusted/gasified in the year *y* (tonnes of carbon)
$Q_{y,fuel}$	=	Quantity of auxiliary fossil fuel used in the year *y* (tonnes)
$EF_{y,fuel}$	=	CO_2 emission factor for the combustion of the auxiliary fossil fuel (tonnes CO_2 per tonne fuel, according to latest IPCC Guidelines)

25. Project emissions from trucks for incremental collection activities will be estimated following the methodological tool "Project and leakage emissions from transportation of freight".

26. Project proponents shall monitor the RDF fate and consumption through e.g. purchase by/delivery to final users.

27. If the project activity includes wastewater release, which are treated anaerobically or released untreated, methane emission shall be considered as project emissions and estimated using the provisions of AMS-III.H.

5.3. Baseline scenario and baseline emissions

28. The baseline scenario is the situation where, in the absence of the project activity, organic waste matter is left to decay within the project boundary and methane is emitted to the atmosphere. The yearly baseline emissions are the amount of methane that would have been emitted from the decay of the cumulative quantity of the waste diverted or removed from the disposal site, to date, by the project activity, calculated as the methane generation potential using the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site".

29. In the case of stockpiles of waste the baseline emission calculations as described in the methodological tool "Emissions from solid waste disposal sites" shall be adjusted. It is recognised that biomass waste disposal practices and the final fate of the disposed waste in stockpiles is highly region and waste specific, therefore the quantity of waste taken as input for the calculations and MCF and *k* values shall be chosen conservatively.

30. For projects utilising MSW, when calculating $BE_{CH4,SWDS,y}$, a MCF of 0.8 may be used[4] to account for the existence of a suppressed demand situation as described in the "Guidelines on the consideration of suppressed demand in CDM methodologies" when all of the following conditions apply:

    (a) It can be demonstrated that waste is being dumped in an uncontrolled manner in human settlement areas under the current practice due to a lack of organized waste collection and disposal system;

    (b) It can be demonstrated that only the municipal solid waste is being treated under the project activity and wastes from other sources such as agricultural or agro-industrial wastes are not being treated under the project activity;

    (c) It can be demonstrated that entire portion of the waste treated under the project activity would comply with the above two conditions.

31. In determining the amount of waste prevented from disposal in the solid waste disposal site (SWDS) ($W_{j,x}$) as input in equation 1 in the tool, the percentage of the biomass that is combusted in the project activity and which would have been dumped in a stockpile in the baseline situation and also would have remained in the stockpile for a sufficient period of time to decay shall be determined. A quantitative analysis shall be carried out using the following options (in the order of priorities):

    (a) Project specific waste disposal data from at least three years prior to the implementation of the project activity;

[4] Deep landfill (>5m) is most likely the technology for disposing MSW in the scenario of constrained availability of area/space within or close to urban areas and where waste scavenging does not occur. And it is also the least cost alternative for providing comparable level of service to the project technology for treating the waste i.e. composting in this case. MCF value is chosen from the definition provided in 2006 IPCC Guideline applicable to unmanaged deep landfills that do not have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and do not include any cover material, mechanical compacting and levelling of the waste.

(b) A control group;

(c) Official data sources.

32. The following factors shall be taken into account in this analysis:

(a) Parts of the biomass may be taken from the stockpile for various reasons. Examples are that the biomass: (a) may be used as a fuel; (b) incinerated to use the ashes as fertilizer; (c) directly applied to land as fertilizer (mulching); (d) composted; (e) or used as a raw material (e.g. panel board production). The various uses shall be analysed and quantified to show what percentage of biomass would have remained in the stockpile;

(b) There may be restrictions for leaving the biomass in a stockpile indefinitely. Examples are restrictions concerning land surface used for stockpiling or height of the stockpile.

33. These two factors shall be quantified and $W_{j,x}$, shall be adjusted accordingly, as the model in the tool assumes that the waste would have remained at the disposal site for sufficient time to fully decay.

34. Due to the high uncertainty in the estimation of methane emissions from stockpiles, conservative assumptions shall be made for the MCF and *k* values given in the tool. As piles have a large surface area to volume ratio anaerobic conditions are not ensured like in the case of SWDS. In addition the homogenous nature of the waste in stockpiles result in a different decay rate compared to normal SWDS that contain mixed wastes. For the purpose of this methodology, project participants shall use an MCF value of 0.36[5] This is the MCF value for an unmanaged shallow SWDS multiplied by 0.89 discount factor, corresponding to 30 per cent uncertainty, as specified in CMP decision 21/CP.7. The *k* value for the relevant waste type must be the lower value from the range provided for the Boreal and Temperate Climate Zone as listed in Table 3.3 in Chapter 3, volume 5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

35. In the case of project activities combusting, gasifying or mechanically/thermally treating only freshly generated wastes, the baseline emissions at any year *y* during the crediting period is calculated using the amount and composition of wastes combusted, gasified or mechanically/thermally treated since the beginning of the project activity (year “x=1”) up to the year *y*, using the first order decay model as referred to in the “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site”. Baseline emissions shall exclude methane emissions that would have to be removed to comply with national or local safety requirement or legal regulations.

$$BE_y = BE_{CH4,SWDS,y}$$ Equation (20)

Where:

BE_y	=	Baseline emissions at year *y* during crediting period (t CO_2e)

[5] Project proponents are encouraged to submit procedures to accurately assess the values for *k* and MCF in the case of stockpiles as a revision to this methodology for EB approval.

