CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-PDD)
Version 03 - in effect as of: 28 July 2006

CONTENTS

SECTION A. General description of project activity

A.1. Title of the project activity:

Daegu Metro 3[th] Urban Railroad
Version 1.3
21/06/2012

A.2. Description of the project activity:

The objective of the project is the establishment and operation of an efficient, safe, rapid, convenient, comfortable and effective modern mass transit system with high ridership capacity linking Chilgok to Beommul in Daegu, Korea. The metropolitan city of Daegu had around 2.5 million inhabitants in the year 2010[1]. The Mass Rapid Transit System (MRTS) proposed is a fully elevated monorail with a length of 24 km and 30 stations expecting to transport in the first operational year around 84 million passengers. The MRTS line will be extended by a total of 4 km until the year 2031[2]. Construction of the metro started 30/06/2009 and the operational start is expected for the year 2015. The project is the third MRTS line in Daegu. Lines 1 and 2 both started construction prior to the year 2000 and are both operational[3]. Line 3 is a critical element as it runs N-S and therefore increases considerably the city coverage as lines 1 and 2 both run E-W(see section A.4.1.4. Map 2) thus making the entire MRTS system more attractive to inhabitants while reducing the necessity of building new roads[4].

The owner of the system is the Daegu Metropolitan City. The MRTS is constructed by the Daegu Urban Railroad Construction Headquarters which is specialized in the construction of rail systems in Daegu in accordance with the Urban Railway Act. The Daegu Urban Railroad Construction Headquarters is an entity of Daegu Metropolitan City. The Daegu Metropolitan City Urban Railroad Construction HQ has been designated by the Daegu Metropolitan City as the Project Participant. Daegu Metropolitan Transit Corporation is the MRTS operator. Daegu Metropolitan Transit Corporation is a Public Corporation established by Daegu Metropolitan City[5].

The geographical boundary of the project is the Metropolitan area of Daegu. Gases included are CO_2 and CH_4.

The **baseline situation** is a continuation of traditional modes of transport including buses, taxis, private cars, motorcycles and bicycles. As of 2009 Daegu had slightly more than 1 million vehicles including around 680,000 private cars, 17,000 taxis, 1,700 buses, and around 110,000 motorcycles[6]. In absence of the project the passengers move from their trip origination to their trip destination by buses, by taxis, by passenger cars, by the existing lines of metro and by NMT (Non Motorized Transport). In the baseline situation these modes of transport would continue to operate and transport passengers from their trip origin to their trip destination. The baseline scenario is comparable to the situation prior to the project. The baseline scenario however incorporates technological advancements in terms of

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[1] http://english.daegu.go.kr/cms/cms.asp?Menu=28

[2] File 24, Chapter 1, table annual operational plan

[3] File 17

[4] File 20c, chapter 1.1 p.3

[5] File 21

[6] File 6a/b for buses ; all other vehicles file 18

emissions per distance driven of various modes of transport as well as eventual fuel changes of baseline modes of transport during the project activity.

In the **project situation** the metro complements other modes of transport and replaces partially trips made by conventional or traditional means of transit by metro, being a more efficient, faster, safer and more reliable transport means.

Emission reductions are achieved through reducing GHG emissions per passenger-kilometre, comparing conventional modes of transport with metro. The metro has as main environmental aspect that the resource efficiency of transporting passengers in Daegu is improved i.e. emissions per passenger kilometre are reduced compared to the situation without project. This is realized through following changes:

- Improved efficiency: metro has lower GHG emissions per passenger-kilometre compared to other modes of transport used in absence of the project.
- Mode switching: The MRTS is more attractive to clients due to reduced transport times, increased safety and reliability. It can thus attract private car, taxi or bus users with higher emission rates to switch to MRTS.
- Load increase or change in occupancy: The MRTS has a centrally managed organisation dispatching trains not available in the current bus based mass transit system. The occupancy rate of vehicles can thus be increased due to organizational measures.

Environmental improvements are achieved through less GHG and other air pollutant emissions, specifically particle matter, SO_2 and NO_x. This is achieved through a more efficient transport system and through using electricity as energy source. See section D for major details.

The **social impact** of metro is basically improved social wellbeing as a result of less time lost in congestion, less respiratory diseases due to less particle matter pollution, and fewer accidents per passenger transported.

Expected is also an improved **economic performance** of the city basically due to less congestion and due to having a modern public transit system with its corresponding positive image. A monetary quantification of these benefits is complex and prone to discussions as developments of the same parameters also take place in absence of the project and a monetization of non-market traded benefits (e.g. estimation of the value of time savings) can lead to differing results depending on the approach used – nevertheless it is clear in a qualitative sense that the project contributes to economic benefits. Latter are basically public goods and cannot be captured effectively by metro through ticket charges as benefits are accrued by users as well as non-users of metro.

The project reduces on average 60,350 tCO_2 per annum in the crediting period.

A.3. Project participants:

Name of Party involved (*) ((host) indicates a host Party)	Private and/or public entity(ies) project participants (*) (as applicable)	Kindly indicate if the Party involved wishes to be considered as project participant (Yes/No)
Republic of Korea (host)	Daegu Metropolitan City Urban Railroad Construction HQ (public entity)	No
Republic of Korea (host)	South Pacific Inc. (private entity)	No
Switzerland	Grütter Consulting AG (private entity)	No

A.4. Technical description of the project activity:

A.4.1. Location of the project activity:

A.4.1.1. Host Party(ies):

Republic of Korea

A.4.1.2. Region/State/Province etc.:

Yeongnam

A.4.1.3. City/Town/Community etc.:

Daegu

A.4.1.4. Details of physical location, including information allowing the unique identification of this project activity (maximum one page):

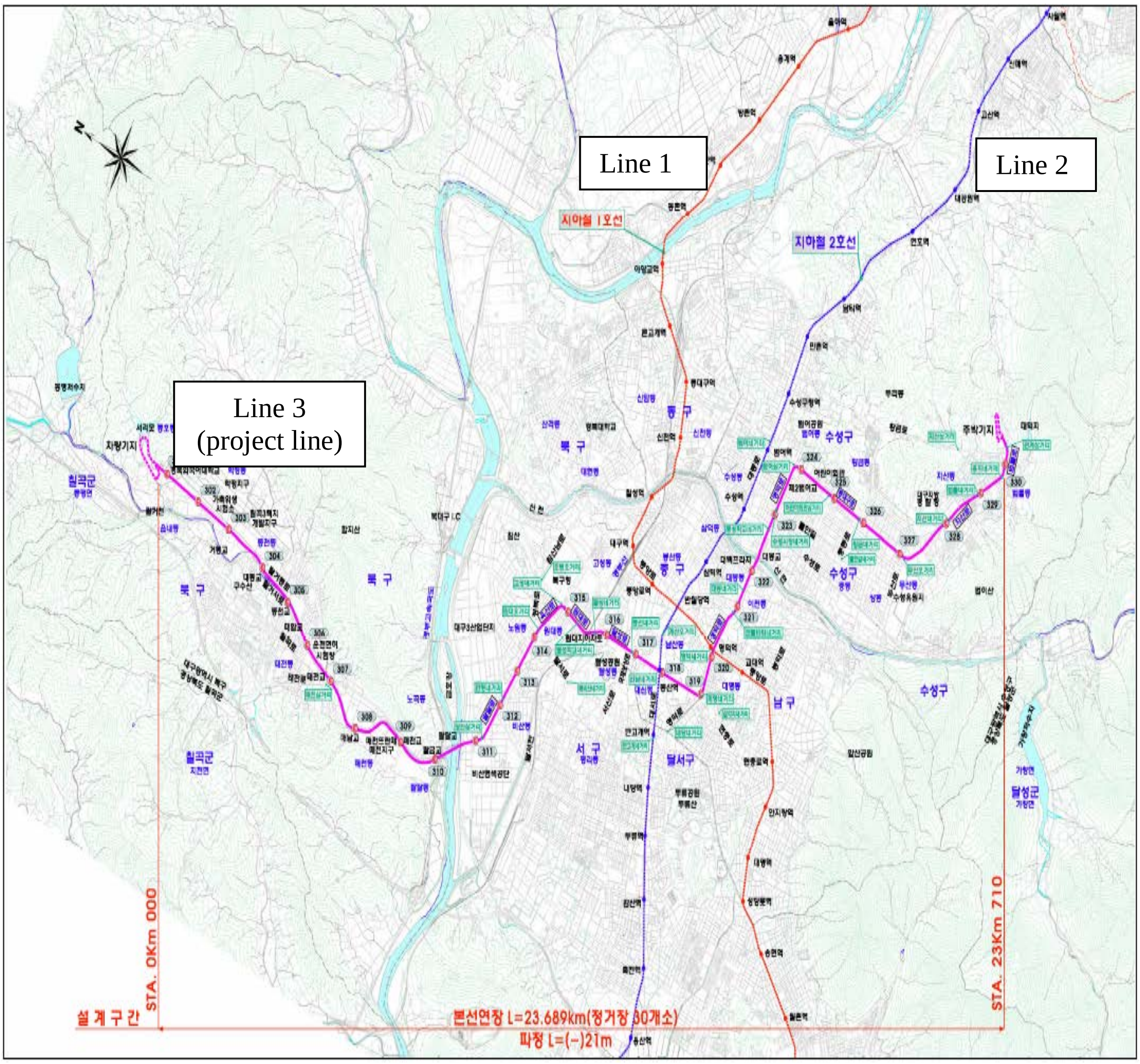
The spatial extent of the project is, according to the methodology, the Metropolitan City of Daegu. The spatial area includes the trip origins and destinations of passengers using the MRTS project line. The geographical coordinates of Daegu are 35°51’ North and 128°36’ East equivalent to Latitude 35.85 and Longitude 128.60.

Map 1: Project Location

Source: www.geology.com

Map 2 shows the project metro line.

Map 2: Project MRTS Line



Source: Daegu Metropolitan Urban Railroad Construction Headquarters, p.7 (File 19)

A.4.2. Category(ies) of project activity:

Sectoral scope 7: Transport as listed in the sectoral scopes for accreditation of the operational entities

A.4.3. Technology to be employed by the project activity:

To compare the pre-project with the project situation a description of the pre-project situation as well as of main features of the project is made.

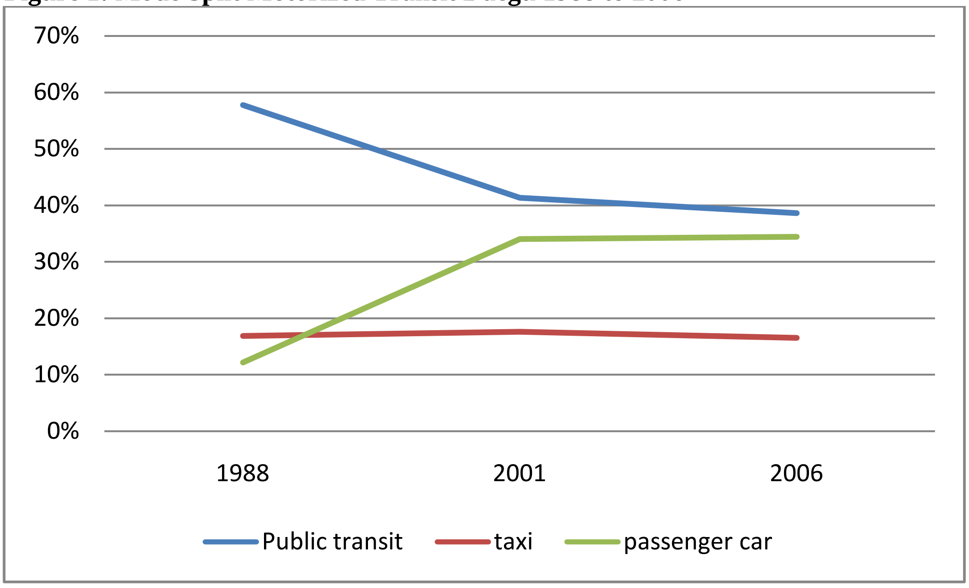
Pre-Project Situation

In absence of the project the passengers move from their trip origination to their trip destination by buses, by taxis, by passenger cars, by motorcycles, by the existing 2 MRTS lines and by NMT (Non Motorized Transport). The CDM project replaces partially these trips by using, at least for part of the

trip, a more efficient, faster, safer and more reliable transport means. The baseline scenario is comparable to the situation prior the project. The baseline scenario however incorporates technological advancements in terms of emissions per distance driven of various modes of transport as well as eventual fuel changes of baseline modes of transport during the project activity.

While the population of Daegu Metropolitan City is stagnant[7] the number of registered cars is increasing resulting in an annual increase of 3.4% of the motorization rate with a rate of 281 passenger cars per 1,000 inhabitants in the year 2009[8]. Thus it is also not surprising that the model split of trips realized is shifting in direction of passenger cars and away from public transit. Between 1988 and 2006 the share of public transit in trip modes has decreased by 19 percentage points from 58% to 39% while the one of cars has increased from 12% to 34% (see Figure below)[9]. This trend away from public towards private means of transit is still continuing - albeit at a reduced rate - since the introduction of the 2 rail-based MRTS lines. The metro lines have as of 2006 a mode share of 7% while buses are still by far the most important means of public transit with a mode share of 32%.

Figure 1: Mode Split Motorized Transit Daegu 1988 to 2006[10]



Source : Based on passenger trips; KOTI for 1988 and Daegu Metropolitan City for 2001 to 2006 data (File 23)

Project System

The initial length of the project metro track is 24 km, with 30 stations. It is planned to extend the line in parts of 1 km with a total extension of 4 km reaching a total line length of 28 km by the year 2031[11]. The metro is fully elevated with distances between stations of 600 to 1,256 m (majority between 700 and 900m)[12]. The peak hour demand expected for the year 2021 is around 7,000 phd (passenger per

[7] File 22 Table 2.1

[8] File 22 Table 2.3

[9] File 23

[10] Excluding other modes

[11] File 24, Chapter 1, table annual operational plan

[12] File 24, chapter 1, stations after change (row 435ff)

hour and direction)[13] which shall be covered through a monorail with 3 carriages running at intervals of 3.5 minutes[14]. The design capacity of the monorail is around 16,000 passengers with a headway of 1.5 minutes and with 4 carriages (see table below). The project projects to have until 2019 some 34 trains totalling 102 carriages[15]. The following two tables show some salient features of the metro.

Table 1: Features of Metro

Feature	Data	Source
Train type	Monorail, metal structure with 3 carriages 15.8 x 2.9 m front and end carriage and 14.6 x 2.9 m middle carriage	File 24, chapter 1, row 749
Track Gauge width	850 mm	File 60
Train capacity	265 passengers (full) and 398 crowded (150% of full)	File 24, chapter 1, row 768
Train capacity with a headway of 1.5 minutes	16,000 passengers with 4 carriages	File 24, chapter 1, row 790
Average scheduled speed	30 km/h	File 24, chapter 1, row 819
Maximum operating speed	70 km/h	File 60
Stoppage time	20 seconds	File 24, chapter 1, row 822

Map 2 in section A.4.1.4. shows the existing metro lines and the project line 3.

The metro has following core features:

- ATC (Automatic Train Control): The ATC system controls the train movement, increases safety, and operates a train directly. The ATC system consists of ATO (Automatic Train Operation), ATP (Automatic Train Protection) and ATS (Automatic Train Supervision).
- ATP (Automatic Train Protection): The ATP system is responsible for the safety of train operations. It protects passengers from various incidents such as unstable train movement, unexpected door opening, wrong traffic signals, speed excess etc. The ATP system has the following features.
    - Train Monitoring system.
    - Keeping a safe distance between each train.
    - Detection of damaged tracks and faults.
    - Restrict the train speed.
    - Brakes are applied if the driver fails to respond to the warnings.
- ATO (Automatic Train Operation): The ATO is capable of operating trains automatically, including starting and stopping, speed adjustment, as well as opening and closing the doors.
- ATS (Automatic Train Supervision): The ATS supervises the real-time status of moving trains, including the distance between each train, and sends orders from the control center to each train operator.

Daegu Metro Line 3 is based on automated railway system. For the main track and railway depot track operation will be operated by the ATP/ATO system. The automated control center will be controlled by number of officials for opening and closing of the entire system and control of unexpected accidents.

[13] File 20c, Table 1.3.2.

[14] File 20c, Table 1.3.5.

[15] File 24, Chapter 1, table annual operational plan (row 145ff)

The project does not involve technology transfer.

A.4.4. Estimated amount of emission reductions over the chosen crediting period:

Years	**Annual estimation of emission reductions in tCO_{2eq}**
2015	56,069
2016	57,448
2017	58,855
2018	60,288
2019	61,751
2020	63,259
2021	64,781
Total estimated reductions 1st crediting period (tonnes of CO_{2eq})	**422,451**
Total number of crediting years (1st crediting period)	7
Annual average over the crediting period of estimated reductions (tCO_{2eq})	**60,350**

A.4.5. Public funding of the project activity:

There is no Official Development Assistance in this project and the project will not receive any public funding from Parties included in Annex I.

SECTION B. Application of a baseline and monitoring methodology

B.1. Title and reference of the approved baseline and monitoring methodology applied to the project activity:

ACM0016: Baseline Methodology for Mass Rapid Transit Projects; Version 2.0

This methodology also refers to the latest approved version of the following tools:

- "Tool for the demonstration and assessment of additionality", Version 05.2.1
- "Tool to calculate baseline, project and/or leakage emissions from electricity consumption", Version 01

B.2. Justification of the choice of the methodology and why it is applicable to the project activity:

This methodology applies to project activities that establish and operate a Mass Rapid Transit System.

Table 2 relates the specific baseline methodology applicability conditions with the proposed project.

Table 2: Applicability Conditions

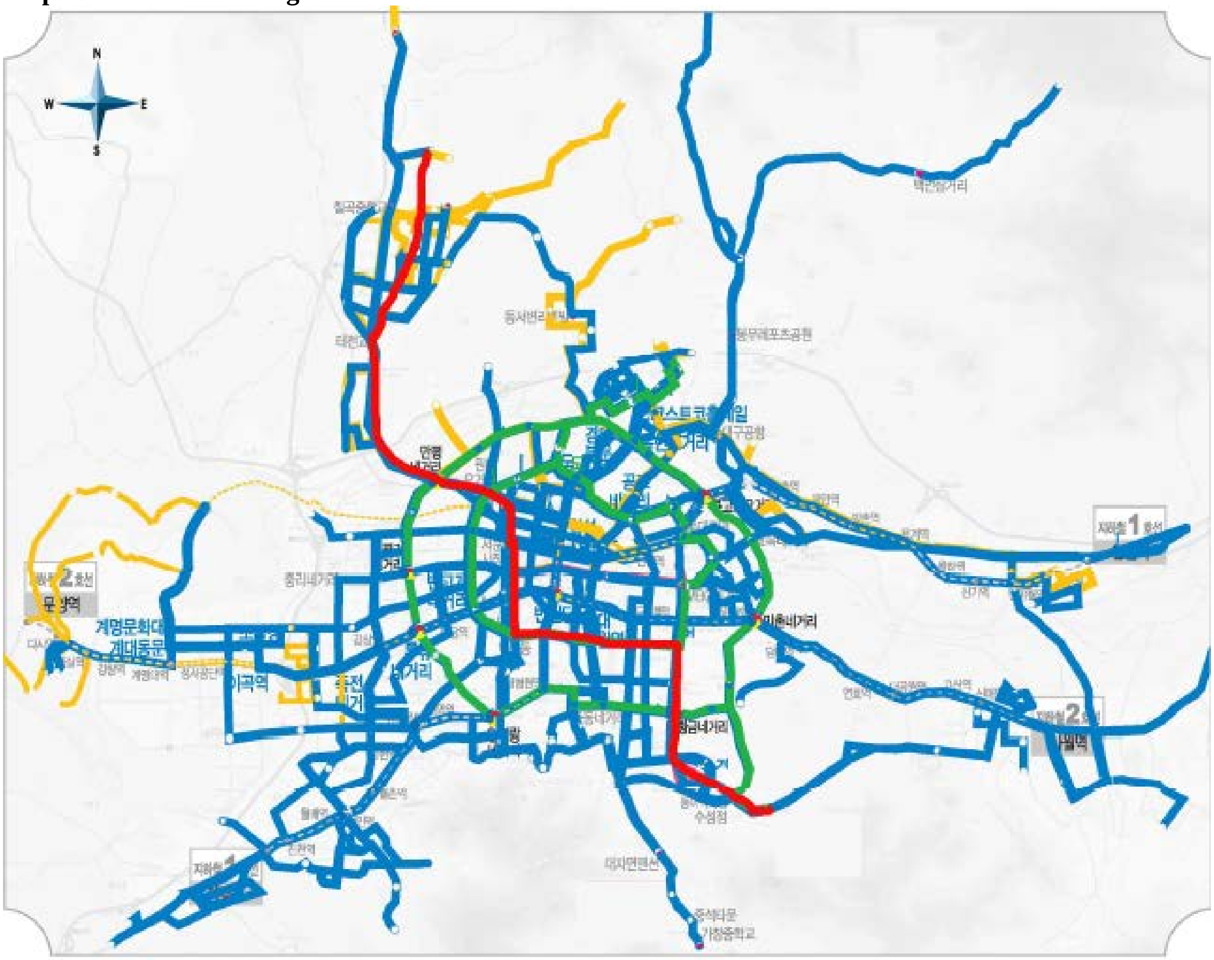
Applicability condition	**Project situation**
The project constructs a new rail-based infrastructure or segregated bus lanes. In the case of rail systems the project needs to provide new infrastructure (new rail lines).The segregated bus lanes or the rail-based MRTS replace existing bus routes operating under	The MRTS is new rail-based mass transit system. The rail infrastructure is new. The bus system is re-structured once the metro is operational. Re-structuring during construction and years prior operation makes no sense as bus routes change over

mixed traffic conditions.	time. This approach was followed by metro Line 2 (operational start 10.2005). Daegu Metropolitan City removed in the year 2006 bus routes overlapping with the metro line 2. Initially overlapping lines were identified with an overlapping rate. This included in total 15 lines. The 5 lines which overlapped Metro Line 2 by around 50% or more where thereafter eliminated i.e. they no longer operate[16]. The same approach is proposed to be used once the metro line 3 is near to entering operations.
The methodology is not applicable for operational improvements (e.g. new or larger buses) of an already existing and operating bus lane or rail-based MRTS.	The MRTS is a new metro with new infrastructure.
The methodology is not applicable for bus lanes replacing an existing rail-based system.	The MRTS is rail-based and not a bus lane.
The methodology is applicable for passenger transport only.	The MRTS is a passenger transport system
Any fuels including electricity, (liquefied) natural gas and biofuel blends can be used in the baseline or project case. • In case of natural gas, the methodology is applicable if equal or more natural gas is used in the baseline than in the project case. The methodology is not applicable in its current form if more natural gas is used in the project compared to the baseline case. • In the case of biofuels, project buses must use the same biofuel blend (same percentage of biofuel) as commonly used by conventional comparable urban buses in the country.	Baseline transport fuels are diesel, gasoline and gaseous fuels. No bio-fuels are used in the baseline or project case[17]. The project uses electricity. Thus more natural gas is used in the baseline than in the project case as passengers switch partially from buses and taxis which use partially gaseous fuels to metro.
The methodology is not applicable for the implementation of air and water-based transport systems.	No air or water-based transport system is implemented. The MRTS is rail based.
The project system partially replaces a traditional public transport system in a given city. The methodology cannot be used in areas where currently no public transport is available.	The MRTS replaces partially traditional bus trips. Public transport is currently available in the project area. Bus routes are existent in the area where the metro line will be established (see map below). Their replacement is discussed in point 1 of the applicability conditions.
The methodology is applicable for urban or suburban trips. It is not applicable for inter-urban transport.	The MRTS is for urban or suburban trips.
The methodology is only applicable if the application of the procedure to identify the baseline scenario results in that a continuation of the current public transport system is the most plausible baseline scenario.	The identified baseline is a continuation of the current urban transit system (see section B.4).

