Towards a more standardised approach to baselines and additionality under the CDM

Determining nationally appropriate performance standards and default factors

Case study I: Whole-building efficiency improvement

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Despite their high technical potential, methodological and organisational barriers have hindered the uptake of building efficiency projects under the CDM. The interaction of building efficiency measures makes it difficult to establish a clear causality between the measure and the resulting emission reductions, which has been the fundamental requirement for CDM methodologies. Also, monitoring of a series of individual measures poses a significant challenge. Furthermore, the number of CERs gained per building is often too small to justify the transaction costs. In particular, monitoring of a large number of buildings requires substantial organisational efforts, resulting in high monitoring costs and risks.

Standardised approaches can provide solutions to these problems. A methodology that evaluates the emission performance of a whole building allows a **combination of measures** and gives **wider flexibility in technology choice**. **Monitoring is streamlined** as it is performed only at the building level; monitoring of each measure is necessary. By applying a performance standard, any change in the emission level is reflected in the emission performance. Although the CDM has conventionally focused on implementation of concrete mitigation technologies (hard measures), **the performance standard also needs to work with management measures** that reduce emissions through operational improvement or behavioural changes (soft measures).

Our recommendations on the key technicalities of the standardised approaches to whole-building efficiency projects are summarised in Table 1. **A careful balance in the choice of aggregation level plays a key role,** as there are numerous factors influencing building emission performance. It is likely that a rather high degree of disaggregation is necessary for development of a performance standard. Further, the data requirements are rather heavy, and the data availability is limited in most host countries. Therefore, it is recommended that the initial efforts focus on **homogeneous, energy-intensive building unit categories** (e.g., residential) in **regions with high potential for replicability** (e.g., East Asia, South Asia, and Middle East & North Africa).

The proposed standardised approach would likely improve the environmental effectiveness, cost effectiveness, and sectoral and project-size distributions. The geographical distribution can be improved provided there is significant international support for institutional capacity building and concerted data collection. **Institutional feasibility will likely be the key concern.** Monitoring, reporting and verification of building data require extensive organisational efforts. The lack of an obvious candidate for a performance standard coordinator and the fragmented nature of the building sector add to institutional complexity. **Limited data availability and institutional capacity in most host countries need to be overcome through international support.**

Table 1: Summary of standardised approach to whole-building efficiency improvement

	Description
System boundary	Project and baseline building units, plus energy systems supplying energy to the building units.
KPI	tCO_2e per m^2 of a building unit.
Aggregation level	(1) Process: Not differentiated. (2) Product: Similar building type and size. (3) Time: New vs. existing building units. If appropriate, differentiate existing building units by building age. (4) Space: Similar climate conditions (or adjustment by heating degree days and cooling degree days), and similar level of economic development (only in areas with an advanced level of economic development).
Data requirements	Disaggregation of building units: • Building unit size, type, and age. • Climate conditions. • Economic development. Calculation of standardised baselines: • Energy consumption. • Refrigerant leakage. • Transmission & distribution loss of energy. • Emission factor for energy consumption and refrigerants leakage. • Techno-economic analysis of building efficiency measures.
Stringency level	Baseline: The mean emission level of peer building units. Additionality: The baseline level adjusted by the improvement in emission performance by non-additional measures (case-specific).
Updating frequency	Annual update.

1.1 Relevance of the sector for standardised approaches

Every year around four billion square meters are constructed worldwide (Richerzhagen et al. 2008). Approximately 30-40% of global primary energy is used in residential and public buildings. The pattern of energy use in a building is strongly related to the building type and the climate zone in which it is located. Importantly, 80-90% of the life-cycle building energy consumption occurs during the operational phase. This clearly shows the need to producing more energy-efficient buildings and renovate existing building stocks (UNEP 2007). Through mitigation measures in the residential and commercial sectors, approximately 3.2, 3.6 and 4.0 billion tCO_2e can be avoided globally from the BAU level in 2020 at zero cost, €14.5/tCO_2e and €73/tCO_2e respectively (Levine et al. 2007).[1] More than half of the mitigation potential is found in developing countries.

Despite the high theoretical potential and urgency of building efficiency improvement, the CDM has not been able to mobilise a significant volume of such projects. CDM projects in this category account for less than 1% of the overall volume of CERs to be generated by the end of 2012; 5 million CERs are expected from the building sector in the context of a total of 2,840 million CERs from all the CDM projects submitted to the UNFCCC (UNEP Risoe Center 2009).

One of the most significant barriers to efficient building design is that buildings are complex systems. Minimising energy use requires optimising the system as a whole by systematically addressing building form, orientation, envelope, glazing area and a host of interaction and control issues involving the building's mechanical and electrical systems (Levine et al. 2007). Furthermore, a combination of different measures would lead to positive (or negative, if badly designed) synergy effects. Therefore, the energy savings and costs of each measure are not additive (Thorne 2003).

Given this technical complexity, one of the key bottlenecks for building efficiency projects under the CDM is the lack of appropriate baseline and monitoring methodologies (Hayashi and Michaelowa 2007; Müller-Pelzer and Michaelowa 2005). Most of the CDM methodologies for the building sector have focused on the technology-specific approach (system-specific approach). There are only a few methodologies[2] that can accommodate holistic, integrated approaches to building efficiency improvement (whole-building approach) mainly because the interaction of measures makes it difficult to establish a clear causality between the measures and

[1] Converted from the original figures of \$20/tCO_2e and \$100/tCO_2e.

[2] These are AMS-II.E "Energy efficiency and fuel switching measures for buildings" and AMS-III.AE "Energy efficiency and renewable energy measures in new residential buildings". The former does not give detailed procedures for emission reduction calculation, so it has not been used widely. The latter is a newly approved methodology that was made available.

the resulting emission reductions. Furthermore, soft (or management) measures[3] have explicitly been excluded from the CDM since they normally do not require capital investment in a mitigation technology and so do not necessarily lead to stable, long-term emission reductions. However, soft measures are as important as deploying technological improvements in reducing building energy consumption (UNEP 2008). In addition, the amount of CERs gained per building is often too small to justify the transaction costs. In particular, monitoring a large number of buildings requires substantial organisational efforts, resulting in high monitoring costs and risks. The lack of whole-building methodologies makes it difficult to increase the financial viability of this project type as the system-specific approach yields a far smaller amount of CERs per building.

Standardised approaches can provide solutions to the above two problems, methodological and organisational barriers. A methodology that evaluates emission performance of a building (e.g., in tCO_2/m^2) would provide three main benefits:

1. **It allows a combination of measures.** The combination of measures would increase the amount of CERs per building and so improves the financial viability of a building efficiency project. Importantly, standardised baselines need to work with soft measures, as any mitigation effort will be reflected in the building emission performance.
2. **It gives wider flexibility in technology choice**. Flexible technology choice is important because building efficiency improvement typically requires a range of different, small measures suitable for specific local circumstances. Also, new measures could be installed over time (UNEP 2008).
3. **It streamlines monitoring requirements**. By using the performance-based methodology, monitoring of emission reductions will be performed at a building level, but not at an equipment level. The monitoring of whole-building emission performance inherently accommodates a complex interaction of measures, and thus avoids the challenging monitoring of the emission impact of each such interaction. In addition, the holistic monitoring approach is especially helpful for residential buildings since they usually do not have centralised control systems for appliances (e.g., lighting in a corridor) or cooling/heating devices. Hence, it is not practical to require monitoring of each measure (UNEP 2008).

The following sections explain how performance standards can be established for whole-building efficiency improvement projects. In our definition, this project category includes both energy efficiency and fuel switching measures. The following key aspects of performance standards are discussed:

- System boundary: A physical boundary for accounting for GHG emissions.
- KPI: An indicator used for comparison of emission performance of the project against peers.

[3] Soft measures include using good standard operation procedures, proper commissioning, good maintenance, optimizing operational conditions, recordkeeping, providing proper consumption information feedback, etc. (Hinostroza et al., 2007).

- Aggregation level: Criteria for identification of peers for the emission performance comparison. Four key dimensions are process, product, time, and space.
- Data requirements: Data required for the development of a performance standard, and availability of such data.
- Stringency level: The level of a performance standard for baseline emissions and/or additionality demonstration.
- Updating frequency: Required frequency for updating of a performance standard over time.

