CONCERTO

OVERALL ENERGY PERFORMANCE OF THE 26 COMMUNITIES

EXECUTIVE SUMMARY

CONCERTO
is an initiative co-funded by
the European Commission
under the Research
Framework Programme

CONCERTO

CONCERTO
IS CO-FUNDED
BY THE EUROPEAN
COMMISSION

Authors

Olivier Pol
AIT Austrian Institute of Technology, Energy department

Lukas Lippert
AIT Austrian Institute of Technology, Energy department

In cooperation with Branislav Iglár and Doris Österreicher (both AIT Energy department)

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WHAT IS CONCERTO?

The CONCERTO initiative was established in 2005 by the European Commission. During its creation, the defining concepts in mind were sustainability, replication and cost effectiveness, and the project aimed at revolutionising and modernising communities' energy systems.

With an initial network of 27 cities, the CONCERTO concept ignited, and five years later 58 cities in 23 countries across Europe are demonstrating and over 70 associated communities benefit from the growing stock of knowledge. The CONCERTO initiative highlights the role and contribution of local authorities (primarily city administrations) as coordinators of integrated actions for sustainable urban development with a focus on energy issues. The cities have a mission to research and demonstrate how energy efficiency and renewable energy use can be incorporated into cities' buildings on a large scale. CONCERTO is itself in every sense on a large scale, with CONCERTO cities comprising a population of approximately 5 Million people with about 500,000 inhabitants directly – or indirectly - affected by CONCERTO activities.

In 2010, after five years of CONCERTO, the results, findings and recommendations are available in several reports and publications:

- The CONCERTO Guide
- Planning and implementation process assessment report & Executive summary
- Report on the quality of integration of renewable energy supply and energy efficiency measures & Executive summary
- Report on the assessment of the overall energy performance of the 26 CONCERTO I communities & Executive summary
- Report on the socio-economic assessment & Executive summary
- Publication on policy recommendations & Executive summary
- 3rd CONCERTO DVD, including all above mentioned publications in electronic format

The purpose of the publications is to share the results of the CONCERTO initiative. The different publications will provide information to relevant actors aiming to implement sustainability projects in cities across Europe. By sharing this knowledge, the publications will provide an outline of what can be done and how local sustainability can become a reality. All publications can be accessed via the European Commission's DG ENERGY website at http://ec.europa.eu/energy/renewables/concerto_en.htm

The CONCERTO initiative at a glance

- 58 cities in 23 countries, close to 70 associated communities
- 1,830,000 m^2 of buildings built or renovated
- 530,000 tons of CO_2 emissions saved per year
- 5,2 million people live in the CONCERTO cities

0. INTRODUCTION

The CONCERTO initiative can be considered as a milestone in the development of European Commission energy research funding programmes because it is the first time that integrated projects have been funded without explicitly targeting specific technologies. Instead, a set of technologies was chosen by cities themselves, depending on their own conception of energy system sustainability at local level and local energy planning activities previously undertaken. The initiative was therefore a catalyst for change in local authorities implementing an integrated vision of their future urban energy systems, by acting both on the energy demand and supply side. This vision was implemented at both the neighbourhood and municipal scale. Combining a new type of funding programme with a new means of tackling energy challenges requires monitoring and some form of impact assessment. This helps determining the energy performance levels reached by cities which benefits from such funding opportunities. Many questions need to be answered: What does such a programme achieve? Is this the best way to fund research and local demonstration activities to further motivate local authorities? Does cities' energy performance improve as a result of this innovative funding programme? Regarding implementation and planning, how should these recommendations be formulated so that willing cities can replicate CONCERTO actions. These questions can only be answered when assessing the overall impact of the initiative.

An essential aspect of overall assessment work concerns technical and energy issues. Demonstration activities are related to newly constructed eco-buildings, existing buildings having undergone high energy performance renovation and energy generation plants based on a high share renewable energy sources, cascade use of resources and polygeneration. Therefore, an impact assessment has to answer the following questions:

- What was built during the five year deadline within in which CONCERTO Cities operated? In order to answer this question, it is essential to use indicators which characterise the quantity of buildings and plants constructed
- How do these buildings and plants perform? Indicators illustrating the expected and actual energy performance of these buildings and plants are to be used when answering this question.
- What is the general impact on avoided CO_2-emissions or primary energy savings? Both common baselines and a unified method are required in order to compare cities that follow different strategies.

The Report on impact assessment and overall energy performance assessment provides an overview on what has been achieved during CONCERTO projects' five year life-span. This is conveyed in terms of technical and energy issues, including all energy efficiency measures and renewable energy systems implemented as demonstration activities within the first generation of CONCERTO projects. A major endeavour of this report is to provide common and objective criteria for assessing the energy performance level of cities and neighbourhoods, even if cities follow different approaches by applying different sets of technologies or by considering the neighbourhood dimension rather than the municipal dimension of their urban energy systems.

The report presents the impact assessment results for each of the cities analysed and for the entire programme. Instead of showing the results successively for each community, the report provides a direct comparative assessment establishing a benchmark for projects with similar typologies (new neighbourhood developments, neighbourhood renovation projects, integration at city scale). Conclusions can be drawn on the impact of single measures as well as a combination of measures.

An assessment of actual energy performance of buildings and plants has only been done when actual monitoring data for a period of at least one year was available at the time of writing. As monitoring and assessment work on the CONCERTO initiative will still be continued after this report, the results presented here should be considered as preliminary.

Relevance

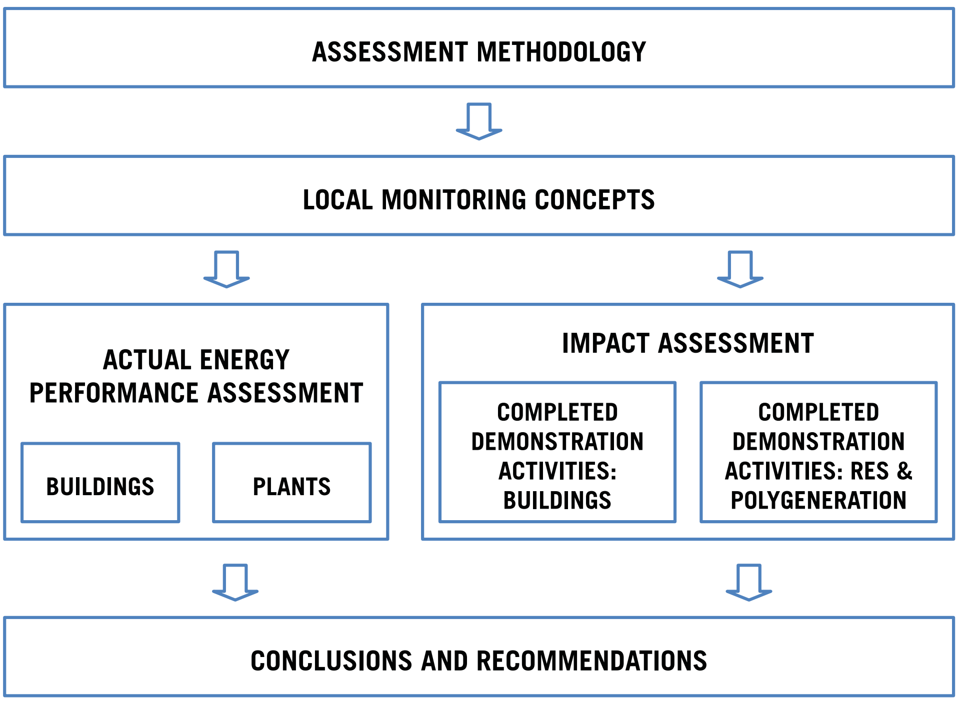
Projects like CONCERTO are not common, so assessing their impact is a unique opportunity to document the progress, summarise the results and provide recommendations for future projects following similar strategies.

The systematic analysis helps to better understand what cities can achieve by implementing specific combinations of measures and following an integrated approach. This is analysed in terms of energy savings and avoided CO_2-emissions in a five year time period.

The analysis also highlights the types of measures which have a significant and direct impact on a city's overall energy balance. It also underlines combinations of measures which can be implemented at the neighbourhood scale, resulting in lasting impact if replicated systematically within each new neighbourhood development or neighbourhood renovation programme.

Despite the limited amount of data available, it still allowed for conclusions to be drawn on the actual performance of buildings and plants, pointing out necessary improvements for future projects.

Structure



Target group

The Report on impact assessment and overall energy performance assessment is expected to find an interested audience among different groups, mainly involved in energy policy strategies at a local, national and European level. In particular, it addresses municipal authorities and local decision makers, since these stakeholders are in a position to initiate integrated projects (in a CONCERTO sense) and handle the highly complex process required for their implementation (as presented in D1.3.5 Planning and implementation process assessment report). Other parts of the report might be valuable for the academic community or practitioners designing and implementing sustainable energy projects in the urban environment. Interested parties could include project developers, utilities, architects and engineers involved in planning and design activities. The report provides local decision makers with a basic overview on the impact of integrated measures.

1. UNIFIED ASSESSMENT METHODOLOGY

System boundaries for energy performance assessment and impact assessment

Defining a set of technical and energy indicators for the assessment of CONCERTO cities requires an initial definition of system boundaries. The report provides a detailed overview of a CONCERTO definition of communities, as well as the physical/geographical boundaries and energy system boundaries.

As mentioned in the Report on the assessment of quality of integration, the main challenge with assessment relates to the fact that there is no coincidence between the geographical demonstration area chosen (neighbourhood/district/city) and common energy system boundaries, which may correspond for instance to an energy conversion plant. In particular, demonstration projects are connected to an energy supply infrastructure (electrical, gas and/or district heating/cooling network) which goes beyond the geographical boundaries of the demonstration area.

That is why the assessment of CONCERTO cities is adapted differently when approaching neighbourhoods or when approaching an entire project. Both assessment approaches are illustrated by Figure 1 and are explained in detail in D.1.3.3. They mainly differ in how energy generated outside the geographical boundaries of a given neighbourhood is considered in the energy balance.

