Industrial Energy Efficient Retrofitting of Resident Buildings in Cold Climates

D.2.1 Demonstrator Munich

Project no:	260058	**Project acronym:**	E2ReBuild
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Partners: Lichtblau; TUM, GWGM, Schwörer

Authors: DI Florian Lichtblau, Architect BDA

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Project Participants

NCCSE	NCC AB, Sweden
MOW	Mostostal Warszawa SA, Poland
Schwörer	SchwörerHaus KG, Germany
Trecodome	Trecodome BV, Netherlands
NCCFI	NCC Rakennus Oy, Finland
Gumpp	Gumpp & Maier GmbH, Germany
Lichtblau	Lichtblau Architekten GBR, Germany
White	White Arkitekter AB, Sweden
SP	SP Sveriges Tekniska Forskningsinstitut, Sweden
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt, Switzerland
HSLU T&A	Hochschule Luzern Technik & Architektur, Switzerland
TUM	Technische Universität München, Germany
Aalto	Aalto-Korkeakoulusäätiö, Finland
GWGM	GWG Städtische Wohnungsgesellschaft München mbH, Germany
Opac38	Office Public d'Amenagement et de Construction de l'Isère, France
PSOAS	Pohjois-Suomen Opiskelija-Asuntosäätiö, Finland
ABV	Akelius Bostad Väst AB, Sweden
Aramis	Stichting Alleewonen, Netherlands
Augsburg	Wohnungsbaugesellschaft der Stadt Augsburg GmbH, Germany
Gallions	Gallions Housing Association Ltd, United Kingdom

Executive Summary

The E2ReBuild Munich Demo Project, main Dates and Facts:

Location	Bavaria/ Munich, Sendling, Badgasteiner-/ Fernpaßstraße
Building Owner, Leader	GWG Städt. Wohnungsgesellschaft München mbH
Planning, Energy and Realisation Management	KLA Kaufmann.Lichtblau.Architekten, München/ Schwarzach
Struct./ Systems planning	MKP Merz.Kley.Partner/ EST Energie.System.Technik
Funding/ Research	KFW, dena, LH München/ E2ReBuild
Construction Dates	Original 1958/ Constr. Phase 1 2010-11 (Phase 2 2012-13)
Net Dwelling Area	3.323 m2 (originally 2.012 m2, + 65 %, phase 2 + 155 %)
Residential Units/ Admin.	46 flats/ district housing office (originally 36 flats)
Envelope Quality Ht’	0.26 W/m2K (originally 1.56 W/m2K)
End (purchased) Energy	28 kWh/m2a (originally 280 kWh/m2a, - 90 %)
Primary Energy	22 kWh/m2a (originally 340 kWh/m2a, - 94 %)
Building Costs	950 €/ m2 GFA (gross, DIN cost groups 300/400, min. low-e fund. ca. 20 %)

The housing estate owned by GWGM was still in its original condition from the late 1950’s when planning began. Typical features included: widely spaced blocks of flats with nondescript outdoor lawn areas; mixed masonry construction with wooden-framed windows and concrete ceilings below non-insulated roofs; spartan, standard floor plans for flats around internal stairwells; massive deficits concerning fire safety, sound insulation, variability and comfort; basic building technology, high energy costs, inacceptable indoor climate.

The planning process for the necessary complete modernisation began in 2007 with a student project entitled “Weiterbauen” (Building further) at the Technical University of Munich, Faculty of Architecture, Wooden Construction). Starting from this basis, the architects with the building owner prepared a catalogue of target specifications concerning:
A / Perfect long time usage: Quantity and quality of flats, accessibility (disabled-friendly) and outdoor areas.
B / Sustainable construction: Substance-conserving, ecological prefab-construction, process and design.
C / Energy for the future: Highest conservation and efficiency, regenerative supply and overall economics.

The planning team led by Kaufmann.Lichtblau.Architekten developed a higher-density ‘Rejuvenation’ model. By incorporating a new building for the district office of GWG, the load-bearing structure of the original buildings could be retained but the access was changed, and the flats were transformed into individual modern residential units with attractive outdoor areas. The new building envelope, including that for an added storey, consists of pre-fabricated wooden elements meeting passive-building standards, with maintenance-free wall cladding and green roofs. Exemplary solutions were developed for life-cycle and energy balances, building science and structural aspects, fire safety, sound insulation and an efficient construction process. The minimal energy demand is primarily covered by renewable sources.

The first building phase was completed in 2012, phase 2 in 2014. Holistic value enhancement was reached, with optimal usage quality, a wooden construction offering active climate protection and energy efficiency which is fit for the future. These qualities promise the highest total economic viability for generations. The E2ReBuild project is very well accepted by the users, is published a lot, received important awards and it attracts visitor groups from whole Europe and many other countries.

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Figure 1 - Before: Demo Munich from Northeast

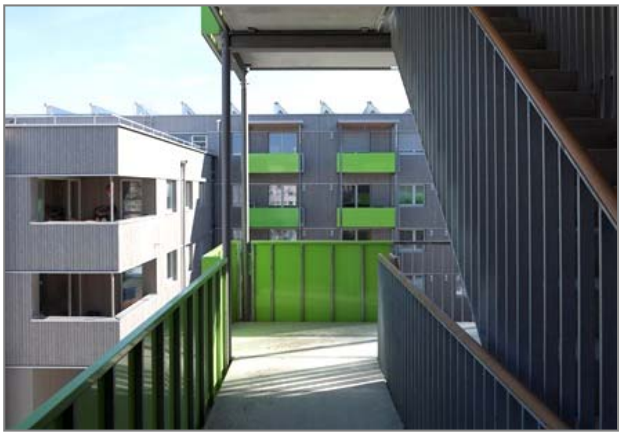

Figure 2 - After renewal: Demo Munich from West

1 Introduction

1.1 E2ReBuild Demonstrations

The demonstration projects in E2ReBuild are the core of the project. E2ReBuild is driven by the demonstration projects, whereas research activities feed into the demonstrations and results of the demos feed into the evaluation and lessons learned in other work packages. The results and conclusions from the demonstrations will be gathered to produce an industrial platform for energy efficient retrofitting (WP6).

The objective of the WP2 projects is to demonstrate seven high energy efficient innovative retrofitting technologies and measures for low energy performing buildings with typologies representative for a large geographical area in Europe.

Each project establishes and demonstrates sustainable renovation solutions that will reduce the energy use to fulfill at least the national limit values for new buildings according to the applicable legislation based on the Energy Performance of Buildings Directives (for 2010) and to reduce the space heat use by about 75% (Munich Demo more than 90 %).

Monitoring and follow-up: Based on recommendations given by WP5, monitoring takes place during at least one year within this project, in some cases for a longer period (Munich Demo two years, also continuing after the completion of this project).

One of the main issues in initial refurbishment discussions concerns costs. This has been treated in depth in deliverable D3.4 *Holistic Strategies for Retrofit* where costs from all demonstration projects are reported, analysed and discussed[1].

The demonstrations are supported by important work carried out in WP1, WP3, WP4 and WP5.

This deliverable is defined as a “demonstrator”. This document is the written record of the achievements of the demonstration project in Munich / Germany.

Figure 3 - The E2Rebuild team visiting Munich Demo Project, March 2012

[1] As report D3.4 is restricted, public information can be found in GEIER, SONJA; EHRBAR, DORIS; SCHWEHR, PETER (2014); Holistic Strategies for the Retrofit to Achieve Energy-efficient Residential Buildings. In: Proceedings 9th International Masonry Conference 2014. Guimarães (P)

1.2 Demonstration Munich, GWGM

Figure 4 - Aerial view existing settlement structure

GWG 'Städtische Wohnungsgesellschaft München mbH' is one of the two big social housing companies, public owned by the City of Munich. GWG holds about 20.000 residential apartments and also commercial facilities. A yearly investment of about 85 million Euros targets maintenance, modernisation and new building in the field of social rental housing. Six local facility management offices serve as contact points for the needs of tenants and maintenance crews.

A large part of the overall housing stock, also of GWG post-war decades in Munich, is functionally outdated, has high operational costs, is inadequate in terms of energy consumption and does not comply with society's living standards of today, let alone of the future. That means, that our central construction tasks lie either in a replacement - ecologically suboptimal - or in the 'Rejuvenation' of our existing residential building stock.

This necessity poses many dangers, however, when thought through it poses unique opportunities: it calls for a fundamental approach and a new interpretation of old housing. Structural sins of the past can be alleviated or even eliminated and the demand for a more sensitive recompression and redesign presents the possibility of sustainable urban corrections linked with high overall economic efficiency and an attractive future orientation.

