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Annex 11a: Monitoring Manual

Program: E-Motion: E-Mobility and Low Carbon Transportation

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Abbreviations

BAU	Business as Usual
BC	Black Carbon
CDM	Clean Development Mechanism
CM	Combined Margin
CNG	Compressed Natural Gas
EEA	European Environmental Agency
EF	Emission Factor
ER	Emission Reduction
EV	Electric Vehicle
GHG	Greenhouse Gases
GWP	Global Warming Potential
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LCV	Light Commercial Vehicles
NCV	Net Calorific Value
PM	Particle Matter
TTW	Tank to Wheel
UNFCCC	United Nations Climate Change Convention
WTT	Well to Tank
WTW	Well to Wheel

1. Introduction

The Programs goal is to accelerate Electric Vehicle (EV) deployment and enable a large-scale regional transition towards electro-mobility in Latin America through financial and technical assistance. The Program implements interventions to kick-start EV mass deployment significantly earlier than under a Business as Usual (BAU) scenario by reducing the risk profile of investments and by comprehensive technical assistance. The key strategic value of the Program is that it functions as market accelerator enabling a far faster uptake of e-mobility than under a BAU scenario avoiding a lock-in of long-lived assets in fossil technology. The Program fills the gap between initial pilots already existing in the region and long-term targets. These interventions are made in a time where e-mobility is commercially not yet viable and thus require initial investment support -like is the case in all countries which have a significant uptake of e-mobility.

The Program focuses on pure electric commercial vehicles i.e. buses, taxis and urban freight vehicles together with the required charging infrastructure and grid upgrades. No private usage vehicles are financed. The main investment area is on electric buses. Investments are linked with new business models and service delivery structures which enhance the attractiveness and sustainability of the public transport sector and thereby is an important component to ensure that current public transport ridership levels are sustained or even increased. The Program has thus also an important contribution towards mode shift.

The Program is implemented by AFD in Argentina, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, Mexico, and Peru. Investment projects with calculated GHG reduction are in Brazil, Colombia, Mexico and Peru.

The report establishes the base for monitoring the Greenhouse Gases (GHG) and air pollution impact of mitigation measures. Monitoring is realized of the direct impact based on financed investment projects.

3. Monitoring Parameters Impact EVs

3.1. Overview

This section is for the approach how to monitor the impact of EVs deployed.

For each investment project specific parameters for the baseline as well as for the project activity need to be calculated or monitored ex-ante (during feasibility assessment) respectively ex-post. The following table indicates default parameters independent of the type of project financed.

Table 1: Default Parameters

Parameter	Value	Source
NCV of diesel	43 MJ/kg	(IPCC, 2006), table 1.2
CO_2 emission factor of diesel	74.1 gCO_2/MJ	(IPCC, 2006), table 1.4
Density of diesel	0.844 kg/l	(IEA, 2005)
Well-to-tank mark-up factor diesel	23%	(UNFCCC, 2014), Table 3
NCV of gasoline	44.3 MJ/kg	(IPCC, 2006), table 1.2
CO_2 emission factor of gasoline	69.3 gCO_2/MJ	(IPCC, 2006), table 1.4
Density of gasoline	0.741 kg/l	(IEA, 2005)
Well-to-tank mark-up factor gasoline	19%	(UNFCCC, 2014), Table 3
Conversion kWh to MJ	3.6 MJ per kWh	standard[1]

[1] https://home.uni-leipzig.de/energy/energy-fundamentals/03.htm#:~:text=Power%20units%20can%20be%20converted,%3D%203.6%20MJ%20%5BMegaJoule%5D.

For each investment projects the carbon grid factor of the country needs to be determined.

