ENERGY SOLUTIONS FOR SMART CITIES AND COMMUNITIES

Evaluation of (Smart) Solutions – Guidebook for Assessment Part II – Final Assessment Report

CONCERTO Premium

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The analysis made in this publication is based on the most recent and most reliable data, which in general dates from September 2013. It should be noted that some of the projects mentioned here are still ongoing and may be subject to changes during the lifespan of their activities.

A great deal of additional information on CONCERTO is available at www.concerto.eu and further information on the European Union's energy policy can be accessed through the website of DG Energy (http://ec.europa.com/energy/).

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Chapter 1

Outline and overview

1.1 The CONCERTO initiative and its projects

CONCERTO is a European Union initiative within the European Research Framework Programme (FP6 and FP7). Responding to the facts that buildings account for 40 % of total energy consumption in the Union, for 33% of CO2 emissions and that 70% of the EU's energy consumption and a similar share of greenhouse gas emission take place in cities, with a huge untapped potential for cost-effective energy savings, CONCERTO aims to demonstrate that the energy-optimisation of districts and communities as a whole is more cost-effective than optimising each building individually, if all relevant stakeholders work together and integrate different energy-technologies in a smart way. The EU initiative under of the European Commission's Directorate General for Energy started in 2005 and has co-funded with more than 175.5 Million € 58 cities and communities in 22 projects in 23 countries.

CONCERTO is a milestone towards the EU targets for 2020:

- 20 % improvement in energy efficiency
- 20 % share of renewable energy
- 20 % reduction of greenhouse gas emissions

The 58 cities and communities are role models and offer innovative approaches for:

- energy efficiency measures
- the use of renewable energy sources and innovative technologies (RES)
- sustainable building and district development
- refurbishment in buildings
- energy transparency for citizens.

In this respect CONCERTO has paved the way to the Smart Cities Innovation Partnership of the European Union, successor of the CONCERTO initiative.

The 58 CONCERTO cities and communities integrate energy efficiency measures with a substantial contribution from local renewable energy sources (RES), smart grids, renewables-based cogeneration, district heating/cooling systems and energy management systems in larger building settlements. These sets of innovative technologies and measures are optimised locally in order to take into account the specific characteristics and possibilities of the local site, climate and cultural differences or local political aspects.

The results so far have been very encouraging: CONCERTO cities and communities have shown that existing buildings can cut their CO_2 emissions, at acceptable costs, by up to 80%. CONCERTO does this by implementing renewable energy sources, innovative technologies and an integrated approach. The CONCERTO initiative proves that if given the right planning, cities and communities can be transformed into pioneers in energy efficiency and sustainability.

1.2 The Meta-Project CONCERTO Premium

CONCERTO Premium is a significant part of the CONCERTO initiative. On behalf of the European Commission CONCERTO Premium contributes to the exchange of information between the projects and serves as platform for the distribution of project results for the different CONCERTO projects. In this context CONCERTO Premium not only focuses on the dissemination of existing results but also generates cross-project analysis and assessments regarding economic, environmental, technical, social and policy issues. In doing so "good practices" of the different CONCERTO projects and implemented measures are identified and made available for the interested public.

Generally, the goal of CONCERTO Premium is the development of a robust data and information base on energy efficiency and renewable energy topics that can be used by different stakeholders, e.g. investors, politicians, energy suppliers, architects, engineers, etc. to guide the decision making process. Therefore, the application of climate protection measures in European cities, towns and neighboring countries, can be expanded with the help of the experience made and the knowledge created in the CONCERTO initiative. By extracting recommendations for policy makers on different levels CONCERTO Premium ensures the link between technological demonstration and EU policy implementation.

1.3 Goals of this document

The final assessment report presented here is one of the main results of the project CONCERTO Premium funded by the EU. This report is the second part of documents that deal with the assessment and analysis of results and successes of individual CONCERTO projects. While in Part 1 the assessment methodology, fundamentals and criteria are presented which can be respectively assigned to the specific objects of assessment as well as to interested stakeholders Part 2 focuses on the specification of the actual results of the assessment and analysis of measures to improve energy efficiency and to increase the use of renewable energy sources. For this purpose, the results are sorted according to the objects of assessment "site", "building" and "energy supply unit" described in Part 1 and assigned to the respective assessment perspectives (economic, macro-economic, environmental, economic-environmental, technical). To ensure transparency and comparability of the results relevant assumptions and boundary conditions, on which the assessment is based, are presented in detail. Where possible and appropriate, the results are grouped according to selected aspects and assigned to e.g. climate zones, regions, economic areas, etc..

With the analysis and assessment particularly the following objectives are pursued:

- performance measurement of individual projects
- elaboration of generalizable findings
- derivation of plausibility corridors and benchmarks for future projects
- testing of the validity and the possibility of interpretation of assessment criteria
- testing of graphical representations of data
- elaboration of the basis for the derivation of trends and recommendations.

This report complements the presentation of results that are immediately accessible through the database and its visualization environment.

Chapter 2

Introduction of CONCERTO projects

2.1 CONCERTO communities

The CONCERTO initiative includes a diversity of applications regarding renewable energy sources and energy efficiency measures on district level. The European Commission has co-funded 22 projects, comprising of 58 communities, which are located in 23 countries in Europe. Each CONCERTO project consists of one to four sites which are specific defined geographical areas of communities or cities. Table 2.1 and Figure 2.1 give an overview over the CONCERTO sites and their geographical distribution within Europe.

The first generation of projects started in 2005, the second end of 2007 and the third generation of projects started in 2010. The average of project duration is five years in which one to four communities and sites elaborated and implemented diverse activities towards the goals of the CONCERTO initiative.

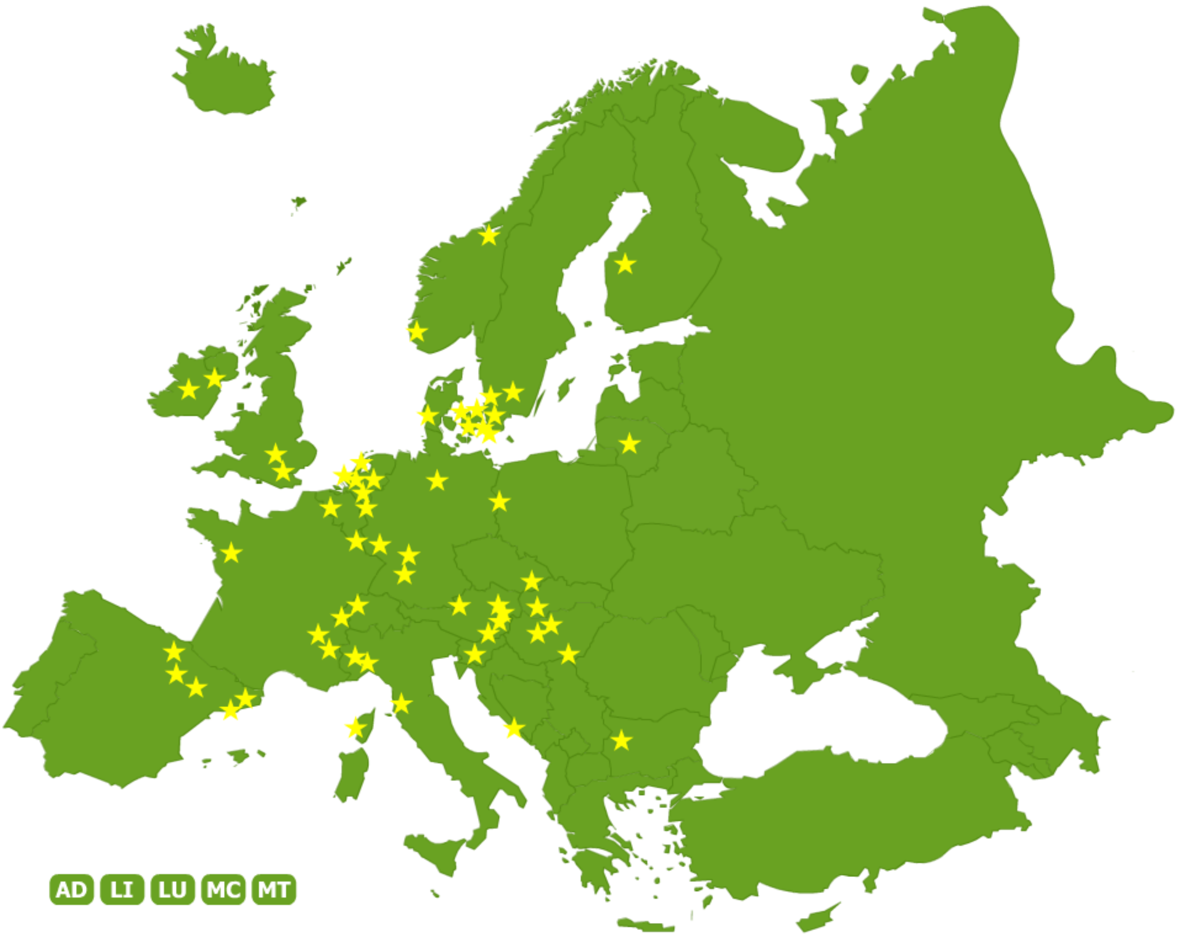


Figure 2.1: CONCERTO sites on the map

All 58 CONCERTO sites use outstanding as well as smart technologies to reduce the environmental impact on district level. The stimulation of energy efficiency measures and increasing use of renewables instead of fossil energy resources are the two pillars in the concept of reducing greenhouse gas emissions and achieving the climate protection targets.

The local players of each site demonstrated that actions applied in different local conditions can meet the goals of Energy 2020 to reduce energy consumption and that will lead to an energy independent Europe. The sites show new approaches in new constructions and retrofitted private or public buildings of residential and non-residential areas. The range of users compasses from single households to multi-family houses, private building owners to public housing and from public use to industrial use.

Generation	Projects	Community	County
1	act2	Hannover	Germany
		Nantes	France
	cRRescendo	Almere	The Netherlands
		Milton Keynes	United Kingdom
		Ajaccio	France
		Viladecans	Spain
	ECO-City	Helsingborg/Helsingør	Sweden/Denmark
		Tudela	Spain
		Trondheim	Norway
	ECOSTILER	Amsterdam New West	The Netherlands
		London Lambeth	United Kingdom
		Måbjerg	Denmark
	Energy in Minds!	Weiz-Gleisdorf	Austria
		Zlín	Czech Republic
		Neckarsulm	Germany
		Falkenberg	Sweden
	POLYCITY	Ostfildern	Germany
		Cerdanyola del Vallès	Spain
		Torino	Italy
	RENAISSANCE	Lyon	France
		Zaragoza	Spain
	SESAC	Växjö	Sweden
		Delft	The Netherlands
		Grenoble	France
	TetraEner	Geneva	France
2	Class1	Stenløse	Denmark
	Concerto AL Piano	Alessandria	Italy
	Green Solar Cities	Salzburg	Austria
		Valby	Denmark
	HOLISTIC	Dundalk	Ireland
		Neuchâtel	Switzerland
		Mödling	Austria
	Remining-Lowex	Heerlen	The Netherlands
		Zagorje	Slowenia
	SEMS	Tulln	Austria
		Weilerbach	Germany
		Słubice	Poland
		Redange	Luxembourg
	SERVE	North Tipperary	Ireland
	SORCER	Hillerød	Denmark
		Apeldoorn	The Netherlands
	STACCATO	Amsterdam Noord	The Netherlands
		Sofia	Bulgaria
		Óbuda	Hungary
3	ECO-Life	Birštonas	Lithuania
		Kortrijk	Belgium
		Høje-Taastrup	Denmark
	GEOCOM	Mórahalom	Hungary
		Galanta	Slovakia
		Montieri	Italy
	PIMES	Vitoria-Gasteiz	Spain
		Sandnes	Norway
		Szentendre	Hungary
	SOLUTION	Cernier	Switzerland
		Hartberg	Austria
		Hvar	Croatia
		Lapua	Finland

Table 2.1: CONCERTO sites

Settlement types

The CONCERTO areas can be classified according to different settlement types. Generally, CONCERTO areas have been defined by the projects themselves and can be explained as restricted areas including all the CONCERTO demonstration projects and buildings concerned by awareness campaigns. A CONCERTO community has one or more project areas. As project areas differ from each other, the classification into settlement types was performed on 134 project areas of the 58 CONCERTO communities. Project areas can be differentiated into several settlement types ranging from single family houses up to multistory apartment blocks and industrial buildings. Table 2.2 displays the distinguished settlements types in CONCERTO project sites according to their designated development areas.

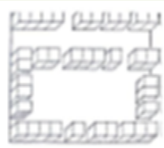
Settlement types	Typical building density	Number of Floors	Typical development areas	
Single Family Houses (SFH) and Multi Family Houses (MFH)	low density	1-2		
Single Family Houses and Multi Family Houses	high density	2		
Terraced Housing	low density	2		
Terraced Housing	medium density	3-5		
Terraced Housing	high density	6-15		
Perimeter Blocks	-	3-4		
City Blocks	-	4-6		
Historic Centre	-	3-5		
Industrial Buildings and Stocks	-	2-4		

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Table 2.2: Settlement types with their typical building density, number of floor and the typical development areas (according to Volwahsen et al. (1980) and Neuffer et al. (2001)), used for classification of CONCERTO project sites into settlement types

Figure 2.2 shows the CONCERTO areas according to their settlement affiliation (multiple naming possible). Mainly areas with single and multifamily houses but also terraced housing blocks participated in CONCERTO projects. Industrial buildings and stocks are also often contained in designated project areas, but might not necessarily be affected by the CONCERTO energy efficiency measures.

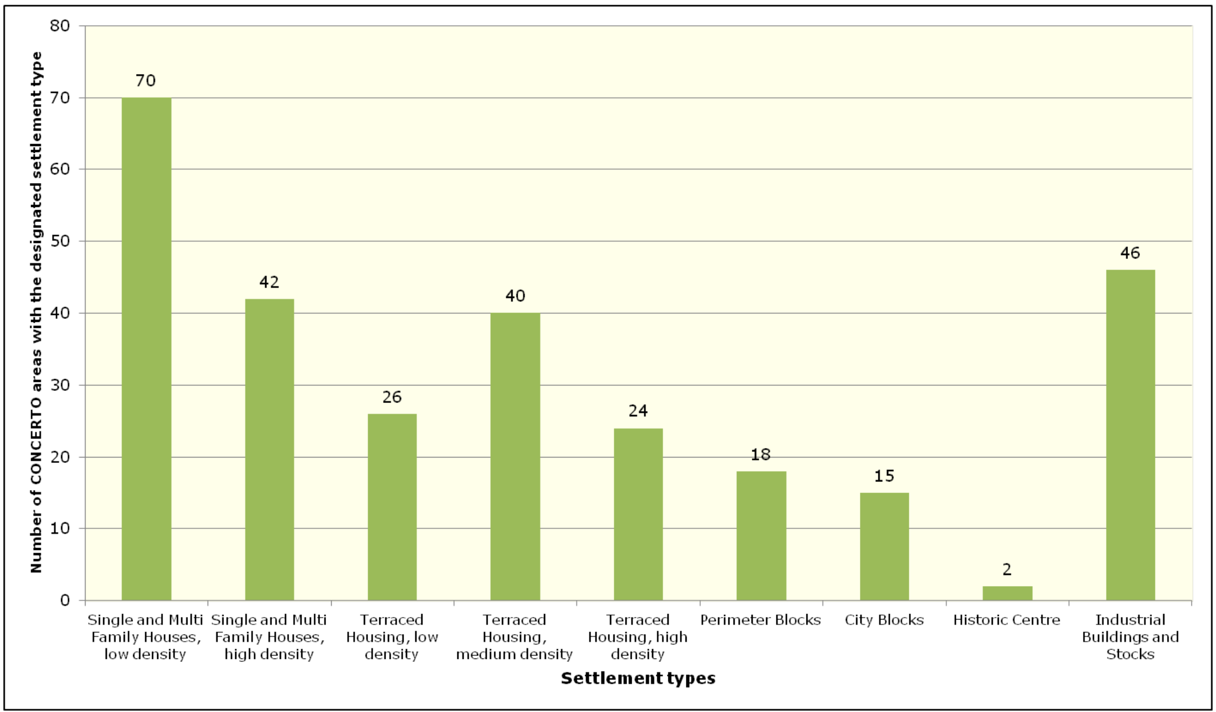

Figure 2.2: 134 CONCERTO sites with their affiliation to settlement types (multiple naming possible)

While some areas consist of only one settlement type, other development areas include multiple settlement types. Figure 2.3 shows that the majority of CONCERTO areas consist of one or two settlement types and thus form homogeneous areas. Less frequent are mixed areas with diverse buildings and heterogeneous settlements.

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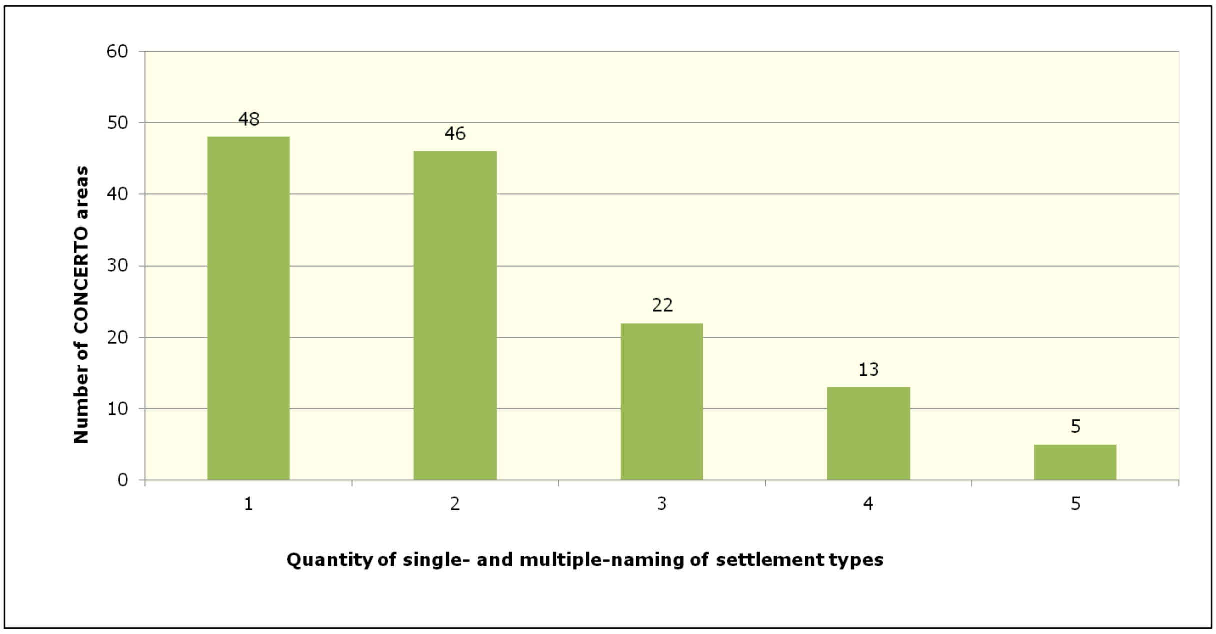

Figure 2.3: Multiple naming of CONCERTO sites in settlement evaluation

2.2 Strategic relevance of CONCERTO

CONCERTO projects were funded with a view to contribute to EU-targets: For 2020, the EU has committed to cutting its emissions to 20% below 1990 levels, to increase the share of renewable energy in final energy consumption to 20%, and achieve a 20% increase in energy efficiency. For 2050, EU leaders have endorsed the objective of reducing Europe's greenhouse gas emissions by 80-95% compared to 1990 levels. The European Commission has published a roadmap for forming the low-carbon European economy required for these goals. Hence, altogether the EU is on a pathway towards an EU-wide transition to a sustainable energy systems, though this emphasize on sustainability and climate change mitigation has shifted in 2013, to greater emphasize of cheap energy and competitiveness. However, in the long term we can only achieve our targets with energy efficiency - the more energy efficient we are, the less it matters what the cost of energy is. Sustainable energy neighbourhoods, such as those created under CONCERTO, are powerful showcases for demonstrating that an energy transition is not a burden but an opportunity. While making communities, less dependent on energy imports and more resilient against energy price increases, such projects are also about quality of life, lower bills and also creates new, local business opportunities In order roll out these achievements long term thinking and decision making is paramount. CONCERTO projects are large scale projects, lasting for at least 5 years, many longer, with the initial planning phase preceding the project application often by several years. A total span of a decade is not unusual. Yet due to their duration and size, large numbers of stakeholders will be involved, will learn and carry the learning forward.

Towns and neighbourhoods are small scale models for countries and Europe. They are immediate to people's everyday lives. Real-life, actual projects, that proof to the local community that sustainable energy concepts work in reality are very effective catalysts for furthering the energy transition, representing a powerful reason to the EU to instigate and fund such projects. The CONCERTO initiative proves that if given the right planning, cities and communities can be transformed into sustainable energy pioneers. Most projects inspired follow-on projects and many policy developments at local and sometimes even at national scale.

Chapter 3

Fundamentals and methodology of assessment

In the scope of CONCERTO Premium results of all CONCERTO projects have been analyzed, summarized and edited. Those results serve to further improve energy efficiency in the building sector while simultaneously expanding the use of renewable energy sources. One focus is the analysis and presentation of the technical possibilities, the effects occurring in energy saving and reduction of environmental impact as well as the economic profitability of measures. The starting point is the analysis of relevant stakeholders and their information needs. A goal to be pursued is to develop and implement specific forms of result representations for individual stakeholder groups. This approach shall allow the application of the CONCERTO Premium results in the specific context of stakeholder specific areas of action and responsibility. Based on an analysis of the information needs a typology of objects of assessment, indicators and assessment criteria was developed and brought together in a matrix. To secure comparable results system boundaries and reference units were determined for the different criteria, values for plausibility checks were researched and forms of representation were developed. Below are presented

- selected results of an analysis of the information needs of relevant stakeholder groups
- selected indicators and assessment criteria
- the typology of objects of assessment and indicator categories
- methodological foundations to ensure transparency and comparability of the results.

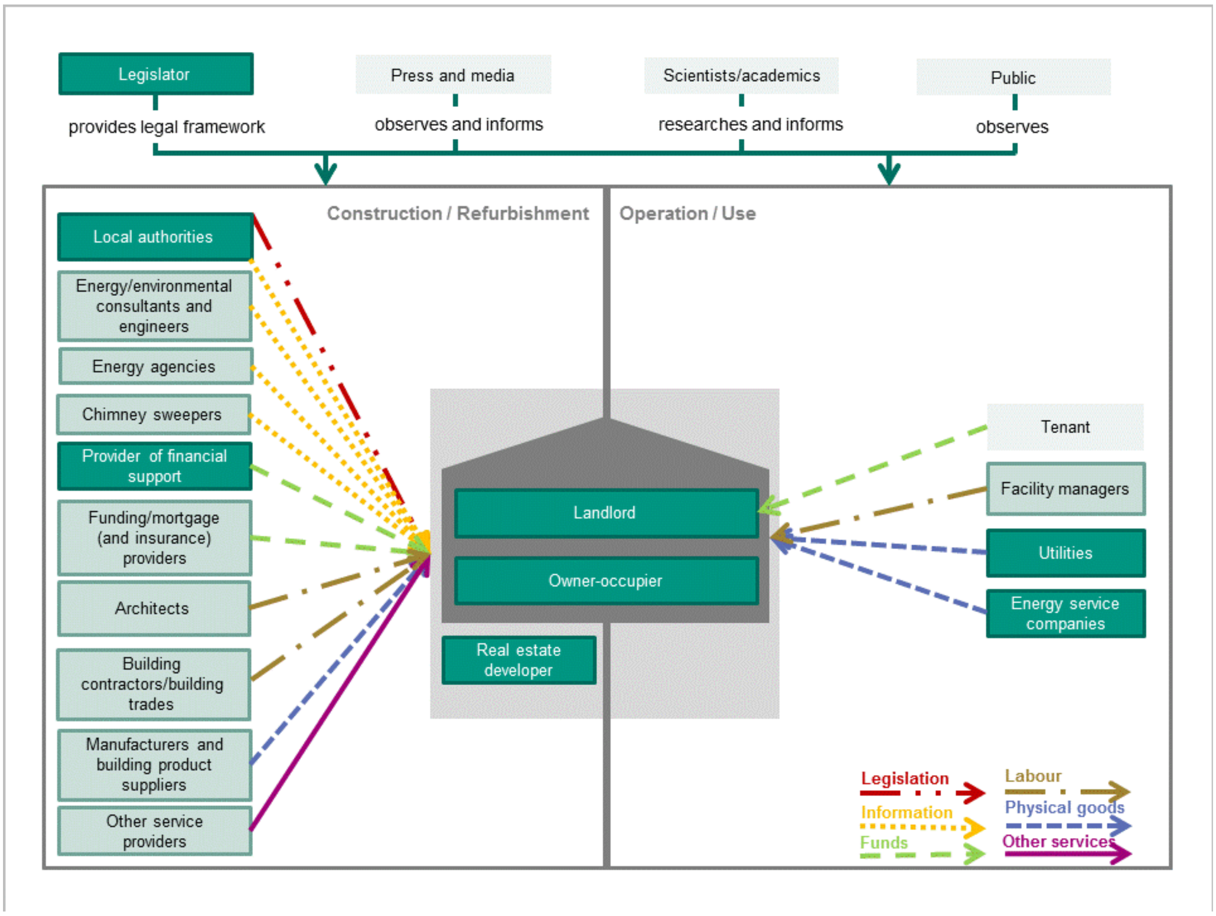

Figure 3.1: Overview over relevant stakeholders

3.1 Stakeholders and their information need

The implementation of energy efficiency and renewable energy projects affects a wide range of different stakeholders. These stakeholders have different professional and personal backgrounds, influence the course of a project on different occasions and can even occupy different roles in different projects. One objective of CONCERTO Premium is a stakeholder-specific provision of information, since a major barrier hampering investments in energy saving and renewable energy technologies is the so-called energy-efficiency gap, summarizing inter alia information gaps and prejudices leading to a spread between what is actually feasible and what is implemented in practice. In CONCERTO Premium 23 target groups for the information provision which can be divided into decision-makers, service-providers and others, displayed in Figure 3.1 have been researched in detail.
After the definition of the CONCERTO Premium stakeholders relevant indicators and aggregation levels have been defined and structured according to the following categories. This definitions were based on literature reviews and expert knowledge.

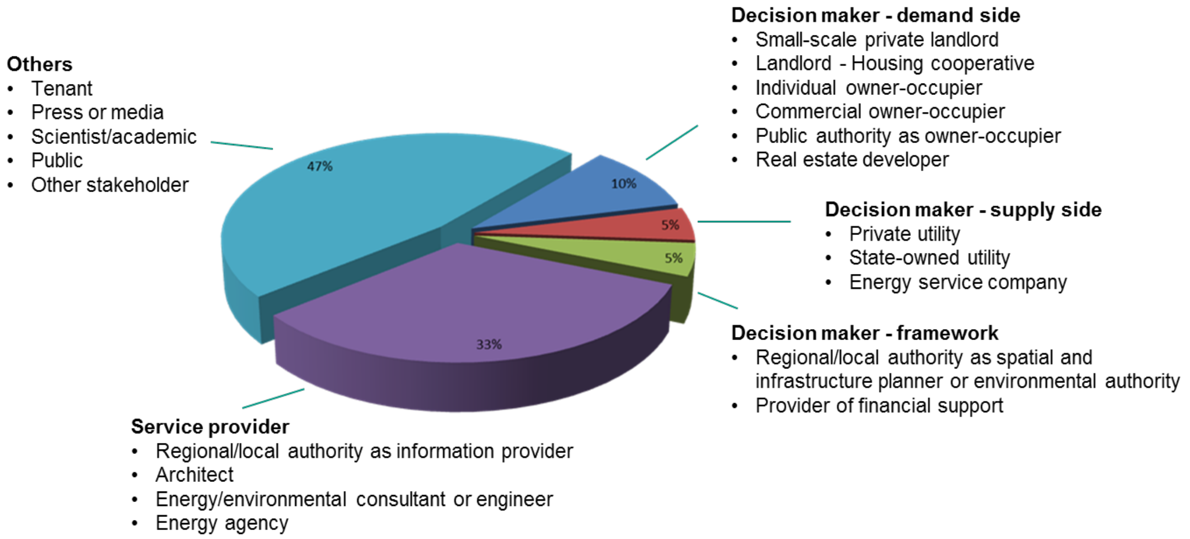

Figure 3.2: Distribution of stakeholders participating in the survey

Indicator categories

- environmental
- economic
- technical
- social
- gap analysis of the implementation process

Aggregation levels

- European/national/regional level
- CONCERTO community
- groups of buildings
- individual buildings
- building components
- CONCERTO community energy supply system
- components of CONCERTO community energy supply system

In a third step a survey between researchers, practitioners and other stakeholders has been conducted to validate the results of the literature study. Figure 3.2 shows the distribution of stakeholders participating in the survey. At the end of the survey duration 110 completed questionnaires from 20 different stakeholders had been completed. The findings of the questionnaire strongly support the stakeholder-specific approach, since a significant variation of interests between stakeholders was found. Second, a general prioritization of information categories on average over all represented stakeholders could be derived with the main interest in economic, environmental and technical information. Third, for the represented stakeholders the rel-

evant information categories and aggregation levels have been identified. All these findings contribute to facilitate the information procurement and support the decision-making process.
In the course of the project slight adjustments of the initial indicator categories and the aggregation levels have been carried out. The macro-economic as well as a combined economic-environmental perspective have been introduced. Furthermore, social indicators were excluded from a quantitative assessment but included in a qualitative analysis. The aggregation levels have been re-named to objects of assessment and a restructering as well as completion was conducted.

Objects of Assessment

- construction elements
  - construction components in terms of materially-constructive solutions
  - technical installations in buildings (optionally with distribution and storage included)
- single buildings
- groups of buildings
- districts
- large-scale energy supply units
- groups of large-scale energy supply units
- CONCERTO area
- CONCERTO site
- *(region)
- *(country)
- *(EU)

The symbol * marks further objects of assessment which are additionally introduced. The additional objects of assessments in brackets are especially important for an up-scaling.

The calculability of demanded indicators is, however, dependent on the data availability for the CONCERTO demonstration projects. The monitoring concept applied in the CONCERTO communities plays therefore the key role concerning an in-depth analysis of the CONCERTO performance. As the opportunities of an effective monitoring are not exhausted in most of CONCERTO communities due to various reasons (financial restrictions, data privacy, etc.) the possibilities in calculating the total range of inquired indicators are limited. In particular a number of technical indicators are excluded from the evaluation.

3.2 Data availability and quality

The assessment of the CONCERTO measures and the CONCERTO impact is strongly depending on the availability and quality of CONCERTO project data. Table 3.1 gives an overview on the quantity and quality of data available for CONCERTO Premium.

The quality of data is being surveyed in the CONCERTO quality assurance process. From the extent and quality of available and analyzable data, generally a hint on the success of the establishment of a monitoring system on the CONCERTO project sites can be derived; though other cases are thinkable where the information flow of valuable monitoring data in high resolution runs dry before reaching the CONCERTO Premium Technical Monitoring Database.

Data quantity corresponds to the number of deliverables, reports and data communicated to CONCERTO Premium; a high data quality is given if

- the data comply with CONCERTO data requirements,
- a clear documentation of the "metadata" is given (for monitoring data e.g. year, unit, application area; further definitions),
- apparently implausible data has been discussed and checked with the respective CONCERTO project.

Generation	Projects	Community	County	Data Quantity	Data Quality
1	act2	Hannover	Germany	high	high
		Nantes	France	high	medium
	cRRescendo	Almere	The Netherlands	high	high
		Milton Keynes	United Kingdom	high	high
		Ajaccio	France	low	low
		Viladecans	Spain	medium	mediumm
	ECO-City	Helsingborg/Helsingør	Sweden/Denmark	high	medium/high
		Tudela	Spain	low	low
		Trondheim	Norway	high	medium/high
	ECOSTILER	Amsterdam New West	The Netherlands	medium	low
		London Lambeth	United Kingdom	medium	low
		Måbjerg	Denmark	low	low
	Energy in Minds!	Weiz Gleisdorf	Austria	high	medium
		Zlín	Czech Republic	high	medium
		Neckarsulm	Germany	high	medium
		Falkenberg	Sweden	high	medium
	POLYCITY	Ostfildern	Germany	high	high
		Cerdanyola del Vallès	Spain	medium	medium
		Torino	Italy	medium	medium
	RENAISSANCE	Lyon	France	medium	medium
		Zaragoza	Spain	medium	low
	SESAC	Växjö	Sweden	high	high
		Delft	The Netherlands	high	medium
		Grenoble	France	high	medium
	TetraEner	Geneva	France	medium	low
2	Class1	Stenløse	Denmark	high	medium/high
	Concerto AL Piano	Alessandria	Italy	low	low
	Green Solar Cities	Salzburg	Austria	medium	medium
		Valby	Denmark	medium	low
	HOLISTIC	Dundalk	Ireland	medium	medium/high
		Neuchâtel	Switzerland	medium	medium
		Mödling	Austria	medium	medium/high
	Remining-Lowex	Heerlen	The Netherlands	low	low
		Zagorje	Slowenia	low	low
	SEMS	Tulln	Austria	high	low
		Weilerbach	Germany	high	low
		Słubice	Poland	high	low
		Redange	Luxembourg	high	low
	SERVE	North Tipperary	Ireland	high	high
	SORCER	Hillerød	Denmark	medium	medium
		Apeldoorn	The Netherlands	low	low
	STACCATO	Amsterdam Noord	The Netherlands	medium	medium
		Sofia	Bulgaria	medium	low
		Óbuda	Hungary	medium	high
3	ECO-Life	Birštonas	Lithuania	low	low
		Kortrijk	Belgium	high	high
		Høje-Taastrup	Denmark	medium	medium
	GEOCOM	Mórahalom	Hungary	low	low
		Galanta	Slovakia	low	low
		Montieri	Italy	low	low
	PIMES	Vitoria-Gasteiz	Spain	medium	medium
		Sandnes	Norway	medium	medium
		Szentendre	Hungary	medium	medium
	SOLUTION	Cernier	Switzerland	high	low
		Hartberg	Austria	high	low
		Hvar	Croatia	high	low
		Lapua	Finland	high	low

Table 3.1: Data quantity and quality available to CONCERTO Premium

Quality assurance process

CONCERTO Premium defined a quality assurance process on four steps to ensure a high data quality (Figure 4). This process comprises on step 1 the data collectors that fill in the data in the CONCERTO data collection sheets manually as well as quality checks on level 3 and 4 in the database respectively in the semantic layer.

Quality assurance - step 1:

In step 1, occurring inconsistencies and ambiguities are being detected and discussed in the CONCERTO Premium team. Discussion results are applied for further inconsistencies and ambiguities of the same type. Structural problems in the CONCERTO data collection sheets are solved and improvements were implemented.

Quality assurance - step 2:

Incompatibilities and implausibilities occurring during data import into the database on step 2 are being reported by an automated error message of the TMD, e.g. format errors or wrong data types in the Excel cells. Then the responsible CONCERTO Premium data collector corrects the data sheet manually.

Quality assurance - step 3:

Step 3 deals with the plausibility of the imported but still unprocessed data in the database. These testing methods are being used:

- Does the value range within the defined minimum and maximum value? The minimum and maximum accepted values are defined, where suitable, for every type of demonstration project by the CONCERTO Premium team.
- Does the value satisfy the requirements of the logical connections? Examples for logical connections between data are:
  - The net floor area of a building must always necessarily being smaller than the gross floor area.
  - The construction year of a refurbished building must always lie ahead of the year of refurbishment.
  - Is the energy supply unit existent in database, to which a district-heating network is connected.

  These required logical connections are defined by CONCERTO Premium and implemented into the semantic layer in course of the development of the database. The implausibilities are being corrected ideally after conferring with the respective CONCERTO project representatives.

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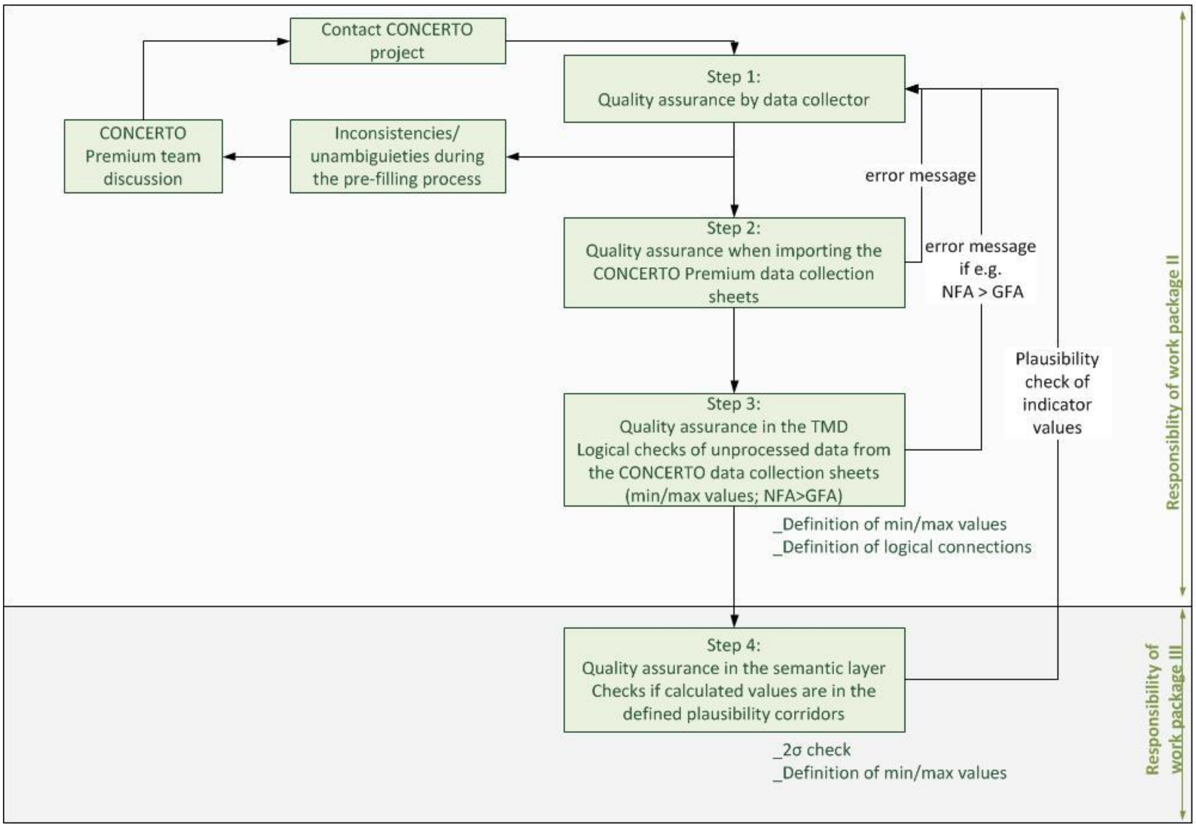

Figure 3.3: Overview on the 4-level CONCERTO quality assurance process

Quality assurance - step 4:

Step 4 deals with the plausibility of the calculated indicators. It is tested if the indicator values deviate in the range $\pm 2\sigma$ from the arithmetic average of the objects of the respective type. The possible deviation is determined by the database derived from values available in the database. Furthermore, ranges for plausible minimum and maximum values for the different indicator types are defined in the database and the calculated indicators checked against them. The CONCERTO quality assurance process helps to ensure a high data quality that is needed for reliable results.

The lion's share of the quality assurance process is implemented; step 1 and 2 are running as well as the checks by means of defined minimum and maximum corridors both for raw and elaborated data (from step 3 and 4). Furthermore, the 2σ-check in step 4 is incorporated and until the end of the project also the check for logical connections inside the raw data will be implemented in the semantic layer.

3.3 System boundaries and general assumptions relating to indicator calculations

Figure 3.4 and Figure 3.5 visualise the system boundaries, the constituting elements and energy flows associated with a CONCERTO area underlying the calculation procedure within the TMD in CONCERTO premium. The system boundaries encompass all CONCERTO demonstration projects within a CONCERTO area. The calculation of the indicators is further based on two different states of the CONCERTO area. The terms "Reference system" and the "CONCERTO system" refer to a pre-CONCERTO and post-CONCERTO scenario respectively. Accounting for the different state variables in the scenarios allows the indicators like the reduction of primary energy demand and CO2 emission savings induced by implementing CONCERTO in a community to be quantified. The "Reference system" tracks the situation before implementing CONCERTO demonstration projects such as retrofitting, new buildings and the installation of energy supply units. For the buildings, CONCERTO reference buildings as well as Non-CONCERTO reference buildings are considered. The CONCERTO reference buildings are differentiated into buildings to be refurbished by insulation measures (i.e. the CONCERTO buildings before the renovation) and hypothetical new buildings (i.e. which serve as a reference for the new CONCERTO buildings). The latter are assumed to have an energetic state according to the national building standard not taking into account the actual state realised in CONCERTO. The Non-CONCERTO reference buildings denote buildings that do not directly undergo CONCERTO measures but whose heat supply is affected by CONCERTO projects. For the energy supply units, building-integrated and large-scale centralised plants are taken into account. For the building-integrated units (BIES) two types are distinguished, firstly, the predominant heat supply technologies in the buildings to be retrofitted, and secondly, a reference heat system that is assumed to heat-supply the hypothetical new buildings (e.g. a standard oil boiler). It is worth mentioning that in case of cogeneration only the share of the input energy carrier allocated to the provision of heat and cold is considered as electricity generated by energy supply units within the system boundaries of the CONCERTO area is taken account of in the "Reference system". The allocation principle is exergy-based reflecting the different energetic values of heat, cold and electricity (assumptions for temperature: ambient 20°C, 100°C heat, 0°C cooling). The centralised energy supply units (CES) consist of two types, the predominant large-scale units already existent before CONCERTO that provide grid-bound heat and a hypothetical reference heat system that corresponds to the large-scale heat supply system installed within CONCERTO. Again, only the exergy-based portion used to produce heat and cold is considered for the existing non-CONCERTO energy supply units. The district heat provided by the non-CONCERTO plants and the reference heat system is allocated both to the CONCERTO reference buildings and the non-CONCERTO buildings in the energy-based portions β and $(1-\beta)$ respectively reflecting the total amount of district heat consumed in the existing buildings to be refurbished and the non-CONCERTO Reference buildings. In addition, all incoming energy flows (e.g. natural gas) are kept track of in the consideration of the system. In the "Reference system" electricity is assumed to be fully sourced from the national mix. The "CONCERTO system" tracks the situation after implementing CONCERTO demonstration projects. These involve predominantly building retrofit, new buildings and the installation of energy supply units. The categorisation of buildings and energy supply units defined in the "Reference system" also holds for the "CONCERTO system". For the CONCERTO buildings the buildings after the refurbishment are taken into account. Furthermore, the new buildings in their real energetic state according to CONCERTO are considered. In order to accurately balance energy flows induced by CONCERTO, the non-CONCERTO buildings serve as objects that consume electricity and heat at least partly generated by CONCERTO energy supply units. The building-integrated energy supply units consist of three types: the ones physically installed in retrofitted buildings; other CONCERTO units that are not installed in CONCERTO buildings; and a reference heat system used to contribute to the district heat supply of non-CONCERTO buildings. For the large-scale ESU the ones installed within CONCERTO are accounted for as well as the non-CONCERTO units that have already been operational before CONCERTO. The two types of large-scale ESU provide complementing shares to the district heat which are assigned to CONCERTO buildings and the non-CONCERTO buildings in the energy-based portions β and $(1-\beta)$ respectively reflecting the total amount of district heat consumed in the CONCERTO buildings and the non-CONCERTO buildings. Like in the "Reference system" all energy input streams provisioning the energy supply units are considered. For electricity, a CONCERTO electricity mix is considered as well as the national electricity mix. The CONCERTO electricity mix is comprised of the electricity generated by small- and large-scale CONCERTO energy supply units (e.g. mCHP, PV). The CONCERTO electricity mix is used to meet the electricity demand in the CONCERTO buildings and the auxiliary energy consumed by building-integrated energy supply units in CONCERTO buildings. If the total supply exceeds the total demand the electricity surplus is assigned to the national mix and receives a credit. If the demand is greater than the supply the missing amount of electricity is sourced from the national grid.