Integral planning processes, especially for big housing companies, should be aimed at a rational, sustainable long-term context of:

- induced energy (traffic) and land consumption in urban planning, for real landscape preserving credibility,
- energy consumption due to production, transport and the minimisation of synthetic materials in construction,
- of operational energy consumption when using the buildings and installations, linked to high quality of use,

- energy input and problem waste on ‘re-use/ down-cycling/ disposal’ after restoration or demolition
- and the easing or reshaping of our social, cultural and economic network of society relationships.

Figure 5 - Site Plan Phase 1 (right, middle) and 2

As the Munich Demo Project we present a GWG housing estate in Munich-Sendling, situated about 5 kilometres West of the City Centre and side by side to the so called ‘Westpark’.

The housing typology consisted of some uniform standard blocks with 3 stories, accessed by inner staircases, built in the post-war decade of the fifties to fulfil urgent housing needs. The resources were quite poor concerning material, construction and design. The result was a lack of variability, technical facilities, daylight and comfort inside the buildings.

The outdoor areas consisted of simple lawn fields and some untended overgrown old trees, entirely shadowing parts of the dwellings. Car parking took place in the surrounding streets. Some building re-densifications of the area became realised in the seventies and eighties, these can easily be identified as ‘alien elements’ in the aerial view (see Figure 4).

The tenants were mainly elderly people with all kinds of social background. As the complex development proposal of the Munich Demo Project of course required empty buildings, the strategy was to translocate all the tenants at an early stage to other GWG dwelling houses in the near surroundings.

When we started a university project in 2006, the buildings were already nearly uninhabited. The students of architecture had to learn measuring the existing old buildings, simulating their energy performance, drawing the plans and writing status reports. The results proved the dramatic quality deficits and climate loads of that generation of buildings, on the other hand the grey energy amount, still incorporated in the primary structure.

Summarized there was a strong fundament and creative motivation for the future architectural designs.

1.3 Existing Buildings

Figure 6 – Before: Building from West, Entrances

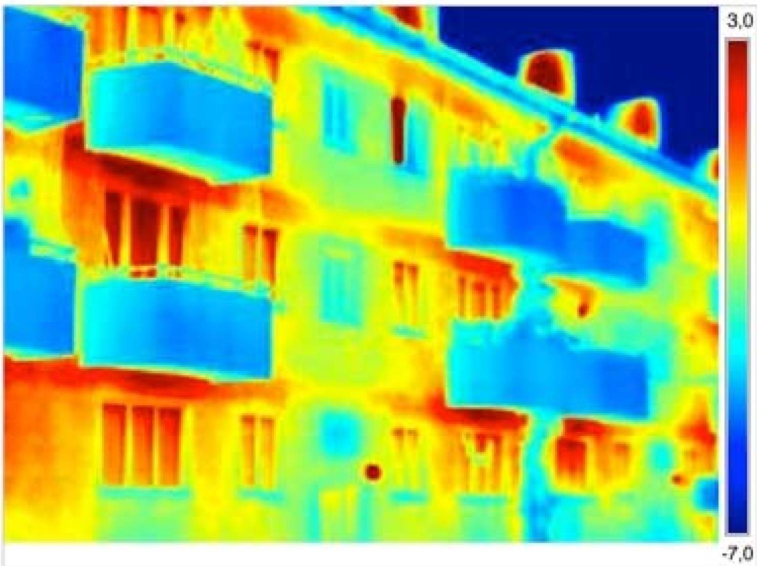

Figure 7 - Before: Building from West, Thermography

The demo buildings in their initial situation: mass commodity of the 1950s, masonry bolts with unit floor plans and individual room heating. After two generations they were still in their original condition for the most part. The heating requirement is approximately at factor 5 above the new construction value according to EnEV 2009. It was only the excellent location that kept the buildings from permanent vacancy.

In 2006/7 the project first focused on a corporate study design dealing sustainable development, led by the chair of wooden constructions at the TU Munich (Prof. Hermann Kaufmann) – with remarkable results. A research project ‘TES Energy Facade’ subsequently followed, parallel the agreement for planning and implementation by the public housing association with our ArGe Kaufmann.Lichtblau – in short: the challenge got serious!

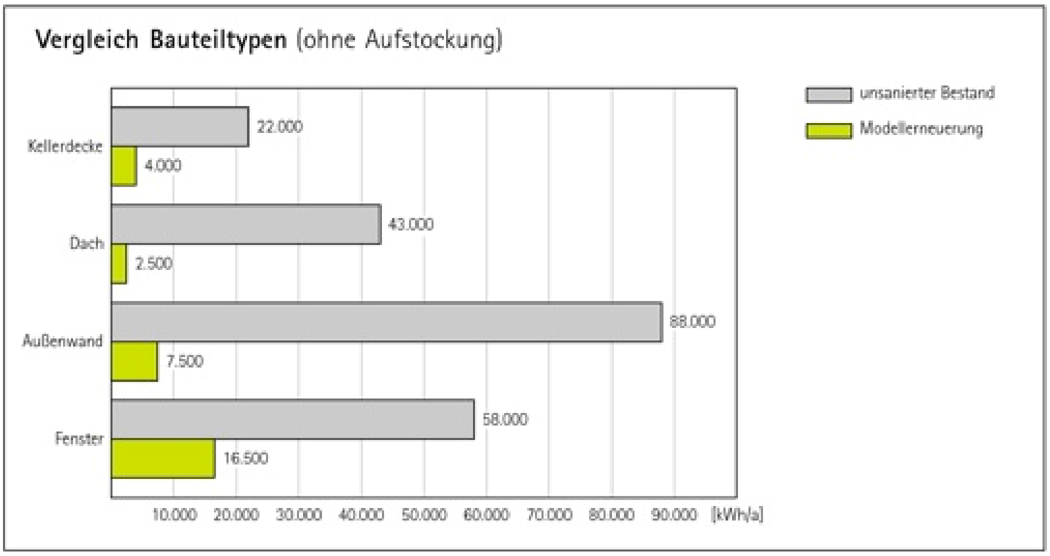

Figure 8 - Envelope components, thermal losses before/ after ..

The simulated room heating energy demand of the pre-retrofit buildings showed the dramatic amount of thermal losses according to components of the building envelope. Hot water was primarily produced by individual electric heaters, the second reason for the high primary energy figure and CO2 emission. In addition, the before analysis showed serious deficiencies in statics, fire safety and building physics (for example acoustics).

Construction dates	Original 1958/ construction phase 1: 2010-11 (phase 2: 2012-13)
	3 floors with inner staircases, concrete block walls, ferroconcrete ceilings, wooden windows (2 single glasses), inclined roof wood with brick tiles
Net dwelling area	Originally 2.012 m2, after 3.323 m2 (+ 65 %)
Units	Originally 36 flats, after 46 flats/ district housing office
Envelope quality Ht’	Originally 1.56 W/m2K, after 0.26 W/m2K
End (purchased) energy	Originally 280 kWh/m2a, after 28 kWh/m2a (10 %)
Primary energy	Originally 340 kWh/m2a, after 22 kWh/m2a (6 %)

The pre-analysis of the original building proved a healthy and stable primary structure, able to carry all future loads. The primary substance weight contains about 80 % of the embodied energy. Waste or resource ? Our basic strategy: Reuse, Reduce, Rejuvenate.

1.4 Holistic Goal Settings

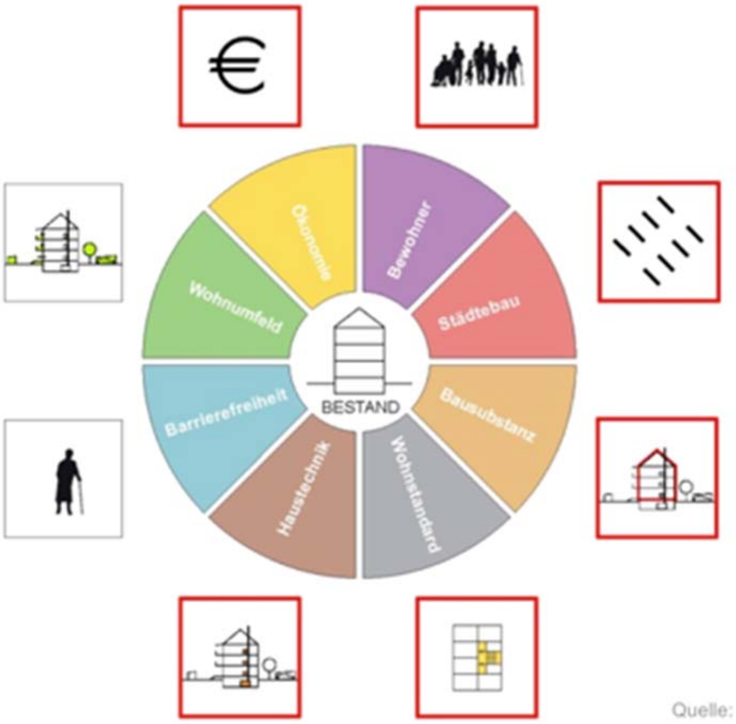

Figure 9 - Holistic Planning Targets (Source: Oberste Baubehörde Bayern)

So the modern engineer's wooden construction was to become the renovation method of the building stock? Until now, a lot was theory as in architecture. The design, it is said, shows the talent; the art begins with the implementation and realisation. The building owner and our planning team – after detailed preliminary discussions – agreed on a set of objectives. This corresponds entirely with the requirements (see Figure 9).