1.2 System boundary

In consideration of a system boundary, it is necessary to distinguish two possible units of analysis for the building efficiency performance: the entire building or a building unit. A building unit is a distinct space within a building allotted to a specific user. For instance, a single family home is one residential building unit while a building with ten apartments has ten residential building units. As explained in Ch. 1.4 below, building types (e.g., residential, commercial, institutional) have important impacts on building energy consumption levels. Therefore, **it is essential to distinguish buildings by type and establish a baseline for each building type.** This helps increase accuracy in estimating emission performance of buildings in a certain building category. The use of building units is especially important for regions in which mixed-use buildings are dominant. By using building units with the same function in a mixed-use building, one can homogenise the sample to be used for establishing a standardised approach. Furthermore, as compared to buildings, the use of building units increases the size of building samples for the emission reduction calculation. The larger sample size would result in a smaller penalty in adjusting the emission reductions by sampling error[4].

There is also a drawback in using the building unit approach. Energy consumption data are monitored either for individual building units or only for a whole building (it depends on the specific setup of monitoring devices for certain energy sources). In case of the latter, the energy consumption monitored at the whole building level needs to be apportioned to individual building units, e.g., in proportion to the gross floor area of the building unit.[5] Thus the apportioned energy consumption does not necessarily reflect the actual energy consumption of a building unit. This can decrease accuracy in estimating the energy performance of the building unit.

[4] If sampling is used in emission reduction calculation, CDM methodologies require a conservative adjustment of emission reductions by sampling error. For the baseline emissions, it requires the use of the lower bound of a confidence interval established for the mean estimate. On the other hand, the project emissions need to be adjusted by using the higher bound of a confidence interval for the mean estimate. As a larger sample size helps narrow the confidence interval, it will eventually lead to a smaller penalty in the emission reductions.

[5] The energy consumed in the common spaces (e.g., corridors) can also be apportioned to individual building units in proportion to the floor area of the building unit.

However, the advantage of the improved homogeneity of building samples and the larger sample size would likely outweigh this disadvantage. Therefore, **the use of building units is recommended**[6].

Emission sources for the operation of a building unit include emissions from energy consumption and refrigerant leakage. The former is related to the consumption of electricity, fuels (e.g., natural gas, coal/coke, fuel oil, propane & liquid propane, biomass), and central building/district energy (e.g., steam, hot water, chilled water). The latter is associated with the use of air conditioners and refrigerators. Furthermore, renewable-energy generating systems (e.g., a photovoltaic system) can be included as negative emission sources if the energy is supplied to other users[7]. All the emission sources that are significant, and under control of, and reasonably attributable to the project shall be included in the boundary. An emission source is commonly considered significant if it contributes more than 1% of the total baseline/project emissions (Michaelowa et al. 2007).

In sum, the system boundary for whole-building efficiency projects should include all the building units constructed by the project (project building units) and the building units monitored for the baseline calculation (baseline building units), plus the spatial extent of the energy supply systems supplying these building units (e.g., electricity grid, central building/district energy systems). Whether the emission sources listed above need to be included in the boundary depends on their significance in the project-specific conditions. Outside the boundary, significant leakage sources need to be accounted for. If biomass is used as a fuel, for instance, leakage could occur due to the diversion of biomass from other uses to the buildings constructed by the project activity[8].

1.3 Key performance indicator

Measuring energy performance per square meter is a common indicator for energy management in buildings and is suitable for project management purposes (UNEP 2008). Two such indicators are used in the analytical literature: (1) an energy use index (EUI), and (2) an energy intensity (EI). Both indicators use annual energy consumption as the numerator of a KPI. For the denominator, an EUI employs the floor area served by the fuel and end-use in question, while an EI employs the total floor area. For example, for a building unit, make the following assumptions:

- The floor area of a building unit is 150 m^2.
- The air-conditioned floor area is 100 m^2.
- Total annual electricity consumption for air-conditioning is 3,000 kWh.

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[6] AMS-III.AE "Energy efficiency and renewable energy measures in new residential buildings" indeed uses building units as the unit of analysis.

[7] If the energy is used by the building unit itself (own consumption), it will simply be considered as zero-(or low-)carbon energy consumption within the boundary.

[8] For procedures to address such leakage, see ACM0006 "Consolidated methodology for electricity generation from biomass residues".

Then the air-conditioning EI would be 20 kWh/m^2 (3,000 divided by 150), while the EUI would be 30 kWh/m^2 (3,000 divided by 100).

The EUI approach measures energy performance of a specific end-use. As the area not served by the end-use (e.g., air conditioning) is excluded from the performance calculation, it is a more accurate indicator of how efficiently the input energy is used to yield a certain output. On the other hand, the necessary measurement of service area for each end-use type adds monitoring complexity. Furthermore, the use of different units in denominator (e.g., air-conditioned area, lighted area) makes it difficult to sum up individual indicators to derive the overall specific emissions of the building unit.

The EI approach is a more straightforward approach that applies the same floor area to any energy end-use in a building unit. It does not establish as clear an input-output relationship as the EUI approach. But the simplicity and objectivity of the approach is appealing, especially in developing countries where precise data are not readily available. The EI approach can be adapted for an emission performance comparison. By using **emissions in the numerator and gross floor area (GFA) in the denominator**, the KPI is expressed as follows:

$$\text{KPI}: \frac{[\text{tCO}_2\text{e}]}{[\text{m}^2]}$$

The project emissions can be calculated as follows[9]:

$$PE_y = \sum_i \sum_j \left(PE_{EC,i,j,y} + PE_{FC,i,j,y} + PE_{CWC,i,j,y} + PE_{HWC,i,j,y} + PE_{SC,i,j,y} + PE_{ref,i,j,y} \right)$$

Where:

PE_y	=	Project emissions of project building units in year *y* (t CO_2e/yr)
$PE_{EC,i,j,y}$	=	Project emissions from electricity consumption of project building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$PE_{FC,i,j,y}$	=	Project emissions from fossil fuel consumption of project building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$PE_{CWC,i,j,y}$	=	Project emissions from chilled water consumption for space cooling of project building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$PE_{HWC,i,j,y}$	=	Project emissions from hot water consumption of project building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$PE_{SC,i,j,y}$	=	Project emissions from steam consumption for space heating of project building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$PE_{ref,i,j,y}$	=	Project emissions from the use of a refrigerant(s) in project building unit *j* in building unit category *i* in year *y* (t CO_2e/yr)

Using the KPI, the baseline emissions can be calculated as follows:

[9] For the sake of simplification, the detailed procedures for the calculation of each emission source are omitted.

$$SE_{BL,i,j,y} = \frac{BE_{i,j,y}}{GFA_{BL,i,j,y}}$$

Where:

$SE_{BL,i,j,y}$	=	Specific emissions of baseline building unit *j* in building unit category *i* in year *y*, defined as emissions per GFA in square metres per year (t CO_2e/(m^2·yr))
$BE_{i,j,y}$	=	Baseline emissions of baseline building unit *j* in building unit category *i* in year y (t CO_2e/yr)
$GFA_{BL,i,j,y}$	=	GFA of baseline building unit *j* in building unit category *i* in year *y* (m^2)

$$BE_{i,j,y} = BE_{EC,i,j,y} + BE_{FC,i,j,y} + BE_{CWC,i,j,y} + BE_{HWC,i,j,y} + BE_{SC,i,j,y} + BE_{ref,i,j,y}$$

Where:

$BE_{i,j,y}$	=	Baseline emissions of baseline building unit *j* in building unit category *i* in year *y* (t CO_2e/yr)
$BE_{EC,i,j,y}$	=	Baseline emissions from electricity consumption of baseline building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$BE_{FC,i,j,y}$	=	Baseline emissions from fossil fuel consumption of baseline building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$BE_{CWC,i,j,y}$	=	Baseline emissions from chilled water consumption for space cooling of baseline building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$BE_{HWC,i,j,y}$	=	Baseline emissions from hot water consumption of baseline building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$BE_{SC,i,j,y}$	=	Baseline emissions from steam consumption for space heating of baseline building unit *j* in building unit category *i* in year *y* (t CO_2/yr)
$BE_{ref,i,j,y}$	=	Baseline emissions from the use of a refrigerant(s) in baseline building unit *j* in building unit category *i* in year *y* (t CO_2e/yr)

Based on the specific emissions of each building unit calculated, plot a cumulative frequency curve of the specific emissions of the building units. An exemplary cumulative frequency curve is shown in Figure 1.