Performance indicators

Based on the chosen system boundaries and the double assessment approach at the neighbourhood and project level, a critical reflexion on the initially proposed indicators have led to the selection of the performance indicators presented in Table 1. The numbers

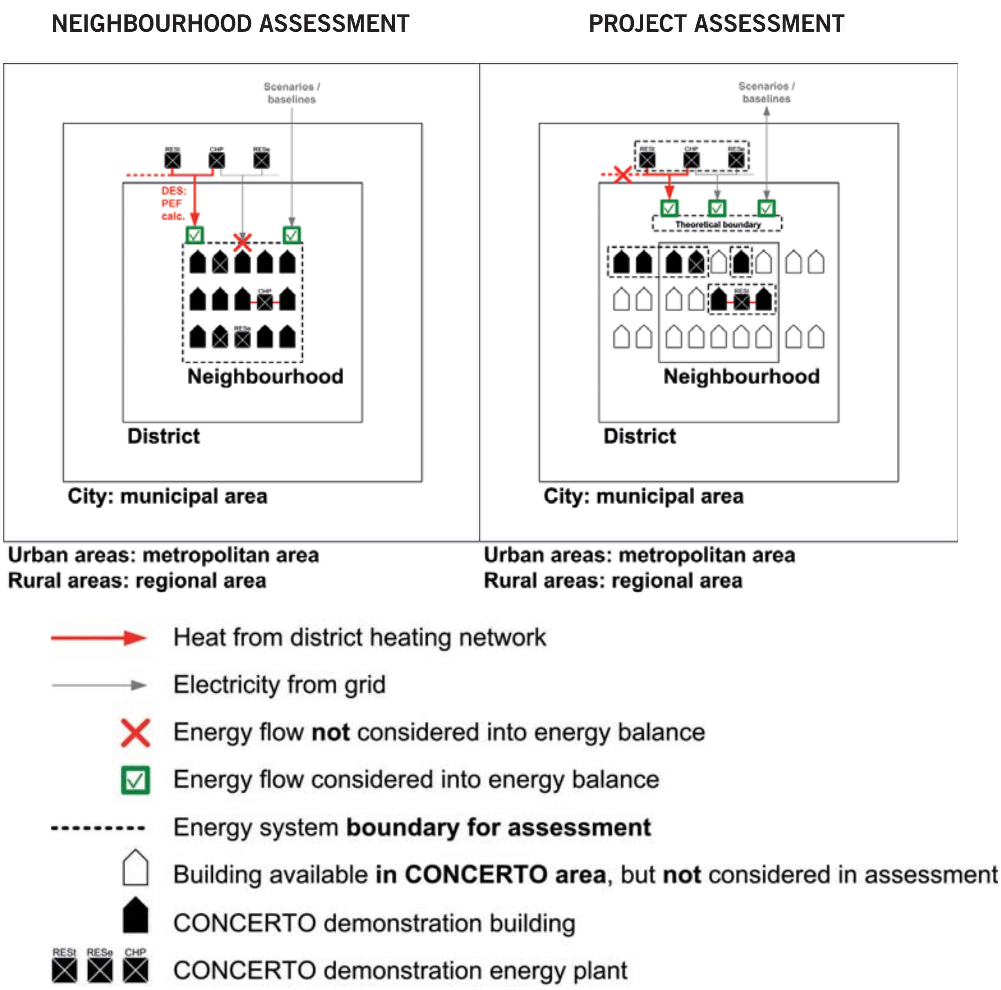


Figure 1: Energy system boundaries for neighbourhood and project assessment

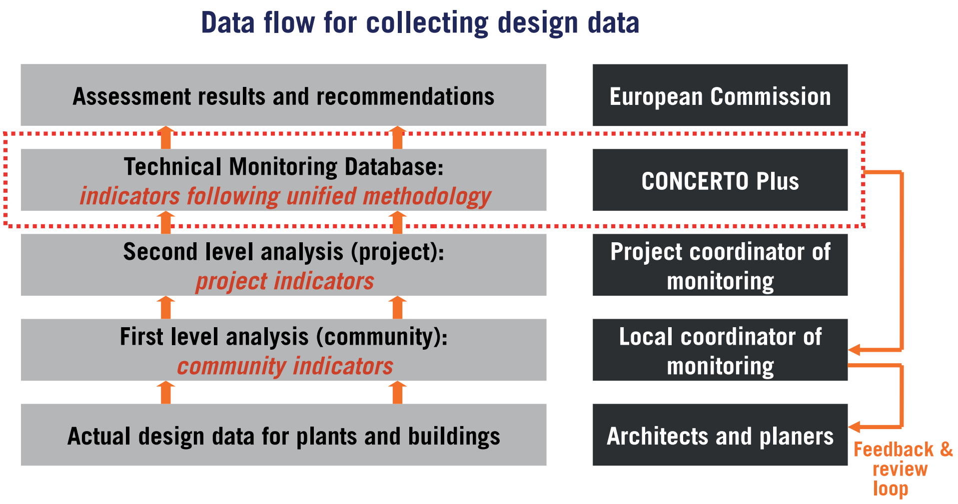


Figure 2: Data collection process for actual building and plant design data

INDICATOR NAME	COMMENTS AND CHARACTERISTICS OF INDICATOR
Total gross floor area of new high performing eco-buildings constructed, in m^2_{GFA} (n°5)	These five indicators characterise how much has been built in 5 years of demonstration activities. They consider for each community all demonstration projects: ⌘ which have been completed by October 2010 ⌘ whose construction activities started before October 2010 and are in progress at the time of writing All planned and confirmed demonstration activities which did not start before October 2010 are not considered as built and are excluded from the assessment.
Total gross floor area of refurbished buildings, in m^2_{GFA} (n°6)	
Total capacity of installed power plants using renewable energy sources, in MW (n°7)	
Total capacity of installed heating and cooling plants using renewable energy sources, in MW (n°8)	
Total capacity of installed cogeneration plants, in MW_{el} and MW_{th}	
Initially requested: Increase in % of renewable energy in electricity consumption of CONCERTO area (n°1) **Proposed and calculated:** Share of electricity from renewable energy sources in electricity use of CONCERTO buildings **Initially requested:** Increase in % of renewable energy in heating / cooling consumption of CONCERTO area (n°2) **Proposed and calculated:** Share of thermal energy from renewable energy sources in thermal energy use of CONCERTO buildings	The initially requested indicator cannot be used in CONCERTO because of lacking data, unsuitable system boundaries and uncertain baselines. The proposed indicators are determined: ⌘ at neighbourhood scale (by considering the system boundaries introduced in Figure 1) ⌘ at project scale (i.e. by balancing energy use and energy generation from renewable energy sources even if the buildings do not directly use renewable energy sources) Both indicators are based on building and plant design data (calculated performance). If available, actual monitoring data is used for energy production from renewable energy sources.
Percentage and absolute reduction in electricity use per m² of each building type (efficiency measures) (n°3a)	Both indicators are based on building design data (calculated performance depending on actual design data). The percentage and absolute reduction is calculated compared to a national/community baseline for new buildings and to the assessed performance before renovation for existing buildings.
Percentage and absolute reduction in thermal energy use per m² of each building type (efficiency measures) (n°3b)	
Overall reduction of primary energy use (n°4)	This indicator is determined based on unified calculation baselines: ⌘ at neighbourhood scale ⌘ at project scale
Avoided CO_2-emissions	This indicator is calculated at project scale, i.e. by adding the individual impact of each single measure in terms of avoided CO_2-emissions.

Table 1: Chosen performance indicators

between brackets refer to the initial numbering of indicators. Two of the initially requested indicators (n°1 and n°2) turned out to be unsuitable and unrepresentative of the CONCERTO initiative and have been replaced by alternative indicators.

Data gathering and processing

Data collected and data collection procedure

The assessment work regarding the overall CONCERTO initiative is characterised by multiple stages in the data communication process. The high complexity is related to the high number of actors involved (contractual partners and third parties) and the administrative and contractual obligations of European funded projects.

To fulfil the ambitions of the impact assessment and energy performance assessment and obtain required indicators, the following types of data had to be collected:

- Actual design data for buildings and plants, showing what was constructed and installed, and how buildings and plants were supposed to perform. Given the limited time period where actual energy use data is available for demonstration projects, actual energy use figures can not be used for the overall energy performance ex-post assessment.
- Actual data regarding energy-use showing how single buildings and plants actually perform. This data is only used as a spot test. The number of buildings and plants monitored, the time period where data is available and the data quality delivered is not statistically satisfying to guarantee a consistent assessment based on energy use monitoring data.

Figure 2 and Figure 3 illustrate the multiple stage data collection process for both actual buildings and plant design data (Figure 2) and actual energy use monitoring data (Figure 3).

The main characteristic of the data collection process is that the expert assessment team (CONCERTO Plus) does not have direct access to the primary data source. As a consequence there was a high risk of misinterpretation for data and indicators forwarded through various reports and databases. The feedback and review loop was a unique guarantee of data quality, but this required a lot of time given the high number of contractual partners and third parties involved who are responsible for collecting primary data.

Main challenges in data collection

The main difficulties in carrying out a comprehensive assessment are mainly due to:

- Differences in implementation stages between cities. In particular, some of the demonstration projects are not completed at the time of writing.
- Lack of a consistent and common data baseline for all cities. The main reason for this is the complex nature of data communication flows, inherent in any large European projects like CONCERTO.

Database structure

The precise definition of data used for the assessment and the minimal requirement set on already collected data were initially defined together with monitoring experts from CON-

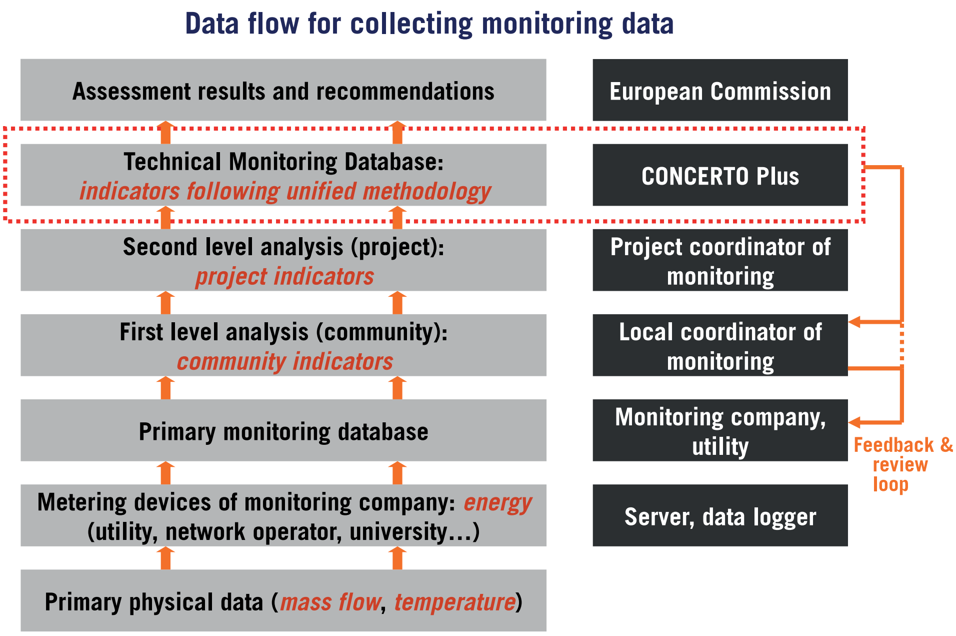


Figure 3: Data collection process for monitoring data

CERTO projects and are reported in the document "agreement on energy performance assessment and monitoring activities". This mainly consists of a unified nomenclature of all energy flows at building, neighbourhood and city scale, as illustrated in Figure 4.

All data is collected in an ad-hoc developed web accessible database (technical monitoring database), guaranteeing transparency in data used for assessment. It also allows for facilitated data update and systematic data post-processing. The database mainly contains all basic design and energy use data for demonstration projects as well as, if relevant, the relationship between buildings and energy generation units (i.e. if renewable energy systems are installed in buildings).