Among other things, this means the widest possible preservation of existing primary structures for the prevention of grey energy and waste from demolition and reconstruction. An upgrade-free economic life expectancy of at least 40 years for complete modernisation – 46 (36 before) flats and new local facility management office, all in the lowest energy standard – essentially covers three central objective areas:

A / Perfect long-time usage: Quantity, quality, accessibility (disabled-friendly) and outdoor areas.

B / Sustainable construction: Substance-conserving, ecological prefab-construction, process and design.

C / Energy for the future: Highest conservation and efficiency, regenerative supply + overall economics.

This 3-point-set of objectives offered different approaches in planning, communicating, contracting, accounting (cost break down) and documentation. The most appropriate way for our case finally turned out to be:

A / Function and Design, B / Envelope Construction, C / Systems and Energy (see 2.1-3).

Needless to mention, that the ecological, the social and the economic strategy of standard refurbishments had to be reconsidered as a whole. The provocative demand of the building owners to the planners: all aforementioned objectives should be reached cost-neutrally within public housing subsidies. The unavoidable extra costs for a prototype with ‘attribute sustainability’ must be financed in full by appropriate subsidies for energy renovations (plus1 €/m^2 rent as a user contribution for minimal energy costs). That should occur through the holistic added value as described, and furthermore a new ‘league of efficiency’ will be reached.

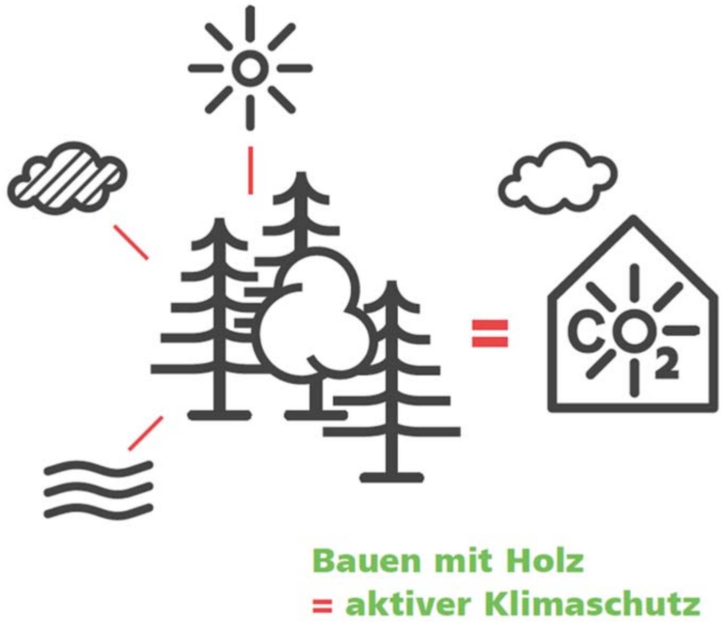

Figure 10 - Timber construction = active climate protection (Source: Holzforschung TUM)

Despite obstacles and risks we accepted the challenge. The strategy of holistic refurbishment we called ‘Rejuvenation’, both for the buildings and the social context. The urgent need for action concerning natural resources in our opinion has to be answered first by the ‘creative resource of exploring synergies’. This proved to be the secret of added values, the attribute of overall economics and the decisive social win-win-win result:

- The City of Munich wins for increasing valuable modern living space,
- The owner GWG for overall profitability with little maintenance need,
- The tenants for tomorrows living comfort with minimum, stable operation costs,
- The neighbourhood for a green urban identity in demographic function.
- The microclimate wins for less heat, dust and noise by building typology,
- The macroclimate and environment for active/ passive relief measures, both materials and emissions.
- Last not least: the planning team, the owners and contractors for winning substantial new knowhow and experience in dealing with the future of our past.

The aforementioned planning attitude onto the final results have been made realisable by appropriate use of all national public subsidies for low-e renovations, supported by becoming a European E2ReBuild Demo Project.

2 Energy Efficient Retrofitting

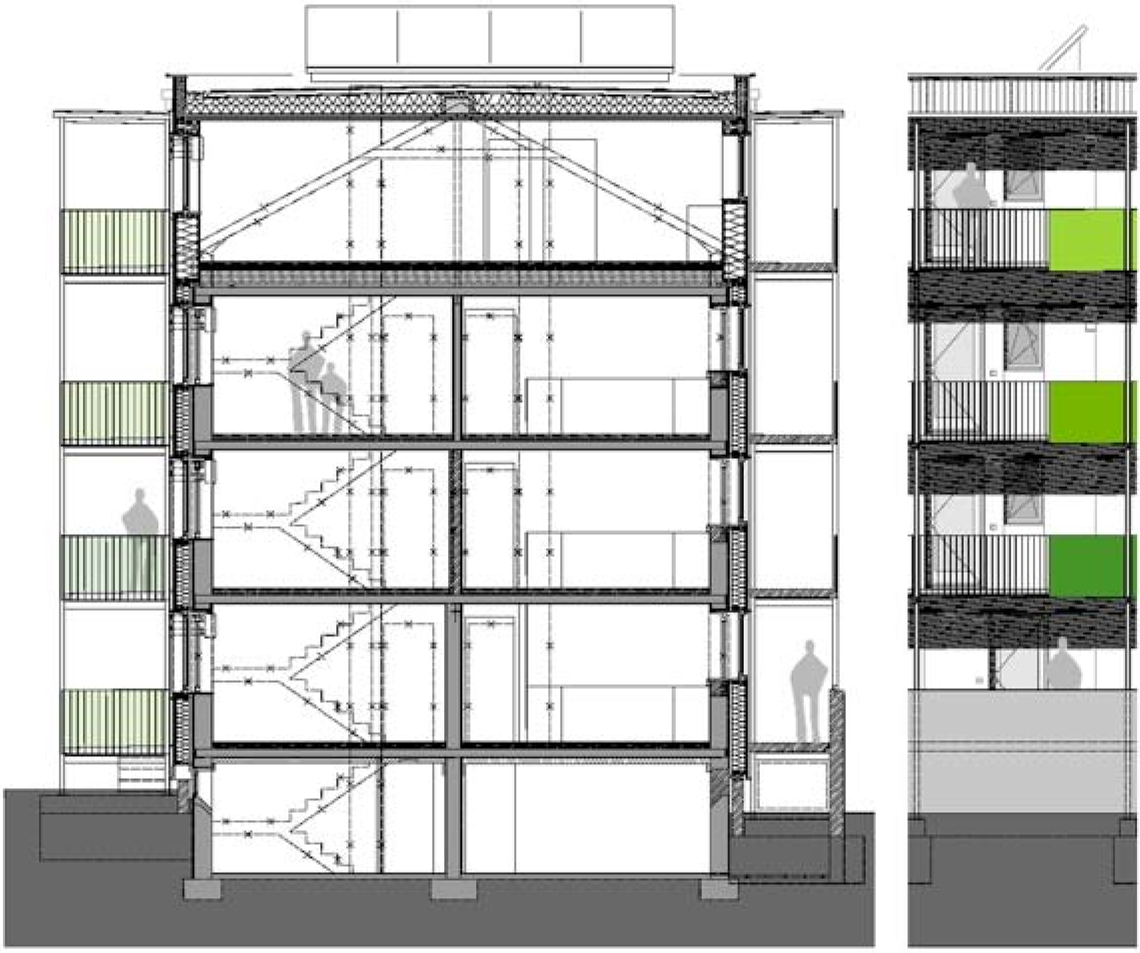

Figure 11 - Total cross section and partial elevation East with access galleries/ balconies

2.1 Function and Design

Figure 12 - House 48: Elevation East with new access galleries, terrace and solar thermal collectors

According to the aforementioned catalogue of goal settings (see 1.4) the first of three sets is:

A / Function and Design: Perfect long-time usage regarding quantity, quality and environment

- Compress rentable living areas of the 1b site by more than 60 % - use building ground, ensure revenue.
- Create market-conform mix of flats with light, attractive layout – offer new living quality.
- Integrate disabled, elderly and child friendly functional residential use – include demography.
- Make the new living environment spacious, social, close to nature and robust – design for urbanity.
- Retain and trim old trees, studies of the sun show daylight quality in each residential area in the quarter.

