RECAST Urumqi – Steigerung der Ressourceneffizienz in einem semiariden Milieu: Urumqi als Modellstadt für Zentralasien

RECAST Urumqi Meeting the Resource Efficiency Challenge in a Climate Sensitive Dryland Megacity Environment: Urumqi as a Model City for Central Asia

Teilvorhaben 3: Förderung nachhaltiger Megastadtentwicklung durch energieeffizientes Wirtschaften in einem semiariden Milieu (FKZ 01LG0502C)

Sub-project 3: Facilitation of Sustainable Megacity Development through Energy Resource Efficiency (grant number 01LG0502C)

Schlussbericht
Final report

Bundesministerium für Bildung und Forschung (BMBF)
Federal Ministry of Education and Research, Bonn/Berlin, Germany
Research Program Framework: Sustainable Development of the Megacities of Tomorrow: Energy and Climate Efficient Structures in Urban Growth Centres

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December 31, 2014

Berichtsblatt

1. ISBN oder ISSN

2. Berichtsart
Bericht

3a. Titel des Berichts
RECAST Urumqi Teilvorhaben 3: Förderung nachhaltiger Megastadtentwicklung durch energieeffizientes Wirtschaften in einem semiariden Milieu

3b. Titel der Publikation

4a. Autoren des Berichts (Name(n), Vorname(n))
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5. Abschlussdatum des Vorhabens
30.09.2014

6. Veröffentlichungsdatum
31.12.2014

7. Form der Publikation
Bericht

8. Durchführende Institution (Name, Anschrift)

ifeu – Institut für Energie-
und Umweltforschung Heidelberg GmbH
Wilckensstraße 3
D-69120 Heidelberg

9. Ber. Nr. Durchführende Institution

10. Förderkennzeichen
01LG0502C

11a. Seitenzahl (Bericht): 67

11b. Seitenzahl (Publikation)

12. Literaturangaben: 31
Dokumente auf CD-ROM: 90

13. Fördernde Institution (Name, Anschrift)

Bundesministerium für Bildung und Forschung (BMBF)
Kapelleufer 1
D-10117 Berlin

14. Tabellen: 14

15. Abbildungen: 41

16. Zusätzliche Angaben --

17. vorgelegt bei (Titel, Ort, Datum)

18. Kurzfassung:
Im RECAST Urumqi Teilprojekt *Energieeffizienz* lag der Schwerpunkt der Aktivitäten auf Maßnahmen zur Steigerung der Energieeffizienz in Gebäuden (Bestand und Neubau) und in einem großen Industrieunternehmen. In enger Zusammenarbeit mit Beteiligten in Regierung, Verwaltung, Industrie und Wissenschaft wurden u.a. folgenden Ziele erreicht:

- Ein Handbuch zur Nachhaltigen Stadtentwicklung Urumqis wurde erstellt und verbreitet.
- Das landwirtschaftliche Ausbildungszentrum in Nanshan wurde energetisch saniert und zum ersten Null-CO_2-Emissions-Gebäude in Urumqi. Der Heizenergiebedarf wurde um 85% reduziert.
- Das erste Passivhaus in Westchina wurde angepasst an die sehr kalten Winter geplant und erfolgreich realisiert. Viele Herausforderungen in Design, Komponenten (Fenster, Wärmerückgewinnung) und Qualitätssicherung wurden gemeistert.
- Ein strikterer Energieeffizienzstandard für neue Gebäude wurde von der Stadt Urumqi ab 2014 eingeführt.
- Für die Optimierung der kohlebasierte PVC-Produktion bei ZhongTai Chemical Co. wurde erstmals ein Energie- und Massenflussmodell eingesetzt. 68 ökonomisch umsetzbareVerbesserungsmöglichkeiten wurden aufgezeigt und z.T. implementiert. Die Umsetzung weiterer Maßnahmen ist in Planung.
- Durch einen deutsch-chinesischen Schüler/Lehreraustausch wurden das Thema Energie an den Schulen Urumqis popularisiert und durch eine deutsch-chinesische Website verstetigt.

Die direkten vermiedenen CO_2-Emissionen betragen ca. 150,000 t pro Jahr; durch indirekte Effekte wurde die Vermeidung von mehr als 400,000 t CO_2 pro Jahr initiiert. Die erzielten Effekte sind nachhaltig: die Stadt Urumqi hat den Energieeffizienzstandard für Neubauten verschärft und ein Förderprogramm zum Bau von Passivhäusern aufgelegt. Ein China-weites Passivhaus-Netzwerk wurde etabliert. Die Methode der Lebenszyklusanalyse (LCA) in der Industrie wird in Urumqi und im Rest von China zunehmend angewandt.

19. Schlagwörter
Gebäude-Energieeffizienz, Passivhaus, kohlebasierte PVC-Produktion, THG-Minderungspotenzial, Klimaschutzkonzept, Xinjiang

20. Verlag: IFEU

21. Preis: -

Document Control Sheet

1. ISBN oder ISSN	2. Type of Report Report
3a. Report Title Facilitation of Sustainable Megacity Development through Energy Resource Efficiency Practice	
3b. Titel of Publication	
4a. Authors of the Report (Family name, first Name(s)) Franke, Bernd Li, Niu Detzel, Andreas Derreza-Greeven, Cassandra Hertle, Hans Busch, Mirjam	5. End of Project 30.09.2014 6. Publication Date 31.12.2014
4b. Authors of the Publication (Family name, first Name(s))	7. Form of Publication Report
8. Performing Organisation (Name, Address) ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH Wilckensstraße 3 D-69120 Heidelberg	9. Originator's Report No. 10. Reference No. 01LG0502C 11a. No. of Pages (Report): 67 11b. No. of Pages (Publication)
13. Sponsoring Agency (Name, Address) Federal Ministry for Education and Research Kapelleufer 1 D-10117 Berlin	12. No. of References: 31 Documents on CD-ROM: 90 14. No. of Tables: 14 15. No. of Figures: 41
16. Supplementary Notes --	
17. presented at (Title, Place, Date)	

18. Abstract:

The RECAST Urumqi *energy efficiency* subproject had a focus on energy efficiency on buildings (existing and new construction) and on identifying suitable energy efficiency options for a major company in the industrial sector. Close cooperation with local stakeholders in government, industry and science resulted in the following achievements:

- A handbook on Sustainable Urban Planning Elements for the Dryland Megacity Urumqi was created and distributed.
- The energy retrofit of an agricultural education centre in the Nanshan area into the first zero-emission building of Urumqi was accomplished; the heat energy demand was reduced by 85%.
- Planning and completion of the first passive house in Western China adapted to very cold winters. Many challenges regarding design, components (windows, heat recovery) and building quality were overcome.
- A stricter energy effciency standard for new buildings was adopted in Urumqi, effective 2014.
- An energy and mass flow model at the coal-based PVC production was implemented at ZhongTai Chemical Co. A total of 68 economically feasible improvements were identified and have been partly implemented.
- The initiation of energy education in schools in Urumqi by way of establishing a student/teacher exchange and a Sino-German website.

Directly avoided CO_2 emissions total 150,000 tonnes per year; indirectly, avoidance of 400,000 tonnes of CO_2 per year was initiated. The impact is long-lasting: the City of Urumqi has tightened building energy standard and increases the support for construction of more passive house buildings; a China-wide passive house network was established. Life-cycle assessment (LCA) in industry is increasingly applied in Urumqi and beyond.

19. Keywords

Energy efficient buildings, passive house, coal-based PVC production, GHG reduction potential, climate protection plan, Xinjiang

20. Publisher: IFEU | 21. Price: -

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1 Overview of the project

1.1 Urumqi development characteristics

Among the world's cities with a population of more than one million Urumqi, the capital of the Xinjiang Uygur Autonomous Region, is the farthest from the ocean. Home to no more than 88.000 people in 1949[1] the city excedeed two million residents in 2003 and has reached three million by 2013. It is expected that Urumqi will reach 4 million by 2020. As evident from Figure 1-1 [from Sterr & Fricke 2014[2]] the GDP of Urumqi is growing at an even higher speed, reflecting the extraordinarily dynamic economic development of this self-proclaimed "Central City of Central Asia". As these changes are accompanied by an accelerating demand for energy, water and material resources, resource efficiency turns to be a key issue for politicians, companies and the civil society.

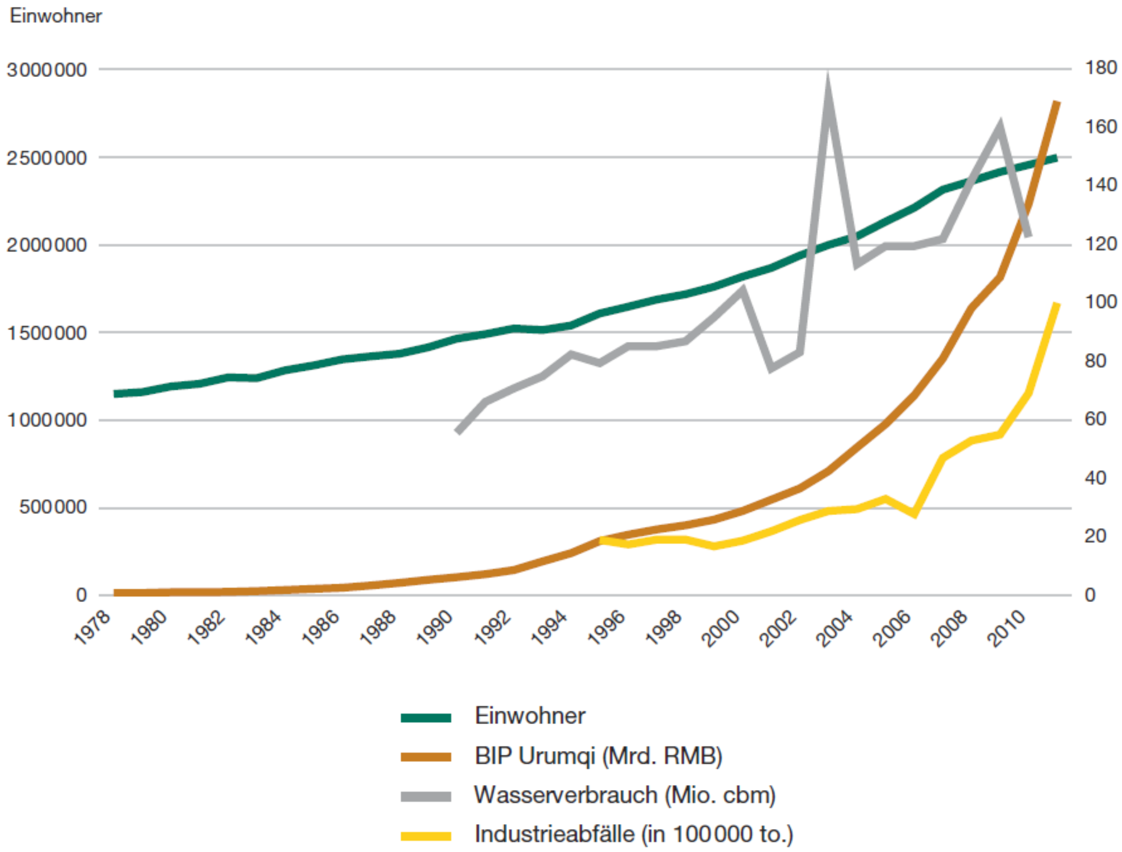


Figure 1-1 Development of population and resource use in Urumqi

This is all the more true, as the Urumqi Region is characterized by extreme continental semi-arid climatic conditions comprised of not more than 200-300 mm of precipitation per year[3] and a potential evapotranspiration that exceeds these precipitation by a factor five or more. Presently drinking water is provided mostly by rivers from the nearby Tianshan mountains; their annual runoff regime is already significantly affected by climate change with melting glaciers and shorter periods of snow cover. Aside from that, winterly inversion layers capture emissions from residential heating

1 Roberts, B. (1993): Ökologische Risiken der Stadtentwicklung und Landnutzung in Ürümqi, Xinjiang, China. Bremen. p. 64

2 Sterr T., Fricke, K. (2014): Urumqi – Umweltherausforderungen an die „Central City of Central Asia". Geographische Rundschau (4) 2014: p. 20-26

3 Autonomous Region Bureau of Surveying and Mapping 2004, p. 12

and industrial production for weeks; during winter times Urumqi ranks among the most polluted cities on earth.

Urumqi's development is not yet on clearly sustainable path. For this reason, a systemic approach was adopted in order to tackle different dimensions of challenges and weaknesses within a common frame. Therefore, emphasis was put on:

- An integrated design for the promotion of sustainability with a thematic focus on three major resource efficiency factors e.g. energy, materials and water.
- A direct partnership with respective high-ranking decision makers in order to facilitate entrance within a highly sensitive political environment and to promote a smooth, effective and well respected implementation of project components.
- An interorganisational approach composed of partners from politics and science as well as from businesses in Urumqi and Germany. This was done in order to build a platform for a fruitful exchange of different experiences, knowledge, minds and opinions, wherever needed, thereby providing opportunities for the generation of more sustainable, widely acceptable and applicable outputs.

These strategies were set into practice and contributed to a broad mutual understanding, new combinations, high motivation and recognition within both regions and a personal engagement far beyond established limits.

1.2 Project structure

The political attention to scientific projects often declines rapidly over time. In contrast to this, the RECAST Urumqi project succeeded in achieving increasing attention within the Xinjiang Government. It involved high-ranking politicians from its very beginning (see

Figure 1-2). Active contact existed to the Department of Total Pollutants Control of MEP Beijing as well since Prof. Dr. Zhao Hualin, the department's current director general, had served as a vice director general at DEP Xinjiang during the preparation phase of the project.

An overview of the Sino-German structure of the RECAST Urumqi project management is provided in Figure 1-3. Since the German Kick-off Conference in the Metropolitan Region of Rhine-Neckar (MRN) in June 2009, the project proceeded under the patronage of Mr. Erken-Tuniyaz, vice governor of Xinjiang, who has welcomed the German delegation several times since. One of the early protagonists of the RECAST Urumqi project, Prof. Dr. Xiaolei Zhang, formerly director of the Institute of Geoecology of CAS Xinjiang, then general director of the Chinese Academy of Sciences (CAS) Xinjiang and now general director of the Xinjiang Department of Science and Technology (DOST) of the government of Xinjiang. Therefore, the project has his continuing and increasing support as the new scientific director on the Chinese side.

The Chinese leadership of the task group "Energy Efficiency" was in the hands of president of the Xinjiang Academy of Environmental Protection Sciences (XJAEPS) together with the Urumqi Construction Committee.

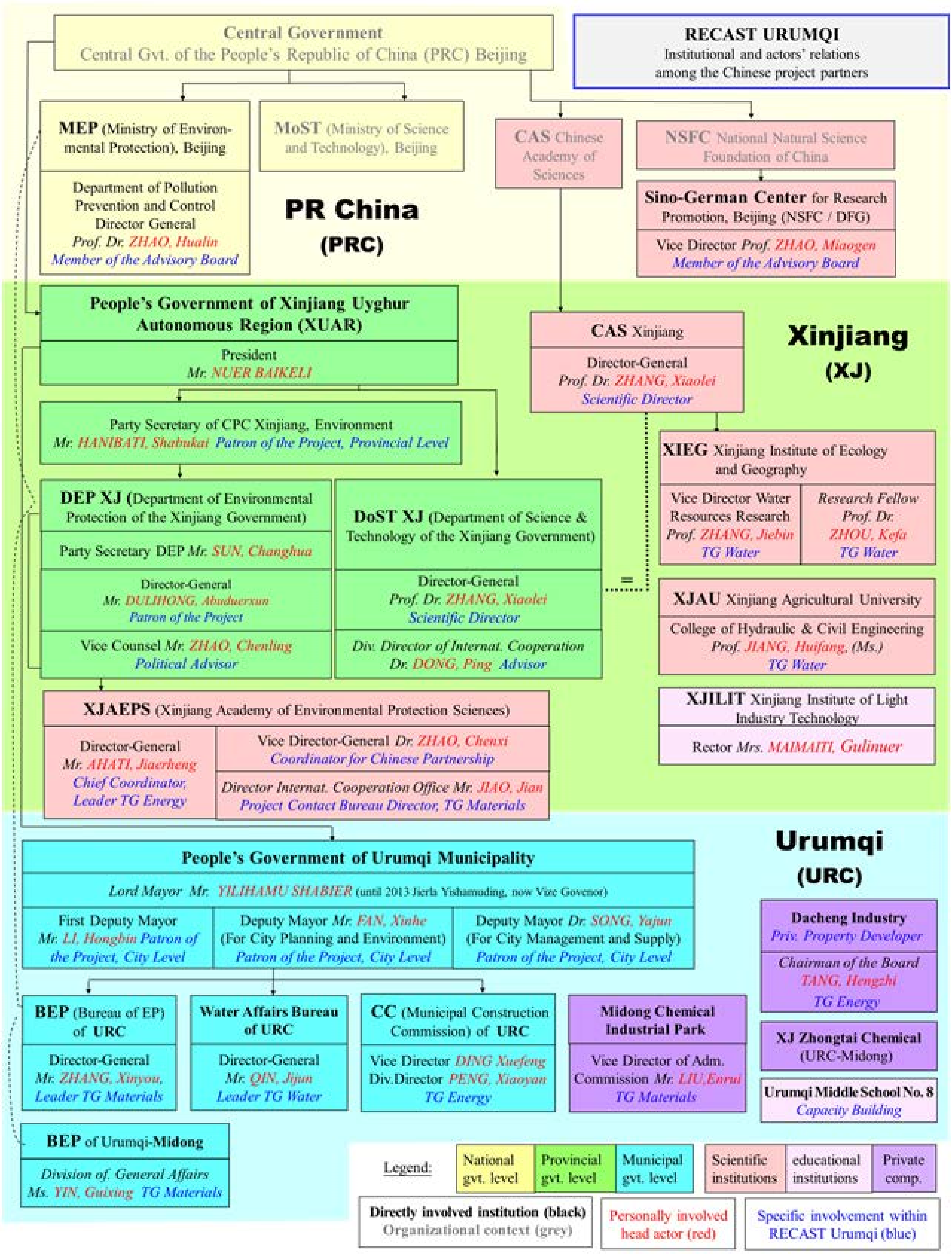


Figure 1-2 RECAST Urumqi - Organizational affiliation of Chinese project partners

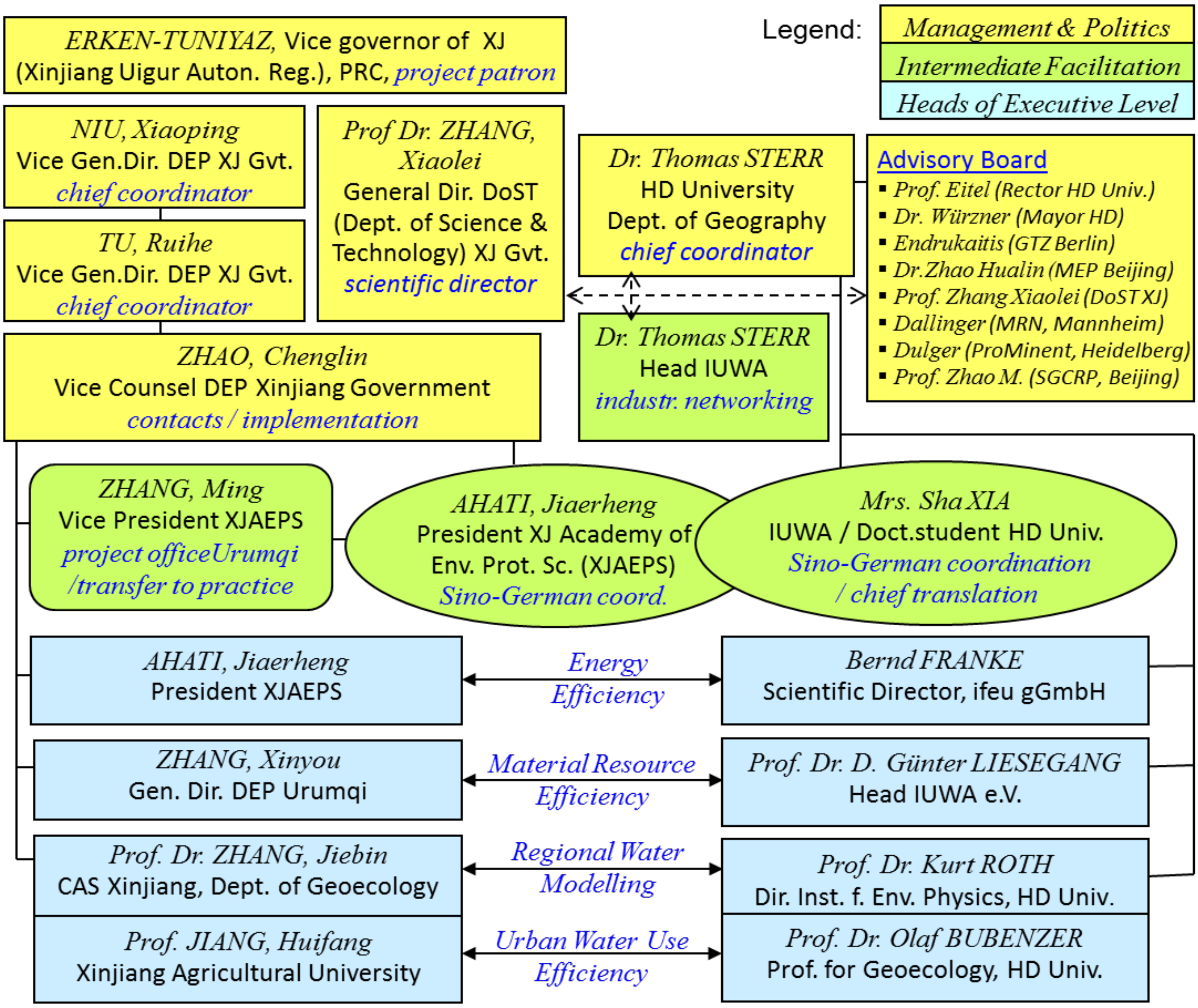


Figure 1-3 Structure of Sino-German RECAST Urumqi project management

2 Task group “Energy Efficiency”

2.1 Introduction

In 2011, the province of Xinjiang in China had a population of 22 million, with an energy consumption of 2,900 PJ. This was associated with emissions of 214 million tonnes of energy-related CO_2, or 9.8 tonnes per capita, 78% of which was derived from coal. Energy production in China’s province of Xinjiang has increased from 1978 to 2011 by factor of 11.8 as evident in the large volumes of coal, crude oil and in recent years of natural gas, to a total of 167 million tonnes of SCE (4,900 PJ) in 2011. In total, the share of coal was 56%, crude oil 22%, natural gas 19% and renewable energy sources (hydro and wind) 3%. About 59% of the energy produced was consumed in the province, while the export of crude oil has remained fairly constant, the share of natural gas and coal (mainly for electricity) has increased in recent years.

Between 1990 and 2011, the population in the Chinese province of Xinjiang increased from 15.3 million to 22.3 million, i.e., by 46%. Residential energy consumption increased by 127% during that period (Figure 2-1), [XJSYB (2005-2013)]. During the same time period, the inflation corrected GDP increased by a factor of 8.0, total energy consumption by a factor of 5.2 and energy-related CO_2 emissions grew by a factor of 5.0.

