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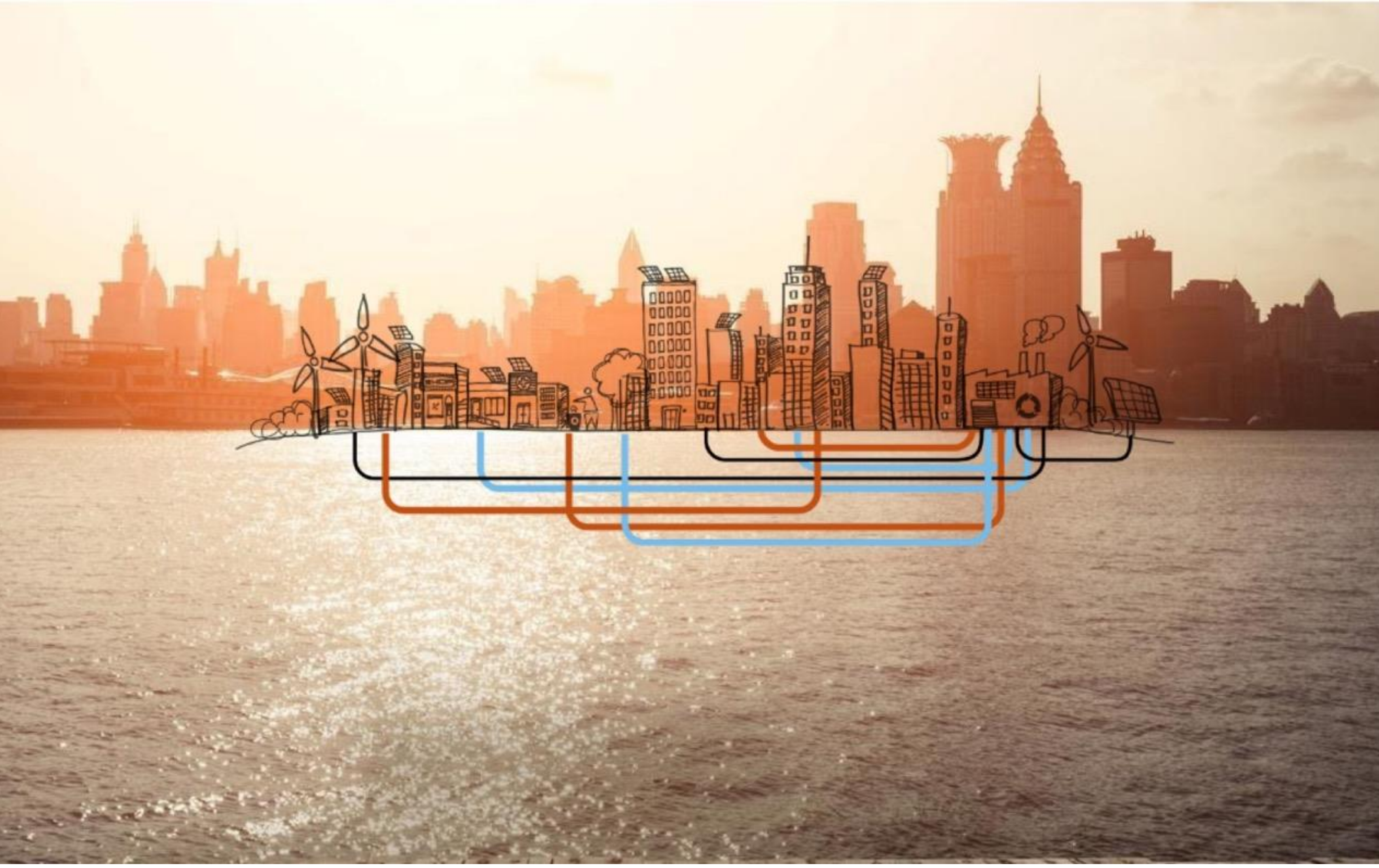
UN Environment District Energy in Cities Initiative

District Energy Projects:

MRV Framework Guidance



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DISTRICT ENERGY IN CITIES INITIATIVE

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About the report

This guidance on measuring, reporting and verifying (MRV) enables projects and cities under the District Energy in Cities Initiative to track progress and the impact on city-wide district energy systems (DES) and. The guidance facilitates the monitoring of projects' impacts, proposing a broad approach to MRV that addresses 1) greenhouse gas emissions and 2) sustainable development. In particular, city authorities and relevant stakeholders (utilities, private sectors, etc.) shall be able to evaluate planned and implemented projects with regards to mitigation impacts and sustainable development benefits.

The target audience of this MRV Guidance is comprised of key stakeholders involved in the developing, implementing and operating of an MRV framework for a DES project. This includes city authorities, policymakers and practitioners, such as utilities and DES operators that want to estimate GHG mitigation and SD impacts. MRV is particularly relevant in the context of Nationally Determined Contribution (NDC) development and implementation, national and local low emission strategies and Nationally Appropriate Mitigation Actions (NAMAs) as well as other mitigation mechanisms. Hence, the focus of the guidance is on the assessment of emission reduction and sustainable development impacts. Under the presented MRV framework, an impact assessment for DES projects should be used, which applies the project specific situations. The impact assessment can also help to inform and enhance the design and implementation of projects, policies and measures. The eventual adoption and adaptation of the MRV framework to the city and project specific situation is carried out in an individual MRV Plan prepared based on this guidance.

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TABLE OF CONTENT

List of Figures

List of Tables

Acronyms and Abbreviations (to be finalised based on final report)

AC	Air-Conditioner / Air-Conditioning
BAT	Best available Technology
BAU	Business-as-usual
BE	Baseline emissions
BTR	Biennial Transparency Report
BUR	Biennial Update Report
CA	Cooperative Approaches
CCHP	Combined Cooling, Heating and Power Generation
CDD	Cooling Degree Days
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CFBC	Circulating Fluidized Bed Combustion
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COEF	Coefficient
COP	Coefficient of Performance
COP	Conference of the Parties (UNFCCC Parties)
DES	District Energy Systems
DOE	Designated Operational Entities
EC	Electricity consumed
EF	Emission Factor
ER	Emission Reductions
ETF	Enhanced Transparency Framework
EU ETS	European Union Emissions Trading System
FBC	Fluidised Bed Combustion
GDP	Gross Domestic Product
GFA	Gross Floor Area
GHG	Greenhouse gases
GJ	Gigajoule
GWP	Global Warming Potential
ICA	International Assessment and Review and International Consultation and Analysis
HDD	Heating Degree Days
IES	Isolated Energy System
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
ITMO	Internationally transferred mitigation outcome
kWh	Kilowatt hour
LE	Leakage emissions
M&E	Monitoring and Evaluation system
MDB	Multi-Developing Banks

MP	Monitoring Plan
MR	Monitoring Records / Report
MRV	Measuring, Reporting and Verification
MWh	Megawatt hour
NAMA	Nationally Appropriate Mitigation Actions
NCs	National Communications
NCV	Net Calorific Value
NDC	Nationally Determined Contribution
NIR	National Inventory Report
NO_x	Nitrogen oxides
PA	Paris Agreement
PBCF	Performance Based Climate Finance
PE	Project emissions
PFBC	Pressurised Fluidised Bed Combustion
QA	Quality Assurance
QC	Quality Control
RBF	Results Based (Climate) Finance
SD	Sustainable Development
SDG	Sustainable Development Goals
SEER	Seasonal Energy Efficiency Ratio
SO	Sulphur monoxide
t	Tonne
TDL	Technical Transmission & Distribution Losses
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standards

1. Introduction

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), requires all countries to periodically report information and data related to national climate actions following some principle of Measurement, Reporting and Verification (MRV). The newly introduced Enhanced Transparency Framework (ETF) request the reporting on emissions data and the progress tracking of countries' Nationally Determined Contributions (NDCs). MRV systems will be a significant component in effectively tracking and improving the implementation of mitigation goals and policies (WRI, 2016, p. 3). However, besides fulfilling these climate reporting requirements, MRV systems have additional benefits for (local) governments, cities and countries.

GHG mitigation projects and countries' NDCs have a strong synergistic overlap with the Sustainable Development Goals (SDG), mainly to energy, agriculture, water, resilience, resource efficiency, disaster risk reduction and infrastructure. Many cities invest in district energy system (DES) projects more for these benefits and less because of the emission reduction. So, GHG emission reduction may be the actual co-benefit, when cities adopt district energy systems to achieve important benefits such as affordable energy provision, reduced reliance on energy imports and fossil fuels, community economic development and community control of energy supply, local air quality improvements and an increased share of renewables in the energy mix. MRV shall help monitor the impact of the DES interventions on emission reduction and selected relevant sustainable development (SD) indicators. The selection of the SD indicators should be based on SDGs for environment, social, growth and development, economic and institutional and consider the local circumstances and priorities. MRV will support the realisation and tracking of urban development plans and help to attract investments for quality of life enhancements. Hence, local and city governments need to improve their capability of GHG accounting and SD tracking.

While most discussions around MRV of climate actions have focused on greenhouse gas (GHG) emissions reductions, many developing countries view the sustainable development impact as the primary policy and project driver and the key selling point to national and local stakeholders. SD indicators on, for instance, job creation, access to modern energy services and improved air quality help promote mitigation actions to the general public. This increases the acceptance of these measures and ensures that they will continue, also when donor financing is no longer available. Therefore, tracking of sustainable development indicators and progress ensures and sustains local political support for implementing climate mitigation actions. The monitoring of these indicators can lead to improved sustainable development impacts by adjusting the actions, if deemed necessary, and promoting the replication of successful measures (CCAP, 2011).

Monitoring of DES activities is often challenging compared to individual mitigation project actions. For instance, the cooling demand in a city is difficult to quantify, as the data are often hidden within a building's total electricity bill and the cooling energy delivered is not measured. Similarly, quantifying heating demand can be difficult if a fuel or energy source is utilized that has other uses such as electricity (appliances) or gas (cooking). To address these challenges, under the UN Environment District Energy in Cities Initiative ('the Initiative'), an MRV approach for projects and cities under the Initiative should be developed.

The generic MRV framework presented in this guidance aims to increase confidence in data, the process and the results by defining methodologies for data collection and analysis. It also ensures that cities put systems in place to collect data and periodically publish results with high levels of transparency and external verification. It is anticipated that a strong MRV framework will empower consumers to compare technology options, lead to evidence-based policy making with the full benefits of DES quantified, leverage other projects and investment in the selected city, and ultimately feed back into building certification schemes. Further benefits are the possible data and performance-based comparability among different activities and the consistency of data collected over years for building up robust evidence for investment decisions.

UN Environment has the responsibility to model good practice and drive the achievement of gender equality in its environmental-related activities, including assessments and analyses, norms, guidelines and methods. A gender lens has been applied to this guideline to make it gender-responsive, including indicators that can help monitor the impact of clean heating and cooling on gender.

For the development and further improvement of the generic MRV framework guidance, it is applied to real case DES projects allowing review and reflection of the approach by partners, cities and other stakeholders. Based on the results, the guidance will be continuously updated in order to enhance its practicability. The work with the city teams to adopt the generic MRV framework to their specific circumstance including demonstration projects and training of relevant stakeholders is deemed as a readiness test for the MRV framework.

The MRV guidance will enable projects and cities under the Initiative to track progress on city-wide district energy plans and their impact. The Initiative will work with cities to define reporting requirements including content and frequency. Furthermore, verification procedures will be put in place to ensure the MRV framework is being implemented appropriately including the cross checking of data and review of data collection and analysis and could include national government verification and assessment of implementation (site assessment and spot checks leading to an examination report).

This guidance supports this objective of the Initiative by providing guidance on a generic MRV framework for DES on a city level. It is taking into account the different potential DES project types (district heating, district cooling, and trigeneration) and covers the tracking of both, GHG emission reductions and the assessment of multiple benefits through key sustainable development indicators.

Objectives of the MRV guidance for DES projects

The general objectives of this guidance are (1) to provide a generic MRV framework for DES in cities, taking into consideration the three main technology types, i.e. district heating, district cooling and trigeneration; and (2) to illustrate how to adopt the generic framework to specific city situations.

The guidance shall support DES activities in cities to monitor their impacts proposing a broad approach to MRV that addresses 1) GHG emissions and 2) sustainable development. In particular, city authorities and relevant stakeholders (utilities, private sectors, etc.) shall be enabled to evaluate planned and implemented projects with regards to GHG impact and sustainable development benefits:

- ***GHG emissions and mitigation actions:*** GHG reductions are determined in relation to a baseline scenario that reflects assumptions, such as possible technology alternatives, economic and population growth that would influence the emission level of cities. These assumptions may change over time, hence the baseline needs be adjusted accordingly to facilitate more accurate measurements, if required.

- ***Sustainable development*** metrics shall help highlight the impact of mitigation actions and DES projects on the local or national economic development, the environmental situation, public welfare or gender inequalities. This may include an increased energy security, reduction of air and water pollution and reduced cost of power and heat supply. Sustainable development benefits are crucial to mobilize and ensure local political support and acceptance. Its monitoring also allows supports the access of funding sources that are interested in both GHG mitigation and promoting sustainable development.

Hence, the target audience of this MRV guidance is comprised of key stakeholders involved in the developing, implementing and operating of an MRV framework for DES projects. This includes cities authorities and policymakers and practitioner users, such as utilities and DES operators that want to estimate GHG mitigation and SDG impacts from DES projects. MRV is in particularly relevant in the context of Nationally Determined Contribution (NDC) development and implementation, national and local low emission strategies and Nationally Appropriate Mitigation Actions (NAMAs) as well as other mitigation mechanisms. It can also help to measure the contribution of district energy to local sustainable development. The focuses of the guidance are on the assessment of GHG emission reduction and SDG impacts. However, the impact assessment can also help to inform and enhance the design and implementation of policies and measures.

The specific objectives are:

- To provide a basic understanding of the MRV concepts and key principles of the generic MRV framework for DES projects;
- To propose an MRV framework design for DES based on the best international practices, including specific performance metrics and indicators
- To specify how the DES MRV framework approach could be adopted for DES activities in individual cities in a specific MRV Plan;
- To assess the possible barriers related to the implementation of the MRV framework and plan.

These specific objectives will be addressed in the following chapters of the report.

Purpose and benefits of MRV frameworks for district energy systems

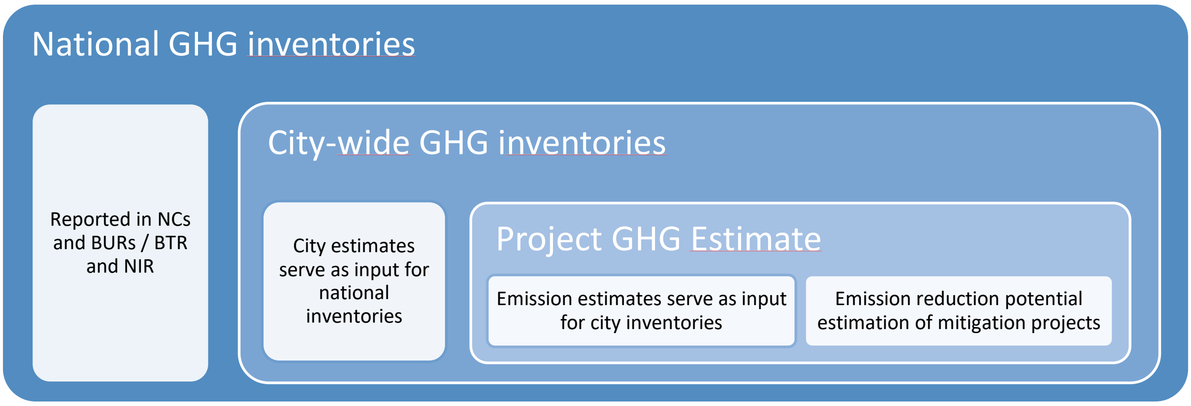
Cities and urban agglomeration are dense centres of living, commerce and of culture resulting in a significant and growing level of energy consumption and GHG emissions. The ability of city authorities to take effective action on GHG mitigating and adaptation to climate change depends on having access to reliable quality data. Planning effective and efficient mitigation action requires a good understanding of the current situation and the potential impact of intervention. Hence, a GHG inventory on city level, which enables the authorities and all stakeholders to understand the emissions contribution of different activities in the community would be a good starting point for identifying relevant areas for mitigation actions (Compare GHGP, 2014, p. 9).

Tracking mitigation action and sustainable development impacts through MRV will help cities, regions and countries to review the progress of their mitigation efforts. The results provide a better understanding of sectoral situations and effectiveness of measures. For many countries, implementing

SDGs and the contribution of mitigation actions at the national and local level is of high priority. A good foundation of data and information through MRV will ***allow for more effective planning, facilitate decision making, help evaluate policy impacts*** and will support the formulation / achievement of GHG targets. The SDGs and SD impacts are related to many actions. The impact may be covered by national statistics, e.g. on poverty, health or education. However, an MRV system in place may assist in tracking the SD impact of mitigation actions by providing data and information that allows the monitoring of the specific SDG. Particularly, if a SDG tracking system does not exist, an MRV system can complement the existing structures (GIZ, 2018).

At the national, regional and city level, an MRV framework can help ***identify priorities with regards to GHG mitigation efforts*** taking into consideration associated challenges and opportunities. It supports designing policy instruments and ensuring consistency and quality of data. Hence, the development of a robust MRV system is important to facilitate the political decision-making process.

Figure 1: Relation between project emission, city and national inventory



Source: Own illustration, considering GIZ, 2018, p. 28

With solid data and information, local governments and stakeholders may identify DES projects as a key solution for heating and cooling demand. A solid MRV framework for DES projects will generate transparency and build trust regarding the effectiveness of projects with regards to their results (e.g. GHG mitigation, SDG contribution), which will ***empower cities to identify relevant opportunities and take action*** (ICLEI, 2014). It will also allow the monitoring of projects' performance and hence any required adjustment during the project implementation and operation over time. For DES projects this will help to enhance the performance of services and energy deliveries for DES projects.

In addition to international reporting requirements under the UNFCCC, ***national reporting on climate change and sustainable development*** is getting more and more important, as citizens become increasingly interested in understanding the impacts of climate change on their lives and businesses. Local governments need to be able to report on and account for actions on reducing climate change impacts and GHG emissions. This will allow for a broader local and national discussion, which can help governments to demonstrate their accountability to civil society and to the public (GIZ, 2018, p. 16).

MRV is the basis for a transparent sharing of information and data between city authorities and with other countries, potential donors and the UNFCCC. Through transparency, donors and other parties will better understand the progress made in the country towards the target in the sector. This will in turn increase credibility. MRV will be an important requirement for fund raising, in particular to ***attract financial support and to improve access to financing*** for the implementation of mitigation actions, such as the introduction of a new DES or the rehabilitation of an existing one. Most donors or funders, such as bilateral or multilateral institutions (multi-developing banks, MDBs), funding facilities, e.g. NAMA Facility or Green Climate Fund) require a project or programme specific MRV system. This usually not only covers GHG emission reductions, but also SDG/co-benefits contributions, the implementation status and the financial flow. Hence, a comprehensive MRV system will support the ***Monitoring and Evaluation*** (***M&E) approach*** of programmes and projects.

MRV is of high relevance in particular for ***Results Based (Climate) Finance (RBF)***. The RBF concept is based on a pay-for-performance mechanism, for which project developers will receive an ex-post financial payment / incentive in relation to the amount of GHG emissions reduced (examples are the market mechanism such as the Clean Development Mechanism (CDM) and other voluntary offsetting mechanisms).

Textbox 1: The Clean Development Mechanism (CDM)

The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets.

The CDM requires the application of a baseline and monitoring methodology in order to determine the amount of CERs generated by a mitigation CDM project activity. Methodologies are classified into different categories, e.g. for large-scale and small-scale CDM project activities. Methodologies often refer to methodological tools, which address specific aspects of the project activity, e.g. to calculate GHG emissions from specific sources.

The CDM is a well established mechanism with currently more than 7,800 registered projects. These projects have issued more than 1.9 billion CERs using 90 approved large-scale and 97 small scale methodologies.

Source: UNFCCC, 2018 and 2019

The Paris Agreement will allow for using international market mechanisms to achieve NDCs. The cooperative approaches (CA) under Article 6.2 allow countries to use "***internationally transferred mitigation outcomes***" (ITMOs) to achieve their NDCs and Article 6.4 establishes a new crediting mechanism. Both mechanisms shall allow countries to collaborate in order to meet their NDC targets in a flexible and cost-effective way through market mechanisms. Cooperative approaches can be used to transfer ITMOs from one country to another. Obviously, this requires a robust accounting and MRV approach, e.g. to avoid double counting. After contentious negotiations, countries failed to agree on the detailed rules regarding the market mechanisms under Article 6 during COP24 in Katowice in December 2018. Talks on this issue will continue in 2019.[1]

Modalities, procedures and guidelines for the ***enhanced transparency framework (ETF) of the Paris Agreement***, including those on flexibility, reporting and review requirements, were adopted by COP 24 (Decision 18/CMA.1). The enhanced framework builds on the existing system by expanding the scope of reporting and review and by converging parallel transparency systems that are currently in

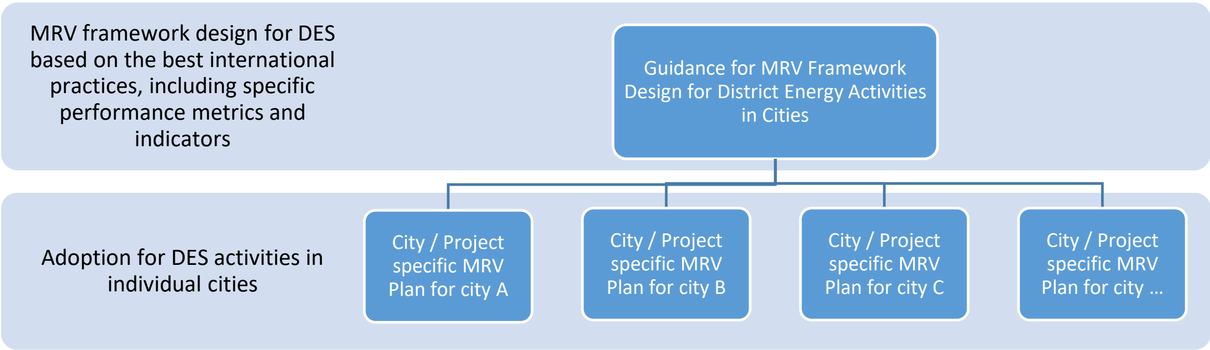
[1] CarbonBrief, 16.12.2018: https://www.carbonbrief.org/cop24-key-outcomes-agreed-at-the-un-climate-talks-in-katowice#article6

place for developed and developing countries (IIED, 2017). The MRV framework for the DES activities should be in-line with the ETF to support countries in meeting future reporting compliances.

How to use the guidance

The generic MRV framework in this guidance for DES projects covers the potential GHG mitigation and sustainable development (SD) benefits related to these projects. Under the framework, an impact assessment for DES projects should be used, which takes into account the DES project specific situations. The adoption and adaption to the city and project specific situation is carried out in an individual MRV Plan prepared based on this guidance.

Figure 2: MRV Guidance and specific MRV / Monitoring Plans

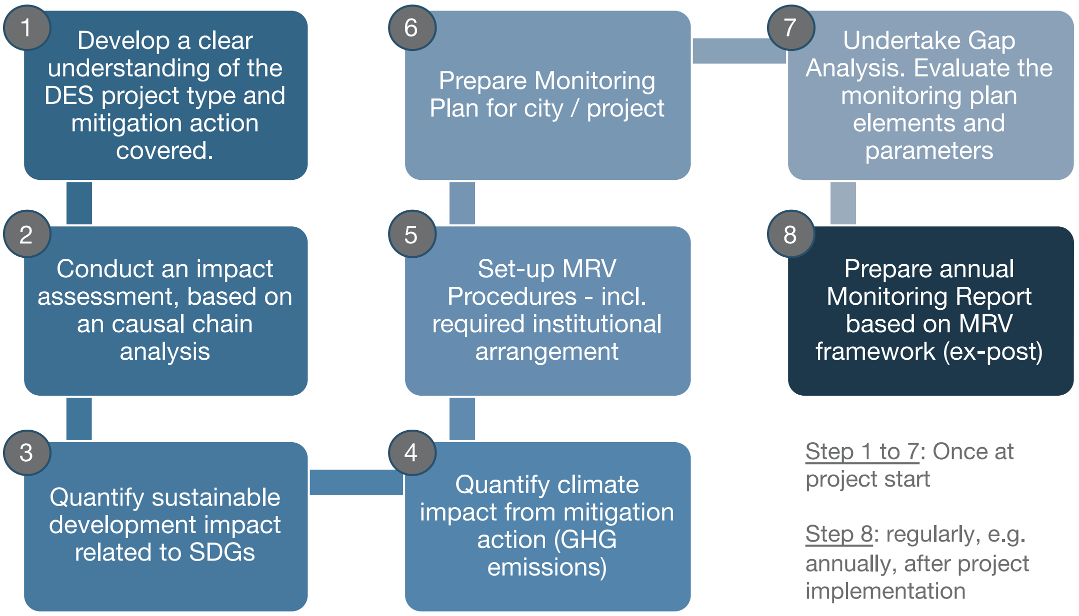


To inform the approach for the emission reduction estimation, an assessment of best-practice MRV methodologies and standards is conducted to derive suitable methods. These methodologies shall follow important basic MRV concepts and key principles including international requirements and standards under the United Nations Framework Convention on Climate Change (UNFCCC)[2]. This shall ensure conformity of the MRV framework with reporting standards under the newly introduced Enhanced Transparency Framework (ETF) under the Paris Agreement (PA).

Figure 3 illustrates the general approach for developing an MRV Plan for DES projects based on the generic MRV framework outlined in this guide.

[2] The report assumes that the users are familiar with the basic UNFCCC processes and regulations on MRV. Background reading for readers/users not familiar with the UNFCCC process and MRV requirements can be found in "Handbook on MEASUREMENT, REPORTING AND VERIFICATION FOR DEVELOPING COUNTRY PARTIES (UNFCCC, 2014) or "MRV 101: UNDERSTANDING MEASUREMENT, REPORTING, AND VERIFICATION OF CLIMATE CHANGE MITIGATION" (WRI, 2016).

Figure 3: General approach for establishing an MRV Plan for DES projects



As illustrated above, depending on the national or local circumstances, a step-wise procedure for adopting the generic MRV procedures and setting up an MRV Plan should be followed:

Step 1: Develop a clear understanding of the DES project type and mitigation action covered. Identify the key characteristics of the DES projects and the underlying technologies.

Step 2: Conduct an impact assessment using a causal chain analysis to identify the envisaged (primary effect) and possible co-benefits (secondary effects) of the project.

Step 3: Quantify the sustainable development impact - For tracking the SDG impact from the project, key indicators and data required need to be identified for the monitoring.

Step 4: Quantify the climate mitigation impact - For tracking the impact from mitigation action, identify and select an applicable methodology as per generic MRV Framework presented in this guidance, or a combination of methodologies; derive key parameters and data required for the baseline and actual mitigation action to determine GHG emission and potential reductions resulting from the project.

Step 5: Set-up project specific MRV Procedures - Provide an overview of the required institutional arrangement and the expected efforts for the MRV work.

Step 6: Prepare an MRV Plan including prescribed monitoring, reporting and verification processes for GHG emission reductions and SD impacts. Consider the country's national MRV system and methods for reporting obligations under the UNFCCC to ensure alignment with the existing reporting (Biennial Update Report - BUR, National Communications - NC) and the future reporting as per the Enhanced Transparency Framework (ETF) under the Paris Agreement.

Step 7: Undertake a gap and barrier analysis to evaluate the MRV Plan elements and parameters with regards to which parameters can be monitored or cannot in the prescribed level of detail using a gap and barrier analysis. Associated barriers and potential gaps for implementation should be determined and discussed. Based on the gap and barrier analysis and relevant stakeholder consultation, adapt the MRV plan and make it implementable and suitable to the local plans and actions. While providing some flexibility on the implementation, e.g. with regard to monitoring frequency, sampling approaches applied, use of default values, general MRV principals such as accuracy, completeness, conservativeness, consistency, comparability and transparency should be respected.

Step 8: Prepare a regular / annual Monitoring Report based on the MRV Plan for periodical reporting on the results of the project.

The steps are described in detail in Chapter 3. The following Chapter 2 will first provide the base concepts and principles for an MRV framework. Before starting the elaboration of an adapted MRV Plan for an individual project or city, it is advised to first read all the steps to understand what should be done. This will facilitate the process and ensure the interlinkage of the steps.