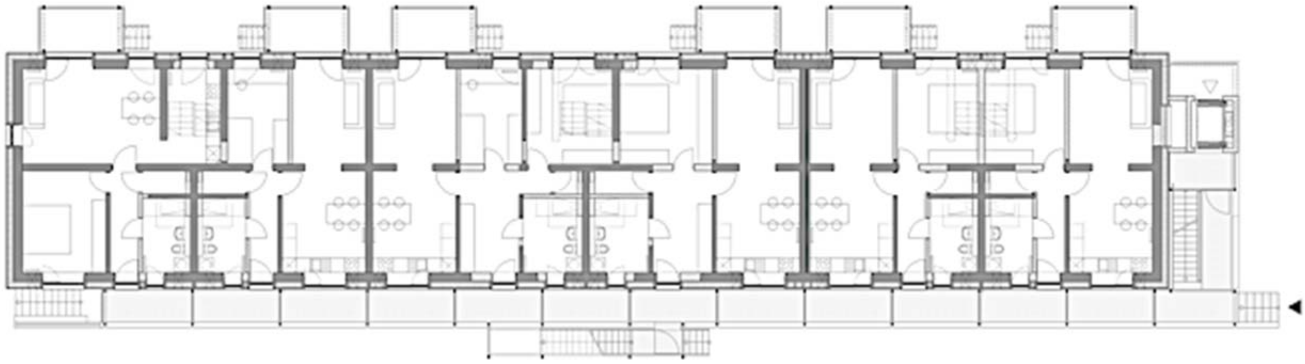

Figure 13 - House 48: Floor plan showing reorganisation and conversion within old carrying structure

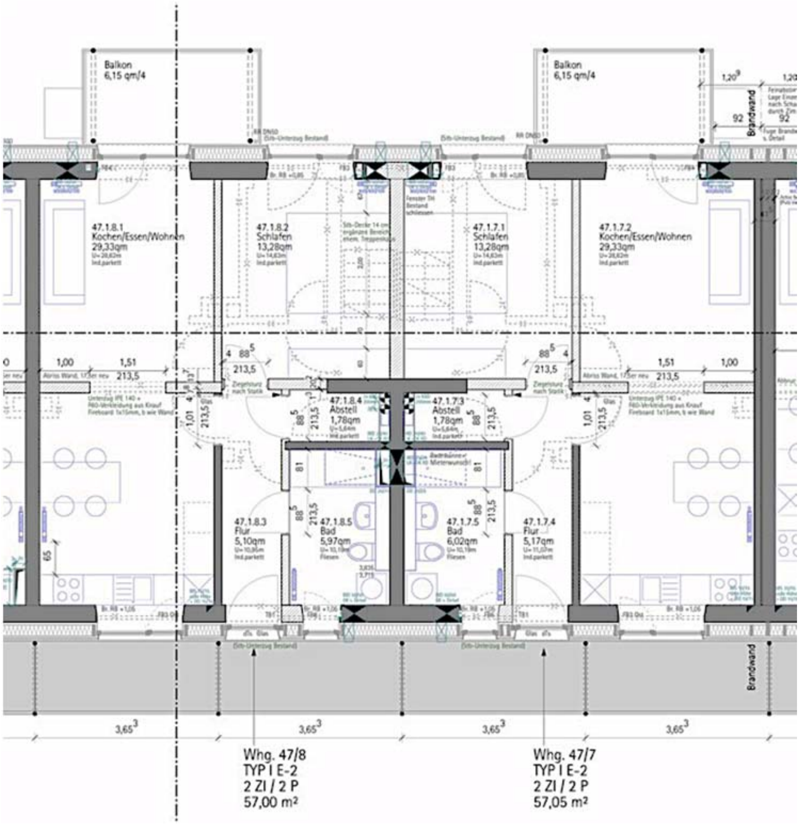

Figure 14 - Floor plan, conversion in detail

Compared to a ‘standard’ refurbishment the expected, decisive long-time achievements realized in the Munich Demo Project for E2ReBuild are in terms of A / Function and Design:

- Re-densification of living space more than double of standard: + 65 % (phase 2 + 155 %) by new parts + storey additions. Barrier-free access by elevators and open galleries, old staircases become part of living space.

- Conversed, day lighted flat design with new kitchens, bathrooms and big balconies (partly terraces) form the core of new life quality. Natural materials as timber flooring and ecologic surface treatment serve healthiness.

- Market friendly mix of flat typologies, barrier-free use and openness for a wide social range and age of residents offer new chances for a changing demography. This really justifies the relatively high expense.

- Defined new building spaces and outdoor facilities should create identity and pleasant usability for all. The social aspects of recreation at home and reduced traffic volume belong to major goals for urban planning.

- The ‘grown’ surroundings are interpreted and newly designed in harmony with sunlight conditions. In our opinion, this is a primary element for regenerative energy supply and durable healthy living conditions.

2.2 Envelope Construction

Figure 15 - Partial section and elevation East

According to the aforementioned catalogue of goal settings (see 1.4) the second of three sets is:

B / Envelope Construction: The physical needs for structure, ecology and design, manufacture process

- Perfectly ecological assembly system of high quality and precision – optimise life cycle balance.
- Constructive integration of sound insulation and fire protection, as well as statics, hvac and solar active components – understand flexibility.
- Digital measurement and prefabrication, low weight and short on-site period – track process efficiency.

- Low maintenance surfaces and many selectable design variations – enable timeless, attractive architecture.
- Best daylight and thermal performance in 'Passivhouse Standard', also airtightness (Blower Door Test).

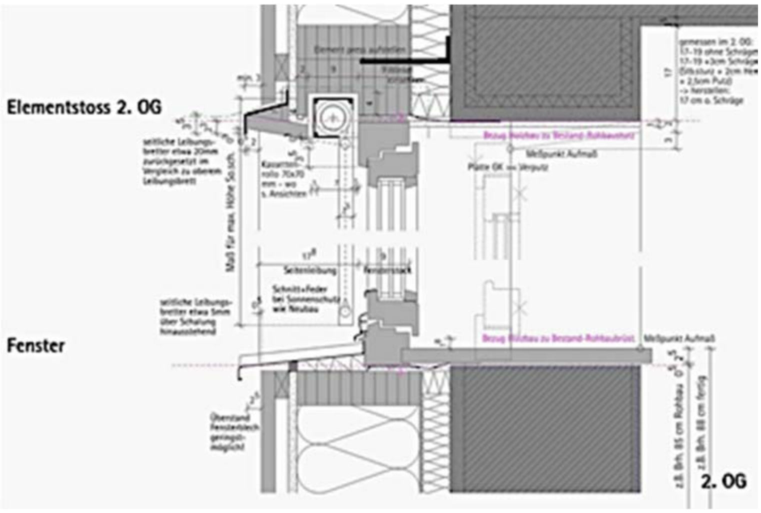

Figure 16 - Detail construction (existing structure dark

Compared to a 'standard' refurbishment the expected, decisive long-time achievements realized in the Munich Demo Project for E2ReBuild are in terms of B / Envelope Construction:

- Conservation and remodelling of carrying building substance: reduction of grey energy and waste disposal. Predominantly light, regenerative raw materials for the new building envelope and extensions ensure active climate protection, digital measuring and prefabrication lead to an effective construction process.

- Stripe fundaments on long sides to carry new timber façade elements, steel access galleries and balconies. Old upper ceiling reinforced by wood construction before attachment of the additional storey.

- TES Energy Facades, prefabricated with cellulose insulation added to existing outside walls, U-wall 0,12 W/m2K. Painted timber windows with triple glazing, U-window 0,9 W/m2K and outside solar control fixtures.

- The roof consists of visible timber beam construction, highly insulated with U-roof 0.11 W/m2K and greening on top. Accessible terraces and thermal solar collectors occupy the whole surface area.

- Constructive facade integration of fire protection details, for example horizontal metal brackets, mineral wool insulation in access areas, or service technics like ventilation devices with heat recovery.

- Visible facade surfaces timeless designed in pre-greyed spruce boards, nature coloured fibre cement claddings for access areas, both for long lifetime without expected maintenance need and contrasted with green railings.