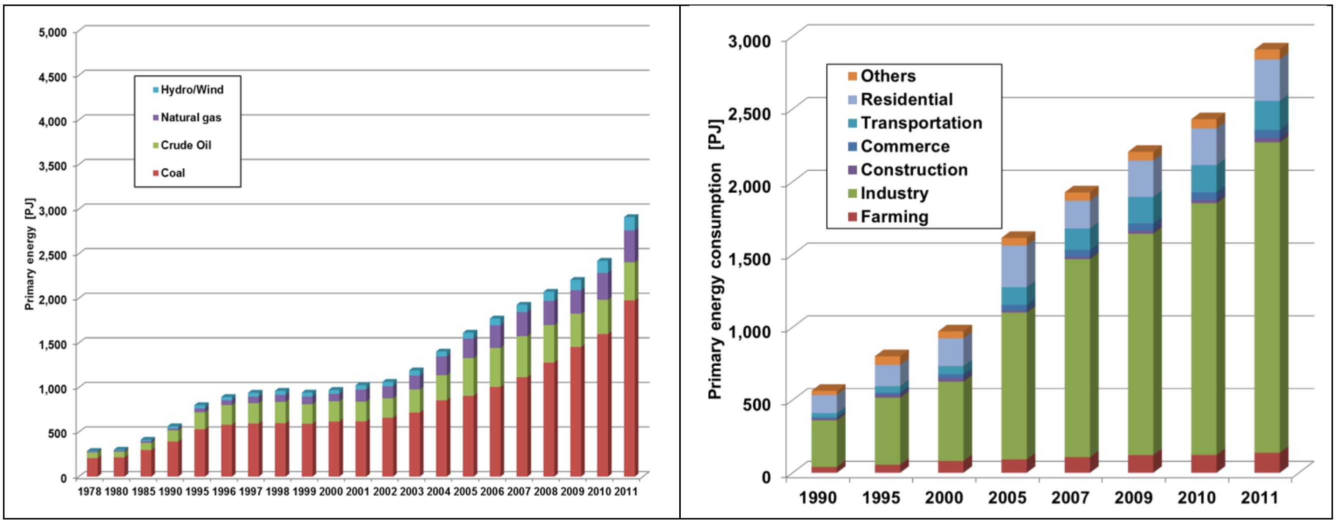


Figure 2-1 Consumption of primary energy in Xinjiang by energy carrier (left); distribution by demand sectors (right)

During the same period, the population of China grew by 18%, the GDP by a factor of 8.6, while the energy-related CO_2 emissions grew by a factor of only 4.3. The energy-related CO_2 emissions per unit GDP decreased by 37% in Xinjiang, whereas they decreased by 58% for the rest of China. This indicates that Xinjiang lags behind other Chinese provinces in decoupling energy growth from economic growth. It is doubtful whether Xinjiang can meet the efficiency targets set by the central government in the 12th Five-year Plan of 0.46 kg CO_2 per RMB (2000) in 2015 (Figure 2-2).

The lion’s share of Xinjiang’s primary energy is consumed in the industrial sector, much of it for the extraction and processing of petroleum and natural gas. The energy balance of Urumqi for 2007 is shown in Figure 2-3. About 541 PJ of primary energy is consumed in the city, accounting for 28% of the Xinjiang total (1,927 PJ). Urumqi uses 25% of Xinjiang’s coal, 50% of its oil, 12% of its natural gas, and 4% of its renewable energy. This resulted in high energy related per-capita CO_2 emissions of 22 tonnes.

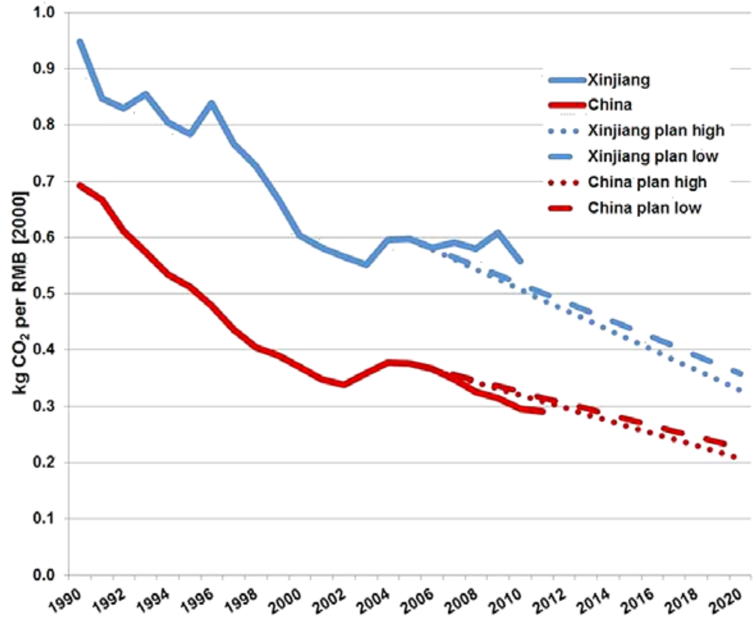


Figure 2-2 Emissions of CO_2 per unit GDP (inflation corrected) in China and Xinjiang, and the predicted decrease if CO_2 emissions per unit GDP in 2020 are 40 to 45% lower than in 2005 (Zhang, 2010)

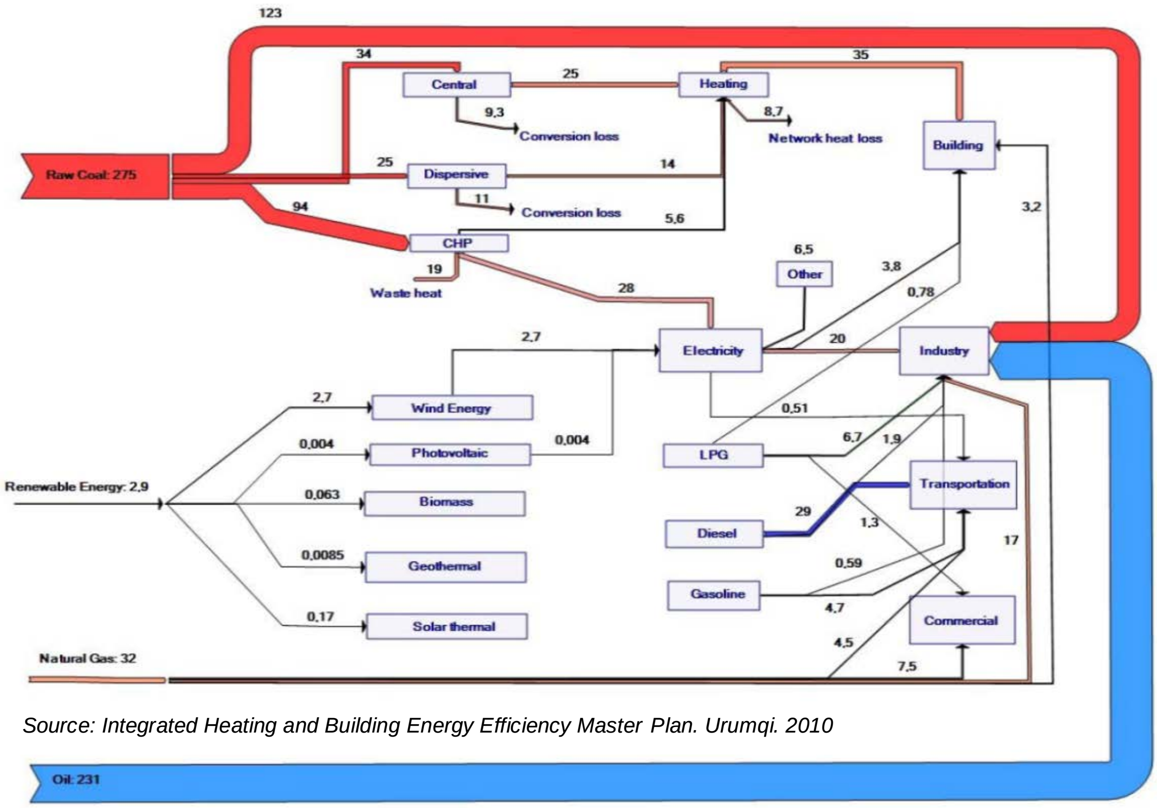


Figure 2-3 Energy balance of Urumqi (2007)

In 2007, the city consumed 14.7 million tonnes of coal (approximately 51% of its primary energy supply) whereby 30% of the coal consumption was used for the heating of buildings. The lack of adequate air pollution control combined with low stack heights in the city center and inversions in the very cold winter results in heavy air pollution (Figure 2-4) with associated severe impacts on human health. Nevertheless, the city will continue to rely heavily on the use of coal over the near term due to large reserves found in Xinjiang, which account for almost 40% of China's total coal reserve as defined by the Chinese category of "Reserves Confirmed through Exploration".

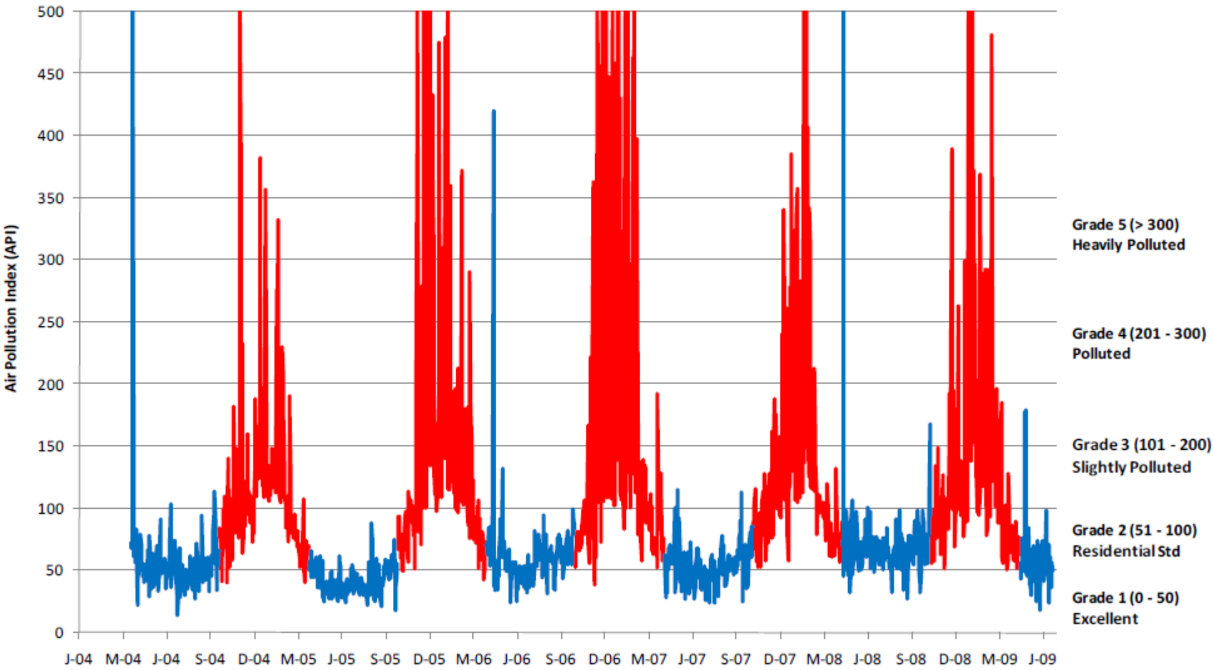


Figure 2-4 Urumqi air pollution index for 2004 to 2008 (heating seasons in red)

The City of Urumqi contracted Owens Corning Shanghai (with support by MVV Decon, Mannheim/Germany) to develop an *Integrated Heating and Building Energy Efficiency Master Plan*[4], which was finalized in May 2010 and has suggested the following key activities:

- A short-term control strategy by switching to low-sulphur fuels during air pollution episodes.
- A 5.6 billion RMB investment into retrofitting the energy efficiency of existing buildings, while using emission trading to provide additional financing.
- Increasing district heating (DH) efficiency establishing with a 40% reduction in coal use from the 2007 baseline by 2020 for all centralized DH companies; lowering the number of existing 45 DH companies, increasing the utilization of waste heat from CHP plants. Since 33% of all heat delivered to the building is lost due to inefficiency (conduction, balancing and water loss), improvement of the distribution network is paramount.
- Higher energy efficiency in construction should be demonstrated by building 50 passive homes by 2012.

While implementation of some of these measures was slow, the City of Urumqi was very quick to realize a major change in the district heat supply in 2013 by converting a large share of the coal-fired center-city heating plants to natural gas. This quickly improved the air quality during the heating season but introduced an ecnomic challenge because it requires large government subsidies to the heating price charges to residential customers.

The energy efficiency projects of RECAST Urumqi were designed to fit into the objectives of the 2010 energy master plan and was adapted later to the changed circumstances of the heat supply. They also build on experiences gained in other projects in Urumqi to define the largest net output for the activities. A major focus was put on energy efficiency on buildings (existing and new construction) and on identifying suitable energy efficiency options for a major company in the industrial sector.

4 *Integrated Heating and Building Energy Efficiency Master Plan, Owens Corning Shanghai. 2010. Prepared under contract with the City of Urumqi.*

2.2 Task group organisation

The Composition of the task group “Energy” is shown in Figure 2-5. The collaboration with the Construction Committee of Urumqi was important for the implementation of the results by decision-makers. The XJAEPS works with local industries on cleaner production projects that RECAST Urumqi supported.

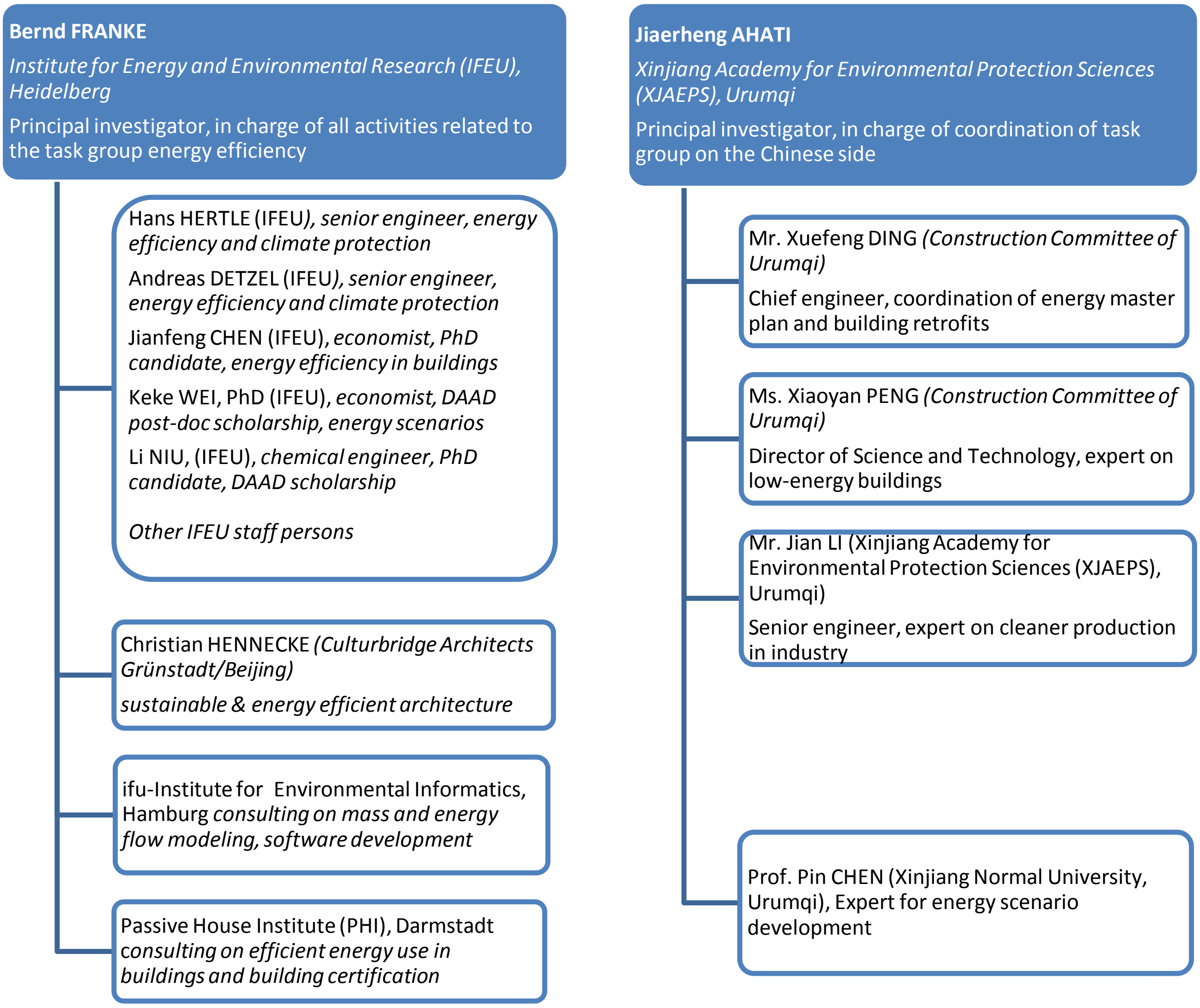


Figure 2-5 Composition of task group “Energy”

2.3 Lowering energy consumption for building heating in Urumqi

Sustainable energy supply and consumption in the housing sector is a great challenge in the Chinese city of Urumqi, where cold winters, with an average temperature of -14.4°C in January, drive the demand for heating to a very high level of 5000 heating degree days for a base temperature of 20°C. Between 1990 and 2010, the population in the Chinese province of Xinjiang increased from fifteen million to twenty-two million, i.e. by 42%. Residential energy consumption increased by 40% during that period [XJSYB 2012], hence the energy consumption per capita remained stable. During the same time period, the inflation corrected GDP per capita increased by a factor of 12 and the energy-related CO_2 emissions from all sectors grew by a factor of 2.9. In 2010, the residential energy consumption per person in Xinjiang reached 11.5 GJ, while the average German consumed almost three times as much (31.6 GJ/capita [UBA 2012]). The average residential electricity consumption per person in Xinjiang in 2010 was 216 kWh per year, while the average German resident in the same year consumed about 8 times as much (1,720 kWh [UBA 2012]), and the average US citizen almost 20 times as much (4,216 kWh/a [EIA 2012]).

The growth of the city as well as the demand for larger apartments with more appliances will increase the pressure on the energy supply system. This is why the RECAST Urumqi project in the Future Megacities Programme focused on realistic options to significantly reduce the energy consumption in the residential sector, for both existing buildings as well as for new buildings.

Energy prices in the residential sector

In order to evaluate technical and policy options to improve the energy efficiency of buildings, it is essential to understand the pricing structure for residential energy sources. In Table 2-1 the prices for electricity, natural gas, and district heat for residents in Urumqi, Germany, and the US in the years 2000 and 2010 are compared. After correction for inflation, the effective price in Urumqi decreased by 19% for electricity, 32% for natural gas and 23% for district heat, respectively. At the same time, prices for electricity in Germany increased by 52%, 31% for natural gas, and 43% for district heat, respectively. In the US, prices for electricity remained constant, however the cost of natural gas did increase by 16%.

Table 2-1 Energy prices for private consumers (including all applicable taxes and surcharges)

	2000	**2005**	**2010**
Electricity			
Urumqi, RMB/kWh (RMB_{2000}/kWh)[a)]	0.42 (0.42)	0.43 (0.37)	0.50 (0.34)
Germany, €/kWh ($€_{2000}$/kWh)	0.14 (0.14)	0.18 (0.17)	0.23 (0.21)
USA, $/kWh ($\$_{2000}$/kWh)	0.082 (0.082)	0.095 (0.082)	0.12 (0.082)
Urumqi, $€_{2000}$/kWh	0.052	0.045	0.042
Germany, $€_{2000}$/kWh	0.14	0.17	0.21
USA, $€_{2000}$/kWh	0.06	0.06	0.06
Natural gas			
Urumqi, RMB/kWh (RMB_{2000}/kWh)	0.13 (0.13)	0.13 (0.11)	0.14 (0.09)
Germany, €/kWh ($€_{2000}$/kWh)	0.039 (0.039)	0.053 (0.050)	0.057 (0.051)
USA, $/kWh ($\$_{2000}$/kWh)	0.026 (0.026)	0.043 (0.038)	0.037 (0.029)
Urumqi, $€_{2000}$/kWh	0.016	0.014	0.011
Germany, $€_{2000}$/kWh	0.039	0.050	0.051
USA, $€_{2000}$/kWh	0.020	0.030	0.024
District heat			
Urumqi[a)], RMB/kWh (RMB_{2000}/kWh)	0.15 (0.15)	0.17 (0.14)	0.17 (0.11)
Germany, €/kWh ($€_{2000}$/kWh)	0.046 (0.046)	0.059 (0.055)	0.073 (0.066)
Urumqi, $€_{2000}$/kWh	0.018	0.018	0.014
Germany, $€_{2000}$/kWh	0.046	0.055	0.066

a) *Values expressed in brackets (e.g. RMB_{2000}) are inflation adjusted using IMF data to express the value of the currency in year 2000.*

b) *Most residents pay a flat fee per m^2 GFA (e.g. 22 RMB/m^2 in 2010). The price was calculated using the average heat end energy demand of 131 kWh/m^2*a (measured in 2007).*

The proportion of residential energy prices for the average national income tells us how the average consumer perceives energy prices (Table 2-2). Over the past decade, Urumqi residents have experienced a considerable ease of pressure on their wallets. The heating cost for the current per-capita living space of 27 m^2, for instance, has decreased from 6.8% to 1.8% of the average wage for district heat, falling even a little lower for natural gas. An average German (WA, 2013), on the other hand, has 45 m^2 of living space and the average US citizen (EIA, 2013) has 60 m^2, respectively. Heating costs in both countries have increased only slightly and are now approximately 1.1% of an average wage if natural gas is used. In Urumqi, the proportion of an average wage to pay for the per capita electricity consumption of 450 kWh of electricity decreased from 2.0% to 0.7%. Although the average German uses almost four times as much, 1.4% of an average wage is required to pay for it. An average US citizen who uses more than nine times the amount of electricity than an Urumqi resident pays the least, at only 1.1% of an average wage.

Table 2-2 Energy prices in per cent of the average national wage per year

	Consumption or floor space per capita	2000	2005	2010
Electricity				
Urumqi	450 kWh/a (2007)	2.0%	1.2%	0.7%
Germany	1,720 kWh/a (2010)	0.9%	1.1%	1.3%
USA	4,216 kWh/a (2010)	1.1%	1.1%	1.1%
Natural gas [a)]				
Urumqi	27 m^2 (2007)	6.2%	3.0%	1.5%
Germany	45 m^2 (2010)	0.7%	0.9%	1.1%
USA	60 m^2 (2009)	0.9%	1.1%	1.1%
District heat [a)]				
Urumqi	27 m^2 (2007)	6.8%	3.5%	1.8%
Germany	45 m^2 (2010)	1.1%	1.4%	1.6%

*a) For reasons of comparison, the end energy use was assumed to be 150 kWh/(m^2*a).*

The prices in Urumqi reflect a policy of the Chinese government to keep energy prices for residents at a low level. The decrease in energy prices (inflation corrected) in China is covered by an increase in subsidies. Prices for energy in Urumqi therefore do not reflect true costs. In 2012, 90% of coal-fired heating plants were replaced by natural gas boilers at an investment cost of 12 billion RMB (1.4 billion €); whilst the annual subsidies for natural gas are estimated to be approximately 1.5 billion RMB (180 million €). The residential customer pays only around one third of the costs; two-thirds are covered by government subsidies. It is therefore important to consider these subsidies as well as the external costs of energy when planning.

Development of the building sector in Urumqi and its heat supply

Urumqi has experienced a rapid growth (Table 2-3) of building space. The gross floor area of residential and office buildings is expected to double to about 210 million m^2 by 2034 accounting for the increase in population and the demand for larger residences; the development in the last years suggests that this value will be reached much earlier.