$BE_{CH4,SWDS,y}$	=	Yearly Methane Generation Potential of the wastes diverted to be disposed in the landfill from the beginning of the project (x=1) up to the year *y*, calculated according to the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" (t CO_2e)

36. In the case of project activities that combust, gasify or mechanically/thermally treat wastes that have partially decayed in a disposal site, the calculation of the yearly methane generation potential of the wastes combusted, gasified or mechanically/thermally treated from the project beginning (x=1) up to the year *y* will consider the age of the wastes at the start of the project. One of the following options may be used:

(a) Estimate the mean age of the wastes contained in the disposal site in the beginning of the project activity ("ā"). It may be estimated as the weighted average age considering the yearly amount of wastes deposited in the SWDS since its beginning of operation up to the year prior to the start of the project:

Equation (21)

$$\bar{a} = \frac{1 \cdot A_1 + 2 \cdot A_2 + 3 \cdot A_3 + ... + a \cdot A_a}{A_1 + A_2 + A_3 + ... + A_a} = \frac{\sum_{a=1}^{a\max} A_a \cdot a}{\sum_{a=1}^{a\max} A_a}$$

Where:

$\bar{a}$	=	Weighted mean age of the wastes present in the SWDS prior to the project start
a	=	Years before project start, starting in the first year of waste disposal (*a*=1) up to the maximal age of the wastes contained in the SWDS at the project start (*a*=amax)
A_a	=	Total amount of waste deposited in the SWDS in each year *a*. It shall be obtained from recorded data of waste disposals, or estimated according to the level of the activity that generated the wastes (for example, considering the amount of wood processed by a sawmill in each year *a*, and estimating the amount of wastes generated and disposed in the SWDS in that year). If the yearly amount of waste deposited in the SWDS cannot be estimated, then an arithmetic mean age may be used (ā = 0.5 x amax). By using this option, the baseline emissions at any year *y* during the crediting period are calculated using the same equation as provided in the last paragraph, nevertheless, the exponential term for the First Order Decay Model "exp [-k_j.(y-x)]" will be corrected for the mean age, and will be substituted by "exp[-k_j.(y-x+ā)]"

(b) Calculate the yearly methane generation potential of the SWDS as described in the methodological tool "Emissions from solid waste disposal sites", considering the total amount and composition of wastes deposited since its start of operation.

The methane generation potential of the wastes removed to be combusted, gasified or mechanically/thermally treated up to the year *y* in the crediting period will be estimated as proportional to the mass fraction of these wastes, relative to the initial amount:

Equation (22)

$$BE_y = \frac{\sum_{x=1}^{y} A_x}{A} BE_{CH4,SWDS,y}$$

Where:

A_x	=	Amount of wastes removed to be combusted, gasified or mechanically/thermally treated in the year *x* (tonnes)
A	=	Total amount of wastes present in the SWDS at the beginning of the project activity (tonnes)
$BE_{CH4,SWDS,y}$	=	Yearly methane generation potential of the SWDS at the year *y*, considering all the wastes deposited in it since its beginning of operation, and without considering any removal of wastes by the project activity

(c) Estimate the quantity and the age distribution of the wastes removed each year *x* during the crediting period,[6] and calculate the methane generation potential of these wastes in the year *y*. For example, in the year x=2 of the project activity, the amount A_2 was removed to be combusted, gasified or mechanically/thermally treated, and this amount can be divided into $A_{2,n}$ parts, each part belonging to the age *n*. In the year *y* the methane generation potential of the portions removed from the SWDS may be estimated as:

[6] Age distribution is the discrete partitioning of the waste by age (i.e. the number of years since it was generated and deposited at the site). The estimation of the age of the portions of waste being removed from the disposal site and combusted, gasified or mechanically/thermally treated each year may be done by topographical modelling of the wastes present in the relevant sections of the disposal site. This approach should include segregation of the wastes into even-age layers or volumetric blocks based on historical or constructive data (design of the disposal site). This information on quantity, composition, and age may be based on (a) historical records of the yearly mass and composition of waste deposited in the section of the disposal site where waste is being removed for combustion, gasification or mechanical/thermal treatment; or (b) historical production data for cases in which the waste at the site is dominated by relatively homogeneous industrial waste materials (e.g. waste by-products from sawmills or finished wood product manufacturing). Option (b) that uses historical industrial production data should apply the following steps. Step1: Estimate the total mass of waste at the disposal site in the section where it is to be removed based on the section's volume and the average density of the waste. Step 2: Apportion the mass of waste in this section into waste types and ages using historical records on the output of products produced in a given year from the industrial facility and factors for the average mass of waste by-products produced per unit of each product.

