Environmental Inventory of UN Buildings and Facilities – Final Report

Date: 30th January 2017

1.0 Introduction

1.1 Background

Buildings and associated facilities[1] are responsible for the largest proportion of the UN's negative environmental impacts, from greenhouse gas emissions, solid waste and wastewater disposal to use of resources such as water and materials.

While UN-wide inventories of greenhouse gas emissions and waste generation provide a solid baseline for understanding the magnitude and source of these negative impacts, they do not provide in-depth information about the underlining factors for those impacts. At the same time, understanding factors such as building's physical properties, for example, is crucial to developing emission and impact reduction strategies.

Furthermore, the shear size of the UN and its diversity in terms of operations and geographical presence creates its own challenges in developing coherent environmental strategies.

1.2 Objective:

Against this background and with the overall aim to reduce negative environmental impacts of UN buildings and associated facilities, the project objective is to create and maintain an inventory of UN buildings as a single reference point in order to:

- Aid planning, development and implementation of impact reduction projects
- Identify and facilitate exchange of good practices
- Benchmark performance

To date, the inventory comprises information about 117 buildings across 24 locations. General information about these buildings is provided under paragraph 2.0 below.

1.3 Methodology

The inventory project comprises the following steps:

Step 1 - Initial consultation and definition of project scope: The inventory includes information related to permanent buildings and their associated facilities that are either owned or leased by UN entities. The information is structured as follows:

- Section 1: General information
- Section 2: Building fabric
- Section 3: Energy and Comfort
- Section 4: Waste management
- Section 5: Water use

Step 2 - Development of inventory format and layout: The inventory is a single Excel spreadsheet allowing simple data entry, updates and analysis.

[1] Systems and equipment used to operate buildings and building sites such as boilers, lifts, lights, water supply and waste management facilities. Facilities used for transportation of personnel and materials to and from buildings are not included.

Step 3 - Data gathering: Majority of data was gathered using a questionnaire distributed via the UN's Issue Management Group (IMG) on Environmental Sustainability Management and the Interagency Network of Facilities Managers (INFM). Data was also gathered and crosschecked using Sustainable UN's (SUN) existing databases and reports such as greenhouse gas and waste inventories, as well as peer review reports. New data will be added to the inventory as it becomes available.

Step 4 - Data analysis and reporting: Data was analyzed and preliminary results presented at the 16th annual meeting of the INFM held in Vienna in May 2016 and at the 21st meeting of the IMG, online, in June 2016. Following this preliminary analysis further data checks and corrections were carried out with final data analysis, conclusions and recommendations presented in this report.

Step 5: Next steps: Findings and recommendations of this report will be discussed by the IMG and INFM in order to establish the most effective way to utilize and maintain the inventory in order to achieve aforementioned project objectives.

1.4 Report structure

Following the introduction, this report provides and overview and analysis of inventory data. The report is finalized with conclusions and a set of recommendations aimed at UN facilities managers as well as IMG/INFM focal points.

2.0 Data Overview and Analysis – General Information

The inventory information currently accounts for:

- Total number of buildings: 117
- Total occupants: 60,000
- Total floor area: 2.5 million square meters
- Total locations: 24
- Total shared premises: 20
- Ownership: 60% owned, 40% leased (two buildings with gross lease)
- Facilities management: 81% self-managed, 19% via external contractor
- Average building age: 35 years (23 years if last major refurbishment considered)

Figure 1 below shows that the majority of buildings included in the inventory are in Europe and within temperate climate regions.

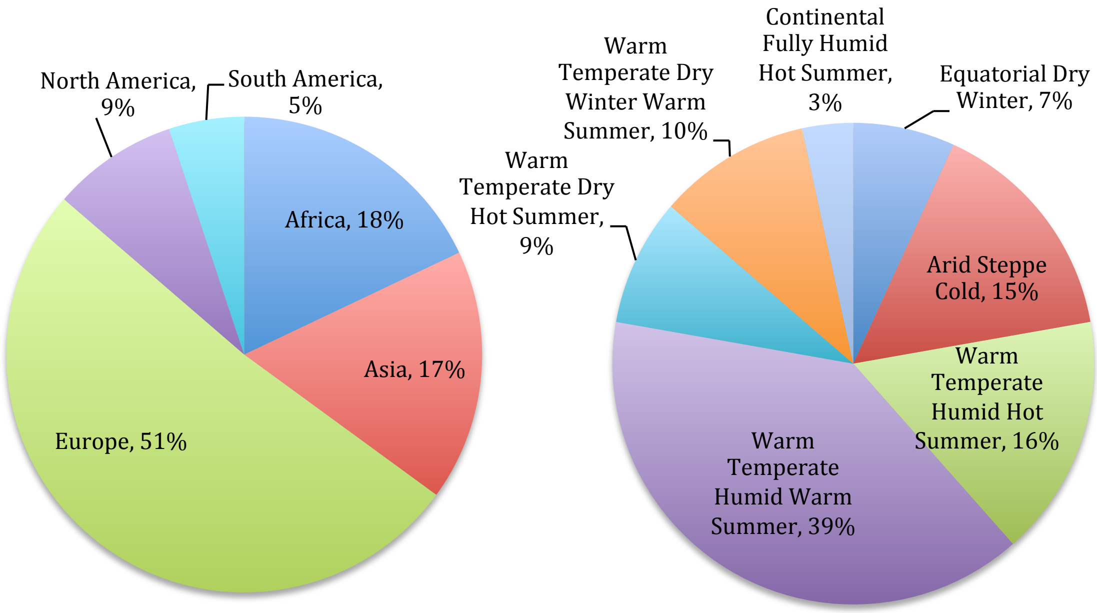


Figure 1: Distribution of buildings by continent and Köppen climate classification[2]

Figure 2 below shows distribution of buildings by main facility type, with offices accounting for 69% of all buildings.