Table 2-3 Area of residential and public buildings in Urumqi (GFA) in 2007 by date of construction and type [million m^2], rounded. (Source: City of Urumqi Construction Committee, 2010)

Year of construction	Residential	Non-residential	Total
Pre-1980	1.7	1.1	2.8 (3%)
1981-1990	11	4.8	16 (14%)
1991-2000	30	12	42 (39%)
2001-2007	34	14	48 (44%)
Total	**77**	**32**	**110 (100%)**

In order to address the air pollution problems and the need for a better heat supply, the City of Urumqi adopted an Integrated Heating and Building Energy Efficiency Master Plan in 2010. This included an investment plan to retrofit buildings to make them more energy-efficient, boost the efficiency of district heating, and impose higher energy efficiency targets on new buildings (City of Urumqi Construction Committee, 2010). The aim is to reduce annual CO_2 emissions from heat generation from 11.2 million tonnes in 2007 to 7.7 million tonnes by the year 2034.

The heat demand of buildings is a function of the building energy efficiency codes for construction or renovation. For buildings built before 1980, the end energy consumption was set to 279 kWh/m^2*a, relative to gross floor area (GFA). For new residential buildings, the so-called '50% Energy Code' (139 kWh/m^2*a) came into effect in 2003. A further reduction to 98 kWh/m^2*a was introduced in 2009 with the so-called '65% Energy Code' (MoHURD, 2008). As of 2007, only 20% of the buildings were built or retrofitted in accordance with the 50% Energy Code. Based on data for 2007, the average net heat demand per m² of GFA is lower than the design value and is estimated to be 131 kWh/m^2 (112 kWh/m^2 for residential, 175 kWh/m^2 for public buildings). The average building stock in Urumqi consumes less heat than one would predict from design objectives which are based on pessimistic climate parameters. As a further factor, retrofits (e.g., new windows) by proprietors have not only increased comfort levels, but have resulted in a decrease in heat demand. In 2007, the end energy demand to heat Urumqi's buildings was thus about 14 TWh per year. However, due to substantial network losses in district heating, the gross heat demand was about 18 TWh per year.

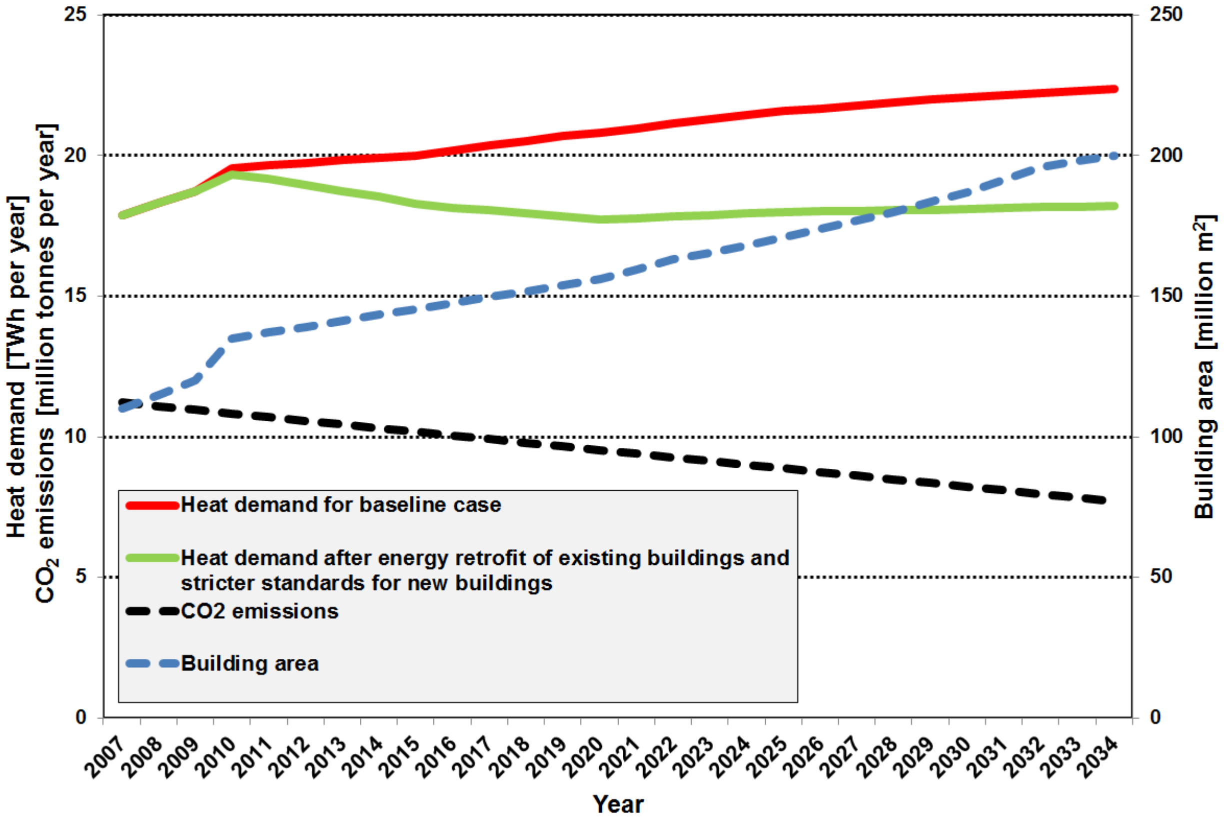


Figure 2-6 Projected heat energy demand and associated CO_2 emissions for buildings in Urumqi *(Source: City of Urumqi Construction Committee, 2010)*

The current retrofit programme in Urumqi envisions that by 2015, a total of 16.2 million m^2 of building area will be renovated to the 50% energy savings standard. If no further action is taken and the energy saving code for new buildings would not be amended, heat demand will increase to 22.5 TWh per year by 2034. The Integrated Energy Master Plan (City of Urumqi Construction Committee, 2010) calls for an acceleration of the building retrofit programme to 28 million m^2, which at a cost of 200 RMB/m^2 (25 €/m^2) amounts to a total of 5.6 billion RMB (690 million €). Implementation of the programme, combined with increasingly strict energy efficiency standards for new buildings and reduction in distribution losses, would essentially result in keeping the total heat demand in 2034 at the level of the year 2007. This would be particularly remarkable achievement as the building area is assumed to increase from 110 to 206 million m^2.

2.4 Overview of contributions from the RECAST Urumqi project with respect to energy efficiency of buildings

Given the recommendations in the Integrated Energy Master Plan, two major issues were indentified for further analysis: (a) improving and financing the energy efficiency of existing buildings; (b) demonstrating that buildings with an extra-low energy consumption can be feasibly and economically built. The specific contribution to improving the energy efficiency of buildings was defined in collaboration with the Xinjiang Environmental Protection Bureau, the Construction Committee of the City of Urumqi and Dacheng International, a real estate developing company. Lighthouse projects are needed to demonstrate that an even higher reduction in the energy demand in existing and new buildings can actually be achieved at reasonable costs. The RECAST Urumqi project contributed to this with the following:

- Development of background materials for optimised planning
- Transforming an existing building into a zero-emission building in Urumqi
- Creating the first passive house in Western China
- Devising a plan to subsidize energy-efficient construction
- Participating in the development of a more stringent standard for new buildings in Urumqi
- Helping to create a network of passive house projects in China and the development of a passive house standard for Urumqi

This resulted in many activities[5], a selection of which is summarized here:

- A Sino-German workshop on the energy efficiency of buildings was organized in Urumqi in January 2007 with presentations from 12 German & Chinese experts, the participation of many Urumqi stakeholders, and resulted in local media coverage.
- A one-day workshop in Heidelberg for a delegation of Chinese specialists (including representatives from Urumqi) on low energy buildings in December 2008 as part of a GTZ sponsored tour of projects in Germany and Poland.
- A five-day workshop in Heidelberg on the planning of low-energy houses in March 2009 with a focus on passive house design, policy development and excursions to objects in Heidelberg and Frankfurt (summary in document 2)
- Publication of a 108-page booklet *Sustainable Elements for the Development for the Dryland Megacity Urumqi* in April 2009 in collaboration with Culturbridge Architects Grünstadt/Germany and Beijing/PR China (documents 30, 31); with lectures given at the Construction Committee, the Xinjiang Architectural Design Institute, the Dacheng International Center and other locations.
- Energy efficiency review in April 2009 of the Dacheng International Center in Urumqi; recommendations to improve energy efficiency and indoor climate in Dacheng International Center on the basis of the current planning status, in collaboration with Culturbridge Architects (document 80)
- A one-week planning session in December 2009 for the renovation of the agricultural training center in the Nanshan area near Urumqi in collaboration with Culturbridge Architects.

5 Key projects are summarized in Action Sheets (document 1), and by the Chinese partners in posters (documents 25, 26)

- Preparation of a design plan in January 2010 for the renovation of the agricultural training center in the Nanshan area near Urumqi in collaboration with Culturbridge Architects and Prof. Wang, University of Xinjiang (document 71)
- Preparation of a preliminary design plan in January 2010 for the new construction of a passive house in Xingfu Rd. in collaboration with Culturbridge Architects and the Xinjiang Architectural Design Institute. Partial funding for this planning was provided by Dacheng Industries directly to Culturbridge Architects (document 72).
- Negotiations in March 2010, for the Nanshan renovation project, with the department for city planning and construction licensing of the City of Urumqi.
- Finalization of design details on the Nanshan renovation project in March 2010 with a review of energy consumption for various options provided by the Passive House Institute in Darmstadt/Germany (document 34).
- Ribbon-cutting ceremony for the start of the Nanshan renovation project on 27 May 2010
- Support for a pCDM project application by the City of Urumqi in May 2010 (see chapter 4.8)
- Finalization of design for the Xingfu Rd. Construction project in July 2010 with a review of energy consumption for various options provided by the Passive House Institute in Darmstadt/Germany (documents 35, 36)
- Initiation of a new low-energy high-rise project (Dacheng Tower B), December 2010
- Contribution to the pCDM methodology for the determination of CO_2 emission factor for CHP heat in the Guang Hui zone, December 2010 (document 90)
- Official inauguration of Urumqi's first zero-emission building with energy certficate, the retrofit of the Nanshan agricultural education center, 17 July 2011 (documents 21, 22, 38)
- Comparison of district heating networks in Germany and Urumqi, together with DAAD scholar Liu Ming, November 2011 (document 17)
- Ground-breaking for Xingfubao, the first passive house in West China, Urumqi, 3 May 2012
- Presentation of the RECAST Urumqi project and its achievements before representatives of the City of Karamay (pop. 420,000) in the North of Xinjiang, 9 May 2012
- Expert workshop on the question *Does the German passive house standard fit to China?*, Heidelberg, 7 November 2012 (document 48)
- Preparation and organization of a tour of senior personnel responsible for the construction of the Xingfubao passive house in Urumqi including a 3-day practical training at the Berufsförderungswerk e.V., Kompetenzzentrum für Nachhaltiges Bauen Cottbus, 19 to 23 November 2012
- Further outreach activities on passive house in the Xinjiang cities of Changji and Karamay, 31 January to 05 February 2013 (documents 58, 59)
- Networking with other passive house projects in China at Passive House Conference in Frankfurt, 19-20 April 2013
- Finalization of details for Xingfubao passive house, April–October 2013 (documents 40, 41)
- Xingfubao construction site quality inspection and workshop, Urumqi, Improvement of ventilation concept, 23-26 September 2013
- Training seminar “Quality control for passive houses”, Urumqi, 09 October 2013
- Presentation of Xingfubao project at a workshop on passive house technology, at Building Energy Research center, Tsinghua University, Beijing, 18 November 2013
- Training and quality management of window installation at Xingfubao, June 2014
- Developing passive house monitoring/auditing system for Xingfubao, June 2014
- Training and quality management of ventilation and heat recovery unit installation at Xingfubao, June 2014 (documents 15, 16,17, 64)
- Blower door workshop and airtightness test at Xingfubao, 18-20 August 2014 (document 8)
- Adaptation of TU Berlin training materials to condition in Urumqi, September 2014 (documents 6, 7)
- Final inspection for passive house certification at Xingfubao, 23-24 September 2014 (documents 9, 10)
- Xingfubao opening ceremony, 25 September 2014 (documents 3, 4, 5, 11, 12, 14)

Starting point of the effort was the 108-page design handbook *Sustainable Elements for the Development for the Dryland Megacity Urumqi* (Figure 2-7), focusing on the design of low energy buildings adapted to cold winters and dry hot summers. The design combined elements of traditional atrium buildings that could be adapted to year-round use of heated indoor spaces. This was demonstrated with designs of prototypes of different building sizes, types and city regions (urban/suburban) in order to visualise how theoretical approaches (A/V ratio, passive cooling etc.) could be put into practice in a meaningful way; balancing ecological, economic, and social factors. An example from the handbook, the *Megablock* prototype is based on the courtyard as regional typology, compact surfaces, mixed-use, passive house, summer heat block-out; grey water treatment is shown in Figure 2-7; for a video visualization see document 82.

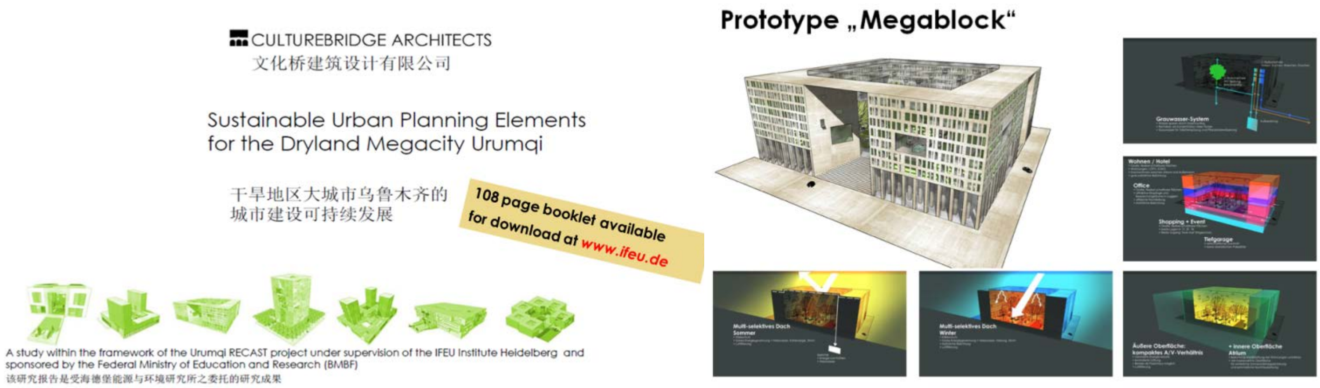


Figure 2-7 Design handbook (left), *Megablock* as prototype (right)

2.5 Lighthouse projects

2.5.1 Lighthouse project 1: Extra low-energy renovation of existing buildings

Quick-fix solutions to a building under construction

The first concrete input for an almost-constructed building was the request to review the energy efficiency of Dacheng International Center built by Dacheng Industries on Beijing South Rd. in Urumqi (Figure 2-8). Because the building was structurally already completed, suggestions for improvement focused on (a) exposing the reinforced concrete ceiling to enhance passive cooling, (b) to use additional shading devices (interior or exterior mounted) to reduce cooling needs during the summer and (c) to change the mechanical ventilation by adding heat recovery. Options (a) and (b) were implemented.

Transforming an existing building into a zero emission building in Urumqi

The refurbishment of the existing Nanshan Agricultural Training Centre with 769 m^2 of net heated floor space, to create the first zero-emission building in Urumqi, was carried out by local partners (Construction Committee of Urumqi, University of Xinjiang, and the Xinjiang New Energy Institute) in cooperation with the German partners IFEU Heidelberg, Culturebridge Architects Grünstadt/Beijing, and the Passive House Institute Darmstadt.

The existing double-storey building is located in the South Mountains about 50 km from Urumqi's city centre. Built in 1995, the building had a gross floor area of 984 m^2. Before transformation, a coal-fired boiler around 300 metres away supplied district heat. The building lacked adequate insulation and was draughty during winter months. The guest rooms lacked toilets and showers and had cast iron windows that were responsible for substantial heat loss. The low quality of the construction promised fair energy savings with standard refurbishment measures, but was not a suitable base for high standard refurbishment, like the Passive House Standard.

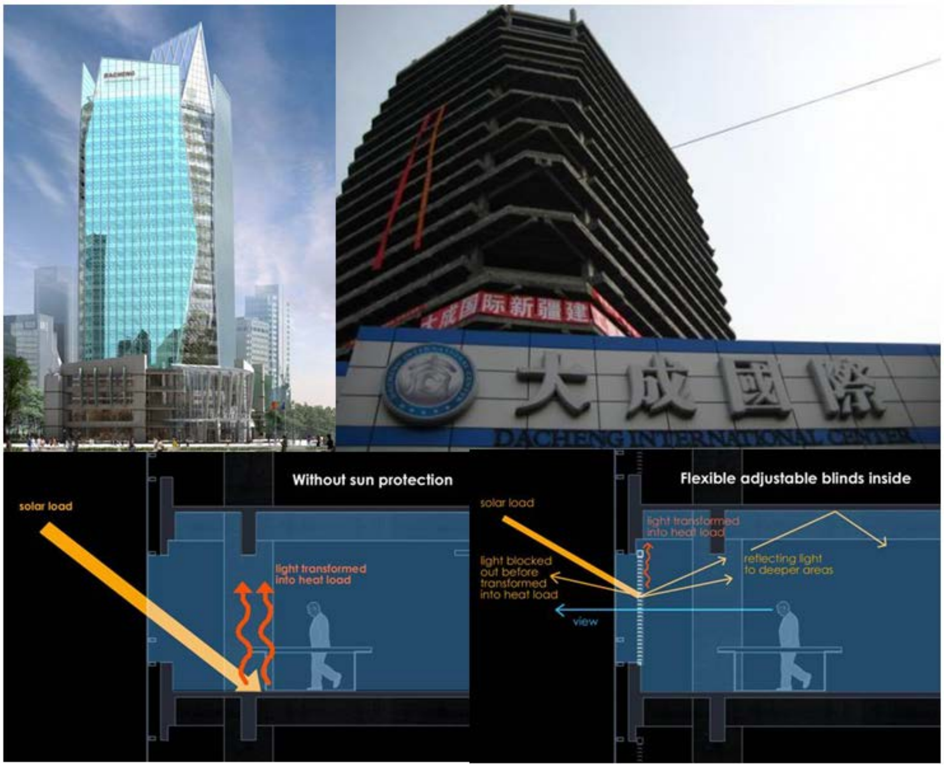


Figure 2-8 Dacheng International Center (clockwise: design concept, construction status in April 2009, analysis of options for enhanced sun protection and passive cooling)

The aim of this prototype project was to introduce various concepts for energy efficiency, with a focus on approved effective and simple high-quality measures that utilise passive solar gains, rather than expensive fault-prone ‘high-tech’ solutions. Thus, in 2010, the German partners (IFEU Heidelberg, Culturebridge Architects Grünstadt/Beijing, and the Passive House Institute Darmstadt) began to refurbish the existing building in cooperation with the local partners (Construction Committee of Urumqi, University of Xinjiang and the Xinjiang New Energy Institute); document 81.

The steps to transformation were: (a) optimising the building design, (b) improving insulation of floor, walls, and windows, (c) installing floor heating and heat recovery systems, and (d) fitting a solar heating system with seasonal storage. The heat demand in the harsh winter climate is now entirely supplied by solar heating with an innovative seasonal storage; the entire demand of electricity is provided by a photovoltaic system.

Given the limited availability of insulation material, a combination of 150 mm extruded polystyrene foam (XPS, a standard insulation material) with casement windows (two double-glazed windows) was selected to achieve a low U-value, reducing the heat transfer coefficient for walls from 1.44 to 0.2 $W/(m^2*K)$. Water-based floor heating with solar water panels served as the primary heating device – supplemented for periods of low solar radiation by electric heaters. High quality, airtight construction and an active ventilation system with heat recovery allowed for a constant comfortable interior temperature even in the extreme winters.

The focus was on simple design features inspired by the passive house concept, on which the German partners based a detailed concept design. The local design partner at the Xinjiang University, Faculty of Architecture, Prof. Wang, produced the construction drawings. During this phase the German partner, Culturebridge Architects, reviewed the drawings and pointed out issues, challenges, and potential for improvement based on their individual experience and advice from the Passive House Institute (document 79).

Heat demand calculations for the pre and post-renovation status were done by both the University of Xinjiang, as well as by the Passive House Institute, Darmstadt/Germany. These calculations are summarised in Table 2-4. All amounts indicated were converted to the net usable floor space.

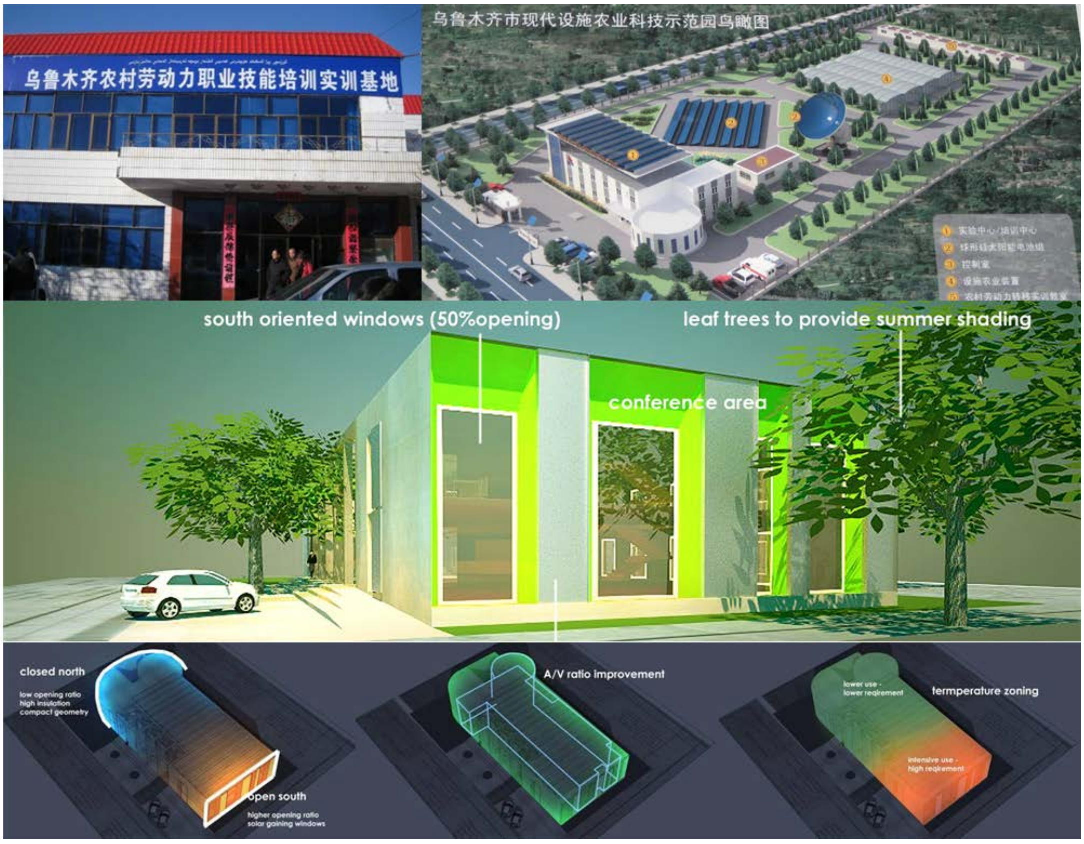


Figure 2-9 Nanshan renovation project (top: current status and originally proposed renovation; middle: improved designs prepared by RECAST Urumqi; bottom: examples of solar orientation, surface ratio, temperature zoning)

Table 2-4 Estimated heat demand relative to usable net floor space; kWh/(m^2*a)

Condition	Prof. Wang, University of Xinjiang/Urumqi	Passive House Institute, Darmstadt/Germany
Current status 2007, pre-retrofit	332	420
After renovation, no heat recovery	68	76
After renovation, with heat recovery	47	
With additional casement windows		68
- plus better insulation (400 mm)		46
- plus heat recovery		27

The heat demand calculated from heat metering in January and February 2011 was 59 kWh/m^2*a which corresponded well with the value predicted from final PHPP modelling (64 kWh/m^2*a). After the successfully completed retrofit, an energy certificate for the renovated building was prepared which provides a transparent representation of the improvements. The project serves as a role model for other projects in the area (Figure 2-10). Starting in 2011, the heating energy demand was reduced by more than 85% and annual emissions of 88 tonnes of CO_2 were avoided. In the annual average, surplus electricity provided by the PV system exceeds the building's electricity demand.