$$BE_y = \sum_{n=nmin}^{nmax} BE_{CH4,SWDS,yn}$$ Equation (23)

Where:

$BE_{CH4,SWDS,yn}$	=	Yearly methane generation potential of the wastes removed since the beginning of the project activity "x=1" up to the year *y* during the crediting period, segregated according to its age "n" at the time of removal (t CO_2e). It is calculated using the tool referred to in AMS-III.G., substituting the exponential term for the First Order Decay Model "exp [-k_j.(y-x)]" by "exp[-k_j.(y-x+n)]"

5.4. Leakage

37. In case of RDF/SB production, project proponents shall demonstrate that the produced RDF/SB is not subject to anaerobic conditions before its combustion end-use resulting in methane emissions. If the produced RDF/SB is not used in captive facilities but sold to consumers outside the project boundary as a fuel, a default 5 per cent of the baseline emissions shall be deducted as leakage to account for these potential methane emissions, unless project proponents can prove otherwise (e.g. by demonstrating that potential risks of methane emissions from RDF/SB are avoided through measures such as appropriate packaging, by showing that monitored moisture content of the RDF/SB is under 12 per cent or by the use of standards that ensure that characteristics of the RDF/SB during the entire lifecycle of the product is not conducive for methane production).

6. Monitoring

38. The emission reduction achieved by the project activity will be measured as the difference between the baseline emission and the sum of the project emission and leakage.

$$ER_y = BE_y - \left(PE_y + Leakage_y\right)$$ Equation (24)

Where:

ER_y	=	Emission reduction in the year *y* (t CO_2e)

39. The amount of waste combusted, gasified or mechanically/thermally treated by the project activity in each year (Q_y) shall be measured and recorded, as well as its composition through representative sampling, to provide information for estimating the baseline emissions. The quantity of auxiliary fuel used ($Q_{,fuel}$) and the non-biomass carbon content of the waste or RDF/SB combusted ($Q_{,non-biomass}$) shall be measured, the latter by sampling. The total quantity of combustion and gasification residues and residues from mechanical/thermal treatment ($Q_{y,ash}$) and the average truck capacity (CT_y) shall be measured. The electricity consumption and/or generation shall be measured.

The distance for transporting the waste in the baseline and the project scenario and the distance for transporting the produced RDF/SB (km/truck) shall also be recorded.[7]

40. In the case of project activities processing newly generated biomass wastes, the project participants shall demonstrate annually, through the assessment of common practices at proximate waste disposal sites, what percentage of the amount of waste combusted, gasified or mechanically/thermally treated in the project activity facilities would have been disposed in a solid waste disposal site without methane recovery in the absence of the project activity and would decay anaerobically in the disposal site throughout the crediting period.

7. Project activity under a programme of activities

41. The methodology is applicable to a programme of activities. No additional leakage estimations are necessary other than that indicated under the leakage section above.

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Document information*

Version	*Date*	*Description*
17.0	28 November 2014	EB 81, Annex 33 Revision to: • introduces supressed demand scenario based on the approach provided under the methodology such as “ACM0014: Treatment of wastewater” and AMS-III.F. • takes into the account the past clarifications issued by the SSC WG, and • streamlines the uncertainty factor used with uncertainty factors/procedures in other methodologies.
16.0	17 July 2009	EB 48, Annex 19 To include additional guidelines for monitoring of project activities involving production and sale of refuse derived fuel (RDF) from biomass solid waste.
15.1	14 December 2007	EB 36, Annex 25 Minor editorial corrections.
15.0	14 December 2007	EB 36, Annex 25 To clarify the applicable MCF (methane correction factor) and *k*

[7] In cases where the RDF/SB is sold in the open market, the project emissions due to auxiliary fuel consumption and transportation of final residues of combustion ($Q_{y,ash}$) may be neglected. The sold RDF/SB is not eligible for a Type I (renewable energy) project component under the same project activity since it is not in the project boundary. The sale invoices of RDF/SB shall be maintained at the project site.