2.3 Systems and Energy

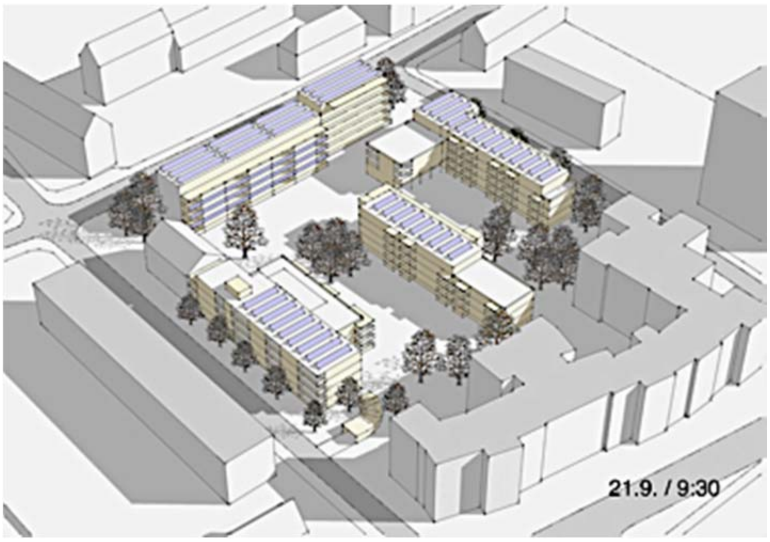

Figure 17- Dynamic simulation sunlight and energy

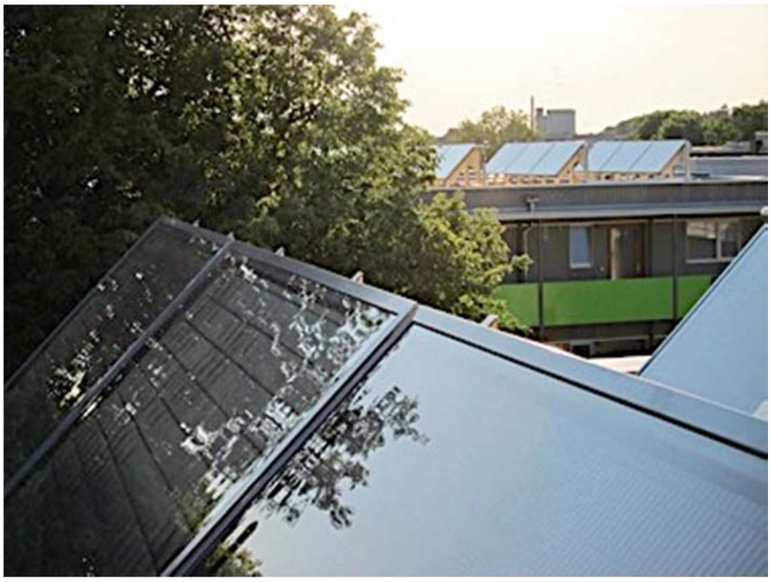

Figure 18- Green roofs with solar thermal collectors

According to the aforementioned catalogue of goal settings (see 1.4) the third of three sets is:

C / Energy and Systems: The energy balanced concept, standards, maintenance, safety and economy

- Minimise demand room heating, ventilation, artificial light to under 50 % of a new construction – achieve supply security.
- As much as possible, provide regenerative energy for heating and electricity – near zero emissions.
- ‘Triple win’ – ease the economic burden of the owner/ tenant/ environment – produce overall profitability.
- Offer simple, safe, long-lasting technology for ease and cosiness – promote good health and comfort.

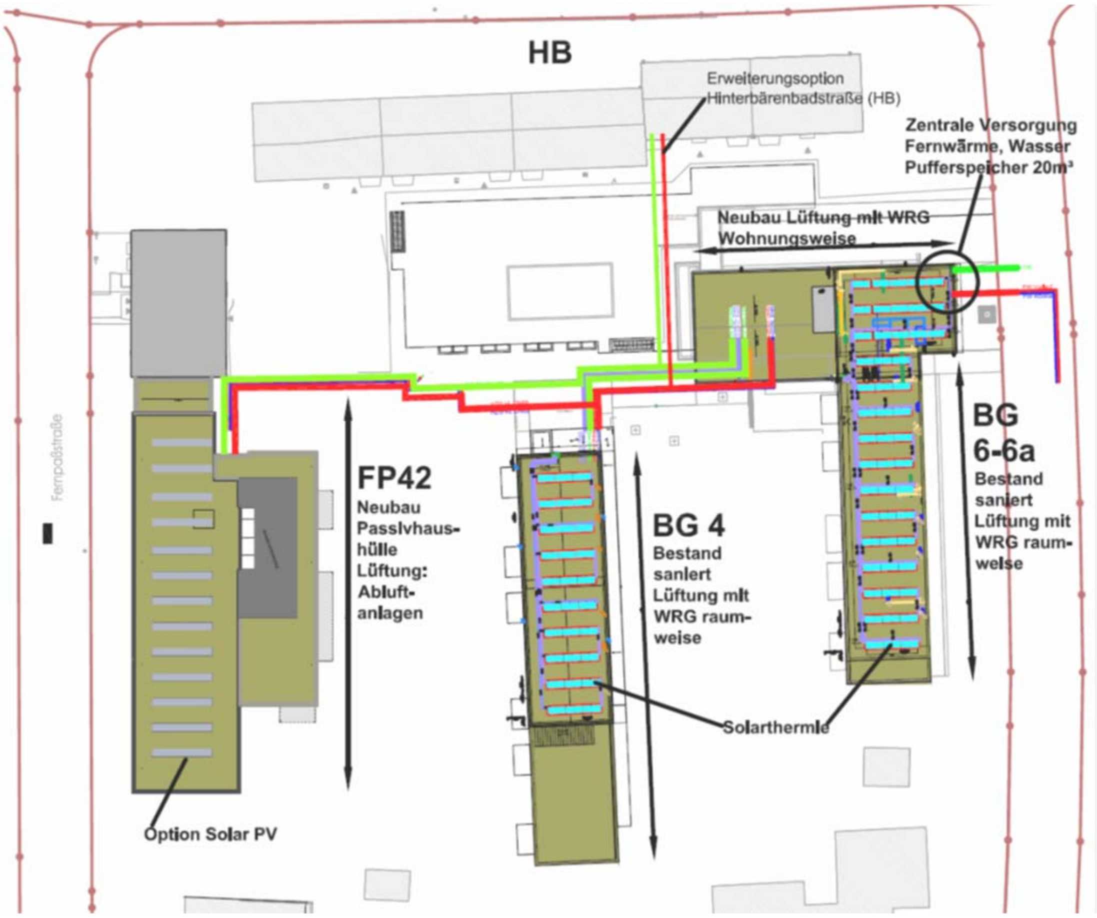

Figure 19 - Technical system design: central district/ solar thermal heating, decentralised ventilation (heat recovery)

Compared to a ‘standard’ refurbishment the expected, decisive long-time achievements realized in the Munich Demo Project for E2ReBuild are in terms of C / Energy and Systems:

- Slow and low-loss thermal building response (‘Passivhouse-Standard’, comfort retention even in case of system failures), external solar-control fixtures. Conscious daylighting in urban and architectural design.

- Central (residual) heating system (CHP combined heat + power, PE-factor 0,35, planned before: wood pellet boiler plant), two central heat storage tanks (20 m3) with dual piping system and fresh hot water substations.

- Space heating and domestic hot water assisted by two solar thermal collector systems (208 m^2) over green roofs, (solar photovoltaic system proportionally provided over green roofs of building phase 2).

- Controlled ventilation of flats (fresh and waste air) with heat recovery, distributed system for flats (facilitated fire safety, lower costs), centralised in the new building for the district office and habitations.

- Tenants operation manual and recommendations (edited by the architects), simple and low maintenance technologies, efficient lighting system etc. contribute to easy understanding of the living environment and unbeatably low operation costs.

3 Rejuvenation Process

The key time frame for the Demonstrator is shown in the table below:

	From	To
Predesign	May 2008	April 2009
Design	May 2009	June 2010
Construction	July 2010	December 2011
Monitoring	January 2012	January 2014

Table 1 - Key Time frame (see also Figure 24)

The key players involved in the retrofitting project are shown in the table below:

Role	Name	Brief	Design	Construct.	Monitoring
Building owner	GWGM Städt.Wohnungsges. München mbH	X	X	X	X
Architects	KLA Kaufmann.Lichtblau. Architekten BDA	X	X	X	
Energy expert	KLA Kaufmann.Lichtblau.		X	X	
Structural engineer	IB Merz.Kley.Partner IB bauart Konstrukt.		X	X	
HVAC engineer	IB EST Energie-System-Technik		X	X	X
Contractor 1	Fa. Müller Holzbau		X	X	
Contractor 2	Fa. HTR Baumeister			X	
Contractor 3	Fa. Zistler HLSE			X	
University	T U - München			X	X
and many others	……..		X	X	

Table 2 - Key players involved (see chapter 3.1)