Table 2-5 Heat transfer coefficients of various components of the Nanshan Training Centre (W/m^2*K)

Component	Current status, pre-retrofit	Theoretical after renovation	Measured after renovation
Roof	1.2	0.15	0.16
External walls	1.5	0.2	0.35
Doors and windows	3.26	1.5	0.85
Ground floor	0.5 (0.3)	0.15	-
Outside gate	4.7	2.5	-

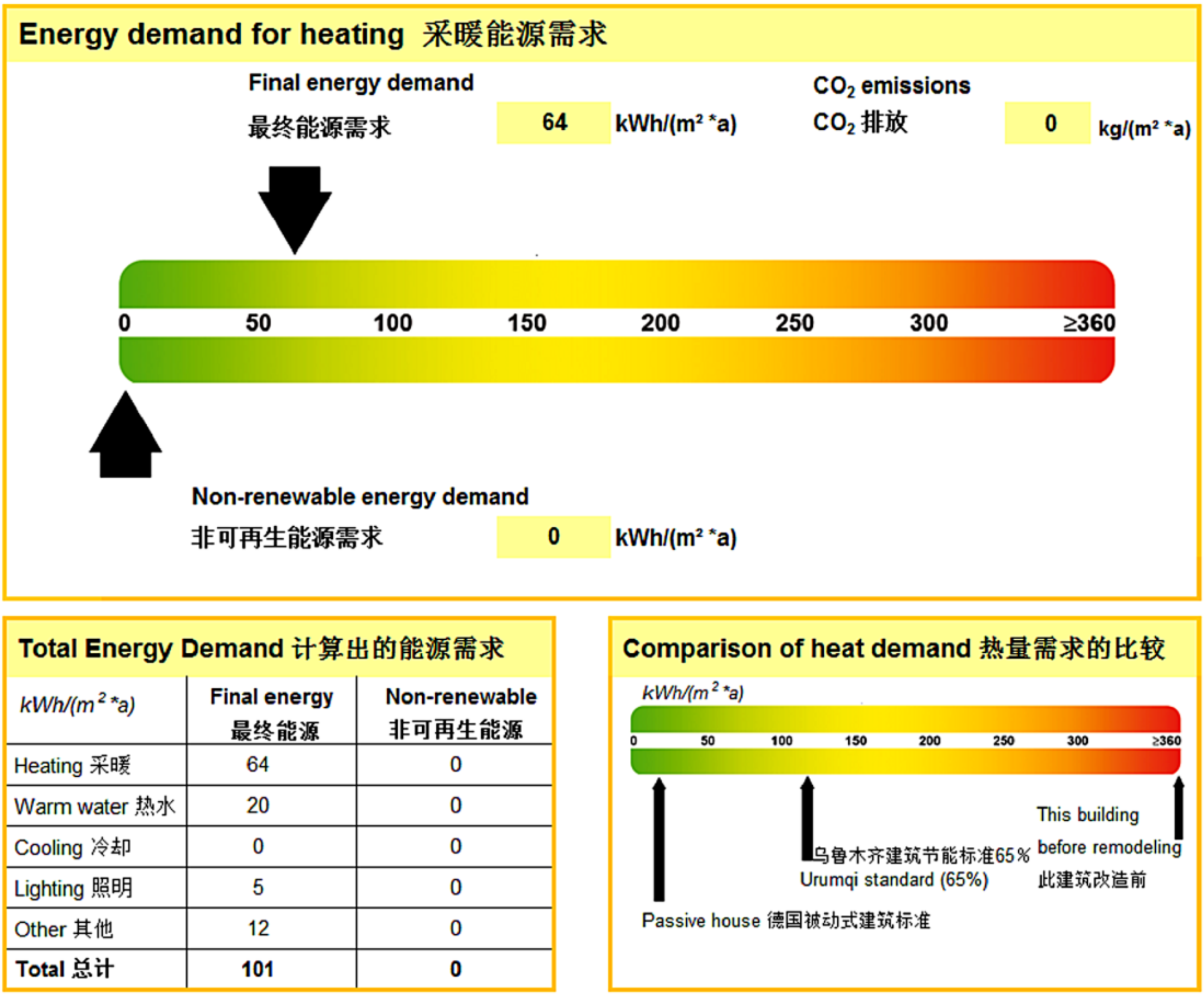


Figure 2-10 Energy certificate of the zero-emission Nanshan Training Centre after retrofit

The joint collaboration with local partners in the prototype projects resulted in an improved understanding of the technical and the economic conditions in China. It was difficult to exploit the potential of insulation as high-quality windows (triple-glazed insulation windows, U-value including frame <0.8) were lacking and aluminium covered XPS panels, as well as heat-insulated dowels were not available at adequate costs in China at that point in time. The maximum savings recommendation by the Passive House Institute could thus not be achieved.

Initially the connection to the existing district heating system appeared to be advantageous as district heat is available at times when the supply from solar panels would be inadequate. However, even if the proprietor were prepared to install a metering device to measure the actual heat consumption, he/she would still be charged at the full rate of 22 RMB per m^2 and year. Furthermore, the district heating company does not allow the use of heat exchangers for hot water supply during the winter season when district heating is available. A separate electric hot water heater is, therefore, commonly installed.

The renovation costs were shared between the proprietor of the building and funds donated to the project by the City of Urumqi. The cost of 2.8 million RMB (345,000 €) was higher than originally planned, which led to amendments being made to the design (e.g., the enclosed entry was omitted). The budget was allocated as follows: 2 million RMB (246,000 €) for energy conservation, 0.35 million RMB (43,000 €) for seismic reinforcement, 0.072 million RMB (8,900 €) for increased functionality, and 0.4 million RMB (49,000 €) for solar energy utilisation. The concrete technical concept might not be replicated in the centre of Urumqi as there is only low capacity for solar heating in high-density dwellings. The achieved reduction of heating demand of 85% in a double-storey building, however, can be transferred to other buildings as long as solar orientation is accounted for and high quality construction can be ensured.

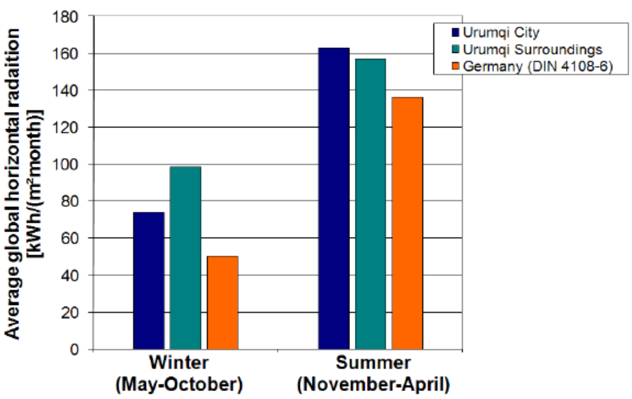
Figure 2-11 Nanshan low-energy renovation project (before and after renovation)

Figure 2-12 Nanshan project inauguration ceremony in July 2011

2.5.2 Lighthouse project 2: The first passive house in West China

There is a great interest in Urumqi for the design of extra-low energy or “green” buildings, from the side of architects, the City of Urumqi construction committee as well as from local developers. However, there is confusion, as to exactly how to define what is “green” and “low energy”. The RECAST Urumqi project has responded to this need on several levels:

- First, a joint understanding of building design and rating concepts and demonstation of examples of passive houses in Germany were established in a workshop in Heidelberg on planning of low-energy houses in March 2009 as well as in many meetings that took place in Urumqi thereafter (documents 37, 43, 46)
- A 108-page design handbook “Sustainable Elements for the Development for the Dryland Megacity Urumqi” (documents 30, 31) was developed, focusing on the design of low energy buildings adapted to the cold winters and dry hot summers. The design combines elements of traditional atrium buildings that could be adapted to year-round use of heated indoor spaces. This was demonstrated with designs of prototypes of different building sizes, usages and city regions (urban/suburban) to visualize how theoretical approaches (A/V ratio, passive cooling etc.) can be put into practice in an attractive way, balancing ecological, economical and social goals. An example of the “Megablock” is shown in Figure 2-7. The handbook was presented in various lectures in Urumqi.
- An analysis of the heating energy needs under the harsh climate conditions in Urumqi (documents 32, 33). The report by the Passive House Institute concludes that the space heating demand can meet the passive house standard of 15 kWh/(m^2*a) as shown in Figure 2-13; see also document 39.



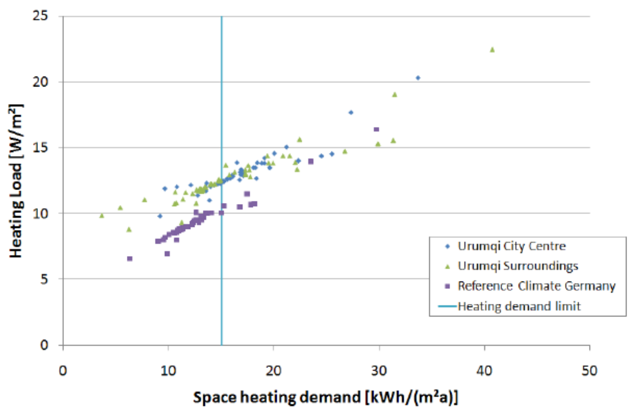


Figure 2-13 Solar gains in winter are higher in Urumqi surroundings compared to the city, mainly due to absence of smog (left); space heating demand can meet the passive house standard simulated with variation of design options (right)

Together with our Chinese partners (Construction Committee of the City of Urumqi and Dacheng Industries Inc., a private investor), we visited numerous super-low energy buildings in Germany and jointly decided to build the first passive house in western China with a mere 13% of the heat demand required for new buildings in Urumqi. The agreement was to provide passive house research and capacity building efforts for the development of a 7,979 m^2 mixed-use building to be called *Xingfubao* (Happiness Castle), with an underground garage, supermarket, restaurants, shops, office, and residences. It was insulated to meet stringent u-values (W/(m^2 K)) for walls: 0.15, roof: 0.13, floor slab: 0.11 and windows: 0.8 as well as an efficient heat recovery system (η = 0.75). Solar collectors on the roof provide hot water during summer; natural gas is used for heating and hot water during winter. The design parameters are summarized in Table 2-6. The *Xingfubao* project combines a sustainable building design that is attractive to clients despite higher construction costs. It demonstrates that a market for energy efficient buildings can be created.

Figure 2-14 *Xingfubao* project (top: original situation, bottom left: inital design status, bottom right: solar gain and heat recovery)

Figure 2-15 The *Xingfubao* project after completion, September 2014

IFEU prepared the initial passive house design together with Culturebridge Architects and the Darmstadt-based Passive House Institute (see document 72 and visualization movie, document 86). The detailed design work was developed by the Xinjiang Architectural Design Institute. Site work was started in May 2012 and completion was in

September 2014. Construction costs are estimated to be around 34 million RMB (4.2 million €), the City of Urumqi provided cash funding of 2.5 million RMB (300.000 €). Figure 2-14 provides an overview of the architectural design, the status at completion is shown in Figure 2-15. The energy balance was determined with the PHPP tool of the Passive House Institute, which is far more detailed than the conventional tool used by architects in China and allows accounting for external and internal heat gains (Figure 2-16 Projected heating energy demands and gains for Urumqi (Passive House Institute, 2010)

).

The fact that a major real estate developer (Dacheng Industry constructs more than 400,000 m^2/a) is investing in an innovative building design indicates the economic potential for high quality and energy-efficient buildings. The project has triggered production for highly efficient building components in Urumqi and has resulted in negotiations with German companies for joint ventures. Training for construction staff started in late 2012 (Figure 2-17) to ensure high standards of construction, benefiting workers and companies alike. The project was featured in the China National TV Evening news (document 67).

Table 2-6 Design parameters for *Xingfubao* compared to the passive house criteria

Parameter	**Projected**	**Passive house criterion**
Specific heating demand	14.1 kWh/(m^2 a)	15 kWh/(m^2 a)
Heating load	15 W/m^2	10 W/m^2
Pressurisation test result	0.6 h^{-1}	0.6 h^{-1}
Specific primary energy demand (heating, cooling, hot water, auxiliary power household electricity)	54 kWh/(m^2 a)	
Specific useful cooling energy demand	4 kWh/(m^2 a)	

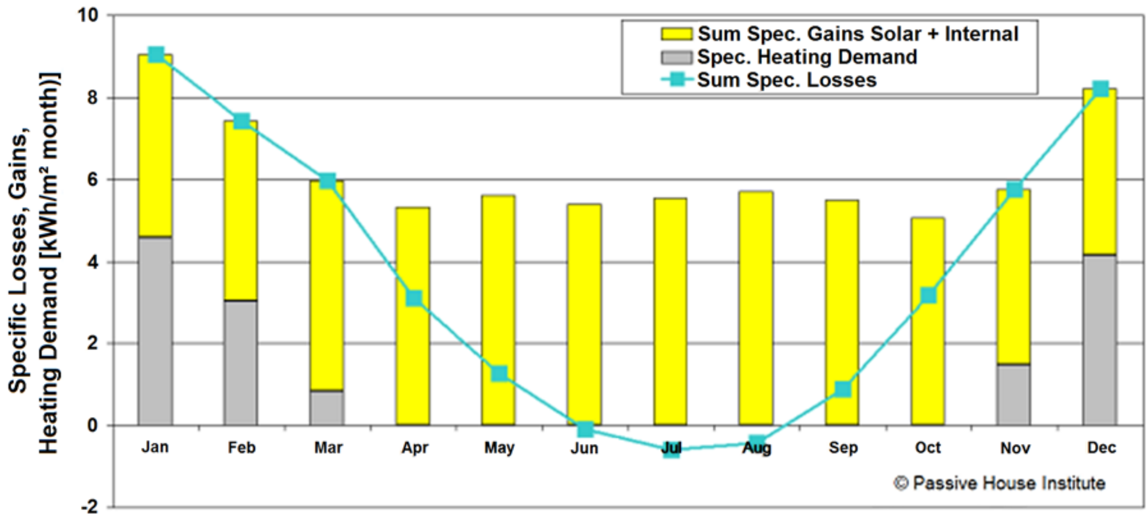


Figure 2-16 Projected heating energy demands and gains for Urumqi (Passive House Institute, 2010)

Capacity building efforts

Several model projects to construct low-energy buildings and passive houses in particular have been implemented in China, with Urumqi as an example. However, these remain insular solutions with hitherto very limited replication. The knowledge and technologies for constructing low-energy housing are in principle available in China. However, architects, building planners, construction companies, and their staff lack experience in combining these technologies to create the complex system that a low-energy house represents: that is, matching equipment, construction materials, construction quality, adequate operation, and maintenance. Furthermore, existing technologies and techniques often need to be adapted to local customs. Tailored capacity-building is therefore paramount to meet these challenges. The target groups, parties involved, and summary of project activities are listed below.

Table 2-7 Capacity building for passive houses: target groups, parties involved, and summary of project activities

Target groups	Party	Activities
Policy makers	Xinjiang Department of Environment	Lecture on energy policy for senior staff, study tour in Germany
City planners	City of Urumqi Construction Committee	3-month training of senior staff person in Germany in 2011, joint pilot projects
Architects and engineers	Xinjiang Institute of Architectural Design and Research	Development of Design Handbook, 3-month training of senior staff person in Germany in 2011, joint pilot projects (retrofit and passive house)
Real-estate developers	Dacheng International Co., Ltd.	Lighthouse project (passive house), feasibility study on passive house high-rise, study tour in Germany
Construction company staff	Happy World Co., Urumqi Gangyuan Architectural Decoration Engineering Co., Beijing	Lighthouse project (passive house), study tour in Germany by senior personnel
University teachers and students	University of Xinijiang, Faculty of Architecture	Development of design handbook, joint pilot projects
Building-component manufacturers	German and Chinese companies manufacturing windows, insulation materials, ventilation systems	Exchange to evaluate marketing opportunities and need for tailored products
Middle-school teachers and students	No. 8 Middle School, Urumqi	Student/teacher exchange, website development

Workshops and conferences: During the course of the project, one international conference and 19 thematic workshops were organized by the Sino-German team, ranging from an overview conference on energy and buildings to workshops on passive house design, and specialised topical workshops related to the lighthouse projects. In all cases, translating workshop materials into Chinese was an essential pre-requisite for success.

Passive house study tours: At the beginning of the project, there were no passive houses to visit in China. In order to gain a better understanding of the design principles and their practical application, visits to a large range of existing passive house sites in Germany were conducted. This triggered interest and strengthened motivation among the local stakeholders, including the local investor Dacheng International, to start the lighthouse project in Urumqi.

Support for 3-month-long scholar visits: The BMBF allocated funding to senior experts from Urumqi to visit Germany for 3 months. This was particularly useful in allowing two experts, Ms. Peng Xiaoyan from the Urumqi City Construction Committee and Mr. Liu Ming from the Xinjiang Institute of Architectural Design and Research, to get a deeper understanding of policies, funding, technical issues, and quality control associated with building energy efficiency in Germany in general and in passive houses in particular. These two individuals are essential in guaranteeing support on the Chinese side.

Architect-to-architect exchange: The design of a passive house requires careful attention to detail. This includes the A/V ratio, passive solar gains, window design, heat bridges, and ventilation system. Culturebridge Architects, the German architecture firm, was responsible for the general building design of the passive house in Urumqi, while the Xinjiang Institute of Architectural Design and Research prepared detailed drawings, taking into account general building standards in China. Many adjustments and iterations were necessary in the collaboration between the two partners, such as reducing the number of heat bridges by eliminating unnecessary support structures for façade mounting.

Practical construction-site training: Given the amount of on-going construction in Urumqi (10 million m^2 per year) and the limited training that migrant construction workers obtain, quality control is a great challenge. The passive house requirements demand great attention to a number of details, such as the installation of 30-cm XPS insulation, the integration with facade design, airtightness of window seals, and ventilation-system design. This was being achieved in three steps: (a) capacity-building at the Training Centre for Sustainable Construction in Cottbus, Germany; (b) a series of training workshop in Urumqi; and (c) air-tightness check with blower door testing following the installation of windows.

The efforts in quality control paid off. The measured air tightness of the building ($0.2\ h^{-1}$) exceeded the required passive house standard ($0.6\ h^{-1}$) by a factor of 3 (Figure 2-18).

Figure 2-17 Capacity building at the Training Centre for Sustainable Construction, Cottbus (2012)

Figure 2-18 Airtight window installation (left), blower door test with Mr. Meyer-Olbersleben (middle), air tightness test certificate (right)

Xingfubao is the first building in Urumqi with active ventilation and heat recovery. This required extensive training in quality control supplemented by an instruction booklet on ventilation system for residents and building staff (Figure 2-19, document 6,7).

Figure 2-19 June 2014 workshop on ventilation system with Tobias Langer, *Kompetenzzentrum Versorgungstechnik im Berufsbildungs- und Technologiezentrum Osnabrück* (left); instruction booklet on ventilation system created by Mr. Mahrin based on training experience in the Young Cities/Iran project of TU Berlin (right)

Certification

The building was officially certified by the Passive House Institute on 25 September 2014. The final heat energy demand was calculated to be 19 kWh/(m^2 a), the total primary energy demand with 190 kWh/(m^2 a). While the heat energy demand exceeded the criterion by 4 kWh/(m^2 a), the building could be certified because it is a pilot project. The difference is due to some thermal bridges (ground floor to underground garage) could have been theoretically avoided but it would have been too expensive to dismantle the section of the building. If the same building would stand in Germany, the heat energy demans would be a mere 7 kWh/(m^2 a); this shows the level of accomplishment.

The certification ceremony for West China's first passive house in Xingfulu (Happiness Rd.) in Urumqi was attended by the vice governor of the Xinjiang province, the vice mayor of Urumqi and Ms. Kundermann, first counsellor for science and technology from the German embassy in Beijing (Figure 2-20). IFEU project director Bernd Franke declared: "This is the first passive house in China's extremely cold climate zone. The technical and economic challenges were great. I am very pleased that our Sino-German team created a lighthouse for the sustainable development of Urumqi. With IFEU support, a passive house standard for Xinjiang is currently being developed. This guarantees many more projects like this one will follow."

Figure 2-20 Passive house certificatation (left), speech by Ms. Kundermann, BMBF repreenttaive at German Embassy Beijing (middle), newspaper report (right)

The German and Chinese partners compared their respective energy demand calculations. The Chinese standard software cannot adequately account for internal heat gains and heat recovery. The Chinese partners were trained in applying the Passive House certification software PHPP; a a Chinese version is in preparation. A publication on this issue is in preparation.

Construction and energy costs are estimated as shown in Table 2-8 based on current energy costs (natural gas). It is evident that the savings pay in heat demand pay off over the expected lifetime of the building.

Table 2-8 Xingfubao: Construction and energy costs

Parameter	**Xingfubao passive house**	**Conventional alternative**
Construction costs (RMB/m^2)	4,500	3,200
Heat energy costs over 50 years (RMB/m^2)	250	2,400
Total	**4,750**	**5,600**

Lessons learnt[6]

The project had to overcome various challenges:

- A specific passive house standard for Urumqi does not yet exist. This required extensive communication.
- Even though district heating is available and would be preferred, the inflexible fee system made the use of natural gas more economical.
- Highly efficient passive house windows were not available in China at the beginning of the project; the project resulted in the first passive house windows to be produced by REHAU, a German window company with production facilities near Shanghai.
- Heat recovery units with an efficiency of >75% were not available in China at the beginning of the project; import from Germany was considered.

6 See also documents 18, 86 and 87

- The project costs may exceed the sale price for the building units; the investor accepted this risk.
- Training of engineers, foremen, and site managers was required to meet the building quality required for the passive house design standard.
- There were some misunderstandings in interpreting the design plans (especially the thermal bridges between ground floor and underground garage). This resulted in improved communication after their discovery.

Crucial for the success of the project achieved thus far was: (a) to share the long-term experience regarding details of passive house design in Germany with our Chinese partners, (b) to understand the interaction of city government and the investor, and (c) to develop incrementally the design and realisation, which included on-site training of engineers and construction workers. As this is the first passive house to be realised in Urumqi, decision-makers were facing many uncertainties. It was imperative to adapt the low-energy design to conditions in Urumqi, to carefully identify potential problems (planning tools, availability of components, quality in construction, marketability) and to provide a three-month training session in Germany for key Chinese experts. The approach to select a challenging prototypical project and to collaborate with a private investor as well as the local government is also recommended in other contexts.