Parameter	**CF_{elec}**
Unit	$kgCO_{2e}/kWh$
Description	Carbon factor of electricity grid
Data source	IFI database latest version
Measurement procedures	Grid factor = GHG emissions for electricity generation / total net national generation (total generation minus losses)
Monitoring frequency	Annual
QA/QC	Compare with previous values. Values based on IFI version 3.1 published 02/2022 are
Comment	

Country	**Grid Factor in $kgCO_2/kWh$**
Argentina	0.288
Brazil	0.150
Colombia	0.208
Costa Rica	0.039
Dominican Republic	0.426
Ecuador	0.280
Mexico	0.359
Peru	0.252

3.2. Equations

Indicators which are required are:

1. Number of EVs financed;
2. GHG impact;
3. Energy impact;
4. $PM_{2.5}$ and NO_x impact.

The 1st indicator is based on the total number of EVs co-financed by the Program. All other indicators require a determination of „baseline“ and of „with project emissions“. Important is that baseline vehicles are NOT the replaced units but the fossil vehicles which would have been purchased in absence of the Program i.e. baseline emissions are related to the performance of new fossil vehicles as sold in the country.

For ***fossil vehicles*** :

$$EF_{km,i,WTW} = \sum_y EF_{km,i,y,TTW} \times UEF_y \quad (1)$$

Where:

$EF_{km,i,WTW}$	Well-to-wheel emission factor per kilometre of vehicle category *i* (gCO_{2e}/km)
$EF_{km,i,y,TTW}$	TTW emission factor per kilometre of vehicle category *i* using fuel type *y* (gCO_2/km)
UEF_y	Upstream emission factor for fuel type *y* (no unit)
i	vehicle category
y	fuel type

TTW emissions:

$$EF_{km,i,TTW} = \sum_y SFC_{i,y} \times NCV_y \times EF_{CO2,y} \times S_{i,y} \quad (2)$$

Where:

$EF_{km,i,TTW}$	Tank-to-wheel emission factor per kilometre of vehicle category *i* (gCO_{2e}/km)
$SFC_{i,y}$	Specific fuel consumption vehicle category *i* using fuel type *y* (kg/km)
NCV_y	Net Calorific Value of fuel type *y* (MJ/kg)
$EF_{CO2,y}$	CO_2 Emission Factor of fuel type *y* (gCO_2/MJ)
$S_{i,y}$	Share of vehicle category *i* using fuel type *y* (%)
i	vehicle category
y	fuel type

Battery Electric Vehicles (BEVs):

$$EF_{km,BEVi,WTW} = EC_i \times CF_{elec} \quad (3)$$

Where:

$EF_{km,BEV,WTW}$	Well-to-wheel emission factor per kilometre of BEV category *i* (gCO_{2e}/km)
EC_i	Electricity consumption of BEV category *i* per kilometre (kWh/km)
CF_{elec}	Carbon factor of electricity grid (gCO_{2e}/kWh)

Emission reductions are then the product of number of vehicles, lifetime mileage and differential EF.

$$ER_i = EV_i \times DD_i \times LS_i \times \left(EF_{km,i,WTW} - EF_{km,EVi,WTW}\right) \times 10^{-6} \quad (4)$$

Where:

ER_i	Emission reduction lifespan of EV category *i* (tCO_{2e})
EV_i	Number of EVs purchased with Program funds of category *i* (no unit)
DD_i	Annual distance driven EV category *i* (km)
LS_i	Lifespan of EV category *i* (no unit)
$EF_{km,i,WTW}$	Well-to-wheel emission factor per kilometre of fossil vehicle category *i* (gCO_{2e}/km)
$EF_{km,EVi,WTW}$	Well-to-wheel emission factor per kilometre of EV category *i* (gCO_{2e}/km)
i	Vehicle category (buses, taxis, LCVs)

Energy savings are calculated by putting fuel consumption into Joules for fossil as well as electric vehicles:

- For fossil vehicles multiply the fuel usage (in kg) with the NCV;
- For EVs multiply the electricity consumed (in kWh) with the standard factor of 3.6 MJ per kWh;

Default parameters listed in table 2 are: NCV, EF_{CO2}, UEF. The CF is listed in chapter 3.1.