[16] File 25

[17] Korea has regulations which promote the usage of biofuels specifically B20 (File 27 and 28) for diesel but on a voluntary base and the market is not (yet) selling this product (File 29). The public transportation system currently uses no biofuel – see confirmation letter File 65.

Map 3: Bus Services Daegu



Project Metro Line Bus Routes Circular Bus Route Intercity Bus Routes

Source: Daegu Metropolitan City

All applicability conditions for using the methodology are thus fulfilled.

B.3. Description of the sources and gases included in the project boundary:

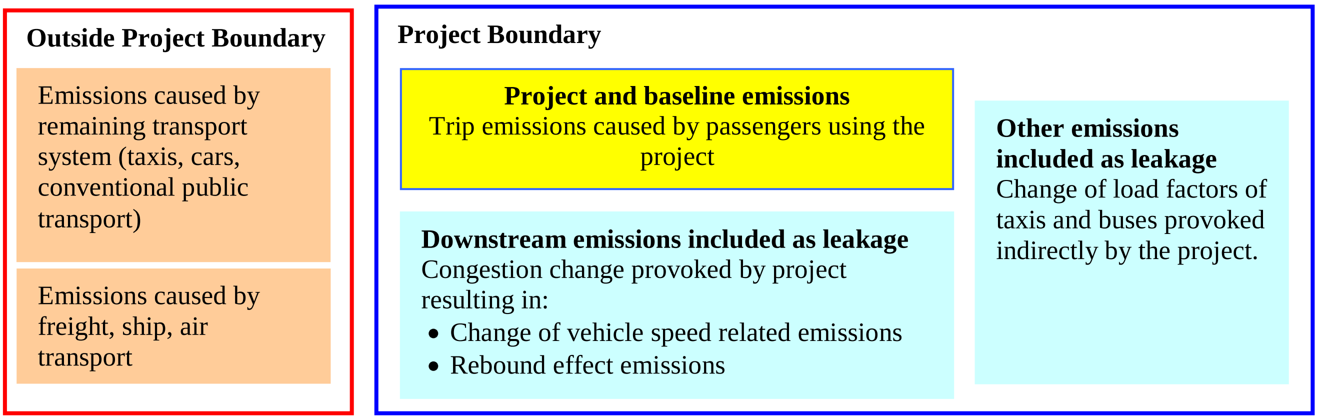
The spatial extent of the project boundary encompasses the Metropolitan City of Daegu. It is based on the origins and destinations of passengers using the project system. As the project cannot control the trip origins or destinations of passengers, the spatial area of the project is the entire Metropolitan City in which the project operates.

For a map of the metro line see Map 2. The metro will have 30 stations. Station names have not yet been determined.

The project boundary also includes the power plants connected physically to the electricity system that supply power to the project. Please refer to Tool to calculate baseline, project and/or leakage emissions from electricity consumption.

The conceptual project boundary is outlined in Figure 2.

Figure 2: Conceptual Project Boundary



The greenhouse gases included in or excluded from the project boundary are shown in Table 3.

Table 3: Emissions Sources Included in or Excluded from the Project Boundary

Source		Gas	Included?	Justification / Explanation
Baseline	Mobile source emissions of different modes of transport for passengers using MRTS	CO_2	Yes	Major emission source
		CH_4	Yes	Included for gaseous fuels used. For liquid fuels vehicle tailpipe CH_4 emissions are excluded. Combined CH_4 and N_2O emissions make in diesel/gasoline vehicles less than 2% of total CO_{2eq} emissions. Its omittance in baseline as well as project emissions is conservative as fuel consumption and thus also CH_4 emissions are reduced through the project.
		N_2O	No	Combined CH_4 and N_2O emissions make in diesel/gasoline vehicles less than 2% of total CO_{2eq} emissions. Its omittance in baseline as well as project emissions is conservative as fuel consumption and thus also N_2O emissions are reduced through the project
Project activity	Project transport system (MRTS)	CO_2	Yes	Major source
		CH_4	No	Not included as MRTS does not use gaseous fuels.
		N_2O	No	See argument above.
	Mobile source emissions of different modes of transport for passengers using MRTS from trip origin to MRTS and from MRTS to trip destination	CO_2	Yes	Major source
		CH_4	Yes	Included for gaseous fuels used. See argument above.
		N_2O	No	See argument above.
Leakage	Emissions due to changes of the	CO_2	Yes	Major emission source
		CH_4	Yes	Included for gaseous fuels used. See argument above.

	load factors of taxis and conventional buses; and due to Congestion change (incl. change of vehicle speed and induced traffic (rebound effect))	N_2O	No	See argument above.

B.4. Description of how the baseline scenario is identified and description of the identified baseline scenario:

BASELINE IDENTIFICATION

Step 1: Identification of alternative scenarios to the proposed CDM project activity that are consistent with current laws and regulations

All options are identified that meet the same requirement as the proposed project activity. Alternatives assessed are public transport systems which are complemented with other modes of transport such as passenger cars, taxis, motorcycles, and non-motorized transport:

- The establishment of a BRT (Bus Rapid Transit);
- The establishment of a different rail-based MRTS;
- The continuation of the current public and individual transport systems, including (future) investments in road based infrastructure if applicable;
- The proposed project activity being implemented at a later date in the future, without being registered as a CDM project activity;
- The project proposal not implemented as a CDM project activity.

All alternatives are consistent with current laws and regulations. This is reflected in the realization of feasibility reports for all possible alternatives.

Step 2: Assessment of Options

The analysis of options identified in Step 1 is based on the "Tool for the demonstration and assessment of additionality".

ALTERNATIVE 1: ESTABLISHMENT OF A BRT

Daegu has already established 2 metro lines. Therefore for passenger convenience it is easier to establish further metro lines than to establish a BRT. The feasibility of a BRT was studied, however the city decided to realize a rail-based MRTS and discussed the various alternatives of a rail-based MRTS in a specific study (see Alternative 2).

BRTs due to their limited phd capacity are also basically used for secondary lines in large metropolitan cities in which a rail-based MRTS have already been established (see e.g. Seoul, Delhi, Beijing, Mexico City). The design capacity of the monorail is around 16,000 passengers with a

headway of 1.5 minutes and with 4 carriages[18]. The table below list the capacity of BRT in terms of passenger per hour per direction.

Table 4: BRT Capacity Passenger-Hour Direction[19]

BRT Project	Phd
Ahmedabad, India	1,000
Amsterdam, Netherlands	1,000
Bangkok, Thailand	1,000
Beijing, China	4,000
Bogota, Colombia	42,000
Brisbane, Australia	7,000
Bucaramanga, Colombia	10,000
Cali, Colombia	12,000
Cartagena, Colombia	14,000
Changzhou, China	7,000
Dalian, China	6,000
Guadalajara, Mexico	9,000
Guatemala City, Guatemala	12,000
Guangzhou, China	27,000
Hangzhou, China	7,000
Hefei, China	3,000
Jakarta, Indonesia	4,000
Jinan, China	3,000
Kunming, China	4,000
Medellin, Colombia	7,000
Mexico City, Mexico	6,000-15,000 (according to line)
Nagoya, Japan	1,000
Nantes, France	1,000
Pereira, Colombia	7,000
Quito, Ecuador	6,000
Seoul, Korea	**7,000**
Xiamen, China	8,000
Zaozhuang, China	1,000
Zhengzhou, China	6,000
Median	7,000
Range	1,000 – 42,000

Source: Colombian BRTs based on File 61, charts 3.78 (p. 224); 3.80 (p. 230); 3.92 (p. 237); 3.99 (p. 244); 3.105 (p. 249); 3.112 (p. 258); 3.121 (p. 265); BRT Guadalajara based on File 62; BRT Guatemala based on File 63; BRTs Mexico City based on PDD Metro Line 12, Mexico City table 4[20]; all others based on ITDP, 2011, see http://www.chinabrt.org/

Also the only operational Korean BRT in Seoul has a capacity of 7,000 passengers per hour and direction only. The capacity of the proposed metro line is more than double. While this capacity can technically be achieved it requires additional space (e.g. passing lanes at stations or overall double lanes i.e. 2 lanes in each direction like used in the trunk route with the highest passenger volume in Bogota). The alternative of a BRT is therefore not considered a feasible alternative basically due to additional space requirements to achieve the desired capacity.

[18] File 24, chapter 1, row 790

[19] Rounded to thousands; based on the BRT line with the highest phd if various lines operate

[20] http://cdm.unfccc.int/Projects/Validation/DB/L6XH6IVX9T82VDCYLXU0VM9ST9PGEJ/view.html

The city due to the fact of already having 2 operational rail lines with a 3rd line being fully compatible and the demanded passenger capacity has therefore opted against a BRT.

ALTERNATIVE 2: ESTABLISHMENT OF OTHER THAN PROJECT RAIL-BASED MRTS

Rail-based systems can be separated where they operate (underground, at level, elevated) or also based on criteria such as technology used[21]. Various rail-based systems including LRT, monorail etc. were studied. The different rail systems can all comply with the expected passenger demand[22]. In terms of projected construction investment the Monorail system is by far less expensive than all other rail alternatives studied with 22-31% lower construction investment required[23]. In terms of operational cost the Monorail is the most expensive system basically due to higher electricity and maintenance cost. Operational costs are between 4 and 25% higher than for other rail-based systems[24]. Monorail was finally considered the most appropriate system based on environmental, financial and technical criteria.[25]

ALTERNATIVE 3: CONTINUATION OF THE CURRENT SYSTEM INCL. FUTURE INVESTMENTS

A continuation of the current transport system complies with all applicable legal and regulatory requirements. A continuation of the current system has various advantages compared to all other options:

- No large-scale public investment requiring additional income/tax sources.
- Lowest technical and financial risk of all options.

The carrying capacity of the current public transport system is in line with the actual transport demand. Increasing passenger demand can be accommodated through the establishment of new routes using also alternate roads, which might imply potentially longer travel distances complying however with the purpose of transporting passengers from their trip origin to their trip destination. Also under business as usual the trend of decreasing mode share of public transit and increasing share of private transit would continue as through economic development more people have the means to acquire and maintain a vehicle and would also use their private vehicle if no modern mass transit system with the required level of convenience, speed and comfort is available. Additional transit demand might also lead to increased trip times due to increased congestion.

Also heavy investment in road infrastructure until the year 2020 is planned in Daegu Metropolitan City totalling 344 km of new or expanded roads with an investment of 8,270,000 million Wong[26] (in comparison the metro line is 24 km with a projected investment of 858,800 million Wong[27]). This shows clearly that investment in road-based transit is still far higher than for rail and that the road

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[21] See e.g. GTZ, File 38, p. 13, Box 2

[22] File 20 chapter 1.3.section 1

[23] File 20 chapter 1.3., table 1.3.7.

[24] File 20 chapter 1.3., section 2 p.23

[25] File 24b, chapter 1, row 131 and FSR File 20 chapter 1.3

[26] File 20c, table 2.1.6.

[27] File 20c, table 1.3.8.

system is being expanded rapidly thus allowing for traffic accommodation also in absence of any new MRTS without major difficulties.

ALTERNATIVE 4: THE PROJECT BEING REALIZED IN A LATER DATE WITHOUT CDM

No national or local policy mandates the implementation of a MRTS. The obstacles faced today of a new metro line, being basically of financial nature, would be the same or even worse in the future. If no MRTS is established now inhabitants of Daegu would continue investing in private means of transit like in the past where the number of registered cars is increasing resulting in an annual increase of 3.4% of the motorization rate with a rate of 281 passenger cars per 1,000 inhabitants in the year 2009[28]. Thus it is also not surprising that the model split of trips realized is shifting in direction of passenger cars and away from public transit (see Figure 1, section A.4.3.). This trend away from public towards private means of transit would continue. As shown above alsomore road infrastructure is built and the more people own cars the more difficult it becomes to get them back on public transit and to achieve high passenger demand corridors. The trend in cities, including Daegu, has been towards decreasing shares of public transit[29] thus making new MRTS not easier but more complex due to lack of passenger demand.

No regulations, laws or requirements exist that in the future MRTS need to built beyond general policy declarations which are however non-binding. A project realization in the future without carbon finance is thus not planned.

Implementing the metro in absence of carbon finance is also studied in Alternative 5.

ALTERNATIVE 5: THE PROJECT WITHOUT CDM

The implementation of the proposed project activity in absence of the CDM is considered as non-feasible due to financial reasons. The details are given in chapter B5 and are not repeated here to avoid duplication.

Step 2 thus identifies next to the baseline 2 alternatives: the project with and without CDM. These two alternatives are addressed in chapter B5. All other alternatives are not feasible.

Step3: Determination of the baseline scenario

If Step 2 results in more than one possible alternative baseline scenario, the most likely baseline scenario is the scenario with the lowest baseline emissions. Alternatives 1 (BRT), 2 (LRT), 4 (Future metro in absence of the CDM) and 5 (project without CDM) are not feasible. The most probable alternative in the future in absence of the project is therefore a continuation of the current transport system. This is thus the baseline for this project.

Baseline Scenario

Baseline emissions include the emissions that would have happened due to the transportation of the passengers who use the project activity, had the project activity not been implemented. This is differentiated according to the modes of transport (relevant vehicle categories) that the passengers

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[28] File 22 Table 2.3

[29] see File 31, table 12, p.28

would have used in the absence of the project. The baseline is a continuation of the current transport system consisting of various transport modes between which the population chooses:

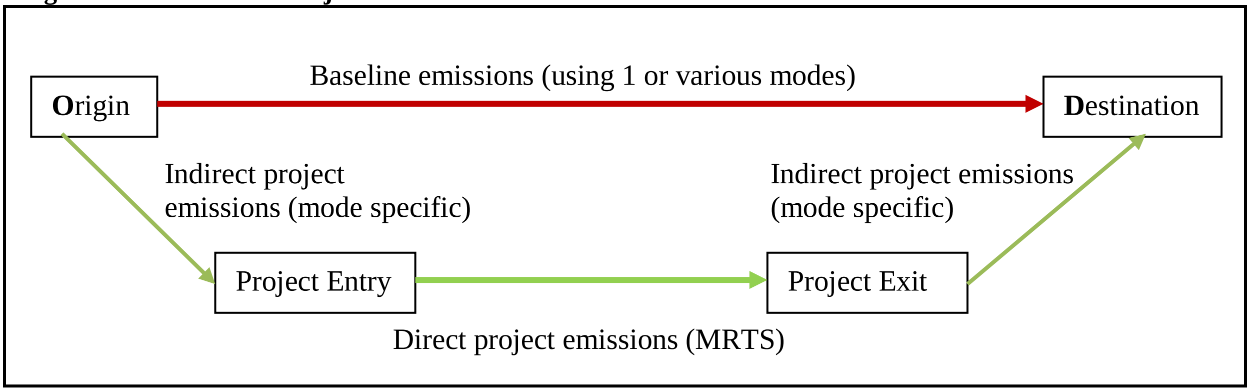
- NMT (Non-Motorized Traffic) with bikes and per foot;
- Private passenger car;
- Taxis;
- Motorcycles (two-wheelers);
- Buses;
- Existing metro network

The existing metro network does not compete with the proposed metro as it does not offer similar route destinations[30]. The project metro line is complementary to the existing metro lines which both run E-W while the new line runs N-S. However users of the metro may potentially realize in the baseline or in the project case part of their trip on the existing metro lines. This mode is thus included as a mode of transport. For all above listed transport modes the emissions per passenger kilometre (PKM) are calculated. To adjust for emission improvement under BAU, a technology improvement factor is applied to all road-based modes.

Baseline emissions are calculated per passenger surveyed. For each passenger surveyed the individual baseline emissions are calculated and multiplied with the individual expansion factor thus getting the baseline emissions of all passengers of the specific week surveyed.

Figure 3 gives an overview of baseline and project emissions, latter being differentiated in indirect and direct project emissions.

Figure 3: Baseline and Project Emissions



For formulas applied see section B.6.

B.5. Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered CDM project activity (assessment and demonstration of additionality):

The project starting date is defined in accordance with EB 41 Paragraph 67. The project starting date is the signature of the first construction contract being 29/06/2009[31]. Based on EB 62 Annex 13 “Guidelines on the demonstration and assessment of prior consideration of the CDM (version 4)” this

[30] See Map 2

[31] File 32

is a new project activity as the project starting date is after August 2^{nd} 2008 (chapter B guidelines). To demonstrate prior consideration the DNA and the UNFCCC must be informed within 6 months of project starting date of the intention to seek CDM status. The UNFCCC was informed as of 04/12/2009[32] and the Korean DNA as of 06/12/2009[33] i.e. the project has made prior consideration in accordance with the EB guidance.

The additionality of the project is determined using the "Tool for the demonstration and assessment of additionality".

STEP 1. IDENTIFICATION OF ALTERNATIVES TO THE PROJECT ACTIVITY CONSISTENT WITH CURRENT LAWS AND REGULATIONS

Sub-step 1a: Define alternatives to the project activity

All options are identified that meet the same requirement as the proposed project activity. Alternatives assessed are public transport systems which are complemented with other modes of transport such as passenger cars, taxis, motorcycles, and non-motorized transport:

1. The establishment of a BRT (Bus Rapid Transit);
2. The establishment of another rail-based MRTS:
3. The continuation of the current public and individual transport systems, including (future) investments in road based infrastructure if applicable;
4. The proposed project activity being implemented at a later date in the future, without being registered as a CDM project activity;
5. The project proposal not implemented as a CDM project activity.

Alternatives 1 and 2 have been assessed in chapter B.4. and have been discarded. Alternative 3 is the baseline situation. Alternative 4 has been discarded in chapter B4 respectively is identical with the alternative 5.

Following alternatives are thus credible, realistic and comparable:

1. Continuation of the current situation
2. Project without CDM

The options BRT, other rail-systems and the option project in the future without CDM are not considered credible, realistic or comparable alternatives as outlined in chapter B.4. They are thus eliminated in Step 1 and not further considered. Step 2 conducts an investment comparison analysis for all alternatives that are **remaining** after Step 1 in accordance with page 6 of ACM0016.

Step 2. Investment analysis

The investment analysis is realized by making the complete investment analysis as prescribed in ACM0016 based on the information as available for the project proponent prior project starting date.

ACM0016 p.6 states:" Conduct an investment comparison analysis for all alternatives that are remaining after Step 1. Use the NPV as indicator." The remaining alternatives are a continuation of the

[32] File 34, see http://cdm.unfccc.int/Projects/PriorCDM/notifications/index_html

[33] File 33

current baseline transport system and the metro in absence of the CDM. A continuation of the current baseline system involves a multitude of actors and modes of transport with private passenger cars, taxis, motorcycles, bikes and bus operators. While these realize investments in their modes of transport it is not only for the trips made by metro passengers. The project owner would not have to make specific investments in the baseline situation thus no comparable investment for the baseline alternative can be identified. The project alternative is a clear investment and the NPV with and without CDM is therefore calculated.

Based on the approved methodology following elements are taken into consideration when applying the investment analysis:

- The investment analysis is undertaken from the perspective of the operator of the public transportation system i.e. of Daegu Metropolitan City, reflecting the costs and revenues from the perspective of the operator.
- If the project is subsidized through public authorities (e.g. the central government), e.g. through grants which do not need to be repaid, the financial assessment is made including as investment the total system costs minus any such public subsidies. The central government subsidizes the investment cost by 60%[34].
- In applying the investment comparison analysis, cost overruns of former investments in MRTS or reduced revenues of former MRTS investments compared to original projections, which make new investments less viable and riskier are considered in the investment analysis.

Korea has experience with various metros in various cities. The following table shows the relation between expected and actual passenger numbers.

Table 5: Relation Expected to Actual Passenger Numbers of Korean Metros (1,000 passenger/day)

City/Line		Expected	Actual	%
Seoul	Line 5	2,410(2001)	827(2001)	34.3
	Line 6	1,319(2001)	284(2001)	21.5
	Line 7	2,363(2001)	703(2001)	29.8
	Line 8	557(2001)	222(2001)	39.9
	Total	6,649	2,036	
Busan	Line 1	1,932(2001)	544(2001)	28.2
	Line 2	1,782(2006)	230(2006)	12.9
	Line 3	276(2006)	65(2006)	23.6
	Total	3,990	839	
Daegu	Line 1	347 (2001)	138 (2001)	39.8
	Line 2	912 (2006)	125 (2006)	13.7
	Total	1,259	263	
Incheon		1,441(2003)	204(2003)	14.2
Gwangju		187(2004)	305(2004)	16.3
Daegjeon		91(2006)	42(2006)	46.2
Average relation actual to projected passenger numbers				**27 %**
Median relation actual to projected passenger numbers				**26 %**

Source: All cities/lines except Daegu Line 2 based on Inha University, 2006, table 17 (File 37); Daegu Line 2 for expected passenger number based on Daegu Metropolitan City Railroad Construction Headquarters and Daegu Metropolitan Transit Corporation for actual passenger numbers (File 40); median and average of all lines calculated by Grütter Consulting

[34] Files 35 and 36

Overall Korean metros only have on average 27% of expected passengers. This situation is idem for Daegu where the two lines on average also have 27% of passengers[35]. Also we cannot identify a trend towards improving projections. Daegu metro line 2 has performed significantly worse i.e. the projection has been more off-track, than Daegu metro line 1.

The experience of Korean metros with lower than expected passenger numbers is by no way singular: it's in fact the "normal" case in most metros worldwide. GTZ/ITDP (Institute for Transportation and Development Policy) states: „Higher cost options such as rail-technologies, also tend to demonstrate greater disparity between projected and actual costs" (p. 16) and also identify reasons for such cost overruns being economic self-interest, technological complexity and psychological factors. These factors are especially relevant for „projects that require tunneling, elevated structures, and advanced technology probably" (p.17)[36]. Similar results are obtained by other international studies in a recent report of Flyvberg looking at 22 urban rail projects where actual passenger demand is 51% lower than forecast with European projects having better forecasts than those of other world regions[37]. Only 2 out of 22 projects achieved the forecasted values. 75% of projects had 40% less passengers than forecasted. 25% of projects had at least 68% less passengers than forecasted. Flyvberg states: "In sum, for urban rail projects forecast ridership is routinely far from achieved. Low actual ridership combined with a high standard deviation show that uncertainty and risk are very high for ridership forecasts for urban rail. To the extent that ridership is the basis for revenues, which is almost always the case, then the high risk regarding ridership translates into an equally high economic risk. The figures show this risk should be taken very seriously in urban rail projects and should occupy a central place in preparing, deciding, and operating such projects."[38] and "The analysis of construction costs show that urban rail projects on average turn out substantially more costly than forecast. At the same time the analysis of ridership show urban rail to achieve considerably fewer passengers than forecast and thus lower revenues. Urban rail is therefore economically risky on two fronts, both as regards costs and as regards revenues. Urban rail is doubly risky and the possibilities for financing cost escalations incurred during construction through increased revenues from more passengers during operations will often be limited"[39]. The risk of having thus projections which are far off the reality is real and has been experienced by numerous comparable projects not only in Korea.