At the end of each chapter and step respectively, a small text box summarises the recommendation and advice as follows:

> *Recommendations and advices are summarised in bullet points at the end of each section.*

2. Basic concepts and principles of MRV frameworks

The main objective of the MRV framework for DES projects is to monitor the impact generated by DES project implemented in cities incl. the measuring, reporting and verifying of GHG emissions reductions and SDG benefits. The framework is based on a comprehensive set of performance metrics and indicators. These indicators will form the core part of the MRV framework and can be used as applicable to the individual local situation in a city project. The MRV framework should be robust and rigorous enough to be able to quantify the emission reductions and SDG benefits.

Key principles and characteristics of MRV frameworks

The key objective of an MRV framework is to capture what is happening and to keep track of achievements with regard to GHG emissions, reductions and co-benefits in cities.

Table 1: Definition of the components of an MRV system

Measurement	Reporting	Verification
• Collection and measurement of the relevant key data and parameters to assess the progress of the overall project and impact of the mitigation measures • Keeping track of GHG emissions, reductions and co-benefits in cities	• Communicating information on GHG emissions, reductions and co-benefits (e.g. within citiy authorities, to stakeholders and to the public) • Presentation and report of the measured data and parameters in a transparent and standardized way	• Checking that the data reported reflect the reality on the ground • Evaluation of the correctness, completeness, consistency and robustness of the data and information reported through a third-party independent verification process

Source: own elaboration, based on UNFCCC, 2013

As illustrated in *Table 1*, an MRV framework consists of the following three main components:

1. The **measurement** of the established key parameters and performance indicators is a process to generate and collect data in an established standard way. When referring to MRV system, the terms "monitoring" and "measurement" are often used interchangeably. However, there is a substantial difference in meaning, as "monitoring" refers to a management function, whereas "measurement" is more an operational function (UNFCCC, 2013)[3]. In the context of the MRV system for DES, the term "measurement" will be used.

2. The **reporting** component refers to the presentation of the measured data and key parameters to relevant stakeholders. The accuracy and reliability of information is key to the success of the reporting process, while the transparency and standardization of the reporting process are also essential because they allow comparison between different reporting activities.

3. The **verification** component refers to the process of the evaluation of the accuracy and reliability of the reported data and information. This process can be performed by either independent experts or by an independent third party (e.g. the Designated Operational Entities –DOE- in the CDM process).

The concept of the MRV framework related to GHG emissions originated from the need to measure, report and verify GHG emissions at a national level (e.g. for countries' National Communications (NC) to the UNFCCC[4]) and / or at a project level (e.g. for CDM projects). In the latter case, the MRV system

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[3] According to UNFCCC (2013), the term "monitoring" consists in the review of the implementation with regards to the planned objectives and goals, whereas "measurement" refers to the operational function of recording and collecting data and parameters that will allow monitoring.
[4] See UNFCCC: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php (Non-Annex-I National Communications to UNFCCC) and http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/3625.php (Annex-I National Communications to UNFFCC (last accessed: 13.03.2015)

did not only serve as measurement and reporting tool to track the development and performance of the mitigations activities but was also crucial for the monetisation of the GHG emission reductions, such as Certified Emission Reductions (CERs) credits.

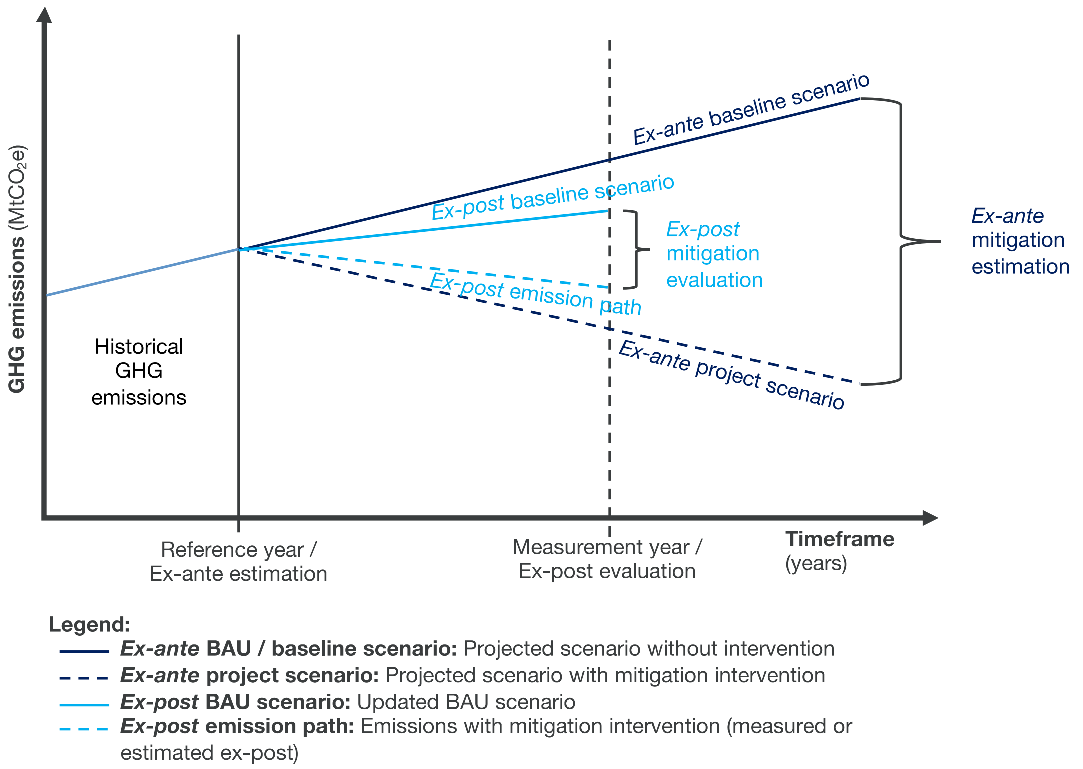
Depending on the type of mitigation action (either seeking international support or "unilateral" actions), the stringency of the MRV system could vary significantly. It has to satisfy the needs of the reporting of the country (e.g. in a country's NDC context and/or other reporting processes to UNFCCC) and, at the same time, it should meet the expectations and requirements of potential funders. For many sectors and project activity types, during the past years the CDM had already provided robust MRV methodologies with stringent verification practices (see *Textbox 1*). For this reason, these well-established methodologies are often used outside the CDM (e.g. for design of NAMAs) as a *basis*, whenever possible and applicable.

For determining the required parameters and data sources one need to distinguish between the *ex-post* MRV and the *ex-ante* projections of GHG emissions and estimates of potential mitigation impacts:

- ***Ex-ante* parameters**: used to estimate the potential GHG emissions due to the likely estimated effects of the mitigation projects, policies or actions prior to the implementation of the respective mitigation action. This process is also referred to as *ex-ante evaluation*;
- ***Ex-post* parameters***:* used to calculate the GHG emissions due to the effects of mitigation projects, policies or actions after their implementation, therefore during and after the implementation period. This process is also referred to as *ex-post evaluation*.

The relationship between the ex-ante and ex-post evaluation is illustrated in Figure 4. Ex-ante and ex-post under the MRV refer to the time of evaluation. Is does not refer to an estimation of the GHG level from today's point of view, i.e. with or without project implementation. Figure 4 shall illustrate that the baseline / project emission estimation at some point of time (today), may have changed in the ex-post perspectives, i.e. retrospectively. The baseline in the figure, hence, does not fit to all real projects or situations and the development may look different depending on the project activity (see example for Belgrade in *Textbox 2*).

Figure 4: Relationship between the ex-ante and ex-post evaluation



Source: Own illustration, based on GHG Protocol, 2014

By extrapolating the historical GHG emissions or projecting the development of key emissions drivers over the lifetime of a programme / project, it is possible to create an ex-ante business-as-usual (BAU) or baseline scenario (see *Textbox 2*). In the same way, it is also possible to project into the future the GHG emissions under the implementation of the mitigation measures (in the illustration: ex-ante project scenario). The difference between these two scenarios will give the ex-ante mitigation estimate.

Once the measures are implemented, it will be possible to evaluate their performance ex-post. Depending on the sector and on the mitigation technologies applied, it will be possible to either measure the GHG emission reductions directly or to measure the GHG emissions of the projects after their implementation. In the latter case, in order to estimate the GHG emission reductions, it will be necessary to deduct the measured GHG emissions of the project from those of the baseline scenario. The baseline scenario could also be dynamically updated year after year with the new data recorded from the previous years.

For many mitigation actions the ex-post determination of emissions under the mitigation scenario may be difficult to base on direct measurements, e.g. for dispersed technologies such as buildings and transport. Here samples and default parameters for determining the baseline and/or project emissions can be used in order to simplify the MRV system. This is needed in those cases in which the monitoring of GHG emissions reductions of the implemented technologies is too complex or costly. This way, the implementation is simpler and more cost-effective than if all parameters have to be rigorously measured. Default values commonly used are often sourced from the Intergovernmental Panel on

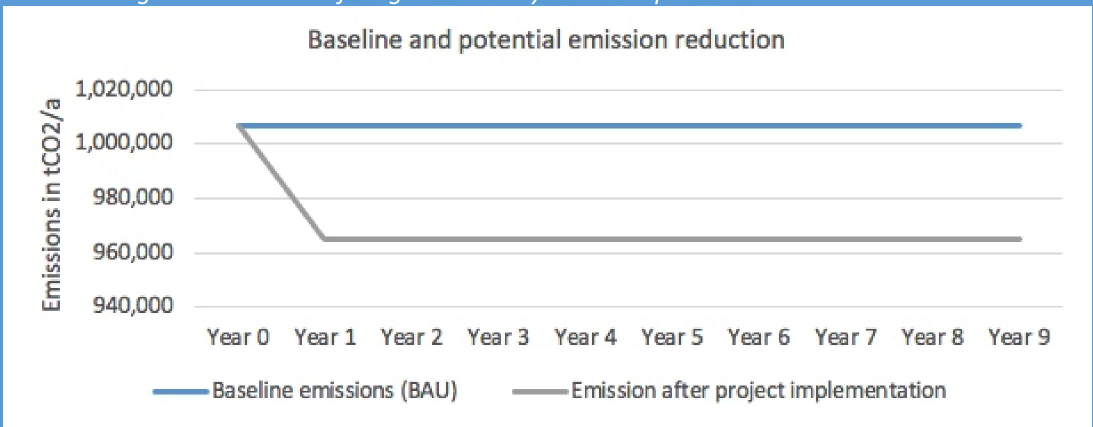
Climate Change (IPCC) that are considered a good approximation to the actual values, if national default values are not available.

Textbox 2: Business-as-usual (BAU) vs. baseline scenario

The emission baseline always depends on the *baseline scenario* and which development is considering herein (e.g. business as usual development, dynamic use and penetration of technologies, fuel type and consumption, efficiency standards etc.). It does not necessarily reflect the business-as-usual (BAU) situation.

Baselines can be projected to be stable, increase or decrease subject to the underlying development. For example, in case district energy shall replace or avoid the future use of conventional air conditioners (ACs), in the baseline scenario without the project, the use of conventional ACs will continue to prevail and even increase due to affordability and economic development. Hence, as a consequence from today's point of view (ex-ante estimation), the baseline under this scenario would increase. In other cases, where, for instance, an existing district heating network exists, the baseline scenario could be rather be a business-as-usual development and hence the emission baseline would be stable, if no other intervention to the network will take place (See *Figure 1*).

Figure 5: Baseline of Belgrade's DH system and potential emission reduction



Source: MRV Plan for District Energy Systems Activities in Belgrade, March 2019

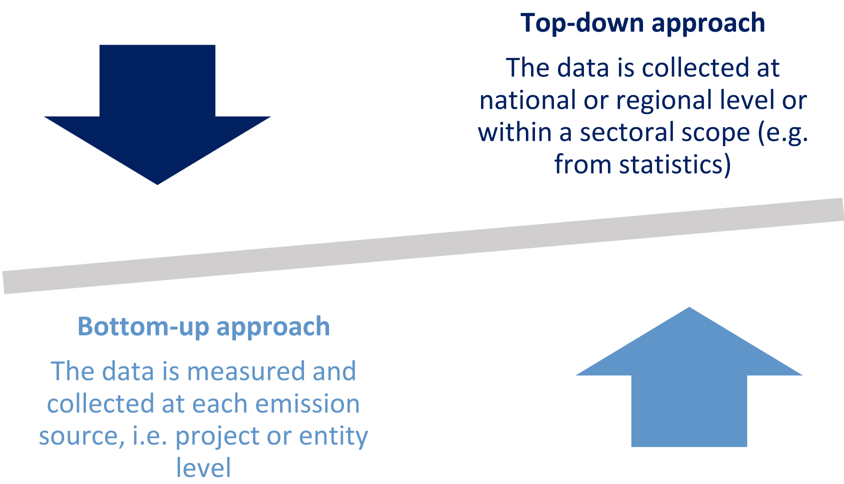
In order to define the *ex-post* component of an MRV system, two approaches are possible (illustrated in *Figure 6*):

- **Top-down approach**: the calculation and/or the modelling of the GHG emissions are based on indicators of statistical chronological series at a macroeconomic level, such as using econometric models or a regression analysis. The data and parameters used for the analysis in this approach are collected at a specific geographical level (e.g. national or regional), economic dimension (e.g. population, gross domestic product (GDP), crude oil price) or within a sectoral scope (e.g. energy demand of sectors, penetration rates of technologies etc.).
- **Bottom-up approach**: the calculation and/or the modelling of the GHG emissions are based on indicators collected at each individual source of information, such as individual projects or entities. The data is then aggregated. The data and parameters used for bottom-up approach are either measured (e.g. through a measuring tool such a gas meter) and collected at the level of each source, project or entity (e.g. the energy used by a project per type of fuel), or pre-

defined (default parameters). The latter obviously need to fulfil a certain degree of conservativeness.

An MRV system could also be built on a combination of the two approaches to reach a good integration of the best elements of both approaches.

Figure 6: Possible data source for MRV: top-down and bottom-up approach



Source: Own illustration

An MRV system should have a good balance among simplicity, rigour and cost-effectiveness to not jeopardise the primary goal of implementing mitigation actions with available funds. In order to guarantee this balance, the design of a robust MRV system should allow more flexibility than the typical CDM approaches in terms of MRV procedures (unless off-set certification shall be generated and be used). Moreover, an MRV system should be practical, and its complexity should not represent a barrier towards the implementation of mitigation actions. The UNFCCC's Low Emission Capacity Building Programme "Guidance for NAMA Design" (UNFCCC, 2013) proposes the following good practices for the development of a robust MRV system (*Table 2*).

Table 2: Good practices for the design of a robust MRV system

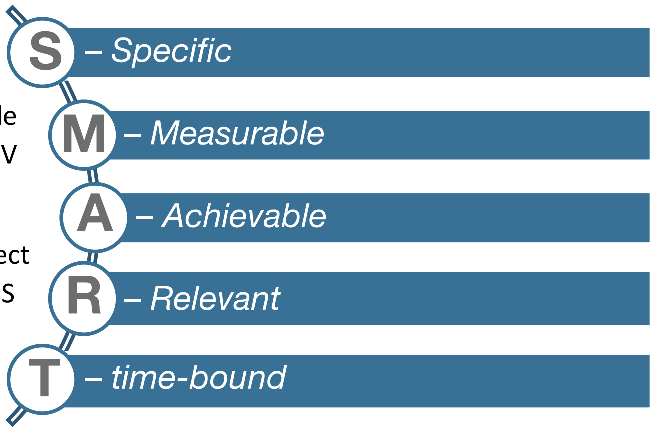
Suggested Good Practice	Description
Accuracy	The measurement of the data and parameters of the MRV system should be conducted in the most precise way as possible and with the least uncertainty: it should be as accurate as the budget can allow. Moreover, if there is the need to make a trade-off in the accuracy of the measurement, one should me more conservative in the estimates and judgments.
Completeness	A mitigation action normally entails several effects with its implementation, not necessarily strictly related to GHG emission reductions only. A comprehensive MRV system should cover all relevant and important impacts related to the activity and effects caused. This in particular includes sustainable development benefits and contributions. In case some of the impacts of the measures are estimated quantitatively, the calculation methodology should be clearly and transparently described, including all the steps of the process.
Conservativeness	All estimates and measurements should be made following a conservative approach, especially in situations when either the measurement or the estimation have high levels of uncertainty or there is no cost-effectiveness in deploying a high level of accuracy in the measurement. The measurement methodology should identify the level of uncertainty in the

Suggested Good Practice	Description
	measurement and include procedures for including conservative values (e.g. using IPCC default values when a measurement is not possible/not cost-effective).
Consistency	At least at a national level, the reporting of data and information should be consistent among different activities, especially in the light of the reporting of NDCs (e.g. harmonisation of MRV systems at a national level). Moreover, within the same project or programme, the measurements taken at different periods of time should be consistent.
Comparability	Similarly to the consistency principle, the information gathered and data measured should be comparable across mitigation actions and across different periods of time, especially in the light of the reporting of NDCs. It is then advised to use clear processes for the measuring and standardised formats for the reporting in order to harmonize the MRV systems at a national level.
Transparency	Funders and the international community give a lot of importance to the transparency of the methodologies and processes used for the measuring and calculations of GHG emission reduction in an MRV system. A robust MRV should include a clear explanation for all the data gathered and calculations performed, in order to allow an independent third-party verification of the results.

Source: adapted from UNFCCC, 2013

From the analysis above the following recommendation for the design of the DES MRV framework can be drawn:

- The indicators to be considered should be **SMART;**



- The MRV system should be compatible with the local and national MRV approach (if it exists or applies);
- The MRV system could be project specific, but also consider all DES mitigation activities included in city-wide projects;
- In order to ensure a successful implementation of the MRV framework, it is recommended to establish a close collaboration among all various stakeholders. Therefore, the general institutional set-up and process, along with clear responsibilities, should be outlined in the MRV system design through an Institutional Plan;
- The implementation of an MRV system will not lead to emission reductions and sustainable development benefits *per se*. Therefore, its design should be as cost-efficient as possible, in order not to represent a barrier to the implementation of mitigation actions;
- Potential capacity building requirements should be considered from the beginning for the implementation of the MRV system, especially in terms of data collection, data quality and data reliability in reporting;
- The effective implementation of the MRV system should start from the central government but then implemented in practice at a sub-national / regional and even municipal level, in

order to ensure alignment with the national MRV and to allow political endorsement and increased enforcement.

MRV requirements in the context of the UNFCCC

At the international level, a robust MRV system can help build trust regarding the effectiveness of mitigation actions by actual and potential funders of mitigation actions (e.g. NAMA). The Paris Agreement (PA) defines the collective target to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Article 2.1 (a), UNFCCC 2015). Countries shall through their NDCs establish individual targets according to their capabilities and national circumstances. This however implicate potential challenges with regards to transparency, MRV and accounting, as the diversity of first NDCs submitted has shown (Wartmann et al., 2018).

The existing framework for MRV under the UNFCCC for developing countries consists of several elements, some implemented at the international level and others at the national level. Internationally relevant are the National Communications and the Biennial Update Report (Wartman et al., 2018):

- ***National Communications (NCs)*** are prepared every four years and need to provide information on the national circumstances, the institutional arrangements, the national GHG inventories, measures implemented regarding both adaptation and mitigation to support the implementation of the UNFCCC, as well as information on existing barriers and gaps (with regards to technology transfer, capacity building and financial support needs)
- ***Biennial Update Report (BUR)*** reports are submitted every two years and provide an updated on the NCs. The focus lies on GHG inventories, information on the domestic mitigation actions and on the support received. BURs are reviewed by the International Consultation and Analysis (ICA)[5].

The domestic level of MRV shall gather and process the information and data needed for the NCs and BURs. It has to be differentiated between ***"emissions"*** and ***"mitigation actions"*** that lead to emission reductions (Wartman et al., 2018):

- ***MRV of emissions***, is performed at different levels (project, corporate, city/province, sectoral or national level) depending on the aggregation. The information on GHG sources, sinks and reservoirs provides the basis for GHG inventories as part of the NCs and BURs.
- ***MRV of mitigation actions***, assess the GHG effects of mitigation programmes and projects, such as NAMAs or CDM projects, providing the mitigation impact achieved compared to a baseline scenario.

[5] Information on adaptation is not mandatory but can be voluntary provided in the BURs. Also refer to the UNFCCC Toolkit on Establishing Institutional Arrangements for National Communications and Biennial Update Reports for support on establishing the national institutional arrangements.

- ***MRV of support,*** covers and tracks the financial support, technology transfer and capacity building received by one Party.

The Paris Agreement newly established an **Enhanced Transparency Framework (ETF)** that includes reporting requirements for both developed and developing countries on mitigation and transparency (Article 13, in UNFCCC, 2015). The Paris Agreement's ETF will replace the BRs and BURs with a ***biennial transparency report (BTR)*** latest from 2024 onwards. From that moment on, the reporting and review guidance will become the same for all countries. Until then the current system will be applied with final submission of BRs (until end of 2022) and last BURs (until end of 2024). In addition, NC under the UNFCCC are still required to be submitted by all countries (Dagnet et al., 2019).

The ETF comprises components on reporting and review for both action and support. In December 2018, COP24 in Katowice adopted the **Modalities, procedures and guidelines for the transparency framework for action and support**[6], presenting new standards built upon existing processes and transparency systems. The ETF and its modalities, procedures, and guidelines applies to all countries. However, in recognition of Parties' different starting points and capacities, it is noted that the ETF will provide "flexibility to those developing country Parties that need it in light of their capacities" (Article 13, Annex, UNFCCC 2015). Under the new reporting process, countries are obliged to regularly report through a BTR (UNFCCC Decision 18/CMA.1, p. 21) on:

- the national GHG inventory (a **National inventory report (NIR)** which may be submitted as a stand-alone report or as a component of a biennial transparency report);
- information necessary to track progress made in implementing and achieving their NDCs;
- information on climate change impacts and adaptation; and
- information on financial, technology-transfer, and capacity-building support provided and mobilized to developing country Parties (this obligation is mandatory only for developed country Parties; but other Parties that provide support should report).

Table 3: Information to be reported by developed and developing country parties according to the Paris Agreement

	National inventory report (NIR)	Information to track NDC implementing progress	Information on climate change impacts and adaptation	Information on support provided	Information on support needed and received
Developed country parties	mandatory	mandatory	encouraged	Mandatory	-
Developing country parties	mandatory	mandatory	encouraged	encouraged	voluntary

Source: UNFCCC Decision 18/CMA.1 and UNEP, 2016

[6] UNFCCC Decision 18/CMA.1, referred to in Article 13 of the Paris Agreement

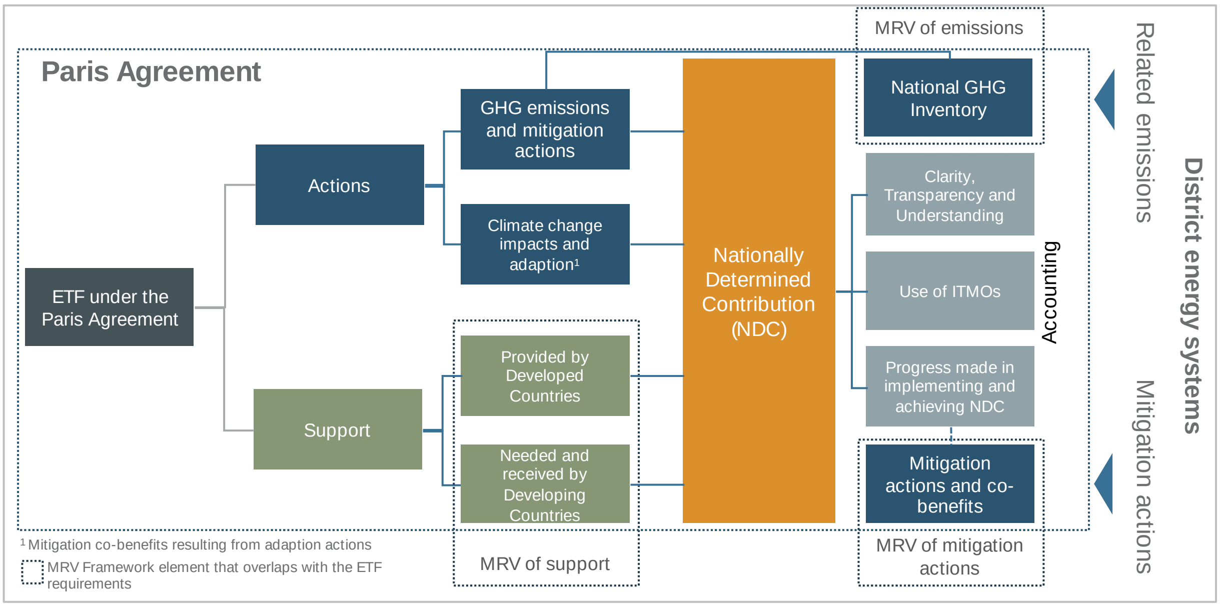
The new reporting requirements for the BTR have increased significantly compared with those of the NCs and BURs, in terms of both the content and details of the information required (Dagnet et al., 2019, p. 8). More effort will be required of developing countries to collect, handle and process all necessary data and information to fulfil the reporting requirements.

According to the PA, Parties are ***accountable*** "for anthropogenic emissions and removals corresponding to their nationally determined contributions […] [and] shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting" (Article 4.13, UNFCCC 2015). This means countries are required to account for the GHG emissions and removals put forward in their NDCs. These commitments affect both developed and developing country Parties, while the latter shall be granted some flexibility.

Tracking the progress of national mitigation efforts, will allow a more effective planning and eventually achievement of the NDC mitigation contribution. Sharing information at UNFCCC level will facilitate other Parties to understand the progress made under the PA both by individual Parties and collectively.

The ETF aims for building mutual trust and confidence among Parties and of promoting effective implementation. All new elements for international reporting under the ETF will be built on the current MRV framework, i.e. the enhanced framework builds on the existing system by expanding the scope of reporting and review, and by converging parallel transparency systems that are currently in place for developed and developing countries (IIED, 2017). Under the PA, countries will need to submit their first biennial transparency report (BTR) and national inventory report (NIR) in accordance with the new modalities, procedures and guidance for the first time at the end of 2024 for the first time at the latest. This will also include the support received and provided by Parties in the form of financial resources, capacity building and technology transfer. As indicated in *Figure 7*, district energy systems need to be considered in the national GHG inventory (emissions) and with regard to the mitigation actions.

Figure 7: ETF process and accounting under the Paris Agreement and potential overlaps with the MRV framework



Source: adapted from Wartmann et al., 2018, p. 29

The suggested MRV framework for DES activities allows for both, the determination of emission levels (in the baseline and project situation) as well as the estimation of emission reduction (difference between baseline and project situation). Under the new ETF the following elements should be considered:

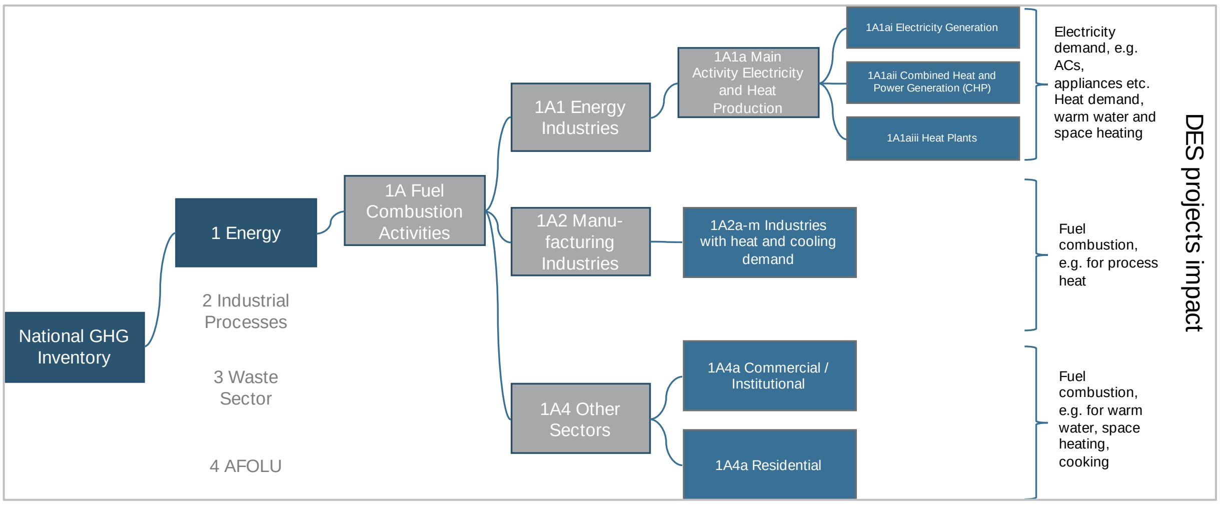
- National GHG inventory systems should be designed and operated consistently to estimate anthropogenic emission by all sources and removals by all sinks of all GHGs following Intergovernmental Panel on Climate Change (IPCC) methodologies (i.e. 2006 IPCC Guidelines for National Greenhouse Gas Inventories).
- Information should be gathered that is necessary to track progress made in implementing and achieving the NDC targets with regards to mitigation (incl. finance and support).
- Institutional mandates and procedures in line with national MRV systems help to strengthen the MRV system and could support secure funding from the government to ensure the continuity of the process (ICAT, 2018, p.110).