Version	*Date*	*Description*
		(decay rate of the waste) values to use for biomass stockpiles in the baseline emissions calculation.
14.0	02 November 2007	EB 35, Annex 32 To broaden the applicability of the approved methodology by including thermal/mechanical treatment of biomass waste to produce refuse-derived fuel (RDF) or stabilized biomass (SB) such as pellets or briquettes.
13.0	27 July 2007	EB 33, Annex 33 Revision of the approved small-scale methodology AMS-III.E to allow for its application under a programme of activities (PoA).
12.0	04 May 2007	EB 31, Annex 26 To exclude AMS-III.E from scope 15, and to clarify that that DOE functions (validation, verification etc.) of project activities applying earlier versions can only be performed by DOEs accredited to all of the sectoral scopes to which the earlier versions of these methodologies respectively belong to.
11.0	23 February 2007	EB 29, Annex 8 Changes include: (a) Applicability of the methodology is expanded to include partially degraded waste with three options being provided to calculate methane emissions avoided i.e. (i) Based on the weighted average age of the waste; or (ii) Based on the yearly methane generation potential of the disposal site and the relative amount of waste removed from it for combustion; or (iii) Based on the profile of the disposal site and historic waste disposal data. (b) To clarify that the methodology is applicable only in cases where it can be demonstrated that organic matter combusted by the project activity would have remained disposed under clearly anaerobic conditions throughout the crediting period in the absence of the project activity.
10.0	23 December 2006	EB 28, Meeting report, Para. 42 To remove the direct emissions limits i.e. 15ktCO_2e/y as well as the interim applicability condition i.e. 25ktCO_2e/y.
09.0	12 May 2006	EB 24, Meeting report, Para. 64 Introduced the interim applicability condition i.e. 25ktCO_2e/y limit for all Type III categories.
08.0	03 March 2006	EB 23, Annex 28 To include detailed guidance on the direct project emissions.

Decision Class: Regulatory
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Business Function: Methodology
Keywords: avoidance of methane emission, solid waste, simplified methodologies, type (iii) projects

* This document, together with the 'General Guidance' and all other approved SSC methodologies, was part of a single document entitled: Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM project activities until version 07.

History of the document: Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM project activities

Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM project activities contained both the General Guidance and Approved Methodologies until version 07. After version 07 the document was divided into separate documents: 'General Guidance' and separate approved small-scale methodologies (AMS).

Version	*Date*	*Description*
07.0	25 November 2005	EB 22, Para. 59 References to "non-renewable biomass" in Appendix B deleted.
06.0	20 September 2005	EB 21, Annex 22 Guidance on consideration of non-renewable biomass in Type I methodologies, thermal equivalence of Type II GWhe limits included.
05.0	25 February 2005	EB 18, Annex 6 Guidance on 'capacity addition' and 'cofiring' in Type I methodologies and monitoring of methane in AMS-III.D included.
04.0	22 October 2004	EB 16, Annex 2 AMS-II.F was adopted; leakage due to equipment transfer was included in all Type I and Type II methodologies.
03.0	30 June 2004	EB 14, Annex 2 New methodology AMS-III.E was adopted.
02.0	28 November 2003	EB 12, Annex 2 Definition of build margin included in AMS-I.D, minor revisions to AMS-I.A, AMS-III.D, AMS-II.E.
01.0	21 January 2003	EB 7, Annex 6 Initial adoption. The Board at its seventh meeting noted the adoption by the Conference of the Parties (COP), by its decision 21/CP.8, of simplified modalities and procedures for small-scale CDM project activities (SSC M&P).

Decision Class: Regulatory
Document Type: Standard
Business Function: Methodology

AMS-III.AQ

Small-scale Methodology

Introduction of Bio-CNG in transportation applications

Version 02.0

Sectoral scope(s): 07

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1. Introduction

1. The following table describes the key elements of the methodology:

Table 4. Methodology key elements

Typical project(s)	Production of Biogenic Compressed Natural gas (Bio-CNG) from biomass and use in transportation applications. The Bio-CNG is derived from various sources such as biomass from dedicated plantations; waste water treatment; manure management; biomass residues etc.
Type of GHG emissions mitigation action	Renewable energy. Displacement of more-GHG-intensive fossil fuel used in vehicles

2. Scope, applicability, and entry into force

2.1. Scope

This methodology comprises activities for production of Biogenic Compressed Natural Gas (Bio-CNG) from biomass including biomass residues and cultivated biomass to be used in transportation applications. Biomass cultivated for production of the Bio-CNG should be sourced from dedicated plantations.

The project activity involves installation and operation of Bio-CNG plant that includes:

Anaerobic digester(s) to produce and recover biogas;

Biogas treatment system that includes processing, purification and compression of the biogas to obtain up-graded biogas such that methane content, its quality and the physical and chemical properties are equivalent to the CNG;

Filling stations, storage and transportation.

This methodology covers the use of Bio-CNG in various types of transportation applications such as Compressed Natural Gas (CNG) vehicles, modified vehicles. Examples include buses, trucks, three-wheeler, cars, jeeps, etc.

If the part of the recovered biogas is injected into a natural gas distribution grid, emission reduction for that component of the project activity can be claimed following the provisions in annex 1 of “AMS-III.H: Methane recovery in wastewater treatment”.

2.2. Applicability

This methodology is applicable if the methane content of the upgraded biogas is in accordance with relevant national regulations and in their absence a minimum of 96 per cent (by volume).

If the project activity utilizes biomass sourced from dedicated plantations, the applicability conditions prescribed in the methodological tool “project emissions from cultivation of biomass” shall apply.