The system boundaries described above correspond to the CONCERTO area

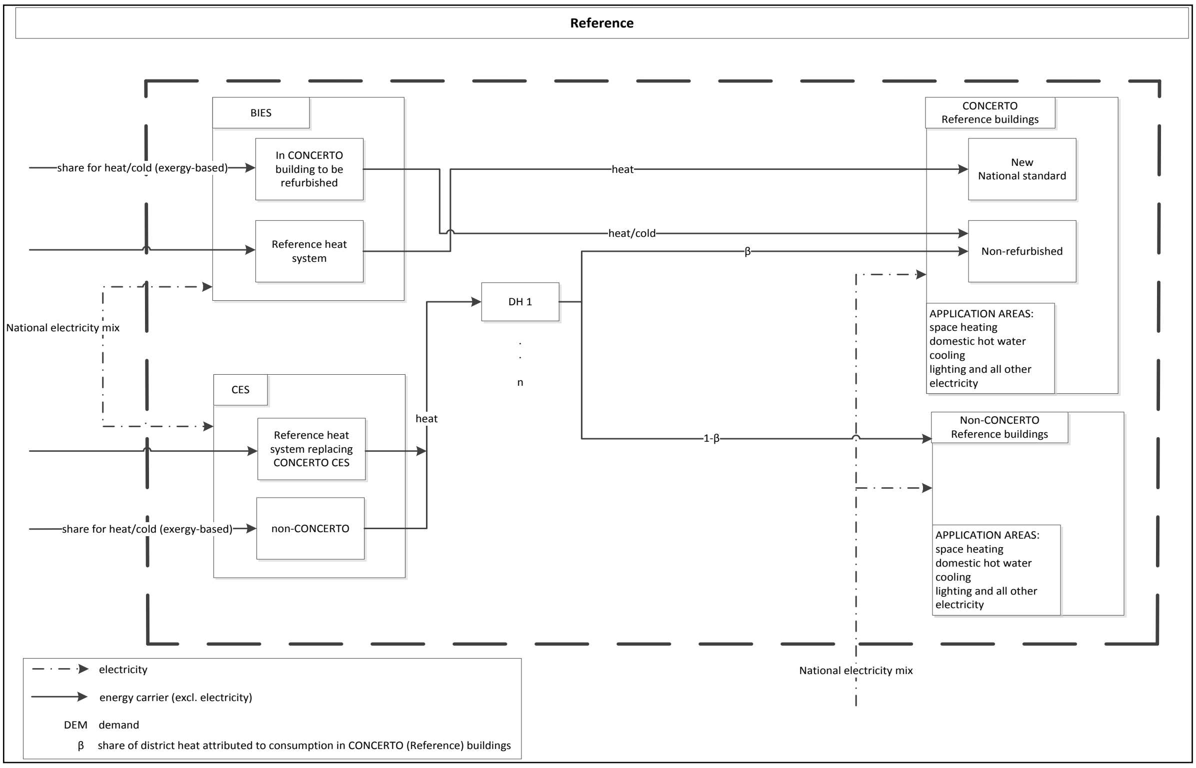

Figure 3.4: System boundaries, elements and energy flows associated with a CONCERTO area in the reference system

level. The underlying principles are used as well for the analysis on the level of individual new and refurbished CONCERTO buildings, CONCERTO BIES and CES as well as the corresponding reference buildings and energy supply units. In the following, system boundaries and general issues and assumptions concerning the indicator calculation methodology are explained:

General issues & assumptions

- Savings on site or area level refer to CONCERTO demonstration objects with enough data available. For buildings, the "number of buildings represented" (provided as a parameter in the data collection sheet) are taken into account. This number is used if several similar buildings were constructed or refurbished but data has been only collected for one representative building.
- Economic calculations take into account capital costs (for profitability calculations total investments are used in case of refurbishments and energy-related additional investments in case of new buildings), interests and energy costs. Maintenance is NOT considered.
- National energy prices (incl. VAT and energy taxes) are used. The goal was to use prices of 2010 but because of data availability prices used

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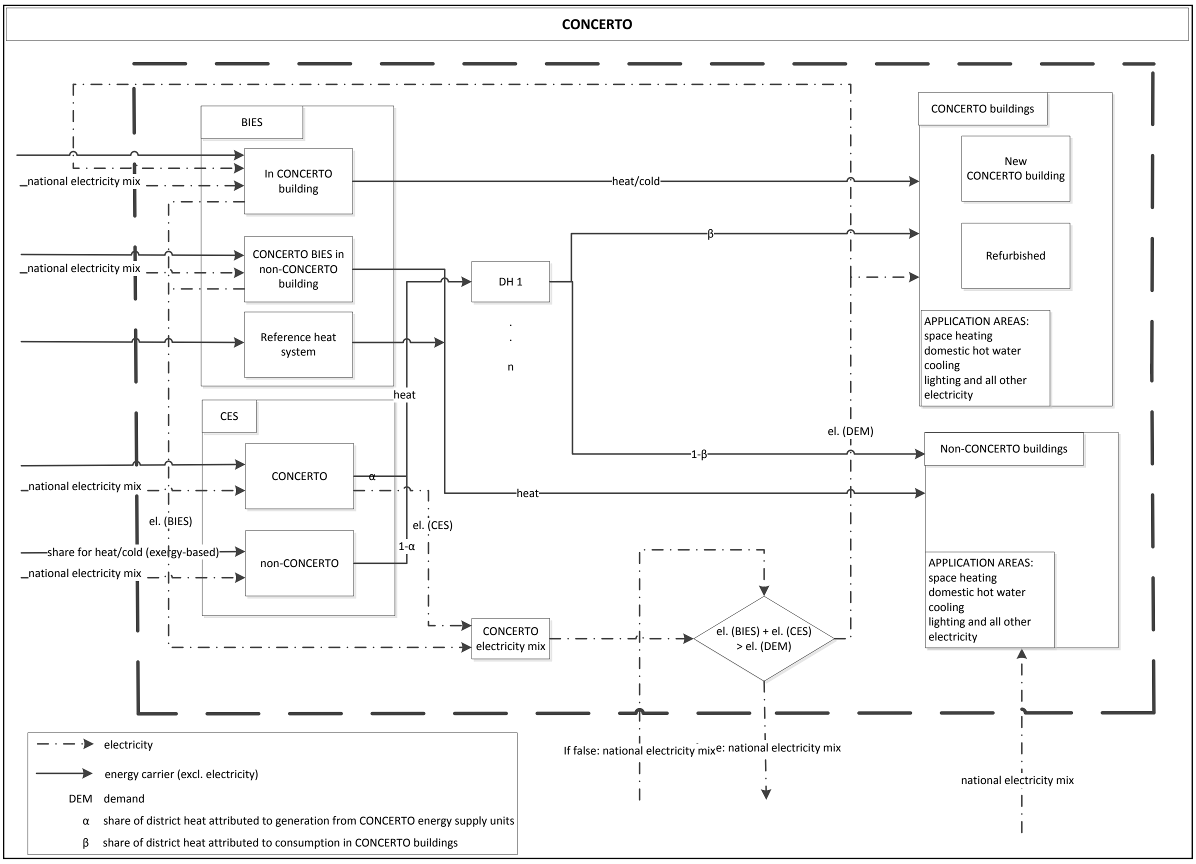

Figure 3.5: System boundaries, elements and energy flows associated with a CONCERTO area in the CONCERTO system

range from 2008 to 2012. Electricity producing ESU indicators (especially PV) are calculated with fictive total self-usage (price of electricity for usage in households is used for calculation of payback period, net present value) and not feed-in tariffs. Currently, feed-in tariffs are being included into the TMD. Thus future calculations could be based on them.

- Two energy price scenarios are used: an annual increase by 3% and by 5% according to European Commission (2012).
- A discount rate of 3% is used for economic calculations according to European Commission (2012).
- Planning horizons of 20 and 30 years are used for energy supply units and buildings, respectively according to European Commission (2012).
- Capital costs are converted into capital costs incl. VAT. If it is not known if VAT is included or excluded, it is assumed that VAT is included.
- The energy carrier "other biomass" is assumed to have the same primary energy factors, emission factors and energy prices like "wood pellets".
- Embedded energy & emissions are only considered for energy carriers, i. e. CO2 emissions for the production of PV modules are not considered.
- If possible, the floor area of buildings is transformed to the gross floor area using building type specific conversion factors according to BKI Baukosten Gebäude (2013).
- Capital costs of buildings are transformed to price level 2010 using price indices for each country according to European Commission - Eurostat (2013). If the price level year was unknown, it was estimated by the year of construction/refurbishment. If this data was unavailable as well, 2008, 2010, 2012 was used for CONCERTO generation 1, 2 and 3 projects.
- Energy demand (calculated) values are not climate corrected. Space heating consumption values are heating degree day corrected to a 10 year average (2002-2011).
- Solar factor 0.7kW/m^2 according to European Solar Thermal Industry Federation (ESTIF) (2004) is used to estimate power of solar thermal panels (for achieving comparability with other energy supply units), as only m^2 are available in most cases.
- Application areas considered in building analyses are: space heating, domestic hot water, space cooling as well as "non-heating non-cooling electricity".
- Electricity produced in buildings is considered as part of the local electricity mix.

- For buildings, final energy input per application area is in case of non-electricity equally distributed to the non-electricity using systems used for this application area.

ESU CONCERTO demo objects

- use of national electricity mix
- exergy-based allocation to heating, electricity and cooling output
- use of national primary energy factors, emissions factors and energy prices according to mainly Gemis (2013) and European Commission - Eurostat (2013), respectively.

ESU reference objects

- heating: "average EU oil boiler" according to Van Holsteijn en Kemna BV for the European Commission (2013)
- cooling: compression chiller
- electricity: national electricity mix of the relevant country
- capital costs of reference energy supply unit are determined by multiplying a specific investment [€ /kW] with the power [kW_p] of the ESU demo object. It is assumed that the same energy output can be produced. Economies of scale are neglected for the reference object.

New and refurbished CONCERTO building demo objects

- primary energy factors and emission factors used:
  - electricity: Use of local electricity mix (mix of CONCERTO BIES and CES in this CONCERTO area supplemented by national mix if demand of CONCERTO buildings exceeds production)
  - district heat: Use of local district heat mix (mix of CONCERTO and non-CONCERTO ESU supplying the district heating network). If the local district heat mix is not calculable, the national district heat mix is used
  - district cooling: District cooling is not used in CONCERTO buildings
  - other energy carriers: National data is used

Reference building for new CONCERTO buildings

- building according to national minimum requirements (as provided in the data collection sheets)
- heating: EU average oil boiler (assumption that final energy flows and energy-related additional costs in data collection sheets refer to an oil boiler as well)
- electricity supply: National electricity mix
- cooling: Same cooling system as demonstration object

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Reference building for refurbished CONCERTO buildings

- it is assumed that former heating system and building envelope could still have been used
- heating: Heating system before CONCERTO refurbishment
- electricity supply: National electricity mix
- cooling: Cooling system before CONCERTO refurbishment

3.4 Ensuring comparability as basis for the assessment

Ensuring comparability of input parameters for the calculation procedures as well as the indicator values is a key factor for a significant and strong assessment. This is why CONCERTO Premium follows two strategies. Firstly, adjustments, corrections and conversions of certain input parameters have been performed as described in section 3.3. Secondly, classifications of comparable objects according to buildings types, climate zones and economic areas have been carried out.

For the climate zones the climate map according to Troll/Paffen (H. E. Landsberg, H. L. (1965)) has been considered. Each CONCERTO site is assigned to the climate zone that it belongs to. All sites lie within cold-temperate boreal zones, cool-temperate zones, and warm-temperate sub-tropical zones. Table 3.2 characterizes the relevant climate zones that occur in CONCERTO and Figure 3.6 shows the geographical extent.

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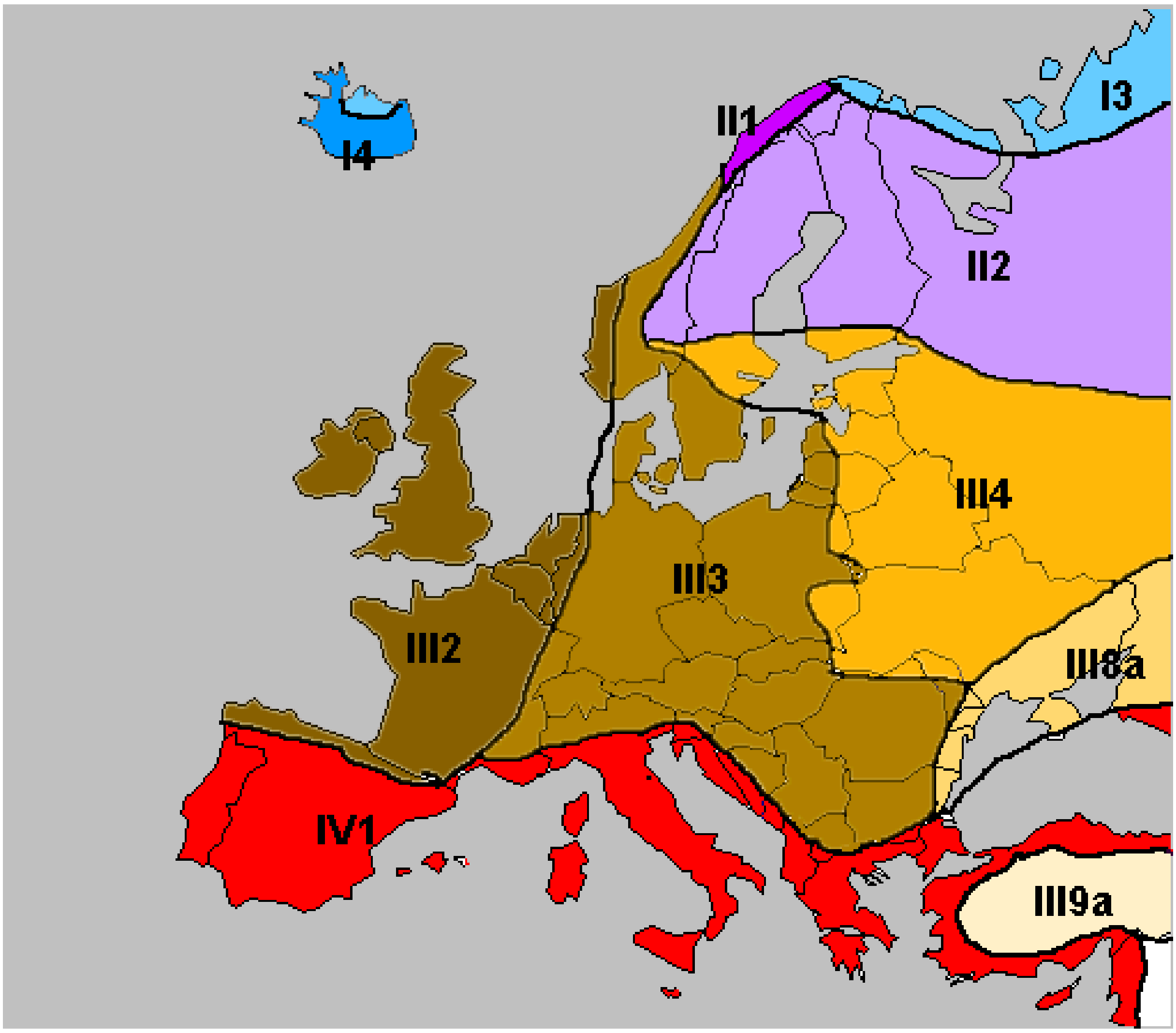

Figure 3.6: Climate map according to Troll/Paffen

	Troll/Paffen climate classification
II	cold-temperate boreal zone
II 2	Continental boreal climates (annual fluctuation 20° to 40° C with long, very cold winters, profilic in snow, but short relatively warm summers (warmest month +10° to $+20^\circ$ C).
III	cool-temperate zones
III 2	oceanic climate (annual fluctuation $< 16^\circ$ C) with mild winters (coldest month above 2° C), autumn and winter, maxima of precipitation and moderately warm summers (warmest month below $+20^\circ$ C).
III 3	Sub-oceanic climates (annual fluctuation 16° to 25° C) with mild to moderately cold winters (coldest month 2° to -3° C), autumn to summer maxima of precipitation, moderately warm to warm and long summers.
IV	warm-temperate sub-tropical zones
IV 1	Dry-summer Mediterranean climates wit humid winters (mostly less than 5 humid months).

Table 3.2: Climate classification according to Troll/Pfaffen

In CONCERTO the economic area is defined using the BKI Länder-Baukosten-Anpassungsfaktoren (country-construction-cost-matching-coefficients). Those matching-coefficients reflect the different construction cost levels within the EU. The following intervals have been defined for the classification:

- economic area 1: matching coefficient ≤ 0.5
- economic area 2: matching coefficient $0.5 < x \leq 0.75$
- economic area 3: matching coefficient $0.75 < x \leq 1.0$
- economic area 4: matching coefficient ≥ 1.0

When the considered demonstration objects are buildings a comparison only makes sense when the building types are the same. In CONCERTO the following types are distinguished:

- residential building - single and two family house (gross floor area < 180 m^2)
- residential building - multiple family house (gross floor area > 180 m^2)
- municipal building
- industrial building
- tertiary non-municipal building

Chapter 4

Assessment tools

4.1 Fundamentals and applications

As part of CONCERTO Premium a number of foundations and tools for data collection and analysis as well as the assessment were developed, tested and used. These tools serve

- the support of data collection (Monitoring guide)
- the immediate data collection (Data collection sheets)
- the calculation of indicators (Indicator guide)
- the definition of assessment principles and criteria (Guidebook for assessment).

In addition, as part of CONCERTO Premium a database structure was developed and implemented, questionnaires for the analysis of the interests of stakeholder groups were elaborated, applied and analyzed.

For the actual assessment - as far as possible - benchmarks and plausibility corridors have been compiled. Moreover, required auxiliary values (including national primary energy factors, emission factors) were researched, stored into the database and used for calculation.

In CONCERTO Premium the mentioned tools have been a necessary requirement for documentation, compilation and evaluation of the actual results, beyond it is recommended to also apply those tools in future projects. They represent in their structure the workflow and information flows from the data collection and preparation over the documentation and compilation up to actual analysis and presentation of results. In particular, the developed and tested guidelines for data collection (montoring guides) - see section 4.2 shall be mentioned. It is suggested to recommend the application of those guides for future projects.

4.2 Monitoring guides

Ideally, in the beginning of a project dealing with monitoring, the monitoring procedure and the data requirements have to be discussed and agreed with the involved project partners. Clear definitions have to be fixed and described in the monitoring guidelines that are binding for all participants.

This ideal monitoring approach proved to be only partially applicable for CONCERTO due to the fact that the projects of generation 1 were almost finished when the data requirements were published. CONCERTO Premium needed to find a way to deal with already existing data in the projects because there would not have been the possibility of collecting a lot further data. Therefore, the CONCERTO Premium data collection procedure offers flexibility in handling different types of data.

The CONCERTO monitoring concept involves the aspects of technical, economic, social and policy monitoring. CONCERTO Premium developed monitoring guides for the different aspects that intend to define a common approach and a standardised methodology which should be applied by all CONCERTO projects to ensure a comparable presentation, evaluation, assessment, analysis and dissemination of the CONCERTO results. These guides aim at providing assistance for the CONCERTO projects for the collection of the data according to the CONCERTO data requirements and at clarifying uncertainties in the data collection. As a further tool for the standardized data collection, suitable data collection sheets (based on Excel®) have been elaborated for each monitoring aspect. Furthermore, the comparability of data delivered by the CONCERTO projects is improved; the data collection sheets provide the opportunity to be precise about what the delivered data represent e.g. investment data is only comparable for demonstration projects of the same type if it is clear which components are contained in the specified values, whether value added tax (VAT) is included and with the indication of the corresponding year of price level. Therefore, CONCERTO Premium tried to incorporate respective fields in the CONCERTO Premium data collection sheets.

CONCERTO technical & economic monitoring

The CONCERTO Technical and Economic Monitoring Guides should provide assistance to gather the required technical, environmental and economic data. The technical and economic monitoring is being performed on the level of the CONCERTO demonstration projects in the CONCERTO areas. The CONCERTO Technical Monitoring Guide aims at providing assistance for the design of the measuring procedure and specifies the parameters of the minimum monitoring requirements for technical and environmental data of the CONCERTO demonstration projects. The minimum monitoring requirements are defined to enable the analysis of the energy performance of a CONCERTO demonstration project and possible improvements. The overall generated, delivered and consumed energy of the demonstration projects in a CONCERTO area needs to be metered and collected. However, the technical monitoring guide is not intended to provide instructions and references to the use of a special measurement technology in particular. The CONCERTO Technical Monitoring Guide covers two major aspects:

A Assistance for developing a monitoring strategy, mainly targeting Generation III projects

B Definition of the data requirements for all CONCERTO projects

The CONCERTO Economic Monitoring Guide supports the CONCERTO projects in their economic research, their conceptual preparation and subsequent implementation of a long-term monitoring for the gathering and assessment of economic data and with their assessment activities. For achieving this objective, an appropriate structure for gathering relevant types of costs is introduced. This cost structure is based on the CEEC Code of Measurement for Cost Planning edited by the European Committee of Construction Economists. The CONCERTO Economic Monitoring Guide is divided into two parts:

1) Determination of construction costs and costs in use – Buildings
2) Determination of construction costs and costs in use - Energy Transformation Units.

CONCERTO social monitoring

For the holistic assessment of the implemented energy efficiency measures in buildings and the integration of renewable energy sources on community scale the acceptance of these measures by the inhabitants and other stakeholders has to be taken into account, though the social monitoring is not an explicit task of CONCERTO Premium. CONCERTO Premium elaborated the CONCERTO Social Monitoring Guide with a focus on supporting CONCERTO projects of generation III in setting up their social research concept and in preparing and conducting social research activities. Furthermore, this guide provides information about possible collection methods for social data, information on the analysis and documentation of the results and finally on the cooperation and data transfer to CONCERTO Premium for CONCERTO projects of all generations.

The social monitoring data are being collected and evaluated in the projects themselves. The results of the social research in the CONCERTO projects has been be unified in a CONCERTO social data collection sheet and transferred to CONCERTO Premium.

CONCERTO policy monitoring
CONCERTO Premium also pays attention to the monitoring of policy impacts and developments of the CONCERTO projects. As soon as low carbon neighbourhood projects such as CONCERTO are considered, automatically political implications become obvious. These projects are usually being influenced by political aspects at various levels. The identification of challenges and barriers in the CONCERTO projects leads to important conclusions and can help future projects to avoid or overcome them successfully, by providing already tested solutions. Policy monitoring has the aim of identifying contextual factors that contribute to successful projects. The hope is that by understanding these factors, an appropriate framework can be encouraged and successful replication becomes more likely. It is the aim of the CONCERTO Premium Policy Monitoring Guide to deal with the capturing of these policy-relevant aspects. The policy monitoring concentrates in particular on local policy measures, but some questions also address national and regional policies, which often set the framework for local policies. The CONCERTO Policy Monitoring Guide explains the subjects covered by the policy questionnaire, providing context as to why these are relevant and also providing some guidance as to what type of information could be relevant. All CONCERTO Monitoring Guides can be found on the CONCERTO webpage for further information.

4.3 Indicator guide

In the context of CONCERTO Premium, diverse economic, technical and environmental indicators have been developed, with which to assess the measures implemented within the projects of the CONCERTO Initiative. An Indicator Guide has been produced in which a complete set of indicators is defined. This document can be seen as can one of the key aspects of the project, in that it represents the interface between the data collection, database, monitoring and visualization activities. The objective of the CONCERTO Premium Indicator Guide is to

- give a clear mathematical description of the CONCERTO Premium indicators
- identify the data requirements of the CONCERTO Premium indicators
- create a link between these data requirements and the CONCERTO Premium data collection sheets

- enable the implementation of the calculation procedures for the CONCERTO Premium indicators based on the CONCERTO Premium database
- provide an indicator pool for the assessment criteria
- improve the understanding of the calculation procedures and the indicators by
- providing selected examples
- give required definitions
  - Typologies of elements in the CONCERTO area
  - Energy flows in the CONCERTO area
  - Typologies of energy carriers, areas of application, buildings and energy
  - supply units
  - Production and consumption of electricity
  - Temporal resolution
  - Allocation approach in case of cogeneration or polygeneration
  - Primary energy and emission factors
  - Balancing energy, system boundaries
  - Build, operating and combined margin method
  - Priorities: Local vs. national data
  - District heating/cooling
  - Calculation of climate corrected energy ouput and consumption
  - Reference buildings and reference energy supply units

The objective of the CONCERTO Premium Indicator Guide is not to

- discuss and interpret the CONCERTO Premium indicators
- cover the social CONCERTO Premium indicators

4.4 Guidebook for assessment

The success and the acceptance of measures intended to enhance the energy efficiency and to increase the usage of renewable energy sources strongly depend on the interests, the motives, the state of knowledge, the available information, the possibility of influencing as well as the willingness to invest of the different stakeholders. By conducting economic, environmental and technical research and by assessing the possible measures the stakeholders obtain information and statements for supporting and justifying their decisions. In this respect, further developing methodological principles for the assessment of economic and environmental benefits of measures in combination with the evaluation of the technical performance and reliability is a sub-task in supporting the usage of renewable energy sources and the enhancement of energy efficiency measures. A special focus of the guidebook is the discussion of which criteria and statements of assessment are tailored to the specific information need and scope of action of the different stakeholders. The developed principles should be applied for the CONCERTO projects and enable scientific analysis. By showing the benefits of measures intended to enhance the energy efficiency and to increase the usage of renewable energy sources the acceptance of solutions supporting a sustainable building and district development should be fostered.

The guidebook concentrates on the assessment of technical, environmental and economic interrelations - also in combination. Questions of the description and assessment of political instruments are reserved for another part of the CONCERTO project.

This guidebook is mainly intended for stakeholders who are interested in the assessment of benefits of measures enhancing the energy efficiency and increasing the usage of renewable energy sources and who directly perform according tasks. Those are i.a.

- successors of current CONCERTO projects
- successors of future CONCERTO projects
- successors of other research tasks in this context
- (junior) researchers
- consultants
- planners
- investors
- representatives of public authorities
- other interested parties

The guidebook starts with a description of relevant stakeholder groups and their roles. Furthermore, the respective objects of assessment are introduced and described. Questions arising in the context of the improvement of the energy efficiency of correspondent objects of assessment at relevant stakeholder groups in connection with selected decision-making situations are composed based on surveys and the experience of the authors. Based on the questions assessment criteria are elaborated, introduced and systemized which can support respective stakeholders in their decision-making and justification of their decisions. Indicators, which can be calculated from the available data, are assigned to those assessment criteria. Moreover, the prerequisites for the interpretability of calculated indicator values, like the transparent statement and a thorough characterization of input parameters, are discussed. Before the performance indicators are characterized comparability issues are considered and strategic and methodological approaches for the handling of European data are introduced. Furthermore, assessment results are significantly influenced by assumptions and boundary conditions. They are introduced and wherever possible hints and suggestions are given. Single assessment approaches are characterized regarding their applicability by different stakeholder groups and regarding concrete objects of assessment. Initially, the basic input and influencing variables are described. Afterwards, input parameters for measuring efforts and benefits are explained in more detail in the form of recurring modules that are referenced by the different assessment approaches. Finally, different types of charts for the visualization and display of calculation results are presented.

4.5 Data collection sheets

CONCERTO Premium set up data collection sheets on different levels of aggregation. Besides the data collection sheets on national and community data, data collection sheets for the CONCERTO area and the different CONCERTO demonstration projects were prepared. These data collection sheets contain the most relevant information categories about the CONCERTO projects. Figure 4.1 gives an overview on the set of data collection sheets. Additionally, CONCERTO Premium prepared the CONCERTO Technical Monitoring Guide and the CONCERTO Economic Monitoring Guide that should support the projects in completing the data collection sheets and clarify uncertainties.

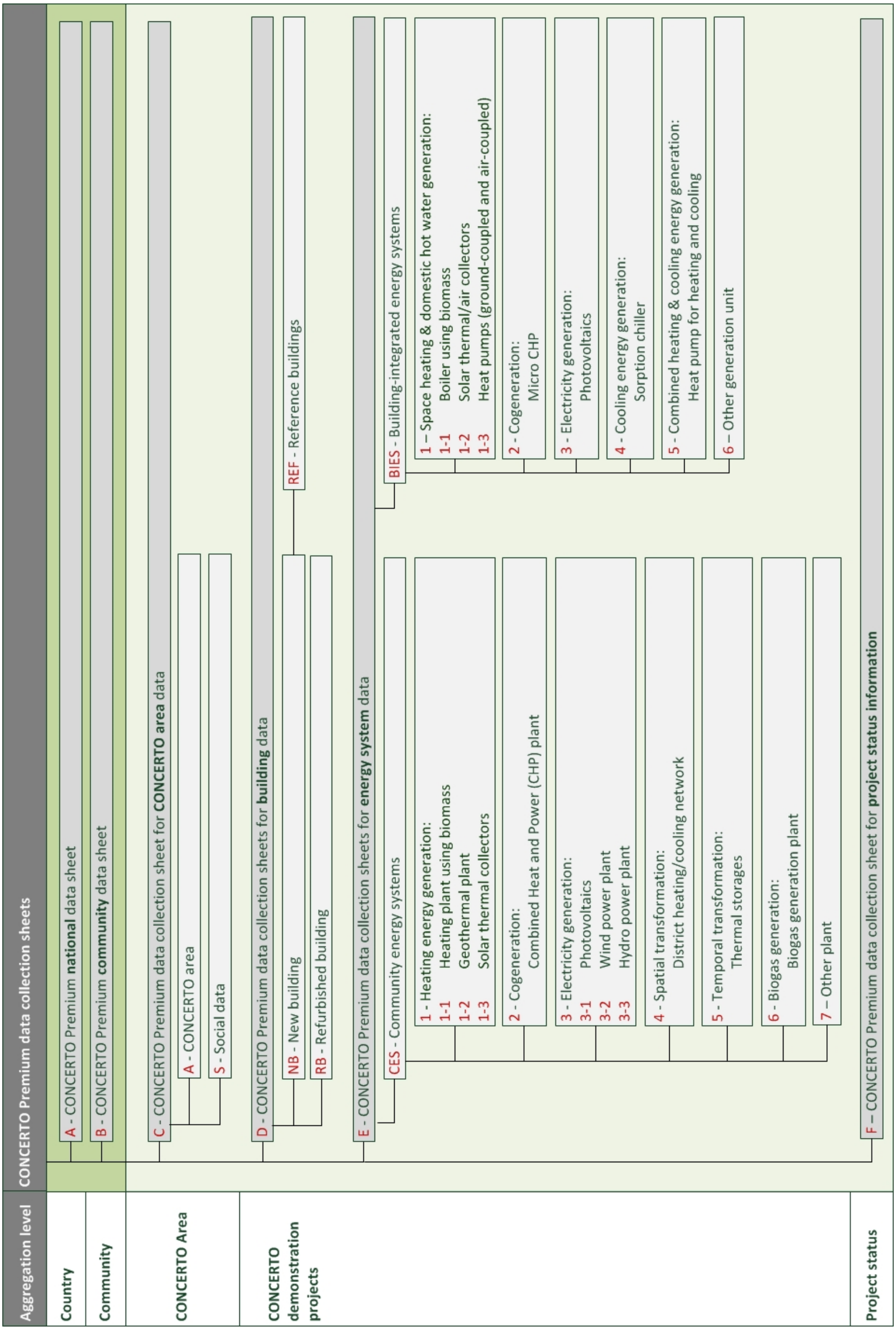

Figure 4.1: Overview on the set of data collection sheets

In the following, an overview on the specific types of data collection sheets is given.

Country level

The calculation of the CONCERTO indicators requires in parts data that is identical for different projects in the same country like emission factors of standardized energy carriers. This country-specific data will be collected by CONCERTO Premium with the national data collection sheet in order to reduce the burden of data collection for the CONCERTO projects.

Community level

The community data collection sheet asks for information that might be available on the level of the community rather than on the level of the CONCERTO area, e.g. housing statistics, information on the energy supply mix of the community etc. This data is intended to fill up gaps in the characterization of the building stock and the energy supply in the CONCERTO area and for the up-scaling of the CONCERTO results. In addition, political instruments used by the local authority are inquired to show possible courses of action to influence the energy and CO2 balance on a community scale.

CONCERTO area level

The CONCERTO area data collection sheet gives a general picture of the CONCERTO area. It contains questions concerning the overall targets, motives, the general building stock and a summary of the implemented CONCERTO demonstration projects in the CONCERTO area. Monitoring of social aspects of the CONCERTO measures is an integral part of the projects and hence the relevant results will be captured by the social data collection sheet. It covers social base data like demographic and contextual information as well as social indicators as a result of surveys conducted amongst occupants and other stakeholders of a CONCERTO area.

CONCERTO demonstration project level

CONCERTO demonstration projects can be buildings as well as energy systems. The data collection sheets for demonstration projects are structured similarly containing these data sections:

- general data
- cost data
- technical and economic monitoring data.

An advantage of the new cost data section is the clear specification of cost components that are included in the specified data. Even if the exact amount of the different cost parts is not known, at least the information that this component is contained in the total costs can be given by ticking the respective boxes. This extensive cost section should not be understood to be filled compulsory and completely by the projects but more being an offer to fill in the different data available in the projects. This is applicable for all cost data in the data collection sheets of the CONCERTO demonstration project level. Furthermore, the total eligible costs, the investment-related grants from CONCERTO and the other parties are intended to be specified in the manner like the total costs. The specifics of the different data collection sheets for demonstration projects are described in the following chapters.

Building data

Building data for new and for refurbished buildings are being collected in two separate data collection sheets. The refurbishment data collection sheet exceeds the content of the new building data collection sheet by the implication of reference energy demand and monitoring values for the time before the refurbishment.

General data section

The general data section asks for static base data of the building like the building type, floor areas and heat transfer coefficients of the building envelope. Also the question for the calculated energy demand, the technologies and energy carriers used to deliver the energy are part of this section. Furthermore, the applied buildings features, e.g. the implementation of energy saving measures etc., can be specified. For the correct interpretation of the indicators, it is important to know about the applied building features because they might have an influence on the investment and costs in use.

Cost data section

Two approaches for the gathering of cost data were elaborated in order to cope with the heterogeneity of the data in the different projects all over Europe. The user can choose from two different possibilities for the specification of the costs data:

- The specification of the total building costs according to the CEEC Code of measurement for Cost Planning or
- The specification of cost data for different packages of measures instead of for every single cost group.

This approach aims at providing a high degree of flexibility, according to the availability of data, the first, the second or even the combination of the two approaches can be chosen. These possibilities are described in more detail in the CONCERTO Premium Economic Monitoring Guide.

Technical and economic monitoring data section
Monitoring data both in the technical and economic dimension are required in this section. In the technical monitoring part, the measured final energy consumption for the different application areas in the building on yearly or monthly basis is of interest; the economic monitoring section asks for costs and revenues of the respective monitoring period.

Costs in use
The "costs in use" according to the CEEC code contain relevant costs of the energy supply, cleaning and general maintenance, inspection and servicing of structure, inspection and servicing of technical installations, insurances and miscellaneous. Energy costs etc. have a high influence on the cost-effectiveness of a technology. Therefore, detailed information on this part is asked in the data collection sheet.

Revenues
Revenues from energy sales and changes in rental incomes can be specified in this subsection. This information should allow conclusions on the profitability of energy efficiency measures and the use of renewable energy sources for landlords.

CONCERTO reference building data
The data collection sheet for new reference buildings is used to collect data as base for the assessment of new CONCERTO buildings. The focus is on providing information about the building standard, the calculated energy demand for heating, domestic hot water, cooling and electricity and the average costs for a reference building. The cost approach according to CEEC cost groups is provided and any kind of applicable grants can be specified. The reference data for a refurbished building is implicated in the data collection sheet for the refurbishment itself. For the calculation of the CONCERTO Premium indicators, the reference for refurbishments was defined to be the energy consumption and costs in use from the time before the refurbishment. Therefore the data collection sheet for refurbishments comprises in its general data section fields for values before and after the refurbishment. Furthermore a list of refurbishment measures was added. Ticking the corresponding boxes indicates the measures taken.

Energy system data

Energy systems are grouped as community energy systems and building-integrated energy systems. The definitions are given in the CONCERTO Premium Technical Monitoring Guide. The data collection sheets for the different energy systems ask for system specific information. A list of the different data collection sheets is given in Figure 1. Generally, the idea of the data collection sheets for energy systems is to picture the data related to the input and output of the energy systems. The following description refers both to community and building-integrated systems.

General data section

The general data section contains information about the characteristics and the technical specifications of the energy system. Characteristics are e.g. the description of technology used, information on the ownership structure and the operator and information on the commissioning data and the status of the energy system. Technical specifications are information about the installed capacity for heating and/or cooling and electricity generation as well as information on the energy carriers used.

Cost data section

The cost/investment data section of the energy systems is structured flexibly as already described above; the total investment and the different components of the total investment can be specified, if available, both for planned and settled costs. In addition to the investment data, the total eligible costs, the investment-related grants from CONCERTO and the other investment-related grants are intended to be specified in the manner like the total investment.

Technical and economic monitoring data section

The monitoring section is subdivided in the technical, environmental and economic monitoring parts, where applicable. The technical and environmental monitoring parts contain information about the input of energy carrier in the energy system, the generated energy output and the direct emissions that occurred in the transformation process. The economic monitoring part is subdivided in costs and revenues.

Costs in use

In this subsection, the energy costs for the energy carriers used and further costs like non-energy requirement-related costs, operation related costs and other costs should be specified as totals per year.

Revenues

The revenues section is applicable only for the community energy systems and the building-integrated CHP and PV and it comprise data fields for data about the revenues for the generated heating/cooling energy and electricity. Furthermore, other revenues like gypsum sales can be specified.

4.6 Database

Flexible data model

The CONCERTO Premium Technical Monitoring Database manages data from 58 European communities, participating in the CONCERTO initiative. One of the IT challenges is the divergence of the data collected from the CONCERTO project sites. Some data fields are commonly used throughout the CONCERTO initiative, but there are also data fields, which are unique for a project site, depending on the country or community, in which it is situated, and/or on the monitoring date. Figure 4.2 illustrates that a different number and in some cases, different types of data fields are used to describe CONCERTO objects in CONCERTO Premium. The table columns in figure 4.2 represent the data fields, and the rows represent the CONCERTO Premium object data sets: buildings, energy networks, energy supply units etc.

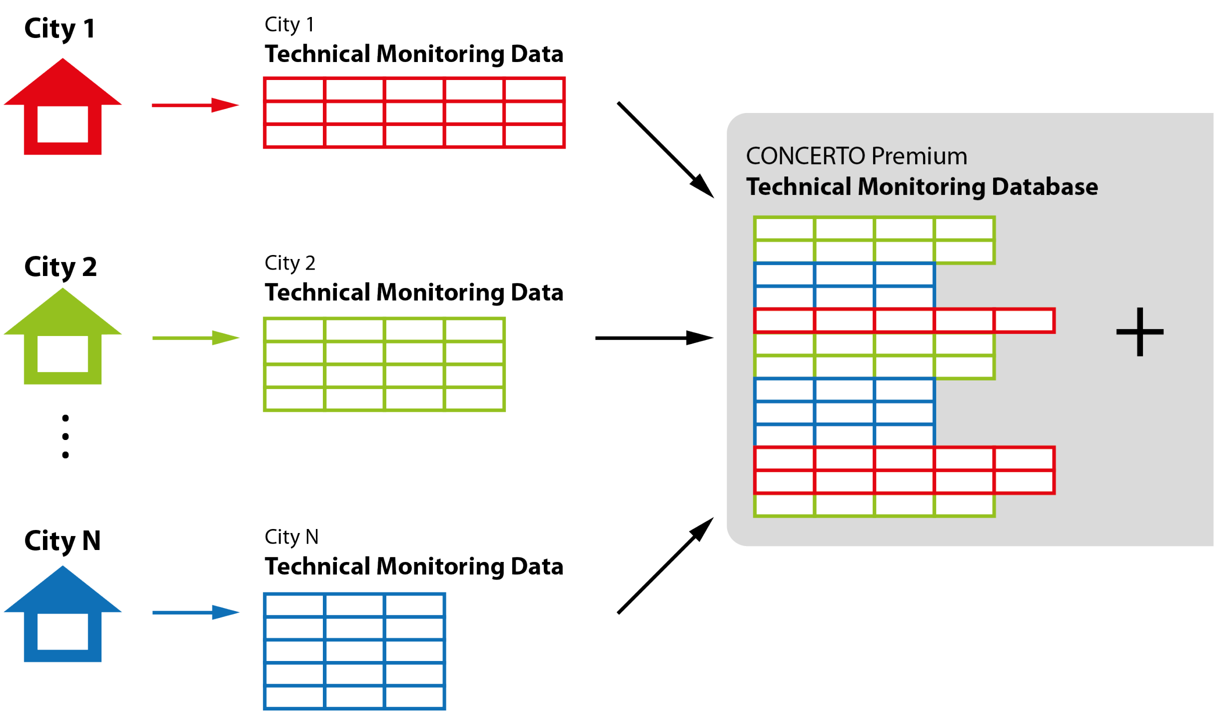

Figure 4.2: Flexible data model of CONCERTO Premium

The CONCERTO Premium Technical Monitoring Database addresses this challenge by using a modern, graph database technology. The system of choice is Neo4j, a high-performance, enterprise grade graph database. It enables the Technical Monitoring Database to use a flexible data model, which considerably facilitates the information management in CONCERTO Premium.

High-efficiency management of complex data patterns

The CONCERTO Premium Technical Monitoring Database manages data of numerous communities' energy systems. The data objects in an energy network, such as buildings, networks and energy supply units are inherently interconnected to a high degree and compose complex network patterns. The graph database is optimal for the management of this kind of data structures. On one side, the searching of complex data patterns in large data sets is much more efficient and flexible than in a relational database. On the other side, the database engine allows for flexible extensions and modifications of the data structure, e.g. adding new types of relationships in runtime, which is used in the persisting of indicators and for the enrichment of data with semantic information. Figure 4.3 shows a small snippet of the graph data structure of the CONCERTO Premium Technical Monitoring Database.

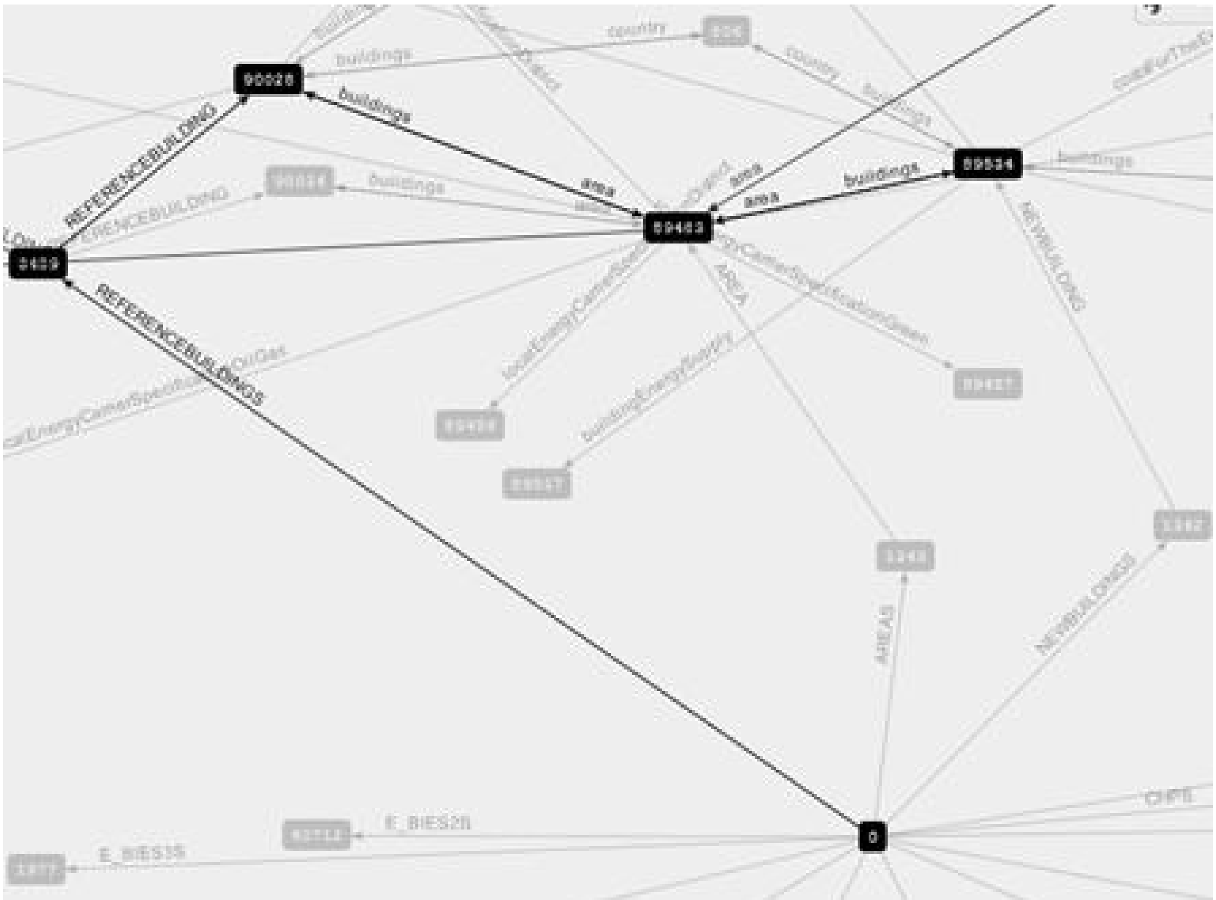

Figure 4.3: High degree of cross-linking between CONCERTO Premium data objects

Data enrichment and semantic queries
In order to facilitate more flexible and user friendly querying of the database, the data layer is enriched with a multiple taxonomy of semantic categories. The taxonomy composes a metagraph, which is interconnected with the graph of CONCERTO objects. Each CONCERTO object can belong to one or more categories. The metagraph is dynamic, it is created from program code during import of the database, and is not part of the data model. If future user scenarios require it, a likely extension of the metagraph would be to compute it during runtime of the database application, thus enabling a dynamic classification of CONCERTO objects.