GHG emissions from district energy in national inventories

For determining the potential contribution of DES to the NDC of a country, the operation of a GHG inventory and the progress tracking of the NDC implementation (mitigation actions) require good data from sectoral and city level. In order to consider the DES impact in the NDCs, the current energy and GHG profile needs to be known for the whole sector and/or individual cities. The accounting of the energy and emission (incl. energy mapping) is an important tool to increase the understanding of GHG profiles and to derive relevant activities. In addition, it helps in analysing the performance of the sector and specific mitigation actions.

In national and local (on city level) GHG inventories DES activities impact emissions due to fuel combustions in several energy related sectors, e.g. electricity and heat / cooling from power, combined heat and power (CHP) or heat plants, manufacturing industries that could consume and supply heat, and the residential and commercial/institutional sector (see *Figure 8*).

Figure 8: DES activities within IPCC's sectoral categories for national inventories



Source: the greenwerk. 2018, considering IPCC Guidance for National GHG Inventories[7]

In order to set setting up a comprehensive picture of the GHG profile of district energy systems and the related sectors such as industries and residential/commercial building sector, both direct and indirect emission (considering scope 1 and 2) related to the energy demand and supply need to be analysed[8]. This can be done by using national / local energy statistics and balances, if available. According to IPCC (2014), most GHG emissions globally are indirect CO_2 emissions from electricity use in buildings. This can differ on a national or city level. Due to the high share of indirect emissions in cities related to the building sector, actual emission strongly depending on emission factors - mainly related to the electricity and heat production (IPCC, 2014, p. 648). Therefore, a solid analysis on the final energy use that is determined by activities and measures within the sector is important to understand energy saving and mitigation potentials and to track the impact of mitigation actions.

For further reading and details see for instance:

- *UNFCCC's Compendium on Greenhouse Gas Baselines and Monitoring - National-level mitigation actions (UNFCCC, 2016).*
- *Handbook on MEASUREMENT, REPORTING AND VERIFICATION FOR DEVELOPING COUNTRY PARTIES (UNFCCC, 2014)*
- *"MRV 101: UNDERSTANDING MEASUREMENT, REPORTING, AND VERIFICATION OF CLIMATE CHANGE MITIGATION" (WRI, 2016).*

[7] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. A refinement of the current inventory guidelines is currently being carried out. The final draft of this report will be considered by the IPCC for adoption/acceptance in May 2019.

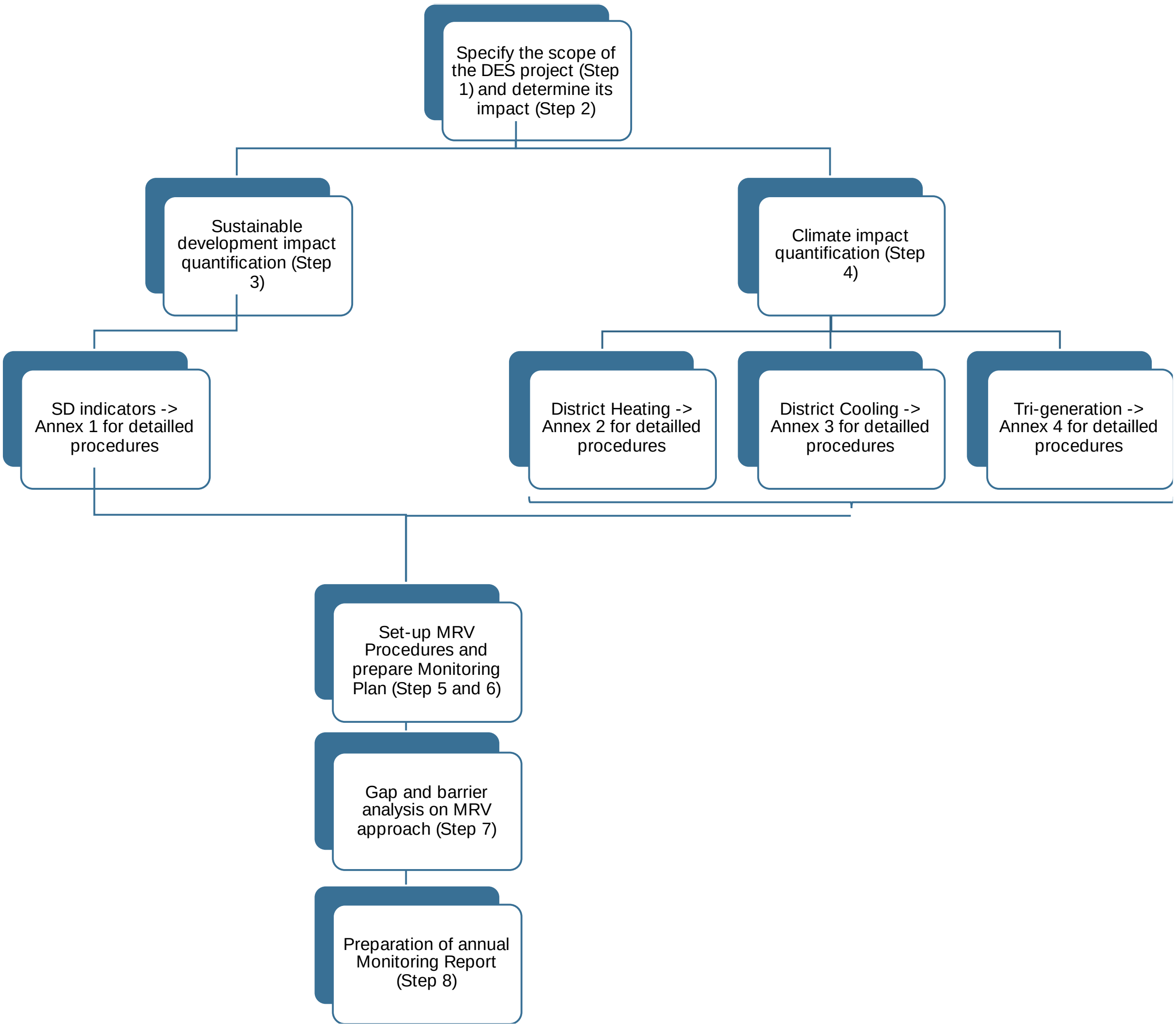
[8] In addition, leakage emissions from refrigerators and air-conditioners (AC) could be considered

3. Steps to design an MRV framework for district energy systems

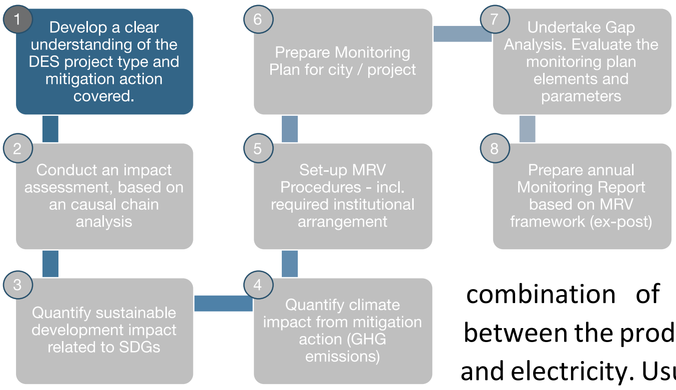
The design of the MRV framework for DES projects is comprised of the evaluation of ex-ante and ex-post data and parameters related to DES mitigation projects. The approach combines two analyses to derive mitigation and sustainable development indicators for the MRV framework: an ***impact assessment*** (causal chain analysis to identify mitigation and sustainable development impacts from DES project) and an ***analysis of the mitigation potential*** following methodologies and standards available for DES technologies.

The aim of this section is to present the 8 steps and the general MRV system approach cities and individual project can follow to set-up an adapted individual MRV system for their activities (see *Figure 9*). This includes the identification of data requirements and monitoring procedures for the GHG mitigation and sustainable development benefits.

Figure 9: Overview of steps to design the MRV framework



The objective of the MRV framework is to measure and ensure the effectiveness of the proposed intervention and measures, e.g. meeting the required standards and expectation (also as a proof for the stakeholders), to provide a credible and transparent approach for quantifying and reporting GHG emission reductions.



Step 1: Identifying different district energy project types

The MRV plan shall focus on and cover emissions reductions (ER) and sustainable development (SD) contribution from DES projects and the underlying technologies. Typically, district energy represents a combination of diverse technologies to create seeking synergies between the production and supply of heat, cooling, domestic hot water and electricity. Usually the following DES project types are differentiated: ***DES providing heat*** (in form of heat-only or co-generation with power generation), ***DES providing cooling energy*** (cooling only or co-generation with power generation), ***DES providing both heat and cooling energy*** (heat / cooling-only or in tri-generation with power generation), fuel switch or energy efficiency measures in existing systems. A combination of these activities is also possible (see *Table 4* for an overview of district heating and cooling technology options).

Table 4: Different DES project types

Typical DES project type	Description / Definition[9]	
NEW / EXPANSION OF DISTRICT HEATING SYSTEM		
Introducing a new or extending a district heating system - a system for distributing centrally generated heat to residential and commercial users. A district heating system supplies heat from co-generation / CHP or heat only plants to a significant area, i.e. a neighbourhood or a city. The primary energy maybe sourced from fossil fuels, renewable energies or waste heat.		
COMBINED HEAT AND POWER (CHP)	Co-generation of electricity in combination with waste heat at a local level. This greatly increases the primary energy efficiency of heating and electricity systems. Combined heat and power (CHP) plants provide district networks with large, centralized heat production that can allow for cost-effective fuel switching in the future if needed.	Fuel source: Sources include coal, oil and gas, biomass, biogas, etc. Conversion technology: Heat capture after steam / gas turbine or combustion engine
DISTRICT HEATING BOILER (incl. biomass fuels)	Provides heat or peak heat load (gas, oil, coal) that is unsuitable for waste heat sources such as from CHP, waste incinerators or industrial waste. For biomass or biogas fuels, boilers can	Fuel source: Sources include natural gas, oil products, electricity, biogas, coal, wood pellets, wood chips Conversion technology:

[9] The potential benefit (e.g. GHG reduction) depends on the respective project circumstances and conditions, e.g. grid emission factor, fuel type etc.

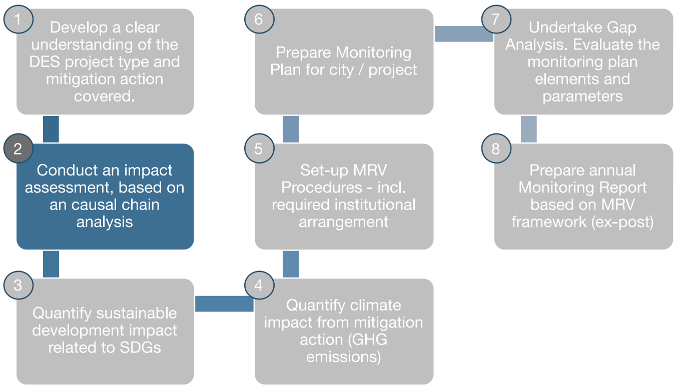
Typical DES project type	Description / Definition[9]	
	provide renewable and CO_2-neutral energy if the biomass is sustainably sourced.	Boiler
WASTE HEAT RECOVERY	Utilisation of waste energy, e.g. through capturing waste heat from new energy sources such as converted CHP plants and industry process, increases overall primary energy efficiency of a city. District heating offers the utilization of low-exergy waste heat (i.e. the use of low valued energy).	<u>Fuel source</u>: Waste heat from an industrial process or low-grade heat from sewage <u>Conversion technology:</u> Heat exchangers
WASTE-TO-ENERGY DISTRICT HEATING PLANT	Utilizes the energy content in non-recyclable, combustible waste providing heat to a district heating network (also as CHP possible).	<u>Fuel source</u>: Municipal solid waste (MSW) and other combustible wastes <u>Conversion technology:</u> Incineration
RENEWABLES HEAT SOURCES: GEOTHERMAL, HEAT PUMPS, SOLAR THERMAL	Renewable energy sources and environmentally friendly technology with low CO_2 emissions, favourably to supply baseload heat demand. Dependent on heat level also CHP possible.	<u>Fuel source</u>: A heat source (e.g., ambient air, water or ground or heat from brine (saline water) from under- ground reservoir) and energy to drive the process (electricity and heat) Sun <u>Conversion technology</u>: Heat exchangers Heat pumps Solar collectors
<u>NEW / EXPANSION OF DISTRICT COOLING SYSTEM</u>		
Introducing a new or extending a district cooling system - a system for distributing centrally generated coolant (e.g. cooled water) to existing and/or new buildings. A district cooling system supplies coolant to an area of several buildings, i.e. a neighbourhood or a city. It includes the district cooling plants, (free) cooling sources and cooling distribution network		
ELECTRIC CHILLERS	(Centralized) Electric chillers typically have much higher COPs than residential and commercial air-conditioning units. Allows using refrigerants with a lower global warming potential (GWP) as compared to decentralized air conditioning.	<u>Fuel source</u>: Electricity <u>Conversion technology:</u> Electric chillers
FREE COOLING	Free cooling requires suitable cooling source, the use of renewable source results in lower carbon emissions.	<u>Fuel source</u>: Cold water from oceans, lakes, rivers or aquifers; waste cool of sources such as liquefied natural gas (LNG) terminals; pumping likely using electricity <u>Conversion technology:</u> Heat exchangers

Typical DES project type	Description / Definition[9]	
ABSORPTION CHILLER DRIVEN FROM SURPLUS HEAT OR RENEWABLE SOURCE	Absorption process utilizes waste heat, enabling high levels of primary energy efficiency. Can be combined with CHP to produce cooling as well as heat (tri-generation).	Fuel source: Surplus heat from renewables, waste incineration, industrial processes, power generation Conversion technology: Integrating absorption chiller with heat source
INTEGRATED / COMBINED / ADDITIONAL APPROACHES		
NEW TRI-GENERATION SYSTEM	Simultaneous generation of electrical energy and thermal energy in the form of cooling and heating in one process from a single heat source such as fossil fuel. Trigeneration is also referred to as CCHP (combined cooling, heating, and power generation)	Fuel source: Sources include coal, oil and gas, biomass, biogas, etc. Surplus heat from renewables, waste incineration, industrial processes, power generation used for cooling (absorption chillers) Conversion technology: Power and heat generation, integrating absorption chiller in a CCHP plant: A Cogeneration System that uses part of the heat generated to operate an absorption chiller, which produces chilled water.
FUEL SWITCH FROM HIGH INTENSE CARBON FUELS TO LOW CARBON FUEL OR RENEWABLE ENERGIES	For heating: Fuel switch from coal/oil to gas, from fossil fuel to renewable, from heating only boilers to waste heat from CHP or industrial waste heat. For cooling: from air conditioners to DES, from compressor-based cooling source to free cooling using sea water, ice storage for cooling etc.	Fuel source: Sources include coal, oil and gas, biomass, biogas, renewables etc. Conversion technology: Power, heat and cooling energy generation
RETROFITTING, REFURBISHMENT AND ENERGY EFFICIENCY IMPROVEMENTS OF DISTRICT ENERGY SYSTEMS	Retrofitting and refurbishment of district energy systems can bring significant energy savings through energy efficiency measures (e.g. upgrading networks to reduce losses and inefficiencies).	Fuel source: May be a combination of all the above Conversion technology: May be a combination of all the above
COLD OR HEAT STORAGE	Thermal energy demand is typically seasonal. Storage enables heat or cooling production to continue throughout a certain period, lowering the use of peaking capacity in a system. Storage periods can range from a few hours and days to seasonal storage.	Fuel source: Cooling energy or heat from district energy network or directly from district energy plant Conversion technology: Storage of hot water, cold water or ice

Source: Adapted from UNEP, 2017, Table 1.1

Identify with the help of the table above the specific measures, intervention and technologies under your project for which the MRV system shall be set-up.

Step 2: Impact assessment



The MRV plan shall capture the impacts of DES projects. These impacts might be manifold and different in significance and magnitude. Therefore, it is helpful to analyse and identify the potential impact, for both SDG and GHG benefits, from DES activities in the beginning in order to be able to focus on major impacts only.

GHG effects are changes in GHG emissions, removals, or storage caused by a project activity, while SDG contribution effects relate to socio-economic, environmental, gender and technological impacts (see Steps 3). There are different effect types: primary effects and secondary effects[10].

- A ***primary effect*** is the *intended* change caused by the DES project activity. The primary effect is defined as a change relative to baseline scenario.
- A ***secondary effect*** is an *unintended* change caused by a project activity (incl. rebound effects). Secondary effects are typically small relative to a project activity's primary effect. In terms of GHG mitigation, secondary effects are classified into two categories:
    - One-time effects, e.g. changes in GHG emissions associated with the construction, installation, and establishment or the decommissioning and termination of the DES project activity.
    - Upstream and downstream effects: Recurring changes in GHG emissions associated with inputs to the project activity (upstream) or products from the project activity (downstream), relative to baseline emissions.

For the secondary effects, in most cases GHG emission can be omitted for simplification, unless they turn out to be significant in the impact assessment. In the impact assessment the primary and relevant secondary effects regarding potential GHG mitigation and sustainable development benefits of the DES project activities within the system boundary are identified. The effects and impact should be mapped in a causal chain[11] to facilitate the identification.

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[10] GHGP, 2005, p. 11

[11] The causal chain analysis could be undertaken following the general guidelines exposed by the GHG Protocol and the World Resources Institute in the "Policy and Action Standard" report (GHG Protocol, 2014). There is also an Excel-based tool available to establish the value chain.

Textbox 3: Rebound effect

Sustainable resource use necessitates efficient use of energy, raw materials and water. Increased efficiency allows products to be manufactured and services to be performed using fewer resources, and often at a lower cost. This in turn influences purchasing behaviour and product use. A rebound effect occurs when the demand for a service, such as energy services, increases as a result of the decreased cost of the service per unit. For example, the (financial) benefits from energy demand savings due to technical efficiency improvement and hence reductions in GHG emissions may result in an increased energy demand the same or other areas (e.g. extended operating hours in lighting). This can oftentimes even cancel out the original savings.

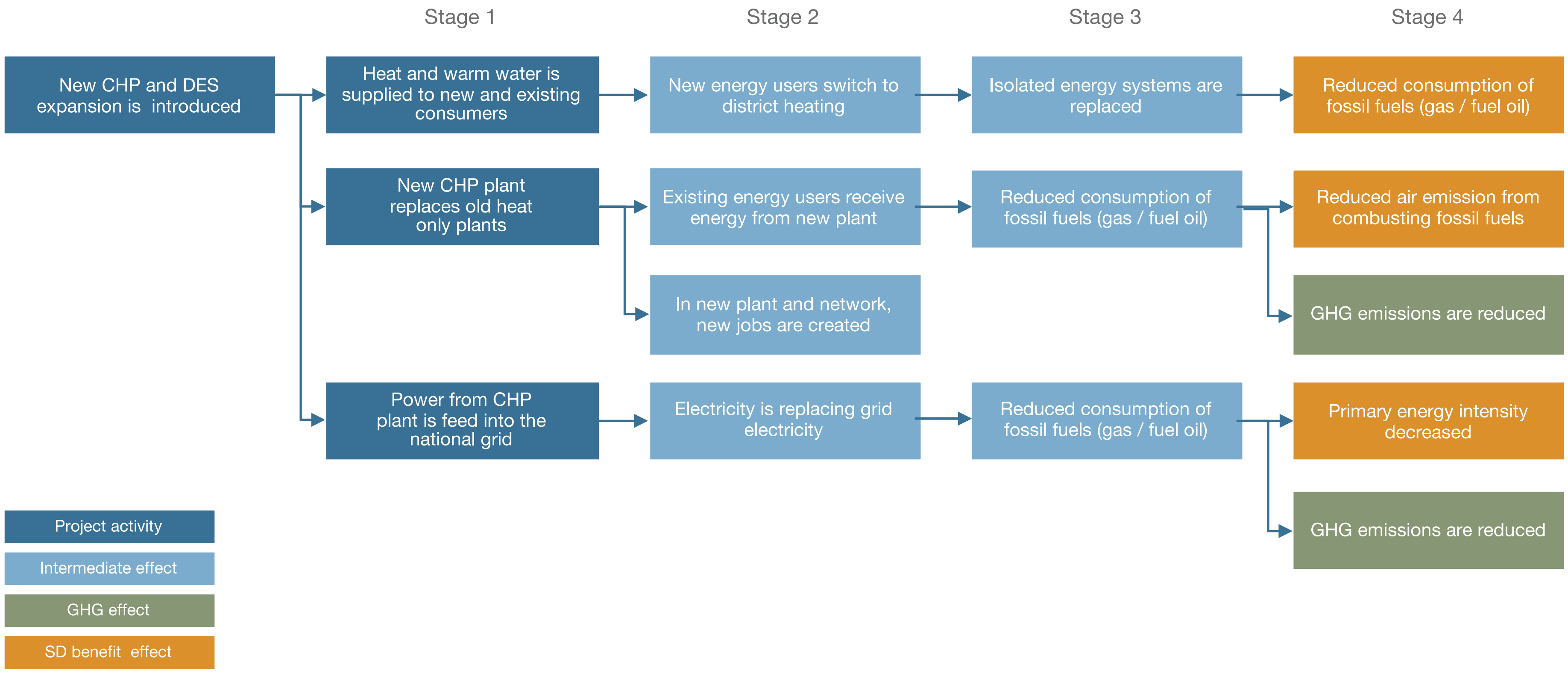
According to the German Environmental Agency (UBA), the direct rebound effect for space-heating use can be estimated to 10 to 30%. Hence, the actual energy savings may be lower than the projected technically feasible savings. However, the impact of any rebound effect depend on specific conditions and can be reduced through the use of suitable instruments.

Source: Adapted from Umweltbundesamt (UBA), 2019

The identified impacts should be evaluated against certain defined criteria (the likelihood that the benefit will occur and the relative magnitude of each benefit). Finally, on the basis of the results of the evaluation of the impacts, key performance indicators can be outlined.

The following figure simplistically illustrates the causal chain for the impact assessment. For each DES project this analysis should be undertaken individually taking into consideration local circumstances.

Figure 10: Impact assessment of DES project (for illustration only)



Source: Own illustration

Once the potential effects are identified, each effect related to GHG and SD benefits will be evaluated based on their "relative magnitude"[12] and "probability" to occur. Based on this evaluation (see *Table 5* below), the relevant and significant impacts can be identified. Only the relevant impacts will be considered for the MRV framework. For the evaluation, the following categories should be applied with regard to the probability and relative magnitude of the effects.

Table 5: Evaluation of the impact model (probability of impact)

Likelihood	Description
very likely	Reason to believe the effect will happen (or did happen) as a result of the DES project. (For example, a probability in the range of 90–100%.)
likely	Reason to believe the effect will probably happen (or probably happened) as a result of the DES project. (For example, a probability in the range of 66–90%.)
possible	Reason to believe the effect may or may not happen (or may or may not have happened) as a result of the DES project. About as likely as not. (For example, a probability in the range of 33–66%.) Cases where the likelihood is unknown or cannot be determined should be considered possible.
unlikely	Reason to believe the effect probably will not happen (or probably did not happen) as a result of the DES project. (For example, a probability in the range of 10–33%.)
very unlikely	Reason to believe the effect will not happen (or did not happen) as a result of the DES project. (For example, a probability in the range of 0–10%.)

Source: Adapted from WRI/WBCSD 2014

Table 6: Evaluation of the impact (relative size)

Relative magnitude	Description
major	The effect significantly influences the effectiveness of the policy or action. The change in GHG emissions or removals and / or SD benefit is likely to be significant in size.
moderate	The effect influences the effectiveness of the policy or action. The change in GHG emissions or removals and / or SD benefit could be significant in size.
minor	The effect is inconsequential to the effectiveness of the policy or action. The change in GHG emissions or removals and / or SD benefit is insignificant in size.

Source: Adapted from WRI/WBCSD 2014

This will allow for the identification and selection of relevant results according to the following matrix:

[12] Compared to the primary GHG effect

Table 7: Evaluation of relevant results

<table>
<tr><th rowspan="2">Likelihood</th><th colspan="3">Magnitude</th></tr>
<tr><th>Minor</th><th>Moderate</th><th>Major</th></tr>
<tr><td>Very likely</td><td rowspan="3"></td><td rowspan="3" colspan="2">Should be included</td></tr>
<tr><td>Likely</td></tr>
<tr><td>Possible</td></tr>
<tr><td>Unlikely</td><td rowspan="2" colspan="3">May be excluded</td></tr>
<tr><td>Very unlinkely</td></tr>
</table>

Source: Adapted from WRI/WBCSD 2014

The identified impacts resulting from the DES project should be considered for the system boundary and for the MRV framework. Defining the system boundary and possible approaches for the GHG emission reduction evaluation and the SD benefit impacts are described in the following sections.

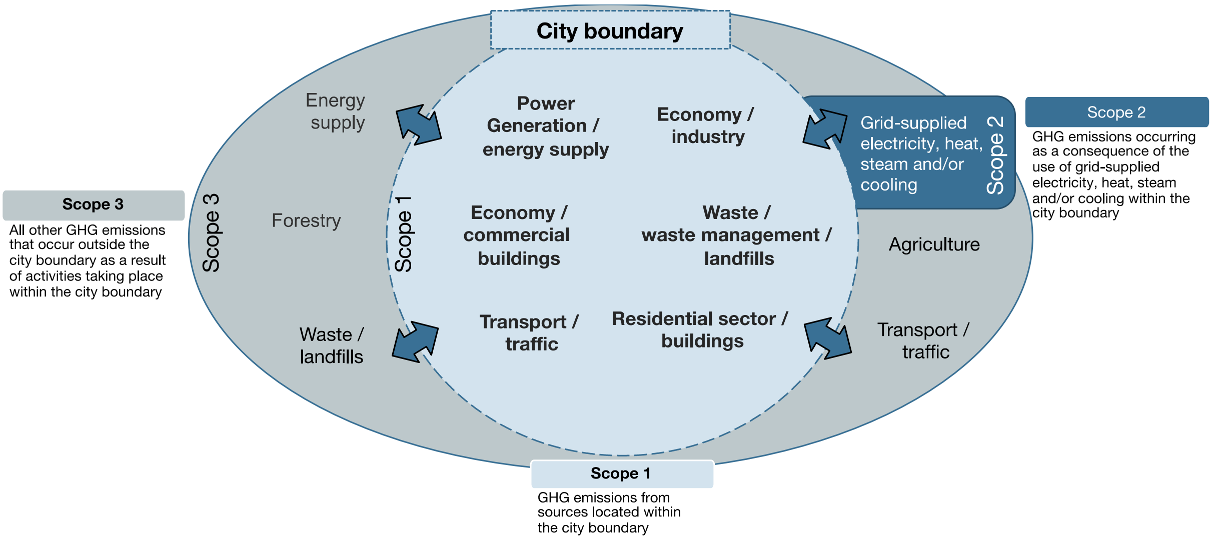
For identifying the potential effects and impacts of your project, consider and map the causal chain of your activities. Evaluate the expected impacts with regards to their probability and relative size.

Assessment boundaries of district energy systems

The assessment and system boundary shall encompass the DES project measures and intervention covering the primary and significant effects related to the energy supplied and delivered. This will include the significant anthropogenic GHG emissions by sources under the control of the project and sustainable development benefits that are reasonably attributable to the DES intervention[13]. It is recommended to follow the definitions for cities' inventories defined by the *Greenhouse Gas Protocol* under its *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories - An Accounting and Reporting Standard for Cities* (GHG Protocoll, 2014). According to the protocol, energy activities taking place within a city can generate GHG emissions that occur inside the city boundary as well as outside the city boundary. Hence, emissions are distinguished into three categories based on where they occur: scope 1, scope 2 or scope 3 emissions.