For this reason the financial analysis is realized with a base case of 30% of expected passengers in line with ACM0016 but also showing the variation of passenger number versus NPV for a range of cases. The magnitude of the risk adjustment is evidenced by the host country experience and is plausible in the international context of metros. While CDM cannot eliminate this problem of projections it can alleviate the financial risk involved with wrong projections and can thus make metros more sustainable and feasible from a financial perspective.

The guidelines for the investment analysis Version 5EB 62 Annex 5 are followed. The financial / economic indicator chosen is the NPV in accordance with the methodology. The principles used for all calculations and their compliance with EB guidance is shown in the following table.

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[35]Average of the two relations actual to projected passenger numbers i.e. not weighted per passenger numbers

[36] File 38

[37] File 39 table 4, p.16

[38] File 39, p.18

[39] File 39, p.18/19

Table 6: Investment Principles and EB Guidelines

EB Guideline[40]	Project
Points 1 and 2: General introduction of Guidance	
Point 3: Period of assessment	The period of assessment taken is 30 years of operation plus the construction period in line with the assessment made by the Ministry of Land, Transport and Maritime Affairs, 2008, chapter 4, assumptions (File 24b). This is a longer period than the maximum period suggested in the guidelines and thus conservative.
Point 4: Salvage value	No salvage value is included as this is considered the technical life span of the rolling stock as well as communication and energy system in line with other metros[41]. Construction and stations can have a longer time period but also need repairs and overhauls. Also the project is only including 40% of total investment as 60% is treated as subsidy from the Central Government.
Point 5: Depreciation and other non-cash items	The NPV is based on cash flow and does not include depreciation or other non-cash items.
Point 6: Time of assessment	All calculations are based on a report realized by the Ministry of Land, Transport and Maritime Affairs in May 2008 (File 43 and full in File 24) prior to the investment decision 22/05/2009 (File 42) which again is prior to the project starting date of 29/06/2009 (File 32)
Point 7: Cesation of implementation	Not relevant for project
Point 8: Provision of spreadsheet	Spreadsheet is provided (File 41)
Point 9: Finance expenditures	Financing expenditures are not included when calculating the NPV.
Point 10: Equity IRR	Not used by project as ACM0016 requires the usage of NPV.
Point 11: Pre-tax benchmark	The project uses NPV with a benchmark for the discount rate based on the Ministry of Land, Transport and Maritime Affairs, 2008, chapter 4, assumptions (File 24b)
Point 12-18: Selection of benchmark	ACM0016 explicitly asks for a NPV. The financial/economic indicator chosen is thus the NPV in accordance with the methodology. The discount rate is from Ministry of Land, Transport and Maritime Affairs, 2008, chapter 4, assumptions (File 24b) In accordance with ACM0016 which states that when applying the investment comparison analysis, cost overruns of former investments in MRTS or reduced revenues of former MRTS investments compared to original projections, which make new investments less viable and riskier, can be considered in the investment analysis (see discussion above)
Point 19: Benchmark analysis	Analysis is made based on NPV as required by ACM0016
Points 20 and 21: Sensitivity analysis	Sensitivity analysis is made assuming following changes: • 10% lower investment costs • 10% lower staff cost • 10% lower energy cost • 10% lower maintenance cost • 10% lower administration cost • 10% increase in revenues • Break-even point (0 NPV) with changing risk parameter These are all important cost/revenue variables and all variables

[40] Guidelines on the Assessment of Investment Analysis Version 4

[41] See e.g. FSR of Rites Ltd. For DMRC, Delhi point 9.4.6. (File 45)

	which constitute more than 20% of cost respectively revenue.

Table 7 shows the major parameters used for the financial assessment.

Table 7: Major Parameters for Financial Assessment

Parameter	Value in 100 million WON
Total investment	10,979
Investment by Central Government (subsidy)	6,587
Investment by Municipality	4,392
Staff cost (annual average)[42]	109
Energy cost (annual average)	66
Maintenance cost (annual average)	84
Administrative cost (annual average)	21
Revenue (annual average)	903
Price of CERs (tsd WON per tCER)	27
Discount rate	5.5%
Risk rates (rate actual to expected passengers)	30%

Sources: All metro data from Ministry of Land, Transport and Maritime Affairs, 5/2008 (File 43); Discount rate Ministry of Land, Transport and Maritime Affairs, 5/2008 (File 24b); CER price based on Pointcarbon average 1 year prior 05/2009 (File 44) and exchange rate 05/2009 based on http://www.oanda.com/currency/converter/; risk rate see Table 6 and corresponding section.

The date of investment decision is 22/05/2009[43]. All the input values used in the investment analysis were clearly applicable at the time of investment decision.

The revenue includes fare-box and other revenues estimated as 10% of fare-box revenues. The fare-box revenues are calculated based on passenger projections (based again on demand forecast models) multiplied with the average actual fare paid. The average actual fare paid is based on the population projections per group (infant, children, students, adults, seniors) with their respective discounts on the full fare resulting in an average projected effective fare of around 800 Won per passenger[44].

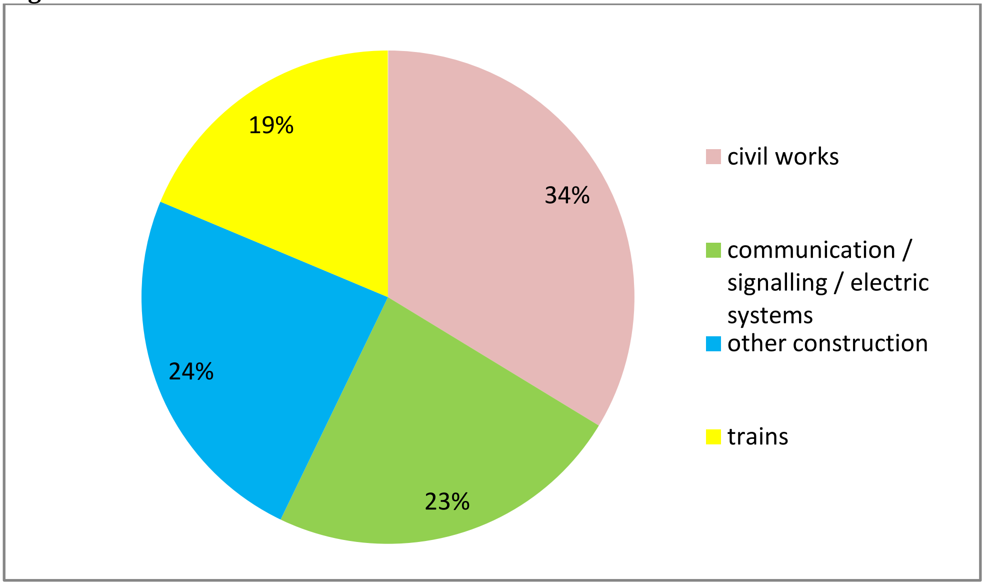
Figure 4 shows the distribution of the investment cost in the major parts. As mentioned 60% of the total investment is paid by the Central Government as a subsidy. The financial calculation for CDM is therefore based only on the 40% paid by the Municipality.

[42] Average of all operational years

[43] File 42

[44] See File 66 for details of the calculation

Figure 4: Investment Elements



Source: File 43; see also finance sheet file 41 sheet "Investment"

The plausibility of core data used is checked in the following paragraphs by comparing values with international literature.

Investment Cost

The investment cost of 1,097,900 million WON is equivalent to around 36 million USD per km of track[45]. This cost is plausible in the international context: IEA estimates initial capital costs for elevated MRTS between 30-75 million USD/km[46] for the year 2002 which is equivalent to 35-89 million USD as of 05/2009[47] with the project metro being in this range. A study published in the year 2008 comparing the capital costs of urban rail per kilometre came to costs of 50-150 million USD per km.[48]

Operational Cost

All operational expenses have been related with the passenger numbers. The average operational cost for the year 2020 (chosen to have an uniform comparison year) per transported passenger is compared with recently established metros or such under construction including Metro Mumbai 1 (also fully elevated), Metro Seoul line 9 and Metro Mexico Line 12.

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[45] 871 million USD at exchange rate 05/2009 with 24 km

[46] table 2.1 page 29, File 46

[47] Based on GDP deflator USA 04/2009 (109.686) in relation to value 10/2002 (92.828) see http://www.forecasts.org/data/data/GDPDEF.htm

[48] File 47, p. 18

Table 8: Comparison of Projected Operational Costs per Passenger (USD per passenger; year 2020)[49]

MM1	Metro Seoul Line 9	Metro Mexico Line 12	Metro Daegu
0.13	0.19	0.29	0.22

Source: MM1 File 48 (1,331.3 million INR/248.3 million passengers; exchange rate 0.024); Metro Seoul Line 9 File 49 (93,650 million Won / 288.1 million passengers; exchange rate 0.00059); Metro Mexico Line 12 File 50 (470 million MXN/133.9 million passengers, exchange rate 0.083); Daegu File 41 (27,807 million WON/ 98.4 million passengers exchange rate 0.00079)

The average cost per passenger of the project is comparable to other metros. Therefore the values of expenses take in the financial assessment are deemed as plausible.

Discount Rate

The discount rate of 5.5% used is conservative. EB 62 Annex 5 has in its Appendix as default return on equity for transport projects in Korea 11.8%. Long-term (10-year) government bond rates also had in the year 2008 (year prior investment decision and year in which financial analysis was made) an average interest rate of 5.57%[50].

NPV Results

The implication of a reduced ridership is a reduction of the fare box revenue and at the same time (to remain conservative) the operational costs are also reduced in the same magnitude to have a conservative assessment (costs will probably reduce in a minor magnitude as not all costs are variable ones e.g. maintenance and administrative cost is largely independent of passenger numbers).

Table 9 shows the financial profitability of the investment in absence of the CER.

Table 9: NPV

Case	NPV in hundred million WON
Rate of 30% actual to projected passengers based on host country experience	-1,760

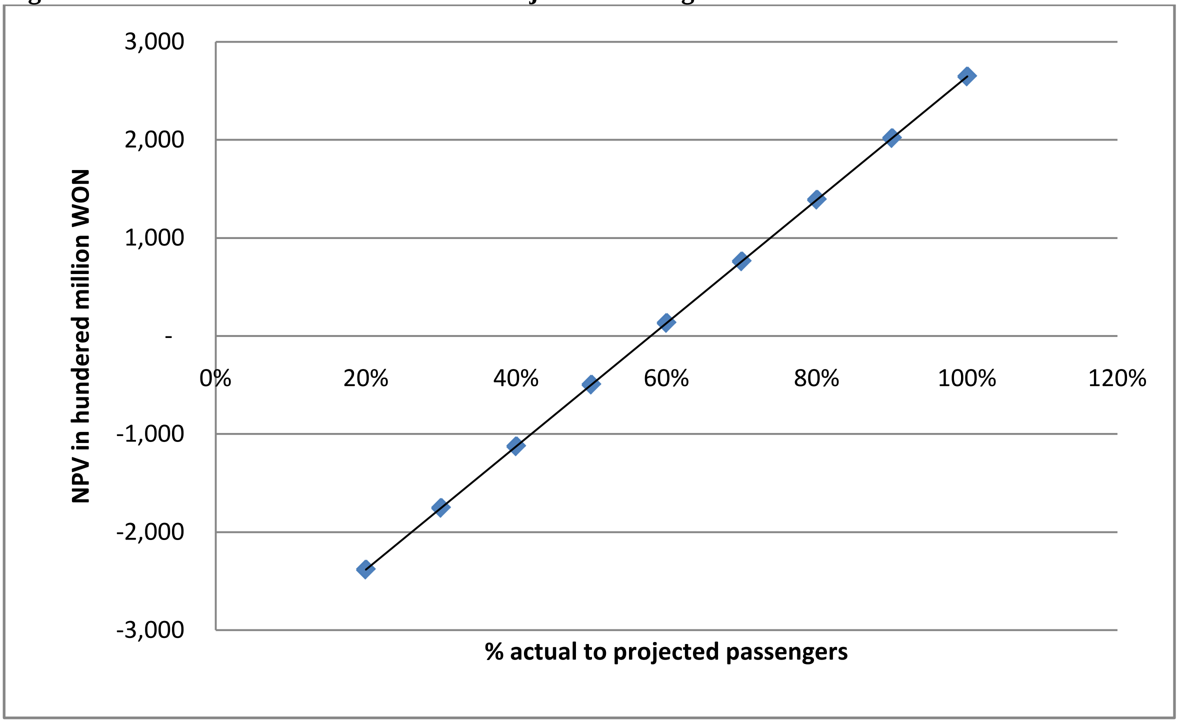
Source: File 41

The following figure shows the relation between passenger numbers and NPV. The break-even is at 58% i.e. the metro has to achieve at least 58% of the projected passengers to reach the break-even point – and this although 60% of the investment cost is subsidized by the Central Government. The performance of implemented MRTS in Korea is off this target with the "best" metro i.e. the one with the highest relation actual to projected passenger numbers achieving 46% of projected passengers (see Table 4).

[49] Based on Feasibility reports for all i.e. projections for all cases; for all based on projection year 2020 to have a fully operational and comparable data year. Exchange rates to USD based on financial assessment report per project

[50] File 51, http://stats.oecd.org/index.aspx?querytype=view&queryname=86

Figure 5: Relation NPV to Rate Actual vs. Projected Passengers



Source: File 41

Table 10 includes the sensitivity analysis based on 30% actual passengers in relation to projected ones.

Table 10: NPV Sensitivity to Parameter Changes Excluding CER Revenues (100 million WON)

Case	Risk case 1
10% lower investment cost	-1,397
10% lower staff cost	-1,724
10% lower energy cost	-1,739
10% lower maintenance cost	-1,733
10% lower administration cost	-1,754
10% higher revenue	-1,478

Source: File 41, based on rate of 30% actual to projected passengers

In all cases the NPV is clearly negative.

The investment cost would need to decrease by 48% to achieve a 0 NPV. This is highly improbable taking into account that the experience of metros worldwide is that construction costs are on average substantially higher than forecast. The average cost escalation of urban rail projects studied by Flyvberg was 45% i.e. costs were 45% higher than forecast. 75% of projects had a cost escalation of 33% at least[51]. Thus it is highly improbable that the project results less expensive than planned.

The staff cost, energy cost, maintenance cost or administrative cost could all individually reach 0 and still the NPV would be negative. This shows that the NPV is not sensitive towards changes of individual cost factors.

[51] File 39, Table 2 and p.16

Fare box revenue would need to increase by 62% to achieve the break-even i.e. 0 NPV. This would mean a fare of 1,780 WON instead of 1,100 as used in the calculations. As higher fare rates than the one used the original FSR however only had fare rates of 1,200 and 1,300 WON[52] i.e. far off the fare rate which would be required.

Overall the project clearly shows that the result of a negative NPV is highly robust. Even very large changes of parameters do not change the result of a negative NPV. From above calculations it is thus clear that the project in absence of the CDM is financially non-feasible.

With carbon finance the probability of a positive NPV is significantly better than without carbon finance. Carbon finance can make a substantial contribution towards making the project financially less risky. Carbon finance can cover for example around 20% of operational cost under the described risk scenario idem to nearly the total administration cost. This means that the financial risk of the project can be reduced substantially through CDM.

Step 3. Common practice analysis

Sub-step 4a. Analyze other activities similar to the proposed project activity:

The investment analysis shall be complemented with an analysis of the extent to which the proposed project type has already diffused in host country. This test is a credibility check to complement the investment analysis (Step 2). All cities or urban areas with more than 1 million habitants which have already implemented a MRTS, including metros (underground, elevated or surface level), LRT (Light Rail Transit) including trams, and BRT (Bus Rapid Transit system) including bus lanes are listed. The proposed project activity is regarded as common practice if MRTS have already been implemented in 50% of the cities with more than 1 million habitants in the host country without using the CDM.

Eurostat, the European Union's statistical agency, has created the concept of Larger Urban Zone (LUZ) in an effort to harmonise definitions of urbanisation in the European Union and in countries outside the European Union. These definitions were agreed between Eurostat and the National Statistics Offices of the different countries of the European Union at the European Commission's Urban Audit of 2004. Eurostat's objective was to have an area from a significant share of the resident commute into the city, a concept known as the "functional urban region." To ensure a good data availability, Eurostat adjusts the LUZ boundaries to administrative boundaries that approximate the functional urban region. SNCA corresponds to this concept. Also in the largest Korean cities a concept of metropolitan cities is used. Other cities however have a population number which corresponds to city population. For these cities the LUZ concept was applied which includes suburban areas of the city which are functionally related. To control latter the expanded city population data is thereby related also to the calculated LUZ data based on relations in the registered 128 EU LUZ cities with city population data. For Seoul the National Capital Area is taken in accordance with LUZ. SNCA also includes Incheon City. The following table shows metropolitan areas in cities with LUZ population in Korea with more than 1 million inhabitants and MRTS systems implemented by these cities[53].

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[52] File 43 point 7.7 line 208

[53] See File 70a/b

Table 11: Cities/Metropolitan Areas with over 1 Million Inhabitants in Korea and MRTS as of Project Starting Date[54]

Metropolitan Area	MRTS
SNCA[55]	Metro, BRT
Busan Metropolitan City	Metro
Daegu Metropolitan City	Metro
Daejeon Metropolitan City	Metro
Gwangju Metropolitan City	Metro
Ulsan Metropolitan City	No MRTS
Changwon	No MRTS
Cheongju	No MRTS
Jeonju	No MRTS
Cheonan	No MRTS
Pohang	No MRTS

Source: File 70; MRTS: rail-based MRTS: http://www.urbanrail.net/as/asia.htm; BRT: http://www.chinabrt.org/defaulten.aspx

Less than 50% of the LUZ in Korea have a MRTS thus complying with the common practice test of the methodology. None of the operating MRTS have used CDM finance.

The steps realized above clearly show that the project activity is not the baseline and is not a viable alternative under BAU.

B.6. Emission reductions:

B.6.1. Explanation of methodological choices:

BASELINE EMISSION CALCULATIONS

Baseline emissions are calculated per passenger surveyed. For each passenger surveyed the individual baseline emissions are calculated and multiplied with the individual expansion factor thus getting the baseline emissions of all passengers of the specific week surveyed. These are multiplied with the total of the passengers of the period to arrive at baseline emissions.

The following steps are made:

Step 1: Conduct a survey, following the procedures presented in Annex 3, in which for each surveyed passenger, the trip distance per transport mode that would have taken place in the baseline is determined.

Step 2: Calculate the individual baseline emissions for each surveyed passenger.

Step 3: Apply an individual expansion factor to each surveyed passenger in accordance with the survey sample design (as defined in Annex 3), and summarize these to get the total baseline emissions of the period (week) surveyed. To get the annual (or monitoring period) baseline emissions the baseline emissions of the surveyed period (week) are calculated per passenger of the period (week) and multiplied with the total passengers transported per year (or monitoring period).

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[54] Based on metropolitan area or LUZ definition as stated in ACM0016, project starting date 29/06/2009

[55] Seoul National Capital Area, includes Incheon

Step 4: Take the lower limit of the 95% confidence interval as total baseline emissions.

PROCEDURE

$$BE_y = \frac{P_y}{P_{SPER}} \sum_p \left(BE_{p,y} \cdot FEX_{p,y} \right) \quad \textbf{(1)}$$

Where:

BE_y	Baseline emissions in the year *y* (g CO_2)
$BE_{p,y}$	Baseline emissions per surveyed passenger *p* in the year *y* (g CO_2)
$FEX_{p,y}$	Expansion factor for each surveyed passenger *p* surveyed in the year *y* (each surveyed passenger has a different expansion factor)
P_y	Total number of passengers in the year *y*
P_{SPER}	Number of passengers in the time period of the survey (1 week)
p	Surveyed passenger
y	Year of the crediting period

The baseline emission per surveyed passenger is calculated based on the mode used, the trip distance per mode and the emission factor per mode:

$$BE_{p,y} = \sum_i BTD_{p,i,y} \cdot EF_{PKM,i,y} \quad \textbf{(2)}$$

Where:

$BE_{p,y}$	Baseline emissions per surveyed passenger *p* in the year *y* (g CO_2)
$BTD_{,p,i,y}$	Baseline trip distance *p* per surveyed passenger using mode *i* in the year *y* (PKM)
$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of mode *i* in the year *y* (g CO_2/PKM)
i	Relevant vehicle category
p	Surveyed passenger
y	Year of the crediting period

(1) Identification of the relevant vehicle categories (modes of transport)

The baseline is a continuation of the current transport system consisting of various transport modes between which the population chooses:

- NMT (Non-Motorized Traffic) with bikes and per foot;
- Private passenger car;
- Taxis;
- Motorcycles;
- Conventional Buses;
- Existing metro lines;

The survey includes also induced traffic i.e. trips which in absence of the project would not have been made.

(2) Determination of the emission factor per passenger-kilometre ($EF_{PKM,i,y}$)

Passenger-kilometre (PKM) is defined as the average passenger trip distance multiplied by the number of passengers. The emission factors per PKM are determined *ex ante* for each vehicle category. Any change in the occupancy rate of taxis and buses influencing the corresponding emission factors is monitored as leakage.

For the existing (baseline) metro lines, the following equation is used:

$$EF_{PKM,i,y} = \frac{TE_{EL,i,y}}{P_{EL,i,y} \cdot TD_{EL,i}} \qquad \textbf{(3)}$$

Where:

$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of baseline metro for year (gCO_2/PKM)
$TE_{EL,i,y}$	Total emissions from baseline metro for year *y* (tCO_2)
$P_{EL,i,y}$	Total passengers transported per year by baseline metro for year *y* (passengers)
$TD_{EL,i}$	Average trip distance of passengers using baseline metro prior to project start (km)
i	Baseline metro
y	Year of the crediting period

The total emissions from baseline metro is calculated using the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”. When applying the tool, the parameter $EC_{BL,k,y}$ in the tool is taken as the amount of electricity used by baseline metro for the year *y*, consistent with the transportation of $P_{EL,i}$ passengers along the average distance $TD_{EL,i}$[56].

$$TE_{EL,i,y} = EC_{BL,i,y} \times EF_{grid,CM} \times (1 + TDL) \times 10^{-6} \qquad (4)$$

Where:

$TE_{EL,i,y}$	Total emissions from baseline metro for year *y* (tCO_2)
$EC_{BL,i,y}$	Quantity of electricity consumed by baseline metro in the year y (MWh)
$EF_{grid,CM}$	Emission factor for electricity generation in the grid based on combined margin (gCO_2/kWh)
TDL	Average technical transmission and distribution losses for providing electricity

The alternative of the Combined Margin (CM) is chosen, determined ex-ante for the entire crediting period. The CM is calculated based on the “Tool to calculate the emission factor for an electricity system”. The tool to calculate baseline, project and/or leakage emissions from electricity consumption is also included. Scenario A of this tool applies as the electricity consumed is from the grid. Option A1 is used to calculate the emission factor of the grid based on the CM.