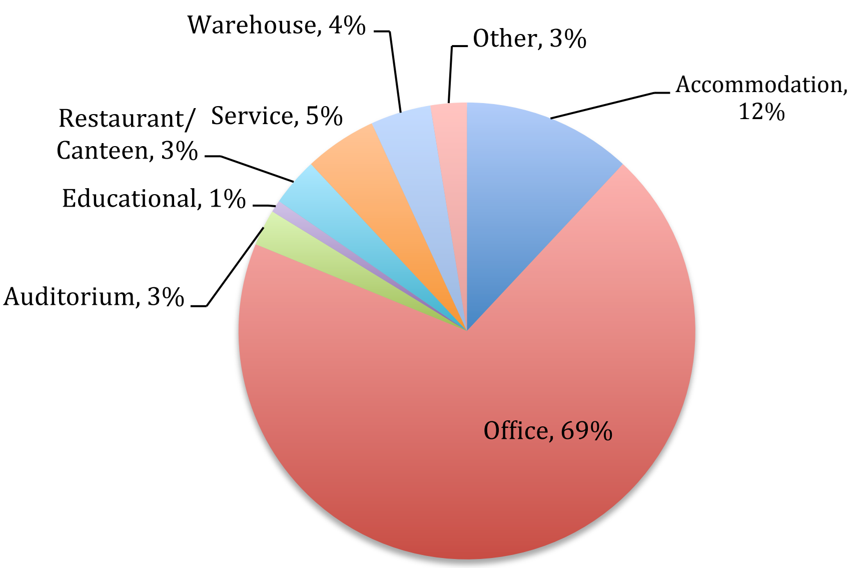


Figure 2: Distribution of buildings by main facility type

[2] http://koeppen-geiger.vu-wien.ac.at/present.htm

3.0 Data Overview and Analysis – Energy

The inventory addresses each aspect of energy hierarchy (see Figure 3), from energy demand reduction using passive design strategies[3] to energy efficient consumption and low carbon and renewable energy generation. Energy hierarchy is a decision-making concept used in green building industry to maximize environmental benefits of new construction and retrofit building projects. The concept advocates prioritization and investment in low-tech solutions such as building orientation and insulation to drive down energy demand of buildings prior to investing in building systems and renewable generation. In simplified terms, the concept seeks to avoid a situation where, for example, solar panels are installed on top of un-insulated buildings with inefficient building services. The reason being that such solar panels would only meet a fraction of such building's high energy demand and would therefore not result in significant reduction of CO_2 emissions.

With respect to UN buildings, hierarchy implementation depends on a number of factors, including but not limited to building ownership, level of retrofit, budget, senior management buy-in, political factors and investment strategy. While the hierarchy may not always be implementable in the prescribed order, it is important that it is followed during a decision making process to ensure no opportunities are missed.

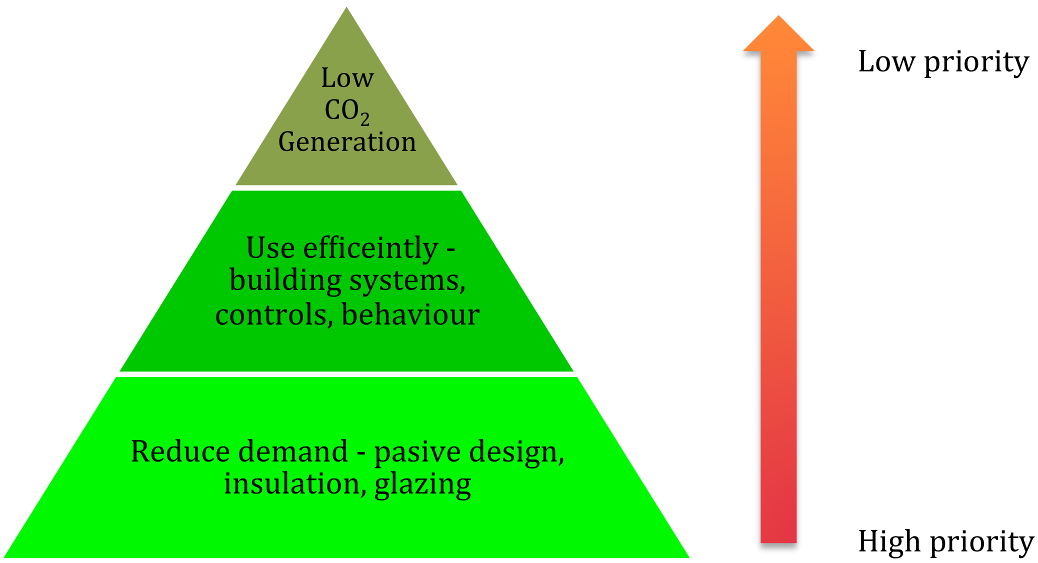


Figure 3: Energy action hierarchy

3.1 Energy demand reduction – passive design strategies

Passive design strategies such as orientation, shading and material selection are used to minimize buildings' energy demand and improve thermal comfort of building occupants. If considered early during the design process, they could achieve great environmental benefits at low or no cost. Table 1 below provides a summary of passive design strategies and associated benefits. Figure 4 shows that out of 117 buildings surveyed only 60 provided an answer to the question relating to passive design strategies, and half of those reported no passive design strategies present. When compared to the rest

[3] Design that takes advantage of climate through passive means such as building orientation, shading and insulation in order to control indoor thermal comfort, air quality and natural light, thus avoiding or minimizing the use of auxiliary heating, cooling, ventilation and lighting.

of the buildings, those that reported one or more passive design strategy have 12% lower energy consumption.

Passive design strategy	Environmental Benefit
Orientation / glazing (windows)	Reduced heating demand, thus lower emissions, through maximizing solar gains during cold months
	Reduced cooling and mechanical ventilation demand by taking advantage of prevailing wind direction
	Reduced demand for artificial lighting
	Occupant comfort (natural light, fresh air, temperature)
Thermal Mass[4] / Material Selection	Reduced heating and cooling demand by stabilizing internal temperatures
Shading	Reduced heating or cooling demand by maximizing or minimizing solar gain
Stack effect[5]	Reduced cooling and mechanical ventilation demand by encouraging stack effect through architectural design
Insulation	Reduced cooling and heating demand by reducing thermal conductivity of external building envelope
Landscape / planting	Reduced cooling demand as a result of shading and insulating properties (i.e. green roofs)