2.5.3 Other activities regarding energy efficiency in buildings

Research into funding possibilities for passive house by changing subsidies

The increased use of natural gas for district heating in Urumqi has changed the economics of energy efficient houses. While the exact additional amount of operating costs in Urumqi's heat supply will not be known until the end of 2015, one can make reasonable estimates. The IFEU team prepared calculations for buildings that are now supplied with district heat from natural gas. These were introduced in discussions with government officials and summarized in a letter to vice mayor Li Hongbin on 20 March 2013 (document 29). It was calculated that over 25 years a 100 m^2 apartment in passive house standard (95% energy savings standard) will save government subsidies of about 71,900 RMB (Figure 2-21). This represents about 36% of the basic construction costs estimated at 200,000 RMB. This money could therefore be used to pay for part of the additional costs. For a 100 m^2 apartment windows that fulfill passive house criteria currently cost about 20,000 RMB, the additional 51,900 RMB could be used for other components (insulation or heat recovery unit).

Over time, as a supply chain for various components is established and experience in building to a 95% standard increases, the government will be able to reduce the subsidy level. In the German experience, the more passive houses are being built; the added investment cost of a home compared to the 65% standard should be on the order of 10%. This indicates that, in time, most of the subsidy can be eliminated at least for new buildings.

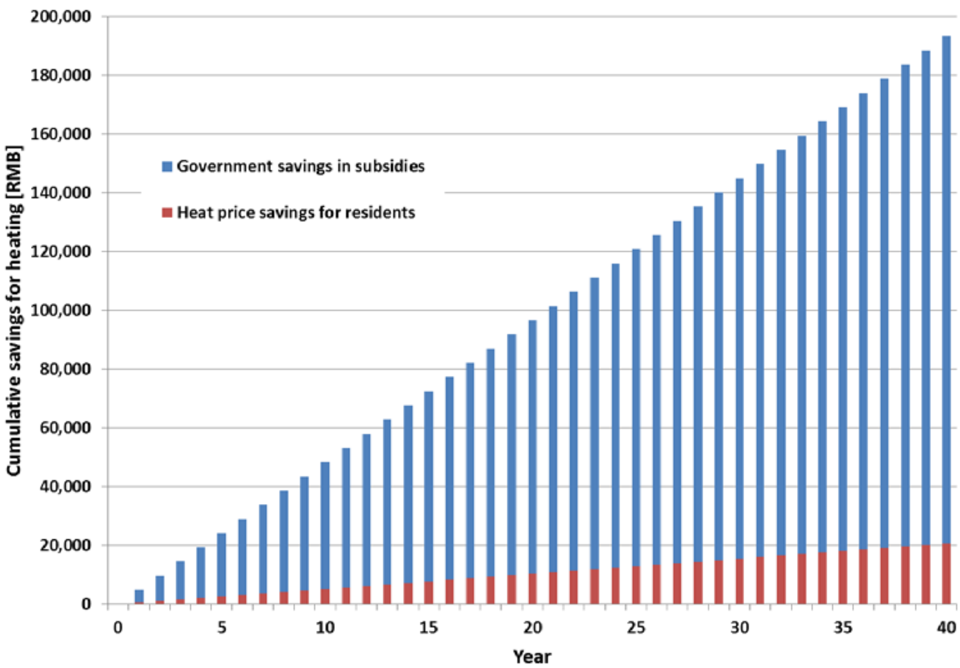


Figure 2-21 Cumulative savings for heating of a passive house compared to average building in Urumqi

It was suggested establishing incentives for apartments with higher energy efficiency standard. This programme should be based on the following principles:

- Energy efficiency standards will be clearly defined.
- Saved government subsidies will be converted to subsidies to investors.
- Implementation of better standards needs to be verified by inspection.

- In addition to the *Xingfubao* (95% savings standard), demonstration projects for more ambitious standards in new constructions are needed, e.g. for the 75% and 85% savings standards.
- Likewise, demonstration projects for more ambitious standards in retrofit of existing buildings, e.g. according to the 65%, 75% and 85% energy savings standard are needed.
- The programme will create jobs in Urumqi and reduce the import of natural gas from Turkmenistan.
- In addition, it was suggested to investigate whether the gas-fired heat plants can be converted to CHP plants.

These suggestions were well received in the ongoing debate over the rising prices for imported naturla gas. Given that the government is not willing to increase heating prices, an energy efficiency fund will be installed given subsidies to extra-low energy projects. This will increase the subsidies set forth in the *Urumqi 2013 Building Energy and Technology Pilot Project Implementation Plan* that was established in January 2013 (document 45).

Feasibility study for super-low energy high-rise building

A feasibility study was conducted together with Dacheng Co. for a 150-metre-high high-rise building, the Dacheng International Tower B, which would be the second-highest building in Urumqi (see Figure 2-22). Although this project is in the first planning stages, the RECAST Urumqi team has analysed the possibility of building a true passive house with a heat energy demand of <15 kWh/(m^2*a) and a primary energy demand of <120 kWh/(m^2*a). The team concluded that this can, indeed, be achieved with an intelligent building design (document 23). The design includes 15 cm insulation on external walls, passive house windows, and a high quality heat recovery system. Simultaneously, the size of the window area and the external shading coefficient in summer need to be optimised in order to keep the cooling demand as low as possible.

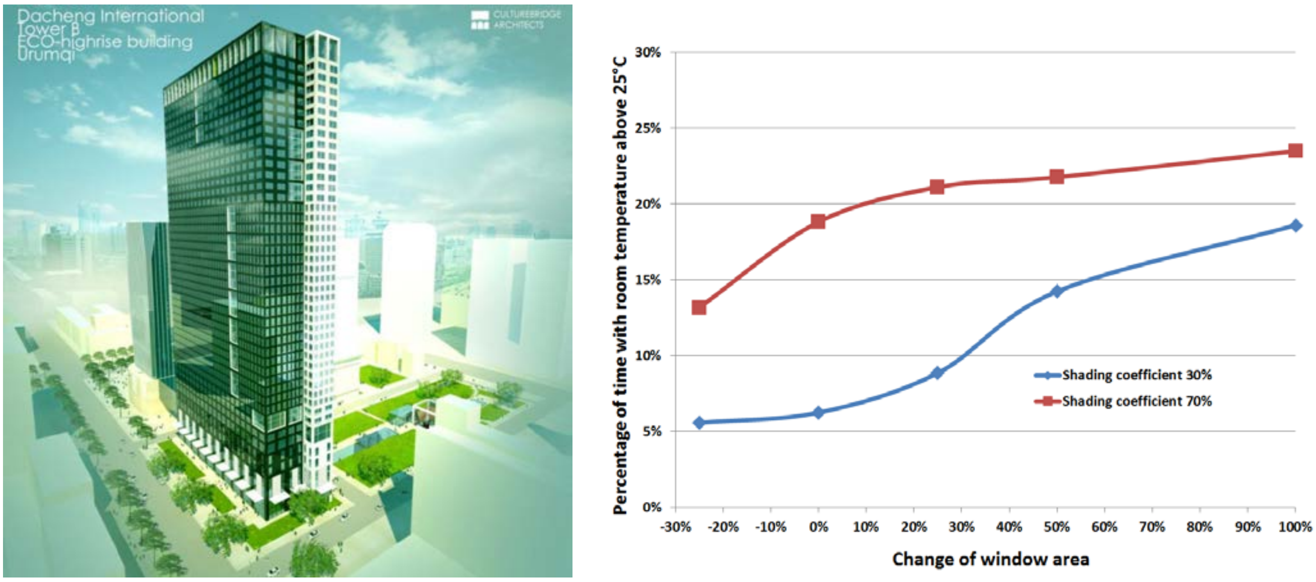


Figure 2-22 Design of the super-low energy high-rise, Tower B in Urumqi (left); percentage of time with room temperature above 25°C (y-axis) as a function of change of window area (x-axis) (right)

Assisting in creating a pCDM to support the energy retrofit of buildings in Urumqi

The renovation of buildings could be financed in part via projects under the Clean Development Mechanism (CDM) of the United Nations Framework Convention on Climate Change (UNFCCC) that allows for additional compensation for energy saving activities based on the related Carbon

Savings. However, a generally accepted methodology for the appproval of CDM projects for building retrofits does not exist. Because the transaction costs for individual buildings are too high, a programmatic CDM (pCDM) appeared to be more feasible.

The Construction Committee of the City of Urumqi intended to organize much of the investment for energy efficiency improvements of buildings through a centralized company. The retrofit in the zone supplied by the Guang Hui (Hi-Tech Zone) Company with a building area of about 2.3 million m^2 and an energy saving potential of 211 GWh per year provided a highly suitable case to demonstrate the carbon savings potential and would be ideal for a Programme of Activities (PoA) by the City of Urumqi. It was estimated that the CER's (certified emission reductions) collected over a 10-year period combined with the fuel savings resulting from energy efficiency were estimated at that time to equate 82 RMB/m^2 or about 37% of the investment required for retrofit. The additionality of the measure can therefore be demonstrated.

The RECAST Urumqi project answered to a request by Construction Committee of the City of Urumqi to start a Programme of Activities (PoA) and conducted a workshop on pCDM on 28 May 2010 in Urumqi. With the assistance of ClimateFocus, an Amsterdam/Beijing based company specializing in CDM implementation the pros and cons of the project were evaluated. ClimateFocus started soliciting suitable clients for the CER's. According to Director Aixing Han, Center of Science and Technology of Construction (CSTC) of the Ministry of Housing and Urban-Rural Development (MOHURD) has already approved the development of a PoA for the energy efficiency improvements of buildings in Urumqi. The Construction Committee was eager of to start with the CDM process, however, external support was necessary due to the limited capacity of the local CDM office. The RECAST Urumqi acted as a link between the various stakeholders and supported this efforts by providing scientific analysis.

The final product of ClimateFocus was a PoA marketing brief (document 90). However, due to rapid decrease in prices for CERs (which dropped from ~14 €/t in 2010 to less than 4 €/t in the year 2013), there was no market demand for the product.

Assiting in the development of stricter standards for new buildings in Urumqi

Beginning in 2010, discussions in the RECAST Urumqi energy efficiency project have focused on a lasting impact by improving the design standard for new buildings. Many design standards were discussed with the staff of the Urumqi Construction Committee. There was hesitation to proceed with stringent standards if no suitable demonstartion projects exist. The successful construction of *Xingfubao*, as extra-low energy building was a major factor in pushing for the new standard. Effective 2014, Urumqi adopted the so-called 75% energy savings standard as the energy efficiency standard of 70 kWh / (m^2 a) gross surface area for new buildings (see Figure 2-23; document 88). Standards for ultra-low-energy buildings, such as passive houses, are in preparation (documents 45, 52). Given the large volume of construction, the potential savings in energy demand and CO_2 emissions are substantial.

A passive house standard for Urumqi and further networking

Combined with achievements of lighthouse projects, the City of Urumqi is currently developing a local passive house standard. IFEU and the Passive House Institute Darmstadt have been asked to be active partners in its development during 2015, wih funding provided by the the Ministry of Housing and Urban and Rural Development (MOHURD), Beijing. Networking with other ongoing passive house projects in China has started in April 2013 at the 17th International Passive House

Conference in Frankfurt/Germany and were coordinated by Dr. GUO Ling[7] from Shenyang, Liaoning province.

The capacity building materials will be utilized for other projects as well. In collaboration with the German Passive House Institute in Germany, partners from Chinese various cities including Urumqi will establish a China Passive House Institute. The website of the *China Passive House Network* (in Chinese and English) has started to share materials and will strengthen the passive house movement in China (Figure 2-24).

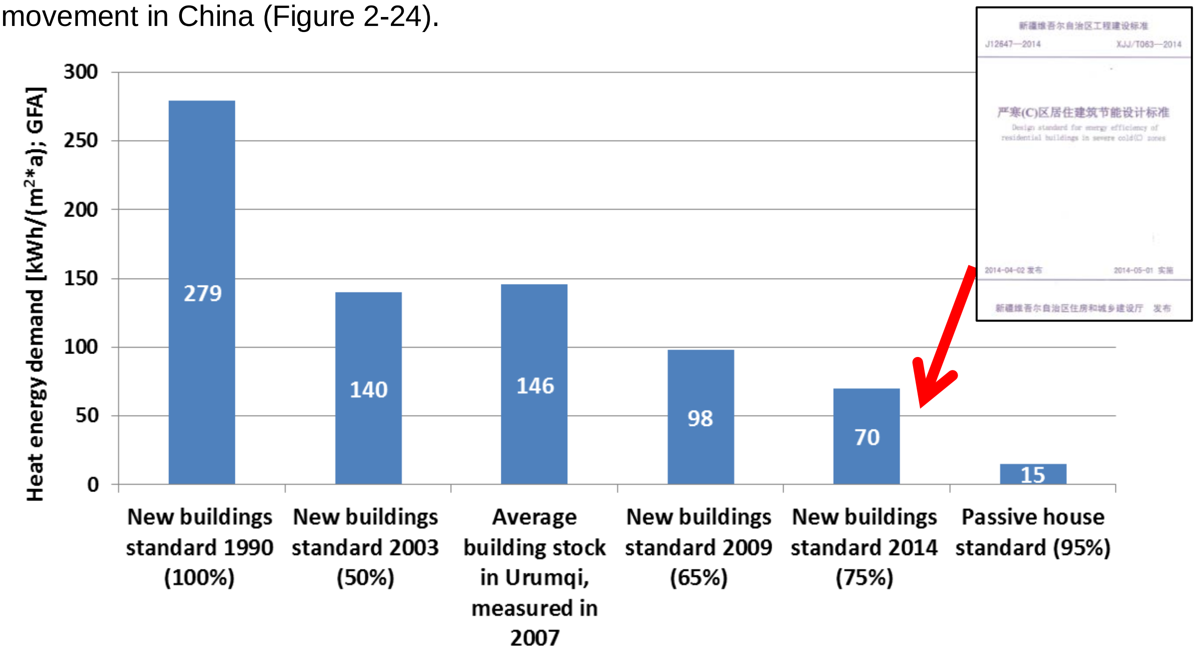


Figure 2-23 Development of standards for heat energy consumption in residential buildings in Urumqi. The 75% standard was developed with contribution from the RECAST Urumqi project and became effective in 2014 (document 88)

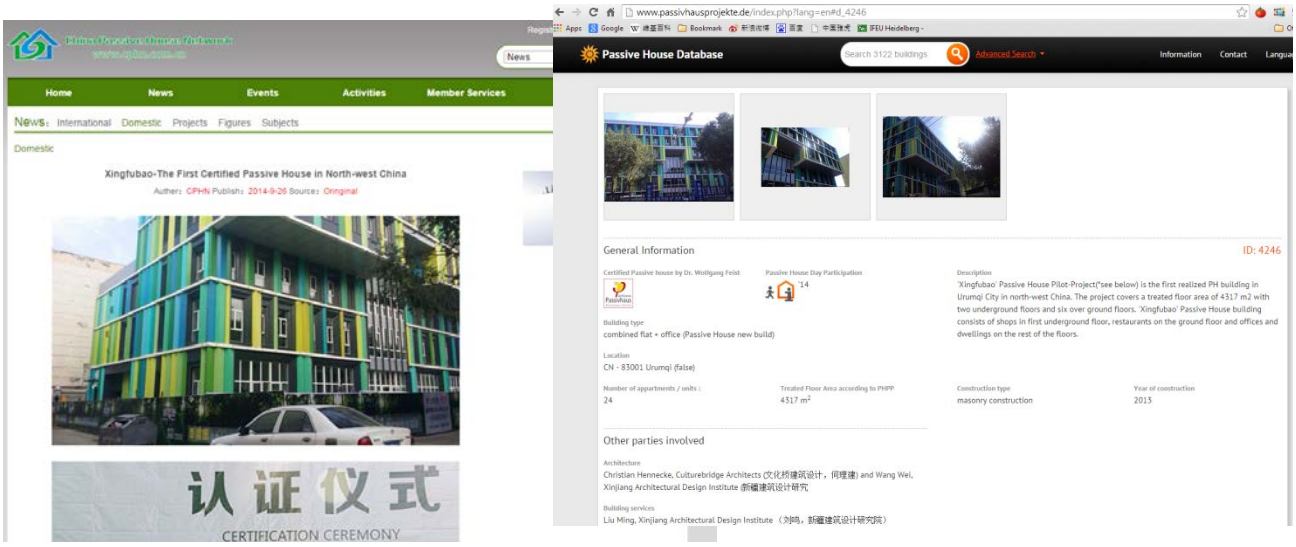


Figure 2-24 Left: news about *Xingfubao* on the website of the newly established *China Passive House Network* (www.cphn.com.cn), right: entry for *Xingfubao* on the Passiv House Database *(http://www.passivhausprojekte.de/index.php?lang=en#d_4246)*

7 This includes projects in Harbin City, Heilongjiang Province; Shijiazhuang City, Hebei Province; Qinhuangdao City, Hebei Province; Yingkou City, Liaoning Province, Nan'an City, Fujian Province). There are 5 five potential projects in Rizhao City, Shandong Province; Nantong City, Jiangsu Province; Chengde City, Hebei Province; and Beijing City.

2.5.4 Conclusion and outlook regarding energy efficient buildings

It is expected that in the near future, ultra-low energy houses (passive houses etc.) will be constructed in larger numbers in Urumqi and other Chinese cities, provided that the technology can be successfully established and that economic incentives are being developed. The demand for high-quality buildings in China is growing, and the central and local governments are increasingly promoting activities to improve energy efficiency in the building sector. Many stakeholders see prototype projects as being an important milestone in this development. The process of careful analysis and demand-driven prototype project development is also considered a suitable approach for other emerging megacities.

The long-term economic feasibility of high-quality, ultra-low energy houses is considered to be high by local investors and government officials. The economic benefit is three-fold: first, in demonstrating that there is a market for such buildings, companies and businesses providing innovative solutions such as architects, energy consultants, and producers of components etc. will develop. Second, there is an indirect benefit resulting from energy savings. Third, the projects demonstrate excellent opportunities for trade in German energy-efficient products and services (heat exchangers, windows, capacity training etc.).

Other extra-low energy building projects will build on the experience gained within the RECAST prototype projects, e.g., a low-energy apartment complex in Qinhuangdao (Hebei province) supported by the German Energy Agency, dena, as well as proposed passive house projects in the cities Karamay and Changji (Xinjiang province). The energy performance standards for new buildings will be revised in the near future in these cities as well. With careful consideration, future projects may be able to achieve even lower energy demands and associated emissions of greenhouse gases than those projected in Urumqi's master plan.

The expertise gained by IFEU and other German partners in the *Xingfubao* project as resulted in an increased demand in further cooperation projects that received direct funding from the Chinese side. Starting in July 2014, IFEU supports the Technological Development Center of Beijing Uni-Construction Group Co., Ltd. (BUCC) in planning for the construction of a passive house in Tianjan, a major harbor city East of Beijing. For this project, IFEU cooperates with the Passive Haus Institut/Darmstadt and Culturebridge Architects/Grünstadt. The 14-storey residential building with an area of 7.000 m^2 will be completed by the end of 2015. The interest in building passive houses increases rapidly in China. These projects are a clear signal that increasing the energy efficiency in buildings is a high priority for Chinese construction companies and decision makers alike.

2.5.5 Lighthouse project 3: Energy and mass-flow analysis for ZhongTai Chemical Co.

Goal of the project

The aim of the project was to identify financially viable solutions that will reduce the environmental impact of the polyvinyl chloride (PVC) production in Xinjiang Province in northwest China. The *energy and mass-flow analysis* method of gathering data over the entire life cycle of a product or process was selected as a suitable approach. This allowed the effective identification of potentials to save energy, resources, and costs.

Background

In 2010, the province of Xinjiang in China had a population of 22 million, with an energy consumption of 2,400 PJ. This was associated with emissions of 214 million tonnes of energy-related CO_2, or 9.8 tonnes per capita, 78% of which is derived from coal. One of the drivers of the sharp increase in energy consumption is Xinjiang's industrial sector, which has grown by a factor of 5.4 between 1990 and 2010 and accounted for 71% of the overall energy consumption in 2010. This is a far higher percentage than in highly-developed countries (e.g., 21% in the US[8] and 30% in Germany[9]). However, the precise sector definitions differ. Strategies for sustainable development in Urumqi and other future megacities clearly need to address the industrial sector. It is therefore imperative to evaluate the industrial sector in the sustainable development of megacities.

The reason for this lies in the reliance of Xinjiang on energy-intensive industries with coal as the main energy resource. As apparent in Figure 2-25, the main energy-consuming industrial sub-sector is oil-processing and coking (24%), followed by the chemical industry (14%), and the metal industry (14%).

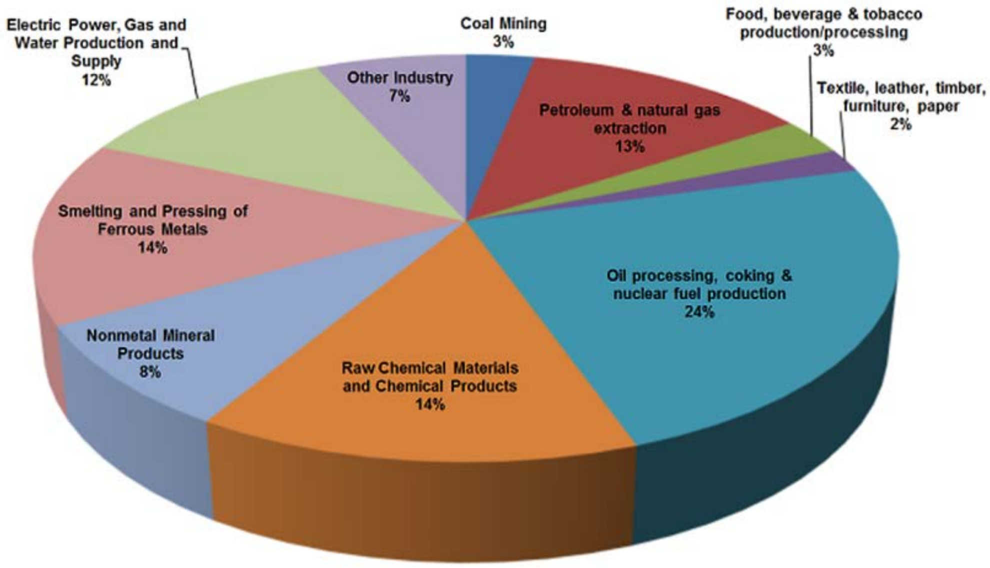


Figure 2-25 Primary energy consumption by industry sub-sector in Xinjiang in 2010

It is imperative to understand the reasons for this development and to analyse the opportunities to combine GDP growth in industry with the reduction of energy demand and subsequent CO_2 emissions. The focus of this study, namely the PVC industry, is a suitable case study as it is a rapidly growing, extremely energy-intensive sector in China. The increasing demand is driven by

8 http://www.eia.gov/totalenergy/data/annual/pecss_diagram.cfm;

9 Calculated from: http://www.bmwi.de/BMWi/Redaktion/PDF/E/energiestatistiken-grafiken

China's fast growth in the construction sector, resulting in the production of twelve million tonnes of PVC in 2010. This equals 37% of the global PVC production, making China the world's largest producer of PVC. The petroleum derived, ethylene based process (petroleum-to-ethylene process, PtE) is the standard process in most Western industrial countries. In China, the coal-based carbide process accounts for 81% of the total PVC production with acetylene as an intermediate raw material (Figure 2-26).

The ZhongTai Chemical Company in Urumqi, Xinjiang Province, is a large company which plans to expand its PVC production from 0.5 million tonnes (2010) to three million tonnes per year by 2015, along with other chemicals from the chlor-alkali process. Compared to the EU-27 production capacity in 2010 of 8.2 million tonnes, it will become a global player in the PVC industry. The RECAST Urumqi project was given the opportunity to collaborate with ZhongTai Chemical Company to identify elements and parameters that could be optimised to improve the energy-efficiency of the operation and to reduce its environmental impact.