The retailers, final users (where applicable) and the producer of the Bio-CNG are bound by a contract that states that the final consumers and retailers shall not claim emission reductions resulting from its consumption. Only the producer of the Bio-CNG can claim emission reductions under this methodology.

The export of Bio-CNG produced under this methodology is not allowed.

The digested residue waste leaving the reactor shall be handled aerobically and submitted to soil application, the proper procedures and conditions not resulting in the methane emissions shall be ensured; otherwise the emissions shall be taken into account as per relevant procedures of “AMS-III.AO: Methane recovery through controlled anaerobic digestion”.

Measures are limited to those that result in emission reduction of less than or equal to 60 kt CO_2 equivalent annually. Where applicable the sum of the emission reductions from all Type III components of a project activity should comply with 60 kt CO_2 equivalent annually.

2.3. Entry into force

The date of entry into force is the date of the publication of the EB 79 meeting report on 1 June 2014.

3. Normative references

Project participants shall take into account the “General guidelines for SSC CDM methodologies”, “Guidelines on the demonstration of additionality of small-scale project activities” provided at: <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html> mutatis mutandis.

This methodology also refers to the latest approved versions of the following approved methodologies, guidelines[31] and tools:

"General guidance on leakage in biomass project activities";

"AMS-III.H: Methane recovery in wastewater treatment";

"AMS-III.AK: Biodiesel production and use for transport applications";

"AMS-III.AO: Methane recovery through controlled anaerobic digestion";

"Tool to calculate baseline, project and/or leakage emissions from electricity consumption";

"Project emissions from cultivation of biomass";

"Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion"

"Upstream leakage emissions associated with fossil fuel use".

4. Definitions

The definitions contained in the Glossary of CDM terms shall apply.

5. Baseline methodology

5.1. Project boundary

The spatial extent of the project boundary encompasses:

The Bio-CNG plant;

Where applicable, transportation of biomass from the point of their origin to Bio-CNG plant;

Where applicable, transportation Bio-CNG from biogas plant to filling stations where it is used by final consumers;

The land at which the cultivation of biomass used for the production of Bio-CNG and/or the area/region from where the waste organic matters for the production of Bio-CNG is sourced;

In cases where project participants carry out modification of gasoline vehicles to enable the use of Bio-CNG, the vehicles shall be included in the boundary.

[31] Please refer to: <https://cdm.unfccc.int/Reference/index.html>.

5.2. Baseline emissions

Baseline emissions are calculated by using one of the two available approaches. Under approach 1 baseline emissions are calculated based on the amount of Bio-CNG produced and distributed, and it is applicable to project activities those are:

Use of Bio-CNG in modified diesel vehicles;[32] and/or

Use of Bio-CNG in modified gasoline vehicles when such vehicles are not included in the boundary.

Under approach 2 baseline emissions are calculated based on the quantity of Bio-CNG filled into converted gasoline vehicles and it is applicable to the project activities that are the production and use of Bio-CNG in modified gasoline vehicles when such vehicles are included in the boundary and are monitored. Approach 2 is not applicable to the modified diesel vehicles.

5.2.1. Approach 1:

It is conservatively assumed that all Bio-CNG produced will displace CNG from fossil origin and the baseline emissions are calculated as follows:

$$BE_y = FS_{Bio-CNG,y} \times NCV_{Bio-CNG} \times EF_{Co2,CNG} \quad \text{Equation (25)}$$

Where:

BE_y	=	Total baseline emission in year *y* (t CO_2e)
$FS_{Bio-CNG,y}$	=	Amount of Bio-CNG distributed/sold directly to retailers, filling stations by the project activity in year *y* (tonnes)
$EF_{Co2,CNG}$	=	CO_2 emission factor of CNG (tCO_2e/GJ), determined using reliable local or national data. IPCC default values (lower value of 95 per cent confidence interval (CI)) shall be used only when country or project specific data are not available or demonstrably difficult to obtain. Values shall be updated if national values or IPCC values changes
$NCV_{Bio-CNG}$	=	Net calorific value of Bio-CNG (GJ/tonne). If it is demonstrated that the methane content of the Bio-CNG is minimum 96 per cent by volume then NCV of CNG shall be used. For NCV of CNG, reliable local or national data shall the used. IPCC default values shall be used only when country or project specific data are not available or demonstrably difficult to obtain. Values shall be updated if national values or IPCC values change

[32] In contrast to the conversion of gasoline (Otto cycle) vehicles to use natural gas or CNG as a fuel, the technologies for conversion of diesel engines will result in a variable efficiency drop (or variable specific fuel consumption) depending on the operational conditions (load and speed). Therefore, the efficiency drop varies according to the transportation service provided by the vehicles during their use. Approach 1 assumes that the diesel vehicles have been converted to run on natural gas, which is then considered being the baseline fuel.