Flexible indicator calculation
The diversity of raw data and location specific indicator calculation rules in CONCERTO poses a challenge on the application logic layer, which is responsible for the indicator calculation. This challenge is addressed by utilizing a rule-based system – Drools – for computation of indicator variables, which require a higher level of flexibility. The rule system analyses the graph pattern of input objects and selects automatically the right rule. The computation result is then processed in further rules or object oriented methods. The rules contain the expert knowledge for computing performance indicators on CONCERTO data.

4.7 Benchmarks

In the assessment process two approaches are followed, the relative comparison with data from CONCERTO projects and the absolute comparison with "external" benchmarks. Additionally, in the evaluation and assessment statistical methods are used. In this context mainly statistical position and scattering parameters, like the mean value, the median and/or quartiles and variances, respectively are used. Those values are considered for comparisons between individual objects and country- or site-specific aggregation values in order to find out if the individual object performs better or worse than the average/median/xx %-quartile. Furthermore, statistical position and scattering parameters of different countries/sites can be compared in order to evaluate the relative performances. The basic requirement is to ensure transparency and comparability. In the case of relative comparisons of results in individual areas, sites or countries a grouping was carried out - for energy consumption by reference to climate zones and for cost figures by reference to economic zones. In case of absolute comparisons with "external" benchmarks it was ensured that they are suitable in terms of time period, objects of assessment and other system boundaries. In general, these values were obtained from the literature or taken from EU documents. CONCERTO results are best understood in the context of benchmarks for assessment. For example, a residential building has to be assessed differently with regard to the final energy demand for space heating when it is located in Norway compared to Spain. As the climate conditions, especially heating degree days, differ widely between countries, the final energy demand of the considered building has to be compared with the average final energy demand of the national building stock or the minimum requirement of the final energy demand according to the national law, for example. In this context, different benchmarks have been identified that are suitable for different indicators. For some indicators country-specific benchmarks are necessary like the specific energy demand or the specific construction costs of a building. For other indicators one value for all European countries is adequate, like the lifetime of an energy supply unit or the costs of carbon emissions. The benchmarks and their assignment to the different indicators can be found in the CONCERTO benchmarking table that is available on www.concerto.eu.

4.8 CONCERTO community sheets

The CONCERTO Community Sheets are three-page-fact-sheet for specific sites, which have been completed for about ten sites and are being completed for additional ones, where the data allows this. These sheets provide background information on the CONCERTO communities before the CONCERTO project took place, characterize the CONCERTO measures and give selected insights from the assessment of these measures. The status before the CONCERTO project is needed in order to allow a potential follower to compare the before CONCERTO situation to his initial situation. The list of CONCERTO measures show the technology mix implemented in this CONCERTO site. Selected insights from the technical, environmental and economic assessment of buildings and energy supply units provide interesting information on the efficiency and efficacy of these measures. The structure of each CONCERTO Community Sheets is

- Page 1
  - CONCERTO community
  - CONCERTO buildings
  - CONCERTO energy supply units
- Page 2
  - CONCERTO insights regarding buildings
- Page 2
  - CONCERTO insights regarding energy supply units

Chapter 5

Assessment results

5.1 Structure and typology

The selection of appropriate methods for the assessment of the economic and environmental benefits of energy efficiency and renewable energy measures including the evaluation of the technical performance and reliability is influenced i.a. by the specific characteristics of the respective object of assessment. Besides the consideration of buildings and energy supply units especially the site (i.e. community) level is focused by CONCERTO. In the CONCERTO projects entire districts are refurbished or newly built. Thereby energy efficiency measures and the usage of renewable energy sources are coordinated on energy supply and energy demand side. Not every method is appropriate for every object of assessment or leads to significant results.

On the other hand assessment criteria can be defined since different stakeholder groups have different information needs. Within CONCERTO Premium the following subject areas are concerned:

- economic performance or benefits - micro-economic part
- economic performance or benefits - macro-economic part
- environmental performance or benefits
- economic-environmental performance or benefits
- technical performance.

Considering those two dimensions a matrix can be elaborated in order to structure the representation of calculation results (Table 5.1). In the following sections the introduced matrix is used to illustrate the context of the shown diagrams and the correspondent combination of letter and number (like [A2]) is provided in the headlines and the caption of each diagram.

	1 general	2 economic	3 macro-economic	4 environmental	5 eco-environmental	6 technical
A site						
B building						
C energy supply unit						

Table 5.1: Objects of assessment and assessment criteria

The analysis of the availability and quality of data is a prerequisite for the description and evaluation of implemented measures. Therefore, indirectly, an evaluation whether and to what extent an appropriate structure for the collection and evaluation of data was developed and applied in each CONCERTO project also takes place. After a brief introduction on data availability and quality selected assessment results are presented to illustrate the individual elements of the CONCERTO Premium assessment matrix

- site level
- building level
- energy supply unit level.

This is complemented by results of the CONCERTO Premium prospective study.

5.2 CONCERTO sites

The 58 sites of CONCERTO chose their individual strategy in order to implement energy efficiency measures and to increase the use of renewable energy sources. The realisation of new constructed and refurbished buildings was influenced by the individual situation at each demonstration area in terms of political, social, economic and city planning aspects. In the end some projects were strongly affected by the economic crisis. Figure 5.1 shows the distribution of constructed or refurbished gross floor area per site. About a quarter of the sites only had new construction activities, another quarter just demonstrated refurbishments and about half of the sites had activities in both sectors.

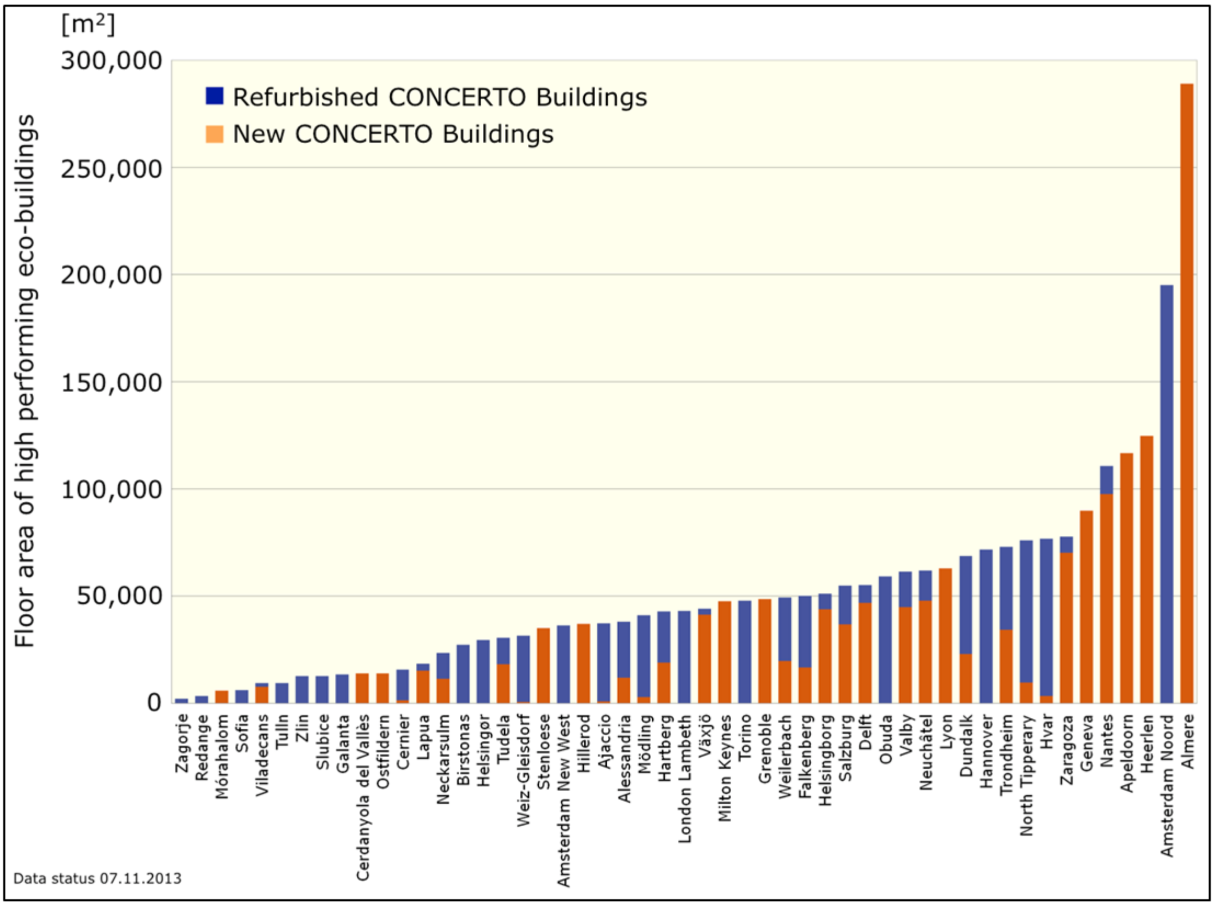

Figure 5.1: Total gross floor area of new constructed and refurbished demonstration buildings in CONCERTO per site [A1]

Following the holistic approach constituted by CONCERTO, the sites not only operated on the building (energy demand) side, but also have been very ambitious in implementing a large number of demonstration objects on the energy supply side. By regarding the distribution of the installed power per site Figure 5.2 shows the enormous variety of the technology mix realised in CONCERTO. Whereas some sites clearly had a focus on one technology, the large share implemented a broad mix. The activities include small building integrated systems as well as large-scale community systems, standing alone or being connected to district heating networks.

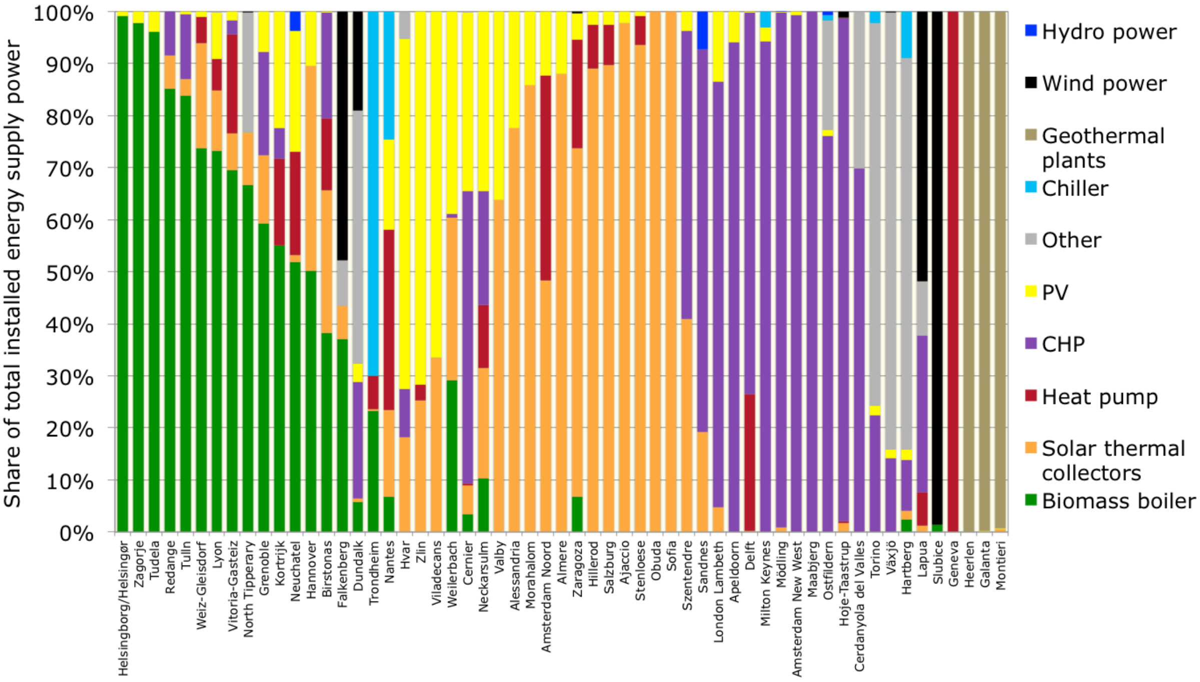

Figure 5.2: Implemented energy supply units in CONCERTO per site [A1]

5.2.1 Achieved goals in CONCERTO sites [A1]

Table 5.3 outlines the achieved goals on the CONCERTO site level. The assessment of the CONCERTO sites is carried out with respect to various criteria. The reduction of fossil primary energy demand of new buildings for space heating compared to the national regulation is the measured variable representing the major goal of the CONCERTO initiative. Here, the specified threshold value amounts to 30%. For refurbished buildings the success is evaluated with the help of two reference values. Firstly, the fossil primary energy demand for space heating after retrofitting is compared to the state before retrofitting. Secondly, the saving of primary energy is calculated with respect to a reference building according to national regulation of a new building in the respective country. Moreover, to account for the desired increase of energy production from renewable energy carriers as well as energy production by polygeneration, the installed capacity of energy supply units based on renewables and the one based on polygeneration is outlined. Finally, another assessment criterion for the CONCERTO sites is found to be the deployment of a monitoring concept. Here, the prevalence of monitoring data is investigated and distinguished between new and refurbished buildings as well as community and building-integrated energy systems. It is important to highlight that the determined shares refer to the number of buildings and energy supply units considered and thus do not relate to amongst others floor areas or quantities of energy. Furthermore

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it is worth noting that the performance indicators cannot be determined for all sites. This is due to two reasons. In the first case, as the calculation procedure relies on a minimum amount of data necessary to derive the indicator, full or partial data incompleteness therefore leads to the performance indicator not being calculable. However, in this case the existence of the demonstration object is known with a data collection sheet created. In the second case, the indicator cannot be computed as no information about the demonstration object is retrieved at all. This is due to the fact that the demonstration object is likely not to exist or although it exists no information has been retrieved during data collection. Furthermore, the sites are ranked with respect to various criteria. These refer to the reduction of fossil primary energy demand of new buildings for space heating compared to the national regulation, the saving of primary energy with respect to a reference building according to national regulation of a new building in the respective country and the deployment of a monitoring concept calculated as the average across all objects.

	Reduction of fossil primary energy demand of new buildings (space heating)		Reduction of fossil primary energy demand of refurbished buildings (space heating)			Installed capacity of Renewable Energy			Installed capacity of Polygeneration			Monitoring concept					
	Compared to reference building according to national regulation		After vs. Before	Compared to reference building according to national regulation		kW_{el}	kW_{th}	kW_{cool}	kW_{el}	kW_{th}	kW_{cool}	NB	RB - before	RB - after	CES	BIES	all objects
Site / Goal	✓(30%)	Ranking	-	✓(0%)	Ranking	-	-	-	-	-	-	-	-	-	-	-	Ranking
Ajaccio, Corsica, FR	x (16%)	28	62%	✓(4%)	7	6	0	0	-	-	-	0%	0%	25%	-	67%	29
Alessandria, IT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41
Almere, NL	✓(73%)	14	-	-	-	95	4787	0	-	-	-	23%	-	-	100%	-	9
Amsterdam, New West, NL	-	-	50%	x (41%)	11	4000	5700	0	4000	5700	0	-	0%	0%	100%	-	20
Amsterdam Noord, NL	(not calculable)	-	68%	-	-	0	1561	0	-	-	-	-	0%	0%	100%	100%	14
Apeldoom, NL	(not calculable)	-	-	-	-	1500	3000	0	1500	3000	0	0%	-	-	0%	-	41
Birštonas, LT	-	-	(not calculable)	-	-	0	0	0	-	-	-	-	-	-	0%	0%	41
Cerdanyola del Vallès, ES	✓(31%)	24	-	-	-	10050	9300	0	10050	9300	0	67%	-	-	0%	-	20
Cernier, CH	✓(56%)	20	90%	-	-	121	185	0	120	183	0	0%	0%	0%	0%	0%	41
Delft, NL	x (25%)	26	81%	-	-	33800	130518	60	33800	50118	60	11%	0%	0%	0%	50%	38
Dundalk, IR	✓(39%)	23	49%	x (57%)	12	2132	228	0	358	228	0	100%	0%	0%	100%	100%	10
Falkenberg, SE	✓(96%)	2	46%	✓(60%)	3	11500	11900	0	-	-	-	0%	0%	0%	67%	-	33
Galanta, SK	-	-	81%	(not calculable)	-	0	1800	0	-	-	-	-	100%	0%	0%	-	20
Geneva, CH	(not calculable)	-	-	-	-	0	0	0	-	-	-	0%	-	-	-	0%	41
Grenoble, FR	✓(76%)	11	-	-	-	548	4579	0	289	513	0	92%	-	-	100%	67%	4
Hannover, DE	-	-	86%	✓(71%)	2	91	681	0	-	-	0	-	57%	49%	75%	100%	6
Hartberg, AT	✓(79%)	7	67%	-	-	520	800	140	80	800	0	0%	0%	0%	25%	75%	31
Heerlen, NL	(not calculable)	-	(not calculable)	-	-	0	0	0	-	-	-	0%	-	-	0%	-	41
Helsingborg SE / Helsingør, DK	✓(69%)	16	(not calculable)	-	-	0	5500	0	-	-	-	0%	-	0%	0%	-	41
Hillerød, DK	✓(75%)	12	-	-	-	0	2300	0	-	-	-	0%	-	-	50%	0%	33
Høje-Taastrup, DK	(not calculable)	-	(not calculable)	-	-	850	0	0	-	-	-	0%	-	-	100%	0%	20
Hvar, HR	(not calculable)	-	62%	-	-	1080	100	100	80	100	0	0%	0%	0%	33%	-	40
Kortrijk, BE	(not calculable)	-	(not calculable)	-	-	0	0	0	-	-	-	0%	-	-	50%	0%	33
Lambeth, London, UK	-	-	57%	x (16%)	8	307	377	0	307	377	0	-	0%	0%	-	0%	41
Lapua, FI	✓(74%)	13	65%	-	-	3000	2600	120	0	250	120	0%	0%	0%	25%	0%	41
Lyon, FR	✓(98%)	1	-	-	-	0	90	95	0	90	90	88%	-	-	-	0%	17
Måbjerg, DK	-	-	-	-	-	28000	76000	0	28000	76000	0	-	-	-	100%	-	1
Milton Keynes, UK	✓(30%)	25	-	-	-	6259	106138	0	6094	6138	0	100%	-	-	100%	100%	1
Mödling, AT	(not calculable)	27	80%	✓(49%)	4	5017	38440	0	5337	38830	0	0%	35%	35%	0%	-	32
Montieri, IT	-	-	(not calculable)	-	-	0	5330	0	-	-	-	-	0%	-	0%	-	41
Mórahalom, HU	✓(86%)	5	67%	-	-	0	0	0	-	-	-	0%	0%	0%	0%	-	41
Nantes, FR	✓(70%)	15	(not calculable)	-	-	182	640	258	-	-	-	0%	-	-	50%	67%	18
Neckarsulm, DE	✓(69%)	17	87%	✓(4%)	1	1006	9285	0	1006	8500	0	0%	25%	0%	100%	67%	19

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	Reduction of fossil primary energy demand of new buildings (space heating)		Reduction of fossil primary energy demand of refurbished buildings (space heating)			Installed capacity of Renewable Energy			Installed capacity of Polygeneration			Monitoring concept					
	Compared to reference building according to national regulation		After vs. Before	Compared to reference building according to national regulation		kW_{el}	kW_{th}	kW_{cool}	kW_{el}	kW_{th}	kW_{cool}	NB	RB - before	RB - after	CES	BIES	all objects
Site / Goal	✓(30%)	Ranking	-	✓(0%)	Ranking	-	-	-	-	-	-	-	-	-	-	-	Ranking
Neuchâtel, CH	✓(51%)	21	63%	x (31%)	10	1181	2940	0	-	-	-	0%	0%	0%	86%	40%	26
North Tipperary, IR	✓(95%)	3	61%	x (23%)	9	6	1953	0	-	-	-	40%	58%	64%	60%	-	12
Óbuda, HU	-	-	30%	-	-	0	1061	0	-	-	-	-	0%	100%	100%	-	7
Ostfildern, DE	✓(83%)	6	-	-	-	1080	7728	1561	950	7728	1456	55%	-	-	100%	75%	5
Redange, LU	(not calculable)	-	99%	(not calculable)	-	0	2810	0	-	-	-	-	0%	0%	0%	-	41
Salzburg, AT	✓(79%)	8	(not calculable)	-	-	0	1561	0	-	-	-	0%	-	0%	60%	0%	36
Sandnes, NO	(not calculable)	-	(not calculable)	-	-	0	0	0	-	-	-	0%	-	-	0%	-	41
Słubice, PL	-	-	(not calculable)	-	-	38000	0	0	-	-	-	-	-	-	100%	-	1
Sofia, BG	-	-	88%	-	-	0	0	0	-	-	-	-	0%	0%	-	-	41
Stenløse, DK	✓(64%)	19	(not calculable)	-	-	10	1113	0	-	-	-	0%	-	-	50%	50%	20
Szentendre, HU	-	-	(not calculable)	-	-	570	396	0	-	-	-	-	-	-	50%	0%	27
Trondheim, NO	(not calculable)	-	(not calculable)	-	-	0	1280	3000	-	-	-	0%	-	0%	0%	50%	37
Tudela, ES	(not calculable)	-	(not calculable)	-	-	-	-	-	-	-	-	0%	-	-	-	-	41
Tulln, AT	-	-	72%	-	-	83	3208	0	163	488	0	-	0%	0%	0%	0%	41
Turin, IT	-	-	(not calculable)	-	-	968	8156	205	968	1166	0	-	-	0%	33%	100%	16
Valby, DK	✓(65%)	18	(not calculable)	-	-	126	0	0	-	-	-	0%	-	-	100%	-	14
Växjö, SE	✓(77%)	9	29%	-	-	404	400	4300	330	400	0	89%	0%	0%	100%	100%	11
Viladecans, ES	✓(46%)	22	50%	-	-	232	0	0	-	-	-	67%	0%	50%	100%	-	13
Vitoria-Gasteiz, ES	(not calculable)	-	-	-	-	11	733	0	11	25	0	0%	-	-	-	0%	41
Weilerbach, DE	(not calculable)	-	77%	✓(42%)	5	1095	15	0	6	13	0	0%	0%	0%	50%	0%	39
Weiz / Gleisdorf, AT	✓(95%)	4	71%	✓(39%)	6	5	5820	90	0	90	90	0%	0%	0%	2%	100%	30
Zagorje, SL	(not calculable)	-	(not calculable)	-	-	50	3000	0	-	-	-	-	-	-	33%	-	20
Zaragoza, ES	✓(76%)	10	(not calculable)	-	-	2	70	80	0	25	80	0%	-	0%	100%	0%	27
Zlín, CZ	(not calculable)	0	(not calculable)	-	-	668	32	0	-	-	-	0%	-	-	100%	100%	7

% refer to the number of buildings represented. The calculation is based on the average of the number of buildings represented per site.
(not calculable) refers to a data collection sheet being created for the demonstration object of the site but the indicator not being calculated due to incomplete data.
\- refers to the demonstration object not existent at the site or to the demonstration object existent at the site but no information retrieved during data collection.

Figure 5.3: Overview of achieved goals in CONCERTO sites [A1]

5.2.2 Economic assessment results [A2]

Heat and electricity generation costs

Figure 5.4 outlines the electricity production costs of several large-scale energy supply units. More precisely, the technologies CHP, PV and wind are considered. For reasons of comparability the benchmark is also depicted. It is the electricity price for end-consumers incl. taxes in 2012 of the respective countries. For CHP the electricity generation cost can be calculated for four communities. With the exception of Torino they are slightly elevated with respect to the national benchmark. For PV, generation cost can be inferred for a greater number of sites. Data could be retrieved from 12 communities. Here, the energy production costs are also higher than the national electricity price. However, in Valby it is possible to generate electricity from PV at lower cost. For wind, the electricity generation costs are at a comparatively low level. They all range below the purchase price of electricity from the grid.

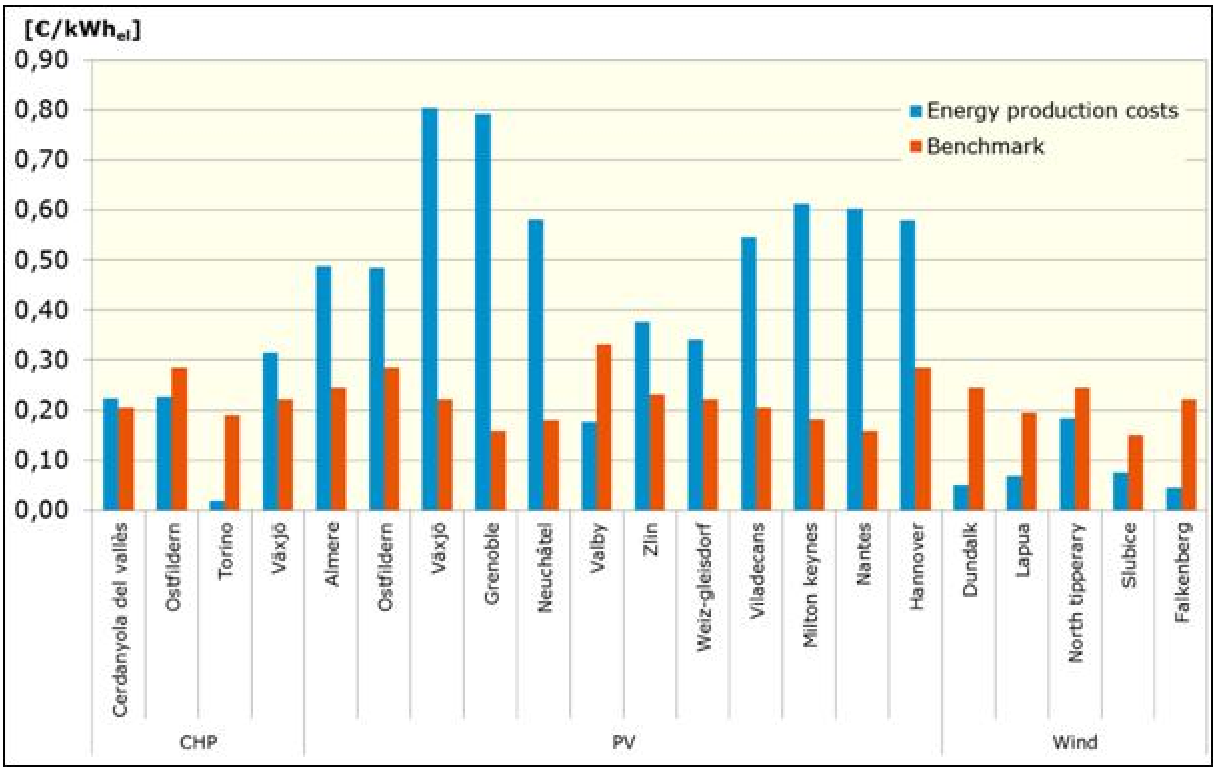


Figure 5.4: Electricity production costs of large-scale energy supply units [A2]

Figure 5.5 illustrates the heat production costs of several large-scale energy supply units. Large-scale biomass boilers, solar thermal systems and large-scale CHP are analysed. A reference heat supply unit (EU reference boiler) serves as a benchmark for the cost of heat production. For biomass boilers the energy production cost are higher in Grenoble and North Tipperary, whereas for Falkenberg and Helsingor they are less. A common trend of cost-effectiveness cannot be found for solar-thermal systems either. For the four demonstration projects considered the heat production cost range below average in Hannover and Óbuda whereas they lie above average in Almere and Neckarsulm. Only for large-scale CHP the cogeneration units are more cost-effective than the reference heat system in all demonstration sites considered.

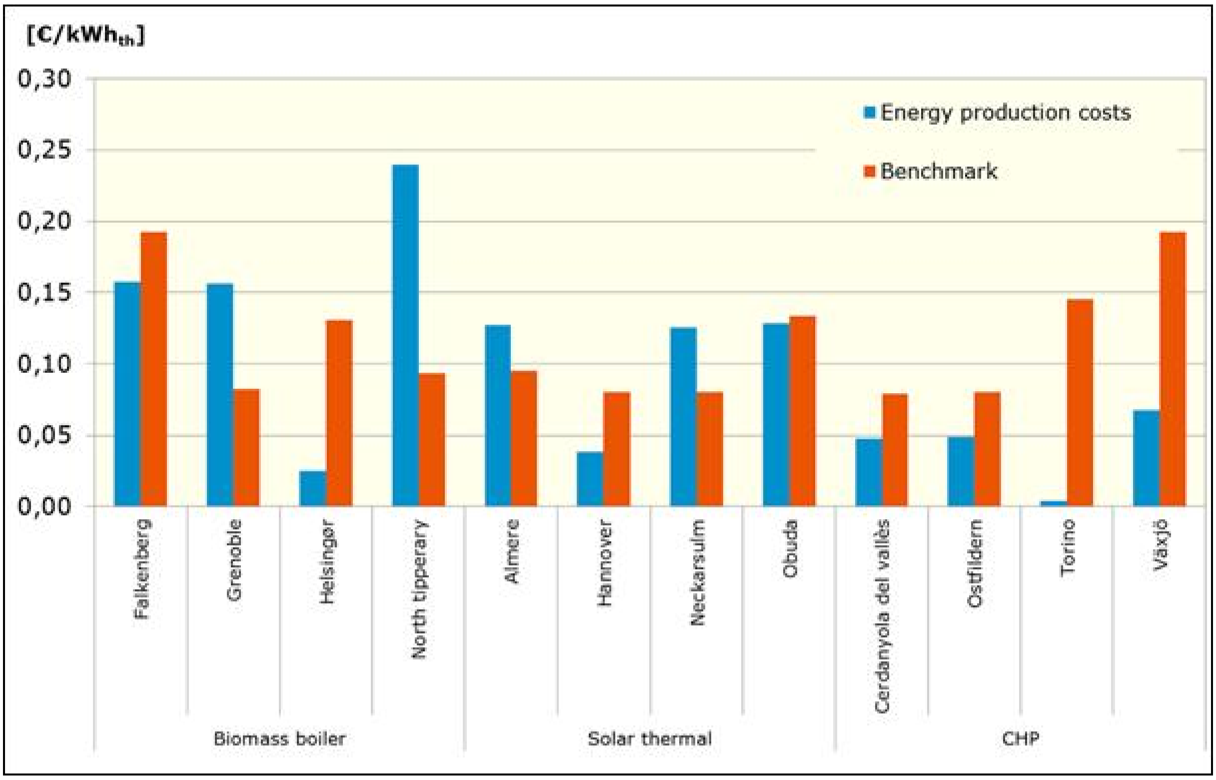


Figure 5.5: Heat production costs of large-scale energy supply units [A2]

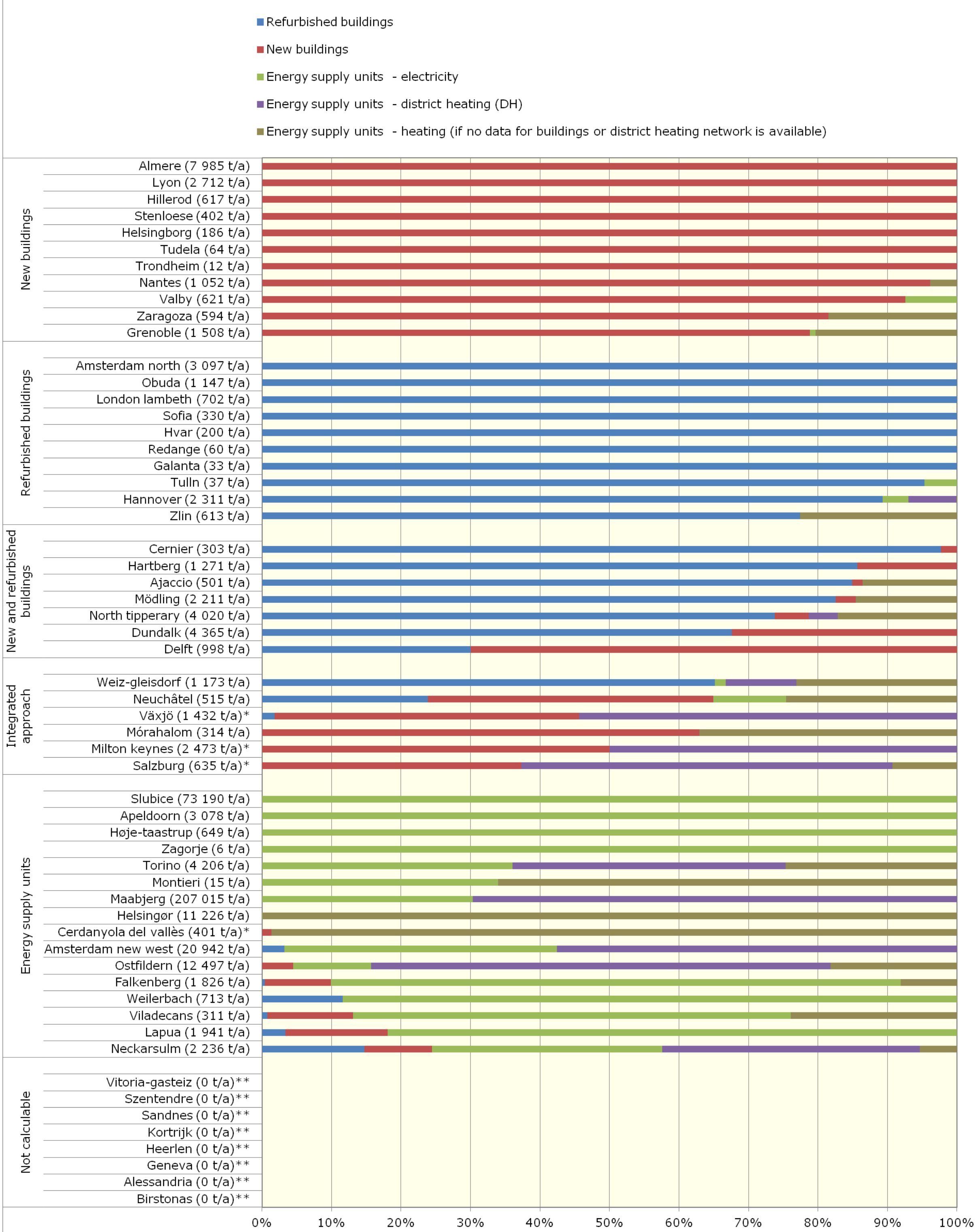
5.2.3 Environmental assessment results [A4]

CO2 emission reductions and non-renewable primary energy savings (calculated) for 58 CONCERTO communities

In Figure 5.6 the CO_2 saving mix of CONCERTO measures is depicted for the involved communities. The figure is divided in different groups covering the different CONCERTO measures. In the first group communities are listed where new building projects contribute at least 70% to the total CO_2 savings.

In the second group, communities are illustrated where refurbished building projects contribute at least 70% to the total CO_2 savings. In the third group, communities with both new and refurbished buildings contributing together at least 70% to the total CO_2 savings are depicted. In the fourth group communities with an integrative approach are depicted, in which none of the measures are predominant. The fifth group illustrates the communities where energy supply units contribute the major part (over 70%) of the CO_2 savings. In this group, the savings are summed up for plants producing electricity and heat (with and without district heating). In the last group, communities are presented for those it is not possible to calculate the breakdown of CO_2 savings due to missing data.

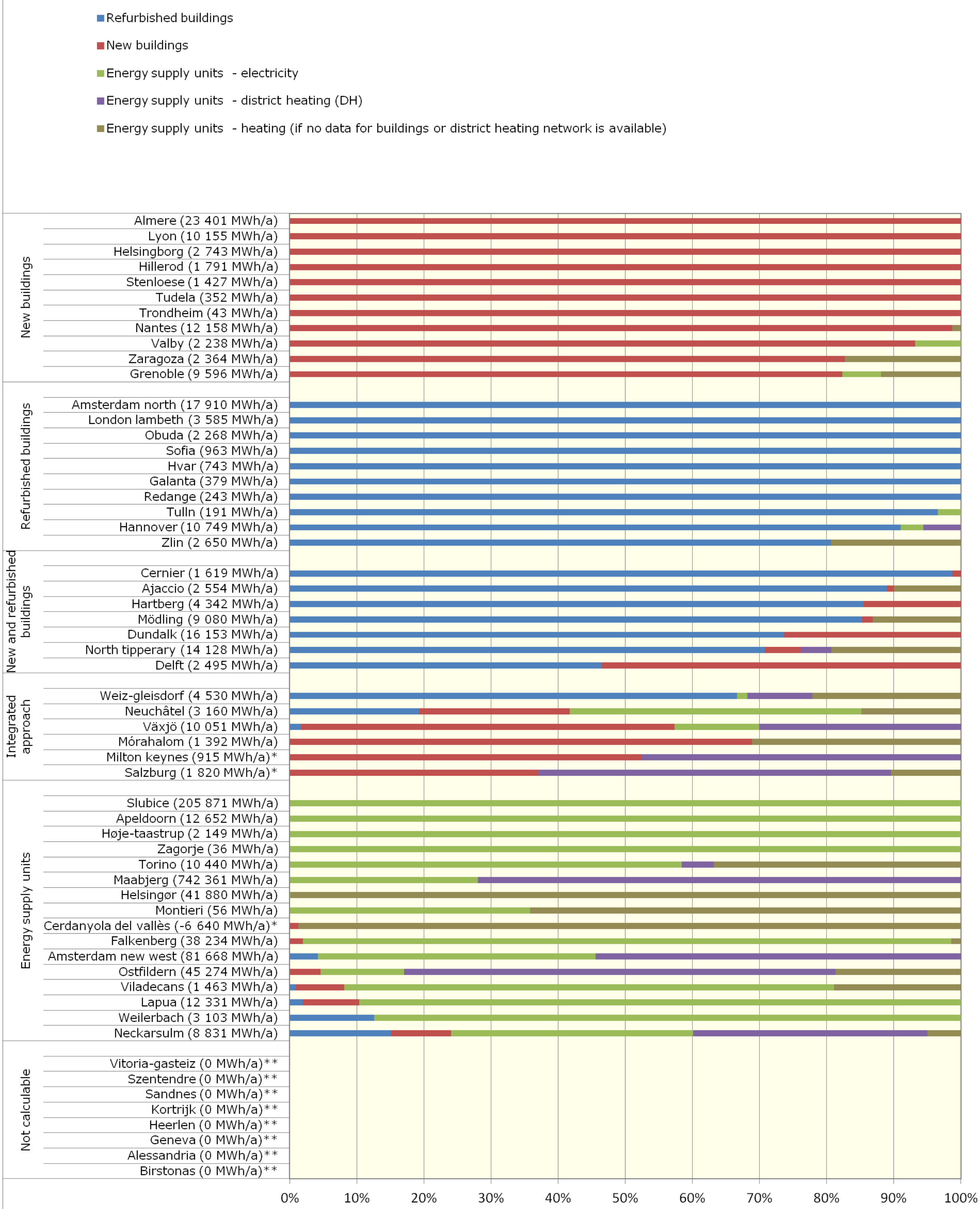
The total CO_2 savings of all taken measures for each individual community is presented on the y-axis. It is evident that the highest CO_2 savings have been realized with energy supply units alone. But this conclusion should be treated with care, as not all of these realized supply-side savings benefit the concerto site, i.e. the energy is often used outside the area. Måbjerg installed a large biogas CHP plant that is connected to a district heating system. With this unit, a total reduction of 207.000 tons of CO_2 per year has been realized. Słubice installed a 38 MW wind park and saved approximately 73.000 tons of CO_2 per year. However, the installation of large-scale energy supply units is not expandable without restriction. When a high realizable potential is reached, other technologies have to be considered and integrated in the mix of projects. Ostfildern in Germany (12 500 t/CO_2 saved p.a.), North Tipperary in Ireland (4.000 t/CO_2 saved p.a.) and Weiz-Gleisdorf in Austria (1.173 t/ CO_2 saved p.a.) are good examples, where significant CO_2 emissions reductions have been achieved with a large set of measures.



* In the analysis an exergy-based allocation procedure has been used. In the marked communities the allocation method leads to negative CO_2 emissions reductions for the electricity generation of single CHP plants that have not been considered in the illustration.
** There are not enough information available to calculate the CO_2 emissions reduction

Allocation procedure:
Refurbished buildings: After refurbishement: national district heating, local electricity; Before refurbishement: national district heating, national electricity is used;
New buildings: Demo building: national district heating, local electricity; Reference building: national district heating, national electricity is used;
Energy supply units - Electricity: Demo: Electricity from CONCERTO ESU that is not consumed in CONCERTO buildings (overproduction); Reference: national electricity mix;
Energy supply units - District Heat: Demo: district heat from CONCERTO ESU that is not consumed in CONCERTO buildings; Reference: oil boiler;
Energy supply units - Heat: Demo: heat from CONCERTO ESU that are neither in buildings with enough data to be included in RB or NB nor connected to a district heating network with enough data to be included in district heat; Reference: oil boiler;
Local electricity mix: Mix of CONCERTO ESU supplemented by national mix, if demand from buildings exceeds CONCERTO ESUs' production;
Local district heat mix: Mix of all ESU connected to this grid (not only CONCERTO).

Figure 5.6: CO_2 emissions reduction (calculated) for 58 CONCERTO communities, data status: 10.10.2013 [A4]



* In the analysis an exergy-based allocation procedure has been used. In the marked communities the allocation method leads to negative CO_2 emssions reductions for the electricity generation of single CHP plants that have not been considered in the illustration.
** There are not enough information available to calculate the CO_2 emissions reduction

Allocation procedure:
Refurbished buildings: After refurbishement: national district heating, local electricity; Before refurbishement: national district heating, national electricity is used;
New buildings: Demo building: national district heating, local electricity; Reference building: national district heating, national electricity is used;
Energy supply units - Electricity: Demo: Electricity from CONCERTO ESU that is not consumed in CONCERTO buildings (overproduction); Reference: national electricity mix;
Energy supply units - District Heat: Demo: district heat from CONCERTO ESU that is not consumed in CONCERTO buildings; Reference: oil boiler;
Energy supply units - Heat: Demo: heat from CONCERTO ESU that are neither in buildings with enough data to be included in RB or NB nor connected to a district heating network with enough data to be included in district heat; Reference: oil boiler;
Local electricity mix: Mix of CONCERTO ESU supplemented by national mix, if demand from buildings exceeds CONCERTO ESUs' production;
Local district heat mix: Mix of all ESU connected to this grid (not only CONCERTO).