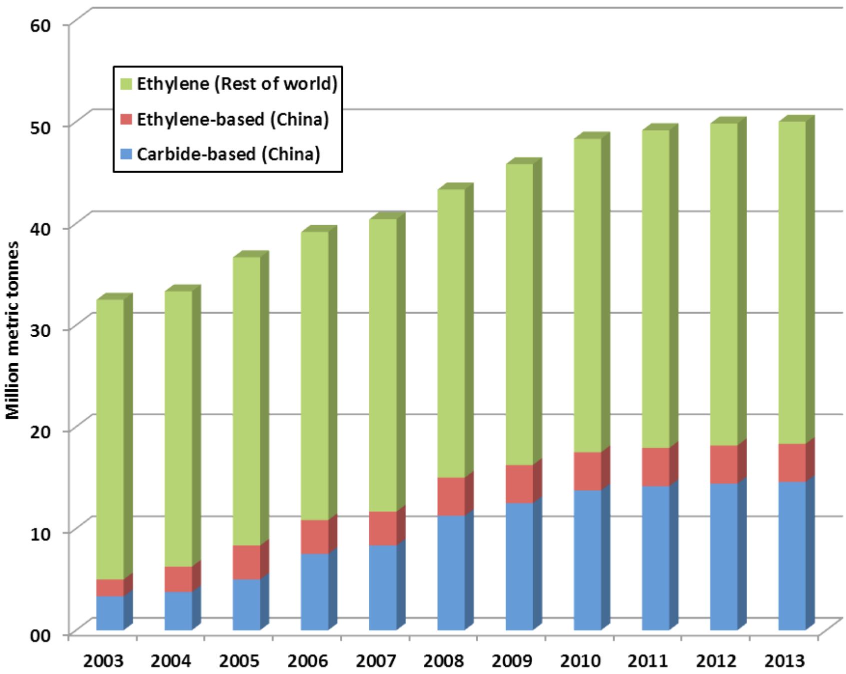


Figure 2-26 PVC production capacity by process in China and rest of the world (Source: Kok, 2009)

Scope of the study

China has issued revised production guidelines that aim to promote clean manufacturing procedures (CPPL, 2002), yet the Xinjiang Department of Environmental Protection (XDEP) was looking for methods that go even beyond the procedures required by these guidelines (a list of questions and the evaluation of limited parameters). It was recognised that the European IPPC – Directive (Directive for Integrated Pollution Prevention and Control), an agency that limits pollution from industrial and diffuse sources by a system of permission and control, could provide valuable recommendations for the Chinese market. Unfortunately, the European regulations are too generalised and too complex to be effectively applied in a Chinese framework.

Energy and mass-flow analysis

Energy and mass-flow analysis (MFA) and modelling as an essential tool is well established in Europe. It is ideally suited to satisfy requests from clients in the supply chain for transparent figures on individual products or services. This can be demonstrated by the publication of eco-profiles for different industrial products and sustainability reports by major companies. The European plastics industry has established industry-wide reporting on the life cycle impacts of major plastic products[10]. All major companies listed on the German stock market DAX report on their sustainability. An independent ranking takes place biannually (IÖW, 2012). An MFA model requires the following steps: (a) a complete list of materials and energy inputs and outputs, (b) a process flow chart, (c) specific data for each component, (d) definition of key parameters for evaluation and (e) an analysis conducted of the potentials to improve the efficiency of energy and water usage in particular sectors.

The energy and mass-flow analysis method was implemented as part of the RECAST Urumqi project using the software Umberto® 5.5 [11]. The motives in selecting this method were the following: (a) transparent assessment of the flow of energy and other resources, pollutant emissions and waste, (b) comparison with energy and environmental indicators of other producers (e.g., in Europe), (c) identification of areas for improvements and cost-cutting, (d) setting of benchmarks for future development, (e) setting the stage for sustainability reporting, (f) help in communication with customers and government agencies and (g) provision of a sound methodology in case of Clean Development Mechanism (CDM) or other types of carbon-trading.

The study at ZhongTai was carried out jointly with the Xinjiang Academy of Environmental Protection Sciences (XJAEPS) as part of cleaner production audits that are mandated by the XDEP. The Chinese partners were trained in the method of a comprehensive energy and material-flow analysis. Furthermore, a Sino-German cooperation base for industrial efficiency was established in July 2011. In addition, to create an energy and mass-flow analysis under Chinese conditions, a Chinese version of the IUWA waste manager was developed and tested by the project partners[12].

The project involved the following steps:

1. Conducting training in energy and mass-flow modelling including input from personnel from ZhongTai and XJAEPS
2. Establishing a comprehensive model of the ZhongTai production plants to identify theoretical options for improvement
3. Implementation of the results in Cleaner Production Audits
4. Comparison of PVC production alternatives under Chinese conditions
5. Analysis of economic constraints in implementation

Training in energy and mass-flow modelling

An initial visit by IFEU to ZhongTai Chemical Company in 2008 resulted in negotiations with XJDEP and others about the collaboration starting in September 2009 (documents 53, 54, 56). A workshop on environmental reporting for companies and an initial training with the Umberto® tool took place in Heidelberg in February 2010, followed by the set-up of a mass-flow model with support from the ifu Institute for Environmental Informatics Hamburg, in Germany in March/April 2010. The joint efforts to set up the comprehensive model are illustrated in Figure 2-27.

A comprehensive energy and mass-flow model of ZhongTai

The major input and output processes of ZhongTai Chemical Company are shown in Figure 2-28. The company has direct access to its primary products (purpose-built coal mines, salt lake, power plants) but also buys electricity, natural gas, and other products (e.g., carbide) from third parties.

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10 http://www.plasticseurope.org/plastics-sustainability/eco-profiles.aspx

11 http://www.umberto.de/en/, see document 49

12 http://www.recast-urumqi.de/, Task group Materials

Figure 2-27 Working together on a comprehensive model of ZhongTai Chemical Co.: hands-on Umberto® training

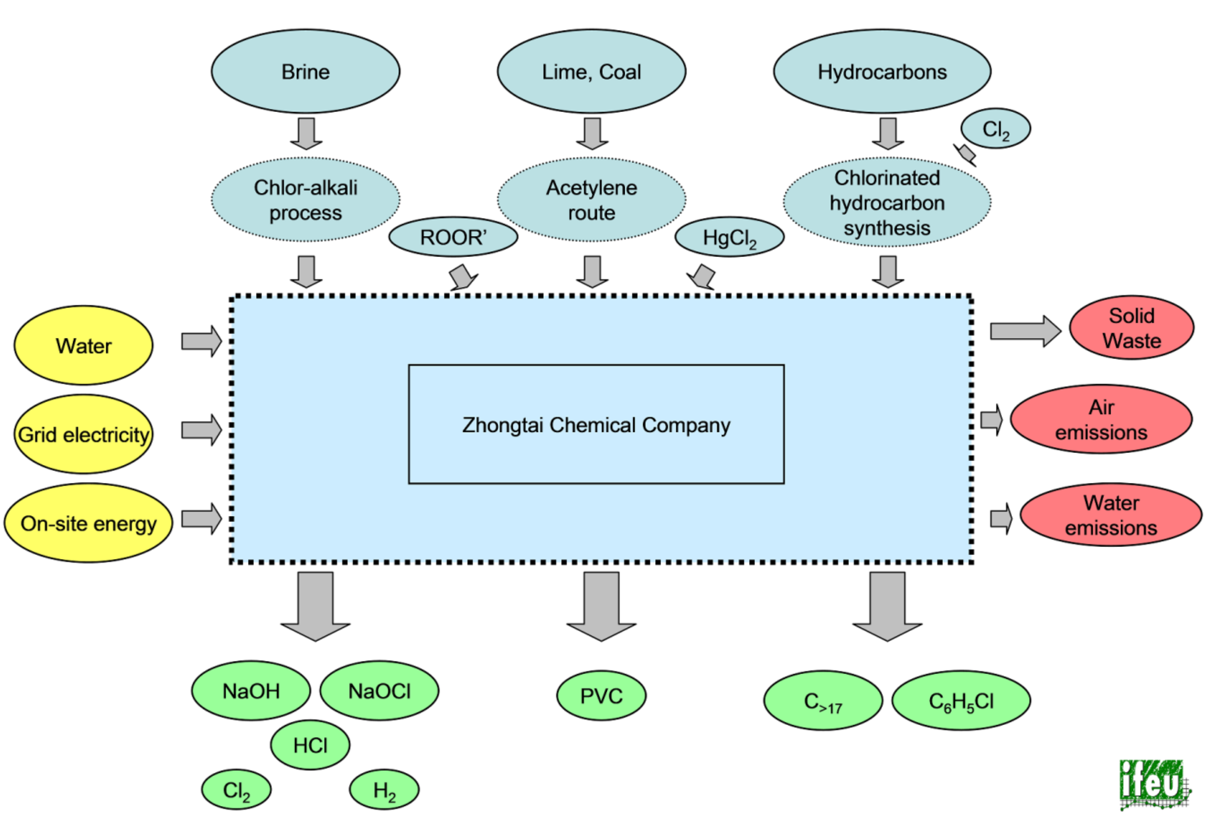

Figure 2-28 Main components of the production processes at ZhongTai Chemical Company

In the first phase, a detailed flow model of the production of suspension PVC (S-PVC) at ZhongTai's plant in Xishan was developed (documents 74, 75). In the second phase, the model was expanded to the newly built production plant in Midong that has an annual production capacity of 600,000 tonnes of PVC resins, 500,000 tonnes of NaOH and other chemical products. For many production steps or machinery within a process line, measured data was not available, so the electricity demand was estimated by allocation based on installed electrical capacity of the equipment. The seasonal variability of energy and water demand at the facility (e.g., cooling-demand is lower during the cold winters) was factored into the model.

Table 2-9 exemplifies the input and output streams data for the Midong factory. The overall consumption of energy when accounting for the pre-products (carbide and chlorine) as well as the electricity is significantly higher than for ethylene-based PVC production. The difference in water consumption (5.7 m^3 per Mg of S-PVC compared to three to four m^3 for European PVC production) is due to less efficient production techniques.

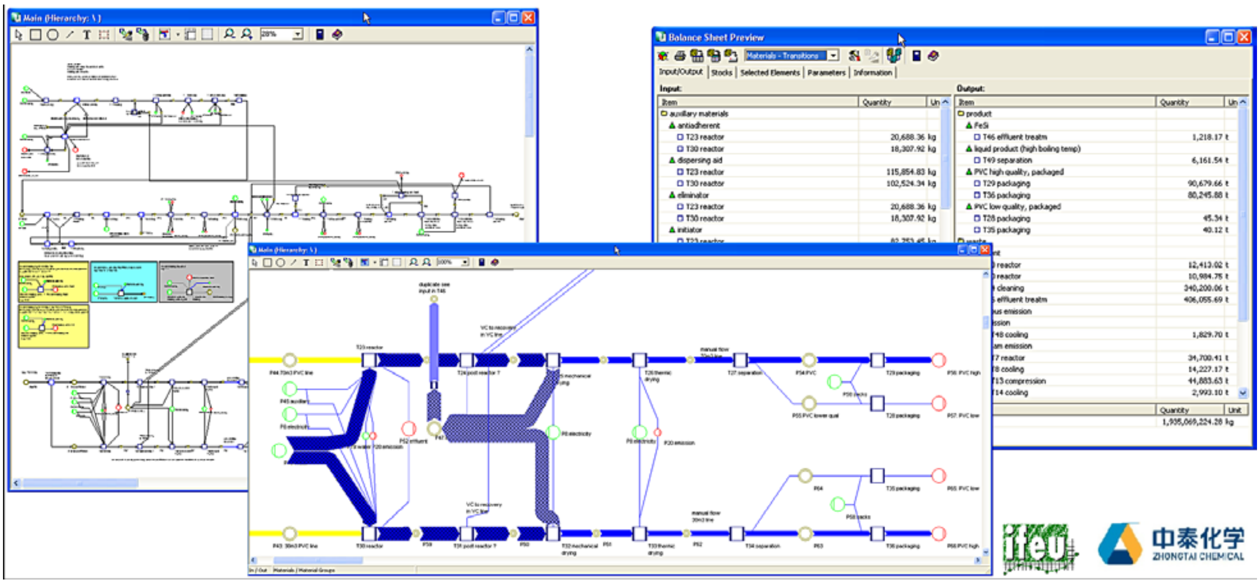

Figure 2-29 Umberto® model of ZhongTai Chemical Co. in Urumqi

Table 2-9 Parameters for S-PVC production at ZhongTai's factory in Midong

Parameter	Unit	Value
Direct emissions of carbon dioxide	Mg CO_2 per Mg PVC	1.2
Energy consumption	GJ per Mg PVC	7.1
Consumption of carbide	Mg per Mg PVC	1.5
Consumption of water	m^3 per Mg PVC	5.7
Carbide slags	Mg per Mg PVC	1.7

Parameters for S-PVC production at ZhongTai

The polymerisation reactor accounts for approximately 82% of the deionised water consumption, whereas various other production steps: (steam striping (9%), vinyl chloride reactor (6%), central cooling (2%), and compressor (1%)) are minor factors. The wastewater, containing PVC particles from the mechanical drying process, is only partly re-used. The major portion is pumped over a distance of fifteen kilometres into evaporation ponds. A reduction in water consumption therefore leads to a reduction of energy and environmental impacts from wastewater disposal.

Figure 2-30 shows the expected decrease of specific electricity consumption per unit PVC with increased production. There are large differences in electricity consumption during months with similar production levels. The data allow a detailed analysis resulting in the identification of specific electricity-use patterns and options to improve processes.

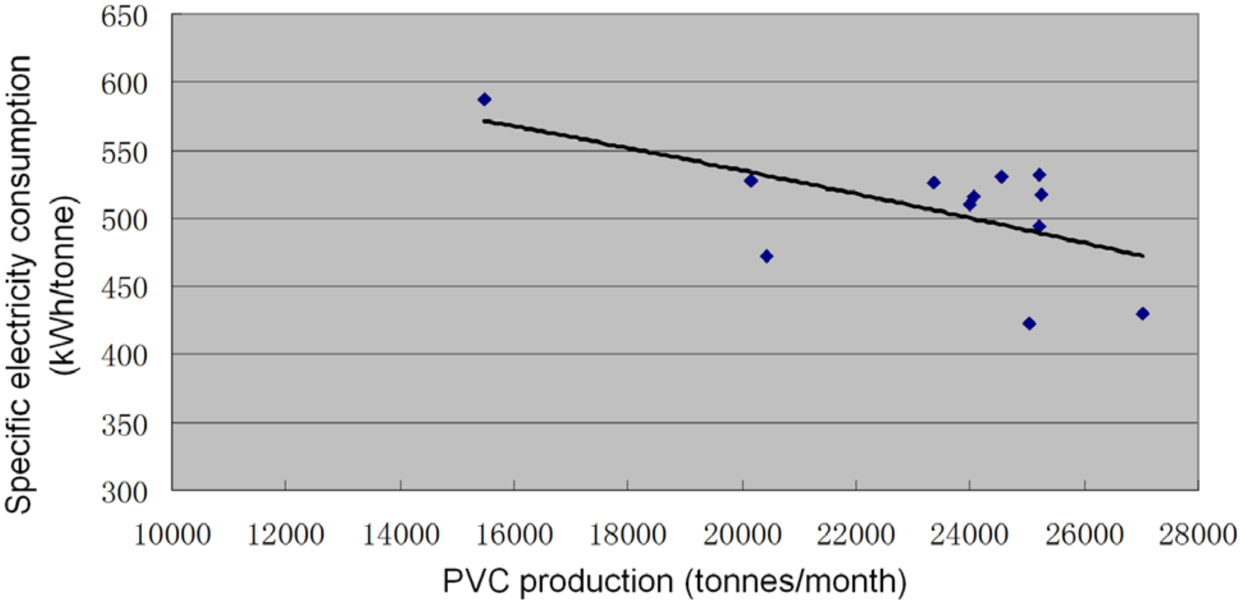

Figure 2-30 Specific electricity consumption per tonne of monthly PVC production at the ZhongTai Midong plant in 2009

Figure 2-31 illustrates the flow of acetylene gas at the plant. Losses mainly occur in the acetylene generator step-up machine and in the washing tower. Despite the fact that there is existing reuse of recovered acetylene from vinyl chloride monomer (VCM) reactors, the analysis revealed that about 4% of the production was lost in the acetylene generator. The suggested optimisation reduces the losses and costs and increases the overall energy efficiency of the process.

Implementing the results in cleaner production audits

Together with partners from the Xinjiang Academy of Environmental Protection Science (XJAEPS) and the Heidelberg-based Institute for Eco-Industrial Analyses (IUWA), IFEU scientists carried out a clean production evaluation for Zhongtai's factory in Midong, the Huatai Industrial Park of Xinjiang Zhongtai Chemical Company. The audit took place between November 2010 and May 2011 and focused on the PVC resins production-line between 2008 and 2010. The site evaluation took approximately one month to complete. The evaluation team conducted a series of investigations of production-lines and assessed the complete production process and the associated pollution by means of investigation, informal meetings, inquiries, interviews, and analysis of written reports. The group collected comprehensive data for the production between 2008 and 2010, analysed the data, and then conducted the audit of the operation (documents 50, 51).

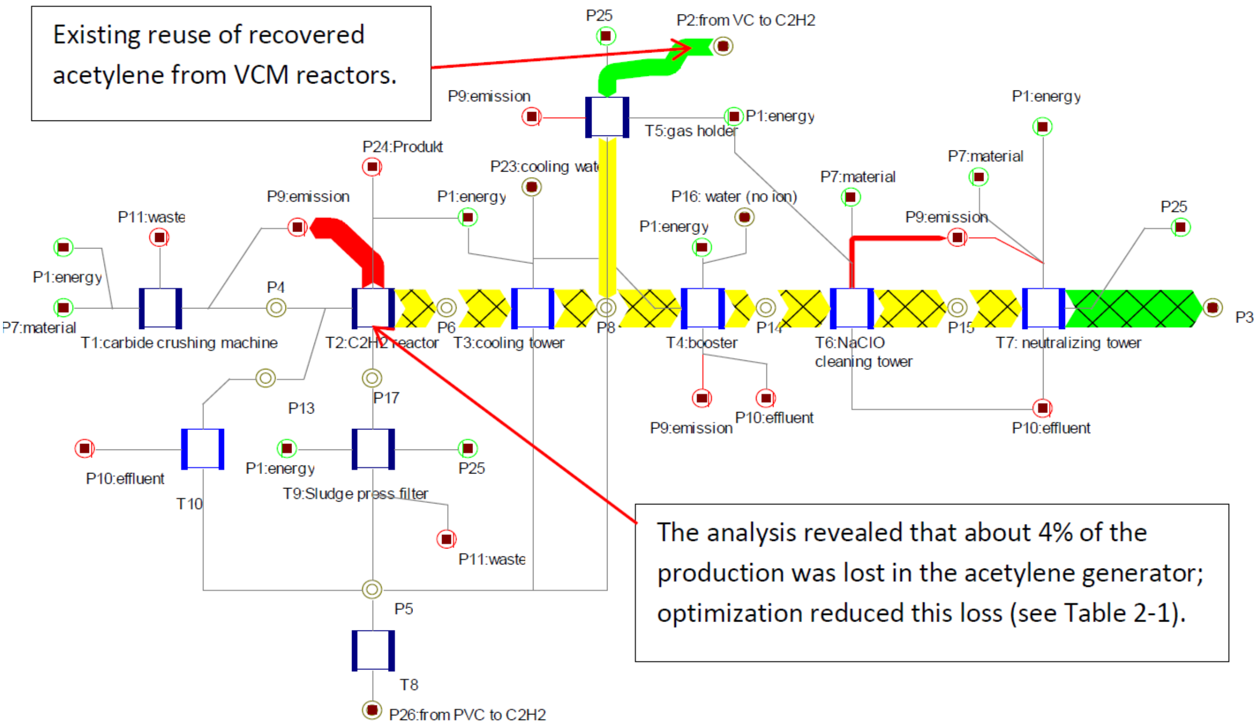

Figure 2-31 Model of the acetylene gas flow (an important intermediate in the PVC production) at the ZhongTai Midong plant using the software tool Umberto®

Table 2-10 provides a comparison of the main production indicators of ZhongTai's process before, and after implementation of the audit recommendations. Carbide and fresh water consumption per unit of product decreased. Specific carbide consumption per tonnes of PVC decreased from 1,507 to 1,421 tonnes PVC in 2008 to 1,421 in 2010, or by 5.7%. Water consumption decreased from 10.9 to 9.9 tonnes per tonne of PVC, the equivalent of 8.8%.

Table 2-10 Change of the main production indicators to achieve the clean production targets for ZhongTai's Midong factory

Parameter	**Unit**	**Pre-2008**	**Short-term target**	**Long-term target**	**2009**	**2010**
Carbide consumption	Mg/Mg of PVC	1.51	1.49	1.43	1.43	1.42
Fresh water consumption	m^3/Mg of PVC	10.9	10.0	9.55	10.1	9.9
Wastewater discharge	m^3/Mg of PVC	3.9	3.7	3.0	3.0	2.6

By means of the audit and the sustainable clean production plan, the company has achieved significant results in energy savings, reduction of production costs, economic-efficiency improvement and a substantial boost in entrepreneurial competitiveness. Previously established targets of clean production have been met to a large degree. As a result, a total of 68 improvements were identified, most of which were implemented (Table 2-11, summarized in documents 50 and 51). For example, acetylene losses were reduced and stricter temperature control was implemented. These interventions reduced the need for cooling or steam in many specific locations. The research collaboration provided detailed insights into the decision-making process on both a technical and financial level. Many improvements were implemented during the year of the audit; other investments require more time and will have a long-term pay-off.

Table 2-11 Random selection from a total of 68 recommended measures to improve energy and resource efficiency at ZhongTai's Midong plant

Description	Investment costs	Benefit
Strict control of cooling tower fan, and circulating water temperature during production	none	Electricity savings of ~1,400 kWh/a, overall savings of 525 RMB/a (63 €/a)
Acetylene condensing water reuse system: dissolved acetylene gas is recovered, discharge in wastewater reduced	~1.2 million (140,000 €)	Save water, reduce wastewater discharges, reduce acetylene gas emissions, overall savings of 130,000 RMB/a (16.000 €/a)
Hot water heat exchanger to complete the single tail-cold ice, change vinyl chloride gas condensing water into liquid	~40.000 RMB (4.800 €)	Reduce cooling needs, savings of 190,000 RMB/a (23.000 €/a)
No further use of water as a cooling medium in winter by circulating water in place of lithium bromide unit to ensure production	~40.000 RMB (4.800 €)	Reduce steam and electricity consumption, savings of 1.3 million RMB/a (150.000 €/a)
Using advanced flow boiling drying instead of the original cyclone drying technology	~20 million (2.4 million €)	Save steam and thus raw coal use (2,700 t/a), savings of SO_2 emissions of 8.7 t/a, savings of 680,000 RMB/a (82,000 €/a)

The adopted plans have generated an annual economic benefit of about 71 million RMB (8.6 million €). The annual savings are as follows: 52,000 t of steam, 7,700 t of coal, 11.5 TWh of electricity, 0.43 million m^3 of water; 1.7 million m^3 of VCM-emissions, 2.4 million m^3 of acetylene, 20 t of SO_2, 460 t of particulate matter; 810,000 m^3 of wastewater with a COD load of 1,200 t; 625 t of industrial waste.