[13] Adapted from UNFCCC CDM Glossary of Terms (http://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20150226124446845/glos_CDM.pdf)

Figure 11: Scopes definitions for city inventories



Source: Own illustration using GHG Protocol, 2014a, p. 32

The scopes for GHG emission differentiate between emissions occurring physically within the city boundary (scope 1), from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries (scope 2) and from those occurring outside the city (scope 3). See *Figure 11*. DES project activities should (at least) consider scope 1 and 2, when determining emissions and emission reductions from their intervention. Hence, the physical delineation of the project boundary for DES activities includes:

- Project activities in which a power plant supplies thermal energy (heat/cooling energy) to the district energy network, the site of the power plant, including the heat/cooling extraction unit(s) and all interrelated production units to account for emissions resulting from changes in power generation and consumption due to the project activity;
- All thermal sources directly serving the chilled/hot water system(s): The heat-only boilers / chillers that supply heat / cooling energy to the district energy system;
- The district energy system, including all equipment such as pipes, sub-stations, pumps and buildings that are or will be connected to the district energy system.
- The electricity system to which the DES is connected (in case of power generation and / or electricity demand from the grid)

Emission can refer to different stages of the life cycle of a product or service. Total emissions from energy systems (e.g. DES) and buildings begin with the "before-use phase" including the extraction of raw materials, transport, manufacturing of products and equipment as well as construction. The "use phase" includes emission from the operations, maintenance and retrofits etc. Finally, the "after-use phase"includes emission related to the demolition, transport, re-use and recycling of material components or energy content and waste processing (final disposal). In general, data for stage I and III are in many cases difficult to gain and lacking. Hence, the full life-cycle assessment is generally difficult to quantify. The majority of emissions stem from the operation phase, e.g. for buildings over 80%-90% of GHG emissions are emitted during this stage, for most conventional energy systems even more. These emissions are measurable, reportable, and verifiable. The consideration of emissions related to the other stages can lead to double counting with other sectors such as industry, forestry, agriculture, and transport (UNEP, 2010). Hence, only the operation phase is included in the MRV approach presented in this guidance for the DES MRV Framework. This is in line with the Common Carbon Metric developed by UNEP's Sustainable Buildings & Climate Initiative (UNEP SBCI, 2010) and UNFCCC's CDM methodologies.

Identify GHG emissions that occur inside the city boundary as well as outside the city boundary: Consider scope 1 and 2 when determine emissions and emission reduction and SD benefits from your DES intervention.

Determine the baseline and project scenarios

The step shall help to get the necessary understanding to define the project / city specific baseline scenario and baseline. The baseline scenario is a reference case and a hypothetical description of what would have most likely occurred in the absence of the DES project. It should describe the reasonable scenario with regards to anthropogenic emissions as well as sustainable development that would take place without the proposed project activity. The baseline scenario is used to estimate baseline emissions and baseline SDG development. There are three generic possibilities for the baseline scenario:

- implementation of the same technologies or practices used in the project activity;
- implementation of an alternative technology or practices; or
- the continuation of current activities, technologies, or practices that, where relevant, provide the same type, quality, and quantity of product or service as the project activity.

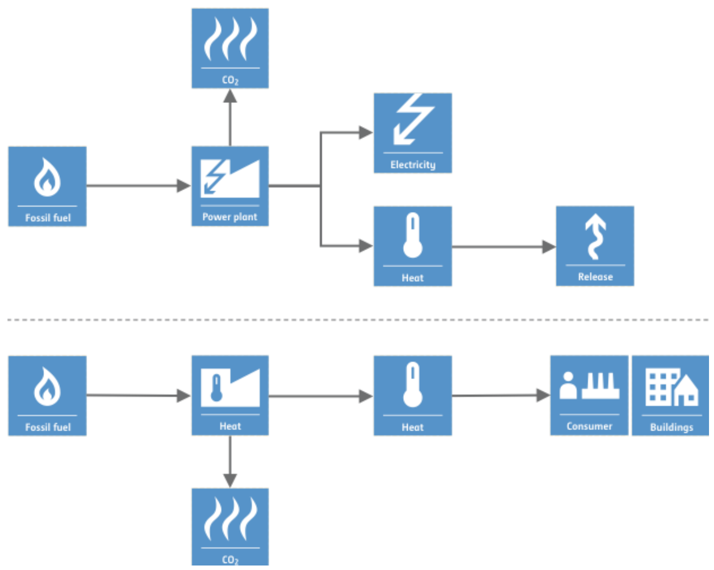
For each DES project in each city, the baseline and project scenario should be determined. This means if, for instance, the current, prevailing situation would continue or another energy supply technology would be used to provide heat and power. The typical DES project intervention is the introduction of a new district heating / cooling system or the energy provision through tri-generation. This accounts for the related anthropogenic emissions by GHG sources and the associated sustainable development that occurs due to the intervention. In the absence of the project the current situation would further exist (business-as-usual scenario) or the energy system would develop differently (alternative baseline scenario). In many cases isolated or individual energy system (IES), such as individual heating unit and boilers or air-conditioning systems, would exist in the baseline scenario.

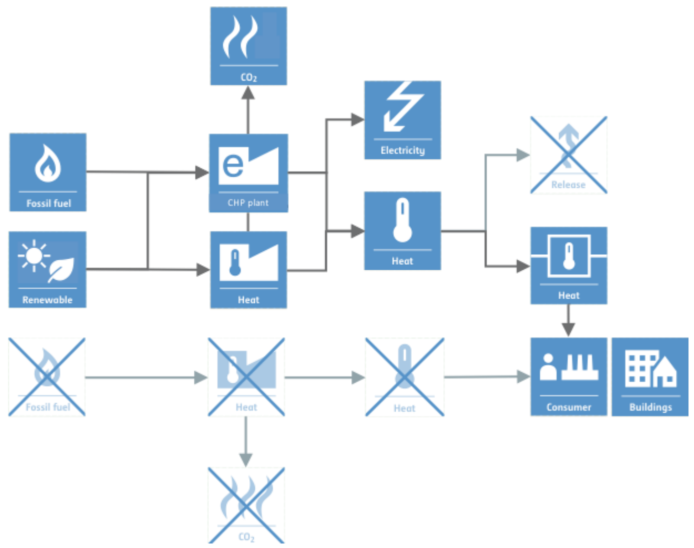
IES are heat / cooling equipment, which provides heat or cooling energy to individual or several users but are not connected to a district heating / cooling system (i.e. a single boiler or chiller in a house). Typically, various IES existed before the start of the DES project activity providing heat / cooling energy to different users.[14] For the individual DES project, it is recommended to identify and map the baseline situation and the project scenario. *Figure 12* below is an exemplary illustration of how the project boundary is defined for a new district energy system.

Figure 12: General baseline and project scenario for DES projects (heating)

<table>
<tr><td>Baseline situation

Fossil fuel is used in a power plant that only supplies grid electricity where the excess heat is lost (released); and

fossil fuel is used in individual boilers that supply heat to users.</td><td>
</td></tr>
<tr><td>Project scenario

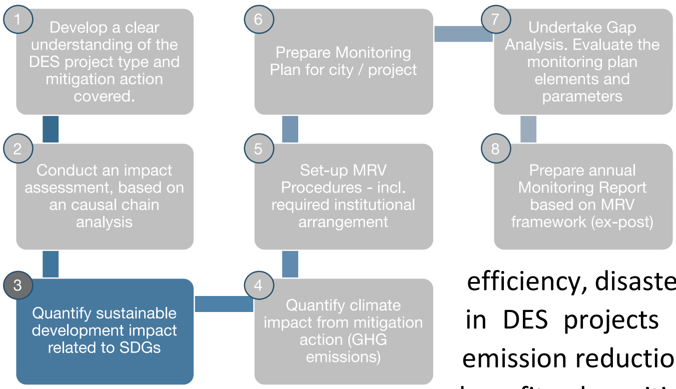
A new district energy network is supplied by heat energy provided by a power plant and/or centralized boilers.</td><td>
</td></tr>
</table>

Source: Adapted from CDM AM0058

[14] Users are heat / coolant consumers, e.g. in residential or commercial buildings. Existing users are users which received energy from an isolated energy system (IES) prior to the implementation of the DES project, or replace such a user (such in the case of house demolition and new construction). New users did not, and would have had, for example, a household level heating, or are in newly established residential areas.

For the quantification of both GHG effects and SD benefits the common baseline scenario and project scenario within the assessment boundary is used and shall be considered in Step 3 and 4.

For the individual DES project, map the baseline situation and the project scenario.



Step 3: How to quantify the sustainable development impact

GHG mitigation projects and countries' NDCs have a strong synergistic connection with the Sustainable Development Goals (SDG), mainly to energy, agriculture, water, resilience, resource efficiency, disaster risk reduction and infrastructure. Many cities invest in DES projects more for these benefits and less because of the emission reduction. So, GHG emission reduction may be the actual co-benefit, when cities adopt district energy systems to achieve important benefits such as affordable energy provision, reduced reliance on energy imports and fossil fuels, community economic development and community control of energy supply, local air quality improvements and an increased share of renewables in the energy mix. The MRV framework shall help monitor the impact of the DES interventions on selected, relevant Sustainable Development (SD) indicators. Modern DES projects in particular, if renewable energies are used, support a more sustainable energy system for providing heat and cooling energy and hence pave the way towards a more sustainable city.

SD co-benefits are benefits generated by DES projects that go beyond GHG mitigation. SD co-benefits are grouped in three main categories: ***socio-economic, environmental and technological***. Strong SD co-benefits will increase local and country ownership, increasing political feasibility and provide support to the implementation of low-carbon measures. Co-benefits are also an incentive for the general public to support, accept and participate in DES projects. A clear contribution to the achievement of SD co-benefits would help strengthening any DES project aiming at securing finance as donors are interested in supporting projects that contribute significantly to sustainable development. Beneficiaries of the co-benefits by DES projects will be primarily the citizens of cities and the end-consumer (incl. businesses and industries) as well as the energy sector (e.g. the utility). For instance, improvement of air quality through reduced emissions from fossil fuels will deliver benefits for the overall urban population. Also access to modern and reliable energy supply will be provided by DES projects.

When identifying co-benefits of DES projects, such as more reliable energy, cleaner air or affordable energy, the UN Sustainable Development Goals (SDGs) and related indicator should be considered for the MRV. The SDGs are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity. The 17 SDGs build on the Millennium Development Goals, while addressing new areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice. The following table summarises the connection between DES activities / sectors and relevant SDGs. SDGs is comprised of many areas of action, whose impacts are often covered by national statistics, e.g. on poverty, health or education. Since some SDGs relate directly to climate action, having an MRV system in place for climate reporting may simultaneously assist a country in tracking its climate-related SDGs, by providing data and information that allow the monitoring of the specific SDG. Particularly if a tracking system for SDGs is not or only partially in place, an MRV system can complement the existing structures (GIZ, 2018).

Table 8: Linkages between DES sectors and SDGs

Sector relevant for DES projects	Most linkages with SDG					
Energy supply	3 GOOD HEALTH AND WELL-BEING	7 AFFORDABLE AND CLEAN ENERGY	8 DECENT WORK AND ECONOMIC GROWTH	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	11 SUSTAINABLE CITIES AND COMMUNITIES	13 CLIMATE ACTION
Building sector			8 DECENT WORK AND ECONOMIC GROWTH	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	11 SUSTAINABLE CITIES AND COMMUNITIES	13 CLIMATE ACTION

Source: Adapted from von Tilburg et al., 2018

In order to keeping track of the SDG impacts of the DES projects, appropriate MRV and indicators are required. SDG co-benefits monitoring will require sufficient capacity and resources for its implementation. In order to avoid creating an additional burden for key stakeholders of the DES MRV framework, e.g. operators and cities, it is suggested to select indicators that currently exist and that are already used at the local and national level. These should be prioritized taking into account the most important impacts from DES project considering the local circumstances and priorities. This should also consider the actual capabilities, difficulties and associated costs, which means finding a balance between a feasible MRV system for co-benefits while limiting its efforts.

Identify the socio-economic, environmental and technological SD benefits resulting from the DES activities. Consider the impact assessment, the project boundary and the baseline scenario as elaborated under Step 2 for your assessment.

Key indicators for sustainable development benefits

Using the list of sustainable development indicators provided in *Table 9* and Annex 1, DES projects and cities can select and assess the indicators, which best support the DES impact assessment (refer to Step 2) and fit to local / national circumstances. Key considerations, when selecting sustainable development indicators, are (adapted from CCAP, 2012):

- Is the indicator or set of indicators aligned with local and national sustainable development priorities?
- Will tracking the indicator or set of indicators help build local, domestic or international political and/or financial support?
- Are the data already collected or can they be collected at reasonable efforts and costs?
- Can the data be collected with reasonable assurance of accuracy?
- Will the indicator or set of indicators facilitate aggregation across policies and/or comparisons within or across sectors?
- Does the indicator or set of indicators align with development interests of prospective contributing countries or institutions?
- Seek sex-disaggregated data for all indicators that concern people

The selection of indicators should be flexible to select indicators that are most appropriate to the specific circumstances, including the financial resources, capacity and data that are available or can realistically be made available. *Table 9* presents possible SD co-benefits that DES projects can deliver including potential indicators to track achievement of objectives and suggestions on were sex-disaggregated data could be collected . It also specifies the contribution to the related SDGs. The selection of the SD indicators should be based on SDGs for environment, social, growth and development, economic and institutional and consider the local circumstances and priorities.

Table 9: SD benefits of DES projects and SDGs indicators

SDG / Category	SDG target	DES Impact	Indicator
		Environment	
11 SUSTAINABLE CITIES AND COMMUNITIES	11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	• Reduced CO_2 and harmful exhaust emissions (Particulate matter, CO, SO_x, NO_x) • Increased visibility due to lower pollution • Improved livelihoods /urban quality of life	• Mean urban air pollution of particulate matter (PM10 and PM2.5) • Mean concentration of CO, SO_x, NO_x in cities • Share of households and commercial users connected to DES
		Socio-Economic	
3 GOOD HEALTH AND WELL-BEING	3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	• Reduced household and ambient air pollution • Improved livelihoods /urban quality of life	• Mean urban air pollution of particulate matter (PM10 and PM2.5) • Mean concentration of CO, SO_x, NO_x in cities • Number of premature mortality and morbidity cases attributed to indoor

SDG / Category	SDG target	DES Impact	Indicator
			air pollution (sex-disaggregated data should be collected for this indicator)
7 AFFORDABLE AND CLEAN ENERGY	7.1: By 2030 ensure universal access to affordable, reliable, and modern energy services 7.2: Increase substantially the share of renewable energy in the global energy mix by 2030 7.3: Double the global rate of improvement in energy efficiency by 2030	• Reduction of fossil fuel consumption (imports) • Increased proportion of population with access to reliable electricity • Peak load management: district cooling has potential to reduce peak load electricity demand from air conditioning and chillers. • Increased proportion of population with primary reliance on clean fuels and technology • If renewables are applied, increased renewable energy share in the total final energy consumption • Decreased Energy intensity measured in terms of primary energy (and GDP)	• Proportion of population with access to reliable electricity (sex-disaggregated data should be collected for this indicator) • Number and time of outages per year, time of overload due to peak demand • Reduced investment required in peak load generating capacity • Proportion of population with primary reliance on clean fuels and technology (sex-disaggregated data should be collected for this indicator) • Renewable energy share in the total final energy consumption • Primary energy by type • Energy intensity measured in terms of primary energy and GDP
8 DECENT WORK AND ECONOMIC GROWTH	8.2: Achieve higher levels of productivity of economies through diversification, technological upgrading and innovation, including through a focus on high value added and labour-intensive sectors 8.3: Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage formalization and growth of micro-, small- and	• Increase job and employment opportunities in DES, including for women. • Increase access to affordable and efficient energy for industries and businesses • Enhances productivity for industries and businesses	• Annual growth rate of real GDP per employed person • Unemployment rate or number of employments by DES (sex-disaggregated data should be collected for this indicator) • Energy intensity measured in terms of

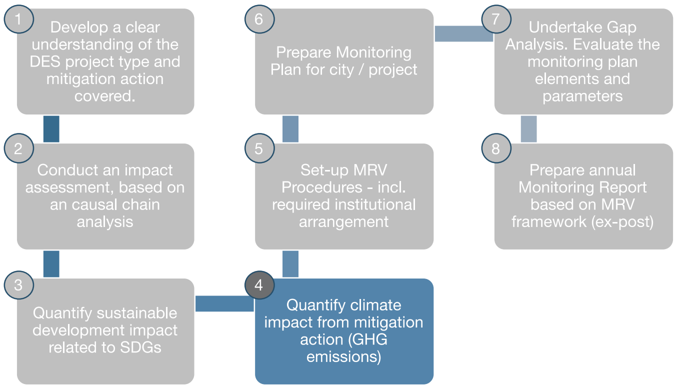
SDG / Category	SDG target	DES Impact	Indicator
	medium-sized enterprises including through access to financial services 8.4: Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation		primary energy and GDP
13 CLIMATE ACTION	13.2: Integrate climate change measures into national policies, strategies and planning	• DES Project can be an important part of an integrated policy/strategy/plan which increases the ability to adapt to the adverse impacts of climate change, and foster climate resilience and lower greenhouse gas emissions	• DES project and activities are integrated in national strategies and plans (including a national adaptation plan, nationally determined contribution (NDC), national communication (NC), biennial update report (BUR) or in future biennial transparency reports (BTR) and national inventory reports (NIR))
Technological			
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all 9.4: By 2030 upgrade infrastructure and retrofit industries to make them sustainable, with increased resource use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, all countries taking action in accordance with their respective capabilities	• Incentivize research, development and access to market for technologies • Use of access gases / heat from industries (waste-heat-recovery) • Private sector incorporated with new business opportunities • New employment opportunities , including for women. • New skills acquired	• Share of households and commercial users connected to DES • Proportion of population with access to reliable electricity (sex-disaggregated data should be collected for this indicator) • Use of industrial waste heat for DES • Total energy and industry-related GHG emissions by gas and sector, expressed as production and demand-based emissions (tCO_2e) / CO_2 emission per unit of value added

Source: Derived from UN DESA, 2018 and Sustainable Development Solutions Network, 2015

Detailed tables per indicator for SD benefits that can be achieved due to DES projects are provided in Annex 1 including procedures for continuously monitoring and reporting. The indications need to be selected and amended to the individual DES projects depending on the local circumstances and priorities. For several projects in one city or region, the project proponent should ensure that no double counting occurs, e.g. indicators such as the proportion of population with access to reliable electricity can be clearly dedicated to the individual activity.

Select appropriate indicators for the identified and relevant the socio-economic, environmental and technological SD benefits resulting from the DES activities.
Try to locate corresponding other sources for the indicators, e.g. aggregated data, if these cannot be measured directly.

Step 4: How to quantify the climate impact

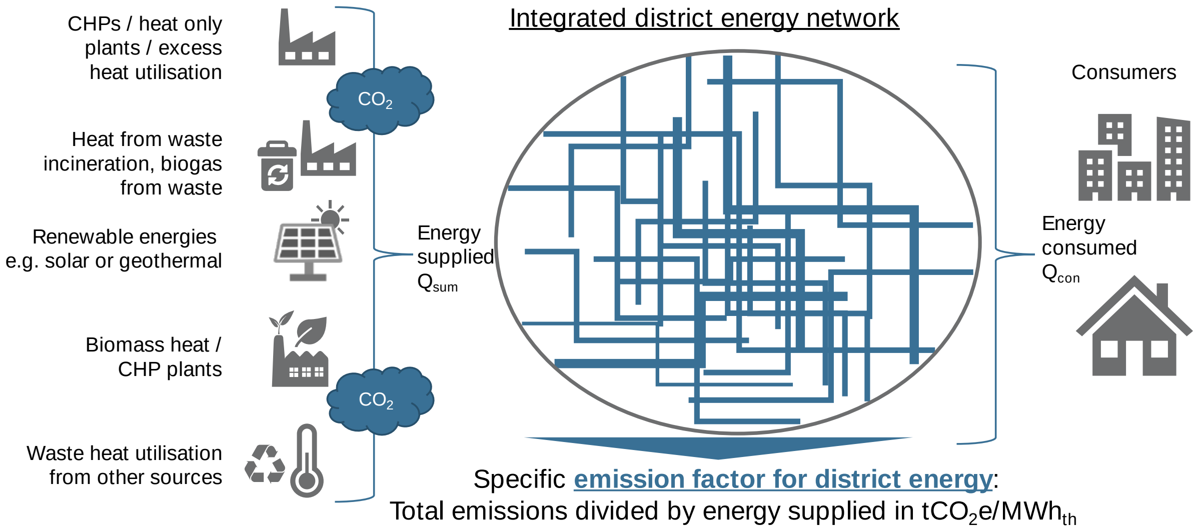


Individual DES projects implemented in cities can be single projects, programmes or city-wide system activities. Hence, it is recommended to use and following corresponding suitable methodologies, e.g. the GHG Protocol for Project Accounting or the Clean Development Mechanism. However, to make the MRV framework practicable the methodologies should be adapted and simplified when possible while ensuring environmental integrity. Furthermore, specific aspects for cities should be considered, e.g. as presented in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories prepared by the GHG Protocol (GHG Protocol, 2014a). Hence, the proposed emission reduction calculation approach is based on these available and appropriate methodologies and standards for the DES project. An overview of these standards is provided in Annex 2, 3 and 4, respectively.

In general, the quantification of the climate impact in terms of reduction of tonnes CO_2 equivalent (tCO_2e) is based on a comparison between the baseline situation and the situation after the DES project implementation representing the mitigation scenario (see *Figure 12*). Hence, the related emissions for both situations need to be determined. The difference between both is the potential emission reduction resulting from the project.

Depending on the baseline situation and the project scenario mapped in Step 2, the emissions of the baseline and the project situation can be determined. *Figure 13* illustrates exemplary the principal approach of determining the emissions from a new district energy system.

Figure 13: Principal approach of determining emissions for DES projects (heating)



Source: Own illustration

The most relevant monitoring parameters to determine the amount of GHG emission and potential emission reduction relate to the ***quantity of heat and cooling energy delivered*** and the used ***fuel type for its generation*** as well as the ***amount of electricity supplied by the grid and/or captive power sources*** in the baseline and DES project scenario. In order to estimate the baseline emissions an analysis of the ***replaced baseline technologies*** is required (e.g. gas / fuel oil boiler, chillers etc.).

Textbox 4: Allocation of GHG Emissions CHP plants

For the determination of an emission factor for district energy (heat or cooling) it may be necessary depending on the district energy system, to assign the total emissions to the different generated energy streams, e.g. steam and electricity. There are several approached, but most common methods to allocate emissions from a CHP plant are:

- Efficiency method: GHG emissions are allocated based on the energy inputs used to produce separate steam and electricity products. Assumes that conversion of fuel energy to steam energy is more efficient than converting fuel to electricity. Actual efficiencies of heat and of power production will not be fully characterized necessitating the use of assumed values
- Energy content method: Allocates GHG emissions according to the useful energy contained in each CHP output stream. Need information regarding the intended use of the heat energy. Best suited where heat can be characterized as useful energy, e.g., for process or district heating. May not be appropriate where heat is used for mechanical work, because it may overstate the amount of useful energy in the heat resulting in a low emission factor associated with the heat stream.
- Work potential method: Allocates emissions based on the useful energy represented by electric power and heat, and defines useful energy on the ability of heat to perform work. Appropriate where heat is to be used for producing mechanical work (where much of the heat energy will not be characterized as useful energy). It may not be appropriate for systems that sell hot water because hot water cannot be used, as steam can, to perform mechanical work.

The efficiency method is the recommended method as it is practically applicable in most cases for district energy projects. The efficiency method ("eta") sets the individual efficiencies for electricity and heat in relation to the sum of both efficiencies. The total emissions are divided according to the two quotients:

$$Share_{el} = \frac{eta_{th}}{(eta_{th} + eta_{el})} \qquad \text{Equation (1)}$$

For an approximation efficiency values for power and heat generation provided in Annex 5 can be used. Please refer to calculation examples in Annex 2.

Source: GHG Protocol, 2006 and Energy Efficiency Council

This approach allows the specification of an ***emission factor for district energy*** under the baseline and the project situation. Besides the estimation of emission reductions, the emission factor expressed in tCO_2e/MWh or tCO_2e/GJ (heat or cooling energy) provides further opportunities and advantages. It allows the continuous tracking of emissions by all plants and energy sources (primary energy / fuel type / emissions) providing energy to the district energy system. Hence, it would support the local and city-wide energy and emission inventory. Furthermore, when regularly reported the emission level and emission factor for district energy could be used as decision making criteria, when comparing alternative energy sources and systems. As a result, such standardised calculations will help policy makers. However, also the energy industry and utilities would also be informed and enabled to move forward when negotiating with building owners or convincing decision makers etc.. It will help determine the energy and climate impact of urban developments or new buildings and facilitate the choice of the best energy supply. Finally, the use of a DES emission factor allows an ex-ante estimation of mitigation action impacts, in particular from energy efficiency measures as well as demand changes. It could be used to determined energy and CO_2 emissions on household level based on the gross floor area following the whole-house approach.

Textbox 5: Normalisation of annual energy data

The energy consumption for heat and cooling energy varies with the outside temperature that drive the demand for heating or cooling needs. Hence, when historical energy demand data are used these data should be normalised for any projection they should be used for.

This normalisation with the help of Heating Degree Days (HDD)[15] and Cooling Degree Days (CDD)[16]: is important for planning of energy systems and even individual heating / cooling devices. DD can be relevant for an ex-ante estimation when determining a (standardized) baseline (e.g. for the emission factor of DES or energy efficiency levels in buildings), in particular if historical data are only available for one or a few years. They are also used to explain peaks and drops on energy consumption in energy balances and the National Communication under the UNFCCC. However, in emission inventories the absolute and real emissions are reported. Also, for an ex-post MRV of GHG emissions real, measurable emissions and emission reduction are relevant.

HDDs and CDDs are defined relative to a base temperature — the outside temperature — below or above which a building is assumed to need heating or cooling. In other words, degree days are the deviation (positive or negative) of the mean monthly temperature T_m from a baseline temperature T_b, below (or above) which heating (or cooling) is needed to sustain the indoor temperature to a comfortable level (Tsikaloudaki et al., 2012).

15 Heating degree days (HDD) are a measure of how much (in degrees), and for how long (in days), the outside air temperature was below a certain level. They are commonly used in calculations relating to the energy consumption required to heat buildings.

16 Cooling degree days (CDD) are a measure of how much (in degrees), and for how long (in days), the outside air temperature was above a certain level. They are commonly used in calculations relating to the energy consumption required to cool buildings.

$$HDD\ (or\ CDD) = \sum_{i=1}^{12} |T_m - T_b|$$

Hence, the degree days can be used to determine the deviation from the historical trend and "normalise" individual annual / monthly figures.

Source: EEA (2019), degreedays.net, CDM ACM0091, Tsikaloudaki et al., 2012

For the determination of the emissions and emission factor the relevant energy and corresponding emission sources need to be specified. The GHGs to be considered per technology are shown in *Table 10* depending on the project type and baseline and project scenario.

Table 10: Emission sources included in the DES project boundary

Source			GHG	Explanation
District heating	Baseline	Fossil fuel consumption for electricity production	CO_2	Major emission source
		Fossil fuel consumption in boilers for heat supply	CO_2	Major emission source
		Electricity consumption for electric heater generated from fossil fuels	CO_2	Major emission source
	Project activity	Fossil fuel consumption for generation of heat and electricity	CO_2	Major emission source
		Fossil fuel consumption in heat-only boilers that supply heat to the district heating system	CO_2	Major emission source
District cooling	Baseline	Electricity and/or thermal energy consumed by baseline cooling technologies	CO_2	Major emission source
		Leakage / discharge of refrigerant	CO_2e	Major emission source
	Project activity	Electricity and/or thermal energy consumed by the district cooling system	CO_2	Major emission source
		Leakage / discharge of refrigerant	CO_2e	Major emission source
Trigeneration	Baseline	Fossil fuel consumption for electricity production	CO_2	Major emission source
		Fossil fuels consumption for steam production in the existing on-site boilers	CO_2	Major emission source
		Leakage / discharge of refrigerant	CO_2e	Major emission source
	Project activity	Fossil fuels consumption for electricity, steam and chilled water production in the trigeneration system	CO_2	Major emission source
		Leakage / discharge of refrigerant	CO_2e	Major emission source

Source: Adapted from CDM AM0058, AM0076 and AM0117

Trace the energy sources used under in the baseline and the project. Consider the relevant GHG emission.

Calculations procedures for the estimation of GHG emission reductions

The GHG emissions reduction achieved by the DES projects will be determined as the difference between the *baseline emissions* and the *DES emission after the project implementation*. General, the emissions reduction is calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad \text{Equation (2)}$$

Where:

ER_y	=	Emission reductions in year y (tCO_2)
BE_y	=	Baseline emissions in year y (tCO_2)
PE_y	=	Project emissions in year y (tCO_2)
LE_y	=	Leakage emissions in year y (tCO_2)

In the following, the general calculation approaches are described for determining the baseline, project and leakage emissions. Detailed procedures and corresponding formulae are provided in Annex 2, 3 and 4.