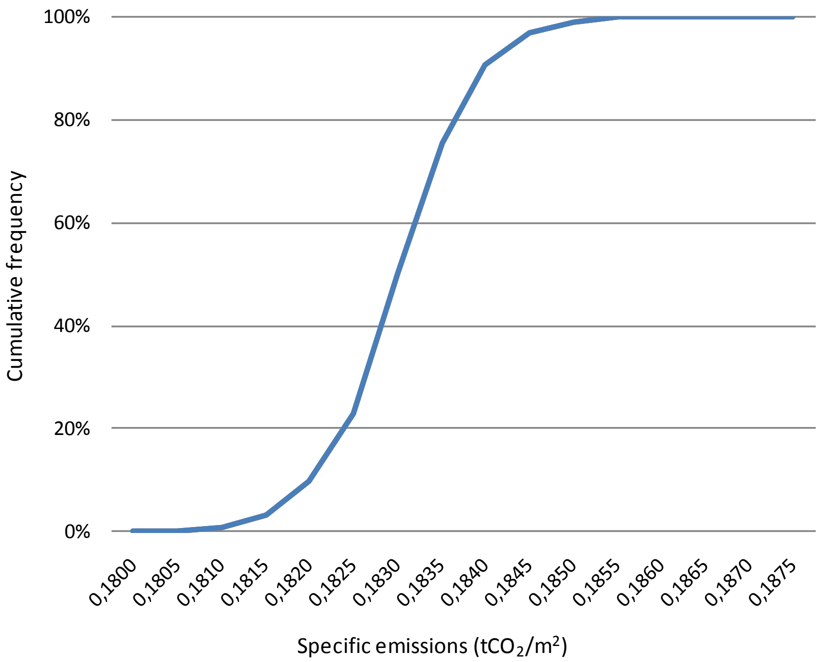


Figure 1: Cumulative frequency curve of specific emissions of building units

Note: The specific emissions figures are only indicative.

Decide on the level of stringency for the performance standard (this issue will be discussed in detail in Ch. 1.6). The chosen level of standard specific emissions ($SSE_{i,y}$) will then be multiplied by the total GFA of the project building units.

$$BE_y = \sum_i SSE_{i,y} \times GFA_{PJ,i,y}$$

Where:

BE_y	=	Baseline emissions of baseline building units in year *y* (t CO_2e/yr)
$SSE_{i,y}$	=	Standard specific emissions of building units in building unit category *i* in year *y*, defined as emissions per GFA in square metres per year (t $CO_2e/(m^2 \cdot yr)$)
$GFA_{PJ,i,y}$	=	Total GFA of project building units in building unit category *i* in year *y* (m^2)

1.4 Aggregation level

Building energy consumption patterns are largely influenced by building type and climate conditions. Furthermore, the level of economic development in the area and the building age are also influential factors (Natural Resources Canada 2003; UNEP 2007; WBCSD 2008b). There are also other factors contributing to the variations in building energy consumption patterns, such as building size, geography, demographics, the number and lifestyle of occupants, etc.

Where distinctive differences in building emission performance are observed (e.g., residential vs. commercial buildings, warm vs. cold climate), buildings need to be categorised into separate groups and a standardised approach needs to be established for each category. Therefore, adding aggregation dimensions increases the number of standardised approaches, while it generally improves the accuracy of the baselines. Given the wide range of determinants for building efficiency levels, a carefully balanced choice of aggregation level plays a key role. The following section discusses how the appropriate aggregation level should be determined for the four dimensions of aggregation.

1.4.1 Process aggregation

The process dimension asks whether standardised approaches are differentiated by technology or process. For instance, one could think of such differentiation in terms of access to certain types of energy and/or building material and technology locally available.

However, **differentiation by technology or energy type would hinder improvement of emission performance beyond the defined technology or energy category.** This would result in a weaker signal for a low-carbon development path.

Furthermore, the wide range of building materials and technologies available today makes it difficult to disaggregate standardised approaches on this basis. A more pragmatic solution would be to use a reasonably defined spatial boundary. The energy access issue can also be addressed in this manner.

1.4.2 Product aggregation

Building type

Above, we broadly defined the product as the GFA of a building unit. We also noted that building energy consumption patterns would be strongly influenced by building type. The following figure shows the influence of building type on building electricity use, taking US buildings as an example. The large variation in the electricity consumption pattern clearly shows the necessity of disaggregating standardised approaches by building type. In general, residential building units are more homogeneous in energy consumption pattern than are commercial and institutional building units. Therefore, it is easier to develop a performance standard for residential building units. Within the commercial or institutional category, some sub-categories (e.g., offices, hotels, supermarkets) are more energy consuming in absolute terms than others (e.g. hospitals, schools). Therefore, **it is recommended to target homogeneous, energy-intensive building unit categories** to ensure that the efforts towards performance standard development pay off eventually.

Table 2: Average energy intensity by building type in the US in 2003

Building type	kWh/m² year	Ratio
Dwellings	147	1
Retail	233	1.6
Schools	262	1.8
Offices	293	2
Hotels	316	2.1
Supermarkets	631	4.3
Hospitals	786	5.3
Restaurants	814	5.5

Source: EIA (2003) (cited in Pérez-Lombard et al. 2008)

The definition of building types poses an important trade-off. The more disaggregated the building types are, the more accurate a standardised approach becomes, thanks to the increased homogeneity of building efficiency patterns. However, the increased number of building types results in higher transaction costs as standardised approaches need to be established for each building type. Thus, the definition **needs to strike a balance between accuracy in emission reduction calculation and transaction costs**. As there is no consensus on a universal classification of building types, especially for non-residential buildings (Pérez-Lombard et al. 2008), it is first necessary to establish a standardised typology of buildings. A CDM methodology for whole-building efficiency projects recently submitted to the UNFCCC provides a list of building types based on the experience of several building codes and building efficiency programmes worldwide[10].

Building size

Also important is the size of a building. As building size increases, the specific energy consumption of the building often decreases thanks to economies of scale. For example, a multi-story residential building can operate a centralised air-conditioning system serving all the building units within the building. The centralised system is likely to result in a lower specific energy consumption level than, e.g., a single-family residential building. On the other hand, increased floor space does not lead to a monotonous improvement in energy intensity ratio. As the Canadian example in Figure 2 shows, building energy intensity can start increasing beyond a certain building size (Natural Resources Canada 2003).

[10] NM0328: "Energy efficiency and fuel switching measures in new buildings". Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/publicview.html?meth_ref=NM0328.

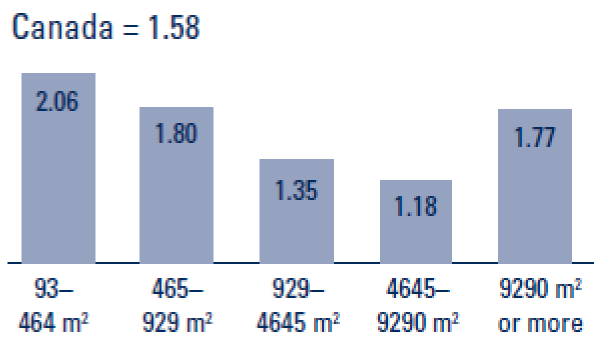


Figure 2: Energy intensity of Canadian commercial and institutional buildings by building size (GJ/m^2)

Source: Natural Resources Canada (2003)

Nonetheless, Figure 2 indicates that definition of a comparable building size is necessary to establishing a standardised approach[11]. Under the CDM, ACM0013, applicable to efficient fossil-fuel power generation projects, first defined a "similar" size as ± 50% of the size of the project power plant. This condition has been adopted in AMS-III.AE for energy efficiency and renewable energy measures in new residential buildings.

The building size can be used as a proxy for the number of occupants, which also has an important impact on the building emission performance. These two parameters are correlated – though not perfectly, as a building can be occupied by fewer people than it is designed for[12]. When deciding on the appropriate level of aggregation, it is important to keep the degree of disaggregation as low as reasonably possible because a highly disaggregated performance standard will increase transaction costs. Differentiation by the number of occupants is possible. But it would greatly increase the complexity of standardised approaches. Number of occupants is an unstable parameter as it can change frequently over time. It would thus lead to frequent reclassification of categories used for development of standardised approaches. Given the overlap between the building size and the number of occupants, and the greater stability of the former, **it is advisable to use only the building size as the basis for differentiation.**

Given the above points, it is recommended that the product be defined as **the GFA of a building unit** that serves **a specific type of building usage** and has **a comparable size** to the project building units.