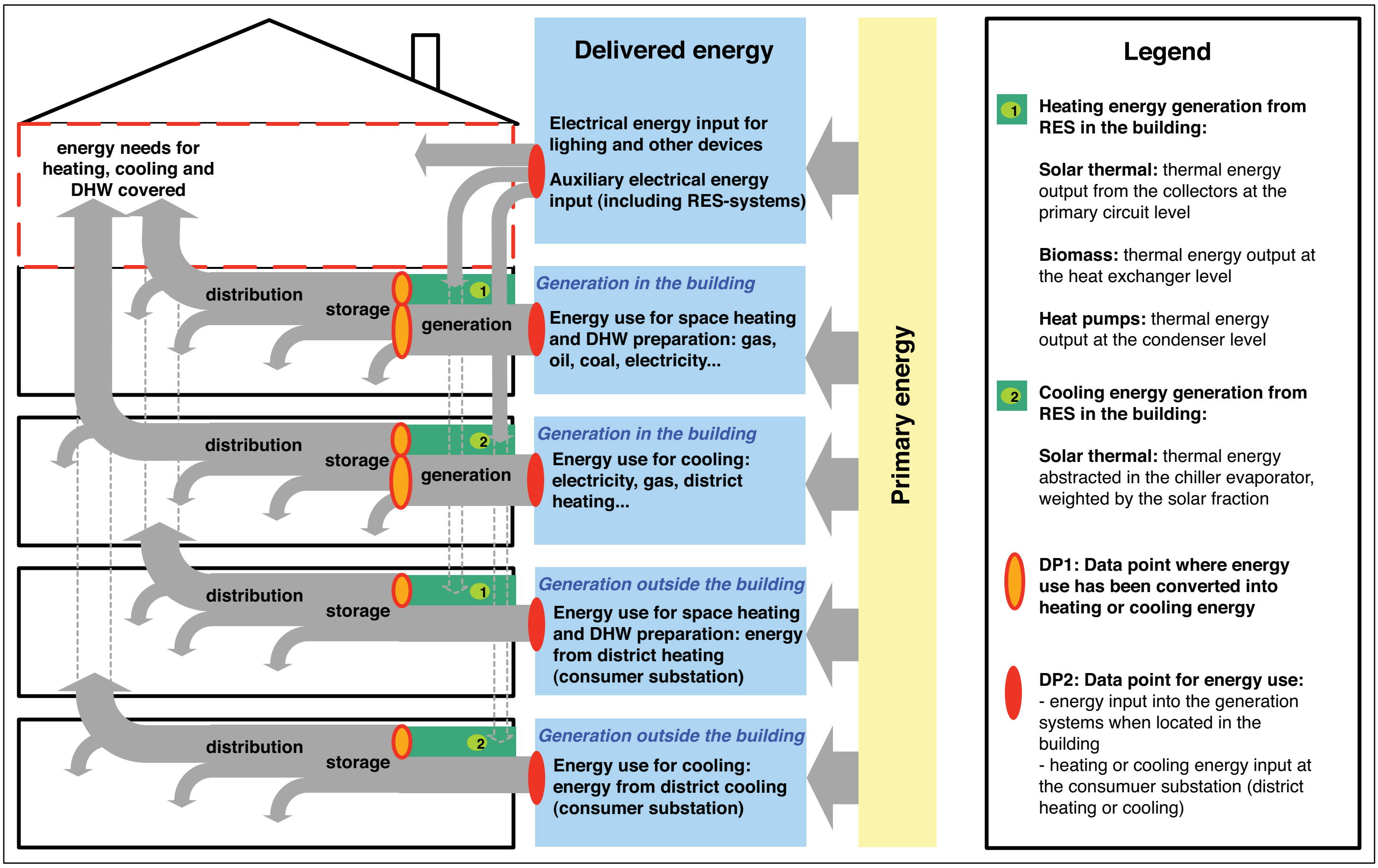
Available data quantity and quality

For transparency reasons, the following quantity and quality indicators for provided and used data were defined:

- High data quantity corresponds to high number of deliverables, reports and data communicated to the assessment expert team (CONCERTO Plus)
- Criteria for high quality data include:
  - A clear and univocal data definition (including units)
  - An explicit reference to external/ internal sources
  - Critical comments on the validity of data communicated
  - Consistency with CONCERTO Plus requirements (in particular with regard to monitoring)

Across the 9 CONCERTO projects, data quality has been estimated as being high for 2 projects, low for 2 others, and medium (i.e. with

Figure 4: Data collection process for monitoring data



data quality varying according to demonstration objects or cities) for the 5 remaining projects.

Data post-processing and calculation baselines
After data collection, data post-processing is a key issue to obtain the key indicators requested. The assessment is not performed by blindly summing up the assessment results provided by each individual project, mainly because different baselines and calculation methods are used (e.g. for calculating avoided CO_2-emissions). A unified assessment methodology has been developed to normalise data according to given characteristics and to make data coming from different cities comparable. The calculation baselines are reported in Annex 2 of the complete report, presenting the conventions used and choices made. The unified approach concerns the following topics:

- Heating and cooling degree days correction to compare performance between cities situated in different climate zones (unified method at the EU level)
- Correction of floor area units to express energy performance ratings as unified ratings in all cities
- Common primary energy factors and CO_2-emissions used to calculate savings based on unified baselines
- Systematic data correction procedure in case of missing data (e.g. for household electricity use)

2. OVERVIEW OF LOCAL MONITORING CONCEPTS

Since the overall assessment results primarily rely on local monitoring concepts implemented by each CONCERTO community, it is worth describing the different local monitoring approaches. An overview of the main characteristics of monitoring approaches is provided in Table 3.

Approaches for monitoring at the community scale
Monitoring of advancement indicators through funding procedure
For the few cities implementing target-group centered approaches (mainly small scale measures targeted to private households, housing companies etc.) distributed over entire municipal areas, annual reporting of absolute quantity indicators could be implemented and used directly when assessing the success of specific funding measures. The main reason for this is that the funding was released on confirmation that the technical measure was implemented. In some cases this reporting was used to review initial objectives, if specific measures turned out to be successful or conversely difficult to implement. Indicators such as annual figures for construction of eco-buildings, renovated one-family houses, installed capacity of individual heating systems or power plants using renewable energy sources could be used and updated annually, based on the funding procedure for these measures.

For the majority of CONCERTO cities, annual reporting on what was built or installed was not a relevant indicator, since new neighbourhood developments or neighbourhood renovation projects usually have implementation phases going far beyond the five year period given for CONCERTO. The annual figures for constructed or renovated buildings during a five years time period does not provide any information on the efficiency of local energy policy, but rather depends on the maturity, time-schedule and construction time foreseen for developing these neighbourhoods.

The assessment therefore only considers the status advancement indicators (n°5, 6, 7, 8) at the time of writing. In CONCERTO, this procedure could be easily applied as the reporting of advancement indicators was a contractual obligation of cities towards the European Commission.

Data gathering using questionnaires distributed among end-users
Questionnaires were used mainly to elaborate on social indicators (e.g. the degree of satisfaction etc.), but also to obtain more detailed information on projects involving directly households (e.g. renovation of one-family houses or installation individual heating systems using renewable energy sources). These questionnaires were used to collect data on the actual performance of individual heating systems, small scale photovoltaic plants or buildings that were renovated.

In CONCERTO, this procedure was mainly used when a centralized monitoring system was not feasible due to costs limitations. The quality of results is of course influenced by all known limits related to the work with questionnaires.

Data collection at utilities and housing companies (billing procedure)
The most common data collection procedure for actual energy use in CONCERTO cities consisted of gathering data which was collected anyway for other reasons (mainly for billing procedures). Typically, data was available from (social) housing companies, associations and cooperatives or energy utilities and network operators.

In CONCERTO, the data obtained from (social) housing companies, associations and cooperatives usually had the highest quality and complied with the general requirements (in the best case, monthly data with separate metering of energy use for domestic hot water and space heating). When data could not be obtained from housing companies (depending mainly on energy billing procedures), it proved difficult to access energy data from utilities and network operators. Even if privacy protection clauses would be respected, there was a general reluctance to share data, with considerable delays for example in communicating historical energy use data for existing building prior to renovation.

Detailed energy use monitoring of single buildings and plants for energy management targets
In some cases, the energy performance of buildings and plants was monitored for energy

TYPE OF MONITORING DATA	SHARE OF DEMONSTRATION PROJECTS WHERE ACTUAL ENERGY USE DATA ARE AVAILABLE
Energy use of new buildings	ca. 35 % of the total gross floor area of constructed buildings
Energy use of refurbished buildings after renovation	ca. 65 % of the total gross floor area of refurbished buildings
Fuel input and energy output of energy generation plants from RES	ca. 50 % of the total installed capacity
Fuel input and energy output of cogeneration plants	ca. 30 % of the total installed electricity capacity

Table 2: Availability of energy-use monitoring data

- ■ is or will be available in the community as a demonstration activity
- R available in the community as a demonstration activity, but not planned initially
- planned, but to be confirmed
- ☒ planned, but will not be implemented or implemented with major delays
- ≡ available in the community, but not part of the demonstration activities

	act2 / Hannover	act2 / Nantes	cRRescendo / Ajaccio	cRRescendo / Almere	cRRescendo / Milton Keynes	cRRescendo / Viladecans	ECO-City / Helsingborg	ECO-City / Helsingør	ECO-City / Trondheim	ECO-City / Tudela	ECOSTILER / Amsterdam	ECOSTILER / London	ECOSTILER / Måbjerg	energy in minds! / Falkenberg	energy in minds! / Neckarsulm	energy in minds! / Weiz Gleisdorf	energy in minds! / Zlin	POLYCITY / Cerdanyola	POLYCITY / Ostfildern	POLYCITY / Torino	RENAISSANCE / Lyon	RENAISSANCE / Zaragoza	sesac / Grenoble	sesac / Delft	sesac / Växjö	TetraEner / Geneva
Monitoring of advancement indicators through funding procedure (yearly reporting in target-group centered approaches)														■	■	■	■									
Collection of energy consumption data using forms distributed among consumers				■	■	■					☒			R	■	■	■			■		■				■
Data collection at utilities and housing companies (billing procedures)	■		■				■	■	■		■			■					■	■					■	
Energy management for chosen buildings (public buildings) assisted by measurement of energy consumption data and real-time data transmission (supply / demand control system)			■							☒				■	R	R	■		■	■						
Energy management for large scale energy plants					■		■	■	■	■	■			■	■	■	■	■	■	■			■		■	■
Ad hoc centralised monitoring concepts at neighbourhood scale																			■	■	■	■	■			
Community energy management assisted by measurement of energy consumption data and real-time data transmission (supply / demand control system)							■			☒								■	■	■						
Permanent large scale metering of comfort parameters and/or large scale detailed metering of energy consumption within the buildings.							■							■							■	■				
Price signals depending on actual hot water consumption or indoor temperature														■												
Presentation of metering results using a Geographical Information System		≡																	■							
Display of metered energy consumption data at end users		☒	☒		☒		≡	R	R					R					■			■			■	

Table 3: Overview on characteristics of monitoring approaches in the CONCERTO cities

management targets, usually by relying on available commercial products.