The evaluation group drew up overall conclusions:

1. The PVC resins production-line and environmental facilities have been operated in a regular manner. The pollution control meets established standards.
2. The main environmental issues are dust, acetylene, and vinyl chloride monomer emissions arising from carbide transportation and fugitive emissions in production.
3. Although the on-site production record is relatively complete, monitoring should be improved by equipment upgrading.
4. The clean production audit was successful in identifying potentials for energy savings, reduction of material consumption, and a decrease in pollution with significant economic and environmental benefits.

The implementation of free and low-cost plans has achieved considerable economic benefits. It was thus demonstrated that there is great potential for improvement among large-scale PVC producers. For further audits, the company will refine the audit system extending its application to cover additional production-lines in the expectation that further economic and environmental benefits can be achieved.

Comparison of PVC production alternatives

For future plant expansions, two major PVC production technologies are currently under consideration: the petroleum derived, ethylene-based process 'Petroleum-to-Ethylene (PtE)' and the coal-based, carbide process using acetylene as input for VCM production. In addition, the third and, not yet, commercially-available PVC production process ‘Coal-to-Ethylene (CtE)’ is also a viable option. This process involves the gasification of coal for the production of ethylene and, like the PtE process, using it as an intermediate feedstock.

The flow diagrams of the three technical options mentioned above are shown in Figure 2-32. A great advantage of both the, CtE and PtE process, compared to the carbide process is the avoidance of mercury as a catalyst. This is of paramount importance as the rapid growth of the PVC industry in China may escalate mercury mining due to the fact that mercury-free catalysts are currently not readily-available for large-scale application. Some key parameters of the LCA are summarised in Table 2-12. The data for the carbide process is based on the data gathered at ZhongTai. The data for the PtE is based on the S-PVC eco-profile for European production facilities (Ostermayer and Giegrich, 2006).

Table 2-12 Key parameter values from the Life Cycle Analysis (LCA) of PVC production alternatives (values per tonne of PVC)

Process/parameter	***Unit***	***Carbide process***		***PtE process***		***CtE process***	
		China	**Xinjiang**	**China**	**Xinjiang**	**China**	**Xinjiang**
Input							
Energy	GJ	150	157	66	72	85	92
Electricity	kWh	6.600	6.600	3.100	3.100	4.300	4.300
Coal	Mg	7.0	7.3	1.1	1.4	3.0	3.2
Oil fuels	Mg	0.042	0.05	0.45	0.45	0.11	0.11
Process water	m^3	9.9	9.9	3.0	3.0	n/a	n/a
Output							
Greenhouse gases	Mg CO_2-eq	11.2	12.0	2.3	3.1	8.8	9.4
Mercury to air	g	2.4	2.4	0.21	0.21	<1	<1
Solid waste	Mg	1.9	2.0	0.15	1.4	n/a	n/a

The GHG balance of the process alternatives is compared in Figure 2-33. The carbide process, which requires the use of a mercury catalyst, results in emissions of twelve tonnes of $CO_{2\text{-eq}}$/tonne of PVC if produced in Xinjiang. This is a factor of 3.8 higher than for PVC from the petroleum-to-ethylene process.

If an additional five million tonnes of PVC per year were to be produced in Xinjiang, the annual associated emissions of $CO_{2\text{-eq}}$ would be approximately 60 million tonnes (Table 2-13). This represents 28% of the energy-related $CO_{2\text{-eq}}$ emissions of the entire Xinjiang province in 2010 (218 million tonnes). In contrast, a feedstock change to petroleum would result in $CO_{2\text{-eq}}$ emissions by about 16 million tonnes per year, a hypothetical reduction of about 74% compared to the carbide process. If CtE would be adopted, the $CO_{2\text{-eq}}$ emissions of 47 million tonnes would be lower than in the case of the carbide process but still quite substantial, i.e., equivalent to 22% of Xinjiang’s emissions in 2010.

Our analysis suggests that if Xinjiang’s PVC industry from the carbide process to ‘CtE’ the CO_2 (and mercury) reduction goals intended by China’s central government can be achieved. Furthermore, ZhongTai Chemical Company could remain independent from raw material imports.

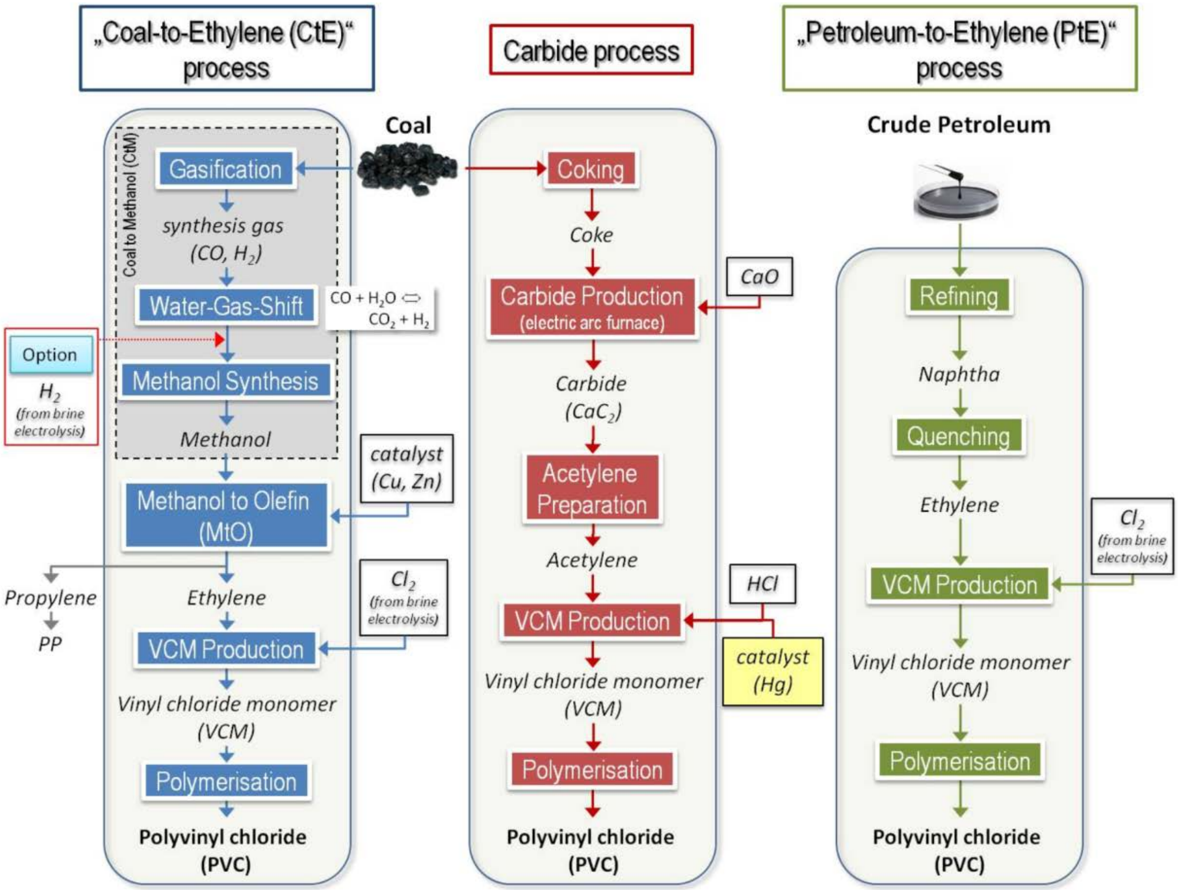

Figure 2-32 Flow diagrams of PVC production alternatives ('coal to ethylene CtE, 'petroleum to ethylene PtE' and the 'Carbide process')

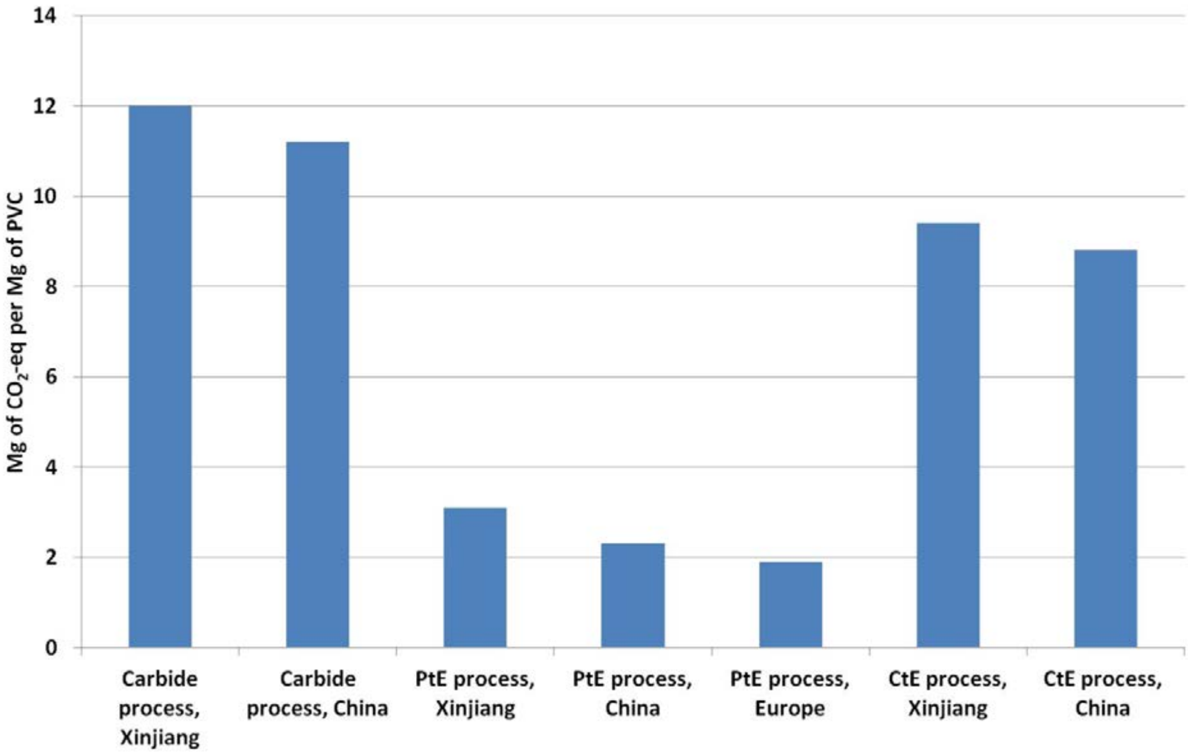

Figure 2-33 Life cycle CO_2-eq emissions of PVC production alternatives for China and Europe

Table 2-13 Hypothetical annual emissions of CO_2-eq for an additional production of five million tonnes of PVC per year in Xinjiang

Option	Annual emission of CO_2-eq [tonnes/year]	Share of Xinjiang's emissions in 2010
Carbide process	60 million	26%
Petroleum-to-Ethylene (PtE)	16 million	7.1%
Coal-to-Ethylene (CtE)	47 million	22%

Analysis of economic constraints in implementation

The potentials and constraints to implement a major feedstock change or technology shift can be summarised as follows.

1. The carbide-based PVC production is more profitable than PtE or (probably) the CtE alternative
2. The PtE option would reduce the amount of petroleum for export to other provinces in China
3. The technological risks for a change to CtE process are significant
4. The technology shift would facilitate the phase-out of mercury

With regard to the first point it becomes clear that at a market price of 6,500 RMB/tonne, PVC production from the carbide process yields high profits of about 2,500 RMB/tonne, mainly due to the low cost of coal in Xinjiang of about 200 RMB/tonne. This situation makes it difficult to implement energy-efficient solutions. However, the situation could change dramatically if the central government was to impose a carbon tax. This is illustrated in Figure 2-34. Under this scenario, production costs were assumed to be 4,000 RMB/tonne for carbide and 5,500 RMB/tonne for the PtE process. The CO_2 emissions were estimated at 11 tonnes (carbide) and 2.1 tonnes (PtE) per tonne of PVC. The carbon tax would have to reach 200 RMB or 24 € per tonne of CO_2 in order to trigger a shift to PtE. By comparison, the European spot market price by the end of January 2013 was 4.70 € per tonne of CO_2 [13]. A further example of the economic situation is that ZhongTai built its own coal power plant in Midong, as electricity costs from the state grid were too high. Surplus electricity cannot be sold at a reasonable price, resulting in suboptimal plant operation.

With regard to the second point − reducing the amount of petroleum for export to other provinces − it can be stated that if petroleum were to be used as feedstock for the production of five million tonnes of PVC per year in Xinjiang, this would require an estimated amount of 2.3 million tonnes of crude oil. In 2010, a total of 25.6 million tonnes of crude oil was produced in Xinjiang. 9.9 million tonnes were imported (mainly from Kazakhstan) and 8.7 million tonnes were consumed in the province [14]. Because the required petroleum amount for PtE-based PVC production is equivalent to almost 9% of Xinjiang's production and 24% of its consumption, that balance would change dramatically. During the two decades from 1990 to 2010, China has become a net importer of petroleum and now imports about half of its domestic consumption (1990: consumption 110 million tonnes, production 140 million tonnes; 2010: consumption 430 million tonnes, production 200 million tonnes) [15]. In contrast to this, China meets its domestic coal consumption with domestic production (1990: consumption 1.1 billion tonnes, production 1.4 billion tonnes; 2010: consumption 3.1 billion tonnes, production 3.2 billion tonnes) [16]. There are indications that China may have to rely on imported coal in the mid-term future[17]. However, the need for imported coal would be relatively

[13] http://www.eex.com/de/Marktdaten/Handelsdaten/Emissionsrechte/EU%20Emission%20Allowances%20|%20Spotmarkt

[14] Xinjiang Statistical Yearbook 2012 (Table 6-4)

[15] China Statistical Yearbook 2012 (Table 7-4)

[16] China Statistical Yearbook 2012 (Table 7-5)

[17] http://www.reuters.com/article/2012/11/20/china-coal-ndrc-idUSB9E8LA00K20121120

modest in level compared to the magnitude of required petroleum imports. Furthermore, imported coal would be supplied chiefly by Australia, thus rendering coal a far more accessible resource compared to petroleum imported from countries with considerably less political stability. A shift to the PtE process at present is likely to be met with considerable opposition as it would increase the need for imports of petroleum.

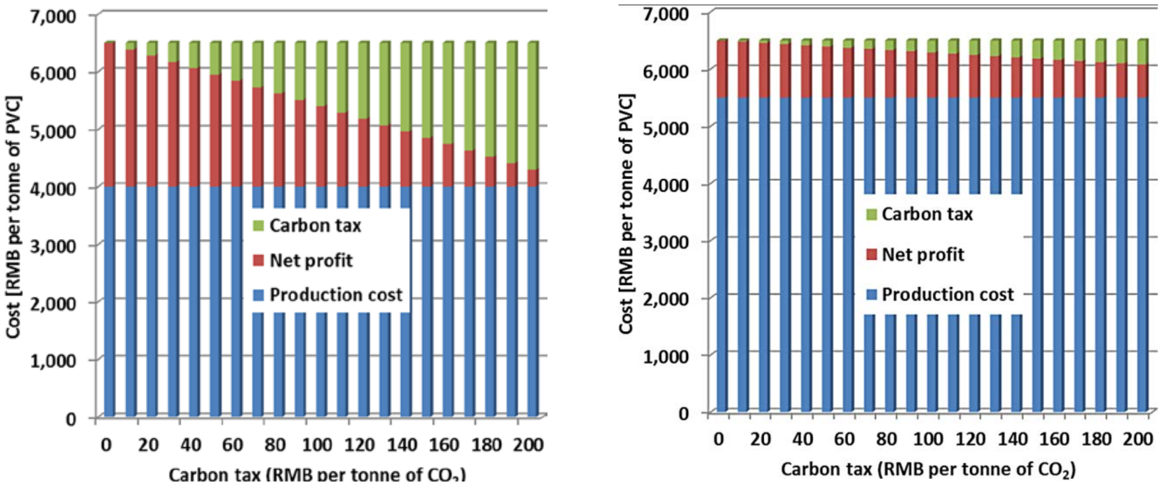

Figure 2-34 Impact of carbon tax on the profit for PVC production with the carbide process (left) and the PtE process (right)

With regard to the third point − technological risks for a change to CtE process − it can be stated that the CtE technology has not yet been implemented at large scale. An ethylene plant is currently under construction in Inner Mongolia Autonomous Region. ZhongTai is carefully observing the feasibility of operation before making investment decisions in Xinjiang.

With regard to the fourth point − facilitating the phase-out of mercury − it can be stated that China has ratified the Minamata Convention in January 2013, a global, legally-binding treaty to prevent mercury emissions and releases prepared under the auspices of the United Nations Environment Programme. The convention calls for a phase-out of the intended uses of mercury and specifically includes the carbide-based VCM production. Shifting PVC production to the PtE or CtE process would eradicate the use of mercury completely for this sector.

Reducing mercury use in ZhongTai's operation

The calcium carbide process with coal as the feedstock requires mercury (Hg) as a catalyst for VCM production from acethylene and hydro-chloric acid (HCl). China's PVC manufacturing industry is the most significant consumer of mercury in the world today, in the order of 1,000 tonnes per year. The carbide process results in large amounts of wastes: mercury-containing catalysts, mercury-containing activated coal, mercury-laced hydrogen chloride and mercury-containing alkaline agents as well as mercury contaminated wastewater. All steps from mercury extraction to the disposal of waste pose potentially serious environmental and health risks.

China has ratified the Minamata Convention in January 2013, a global, legally-binding treaty to prevent mercury emissions and releases prepared under the auspices of the United Nations Environment Program. Then ultimate goal is the phase-out of mercury use.

To better understand the mercury flows in VCM production using the carbide process, a mercury balance of the Midong plant of ZhongTai Chemical Co. was carried out and recycling options for mercury-laced waste water and waste acid were evaluated. A site inspection revealed that workers manually fill used mercury catalyst into bags for shipment to the recycling company. For occupational health and safety reasons, pneumatic technology would be preferable; an option that ZhongTai Chemical Co. is considering but has not yet realized.

To reduce the amount of mercury in the VCM production following options were identified by IFEU (1) feedstock change (alternative production technologies without a mercury catalyst), (2) use of mercury-free catalyst, (3) use of low-mercury catalyst. For option 1, alternative production processes ("Coal-to-Ethylene (CtE)" and "Petroleum-to-Ethylene (PtE)") were identified and analyzed. For options 2 and 3, IFEU collaborated with the China Council for International Cooperation on Environment and Development (CCICED) in drafting the "Special Policy Study of Mercury Management in China". The mercury topic is also addressed by the Xinjiang Academy of Environmental Protection Science.

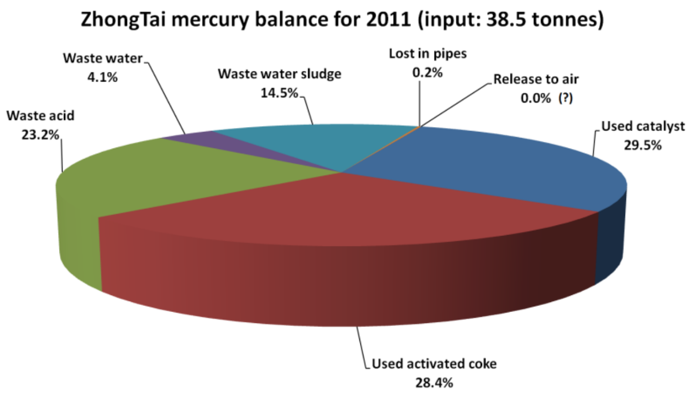

Figure 2-35 Mercury balance of ZhongTai (left), manual collection of used mercury catalyst (right)

As a result of the survey, a mercury balance for ZhonTai's operation in 2011 was derived and is shown in Figure 2-35. While most of the mercury is being recycled, the process of manual collection of used catalyst is far more being an adequate solution.

The following impacts were achieved:

- ZhongTai Chemical Co. has shown transparency, provided sensitive production information and has demonstrated readiness to optimize the processes.
- It is expected that manual collection of mercury catalyst (Figure 2-35) will soon be replaced by pneumatic technology.
- Waste water from the VCM process containing mercury is now being evaporated and no longer discharged into the sewage treatment plant.
- Workshops were carried out together with GIZ with representatives of China's PVC industry who were keen to learn from experience at ZhongTai.
- The use of a low-mercury catalyst (6% Hg compared to current 12% Hg) will be implemented in a shorter timeframe; recent test results are encouraging to this end.
- Research into mercury-free and low-mercury catalyst for the carbide system is on-going.
- Alternative production processes (CtE and PtE) will significantly reduce of mercury flow since both avoid the use of mercury as a catalyst but are currently not economical because of the low price of coal.
- Capacity building has established an international perspective of Chinese partners, e.g. the growing need to provide life-cycle impact data for products exported to Europe.

Conclusions and outlook

The industrial sector is a major consumer of energy resources and contributes substantially to the emissions of greenhouse gases in City of Urumqi and the entire province of Xinjiang. For the sustainable development of megacities, it is imperative to address the specific conditions in industry and also in each sub-sector.

It was demonstrated in the RECAST Urumqi project that a mass and energy-flow analysis of a complex industrial facility is a helpful tool to determine technological options to improve the energy efficiency and environmental performance of companies in China. It was also shown that an analysis can be conducted in a reasonable timeframe. The Lighthouse Project has not only resulted in the optimisation of the plant operation, but has also strengthened life cycle thinking in industry, government agencies, and the research organisations with whom we worked. It appears to be the method of choice for complex facilities and can be easily adapted to different economic and geographic settings.

In order to offer viable options to further reduce the energy-demand and greenhouse gas emissions from PVC production, one has to consider that the carbide process is the most profitable option under the present economic conditions. Strong economic incentives or regulatory decisions are needed to trigger investments into alternative production methods (PtE or CtE). Although the policy of the Chinese central government to use coal as a feedstock for PVC production in Xinjiang might be understandable, in light of the abundance of coal in the region and in order to limit petroleum imports, there remains the necessity to address the environmental disadvantages of the carbide process as well: high CO_2 emissions and the use of a mercury catalyst. With this aim in mind, a carbon tax and a regulatory requirement to phase out mercury catalysts would be suitable instruments.

If such policies were to be implemented, a shift to a more energy-efficient PVC production process could take place at ZhongTai and other PVC producers in Xinjiang, as well as the rest of the country, thus yielding substantially lower CO_2 emissions in the future.

2.6 Analysis of low-carbon options for Xinjiang

China has ambitious goals for GDP growth while reducing the energy intensity per unit GDP (and even more so the CO_2 emission) at the same time. In December 2009, China's prime minister, Wen Jiabao, promised at Copenhagen Climate Summit, that China is going to reduce the CO_2 emission per unit GDP by 40% to 45% by the year 2020 compared to the level of 2005. While this goal is not binding by international law, the situation may change once it will be written in the Outline of Twelfth Five-year (2011-2015) plan for national economic and social development of China which has legal binding power domestically. Xinjiang, with abundant fossil fuel resources (coal, natural gas) as well as large areas to develop renewable energy (photovoltaic and solar thermal power plants as well as wind parks), faces challenges and opportunities in fulfilling the emission target. The following activities have been performed by the task group "Energy efficiency" to support the shaping of a sustainable energy plan for Urumqi and Xinjiang:

- ***Cooperative support for policy making***, including meetings, talks and opinion exchange with politicians from the Xinjiang Environmental Protection Ministry, who expressed its willingness to seek help from Germany concerning capacity building and intellectual support in order to facilitate a more sustainable development path in the energy sector. Presentations, trainings and software introduction have been done to introduce German economic, legal and regulatory framework in motivating energy efficiency and environmental amelioration.
- ***Building up a research network***, including visits and discussions with research staffs from Xinjiang New Energy Research Institute, the Xinjiang Academy of Environmental Protection

Sciences and the University of Xinjiang. Topics involved the renewable energy development, solar power development in Xinjiang, electricity and heat pricing reform.