Figure 5.7: Non-renewable primary energy savings (calculated) for 58 CONCERTO communities, data status: 10.10.2013 [A4]

Figure 5.7 presents the non-renewable primary energy demand reductions for the 58 CONCERTO communities. The groups are structured in the same way like the CO_2 emission savings. Analogously to the CO_2 savings, Måbjerg and Słubice achieved the highest non-renewable primary energy demand reductions with 742 GWh/a and 206 GWh/a.

Table 5.2 summarizes statistical characteristic quantities for CO_2 savings and non-renewable primary energy demand reductions.

	CO_2 savings [tCO_2/a]	Primary energy demand reductions (non-renewable) [MWh/a]
number	58	58
arithmetic mean	7,695	27,558
sum	384,748	1,377,895
minimum	6	-6,640[1]
lower quartile	348	1,436
median	855	2,923
upper quartile	2,432	11,806
maximum	207,015	742,361
standard deviation	30,692	107,864

Table 5.2: Statistical characteristic quantities for CO2 savings and non-renewable primary energy demand reductions

Primary energy demand (calculated) of new buildings

Buildings in the analysis are differentiated into refurbished and new constructed buildings as well as into small and large buildings with a floor area smaller/larger than 180m^2. The energy performance of the demonstration buildings are itemized for space heating and domestic hot water and compared with the performance of the reference buildings and the national building stock. An additional benchmark marks the low-energy house standard according to the German definition in final energy diagrams.

The primary energy demand includes all conversion and distribution losses as well as the processing energy necessary to deliver the energy carrier to the building where it is eventually consumed. Naturally, it is strongly influenced by climate conditions. Therefore results are shown here differentiated by climate zones.

[1] In the analysis an exergy-based allocation procedure has been used. In some communities the allocation method leads to negative CO_2 emissions reductions for the electricity generation of single CHP plants that have not been considered in the illustration.

CONCERTO buildings have a much lower primary energy demand and additionally show an increased share of renewable energy of total consumption than the reference buildings, i.e. new buildings constructed according to the national standard.

Figure 5.8 shows the average primary energy demand for new residential CONCERTO buildings <180 m² for climate zone III2 and III3. The differentiation between calculated renewable and non-renewable primary energy demand shows that in North Tipperary and Weiz-Gleisdorf the newly constructed buildings are supplied almost completely with renewable energy carriers.

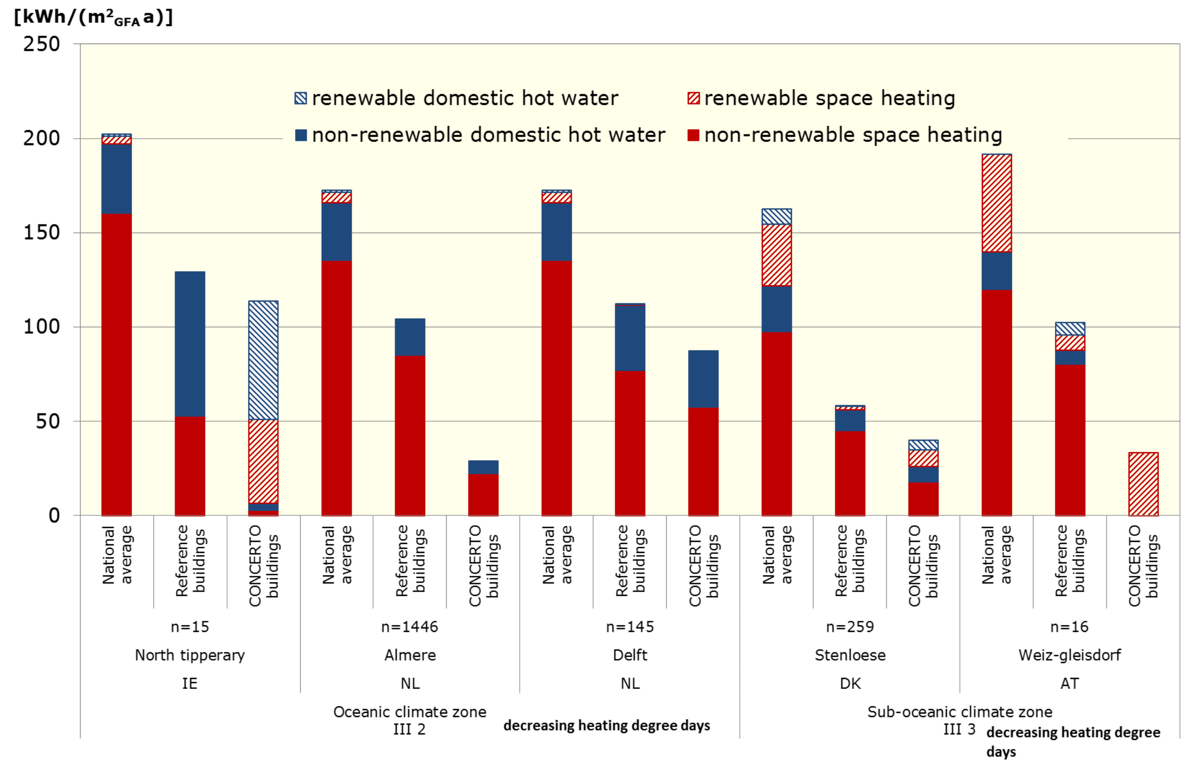


Figure 5.8: New residential CONCERTO buildings <180 m², average primary energy demand, calculated, climate zones III2 + III3 [A4]

In Figure 5.9 the average primary energy demand for new residential buildings is depicted again for climate zone II2 and III2 focusing on new residential buildings >180 m². Lapua was able to reduce especially the non-renewable energy demand for space heating from 193 kWh/(m²a) to 27 kWh/(m²a). Also in climate zone III2 extraordinary reductions have been realized. For example Milton Keynes reduced the non-renewable primary energy demand for space heating by 91% in comparison to the energy demand of the national building stock. In North Tipperary, Lyon and Nantes a high share of renewable energies is used for heating and hot water preparation.

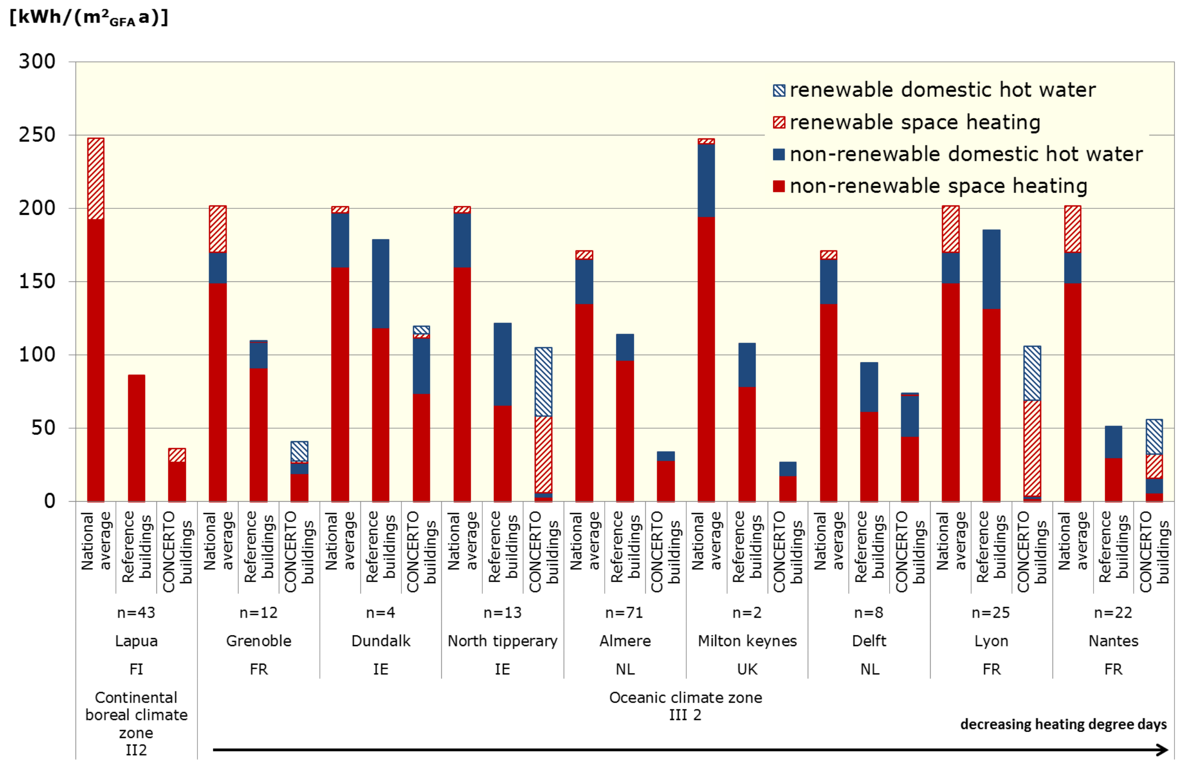


Figure 5.9: New residential CONCERTO buildings >180 m^2, average primary energy demand, calculated, climate zones II2 + III2 [A4]

Figure 5.10 illustrates the calculated average primary energy demand for new residential CONCERTO buildings >180 m^2 in climate zone III3. Each community achieved high reductions compared to the average energy demand of the national building stock and the national minimum requirement of the reference buildings. The communities are ordered according to the heating degree days. Communities located in colder regions with high heating degree days are depicted left, communities with lower heating degree days right. Interestingly the energy demand seems not necessarily to be correlated with the average temperature. In colder regions like in Trondheim/ Norway and Falkenberg/ Sweden also low energy demand values are possible to achieve.

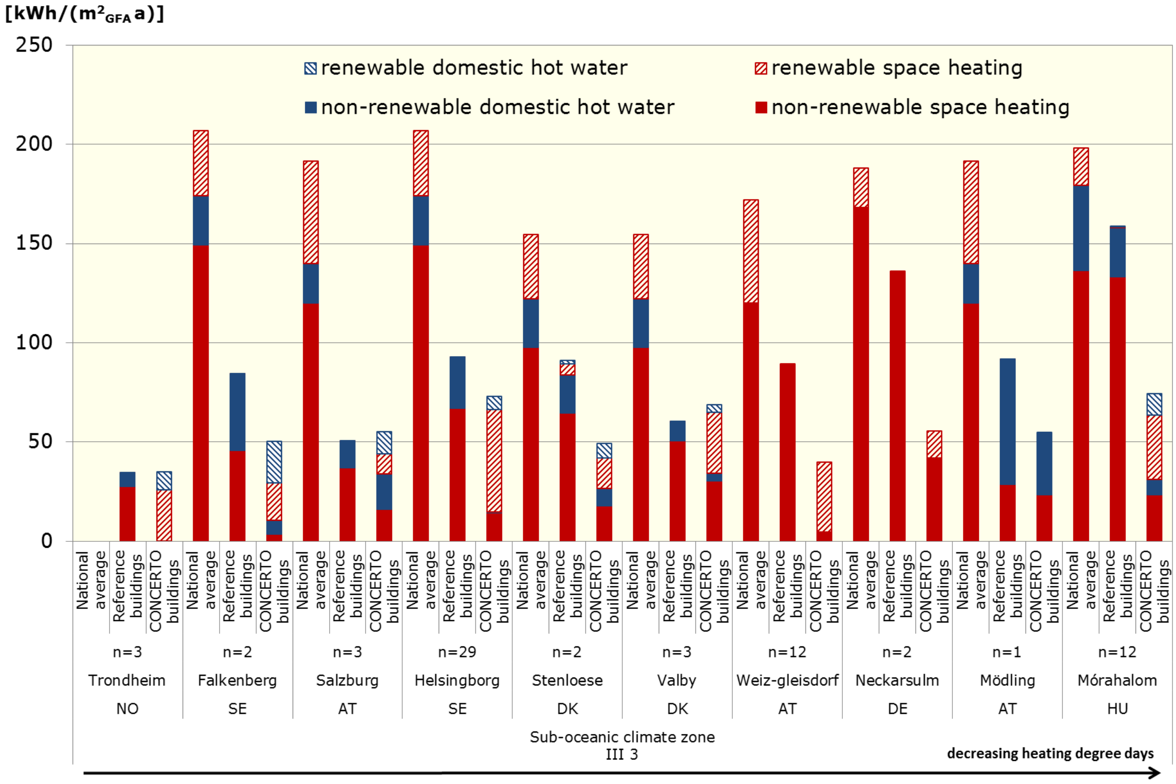


Figure 5.10: New residential CONCERTO buildings >180 m2, average primary energy demand, calculated, climate zone III3 [A4]

Figure 5.11 continues with listing the calculated average primary energy demand for new residential CONCERTO buildings >180 m^2 in climate zone III3 and IV1. It is evident that on average the energy demand in climate zone IV1 is lower than the demand in climate zone III3. Only the national average primary energy demand of Ajaccio/France stands out. This outlier can be explained by the fact that Ajaccio is located on the island Corsica belonging to climate zone IV1 whereas the most part of France belongs to climate zone III2.

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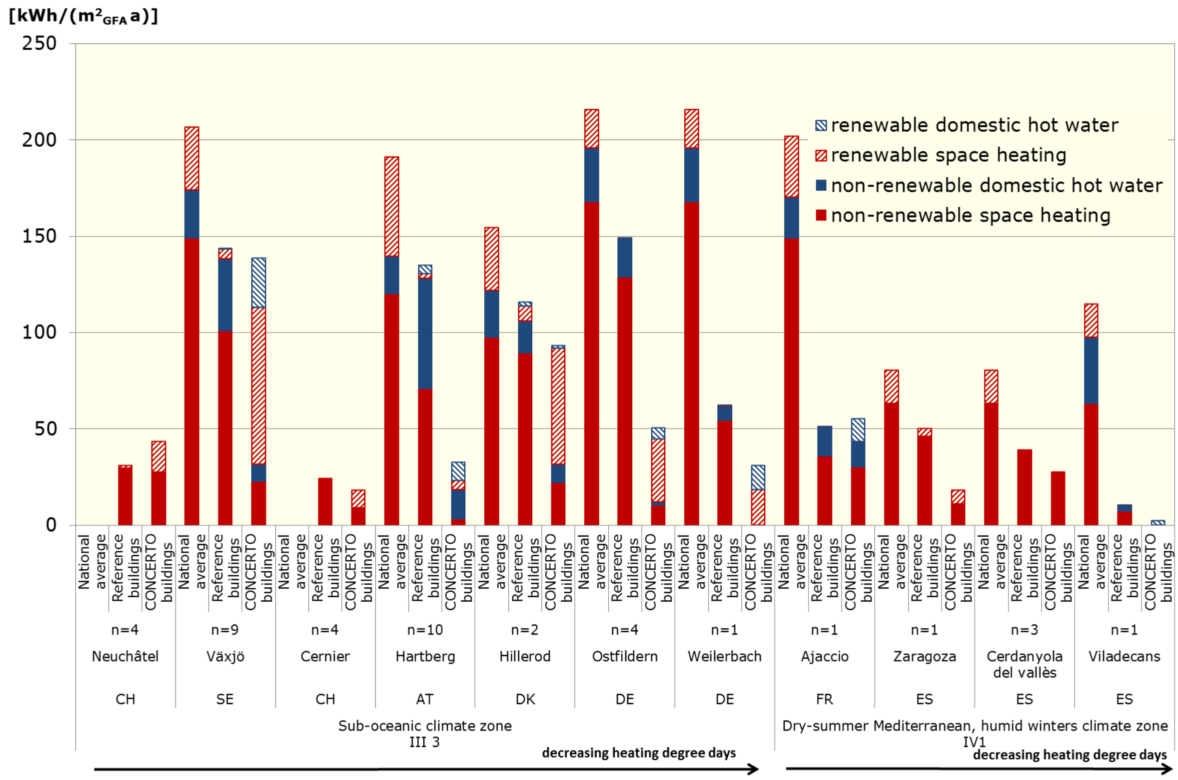

Figure 5.11: New residential CONCERTO buildings >180 m², average primary energy demand, calculated, climate zones III3 + IV1 [A4]

Primary energy demand (calculated) of refurbishments

Looking at the primary energy demand of the CONCERTO buildings before the refurbishment compared to national average clearly shows that here a refurbishment was necessary. After the refurbishment the CONCERTO buildings display a greater share of renewable energy usage than the average national building.

The following part focuses on the energy performance of refurbished residential buildings. Figure 5.12 shows the calculated average primary energy demand of buildings <180 m². Cernier and Falkenberg reduced the calculated non-renewable primary energy demand to a very low level of 7 kWh/(m²a) and 20 kWh/(m²a). However, especially in Cernier with a sample of one building the results cannot be seen as representative. Falkenberg remarkably used already a high share of renewable energy for space heating before the refurbishments took place. The CONCERTO area has succeeded in continuing with reducing both, the renewable and non-renewable primary energy demand.

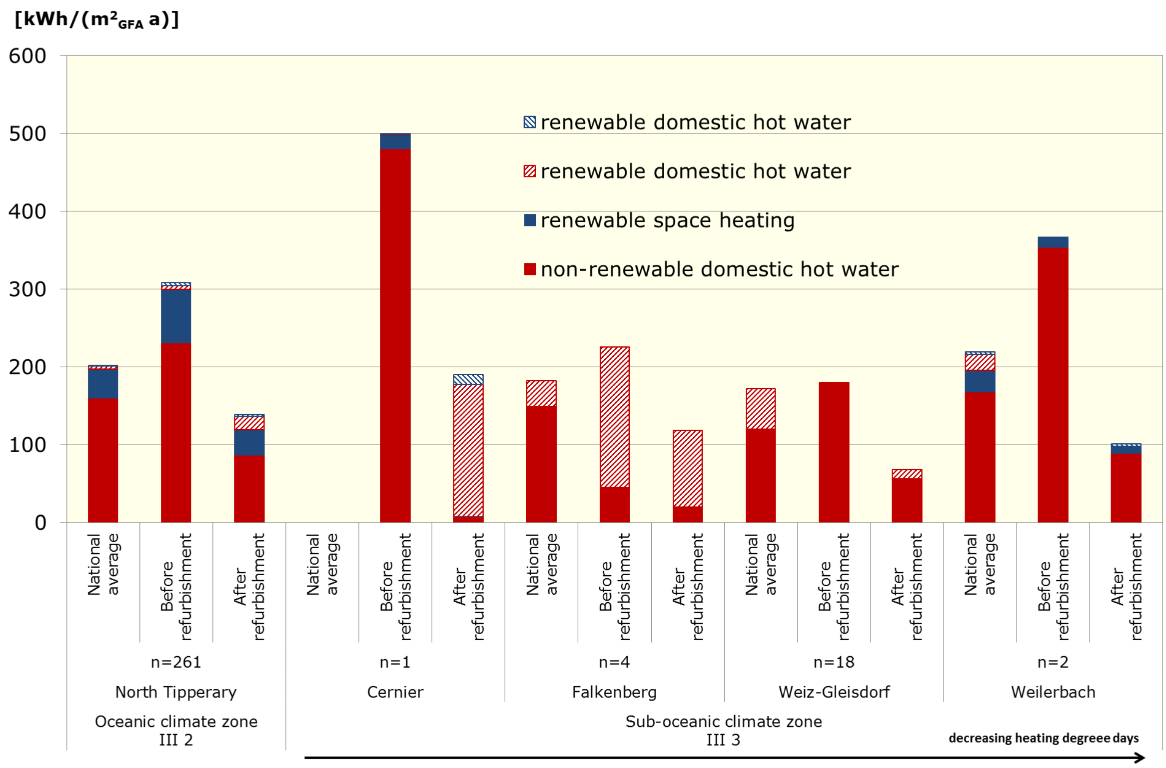

Figure 5.12: Refurbished residential CONCERTO buildings <180 m², average primary energy demand, calculated, climate zones III2 + III3 [A4]

Figure 5.13 presents the average primary energy demand of refurbished residential CONCERTO buildings >180 m² in climate zone II2 and III2. The primary energy demand follows the pattern that the consumption data before refurbishment show the highest values, followed by the national average values and the values of the refurbished CONCERTO building. In Lapua and Amsterdam North the average primary energy demand for space heating before the refurbishment undercut even the average demand of the national building stock. One building in Redange realizes an outstanding performance, where the non-renewable part of the primary energy is reduced from 343 kWh/(m²a) to 2 kWh/(m²a). When the renewable part is included, the building achieves 50 kWh/(m²a).

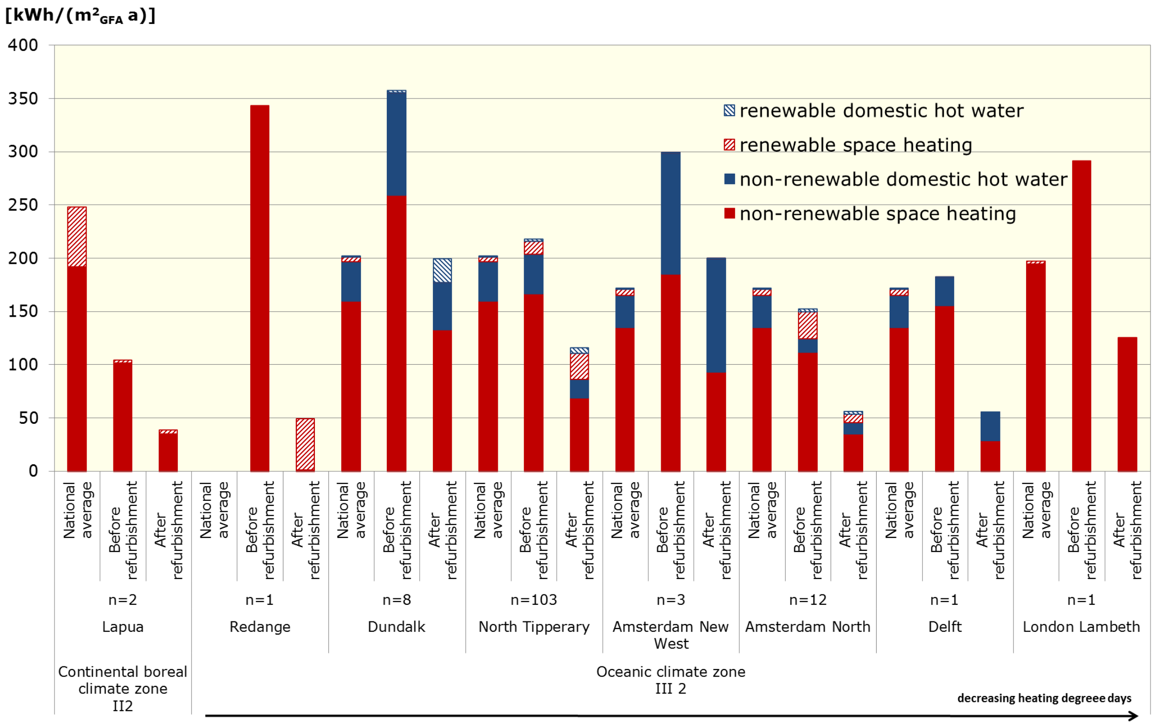

Figure 5.13: Refurbished residential CONCERTO buildings >180 m², average primary energy demand, calculated, climate zones II2 + III2 [A4]

In Figure 5.14 the first part of the calculated average primary energy demand for buildings >180 m² in climate zone III3 is depicted. The range of the calculated non-renewable primary energy demand for space-heating before the refurbishment goes from 40 kWh/(m²a) to 229 kWh/(m²a) (cf. Figure 5.15). The values after the refurbishment lie within 8 kWh/(m²a) and 65 kWh/(m²a). The reduction compared to the situation before the refurbishment ranges therefore between 29% and 86%.

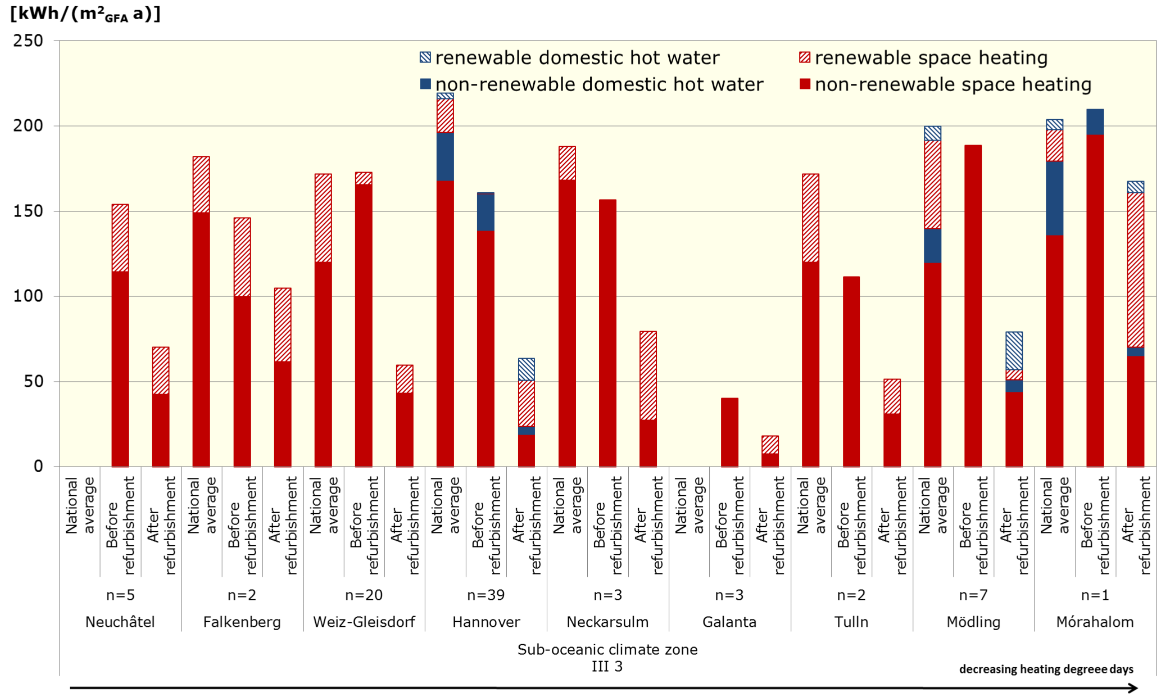

Figure 5.14: Refurbished residential CONCERTO buildings >180 m^2, average primary energy demand, calculated, climate zones III3 [A4]

Figure 5.15 illustrates the second part of the communities in climate zone III3 as well as the communities in climate zone IV1. CONCERTO communities in the latter climate zone reduced the non-renewable primary energy demand that is needed for space heating by 50% and 62%. On the island Hvar in Croatia, for example, measures are taken for reducing the primary energy demand that is used for the hot water preparation. The non-renewable primary energy for DHW can therefore be reduced by 74%.

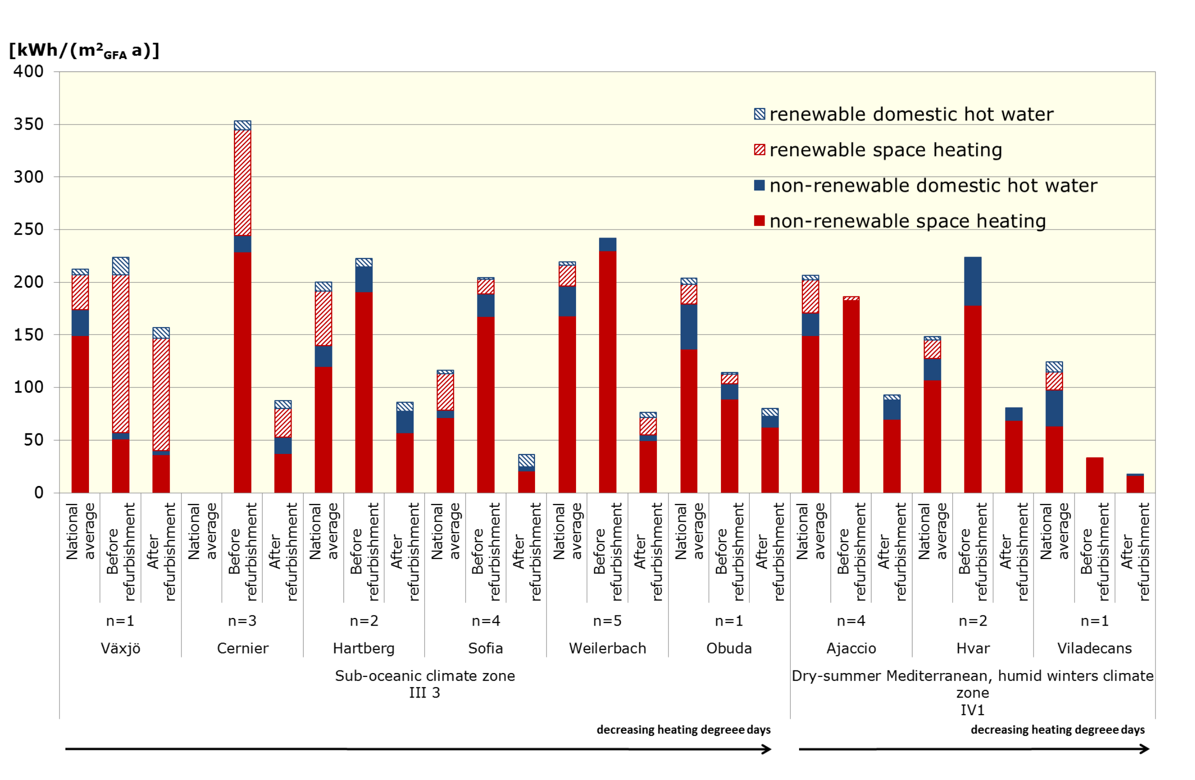

Figure 5.15: Refurbished residential CONCERTO buildings >180 m^2, average primary energy demand, calculated, climate zones III3 + IV1 [A4]

5.2.4 Technical assessment results [A6]

Figure 5.16 and Figure 5.17 depict the degree of CONCERTO electricity self-supply for the CONCERTO communities. Here the electricity produced from CONCERTO energy supply units, building-integrated and community energy supply units, is related to the electricity consumed in CONCERTO buildings, new and refurbished buildings. The ratio refers to CONCERTO demonstration objects only, i.e. remaining buildings in the CONCERTO area are not considered and thus a comprehensive assessment of the CONCERTO area is not possible. The resulting ratio is plotted in the diagrams. A value greater than 0 is calculated for 28 out of the 58 communities.

Figure 5.16 plots the degree of CONCERTO electricity self-supply where it is greater than 1%.

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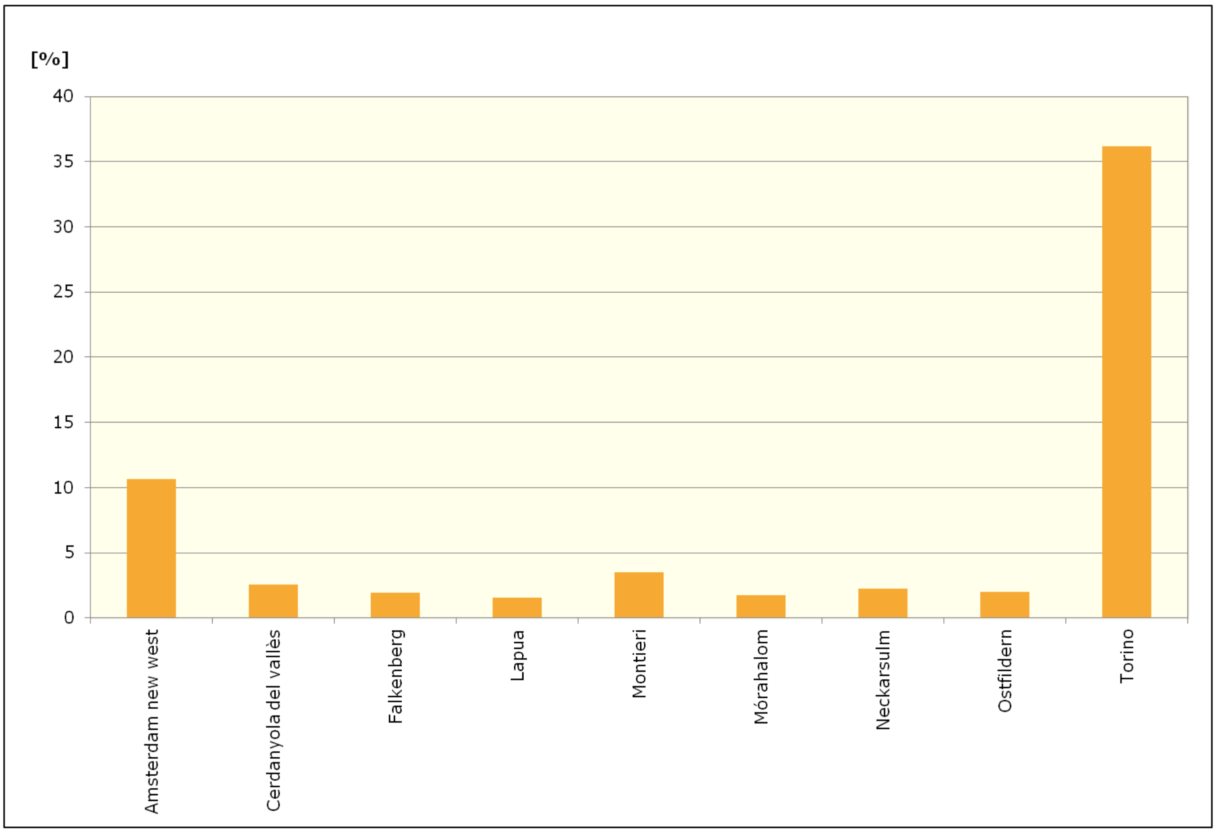

Figure 5.16: Degree of CONCERTO electricity self-supply where it is greater than 1% [A6]

The ratio for the remaining communities is visualized in Figure 5.17.

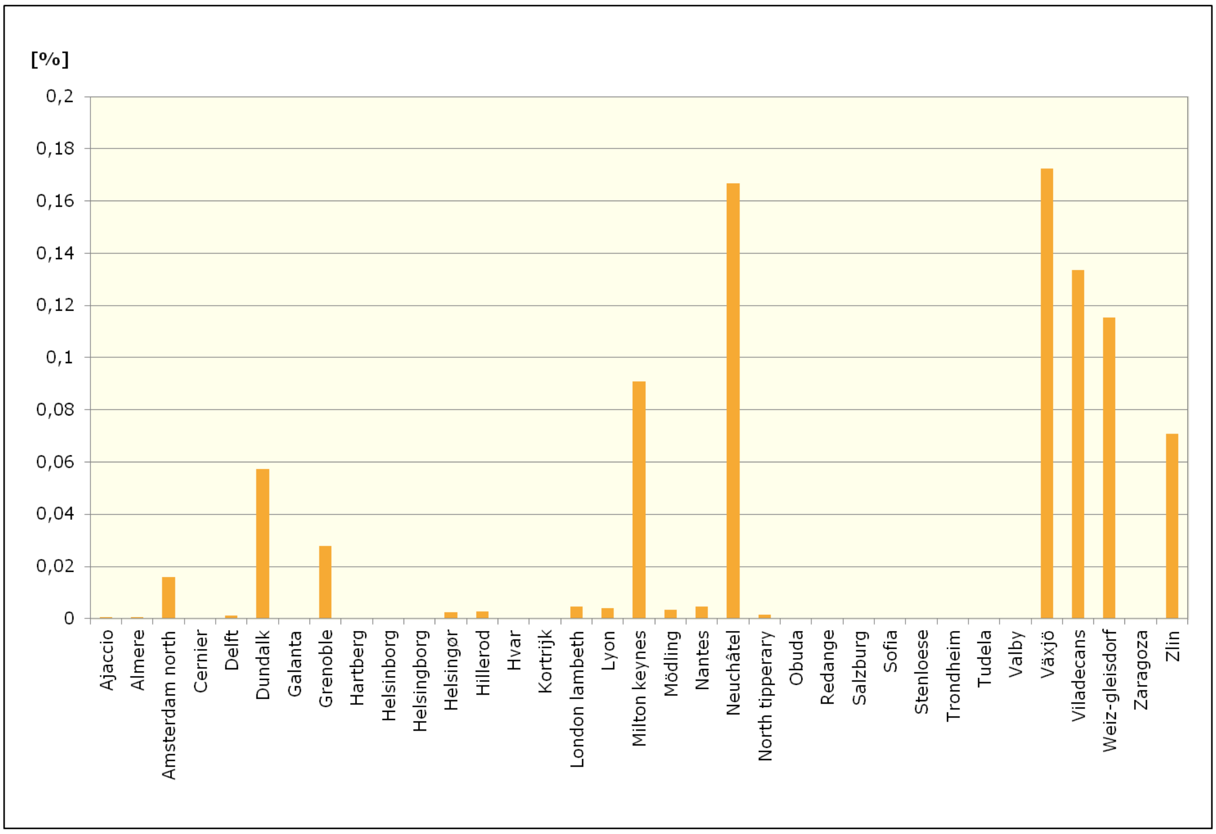

Figure 5.17: Degree of CONCERTO electricity self-supply where it is smaller than 1% [A6]

Among the highest-performing sites Torino achieves an outstanding result with 36% of electricity self-supplied. However, it should be noted that this share is driven by the comparatively low level of electricity consumption in Torino due to the small number of buildings. Second ranks Amsterdam new west with 11%. Third is Montieri reaching 4%. However, as can be seen from Figure 5.17. the majority of sites achieve degrees of CONCERTO electricity self-supply close to 0%.

5.3 CONCERTO buildings

In CONCERTO a large number of demonstration activities has been performed on buildings, including low-energy residential and non-residential new construction as well as refurbishment of existing buildings of all kinds. More than 4,500 building objects are registered in the Technical Monitoring Database and depending on the provided data and respectively the data quality indicators have been calculated and their performance in terms of general, economic, environmental and technical aspects has been assessed. This chapter gives an overview about the most important results.

Generally, the assessment of small and large residential buildings is focused because of two reasons. Firstly, the vast majority of buildings in CONCERTO are residential buildings and secondly objects of the other building types are quite heterogeneous so that comparability cannot be assured. In some cases, when significant results can be shown also municipal, industrial and tertiary-non-municipal buildings are considered. Anyway, each figure contains information on the building type taken into account in its caption.

5.3.1 Analysis of data availability and quality in detail for buildings [B1]

The following statements refer to the data status 01.10.2013.

New buildings

The analyzed data set comprises 3,122 CONCERTO demonstration buildings. In order to get significant results the buildings are classified by the building type (residential, municipal, tertiary non-municipal, industrial), building size (<180m² gross floor area, >=180m² gross floor area) and countries. Theoretically eight building classes per country exist (four building types * two building sizes).

Information on the building type are available for 3,065 (98.2%) buildings, information on the building size for 3,062 (98.1%) and on the country for 3,122 (100%) buildings. Table 5.3 gives a detailed overview on the availability of information needed for the classification of the buildings.

Size-Type	Residential	Municipal	Tertiary-Non-Municipal	Industrial	No information	Total
< 180 m2	2,568	0	3	0	0	2,571
> 180 m2	381	35	63	4	8	491
No information	6	3	2	0	49	60
Total	2,955	38	68	4	57	3,122
valid	2,949	35	66	4	0	3,054
invalid	6	3	2	0	57	68

Table 5.3: Overview on the availability of information needed for the classification of the buildings in case of new buildings

Of a total of 3,122 CONCERTO demonstration buildings 3,054 (97,8%) can be classified according to the mentioned criteria and therefore can be further assessed.

Table 5.18 gives an overview over the distribution of buildings on the classes.

Type	Size	Country	N
?	>=180 m^2	Germany	1
		Norway	1
		Slovenia	1
		Spain	1
	?	France	6
		Germany	4
		Netherlands	38
		Slovenia	1
IND	>=180 m^2	Austria	3
		Germany	1
MUN	>=180 m^2	Austria	1
		Denmark	9
		Finland	2
		France	3
		Germany	5
		Netherlands	3
		Norway	5
		Spain	4
		Sweden	2
		Switzerland	2
	?	Austria	1
		Luxembourg	2
		Netherlands	1

Type	Size	Country	N
RES	<180 m^2	Austria	23
		Czech Republic	6
		Denmark	68
		Germany	95
		Ireland	26
		Netherlands	455
	<180 m^2	Austria	32
		Croatia	3
		Czech Republic	9
		Denmark	7
		Finland	6
		France	48
		Germany	49
		Hungary	1
		Ireland	21
		Netherlands	29
		Norway	2
		Spain	7
		Sweden	40
		Switzerland	7
		United Kingdom	2
	<180 m^2	Belgium	4
		Germany	1
		Switzerland	1

Type	Size	Country	N
TNM	<180 m^2	Germany	26
		Netherlands	10
	>=180 m^2	Austria	6
		Czech Republic	2
		Denmark	3
		France	12
		Germany	2
		Ireland	5
		Netherlands	24
		Spain	2
		Switzerland	4
		United Kingdom	3
	?	Netherlands	
		Switzerland	1

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Figure 5.18: Overview over the distribution of buildings on the classes in case of new buildings

For the assessment of CONCERTO measures indicators have been calculated. For the calculation of indicators input data is required. In the following the availability and plausibility of input data for the indicator calculation is analyzed. In some cases the mere availability of input data is not sufficient. In order to come to significant statements so-called meta-data must be also known. If the actual data and the associated meta-data are available the data set is defined to be valid for the analysis.

Analysis of availability and plausibility: energy and emission data

For the calculation of CO_2 emission and final/primary energy reductions data concerning the CONCERTO demonstration building and a reference building must be available. In case of CONCERTO the reference building is a fictive building complying with the national building standard. Table 5.4 gives an overview over valid cases.

	CO_2-Emissions (calculated		Final Energy Demand (calculated)		Fossil Primary Energy Demand (calculated)	
Total number of CONCERTO demo buildings	3,122					
	valid	valid [%]	valid	valid [%]	valid	valid [%]
demo	2,172	69.6 %	2,199	70.4 %	2,171	69.5 %
reference	1,898	60.8 %	1,898	60.8%	1,898	60.8 %
plausible	1,898	60.8 %	1,898	60.8%	1,898	60.8 %

Table 5.4: Overview over valid cases for energy and emission data

Of a total of 3,122 CONCERTO demonstration buildings for 1,898 (60,8%) buildings CO_2 and final/fossil primary energy demand reductions can be calculated.

Analysis of availability and plausibility: energy-related additional construction costs

For certain indicators the energy-related additional construction costs are needed. Available energy-related additional construction costs are only valid if information on the price level and on VAT included/excluded is also known. Table 5.7 shows that only for 53 buildings out of 3,122 (1.7%) energy-related additional construction costs are available and only for 42 buildings out of 3,122 (1.3%) those energy-related additional construction costs are plausible.

	Energy-related additional construction costs	
	total	[%]
Total number of CONCERTO demo buildings	3,122	
Energy-related additional construction costs **available**	53	1.7%
Energy-related additional construction costs **plausible**	42	1.3%

Table 5.5: Overview over valid cases for energy-related addtonal costs in case of new buildings

Analysis of availability and plausibility: grants

For certain macro-economic indicators CONCERTO grants are needed. For 2,686 buildings out of 3,122 (86%) CONCERTO grants are available and plausible.

Analysis of availability and plausibility: construction costs

When analyzing construction costs the price level and information on VAT included/excluded must also be known for the data set to become valid. For 488 buildings out of 3,122 (15.6%) construction costs are available and for only 333 data sets (10.7%) the data is also plausible (see Table 5.6.)

	Construction costs	
	total	[%]
Total number of CONCERTO demo buildings	3,122	
Construction costs **available**	488	15.6%
Construction costs **plausible**	333	10.7%

Table 5.6: Overview over valid cases for construction costs

When calculating indicators different types of input data is combined (i.a. divided, subtracted, etc.) which leads in some cases to another reduction in valid data sets. The following table summarizes the consequences concerning input data availability and plausibility on the indicator calculations.

	plausible	plausible [%]
Total number of CONCERTO demo buildings	3,122	
CO_2 emission reduction	1,898	60.8%
Final energy demand (calculated) reduction	1,898	60.8%
Fossil primary energy demand (calculated) reduction	1,898	60.8%
saved kg CO_2 emissions per CONCERTO grant	1,736	55.6%
saved kWh final energy demand (calculated) per CONCERTO grant	1,741	55.7%
saved kWh fossil primary energy demand (calculated) per CONCERTO grant	1,736	55.6%
specific construction costs	333	10.7%
CO_2 mitigation costs	18%	0.57%
equivalent price of saved kWh final energy demand (calculated)	18	0.57%

Table 5.7: Overview over valid cases for energy-related additional costs

Refurbishments

The analyzed data set comprises 1,537 CONCERTO demonstration buildings. In order to get significant results the buildings are classified by the building type (residential, municipal, tertiary non-municipal, industrial), building size (<180m^2 gross floor area, >=180m^2 gross floor area) and countries accordingly to the procedure with new buildings.