Parameter	**SFC_i**
Unit	l/km or km/l or g/km
Description	Specific fuel consumption vehicle category *i* using fuel type *y*
Data source	Vehicle operator
Measurement procedures	Measurement based on records of operator of comparable vehicles with the same emission standard as baseline vehicles; fallback option based on COPERT model (EEA, 2020) using preferably Tier 3 approach with average speed, gradient, load factor and emission standard for each identified vehicle category
Monitoring frequency	Prior project start during project due diligence
QA/QC	If based on measurements compare with COPERT
Comment	Required for baseline vehicle emissions Needs to be separated for diesel, gasoline, CNG vehicles

Parameter	**$PM_{2.5,i}$**
Unit	g/km

Description	$PM_{2.5}$ emissions of vehicle category *i*
Data source	(EEA, 2020)
Measurement procedures	Based on COPERT model (EEA, 2020) using preferably Tier 3 approach with average speed, gradient, load factor and emission standard for each identified vehicle category
Monitoring frequency	Prior project start during project due diligence
QA/QC	
Comment	Required for baseline vehicle emissions; the same approach is also used to determine NO_x emissions of baseline vehicles required for the indicator air pollutants emissions

Parameter	**EC_i**
Unit	kWh/km
Description	Electricity consumption of BEV category *i* per kilometre
Data source	Vehicle operator
Measurement procedures	In general through measurements with datalogger at charging stations; can be related with invoices from charging stations (for taxi operators); vehicles in general do not have electricity measurement; In cases of ultra-fast charging at bus stops or trolleybus lines the total electricity consumption and the total fleet mileage is taken as individual consumptions are not known.
Monitoring frequency	Continuously with monthly records
QA/QC	Comparison with previous months and same month of last year
Comment	For project activity emissions; Ex ante estimates during feasibility phase based on average estimates per vehicle type and country

Parameter	**DD**
Unit	Km
Description	Annual distance driven EV category *i*
Data source	Vehicle operator
Measurement procedures	GPS or odometer
Monitoring frequency	Continuously with annual records
QA/QC	Comparison with previous years
Comment	For project activity emissions; Ex ante estimates during feasibility phase based on average estimates per vehicle type and country

Parameter	**LS**
Unit	Years
Description	Lifespan of EV category *i*
Data source	Vehicle operator
Measurement procedures	Estimation based on concession contracts or average commercial lifespan
Monitoring frequency	Prior project start during project due diligence

4. Monitoring Impact Public Transport Measures

4.1. Introduction

This section is for the approach how to monitor the impact of Public Transport measures.

4.2. Monitoring of Impact of Measures

A clear description of each measure realized including the following aspects as minimum must be realized:

- Description of measure;
- Entity responsible for implementing the measure;
- Year when measure was implemented;
- Investment cost for measure;
- Reason why this should attract additional passengers.

The equation used to measure the impact are:

$$EF_{km,i,WTW} = \left\{\sum_y SFC_{i,y} \times NCV_y \times EF_{CO2,y} \times UEF_y + EC_i \times CF_{elec} \times \frac{N_{i,y}}{N_i}\right\} \quad (5)$$

Where:

$EF_{km,i,WTW}$	Well-to-wheel emission factor per kilometre of vehicle category *i* (gCO_{2e}/km)
$SFC_{i,y}$	Specific fuel consumption of vehicle category *i* using fuel type *y* (g/km)
NCV_y	Net calorific value of fuel type *y* (MJ/g)
$EF_{CO2,y}$	CO_2 emission factor of fuel type *y* (gCO2/MJ)
UEF_y	Upstream emission factor for fuel type *y* (no unit)
EC_i	Electricity consumption of EV category *i* per kilometre (kWh/km)
CF_{elec}	Carbon factor of electricity grid (gCO_{2e}/kWh)
$N_{i,y}$	Number of vehicles of vehicle category *i* using fuel type *y* (no unit)
N_i	Number of vehicles of vehicle category *i* (no unit)

The emission factor per pkm results from the emission factor per km divided by the occupation rate per vehicle category:

$$EF_{pkm,i} = \frac{EF_{km,i,WTW}}{OC_i} \quad (6)$$

Where:

$EF_{pkm,i}$	Emission factor per passenger-kilometre of vehicle category *i* (gCO_{2e}/pkm)
$EF_{km,i,WTW}$	Well-to-wheel emission factor per kilometre of vehicle category *i* (gCO_{2e}/km)
OC_i	Average occupation rate of vehicle category *i* (passengers)

Baseline emissions are then the additional pkm on public transport multiplied with the differential emission factor of baseline modes with bus-based public transport.

$$ER_{PT} = \sum_i (S_i \times (EF_{pkm,i} - EF_{pkm,PT})) \times AP_{PT} \times TD_{PT} \quad (7)$$

Where:

ER_{PT}	Emission reduction due to increased usage of public transport (tCO_{2e})
S_i	Share of additional PT passengers which would have used vehicle category *i* (%)
$EF_{pkm,i}$	Emission factor per passenger-kilometre of vehicle category *i* (gCO_{2e}/pkm)
$EF_{pkm,PT}$	Emission factor per passenger-kilometre of public transport (gCO_{2e}/pkm)
AP_{PT}	Additional passengers on public transport (million passengers)
TD_{PT}	Average trip distance of public transport user (km)
i	Baseline vehicle category (cars, taxis, motorcycles)

The additional passengers on PT are directly due to usage of electric buses and due to measures taken with programs to improve PT. The share per baseline passenger mode is based on the mode share of motorized transport in absence of buses.

GHG and air pollutant emission reductions are calculated with the same equations. Energy savings are calculated by putting fuel consumption into Joules for fossil as well as electric vehicles:

- For fossil vehicles multiply the fuel usage (in kg) with the NCV;
- For EVs multiply the electricity consumed (in kWh) with the standard factor of 3.6 MJ per kWh.

Parameter	**AP_{PT}**
Unit	Passengers
Description	Additional passengers on public transport
Data source	Vehicle operator
Measurement procedures	Based on ticketing or passenger counting systems Alternative 1 (preferred): Calculate an expected passenger number based on the simple trend of the last 5 years. This would be the passenger number in absence of the project. This number is compared with the actual passenger number after implementation of the measure. Alternative 2: Comparison of passenger numbers prior measure (year immediately prior measure) with year after establishment of measure: additional passengers = passengers after – passenger prior measure
Monitoring frequency	Prior and once after implementation of measure
QA/QC	Comparison ticketing numbers with revenues
Comment	Only for passenger transport system where a measure has been implemented

Parameter	**TD_{PT}**
Unit	Km
Description	Average trip distance of public transport user
Data source	Public transport operator or survey of PT users by 3rd party or household survey
Measurement procedures	Operational system of PT operator or surveys
Monitoring frequency	Prior and once after implementation of measure
QA/QC	Control with older studies
Comment	Only for passenger transport system where a measure has been implemented

Parameter	**S_i**
Unit	%
Description	Share of additional PT passengers which would have used vehicle category *i*
Data source	Mode share surveys or household surveys
Measurement procedures	The mode share of alternatives to PT is based on all modes except walking and Public Transport (walking is excluded from all surveys as this is not affected; PT is the new mode and thus needs to be excluded). This is taken as 100%. Other mode shares are e.g. car, taxi, motorcycle, cycling. The mode share is taken as share of trips. Example mode split survey: 30% walking 40% public transport 20% cars 7% motorcycles 3% cycling 100% = total minus walking and PT. Thus new mode shares in absence of excluded modes: Cars: 67% (20%/(100%-70%)) Motorcycles: 23% Cycling: 10%
Monitoring frequency	Latest available survey
QA/QC	
Comment	

Parameter	**OC_i**

Unit	Passengers
Description	Average occupation rate of vehicle category *i*
Data source	Road surveys, household surveys realized by 3rd parties
Measurement procedures	Based on 3rd party reports
Monitoring frequency	Latest available data
QA/QC	
Comment	

All other parameters required for determination of the emission factor per pkm per vehicle category are determined in the same manner as described in chapter 3.

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