In the CONCERTO building sector, this was mainly done for public buildings (schools, office buildings etc.) in order to point out abnormal energy use patterns or highlight energy saving potential. At the plant level, the commonly used systems for monitoring performance were further used. In many cases the overall plant energy performance can be assessed on a monthly basis by using fuel input and generated heat or electricity. However, in many cases there were incomplete datasets (e.g. the generated amount of heat and electricity was communicated, but the fuel consumption was omitted), showing a clear reluctance from utilities to transparently communicate the real performance of their plants.

Centralised monitoring concepts, real-time monitoring and energy management

Last but not least, there are some rare examples of cities where ad-hoc centralized monitoring systems are installed, quite often in the framework of academic research activities funded by CONCERTO. The few projects following this approach aim to monitor all energy flows in a given neighbourhood and have therefore the most ambitious concepts in terms of energy use monitoring activities. In some cases there have been attempts to combine the centralised energy monitoring concept to a real-time energy management system. This turned out to be very challenging and has yet to lead to substantial results.

Overview on energy-use monitoring data available in every community

Table 2 provides an overview of the quantity of actual energy use monitoring data available in proportion to the total amount of buildings and plants constructed or in construction by October 2010. Monitoring data is only considered if data sets are available for at least one year.

3. IMPACT ASSESSMENT

Completed demonstration activities: buildings

By October 2010, ca. 1.150.000 m^2_{GFA} of buildings have been built or renovated towards improved energy performance standards going beyond the minimal energy performance requirements applicable at the local or national level. As shown by Figure 6, more than half of these buildings are new buildings in the residential sector. More than one quarter represents new non-residential buildings (mainly office buildings and schools) whereas less than one quarter are renovated buildings. This definitely proves that there is a high focus on constructing new buildings. Excluding the neighbourhood projects in Almere (The Netherlands) which include the highest number of demon-

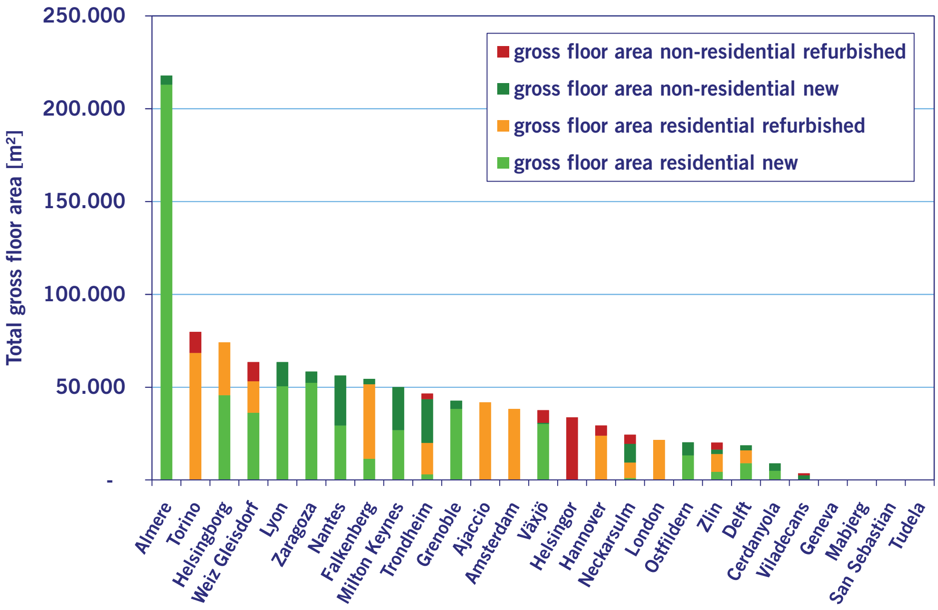


Figure 5: Constructed and renovated gross floor area of buildings in CONCERTO cities [in m²]

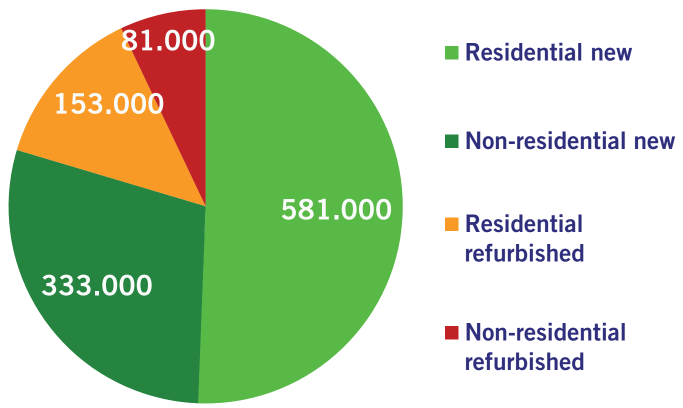


Figure 6: Constructed and renovated gross floor area of buildings in CONCERTO, in [m²]

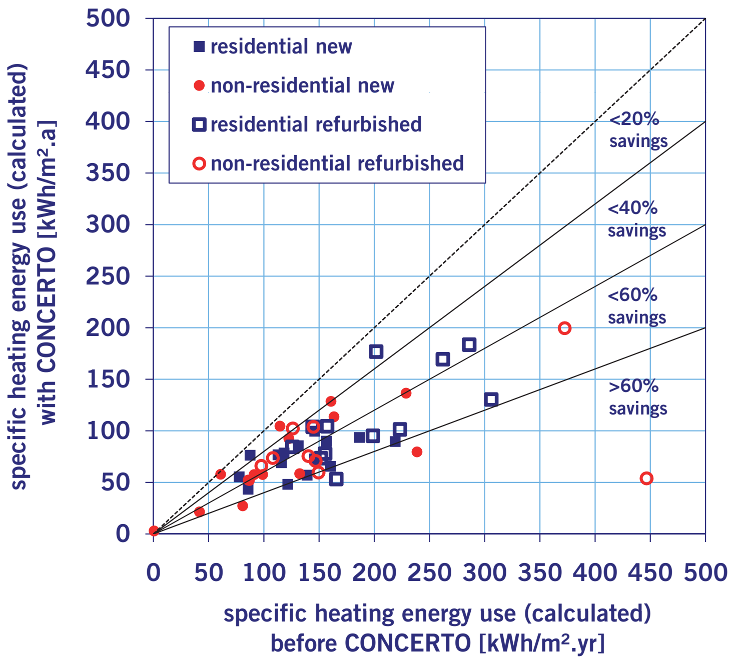


Figure 7: Specific heating energy use before and after CONCERTO (design data, heating degree days corrected, including heating energy for domestic hot water preparation, referred to heated gross floor area). Each plot represents a building type (average) in a CONCERTO community.

stration buildings, there is an average of ca. 40.000 m^2_{GFA} of buildings newly built or renovated per community.

Thermal performance

When considering thermal performance, the calculated average savings of final heating energy use are between 40 % and 50 % (min. 15 %, max 65 %), depending on the building type (see Table 4). In the new built sector, the savings always refer to the current national or local building code requirements at the time the building was designed. For existing buildings, the savings are expressed in relation to the estimated energy use of buildings before renovation. Expressed in percentage, the savings do not show significant differences between building types.

In absolute terms, and considering a normalisation of heating energy use for space heating following the heating degree days correction method proposed by EUROSTAT (HDD18/15, European average of 3386), Figure 7 and Figure 8 show the final heating energy use savings for the different building types, resulting mainly from thermal improvement measures of the building envelope and, in very few cases, measures aimed at reducing heating energy use for domestic hot water preparation (considering final energy use, regardless of the heat energy carrier, is an indicator of energy efficiency improvements in the buildings).

The main conclusions are:

- In the new built sector, the best thermal performances (below 50 $kWh_{FE,HDD18/15}/m^2_{GFA}.a$) were reached in the non-residential sector. The majority of new buildings (in particular residential buildings) have a specific final energy use for heating ranging from 50 $kWh_{FE,HDD18/15}/m^2_{GFA}.a$ to 80 $kWh_{FE,HDD18/15}/m^2_{GFA}.a$, i.e. still far from very low energy building standards. In fact, and as it can be noted from the distribution of U-values of external walls (see Figure 9), there were very few examples of passive houses in the first 26 CONCERTO cities. First assessments made on CONCERTO 2 and 3 cities (projects having started 2007 and later) confirm a general improvement in energy performance levels in the new built sector in more recent projects.
- Even if the renovation sector shows the highest specific savings (specific final energy use for heating reduced by 70 $kWh_{FE,HDD18/15}/m^2_{GFA}.a$ in average), the energy performance levels reached after renovation are still very low, as shown by Figure 7 and Figure 8. This is confirmed by the description of renovation

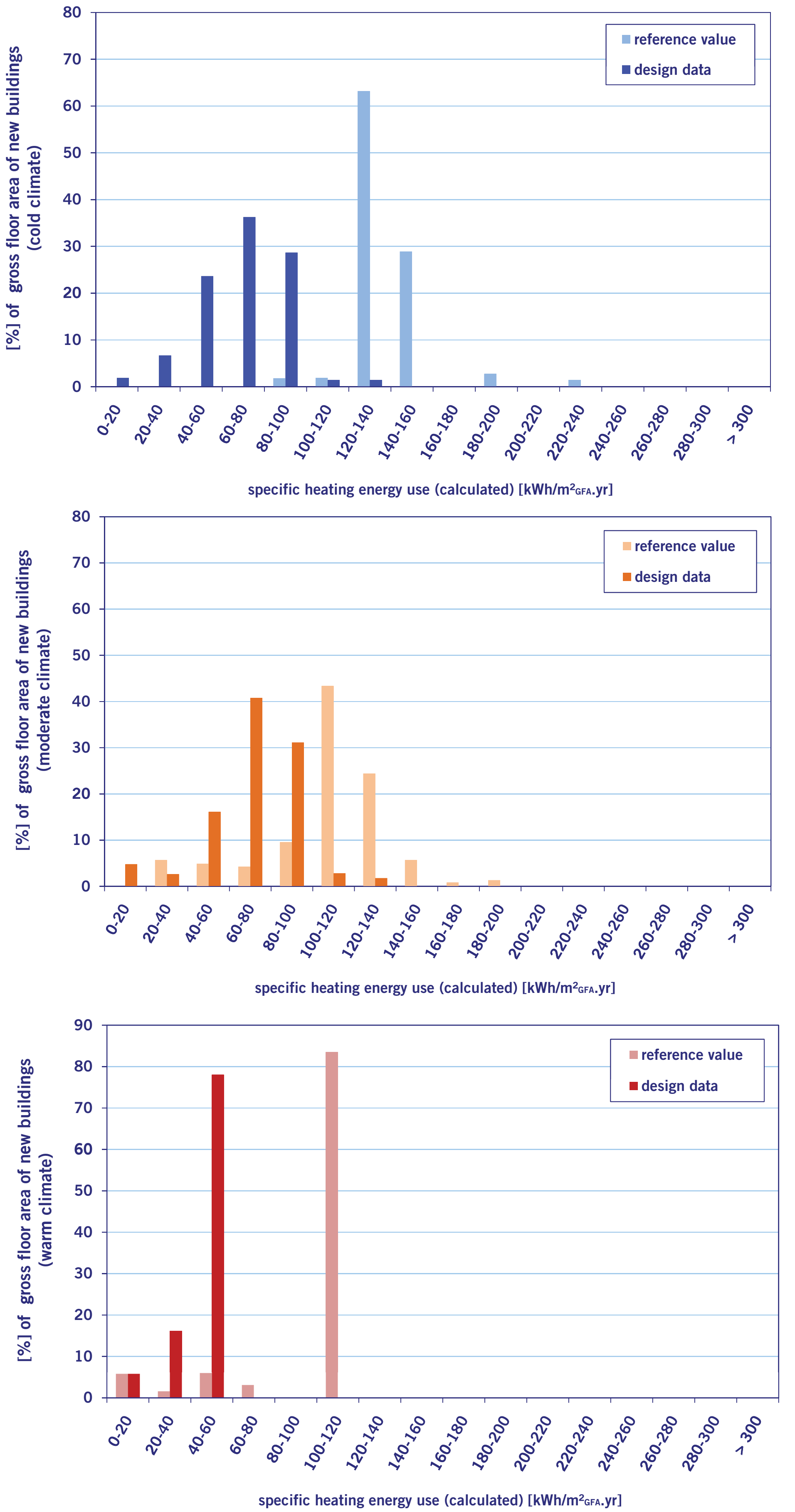


Figure 8: Distribution of specific heating energy use for the new build sector (design data, including heating energy for domestic hot water preparation, without heating degree day correction, assessment according to climate zone, referred to heated gross floor area)