Information on the building type is available for 1,252 (81.4%) buildings, information on the building size for 997 (64.8%) and on the country for 1,252 (100%) buildings. Table 5.8 gives a detailed overview on the availability of information needed for the classification of the buildings.

Size-Type	Residential	Municipal	Tertiary-Non-Municipal	Industrial	No information	Total
< 180 m2	456	5	0	0	0	461
> 180 m2	401	101	32	2	0	536
No information	114	141	0	0	285	540
Total	971	247	32	2	285	1,537
valid	857	106	32	2	0	997
invalid	114	141	0	0	285	540

Table 5.8: Overview on the availability of information needed for the classification of the buildings in case of refurbishments

Of a total of 1,537 CONCERTO demonstration buildings 997 (64,8%) can be classified according to the mentioned criteria and therefore can be further assessed.

The following table gives an overview over the distribution of buildings on the classes.

Type	Size	Country	N
RES	<180 m^2	Austria	25
		Croatia	35
		Czech Republic	9
		Germany	51
		Ireland	258
		Italy	1
		Luxembourg	7
		Poland	4
		Sweden	10
		Switzerland	1
	>180 m^2	Austria	31
		Bulgaria	3
		Croatia	50
		Czech Republic	6
		Denmark	2
		Finland	1
		France	5
		Germany	111
		Hungary	1
		Ireland	96
		Italy	30
		Lithuania	15
		Luxembourg	7
		Netherlands	16
		Norway	2
		Poland	8
		Slovak Republic	28
		Spain	12
		Sweden	26
		Switzerland	4
		United Kingdom	2
TNM	>180 m^2	Austria	11
		Croatia	2
		Czech Republic	3
		Denmark	1
		Ireland	10
		Luxembourg	1
		Switzerland	4

Type	Size	Country	N
IND	>180 m^2	Austria	1
		Czech Republic	1
MUN	<180 m^2	Austria	1
		Czech Republic	1
		Ireland	3
	>180 m^2	Austria	19
		Bulgaria	1
		Croatia	36
		Czech Republic	2
		Denmark	8
		Finland	2
		France	1
		Germany	8
		Hungary	2
		Ireland	7
		Italy	1
		Lithuania	3
		Luxembourg	1
		Netherlands	1
		Slovenia	1
		Spain	3
		Sweden	2
		Switzerland	3
IND	>180 m^2	all countries	2
MUN	<180 m^2		5
	>180 m^2		101
RES	<180 m^2		401
	>180 m^2		456
TNM	>180 m^2		32
IND	all sizes		2
MUN			106
RES			857
TNM			32
all types			997

Like in case of new buildings, for the assessment of CONCERTO measures indicators have been calculated. For the calculation of indicators input data is required. In the following the availability and plausibility of input data for the indicator calculation is analyzed. In some cases the mere availability of input data is not sufficient. In order to come to significant statements so-called meta-data must be also known. If the actual data and the associated meta-data are available the data set is defined to be valid for the analysis.

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Analysis of availability and plausibility: energy and emission data

For the calculation of CO_2 emission and final/primary energy reductions data concerning the CONCERTO demonstration building BEFORE the CONCERTO measures and AFTER must be available. Tables 5.9 and 5.10 give overviews over valid data sets in case of demand-based and consumption based considerations.

	CO_2-emissions demand-based (calculated)	final energy demand demand-based (calculated)	fossil primary energy demand demand-based (calculated)
after	644	686	644
before	645	645	644
reduction	536	536	536
plausible	536	536	536
plausible in % of 1,537	34.9 %	34.9 %	34.9%
plausible in % of 997	53.8 %	53.8 %	53.8 %

Table 5.9: Overviews over valid data sets in case of demand-based considerations

Of a total of 1,537 CONCERTO demonstration buildings for 536 (35%) buildings CO_2 and final/fossil primary energy demand reductions can be calculated.

	CO_2-emissions consumption-based (metered)	final energy demand consumption-based (metered)	fossil primary energy demand consumption-based (metered)
after	267	268	267
before	277	277	277
reduction	142	113	145
plausible	142	113	145
plausible in % of 1,537	9.2 %	7.4 %	9.2%
plausible in % of 997	14.2 %	11.3 %	14.5 %

Table 5.10: Overviews over valid data sets in case of consumption-based considerations

Of a total of 1,537 CONCERTO demonstration buildings for 113-145 (7.4-9.4%) buildings CO_2 and final/fossil primary energy demand reductions can be calculated.

Analysis of availability and plausibility: energy-related additional construction costs

For certain indicators the energy-related additional construction costs are needed. Available energy-related additional construction costs are only valid if information on the price level and on VAT included/excluded is also known.

The analysis shows that for 755 buildings out of 1,537 (49.1%) energy-related additional construction costs are available and for 579 buildings out of 1,537 (37.7%) those energy-related additional costs are plausible.

	Energy-related additional construction costs	
	total	[%]
Total number of CONCERTO demo buildings	1,537	
Energy-related additional construction costs **available**	755	49.1%
Energy-related additional construction costs **plausible**	579	37.7%

Table 5.11: Overview over valid cases for energy-related additional costs in case of refurbishments

Analysis of availability and plausibility: grants

For certain macro-economic indicators information on provided CONCERTO grants are needed. For 219 buildings out of 1,537 (14.2%) CONCERTO grants are available and plausible.

When calculating indicators different types of input data is combined (i.a. divided, subtracted, etc.) which leads in some cases to another reduction in valid data sets. Table 5.12 summarizes the consequences concerning input data availability and plausibility on the indicator calculations.

			plausible sets		
			absolute	% of 1,537	% of 997
reductions	demand-based (calculated)	CO_2 emission reduction	536	34.9%	53.8%
		final energy reduction	536	34.9%	53.8%
		fossil primary energy reduction	536	34.9%	53.8%
	consumption-based (metered)	CO_2 emission reduction	142	9.2%	14.2%
		final energy reduction	113	7.4%	11.3%
		fossil primary energy reduction	145	9.4%	14.5%
	demand (calculated) versus consumption (metered)	CO_2 emission reduction	142	9.2%	14.2%
		final energy reduction	113	7.4%	11.3%
		fossil primary energy reduction	145	9.4%	14.5%
additional costs vs savings	demand-based (calculated)	additional costs per saved kg CO_2	398	25.9%	39.9%
		additional costs per saved kWh final energy	398	25.9%	39.9%
	consumption-based (metered)	additional costs per saved kg CO_2	141	9.2%	14.1%
		additional costs per saved kWh final energy	112	7.3%	11.2%
	demand (calculated) versus consumption (metered)	additional costs per saved kg CO_2	141	9.2%	14.1%
		additional costs per saved kWh final energy	112	7.3%	11.2%
reductions vs grants	demand-based (calculated)	CO_2 emission reductions per CONCERTO grant	49	3.2%	4.9%
		final energy reductions per CONCERTO grant	49	3.2%	4.9%
		fossil primary energy reductions per CONCERTO grant	49	3.2%	4.9%
	consumption-based (metered)	CO_2 emission reductions per CONCERTO grant	3	0.2%	0.3%
		final energy reductions per CONCERTO grant	3	0.2%	0.3%
		fossil primary energy reductions per CONCERTO grant	3	0.2%	0.3%
	demand (calculated) versus consumption (metered)	CO_2 emission reductions per CONCERTO grant	3	0.2%	0.3%
		final energy reductions per CONCERTO grant	3	0.2%	0.3%
		fossil primary energy reductions per CONCERTO grant	3	0.2%	0.3%
Investment vs grants			117	7.6%	11.7%

Table 5.12: Summary on consequences concerning input data availability and plausibility on the indicator calculations

5.3.2 Economic assessment results [B2]

Total construction costs for new buildings

For new buildings an exemplary consideration of specific construction costs of residential single/two family houses and multi-family houses is conducted.

The question under consideration is if specific construction cost figures of energy optimized buildings are significantly higher than of conventional buildings in the CONCERTO countries. (This consideration is of course only based on CONCERTO demonstration objects.) This question is especially of interest when evaluating the economic benefits as well as when assessing the financeability of energy-optimized new buildings.

For comparability reasons, the diagrams displays specific values, that means the total construction costs are divided by the total gross floor area [€/m^2]. More details to secure the interpretability and comparability are also specified in the header of the graph.

Figure 5.19 and Figure 5.20 show average values aggregated on country level and box plots for each CONCERTO country for which data is available, respectively. Furthermore, construction costs have been adjusted to a common base year (year: 2010) using country-specific construction cost indices according to European Commission - Eurostat (2013). The gross floor area is used as reference unit. If the gross floor area is not specified for an object average conversion factors have been applied. Objects for which only floor areas according to national definition are available have been excluded since no conversion factors are known. The construction costs are including VAT. The displayed benchmarks (corridors for typical construction costs with lower and upper limits) are average construction costs for conventional buildings (buildings without a special emphasize on energy-optimization), which have been the result of an extensive literature review.

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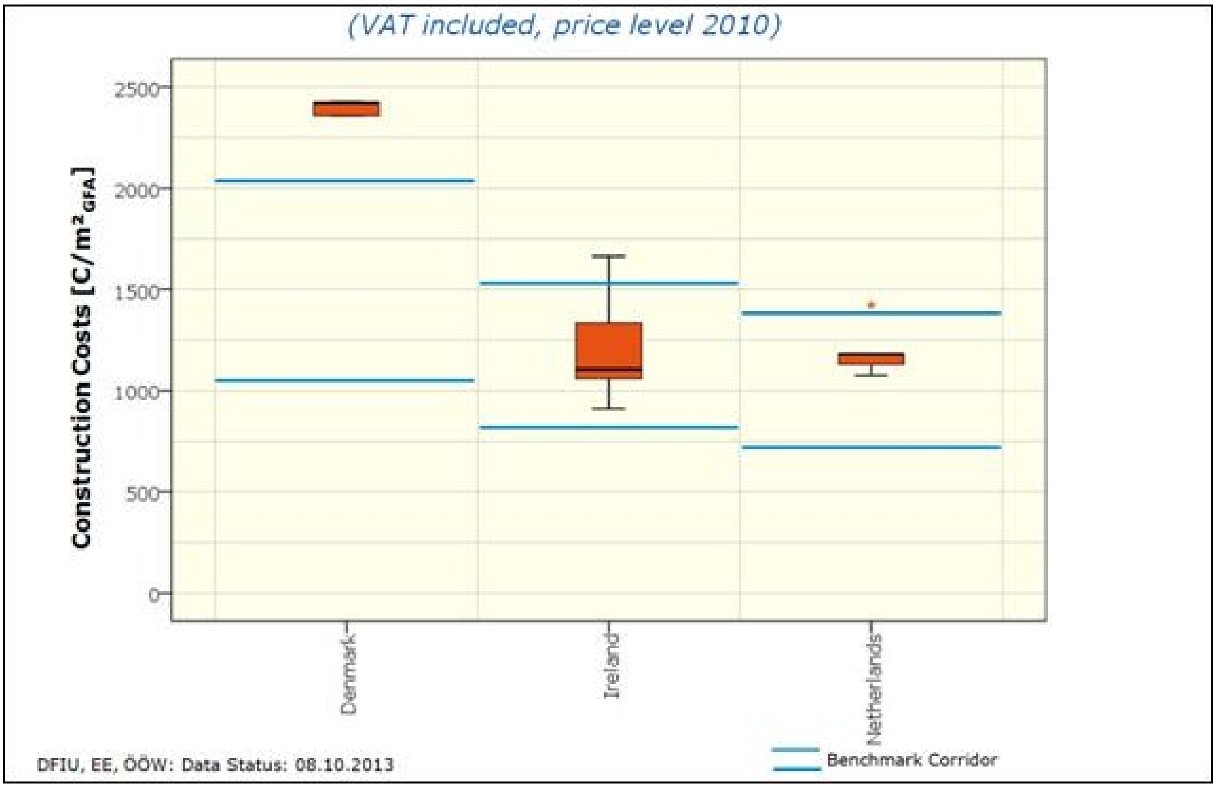

Figure 5.19: Construction costs of new residential buildings with gross floor area < 180m^2 [B2]

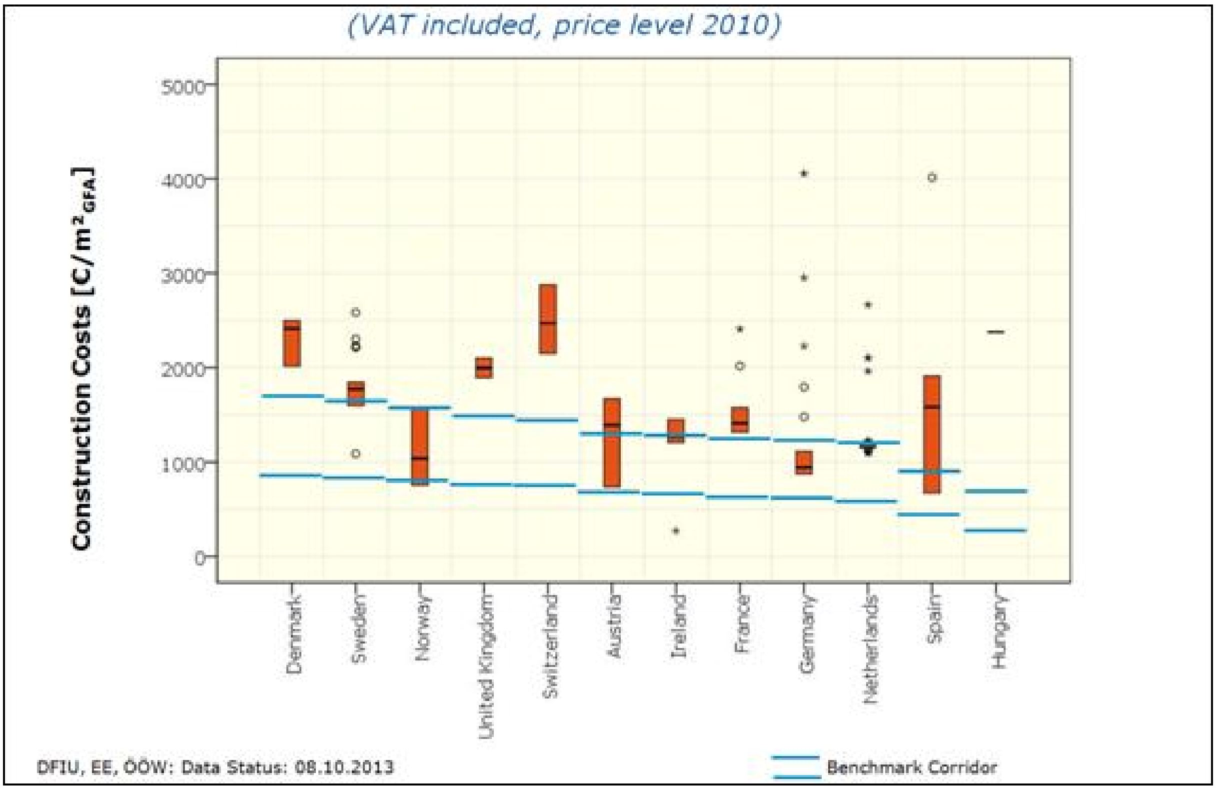

Figure 5.20: Construction costs of new residential buildings with gross floor area > 180m^2 [B2]

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In the analysis of the data it is shown that in some countries in CONCERTO it was possible to realize energy-optimized buildings within an average cost frame/budget of standard new buildings. In case of small residential buildings this is possible in Ireland and the Netherlands (see Figure 5.19), in case of large residential buildings, there are also a number of similar examples (see Figure 5.20). At the same time it becomes clear that this form of analysis/assessment leads to useful statements.

Additionally, 5.21 illustrates construction costs of energy-optimized municipal buildings in CONCERTO. Because of heterogeneity reasons no benchmarks could be found.

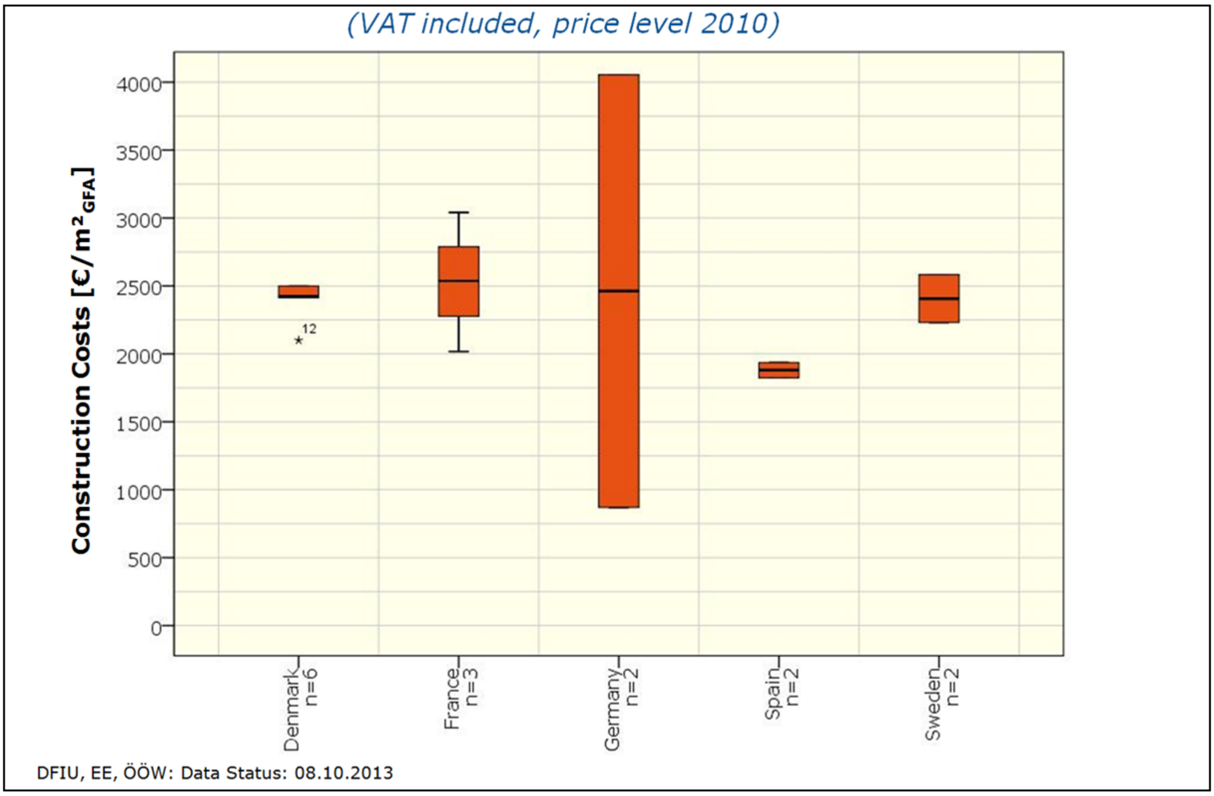

Figure 5.21: Construction costs of new municipal buildings [B2]

Energy-related additional construction costs for new buildings

In case of new buildings, energy-related additional costs are often discussed. This is problematic, since not always the reference case can be defined clearly. As reference case e.g. the energy standard according to national regulations can be chosen. This is the case for CONCERTO.

Often, in case of new buildings the energy-related additional costs are significantly overestimated. Therefore, despite poor data basis, an evaluation was carried out - both in absolute and relative terms. Figure 5.22 shows the energy-related additional costs in absolute terms as box plot.

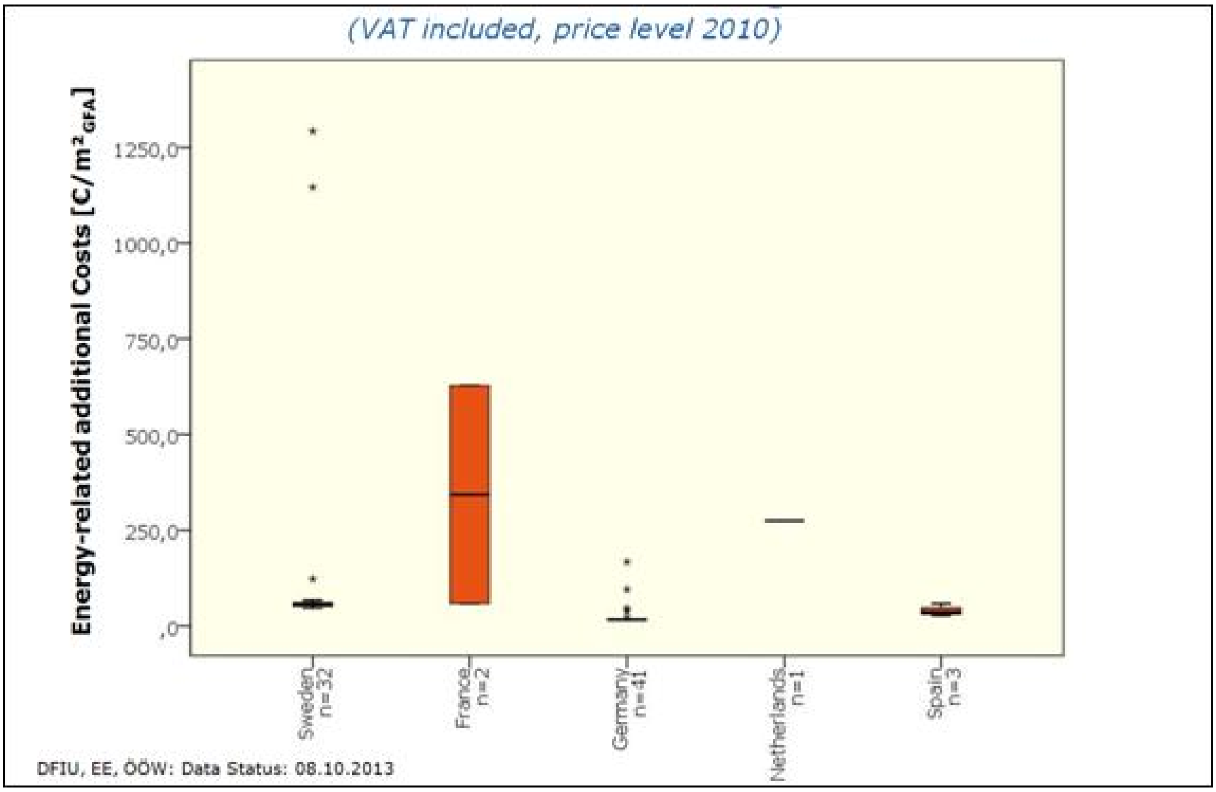

Figure 5.22: Energy-related additional costs of new residential buildings in absolute terms [B2]

In Figure 5.23 the energy-related additional costs in relative terms as additional percentage of the costs for the reference case (costs for the reference case correspond to 100%) are illustrated.

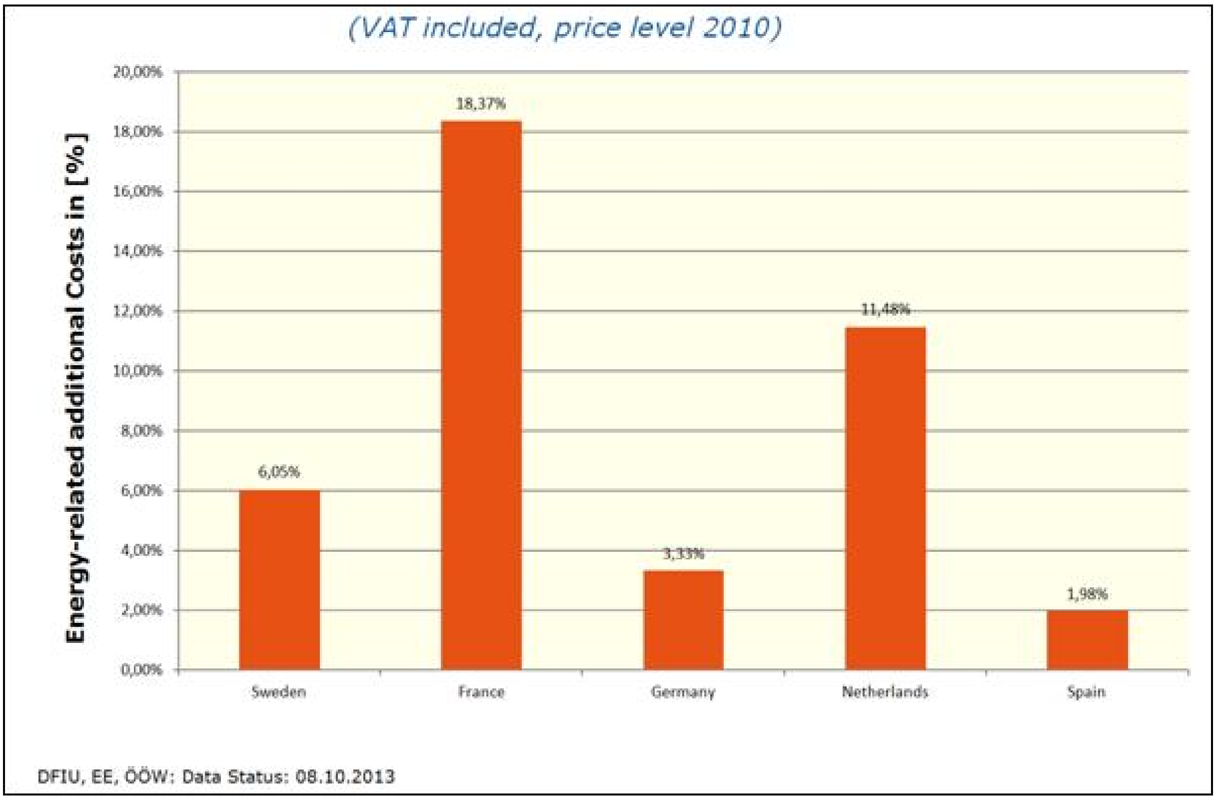

Figure 5.23: Energy-related additional costs of new residential buildings in relative terms [B2]

The analysis shows that for selected CONCERTO residential objects the energy-related additional costs occur in the dimension of 5-15% of the usual construction costs for new buildings.

Energy-related additional construction costs for refurbishments

Like in case of new buildings the energy-related additional construction costs also play an important role in case of refurbishments. Often energy efficiency measures can be coupled with other maintenance or non-energy-related modernization measures that have to be undertaken anyway. In these cases, efficiency measures seem to be exceptionally attractive. The following analysis illustrates the additional financial effort for energy efficiency measures in CONCERTO.

Since the public building sector is especially focused as model sector for nearly zero-energy efficiency requirements Figure 5.24 shows energy-related additional costs for refurbishments of municipal buildings.

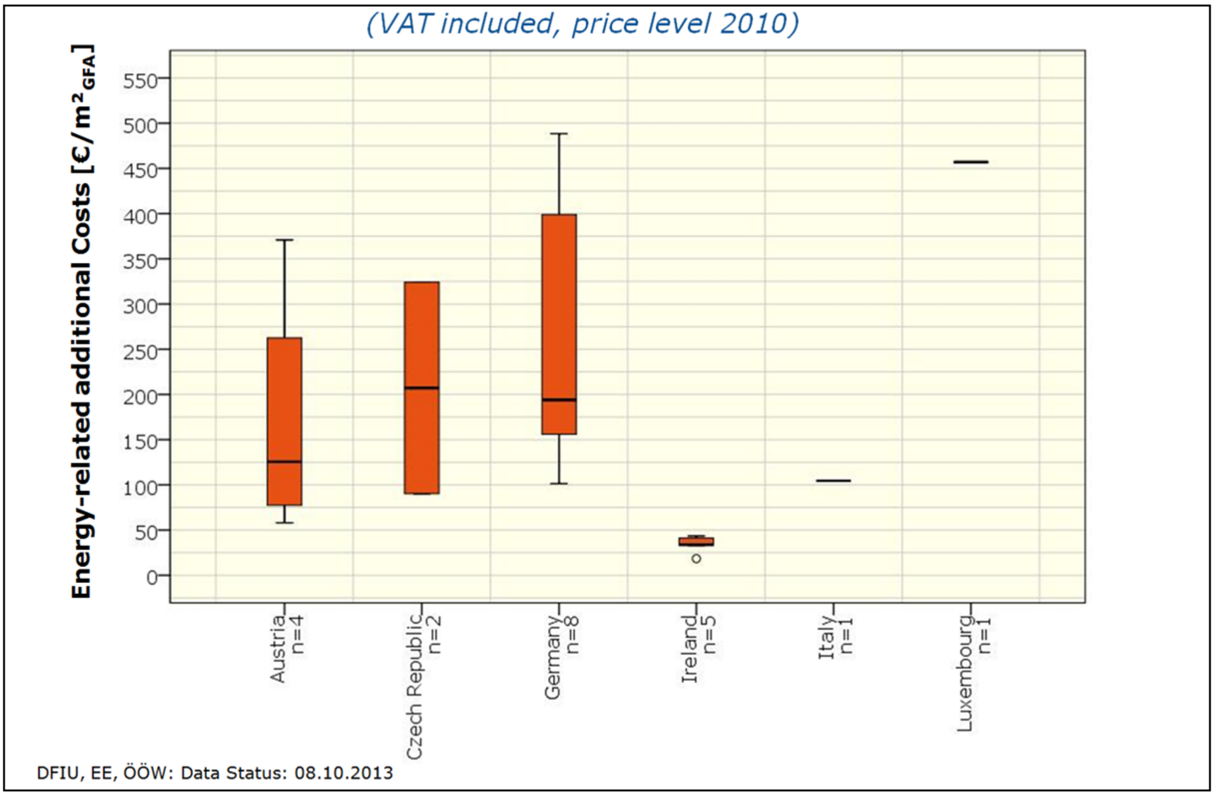

Figure 5.24: Energy-related additional costs of refurbishments of municipal buildings [B2]

Furthermore, also the energy-related additional costs for refurbishments of tertiary-non-municipal buildings is illustrated in Figure 5.25.

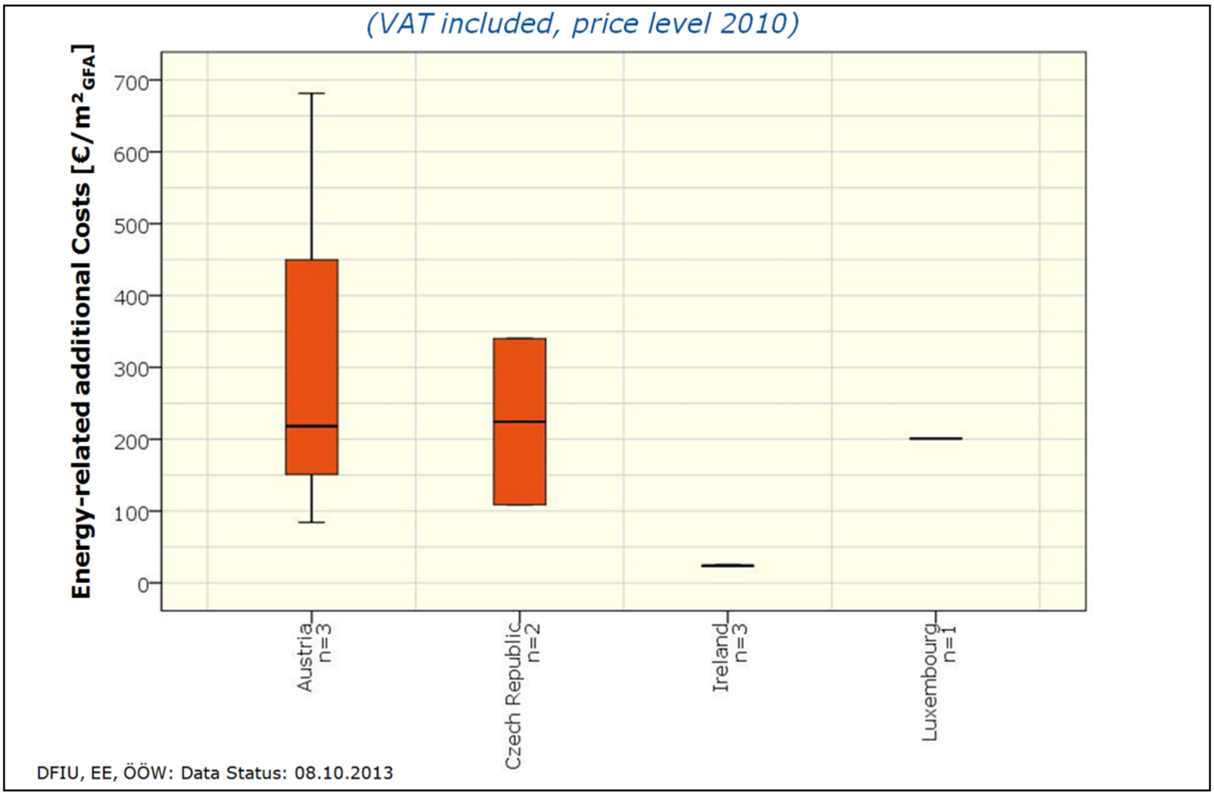

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Figure 5.25: Energy-related additional costs of refurbishments of tertiary-non-municipal buildings [B2]

Dynamic payback period for refurbishments
The analysis of the static and dynamic payback period is a widely used method. It is therefore included in the assessment and evaluations. When interpreting payback periods it should be noted that in contrast to other investments in the industrial sector measures are economically justifiable if they amortize within their lifetime (here an average of 30 years). Figure 5.26 and Figure 5.27 show that this is true for most cases.

The influence of boundary conditions becomes also clear. In a dynamic analysis, the results are strongly influenced by the parameters like the discount rate and the energy price increase rate. As can be seen in Figure 5.26 and Figure 5.27 higher assumed energy price increase rates have a positive influence on the dynamic payback periods. Therefore, for calculations related to the justification of laws or funding decisions, parameter variations (sensitivity analyzes) are strongly recommended.

Furthermore, the effects of grants are visualized since Figure 5.26 does not consider grants and Figure 5.27 does. The consideration of grants also positively influences the payback periods.

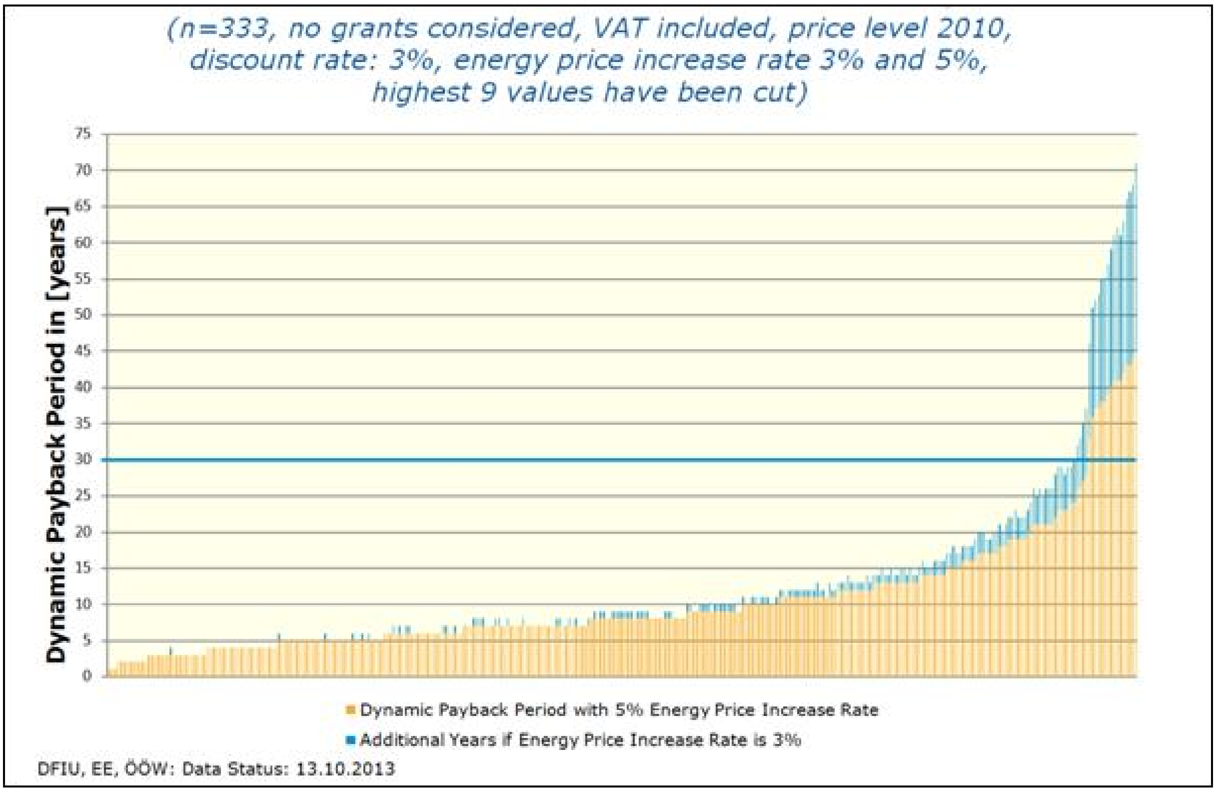

Figure 5.26: Dynamic payback period, demand-based (calculated), for refurbishments of residential buildings with energy price increase rates of 3% and 5%, no grants considered [B2]

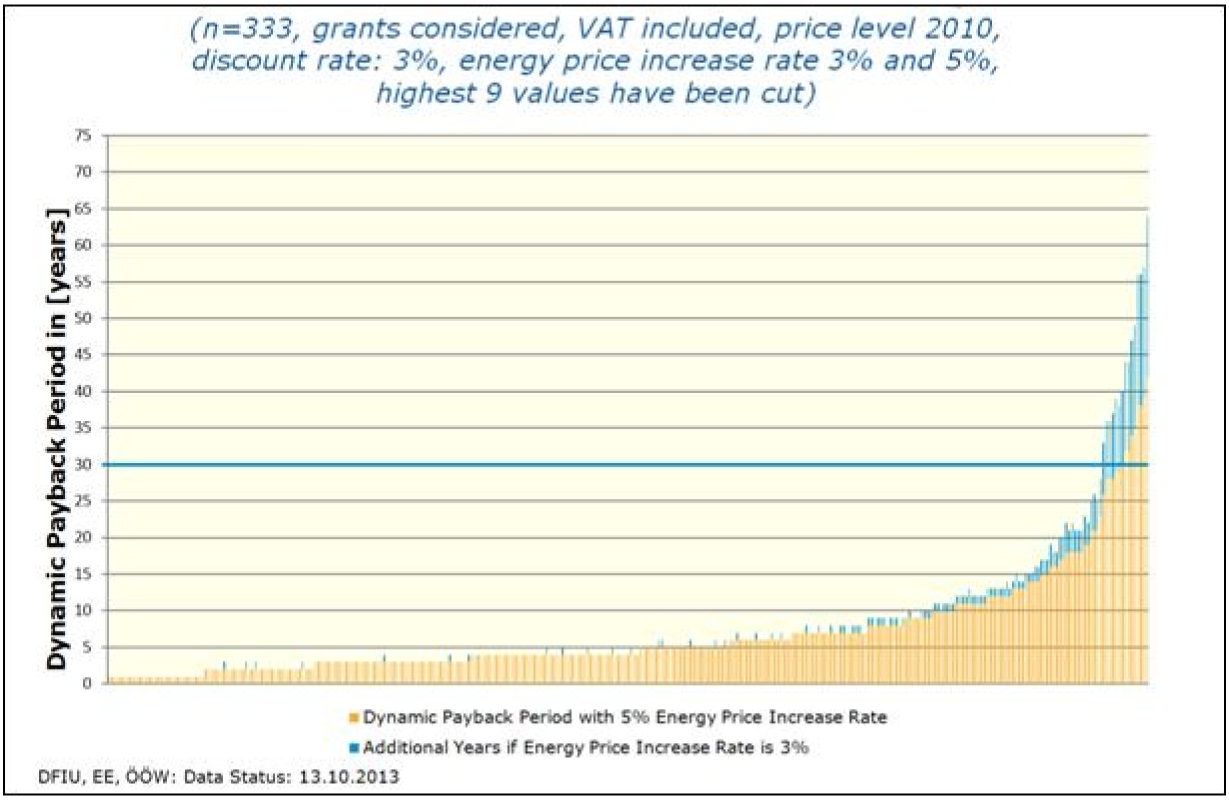

Figure 5.27: Dynamic payback period, demand-based (calculated), for refurbishments of residential buildings with energy price increase rates of 3% and 5%, CONCERTO grants considered [B2]

Note: In Figure 5.26 and Figure 5.27 the values are brought to the next higher round figure. This is why the increase of the energy price increase rate from 3% to 5% is not always noticeable.

Annuity consideration of the costs before and after the refurbishment

The indicator dynamic payback period tends to raise the understanding that economic benefits will only occur after the investment has amortized, far in the future. This is not true since cost savings are realized from the beginning on. Otherwise, if no cost savings were achieved the measure would not pay off at all. In order to prevent misunderstandings considerations of annuities are recommended. Here, the annuity of the energy costs before the refurbishment is compared with the sum of the annuity of construction costs and the annuity of energy costs after the refurbishment. Generally, an annuity is a terminating "stream" of fixed payments, i.e., a collection of payments to be periodically spent over a specified period of time. In this context, the annuity of the construction costs can be interpreted as perpetuation of a single upfront investment over the expected lifetime of the energy efficiency or renewable energy measures. The annuity of energy costs, however, can be seen as average energy costs per year when an energy price increase rate of 5% is considered.