Table 1: Passive design strategies and associated environmental benefits

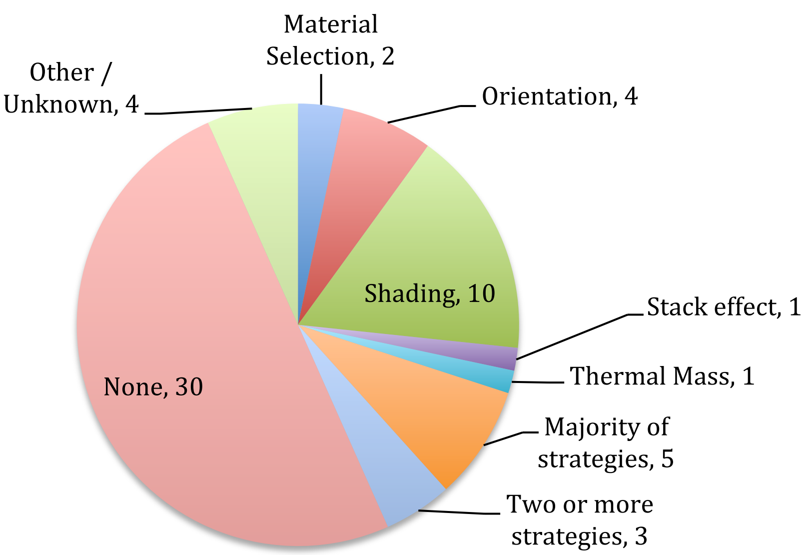


Figure 4: Number of buildings and passive design strategies

[4] Thermal mass is the ability of a material to store heat. Heavy materials such as stone and concrete have high thermal mass and are beneficial in regulating internal temperatures particularly in climates where there is a large difference in day and night outdoor temperature. For example, on a hot day the heat gets stored within the material with high thermal mass and it is then released at night providing passive heating.
[5] Stack effect refers to the natural movement of air from hot to cold or high to low pressure. Architectural features such as chimneys and turrets can encourage such movement.

3.2 Energy demand reduction - building fabric insulation

Building fabric comprises walls, roofs, floors, windows and doors. Given that up to 65% of building's heat can be lost through the fabric (see Figure 5), it plays a significant role in energy demand reduction in temperate climates. Similarly, in warmer climates, heat gains through building fabric will have a significant impact on cooling energy demand.

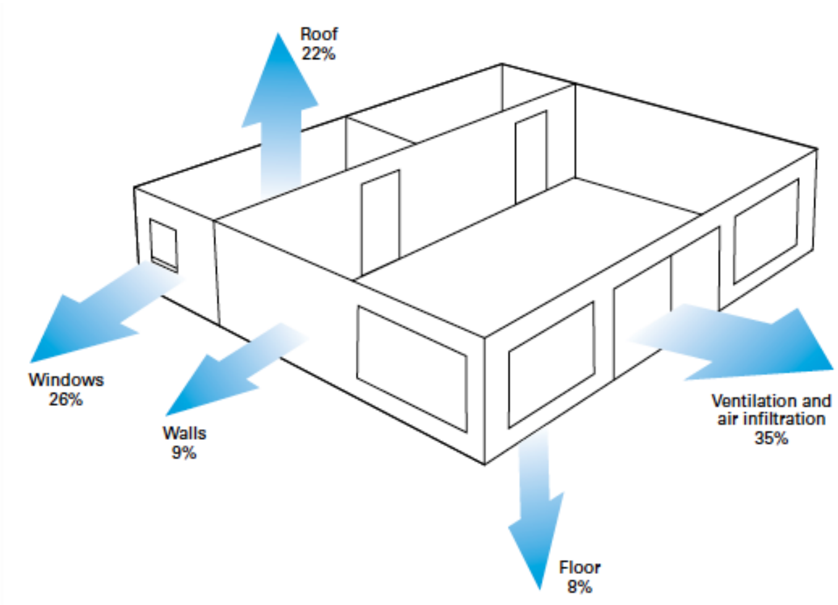


Figure 5: Typical commercial building's heat losses during heating season[6]

Figure 6 provides a breakdown of levels of insulation present within surveyed buildings. It shows that only 17% of all surveyed buildings have all three major building elements insulated. There are two factors that appear to affect the level of insulation, namely building age and location. Among newer buildings, up to 10 years old, over 50% have insulated roofs, walls and floors. The remaining newer buildings with lower or no insulation are located in moderate climates with low heating and cooling demands.

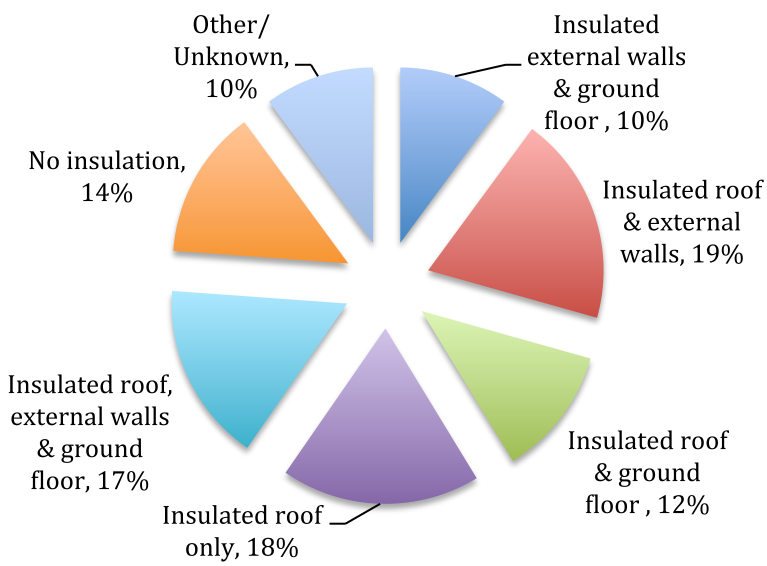


Figure 6: Building insulation levels

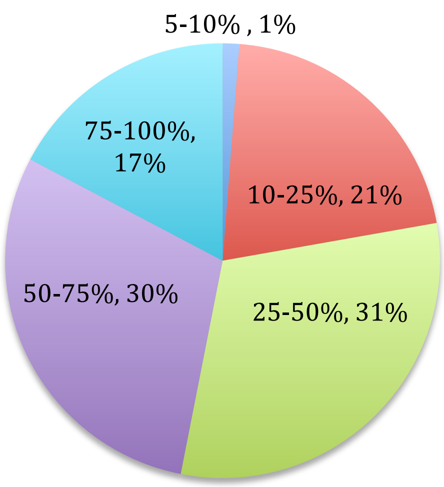
[6] Source: https://www.carbontrust.com/resources/guides/energy-efficiency/buildings-energy-efficiency/

Regarding type of insulation material, information was provided for only 34 out of 117 buildings. Over 55% of those 34 buildings have either expanded polystyrene (EPS) or extruded polystyrene (XPS) rigid board insulation. Such materials are associated with very good thermal insulation properties, however XPS boards are associated with worse life-cycle environmental properties due to climate and ozone depletion effects of blowing agents used in their manufacture. The remaining 45% of buildings that provided information on insulation materials typically use either glass or stone (mineral) wool insulation. The inventory did not seek information about thermal conductivity of building elements; as such information was not available to respondents.