measures implemented in existing buildings: there have been very few examples of comprehensive renovation works in CONCERTO for different reasons (mainly costs, acceptance and difficulty to implement measures in occupied conditions). Rare exceptions confirm however that housing companies having undergone advanced renovation works prior to CONCERTO continued reaching high performance levels during CONCERTO.

Electrical performance

Quantifying electrical energy savings in the building sector is challenging. This is mainly due to the fact that the overall electricity consumption of buildings is usually not considered when calculating building energy performance by following local or national calculation methods. In the best cases, only auxiliary electricity use for HVAC systems is included in building energy performance certificates. As CONCERTO attempts to consider all energy flows in the built environment, electricity use for household appliances, office devices, lighting etc. have to be included in the assessment. Given a very inhomogeneous definition of targets related to electricity use reduction in CONCERTO, a systematic data correction procedure was applied to include missing data on electricity use (quite often household electricity use was not specified in final energy performance ratings) and therefore enable one to quantify the percentage electricity savings in relation to the overall electricity use. As a result, a rather homogeneous distribution of expected average electricity savings (20%) can be noted for all building types in CONCERTO (see Table 4).

Final energy savings and avoided CO_2-emissions due to energy efficiency measures in buildings

On average in all cities assessed, final heating energy use has been reduced by 60 $kWh_{FE,HDD18/15}/m^2_{GFA}.a$ due to energy efficiency measures applied in buildings, corresponding in total to 68.200 $MWh_{FE,HDD18/15}/m^2_{GFA}.a$ and 21.000 t_{CO2}/a when considering gas boiler with an efficiency of 90 % as reference heating system for all buildings.

With regard to electricity, average savings of 12 $kWh_{FE}/m^2_{GFA}.a$ are calculated for all buildings, corresponding in total to 13.400 MWh_{FE}/a and 8.300 t_{CO2}/a when considering the average European electricity mix and related CO_2-emissions.

From an energy efficiency point of view, the main savings are therefore found on the heating side.

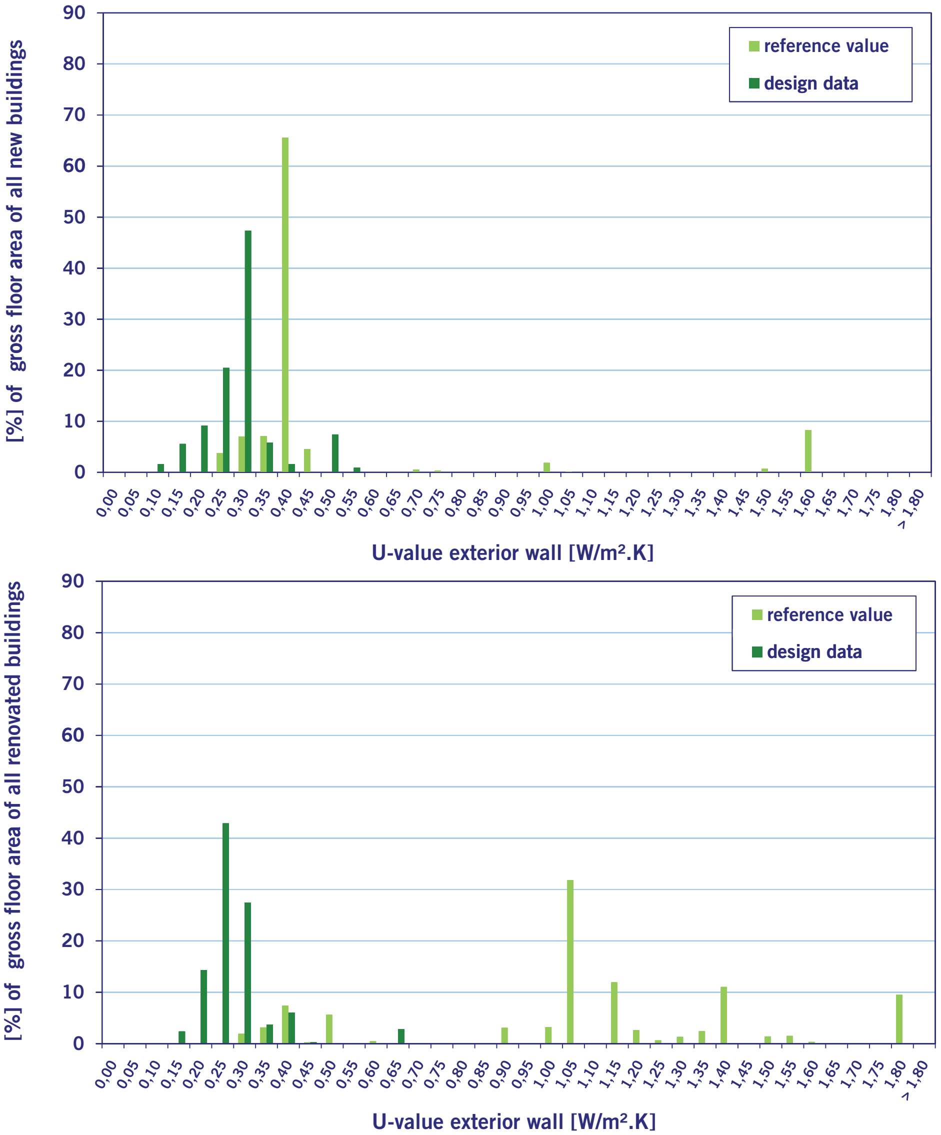


Figure 9: Distribution of U-values of external walls for new buildings (top) and existing buildings being renovated (bottom), considering all climate zones

Completed demonstration activities: renewable energy systems and polygeneration

Technologies used in the different cities

An overview of all demonstration technologies used in each community is provided in Table 5. This confirms that in terms technology frequency, solar technologies play a leading role in CONCERTO (16 cities having photovoltaics, 13 cities having solar thermal systems). Solid biomass firing for heating production is also employed in a large number of cities (five cities having large scale biomass boilers connected to district heating, six cities implementing individual biomass boilers in one-family houses or larger buildings). Biogas is used in six cities for combined heat and electricity production and in one community for heat production only. Four cities have large scale gas-CHP connected to district heating whereas three cities have installed micro or mini CHP plants deserving only the buildings they are installed at. District heating networks were extended in six cities and absorption chillers were connected in five cities to existing district heating network infrastructure.

Installed capacity of renewable energy systems and cogeneration plants

In terms of installed capacity, 60 MW of renewable energy plants have been installed in the assessed CONCERTO communities, excluding large biogas generation plants. More than 45 MW of this capacity relates to thermal systems (more than one third are biomass plants, both large scale and small scale wood pellets, wood chips and biogas boilers), whereas the remaining 15 MW include electrical power systems, as shown by Figure 10.

The total installed capacity of cogeneration plants amounts approximately to 20 MW_{el} and 24 MW_{th}, with the highest capacity installed at large scale gas driven CHP plants. The installed capacity of cogeneration plants driven exclusively by renewable energy sources (biogas) is lower than 1 MW, as well as the installed capacity of small scale individual CHP plants (engines) installed at buildings. The installed capacity of absorption chillers driven thermally by renewable energy sources is below 500 kW in CONCERTO.

The distribution of installed capacity across communities is relatively inhomogeneous. In particular, 11,5 MW of wind turbines and the 10 MW of thermal use of lake water are all installed in two cities (respectively Falkenberg (Sweden) and Geneva (Switzerland)). Large CHP units with electrical capacities of 4 MW and 12 MW are installed respectively in Amsterdam (The Netherlands) and Cerdanyola (Spain).

Generated heat and electricity from renewable energy systems and cogeneration plants

As shown by Figure 11, the 67 MW of installed renewable energy systems produce ca. 104 GWh/a (ca. 74 GWh/a of heating energy and 30 GWh/a of electrical energy). Solar systems (photovoltaics and solar thermal systems) have one quarter of the overall installed RES capacity, but generate less than 1/8 of the overall energy gained from renewable energy sources (excluding biogas generation). In addition, the large scale biogas plants in CONCERTO generate the equivalent of 200 GWh/a of gas, thus corresponding to 2/3 of the overall energy generated from renewable energy sources.

Cogeneration plants generated approximately 90 GWh/a of electricity and 80 GWh/a of heating energy.