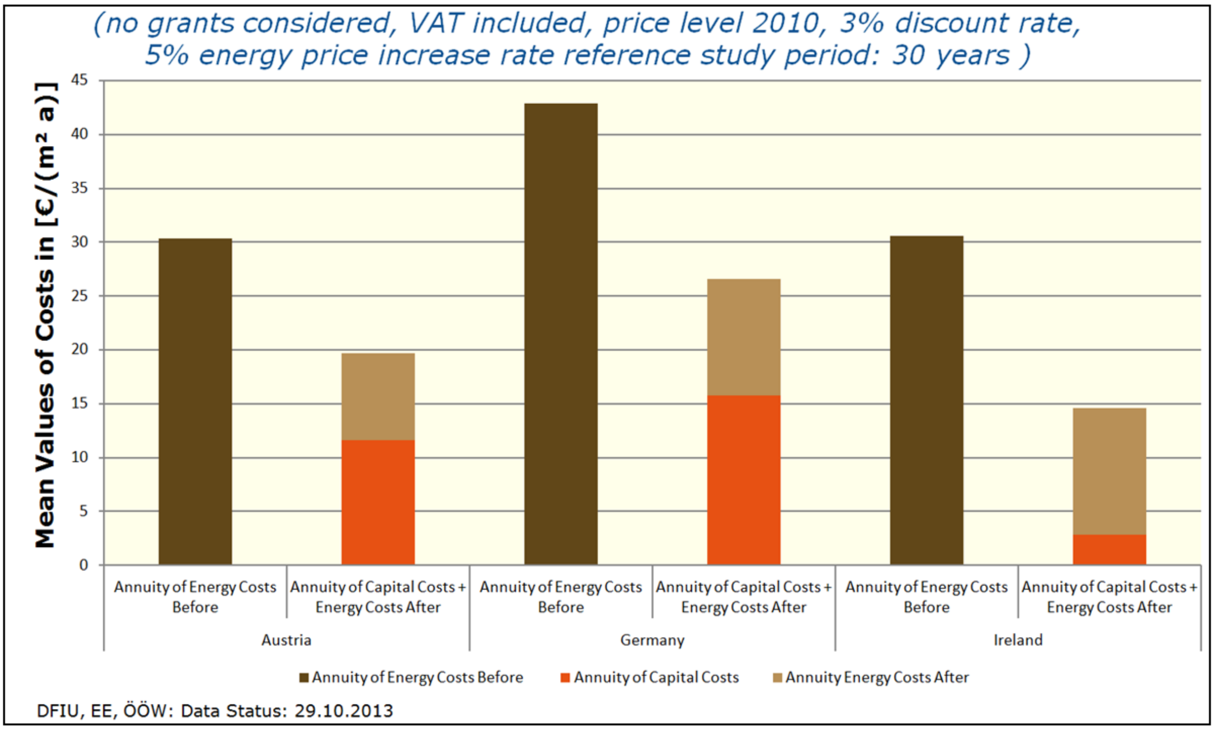

Figure 5.28: Annuity of capital costs + annuity of energy costs after vs annuity of energy costs before, mean values, demand-based (calculated), for refurbishments, residential buildings, GFA < 180m² [B2]

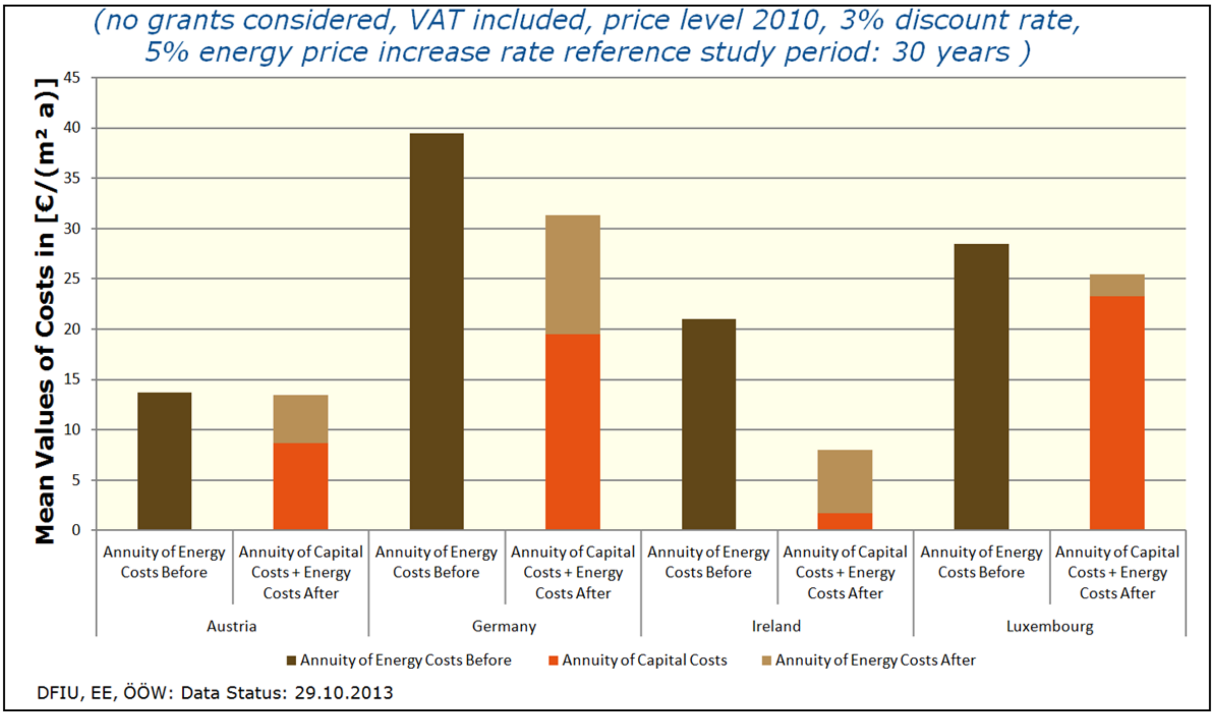

Figure 5.29: Annuity of capital costs + annuity of energy costs after vs annuity of energy costs before, mean values, demand-based (calculated), for refurbishments, municipal buildings, GFA > 180m^2 [B2]

Figures 5.28 and 5.29 show that the annuity of energy costs before the refurbishment has generally been higher than the sum of the annuity of construction costs and the annuity of energy costs after the refurbishment in CONCERTO. Therefore, the annuity consideration shows that the implemented measures trigger annual cost savings from the beginning on.

5.3.3 Macro-economic assessment results [B3]

Besides micro-economic considerations concerning energy efficiency and renewable energy measures also macro-economic evaluations play an important role in the context of an overall assessment. Particularly, the assessment category positive effects of grants provided is of special interest in CONCERTO. Especially, legislators, local authorities and grant providers are target groups in focus.

Macro-economic impact in case of new buildings and refurbishments

In order to get an impression about the positive effects of a grant programme performance indicators like the triggered investment per grant, the triggered energy savings per grant and the triggered CO_2 emission savings per grant can be calculated. In all cases multipliers are derived that quantify the acceptance and the success of the grants provided.

Figures 5.30 and 5.31 illustrate the indicators fossil primary energy reductions per grant and CO_2 emission reductions per grant in case of new buildings, respectively.

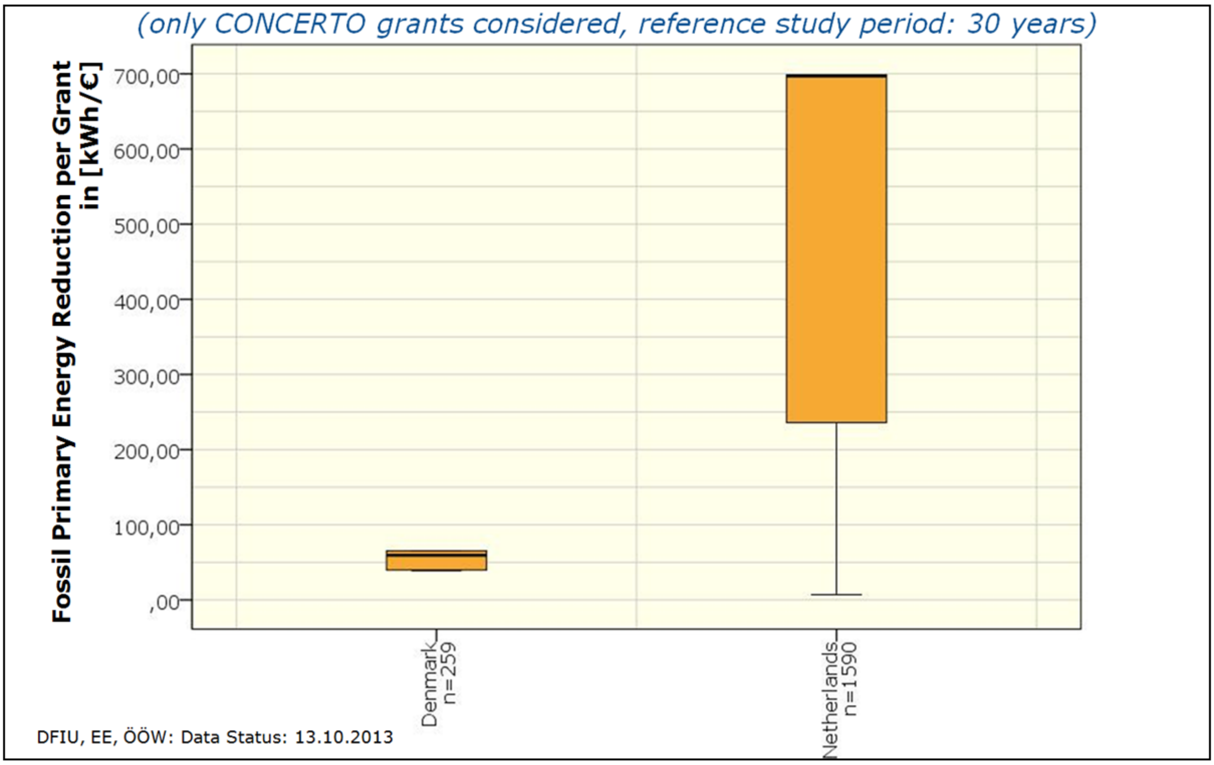

Figure 5.30: Fossil primary energy reduction per grant, demand-based (calculated), for new buildings, residential buildings, GFA < 180m^2 [B3]

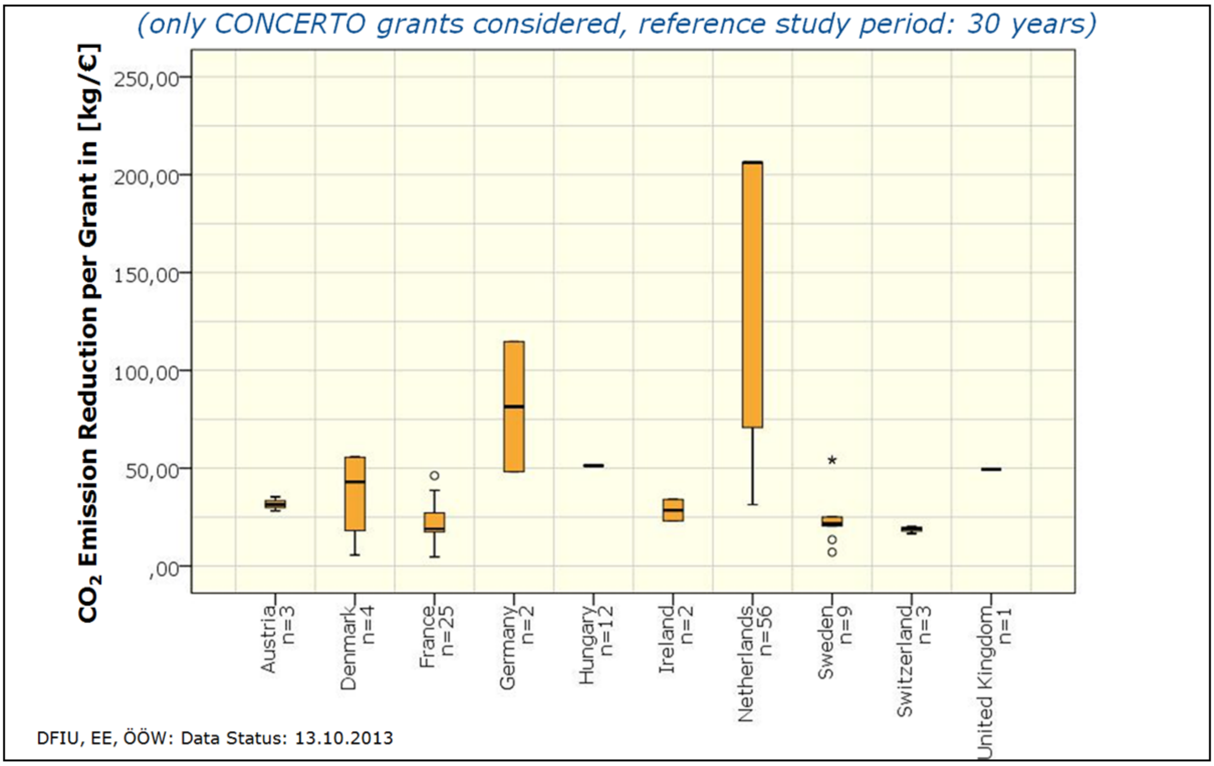

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Figure 5.31: CO_2 emission reduction per grant, demand-based (calculated), for new buildings, residential buildings, GFA > 180m² [B3]

Figures 5.32 and 5.33 illustrate the indicator triggered investment per grant in case of refurbishments for small and large residential buildings.

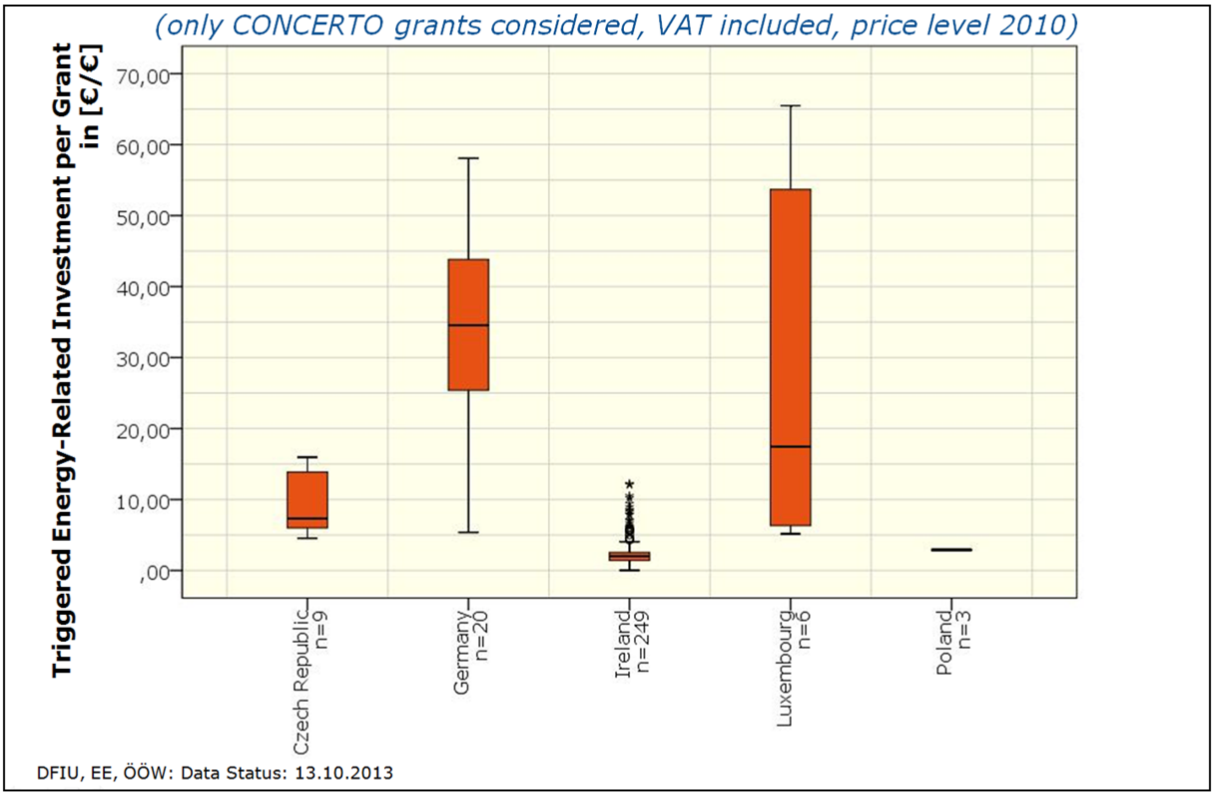

Figure 5.32: Triggered energy-related investment per grant, for refurbishments, residential buildings, GFA < 180m² [B3]

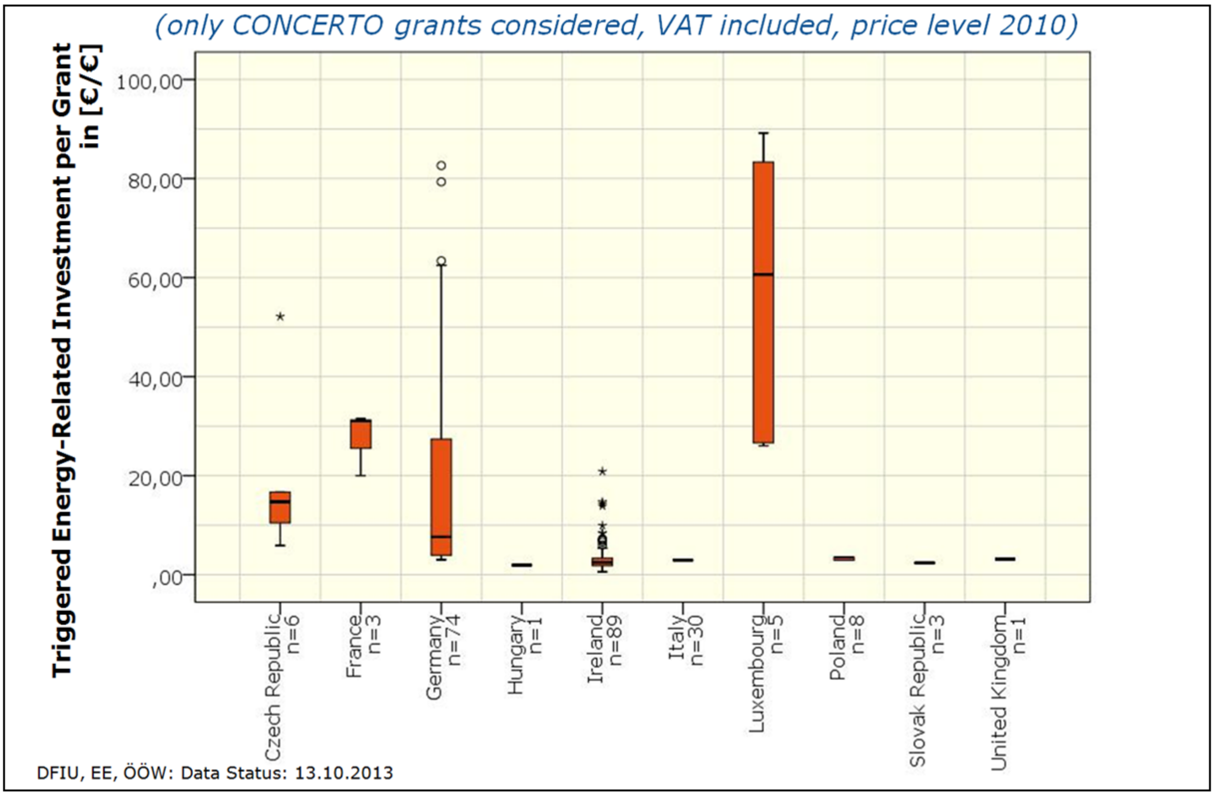

Figure 5.33: Triggered energy-related investment per grant, for refurbishments, residential buildings, GFA > 180m² [B3]

The multipliers are quite high in CONCERTO since the financial CONCERTO support was relatively low. CONCERTO support is based on scale of unit costs. The range of eligible costs for buildings were set to 25 to 100 [€/m² built or refurbished] depending on the CONCERTO generation. Around 35% of the eligible costs was granted as direct financial support. Anyway, from a macro-economic point of view the CONCERTO initiative was a great success since a multitude of positive effects have been triggered by the applied financial support scheme.

5.3.4 Environmental assessment results [B4]

Starting point for calculations of economic advantageousness of measures to improve the energy quality of existing buildings (here residential buildings) is the amount of saved energy by the energy measure. This amount is determined by calculation in the planning phase of a modernization measure. It may alternatively be calculated by a comparison of metered energy demand before and after the measure. Both values should be degree-day adjusted (climate-corrected) to ensure comparability. Only the actual energy savings lead to an actual reduction in heating costs. A computational overestimation of savings leads to problems in demonstrating the economic advantageousness in reality.

Final energy demand versus consumption for refurbishments
Respective analysis of data in residential buildings revealed the following: For small residential buildings (see Figure 5.34) the data scatter strongly even after a weather adjustment - also because of the great influence of individual user behavior. In tendency, however, the savings in computational evaluations are partly clearly overestimated - in reality they are thus smaller than expected. Especially with private building owners, this leads to uncertainty and even financial problems. As a consequence, calculation rules need to be adapted and consumption forecasts must be closer to real consumptions.

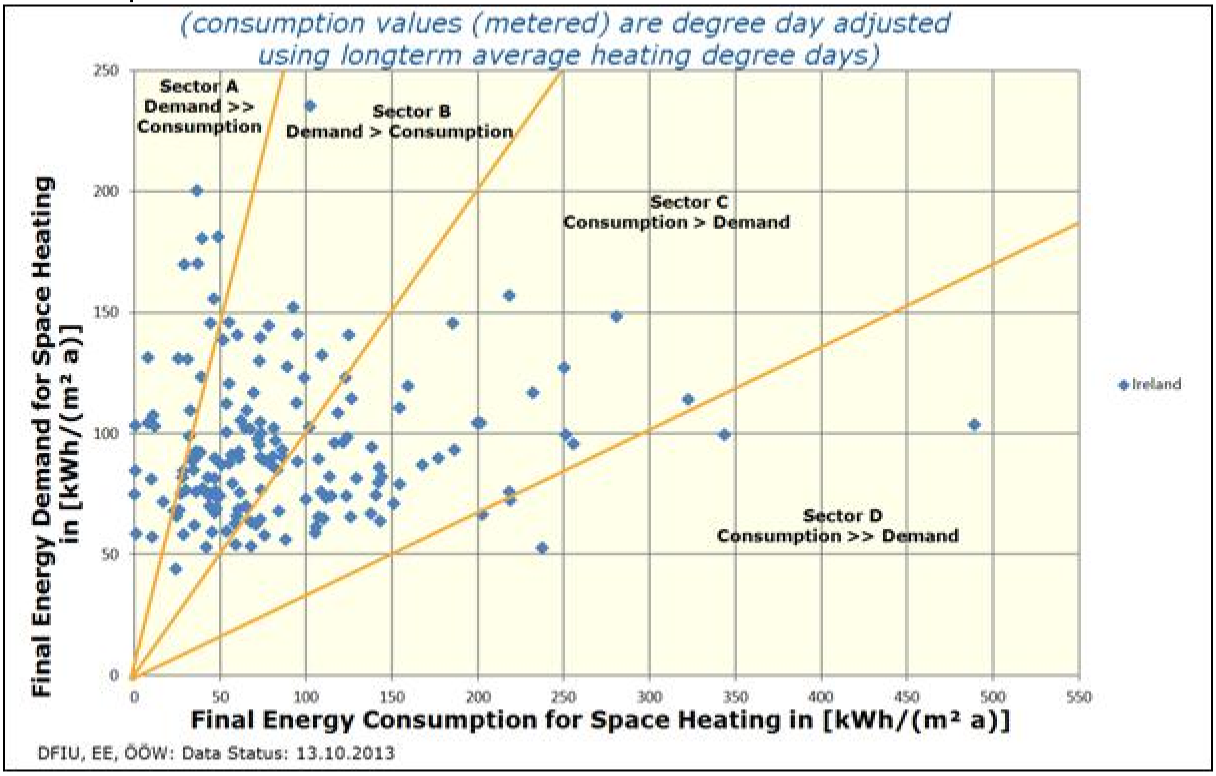

Figure 5.34: Final energy consumption (metered) versus demand (calculated) for space heating in case of refurbishments of residential buildings with a gross floor area < 180m^2, consumption values are degree-day adjusted [B4]

For large residential buildings (see Figure 5.35) the situation is similar. When considering data from Germany the match of demand and consumption values is good in the present case - in multi-family buildings, differences in user behavior are generally balanced better. In general, however, the same applies here, computational predictions of the amount of energy savings are subject to uncertainties. This should be given more attention in future discussions on the economics of measures. Not to be forgotten is the question if a degree-day adjustment (climate-correction) was performed or not.

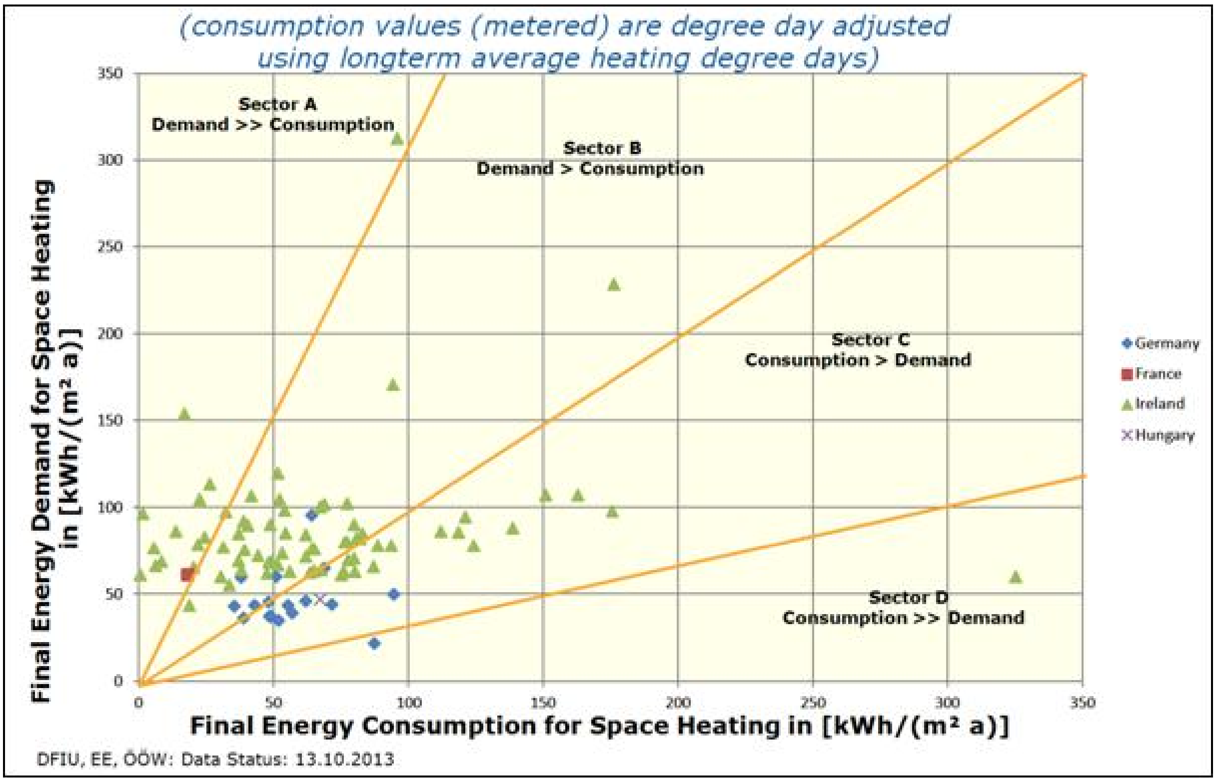

Figure 5.35: Final energy consumption (metered) versus demand (calculated) for space heating in case of refurbishments of residential buildings with a gross floor area > 180m^2, consumption values are degree-day adjusted [B4]

The amount of pre-calculated and actual energy savings (this is distinguished in the following) is the starting point for the following analysis of economic advantageousness.

Fossil primary energy demand and CO_2 emissions before versus after in case of refurbishments

Figure 5.36 shows the average fossil primary energy demand (calculated) for space heating before (left bar) and after (right bar) CONCERTO refurbishments as average on site level. Furthermore, the red bar in the middle visualizes a proxy for the fossil primary energy demand for space heating if only building integrated energy efficiency measures are considered. The corresponding values are derived by taking into account the relative final energy demand reductions of the refurbishment. Since final energy demand reductions are achieved (under certain assumptions) by efficiency measures (insulation, more efficient heating technology) the final energy demand reduction in percent was transferred to the fossil primary energy demand for space heating before the refurbishment in order to estimate the fossil primary energy demand for space heating if only building integrated energy efficiency measures were considered.

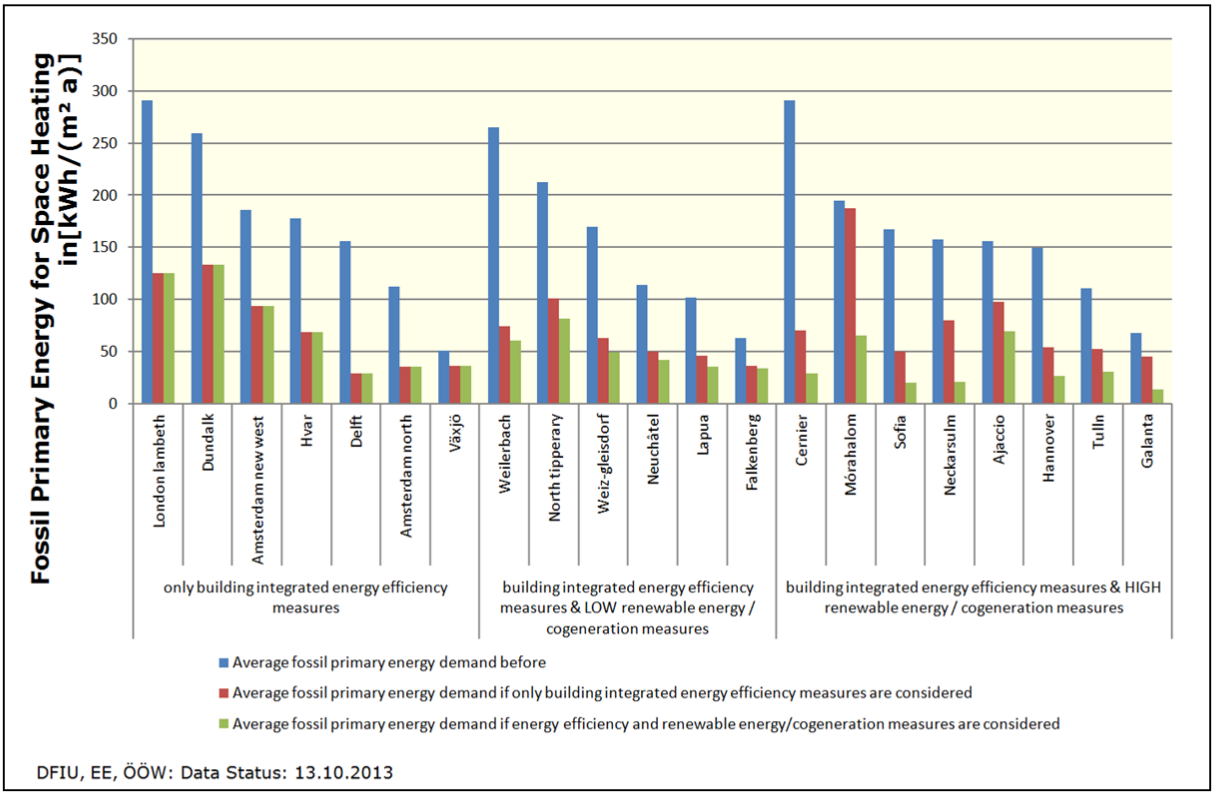

Figure 5.36: Fossil primary energy demand (calculated) for space heating, before vs after CONCERTO, for refurbishments [B4]

The sites have been classified in three categories. The first category contains sites in which only building integrated energy efficiency measures were realized in the buildings. In the second category sites are included in which building integrated energy efficiency measures and measures leading to LOW renewable energy/cogeneration effects were implemented. Finally, the third category comprises sites in which building integrated energy efficiency measures and measures leading to HIGH renewable energy/cogeneration effects were implemented.

Figure 5.37 illustrates a similar analysis in terms of CO_2 emissions. Basically, the same reasoning was followed as in case of fossil primary energy demand.

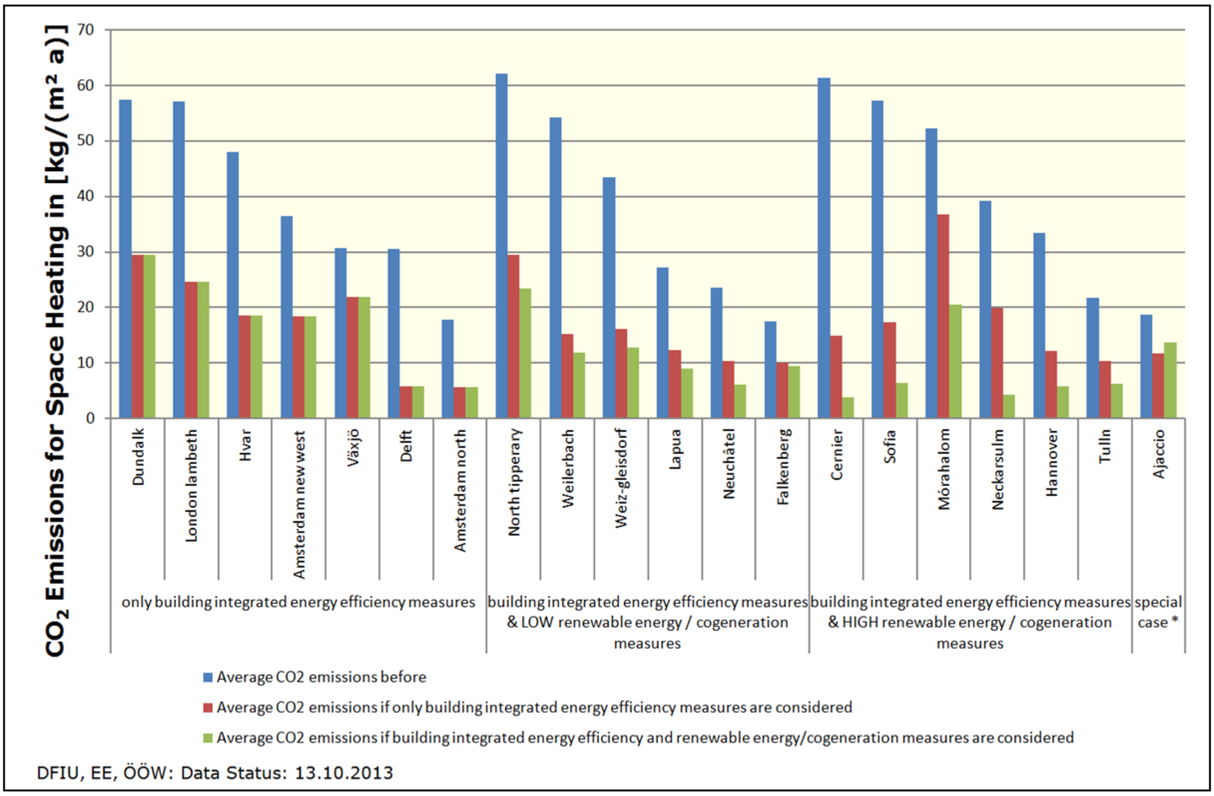

Figure 5.37: CO_2 emissions, demand-based (calculated), for space heating, before vs after CONCERTO, for refurbishments [B4]

In Ajaccio, France, an interesting special case (*) can be recognized. The energy carrier for space heating was substituted from electricity to gas. In this case, electricity has a higher primary energy factor than gas but a smaller CO_2 emission factor since a high share of nuclear power is used in the French electricity mix. This is why the energy carrier substitution has a positive effect on the fossil primary energy demand (see Figure 5.36 a further reduction (decreasing values from red to green bar) can be observed) but a negative effect on the CO_2emissions (see Figure 5.37 increasing values from red to green bar) can be observed).

5.3.5 Economic-environmental assessment results [B5]

Equivalent price of energy for refurbishments

The consideration of the equivalent price of energy is specifically recommended by the authors. Here, the costs for saving one unit of energy (here kWh final energy) can be contrasted with the costs for the delivery or production of a kWh of energy (benchmark). Regarding the basics of calculation and evaluation it is referred to the guidebook of assessment – also see section 4.4.

When evaluating Figure 5.38, Figure 5.39, Figure 5.40 and Figure 5.41 it becomes clear that for selected cases the costs of saving energy already lie below the costs of production. Since this is also dependent on the considered energy carrier energy prices for gas, heating oil and district heat are drawn into the diagram as benchmarks. Furthermore, future energy price levels in 15 years assuming 3% and 5% energy price increase rates are inserted.

Figure 5.38 and Figure 5.39 show box plots based on demand (calculated) values for small and large residential buildings.

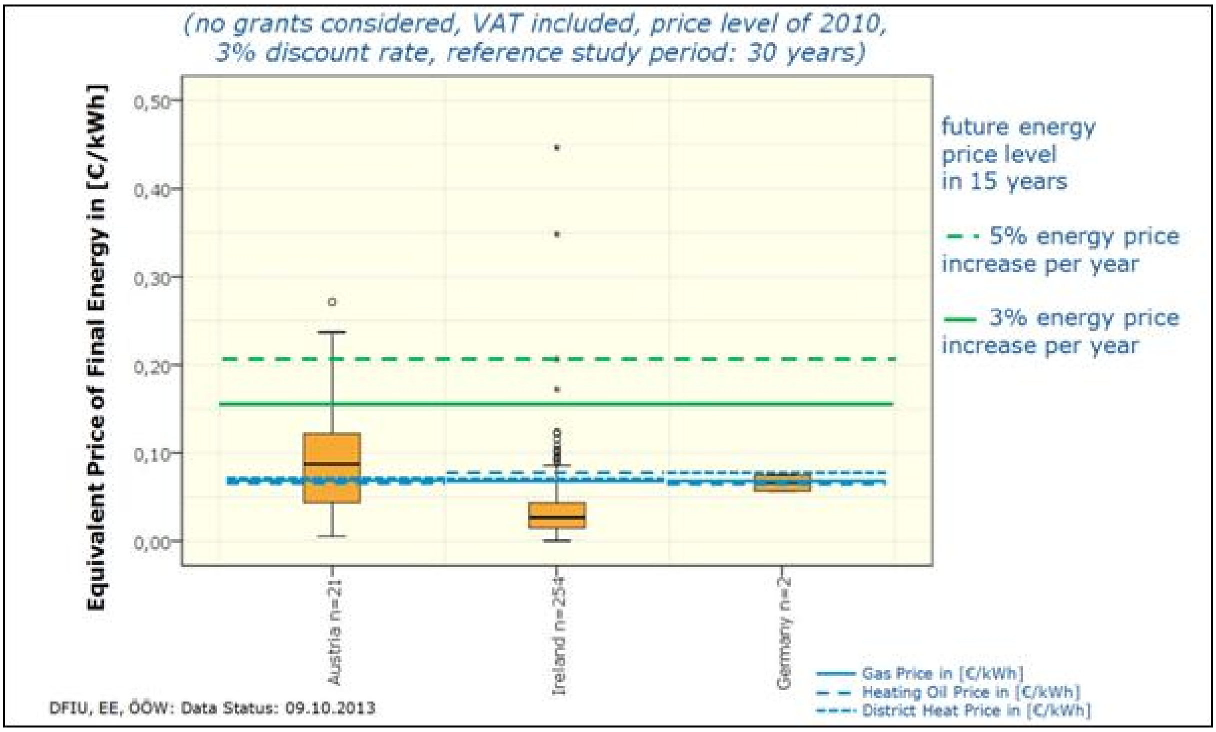

Figure 5.38: Equivalent price of energy, demand-based (calculated), for refurbishments of residential buildings with a gross floor area <180 m^2 [B5]

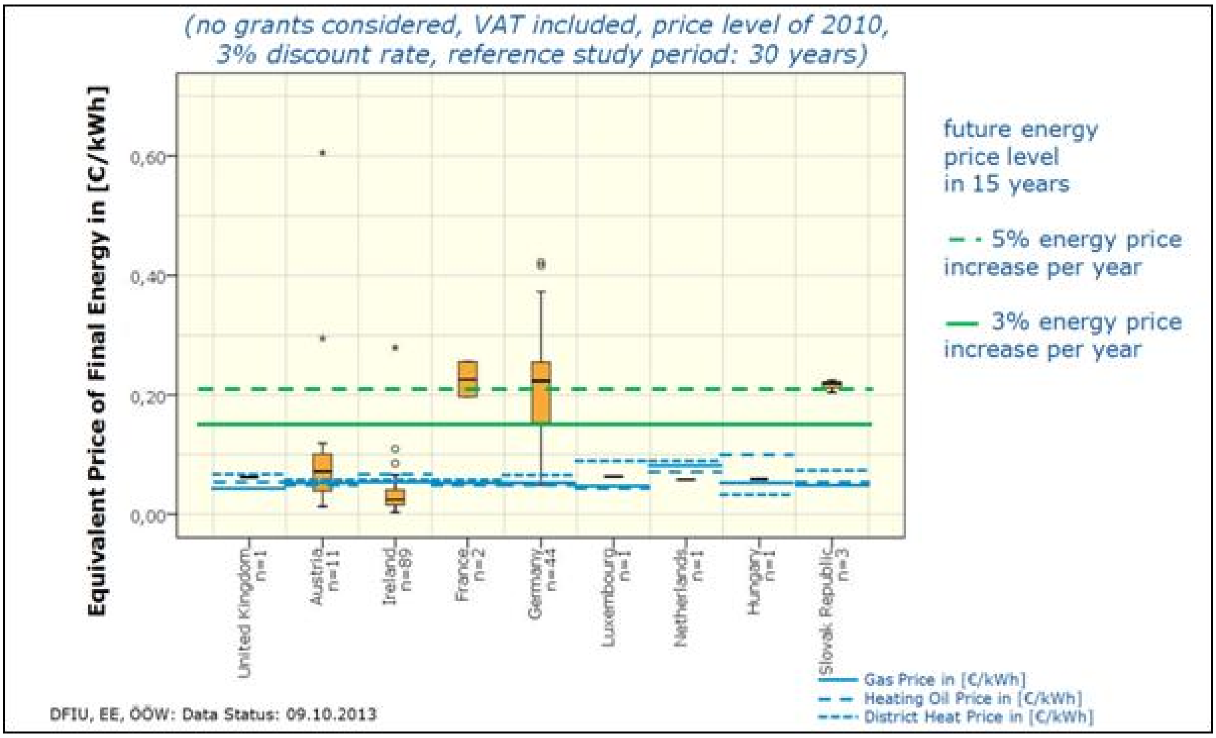

Figure 5.39: Equivalent price of energy, demand-based (calculated), for refurbishments of residential buildings with a gross floor area >180 m² [B5]

However, practically significant are only the statements in Figure 5.40 and Figure 5.41 based on real savings (based on metered values) for small and large residential buildings. Again, it is clear that lower real savings adversely affect the economic advantageousness of statements.

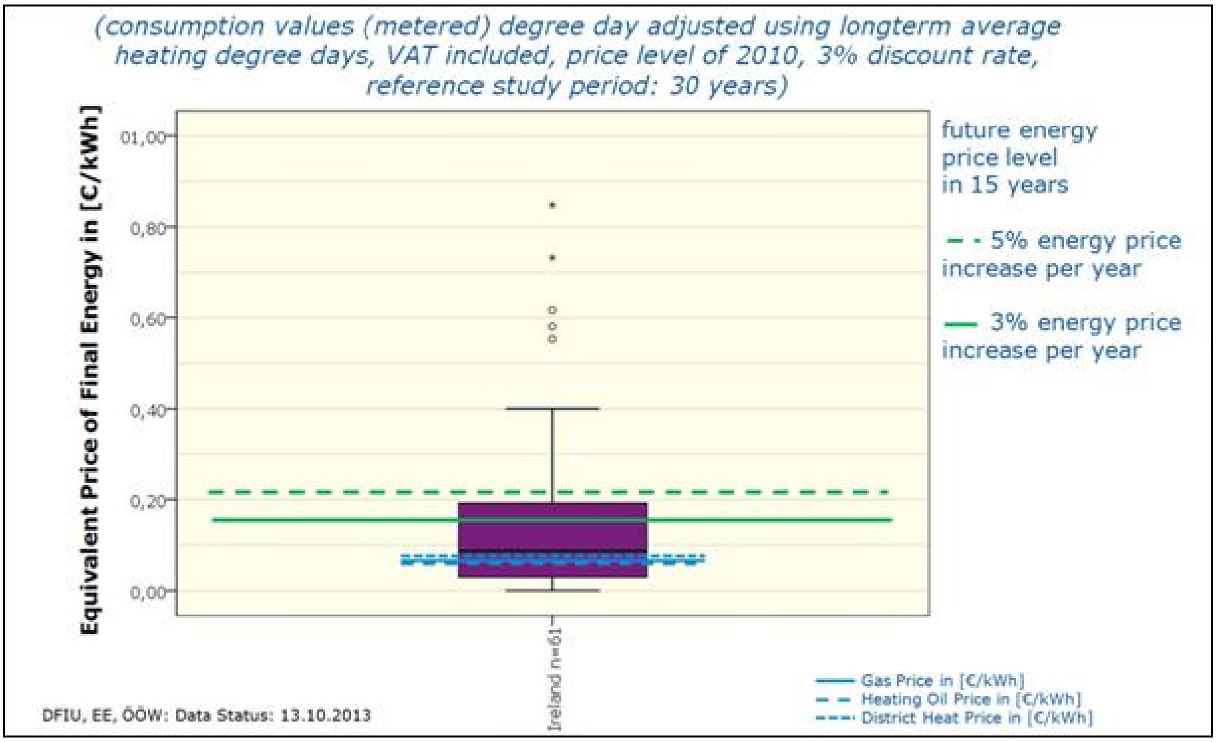

Figure 5.40: Equivalent price of energy, consumption-based (metered), for refurbishments of residential buildings with a gross floor area <180 m^2 [B5]

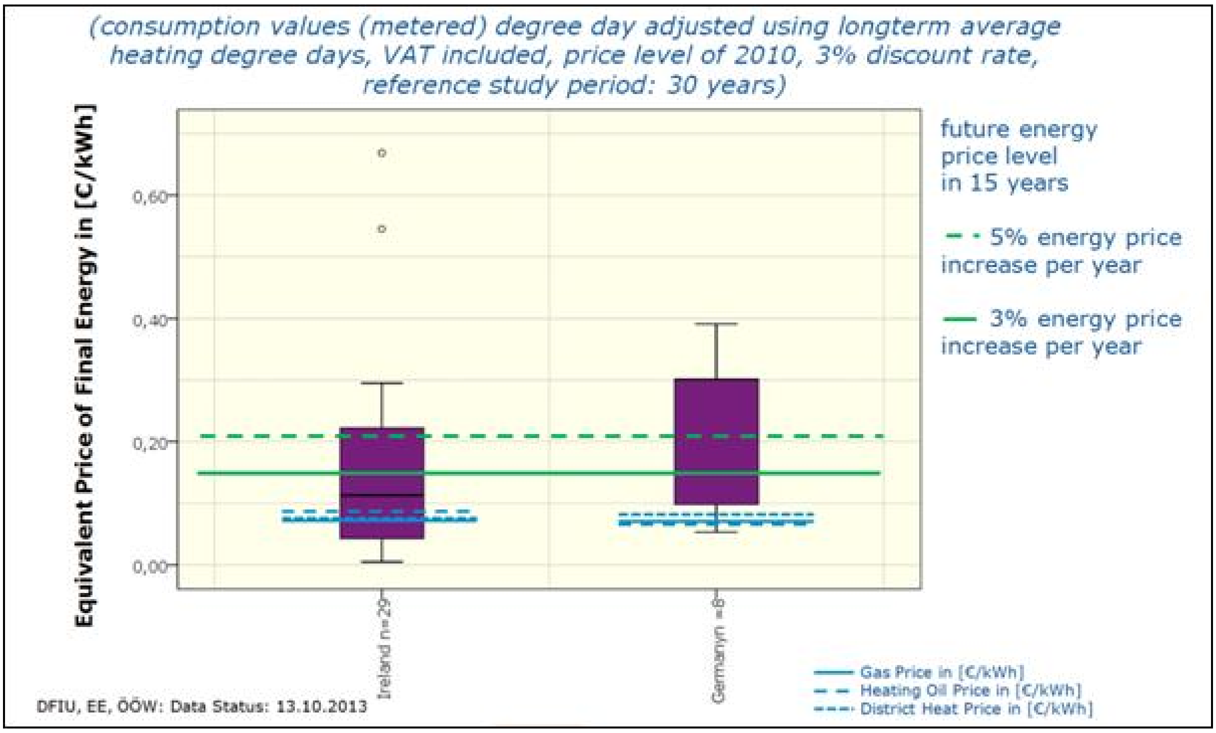

Figure 5.41: Equivalent price of energy, consumption-based (metered), for refurbishments of residential buildings with a gross floor area >180 m^2 [B5]

CO_2 mitigation costs

Another evaluation criterion, which is recommended for increased use, is the amount of CO_2 mitigation costs. These are inter alia influenced by the choice of boundary conditions in the calculation - the relevant information in the graph is to be considered. Negative mitigation costs occur particularly when the measures will lead to significant savings in energy and energy costs. As benchmarks damage costs by external effects can be used (30 €/ton from EU sources, 20-280 €/ton with an average of 70 €/ton from literature of Umweltbundesamt in Germany).