[11] An argument against differentiation by building size is that economies of scale are also a means to improve building efficiency. However, a standardised baseline should not discriminate against smaller buildings. Construction of large buildings is not always possible (if there are no resources for it) or necessary (if there is no demand for it). Therefore, we consider it necessary to differentiate by building size.

[12] It is clear that unoccupied building units need to be excluded from the basis for the standardised baselines.

1.4.3 Temporal aggregation

Building age

The temporal dimension assesses the age or vintage of peers for comparison. Building age is an important factor influencing building energy performance (Natural Resources Canada 2003; WBCSD 2008b). The Canadian example in Figure 3 shows that newer buildings are more energy efficient, but does not necessarily indicate that the oldest are the least efficient (e.g., see buildings constructed before 1920). Construction standards, techniques, materials and types available around the year of construction exert a direct impact on specific energy use (Natural Resources Canada 2003).

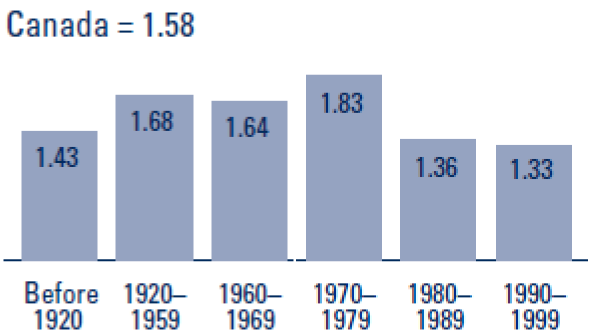


Figure 3: Energy intensity of Canadian commercial and institutional buildings by year of construction (GJ/m^2)

Source: Natural Resources Canada (2003)

As mentioned above, **an apparent need for temporal disaggregation is a distinction between new and existing buildings.** Within the existing building category, however, the causality between building age and energy performance can be obscure in some cases (e.g., the Canadian case above). Therefore, it is necessary to judge on a case-by-case basis whether such differentiation makes sense. If there is a clear relationship between the building age and efficiency, and the efficiency level of old buildings are far lower than the newer ones, it makes sense to differentiate the existing buildings by building age (i.e., a less stringent baseline for older buildings, a more stringent one for newer buildings). In such a case, establishing different levels of standardised approaches would help incentivise old buildings to improve their efficiency, while keeping the baseline for newer buildings at a reasonably stringent level.

1.4.4 Spatial aggregation

Climate conditions

The spatial dimension determines the geographical boundary in which the peers are located. As to spatial aggregation, the key determinant is climate conditions

(ASHRAE 2002). Figure 4 shows the influence of climate conditions on building energy use patterns, taking the US as an example. Obviously, heating demand is higher in colder climates, while hotter regions require more energy for cooling. Climate also strongly influences building design. For example, colder climates tend to have better air tightness and insulation. Humidity and rainfall are also important factors, as is temperature (WBCSD 2008b).

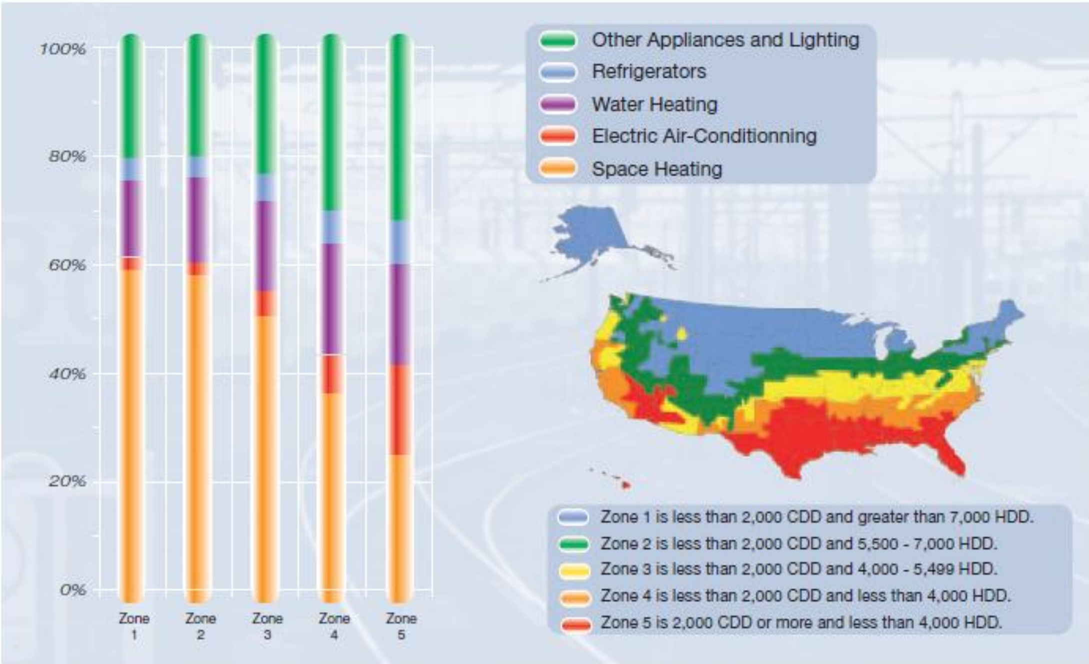


Figure 4: Energy consumption of US residential buildings by climate zone

Source: US EIA (2001) (cited in UNEP 2007)

The Köppen climate classification defines six major groups[13], which are used by organisations such as the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) (WBCSD 2008b). Spatial disaggregation by climate conditions is essential (e.g., based on the Köppen climate classification). Accordingly, **standardised approaches need to be established for each climate classification.**

However, such spatial disaggregation can be a complex exercise if the area concerned accommodates multiple climate zones. **Alternatively, a climate-neutral standardised approach can be established, and it can be adjusted by the impact of the local climate conditions.** Such adjustment is commonly performed by a regression analysis using heating degree days (HDD) and cooling degree days (CDD) as independent variables representing the key climate conditions. For instance, the ASHRAE, the US EPA's Energy Star® building energy performance ratings and AMS-III.AE under the CDM employ this approach (ASHRAE 2002; US

[13] Group A: Tropical/mega-thermal climates, Group B: Dry (arid and semiarid) climates, Group C: Temperate/meso-thermal climates, Group D: Continental/micro-thermal climate, Group E: Polar climates, and Group H: Alpine climates.

EPA 2009d)[14]. HDD and CDD are common measures that reflect the heating and cooling requirements of a building, relative to the average temperature. In most rating models, HDD and CDD are determined to have statistically significant impacts on energy use. The US EPA also performed analysis to determine whether humidity effects require additional adjustment beyond HDD and CDD, but could not determine that a separate relationship for humidity was statistically significant. Most of the numerous climate conditions that may influence a building's operation are correlated with each other. Thus, it is not feasible to identify separate adjustments for each characteristic. The US EPA's analysis reveals that HDD and CDD are good indicators for climate conditions (US EPA 2009d). Though the analysis was conducted in the US context, the insight is very valuable given that the US accommodates various climate conditions (see Figure 4).

Economic development

Level of economic development is often said to influence building energy consumption (e.g., WBCSD 2008b). As the term economic development is very broadly defined, we use income level as one of the key indicators for level of economic development. It makes intuitive sense to say, "The higher the income, the more energy people consume." However, an extensive survey on urban household energy consumption patterns in 45 cities in 13 developing countries shows that, although income is strongly related to the energy type chosen, it is not as related to the total quantity of energy used, except in the higher income class (Barnes et al. 2004). Figure 5 shows that the total energy consumption of households with low or moderate incomes is quite comparable. The explanation lies in the fact that households shift from lower-efficiency traditional fuels to higher-energy-value modern fuels as they move up the income ladder (Barnes et al. 2004).

[14] The detailed procedures are available in ASHRAE (2002), US EPA (2009d), and AMS-III.AE (http://cdm.unfccc.int/UserManagement/FileStorage/CDM_AMS02DI2P0YCXF0W6W3D6HV1KX6NWQ8O0).