Baseline emissions (BE) from heat generation are estimated by multiplying the quantity of heat supplied (**Q_y**) by the CO_2 emission factor for heat generation. To determine the CO_2 emission factors, a benchmarking calculation based on available utility data, statistics, or census / surveys information of the existing energy supply (IESs or DES) shall be conducted. The baseline for existing installations shall be calculated based on their weighted average energy demand in the past. If there are no existing installations in the baseline the energy demand shall be calculated based on a benchmark approach taking into account similar IESs in the project / benchmark boundary (e.g. in the city). The **project emissions (*PE_y*)** comprise CO_2 emissions from fossil fuel combustion associated with the production of heat and electricity in the DES energy plants, e.g. co-generation plant; and CO_2 emissions from fossil fuel combustion in all other sources, e.g. heat-only boilers. In cases where the project will result in a decrease in electricity supply to the grid, e.g. due to heat extraction from a power plant, leakage needs to be considered. As a consequence of the project activity, the heat extraction may result in an increase in the electricity supply from other power plants connected to the grid and their related emissions.

The **baseline emissions related to district cooling** are estimated using a benchmark approach in the same way as for district heating. However, the approach depends on the technology used by the benchmark installation in the baseline, i.e. if the benchmark installation is using electricity driven technology or absorption technology. Quantity of energy **$Q_{B,y}$** consumed in the baseline by baseline cooling technologies in year *y* (MWh/a) is multiplied by the emission factor for electricity generation (tCO_2/MWh) or the CO_2 emission factor of used in the baseline absorption technology (tCO_2e/GJ). **Project emissions from district cooling** include emissions from energy consumption associated with the generation of cooling output in the new district cooling plant(s). In addition, emissions due to the leakage of refrigerants during from the project need to be taken into consideration. Changing the refrigerant can also reduce emissions.

To **determine the baseline emissions related to trigeneration,** the calculations depend on (a) the source of electricity; and (b) the technology that would have been used to produce heating and/or cooling, in the absence of the project activity. **Project emissions** account for emissions as a result of the production of electricity, heat and cooling due to the combustion of fossil fuels in the trigeneration system as well as the potential discharge of refrigerant. The project emissions from fossil fuel combustion by the DES project are calculated equivalent to the project emission for district heating / cooling systems.

Emission factor and benchmark

The benchmark boundary for determining the DES emission factor is the whole city or the city area, where the project is implemented. In addition to the heating / cooling installation that will be replaced by the project activity, the benchmark boundary shall cover the baseline heating / cooling installations that would continue providing heating / cooling after the project implementation.

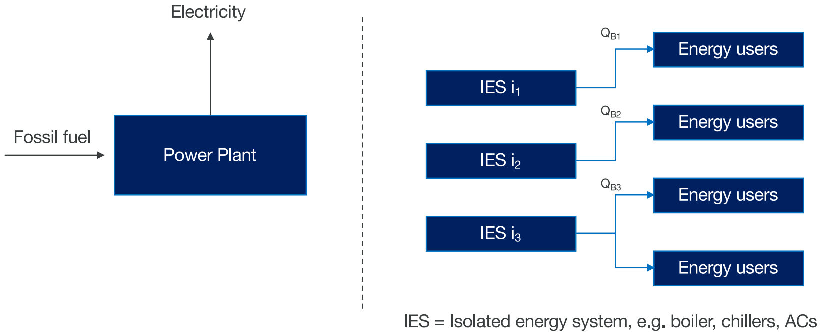
The heat / cooling output of the installations that would continue providing heat / cooling after the project implementation shall be at least equal to the output of the project activity. If the demand for energy is reduced due to refurbishments and retrofitting of buildings, an overall balance of the energy demand for the buildings is recommended (measured in kWh/m^2/a). In case the DES project is to supply energy to a greenfield settlement, where no existing installation could be identified, the expansion of the benchmark boundary is deemed necessary. New buildings shall be included in the benchmark determination, assuming the best available technology (BAT) is used in terms of efficiency and emission (considering economic viability) in a country. The following figure illustrates the points to measure energy supplied within a DES (Q_B, Q_e *and* Q_n) and where they should be located.

Figure 14 illustrates an example of a project that introduces a new CHP plant and replaces individual heating systems such as boilers in households. The figure compares the baseline situation and the project case. In the baseline scenario, fossil fuel is used in a power plant that only supplies grid electricity, and fossil fuel / electricity is used in individual boilers, chillers or ACs that supply heat and cooling energy to users. Under the project situation, this is combined to an integrated system.

Figure 14: General DES baseline and project scenario

Baseline situation

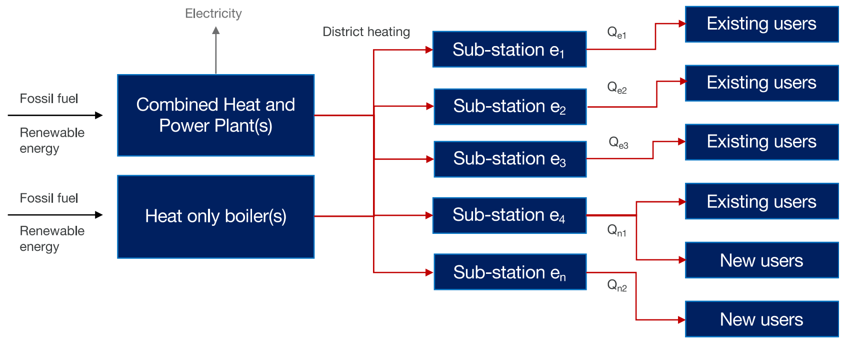
Fossil fuel is used in a power plant that only supplies grid electricity; fossil fuel / electricity is used in individual boilers, chillers or ACs that supply heat and/or cooling energy to users.



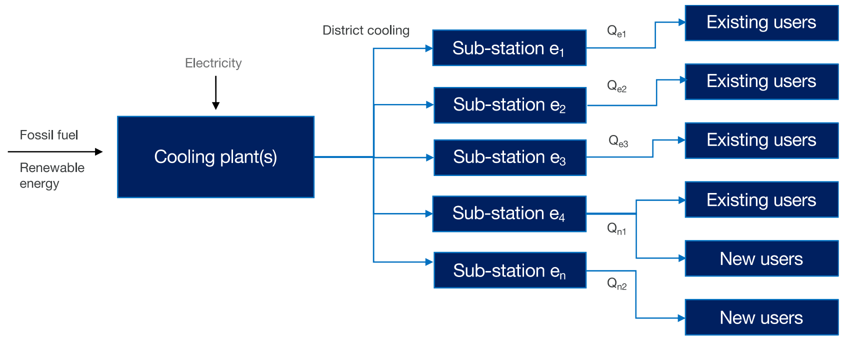
Project scenario

A new district energy network is supplied by heat / cooling energy provided by a power / cooling plant and/or centralized boilers. Less-efficient technologies are no longer in use.

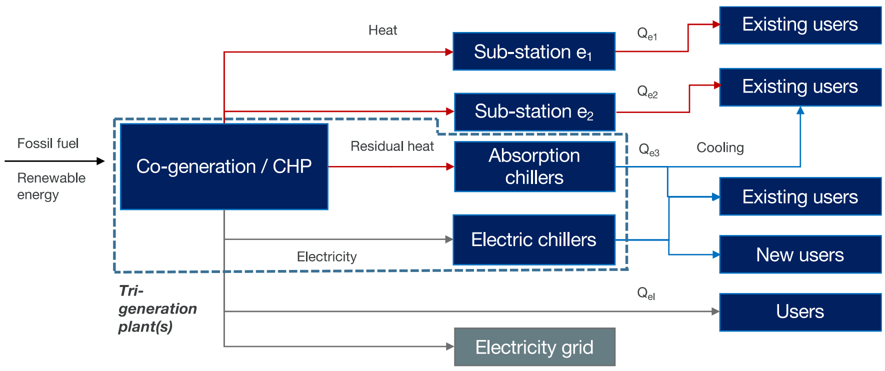
Heating



Cooling



Trigeneration



Source: Adapted from CDM AM0058, AM0076 and AM0117

Annexes 2, 3 and 4 provide detailed procedures distinguished between the three technologies ***district heating, district cooling and trigeneration***, including formulae and parameter specifications.

Calculate the baseline, project and leakage emissions for your project based on the energy consumed in the baseline situation and the project scenario. Follow the detailed procedures provided by this guideline and referenced standards related to the technology.

Key indicators and parameters to monitor climate impact

The following table summarises key indicators to be monitored according to the methodological procedures presented in the previous section. Not all indicators may be applicable to all district heating projects, for example, heat-only projects do not involve electricity generation. Hence, depending on the project type and scope as well as the measuring method, the indicators apply. Detailed description and monitoring procedures are provided in the respective Annexes 2, 3 and 4.

Table 11: Key monitoring parameters for DES projects

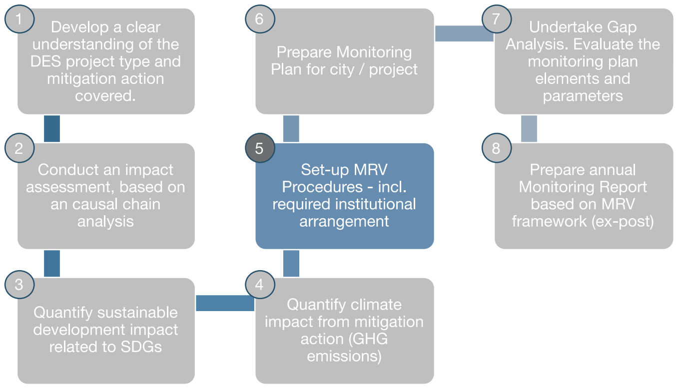
	Data to monitor	Type of monitoring
District heating	Q_y in GJ/a or MWh/a Quantity of heat supplied by DES project	Continuously during project lifetime (ex-post)
	$EF_{BL,HG,e}$ / $EF_{BL,HG,n}$ in tCO_2/MWh or GJ CO_2 emission factor for heat generation in the baseline	Determined once ex-ante
	$EG_{PJ,y}$ in MWh/a Monitored, actual quantity of electricity supplied to the grid	Continuously during project lifetime (ex-post); if electricity generation is involved in the project
	$EF_{BL,EL}$/ $EF_{EF,j,y}$ in tCO_2/MWh Baseline emission factor for the electricity generation	Grid emission factor (annually ex-post) or determined for replaced captive power plant (ex-ante); if electricity generation is involved in the project
	$FC_{i,j,y}$ (Q_{prim}) GJ/a or MWh/a Primary energy fuel consumption	Direct and continuous metering of fuel consumption during project lifetime (ex-post)
District cooling	$Q_{B,y}$ in GJ/a or MWh/a Quantity of energy consumed that would be consumed by the baseline electricity consumer	Calculated using $C_{P,r,y}$
	$C_{P,r,y}$ in MWh/a Cooling output of new district cooling plant	Continuously during project lifetime (ex-post). Direct and continuous metering onsite
	$F_{r,y}$ in g/hour Average flow rate (integrated over the year) of new district cooling plant	If $C_{P,r,y}$ is calculated, continuous metering onsite
	$\Delta T_{r,y}$ in °C Temperature difference between supply and return of chilled water from/to new district cooling plant	If $C_{P,r,y}$ is calculated, continuous metering onsite

Data to monitor		Type of monitoring
	$EF_{BL,EL}$/ $EF_{EF,j,y}$ in tCO_2/MWh Baseline emission factor for the electricity generation	Grid emission factor (annually ex-post) or determined for replaced captive power plant (ex-ante)
	$EC_{PJ,j,y}$ GJ/a or MWh/a Quantity of electricity consumed by the project	Direct and continuous metering onsite. Continuously during project lifetime (ex-post)
	$TDL_{j,y}$ in % Transmission & distribution loss	Data from utility or an official government body (ex-post)
	$R_{k,y}$ in tonnes Quantity of refrigerant filled in the district cooling system	Continuously during project lifetime (ex-post)
Tri-generation	Q_y in GJ/a or MWh/a Quantity of heat supplied by DES project	Continuously during project lifetime (ex-post)
	$EG_{PJ,y}$in MWh/a Monitored actual quantity of electricity supplied to the grid / replacing captive power plant(s)	Continuously during project lifetime (ex-post)
	$EF_{BL,EL}$/ $EF_{EF,j,y}$ in tCO_2/MWh Baseline emission factor for the electricity generation	Grid emission factor (annually ex-post) or determined for replaced captive power plant (ex-ante)
	$FC_{i,j,y}$ in GJ/a or MWh/a Fuel consumption tri-generation plant	Direct and continuous metering of fuel consumption, Continuously during project lifetime (ex-post)
	$C_{P,r,y}$ in MWh/a Cooling output of trigeneration plant	Direct and continuous metering onsite. Continuously during project lifetime (ex-post)
	$R_{k,y}$ in tonnes Quantity of refrigerant filled in the district cooling system	Continuously during project lifetime (ex-post)

The procedures for determining the parameters should be described in a detailed Monitoring / MRV Plan for each project, which will facilitate the process of monitoring and recording of information (see Step 5 and 6). This should include details for assumptions/default values used and sources of the values, the sources of monitored parameters, the frequency of monitoring and reporting of monitored parameters, a description of data storage plan, responsibilities of different actors in regards to monitoring and reporting, the methodologies to be applied to calculate mitigation benefits and the accuracy level to be applied. The tables in Annexes 2, 3 and 4 are providing recommendations on the procedures for each parameter related to district heating, district cooling and tri-generation.

Identify the relevant parameters for your project and compiled them together with corresponding procedures in a detailed monitoring plan, divided by ex-post measures parameters and those to be determined ex-ante.

Step 5: Setting up MRV procedures



It is recommended to develop an individual MRV or Monitoring Plan for each DES project (see Step 6). The MRV Plan covers the parameters to be monitored based on the methodology followed to determine the emission reduction (see the section above) and shall include corresponding indicators for the sustainable development benefits. In addition, it should define the institutional set-up, responsibilities and data recording, reporting and verification procedures as generically presented below. For the MRV procedure these important questions need to be answered:

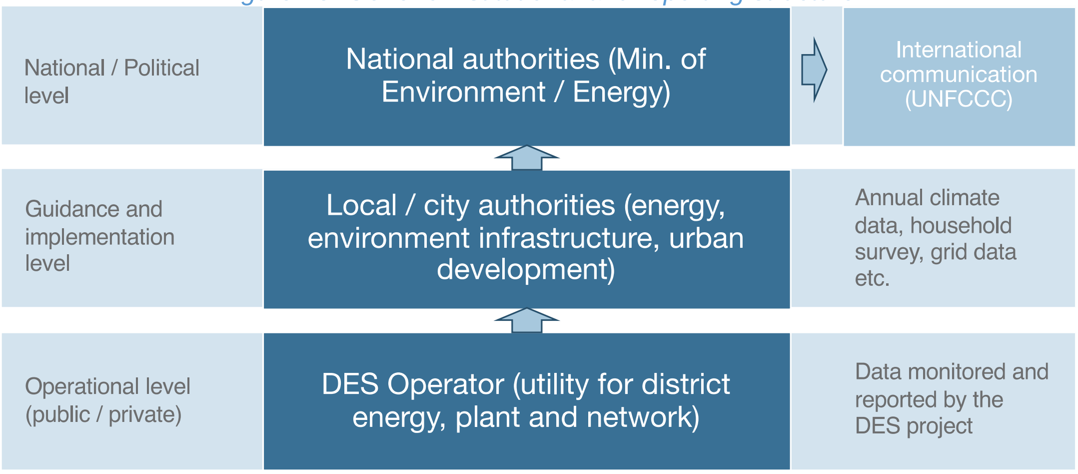
- How are data and information currently collected and reported? Which data are available?
- How are data reported to the authorities? How are responsibilities defined?
- What are barriers / challenges?
- How are aggregated data and reports handled and reported to the national level?
- How can the MRV Framework be aligned with the national MRV, in particular in the light of upcoming requirements under the Paris Agreement?
- Which technical assistance, staff support and financial resources are required to effectively implement the MRV plan?

Institutional set-up and responsibilities

Information and data on key indicators and parameters may be available and dispersed among different sources and stakeholders. Typically, different stakeholders are involved in the DES project and the MRV. Accordingly, clear institutional arrangements are important to coordinate the MRV approach. If different stakeholders are taking over responsibilities under the MRV process, an MRV coordinator should have the overall responsibility and should lead the processes for data collection, management and reporting. This coordinating responsibility should lay with the local / city authority but could also be delegated to DES operators and projected implementers (e.g. utilities).

The MRV operational and management system usually covers three different levels: National / political level, where policy instruments and regulations are developed; the local and implementation level, where local / city authorities coordinate different activities in line with the local / national strategies; and the operational level, where the DES infrastructure is constructed and operated. As outlined in the following figure the data and information flow for tracking the results of the DES project ranges from the operational to the political level following national reporting procedures.

Figure 15: Generic institutional and reporting structure



Source: Own illustration

The local / city authorities usually provide general guidance and strategic indications on the overall DES development, interacting with different stakeholders involved on the operational level (both public and private). Together with the national policy level, it will facilitate the implementation of the enabling activities, such as the definition of the long-term strategy and effective policy instruments to support the DES implementation. An important responsibility is the coordination with the DES operators to get relevant information and data on the performance of the DES.

The city authorities should provide support and available data and information, e.g. on IES usage and dissemination, SDG indicators such as air quality etc. It shall have overall coordination for the implementation of the MRV framework, for both the mitigation outcomes and the SD impacts. This will require availability within local authorities of the necessary technical capacity to perform the tasks required for MRV purposes. The activities should be performed in close cooperation with the DES operators who know the output / performance of their systems. The DES Operators should collect all relevant data on the energy system. Together with other public entities the city authorities also need to collect the relevant data for the MRV of the SD contributions, if it is not available in-house (for instance air quality data). Hence, the authorities should ensure the exchange of information and data with relevant public entities and to the national level for the official communications to UNFCCC and to other national and international stakeholders.

Try to answer the question how are data and information currently collected and reported? Which data are available?
Which entity on national, local and operational level needs to be involved? How are responsibilities defined and allocated?

Data recording, reporting and verification (data quality control)

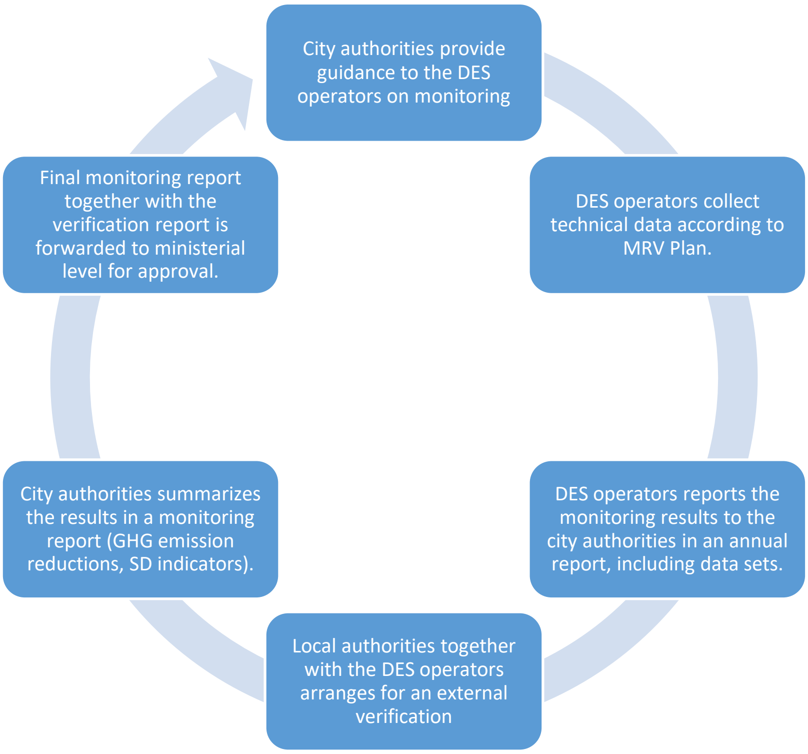
The reporting and verification process will define the reporting requirements and verification procedures taking into consideration the methodology standards and stakeholder requirements. The procedures and approaches for data collection should be clearly documented. A minimum of annual data collection of the constantly measured data and a biennial reporting is recommended.

Alternatively, the reporting frequency could be more frequent in line with national and internal reporting frequency requirements.

After annual data collection, a short report on intermediate emissions reductions and SD impact should be produced by the city authorities, which can be provided to the national authorities (ministries) to estimate the NDC contribution and undertake the communication towards the UNFCCC. Also potential donors would be interested in a regular update on the performance of the DES project. These reports can also be used for internal purposes and reporting to other institutions involved.

The main responsibility of the MRV framework therefor lies with the city authorities, which should set-up a database and information system. The general proposed process flow for the MRV framework is as follows:

Figure 16: Generic process on data recording, reporting and verification



Source: Own illustration

1. The city authorities provide guidance to the DES operators on how the monitoring should be conducted and data should be collected with regards to emission reduction calculations by adapting the generic MRV framework to the local situation (preparation of MRV Plan).
2. The DES operators will collect the technical data according to the monitoring procedures defined together with the local / city authorities in accordance with the generic MRV framework of the DES Initiative. The operator should ensure all related requirements such as record keeping and quality control.
3. The DES operators will report the monitoring results (monitoring records) to the city authorities in an annual report, including data sets.

4. The local authorities, together with the DES operators, arrange for an external verification entity to verify the annual monitoring results. The verification could result in corrective actions.
5. The city authorities collect all monitoring data and reports, combine and store them in a central monitoring database and summarize the results in a monitoring report (see draft structure in Annex 3). This report contains information on GHG emission reductions, progress in the SDG indicators, collected from other public sources, e.g. statistics.
6. The final monitoring report together with the verification report of the external verifier is then forwarded to the ministerial level, where the results checks and approved. It will be used for the national communication to the UNFCCC and a potential donor.

The city authorities will be responsible for the preparation of monitoring reports based on the monitoring records and according to the methodology at least once every second year. It is suggested that the national authorities responsible for national MRV support the city authorities in fulfilling MRV requirements. The monitoring reports will aggregate all required monitoring information, i.e. monitoring records. Each monitoring report will unambiguously set out the data on emission reductions generation and SD impact during the monitoring period consistent with the requirements of the MRV framework.

Record keeping procedures undertaken by the city authorities shall ensure that the monitoring records assigned to a monitoring period can be clearly attributed to the DES activities and will again prevent double counting of emission reduction data. The use of a monitoring database including parameters and identification (e.g. from each plant and sub-station) records will support the data handling and ensure that double counting of emission reduction is not possible with any other programme or activity. Also, the start and end date of each monitoring period (usually 1 year), together with the corresponding monitoring records for that monitoring period will be recorded in the database.

The MRV process and results should be well documented, which will support enhancing the availability of information over time for subsequent monitoring periods and generate archived historical records.

Quality assurance and quality control procedures

Quality assurance and quality control (QA/QC) procedures and measures should be defined. QA/QC measures will help to ensure the quality of data, which in turn will increase the reliability and confidence in the results. ***Quality control*** is the procedure of measures that are performed by the personnel compiling the data to ensure the quality of the data, while ***quality assurance*** is a planned review process conducted by personnel who are not directly involved in the data collection, compiling and processing (ICAT, 2018, p. 111).

The local authorities should overall be responsible for coordinating QA/QC activities. The authority may designate responsibilities for implementing and documenting these QA/QC procedures to other agencies or organisations, however it should ensure that other organisations involved are following the QA/QC procedures (IPCC, 2000). It is good practice to designate a QA/QC coordinator, who would be responsible for ensuring that the objectives of the QA/QC programme are implemented (IPCC, 2000, p. 8.6).

It is recommended to include the QA/QC procedures in the MRV Plan. The plan should outline QA/QC activities that will be implemented, contain an outline of the processes to organise, plan, and implement these activities. In developing and implementing the QA/QC procedures, it may be useful to refer to the standards and guidelines published by the International Organization for Standardization (ISO) (see IPCC, 2000, p. 8.7)

QA/QC measures should focus primarily on data collection activities and can encompass a variety of activities, including site audits, central data control, site technician reminders, and maintaining service sheets (GHG Protocol, 2005, p. 76). Furthermore QA/QC could comprise data processing and storage.

Quality control

Quality control applies to data and processes on data handling, documentation, and emission calculation activities (e.g., ensuring that correct unit conversions are used). Guidance on quality control procedures is summarised in *Table 12*.

Table 12: Recommended quality control measures

Data gathering, input, and handling activities	Data documentation	Calculating emissions and checking calculations
•Check a sample of input data for transcription errors •Identify spreadsheet modifications that could provide additional controls or checks on quality •Ensure that adequate version control procedures for electronic files have been implemented •Others	•Confirm that bibliographical data references are included in spreadsheets for all primary data •Check that copies of cited references have been archived •Check that assumptions and criteria for selection of boundaries, base years, methods, activity data, emission factors, and other parameters are documented •Check that changes in data or methodology are documented •Others	•Check whether emission units, parameters, and conversion factors are appropriately labeled •Check if units are properly labeled and correctly carried throughout the calculations •Check that conversion factors are correct •Check the data processing steps (e.g., equations) in the spreadsheets •Check that spreadsheet input data and calculated data are clearly differentiated •Check a representative sample of calculations, by hand or electronically •Check some calculations with abbreviated calculations (i.e., back of the envelope calculations) •Check the aggregation of data across source categories, business units, etc. •Check consistency of time series inputs and calculations •Others

Source: GHG Protocol, 2015, p. 76

Quality assurance

For data quality assurance, the data and information provided to the city authorities by the DES operators should be checked internally through a technical review by a person not involved in the data collection and processing to ensure the accuracy and completeness of data. In case of errors, corrective action will be applied to avoid future similar mistakes. For data quality assurance the reviewer should review and check (GHG Protocol, 2005):

a) The accuracy, completeness, and consistency of all monitored data.
b) The validity of any assumptions made during the project development phase regarding baseline emissions and project activity emissions. This requires analysing collected data to:
   - verify that each project activity has been implemented and is performing as expected;
   - ensure data have been properly entered into data templates, forms, or software;
   - verify that any parameter values used to estimate the baseline emissions continue to be valid, e.g. assess the representativeness and applicability of emission factors and other parameters
   - assess calculation results to ensure data have been properly processed.

In addition, an ***expert peer review*** may be initiated by local authorities consisting of a review of calculations or assumptions by DES experts, such as from the District Energy in Cities Initiative. The objective of the review is to ensure that the results, assumptions, and methods are reasonable as judged by those knowledgeable in the specific field (IPCC, 2000, 8.15).

To assure the quality of data handling, training should be provided to monitoring personnel in line with the MRV framework adapted to the specific DES. The city authority, e.g. with the help of the DES Initiative should provide all necessary information and training material that enables every DES operator to conduct the monitoring process as required by the MRV framework. For the QA/QC procedures, it is also recommended to use IPCC's QUALITY ASSURANCE AND QUALITY CONTROL of the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000)

Subject to the requirements of potential project donors, there might be additional requirements on the MRV system, e.g. donors might wish to send own QA/QC teams to check the project performance.

Verification procedures

It is recommended that the DES operator and the city authorities prepare a monitoring protocol that allows for a third-party verifier to confirm all relevant data. A monitoring database should be established that contains all specific data required. This database is going to be operated and maintained by the city authorities, e.g. the municipal heating/cooling authority, potentially under supervision of the national ministries responsible to the national MRV.

The DES operator and the city authorities will be responsible for the preparation of monitoring record(s) (MR), e.g. in form of Excel spreadsheets or other raw-data, and for communication with an appointed verifier during verification activities. Verification needs to occur for the baseline (e.g. benchmark) and the DES activities (e.g. energy provided).

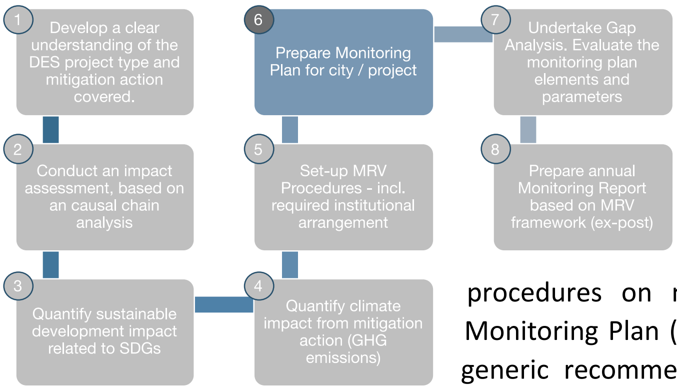
The objective of the verification is to have an independent third-party auditor to ensure that the MRV Plan is being implemented as planned. The verification also ensures that emissions reductions and SD benefits are real and measurable, if possible. Auditors should be accredited entities, such as under the CDM or under another accreditation system.