Under the condition of:

$$FS_{Bio-CNG,y} \leq FP_{Bio-CNG,y}$$ Equation (26)

Where:

$FP_{Bio-CNG,y}$	=	Quantity of the Bio-CNG produced by the project activity in the year *y* (tonnes)

5.2.2. Approach 2:

In cases where the project activity also undertakes the conversion of gasoline vehicles including those vehicles in the project boundary, the baseline emission calculations are calculated as per equations 3 and 4 below.

$$FC_{gasoline,k,y} = FC_{Bio-CNG,k,y} \times \frac{NCV_{Bio-CNG}}{NCV_i} \times n \times f_{FO,gasoline}$$ Equation (27)

Where:

$FC_{gasoline,k,y}$	=	Amount of gasoline of fossil origin which would have been consumed in the baseline by vehicle *k* in the year *y* (tonnes)
$FC_{Bio-CNG,k,y}$	=	Bio-CNG consumed by the project vehicle *k* in the year *y* (tonnes)
$NCV_{Bio-CNG}$	=	Net calorific value of Bio-CNG (GJ/tonne). The net calorific value of the Bio-CNG shall be determined based on direct measurement of a representative sample
NCV_i	=	Net calorific value of gasoline (GJ/tonne) that was used by project vehicle *k*. In case the gasoline is blended with biofuels the NCV of the blended gasoline shall be used. For *NCVi* reliable local or national data shall be used. IPCC default values (lower value of 95 per cent CI) shall be used only when country or project specific data are not available or demonstrably difficult to obtain. Values shall be updated if national values or IPCC values changes
n	=	Discount factor to account for the possible drop in the fuel efficiency of the retrofitted Bio-CNG vehicles. A default value of 0.95 shall be used for converted vehicles that previously used gasoline
$f_{FO,gasoline}$	=	Fraction of gasoline of fossil fuel origin. 1.0 if pure gasoline has been displaced. In cases where national regulations require mandatory blending of the fuels with biofuels then the fraction of gasoline (on mass basis) in the blend should be applied

Total baseline emissions for approach 2 are calculated on an annual basis as below:

$$BE_y = \sum_k FC_{gasoline,k,y} \times NCV_{gasoline} \times EF_{CO2,gasoline}$$ Equation (28)

Where:

BE_y	=	Total baseline emission in year *y* (t CO_2e)
$NCV_{gasoline}$	=	Net calorific value of gasoline (GJ/tonne), determined using reliable local or national data. IPCC default values (lower value of 95 per cent CI) shall be used only when country or project specific data are not available or demonstrably difficult to obtain. Values shall be updated if national values or IPCC values change
$EF_{CO2,gasoline}$	=	CO_2 emission factor of gasoline (t CO_2e/GJ)

Under the condition of:

$$\sum FC_{Bio-CNG,k,y} \leq FP_{Bio-CNG,y}$$ Equation (29)

Where:

$FC_{Bio-CNG,k,y}$	=	Total consumed Bio-CNG by all project vehicles in year *y* (tonnes)

In the cases where project proponents apply both approach 1 and 2, project proponents shall describe in the PDD how the double counting of emission reductions has been avoided.

5.3. Project emissions

The project emissions should be calculated as follows:

$$PE_y = PE_{elec,y} + PE_{fuel,y} + PE_{transport,y} + PE_{cultivation,y} + PE_{CH4,y}$$ Equation (30)

Where:

PE_y	=	Project emissions in year *y* (t CO_2e)
$PE_{elec,y}$	=	Project emissions due to electricity consumption in year *y* (t CO_2)
$PE_{fuel,y}$	=	Project emissions due to fossil fuels consumption in year *y* (t CO_2)
$PE_{transport,y}$	=	Project emissions from transportation of the biomass from the places of their origin to the biogas production site and where applicable, transportation Bio-CNG from biogas plant to filling stations where it is used by final consumers in year *y* (t CO_2)
$PE_{cultivation,y}$	=	Project emissions from biomass cultivation in a dedicated plantation in year *y* (t CO_2e)
$PE_{CH4,y}$	=	Project emissions due to the physical leakage of methane from the systems affected by the project activity for production, processing, purification, compression; storage and filling of the Bio-CNG in year *y* (t CO_2e)

5.3.1. Calculation of $PE_{elec,y}$

The emissions include electricity consumption (including auxiliary use) $PE_{elec,y}$ associated with the operation of Bio-CNG plant, calculated as per the parameter $PE_{EC,y}$ in the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”.

5.3.2. Calculation of $PE_{fuel,y}$

The emissions include fossil fuel consumption (including auxiliary use) $PE_{fuel,y}$ associated with the operation of Bio-CNG plant, calculated as per the parameter $PE_{FC,j,y}$ in the “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”, where each combustion processes *j* in the tool should correspond to one of the fossil fuel consumption sources of the plant.

In cases where it is demonstrated that the energy requirements of the biogas production and treatment system and Bio-CNG plant are met only by renewable energy source the values of $PE_{elec,y}$ and $PE_{fuel,y}$ are considered as zero.