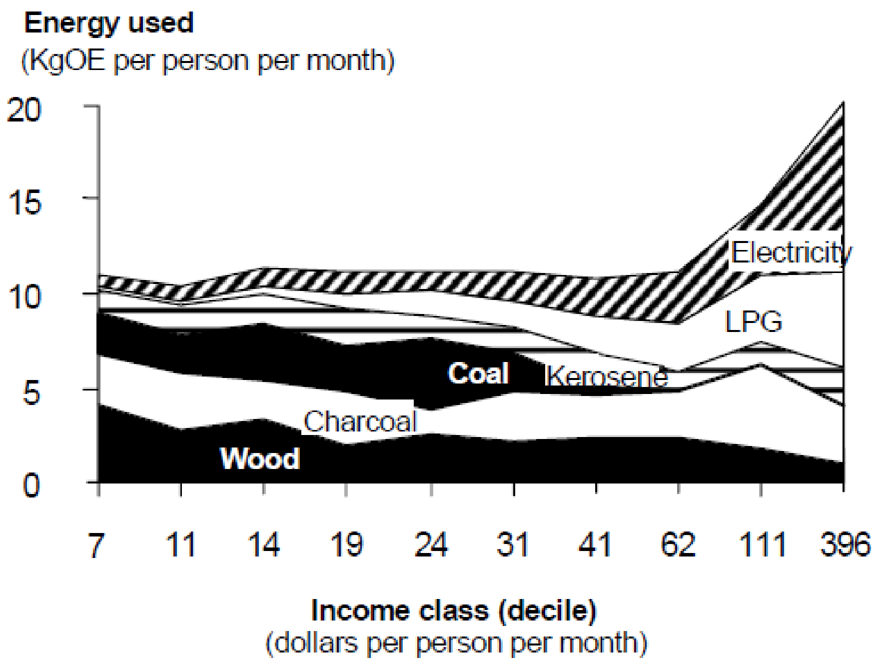


Figure 5: Income class and quantity of fuels consumed in 45 cities in 13 developing countries in Africa, Asia, Latin America and the Caribbean and the Middle East

Note: The cities covered in the survey are as follows:

- Africa: Botswana, Burkina Faso, Cape Verde, Mauritania, Zambia, and Zimbabwe.
- Asia: Indonesia, India, Thailand, and the Philippines.
- Latin America and the Caribbean: Bolivia and Haiti.
- Middle East: Yemen.

Source: Barnes et al. (2004)

The above analysis is limited to urban household energy consumption patterns, and thus excludes other building types (e.g., commercial, institutional) or residential buildings in rural areas. However, we expect similar patterns elsewhere because the total energy consumption stays at a comparable level until the level of economic development of the area reaches a certain level, but the choice of energy type is always strongly influenced by the economic conditions.

This indicates that differentiation by level of economic development is necessary only if the area has reached a certain threshold level (e.g., $60 per person per month, using a household income level as a proxy for economic development). Differentiation for lower levels of economic development does not seem justifiable. Although level of economic development is strongly related to the choice of energy type, it is not recommended that standardised approaches be disaggregated by energy type. Again, **standardised approaches should be neutral of energy type in order to provide a clear signal for a low-carbon development path**.

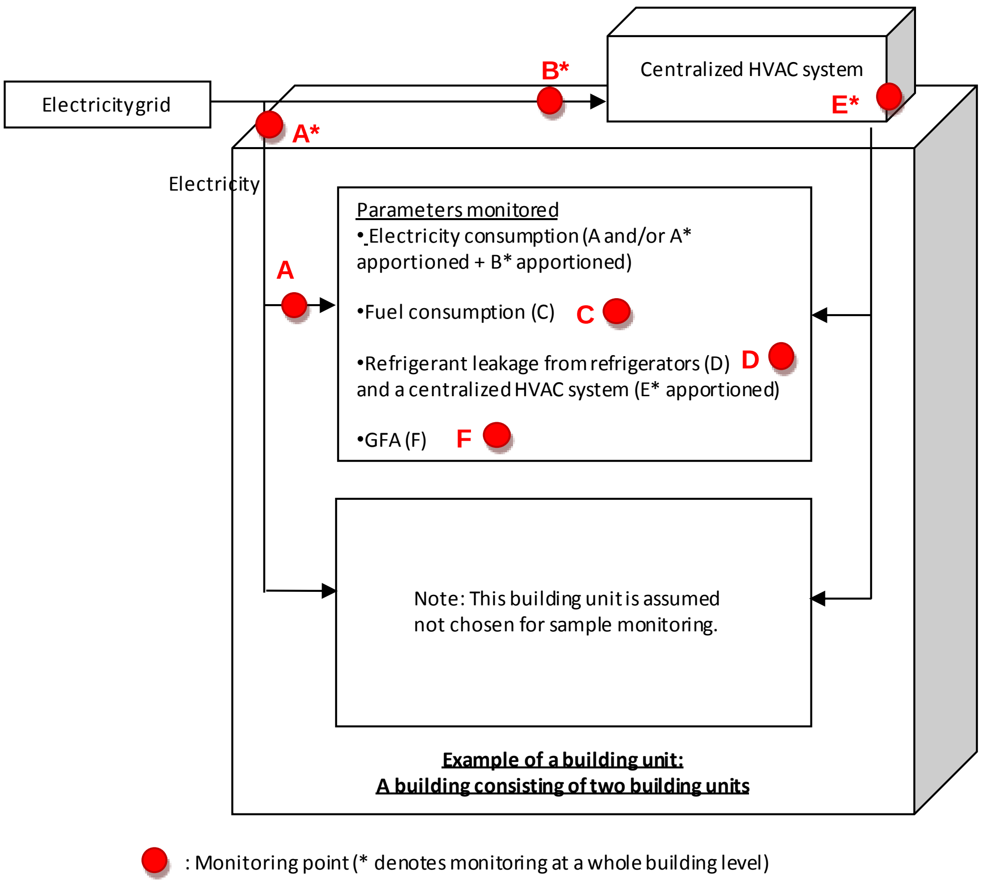
Considering the above discussion, the spatial boundary for the establishment of a standardised approach should have comparable climate conditions and, if appropriate, a comparable level of economic development. The **appropriate boundary will most likely be sub-national, but can be national or supra-national depending on the specific situation**.

1.5 Data requirements

Monitoring parameters

In order to operationalise the standardised approach, it is first necessary to collect data required for the disaggregation of building units. The required data are: building type, size and age, climate conditions, and level of economic development.

Provided the above data for building disaggregation are available, the next step is to collect the data required for the standardised approach calculation, as summarised in Figure 6 and Table 3. The figure and the table assume an exemplary building that consists of two building units. The building unit has electricity supplied by the grid, cooling by a centralised HVAC system (driven by electricity), and hot water by natural gas. Other types of energy are not utilised. Therefore, electricity consumption, fuel consumption, and refrigerant leakage are the main emission sources of the building unit[15].



[15] If there are other types of energy consumed, they should be added to the emission sources.

Figure 6: System boundary and monitoring points for whole-building efficiency projects

Table 3: Key monitoring requirements for whole-building efficiency projects

Monitoring point	Data to monitor	Type of monitoring
A or A*	Electricity consumption	Direct and continuous metering of electricity consumption. If available, utility billing records can be used.
	Emission factor of the grid electricity	As per CDM Tool to calculate emission factor for an electricity system.[16]
	Transmission & distribution loss	Data from utility or an official government body.
B	Electricity consumed in the centralised HVAC system	Direct and continuous metering of electricity consumption. If available, utility billing records can be used.
C	Fuel consumption	Direct and continuous metering of fuel consumption. If available, utility billing records or fuel purchase invoices can be used.
	Net calorific value of the fuel	Values provided by the fuel supplier in invoices, own measurement, or regional or national default value.
	CO_2 emission factor of the fuel	Values provided by the fuel supplier in invoices, own measurement, or regional or national default value.
D	Refrigerant leakage from refrigerators	IPCC default value.
E*	Refrigerant leakage from the centralised HVAC system	Inventory data of refrigerant cylinders, or IPCC default value.
F	GFA of a building unit	Building plan, or onsite measurement.

In addition, data for techno-economic analysis of building efficiency measures will be necessary in order to determine the appropriate level of stringency of a performance standard for additionality demonstration (further discussed in Ch. 1.6). Such data include the maturity stage, cost-effectiveness, and appropriateness of the measures.

[16] Available at: http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.pdf.

Data availability

Data on building type, size and age are not readily available in most developing countries. The GFA of building units can be obtained through building plans or onsite measurement. The former are available from, e.g., the building owner, real estate agents, government agencies regulating building constructions. Furthermore, data on level of economic development may also be difficult to obtain as frequent census surveys are not very common in developing countries. Therefore, extensive building occupant surveys are first required.

On the other hand, climate data are well-published for many developing countries. For instance, the world map of the Köppen climate classification can be obtained from publicly available sources (e.g., Kottek et al. 2006). More detailed data can be collected through weather stations, which are often located at airports and operated by the government. Also, a wealth of climate data has been arranged by the World Meteorological Organisation (WMO 2010).