For all other fuel-based vehicle categories, the emission factor per PKM is calculated as:

$$\mathrm{EF_{PKM,i,y}} = \frac{\mathrm{EF_{KM,i,y}}}{\mathrm{OC_i}} \qquad \textbf{(5)}$$

[56] The trip distance is only monitored prior project start. The electricity consumed and the passengers transported are monitored annually to track technological improvements in the rail-based system leading to changes in the emission factor per passenger transported.

Where:

$EF_{PKM,i}$	Emission factor per passenger-kilometre of vehicle category *i* in the year *y* (g CO_2/PKM)
$EF_{KM,i}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
OC_i	Average occupation rate of vehicle category *i* prior project start (passengers)
i	Relevant vehicle category
y	Year of the crediting period

(2.1.) Determination of the average occupation rate (OC_i)

In the case of taxis, the driver is not included.

For buses:

$$OC_B = \frac{PBL_B \times TDBL_{P,B}}{DD_B} \qquad \textbf{(6)}$$

Where:

OC_B	Average occupation rate of buses prior project start (passengers)
PBL_B	Passengers transported by baseline buses prior project (passengers)
$TDBL_{P,B}$	Average trip distance of passengers using baseline bus (kilometer)
DD_B	Distance driven by all baseline buses (kilometer)

(2.2) Determination of the emission factors per kilometre ($EF_{KM,i,y}$)

Relevant fuel types, for each vehicle category, have to be identified. The emission factor per kilometre is re-calculated annually based on the recorded share of fuels per category. In case biofuel blends are used the biofuel share of the blend is accounted for with zero emission factor ($EF_{CO2,x,y}$). In the case of Daegu currently no biofuels are used.

Buses operating in Daegu are all large units[57]. No BRT bus lane was operational prior to project start.

The emission factor per kilometre is not constant but annually updated. Two options can be used to calculate $EF_{KM,i,y}$. For each vehicle category the project can choose which option to take. During the crediting period the project cannot change between one and the other option, i.e. the decision is fixed for the crediting period. Rail-based vehicles must monitor annually the electricity consumption plus passengers transported (see formula 3). For all road-based vehicle categories option (2) using a fixed technology improvement factor is used. Formula (6) of the methodology is therefore not used.

As only one bus category buses exists formula (8) of the methodology is not used.

For option (2) the following formula applies:

$$EF_{KM,i,y} = (IR_i)^{t+y} \cdot \frac{\sum_x \left(SFC_{i,x} \cdot NCV_{x,y} \cdot EF_{CO2,x,y} \cdot N_{x,i}\right)}{N_i} \qquad \textbf{(7)}$$

[57] File 15a/b

Where:

$EF_{KM,i,,y,}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
$SFC_{x,i}$	Specific fuel consumption of vehicle category *i* using fuel type *x* prior project start (g/km)
$NCV_{x,y}$	Net calorific value of fuel *x* in the year *y* (J/g)
$EF_{CO2,x,y}$	Carbon emission factor for fuel type *x* in the year *y* (g CO_2/J)
$N_{x,i}$	Number of vehicles of category *i* using fuel type *x* prior to project start (units)
$N_{x,i}$	Number of vehicles of category *i* prior to project start (units)
IR_i^{t+y}	Technology improvement factorfor the vehicle of category *i* per year *t+y* (ratio)
i	Relevant vehicle category
x	Fuel type
t	Years of annual improvement (dependent on age of data per vehicle category)
y	Year of the crediting period

The technology improvement factor is taken from the methodology and is listed in the following table.

Table 12: Default Technology Improvement Factors (per annum)

Vehicle category	Technology Improvement Factor IR
Buses	0.99
Passenger cars	0.99
Taxis	0.99
Motorcycles	0.99

Source: ACM0016, Table 2

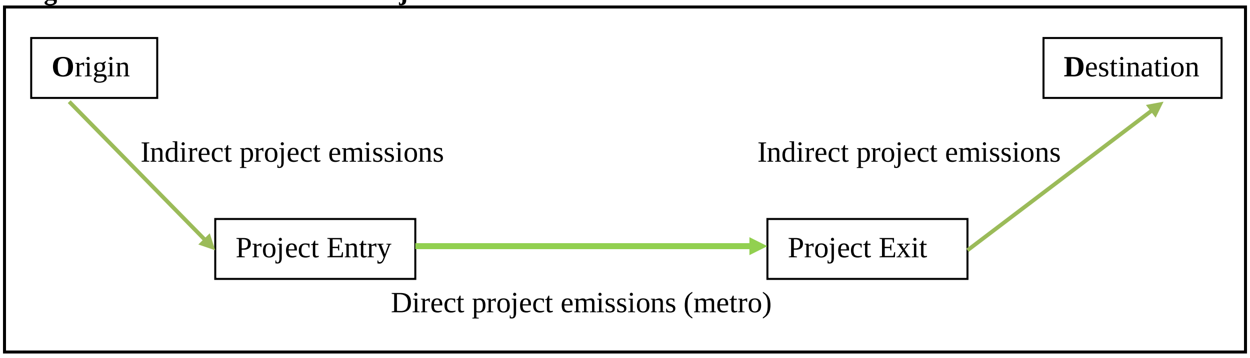
Baseline emissions include the entire emissions which would have been caused by the project passenger in absence of the project from his trip origin to his trip destination. The origin and destination of the trip is assumed to be equal for the baseline as for the project case with exception of induced traffic included only as project but not as baseline trips. The trip distance and the modes used between O and D are however different in the baseline than in the project case. The trip distance may vary as some passengers using the project MRTS may be willing e.g. to make detours due to the higher speed of the MRTS versus conventional bus transport. To fully capture all potential changes the methodology thus compares emissions per O-D trip of the baseline with emissions per O-D trip of the project. The data to determine O-D mode(s) and distances per mode are derived from a representative survey of project passengers realized annually. Total baseline emissions are calculated thereafter annually based on these parameters, the emissions per PKM and the amount of passengers transported by the project.

Project passengers are those which use the project metro line.

PROJECT EMISSION CALCULATIONS

Project emissions are based on the electricity consumed by the metro for train traction (direct project emissions) plus emissions caused by project passengers from their trip origin to the entry station of the metro and from the exit station of the metro to their final destination (indirect project emissions).

Figure 6: Direct and Indirect Project Emissions



Project emissions are calculated as follows:

$$PE_y = DPE_y + IPE_y \quad \textbf{(8)}$$

Where:

$PE_{,y,}$	Project emissions in the year *y* (tCO_2)
DPE_y	Direct project emissions in the year *y* (tCO_2)
IPE_y	Indirect project emissions in the year *y* (tCO_2)
y	Year of the crediting period

Determination of direct project emissions (DPE_y)

The project activity involves an electricity-based transport system. The emissions from electricity consumption are based on the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption". Only electricity consumed for train propulsion is included in rail-based MRTS. Formulas (10) and (11) of the methodology are thus not required.

$$DPE_y = EC_{PJ,y} \times EF_{grid,CM} \times (1+TDL) \times 10^{-6} \quad (9)$$

Where:

DPE_y	Direct project emissions in the year *y* (tCO_2)
$EC_{PJ,y}$	Quantity of electricity consumed by project metro for traction in the year y (MWh)
$EF_{grid,CM}$	Emission factor for electricity generation in the grid based on combined margin (gCO_2/kWh)
TDL	Average technical transmission and distribution losses for providing electricity

The alternative of the Combined Margin (CM) is chosen, determined ex-ante for the entire crediting period. The CM is calculated based on the "Tool to calculate the emission factor for an electricity system". The tool to calculate baseline, project and/or leakage emissions from electricity consumption is also included. Scenario A of this tool applies as the electricity consumed is from the grid. Option A1 is used to calculate the emission factor of the grid based on the CM.

Determination of indirect project emissions (IPE_y)

Indirect project emissions are those caused by passengers from their trip origin up to the project activity entry station, and from the project activity exit station up to the trip final destination. The survey realized identifies the origin, the project entry station, the project exit station and the final

destination of the passenger plus the modes used between the different points, e.g. bicycle from origin to project entry station and taxi from project exit station to final destination. The distances between origin and entry and between exit and destination are calculated based, e.g. on public transit routes, electronic maps and GPS (Global Positioning System) (identical to baseline trip determination). The emission factors per passenger-kilometre used for indirect project emissions are identical to the baseline passenger-kilometre factors ($EF_{PKM,i,y}$).

Following core steps are realized:

Step 1: Realize a survey in which for each surveyed passenger the trip distance per mode used to/from the MRTS is determined.

Step 2: Calculate for each surveyed passenger his indirect project emissions.

Step 3: Apply to each surveyed passenger an individual expansion factor in accordance with the survey sample design and summarize these to get the total indirect project emissions of the week surveyed. To get the annual (or monitoring period) indirect project emissions the indirect project emissions of the surveyed week are calculated per passenger of the week and multiplied with the total passengers transported per year (or period).

Step 4: Application of the upper 95% confidence interval to the total indirect project emissions.

The detailed corresponding formulas are included in Annex 3.

$$IPE_y = \frac{P_y}{P_{SPER}} \sum_p \left(IPE_{p,y} \cdot FEX_{p,y} \right) \quad \textbf{(10)}$$

Where:

IPE_y	Indirect project emissions in the year *y* (g CO_2)
$IPE_{p,y}$	Indirect project emissions per surveyed passenger *p* in the year *y* (g CO_2)
$FEX_{p,y}$	Expansion factor for each surveyed passenger *p* surveyed in the year *y* (each surveyed passenger has a different expansion factor)
P_y	Total number of passengers in the year *y*
P_{SPER}	Number of passengers in the time period of the survey (1 week)
p	Surveyed passenger
y	Year of the crediting period

The indirect project emissions per surveyed passenger are calculated based on the transport mode used, the trip distance per mode and the emission factor per mode.

$$IPE_{p,y} = \sum_i IPTD_{p,i,y} \times EF_{PKM,i,y} \quad \textbf{(11)}$$

Where:

$IPE_{p,y}$	Indirect project emissions per surveyed passenger *p* in the year *y* (g CO_2)
$BTD_{,p,i,y}$	Indirect project trip distance *p* per surveyed passenger using mode *i* in the year *y* (PKM)
$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of mode *i* in the year *y* (g CO_2/PKM)
i	Relevant vehicle category

p Surveyed passenger
y Year of the crediting period

Based on the surveyed passenger and the survey design the corresponding expansion factors are applied to calculate total indirect project emissions. Total indirect project emissions are determined based on the upper limit of the 95% confidence interval as results are based on a sample/survey. For the entire survey design see Annex 3. The same method of expansion factors is used as outlined in the baseline section.

Indirect project emissions are only included for the project passengers. Passengers transported are based on passengers entering stations. Project passengers are those which enter stations of the project metro.

LEAKAGE EMISSION CALCULATIONS

Leakage emissions include the following sources:

- Emissions due to changes of the load factor of taxis and buses of the baseline transport system due to the project; and,

- Emissions due to reduced congestion on affected roads, provoking higher average vehicle speed, plus a rebound effect.

The impact on traffic (additional trips) induced by the new transport system is included as project emissions and thus is not part of leakage. This is addressed by including, as project emissions, the emissions from the trips of passengers who would not have travelled in the absence of the project.

Leakage emissions are calculated as follows:

$$LE_y = LE_{LFB,y} + LE_{LFT,y} + LE_{CON,y} \quad \textbf{(12)}$$

Where:
LE_y Leakage emissions in the year *y* (tCO_2)
$LE_{LFB,y}$ Leakage emissions due to change of load factor buses in the year *y* (tCO_2)
$LE_{LFT,y}$ Leakage emissions due to change of load factor taxis in the year *y* (tCO_2)
$LE_{CON,y}$ Leakage emissions due to reduced congestion in the year *y* (tCO_2)
y Year of the crediting period

If $LE_y < 0$, then leakage is not included
If $LE_y > 0$, then leakage is included

Determination of emissions due to change of load factor of buses ($LE_{LFB,y}$)

The project could have a negative impact on the load factor of the conventional bus fleet. Load factor changes are monitored for the entire city as the potential impact is not necessarily in the proximity of the project MRTS (buses can be used in other parts of the city). The load factor of buses is monitored in the years 1, 4 and 7 of the crediting period. Leakage from load factor change of buses is only included if the load factor of buses has decreased by more than 10 percentage points comparing the monitored value with the baseline value, and are calculated as:

$$LE_{LFB,y} = \frac{1}{10^6} \cdot N_{B,y} \cdot AD_B \cdot EF_{KM,B,y} \cdot \left(1 - \frac{OC_{B,y}}{OC_B}\right) \quad \textbf{(13)}$$

Where:

$LE_{LFB,y}$	Leakage emissions due to change of load factor of buses in the year *y* (tCO_2)
$N_{B,y}$	Number of baseline buses in the year *y* (buses)
AD_B	Average annual distance driven by baseline buses (km/bus)
$EF_{KM,B,y}$	Emission factor per kilometre of baseline buses in the year *y* (g CO_2/km)
$OC_{B,y}$	Average occupancy rate of baseline buses in the year *y* (passengers)
OC_B	Average occupancy rate of baseline buses prior project start (passengers)
y	Year of the crediting period

The occupancy rate of buses is monitored through visual occupation studies (see Annex 3).

Determination of emissions due to change of load factor of taxis ($LE_{LFT,y}$)

The project could have a negative impact on the load factor of taxis. Load factor changes are monitored for the entire city as taxis operate all over the city and are not confined to deliver their services in certain areas. The load factor of taxis is monitored in the years 1, 4 and 7 of the crediting period. This leakage is calculated as:

$$LE_{LFT,y} = N_{T,y} \cdot AD_T \cdot EF_{KM,T,y} \cdot \left(1 - \frac{OC_{T,y}}{OC_T}\right) \cdot \frac{1}{10^6} \quad \textbf{(14)}$$

Where:

$LE_{LFT,y}$	Leakage emissions due to change of load factor of taxis in the year *y* (tCO_2)
$N_{T,y}$	Number of taxis in the year *y* (taxis)
AD_T	Average annual distance driven per taxi (km/taxi)
$EF_{KM,T,y}$	Emission factor per kilometre of taxis in the year *y* (g CO_2/km)
$OC_{T,y}$	Average occupancy rate of taxis in the year *y* (passengers)
OC_T	Average baseline occupancy rate of taxis prior project start (passengers)
y	Year of the crediting period

The maximum load factor change attributed to taxis is the emission reductions due to passengers switching from taxis to the project (calculated by the emission factor per passenger-kilometre for taxis, the trip distance and the number of passengers transported by the project, which would have used taxis in absence of the project). This maximum condition is established as load factors might worsen citywide also due to factors external to the project and leakage from a load factor change taxis due to the project can at maximum be according to the number of passengers transported by the project which in absence of latter would have taken a taxi.

The occupancy rate of taxis is monitored through visual occupation studies counting the number of passengers (see Annex 3).

The parameter emission factor per kilometre of baseline taxis in the year *y* ($EF_{KM,T,y}$) is calculated using the equation for $EF_{KM,i,y}$ presented in the baseline emissions section, substituting *i* for T (taxis).

Determination of emissions due reduced congestion ($LE_{CON,y}$)

The project activity may reduce the number of remaining buses and potentially other vehicles on roads used by mixed traffic and thus also congestion. It is not possible however to determine *ex-ante* if this effect will result in positive leakage emissions (i.e. emissions increase) or negative leakage emissions (i.e. emissions reductions). Two effects resulting from reduced congestion are considered:

- Induced traffic effect (or rebound effect), i.e. more trips of passenger cars on the “affected roads”;
- Changes in vehicle speed effect, i.e. change of emissions due to reduced or increased speed of cars on “affected roads”.

The corresponding emissions are calculated as:

$$LE_{CON,y} = LE_{REB,y} + LE_{SP,y} \quad \textbf{(15)}$$

Where:

$LE_{CON,y}$ Leakage emissions due to reduced congestion in the year *y* (tCO_2)
$LE_{REB,y}$ Leakage emissions due to induced traffic / rebound effect in the year *y* (tCO_2)
$LE_{SP,y}$ Leakage emissions due to changing vehicle speed in the year *y* (tCO_2)

Determination of emissions due to induced traffic/rebound effect ($LE_{REB,y}$)

The concept to capture emissions from induced traffic (or rebound effect) includes the following assumptions (induced traffic is measured for passenger cars and taxis):

- The distance driven on the affected roads of all additional cars/taxis is considered as additional trip distance, i.e. it is assumed that formerly used alternative routes are shorter, which is a conservative assumption;
- All additional cars/taxis on the affected roads are considered to be induced by the project and not by external effects such as general traffic growth, which again is a conservative assumption.

The monitoring is realized through measurements of traffic flows and distance driven of passenger cars and taxis on the affected roads. Monitoring is realized annually.

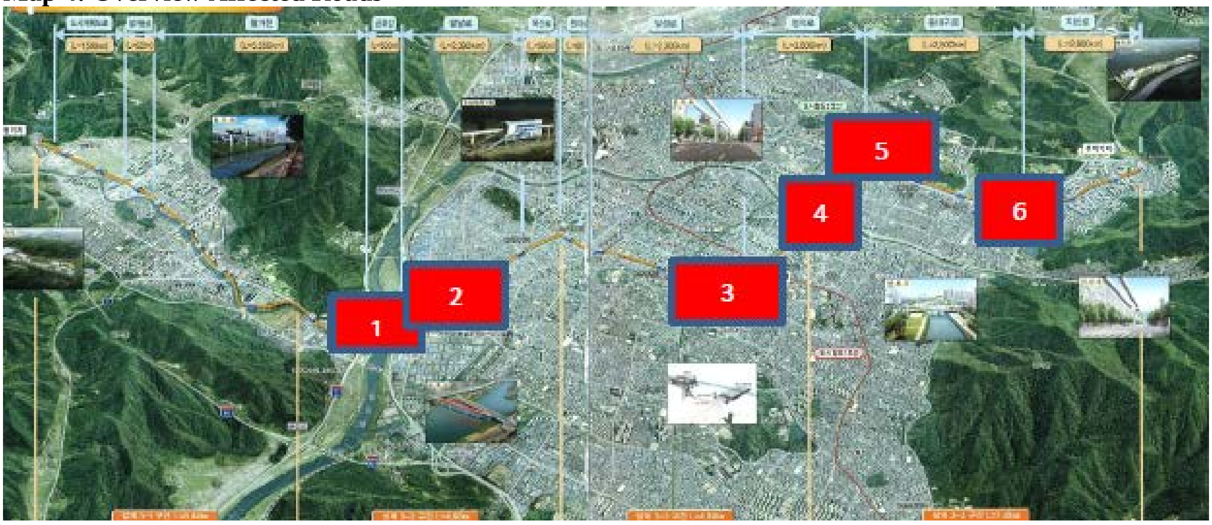
As a first step the “affected roads” are identified. According to the definition of the methodology “affected roads” are the roads influenced by the establishment of the MRTS. Affected roads are those inside a radius of minimum 1 kilometer running parallel to the MRTS line (roads on both sides of the MRTS line are included). Only roads with large traffic volumes are included. The following table list the “affected roads” of the project and the map shows the site of the “affected” roads.

Table 13: Affected Roads of Project Metro

ID	Affected Road
1	Paldalro Road, Wondae Intersection to Palgeugyo Intersection (points 1 and 2)
2	Myeongdeongro, Goongjeonmeti on intersection to Bangogae Intersection (points 3and 4)
3	DongdaegugroYongji Intersection to Patima Intersection (points 5 and 6)

Source: File 59

Map 4: Overview Affected Roads



Source: File 59, point 1-6 vehicle measurements

Vehicle speed refers to average speed, i.e. total distance divided by total time, on the affected road. Taxis and passenger cars are treated identical. This condition is monitored for each affected road.

The rebound effect for the affected roads is calculated as:

$$LE_{REB,y} = \frac{1}{10^6} \cdot \sum_i \left(TDIZ_{i,y} \cdot EF_{KM,i,y} \cdot \left(NIZ_{i,y} - NIZ_{i,BL} + NIZ_{i,MS,y} \right) \right) \quad \textbf{(16)}$$

Where:

$LE_{REB,y}$	Leakage emissions due to rebound effect in the year *y* (tCO_2)
$NIZ_{i,y}$	Number of cars/taxis per annum using the affected roads in the year *y* (cars, taxis)
$NIZ_{i,BL}$	Number of cars/taxis per annum using the affected roads in the baseline (cars, taxis)
$NIZ_{i,MS,y}$	Number of cars/taxis per annum not used anymore due to mode shift to the MRTS in the year *y* (cars, taxis)
$TDIZ_i$	Average trip distance made by cars/taxis on the affected roads in the year *y* (km)
$EF_{KM,i,y}$	Emission factor per kilometre of cars and taxis in the year *y* (g CO_2/km)
i	Cars, taxis
y	Year of the crediting period

The number of cars and taxis per annum not used anymore due to mode shift to the MRTS in the year *y* is calculated as:

$$NIZ_{i,MS,y} = \frac{MS_{i,s} \cdot P_y}{OC_i} \quad \textbf{(17)}$$

Where:

$NIZ_{i,MS,y}$	Number of cars/taxis per annum not used anymore due to mode shift to the metro in the year *y* (cars, taxis)
$MS_{i,y}$	Net share of passengers using the metro which would have used mode *i* in the year *y* (%)
P_y	Passengers transported by the project in the year *y* (passengers)

OC_i Average occupation rate of vehicle category *i* prior project start (passengers)
i Cars, taxis
y Year of the crediting period

The net share of passengers with mode switch from car/taxi to the MRTS is based on the percentage of passengers which would have used in the baseline cars/taxis at least partially for their trip minus the share of passengers of the MRTS which use cars/taxis partially for their trip (to and/or from the MRTS).

Determination of emissions due to changes in vehicle speed ($LE_{SP,y}$)

Leakage emissions due to changes in vehicle speed are determined only for cars and taxis, as presented below. The non-inclusion of other vehicles such as buses or trucks is conservative as a reduced congestion also leads to reduced emissions of remaining buses plus trucks on affected roads due to the speed effect. If speed measurements for cars/taxis realized show that the EF for cars/taxis for the year *y* is lower than the baseline emission factor (thus leading to negative leakage) the project proponent can choose to not include this factor and thus avoid measurements of numbers of cars/taxis and trip distance of cars/taxis.

$$LE_{SP,y} = \frac{1}{10^6} \cdot \sum_i \left(NIZ_{i,y} \cdot TDIZ_{i,y} \cdot \left(EF_{KM,VP,i,y} - EF_{KM,VB,i} \right) \right) \quad \textbf{(18)}$$

Where:
$LE_{SP,y}$ Leakage emissions due to changes in vehicle speed of cars and taxis in year *y* (tCO_2)
$NIZ_{i,y}$ Number of cars/taxis using the affected roads in the year *y* (cars, taxis)
$TDIZ_{i,y}$ Average trip distance made by cars/taxis on the affected roads in the year *y* (km)
$EF_{KM,VP,,i,y}$ Emission factor per kilometre of cars/taxis at project speed in the year *y* (g CO_2/km)
$EF_{KM,VB,i}$ Emission factor per kilometre of cars/taxis at baseline speed (g CO_2/km)
i Cars, taxis
y Year of the crediting period

The project speed on the determined routes is monitored annually on the affected roads. Vehicle speed is monitored under moving conditions. The same method is used for baseline and project speed determination.