Verification should occur every one or two years. The verification will consist of:

- Desk review of monitoring record (reports);
- Site visits/interviews of key stakeholders, e.g. DES operator;

- Drafting of a verification report;
- Providing feedback on the report by city authorities and the DES operators;
- Finalization the verification report.

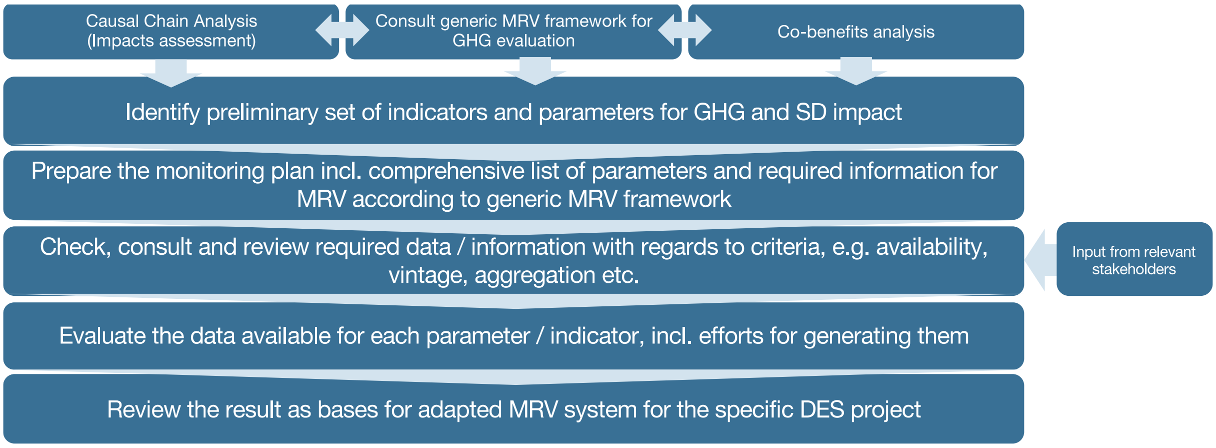
*S*et-up clear MRV Procedures including QA/QC provisions in collaboration with all stakeholders. Agree on institutional set-up and responsibilities as well as data recording, reporting and verification process. Identify the entity or person that is responsible for monitoring key indicators and parameters for GHG and SDG.



Step 6: Preparation of MRV Plan for specific city level

Monitoring should be conducted in a fashion that allows a complete, consistent and transparent quantification of GHG reductions and SD benefit determination. Hence, it should follow prescribed procedures on measuring, reporting and verifying. The MRV or Monitoring Plan (MP) for city level and DES activities shall reflect the generic recommendations on MRV in this guidance and adapt the required procedures to the local circumstances to provide this prescription The MP will include and describe the specific situation and the detailed project intervention, the process of collecting the data used to quantify GHG reductions, SD benefits and to validate underlying assumptions in the quantification. Hence, the MP is a working document that describes the procedures for collecting data on the project and related to baseline emission estimates. The plan shall reflect the work and results of the previous steps and be used as a comparison for the current status for the stakeholders (reality check) (see *Figure 17* and Step 7). It shall also help to ensure and control the quality of the collected data (compare GHG Protocol, 2005).

Figure 17: Steps for preparing a specific MRV Plan



Source: Own illustration

The MP is important to adapt the MRV approach to the city level and to ensure that all required data are collected, reported and analysed. Hence, it is recommended to create a plan for monitoring key GHG and SDG indicators and parameters. The MP is the adapted procedures for the individual projects and cities for obtaining, recording, compiling, analysing, reporting and verifying data and information relevant for tracking process and for estimating GHG and SDG impacts. Based on this guidance the MP should be developed during the planning phase of the project before implementation and be adjusted, if necessary, during the implementation.

In order to prepare the MP you can use the elements of the generic MRV framework and adapt the presented procedures for GHG and SD impact estimation. The MP shall include the following content to be robust and detailed:

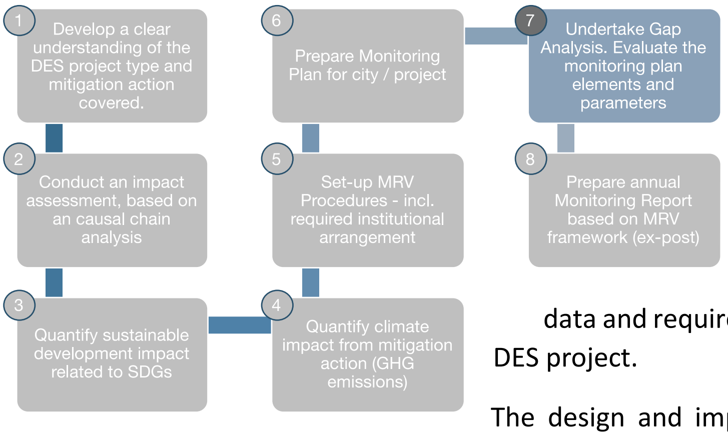
- **Description of project**: Describing the purpose and general description of DES project, incl. details of the location and technologies/measures undertaken.
- **Description of measuring approach and system**: Identified mitigation measures, results of the impact assessment, definition of the system boundary, sources and GHGs as well as baseline and project scenarios. Presentation of the calculation procedures for the estimation of GHG emission reductions, incl. emission reduction data and parameters used. The description should cover:
  - Identification of the period over which GHG reductions will be quantified
  - How to quantify the GHG reductions as the sum of all primary effects and significant secondary effects for all project activities
  - Document the calculation approach to be applied to quantify GHG reductions and any uncertainties / assumptions associated.
- **Description of how the project contributes to sustainable development**, with data and parameters of SD benefits.
- **General MRV procedures**: Outlining the institutional set-up and responsibilities in particular with regards to data recording, reporting and verification (data quality control).
  - Include information on necessary skills and competencies to undertake the procedures. Propose any training required to in order for the personnel to implement the tasks.

- Elaborate the process on generating, recording, compiling and reporting data on monitored data and parameters.
- Specify the frequency for monitoring and reporting of key indicators and parameters, e.g. monthly, quarterly, or annually. The frequency should consider the recommendations in Annexes 2, 3 and 4 and should take into account the needs of national report procedures under the national MRV system and of the involved stakeholders, as well as cost and data availability.
- Define the QA/QC process to ensure the quality of data, as well as record keeping and internal documentation.
- Consider potential continual enhancements of the MRV approach (reflecting any gaps and barriers – see Step 7).

An MP template is attached in Annex 6. The MP for a project should be updated whenever the methodologies or procedures applied to estimate, calculate, or measure project or baseline emissions are changed (GHG Protocol, 2005).

Makes use of the guidance and procedures provided in this generic MRV framework to adapt the MRV approach to your local city specific situation and prepare a project specific MRV Plan.

Step 7: Identify gaps and barriers for the implementation city and project level



The main objective of the gap and barrier analysis of the MRV Plan is to confirm and check the compliance and capability of the specific DES project, including its operators and institutions, with potential MRV requirements. This assessment shall ensure that the MRV approach covers the relevant impacts, using SMART indicators. It shall help identify existing sectoral data and required data for tracking the progress and impact of the DES project.

The design and implementation of a specific MRV system may be confronted with different barriers (e.g. technological, financial, infrastructural, knowledge, social, political and institutional). A strong MRV system requires a robust determination approach of GHG emissions estimates, the use of appropriated monitoring devices and a clear process for the report and verification of the data. Each of these elements could potentially represent a challenge for the implementation of the MRV framework and plan. Possible barriers of the MRV system are shown below.

Table 13: Potential barriers for the MRV framework implementation

Barrier	Description of the barrier	Possible mitigation of the barrier
Implementation costs of the MRV system	Elevated implementation costs of the MRV system.	Elaborate a cost-benefit assessment for the MRV system before its implementation (Related to level of accuracy)
Operating costs of the MRV system or verification third party services	Elevated operating costs of the MRV system (devices and staff assigned to it) or expensive third party services related to the verification of the GHG emission reductions.	Elaborate a cost-benefit assessment for the MRV system before its implementation.
Insufficient data availability	Insufficient data availability due to the lack or inefficiency of prior monitoring system.	Temporary use of IPCC's default values, update of the calculations with measured values as soon as MRV system is implemented.
Insufficient data quality	Insufficient quality of data collected due to the use of inappropriate techniques or monitoring devices.	Specify the uncertainty level on the calculations, updating monitoring and report techniques, use of monitoring devices aligned with international standards.
Low availability of suitable monitoring devices	Little or no availability of suitable equipment in the country capable of performing monitoring operations ensuring an appropriate level of data accuracy.	On short term: Importation of monitoring devices; On long term: encourage the private sector for the national production of suitable monitoring devices.
Limited availability of maintenance and calibration of monitoring devices	Little or no availability in the country for maintenance and calibration of monitoring devices.	On short term: importation of monitoring devices On long term: encourage the private sector to build up capacity.
Limited capacities at local / governmental level for the management of the MRV system	Limited capacities for the management of an MRV system.	Capacity building through specific trainings and workshops for the management of the MRV system.
Complexity of (CDM) baseline methodologies	(CDM) methodologies can be strict and difficult to manage for the calculations of GHG reductions.	Creation of new simpler methodologies based on CDM ones, e.g. by developing standardised baseline, where suitable.
Lack of capable local professionals in the country or necessity of technical advice.	Monitoring implementation and operation can be a new field for local professionals. In case there is a lack of these capacities within the private sector in the country it would be necessary to hire foreign companies to do this.	On short term: hiring foreign companies to implement and manage the MRV system. On long term: encourage the private sector to fill this niche.
Lack of institutional technical capacity particularly at municipality / city level	Local government officials are not familiar with MRV processes and technologies, also the municipalities are overloaded with other tasks	Provide technical support to build capacity at the municipal level
Lack of experience for MRV technologies	A lack of experience within the use and application of any technology could represent a barrier for the MRV	On short term: hire foreign companies to implement the technologies, use of IPCC's default values until MRV system is

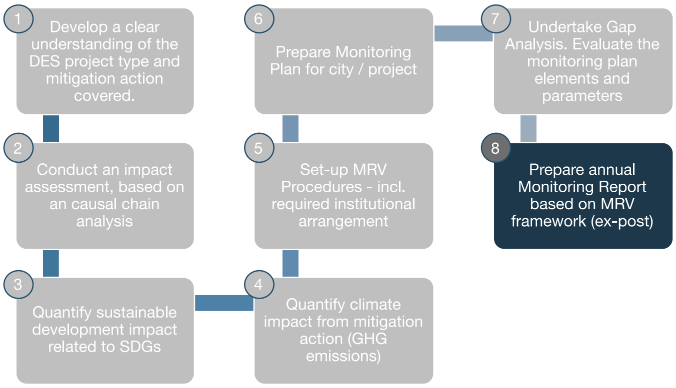
Barrier	Description of the barrier	Possible mitigation of the barrier
(meters etc.) within the country	implementation, as there would be a lack of knowledge about the parameters to be monitored or its frequency and the operation of the plant.	implemented. On long term: learning from pilot plants implemented, use of the measured values by the MRV system.
Possible inefficiency of institutional organization for the MRV system	If the MRV system design does not define clear responsibilities for each involved stakeholder, there is a risk that the implementation of the system does not succeed due to failure in terms of clear tasks and responsibilities.	Creation of a management set-up of the MRV system including an institutional and organisational level, with the responsibility of supervising the MRV system in all its phases.
Continuity of MRV operations despite a possible change of local / national government	If possible changes in local / national government occur, there is a risk that the continuity of MRV operations may be impacted.	Through the quantification and dissemination of expected benefits of DES, make sure this is fully agreed by stakeholders, both public and private, and is seen as an important priority for the country.

The analysis shall provide a general assessment basis, e.g. by using checklist feeding into a multi-criteria analysis, for instance, of existing data flow, current reporting frequency, existing verification procedures within the energy and building sector in the city / country, in which the DES projects are implemented.

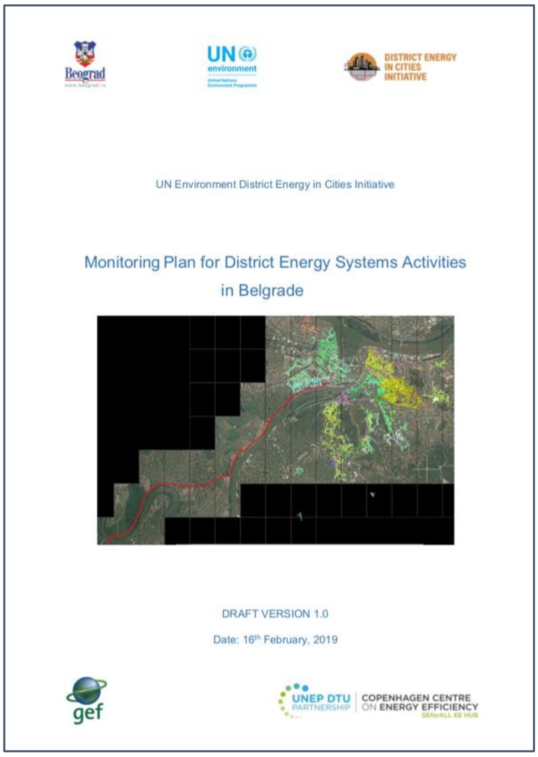
As illustrated in *Table 13*, based on the identified indicators and parameters related to the impact (GHG mitigation, SD co-benefits), a list comprising all relevant information and data that may be necessary for a robust MRV system should be prepared. With regards to the GHG impact, relevant parameters can be derived from the generic MRV framework depending on the DES technology applied. The list should be comprehensive, even though maybe not all parameters will be required in the end for the MRV system (e.g. in case of default values that can be applied). The analysis will help to evaluate the availability of ready-to-start information, so that the eventual MRV approach can be drafted accordingly (MRV plan). It may also reveal that data would need to be newly generated or gathered in future or are generally not available. Based on this information the readiness to start the MRV can be assessed, allowing identifying data / information gaps and how to overcome them.

Conduct an analysis of potential barriers for the adaption and implementation of the MRV in the specific city and DES project context. Consider potential measures to overcome the barriers. Use this analysis as MRV readiness test and consult it with relevant stakeholders.

Step 8: Prepare annual Monitoring Report based on MRV framework



A transparent reporting of the results, methodology and assumptions used is important to ensure plausibility of the GHG and SDG impact. It will also provide decision makers and stakeholders required information to properly interpret the assessment and results. Hence, a Monitoring Report (MR) should be prepared based on the procedures outlined in the MP for the individual DES project on city-level. The report is standardised and shall present the results of the project and its impact on an annual basis. A template for the Monitoring Reports is attached in Annex 7.


Beograd

UN environment

DISTRICT ENERGY IN CITIES INITIATIVE

UN Environment District Energy in Cities Initiative

Monitoring Plan for District Energy Systems Activities in Belgrade

DRAFT VERSION 1.0

Date: 16th February, 2019

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UNEP DTU PARTNERSHIP | COPENHAGEN CENTRE ON ENERGY EFFICIENCY

The Monitoring Report shall include the mitigation results and SD benefits. For the calculation of the emission reduction, an appropriate and corresponding Excel Spreadsheet should be used to document the calculation. It helps to estimate the baseline, project and leakage emissions according to the procedures of this general MRV guidance. The following information is recommended to be included:

- **General information**: name of project, monitoring period, responsible entity / person.
- **General description** of project activity
- **Description of monitoring approach and system** (incl. Result of the impact assessment: All GHG and SDG impacts identified, using a causal chain, illustrating those impacts are included in the project boundary. Defined baseline scenario
- **Emission reduction data and parameters**: values for relevant parameters for the assessment period, including assumptions and methods used.
- **Calculation of emission reductions**: Estimated GHG impacts calculated for the assessment period using the measures / estimated values for each parameter. All data sources to estimate key parameters, including measurements, emission factors, GWP values and assumptions.
- **Sustainable Development Benefits** - Description how the project contributes to sustainable development (SD). Reporting on key SDG indicators for the project.

On an annual basis, collect the necessary data, determine and calculate the impact of your project with regards to emissions, emission reductions and SD benefits. Present the results in an individual and specific Monitoring Report.
In your reporting, differentiate between current and future emissions level as reported in emission inventories and emission reductions from mitigation actions.

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Annex 1: SDG indicators for district energy systems

This Annex provides detailed tables per SD benefit indicator that can be achieved due to DES projects. Each parameter table includes procedures for continuously monitoring and reporting. The indications should be selected and amended to the individual DES projects depending on the local circumstances and priorities. The compilation of parameters is based on the Sustainable Development Goals Knowledge Platform (UN DESA, 2018) and Sustainable Development Solutions Network (SDSN, 2015), which can be consulted for more background information. For additional current data on SDG indicators, see also SDG Tracker (https://sdg-tracker.org) and Our World in Data database (https://ourworldindata.org).

Key parameters to track the project status and sustainable development benefits (not exhausted):

Data / Parameter:	**Share of households and commercial users connected to DES**
Data Unit:	%
Description:	Share of households and commercial users connected to DES within a city or country. Calculated based on connected versus total households / commercial users.
Measurement and QC procedures (if any):	Annual statistics
Monitoring frequency:	Annual reporting
Comment:	Related to SDG 9 Industry, Innovation and Infrastructure and SDG 11 Sustainable Cities and Communities

Data / Parameter:	**Mean urban air pollution of particulate matter (PM10 and PM2.5)**
Data Unit:	Concentration of PM 10 and 2.5 (µg/m^3 or ppm)
Description:	The parameter provides the mean urban air pollution of particulate matter (PM10 and PM2.5) at different measurement points within a city.
Measurement and QC procedures (if any):	Continuous measurements
Monitoring frequency:	Continuous monitoring and at least daily recording of daily average
Comment:	If available, data should be used provided by measuring stations e.g. operated by national / local environmental agency that determine the outside air quality (usually measured values are available in the form of city- / nationwide maps, history graphics and tables). Related to SDG 11 Sustainable Cities and Communities. Reduction of pollutants improves quality of life and reduces impacts on human health and on the natural environment

Data / Parameter:	**Mean concentration of CO, SO_x, NO_x in cities**
Data Unit:	Concentration of air pollutants in the atmosphere µg/m^3 or ppm
Description:	The amount of pollutants in the atmosphere including SOx, NOx and particulates, measured in parts per million (µg/m^3 or ppm)
Measurement and QC procedures (if any):	Continuous measurements
Monitoring frequency:	Continuous monitoring of daily one-hour maximum and one-hour average values; at least daily recording.
Comment:	If available, data should be used provided by measuring stations e.g. operated by national / local environmental agency that determine the outside air quality (usually measured values are available in the form of city- / nationwide maps, history graphics and tables). Related to SDG 11 Sustainable Cities and Communities and SDG 3 Good Health and well-being

Data / Parameter:	**Proportion of population with access to reliable electricity**
Data Unit:	% of population with reliable access to electricity grid.
Description:	Proportion of population with access to reliable electricity, measured as the share of people with electricity access at the household level. It comprises electricity sold commercially, both on-grid and off-grid.
Measurement and QC procedures (if any):	National / city level statistics; utility / grid operator data
Monitoring frequency:	Annually
Comment:	Related to SDG 7 Affordable and clean energy (Indicator 7.1.1) and SDG 9 Industry, Innovation and Infrastructure. If possible get sex disaggregated data.

Data / Parameter:	**Power outages**
Data Unit:	Minutes / hours of electricity outage per month or year
Description:	Power outages are the average number of power outages that households or establishments experience in a typical month.

Measurement and QC procedures (if any):	National / city level statistics; utility / grid operator data
Monitoring frequency:	Annually
Comment:	Related to SDG 7 Affordable and clean energy (Indicator 7.1.1) and SDG 9 Industry, Innovation and Infrastructure and

Data / Parameter:	**Proportion of population with primary reliance on clean fuels and technology**
Data Unit:	% of total population with reliable access to clean fuels and technologies for cooking.
Description:	Proportion of population with access to clean energy at city and national level measured as the share of the total population with access to clean fuels and technologies for cooking.
Measurement and QC procedures (if any):	City level statistics. If national data is available, comparison against such data.
Monitoring frequency:	Annually
Comment:	Related to SDG 7 Affordable and clean energy (Indicator 7.1.2). Access to clean fuels or technologies such as clean cookstoves reduce exposure to indoor air pollutants, a leading cause of death in low-income households. Get sex disaggregated data to understand if access to clean technologies has an impact on women health and life quality.

Data / Parameter:	**Primary energy by type**
Data Unit:	% of primary energy type
Description:	Share of primary energy types (fossil fuels such as oil, gas, coal and renewable sources such as solar, wind, hydro and biomass) at city and national level
Measurement and QC procedures (if any):	National / city level statistics and energy balances.
Monitoring frequency:	Annually
Comment:	Related to SDG 7 Affordable and clean energy

Data / Parameter:	**Renewable energy share in the total final energy consumption at city level**
Data Unit:	% of final energy consumption

Description:	Renewable energy share in the total final energy consumption (thermal and electricity) measured as renewable energy (inclusive of solar, wind, geothermal, hydropower, bioenergy and marine sources) as a share of final (not primary) energy consumption. Energy mix includes electricity, transportation and cooking/heating fuels.
Measurement and QC procedures (if any):	National / city level statistics; utility data
Monitoring frequency:	Annually
Comment:	Related to SDG 7 Affordable and clean energy (Indicator 7.2.1).

Data / Parameter:	**Energy intensity measured in terms of primary energy and GDP**
Data Unit:	MWh or GJ per GDP
Description:	Energy intensity measured as the energy intensity of economies (collectively across all sectors). Energy intensity is measured as the quantity of kilowatt-hours produced per 2011 international-$ of gross domestic product (kWh per 2011 int-$).
Measurement and QC procedures (if any):	National / city level statistics
Monitoring frequency:	Annually
Comment:	Related to SDG 7 Affordable and clean energy (Indicator 7.3.1) and SDG 8 Decent work and economic growth

Data / Parameter:	**Unemployment rate or number of employments by DES**
Data Unit:	Number of employees Unemployment rate in %
Description:	Unemployment rate in a city or number of employments by DES
Measurement and QC procedures (if any):	City level statistics, DES operation reports
Monitoring frequency:	Annually
Comment:	SDG 8 Decent work and economic growth. Get sex disaggregated data to monitor that women are not left behind in the new employments generated through DES.

Annex 2: GHG emission reduction from district heating

The generic MRV framework for district heating is based on existing methodologies that may be used or be adapted for the DES project situation to ensure accuracy while being practicable and feasible. The methodologies were assessed with regard to their capability to serve as a blueprint for the individual MRV Plans adapted to project / city activities. District cooling procedures can be found in Annex 3, procedures for tri-generation can be found Annex 4.

Table 14: Overview of relevant accounting and reporting methodologies for district heating

DES Project Type	Standard	Methodology	Description	Important monitoring parameters
General	GHGP	The GHG Protocol for Project Accounting	Provides specific principles, concepts, and methods for quantifying and reporting GHG reductions from climate change mitigation projects	General procedures only.
	GHGP	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories	Accounting and Reporting Standard for Cities	General procedures only
	UNEP Program's Sustainable Buildings & Climate Initiative (UNEP-SBCI)	Common Carbon Metric	Common Carbon Metric is to support greenhouse gas (GHG) emissions reductions through accurate measurement of energy efficiency improvements in building operations	Derived from building performance data: Energy Intensity = $kWh/m^2/year$ Carbon Intensity = $kgCO_2e/m2/year$
District heating	UNFCCC / CDM	ACM0026: Fossil fuel based cogeneration for identified recipient facility(ies)	Installation of a facility to supply i) electricity to recipient facility(ies) and to a power grid, and ii) heat to recipient facility(ies) implemented either by the owner(s) of the recipient facility(ies) or by a third party (e.g. energy service company (ESCO))	
	UNFCCC / CDM	AM0058: Introduction of a new primary district heating system	Introduction of a district heating system supplying heat from a fossil fuel-fired power plant and/or by new centralised boilers. It replaces decentralised fossil fuel fired heat only boilers.	Quantity of heat from the cogeneration plant and from all heat only/peak load boilers in the project; Quantity of heat supplied from each sub-station to the buildings.
	UNFCCC / CDM	AM0048: New cogeneration project activities	Fossil-fuel-fired cogeneration project supplying heat and	Quantity of electricity generated by the project and supplied to recipient

DES Project Type	Standard	Methodology	Description	Important monitoring parameters
		supplying electricity and heat to multiple customers	electricity to multiple project customers.	facility(ies) and/or the power grid; Quantity of steam or hot water generation by the project and supplied to recipient facility(ies) and/or heat networks.
	UNFCCC / CDM	AMS-I.C.: Thermal energy production with or without electricity	Thermal energy production using renewable energy sources including biomass-based cogeneration and/or trigeneration. Projects that seek to retrofit or modify existing facilities for renewable energy generation are also applicable.	Thermal energy (mass flow, temperature, pressure for heat/ cooling) delivered by the project Amount of grid and/or captive electricity displaced; Quantity of biomass and fossil fuel consumed
	UNFCCC / CDM	AMS-II.K.: Installation of co-generation or tri-generation systems supplying energy to commercial buildings	Installation of fossil-fuel-based cogeneration or trigeneration systems. Generated electricity and cooling, and/or heating are supplied to commercial, non-industrial buildings.	Amount of grid and/or captive power supplied by the project; Amount of cooling and/or heating energy supplied by the project

Source: Own analysis based on methodology analysis (not exhausted)

Within the methodologies, the project boundary, baseline, assessment of additionality and emission reduction calculation is defined, i.e. detailed procedures for quantifying the GHG mitigation of a project or programme. Hence, a review of those methodologies and the related definitions will result in a good overview of possible options to define the emission and project boundary, baseline and emission reduction calculation. Based on the analysis the following methodologies are deemed most relevant for DES projects.

The proposed procedures follow mainly CDM methodology ACM0026 and AM0058. However, where possible and feasible simplification is suggested.

Baseline and baseline emissions district heating

The baseline emissions include emissions from fossil fuels fired for the production of heat and emissions from the generation of electricity.

$$BE_y = BE_{HG,y} + BE_{EL,y} \quad \text{Equation (3)}$$

Where:

BE_y = Baseline emissions during the year *y*, (tCO_2e)

$BE_{HG,y}$	=	Baseline emissions from the generation of heat during the year *y*, (tCO_2e)
$BE_{EL,y}$	=	Baseline emissions from the generation of electricity during the year *y*, (tCO_2e)

The baseline emissions from the generation of electricity only need to be determined for projects that involve heat extraction from an existing power plant, e.g. combined heat and power plants (CHP).

Baseline emissions from heat generation are estimated as follows:

$$BE_{HG,y} = \sum_{e} Q_{e,y} \times EF_{BL,HG,y}$$ Equation (4)

Where:

$BE_{HG,y}$	=	Baseline emissions from the generation of heat during the year *y*, (tCO_2e)
$Q_{e,y}$	=	Quantity of heat supplied that was generated in the project facility *e* in the year *y*, (GJ)
$EF_{BL,HG,y}$	=	Baseline CO_2 emission factor for heat generation in year *y* (tCO_2/GJ)
$EF_{BL,HG,n}$	=	CO_2 emission factor for heat generation in the baseline associated with sub-station n (tCO_2/GJ)

Heat generated by the project facility could have been produced by different facilities and would have therefore different emission factors. To account for this, the baseline emission factor for heat generation ($EF_{BL,HG,y}$) shall be calculated as follows:

To determine the CO_2 emission factors, a benchmarking (available utility data, using statistics, census / surveys) of the existing IESs or DES' shall be conducted.

$$EF_{BL,HG,y} = \frac{\sum_k HG_{BL,HG,k} \times EF_{BL,HG,k,y}}{\sum_k HG_{BL,HG,k,y}}$$ Equation (5)

Where:

$EF_{BL,HG,y}$	=	Baseline emission factor for heat generation in year *y* ($t\ CO_2/GJ$)
$HG_{BL,HG,k}$	=	Maximum amount of heat that would have been generated in a baseline by technology *k* in year *y* (GJ)
$EF_{BL,HG,k,y}$	=	Baseline emission factor for heat generation in a baseline by technology *k* in year *y* ($t\ CO_2/GJ$)
K	=	Technology that would have been used in a baseline to generate heat

Baseline emission factor for heat generation ($EF_{BL,HG,k,y}$) depends on baseline technology and may be influenced by the following factors:

- The efficiency of the identified baseline boiler technology ($\eta_{BL,HG}$);

- The fuel type identified as baseline fuel type (e.g. fuel oil, natural gas, LPG or wood etc.) and respectively the CO_2 emission factor of this fuel ($COEF_{BL,HG,i}$).