In many cases, electricity consumption data are readily available through utility billing records. These can be collected through each building occupant, or centrally through the utility database. Fuel consumption data can also be derived from utility billing records if the fuel is supplied by a utility (e.g., natural gas). If fuel is purchased individually (e.g., LPG cylinder), fuel purchase invoices need to be collected from the building occupant.

The emissions from the use of refrigerants occur as leaks or by diffusion during the use phase of the equipment containing the refrigerants. Such emissions can be detected through equipment servicing. In practice, these emissions are difficult to monitor for small equipment used in building units (e.g., air conditioners, refrigerators), thus the use of IPCC default values for refrigerant leakage is recommended (Ashford et al. 2006). For larger equipment (e.g., central building/district cooling systems), inventory data of refrigerant cylinders consumed can be used.

Some techno-economic data of building efficiency technologies are available at an aggregate level (e.g., Levine et al. 2007). However, data availability is not universal. Given the high degree of disaggregation required for the standardised approach, the data need to be much more elaborated, reflecting the local conditions.

1.6 Stringency level

Standardised approaches are considered appropriate for both baselines and additionality. Whole-building efficiency projects typically involve a range of energy efficiency and fuel switching measures, implementation of which will be spread over the duration of the crediting period. For this reason, it would be difficult to undertake a solid barrier or investment analysis for the whole range of measures at the start of the project activity. Moreover, the standardised approach provides a good basis for assessing whether the efficiency of building units constructed during the project activity exceeds the common practice in the relevant geographical boundary. The use of emission-rate-based standardised additionality testing in AM0070 was justified with the same rationale.

The US offset programmes use standardised approaches to additionality testing based on either an emission rate, specifications on technology or practice, or a market penetration rate. The market penetration approach requires a clear definition of a mitigation measure and good overview of the market share of each measure. As there is likely a wide range of measures involved in a whole-building efficiency project, this approach faces difficulties in implementation. Specifications on technology or practice are possible. For instance, a building project that exceeds the efficiency level stipulated in the applicable energy standard by x% can be deemed additional. This approach has been used for whole-building efficiency projects in the RGGI offset programmes in the US. However, it is feasible only if there exists an energy standard applicable under the local conditions (e.g., Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) for India). If such a standard does not exist, application of an energy standard used in industrialised countries (e.g., ASHRAE) could be an option as a conservative alternative. However, the appropriateness of such extrapolation may require case-by-case judgement. Among the three options, the emission-rate approach seems to be most widely applicable in developing countries. The determined level of emission performance would serve as the basis for assessing whether the building efficiency level exceeds the reference level in the relevant geographical area.

Stringency level for baselines

In order to derive an appropriate stringency level for a standardised approach, it is necessary to distinguish new and existing buildings. In principle, the baseline needs to reflect the level of emissions that would occur in the absence of the project activity. As a standardised approach is designed to serve multiple projects, it should "on average" represent the BAU emission level of these projects.

If it were possible to clearly identify the most economically attractive course of action (i.e., baseline approach 48.b), the set baseline would be a reasonable basis for the multi-project baseline. Given the complexity of whole-building efficiency projects, however, such an approach is likely to face challenges in practice. An alternative approach would be to look at what the common level of emission performance is for newly constructed buildings. This is similar to baseline approach 48.c which sets the baseline level as the average of the top 20% of performer buildings built in the last five years. However, the universal application of the top 20% average level is debateable because such a level is far below the common practice level (i.e., the mean) and so does not necessarily provide sufficient CER revenues to incentivise investment in low-carbon measures.

The top 20% average level works as a reasonable safety valve if building units are not appropriately disaggregated by the key criteria discussed in Ch. 1.4. Without the disaggregation, all building units will be captured in a single distribution curve as shown in Figure 7. Assume two CDM projects targeting efficiency improvement of (1) new buildings in a mild climate, and (2) old buildings in a cold climate. The former emits less CO_2 per m^2 as the buildings are built efficient and there is low demand for cooling or heating (the dashed circle on the left). The latter has higher emission intensity due to the use of inefficient building materials and technologies and the high heating demand (the dashed circle on the right). A standardised approach set at the top 20% average level would be suitable for the former category. But it is very likely too stringent for the latter. The catch-all approach covering any type of building efficiency project sets a stringent baseline as we do not know which part of the distribution curve a CDM project will target. Given the uncertainty, the baseline needs to be conservative in order to protect the environmental integrity of the CDM.

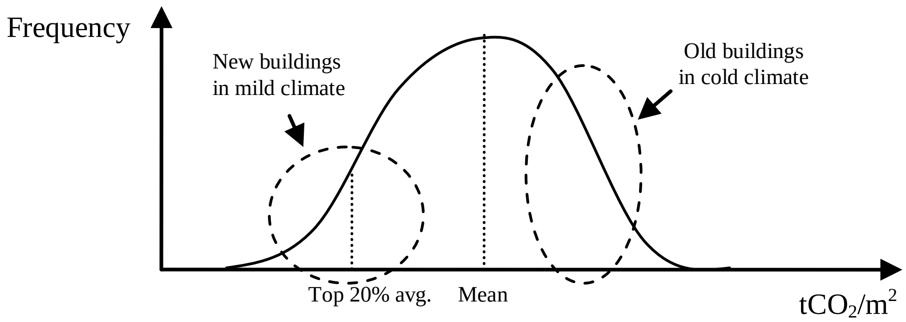


Figure 7: Distribution of emission performance of all buildings

If the building units are classified into different groups according to the key aggregation criteria, the distribution curve can be drawn for each category. Such a distribution curve has a narrower range as the buildings in a certain category are more homogeneous in terms of emission performance. As a standardised approach is designed for a specific target group, there is lower uncertainty in the baseline level. In this case, the mean emission performance of the respective category can set a reasonable baseline level. Thus, it is not necessary to use the overly stringent top 20% average level.

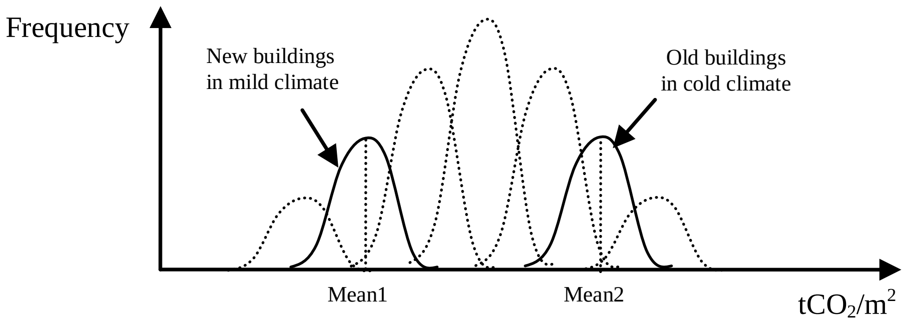


Figure 8: Distribution of emission performance of buildings by category

If standardised approaches are appropriately disaggregated, we argue that **the mean emission performance of each category would represent the most reasonable baseline level**. We proposed some guidance on the aggregation level in Ch. 1.4, but its application needs to be evaluated against the project-specific conditions.

Stringency level for additionality testing

In general, the same level of stringency can be used for the baseline emissions and the additionality testing of new installation projects. This argument is based on two assumptions: (1) the baseline is set at (or beyond) the level that represents the most economically attractive alternative, and (2) the baseline level does not differ significantly for new buildings in the respective category. Although the second assumption is likely to be valid, the first one needs further assessment. As whole-building efficiency projects are technically complex, we argued above that it is practically challenging to identify the most economically attractive course of action. Therefore, the mean of the actual emission performance of peer building units was proposed as the baseline level. This baseline level does not guarantee that there are no further efficiency measures that can be implemented in an economically attractive manner. As the first condition is not met, the baseline and additionality levels cannot automatically be set the same. Consequently, the differentiation of the baseline and additionality levels has to be made for both new and existing building projects.

The stringency level for additionality testing needs to be set at a level that can on average avoid crediting of non-additional projects. Therefore, the baseline level needs to be adjusted by the improvement in emission performance expected from the implementation of non-additional measures (Figure 9).