BUILDING TYPE	HEATING ENERGY USE	ELECTRICITY
Residential new	45 %	20 %
Non-residential new	40 %	20 %
Residential refurbished	40 %	20 %
Non-residential refurbished	50 %	20 %

Table 4: Average savings (calculated figures based on actual design data of constructed or renovated buildings)

Category	Technology	act2 / Hannover	act2 / Nantes	cRRescendo / Ajaccio	cRRescendo / Almere	cRRescendo / Milton Keynes	cRRescendo / Viladecans	ECO-City / Helsingborg	ECO-City / Helsingør	ECO-City / Trondheim	ECO-City / Tudela	ECOSTILER / Amsterdam	ECOSTILER / London	ECOSTILER / Måbjerg	energy in minds! / Falkenberg	energy in minds! / Neckarsulm	energy in minds! / Weiz Gleisdorf	energy in minds! / Zlin	POLYCITY / Cerdanyola	POLYCITY / Ostfildern	POLYCITY / Torino	RENAISSANCE / Lyon	RENAISSANCE / Zaragoza	sesac / Grenoble	sesac / Delft	sesac / Växjö	TetraEner / Geneva
Biomass heating	Heating plant - biomass (connected to DH and mini-DH)	R					X	≡	■	≡	■				R	R	■									≡	
	Small scale/individual heating boilers (wood pellets)	R	R							X	■				■	■	■					■	X			≡	
	Heating plant - biogas								≡	R																	
Solar technologies	Small scale solar thermal (one-family houses)	X							≡		X				■	■	■	■					X			≡	
	Large scale solar thermal (other individual systems)	■	X	■	■		■	■	X	■	■				R	R	■	■	X	≡		■	■	■		≡	
	Large scale solar thermal connected to district heating				■			■							≡	■			X								
	Solar air collectors			■					≡						■												
	Small scale PV (one-family houses)	X									≡					■	■	■		≡						≡	
	Large scale PV (other)	■	■	R	■	■	■	R	R		X	■	■			■		■		■	■	■	■	■	■	■	
CHP technologies	CHP - biomass				X	X	X	≡		≡					≡	≡				≡						≡	
	CHP - biogas							■	≡			■		■			■	■	X							■	
	CHP - gas					■	X	≡	≡				■						■		■						
	Co-firing biomass in existing CHP	R								≡														■			
	Micro CHP (buildings) - gas engine																							■			
	Stirling engine / linear generator														X	R	R										
	ORC plants															≡				≡							
Cooling technologies	Absorption cooling - driven by district heating							≡		■									■	■	■					■	
	Absorption cooling - driven by solar energy										X												X				
	Absorption cooling - driven by hot exhaust gas																		■								
	Adsorption cooling - driven e. g. by solar energy							X											X								
	Absorption heat pump for heating and cooling (driven by gas)			X																							
	Ground coupled heat pumps	R	X			■		≡	■	■						R				■			R				
	Exhaust air coupled heat pumps							■	≡	≡	■				■							■					
Others	Wind power plants (large and small scale)							■		X	X		X		■								X			R	
	Hydro power plants (small scale)																			■				X		≡	
	Biogas generation plants							■				■														■	
	Hot gases used for waste fired power plants									■		■															
District energy	District heating extension/new district heating (not RES)		■		R			■	■	■			■		■	■	■		■	≡	■			■	R		
	District cooling network							≡											■							■	■
	Low temperature district heating/cooling (with heat pumps)									■					■	■									X		■
Storage	Seasonal storage of municipal waste									■																	
	Seasonal storage of heat							X								≡											
Drying	Solar sludge drying plants															■											
	Crop drying plants connected to DH															X											

- ■ technology is or will be available in the community as a demonstration activity
- R technology available in the community as a demonstration activity, but not planned initially
- X technology planned, but will not be implemented or implemented with major delays
- ≡ technology available in the community, but not part of the demonstration activities

Table 5: Overview on technologies implemented in each community

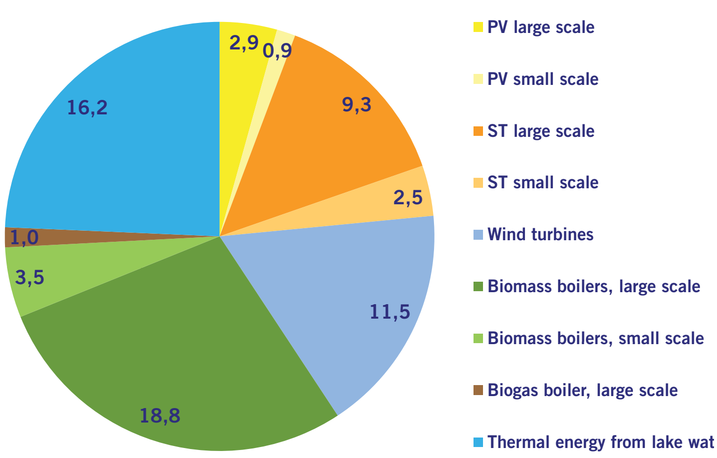


Figure 10: Installed capacity of renewable energy technologies [MW], total = 67 MW

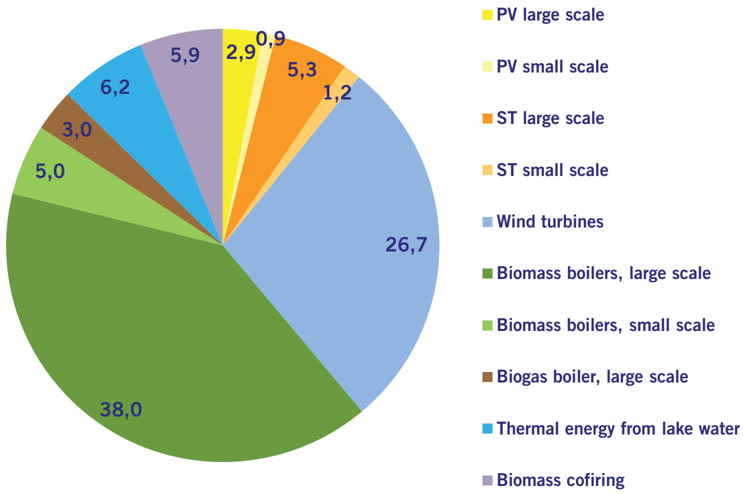


Figure 11: Delivered energy from renewable energy sources [GWh/a], total = 104 GWh/a

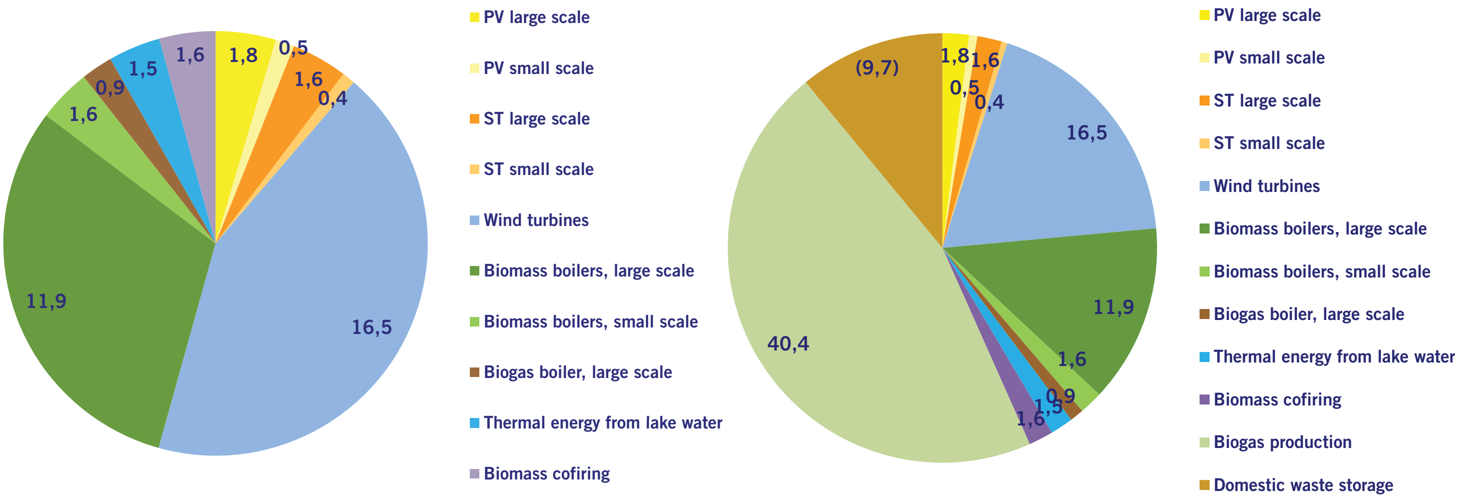


Figure 12: Avoided CO_2-emissions by using renewable energy technologies [Mt_{CO2}/a], total = 40 + 40 (biogas) = 80 Mt_{CO2}/a

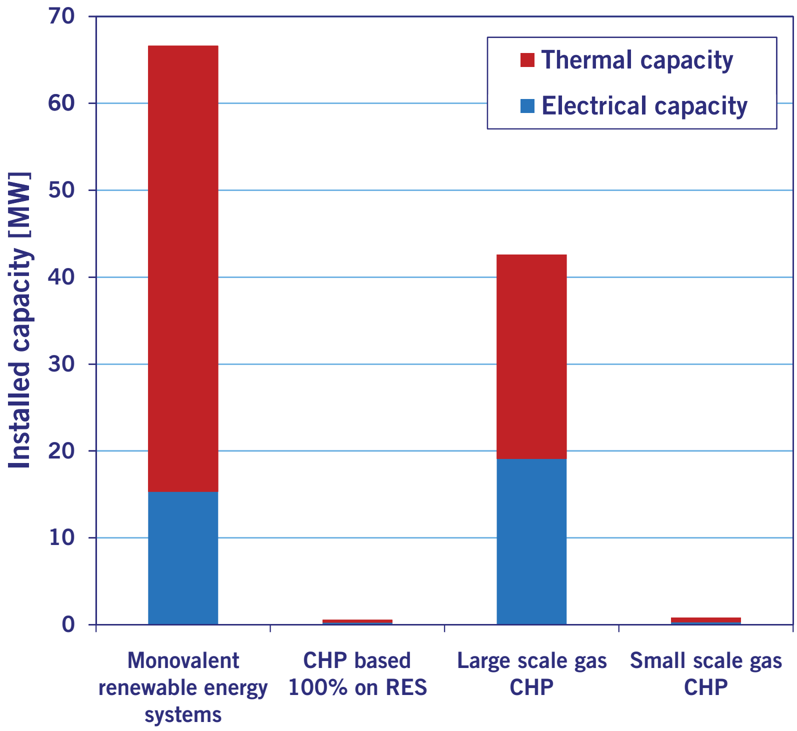


Figure 13: Installed capacity of renewable energy systems and cogeneration plants

Avoided CO_2-emissions due to renewable energy systems and cogeneration plants

Ca. half of the total quantity of avoided CO_2-emissions (ca. 40.000 t_{CO2}/a) by renewable energy systems is due to the contribution of large scale biogas plants. The other half is due to other renewable energy sources, with the highest contribution (over 16.000 t_{CO2}/a) from the five wind turbines installed in Falkenberg. At this point it is worth mentioning the domestic waste storage concept implemented in Trondheim, allowing reducing the peak demand for oil boilers in the district heating network. This contributes to avoid ca 9700 t_{CO2}/a and is therefore mentioned in the impact assessment, even if not related to RES.

The contribution of all demonstration activities towards avoided CO_2-emissions in CONCERTO cities is shown by Figure 16. The demonstration activities in the assessed CONCERTO cities have contributed to avoiding 137.000 t_{CO2} emissions of. The savings are distributed as shown on Figure 15.