5.3.3. Calculation of $PE_{transport,y}$

Project emissions from transportation of the biomass and/or waste organic matters from the places of their origin to the biogas production site and where applicable, transportation Bio-CNG from biogas plant to filling stations where it is used by final consumers have to be accounted following the procedures in “AMS-III.AK: Biodiesel production and use for transport applications” if the transportation distance is more than 200 km, otherwise they can be neglected.

5.3.4. Calculation of $PE_{cultivation,y}$

If the project activity utilizes biomass sourced from dedicated plantations, project emissions from biomass cultivation shall be calculated as per the methodological tool “Project emissions from cultivation of biomass”.

5.3.5. Calculation of $PE_{CH4,y}$

Project emissions associated with the physical leakage of methane from the systems affected by the project activity are calculated as follows:

$$PE_{CH4,y} = PE_{AD,y} + PE_{Bio-CNG,y} \quad \text{Equation (31)}$$

Where:

$PE_{AD,y}$	=	CH_4 leakage emissions from the anaerobic digesters in year *y* (t CO_2e)
$PE_{Bio-CNG,y}$	=	Project emissions of CH_4 from biogas and Bio-CNG processing, upgrading, purification, compression, storage and transportation (leaks and dissolved in wastewater) in year *y* (t CO_2e)

5.3.6. Methane emissions from physical leakage emissions from the anaerobic digesters ($PE_{AD,y}$)

Methane emissions due to physical leakages from the digester and recovery system ($PE_{AD,y}$) shall be estimated using a default factor of 0.05 m³ biogas leaked/m³ biogas produced. For ex ante estimation the expected biogas production of the digester may be used, for ex post calculations the effectively recovered biogas amount shall be used for the calculation.

5.3.7. Methane emissions from physical leakage due to the biogas treatment system ($PE_{Bio\text{-}CNG,y}$)

The following project emission sources shall be determined as per the relevant procedures in annex 1 of “AMS-III.H: Methane recovery in wastewater treatment”:

Methane emissions from the discharge of the upgrading equipment are determined;

Fugitive methane emissions from leaks in compression equipment;

Methane emissions due to the vent gases from upgrade equipment;

Methane emissions related to physical leakage from filling operations shall be computed as per the procedures for calculating emissions from compressor leaks as per paragraph 32 b) above;

Where applicable methane emissions associated with the physical leakage of the upgraded biogas from the dedicated pipelines;

Where applicable methane emissions due to physical leakage from Bio-CNG/biogas filled bottles (e.g. mobile cascades) which are used for the storage and transportation of Bio-CNG/biogas.

The digested residue waste leaving the reactor shall be treated aerobically, and disposed in land properly, such as to avoid methane emissions. If disposed under anaerobic conditions (e.g. landfill) the methane emissions shall be estimated and discounted as project emissions following the relevant provisions in “AMS-III.AO: Methane recovery through controlled anaerobic digestion”.

5.4. Leakage

Leakage emissions $LE_{BIOMASS,y}$ due to competing use of biomass shall be accounted for as per the approved “General guidance on leakage in biomass project.

The substitution of Bio-CNG for CNG from fossil origin reduces indirect (“upstream”) emissions associated with the production of fossil CNG and is treated as negative leakage $LE_{PROCESS,y,CNG}$ that can be calculated as per the latest approved version of the tool “Upstream leakage emissions associated with fossil fuel use”.

The substitution of Bio-CNG for gasoline reduces indirect (“upstream”) emissions associated with the production of gasoline and is treated as negative leakage $LE_{PROCESS,y,GAS}$ (leakage emissions related to production and refining of the gasoline) that can be calculated using the latest approved version of the tool “Upstream leakage emissions associated with fossil fuel use”.

Negative leakage emissions related to the avoided production of fossil fuel (CNG, gasoline) (t CO_2/yr) shall be calculated as per the equation below:

$$LE_{PROCESS,y,FF} = LE_{PROCESS,y,CNG} + LE_{PROCESS,y,GAS}$$ Equation (32)

Where:

$LE_{PROCESS,y,FF}$	=	Leakage related to the avoided production of fossil fuel (t CO_2/yr)

5.5. Emission reductions

The emission reductions achieved by the project activity shall be calculated as the difference between the baseline emissions and the sum of the project emissions and leakage.

$$ER_y = BE_y - PE_y - LE_{BIOMASS,y} + LE_{PROCESS,y,FF}$$ Equation (33)

Where:

ER_y	=	Emission reductions in the year *y* (t CO_2e)

6. Monitoring methodology

Relevant parameters shall be monitored as indicated in the Tables below.

Parameters for determining project emissions from biomass cultivation shall be monitored as per relevant provisions of “AMS-III.T: Plant oil production and use for transport applications”.

Parameters for calculating methane emissions from physical leakage of methane from the systems affected by the project activity for production, processing, purification, compression; storage and filling of the Bio-CNG shall be monitored as per the procedures prescribed in AMS-III.H.

Parameters for establishing methane emissions from residue waste disposed under anaerobic conditions shall be monitored as per relevant procedures of AMS-III.AO.