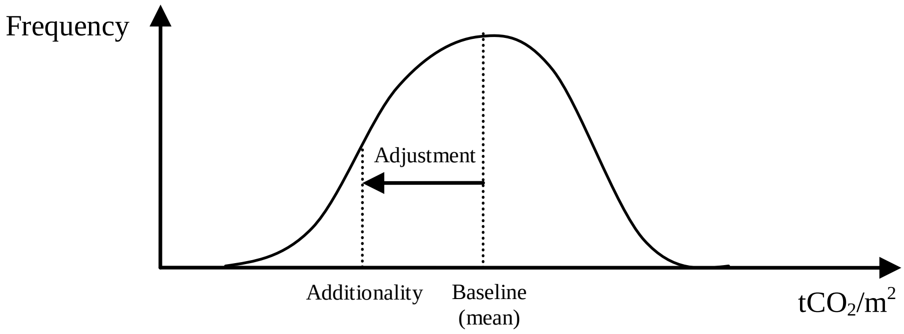


Figure 9: Baseline adjustment for additionality testing

The identification of non-additional measures requires detailed techno-economic analysis. Conventionally, the additionality of a CDM project is assessed by the investment and/or barrier analyses, complemented by the common practice analysis. A similar analysis can be conducted for the standardised approach, but at a more aggregate level. An example of such an analysis, found in Levine et al. (2007), summarised selected key building efficiency measures in five world regions based on three criteria: the cost-effectiveness, maturity, and appropriateness of the measure (Table 4)[17]. The first criterion is essentially the investment analysis, and the second and third criteria correspond to the barrier analysis. The analysis can help identify non-additional measures (e.g., a very mature, cost-effective, and appropriate measure)[18].

[17] Appropriateness includes climate, technological and cultural applicability.

[18] As to the cost-effectiveness criterion, it is of note that the costs of a measure do not necessarily reflect the real financial attractiveness of the measure. The transaction costs associated with the adoption of the measure needs to be considered as well. In particular, the "split incentives" that exist between tenants and landlords would increase the transaction costs.

Table 4: Applicability of building efficiency technologies in different regions

Energy efficiency or emission reduction technology	Developing countries						OECD						Economies in transition, Continental		
	Cold climate			Warm climate			Cold climate			Warm climate					
	Technology stage	Cost/ effectiveness	Appropri-ateness	Technology stage	Cost/ effectiveness	Appropri-ateness	Technology stage	Cost/ effectiveness	Appropri-ateness	Technology stage	Cost/ effectiveness	Appropri-ateness	Technology stage	Cost/ effectiveness	Appropri-ateness
Structural insulation panels	blue	blue	blue	green	green	red	blue	green	green	green	green	green	green	blue	blue
Multiple glazing layers	blue	blue	blue	blue	green	red [1] green [2]	~	blue	blue	blue	blue	green	blue	blue	blue
Passive solar heating	blue	green	green	blue	green	red	blue	green	blue	blue	green	green	blue	green	blue
Heat pumps	green [3]	red	red	green blue [4]	red [5] green [6]	red [7] green [8]	blue [9]	green	green	~ [10] blue [11]	green [12] blue [13]	green [14] blue [15]	blue [16]	green	green
Biomass derived liquid fuel stove	blue	green	blue	green	red	red	~	green	blue	~	green	red	~	blue	blue
High-reflectivity bldg. materials	red	red	red	green	blue	green	blue	green	green	~	green	blue	blue	green	green
Thermal mass to minimize daytime interior temperature peaks	~	blue	green	~	blue	red [17] blue [18]	~	blue	green	~	blue	red [19] blue [20]	~	blue	blue
Direct evaporative cooler	red	red	red	~	blue	red [21] blue [22]	red	red	red	~	blue	red [23] blue [24]	red	red	red
Solar thermal water heater	~	blue	blue	blue	blue	blue	~	blue	blue	~	blue	blue	~	blue	blue
Cogeneration	blue	green	green	green	red	red	~	green	blue	~	green	green	blue	green	blue
District heating & cooling system	blue	green	green	red	red	red	~	green	blue	blue	green	green	blue	green	blue
PV	blue	green	green	red	red	red	~	green	blue	blue	green	green	blue	green	green
Air to air heat exchanger	blue	green	blue	blue	green	blue	blue	blue	blue	blue	blue	blue	blue	green	blue
High efficiency lightning (FL)	~	green	blue	~	green	blue	μ	red	blue	μ	red	blue	blue	green	blue
High efficiency lightning (LED)	~	red	blue	~	red	blue	red	red	blue	red	red	blue	red	green	blue
HC-based domestic refridgerator	green	green	blue	green	green	blue	~	blue	blue	blue	green	red [25] blue [26]	blue	green	blue
HC or CO_2 air conditioners	red	~	μ	red	~	μ	red	green	green	red	red	μ [27] green [28]	red	~	green
Advance supermarket technologies	red	blue	blue	red	blue	blue	~	blue	blue	green	blue	blue	green	blue	blue
Variable speed drives for pumps and fans	~	green	green	~	green	green	~	green	green	~	green	green	~	green	green
Advanced control system based on BEMS	blue	green	green	blue	green	green	blue	green	green	blue	green	green	blue	green	green

Visual representation	Stage of technology	Cost/Effectiveness	Appropriateness
red (small dot)	Research phase (including laboratory and development) [R]	Expensive/Not effective [$$/-]	Not appropriate [-]
green (medium dot)	Demonstration phase [D]	Expensive/Effective [$$/+]	Appropriate [+]
blue (large dot)	Economically feasible under specific conditions [E]	Cheap/Effective [$/+]	Highly appropriate [++]
~	Mature Market (widespread commercially available without specific governmental support) [M]	'~' Not available	'~' Not available
μ	No Mature Market (not necessarily available/not necessarily mature market)		

Source: Levine et al. (2007)

Note: [1] For heat block type; [2] For Low-E; [3] Limited to ground heat source, etc.; [4] For air conditioning; [5] For hot water; [6] For cooling; [7] For hot water; [8] For cooling; [9] Limited to ground heat source, etc.; [10] For cooling; [11] For hot water; [12] For hot water; [13] For cooling; [14] For hot water; [15] For cooling; [16] Limited to ground heat source, etc.; [17] In high humidity region; [18] In arid region; [19] In high humidity region; [20] In arid region; [21] In high humidity region; [22] In arid region; [23] In high humidity region; [24] In arid region; [25] United States; [26] South European Union; [27] United States; [28] South European Union.

A detailed techno-economic analysis needs to consider building efficiency measures that improve the building emission performance beyond the common practice level (i.e., the baseline). **The expected improvement in emission performance from non-additional measures is to be subtracted from the baseline in order to derive the additionality level**.

1.7 Updating frequency

Building energy consumption levels change greatly over time. Weather conditions have particularly strong impacts on energy consumption levels, so actual weather conditions need to be taken into account. This requires annual monitoring of the energy consumption data. Such annual monitoring can also incorporate autonomous improvement of the building energy performance (e.g., by adoption of efficient appliances over time). As emissions from the use of refrigerants are much more predictable[19], it is not necessary to require frequent updating of this parameter.

Update of the emission factors of the energy supplied to the building units can require extensive data collection efforts. If the energy supply systems are centralised (electricity grids, district cooling/heating systems), it is easier to collect the necessary data. However, data collection from the decentralised energy supply systems (e.g., fuels, central building energy systems) will likely be very laborious. If significant changes in the emission factors are not expected over time[20], they should be kept constant for the lifetime of the energy systems.

The GFA data need to be updated at a certain time interval in order to reflect possible changes in building size (AMS-III.AE sets the time interval as every third year). The typical frequency of building renovation in the relevant area can be a basis for the updating frequency of this parameter.

The techno-economic analysis of building efficiency measures requires extensive efforts. Therefore, updating frequency of the analysis should be kept as low as possible. The CDM requires additionality assessment of a project at the renewal of a crediting period, i.e. every seven years. This should serve as a reasonable basis for the updating frequency.