3.3 Energy demand reduction – glazing (windows, curtain wall)

Glazed areas typically have lower insulating properties compared to walls and roofs, resulting in greater heat transfer between the building interior and exterior. Such increased heat transfer can cause an increase in energy needed to heat or cool the building. The degree of increase will depend on the proportion of building's façade being glazed, the orientation of the glazing and its thermal properties (e.g. single or double glazed). At the same time, large areas of glazing can be beneficial in terms of daylight provision and can lead to decrease in energy use for lighting. In cold climates, large glazed areas on equator-facing elevations can result in passive heat gains and decreased heat loads.

Figure 7 provides the summary of inventory results related to glazed area and glazing type. Results, based on 81 buildings for glazed area proportion and 92 buildings for glazing type, show relatively high glazed areas overall and relatively high proportion of single glazed buildings at 35%. However, the majority of these single-glazed buildings are in warm climates where there is little need for space heating, and comfort cooling is provided by natural ventilation. The average energy intensity of these buildings is 128 kWh/m^2, which is significantly lower than the overall average of 190 kWh/m^2. The average intensity of single-glazed buildings in northern Europe is slightly higher than the average at 198 kWh/m^2.



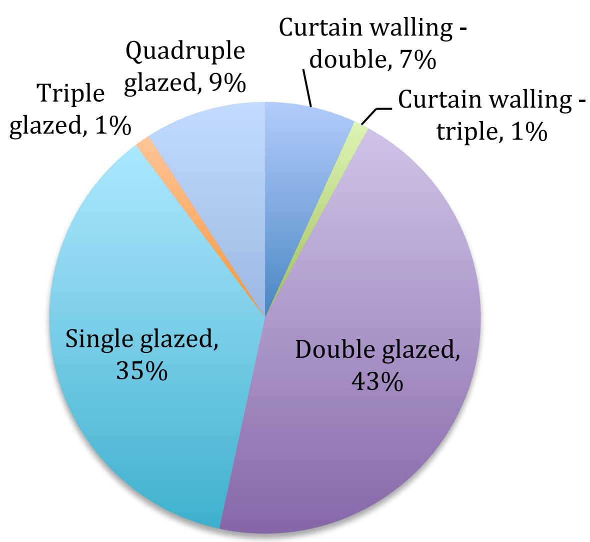


Figure 7: Proportion of buildings by glazing area and glazing type

3.4 Energy consumption – building energy intensity

As stated above the overall average building energy intensity is 190 kWh/m²/year with the average for office buildings being 175 kWh/m²/year. The average intensity of naturally ventilated offices is 138 kWh/m²/year, while the average of air-conditioned offices is 234 kWh/m²/year. Figure 8 below compares the UN average with international good practice benchmarks.

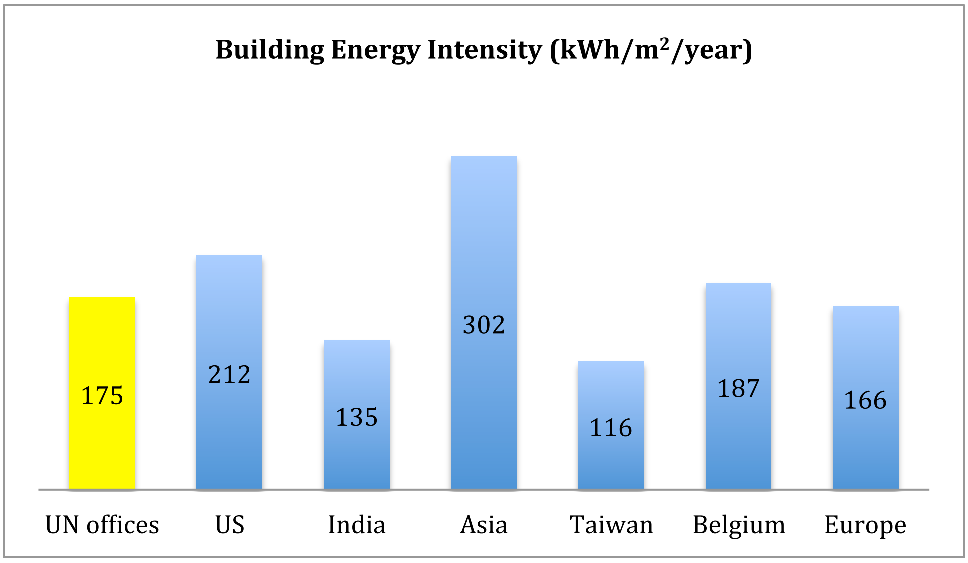


Figure 8: Building Energy Intensity comparison[7]

3.5 Energy consumption: heating, cooling and ventilation

Approximately half of all energy within a typical UN office building is used for heating, cooling and ventilation. Additionally, energy used for lighting can contribute to up to 25% of the overall energy use. The remaining energy is typically used by plug-in equipment and for hot water generation.[8]

Figure 9 shows proportions of buildings using different types of space heating. The largest proportion of buildings (27%) relies on district heating. All of these buildings are within three locations, namely Geneva, Turin and Rome. The second largest proportion (23%) includes buildings with centralized gas/oil boiler heating. Both of these heating types are typically associated with significantly lower emissions of greenhouse gases than electrically powered heating. 15% of buildings rely on split air-conditioning units for heating and cooling. It is interesting to note the majority of these buildings have limited or no electrical metering and were not able to provide total annual energy consumption. Finally, low carbon technologies, including ground-source and air-source heat pumps, and gas-driven combined heat and power (CHP) plant are used in only four buildings. When compared to gas boilers heat pumps are typically three times more efficient while electricity generated by CHP plant is associated with significantly lower emissions than grid electricity generated from fossil fuels. Within the inventory the single building that utilizes ground source heat pumps has 35% lower energy intensity than the average building.