3.1 Concept and Team Formation

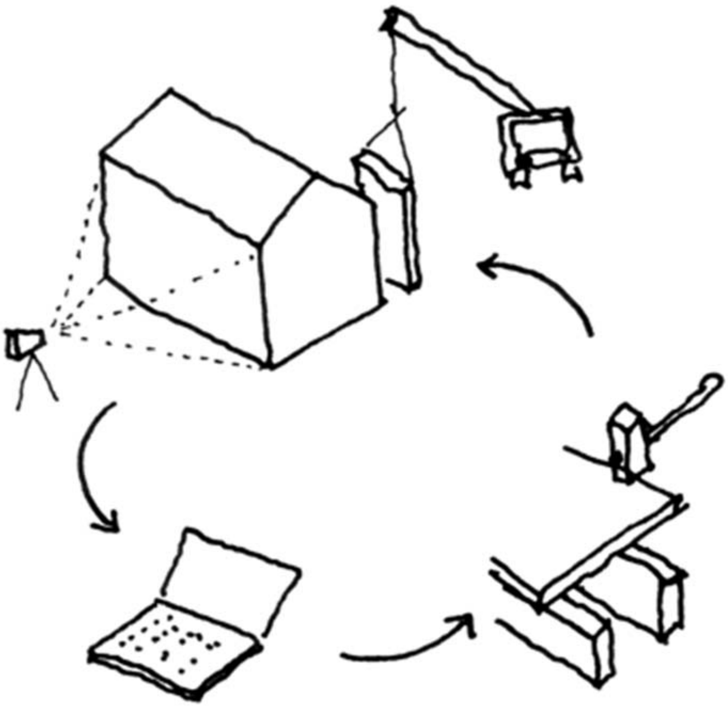

Figure 20 - Cycle process for innovative refurbishment

As the buildings were no more inhabited when the rejuvenation process began, there was no direct user impact. But the planning team had intensive discussions with the owner GWG, the authorities and the neighbourhood. The basic ideas of a cycle process for innovative refurbishment resulted from our student project entitled “Weiterbauen” (Building further) at the Technical University of Munich, Faculty of Architecture (Prof. Hermann Kaufmann, Florian Lichtblau, Frank Lattke). An exhibition presenting the results convinced the owner GWG to venture a ‘Leuchtturm’ (lighthouse) project and assigned Kaufmann.Lichtblau.Architects.

Figure 21 - Early architectural design conceptions

Figure 22 - Digital on-site measuring (balconies off)

A design team of architects and engineers was formed, responsible for planning and managing the whole project process. Following specific tasks, related to the pilot character, were conducted by the architects:

Architecture + Management (Kaufmann.Lichtblau.Architekten, A-Schwarzach/ D-München)
- Main design concept, cost accounting, building permission, documentations
- Energy simulations, concept and optimisation, grant applications, documentations
- Planning management and coordination, construction and technical developments
- Construction design and tendering documents, support for quotation and contracting
- Production- and site- management of the whole building process, documentation
- Final cost verification, including management of warranties and removal of defcts

Engineering (MKP Merz, Kley, Partners, A-Dornbirn)
- Static consulting, calculation and design of old and new load bearing structures
- Support for construction design, tendering documents, static approvals and supervision

Building Physics (bauart Konstruktions GmbH, München)
- Fire safety, support for constructive details and tendering, approval documentation
- Sound performance simulation, support for construction details and supervision

Building services, HVAC (IB EST Energie-System-Technik, Miesbach)
- Specification and planning of energy production space heating and domestic hot water
- Planning of control and distribution systems of heat, ventilation and electrical equipments
- Construction design and tendering documents, support for quotation and contracting
- On site- management of the building process, cost verification and documentation
- Monitoring concept, equipment and implementation together with TU-Munich

The project management and the contracting were in the hands of the client GWG München.

3.2 Planning and Contracting

Figure 23 - Architects workshop with H. Kaufmann

The planning team headed by Kaufmann.Lichtblau.Architekten developed a higher-density renovation model. By incorporating a new building for the district office of GWG, the load-bearing structure of the original buildings could be retained, but the accesses were changed and the flats were transformed into individual, modern residential units with big balconies and attractive outdoor areas. The design phase needed more than two years until all building permissions were achieved and the main firms contracted (see Figure 24).

Figure 24 - Timetable Design, Construction, Monitoring Phase

The climatic and constructive building envelope, including that for the new part and added storeys, consists of pre-fabricated wooden elements meeting passive-building standards, with maintenance-free wall cladding and green roofs. Exemplary solutions were developed for life-cycle and energy balances, building science and structural aspects, fire safety, sound insulation and an efficient construction and mounting process.

The approval documentation and technical design specifications resulted in a public tendering which finally led to a contract with the cheapest providers of all crafts, including the main role of the timber manufacturer.

Figure 25 - Digital construction planning

The building stock had been measured and drawn entirely by the architects for planning purposes. Later on the contractor for timber works measured the existing buildings again digitally. A tachymetry total station was used to gather the relevant data point by point. The connection to a laptop enabled to develop a 3D model on site with the advantage to check for completeness.

Production design of the timber framework was then done on the basis of the model, defining every piece of timber with parametric information to be processed by a digital cutting machine. For each building more than 80 construction design plots had to be controlled, simultaneously by the architects and all engineers for statics and fire protection, building physics and technical systems.

The possible degree of prefabrication, logistic questions and warranty claims, as well as intensive technical and cost items accompanied the work preparation process. Kaufmann.Lichtblau.Architects tried to harmonise each phase of this process, always keeping in view the priorities of our target catalogue for the best of our client GWG. Besides advancing of professional competence this was also a challenge for cultivating human communication.

3.3 Construction Period

Figure 26 - Architects start on-site job

The main contribution of Munich Demo to E2ReBuild is a real holistic approach in the most consequent realisation compatible with the complex boundary conditions. Construction work on-site (Phase 1) began in the middle of 2010 with partial demolition and structural works. It ended after about 17 months in December 2011, when the new tenants moved in. The refurbishment of the courtyards and gardens were the last task and were completed in spring 2012.

An overview to the most important steps is given in the timetable, see Figure 24:

The starting point in July 2010 was the carrying out of various preparation works. Followed by a completely new underground garage, concrete works for external foundations and new staircases, as well as a fundamental conversion of the two existing buildings' ground plans. Also the entire technical equipment had to be replaced. Consideration of birds nesting season and the protection of existing trees were important tasks.

Meanwhile validation was done for production design of the timber frame based on the digital model, defining every piece of timber with parametric information to be processed by a digital cutting machine. After some experimental tests the prefabrication of the TES timber elements started in March 2011, the adventure of transport and mounting, window setting and closing of the facades took place from May to October 2011.

Also in 2011 the new technics were installed for heating, ventilation, sanitary and electrics. Solar thermal facilities were mounted on the green roofs and two big central heat storages in the basement. Additional heat needed is supported by the district heating system. The distribution ductwork sometimes collided with interior construction, air tightness, sound and fire protection works - crisis management for the jours fixes.

From October to December 2011 the steel construction was erected for staircases, arcades and balconies, while the interior of the apartments was finished. This maybe was the most difficult phase of the whole construction process, as unforeseeable delays and faults crossed over. Winter time threatened to hinder works additionally and all of us became a little nervous, if the experiment would succeed in the end. It did.

Finally, three months late, the buildings were occupied by the new tenants and the GWG-administration in January 2012. Monitoring started as well and functioned more or less satisfyingly in March (too sophisticated technics used, paired with insolvency of the control system contractor). The final act of the construction period was the verification of costs, including the management of warranties and removal of defects in the year 2012.

Figure 27 - Mounting Facade elements (incomplete)

Figure 28 - Construction site aerial view July 2011

Some statistics: the architect's analogue archive in the end contains more than 60 lever arch files with paper, the digital server loaded data of about 40 gigabytes and - there were many, many years of architects lifetime spent on the elaborate pilot project in Munich. But: it was a valuable experience to build up.

4 Results and Summing Up

Figure 29 - View from access galleries house 48 to house 47 Façade West.

4.1 Conclusions and Experiences

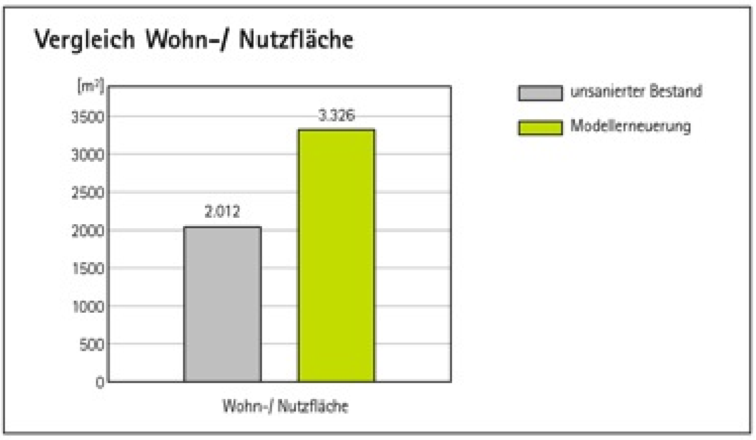

Figure 30 - Rented living space before / after + 65 %

Figure 31 - Green living space looking North

The main conclusions are: That ‘hard and soft facts’ of the realized and documented ‘rejuvenation project’ (see figures) in our opinion do comply with the requirements, that should be fulfilled for the next two generations, that means for 50 years from now. The sampled monitoring data - despite the necessary ‘swing in’ of interior temperature, humidity, system control and user behaviour - show the calculated values or better. The decisive indoor qualities as well as summer and winter comfort got best notes of the tenants in the questionnaires.