Given that energy consumption data require annual updating, **it would be appropriate for standardised approaches for these types of projects to be updated every year.**

1.8 Implications of the standardised approach

Environmental effectiveness

The environmental effectiveness of the standardised approach depends primarily on whether a performance standard can be set at the right level of stringency. It is generally possible to set appropriate baseline and additionality levels based on the proposed procedures. The disaggregation of building units will help increase the accuracy of the standardised approaches. The holistic, integrated approach will

[19] Refrigerant leakage patterns are well studied and default leakage rates are available in the IPCC inventory guideline (Ashford et al. 2006).
[20] For example, emission factors of fuels are not likely to change significantly over time.

increase the amount of CERs per building and simplify the overall monitoring requirements, **contributing to the scaling up of mitigation efforts in this sector.**

Cost effectiveness

The key to the cost effectiveness of the standardised approach is the level of aggregation. As there are many major factors influencing the building emission performance, it is most likely that multiple performance standards need to be established. If the necessary disaggregation would lead to a high number of performance standards, however, it is possible to focus on more homogeneous, energy-intensive building unit categories in order to be cost-effective. Given the significant replicability potential of building efficiency improvement projects, concerted efforts for establishing performance standards **would most likely lead to a significant reduction of overall transaction costs.**

Distributional considerations

Building projects are currently under-represented and commonly have micro- to small-scale emission reductions. Therefore, **standardised approaches are likely to improve sectoral and project-size distribution.** The impact on geographical distribution depends largely on the institutional capacity of host countries. As shown in earlier sections, the standardised approaches for this project category are very data-intensive, and the current availability of the required data is rather limited in most developing countries. Without international support, the approach may only be feasible in advanced developing countries. Hence, international support to host countries is essential for improving geographical distribution.

Institutional feasibility

Institutional feasibility will likely be the key concern. The limited availability of data creates a need for significant efforts of data collection. However, monitoring, reporting and verification of building data require extensive organisational efforts – this is one of the key reasons why building projects have not been implemented widely under the CDM. As opposed to large industries where industry associations are normally existent, the building sector does not have an obvious candidate for coordination of standardised approach development. The fragmented nature of the sector also adds complexity. Clearly, **significant international support for institutional capacity building and concerted data collection is necessary**.

1.9 Recommendations for further work

The development of standardised approaches for the building sector can be complex because a relatively high degree of disaggregation is necessary. Therefore, it is advisable to target more homogeneous, energy-intensive building unit categories first. The most prominent candidate for a pilot study would be residential building units. In the non-residential building unit categories, offices are likely the most replicable sub-category.

Judging from the IPCC's projection of CO_2 emission growth through 2030 shown in Figure 10, **the potential of CDM building projects would be most significant in East Asia, South Asia, and Middle East & North Africa**. Therefore, the initial efforts towards standardised approaches should ideally be put in these regions.

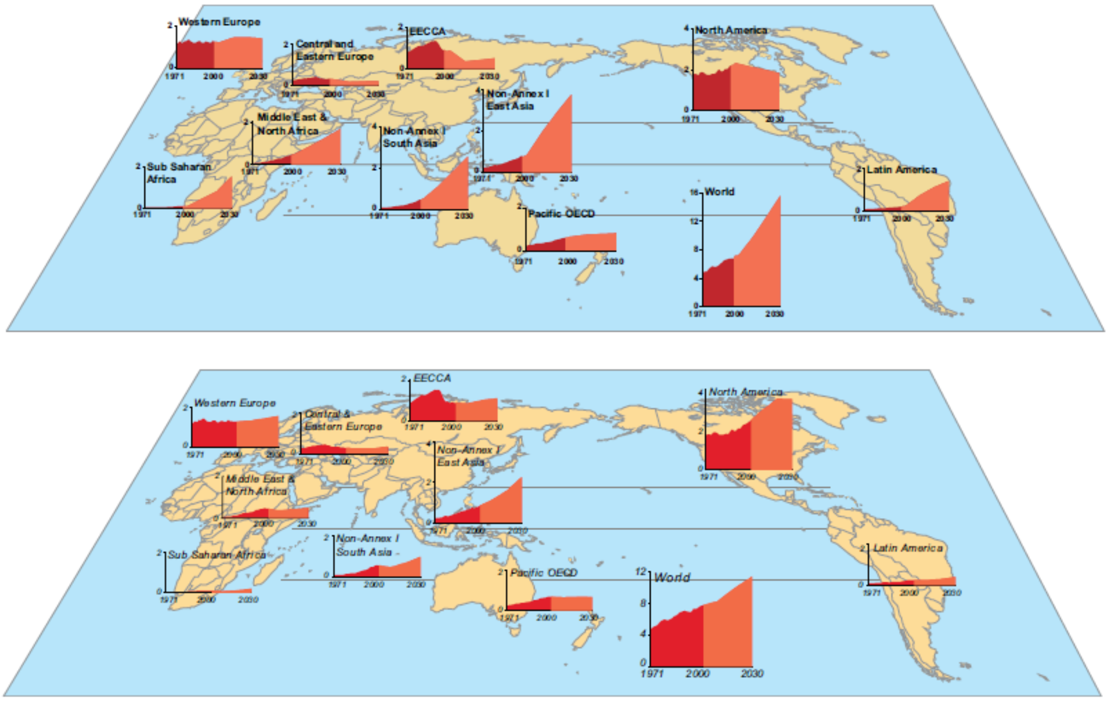


Figure 10: Projection of CO2 emissions from buildings through 2030, including emissions from the use of electricity: A1B (top) and B2 (bottom) IPCC SRES scenarios

Source: Levine et al. (2007)

Note: A1B scenario assumes a rapid growth of the world's economy, while B2 scenario describes a world with localised economies growing less rapidly.

The necessary steps for development of standardised approaches are summarised in Figure 11. Major **efforts should be put into data collection,** as availability of the necessary data is very limited in CDM host countries. The first step of data collection is to establish a database of building units with information on their size, type and age as well as climate conditions of their locations. If required, the level of economic development also needs to be surveyed. Except for climate conditions, for which data are readily available in the public domain, **the data collection will very likely require an extensive building occupant survey.** This database will serve as the basis for the identification of the baseline building units.

Secondly, all or a random sample of the building units needs to be monitored on energy consumption, refrigerant leakage, transmission & distribution loss in energy supply to these building units, and emission factors for energy consumption and refrigerant leakage. **The key parameters here are energy consumption and emission factors.** Other data should require less effort as default factors are available in IPCC reports or existing CDM methodologies. It is most efficient to partner with local utilities to obtain energy consumption data centrally from their databases. On the other hand, there could be consumption of energy that building occupants individually purchase or obtain (e.g., LPG cylinders, charcoal). In this case, one needs to conduct a building occupants survey or exclude these energy sources for conservative simplification[21]. The calculation of emission factors would require data from (captive) power plants or the central electricity authority if they organise such data. If district solutions to cooling, heating and/or hot water supply are applied to the baseline building units, the necessary data can be obtained from the utilities. Once the above data have been collected, a performance standard for baseline emissions can be established.

Lastly, the identification of non-additional measures would require detailed techno-economic analysis of building efficiency measures in the concerned area. The measures will need to be evaluated on, e.g., cost-effectiveness, maturity and appropriateness. **Thorough assessment of locally available building efficiency measures should be performed by independent experts with local expertise.**

[21] It is likely conservative because a building efficiency improvement project would reduce the consumption of these energy sources. Thus, the exclusion would result in a lower amount of CERs than the emission reductions that the project would actually achieve.

Development of the benchmarking approach

(1) Definition of the system boundary
- Identification of project/baseline building units as well as energy systems supplying energy to the building units.

(2) Identification of key performance indicator
- tCO_2e per m^2 of a building unit.

(3) Selection of peers for comparison (choice on the aggregation level)
- Process: No differentiation.
- Product: Differentiate by building type and size.
- Time: Differentiate between new and existing building units. Consider whether further disaggregation is necessary for existing building units by building age.
- Space: Differentiate by climate condition, or make adjustment by HDD and CDD. If necessary, consider differentiation by level of economic development.

Data collection

For disaggregation of building units:
- Building unit size, type, and age.
- Climate conditions.
- Economic development.

For calculation of standardised baselines:
- Energy consumption.
- Refrigerant leakage.
- Transmission & distribution loss of energy.
- Emission factor for energy consumption and refrigerants leakage.
- Techno-economic analysis of building efficiency measures.

Selection of the stringency level

- Baseline: The mean emission level of peer building units.
- Additionality: The baseline level adjusted by the improvement in emission performance by non-additional measures (case-specific).

Performance standard update

Annual update of the benchmark based on ex-post monitoring:
- Energy consumption (every year)
- Refrigerant leakage (need not be frequently; can be based on default values).
- Transmission & distribution loss of energy; emission factor for energy consumption and refrigerants leakage (case-specific).
- GFA of building units (consider the typical frequency of building renovation).
- Techno-economic analysis of building efficiency measures (every seven years).

* Frequency of monitoring shown in parenthesis.

Figure 11: Flow chart of development of standard approaches to whole-building efficiency improvement projects

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