The number of cars and taxis on the affected roads are monitored through visual or electronic counting.

To determine the emission factor per kilometre of cars/taxis at project speed and baseline speed the speed dependency factor for passenger cars developed by CORINAR is used. The same vehicle speed is used for passenger cars and taxis. The latest version of the Emission Inventory Guidebook CORINAIR (8/2007)[58] is thereby used. V_B and V_P in this case refer to moving speed, i.e. the speed of the vehicle under moving conditions. The CORINAIR speed emission factor is only for relative speed changes.

[58] File 53

To determine the correct CORINAIR formula the average speed, Euro category and engine capacity need to be determined. A matching between the CORINAIR categories and the vehicle categories in India is thereby made. Core categories used by CORINAIR are thereby[59]:

- Euro: pre-Euro 1 and Euro 1, 2, 3, 4
- Engine capacity: <1.4 liter, 1.4-2.0 liter and >2.0 liter
- Speed range: < 10 km/h, 10-130 km/h, > 130 km/h

The respective conditions as of present (baseline) in Korea are:

- Euro: Korea has the Euro 4 standard for passenger cars since 2007. Therefore this category is used[60].
- The majority of vehicles sold in Korea are 1.4-2.0 liters[61].
- The following table shows the measured circulating speeds on the affected roads. All of them are in the range between 38 and 42 km/h. For CORINAIR thus the category 10-130 km/h is taken.

Table 14: Measured Average Circulating Speed on Affected Roads (Baseline Situation; in km/h)

ID	Affected Road	Average Circulating Speed (km/h)
1	Paldalro Road, Wondae Intersection to Palgeugyo Intersection	41
2	Myeongdeongro, Goongjeonmeti on intersection to Bangogae Intersection	38
3	DongdaegugroYongji Intersection to Patima Intersection	42

Source: File 59

For gasoline vehicles based on the criteria of CORINAIR as in table 8-9[62] the following category is used to determine the relevant parameters based on above listed information:

- Average emission standard: Euro 4
- Average engine capacity: 1.4-2.0
- Average speed range: 10-130 km/h

The general formula for gasoline vehicles Euro 1 or later is[63]:

$$EF = \left(a + c \times V + e \times V^2\right) / \left(1 + b \times V + d \times V^2\right) \quad \textbf{(19)}$$

a,b,c,d,e CORINAR speed parameters (see Table 8-9, B 710-45, CORINAIR 2007)
V Moving speed
EF Emission factor of pollutant (in this case FC = Fuel Consumption)

Based on the range determined the parameters for fuel consumption are[64]:

[59] File 53, table 8-9, B710-45

[60] File 52, http://eng.me.go.kr/content.do?method=moveContent&menuCode=pol_cha_air_pol_tra_enhancing

[61] File 54, http://www.koreauspartnership.org/facts/autos.htm

[62] File 53

[63] CORINAIR formula (21) on page B710-44

[64] Table 8-9, B 710-45, CORINAIR 2007

a = 1.74*10^{2}
b = 6.58*10^{-2}
c = 3.64*10^{-1}
d = -2.47*10^{-4}
e = 8.74*10^{-3}

The EF in gCO_2 for gasoline cars and taxis is therefore:

$$EF_{KM,VB,i,G} = \left[\frac{a + c \times V_B + e \times V_B^2}{1 + b \times V_B + d \times V_B^{\ 2}}\right] \times NCV_G \times EF_{CO2,G} \quad \textbf{(20)}$$

$$EF_{KM,VP,i,G} = \left[\frac{a + c \times V_P + e \times V_P^2}{1 + b \times V_P + d \times V_P^{\ 2}}\right] \times NCV_G \times EF_{CO2,G} \quad \textbf{(21)}$$

Where:

$EF_{KM,VB,i}$	Emission factor per kilometre of gasoline cars/taxis at baseline speed (gCO_2/km)
V_B	Average moving speed of cars/taxis prior to project start (km/h)
$EF_{KM,VP,i}$	Emission factor per kilometre of gasoline cars/taxis at project speed (gCO_2/km)
$V_{P,y}$	Average moving speed of cars/taxis in the year *y* (km/h)
i	Cars, taxis
a,b,c,d,e	CORINAIR parameters based on Table 8-9, B. 710-45, CORINAIR 2007
$NCV_{G,y}$	Net calorific value of gasoline in the year *y* (J/g)
$EF_{CO2,G,y}$	Carbon emission factor for gasoline in the year *y* (gCO_2/J)

V in this case refers to moving speed i.e. the speed of the vehicle under moving conditions.

For diesel vehicles based on the criteria of CORINAIR as in table 8-15[65] the following category is used to determine the relevant parameters based on above listed information:

- Average emission standard: Euro 3[66]
- Average engine capacity: >2.0[67]
- Average speed range: 10-130 km/h

The general formula for diesel vehicles Euro 1 or later is[68]:

$$EF = \left(a + c \times V + e \times V^2\right) / \left(1 + b \times V + d \times V^2\right) + f / V \quad \textbf{(22)}$$

a,b,c,d,e,f	CORINAR speed parameters (see Table 8-15, B 710-49, CORINAIR 2007)
V	Moving speed
EF	Emission factor of pollutant (in this case FC = Fuel Consumption)

[65] CORINAIR 2007, p. B710-49

[66] Euro 4 is not yet listed in Corinair

[67] In diesel categories are > and < 2.0

[68] CORINAIR formula (23) on page B710-49

Based on the range determined the parameters for fuel consumption are[69]:

a = $1.95*10^{2}$
b = $7.19*10^{-2}$
c = $1.87*10^{-1}$
d = $-3.32*10^{-4}$
e = $9.99*10^{-3}$
f = 0

The EF in gCO_2 for diesel cars and taxis is therefore:

$$EF_{KM,VB,i,D} = \left[\frac{a + c \times V_B + e \times V_B^{\ 2}}{1 + b \times V_B + d \times V_B^{\ 2}}\right] \times NCV_D \times EF_{CO2,D} \qquad \textbf{(23)}$$

$$EF_{KM,VP,i,D} = \left[\frac{a + c \times V_P + e \times V_P^{\ 2}}{1 + b \times V_P + d \times V_P^{\ 2}}\right] \times NCV_D \times EF_{CO2,D} \qquad \textbf{(24)}$$

Where:

$EF_{KM,VB,i}$	Emission factor per kilometre of diesel cars/taxis at baseline speed (gCO_2/km)
V_B	Average moving speed of cars/taxis prior to project start (km/h)
$EF_{KM,VP,i}$	Emission factor per kilometre of diesel cars/taxis at project speed (gCO_2/km)
$V_{P,y}$	Average moving speed of cars/taxis in the year *y* (km/h)
i	Cars, taxis
a,b,c,d,e	CORINAIR parameters based on Table 8-15, B. 710-49, CORINAIR 2007
$NCV_{D,y}$	Net calorific value of diesel in the year *y* (J/g)
$EF_{CO2,D,y}$	Carbon emission factor for diesel in the year *y* (gCO_2/J)

For LPG vehicles based on the criteria of CORINAIR as in table 8-19[70] the following category is used to determine the relevant parameters based on above listed information:

- Average emission standard: >Euro 1
- Average engine capacity: all categories
- Average speed range: 10-130km/h

The general formula for LPG vehicles is[71]:

$$EF = 0.00720V^{2} - 0.9250V + 74.625 \qquad \textbf{(25)}$$

Where:

V	Moving speed
EF	Emission factor of pollutant (in this case FC = Fuel Consumption)

[69] Table 8-15, B 710-49, CORINAIR 2007

[70] CORINAIR 2007, p. B710-51 (file 53)

[71] CORINAIR table 8-19 on page B710-51

The EF in gCO_2 for LPG cars and taxis is therefore:

$$EF_{KM,VB,i,LPG} = \left[0.00720V_B^{\ 2} - 0.9250V_B + 74.625\right] \times NCV_{LPG,y} \times EF_{CO2,LPG,y} \quad \textbf{(26)}$$

$$EF_{KM,VP,i,LPG,y} = \left[0.00720V_{P,y}^{\ 2} - 0.9250V_{P,y} + 74.625\right] \times NCV_{LPG,y} \times EF_{CO2,LPG,y} \quad \textbf{(27)}$$

Where:

$EF_{KM,VB,I,LPG}$ Emission factor per kilometre of LPG cars/taxis at baseline speed (gCO_2/km)
V_B Average moving speed of cars/taxis prior to project start (km/h)
$EF_{KM,VP,I,LPG}$ Emission factor per kilometre of LPG cars/taxis at project speed (gCO_2/km)
$V_{P,y}$ Average moving speed of cars/taxis in the year *y* (km/h)
i Cars, taxis
$NCV_{LPG,y}$ Net calorific value of LPG in the year *y* (J/g)
$EF_{CO2,LPG,y}$ Carbon emission factor for LPG in the year *y* (gCO_2/J)

EMISSION REDUCTIONS

$$ER_y = BE_y - PE_y - LE_y \quad \textbf{(28)}$$

Where:

ER_y Emission reductions in year *y* (t CO_2/yr)
BE_y Baseline emissions in year *y* (t CO_2/yr)
PE_y Project emissions in year *y* (t CO_2/yr)
LE_y Leakage emissions in year *y* (t CO_2/yr)

If for a certain year $LE_y < 0$, then leakage is not included in the calculation of emission reductions. If $LE_y > 0$, then it is included.

SENSITIVITY ANALYSIS

A sensitivity analysis is carried out for data and parameters, which are used to calculate baseline, project and leakage emissions. The sensitivity analysis is performed on all parameters except default and IPCC values listed as monitored values/parameters or values to be monitored. The sensitivity analysis is based on calculating the change of the data parameter that would be required to reduce emission reductions by 5%. This value gives an indication of the magnitude of change of the data parameter required to significantly change calculated emission reductions. Steps to carry out the sensitivity analysis include:

- Carry out a sensitivity analysis on these parameters calculating the level of change of the parameter required to reduce emission reductions by 5% below that originally estimated;
- Assess the result in light of possible data uncertainty. As sensitive parameter/data are considered those where a change of less than 10% leads to a reduction of ERs of more than 5%. In these cases an explanation shall be given to ensure that the data value used is correct and conservative.

See Annex 3 for the sensitivity analysis.

B.6.2. Data and parameters that are available at validation:

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / Parameter:	**$SFC_{C,\ G/D/LPG}$**
Data unit:	g/km
Description:	Specific fuel consumed of passenger cars using gasoline, diesel or LPG
Source of data used:	Korea Energy Management Corporation. 2010, p.50 (File 1)
Value applied:	Cars gasoline: 58.46 Cars diesel: 62.60 Cars LPG: 55.91
Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on national literature. To check plausibility the value is compared with: - IPCC 1996 (last available source for fuel consumption data vehicles): gasoline cars as lowest US values 11.8 l/100km (table 1-27) and as lowest European value 8.1 l/100km (Table 1-36). Both values are higher than the one used by the project (7.9 l/100km) - IPCC 1996 reports for diesel cars as lowest US values 10.0 l/100km (table 1-30) and as lowest European value 7.3 l/100km (Table 1-37). The Korean value is close to the lowest European one (7.4 l/100km) Gasoline cars represent 71% of vehicles and diesel cars 16% thus being the 2 dominant and most important categories.
Any comment:	To transform from litres to grams the specific weight of gasoline, diesel and LPG was taken based on IEA, 2005, table A.3.8 Calculation: Gasoline: 7.9 (l/100km) / 100 * 0.741 (kg/l) * 1,000 = 58.46 g/km Diesel: 7.4 (l/100km) / 100 * 0.844 (kg/l) * 1,000 = 62.60 g/km LPG: 10.7 (l/100km) / 100 * 0.522 (kg/l) * 1,000 = 55.91 g/km

Data / Parameter:	**$N_{C,G/D/LPG}$**
Data unit:	Vehicles
Description:	Number of passenger cars using fuel type: gasoline, diesel or LPG
Source of data used:	Korea Transportation Safety Authority, Table 4-24, p. 133, 2009 (File 4)
Value applied:	Gasoline: 461,761 (71%) Diesel: 105,295 (16%) LPG: 84,668 (13%)
Justification of the choice of data or description of measurement methods and procedures actually applied :	Official registration statistics
Any comment:	This data is monitored annually. Percentages and not absolute figures are required for calculations.

Data / Parameter:	**$SFC_{T,LPG}$**
Data unit:	g/km
Description:	Specific fuel consumed of LPG taxis
Source of data used:	Daegu Metropolitan City Public Transportation Division, 2011 (File 5)
Value applied:	94.26
Justification of the choice of data or description of measurement methods and procedures actually applied :	Official statistic
Any comment:	To transform from litres to grams the specific weight of LPG was taken based on IEA 2005, table A.3.8 Calculation: LPG: 18.1 (l/100km) / 100 * 0.522 (kg/l) * 1,000 = 94.26 g/km

Data / Parameter:	**$N_{T,LPG}$**
Data unit:	Vehicles
Description:	Number of taxis using LPG
Source of data used:	Daegu Metropolitan City Public Transportation Division, 2011 (File 5)
Value applied:	17,079 (100%)
Justification of the choice of data or description of measurement methods and procedures actually applied :	Official registration statistics (licensed number including corporation and private units)
Any comment:	This data is monitored annually. Percentages and not absolute figures are required for calculations.

Data / Parameter:	**$SFC_{B,D}$**
Data unit:	g/km
Description:	Specific fuel consumed of diesel buses
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.4, 2010 (File 6)
Value applied:	334.48
Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on records of total fuel consumed and total distance driven; As total fuel consumed and total distance driven is recorded no separation in bus size is required (latter is required if only SFC data is available to weight SFC per bus size)
Any comment:	To transform from litres to grams the specific weight of diesel was taken based on IEA2005, table A.3.8

	Calculation: 9,717,259 liter / 24,516,273 km * 0.844 kg/l * 1,000 = 334.48

Data / Parameter:	**$SFC_{B,CNG}$**
Data unit:	g/km
Description:	Specific fuel consumed of CNG buses
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.4, 2010 (File 6)
Value applied:	336.75
Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on records of total fuel consumed and total distance driven; As total fuel consumed and total distance driven is recorded no separation in bus size is required (latter is required if only SFC data is available to weight SFC per bus size)
Any comment:	To transform from m^3 to grams the specific weight of CNG was taken based on molar mass (CH_4 has a molar mass of 16g per mol. 16g/mol * 1000 l/m^3 / 22.4 l/mol = 714g/m^3 Calculation: 62,050,306 m^3 / 131,564,657 km * 0.714 kg/m^3 * 1,000 = 334.48

Data / Parameter:	**$N_{B,D/CNG}$**
Data unit:	Vehicles
Description:	Number of diesel and CNG buses
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.2, 2010 (File 6)
Value applied:	Diesel: 198 CNG: 1,460
Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on operational units
Any comment:	

Data / Parameter:	**EF_{Grid}**
Data unit:	$kgCO_2$/kWh
Description:	Emission factor for the grid
Source of data used:	KEPCO, 2010 (File 3a/b)
Value applied:	0.67379
Justification of the choice of data or description of measurement methods and procedures actually applied :	Official data; follow procedures as in “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”

Any comment:	

Data / Parameter:	**TDL**
Data unit:	---
Description:	Average technical transmission and distribution losses for providing electricity
Source of data used:	KEPCO, p. 116 data year 2009 (File 12)
Value applied:	1.67%
Justification of the choice of data or description of measurement methods and procedures actually applied :	Official value
Any comment:	

Data / Parameter:	**OC_C**
Data unit:	Passengers
Description:	Average occupation rate of passenger cars
Source of data used:	Korea Transport Institute, 2010, p.9 (File 2)
Value applied:	1.21
Justification of the choice of data or description of measurement methods and procedures actually applied :	Survey of independent organization
Any comment:	

Data / Parameter:	**OC_T**
Data unit:	Passengers
Description:	Average occupation rate of taxis
Source of data used:	Daegu Metropolitan City Public Transportation Division, 2011 (File 5)
Value applied:	0.55
Justification of the choice of data or description of measurement methods and procedures actually applied :	Survey of independent organization
Any comment:	Excluding driver Is monitored also for determination of leakage occupation rate.

Data / Parameter:	**OC_B**
Data unit:	Passengers

Description:	Average occupation rate of buses
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.4, 2010 (File 6)
Value applied:	13 (26%)
Justification of the choice of data or description of measurement methods and procedures actually applied :	Calculation based on PKM divided by total distance buses
Any comment:	Is monitored also for determination of leakage occupation rate. Calculation: Passengers: 285,306,462 (File 6, Daegu Metropolitan City Public Transportation Division, p.2, 2010) Average trip distance: 7.3 km (File 8, Korea Transportation Safety Authority, p.273, 2011 (average trip time of 24.9 minutes) and Daegu Metropolitan City, 2010, p.80 (average speed of 17.7km/h) Distance driven buses: see parameter SFC above Occupation = PKM / DD = 285,306,462 passengers * 7.3 km / (24,516,273km + 131,564,657km) = 13.4 passengers Occupation percentage = passengers / bus capacity = 13.4 / 52 = 26% Bus capacity: 52 (File 15, Daegu Metropolitan City Public Transportation Division, 2010)

Data / Parameter:	**PBL_B**
Data unit:	Passengers
Description:	Passengers transported by baseline buses per year
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.2, 2010 (File 6)
Value applied:	285,306,462
Justification of the choice of data or description of measurement methods and procedures actually applied :	Official records
Any comment:	

Data / Parameter:	**$TDBL_{P,B}$**
Data unit:	Kilometer
Description:	Average trip distance of passengers using buses prior project start
Source of data used:	Korea Transportation Safety Authority, p.273, 2011 and Daegu Metropolitan City, 2010, p.80 (File 8)
Value applied:	7.3

Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on average trip time of 24.9 minutes and average speed of bus of 17.7km/h
Any comment:	
Any comment:	

Data / Parameter:	**DD_B**
Data unit:	Km
Description:	Total distance driven by baseline buses per year
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.4, 2010 (File 6)
Value applied:	156,080,930
Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on CNG distance drive and diesel distance driven (see parameter SFC above)
Any comment:	

Data / Parameter:	**AD_B**
Data unit:	Km
Description:	Average annual distance driven of buses
Source of data used:	Daegu Metropolitan City Public Transportation Division, p.4, 2010 (File 6)
Value applied:	94,138
Justification of the choice of data or description of measurement methods and procedures actually applied :	Based on annual distance driven of all buses of (D_B see above) and the average operational fleet (see above)
Any comment:	Used for leakage load factor change buses if calculation is required. Data is updated if leakage occurs in occupation rate buses with the same source.

Data / Parameter:	**$TD_{EL,R}$**
Data unit:	Km
Description:	Average trip distance of baseline metro passengers prior project start
Source of data used:	Daegu Metropolitan Transit Corporation, 2010, p.91 (File 1)
Value applied:	8.1
Justification of the choice of data or description of	

measurement methods and procedures actually applied :	
Any comment:	

Data / Parameter:	**AD_T**
Data unit:	Km
Description:	Average annual distance driven of taxis
Source of data used:	Daegu Metropolitan City Public Transportation Division, 2011 (File 5)
Value applied:	67,346
Justification of the choice of data or description of measurement methods and procedures actually applied :	
Any comment:	Used for leakage load factor change taxis if calculation is required

Data / Parameter:	**$NIZ_{C,T,BL}$**
Data unit:	Vehicles
Description:	Number of cars/taxis on roads affected per annum in the baseline
Source of data used:	South Pacific, 2011 (File 59)
Value applied:	see Table 15 below
Justification of the choice of data or description of measurement methods and procedures actually applied :	Measurement on affected roads from 06.00 to 20.00. Multiplication without expansion factor by 360 for year. 2 points per affected road. Same procedure will be applied during monitoring to ensure consistency.
Any comment:	The same measurements will be realized annually to determine the leakage congestion and speed.

Table 15: Number of Vehicles Baseline on Affected Roads (per annum)

ID	Affected Road	Number of cars	Number of taxis
1	Paldalro Road	8,550,180	6,401,880
2	Myeongdeongro	7,232,220	5,767,200
3	DongdaegugroYongji	8,967,600	6,645,600

Data / Parameter:	**V_B**
Data unit:	Km/h
Description:	Vehicle baseline speed on affected roads.
Source of data used:	Daegu Metropolitan City, 2010 (File 59a)
Value applied:	**Table 16: Baseline Moving Speed on Affected Roads**

	ID | Affected Road | Average moving speed 1 | Paldalro Road | 41 2 | Myeongdeongro | 38 3 | DongdaegugroYongji | 42
Justification of the choice of data or description of measurement methods and procedures actually applied :	Regular measurements made citywide
Any comment:	The average moving speed is measured as this is required for vehicle speed change.

The technology improvement factor IR used for buses, cars and taxis is not included as this is a default factor of the methodology.

B.6.3. Ex-ante calculation of emission reductions:

BASELINE EMISSIONS

Details of the calculation are found in Annex 3.

Table 17: Estimated Baseline Emissions (tCO_2)

2015	2016	2017	2018	2019	2020	2021
93,909	95,759	97,646	99,569	101,531	103,555	105,596

PROJECT EMISSIONS

Details of the calculation are found in Annex 3.

Table 18: Estimated Project Emissions (tCO_2)

2015	2016	2017	2018	2019	2020	2021
37,840	38,311	38,791	39,281	39,780	40,296	40,815

LEAKAGE EMISSIONS

Leakage emissions are based on load factor change and leakage due to reduced congestion (rebound and vehicle speed change). No changes of load factor and no positive leakage in the rebound/speed effect are projected. Therefore leakage is projected to be 0. The experience with CDM projects in MRTS has shown that no negative change in occupation rates occur thus not leading to leakage for change of occupation rate (see project 0671 BRT TransMilenio with monitoring report year 2008). Also the modelling made in MRTS projects under validation using AM0031 (in AM0031 the congestion impact including the speed and the rebound effect is modelled and calculated ex-ante) has shown in projects under validation that the congestion impact is with one exception negative i.e. the speed effect is larger than the rebound effect or the rebound effect is already negative i.e. the projection reduces emissions even more. Therefore it is conservative to assume ex-ante that leakage will be 0. However the corresponding parameters will be monitored in accordance with the methodology and leakage is thus monitored.

B.6.4 Summary of the ex-ante estimation of emission reductions:

Year	Estimation of project activity emissions (tCO_{2e})	Estimation of baseline emissions (tCO_{2e})	Estimation of leakage (tCO_{2e})	Estimation of overall emission reductions (tCO_{2e})
2015	37,840	93,909	0	56,069
2016	38,311	95,759	0	57,448
2017	38,791	97,646	0	58,855
2018	39,281	99,569	0	60,288
2019	39,780	101,531	0	61,751
2020	40,296	103,555	0	63,259
2021	40,815	105,596	0	64,781
Total (tCO_{2e})	**275,114**	**697,565**	**0**	**422,451**

B.7. Application of the monitoring methodology and description of the monitoring plan:

B.7.1 Data and parameters monitored:

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards and national regulations.