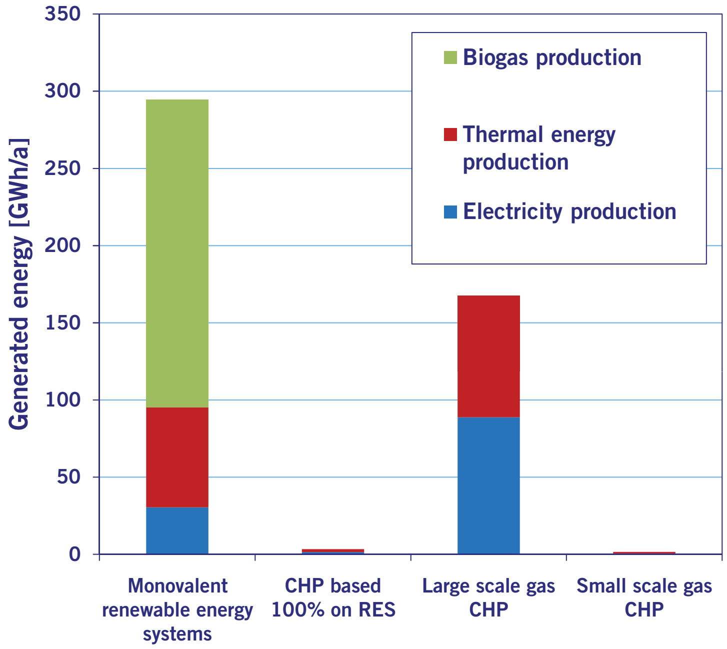


Figure 14: Generated energy from renewable energy sources and cogeneration plants

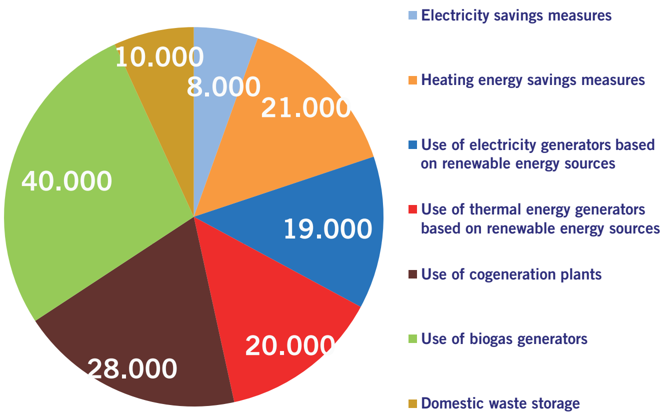


Figure 15: Repartition of the total avoided CO2-emissions (in tCO2/a) according to different measures in CONCERTO

Figure 16 clearly shows the major contribution of large scale energy supply units based on renewable energy sources and cogeneration in five cities. All other cities have a rather balanced contribution of demand-side and supply-side measures for avoided CO_2-emissions. For these latter cities, it makes sense calculating the share of renewable energy sources in the overall energy use of buildings. For the first five cities, the amount of energy generated from renewable energy sources and cogeneration clearly exceeds the energy use of CONCERTO buildings.

Share of renewable energy sources in total energy use

Excluding the large scale wind turbines, ca. 8 % of the total electricity used in CONCERTO demonstration buildings is covered by renewable energy sources, mainly photovoltaics. This ratio ranges from 2 % to 88 %, depending on the projects. The projects having a high share of electricity generated by locally available renewable energy sources use photovoltaic systems which are mainly not installed at eco-buildings, but within the CONCERTO area boundaries.

At the neighbourhood scale, (i.e. considering only the onsite generation within the geographical neighbourhood boundaries), the share of self-coverage with electricity from renewable energy sources (monovalent systems) never exceeds 10 %. This share increases when using CHP technologies from renewable energy sources (e.g. biomass).

From a thermal energy point of view, the use of large scale biomass boilers connected to a district energy infrastructure allows entire neighbourhoods to be supplied to a large extent by heat generated from renewable energy sources. At neighbourhood scale, the highest share of renewable energy sources used to supply heat to a neighbourhood (biomass and solar) obtained in CONCERTO amounts to nearly 60 %.

As the share of renewable energy sources in

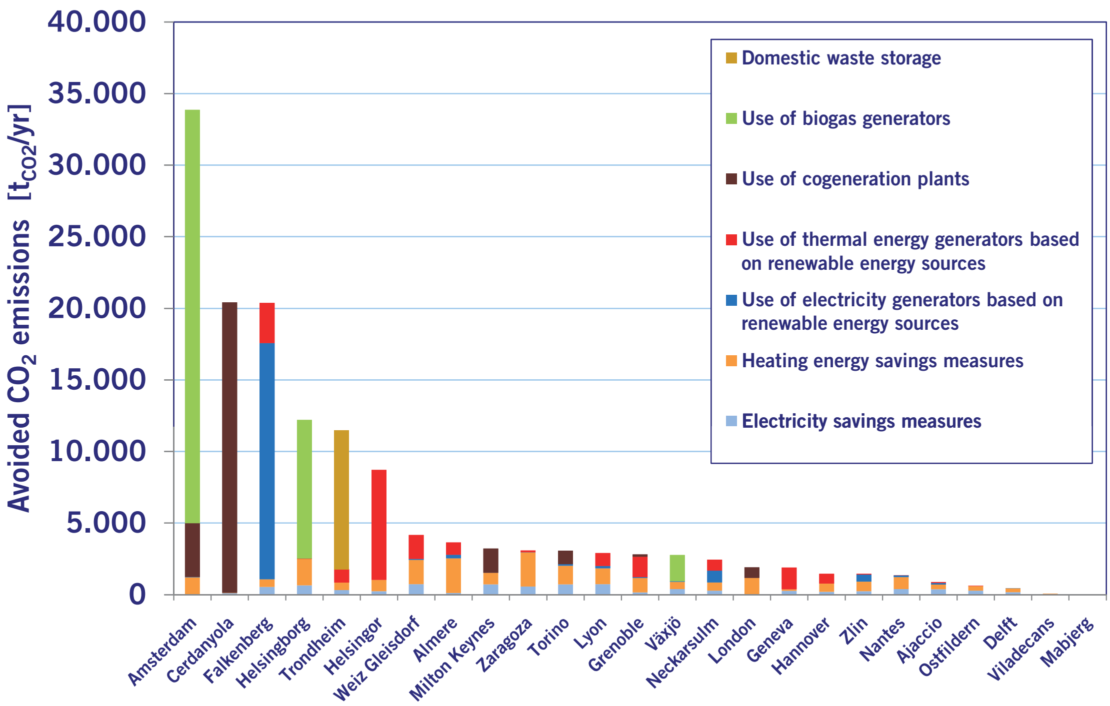


Figure 16: Avoided CO_2-emissions (in t_{CO2}/a) per community (calculation with unified baselines at European level)

total energy use is not a representative indicator for CONCERTO, a combined assessment from a final energy and primary energy viewpoint has been performed. The assessment results are presented in the report on the quality of integration.

4. ACTUAL ENERGY PERFORMANCE ASSESSMENT BASED ON ENERGY USE MONITORING DATA

Although there is a lack of systematic and long-term monitoring data from CONCERTO demonstration building and plants at the time of writing, analysing available monitoring data (monitoring period ending in summer 2010) allows initial conclusions to be drawn regarding:

- actual savings in demonstration buildings
- actual performance of energy plants
- potential for further improving energy performance of buildings and plants

Single building assessment

The residential new-built sector shows monitoring results which are on average very close to the expected and calculated figures, at the very least for space heating energy use. This can be explained by a rather predictable energy use in the residential sector based on current calculation methods, and also by a rather simple configuration and operation of HVAC systems in the residential sector compared to the tertiary sector. In particular, it seems that influence of user behaviour has been quite limited in the CONCERTO demonstration housing sector.

In the tertiary sector, the first monitoring results available are in some cases far from expectations (and not reported in Figure 17), mainly due to operation failures and necessary adaptations in the first year of operation. Available short-term monitoring data can therefore not be used in a final assessment. At least one or two years of additional monitoring activities in these buildings should be used to obtain a satisfactory monitoring data base for actual energy performance assessment in the tertiary sector.

The highest divergences are visible in the housing renovation sector (see Figure 18). Some of the buildings monitored show outstanding performance levels, in some cases going beyond expectations. In other cases, the monitoring results confirm the conclusions already drawn when analysing the type of renovation measures implemented in the existing CONCERTO housing stock. Partial renovation measures (window replacement and thermal roof insulation) are not enough to guarantee substantial thermal energy savings.

Single plant assessment

The actual performance of solar thermal and photovoltaic systems in CONCERTO is satisfying, as shown by Figure 19 and Figure 20. However for solar thermal collectors, the expected heat output in kWh/m².a is not sufficient to assess the quality of the solar thermal system. This is because high figures can also be obtained with high distribution and storage losses in the building supplied. Unfortunately, the monitoring systems were not always designed to provide all data necessary for a complete system performance assessment.

Similarly, the number of full load operating hours for large scale biomass boilers (as shown by Figure 22) can be an indicator of appropriate boiler sizing. In particular, a low number of full load operating hours can indicate a plant over-sizing or can mean a rather low heat demand during the operation year (due to heating energy saved in buildings or too low connection rate). In any case, it indicates that additional heat consumers should connect to the district heating network to increase its return on investment.

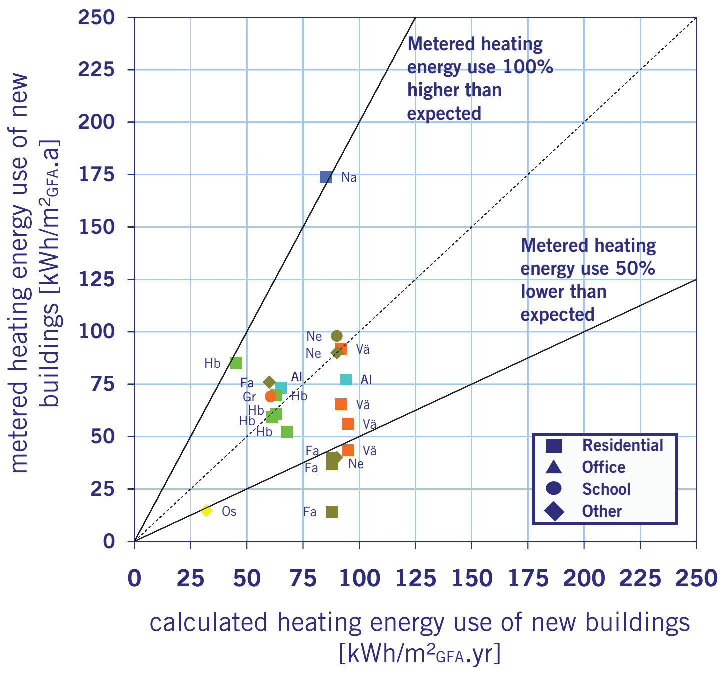


Figure 17: Expected and monitored energy performance of new buildings

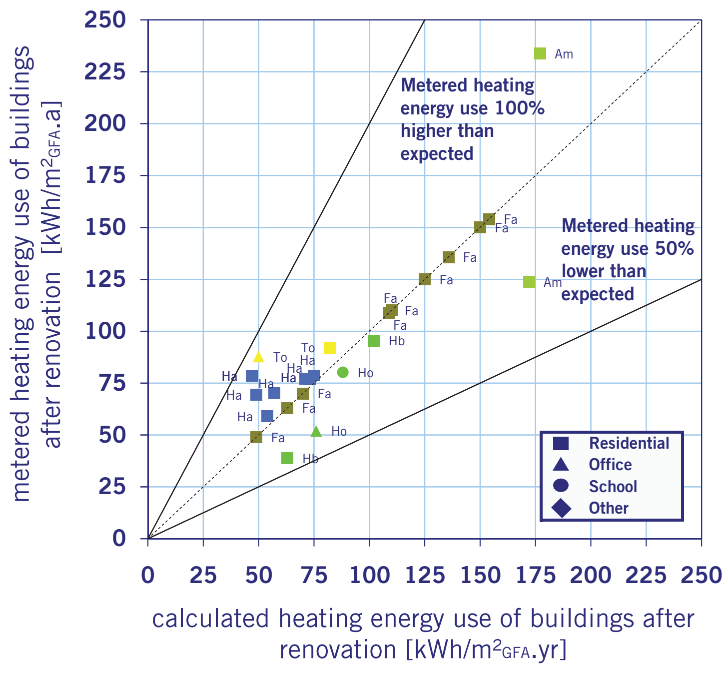


Figure 18: Expected and monitored energy performance of existing buildings after renovation