[7] Sources of information: U.S. https://portfoliomanager.energystar.gov ; India: https://www.beeindia.gov.in ; Others: http://www.internationalsustainabilityalliance.org

[8] Based on existing information such as peer review reports and greenhouse gas inventories

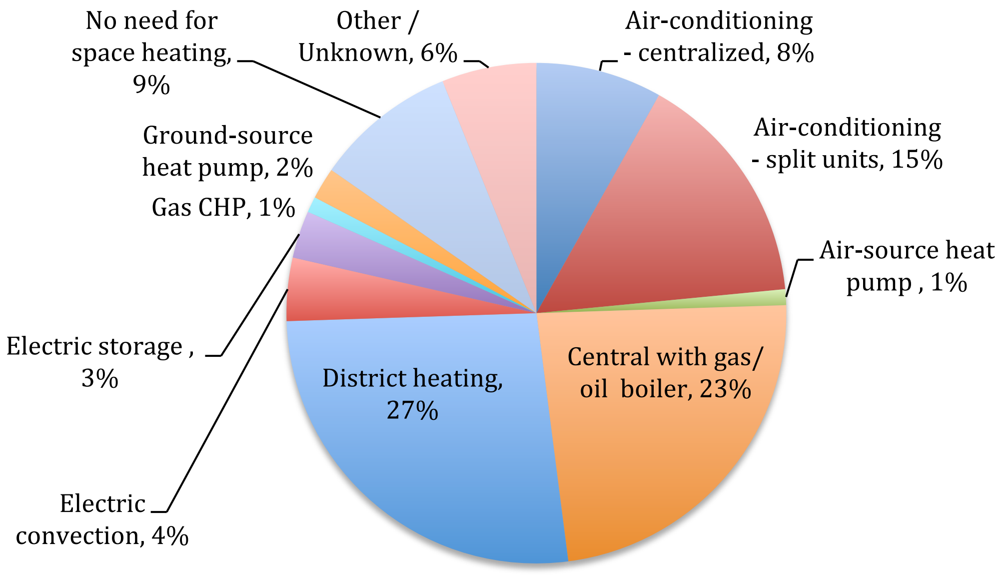


Figure 9: Proportion of buildings by type of space heating

Figure 10 shows that the majority of cooling (54%) is provided by centralized air-conditioning systems followed by split air-conditioning units (20%). Relatively large proportion of buildings (9%) use 'free' energy from ground and surface water to provide cooling. Finally, data shows that buildings requiring cooling consume twice as much energy overall than those that do not require it.

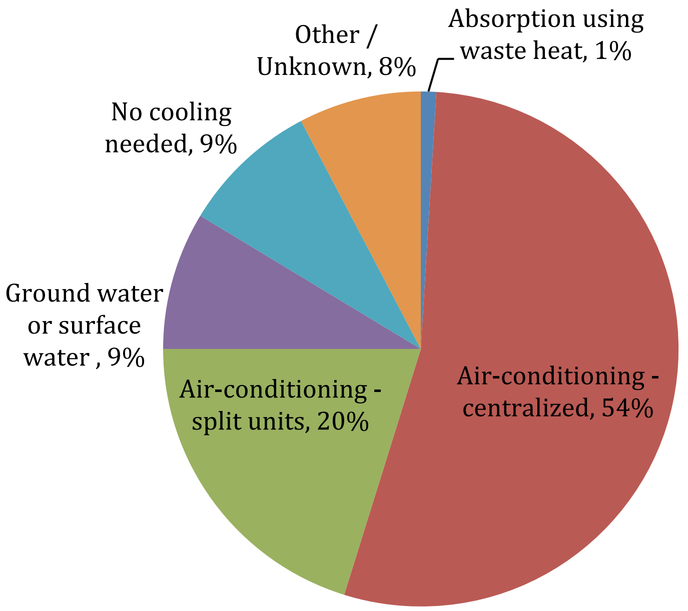


Figure 10: Proportion of buildings by type of space cooling

Figure 11 shows that majority of buildings (56%) rely on mechanical ventilation, while a relatively large proportion (27%) rely on mixed mechanical and natural ventilation. The average energy intensity of mechanically ventilated buildings is 189 kWh/m^2, while it is 147 kWh/m^2 for mixed mode ventilation and 102 kWh/m^2 for naturally ventilated buildings.

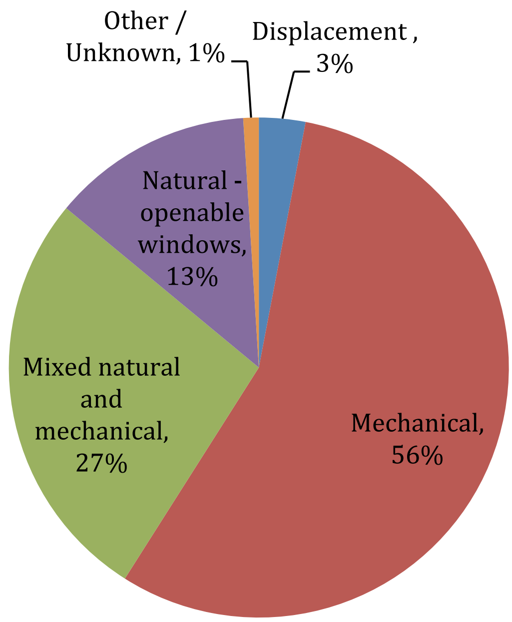


Figure 11: Proportion of buildings by type of ventilation

3.6 Energy consumption – lighting

As stated above, lighting can be responsible for up to a quarter of energy use in an office building. The inventory demonstrates that energy efficient fittings, including T5 fluorescent tubes, compact fluorescent and LED lights, comprise 67% of all lighting. At the same time, the relatively large proportion (one third) of inefficient lighting, including T8, T12, halogen and incandescent lights, offer an opportunity for energy saving.

According to information provided for 77 buildings, presence/occupancy sensors cover approximately 20% of the floor area of those buildings. Information regarding daylight sensors was provided for 69 buildings and 26% of the total floor area of those buildings is covered.