Presented in Figure 5.42 are CO_2 mitigation costs based on calculated CO_2 emission savings ordered by ascending values. In Figure 5.42 the highest 3 values have been cut so that the values of the interesting corridor can be better visualized and benchmarks can be displayed.

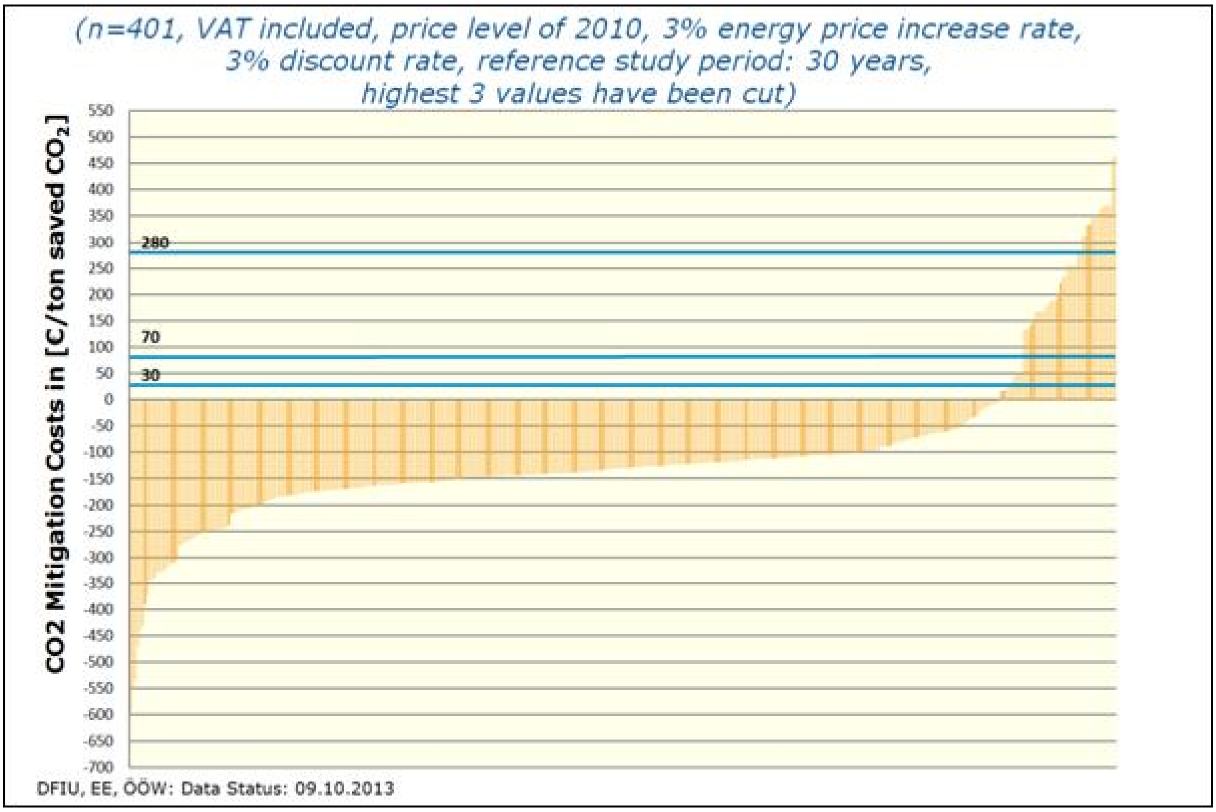

Figure 5.42: CO_2 mitigation costs, demand-based (calculated) for refurbishments (highest 3 values have been cut) [B5]

Figure 5.43 is based on actual savings. In Figure 5.43 the highest 11 values have been cut so that the values of the interesting corridor can be better visualized and benchmarks can be displayed.

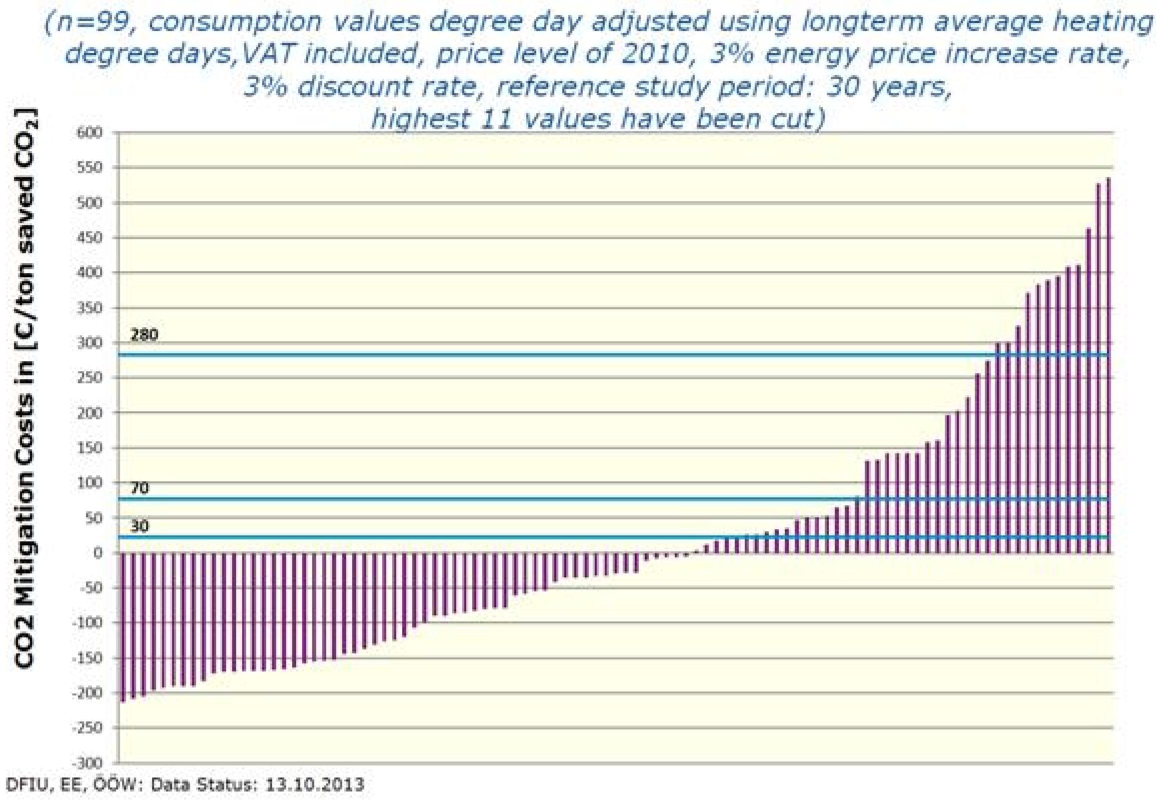

Figure 5.43: CO_2 mitigation costs, consumption-based (metered) for refurbishments (highest 11 values have been cut) [B5]

It becomes clear that the prevention costs are often below the damage costs. This is a macro-economic perspective. The assumed amount of the damage costs has a major impact.

The Figure 5.44 specifies for plausibility checks values from the literature.

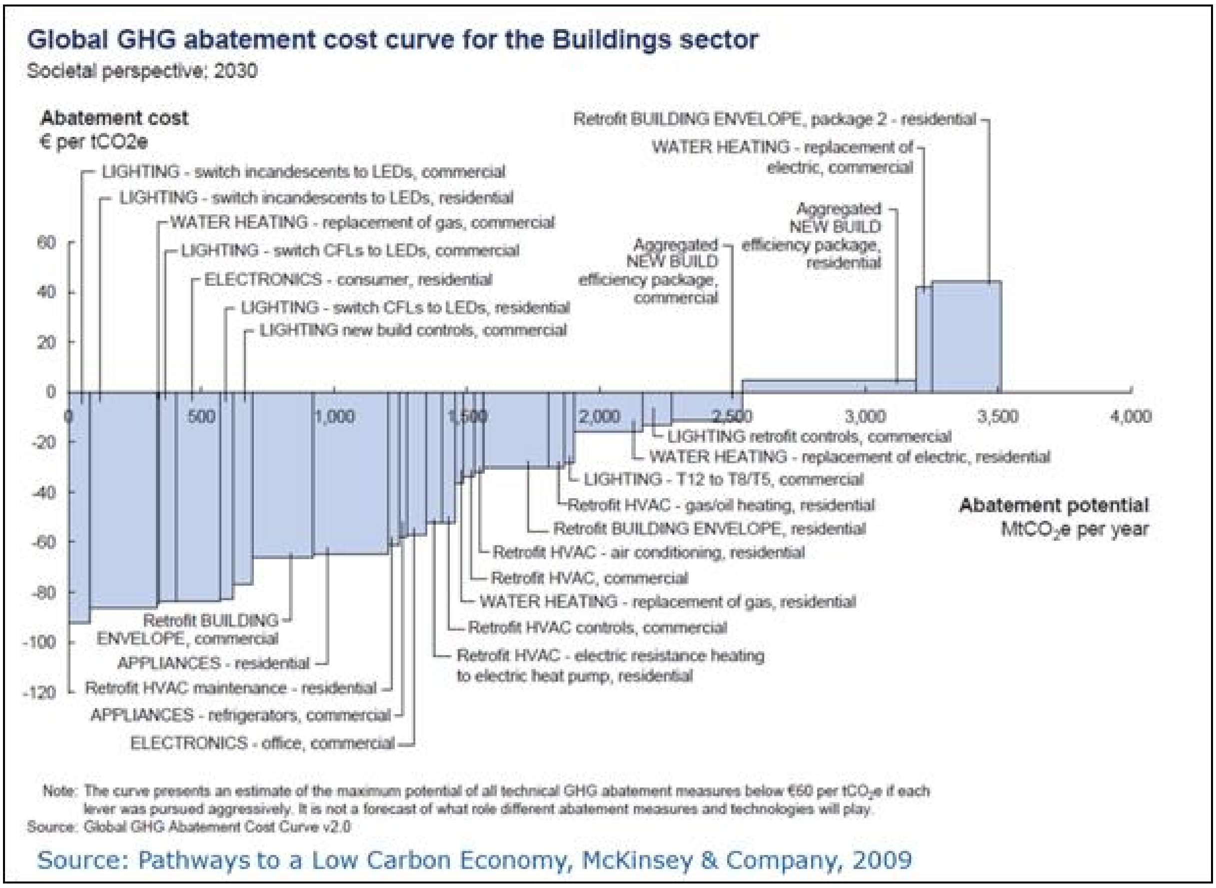

Figure 5.44: CO_2 mitigation costs according to McKinsey [B5]

5.3.6 Techinal assessment results [B6]

U-values (best achieved) for CONCERTO new und refurbished buildings

U-values give an overall rating of the insulation quality of building elements, like walls, roofs, grounds. They measure the rate of heat transfer through a building element over a given area under standardised conditions. Figures 5.45 and 5.46 show best achieved u-values in CONCERTO for new and refurbished buildings in dependence of climatic conditions expressed in heating degree days (ten year average of heating degree days $[Kd]_{15,18}$). The diagrams have been generated using scatter-plots and drawing curves of best achieved u-values in the scatter-plots in order to visualize interrelations.

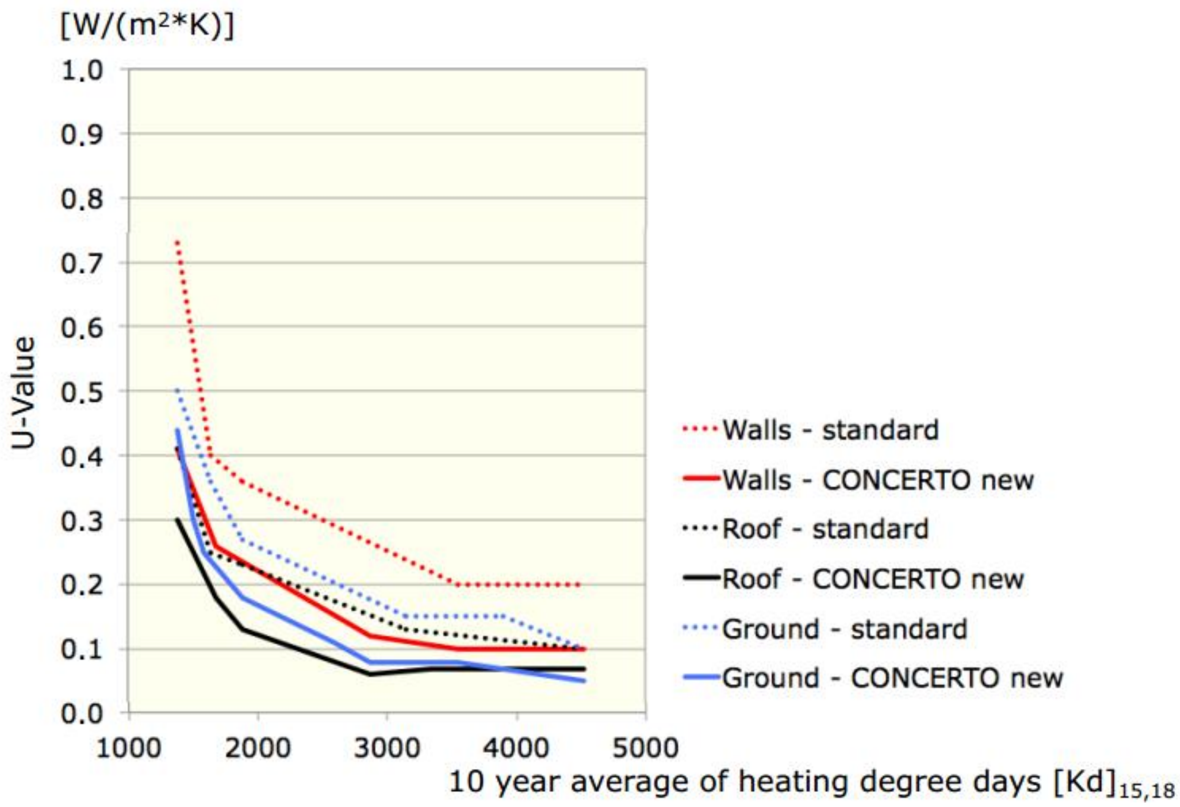

Figure 5.45: U-values (best achieved) in CONCERTO new buildings [B6]

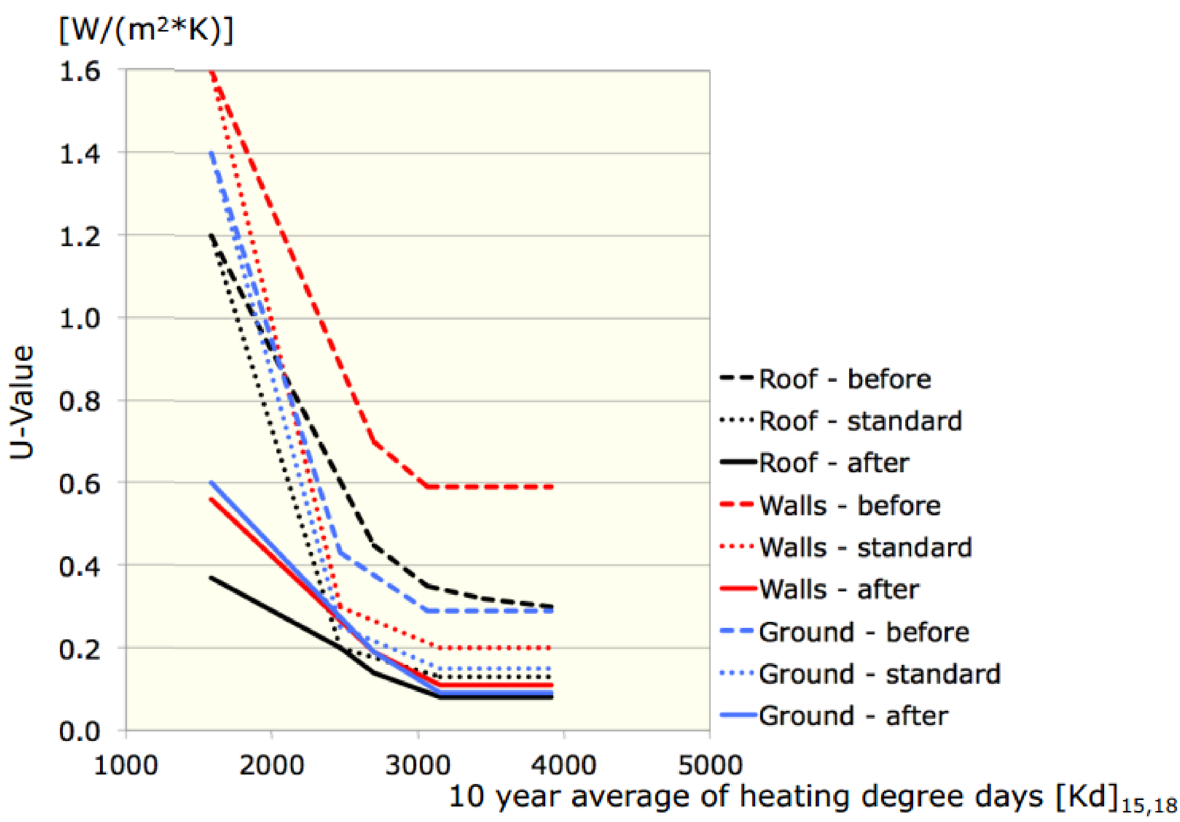

Figure 5.46: U-values (best achieved) in CONCERTO refurbished buildings [B6]

Generally, Figures 5.45 and 5.46 illustrate that u-values improve from southern to northern Europe. In northern Europe very low u-values have already been achieved so that there is not much potential for optimization left in comparison to other fields. An interrelation of u-values with heating degree days (10 year average) can be assumed. U-values used in CONCERTO are consistently below national standard, significantly below "before CONCERTO", reflecting the principle that "energy efficiency must come first, then renewables". Furthermore, the goal of 30% energy reduction in case of new buildings and refurbishments to national new building standards can also be identified in Figures 5.45 and 5.46 since better insulation quality normally corresponds to lower energy demands.

5.4 CONCERTO energy supply units

Within the CONCERTO demonstration projects we find different types of energy supply units. They have been grouped into building integrated energy supply units (BIES) like small solar thermal collectors or small biomass boilers and community energy supply units (CES) like large combined heat and power (CHP) plants or wind turbines. Also district heating networks, which join the buildings to the supply units and played an important role within CONCERTO, biogas plants and large-scale storages belong to the second group. Assessment has been performed under economic, environmental, eco-environmental and technical aspects and the important results are presented in the following chapters.

5.4.1 Analysis of data availability and quality in detail for energy supply units [C1]

For the energy supply units (ESU) within the CONCERTO demonstration objects 19 different data collection sheets (DCS) have been prepared for data acquisition and import into the database. Here basic data, technical details, economic and monitoring values can be filled in. The ability of indicator calculation strongly depends on the raw data provided and the quality of the indicators is mainly influenced by it as well. Chapter 4 describes the availability and quality of the raw data. This chapter discusses the availability and quality of calculated indicators. As the calculation of an indicator needs at least two parameters from the ESU, it can be seen as a representation of information density per ESU. The more complex an indicator gets, the more parameters of one ESU are needed.

Figure 5.47 shows different selected indicators (with rising requirement towards detailed data from left to right) of three ESU types. The indicator "capital costs" in [€/kW] needs the total investment figure and the installed capacity as input. Usually these two figures are available, but for small solar thermal collectors we notice a lack of about a third. The environmental indicator "CO_2 emission reduction" in [t/a] and the economic indicator "energy production costs" in [€/kWh] are more complex. Here they have been calculated based on the design values, not the monitored values. The "full load hours" in [h/a] are not so complex by calculation, as they need the installed capacity and the monitored energy output throughout a year. One has to keep in mind that the presented diagrams also include CONCERTO generation 3 projects, which are still running.

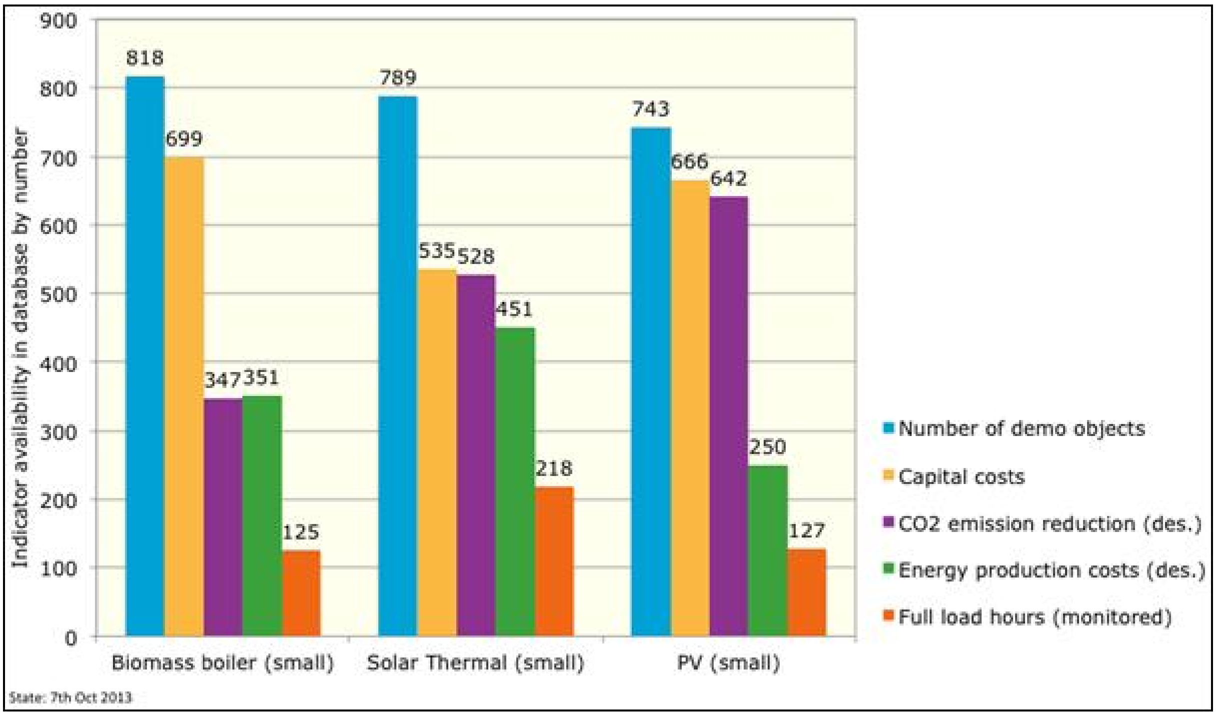

Figure 5.47: Indicator availability in database of small biomass boilers, small solar thermal plants and small photovoltaic systems compared to the total number of demonstration objects

Looking at the small biomass boilers we see, that for only a small number the monitored full load hours can be calculated. A large part of the boilers (i.e. 340) without monitored heat production are the SERVE wood log stoves, where a measurement of heat production is not possible as heat is directly transferred to the air of the rooms. With the solar thermal collectors it should be possible to monitor every system, as a heat meter can be easily installed at the pipes. But as monitoring equipment is expensive, it is a good approach to define a control sample and perform a detailed monitoring on it. Nevertheless it should be made sure that every community provides monitoring data of a relevant sample size. Almost all PV systems should have an electricity meter, as usually they need it for tariffing purposes. Here it is just a question of acquiring the data from the owners.

In Figure 5.48 it can be seen that for large PV systems and for wind power plants the availability of indicators is rather good. Geothermal plants and large solar thermal plants are ranging at the end of the list. District heating networks played an important role within CONCERTO to connect and integrate renewable energy sources in the supply structure of buildings. So far 126 district heating networks have been acquired in the database. The important indicators for comparison with fossil energy carriers "primary energy factor" (PEF) and "CO_2 emission factor" can be calculated for 59 systems so far.

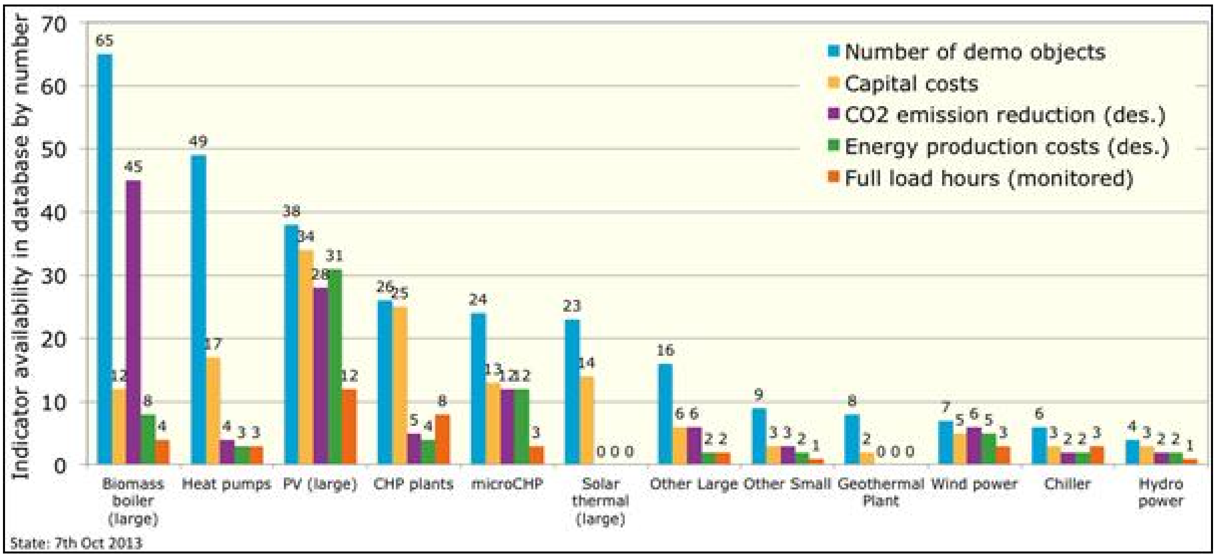

Figure 5.48: Indicator availability in database of different energy supply units compared to the total number of demonstration objects

In the database not only the raw data is subjected by automatic quality and plausibility checks, but also the calculated indicators can indicate wrong constellations of provided data. It is distinguished between incorrect and implausible values of an indicator. The actual corridors have been defined in the "Guidebook for Assessment". Figure 5.49 shows the spread of the indicator "Equivalent full load hours" (derived from the indicator "Annual average power") for all energy supply units, based on calculated design data and excluding incorrect values larger than 8,760.

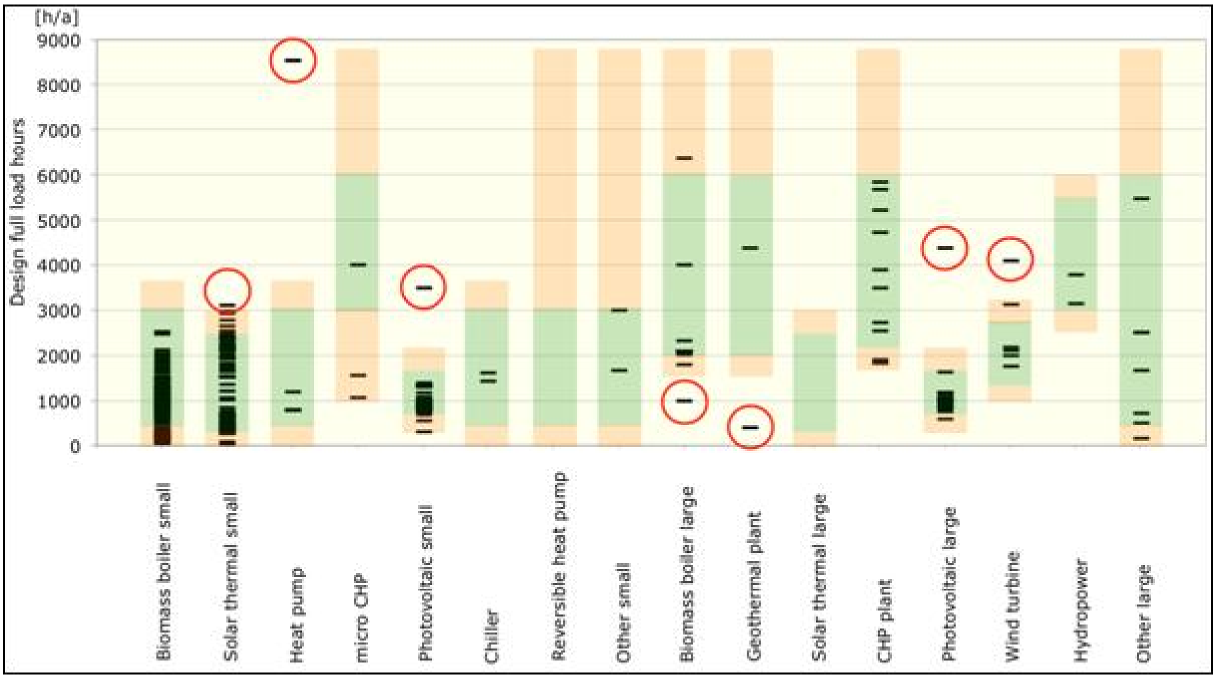

Figure 5.49: Full load hours (design values) of different energy supply unit types with plausibility corridors. Implausible values marked with red circle, conspicuous values lying in the orange ranges

It can be seen that only few objects in database cause implausible indicator values (red circle). A larger number of calculated indicators lie within the conspicuous corridors (orange background) and is considered with a more detailed checking during the assessment procedures. This checking takes into account different types, locations, models and installation options of the relevant energy supply units. The people from the individual CONCERTO projects are contacted and asked for cross-checking or for providing additional information.

The same procedure is performed with monitoring data and can hint to errors within the monitoring system or dysfunction of energy supply units. Figure 5.50 shows the current situation of the data for monitoring period 1.

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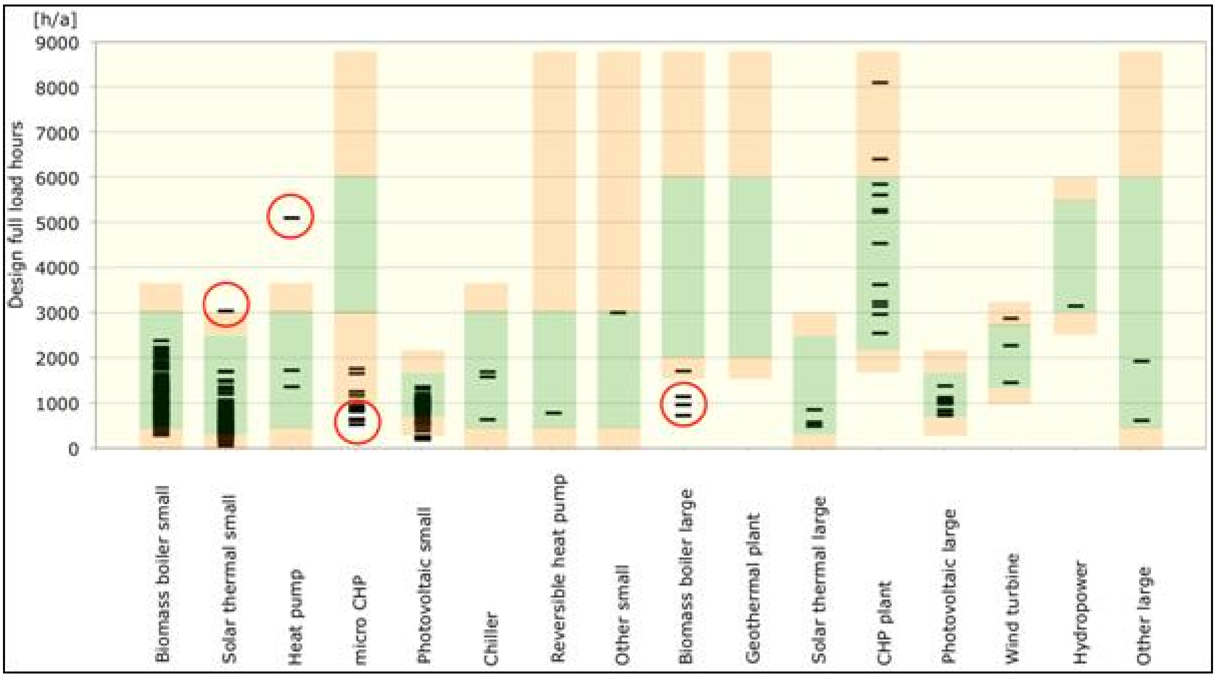

Figure 5.50: Full load hours (monitored values during first year after commissioning) of different energy supply unit types with plausibility corridors. Implausible values marked with red circle, conspicuous values lying in the orange ranges

5.4.2 Economic assessment results [C2]

As the energy production costs not only take the costs for energy carrier into account, but also the investment money, this indicator is a good measure to compare different technologies. Figure 5.51 shows the energy production costs for all CONCERTO demonstration objects with a relevant number, grouped by the type of energy they provide and secondly by the type of energy supply unit. The calculation is based on design data and performed without any grants.

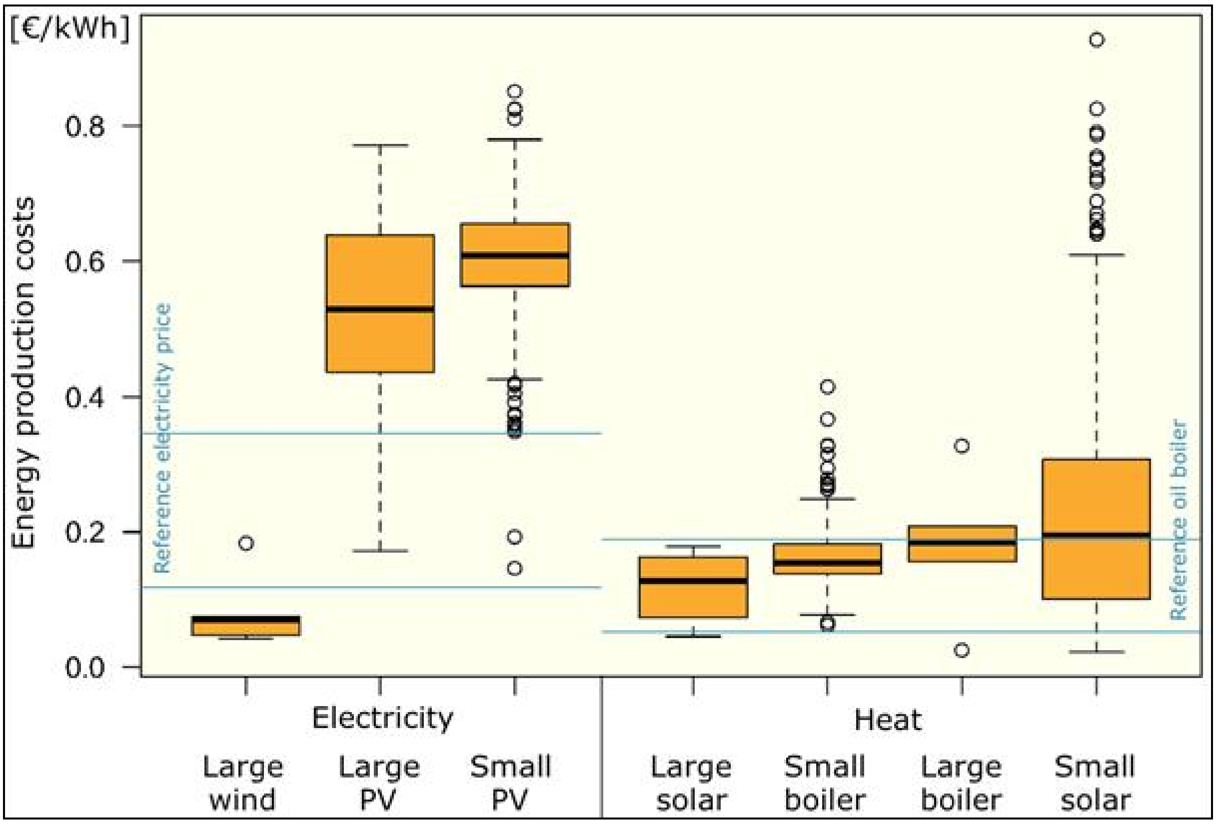

Figure 5.51: Boxplot showing energy production costs of all CONCERTO demonstration energy supply units (interest rate 3%, increase of energy price 5%/a, life-time 20 years, no grants considered) [C2]

It can be stated that most of the large wind power plants are already below the consumer electricity price (range between blue lines). Some of the large photovoltaic (PV) plants are touching the zone of the EU electricity prices, the small PV have still higher costs. In the field of heat production the large solar thermal plants in terms of production costs can compete with the heat from gas boilers, most of the small biomass boilers can as well. But large boilers and small solar thermal collectors have a relevant number of samples ranging above that corridor. If a large sample for an individual technology is available, more detailed analysis can be performed (e.g. grouping by years, size or technology). Within the database there is a relevant number of small biomass boilers, small solar thermal collectors and small PV systems.

In Figure 5.52 building integrated photovoltaic systems within the CONCERTO initiative have been analysed according to their specific capital costs, the dynamic payback period and the resulting energy production costs. The capital costs base on full investment costs without regarding any grants, which have been related to the according installed peak power. The dynamic payback period and energy production costs take the time value of money into account and have been calculated for an interest rate of 3%, an assumed life-time of 20 years and an increase of energy price of 5% per year. For the dynamic payback period a unified price for electricity of 25.28 € Cent/kWh (for the first year) has been regarded. There are not yet any systems available in CONCERTO, which have been commissioned after 2010.

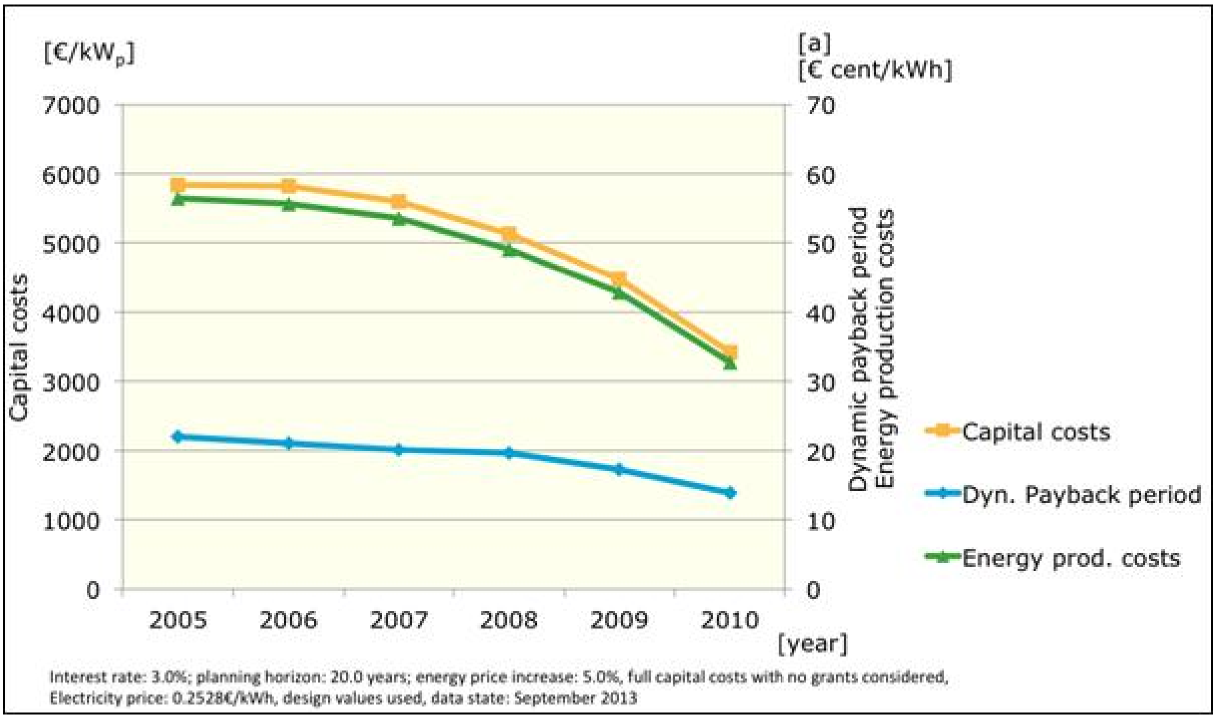

Figure 5.52: Economic indicators of small PV systems within CONCERTO grouped by years [C2]

The development of capital costs for building integrated PV systems shows a strong decrease from 2005 until 2010. In average over all available CONCERTO demonstration systems the reduction has been 2,413 €/kW$_{peak}$, 41% respectively within those 6 years.

The diagram has to be read very carefully, as in most European countries there is a special feed-in tariff for PV-generated electricity and the used energy price is not representative for all European countries. But still the diagram shows that by 2010 the energy production costs are about 30 € Cent/kWh and by the year 2007/2008 the payback time without any grants (funding subsidy or feed-in tariff) has in average undercut the assumed life-time of 20 years.

The diagram shows a trend of further decreasing capital costs for building integrated PV systems. This and a better performance of PV modules (efficiency factor or performance ratio) will lead to lower energy production costs and payback times. According to a recent study of Fraunhofer-Institut für Solare Energiesysteme (ISE) (2012) the energy production costs of small systems have undercut 15 € cent/kWh in 2012 (example of Germany and Spain) and are to fall below 8 € cent/kWh in Spain and below 12 € cent/kWh in Germany by 2030. Payback periods will then be clearly below 10 years.