Therefore three different approaches exist on how it shall be determined:

Approach 1 - applicable if heat in the baseline scenario would have been supplied to the recipient facility from the existing heat network. Baseline emission factor for heat generation shall be determined as follows:

$$EF_{BL,HG,k,y} = \frac{\sum_m (HG_{m,y} \times EF_{BL,HG,m})}{\sum_m HG_{m,y}}$$ Equation (6)

Where:

$EF_{BL,HG,k,y}$	=	Baseline emission factor for heat generation in the baseline by technology *k* in year *y* (t CO_2/GJ)
$HG_{m,y}$	=	Heat supplied by the heat generation facility *m* within the heat network in year *y* (GJ)
$EF_{BL,HG,m}$	=	Baseline emission factor for heat generation of the operating heat generation facility *m* (t CO_2/GJ)
m	=	All operating heat generation facilities within the heat network

The baseline emission factor for heat generation of the operating heat generation facility *m* should be determined using approach 2 below.

Approach 2 - applicable if heat in the baseline scenario would have been supplied by heat generation facility(ies) / IES. Baseline emission factor for heat generation shall be determined as follows:

$$EF_{BL,HG,i,y} = Average_i \left(\frac{COEF_{BL,HG,i}}{\eta_{BL,HG}} \right)$$ Equation (7)

Where:

$EF_{BL,HG,i,y}$	=	Baseline emission factor for heat generation in a baseline by technology *i* in year y(t CO_2/GJ)
$COEF_{BL,HG,i}$	=	CO_2 emission factor of the fuel used in the baseline heat generation facility (t CO_2/GJ)
$\eta_{BL,HG}$	=	The energy efficiency of the baseline heat generation facilities / IES *i*
i	=	All heat generation facility / IESs existing prior to the implementation of the project activity

$EF_{BL,HG}$ shall be determined as the CO_2 emission factor of the fuel identified as the baseline fuel in the baseline heat generation facility;

Where the operation of existing heat generation facility is the most plausible baseline scenario, the efficiency ($\eta_{BL,HG}$) can be determined using the default values in Annex 5, if no specific data is available.

Where operation of new heat generation facility(ies) as the most plausible baseline scenario, the baseline fossil fuel is the same as that used by the project facility and the efficiency ($\eta_{BL,HG}$) shall correspond to the maximum efficiency at the optimal operating conditions, provided by the manufacturer.

As a conservative alternative, the efficiency of 100% can be used for cases where operation of existing or new heat generation facility as the most plausible baseline scenario;

Approach 3 - applicable if heat in the baseline scenario would have been supplied to the recipient by the combination of the heat network and by existing or new heat generation facility (combination of Option 1 and Option 2). Where the historical data for the recent three years is available, the weighted average emission factor can be used. Otherwise, baseline emission factor for heat generation shall be determined as a minimum between emission factors for Approach 1 and Approach 2.

To determine $COEF_{BL,HG,i}$ for the fuel type used by IES *i*, national or IPCC default values can be used, if nor specific values are available (e.g. from fuel supplier). The efficiency of the heat generation in IES *i* default values from CDM tools shall be used, unless more accurate data and information are available for the benchmark installation. Default values are provided in Annex 5.

Baseline emissions from the power generation: The *ex post* calculation of baseline emissions from the power generation is based on the actual monitored electricity generated and supplied to the grid or any direct recipient in the DES project.

Baseline emissions due to electricity generation ($BE_{EL,y}$) are calculated based on i) the amount of electricity generated and supplied to recipient facility(ies), if applicable, and to the grid by the project and ii) the corresponding baseline emission factors associated with the electricity supplied.

$$BE_{EL,y} = EG_{PJ,Grid,y} \times EF_{BL,grid,y} + \sum_l EG_{PJ,l,y} \times EF_{BL,f,y} \quad \text{Equation (8)}$$

Where:

$BE_{EL,y}$	=	Baseline emissions for electricity generation in year *y* (tCO_2)
$EG_{PJ,l,y}$	=	Amount of electricity generated and supplied to recipient facility(ies) *l* by the project facility in year *y* (MWh)
$EF_{BL,f,y}$	=	Baseline emission factor for electricity supplied to recipient facility(ies) in year *y* (tCO_2/MWh)
$EG_{PJ,Grid,y}$	=	Electricity supplied to the grid by the project facility in year *y* (MWh)
$EF_{BL,grid,y}$	=	Baseline emission factor for electricity supplied to the grid in year *y* (tCO_2/MWh).

To determine the parameter $EF_{BL,grid,y}$ it is recommended to i) use national values published by designated authorities, e.g. Ministry of Energy, or ii) determine the combined margin, calculated according to the latest version of the CDM TOOL 07 - "Tool to calculate the emission factor for an electricity system"[17] ($EF_{grid,CM,y}$).

The baseline emission factor for electricity supplied to recipient facility(ies) can be determined as follows:

$$EF_{BL,f,y} = \frac{\sum_j EG_{BL,f,j,y} \times EF_{BL,f,j,y}}{\sum_j EG_{BL,f,j,y}}$$ Equation (9)

Where:

$EF_{BL,f,y}$	=	Baseline emission factor for electricity supplied to the recipient facility(ies) in year *y* (tCO_2/MWh)
$EG_{BL,f,j,y}$	=	Maximum amount of electricity that would have been generated in the baseline by technology/source *j* in and supplied to the recipient facility(ies) year *y* (MWh)
$EF_{BL,f,j,y}$	=	Baseline emission factor for electricity generation in the baseline by technology/source *j* in year *y* (tCO_2/MWh)
J	=	Technology/source that would have been used in the baseline to generate electricity

Baseline emission factor for electricity generation supplied to the recipient facility(ies) ($EF_{BL,f,j,y}$) depends on the baseline technology as identified in the baseline scenario determination process, and therefore have three different approaches on how it shall be determined:

Approach 1 - applicable for the amount of electricity that would have been supplied to the recipient facility(ies) in the baseline scenario by the power grid. Baseline emission factor $EF_{BL,f,j,y}$ shall be i) derived from national values published by designated authorities, e.g. Ministry of Energy, or ii) determined as the combined margin, calculated according to the latest version of the "Tool to calculate the emission factor for an electricity system"; This approach applies to project activities where in the baseline scenario the electricity would have been supplied by the power grid to the existing and/or greenfield recipient facilities;

Approach 2 - applicable for the amount of electricity that would have been supplied to the recipient facility(ies) in the baseline scenario by captive power plant(s). Baseline emission factor for electricity generation shall be determined as follows:

$$EF_{BL,f,j,y} = \frac{EF_{BL,EG}}{\eta_{BL,EG}} \times 3.6$$ Equation (10)

[17] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf/history_view

Where:

$EF_{BL,f,j,y}$	=	Baseline emission factor for electricity supplied to the recipient facility(ies), generated in the baseline by technology *j* in year *y* (tCO_2/MWh)
$EF_{BL,EG}$	=	CO_2 emission factor of the fuel used in the baseline captive power plant (tCO_2/GJ)
$\eta_{BL,EG}$	=	Energy efficiency of the baseline fossil fuel fired power plant (fraction)
J	=	Technology that would have been used in the baseline scenario to generate electricity supplied to the recipient facility(ies).

$EF_{BL,EG}$ shall be determined as the CO_2 emission factor of the fuel identified as the baseline fuel in the baseline power plant.

The energy efficiency of the captive power plant ($\eta_{BL,EG}$) can be determined according to *Table 18* in Annex 5.

Approach 3 - applicable for the amount of electricity that would have been supplied to the recipient facility(ies) in the baseline scenario by the combination of the power grid and captive power plant (combination of Approach 1 and Approach 2). Where the historical data for the recent three years is available, the weighted average emission factor can be used based upon the above two methods and historical shares of grid connected power versus captive power. Otherwise, baseline emission factor for electricity generation shall be determined as the minimum between emission factors for Approach 1 and Approach 2.

Project emissions district heating

Project emissions (PE_y) are calculated as the CO_2 emissions from fossil fuel(s) combustion associated with the production of heat and electricity, e.g. in a cogeneration plant. Hence, the project emissions PE_y comprise:

- CO_2 emissions from fossil fuel combustion associated with the production of heat and electricity in the DES energy plants, e.g. co-generation plant;
- CO_2 emissions from fossil fuel combustion in all other sources, e.g. heat-only boilers.

PE_y will be estimated as $\Sigma_j PE_{FC,j,y}$ where $PE_{FC,j,y}$ (i.e. the CO_2 emissions from fossil fuel combustion) is calculated based on the quantity of fuels combusted and the CO_2 emission coefficient of those fuels, as follows:

$$PE_{FC,j,y} = \sum_{i} FC_{i,j,y} \times COEF_{i,y}$$ Equation (11)

Where:

$PE_{FC,j,i}$	=	Are the CO_2 emissions from fossil fuel combustion in process j during the year y (tCO_2/yr)
$FC_{i,j,y}$	=	Is the quantity of fuel type i combusted in process j during the year y (mass or volume unit/yr)
$COEF_{i,y}$	=	Is the CO_2 emission coefficient of fuel type i in year y (tCO_2/mass or volume unit)
i	=	Are the fuel types combusted in process j during the year y

The CO_2 emission coefficient $COEF$ is calculated based on net calorific value and CO_2 emission factor of the fuel type i, as follows

$$COEF_{i,y} = NCV_{i,y} \times EF_{CO2,i,y}$$ Equation (12)

Where:

$COEF_{i,y}$	=	Is the CO_2 emission coefficient of fuel type i in year y (tCO_2/mass or volume unit)
$NCV_{i,y}$	=	Is the weighted average net calorific value of the fuel type i in year y (GJ/mass or volume unit)
$EF_{CO2,i,y}$	=	Is the weighted average CO_2 emission factor of fuel type i in year y (tCO_2/GJ)
i	=	Are the fuel types combusted in process j during the year y

For determining $NCV_{i,y}$ and $EF_{CO2,i,y}$ national or IPCC default values can be applied, if specific data are not available.

Dedication and allocation of emission to power and heat fraction in CHP plants

For determining a emission factor for district energy systems the allocation of emission to the power and heat fraction of CHP plants may be necessary. It is recommended to apply a consistent method to allocate GHG emissions from CHP systems in the case. The so-called "efficiency approach" ("eta") is derived from the EU CHP Directive and sets the individual efficiencies for electricity and heat in relation to the sum of both efficiencies. The total emissions are divided according to the two quotients:

$$Share_{el} = \frac{eta_{th}}{(eta_{th} + eta_{el})}$$ Equation (13)

For an approximation efficiency values for power and heat generation provided in Annex 5 can be used:

	eta_{th}	eta_{el}	$Share_{el}$	$Share_{th}$
Default calculation steam turbine	80%	45%	64%	36%
Default calculation gas turbine	92%	42%	69%	31%

Default calculation reciprocal turbine	90%	49%	65%	35%
Default calculation microturbine turbine	92%	62%	60%	40%
Average			**64%**	**36%**

Leakage emission district heating

Leakage emissions are calculated as follows:

$$LE_y = LE_{EL,y} + LE_{FS,y} \quad \text{Equation (14)}$$

Where:

LE_y	=	Leakage emissions in the year *y*, (tCO_2e)
$LE_{EL,y}$	=	Leakage emissions from the decrease in the electricity supply to the grid during the year *y*, (tCO_2e)
$LE_{FS,y}$	=	Leakage emissions from fuel switch during the year *y*, (tCO_2e)

Leakage due to decrease in electricity supply to the grid from the power plant: The decrease in the electricity supply to the grid, as a consequence of the project activity may result in an increase in the electricity supply from other power plants connected to the grid and their related emissions. In this case, leakage emissions are to be accounted for as per the equation below:

$$LE_{EL,y} = max\left(\left(EG_{min,hist} - EG_{PA,y}\right), 0\right) \times max\left(\left(EF_{grid} - EF_{BL,EL}\right), 0\right) \quad \text{Equation (15)}$$

Where:

$LE_{EL,y}$	=	Leakage emissions from the decrease in the electricity supply to the grid during the year *y*, (tCO_2e)
$EG_{min,hist}$	=	Minimum historic annual amount of electricity supplied to the grid over the three most recent years prior to the start of the project activity, (MWh)
$EG_{PA,y}$	=	Monitored actual quantity of electricity supplied by the project activity to the grid in the year *y*, (MWh)
EF_{grid}	=	Emission factor of the electricity grid system (tCO_2/MWh)
$EF_{BL,EL}$	=	Baseline emission factor for the electricity production, as calculated in the baseline emissions section (tCO_2/MWh)

EF_{grid} shall be i) derived from national values published by designated authorities, e.g. Ministry of Energy, or be calculated using the latest version of the CDM "Tool to calculate the emission factor for an electricity system", if no official grid emission factor is available.

Leakage due to fuel switch: No calculation of leakage effect is required for project activities using the same fossil fuel type in the project activity (power plant and centralized boiler) and in the heat-only boilers of baseline scenario.

In cases, where the fossil fuel used in the project activity and IESs in baseline scenario are different, upstream emissions associated with the fuel extraction, processing, liquefaction, transportation, re-gasification and distribution of fossil fuels may be significant and may need to be considered as part of leakage emissions $LE_{FS,y}$. This Leakage may include mainly (i) fugitive CH_4 emissions; (ii) CO_2 emissions from the process of CO_2 removal from the raw natural gas stream in order to upgrade the natural gas to the required market conditions; and (iii) CO_2 emissions from associated fuel combustion and flaring. For determining this leakage please refer to the latest version of the CDM TOOL 15 “Upstream leakage emissions associated with fossil fuel use”[18].

Key parameters for district heating systems

Monitoring parameters:

Data / Parameter:	Q_y
Data Unit:	GJ or GWh_{heat}
Description:	Quantity of heat supplied by heat sources / substation. Sub-station are heat distribution nodes of the DES network.
Source of data	On-site measurements of heat meter at supply side of any heat source / substation. If data of individual heat substation in the delivery point (e.g. building) are available use those, otherwise aggregated / group heat substation.
Measurement criteria / means of measurement	Hourly measurement of supply and return flow temperatures and water flow in m^3 /h (for hourly measurements). This parameter should be determined as the difference of the enthalpy of the process heat (steam or hot water) supplied minus the enthalpy of the feed-water, the boiler blow-down and any condensate return to the heat generators. The respective enthalpies should be determined based on the mass (or volume) flows, the temperatures and, in case of superheated steam, the pressure. Steam tables or appropriate thermodynamic equations may be used to calculate the enthalpy as a function of temperature and pressure
Monitoring frequency:	Measured / Calculated based on continuously monitored data and aggregated as appropriate; registered for the project at least on an annual basis

[18] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-15-v2.0.pdf/history_view

QA/QC procedures:	The meter readings at sub-stations should be crosschecked against the meter readings of the point of heat supply (plants output) as well as against primary fuel / energy input (e.g. purchased fuel and payment invoices for purchased fuel - $FC_{n,I,t}$) to ensure that the heat records are plausible and reliable. Moreover, the corresponding meters have to be subject to regular maintenance in order to ensure measurements with a low degree of uncertainty. Data to be stored electronically (database).
Comment:	All heat supplied to final consumers should be measured at sub-stations as part of the MRV / monitoring plan. For this purpose, each sub-station should have a unique identifier.

Data / Parameter:	$EG_{PJ,y}$
Data Unit:	MWh/a
Description:	Monitored actual quantity of electricity supplied to the grid in the year *y*, (MWh)
Source of data	Electricity meter(s)
Measurement criteria / means of measurement	Measurements are undertaken using energy meters. If applicable, measurement results shall be cross checked with records for sold/purchased electricity (e.g. invoices/receipts)
Monitoring frequency:	Continuous monitoring, hourly measurement and at least monthly recording
QA/QC procedures:	The meter readings should be cross-checked against invoices. Moreover, the corresponding meters have to be subject to regular maintenance in order to ensure measurements with a low degree of uncertainty. Data to be stored electronically (database)
Comment:	-

Data / Parameter:	$FC_{n,i,t}$
Data Unit:	Mass or volume unit at reference conditions per year (in m^3, tonne or l)
Description:	Quantity of fossil fuel type *i* fired in the plants providing heat to the DES in the time period *t*
Source of data	Onsite measurements

Measurement criteria / means of measurement	Use either mass or volume meters, including energy content defined by fuel supplier. In cases where fuel is supplied from small daily tanks, rulers can be used to determine mass or volume of the fuel consumed, with the following conditions: The ruler gauge must be part of the daily tank and calibrated at least once a year and have a book of control for recording the measurements (on a daily basis or per shift); Accessories such as transducers, sonar and piezoelectronic devices are accepted if they are properly calibrated with the ruler gauge and receiving a maintenance per supplier specifications; In case of daily tanks with pre-heaters for heavy oil, the calibration will be made with the system at typical operational conditions
Monitoring frequency:	Continuously, aggregated at least annually
QA/QC procedures:	The consistency of metered fuel consumption quantities should be cross-checked with an annual energy balance that is based on purchased quantities and stock changes.
Comment:	-

The following Data and parameters are relevant for the emission reduction calculation, but only need to be determined once, for the assessment period. A continuous monitoring is not required:

Data / Parameter:	$EF_{BL,EG}$, $EF_{BL,HG}$, $EF_{BL,HG,m}$
Data Unit:	tCO_2/GJ
Description:	CO_2 emission factor of the fuel used in baseline power plant(s). CO_2 emission factor of fuel used in the operating heat generation facility *m*
Source of data	The following data sources may be used if the relevant conditions apply:

Data source	**Conditions for using the data source**
(a) Values provided by the fuel supplier in invoices or contract	This is the preferred source
(b) Measurements by the project participants	If (a) is not available
(c) Regional or national default values	If (b) is not available These sources can only be used for liquid fuels and should be based on well-documented, reliable sources (such as national energy balances)

	(d) IPCC default values at the lower limit of the uncertainty at a 95 per cent confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories	If (c) is not available
Measurement criteria / means of measurement	For (a) and (b): Measurements should be undertaken in line with national or international fuel standards	
Comment:	For (a): if the fuel supplier does provide the NCV value and the CO_2 emission factor on the invoice and these two values are based on measurements for this specific fuel, this CO_2 factor should be used. If another source for the CO_2 emission factor is used or no CO_2 emission factor is provided, options (b), (c) or (d) should be used	

Data / Parameter:	$EG_{BL,f,j}$
Data Unit:	MWh
Description:	Maximum amount of electricity that would have been generated in the baseline by technology/source j in and supplied to the recipient facility(ies)
Source of data Measurement criteria / means of measurement	Historical records
Comment:	Appropriate meter for the existing recipient facility(ies)

Data / Parameter:	$HG_{m,y}$
Data Unit:	GJ
Description:	Heat supplied by the heat generation facility m within the heat network in year y
Source of data Measurement criteria / means of measurement	Historical records
Comment:	This parameter is used to calculate emissions due to historical use of heat

Data / Parameter:	$HG_{BL,HG,k}$
Data Unit:	GJ

Description:	Maximum amount of heat that would have been generated in a baseline by technology k
Source of data Measurement criteria / means of measurement	Historical records
Comment:	This parameter is used to calculate emissions due to historical use of heat

Data / Parameter:	$COEF_{BL,HG,j}$
Data Unit:	tCO_2/GJ fuel
Description:	CO_2 emission factor of the fossil fuel used in baseline IES *j*
Source of data Measurement criteria / means of measurement	The following data sources may be used if the relevant conditions apply: (see table below)
Comment:	Once during the first year of the project For (a) and (b) measurements should be undertaken in line with national or international fuel standards

Data sources	Condition for using the data sources
(a) Values provided by the fuel supplier in invoices	This is the preferred source
(b) Measurements by the project participants	If (a) is not available
(c) Regional or national default values	If (a) and (b) are not available
(d) IPCC default average values as provided in table 1.4 of Chapter 1 of vol. 2 (Energy) of 2006 IPCC Guidelines on National GHG Inventories	If other options are not available

Data / Parameter:	$\varepsilon_{BL,HG,j}$
Data Unit:	%
Description:	Energy efficiency of the heat generation in IES *j*
Source of data Measurement criteria / means of measurement	Derive a representative benchmark (e.g. literature, statistics or of sample measurements) of $\varepsilon_{BL,HG}$ for categories of similar boiler types (e.g. for new gas-fired boilers) at the project site prior to the implementation of the project activity or at other sites with comparable circumstances. Alternative use manufacturer data or default values as presented Annex 2.
Comment:	-

Data / Parameter:	$\eta_{BL,EL}$
Data Unit:	%
Description:	Efficiency of the power plant used prior to the start of the implementation of the project activity
Source of data Measurement criteria / means of measurement	Can be either measured according to the manufacturers' procedures to measure efficiency at the commissioning or the plant; or taken from the manufacturer's specification of efficiency at optimum load; alternatively default values as provided in Annex 2.
Comment:	Efficiency is on NCV basis

<table>
<tr><td>Data / Parameter:</td><td>$NCV_{BL,i}$ / $NCV_{DES,i}$ - Net calorific value of fossil fuel consumed by baseline/project</td></tr>
<tr><td>Data Unit:</td><td>TJ/mass or volume units of fuel in year y</td></tr>
<tr><td>Description:</td><td>Net calorific value of fossil fuel consumed by baseline/project category i</td></tr>
<tr><td>Source of data
Measurement criteria / means of measurement</td><td>The following data sources may be used if the relevant conditions apply:
<table>
<tr><th></th><th>Data source</th><th>Conditions for using the data source</th></tr>
<tr><td>(a)</td><td>Values provided by the fuel supplier</td><td>This is the preferred source if the carbon fraction of the fuel is not provided</td></tr>
<tr><td>(b)</td><td>Measurements of a sample of fuel</td><td>If (a) is not available</td></tr>
<tr><td>(c)</td><td>Regional or national default values</td><td>If (a) is not available
This source can only be used for liquid fuels and should be based on well documented, reliable sources (such as national energy balances)</td></tr>
<tr><td>(d)</td><td>IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in Table 1.2 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories</td><td></td></tr>
</table>
For (a) and (b): measurements should be undertaken in line with national or international fuel standards</td></tr>
</table>

Frequency:	For (a) and (b): the NCV should be obtained for each fuel delivery, from which weighted average annual values should be calculated.
	For (c): review the appropriateness of the values annually.
	For (d): any future revision of the IPCC Guidelines should be taken into account

Data / Parameter:	$EG_{min,hist}$
Data Unit:	MWh
Description:	Minimum annual amount of electricity supplied by the power plant to the grid prior to the start of the project activity
Source of data Measurement criteria / means of measurement	Historic electricity generation data of last 3 years before project implementation
Comment:	-

Annex 3: GHG emission reduction from district cooling systems

The generic MRV framework for district cooling systems is based on existing methodologies adapted for the DES project situation to ensure accuracy while being practicable and feasible. The methodologies shall serve as a blueprint for the individual MRV Plans adapted to project / city activities. Procedures for district heating can be found in Annex 2, and for tri-generation in Annex 4.

Table 15: Overview of relevant accounting and reporting methodologies for district cooling

DES Project Type	Standard	Methodology	Description	Important monitoring parameters
General	GHGP	The GHG Protocol for Project Accounting	Provides specific principles, concepts, and methods for quantifying and reporting GHG reductions from climate change mitigation projects	General procedures only.
	GHGP	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories	Accounting and Reporting Standard for Cities	General procedures only
District cooling	UNFCCC / CDM	AM0084: Installation of cogeneration system supplying electricity and chilled water to new and existing consumers	Installation of a new cogeneration plant producing chilled water and electricity.	Electricity generated and consumed by the project; Chilled water generated by the project.
	UNFCCC / CDM	AM0117: Introduction of a new district cooling system	Introduction of a district cooling system supplying coolant from a new cooling plant(s). It replaces baseline cooling technologies.	Average flow rate (integrated over the year) of new district cooling plant; Number of the operating hours of the new district cooling plant.

Source: Own analysis based on methodology analysis (not exhausted)

The proposed procedures follow mainly CDM methodology AM0117. However, where possible and feasible simplification is suggested.

Baseline and baseline emissions district cooling

Baseline emissions are estimated using one of the two approaches below. The choice of the approach is determined by the technology used by the baseline installation, which is determined by a benchmarking approach.

The benchmark boundary is a city where the project activity is located. In addition to the cooling installation that to be replaced by the project activity, the benchmark boundary shall cover the cooling installations that would continue providing cooling after the project implementation. The cooling output of the cooling installations that would continue providing cooling after the project implementation shall be at least equal to the cooling output of the project activity. To meet this requirement, the benchmark boundary can be expanded to another city with the similar climatic conditions. For example, in case the project activity is to supply coolant to a greenfield settlement, where no existing cooling installation could be identified, the expansion of the boundary is deemed required. The expansion of the benchmark boundary shall be justified in the MP and validated. New buildings shall be included in the benchmark determination. For this purpose, new buildings are assumed to be existent before the start of the project and use the best available technology (BAT) in a host country.

For the benchmarks, a **seasonal energy efficiency ratio (SEER)** is determined for the existing installations included in the benchmark boundary using one of the two options[19] below.

Option	Existing installation	New installation (greenfield buildings
1	Directly from manufacturer of the baseline cooling technology (preferred).	
2	SEER of the best available technology (BAT) in a host country for a building with the same function (e.g. office, apartments) and similar gross floor area (GFA), i.e. in the range from 50 % to 150 % of the baseline building GFA.	SEER of the (BAT) in a host country for a building with the same function (e.g. office, apartments) and similar gross floor area (GFA), i.e. in the range from 50 % to 150 % of the baseline building GFA.

For the **SEER Benchmark determination**, the following steps shall be applied:

1. Rank all installations included in the benchmark boundary in order of decreasing SEER;
2. Plot the SEER values (y axis) as a function of the cumulative cooling output (x-axis);
3. Identify the benchmark installation that corresponds to at least 80% of the cumulative cooling output;
4. Match the value of the benchmark SEER that corresponds to at least 80% of the cumulative cooling output determined in step 3 above.

Baseline emissions

Approach 1. The benchmark installation is using electricity driven technology. Baseline emissions (BE_y) shall be determined by applying following equation.

$$BE_{EC,y} = \sum_{j} Q_{B,y} \times EF_{EF,k,y} \times (1 + TDL_{j,y})$$ Equation (16)

[19] Could also be calculated based on cooling output energy and energy input

Where:

$BE_{EC,y}$	=	Baseline emissions from electricity consumption in year y (tCO_2/yr)
$Q_{B,y}$	=	Quantity of electricity that would be consumed by the baseline electricity consumer j in year y (MWh/yr)
$EF_{EF,j,y}$	=	Emission factor for electricity generation for source j in year y (tCO_2/MWh)
$TDL_{j,y}$	=	Average technical transmission and distribution losses for providing electricity to source j in year y

The emission factors for electricity generation ($EF_{EL,j,y}$) depends on the baseline situation, i.e. if electricity consumption is meet with electricity a) from the grid b) from off-grid fossil fuel fired captive power plant(s) or c) from both. For power from the grid, the grid emission factor (EF_{grid}) is calculated using the latest version of the CDM "Tool to calculate the emission factor for an electricity system", if no official grid emission factor is available. For captive power generation conservative default values can be applied, as provided in Annex 5.