The over-all feedback of professionals, public and the GWG tenants (see deliverable D3.3) is more than enjoyable. Finally also the total costs for our prototypical new approach focusing long-time orientation of ecology and economy seem to be ‘bearable’ in comparison with standard refurbishment. Not only, that we were able to gather about 20 % of building costs by normal national and local low-e subsidies for our client, also the tenants profit of stable minimum energy costs and service charge.

The Munich E2ReBuild project received important awards, conference lectures and publications, also attracting visitor groups from all over Europe and foreign countries - an ‘ecorational’ success story for the courageous owners GWG and the City of Munich.

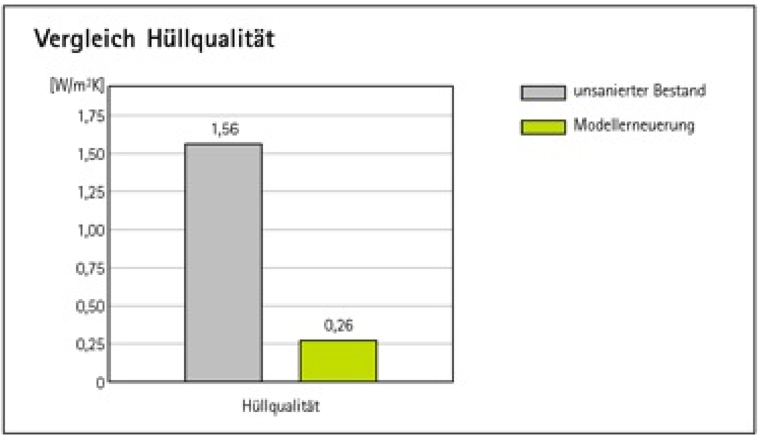

Figure 32 - Envelope thermal quality before/ after 16 %

Figure 33 - New and rejuvenated buildings harmonised

These are 10 important lessons learned, just short remarks, not in terms of ‚right or wrong’, but of 'difficult and improvable’:

1. Pre-analysis of (hidden) substance qualities (deficiencies)
2. Measuring and measurement communication
3. Cooperation models and contractor choice
4. Late decisions joined to conversion surprises
5. Planning prefabrication and coordination firms
6. Inadequate prefab-standard / on site mounting
7. Overdone security and scaffolding expense
8. Mounting delays compromise time management
9. Last finishing and fault removal late December
10. Circulate high success of added values and implement urgent holistic lifecycle standards to common practice.

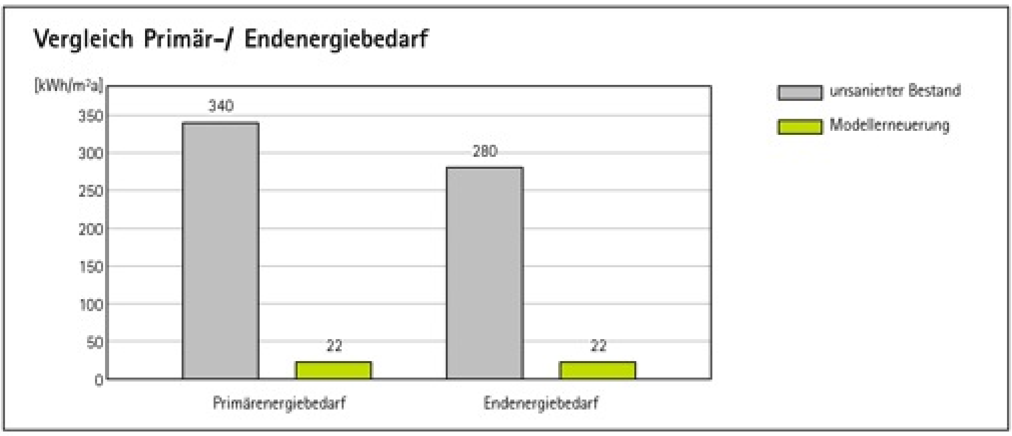

Figure 34 - Primary/ purchased energy need before/ after 6/ 8 % (excluding auxiliary/ household electricity)

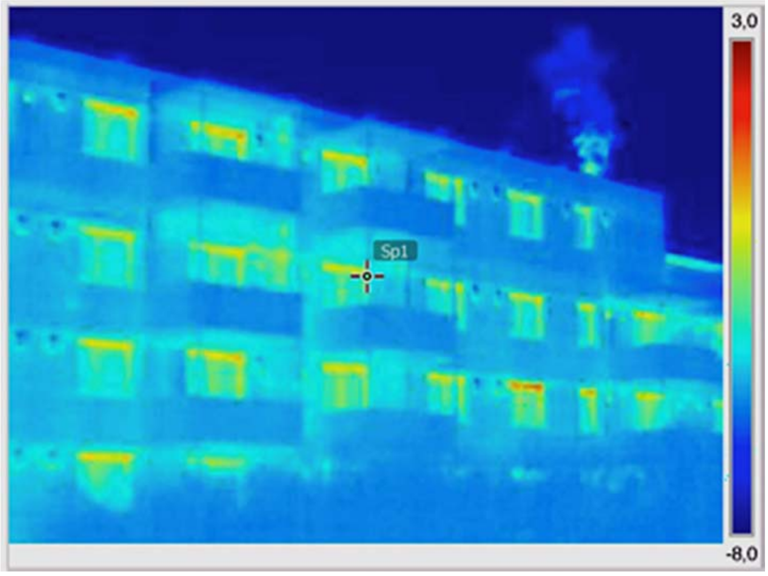

Figure 35 - Thermographic quality assurance - all ok

Furthermore, we estimate the cost-cutting potential of the demonstrated innovative refurbishment strategy as absolutely high, especially combined with an absolute essential ‘cost truth’ to come. So the future should demonstrate that the social and individual over-all economy can prove to be on a truly right way with the results achieved.

The ‘TES Energy Façade’ and their principles are best documented in the Augsburg Demo Project. More information in detailed aspects and comparisons to all Demo Projects are given in different important deliverables of work packages 1, 3, 4 and 5 in E2ReBuild.

4.2 Replication Potential

Figure 36 - Replication potential example for Europe?!

The theoretical replication potential for the City of Munich, for Germany and for Europe we consider as really high. As is to be seen in the figure above, already the nearest surrounding would offer many possibilities, but most of them will stay unused as buildings get short life standard renovations or are broken down. TES Energy Façade research published the German numbers and described first steps for opening up this market potential.

The issues of our target catalogue focus the main features of sustainable lifecycle refurbishment in Europe:

A / Perfect long-time usage: Quantity and quality of flats, accessibility (disabled-friendly) and outdoor areas.
B / Sustainable construction: Substance-conserving, ecological prefab-construction, process and design.
C / Energy for the future: Highest conservation and efficiency, regenerative supply and overall economics.

A large part of the post-war housing stock all over Germany is functionally outdated, has high operational costs, is inadequate in terms of energy consumption and does not comply with society's living standards of today, let alone of the future. That means, that our central construction tasks lie either in a replacement - only where unavoidable - or in the 'rejuvenation' of our existing residential building stock.

This necessity poses many dangers, however, when thought through it poses unique opportunities: it calls for a fundamental approach and new interpretation of old housing. Structural sins of the past can be alleviated or even eliminated and the demand for a more sensitive recompression and redesign presents the possibility of sustainable urban corrections linked with high over-all economic efficiency and an attractive future orientation.

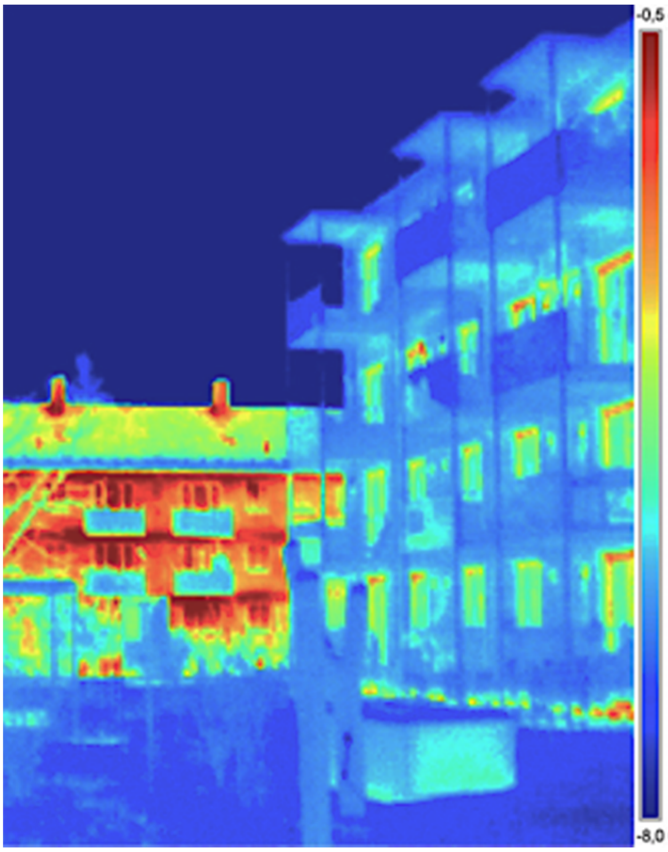

Figure 37 / 38 - Thermografical and visual comparison between original and refurbished buildings

The Munich- Sendling Fernpaßstrasse represents a flagship in the big portfolio of the municipal GWG company. The actually biggest timber project in our hometown (together with phase 2) was officially presented and inaugurated under prominent participation in spring 2012.