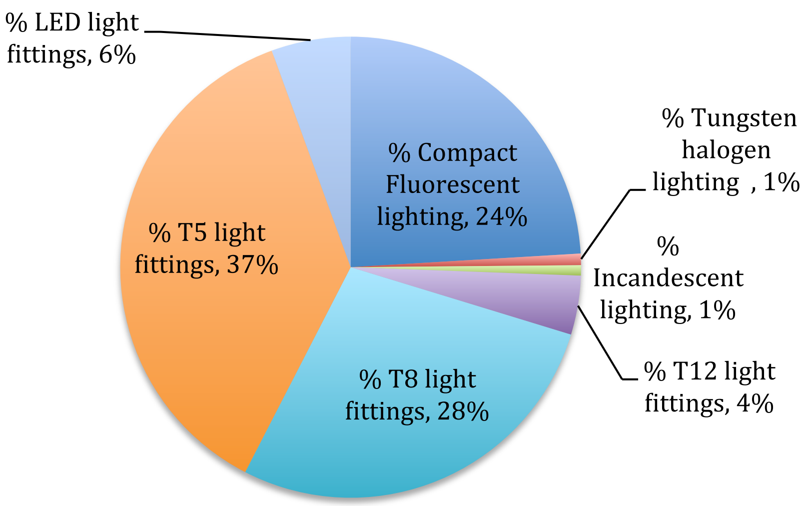


Figure 12: Proportion of total floor area by type of light fitting

3.7 Energy consumption – hot water

Energy related to hot water generation typically ranges from 1 to 3% of the total office building energy demand to 20% of the residential building demand. The inventory shows that at least 38% of buildings use electricity to generate hot water, which is likely to be associated with higher greenhouse gas emissions than onsite combustion using gas or oil.

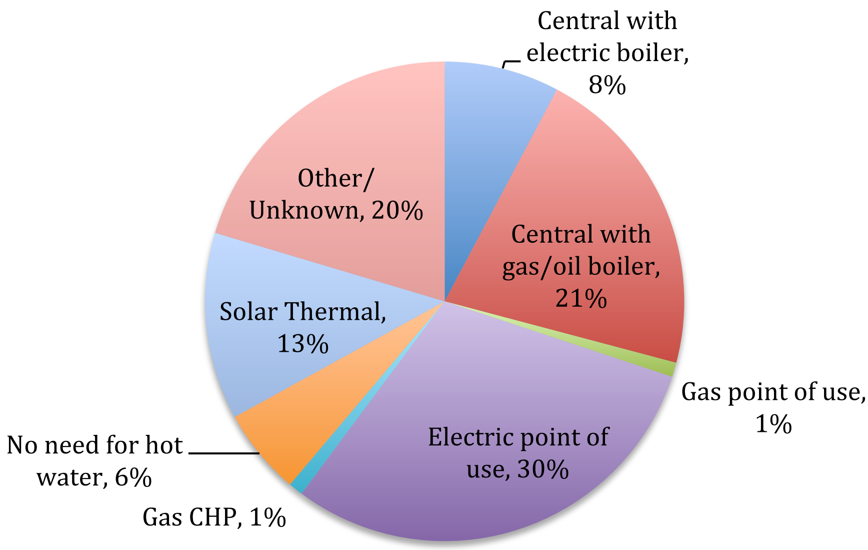


Figure 13: Proportion of buildings by hot water generation type

3.8 Energy Consumption – metering and monitoring

Having extensive network of sub-meters within an automated building management system is a prerequisite for effective monitoring and management of energy consumption. Based on information for 67 buildings, the inventory shows that over half of all buildings rely on utility meters only or do not have meters.

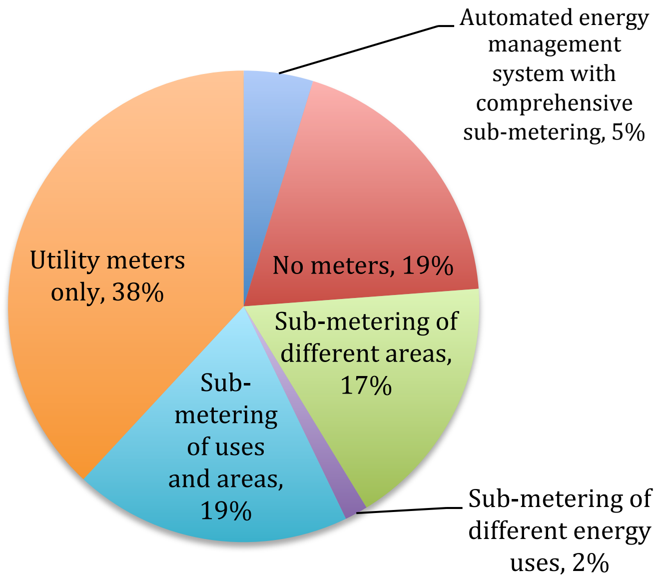


Figure 14: Proportion of buildings by energy metering type

Regarding responsibility for energy bills, UN entities have responsibility in over 70% of buildings, while building owners; facility management contractors and other non-UN entities have responsibility in the remaining buildings. It is unclear, form information provided, whether these latter entities have green leases or other similar tenant – building owner arrangements, aimed at reducing energy use, in place.

3.9 Energy generation – mains power fuel type

The type of fuel used to generate electricity will determine the emission factor associated with electrical energy consumption. Results in Figure 15 below show that the largest proportion of fuel are oil products, which are associated with high greenhouse gas emissions. Majority of 28% who selected 'other or unknown' did not provide additional information, thus it is assumed that respondents were not able to source reliable information.

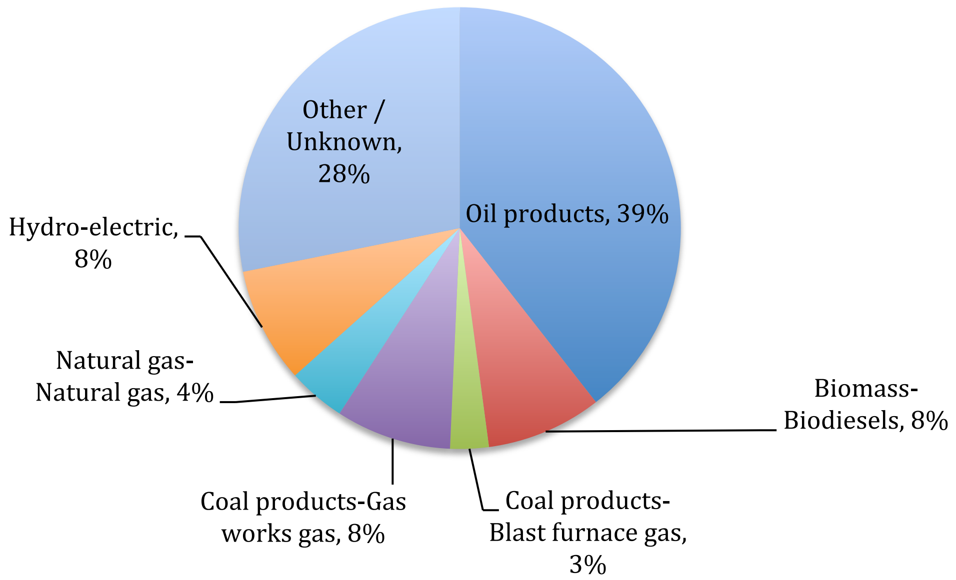


Figure 15: Proportion of buildings by fuel type

3.10 Energy generation – renewable energy technologies

Regarding on-site renewables, 17 buildings reported one or two technologies installed. These are predominantly solar photovoltaic panels, followed by solar thermal and ground source heat pumps.