The influence of grants plays an important role when regarding economic indicators like energy production costs, annuities or payback periods. CONCERTO grants could be combined with other municipal, regional or national funds. Figure 5.53 shows for 94 building integrated solar thermal systems of Weiz-Gleisdorf, Austria (Energy in Minds!), the influence of grants on the static payback period. At Weiz-Gleisdorf only systems for heating and domestic hot water preparation had been funded. The static payback period was calculated against a reference oil boiler.

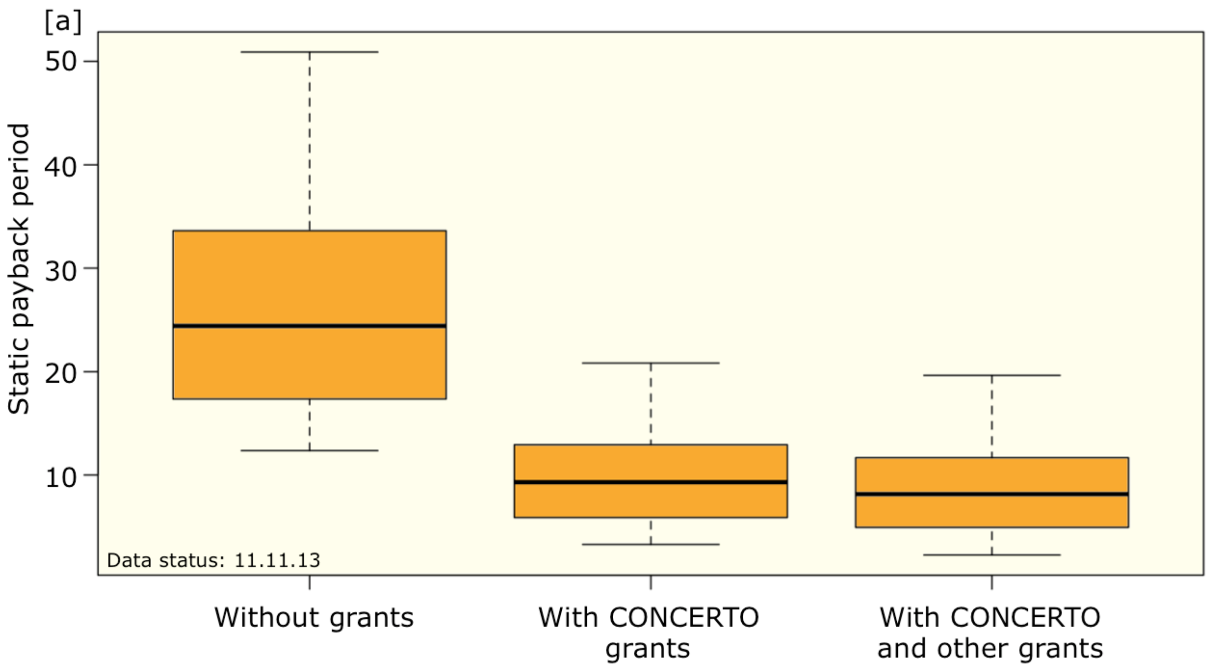

Figure 5.53: Static payback periods of 94 small-scale solar thermal systems with and without grants considered (the 10 lowest and 10 highest values have been erased as statistical outliers)) [C2]

It can be seen that without considering grants, but taking the total investment (reduced by the costs of the reference system) into account, the payback periods are between 12.3 and 50.9 years (the median value being lower than 25 years). CONCERTO funds lead to an essential reduction down to values between 3.3 and 20.8 years. When additionally other provided grants are included in the calculation, the building integrated solar thermal units aback after 2.3 and 19.7 years (median 7 years). In the last case all regarded investments pay back within a period lower than the expected life-time of 20 years. The influence of providing grants is essential for the user.

5.4.3 Macro-economic assessment results [C3]

Figure 5.54 shows the distribution of the triggered investment per grant grouped by the type of small building integrated energy supply units. Only CONCERTO grants have been taken into account, other additional grants are excluded here.

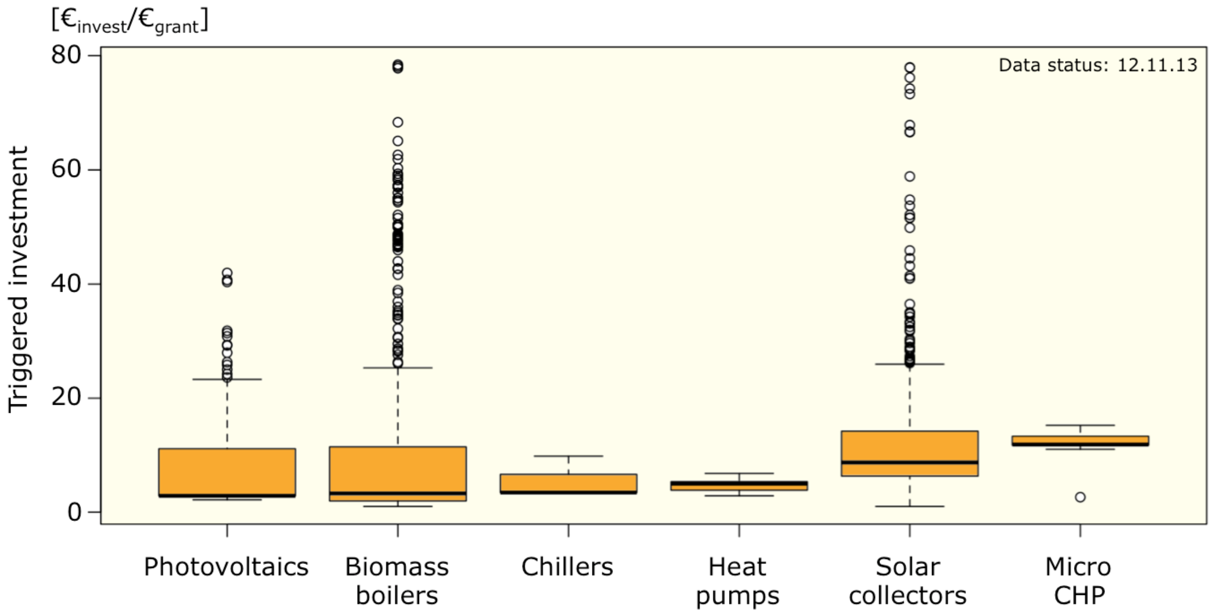

Figure 5.54: Statistical box plot of triggered investment per grant for CONCERTO demonstration objects (building integrated energy supply units), only CONCERTO grants considered, 18 values above 80 are not displayed [C3]

It can clearly be seen that the triggered investment per grant is having a wide spread (although 18 values larger than 80 have been excluded in the diagram). Where there is a large number of CONCERTO demonstration objects available - i.e. photovoltaics, biomass boilers and solar thermal collectors - we accordingly see a large range of triggered investment. The median values are lying between 3 €/€ with photovoltaics and 12 €/€ with micro cogeneration units (CHP), which means that for 1 Euro of funding additionally 2 Euros to 11 Euros respectively have been invested. The stimulation of the peoples' investment has been quite different throughout CONCERTO. Some definitely have been stimulated by the grants, but others would have invested anyway without any grants and took the CONCERTO funding as a nice add-on. A third group combined CONCERTO grants with other municipal, regional or national funds and then was convinced to invest the remaining money by themselves.

5.4.4 Environmental assessment results [C4]

The environmental impact of implementing efficient energy supply units based on renewable energy sources is mainly expressed by two indicators here: primary energy and CO_2 emission reduction. For all energy supply units with a given set of raw data in the database the annual CO_2 emission reduction (compared to a reference system) can be calculated.

Figure 5.55 shows the CO_2 emission reduction of building integrated energy supply units within CONCERTO. Figure 5.56 shows the same indicator for community energy systems. It can be stated that the large electricity producing plants (wind power and cogeneration) contribute a large share of CO_2 emission reduction within CONCERTO.

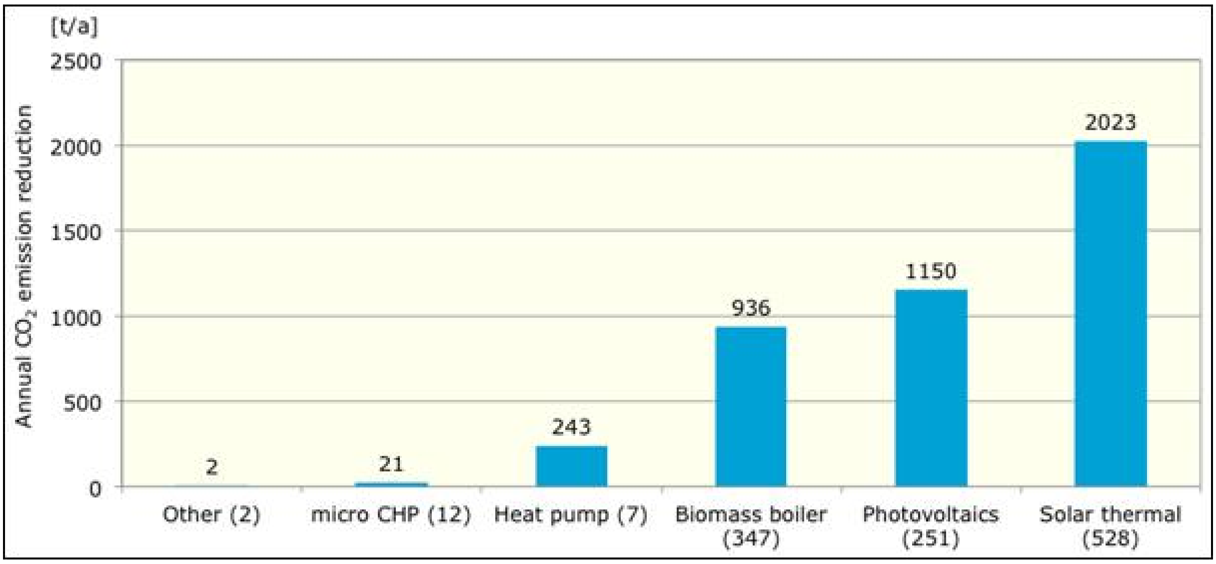

Figure 5.55: Annual CO_2 emission reduction by building integrated energy supply units (based on calculated energy output) [C4]

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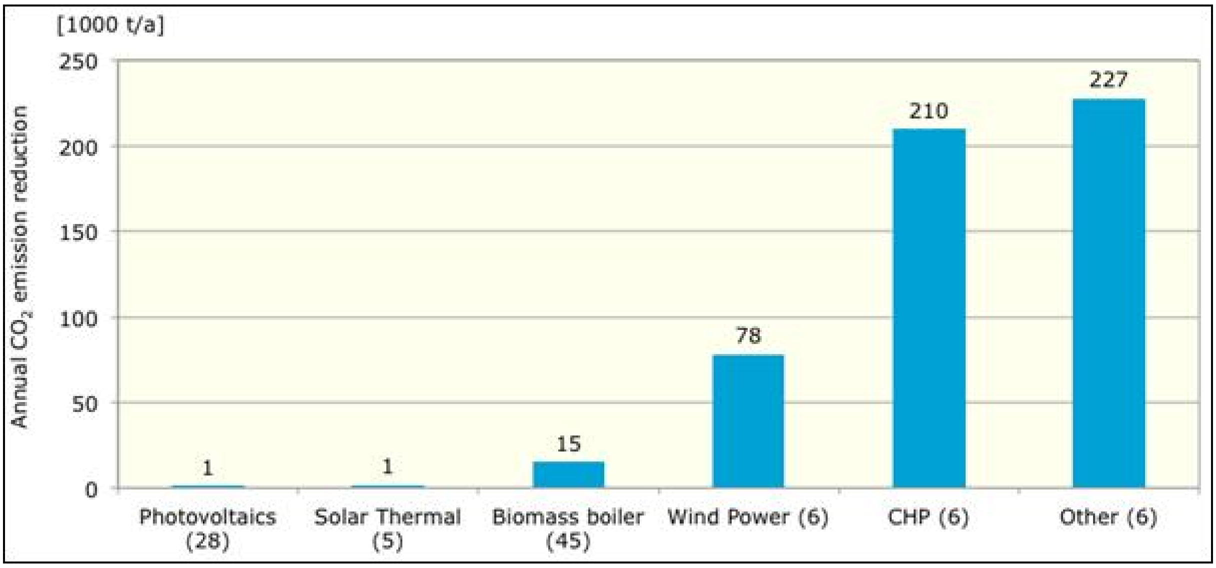

Figure 5.56: Annual CO_2 emission reduction by community energy supply units (based on calculated energy output) [C4]

The measures on district heating systems have also been evaluated in terms of environmental issues. Figure 5.57 shows the achieved primary energy factor of the added CONCERTO demonstration supply. It can be stated, that in general the achieved primary energy factors of the CONCERTO district heating activities undercut the reference boiler (and even most of the national average values from GEMIS) by far and therefore induced a large reduction of primary energy consumption in the field of heating and domestic hot water preparation.

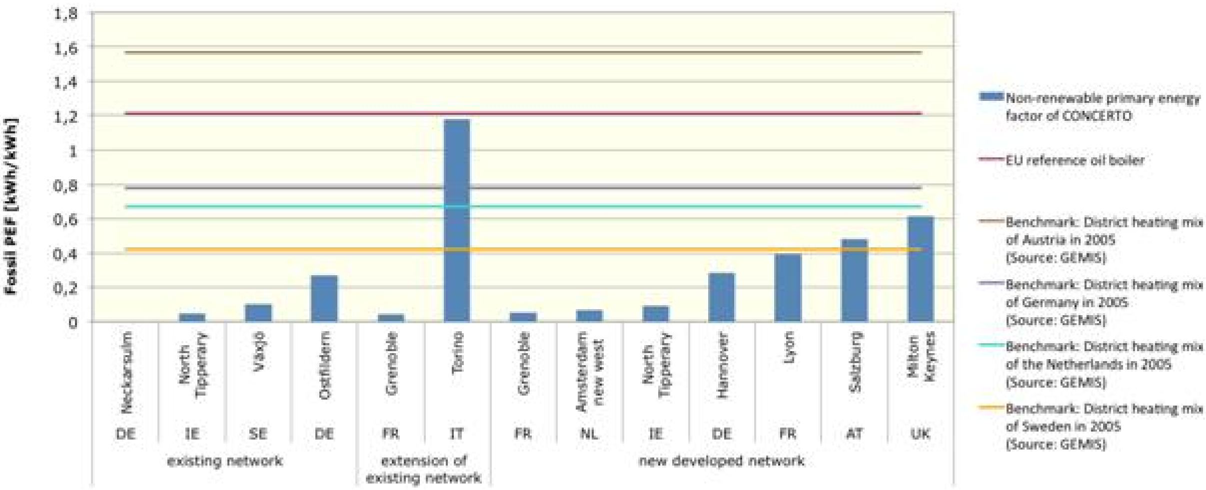

Figure 5.57: Fossil primary energy factor (non-renewable) of CONCERTO district heating networks, only new CONCERTO energy supply units considered

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5.4.5 Eco-environmental assessment results [C5]

Economic and environmental aspects have been combined within special indicators. The CO_2 mitigation costs declare how much money has to be spent to avoid the emission of one tonne of CO_2 in comparison to a reference system. In the case of heat energy a standard reference boiler is used for calculating the saved amount of CO_2 emission. In case of electricity the national electricity grid mix of the particular country is taken as the reference.

Figure 5.58 shows the CO_2 mitigation costs for different energy supply unit types as a boxplot across all CONCERTO demonstration objects, except the photovoltaics from France, Sweden and Switzerland. As in those countries (due to large share of hydropower or nuclear power) the CO_2 emission factors of the national electricity grid (Gemis (2013)) are very low, the calculated CO_2 mitigation costs are very high (see Figure 5.59). It can be seen, that only the wind power plants and the large solar thermal plants consistently have negative CO_2 mitigation costs. Except the microCHP systems all other energy supply units have some samples within the range of 0 and 70 €/t (the "external cost of damage point estimation, 2007" as benchmark). This means there are energy supply systems, which can avoid CO_2 emissions at a reasonable level. But often the CO_2 mitigation costs exceed the benchmark by far, especially the small solar thermal collectors are striking with several values even above 1,000 €/t.

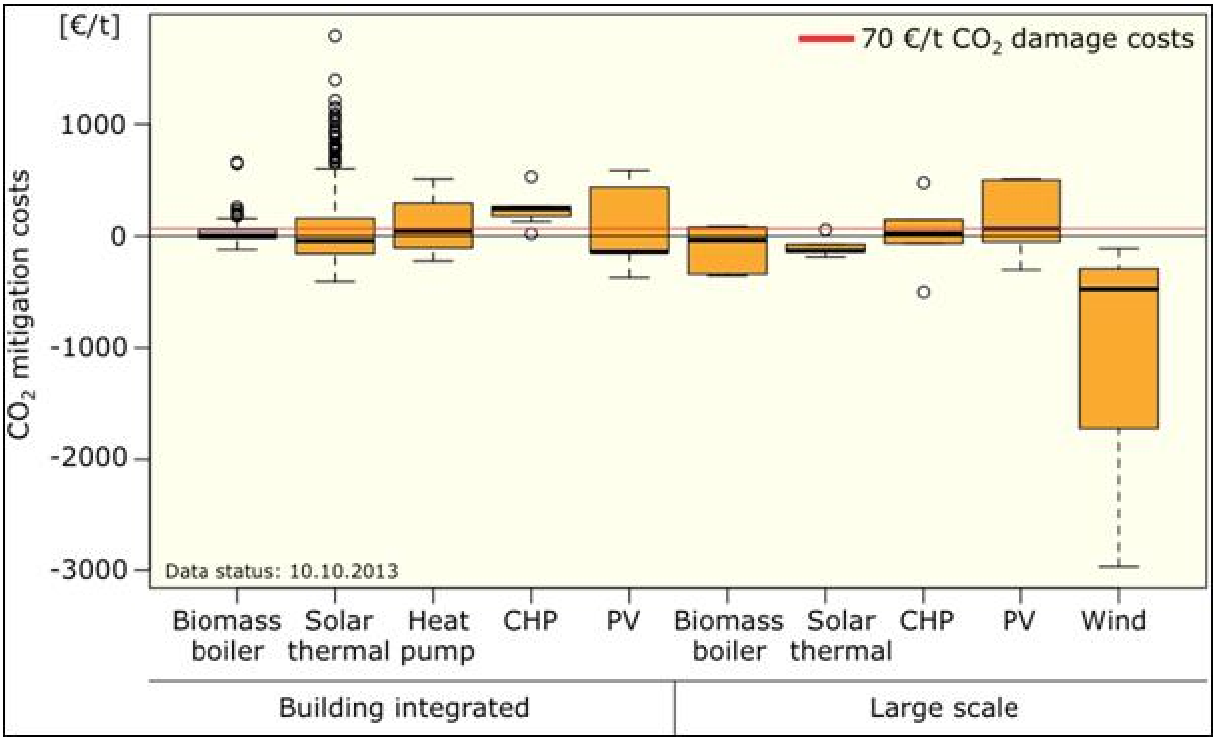

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Figure 5.58: CO_2 mitigation costs of CONCERTO energy supply units without photovoltaics in France, Sweden and Switzerland (life-time 20 years, 3% discount rate, 5% energy price increase per year) [C5]

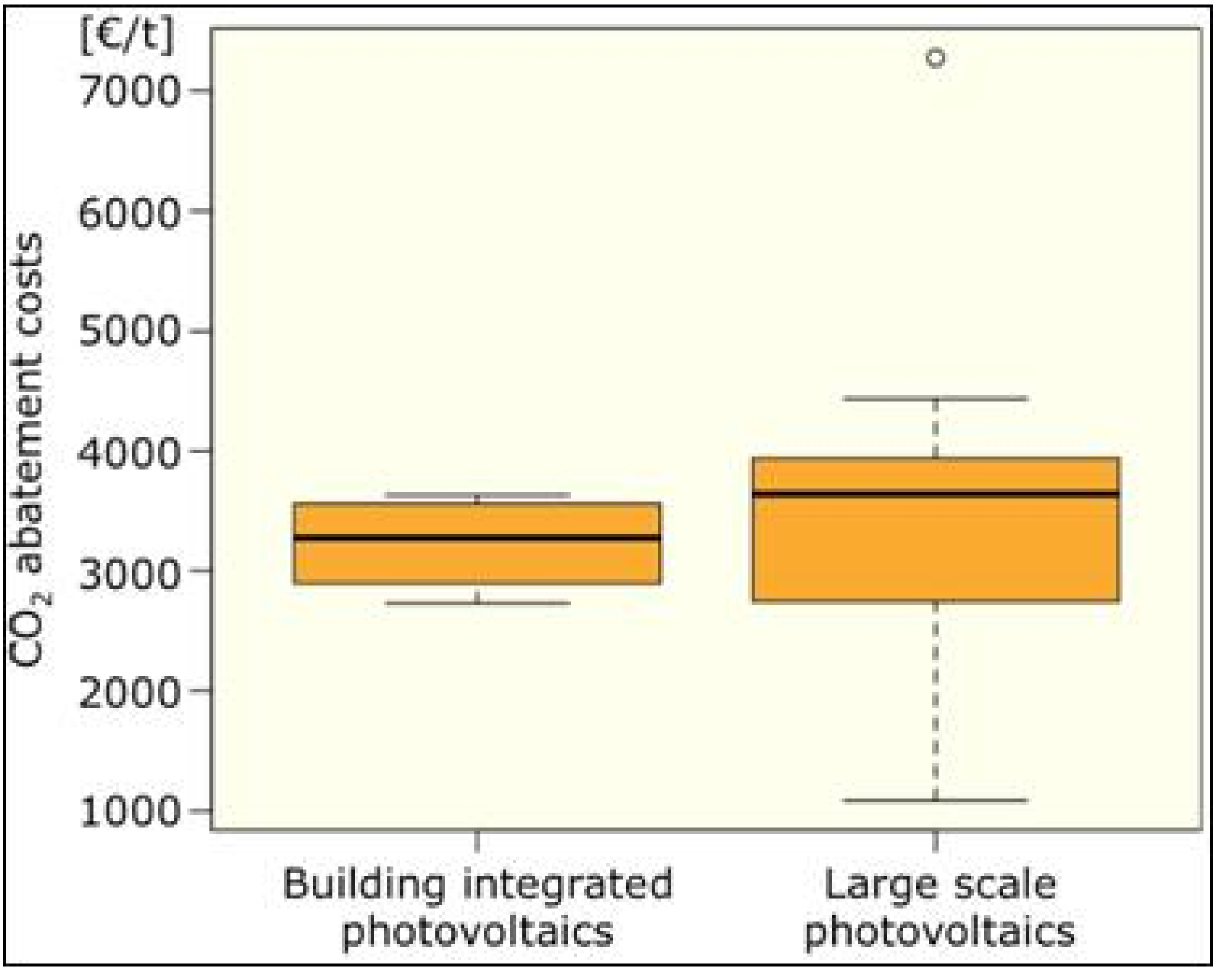

Figure 5.59: CO_2 mitigation costs of CONCERTO photovoltaics in France, Sweden and Switzerland (life-time 20 years, 3% discount rate, 5% energy price increase per year) [C5]

5.4.6 Technical assessment results [C6]

A methodology for a detailed technical assessment has been developed. The following technical indicators are calculable by the technical monitoring database (TMD):

- Annual average power (equivalent full load hours, specific yield)
- Efficiency

The overall heat transfer coefficient of a building's envelope is not a calculated indicator but can be filled as raw data into the data collections sheets and is then stored as metadata of the building into the TMD. The indicator "capacity utilization" as defined in the "Guidebook for Assessment" is based on high resolution monitoring data. As the TMD so far handles yearly and monthly data, its calculation is decrepit. The indicator "Quality of prediction" / "Degree of congruence of calculated annual final energy demand and monitored consumption" can easily be generated by combining the calculated and the metered energy output of an energy supply system.

Figure 5.60 shows the calculated annual specific yield of building integrated PV systems in CONCERTO compared to the measured annual specific yield (first monitoring year). The values are shown in relation to the possibly available solar radiation (average horizontal global radiation from 2002 until 2011) on the X-axis. The trend lines are of the type "linear" and some CONCERTO sites are displayed on the X-axis as an orientation for the reader.

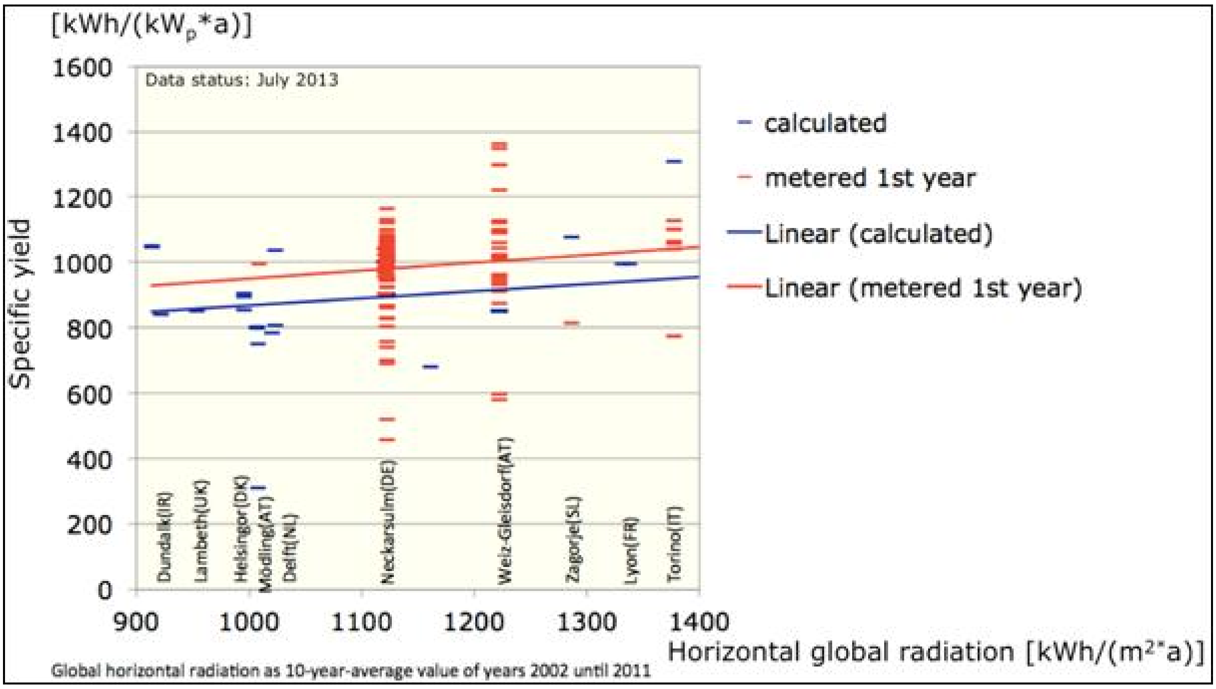

Figure 5.60: Specific yield sorted by available solar global radiation (10 year average) and separated by calculated and metered values [C6]

The calculation of performance has often been done just with a fixed value per site. For example in Neckarsulm the predicted yield of 900 kWh/(kW_{peak}*a) had been used without regarding orientation or performance ratio of the individual system. At Weiz-Gleisdorf 850 kWh/(kW_{peak}*a) and at Mödling 800 kWh/(kW_{peak}*a) have been used. Those values relate to standard radiation values derived from test-reference years or averaged climate data, so that there is an incline of the blue linear trend line. The measured values spread widely and some systems perform significantly below the predicted values. In average – and that is presented by the red linear trend line – the systems performed about 100 kWh/(kW_{peak}*a) better that calculated. The reasons may be unrealistic prediction values (too low), higher solar radiation during the monitoring period than averaged years or better efficiency of the PV cells than calculated.

For the calculation of the efficiency two values in the data collection sheets are needed: the amount of energy carrier feeding the energy unit and the amount of energy produced by the unit. The indicator was implemented in the TMD, but unfortunately there is very few data so far. Concerning small biomass boilers there is only one pellet boiler at Hannover where the efficiency could be measured for 3 years at 0.79, 0.75 and 0.72 kWh_{out}/kWh_{in}.

In Weiz-Gleisdorf, Austria, two wastewater heat pumps have been implemented, which achieve seasonal performance factors of 4.4 and 5.0 respectively (metered values). In Neckarsulm, Germany, a heat pump had been installed to raise the efficiency of an existing heat storage. Here a seasonal performance factor of 4.2 could be reached. Figure 5.61 shows the metered efficiencies of 6 micro CHP (combined heat and power) units in Grenoble. Two of them reach good values (5+6) and three of them lie within an acceptable range (2,3 and 4). The first one did not perform well, but there seems to be a problem with the metered data, as the resulting power to heat ratio is implausibly high.

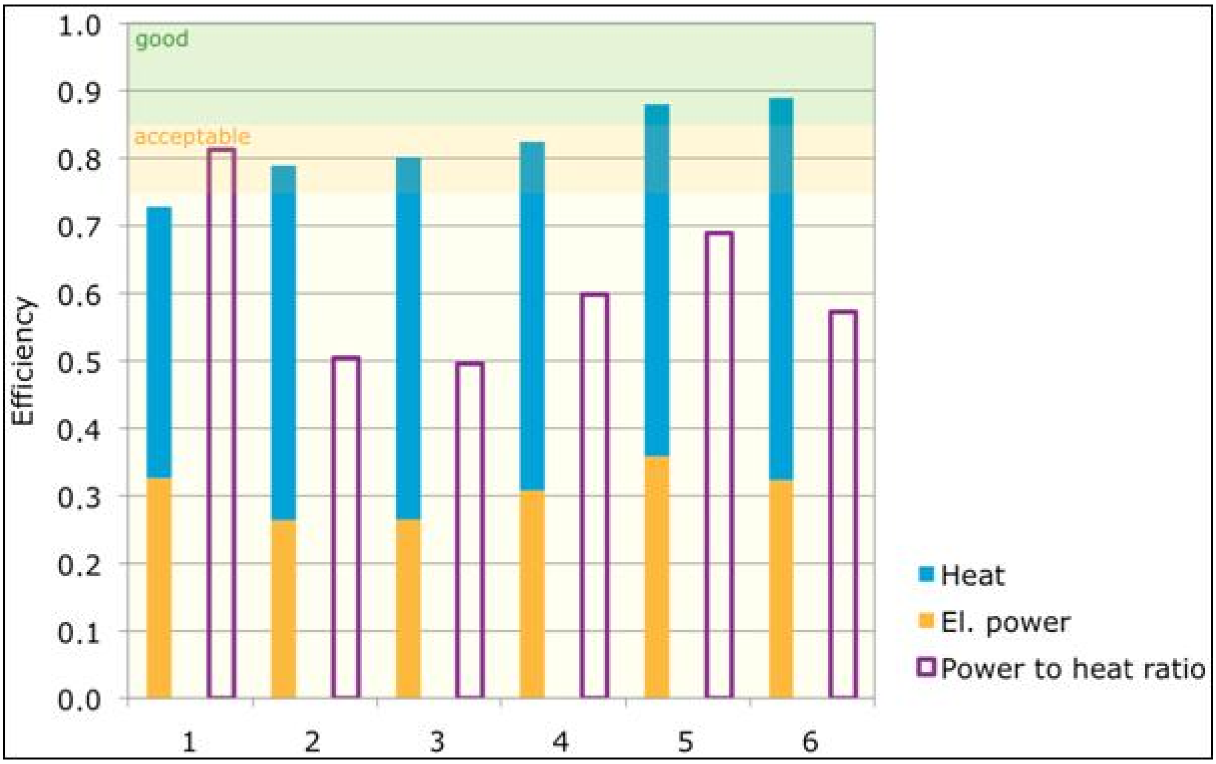

Figure 5.61: Metered efficiencies of micro CHP units at the "De Bonne" area in Grenoble [C6]

5.5 CONCERTO technology prospective study

Solutions and products in the field of information technology (IT) or information and communication technology (ICT) play an increasing role in the building and energy sector. This applies to the single building level, the district level and the country level. Their application even exceeds national borders, when challenging the distribution of energy across the Europe. IT is expected to play a key role in reaching the EU 2020 and 2050 goals: a "smart grid", the matching of energy demand and supply as well as the intelligent distribution and usage of energy, won't be possible without the corresponding infrastructure and real-time monitoring and management of that infrastructure.

The technology prospective study (DR3) gives a summary on the different IT solutions implemented in CONCERTO, describing how exactly they were implemented as well as the results and the experiences made from their application. It includes an overview of the current state of technology, a description of current legal and policy aspects dealing with IT-implementation and the numerous case studies from the CONCERTO demonstration and research projects. An outlook to the future potentials for using the described technologies from a technical, financial, legal and political point of view was given. Although the CONCERTO projects have not been projects of fundamental research but have a focus on demonstrating sustainable concepts for the future development of districts and communities, accompanied by research activities, they have shown excellent examples of IT solutions in the described fields of application. The projects have proved for different important IT solutions that they are working in real situations and that they are helpful for improving planning and operation activities and for reducing CO_2 emissions from buildings, neighbourhoods and cities. Furthermore some examples have revealed hints to just existing challenges for the wider implementation of innovative IT solutions. Even from a today's point of view many of the examples are innovative or have innovative aspects, although the first projects already started with the first CONCERTO call in 2005.

The technology prospective study has shown a broad range of approaches, which have been adapted to the individual situation of a project and which have always been related to practice. CONCERTO has enabled technology transfer between different cities and even countries and due to the good dissemination activities within the projects many people have been involved.

Within the technical scope there is a strong trend to more complex systems, bringing different fields of city development and management together. With the systems becoming more complex, there is the need for more assistance to the user. Solutions will have a market, if they manage to integrate more "intelligence" to the IT product and keep the interface to the different stakeholders or users simple and intuitive. As the system borders expand or even are dissolved, standardization and interfaces will be necessary. With the increasing share of renewable energy sources (more fluctuating energy production) and progressive implementation of decentralized energy production, the management of supply and demand will become very important. CONCERTO projects have testes different approaches or components of a future "smart grid". The analysis of legislation has shown that the framework for smart technologies has been set many years ago and that many technological issues have been or are being standardised. Nevertheless, it cannot be said for certain that all necessary smart technologies will reach wide spread market penetration in time to fulfil their part in reaching the 20-20-20 target. In general terms the main obstacles, which will under business-as-usual assumptions prevent the necessary investments from taking place or delay them far beyond the 2020 deadline, are problems related to permit granting (lengthy and ineffective permit granting procedures, along with public opposition), regulation (framework not geared towards delivering European infrastructure priorities) and financing (limited financing capacities of operators, lack of adapted funding instruments and sufficient support), as identified by COM(2011) 658 final - guidelines for trans-European energy infrastructure (Proposal) (European Commission, 2011).

With the expanding interconnections (infrastructure, trade, energy) across the borders of a city or a country it will become increasingly important to fix the legal framework. A big focus and challenge will be the privacy of each citizen when looking at the emerging markets in smart meters and smart grid. Research and development will have to answer the question how detailed real-time data on one hand and preserving the individual's privacy on the other will be matched.

Concerning economic aspects of IT integration, the claim for cost-optimal solutions in the EPBD should also be pursued here. CONCERTO projects have provided very little information on the economics, but pointed out, that IT-solutions have to be planned and integrated in the early planning stage to have a chance of becoming economically feasible at all. Calculation scenarios in this study have shown, that especially for private usage and small non-residential buildings payback for monitoring cannot always be achieved yet under certain conditions. The challenge for the market is to provide low-cost solutions with still a high accuracy and reliability. Nevertheless it could be shown that there is a realistic saving potential in energy consumption in both the residential and non-residential sector and that this potential should be activated on the EU's way to the 2020 or 2050 goals.

Chapter 6

Conclusions

6.1 Conclusions concerning the methodology

In the decision process of improving the energy efficiency of buildings and facilities and of increasing the use of renewable energy sources, a large number of stakeholders are involved. Depending on their interests, goals, areas of action and objects of assessment they need specific information. These range from issues concerning the technical performance and reliability of systems to the assessment of the economic advantageousness and up to questions about the effects of funding schemes. In the course of the project, it has proven to be advantageous to develop a system of indicators and evaluation criteria, which on the one hand covers the previously researched information needs of relevant stakeholder groups and on the other hand helps to analyze and present the available data. It is recommended to consider the interests of the following stakeholder groups:

- private developers and property owners
- housing companies
- municipalities
- energy supplier
- grant provider
- scientists.

Furthermore, at least the following objects of assessment should be accounted for:

- sites/communities
- energy supply units
- buildings.

The scope of assessment should comprise the following categories:

- economic
- macro-economic

- environmental
- economic-environmental
- technical

interrelations.

Based on an analysis of a survey consulting selected stakeholder groups it can be stated that it is important to meet the respective information needs. With the guidebook for assessment (s. Anex 8.6) foundations are provided. It is i.a. shown which indicators and assessment criteria should be considered for which objects of assessment and questions. It is recommended to further develop this approach in order to provide even more targeted information in the future. A major impact on the willingness to act of stakeholders has the chosen method of assessment and presentation of economic advantageousness. Here it is recommended that in the future the focus should be more on indicators like the equivalent price of energy and the CO_2 mitigation costs.

In the area of evaluation and assessment the importance of securing transparency and comparability became clear. It is recommended to emphasize this even more in the future. In particular, boundary conditions have to be described in detail and must be stated clearly. An analysis of energy data is only useful in accordance with climatic zones, an assessment of cost information only in the context of economic zones, as well as information on the price level, on VAT included/excluded as well as considered cost groups.

6.2 Conclusions concerning assessment results

The objectives of CONCERTO regarding buildings have generally been met and even in some cases exceeded. Almost every CONCERTO community clearly reduced the energy demand of buildings and the CO_2-emissions. Also the installed capacity of renewable energies has considerably been increased by most CONCERTO communities. The set target of reducing the energy demand of new buildings by 30% compared to the reference building according to the national regulation has been achieved in the CONCERTO communities with few exceptions. Most communities reached on average even a primary energy reduction of 70% and more. However, these performances have been achieved based on calculated design data but have to be confirmed with metered data. The same holds for the per-

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formances of refurbished buildings. A reduction of primary energy demand by 70% for space heating is not uncommon for residential buildings that have been refurbished in CONCERTO.

Generally, for energy supply unit types with a large number in the database (building integrated biomass boilers, solar thermal collectors and photovoltaic systems) statistical analysis and deriving general conclusions could be performed. For objects with a small number the focus had to be rather on individual examination in context of the location and specific situation of the demonstration project. The main parameters for energy supply units are often available, but for a more detailed technical and economic assessment the data precision would have to be improved in the future.

The CONCERTO sites have implemented a very broad mix of technologies, individually adapted to the local situation and their defined goals. From an economic point of view the feasibility depends strongly from the individual implementation as the examination of energy production costs and payback periods has shown. From an environmental point of view all energy supply units based on renewable energies and the large number of implemented district heating networks contributed to the strong reduction of primary energy consumption and CO_2 emissions.

Regarding large scale energy supply units (ESUs) the following general conclusions can be drawn: new emerging electricity and heat generating technologies can be already competitive with today's technology standard; especially innovative heat generating technologies are cost-effective compared to standard reference heating systems; and CHP is the most promising innovative technology with respect to economic competitiveness.

Finally, in terms of the regional distribution of CONCERTO communities, it is evident that all communities are able to achieve the CONCERTO goals irrespective the climate zone they are assigned to. Communities in cold-temperate boreal zones (II2) and cool-temperate zones (III2 and III3) have reduced the calculated non-renewable primary energy demand for space-heating more effective than communities in warm-temperate sub-tropical zones.

6.3 Conclusions concerning funding schemes

To reduce the administrative burden a meaningful and robust approach to organize future financial support schemes should be established. Out of the CONCERTO experience the following advice can be given.

Unfortunately, the database itself does not give concrete evidence for a fixed rate support.

in case of new buildings:
The energy-related additional costs were requested, but hardly available in the projects. There is little reliable information in the TMD (data gaps and data uncertainties) concerning energy-related additional costs for new buildings. As an alternative, it was examined whether and to what extent energy-efficient buildings can be implemented in the general budget of new buildings. This is partially true.

in case of refurbishments:
In the data analysis, it is assumed that the reported cost data for the modernization refers to the energy modernization (data uncertainty). Data sets are available in the TMD but they are eventually not reliable.

Since national minimum requirements and costs have changed in some countries since the start of the CONCERTO projects, the figures collected from the past - even with better data status - are barely applicable as basis for statements reaching into the future.

However, it is clear that the situation is very different - in relation to

- the price level of such measures in Europe
- regional construction culture and stakeholder structure
- the level of the initial situation (baseline) and the aimed energy level ("energy standards").
- the energy costs
- the type of implemented measures
- the economic profitability of single measures (economically profitable, economically profitable with financial support, not economically profitable even with financial support)

Therefore, the following general approach is recommended:

a) Firstly, the energy standard for the next funding period should be defined. This should be done separately for new construction (carbon neutral?) and for the existing building stock.

b) In our view, an approach that provides a percentage of the eligible costs as financial support appears particularly promising. It should be examined whether this percentage must be determined separately for each group of measures.

Overall, we suggest the following modular system of measures.
We recommend structuring the financial support according to different packages:
Package 1 Energy and climate protection concept
Package 2 Consulting, planning, project management
Package 3 Short-term and long-term monitoring including documentation and continued support
Package 4 Financial support for innovative solutions - A list of innovative solutions must be provided.
Package 5 Sharing of benefits of realized effects (based - e.g. on the avoided external cost of CO_2) 5a) / or: Percentage of the eligible costs 5b)
Package 6 External scientific support and evaluation.

When financial support is provided based on eligible costs the following items should be considered:

- binding rules for the calculation of eligible costs must be provided
- eligible costs must be calculated according to those rules (confirmation of accuracy by signature of liable institution)

6.4 Summary of key conclucions

Key Conclusions in short concerning the methodology:

- The evaluation of economic advantageousness & profitability and affordability requires transparency, comparability as well as appropriate methods and benchmarks.
- The quality of the collection of relevant economic, environmental and technical data in research projects must be improved. The application of the CONCERTO Premium Monitoring Guides is recommended.
- Criteria such as compliance with a cost frame, internal rate of return, equivalent price of energy and CO_2 mitigation cost are recommended.
- When interpreting payback periods it should be noted that in contrast to other investments in the industrial sector measures are economically justifiable if they amortize within their lifetime (here an average of 30 years).
- In tendency, the savings in computational evaluations are partly clearly

overestimated - in reality they are thus smaller than expected. Especially with private building owners, this leads to uncertainty and even financial problems. As a consequence, the assessment methodology needs to be adapted so that ex-post evaluations should necessarily be based on consumption (metered) values.

- For funding measures inter alia the determination of the "leverage" - € induced investment / € funding is recommended.

Key conclusions in short concerning the assessment results:

- The CONCERTO initiative proved highly successful. Based on indicators being calculable 93% of the communities reached the goal for new buildings to accomplish a minimum of 30% energy demand reduction. In the present context, this is determined by the fossil primary energy demand reduction for space heating compared a reference building according to national regulation. Thereof a share of 81% reached a reduction of 50% or even higher.
- For the calculable refurbished buildings 50% performed better than a reference building according to national regulation with regard to the reduction of fossil primary energy demand for space heating.
- Polygeneration was deployed in 42% of the CONCERTO communities.
- District heating networks proved to be a good measure for improving the efficiency of energy supply and for integrating renewable energies into the energy mix on a large scale.
- The monitoring concept provided monitoring data from 70% of the CONCERTO sites.
- With declining system costs and rising energy prices, the solar water heating and solar power generation approaches the threshold of economic profitability.
- In case of new buildings energy-efficient solutions can already be realized within a comparative framework of average building costs / financial budget - a prerequisite is the integral design.
- The situation in the area of additional thermal insulation is differentiated. The economic advantageousness depends on conditions such as: coupling with maintenance, current price level, baseline (initial situation in energy terms), etc.
- By the holistic approach the CONCERTO communities could achieve outstanding results in both increasing the efficiency on the demand side and reducing the usage of fossil energy sources.

Key conclusions in short concerning the funding approach:

- The realization of experimental-, demonstration- and example-projects remains indispensable. The promotion of such projects makes sense.

- The use of grants will remain necessary and useful. It serves:
  - a triggering of private activities (incentive / trigger).
  - the promotion of the market introduction of new products.
  - the closing of the gap to economic profitability.
- The financial support of the monitoring should be expanded-conditional on the provision of data.

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