The focus is on attaining industrial cost-saving production and in doing efficiently enlarge the building stocks' slowing restoration rate, using the most natural, healthy and environmentally friendly materials and processes as possible. Our building stock is diverse and asks for a multitude of quality solutions to be developed. Only through competently optimised architectural planning under equal observation of effective land use, ecological structural engineering, zero-emission building operation as well as first class use and creative design quality a macroeconomic affordable and genuine sustainability can be achieved.

Let us hope, that European politicians discover very soon a comprehensive dynamic CO2-tax and an intensive engagement for ecological cost truth as 'stakeholders perpetuum mobile' for sustainable development. Only 'Solar (light, energy, material) construction and restoration' as we know it does not harm anybody, it presents the basis for social and personal freedom and in doing so embodies true modernism.

4.3 Final Remarks Author

Some more lessons learned: In Munich Demo the planning team and his building contractor also had to verify, that the theoretical innovation potential of construction methods and processes is absolutely case specific and can just succeed step by step, according to the competence, the will and the potential of the contractors to realize it. Together with the owners, the tenants and our planning partners we have to improve in

- arranging and developing innovative methods and details with firm partners and craftsmen,
- measurement sequences in complex conversion processes like the Munich project,
- finding ways to establish new regulations in order to get convenient realization partners
- and the everlasting trust in professional optimism, to encounter violent commercialism.

Maybe a fundamental change of human awareness and communication quality plays the main role for reaching really future suitable standards.

As some final remarks we can say, that the collaborative catalogue of objectives has been successfully realized in good quality. This would not have been possible to demonstrate the same way without the E2ReBuild participation. Our client GWG and the architectural consortium K.L.A. had consciously stepped into unknown territory and also reached some, may be unpredictable, imaginary limits - not unusual with a prototype.

But it proved to be worthwhile, the resonance is much more than positive. The overall result represents the simple fact, that truly sustainable architecture in renewal of the existing building stock cannot be achieved satisfyingly with actual standard methods, standard processes or standard investigation of time and money.

The reward for all the struggles is a strong and durable added global value, high qualities of function and comfort, building construction, systems and design, combined with unbeatable long-time ecology and overall economy - a success for society and individuum: Most of the tenants love their new homes. This result refers to the buildings long lifetime cycle – comparable directly to nature related, real sustainable forestry.

We should all and everywhere get used to remove obstacles together and try to really solve the priority needs of our actual global and local unfortunate situation. Sun is shining bright enough everywhere - if we do.

Figure 39 - Static detection: The E2Rebuild team enters Munich access galleries, March 2012

Appendix A Original BEST Sheet

Building Energy Specification Table (BEST)

Community / site	Munich/Germany	Sending	BEST no.	1		

1,1	Building Category	residential retrofitted	total area / category / BEST sheet [2]	2476	m^2	
		[1] house nr. 47+48				
1,2	Local Climate		January average outside temperature	°C	-1,8	
			August average outside temperature	°C	16,7	
	Climatic Zone	central europe	Average global horizontal radiation	kWh/m^2 yr	1076	
	(national definition)	temperature 16,5-18,0 °C	Annual heating degree days [3]	°Cd/yr	4265	

1,3	Maximum requirements of building fabric			Existing building [5]	National regulation for new built [6]	suggested specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	1,6	0,35	0,13	63
	Roof	U	W / m2K	1,3	0,3	0,1	67
	Ground floor	U	W / m2K	0,85	0,4	0,16	60
	Glazing	U_g	W / m2K	2,8	1,5	0,7	53
	Average U-value	U_{av}	W / m2K	1,4	0,65	0,3	54
	Glazing	g	total solar energy transmittance of glazing	0,8	-	0,5	
	Shading	Fs	Shading correction factor	0,9	-	0,75	
	Ventilation rate [4]		air changes/hr	1	0,7	0,5	29

2 Building Energy Performance

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing	suggested energy carrier		specify energy efficiency measures [13]	Existing building [5]	regulation / normal practice for new built	suggested specification [7]	% Energy savings [8]
Heating + ventilation							
diverse fossil	biomass/solarth.	kWh/m^2yr	building envelope, central heating	280	70	25	64
Cooling + ventilation							
		kWh/m^2yr					
Ventilation (if separate from heating/cooling)							
		kWh/m^2yr					
Lighting							
	electricity	kWh/m^2yr	low energy technics	20	15	10	
Domestic Hot Water (DHW)							
electricity	biomass/solarth.	kWh/m^2yr	central regenerative heating	25	20	5	
Other energy demand							
		kWh/m^2yr					
		kWh/m^2yr	Subtotal sum of energy demand	325	105	40	62
	Appliances (please indicate, but costs are not eligible)						
	electricity	kWh/m^2yr	low energy appliances	25	15	10	33

2,2 RES contribution per m2 of total used conditioned area (kWh / m2 yr)

total production kWh/yr	m^2 installed	kW installed	specify RES measures	Existing building [5]	National regulation / normal practice	suggested specification [7]	RES contribution [%] [8]
110000	210	110	solarthermal heating + hot water	0	0	30	
		kWh/m^2yr	Subtotal sum of RES contribution	0	0	30	

3 Building Energy Use per m^2 of total used/heated floor area (kWh/m2 yr)

kWh/m^2yr	Subtotal sum of energy demand	325	105	40	62
kWh/m^2yr	Subtotal sum of RES contribution	0	0	30	
kWh/m^2yr	Total Building Energy Use	325	105	10	90

4 Other national overall energy performance targets or criteria (additional information, mandatory if existing)

	Units [9]	explain content and scale [10]	Existing building	National regulation for new built (2006)*	suggested specification
		heating + hot water	ca. 280	ca. 100	ca. 35

Appendix B Energy Data

Munich Before

EnEV 2009 - average consumption over 3 years

	Energy Demand Before [kWh/m2 NFA]	Source	PE conv. fact. fp [kWh PE / kWh S] national /local	PE national [kWh/m2 NFA]	PE conv. fact. fp [kWh PE / kWh S] acc. EN 15603	PE based on EN 15603 fp [kWh/m2 NFA]
Heating Source 1	280,0	Decentralised	1,1	308	1,1	308
Heating Source 2				0		0
DHW Source 1	12,5	Electricity	2,6	33	3,31	41
DHW Source 2				0		0
Auxiliary	0,0	Electricity	2,6	0	3,31	0
Losses Source 1				0		0
Losses Source 2				0		0
Total	**292,5**			**341**		**349**
Delivered to the grid				0		

Munich Afterwards

Calculation in PHPP

	Energy Demand Afterwards [kWh/m2 NFA]	Source	PE conv. fact. fp [kWh PE / kWh S] national /local	PE national [kWh/m2 NFA]	PE conv. fact. fp [kWh PE / kWh S] acc. EN 15603	PE based on 15603 fp [kWh/m2 NFA]
Heating Source 1	19,0	District heating	0,35	7	1,3	25
Heating Source 2	3,0	Solar thermal	0	0	0	0
DHW Source 1	3,5	District Heating	0,35	1	1,3	5
DHW Source 2	9,0			0		0
Auxiliary	5,5	Electricity	2,6	14	3,31	18
Losses Source 1				0		0
Losses Source 2				0		0
Total	**40,0**			**22**		**47**
Delivered to the grid						

Conversion factors fp (total) acc. EN 15603:2008* Table E1 - Annex E		
Electricity (UCTE Mix)	3,31	[kWh PE / kWh S]
Local-/District heating	1,3	[kWh PE / kWh S]

Reference national conversion factors: DIN V 18599/1 2007

Appendix C Munich Documentation Poster

The full sized poster can be found at
http://www.e2rebuild.eu/en/demos/roosendaal/Documents/E2REBUILD_Munich_demo.pdf