Approach 2. The benchmark installation is using absorption technology. Baseline emissions shall be determined as follows:

$$BE_y = \frac{Q_{B,y}}{3600} \times EF_{FF,y} \qquad \text{Equation (17)}$$

Where:

BE_y	=	Baseline emissions in year *y* (tCO_2e/yr)
$Q_{B,y}$	=	Quantity of energy consumed in baseline by baseline cooling technologies in year *y* (MWh/yr)
$EF_{FF,y}$	=	CO_2 emission factor of the least carbon intensive energy source used in the absorption baseline technology (tCO_2e/GJ)

The **quantity of energy consumption of baseline cooling technologies** is determined as follows:

$$Q_{B,y} = \sum_{r} C_{P,r,y} \times SEER_B \qquad \text{Equation (18)}$$

Where:

$Q_{B,y}$	=	Quantity of energy consumed in baseline by baseline cooling technologies in year *y* (MWh/yr)

$C_{P,r,y}$ = Cooling output of new district cooling plant *r* in year *y* (MWh/yr)

$SEER_B$ = The benchmark Seasonal Energy Efficiency Ratio of the baseline cooling technology

The **cooling output, $C_{P,r,y}$, of the new district cooling plant** can be obtained as follows:

Option 1: Direct measurement of the cooling energy (e.g. MWh_{th}), or

Option 2: Calculated based on measurements of temperature differences, flow rate of chilled water and system operating hours per year:

$$C_{P,r,y} = c_P \times F_{r,y} \times \Delta T_{r,y} \times h_{r,y} \times 3.6 \times 10^9$$ Equation (19)

Where:

$F_{r,y}$ = Average flow rate (integrated over the year) of new district cooling plant r in year *y* (g/hour)

$\Delta T_{r,y}$ = Temperature difference between supply and return of chilled water from/to new district cooling plant r in year *y* (°C)

$h_{r,y}$ = Number of the operating hours of the new district cooling plant r in year *y* (hours)

c_P = Specific heat capacity of coolant (J/g))

Project emissions district cooling

Project emissions (PE_y) include emissions from energy consumption associated with the generation of cooling output in the new district cooling plant(s).

$$PE_y = PE_{EC,y} + PE_{FC,j,y}$$ Equation (20)

Where:

PE_y = Project emissions in year *y* (tCO_2e/yr)

$PE_{EC,y}$ = Emissions from electricity consumption associated with the generation of cooling output in the new district cooling plant(s) (tCO_2e/yr)

$PE_{FC,j,y}$ = CO2 emissions from fossil fuel combustion associated with the generation of cooling output in the new district cooling plant(s) (tCO_2e/yr)

The project emissions from consumption of electricity by the project activity ($PE_{EC,y}$) is calculated as follows.

$$PE_{EC,y} = \sum_j EC_{PJ,j,y} \times EF_{EF,j,y} \times (1 + TDL_{j,y})$$ Equation (21)

Where:

$PE_{EC,y}$	=	Project emissions from electricity consumption in year y (tCO_2/yr)
$EC_{PJ,j,y}$	=	Quantity of electricity consumed by the project electricity consumption source j in year y (MWh/yr)
$EF_{EF,j,y}$	=	Emission factor for electricity generation for source j in year y (tCO_2/MWh)
$TDL_{j,y}$	=	Average technical transmission and distribution losses for providing electricity to source j in year y

The emission factors for electricity consumed ($EF_{EL,j,y}$) depends on the power supply, i.e. if electricity sourced a) from the grid or b) from off-grid fossil fuel fired captive power plant(s) or c) from both. For power from the grid, the grid emission factor (EF_{grid}) is calculated using the latest version of the CDM "Tool to calculate the emission factor for an electricity system", if no official grid emission factor is available. For captive power generation conservative default values can be applied, as provided in Annex 5.

The project emissions from fossil fuel combustion by the DES project ($PE_{FC,j,y}$) shall be calculated equivalent to the project emission for district heating systems as presented in Annex 2 above.

Leakage emission district cooling

Leakage emissions from refrigerant leakage emissions are calculated as follows:

$$LE_y = LE_{Ref,y} + LE_{Ref,sc}$$ Equation (22)

Where:

LE_y	=	Leakage emissions in year *y* (tCO_2/yr)
$LE_{Ref,y}$	=	Refrigerant leakage emissions from the project in year *y* (tCO_2)
$LE_{Ref,sc}$	=	Refrigerant leakage emissions from the baseline cooling equipment that is scrapped as a result of the project activity (only accounted in the first year of the crediting period) (tCO_2)

Emissions due to the **refrigerants leakage** during the project activity is calculated as:

$$LE_{Ref,y} = \sum_{k} R_{k,y} \times GWP_k$$ Equation (23)

Where:

$LE_{Ref,y}$	=	Refrigerant leakage emissions from the project in year *y* (tCO_2)
$R_{k,y}$	=	Average annual quantity of refrigerant k used in the district cooling system in year y to replace refrigerant that has leaked in the same year (tonnes/year)
GWP_k	=	Global Warming Potential of the refrigerant k

Emissions due to the refrigerant leakage from the baseline cooling equipment that is scrapped as a result of the project activity are calculated (only for the first year of the crediting period) as below:

$$LE_{Ref,SC} = \sum_{z} R_z \times GWP_z$$ Equation (24)

Where:

$LE_{Ref,SC}$	=	Refrigerant leakage emissions from the baseline individual cooling equipment that is scrapped as a result of the project activity (tCO_2e)
R_z	=	Quantity of refrigerant z leaked from the baseline individual cooling equipment that is scrapped as a result of the project activity (tonnes)
GWP_z	=	Global Warming Potential of the refrigerant z

For determining ex-ante estimation for $R_{k,y}$ and R_z provided default factor listed in *Table 20* in Annex 5: Default factors can be used, if manufacturers data are not available. During operation inventory / operation data shall be used preferably.

Emissions due to **use of freshwater** could be additional considered in cases where freshwater is produced through desalination.

Key parameters for district cooling systems

Monitoring parameters:

Data / Parameter:	$C_{P,r,y}$
Data Unit:	MWh
Description:	Cooling output of new district cooling plant r in year *y*

Source of data	Meter
Measurement criteria / means of measurement	Based on integrated measurements by project participants based on: (a) Differential temperature of supply and return chilled water, and Chilled water flow
Monitoring frequency:	Continuous
QA/QC procedures:	Meter should be subject to regular maintenance and calibrations in order to ensure measurements with low degree of uncertainty. Data is to be stored electronically
Comment:	This parameter has to be monitored if the option 1 is chosen to determine the cooling output of the new district cooling plant

Data / Parameter:	$F_{r,y}$
Data Unit:	g/hour
Description:	Average flow rate (integrated over the year) of new district cooling plant r in year y
Source of data	Meter
Measurement criteria / means of measurement	
Monitoring frequency:	Continuous
QA/QC procedures:	Meter should be subject to regular maintenance and calibrations in order to ensure measurements with low degree of uncertainty. Data is to be stored electronically
Comment:	This parameter has to be monitored if the option 2 is chosen to determine the cooling output of the new district cooling plant

Data / Parameter:	$\Delta T_{r,y}$
Data Unit:	°C
Description:	Temperature difference between supply and return of chilled water from/to new district cooling plant r in year y
Source of data	Meters
Measurement criteria / means of measurement	

Monitoring frequency:	Continuous
QA/QC procedures:	Meter should be subject to regular maintenance and calibrations Data is to be stored electronically
Comment:	This parameter has to be monitored if the option 2 is chosen to determine the cooling output of the new district cooling plant

Data / Parameter:	$h_{r,y}$
Data Unit:	hours
Description:	Number of the operating hours of the new district cooling plant r in year y
Source of data	Plant records
Measurement criteria / means of measurement	
Monitoring frequency:	Continuous
QA/QC procedures:	
Comment:	This parameter has to be monitored if the option 2 is chosen to determine the cooling output of the new district cooling plant

Data / Parameter:	$F_{r,y}$
Data Unit:	g/sec
Description:	Average flow rate (integrated over the year) of coolant new district cooling plant r in year *y*
Source of data	Flow Meter
Measurement criteria / means of measurement	Yearly average
Monitoring frequency:	Continuous
QA/QC procedures:	Meters should be subject to regular maintenance and calibrations in order to ensure measurements with low degree of uncertainty. Data is to be stored electronically
Comment:	-

Data / Parameter:	$SEER_{B,i}$
Data Unit:	-
Description:	Seasonal Energy Efficiency Ratio of the baseline cooling technology i
Source of data	From manufacturers of the baseline cooling technology
Measurement criteria / means of measurement	-
Monitoring frequency:	Every 3 years
QA/QC procedures:	-
Comment:	-

Data / Parameter:	$\boldsymbol{R_{k,y}}$
Data Unit:	Tonnes/a
Description:	Average annual quantity of refrigerant k used in year y to replace refrigerant that has leaked during the year.
Source of data	In order of preference: 1. Inventory data / records by the plant operator of refrigerant cylinders consumed in year y. 2. Manufacturers data and/or as printed on appliance label and documented in technical specifications. 3. The default value (as per Annex 5)
Measurement criteria / means of measurement	In case monitoring is applied, the inventory data should be based on inventory of refrigerant cylinders consumed in year y, e.g. the total annual amount of refrigerant ordered as indicated in purchase orders cross checked against invoices
Monitoring frequency:	Annually
QA/QC procedures:	All meters and scales will be calibrated as per manufacturers' recommendations Cross-check the quantities of refrigerants consumed with typical leakage rates of the RAC unit and with purchase records.
Comment:	-

Data / Parameter:	R_z
Data Unit:	tonnes
Description:	Quantity of refrigerant z leaked from the baseline individual cooling equipment that is scrapped as a result of the project activity
Source of data	
Measurement criteria / means of measurement	-
Monitoring frequency:	Only for the first year
QA/QC procedures:	
Comment:	-

Data / Parameter:	GWP_k, GWP_z
Data Unit:	-
Description:	Global Warming Potential of the refrigerant k and z
Source of data	Records from the plant operator
Measurement criteria / means of measurement	Intergovernmental Panel on Climate Change (IPCC)'s latest reports or any other relevant scientific body's assessment
Monitoring frequency:	
QA/QC procedures:	-
Comment:	Shall be updated according to any future COP/MOP decisions

The following Data and parameters are relevant for the emission reduction calculation, but only need to be determined once, for the assessment period. A continuous monitoring is not required:

Data / Parameter:	**Baseline cooling technologies**
Data Unit:	-
Description:	Categories grouped by type of Baseline cooling technologies used in the absence of the project. The following needs to be clearly documented for each technology for the last 3 years. If the age of the building is less than 3

	years, document the information from the start of the building's commissioning: Number of buildings in the project boundary supported by the technology Annual cooling output from the technology
Source of data Measurement criteria / means of measurement	-
Comment:	-

Data / Parameter:	$c_{P,r,y}$
Data Unit:	J/g
Description:	Specific heat capacity of coolant
Source of data Measurement criteria / means of measurement	Coolant provider or default value for water (4.2 MJ/t°C)
Comment:	-

NCV_i, and $EF_{FF,y}$, $COEF_{BL,HG,j}$ are equivalent to the parameters described for district heating systems in Annex 2 above.

Annex 4: GHG emission reduction from trigeneration

The general approach for the calculation of emissions reduction from trigeneration projects is to account for total emissions due to the production of electricity, heat and cooling before and after the implementation of the project activity. The MRV approach is based on existing methodologies and serve as a blueprint for the individual MRV Plans adapted to project / city activities. Procedures for district heating can be found in Annex 2, and for district cooling in Annex 3.

Table 16: Overview of relevant accounting and reporting methodologies for trigeneration

DES Project Type	Standard	Methodology	Description	Important monitoring parameters
General	GHGP	The GHG Protocol for Project Accounting	Provides specific principles, concepts, and methods for quantifying and reporting GHG reductions from climate change mitigation projects	General procedures only.
	GHGP	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories	Accounting and Reporting Standard for Cities	General procedures only
Tri-generation	UNFCCC / CDM	AM0076: Implementation of fossil fuel trigeneration systems in existing industrial facilities"	Installation of an on-site fossil-fuel-based trigeneration plant to supply electricity, steam and chilled water to an industrial facility.	Electricity produced/ purchased/ sold by the trigeneration plant; Quantity of fuels used in the trigeneration plant; Quantity, temperature and pressure of steam produced by the trigeneration plant; Quantity and temperature of chilled water produced by the trigeneration plant.
	UNFCCC / CDM	AMS-II.K.: Installation of co-generation or tri-generation systems supplying energy to commercial buildings	Installation of fossil-fuel-based cogeneration or trigeneration systems. Generated electricity and cooling, and/or heating are supplied to commercial, non-industrial buildings.	Amount of grid and/or captive power supplied by the project; Amount of cooling and/or heating energy supplied by the project

Source: Own analysis based on methodology analysis (not exhausted)

The proposed procedures follow mainly CDM methodology AMS-II.K. However, where possible and feasible simplification is suggested.

Baseline and baseline emissions trigeneration

The baseline scenario for baseline emission calculations shall depend on: (a) the source of electricity; and (b) the technology that would have been used to produce heating and/or cooling, in the absence of the project activity. The following baseline options are considered:

(a) Electricity is imported from the grid and/or produced in an onsite captive power plant;

(b) Cooling (e.g. chilled water) is produced in a vapour compression system driven by electricity;

(c) Heating (e.g. hot water or steam) is produced using fossil fuel or electricity.

In cases of the installation of new trigeneration system, a reference plant shall be defined as the baseline scenario. The reference plant shall be based on common practice for similar capacity, new heating and cooling systems and sources of electricity in the same sector (e.g. commercial, residential) and in the same benchmark boundary (city).

The baseline emissions, BE_y, are calculated using the following equation:

$$BE_y = BE_{grid,y} + BE_{capt,y} + BE_{BC,y} + BE_{BH,y} \quad \text{Equation (25)}$$

Where:

$BE_{grid,y}$	Baseline emissions associated with the grid electricity displaced by the project in year *y* (tCO_2e/year)
$BE_{capt,y}$	Baseline emissions associated with the electricity produced by a captive power plant in year *y* (tCO_2e/year)
$BE_{BC,y}$	Baseline emissions associated with the cooling (e.g. chilled water) produced in year *y* (tCO_2e/year)
$BE_{BH,y}$	Baseline emissions associated with the heat (e.g. steam or hot water) produced in year *y* (tCO_2e/year)

Baseline electricity related emissions are calculated as follows:

(a) If the project activity displaces electricity that was previously obtained from the grid or would have been obtained from the grid, the baseline emissions include the CO_2 emissions of the power plants connected to the grid. The baseline emissions ($BE_{grid,y}$) are calculated based on the amount of grid electricity displaced by the project activity times the emission factor of the grid.

$$BE_y = EG_{PJ,y} \times EF_{grid,y} \quad \text{Equation (26)}$$

Where:

BE_y	=	Baseline emissions in year *y* ($t\ CO_2$)
$EG_{PJ,y}$	=	Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the project in year *y* (MWh)
$EF_{grid,y}$	=	Grid emission factor for grid connected power generation in year *y* (tCO_2/MWh)

(b) If the project activity displaces electricity that was previously obtained from captive power plant(s), the baseline emissions ($BE_{capt,y}$) include the CO_2 emissions calculated based on the amount of captive power plant electricity displaced by the project activity times the emission factor of the captive power plant(s) calculated:

$$BE_{capt,y} = \sum_i EG_{PA,y} \times EF_{BL,EL}$$ Equation (27)

Where:

$BE_{capt,y}$	Baseline emissions for the amount of electricity displaced by the captive power plants in year *y* (tCO_2e/year)
$EG_{PA,y}$	Amount of electricity displaced by project in year *y* (MWh_e) from captive power plant *i*
$EF_{BL,EF}$	Baseline emission factor for the electricity generation, (tCO_2/MWh)

The emission factor of each captive power plant ($EF_{BL,EF}$) is calculated according to the procedures described for **Baseline emissions from the power generation** in the district heating section (see Equation 9).

In case the trigeneration project displaces electricity from a captive power plant as well as from the grid, then the weighted average emission factor for the displaced electricity is calculated using values based on the relative historical, prior three year ratios of electricity from captive plants and the grid. For new facilities, the most conservative (lowest) emission factor of the two power sources should be used.

Baseline emissions associated with the electricity consumed, whether it is from captive power plants and/or power from the grid, **to produce chilled water** within the project boundary are determined per the follwoing equation.

$$BE_{BC,y} = EF_{EL} \times \sum_i \frac{C_{P,i,y}}{COP_{c,i}}$$ Equation (28)

Where:

$BE_{BC,y}$	Baseline emissions for chilled water produced in the project activity in year *y* (tCO_2e/year)
EF_{EL}	Electricity emission factor of the grid and/or of the captive plant(s), calculated as described above
$COP_{c,i}$	The Coefficient of Performance (COP) of the baseline scenario chiller(s) *i* (MWh_{th}/MWh_e). The COP is defined as 'cooling output divided by electricity input'
$C_{p,i,y}$	Cooling output of baseline scenario chiller(s) *i* in year *y* (MWh_{th}/year)

The **baseline scenario chiller COP** is determined as follow:

a) If the baseline scenario is an existing chiller or chillers, then the COP shall be based on existing chiller performance data from last three years. In the case where multiple chillers exist, average performance data shall be used in a conservative manner with consideration of the historic output and power consumption of each chiller;
b) If the baseline scenario is a chiller or chillers that would have been built (i.e. not existing chillers), the COP shall be determined as the highest COP full load performance value provided by two or more manufacturers for chillers commonly sold in the country for the indicated (commercial) application.

The **cooling output of each baseline scenario chiller** i (in MWh_{th}/year) is calculated using measured values of the total chilled water mass flow-rate and of the differential temperature of incoming and outgoing chilled water; as recorded on an hourly basis equivalent to Equation 14 on the cooling output, $C_{P,r,y}$, of the new district cooling plant.

For **trigeneration projects replacing baseline IES for steam / hot water generating (e.g. boiler)**, that use fossil fuel the baseline emissions are based on the equivalent amount of fuel that would have been used in the absence of the project activity. Please refer to the equivalent procedures on **Baseline emissions from heat generation** in Annex 2 and the approach in Equation 3.

Project emissions trigeneration

Project emissions, $PE_{trig,y}$ account for emissions due to the production of electricity, heat and cooling due to the combustion of fossil fuels in the trigeneration system. The project emissions from fossil fuel combustion by the DES project ($PE_{FC,j,y}$) shall be calculated **equivalent to the project emission for district heating systems** as presented above in Annex 2.

Leakage emission trigeneration

Leakage emission account for emissions associated with any refrigerants used in new project cooling equipment (e.g. electrical compression chillers which are an integral part of a tri-generation system or in the case of a new facility where electrical compression chillers are used as a backup). Leakage emissions from refrigerant leakage are determined equivalent to the procedures presented for district cooling in Annex 3.

Key parameters for trigeneration systems

Monitoring parameters:

Data / Parameter:	Q_y
Data Unit:	GJ or GWh_{heat}
Description:	Quantity of heat supplied by heat sources / substation. Sub-station are heat distribution nodes of the DES network.
Source of data	On-site measurements of heat meter at supply side of any heat source / substation. If data of individual heat substation in the delivery point (e.g. building) are available use those, otherwise aggregated / group heat substation.
Measurement criteria / means of measurement	Hourly measurement of supply and return flow temperatures and water flow in m^3 /h (for hourly measurements).

	This parameter should be determined as the difference of the enthalpy of the process heat (steam or hot water) supplied minus the enthalpy of the feed-water, the boiler blow-down and any condensate return to the heat generators. The respective enthalpies should be determined based on the mass (or volume) flows, the temperatures and, in case of superheated steam, the pressure. Steam tables or appropriate thermodynamic equations may be used to calculate the enthalpy as a function of temperature and pressure
Monitoring frequency:	Measured / Calculated based on continuously monitored data and aggregated as appropriate; registered for the project at least on an annual basis
QA/QC procedures:	The meter readings at sub-stations should be crosschecked against the meter readings of the point of heat supply (plants output) as well as against primary fuel / energy input (e.g. purchased fuel and payment invoices for purchased fuel - $FC_{n,i,t}$) to ensure that the heat records are plausible and reliable. Moreover, the corresponding meters have to be subject to regular maintenance in order to ensure measurements with a low degree of uncertainty. Data to be stored electronically (database).
Comment:	All heat supplied to final consumers should be measured at sub-stations as part of the MRV / monitoring plan. For this purpose, each sub-station should have a unique identifier.

Data / Parameter:	$EG_{PJ,y}$
Data Unit:	MWh/a
Description:	Monitored actual quantity of electricity supplied to the grid in the year *y*, (MWh)
Source of data	Electricity meter(s)
Measurement criteria / means of measurement	Measurements are undertaken using energy meters. If applicable, measurement results shall be cross checked with records for sold/purchased electricity (e.g. invoices/receipts)
Monitoring frequency:	Continuous monitoring, hourly measurement and at least monthly recording
QA/QC procedures:	The meter readings should be cross-checked against invoices. Moreover, the corresponding meters have to be subject to regular maintenance in order to ensure measurements with a low degree of uncertainty. Data to be stored electronically (database)
Comment:	-

Data / Parameter:	$FC_{n,i,t}$
Data Unit:	Mass or volume unit at reference conditions per year (in m^3, tonne or l)
Description:	Quantity of fossil fuel type *i* fired in the plants providing heat to the DES in the time period *t*
Source of data	Onsite measurements
Measurement criteria / means of measurement	Use either mass or volume meters, including energy content defined by fuel supplier. In cases where fuel is supplied from small daily tanks, rulers can be used to determine mass or volume of the fuel consumed, with the following conditions: The ruler gauge must be part of the daily tank and calibrated at least once a year and have a book of control for recording the measurements (on a daily basis or per shift); Accessories such as transducers, sonar and piezoelectronic devices are accepted if they are properly calibrated with the ruler gauge and receiving a maintenance per supplier specifications; In case of daily tanks with pre-heaters for heavy oil, the calibration will be made with the system at typical operational conditions
Monitoring frequency:	Continuously, aggregated at least annually
QA/QC procedures:	The consistency of metered fuel consumption quantities should be cross-checked with an annual energy balance that is based on purchased quantities and stock changes.
Comment:	-

$C_{P,r,y}$ and corresponding parameters are to be equivalently applied as presented for district cooling systems above in Annex 3.

The following Data and parameters are relevant for the emission reduction calculation, but only need to be determined once, for the assessment period. A continuous monitoring is not required:

NCV_i, and $EF_{FF,y}$, $COEF_{BL,HG,j}$ are equivalent to the parameters described for district heating systems above in Annex 2.

Annex 5: Default factors

Table 17: Default efficiency for thermal applications

Technology of the energy generation system	Default efficiency
New natural gas fired boiler (w/o condenser)	92%
New oil fired boiler	90%
Old natural gas fired boiler (w/o condenser)	87%
New biomass fired boiler (on dry biomass basis)	85%
Old oil fired boiler	85%
Old biomass fired boiler (on dry biomass basis)	80%
Old coal fired boiler	80%
Other	100%

Source: CDM TOOL09, Methodological tool - Determining the baseline efficiency of thermal or electric energy generation systems, Version 02.0, p. 12

Table 18: Default efficiency for grid connected power plants

Grid power plant			
Generation technology	Commissioning year		
	y≤2000	2000<y≥2012	y>2012
Coal			
Subcritical	37%	39%	39%
Supercritical	-	45%	45%
Ultra-supercritical	-	50%	50%
Integrated Gasification Combined Cycle (IGCC)	-	50%	50%
Fluidised Bed Combustion (FBC)	35.5%	-	-
Circulating Fluidized Bed Combustions (CFBC)	36.5%	40%	40%
Pressurized Fluidized Bed Combustion (PFBC)	-	41.5%	45%
Oil/natural gas			
Steam turbine	37.5%	39%	44%
Reciprocal gas engine	33%	40%	48.5%
Open cycle gas turbine	30%	39.5%	42%
Combined cycle gas turbine	46%	60%	62%
Biomass[16]			
IGCC	40%		
Other	35%		
Cogeneration[20]			
Steam turbine	83.5%		
Gas turbine	78.8%		
Reciprocal engine	88.8%		
Mircoturbine (up to 500kW)	77.7%		

Source: CDM TOOL09, Methodological tool - Determining the baseline efficiency of thermal or electric energy generation systems, Version 02.0, p. 12/13

[20] The values are the overall efficiency, for electric efficiency, use the power-only default values.

Table 19: Conservative default values for emission factors (EF) for electricity consumption from an off-grid captive power plant

Baseline electricity consumption	Project or leakage electricity consumption
0.4 t CO2/MWh if: i. The electricity consumption source is a baseline electricity consumption source; or ii. The electricity consumption source is a project electricity consumption source and the electricity consumption of all baseline electricity consumptions sources at the site of the captive power plant(s) is greater than the electricity consumption of all project electricity consumption sources at the site of the captive power plant(s).	**1.3 t CO_2/MWh** if: i. The electricity consumption source is a project or leakage electricity consumption source; or ii. (ii) The electricity consumption source is a baseline electricity consumption source; and the electricity consumption of all baseline electricity consumptions sources at the site of the captive power plant(s) is less than the electricity consumption of all project electricity consumption sources at the site of the captive power plant(s)

Source: CDM TOOL05, Methodological tool - Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation, Version 03.0, p. 11

Table 20: Default parameters for Refrigeration/Air Conditioning Equipment

Type of Equipment	Charge Capacity (kg) j	Installation Emission Factor k (% of capacity)	Operating Emissions x (% of capacity/yr)	Refrigerant Remaining at Disposal y (% of capacity)	Recovery Efficiency z (% of remaining)
Domestic Refrigeration	0.05 – 0.5	0.2	0.1	80	70
Stand-alone Commercial Applications	0.2 – 6	0.5	1	80	70
Medium & Large Commercial Refrigeration	50 – 2,000	0.5	10	100	70
Industrial Refrigeration including Food Processing and Cold Storage	10 – 10,000	0.5	7	100	90
Chillers	10 – 2,000	0.2	2	100	95
Residential and Commercial A/C including Heat Pumps	0.5 – 100	0.2	5	80	80

Source: CDM TOOL28 Methodological tool -Calculation of baseline, project and leakage emissions from the use of refrigerants, Version 01.0, p.7 [21]

Table 21: Global warming potential of selected refrigerant

GWP Refrigerant					
Refrigerant type	HFC R134a	Ammonia (NH_3)	HFC R-1233zd	HFC R-1234yf	R514A (HFC-1336)
GWP_{100}	1300	-	<1	<1	2

Source: IPCC, 2013

[21] Based on Chapter 7, Volume 3, Table 7.9: Emissions of Fluorinated Substitutes for Ozone Depleting Substances, 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Annex 6: Template and structure of MRV Plan

Please use the proposed structure for preparing the MRV / monitoring plan. See also separated Word template.

1. Description of project
    1.1. Purpose and general description of DES project
    1.2. Location and technologies/measures
2. Description of monitoring approach and system
    2.1. General MRV approach
        2.1.1. Mitigation measures of district energy system
        2.1.2. Causal chain analysis: impact assessment
        2.1.3. System boundary, sources and GHGs
        2.1.4. Baseline and project scenario
    2.2. Calculations procedures for the estimation of GHG emission reductions
        2.2.1. GHG emission reduction estimation approach
        2.2.2. Ex-ante GHG emission reduction estimation
        2.2.3. Emission reduction data and parameters
            2.2.3.1. Data and parameters fixed ex ante
            2.2.3.2. Data and parameters to be monitored
    2.3. Sustainable development benefits
        2.3.1. Description how the project contributes to sustainable development
        2.3.2. Data and parameters of SD benefits
3. MRV procedures
    3.1. Institutional set-up and responsibilities
    3.2. Data recording, reporting and verification

Annex 1: List of parameters to be monitored

Key parameters for district energy systems

SD co-benefits indicators

Annex 2: Default factors applied

Annex 3: ER Calculation spreadsheet

Annex 7: Template and structure of Monitoring Report

MONITORING REPORT	
DES project activity	
Version number of this monitoring report	
Completion date of this monitoring report	
Duration of the monitoring period	
Monitoring report number	
Responsible entity and contact	
City / country	
Amount of GHG emission reductions achieved in this monitoring period	

SECTION A. Description of project activity

A.1. General description of project activity

>>

A.2. Location of project activity

>>

SECTION B. Description of monitoring approach and system

>>

B.1. Result of the impact assessment

Result of the impact assessment: All GHG and SDG impacts identified, using a causal chain, illustrating those impacts are included in the project boundary. Defined baseline scenario

SECTION C. Emission reduction data and parameters

Present values for relevant parameters for the assessment period, including assumptions and methods used.

C.1. Data and parameters fixed ex ante

(Copy this table for each data or parameter.)

Data / Parameter:	
Data Unit:	
Description:	
Source of data	
Value(s) applied	
Choice of data or measurement methods and procedures	
Purpose of data/parameter	
Comment	

C.2. Data and parameters monitored

(Copy this table for each data or parameter.)

Data / Parameter:	
Data Unit:	
Description:	
Measured/calculated/ default	
Source of data	
Value(s) of monitored parameter	
Monitoring equipment	
Measuring/reading/recording frequency	

Calculation method (if applicable)	
QA/QC procedures	
Purpose of data/parameter	
Comments	

SECTION D. Calculation of emission reductions

Estimated GHG impacts calculated for the assessment period using the measures / estimated values for each parameter. All data sources to estimate key parameters, including measurements, emission factors, GWP values and assumptions.

D.1. Calculation of baseline emissions

>>

D.2. Calculation of project emissions

>>

D.3. Calculation of leakage emissions

>>

D.4. Calculation of emission reductions

	Baseline GHG emissions (t CO_2e)	Project GHG emissions (t CO_2e)	Leakage GHG emissions (t CO_2e)	GHG emission reductions (t CO_2e)
Total				

SECTION E. Sustainable Development Benefits

Description how the project contributes to sustainable development (SD). Description and reporting of key SD indicators/paramters for the project.

E.1. Description how the project contributes to sustainable development (SD)

>>

E.2. **Data and parameters of SD benefits**

(Copy this table for each data or parameter.)

Data / Parameter:	
Data Unit:	
Description:	
Measured/calculated/ default	
Source of data	
Value(s) of monitored parameter	
Monitoring equipment	
Measuring/reading/ recording frequency	
Calculation method (if applicable)	
QA/QC procedures	
Purpose of data/parameter	
Comments	