In addition to the parameters listed in the tables below, the provisions on data and parameters monitored in the tools referred to in this methodology apply.

Data / Parameter:	**$NCV_{G/D,LPG,CNG}$**
Data unit:	MJ/kg
Description:	Net calorific value of gasoline and diesel
Source of data to be used:	IPCC 2006, table 1.2
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Gasoline: 42.5 Diesel: 41.4 LPG: 44.8 CNG: 46.5
Description of measurement methods and procedures to be applied:	Monitoring frequency: annual Any future revision of the IPCC Guidelines is taken into account.
QA/QC procedures to be applied:	lower 95% confidence interval
Any comment:	

Data / Parameter:	**$EF_{CO2,G/D/CNG/LPG}$**
Data unit:	gCO_2/MJ
Description:	CO_2 emission factor for gasoline, diesel, CNG and LPG
Source of data to be used:	IPCC 2006, table 1.4, lower 95% confidence interval
Value of data applied for the purpose of calculating expected emission	Gasoline: 67.5 Diesel: 72.6 CNG: 54.3

reductions in section B.5	LPG: 61.6
Description of measurement methods and procedures to be applied:	No national value; IPCC default value lower 95% confidence interval Monitoring frequency: annual Any future revision of the IPCC Guidelines is taken into account.
QA/QC procedures to be applied:	
Any comment:	In case biofuel blends are used in liquid fuels the biofuel share of the blend is accounted for with zero emission factor. The usage of biofuel is monitored annually for diesel and gasoline. The EF is thereafter adjusted based on the biofuel contents e.g. if the biofuel contents is 10% then the IPCC EF is multiplied with (100%-10%) to get the EF used. The baseline emission factors must, if the biofuel contents changes over time be adjusted.

Data / Parameter:	**$EF_{KM,B,CH4}$**
Data unit:	gCO_{2eq}/km
Description:	CH_4 emission factor of CNG buses per kilometre in CO_{2eq}
Source of data to be used:	IPCC 2006, table 3.2.4.
Value of data applied for the purpose of calculating expected emission reductions in section B.5	162.0
Description of measurement methods and procedures to be applied:	IPCC value as no national measurements exist Monitoring frequency: annual
QA/QC procedures to be applied:	
Any comment:	Any future revision of the IPCC Guidelines is taken into account. The methodology requires that CH_4 emissions of vehicles using gaseous fuels are included. Value of 7,715 mg CH_4 of IPCC is multiplied with the GWP of 21 for CH_4 to calculate CO_{2eq}

Data / Parameter:	**$EF_{KM,LPG,C/T,CH4}$**
Data unit:	gCO_{2eq}/km
Description:	CH_4 emission factor of LPG cars and taxis per kilometre in CO_{2eq}
Source of data to be used:	IPCC 2006, table 3.2.4.
Value of data applied for the purpose of calculating expected emission reductions in section B.5	0.5
Description of measurement methods and procedures to be applied:	IPCC value as no national measurements exist Monitoring frequency: annual
QA/QC procedures to be applied:	
Any comment:	Any future revision of the IPCC Guidelines is taken into account. The methodology requires that CH_4 emissions of vehicles using gaseous fuels are included. 24 mg CH_4 of IPCC is multiplied with the GWP of 21 for CH_4 to calculate CO_{2eq}

Data / Parameter:	$\mathbf{N_{x,C/T}}$
Data unit:	Vehicles
Description:	Number of passenger cars (C) and taxis (T) using fuel type *x*
Source of data to be used:	Korea Transportation Safety Authority
Value of data applied for the purpose of calculating expected emission reductions in section B.5	No change projected
Description of measurement methods and procedures to be applied:	Registration statistics Monitoring frequency: annual
QA/QC procedures to be applied:	latest available data not elder than 3 years
Any comment:	Required to check if passenger cars or taxis use different fuels than those used for calculating the baseline parameter.

Data / Parameter:	**P**
Data unit:	Passengers
Description:	Total passengers transported by the project
Source of data to be used:	Daegu Metropolitan Transit Corporation
Value of data applied for the purpose of calculating expected emission reductions in section B.5	**Table 19: Million Passengers per Year** 2015: 84; 2016: 87; 2017: 89; 2018: 92; 2019: 95; 2020: 98; 2021: 100 For projections based on File 14, Daegu Metropolitan City, 2006
Description of measurement methods and procedures to be applied:	Turnpike controls at stations and electronic smart cards. Passengers are included which enter stations of the project metro (Get On) including transfer passengers. Monitoring frequency: Continuously, aggregated at least annually
QA/QC procedures to be applied:	Checked with ticket sales (average fare and income from ticket).
Any comment:	

Table 19: Million Passengers per Year

2015	2016	2017	2018	2019	2020	2021
84	87	89	92	95	98	100

Data / Parameter:	$\mathbf{EC_{PJ}}$
Data unit:	MWh
Description:	Electricity consumed by project metro
Source of data to be used:	Daegu Metropolitan Transit Corporation
Value of data applied for the purpose of calculating expected emission reductions in section B.5	20,342 For projections based on File 13, Daegu Metropolitan Transit Corporation, 2010, p.5
Description of measurement methods and procedures to be applied:	Traction energy only Monitoring frequency: Continuously, aggregated at least annually There are two substation converters for the station which include the shops and station office electricity (AC), and traction electricity (DC). The transformer converts 22.9 kV to 1500 DC for traction energy. The measurement of DC1500V for the train is checked in the rectifier which includes the watt-hour meter of Daegu Metropolitan Transit Corporation.

	Total electricity consumed is registered by KEPCO which owns and calibrates the meters. Traction energy is only recorded by Daegu Metropolitan Transit Corporation. The DTRO equipment is not calibrated since it is attached in the rectifier (see for details File 68 and see Figure 7 section B.7.2.). The traction energy as recorded by Daegu Metropolitan Transit Corporation is taken as data.
QA/QC procedures to be applied:	Control of plausibility with electricity invoices. The electricity invoices include traction plus station electricity usage. The plausibility is checked through comparison with previous years as well as with share of traction electricity as percentage of total electricity usage of other metro lines. The electricity meters are calibrated by the local electricity board. The electricity meters are not owned or managed by Daegu Metropolitan Transit Corporation but by KEPCO. Latter is also responsible for their periodic calibration. Electricity meters are calibrated, depending on the electricity meter type, every 7 to 15 years based on regulations of the Ministry of Knowledge Economy (File 67).
Any comment:	Used to calculate together with the emission factor grid the DPE as per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”.

Data / Parameter:	**MS_i**
Data unit:	Percentage
Description:	Net share of passengers using the metro which would have used baseline mode *i* (%)
Source of data to be used:	Survey realized by external survey company
Value of data applied for the purpose of calculating expected emission reductions in section B.5	For projections a survey on the existing metro lines of Daegu: Passenger car: 24% Taxi: 8% Motorcycle: 0% Bus: 69% NMT and induced traffic:01% The total is more than 100% as passengers can use various modes in the baseline from their trip origin to their trip destination.
Description of measurement methods and procedures to be applied:	Survey. Monitoring frequency: annual
QA/QC procedures to be applied:	See Annex 3 for the survey design
Any comment:	Only used for leakage calculation of rebound effect.

Data / Parameter:	**N_B**
Data unit:	Buses
Description:	Number of buses circulating in the city
Source of data to be used:	Daegu Metropolitan City Public Transportation Division
Value of data applied for the purpose of calculating expected emission reductions in section B.5	None as no change in occupation rate of buses is previewed
Description of measurement methods and	Monitoring frequency: year 1, 4 and 7

procedures to be applied:	
QA/QC procedures to be applied:	
Any comment:	Monitoring is only if required i.e. if a change of occupation rate is registered

Data / Parameter:	**$OC_{B,T}$**
Data unit:	Passengers
Description:	Average occupancy rate of buses and taxis
Source of data to be used:	Survey realized by project proponent or 3rd party report (e.g. made by Daegu Metropolitan City Public Transport Division)
Value of data applied for the purpose of calculating expected emission reductions in section B.5	No change of occupation rate previewed to baseline. Practical experience of a comparable MRTS (TransMilenio Bogota, which has a comparable outreach) has shown no negative change (reduced occupation rate) of occupation rates of baseline vehicles. See verification report TransMilenio 2009 (project 0672) (published on www.unfccc.int).
Description of measurement methods and procedures to be applied:	Independent published data or in accordance with TORs of methodology Monitoring frequency: Year 1,4, and 7
QA/QC procedures to be applied:	
Any comment:	

Data / Parameter:	**$NIZ_{C,T}$**
Data unit:	Vehicles
Description:	Number of cars/taxis using affected roads
Source of data to be used:	Survey realized by project proponent or 3rd party report
Value of data applied for the purpose of calculating expected emission reductions in section B.5	No projections as no speed change is expected, thus not requiring this parameter.
Description of measurement methods and procedures to be applied:	Visual counting. Monitoring frequency: annual
QA/QC procedures to be applied:	Same roads, same data points, same hours and same number of days are monitored as in the baseline study (File 59b and c).
Any comment:	

Data / Parameter:	**$TDIZ_{C,T}$**
Data unit:	Kilometres
Description:	Distance driven by taxis and passenger cars on affected roads
Source of data to be used:	Survey realized by project proponent or 3rd party
Value of data applied for the purpose of calculating expected emission reductions in section B.5	No projections as no speed change is expected, thus not requiring this parameter.
Description of measurement methods and procedures to be applied:	Visual tracking of samples of vehicles entering/exiting the affected roads registering the entry and the exit point and measuring the distance by GPS or other means Monitoring frequency: annual

QA/QC procedures to be applied:	
Any comment:	

Data / Parameter:	**V_P**
Data unit:	Km/h
Description:	Vehicle project speed on affected roads; Average moving speed is recorded.
Source of data to be used:	Survey realized by project proponent or 3rd party
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Same speed as under baseline is expected
Description of measurement methods and procedures to be applied:	On-board measurements determining the average moving speed (when circulating) on the affected road based e.g. on GPS measuring or measurement of speed and distances/time through electronic surveillance. Monitoring frequency: annual
QA/QC procedures to be applied:	Same roads, same data points, same hours and same number of days are monitored as in the baseline study (File 59a).
Any comment:	Only passenger cars and taxis

Data / Parameter:	**$EC_{EL,R}$**
Data unit:	MWh
Description:	Quantity of electricity consumed by the baseline metro lines per annum
Source of data to be used:	Daegu Metropolitan Transit Corporation
Value of data applied for the purpose of calculating expected emission reductions in section B.5	68,142 (File 9, Daegu Metropolitan Transit Corporation, 2010 traction energy only, p-4)
Description of measurement methods and procedures to be applied:	Monitoring frequency: annual
QA/QC procedures to be applied:	
Any comment:	Required to establish the emission factor per PKM for existing metro

Data / Parameter:	**$P_{EL,R}$**
Data unit:	Passengers
Description:	Total passengers transported by baseline metro lines per year
Source of data to be used:	Daegu Metropolitan Transit Corporation
Value of data applied for the purpose of calculating expected emission reductions in section B.5	111,780,000 (File 10, Daegu Metropolitan Transit Corporation, 2010, p.81)
Description of measurement methods and procedures to be applied:	Monitoring frequency: annual
QA/QC procedures to be applied:	

Any comment:	Required to establish the emission factor per PKM for suburban rail

TC_{PJ}, DD_{PJ} and SFC_{PJ} are not monitored as the project uses only electricity as fuel.

DPE and IDPE are calculated and not monitored values and therefore not listed.

BTD_P, $IPDT_P$, P_{SPER}, FEX_P, are resultants from the survey (see Annex 3). They are calculated per surveyed passenger and then expanded to the total of passengers in the monitored time period.

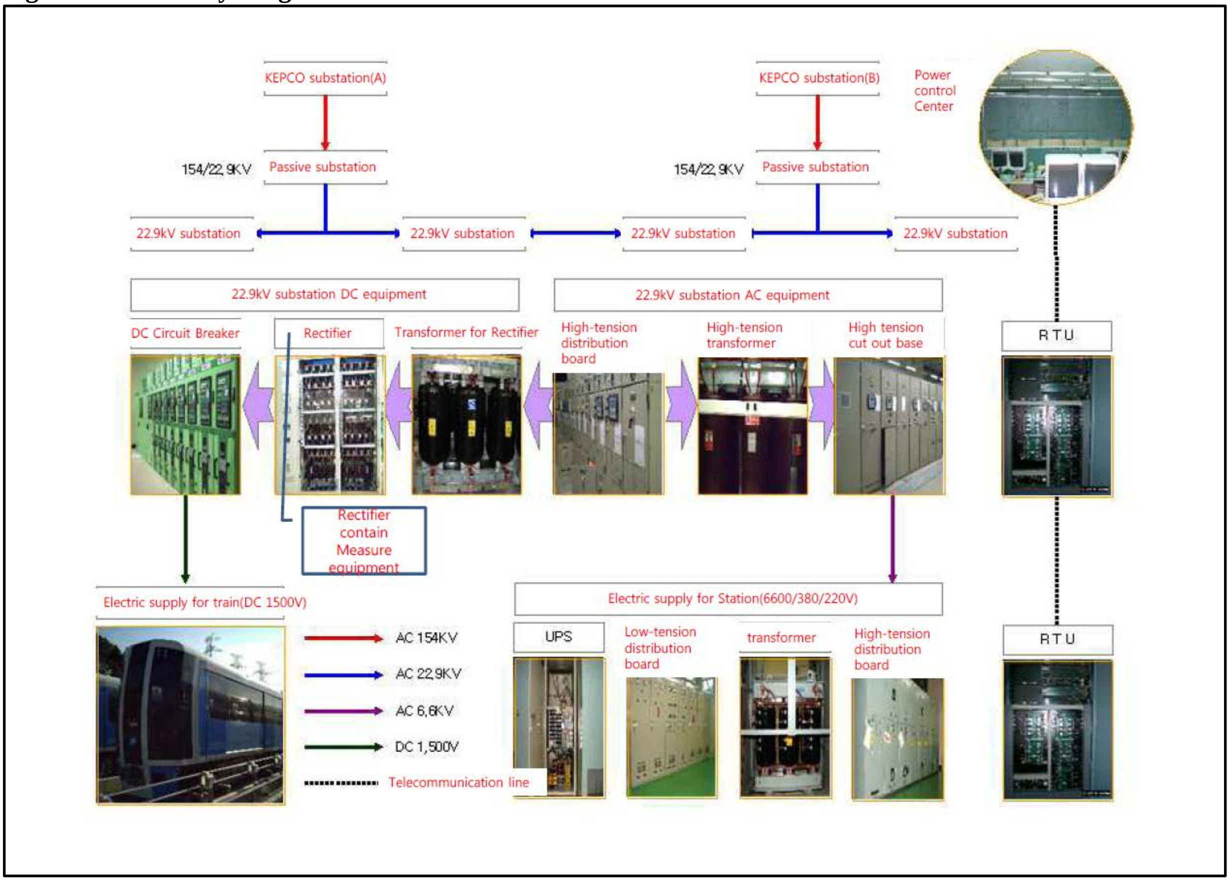
B.7.2. Description of the monitoring plan:

A monitoring manual for the project has been developed by Grütter Consulting AG and can be reviewed by the validator. It defines all responsibilities and procedures. For each data parameter the information sources, units, frequency of measurement as well as data quality assurance processes are described in detail. Also steps are provided how to proceed in case of problematic data. The staff will be trained on usage of the manual. Grütter Consulting AG will take the role of data quality control and quality assurance while also realizing the monitoring report during the entire crediting period. Grütter Consulting AG is the author of the methodology used for this project and a consultancy specialized in GHG transport projects since 1992. It is in charge of numerous comparable CDM transport projects and has thus a profound know-how on monitoring such types of projects. See Annex 4 for details of the manual.

The survey design as well as the statistical analysis of the survey will be realized by Grütter Consulting AG which has a staff exclusively and highly qualified for survey design and statistical analysis. The survey realization will be done by an external specialized company with quality control through South Pacific Inc. Grütter Consulting AG and its staff also developed the methodology including the survey design included in the methodology and is thus highly competent to perform this important task. All other data not under direct control of the metro (load factor studies, speed studies, congestion studies) will be collected or contracted and supervised by South Pacific Inc. with QA/QC done by Grütter Consulting AG. Through managing worldwide numerous Mass Transit projects in various cities data values obtained are also cross-checked to improve data reliability.

Concerning traction energy usage there are two substation converters for the station which include the shops and station office electricity (AC), and traction electricity (DC). The transformer converts 22.9 kV to 1500 DC for traction energy. The measurement of DC1500V for the train is checked in the rectifier which includes the watt-hour meter of Daegu Metropolitan Transit Corporation. Total electricity consumed is registered by KEPCO which owns and calibrates the meters. Traction energy is only recorded by Daegu Metropolitan Transit Corporation. The DTRO equipment is not calibrated since it is attached in the rectifier.

Figure 7: Electricity Diagram



Source: Daegu Metropolitan Transit Corporation (File 68)

For the survey on mode of transport see the Annex 3.

B.8. Date of completion of the application of the baseline study and monitoring methodology and the name of the responsible person(s)/entity(ies):

Completion date: 10/10/2011

The PDD as well as the methodology used for this PDD was developed by Grütter Consulting AG. Staff involved in the elaboration of this PDD include Dr. Jürg M. Grütter, CEO Grütter Consulting AG and Rohini Balasubramanian, India Country Manager Grütter Consulting AG and staff of South Pacific Inc.

Grütter Consulting AG is responsible for the baseline determination of the project and author of the methodology used for this project.

Contact person: Jürg M. Grütter
jgruetter@gmail.com
www.transport-ghg.com

Grütter Consulting AG and South Pacific Inc. are also project participants as listed in Annex 1.

SECTION C. Duration of the project activity / crediting period

C.1. Duration of the project activity:

C.1.1. Starting date of the project activity:

29/06/2009[72].

C.1.2. Expected operational lifetime of the project activity:

Infrastructure minimum 30 years

C.2. Choice of the crediting period and related information:

C.2.1. Renewable crediting period:

C.2.1.1. Starting date of the first crediting period:

01/01/2015

C.2.1.2. Length of the first crediting period:

7 years, 0 months

C.2.2. Fixed crediting period:

C.2.2.1. Starting date:

Not applicable

C.2.2.2. Length:

Not applicable

SECTION D. Environmental impacts

D.1. Documentation on the analysis of the environmental impacts, including transboundary impacts:

The project has realized through Hankook Environment & Consultation Co.Ltd. an EIA[73]. 09/07/2008 the project got its construction and operation approval[74].

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[72] File 32

[73] File 56

[74] File 57

The project reduces the usage of fossil fuel and the corresponding emission of pollutants caused by fossil powered vehicles due to mode switch towards the metro.A positive impact on potential transboundary air pollution can be expected due to reduced emissions of air pollutants due to reduced fuel usage and minor vehicle kilometres (PM and NO_x basically). Transboundary air pollution is a particular problem for pollutants that are not easily destroyed or react in the atmosphere to form secondary pollutants. Typical transboundary air pollutants are carbon monoxide, PM10, non-methane VOCs[75] and NO_x (resulting potentially in ground-level ozone which again is a major component of smog) or sulphur dioxide (SO_2 together with NO_x are primary precursors of acid rain).

D.2. If environmental impacts are considered significant by the project participants or the host Party, please provide conclusions and all references to support documentation of an environmental impact assessment undertaken in accordance with the procedures as required by the host Party:

The EIA has identified the environmental impacts of the project as listed in the following table.

Table 20: Anticipated Environmental Impacts of the Project

Area	Anticipated Impact
Topography	No change due to elevated train; earthwork for structures.
Plants and animals	Cutting of 3,660 trees. No significant impact on land animals. Some water animal disturbance due to insertion of earth in rivers during construction.
Air quality	Temporary negative impact near to construction site during construction works.
Water quality	During construction earth flows into river and waste-water of construction workers; during operation waste-water of stations
Noise and vibration	During construction basically due to road braking; during operation in accordance win railway standard; in two school areas the school noise standard will be slightly surpassed
Waste material	During construction debris and waste-oil; during operations waste from passengers and waste at depots

The Ministry of Land, Transportation and Maritime affairs approved 22/05/2009 in accordance with the “Metro Act” Art. 4, clause 3 the Daegu metro construction under the condition that it complies with the environmental impact, transportation impact assessment and disaster impact assessment and is in accordance with general acts and regulations[76]. The Ministry of Land, Transportation and Maritime Affairs certifies that the Traffic Impact Assessment for Daegu Metro Line 3 is in accordance with the “Environment, Traffic, Disaster Assessment Act” Art. 20, clause 1 as of 19/12/2008[77]. The same Ministry also confirms that the environmental impact assessment or Daegu Metro Line 3 has been realized in accordance with the “Environment, Traffic, Disaster Assessment Act” Art. 20, as of 27/10/2008[78].

SECTION E. Stakeholders’ comments

[75] Volatile Organic Components

[76] File 64

[77] File 64

[78] File 64

E.1. Brief description how comments by local stakeholders have been invited and compiled:

The project realized following stakeholder meetings recorded also in the EIA[79]:

- 16/01/2006 meeting to discuss the line plan
- 03/06/2007 consultation meeting
- 30/05/2007 stakeholder meeting
- 17/08/2007 presentation at the Construction Forum at the Munhwa International Conference Meeting Room
- 16/01/2008 Stakeholder Meeting for Environmental Impact Explanation at the Hall of Daegu People

The stakeholder meeting held 30/05/2007 was announced through the press on 14/05/2007 and was public. It was held at the Daegu Art Center National Room[80].

E.2. Summary of the comments received:

A report on the stakeholder meeting of 30/05/2007 was realized[81]. The project was presented and thereafter discussed. Following major elements were highlighted:

- Usage of the most advanced technology to avoid noise and vibrations and to protect the townscape.
- With a monorail the smaller pillar size allows to maintain the road.
- Partially the metro would need to be made underground if based on a LRT due to road space availability.
- The monorail appears as the most feasible option under financial considerations.

E.3. Report on how due account was taken of any comments received:

Comments raised during the stakeholder meeting were responded. The final design approved is based on the monorail proposal without underground section.

[79] File 56b

[80] File 58

[81] File 58

Annex 1

CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY

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Annex 2

INFORMATION REGARDING PUBLIC FUNDING

There is no Official Development Assistance in this project and the project will not receive any public funding from Parties included in Annex I.