14 buildings are connected to off-site renewable energy sources, including hydro, wind and geothermal.

4.0 Data Overview and Analysis – Waste

Waste information was provided for 46 out of 117 buildings. Based on this information the overall annual per capita waste generated is 250kg. The annual per capita waste generation for office buildings is 218kg. These figures are significantly lower than the UN-wide figures of 547kg (with peacekeeping) and 364kg (without peacekeeping)[9].

[9] http://www.greeningtheblue.org/sites/default/files/movingtoward_digi_broch-2.pdf

Figure 16 below shows relatively high rate of reuse and recycling at 45% as well as high diversion from landfill rate. The rate of recycling is greater than the UN-wide average of 26% but lower that the UN-wide average of 64% when peacekeeping is excluded.

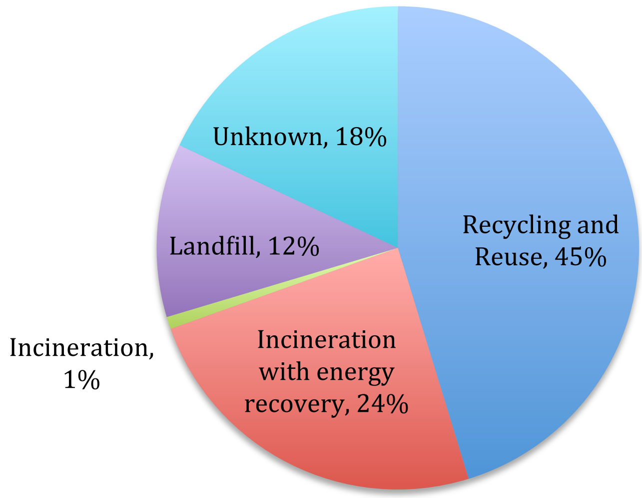


Figure 16: Proportion of total waste by disposal method

Regarding waste management practices, 26 buildings reported to have adequate procedures and facilities to identify, separate, safely store and collect all or majority of hazardous waste types.

Only one building reported to have a waste management policy, while further three reported to have a waste action plan.

Regarding source of waste data, seven out of 46 buildings relied on waste transfer notes with remaining buildings using estimation.

5.0 Data Overview and Analysis – Water

Water section comprises data on consumption of mains water, borehole water, rainwater and grey water. Data was provided for a total of 69 buildings out of 117, with over 70% of data coming from meter readings and remainder being estimated.

Figure 17 shows how an average UN office included in the inventory performs against typical international benchmarks.

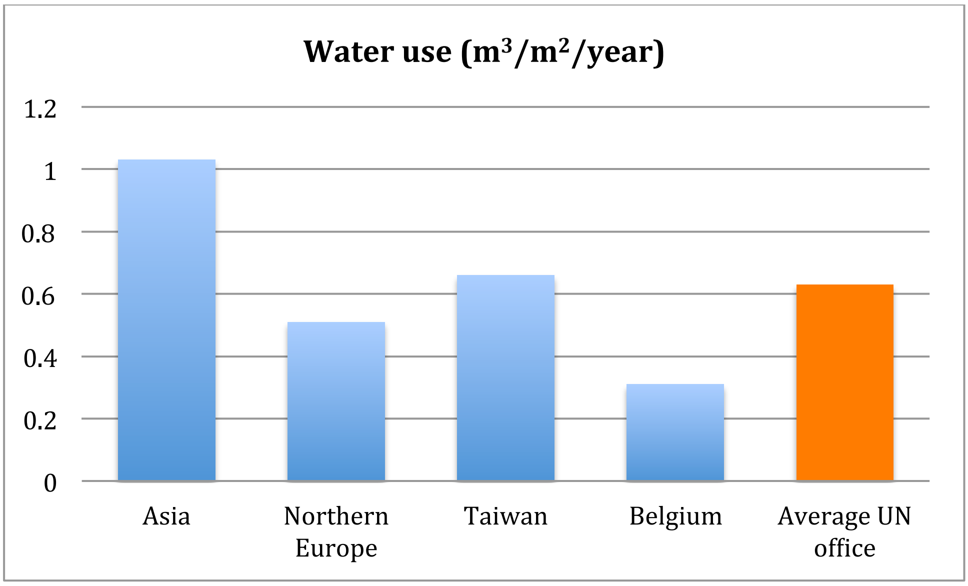


Figure 17: Typical water use in offices – comparison with international benchmarks[10]

In terms of annual water consumption per capita, the inventory average for all buildings is 25.7m^3 and 25.5m^3 for offices. Based on 251 working days in a year, the average daily per capita consumption is 102 litres. These figures are high when compared to good and typical practice of 25 and 41 litres / person / working day outlined within 2015 Real Estate Environmental Benchmarks[11].

Finally, greywater accounted for 3.1% and rainwater for 0.4% of total consumption.

6.0 Conclusions

The largest proportion of UN's greenhouse gas emissions, waste generation and water consumption originates from its buildings and associated facilities. At the same time, there is no single point of reference where information about the underlying factors causing these negative impacts can be obtained.