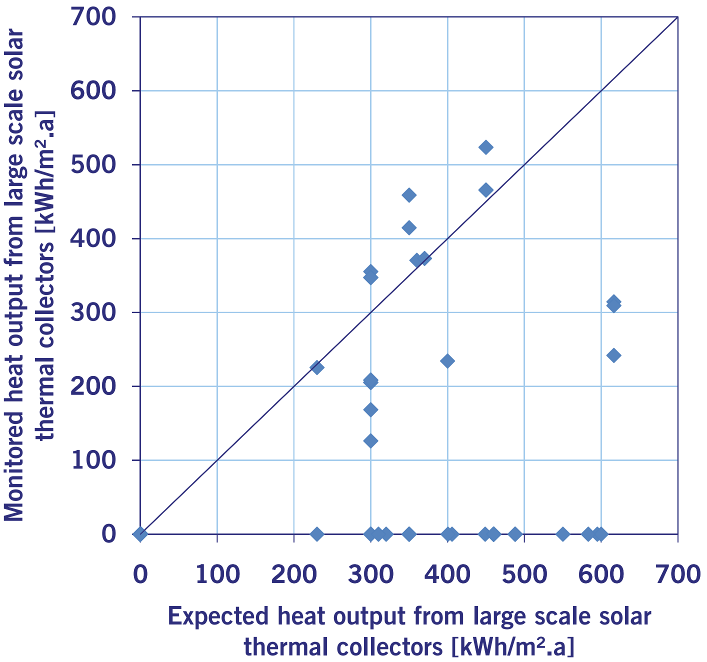


Figure 19: Expected and monitored energy performance of large-scale solar thermal collectors

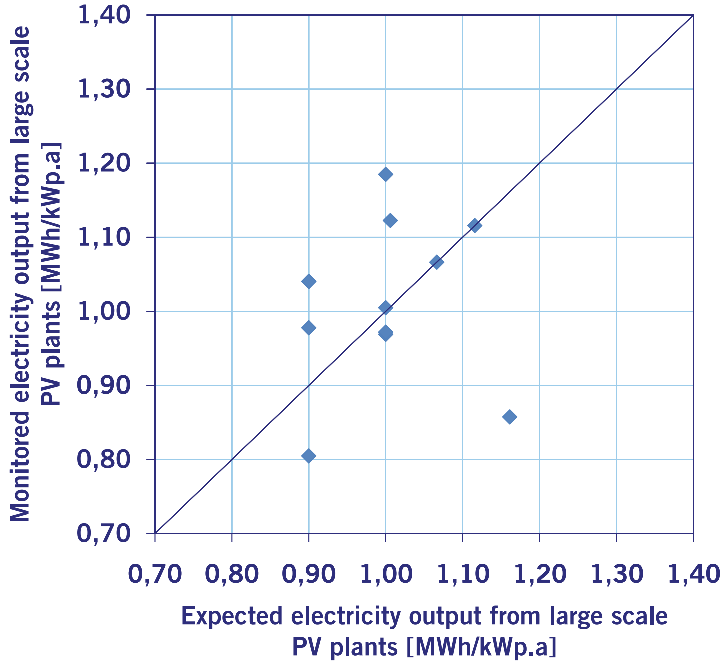


Figure 20: Expected and monitored energy performance of large-scale PV plants

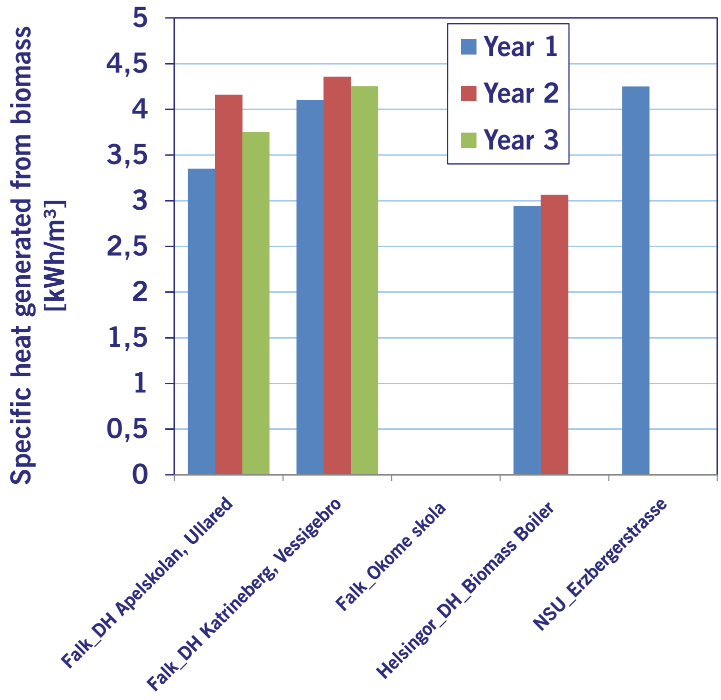


Figure 21: Monitored specific heat generated from solid biomass combustion

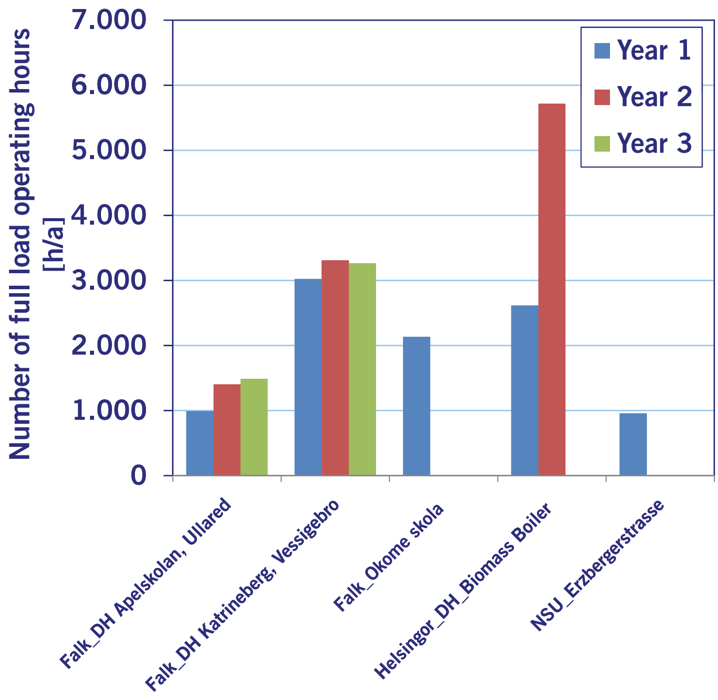


Figure 22: Monitored number of full load operating hours of large scale biomass boilers

5. GENERAL CONCLUSIONS AND RECOMMENDATIONS

The energy impact assessment work done on the CONCERTO initiative leads to three major conclusions related to the most effective combinations of measures for cities targeting a sustainable urban energy system development, the general effectiveness of monitoring activities, and future necessary improvement related to energy in the urban environment.

Most effective combination of measures?

The variety of community approaches in CONCERTO as well as the results shown by the quantification of avoided CO_2-emissions in CONCERTO projects confirms the necessity for cities to follow a triple approach.

1) The city approach

The fact that large scale biogas generation plants and wind turbines as well as gas cogeneration plants and waste incinerators led to the highest amount of avoided CO_2-emissions in CONCERTO is a confirmation that these types of supply side measures have to be considered as high priority measures in local sustainable energy action plans. The construction of such facilities has to take into account the existing energy infrastructure characteristics (concentration, network availability and capacity). If this is done, it allows harnessing renewable energy source potentials at the place where they are available in high concentration (biogas, landfill gas, wind turbines etc.), bringing significant benefits to existing cities. Combining these supply-side measures with a target-group centered approach (i.e. targeting specific users as housing companies, private households) for implementing large scale renovation measures is a very effective way to implement measures covering entire municipal areas.

2) The new-neighbourhood approach

As proven by CONCERTO, the city approach alone is not sufficient enough to guarantee a sustainable urban energy system development, mainly because it offers very few possibilities for limiting the energy demand in the urban built environment: empowering the renewable energy system and polygeneration capacities cannot be economically feasible if energy use in the built environment continues to increase. Since the construction of new neighbourhoods implies an increased energy demand in a city, neighbourhood planning should always be done in a way to minimize energy use. CONCERTO confirms that local authorities can use many instruments to limit energy demand in very early project phases (urban masterplanning and local energy planning phases). Nevertheless, the share of onsite renewable energy sources in the total energy use of new and efficient neighbourhood projects has still been very low in CONCERTO (maximal of 10 % of electricity needs covered, 60 % of heating energy needs covered). As such, the necessity to combine the new neighbourhood approach with the city approach is crucial. Conversely, there is still an unexploited potential for onsite renewable energy sources in future projects.

3) The existing neighbourhood approach

Neighbourhood regeneration programmes are the best opportunity to integrate energy criteria into projects undertaken to improve services, infrastructure quality and quality of life in existing neighbourhoods (see report on planning and implementation process assessment). The highest savings in CONCERTO were obtained when thermal renovation measures were combined with supply-side measures such as connection to district heating infrastructure or construction of a heat distribution network in the neighbourhood to distribute heat from small-scale CHP or biomass boilers.

Successful approaches to monitoring

The high variety of monitoring approaches in CONCERTO confirms that there are different ways to assess the effectiveness of measures. Monitoring the installed capacity of renewable energy systems and the gross floor area of buildings constructed is a very practical way to trace the progress of a project or programme. An annual update on such indicators provides the opportunity to implement corrective actions where necessary. Nevertheless, long-term monitoring of buildings and plants energy performance is required to verify whether or not buildings and plants really operate as planned. The time allocated to monitoring activities in CONCERTO was far too short. It would need to be extended for a more comprehensive assessment of the quality of demonstration projects. In particular, access to already available data (e.g. for billing reasons) should be facilitated in future, as requested for instance for smart metering programmes.

Improving performance

Analysing both the calculated building energy performance ratings after renovation and the first energy use monitoring data of such buildings confirms that in general, CONCERTO was not very ambitious in terms of energy standards reached after renovation. There are very few examples of comprehensive renovation measures anyway, and the actual energy performance levels obtained after renovation are in some cases low.

In the future, significant improvements would be necessary also in the tertiary sector. Improvements should aim to deal with complex HVAC system design and operation patterns in commercial buildings and guarantee a high energy performance once in operation.

NOTES

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