Annex 3

BASELINE INFORMATION

A.1. BASELINE EMISSIONS

A.1.1. Formulas

$$BE_y = \frac{P_y}{P_{SPER}} \sum_p \left(BE_{p,y} \cdot FEX_{p,y} \right)$$

Where:

BE_y	Baseline emissions in the year *y* (g CO_2)
$BE_{p,y}$	Baseline emissions per surveyed passenger *p* in the year *y* (g CO_2)
$FEX_{p,y}$	Expansion factor for each surveyed passenger *p* surveyed in the year *y*(each surveyed passenger has a different expansion factor)
P_y	Total number of passengers in the year *y*
P_{SPER}	Number of passengers in the time period of the survey (1 week)
p	Surveyed passenger
y	Year of the crediting period

$$BE_{p,y} = \sum_i BTD_{p,i,y} \cdot EF_{PKM,i,y}$$

Where:

$BE_{p,y}$	Baseline emissions per surveyed passenger *p* in the year *y* (g CO_2)
$BTD_{,p,i,y}$	Baseline trip distance *p* per surveyed passenger using mode *i* in the year *y* (PKM)
$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of mode *i* in the year *y* (g CO_2/PKM)
i	Relevant vehicle category
p	Surveyed passenger
y	Year of the crediting period

$$EF_{PKM,i,y} = \frac{TE_{EL,i,y}}{P_{EL,i,y} \cdot TD_{EL,i}}$$

Where:

$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of suburban rail / metro for year *y* (gCO_2/PKM)
$TE_{EL,i,y}$	Total emissions from suburban rail / metro for year *y* (tCO_2)
$P_{EL,i,y}$	Total passengers transported per year by suburban rail / metro for year *y* (passengers)
$TD_{EL,i}$	Average trip distance of passengers using suburban rail / metro prior to project start (km)
i	Suburban rail / metro
y	Year of the crediting period

$$TE_{EL,i,y} = EC_{BL,i,y} \times EF_{grid,CM} \times (1 + TDL) \times 10^{-6}$$

Where:

$TE_{EL,i,y}$	Total emissions from suburban rail / metro for year *y* (tCO_2)
$EC_{BL,i,y}$	Quantity of electricity consumed by suburban rail / metro in the year y(MWh)
$EF_{grid,CM}$	Emission factor for electricity generation in the grid based on combined margin (gCO_2/kWh)
TDL	Average technical transmission and distribution losses for providing electricity

$$EF_{PKM,i,y} = \frac{EF_{KM,i,y}}{OC_i}$$

Where:

$EF_{PKM,i}$	Emission factor per passenger-kilometre of vehicle category *i* in the year *y* (g CO_2/PKM)
$EF_{KM,i}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
OC_i	Average occupation rate of vehicle category *i* prior project start (passengers)
i	Relevant vehicle category
y	Year of the crediting period

$$OC_B = \frac{PBL_B \times TDBL_{P,B}}{DD_B}$$

Where:

OC_B	Average occupation rate of buses prior project start (passengers)
PBL_B	Passengers transported by baseline buses prior project (passengers)
$TDBL_{P,B}$	Average trip distance of passengers using baseline bus (kilometer)
DD_B	Distance driven by all baseline buses (kilometer)

$$EF_{KM,i,y} = \frac{\sum_x \left(SFC_{i,x,y} \cdot NCV_{x,y} \cdot EF_{CO2,x,y} \cdot N_{x,i}\right)}{N_i}$$

Where:

$EF_{KM,i,,y,}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
$SFC_{x,i}$	Specific fuel consumption of vehicle category *i* using fuel type *x* prior project start (g/km)
$NCV_{x,y}$	Net calorific value of fuel *x* in the year *y* (J/g)
$EF_{CO2,x,y}$	Carbon emission factor for fuel type *x* in the year *y* (g CO_2/J)
$N_{x,i}$	Number of vehicles of category *i* using fuel type *x* prior to project start (units)
$N_{x,i}$	Number of vehicles of category *i* prior to project start (units)
i	Relevant vehicle category
x	Fuel type
y	Year of the crediting period

$$EF_{KM,i,y} = \left(IR_i\right)^{t+y} \cdot \frac{\sum_x \left(SFC_{i,x} \cdot NCV_{x,y} \cdot EF_{CO2,x,y} \cdot N_{x,i}\right)}{N_i}$$

Where:

$EF_{KM,i,,y,}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
$SFC_{x,i}$	Specific fuel consumption of vehicle category *i* using fuel type *x* prior project start (g/km)

$NCV_{x,y}$	Net calorific value of fuel *x* in the year *y* (J/g)
$EF_{CO2,x,y}$	Carbon emission factor for fuel type *x* in the year *y* (g CO_2/J)
$N_{x,i}$	Number of vehicles of category *i* using fuel type *x* prior to project start (units)
$N_{x,i}$	Number of vehicles of category *i* prior to project start (units)
IR_i^{t+y}	Technology improvement factorfor the vehicle of category *i* per year *t+y* (ratio)
i	Relevant vehicle category
x	Fuel type
t	Years of annual improvement (dependent on age of data per vehicle category)
y	Year of the crediting period

A.1.2. Data Used

Table A.1. Baseline Parameters

Parameter	Description	Value	Unit	Source
$EF_{grid,CM}$	Emission factor of grid	0.67379	tCO_2/MWh	File 3
TDL	Average technical transmission and distribution losses for providing electricity	1.67%	percentage	File 12
$EC_{EL,R}$	Quantity of electricity consumed by the existing metro	68,142	MWh	File 9
$P_{EL,R}$	Passengers transported by the existing metro	111,780,000	Passengers	File 10
$TD_{EL,R}$	Average trip distance of passengers using the existing metro	8.1	km	File 11
$SFC_{C,G}$	Specific fuel consumption gasoline cars	7.9	l/100km	File 1
$SFC_{C,D}$	Specific fuel consumption diesel cars	7.4	l/100km	File 1
$SFC_{C,LPG}$	Specific fuel consumption LPG cars	10.7	l/100km	File 1
$SFC_{T,LPG}$	Specific fuel consumption LPG taxis	18.1	l/100km	File 5
$FC_{B,D}$	Fuel consumption all diesel buses year 2009	9,717,259	Litre	File 6
$FC_{B,CNG}$	Fuel consumption all CNG buses year 2009	62,050,306	m^3	File 6
$DD_{B,D}$	Distance driven all diesel buses year 2009	24,516,273	Km	File 6
$DD_{B,CNG}$	Distance driven all CNG buses year 2009	131,564,657	Km	File 6
NCV_G	Net calorific value gasoline	42.5	MJ/kg	IPCC 2006, table 1.2
NCV_D	Net calorific value diesel	41.4	MJ/kg	IPCC 2006, table 1.2
NCV_{CNG}	Net calorific value CNG	46.5	MJ/m^3	IPCC 2006, table 1.2
NCV_{LPG}	Net calorific value LPG	44.8	MJ/kg	IPCC 2006, table 1.2
$EF_{CO2,G}$	CO_2 emission factor gasoline	67.5	gCO_2/MJ	IPCC 2006, table 1.4
$EF_{CO2,D}$	CO_2 emission factor diesel	72.6	gCO_2/MJ	IPCC 2006, table 1.4

$EF_{CO2,CNG}$	CO_2 emission factor CNG	54.3	gCO_2/MJ	IPCC 2006, table 1.4
$EF_{CO2,LPG}$	CO_2 emission factor LPG	61.6	gCO_2/MJ	IPCC 2006, table 1.4
$EF_{CH4,CNG}$	CH_4 emission factor of CNG buses	162.0	gCO_2/km	IPCC 2006, table 3.2.4
$EF_{CH4,CNG}$	CH_4 emission factor of CNG light vehicles	9.9	gCO_2/km	IPCC 2006, table 3.2.4
$EF_{CH4,LPG}$	CH_4 emission factor of LPG light vehicles	0.5	gCO_2/km	IPCC 2006, table 3.2.4
	Specific weight gasoline	0.741	kg/l	IEA, 2005, table A.3.8
	Specific weight diesel	0.844	kg/l	IEA, 2005, table A.3.8
	Specific weight CNG	0.714	kg/m^3	Based on molar mass
	Specific weight LPG	0.522	kg/l	IEA, 2005, table A.3.8
IR	Technology improvement factor	0.99	no unit	ACM0016
	Share gasoline cars	71%	%	File 4
	Share diesel cars	16%	%	File 4
	Share LPG cars	13%	%	File 4
	Share LPG taxis	100%	%	File 5
$N_{B,D}$	Number of diesel buses	198	vehicles	File 6
$N_{B,CNG}$	Number of CNG buses	1,460	vehicles	File 6
PBL_B	Passengers transported all buses 2009	285,306,462	passengers	File 6
$TDBL_{P,B}$	Average trip distance of passenger on bus	7.3	km	File 8
OC_C	Occupation rate cars	1.21	passengers	File 2
OC_T	Occupation rate taxis	0.55	passengers	File 5
MS	Share of passengers using mode *i* for the baseline trip	See table A2	%	File 55
P	Passengers transported by the project	See table A5	passengers	File 14
$BTD_{PS,i}$	Baseline trip distance of the surveyed passenger using mode *i*	Value per passenger surveyed	km	File 55

Table A2. Mode Share of Surveyed Passengers[82]

Mode	Share of passengers using this mode
Passenger car	24%
Taxi	8%
Bus	69%
Motorcycle	0%
NMT incl. induced	0%
Rail	0%

Table A3. Emissions per Kilometre of Modes (gCO_2/km)

Mode	2015	2016	2017	2018	2019	2020	2021
Passenger car	161	159	158	156	155	153	152
Taxi	250	248	245	243	240	238	236
Bus	952	942	933	924	915	905	896

Technology improvement factor for each year based on data year source.

Table A4. Emissions per Passenger-Kilometre of Modes (gCO_2/PKM)

Mode	2015	2016	2017	2018	2019	2020	2021
Passenger car	133	132	130	129	128	127	125
Taxi	455	451	446	442	437	433	429
Bus	71	70	69	69	68	67	67
Existing metro	52	52	52	52	52	52	52

[82]Passengers can use more than 1 mode for their trip and therefore the cumulative percentage is more than 100%

A.1.3. Results

Table A5. Baseline Emissions

Parameter	unit	2015	2016	2017	2018	2019	2020	2021
Number of passengers	passengers	84,146,005	86,670,385	89,270,497	91,948,612	94,707,070	97,571,435	100,498,578
Average baseline emission factor	gCO_2/passenger	1,116	1,105	1,094	1,083	1,072	1,061	1,051
Total baseline emissions	**tCO_2**	**93,910**	**95,760**	**97,646**	**99,570**	**101,531**	**103,556**	**105,596**

A.2. PROJECT EMISSIONS

A.2.1. Formulas

$$PE_y = DPE_y + IPE_y$$

Where:

$PE_{,y,}$	Project emissions in the year *y* (tCO_2)
DPE_y	Direct project emissions in the year *y* (tCO_2)
IPE_y	Indirect project emissions in the year *y* (tCO_2)
y	Year of the crediting period

$$DPE_y = EC_{PJ,y} \times EF_{grid,CM} \times (1+TDL) \times 10^{-6}$$

Where:

DPE_y	Direct project emissions in the year *y* (tCO_2)
$EC_{PJ,y}$	Quantity of electricity consumed by project metro for traction in the year y (MWh)
$EF_{grid,CM}$	Emission factor for electricity generation in the grid based on combined margin (gCO_2/kWh)
TDL	Average technical transmission and distribution losses for providing electricity

$$IPE_y = \frac{P_y}{P_{SPER}} \sum_p \left(IPE_{p,y} \cdot FEX_{p,y} \right)$$

Where:

IPE_y	Indirect project emissions in the year *y* (g CO_2)
$IPE_{p,y}$	Indirect project emissions per surveyed passenger *p* in the year *y* (g CO_2)
$FEX_{p,y}$	Expansion factor for each surveyed passenger *p* surveyed in the year *y* (each surveyed passenger has a different expansion factor)
P_y	Total number of passengers in the year *y*
P_{SPER}	Number of passengers in the time period of the survey (1 week)
p	Surveyed passenger
y	Year of the crediting period

$$IPE_{p,y} = \sum_{i} IPTD_{p,i,y} \times EF_{PKM,i,y}$$

Where:

$IPE_{p,y}$ Indirect project emissions per surveyed passenger *p* in the year *y* (g CO_2)

$BTD_{,p,i,y}$ Indirect project trip distance *p* per surveyed passenger using mode *i* in the year *y* (PKM)

$EF_{PKM,i,y}$ Emission factor per passenger-kilometre of mode *i* in the year *y* (g CO_2/PKM)

i Relevant vehicle category

p Surveyed passenger

y Year of the crediting period

A.2.2. Data Used

Table A6. Project Parameters

Parameter	Description	Value	Unit	Source
$EF_{grid,CM}$	Emission factor of grid	0.67379	tCO_2/MWh	File 3
TDL	Average technical transmission and distribution losses for providing electricity	1.67%	percentage	File 12
$EC_{M,y}$	Quantity of electricity consumed by the metro (trains only)	20,342	MWh	File 13
$EF_{PKM,i}$	Emission factor per passenger-kilometre of mode "i"	See table A4	gCO_2/PKM	File 55
$IPTD_{PS,i}$	Indirect project trip distance of the surveyed passenger using mode "i"	Value per passenger surveyed	km	File 55
P	Passengers transported by the project	See table A5	passengers	File 14

A.2.3. Results

Table A7. Project Emissions

	unit	2015	2016	2017	2018	2019	2020	2021
Direct project emissions	tCO_{2eq}	13,935	13,935	13,935	13,935	13,935	13,935	13,935
Indirect project emissions	tCO_{2eq}	23,905	24,376	24,856	25,345	25,845	26,360	26,879
Total project emissions	**tCO_{2eq}**	**37,840**	**38,311**	**38,791**	**39,281**	**39,780**	**40,295**	**40,815**

A.3. LEAKAGE EMISSIONS

A.3.1. Formulas

$$LE_y = LE_{LFB,y} + LE_{LFT,y} + LE_{CON,y}$$

Where:

LE_y	Leakage emissions in the year *y* (tCO_2)
$LE_{LFB,y}$	Leakage emissions due to change of load factor buses in the year *y* (tCO_2)
$LE_{LFT,y}$	Leakage emissions due to change of load factor taxis in the year *y* (tCO_2)
$LE_{CON,y}$	Leakage emissions due to reduced congestion in the year *y* (tCO_2)
y	Year of the crediting period

If $LE_y < 0$, then leakage is not included

If $LE_y > 0$, then leakage is included

$$LE_{LFB,y} = \frac{1}{10^6} \cdot N_{B,y} \cdot AD_B \cdot EF_{KM,B,y} \cdot \left(1 - \frac{OC_{B,y}}{OC_B}\right)$$

Where:

$LE_{LFB,y}$	Leakage emissions due to change of load factor of buses in the year *y* (tCO_2)
$N_{B,y}$	Number of baseline buses in the year *y* (buses)
AD_B	Average annual distance driven by baseline buses (km/bus)
$EF_{KM,B,y}$	Emission factor per kilometre of baseline buses in the year *y* (g CO_2/km)
$OC_{B,y}$	Average occupancy rate of baseline buses in the year *y* (passengers)
OC_B	Average occupancy rate of baseline buses prior project start (passengers)
y	Year of the crediting period

$$LE_{LFT,y} = N_{T,y} \cdot AD_T \cdot EF_{KM,T,y} \cdot \left(1 - \frac{OC_{T,y}}{OC_T}\right) \cdot \frac{1}{10^6}$$

Where:

$LE_{LFT,y}$	Leakage emissions due to change of load factor of taxis in the year *y* (tCO_2)
$N_{T,y}$	Number of taxis in the year *y* (taxis)
AD_T	Average annual distance driven per taxi (km/taxi)
$EF_{KM,T,y}$	Emission factor per kilometre of taxis in the year *y* (g CO_2/km)
$OC_{T,y}$	Average occupancy rate of taxis in the year *y* (passengers)
OC_T	Average baseline occupancy rate of taxis prior project start (passengers)
y	Year of the crediting period

$$LE_{CON,y} = LE_{REB,y} + LE_{SP,y}$$

Where:

$LE_{CON,y}$	Leakage emissions due to reduced congestion in the year *y* (tCO_2)
$LE_{REB,y}$	Leakage emissions due to induced traffic / rebound effect in the year *y* (tCO_2)
$LE_{SP,y}$	Leakage emissions due to changing vehicle speed in the year *y* (tCO_2)

$$LE_{REB,y} = \frac{1}{10^6} \cdot \sum_i \left(TDIZ_{i,y} \cdot EF_{KM,i,y} \cdot \left(NIZ_{i,y} - NIZ_{i,BL} + NIZ_{i,MS,y}\right)\right)$$

Where:

$LE_{REB,y}$	Leakage emissions due to rebound effect in the year *y* (tCO_2)
$NIZ_{i,y}$	Number of cars/taxis per annum using the affected roads in the year *y* (cars, taxis)
$NIZ_{i,BL}$	Number of cars/taxis per annum using the affected roads in the baseline (cars, taxis)
$NIZ_{i,MS,y}$	Number of cars/taxis per annum not used anymore due to mode shift to the MRTS in the year *y*(cars, taxis)
$TDIZ_i$	Average trip distance made by cars/taxis on the affected roads in the year *y* (km)
$EF_{KM,i,y}$	Emission factor per kilometre of cars and taxis in the year *y* (g CO_2/km)
i	Cars, taxis
y	Year of the crediting period

$$NIZ_{i,MS,y} = \frac{MS_{i,s} \cdot P_y}{OC_i}$$

Where:

$NIZ_{i,MS,y}$ Number of cars/taxis per annum not used anymore due to mode shift to the metro in the year *y* (cars, taxis)
$MS_{i,y}$ Net share of passengers using the metro which would have used mode *i* in the year *y* (%)
P_y Passengers transported by the project in the year *y* (passengers)
OC_i Average occupation rate of vehicle category *i* prior project start (passengers)
i Cars, taxis
y Year of the crediting period

$$LE_{SP,y} = \frac{1}{10^6} \cdot \sum_i \left(NIZ_{i,y} \cdot TDIZ_{i,y} \cdot \left(EF_{KM,VP,i,y} - EF_{KM,VB,i} \right) \right)$$

Where:

$LE_{SP,y}$ Leakage emissions due to changes in vehicle speed of cars and taxis in year *y* (tCO_2)
$NIZ_{i,y}$ Number of cars/taxis using the affected roads in the year *y* (cars, taxis)
$TDIZ_{i,y}$ Average trip distance made by cars/taxis on the affected roads in the year *y* (km)
$EF_{KM,VP,,i,y}$ Emission factor per kilometre of cars/taxis at project speed in the year *y* (g CO_2/km)
$EF_{KM,VB,i}$ Emission factor per kilometre of cars/taxis at baseline speed (g CO_2/km)
i Cars, taxis
y Year of the crediting period

A.3.2. Data Used

Table A8. Leakage Parameters

Parameter	Description	Value	Unit	Source
AD_B	Average distance driven by buses per annum	94,138	kilometre	File 6
OC_B	Occupation rate buses baseline	26%	%	File 6, 8, 15
AD_T	Average distance driven by taxis per annum	67,346	kilometre	File 5
$NIZ_{i,BL}$	Number of cars/taxis using affected roads in the baseline	Table A10	vehicles	File 59
V_{BL}	Baseline speed of vehicles on affected roads (moving speed)	Table A10	km/h	File 59

Table A9. Number of Vehicles and Speed on Affected Roads

ID	Affected Road	Number of cars	Number of taxis	Average moving speed	Average total speed
1	Paldalro Road	8,550,180	6,401,880	41	28
2	Myeongdeongro	7,232,220	5,767,200	38	25
3	DongdaegugroYongji	8,967,600	6,645,600	42	24

A.3.3. Results

No leakage is projected.

A.4. EMISSION REDUCTIONS

A.4.1. Formulas

$$ER_y = BE_y - PE_y - LE_y$$

Where:

ER_y	Emission reductions in year "y" (t CO_2e/yr)
BE_y	Baseline emissions in year "y" (t CO_2e/yr)
PE_y	Project emissions in year "y" (t CO_2/yr)
LE_y	Leakage emissions in year "y" (t CO_2/yr)

A.4.2. Results

Table A10. Emission Reductions in tCO_2

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021
Baseline emissions	tCO_2	93,909	95,759	97,646	99,569	101,531	103,555	105,596
Project emissions	tCO_2	37,840	38,311	38,791	39,281	39,780	40,296	40,815
Leakage emissions	tCO_2	-	-	-	-	-	-	-
Emissions reductions	**tCO_2**	**56,069**	**57,448**	**58,855**	**60,288**	**61,751**	**63,259**	**64,781**

A.5. SENSITIVITY ANALYSIS

A sensitivity analysis is carried out for data and parameters, which are used to calculate baseline, project and leakage emissions. The sensitivity analysis is performed on all parameters except default and IPCC values listed as monitored values/parameters or values to be monitored. The sensitivity analysis is based on calculating the change of the data parameter that would be required to reduce emission reductions by 5%. This value gives an indication of the magnitude of change of the data parameter required to significantly change calculated emission reductions. Based on the methodology sensitive parameters are those where a change of less than 10% leads to a reduction of ERs of more than 5%.

Table A11: Sensitivity Analysis

Parameter	% Change required for 5% less ERs	Sensitive or Not	Comment
Project passengers	4% less passengers	Sensitive	Data is monitored continuously and checked with ticket sales. Core data for project owner and thus also adequate monitoring of latter. Fare dodgers are not counted thus understating also potentially passenger numbers.
Metro electricity consumption	>10% increase	Not sensitive	
Specific fuel consumption gasoline cars	>10% lower fuel consumption	Not sensitive	
Specific fuel consumption diesel cars	> 10% lower fuel consumption	Not sensitive	
Specific fuel consumption LPG cars	> 10% lower fuel consumption	Not sensitive	
Specific fuel consumption taxis	>10% lower fuel consumption	Not sensitive	
Specific fuel consumption diesel buses	> 10% lower fuel consumption	Not sensitive	
Specific fuel consumption CNG buses	> 10% lower fuel consumption	Not sensitive	
Passengers existing metro	> 10% more passengers	Not sensitive	
Electricity consumptionexisting metro	> 10% less consumption	Not sensitive	
Average trip distance	> 10% longer trip	Not sensitive	

existing metro			
Occupation rate passenger cars	10% higher occupation rate	Not sensitive	
Occupation rate taxis	>10% higher occupation rate	Not sensitive	

A.6. PASSENGER SURVEY DESIGN

The methodological design of the survey follows the methodology ad is detailed during project execution based on the actual passenger flow numbers.

Technical Summary Data Sheet of the Survey
Strategy and sample design in the Metro Daegu Line 3

Parameter	Main parameters: • Baseline emissions; • Indirect project emissions. Secondary parameters and inputs: • Proportion of passengers proportion using each mode of transport, with the project and in absence of the project; • The average distance travelled by these modes with the project and in absence of the project.
Target population	Passengers over 12 years using Metro Daegu Line 3.
Sample frame	Passenger flow in all the stations of Metro Daegu Line 3.
Sample design	Two staged probabilistic design: • First stage: stratified – simple random sampling (SRS); • Second stage: systematic sampling based on passengers flow per station. Stratum: Stations. Sub stratum: Days in the week and hours.
Relative error level (CV)[83]	For the survey a global desired level of precision (relative standard error or coefficient of variation – CV) between 5% and 10% for the parameters of interest, which implies at the same time having precision levels of 90/10 is targeted. Results obtained are based on a 95% confidence level using the more conservative boundary.
Coverage	Urban area where Metro Daegu Line 3operates.
Size of Universe	Generally, in one day Metro Daegu Line 3 mobilizes around 240,000passengers.
Sample size	The sample size is estimated to be around 4-7,000 surveys in the measuring week with a re-test sample size of around 50% of the original sample[84]. The exact number will be determined based on the actual passenger volumes per hour and per station.
Pilot Test	The pilot test corresponds to a survey realized July 2010 during an entire week in a continuous manner on Daegu metro Lines 1 and 2. 804 passengers of were interviewed. The sample was distributed according to the average flow along the 2 operating lines of Daegu metro at the moment of the survey.
Sample	Once annually during an entire week plus one re-test per annum.