The environmental inventory of UN buildings project addresses this information gap in order to:

- Aid planning, development and implementation of impact reduction projects
- Identify and facilitate exchange of good practice
- Benchmark performance

The inventory provides information about 117 UN-owned and leased buildings in 24 locations across five continents. While this is a sufficiently large sample to provide meaningful benchmarks, it is relatively small compared to thousands of buildings occupied by UN entities across the world. Furthermore, it is important to take into account the location of these buildings, which is predominantly in developed or

[10] http://www.internationalsustainabilityalliance.org/filelibrary/6%20-%20ISA%20Documents%20&%20Presentations/ISA%20Documents%20for%20General%20Area/Reports/ISA_Benchmark_Report_2013_small.pdf
[11] http://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/REEB%20Benchmarks%202015%20-%20Final.pdf

transition countries with good infrastructure, when interpreting results of the inventory.

6.1 Energy

Regarding energy and its associated greenhouse gas emissions, the inventory provides information on all aspects of energy hierarchy from energy demand reduction to energy efficient consumption and low carbon generation.

The average energy intensity of buildings included in the inventory suggests that UN buildings perform well against international good practice benchmarks. At the same time, UN buildings do not perform

In terms of average energy consumption there appears to be a discrepancy between building energy intensity, which is in the realm of good and best international practice, and relatively average to poor fabric and building systems specification. This could be due to inaccuracies in the reported data and more attention should be paid to comparative trends observed than to actual consumption figures.

The inventory suggests that passive design strategies are not widely implemented as the relevant information was provided for only half of the buildings and half of those reported no such strategies in place. The energy saving benefit of having these strategies is somewhat confirmed by the 12% lower average building energy intensity values. However, given the geographical spread and small sample size, this figure may not be the most accurate representation of the associated benefit.

Regarding, insulation of building elements and glazing, the performance is commensurate with building age, except in warm climates where benefits of insulation are not as significant. On average, UN entities occupy relatively old buildings both in terms of original construction and when the latest major refurbishment is considered. Data shows that buildings that are up to 10 years old perform twice as good in terms of energy than the UN average building.

It is evident that naturally ventilated and mixed-mode buildings use 50% and 75%, respectively, of the energy used by mechanically ventilated and air-conditioned buildings. Furthermore, the large majority of buildings have no appropriate energy-monitoring infrastructure relying on utility meters only.

In terms of mains energy generation, fossil fuels are still the predominant source of energy further strengthening the argument for energy demand reduction and efficient consumption. However, at 16%, hydropower and biodiesels account for relatively significant proportion of buildings.

There is a limited on-site renewable energy generation with only 17 buildings reporting one or more renewables installed.

THUS….

6.2 Waste

The inventory shows relatively low per capita waste quantities with high recycling and diversion from landfill rates. The inventory also confirms that it is difficult to obtain waste data, with less than 40% of buildings providing waste data and only 15% of those not relying on estimates but using data from waste transfer notes. Furthermore, only one building reported to have a waste management policy and three have a waste management action plan.

Thus, further work and capacity building is definitely necessary before robust quantitative data becomes available.

6.3 Water

The inventory confirms that UN's water consumption rates are similar to international averages when normalized by floor area. Given that 70% of data provided is metered, the actual consumption figures are likely to be accurate. At the same time, the average per capita consumption figure appears to be significantly higher when compared to good practice benchmarks. One of the reasons for this difference could be a relatively low level of rainwater and greywater use.

7.0 Recommendations

The following recommendations are mainly aimed at UN facilities managers as well as IMG and INFM focal points.

7.1 Inventory-related recommendations

- **Improve data quantity and quality:** While the inventory provides a good insight into performance of the UN buildings stock, a large proportion of respondents were not able to answer all questions. Furthermore, the inconsistency between quantitative and qualitative energy and waste data indicates likely inaccuracies. Thus, focal points are encouraged to improve data collection with meters and build local organizational capacity for data collection, scrutinize data prior to submission or ..whatever… and seek assistance from SUN where necessary.

- **Assist with maintenance and expansion of the inventory:** Focal points are encouraged to share new and update existing information on an ongoing basis. While an inventory specific survey is not intended in the near future, information gathering will be conducted through existing means such as greenhouse gas, waste and water inventories, peer reviews and EMS-related environmental reviews. It is also hoped that environment will remain a topic of the regular INFM benchmarking exercise.

7.2 Technical recommendations

- **Engage building owners and facilities contractors:** A large proportion of UN buildings is leased and / or managed by private contractors. Furthermore, some buildings are leased on an all-inclusive basis where the UN does not pay utility bills. It is therefore essential to pro-actively engage these non-UN entities on all the key environmental topics. Data collection for the purposes of annual inventories could provide a good opportunity for such engagement.

- **Consider leasing newer buildings:** UN building stock is relatively old and the inventory showed direct correlation between building age and energy efficiency with newer buildings performing significantly better.

- **Always apply energy hierarchy approach when considering energy efficiency improvements:** Evidence from existing buildings shows that specifying solar panels, for example, as part of an energy retrofit or as a one-off project is not necessarily the most feasible solution in terms of funds spend and associated environmental benefits. Upgrading glazing or light fittings, for example, may result in greater energy savings and quicker payback times than installation of on-site renewables. While the exact hierarchy of activities will vary from building to building, consideration of activities in the order of the energy hierarchy will ensure that no opportunity is missed.

- **Improve energy metering and monitoring infrastructure and practices:** Experience shows that whether an office has extensive metering infrastructure or relies on utility meters only, investment in sub-metering, automated systems and / or procedures is a prerequisite to effective energy management. This is a single area where most if not all of the buildings within the inventory can improve on.

- **Improve waste management practices at all levels:** Low response level to the inventory, unrealistic figures and lack of policy in place, indicate that there is a significant amount of work needed to improve waste management in the UN. Improvements are likely to be needed at multiple levels from corporate policy and action plan development to capacity building of personnel dealing with waste on site to waste accounting practices. SUN team has already delivered training on waste accounting for the purposes of the UN-wide waste inventory and will be producing further guidance and training material in 2017.

- **Consider opportunities for reduced water consumption:** UN building water consumption is in the average realm when compared to other existing buildings. However, the inventory has shown that per capita consumption is relatively high while rainwater harvesting and greywater recycling is seldom implemented. In addition to water re-use, consideration should be given to flow rates of taps, volumes of WC cylinders and irrigation of soft landscape.

- **Consider certification against third-party environmental rating standards:** While third-party certification standards, such as BREEAM and LEED, have been used to independently verify green credential of buildings for over 25 years, there is only 10 buildings within the inventory that have been certified. Such standards have driven the green building sector and can provide a solid framework to improve environmental performance, reduce operating costs, improve productivity and ensure comfort for building occupants.