The applicable requirements specified in the “General guidelines for SSC CDM methodologies” (e.g. calibration requirements, sampling requirements) are also an integral part of the monitoring guidelines.

Evidence shall be provided to demonstrate that the modification of gasoline vehicles has been implemented.

In the case of approach 2, the filling stations must be equipped with the following devices/systems:[33]

[33] The PPs are encouraged to propose a revision of the methodology for allowing/including other alternative procedures.

Automatic Number Plate Recognition (ANPR); or Electronic Vehicle Identification (EVI);

Automatic locking and unlocking function of dispenser directly controlled by equipped device/system responsible for project vehicle identification to ensure that all the Bio-CNG that is produced is only consumed in the project vehicles;

System for logging of the data on quantity of Bio-CNG filled into identified project vehicles;

Natural gas analyzer capable of analysing ethane and propane to ensure that the gas delivered to the vehicle by the dispenser does not contain ethane or/and propane.

6.1. Parameters to be monitored

Data / Parameter table 11.

Data / Parameter:	$FC_{Bio\text{-}CNG,k,y}$
Data unit:	t
Description:	Bio-CNG consumed by the project vehicle *k* in the year *y*
Measurement procedures (if any):	Measurements of the amount of Bio-CNG filled into vehicles of the end users are undertaken using calibrated meters at the filling station site. Measurements results shall be cross-checked with production and sales data
Monitoring frequency:	Continuously
Any comment:	-

Data / Parameter table 12.

Data / Parameter:	$FS_{Bio\text{-}CNG,y}$
Data unit:	t
Description:	Amount of Bio-CNG distributed/sold directly to retailers, filling stations by the project activity in year *y*
Measurement procedures (if any):	Measurements of the amount of Bio-CNG distributed/sold to retailers/filling stations are undertaken using calibrated meters at the delivery section of Bio-CNG production site. Measurements results shall be cross checked with records for sold amount (e.g. invoices/receipts) and with the amount of biogas produced
Monitoring frequency:	Continuously or in batches
Any comment:	-

Data / Parameter table 13.

Data / Parameter:	$FP_{Bio\text{-}CNG,y}$
Data unit:	t
Description:	Quantity of the Bio-CNG produced by the project activity in the year *y*
Measurement procedures (if any):	Measurements are undertaken using calibrated meters at the outlet of the biogas upgrading section of the Bio-CNG production site
Monitoring frequency:	Continuously
Any comment:	-

Data / Parameter table 14.

Data / Parameter:	**$NCV_{Bio-CNG}$**
Data unit:	GJ/t
Description:	Net calorific value of Bio-CNG
Measurement procedures (if any):	Measured according to relevant national/international standards through sampling. Analysis has to be carried out by accredited laboratory
Monitoring frequency:	Monthly or as prescribed by the applied national/international standard
Any comment:	-

Data / Parameter table 15.

Data / Parameter:	**NCV_i**
Data unit:	GJ/t
Description:	Net calorific value of gasoline/blended gasoline that was used by project vehicle *k*
Measurement procedures (if any):	Measured according to relevant national/international standards. Analysis has to be carried out by accredited laboratory
Monitoring frequency:	At the validation, and annually during the crediting period
Any comment:	-

Data / Parameter table 16.

Data / Parameter:	**$w_{CH4,y}$**
Data unit:	%
Description:	Methane content in the Bio-CNG
Measurement procedures (if any):	The fraction of methane in the gas should be measured with a continuous analyzer or, alternatively, with periodical measurements at a 90/10 sampling confidence/precision level. It shall be measured using equipment that can directly measure methane content in the biogas - the estimation of methane content of biogas based on measurement of other constituents of biogas such as CO_2 is not permitted. The methane content measurement shall be carried out at the location where $FP_{Bio-CNG,y}$ is measured
Monitoring frequency:	Continuous/periodic
Any comment:	-

Data / Parameter table 17.

Data / Parameter:	**$f_{FO,gasoline}$**
Data unit:	%
Description:	Fraction of gasoline from fossil fuel origin in the displaced gasoline
Measurement procedures (if any):	As per the following options (in preferential order): (i) Data from the supplier of the gasoline; (ii) If it accrues to national regulations requiring mandatory blending of biofuels, the regulatory blend fraction may be used; (iii) If measured, it shall be according to relevant national/international standards through sampling
Monitoring frequency:	Continuously or in batches
Any comment:	-

6.2. Project activity under a programme of activities

The methodology is applicable to a programme of activities.

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Document information

Version	*Date*	*Description*
02.0	1 June 2014	EB 79, Annex 17 Revision to: (a) Expand the applicability of the methodology to: (i) Use of Bio-CNG in modified diesel vehicles; (ii) Injection of biogas into natural gas grid; (b) Include a reference to the methodological tool "Project emissions from cultivation of biomass".
01.0	26 November 2010	EB 58, Annex 18 Initial adoption.

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