[83]Relative error level refers to the coefficient of variation (CV), which is calculated as the ratio between the standard deviation of the average and the population average.

[84]The re-test sample size is determined based on the variances encountered in the original sample; sample size based on testing made in DMRC, Metro Mexico Line 12 and SML 9 Seoul. The sample size determination can be made once the metro is operational and thus knowing influx of passengers per hour per day per station.

frequency	
Method of information collection	The information will be obtained through the face-to-face application of the established questionnaire on a random base.
Consistency of the survey results	The internal consistency of the results of the survey must be carefully checked. The reliability will be measured using the Cronbach's alpha. A reasonable coefficient is over 0.7, values over 0.9 should be rechecked to avoid redundancy of data. In case the survey does not demonstrate internal consistency in their results, it will be rejected and another survey could be arranged.

Passenger Survey

SECTION A: DATA CONCERNING SURVEYOR

Survey ID (correlative number): …………………………….
Interviewer:……………………………
Date: .-………………………………….
Time:…………………………………….
Point (station) where interview was performed:…………………………..

Survey response/completeness:
☐ Survey was fully completed
☐ Survey was fully or partially not responded

Comments/Observations of surveyor:…………………………..

SECTION B: GENERAL DATA OF INTERVIEWED PERSON

This section can also be filled out at the end of the interview!

Age of surveyed person:
☐ 12-17 years ☐ 18-25 years ☐ 26-35 years ☐ 36-45 years ☐ 46-55 years ☐ 56-65 years ☐ over 65 years

Gender of the surveyed person
☐ female ☐ male

Socio-economic level of the surveyed person
☐< 1 minimum wage ☐ 1-2 minimum wages ☐ 2-4 minimum wages ☐ 4-6 minimum wages ☐> 6 minimum wages

---

SECTION C: TRIP DATA OF INTERVIEWED PERSON

Question 1

“Describe the trip you are currently realizing”

1.1. Your trip origin (home, office, others) Address:………………………………
1.2. Your entry station of Metro Daegu Line 3(station name):……………………
1.3. Your exit station of Metro Daegu Line 3 (station name):……………………
1.4. After exiting Metro you go where ? Address:…………………………………….

Notes: ……………………………………………………………………………………………

Explanations for the interviewer:

- *The question refers to the current trip the passenger is making.*
- *The trip origin and the trip destination must be identified with a clear address. Use a map if it is unclear. If the person does not know or does not want to disclose this information then stop at this point.*
- *The* Metro *stations identified in 1.2 and 1.3. must be listed with their official names. Metro stations must be of line 3. If the person used before/after Metro Line 1 or 2 the transfer station to Line 3 is indicated.*

Question 2

"How did you reach the Metro Line 3 entry station?"

Tick 1: ☐ Bus ☐ Taxi ☐Car ☐ Motorcycle ☐Cycle or walk☐Metro Line 1 or 2

Explanations for the interviewer:

- *Only tick 1 answer (the mode used for the longest stretch of this trip segment)*

Question 3

"How will you reach your office/home/other place after exiting the Metro Line 3 station?"

Tick 1: ☐ Bus ☐ Train ☐ Taxi ☐ Car ☐ Motorcycle ☐ Cycle or walk ☐Metro Line 1 or 2

Explanations for the interviewer:

- *Only tick 1 answer (the mode used for the longest stretch of this trip segment)*

Question 4

"Assuming that Metro Line 3 would not exist: Would you have made the trip you are currently doing anyway or would you have stayed at home/office/origin??"

☐ I would have stayed at home/office/origin➔*The questionnaire is terminated*
☐ I would have made the trip" ➔*Continue below (question 5)*

Explanations for the interviewer:

- *The purpose of this question is to know if the passenger made this trip only because the metro exists. In absence of the metro he would not have made any trip and would have stayed at his point of origin.*

Question 5

"Have you moved your home or workplace since 2015?"
☐ No ➔*continue below (question 6)*

☐ Yes: “Has the availability of Metro Line 3been an important factor when choosing the location of your new home or new workplace?”
☐ No ➔*continue below (question 6)*
☐ Yes ➔ “What was your former trip starting point and trip destination at the time before you moved your home or workplace ?”
Starting point address:………………………….
Destination point address: ………………………..

Question 6

“Assuming that Metro Line 3 you are currently using would not exist: How would you have made the same trip you are doing now??”

From Home/Office/Others (Address) ……… ….. to point (Address) …………… by *……………….

From point (Address)……………… …………... to point (Address) …………….by *……………...

From point (Address)……………… …………... to point (Address) …………….by *……………...

From point (Address)……………… …………... to point (Address) …………….by *……………...

*can be
☐ Bus
☐Metro Line 1 or 2
☐ Taxi
☐Car
☐ Motorcycle
☐Cycle or per foot
It can NOT be Metro Line 3

Explanations for the interviewer:
- *For each segment of the trip make a separate answer*

Question 7

“Have you used a taxi in the last 6 months?”
☐ Yes ☐ No

Question 8

“Do you have a car / car pool / access to company car and have you used a car / car pool or company car in the last 6 months?”
☐ Yes ☐ No

Question 9

“Do you have a motorcycle / scooter or share a motorcycle / scooter and have you used this in the last 6 months?”
☐ Yes ☐ No

A.7. DETERMINATION OF HE COMBINED MARGIN

Step 1. Identify the relevant electricity system

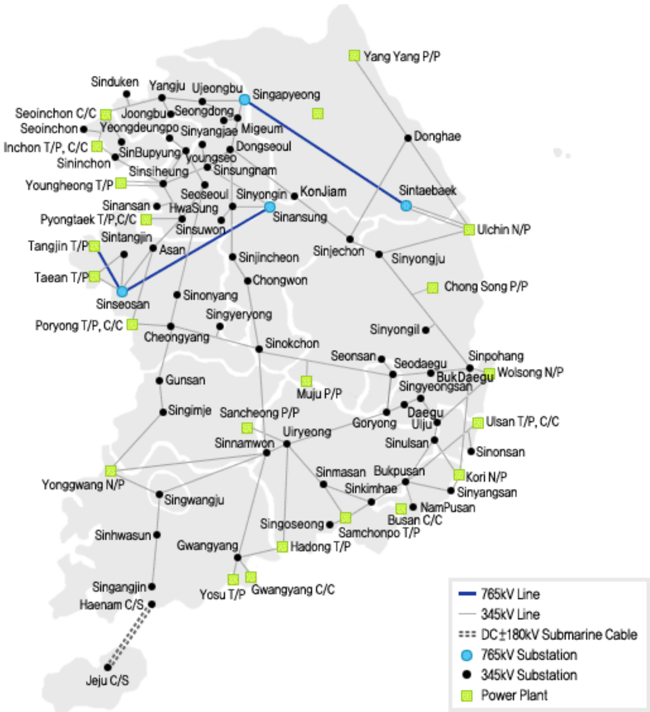
For determining the electricity emission factors, a **project electricity system** is defined by the spatial extent of the power plants that are physically connected through transmission and distribution lines to the project activity (e.g. the renewable power plant location or the consumers where electricity is being saved) and that can be dispatched without significant transmission constraints.

Similarly, a connected electricity system, e.g. national or international, is defined as an electricity system that is connected by transmission lines to the project electricity system. Power plants within the connected electricity system can be dispatched without significant transmission constraints but transmission to the project electricity system has significant transmission constraint.

In Figure 1 shows the geographical extent of the electricity system identify all grid power plants/units connected to the system. The project electric power system is connected with the whole Korean National Grid System.

Project electricity system is defined as the national grid by default.

Figure 1. Connected Electricity System in Republic of Korea



Source: http://www.kpx.or.kr/english/ see "Transmission Map"

Step 2. Choose whether to include off-grid power plants in the project electricity system (optional)

Project participants may choose between the following two options to calculate the operating margin

and build margin emission factor:

Option I: Only grid power plants are included in the calculation.
Option II: Both grid power plants and off-grid power plants are included in the calculation.

The option I has been chosen. In this option only grid plants are included in the calculation.

Step 3. Select a method to determine the operating margin (OM)

The "Tool to calculate the emissions factor for an electricity system" provides four methods to calculate the operating margin:

a. Simple OM
b. Simple adjusted OM
c. Dispatch data analysis OM
d. Average OM

The Simple OM method can only used if low-cost/must-run[85] resources constitute less that 50% of total grid generation in: 1) average of the five most recent years, or 2) based on long-term averages for hydroelectricity production. In Korea the low-cost/must run resources have been less than 50% for the last five years (2005-2009), see table E1, the average low-cost/must run generation holds 40.0% of total grid generation[86]. Therefore this method is applicable in order to calculate the OM emission factor

Table E1: Low-cost/must-run generation Republic of Korea

Type	2005 (MWh)	2006 (MWh)	2007 (MWh)	2008 (MWh)	2009 (MWh)	Averagelastfi veyears
Hydro	5.188.888	5.218.621	5.042.462	5.562.651	5.641.162	5.330.757
Coal (anthracite)	5.789.778	5.709.388	6.061.545	6.928.993	7.977.658	6.493.472
Nuclear	146.779.023	148.748.887	142.937.164	150.957.936	147.770.807	147.438.763
Alternative energy	404.101	511.223	830.824	1.373.425	1.790.609	982.036
Low-cost/must-run	**158.161.790**	**160.188.119**	**154.871.995**	**164.823.005**	**163.180.236**	**160.245.029**
No low-cost / must-run	**206.477.541**	**220.992.590**	**248.252.506**	**257.532.121**	**270.423.509**	**270.423.509**
Total grid generation	**364.639.331**	**381.180.709**	**403.124.501**	**422.355.126**	**433.603.745**	**400.980.682**
% Low-cost / must-run	**43,4%**	**42,0%**	**38,4%**	**39,0%**	**37,6%**	**40,0%**

Source: Korea Electric Power Corporation, 2010. See File CM, sheet GEN_05_06_07_09_09

For the simple OM, the simple adjusted OM and the average OM, the emissions factor can be calculated using either *"Ex ante option" or "Ex post option"*. The Operating Margin Emission Factor

[85] Low-cost/must-run resources are defined as power plants with low marginal generation costs or power plants that are dispatched independently of the daily or seasonal load of the grid. They typically include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. If coal is obviously used as must-run, it should also be included in this list, i.e. excluded from the set of plants.

[86]As the anthracite was used as must-run resource, it was excluded from the set of plants for calculating Operating Margin and the bituminous coal was included in OM calculation.

is calculated ex-ante[87] using a 3-year generation- weighted average of the grid power plants based on the most recent data available at the time of submission of the CDM-PDD.

Step 4. Calculate the operating margin emission factor according to the selected method

The simple OM emission factor is calculated as the generation-weighted average CO_2 emissions per unit net electricity generation (tCO_2/MWh) of all generating power plants serving the system, not including low-cost/must-run power plants/units.

The simple OM may be calculated:

Option A: Based on the net electricity generation and a CO_2 emission factor of each power unit;

Option B: Based on the total net electricity generation of all power plants serving the system and the fuel types and total fuel consumption of the project electricity system.

Option A is chosen because the data on fuel consumption and electricity generation is available by power unit in Korea.

For Option A, the formula used is:

$$EF_{grid,OMsimple,y} = \frac{\sum_m FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{\sum_m EG_{m,y}}$$

Where:

$EF_{grid,OMsimple,y}$	Simple operating margin CO_2 emission factor in year y (tCO_2/MWh)
$FC_{i,m,y}$	Amount of fossil fuel type *i* consumed by power plant *m* in year *y* (Mass or volume unit)
$NCV_{i,y}$	Net calorific value (energy content) of fossil fuel type *i* in year *y* (GJ/mass or volume unit)
$EF_{CO2,i,y}$	CO_2 emission factor of power unit *k* in year *y* (tCO_2/GJ)
$EG_{m,y}$	Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)
m	All grid power units serving the grid in year *y* except low-cost/must-run power units
i	All low-cost/must run grid power units serving the grid in year *y*
y	The relevant year, 2007, 2008 and 2009.

The values used in the calculation were taken from the following references and sources:

- The emission factors for fuel combustion are values taken from the IPCC default values at the lower limit of the uncertainty al 95% confidence interval as provided in table 1.4 of Chapter of

[87] Ex-ante option: The emission factor is determined once at the validation stage, thus no monitoring and recalculation of the emissions factor during the crediting period is required. For grid power plants, use a 3- year generation –weighted average, based on the most recent data available at the time submission of the CDM-PDD to the DOE for validation.

Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories.

- The Fuel Consumption data from 2007 to 2009 are taken from the "Statistics of Electric Power in Korea 2008, 2009 & 2010, KEPCO".
- The Net Calorific Values data from 2007 to 2009 are taken from the "Statistics of Electric Power in Korea 2008, 2009 & 2010, KEPCO".
- The Korean net electricity generation data from 2007 to 2009 are taken from the "Statistics of Electric Power in Korea 2008, 2009 & 2010, KEPCO".

The following are the information sources of the variables and parameters used for calculating the emission factor for the electricity system (combined margin emissions factor - CM).

Table E2: General information sources of the used data in the CM calculations

Variable	Unit	Source
Electrical Generation	MWh/year	KEPCO*
Fuel Consumption	ton, kl	KEPCO
Net Calorific Value	kcal/kg, kcal/l	KEPCO
Emission Factor of fossil fuel type	tCO_2/GJ	IPCC**

* Korea Electric Power Corporation
**Intergovernmental Panel on Climate Change (www.ipcc.ch)

Table E3: Emission factor by fuel type

Fuel type	CO_2 Emission factor (tCO_2/TJ)	CO_2 Emission factor (tCO_2/GJ)
Diesel	72,600	0.0726000
Natural Gas (LNG)	54,300	0.0543000
Residual Fuel Oil	75,000	0.0750000
Bituminous Coal	89,500	0.0895000
Diesel	72,600	0.0726000

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, lower 95% confidence interval. See File CM sheet COEF

The development of the equation of the Operating Margin (OM) emission factor is:

$$EF_{grid,OM-adj,y} = (1-\lambda_y)\frac{\sum_{i,m} FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{\sum_m EG_{m,y}} + \lambda_y \frac{\sum_{i,k} FC_{i,k,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{\sum_k EG_{k,y}}$$

Table E4: OM for Republic of Korea 2007-2009

OM	2007	2008	2009
$EF_{grid,OM-adj,y}$	**0.7210**	**0.7331**	**0.7546**

Source: calculation see File CM sheet EFGrid07-09

The $EF_{grid,OMsimple,y}$ is calculated as the weighted average of the results for 2007, 2008 and 2009

$$EF_{grid,OMsimple,y} = 0.7366 \frac{tCO_2}{MWh}$$

Step 5.Calculate the build margin emission factor

Option 1 is chosen: For the first crediting period, calculate the build margin emission factor ex ante based on the most recent information available on units already built for sample group m at the time of CDM-PDD submission to the DOE for validation. This option does not require monitoring the emission factor during the crediting period.

Capacity additions from retrofits of power plants are not be included in the calculation of the build margin emission factor.

The sample group of power units *m* used to calculate the build margin is determined as per the following procedure, consistent with the data vintage selected above:

a). Identify the set of five power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently (SET5-units) and determine their annual electricity generation ($AEG_{SET\text{-}5\text{-}units}$, in MWh);

b). Determine the annual electricity generation of the project electricity system, excluding power units registered as CDM project activities (AEG_{total}, in MWh). Identify the set of power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently and that comprise 20% of AEG_{total} (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) (SET ≥ 20%) and determine their annual electricity generation ($AEG_{SET} \geq 20\%$, in MWh);

c). From $SET_{5\text{-}units}$ and SET ≥ 20% select the set of power units that comprises the larger annual electricity generation (SET_{sample});

Identify the date when the power units in SET_{sample} started to supply electricity to the grid. None of the power units in SET_{sample} started to supply electricity to the grid more than 10 years ago[88]. Therefore SET_{sample} is used to calculate the build margin and steps (d), (e) and (f) of the tool are ignored.

In Korea, the option ex ante is used to calculate the construction margin, by means of additions to the capacity of the electric system which should comprise 20% of the most recent increases to the generation system. This combination has been selected because data ex ante is available, and due to the fact that the 20% recently incorporated to the generation system has an annual electricity generation greater than the 5 power plants lately incorporated to the system.

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

$EF_{grid,BM,y}$	Build margin emission factor in year *y* (tCO_2/MWh).
$EG_{m,y}$	Electricity supplied to the grid by each plant *m* in the year *y* (MWh).
$EF_{EL,m\,y}$	CO_2 emission factor for each plant *m* in the year *y* (tCO_2/MWh).
m	Power units included in the build margin.
y	Most recent year with data available

[88] File 4b table 7

The CO_2 emission factor of each power unit *m* ($EF_{EL,M,y}$) is calculated with the guidance in Step 4 (a) option A1 using for y the most recent historical year for which power generation data is available and using for *m* the power units included in the build margin.

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}}$$

Where:

$EF_{EL,m,y}$	CO_2 emission factor of power unit *m* in year *y* (tCO_2/MWh).
$FC_{i,m,y}$	Amount of fossil fuel type *i* consumed by power unit *m* in year *y* (Mass or volume unit).
$NCV_{i,y}$	Net Calorific Value (energy content) of fossil fuel type *i* in the year *y* (GJ/mass or volume unit).
$EF_{CO2,i,y}$	CO_2 emission factor of fossil fuel type *i* in year *y* (tCO_2/GJ).
$EG_{m,y}$	Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh).
m	All power units serving the grid in year *y* except low-cost/must-run power units.
y	The relevant year 2009

Table E5: BM for Republic of Korea 2009

Parameter	Value
Generation of 20% of electricity generation 2009 (MWh)	86,720,749
Generation of most recent added plants which compromise 20% of 2009 generation (MWh)	94,702,282
Generation of 5 plants that have entered more recently (MWh)	5,227
Emissions generation most recent added plants which compromise 20% of 2009 generation (tCO_2)	57,859,350

Source: File CM, sheet BM 2009

The 2nd option (Step 5) is clearly the larger annual generation and is thus taken. The sample group of power units *m* used to calculate the build margin consist in the set of power capacity additions in the electricity system that comprise 20% of the system generation and that have been added most recently.

The result of built margin emission factor: $EF_{grid,BM,y}$ = 0,6110 tCO_2/MWh[89]

$$EF_{grid,BM,y} = 0{,}6110\ tCO_2/MWh$$

Step 6. Calculate the combined margin emissions factor

The emission factor of the project is calculated ex-ante using the following formula:

$$EF_{grid,CM,y} = w_{OM} \times EF_{grid,OM,y} + w_{BM} \times EF_{grid,BM,y}$$

Where:

$EF_{grid,CM,y}$	Combined margin CO_2 emission factor in year y (tCO_2/MWh)
$EF_{grid,BM,y}$	Build margin CO_2 emission factor in year y (tCO_2/MWh)

[89] File CM, sheet BM2009

$EF_{grid,OM,y}$ Operating margin CO_2 emission factor in year y (tCO_2/MWh)
w_{OM} Weighting of operating margin emissions factor. The default weight factor is 50%
w_{BM} Weighting of build margin emissions factor (50%). The default weight factor is 50%

The result of the Combined Margin CO_2 emission factor is:

$$EF_{grid,CM,y} = (0.5 \times 0.7366 + 0.5 \times 0.6110)\frac{tCO_2}{MWh}$$

$$EF_{grid,CM,y} = 0.6738\frac{tCO_2}{MWh}$$

Annex 4

MONITORING INFORMATION

Some additional details are given concerning the monitoring manual prepared by Grütter Consulting AG for the project.

The objective of this manual is to collect all required data by the Monitoring and Verification Protocol in a manner that guarantees an optimal quality of monitoring. This manual therefore establishes which procedures are needed to follow, the structural organization and also the key elements of the required data.

This manual is intended for all personnel in charge of data gathering and processing for the project. It was written by Jürg M. Grütter, Grütter Consulting AG.

The manual is divided into the following parts:

- Structure and Responsibilities: establishes who is responsible for monitoring
- Data: Includes an overview of all data required for monitoring

Organizational Structure and Responsibilities

The **responsibilities** of **Daegu Metropolitan City Urban Railroad Construction HQ** are:

1. Deliver all information required for monitoring.
2. Perform data and information quality control according to this manual.
3. File all documents in the manner and timing that this manual demands.

The **responsibilities** of **South Pacific Inc.** are:

1. Collect from Daegu Metropolitan City Urban Railroad Construction HQ and from other involved institutions all data required
2. Contract and supervise the survey company

Grütter Consulting AG is responsible for the monitoring reports for the entire crediting period. Core responsibilities of Grütter Consulting AG are:

1. Check data quality
2. Realize an annual monitoring report.
4. Answer all inquiries and additional information requests by the DOE for the verification report of the CERs. Furthermore, reply to all inquiries received during the process of issuance by UNFCCC.

All data must be filed electronically. Hard copy reports and mails are to be scanned to have an electronic copy. All documents are to be saved for minimum two (2) years after the last CERs were emitted.

For each data a sub-chapter or control spreadsheet has been realized. The following table summarizes all data required for monitoring.

Index	Indicator	Gathering frequency	Data source
1	Fuel types used by cars and taxis	Annual	Korea Transportation Safety Authority
2	Passengers transported	Monthly	Daegu Metropolitan Transit Corporation
3	Traction electricity consumption	Monthly	Daegu Metropolitan Transit Corporation
4	Passenger survey for indirect project and baseline emission per passenger and mode share baseline	Annual	South Pacific Inc. & Grütter Consulting. – realized by external survey company
5	Number of buses and taxis	Year 1, 4, 7	Taxis Korea Transportation Safety Authority and for buses Daegu Metropolitan City Public Transportation Division
6	Occupation rate buses and taxis	Year 1, 4, 7	Daegu Metropolitan City Public Transportation Division
7	Number of cars/taxis using affected roads	Annual	South Pacific Inc. or 3rd party study
8	Trip distance of cars/taxis on affected roads	Annual	South Pacific Inc. or 3rd party study
9	Speed of cars/taxis on affected roads	Annual	South Pacific Inc. or 3rd party study
10	Net Calorific Value	Annual	IPCC
11	Emission factors of fuels	Annual	IPCC
12	Electricity consumption metro line 1&2	Annual	Daegu Metropolitan Transit Corporation
13	Passengers transported metro line 1&2	Annual	Daegu Metropolitan Transit Corporation

AS EXAMPLE FUEL TYPE CONSUMED

Parameter

$N_{x,C/T}$

Monitored Data

The fuel type consumed by cars and taxis in Daegu needs to be recorded.

Data Unit

Percentage of fuel type per vehicle category.

Measurement Frequency

Annual. Data can be maximum 3 years old.

Information Source

Korea Transportation Safety Authority

Quality Control

Check with values of previous year.

Comment

Baseline data parameter specific fuel consumption cars (SFC_C) and taxis is adjusted according to the fuel mixture used.

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