- ***Research*** by IFEU research staff. As to the historical economic development path and energy consumption of China, the electric power sector is of essential importance for emission reduction and environmental protection. In depth analysis concerning the legal, economic and regulatory framework, initiatives and instruments, the potentials and challenges, as well as electricity pricing methodology have been done.
- ***Interviews with stakeholders***, including professor Zhou Haihuan, researcher for the Provincial Development and Reform Commission which is responsible for drafting energy development planning and submit thereafter for the examination and approval of National Development Reform Commission, responsible for Xinjiang's energy planning. According to the interview, significant energy structure and renewable energy generation fuel mix have been proposed for Xinjiang province. Of great interest is the development of the wind energy potential, solar thermal and photovoaltaic power plants in Xinjiang and their integration into the Chinese grid and the establishment of smart grid systems to balance supply an demand.
- ***Excursions in Xinjiang***, e.g. to the Sino-German joint venture Gold Wind power company, and Sun Oasis company in October 2009. Issues concerning renewable energy industry, such as technology adopted, manufacture capacity, industrial structure and the current environmental impact have been investigated during the site visits.
- ***Research on regional energy development and emission scenarios.*** RECAST Urumqi has analyzed the emissions of CO_2 in Xinjiang.

The research has been ongoing during the course of the project. Results were presented in a poster *Reneqable Energy Roadmap* and presented in reports and workshops (documents 65, 73, 85). Wind and solar energy have the large potentials for expannsion in Xinjiang. The the total area of the province is suitable for solar PV as long as long as there is no competing area use. Joint work with Prof. Winkler, University of Johannesburg revealed that predicted solar power potential based in irradiance maps from satellite data have inaccuracies which are likely to result from the flawed recognition and parameterisation of aerosols (document 20).

About 7 % of Xinjiang's surface area show a capacity factor of >24 % corresponding to 2,100 full load hours for wind power. The 12th 5-year plan for Xinjiang has a target to increase the installed capacity from 2.2 GW in 2011 to about 8.5 GW in 2015.

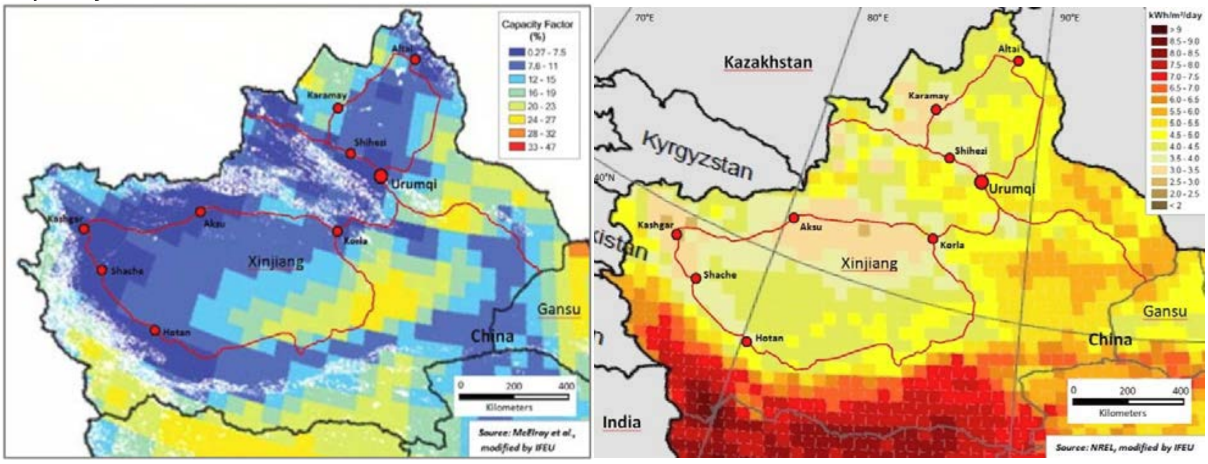

Figure 2-36 Wind and solar power potential for Xinjiang

A detailed analysis of the bioenergy potential for electricity generation was provided in a report by the Chinese partners XJAEPS in close cooperation with IFEU (Jian et al., 2012, document 89). There is a potential for sustainable cultivation of 17.72 million tons of solid biomass per year in Xinjiang by 2030. Of this, 11.07 million tonnes of cotton residues and tamarisks for are suitable for co-generation of heat and electric power. At about 21.3 GJ per tonne, this amounts to 236 PJ of primary energy or about 8% of Xinjiang's primary energy consumption in 2011. For the time after 2030 we assume no further growth in biomass production as the arable land sources are limited and the study from Xinjiang Academy already considered the arable land available.

Electricity scenario

There is a significant potential to increase the efficiency of electricity use. For the expected annual growth rate of GDP from 2010 to 2010 of 10%, and a kWh/GDP ratio decrease based on the past decade (-2.3%), electricit demand would increase by a factor of 5 from 2010 to 2040. A super efficient pathway for Xinjiang could limit electricity demand for the next decades to less than 100 TWh/a. Detailed research would be needed to determine the pathway to achieve such a goal (Figure 2-37).

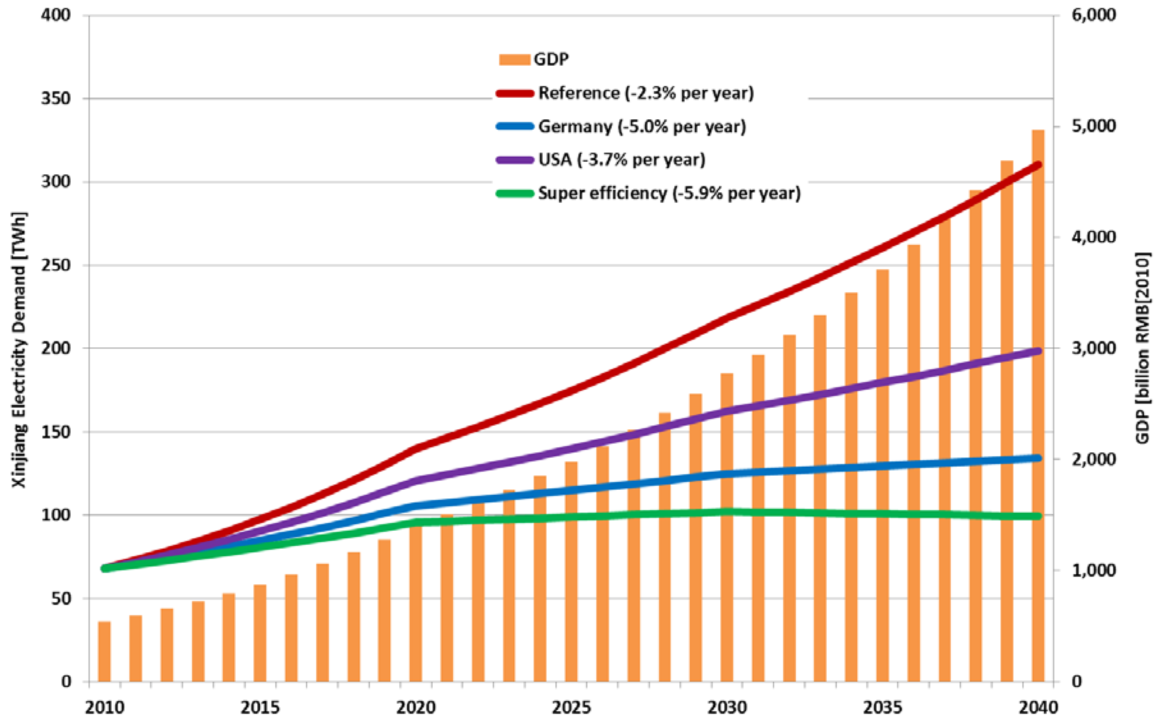

Figure 2-37 Xinjiang GDP and electricity projections

Outreach activities included presentations during a workshop in Urumqi on 4 November 2009 (document 57), a lecture on energy policy was given before senior staff of the Xinjiang Department of Environment on 18 March 2010 (document 70), and in workshops with project partners in September 2014.

2.7 Review of Coal-based synthetic natural gas (SNG) production: A case study for Xinjiang

The Xinjiang province is a major producer of natural gas and accounted for a quarter of China's domestic production (915 of 3,974 PJ as of 2011). This will drastically change if the ambitious plan to produce large quantities of synthetic natural gas (SNG) from coal are carried out. The 12th 5-year plan for Xinjiang has an SNG target of about 2,800 PJ which is equivalent to about 66% of China's total domestic production of natural gas in 2012 (Figure 2-38). In order to evaluate this development, the RECAST Urumqi project started a comprehensive evaluation of the ambitious programme to produce coal-based synthetic natural gas (SNG) in Xinjinang.

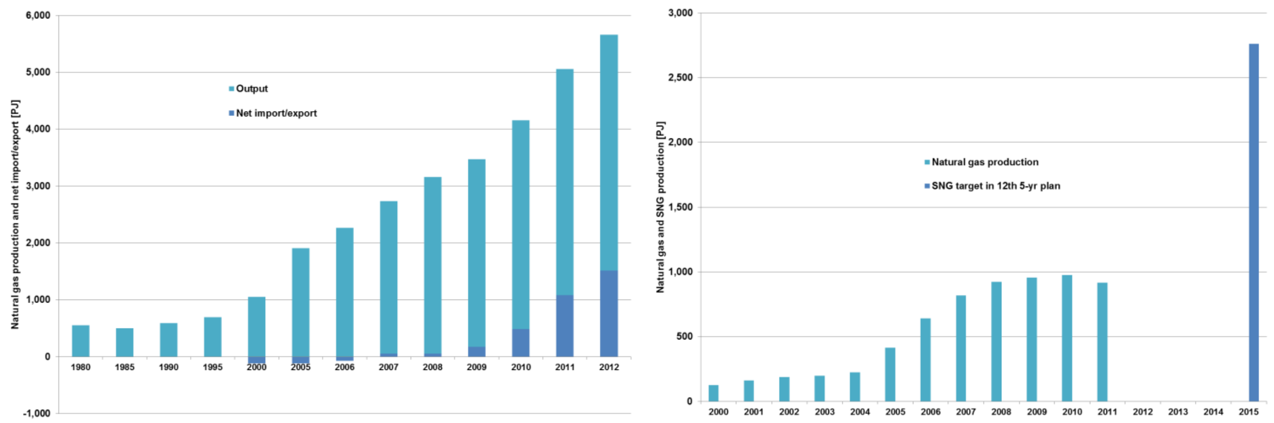

Figure 2-38 left: China natural gas production and net import/export, 1980 to 2012 (CESYB); right: Xinjiang gas production and projected SNG production by 2015 (CESYB)

The primary energy demand and associated CO_2 emissions were compared for the production of heat and electricty in Beijing, Shanghai and Guandong for the following options:

- Production of SNG and pipeline transport to destination
  (SNG to heat, SNG to electricity)
- Production of electricity in Xinjiang coal power plants, long-distance electricity transmission to destination *(electricity to heat with heat pumps, direct electricity use)*
- Extraction of coal and transportation for use at destination
  (coal to heat, coal to electricty)

The flow of coal is depicted in Figure 2-39; the resulting GHG emissions are shown in Figure 2-40. The following conclusions can be made from the assessment:

If SNG from Xingiang is used to provide heat in buildings in Beijing, GHG emissions are about a factor of three larger compared to heat pump provided with coal-based electricity from Xinjiang. From a GHG mitigation strategy point of view, SNG production in Xinjiang can only be a viable option if the process includes CCS (carbon capture and storage). In addition, SNG production requires a large amount of water (6–12 litres of water per m^3 of SNG). A large SNG plant in the Urumqi/Changji area with an annual coal input of 90 milion tonnes would easily double the industrial water demand in the region which already exceeds the sustainable level. In consequence, coal-based SNG production is not to considered as a viable option for Xinjiang.

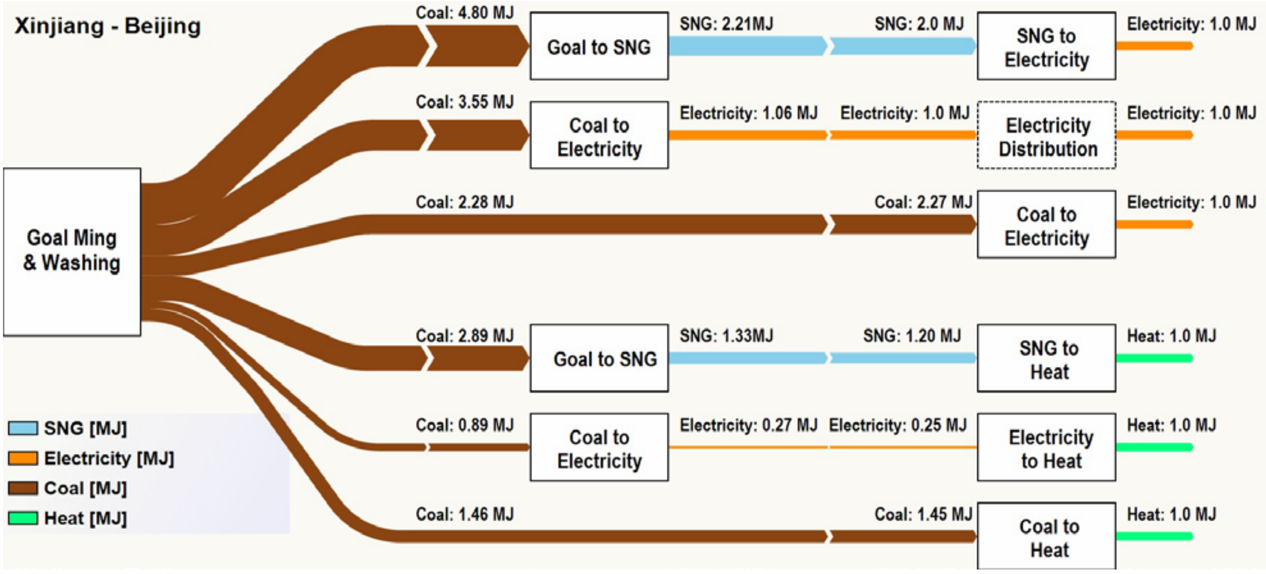

Figure 2-39 Coal demand for providing electricity and heat in Beijing

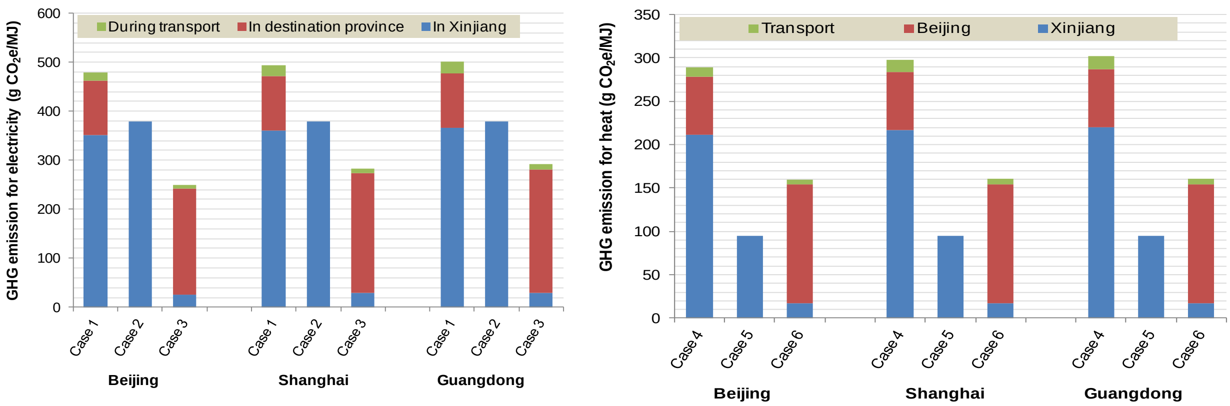

Figure 2-40 GHG emission for providing electricity (left) and heat (right) in destination provinces

2.8 Energy conservation in schools: Sino-German initiatives

Three initiatives were started in the context of energy conservation in schools:

- A partnership was initiated between Urumqi Middle School No. 8 and *Internationale Heidelberg Gesamtschule* (IGH) with a focus on energy conservation eductation. Partial transport funding for students and teachers was gratefully provided by Robert Bosch Stiftung, Stuttgart. Eight students age 16 to 18 from Urumqi and their teacher visited Heidelberg in May 2009, participated in IGH's E-Team activities and participated in *Energiekarawane,* a public event in the streets of Heidelberg.[18] The visit of the German students in Urumqi had to be cut to just one day because of the riots in Urumqi on 5 July 2009; another visit took place in September 2010. More information about the school exchange is found in documents 77 and 78.
- Training material in Chinese was provided for the KlimaNet website, a virtual classroom with educational material funded by the Ministry of Environment of the German State of

18 http://www.igh.hd.bw.shule.de/joomla/index.php?option=com_content&task=view&id=252&Itemid=234. http://ww2.heidelberg.de/diaschau/energiekarawane_2009/slides/klimasuchtschutz_2008_middle-school-5.html

Baden-Württemberg for the website.[19] This allows to reach students and teachers in other Chinese cities as well.

- School buildings are highly suitable to be built as passive houses because of high occupancy and heat load. This was demonstrated in a workshop by visits at the Frankfurt-Riedberg school and meetings with City of Frankfurt officials since Frankfurt has adopted a local law that all new school buildings be designed as passive houses. The Construction Committee of the City of Urumqi entered into the process of selecting a new school construction project that could be built as a pilot passive house project.

Figure 2-41 Students from Urumqi lobby for climate protection together with Heidelberg's Lord Mayor Dr. Würzner (left); the *KlimaNet* website with a virtual school tour on energy (right)

2.9 Networking and outreach

The RECAST Urumqi task group "Energy efficiency" stayed in close cooperation with the task groups "Water" and "Materials" by coordinating the work plans through monthly project meetings, participation in workshops with the Chinese project partners as well as the following activities:

- All task groups participated in the household survey, including the questionnaire design and the interpretation of the results.
- The two other task groups have been actively evaluating the potential of water conservation, gray water recycling in the lighthouse project "New construction of extra-low energy buildings" and the recycling of waste materials (reuse of bricks from the existing building for the interior construction of the new building). In addition, the options for the closed-loop recycling of concrete (replacing gravel with crushed concrete from demolition waste) was investigated; it was dismissed because of lack of economic viability (document 44).
- In the lighthouse project "Energy and mass-flow analysis for ZhongTai Chemical Co.", the energy and mass flow model includes data on water and waste flows. A feasible option to increase the efficiency of water recycling was identified but was dismissed because of lack of economic viability.
- There was intensive information exchange and collaboration with DAAD visiting scholar Dr. Ping Chen, from the Xinjiang Academy for Environmental Protection Sciences, during his stay in Heidelberg from October to December 2009

19 http://www.uvm.baden-wuerttemberg.de/servlet/is/42140/

Networking was also established with other BMBF sponsored projects from the Future Megacities programme beyond the conferences in Essen (October 2010) and Hamburg (July 2013):

- Information exchange with the Shanghai project took place during a workshop on low-energy buildings in March 2009
- German and Chinese project partners from the Urumqi, Shanghai, and Hefei presented at the Urban Academy (Elements of a Sustainable City – Architecture, Urban Form and Mobility) on 6 June 2010 in Shanghai in connection with the Expo 2010
- Visitors from Urumqi met their South African counterparts in mutual visits during their conferences in July 2010
- Results from the RECAST Urumqi energy efficiency project were presented at the Enerkey status conference in Johannesburg, March 2011; resulting in cooperation with Prof. Winkler, University of Johannesburg on solar energy data analysis
- Representatives from the Enerkey project in Gauteng/South Africa and the IGNIS project in Addis Abeba/Ethiopia presented their findings at the July 2011 RECAST Urumqi Status Workshop in Urumqi
- The experience in quality management on construction gained by TU Berlin in the Young Cities project in Tehran/Iran was utilized. Bernd Mahrin participated in the June 2014 quality management workshop on ventilation systems and organized the preparation of an instruction booklet for ventilation system based on the training experience gained in Iran.

Other outreach activities with lectures on the project included the following:

- Conference in Leipzig University “Megacities: Risk, Vulnerability and Sustainable Development”, 7-9 September 2009
- International Conference on Green and Energy Efficient Building (IGEBC) in Beijing, January 2010
- Workshop on Sustainable Building of Chinese Low Energy Houses at the Chinese Academy for Environmental Planning (CAEP), February 2010
- Annual conference of Energy Efficient Cities of Ukraine, Vinnitsa, Ukraine, 29 March 2011
- Support of the project China Council for International Cooperation on Environment and Development (CCICED) “Special Policy Study of Mercury Management in China”, 26-28 May 2011
- Contribution to side event “Governance for Sustainable Development in Cities” at 17th Conference of the Parties (COP17) to the United Nations Framework, Durban South Africa (document 42)
- Presentation of RECAST Urumqi project in a panel discussion forum organized by the Future Megacities Project at the Hannover Messe, 05 April 2012
- Lecture on Energy Efficient Buildings in Urumqi/China at the 1st International Symposium Sustainability for New Neighbourhoods & Buildings in El Gouna/Egypt, 12 April 2012
- Lecture on City Energy Strategies: Examples from Germany, China, USA and Japan at the Energy Days in Banja Luka/Bosnia and Herzegovina, 20 April 2012
- Visit of Tianye Chemical Xinjiang Tianye (Group) Co., Ltd. (PVC production of more than 2 million tonnes per year), in Shihezi, Xinjiang, 07 May 2012
- Presentation of the RECAST Urumqi project and its achievements before representatives of the City of Karamay (pop. 420,000) in the North of Xinjiang, 09 May 2012
- 13th Climate Technology Initiative (CTI) Workshop in Berlin, 04-05 October 2012, document 60
- Cooperation with dena, Deutsche Energieagentur in support of the dena roadshow on energy conservation in buildings in Urumqi, 09 October 2012
- Representing the Future Megacities programme at “Future World Energy Summit” in Abu Dhabi, UAE, 14-18 January 2013

- Outreach activities on passive house in the Xinjiang cities of Changji and Karamay, 31 January to 05 February 2013
- Networking with other passive house projects in China at Passive House Conference in Frankfurt, 19-20 April 2013
- *Ressourceneffizienz-Kolloqium*, Hochschule Pforzheim, 02 May 2013, document 62
- Dena-Workshop „Eco-Index of Cities in China“, Berlin, 16 August 2013
- 10th BMBF-FONA Forum, Leipzig, 09-11 September 2013
- 3rd International Symposium on Architecture Heritage Preservation and Sustainable Development, Historic Building Conservation and Green Regeneration Technology, University of Tianjin, 16-17 November 2013, document 61
- Workshop on passive house technology, at Building Energy Research center, Tsinghua University, Beijing, 18 November 2013

2.10 Achievements compared to milestone planning

The actual goals and milestones set forth in the proposal have largely been met. The RECAST Urumqi sub-project *Energy efficiency* made substantial contributions to increase the energy efficiency of buildings (existing and new construction) and in industry (PVC production). Further, low-carbon development options for Xinjiang were analyzed. Close cooperation with local stakeholders in government, industry and science resulted in the following achievements:

- A handbook on Sustainable Urban Planning Elements for the Dryland Megacity Urumqi was created and was widely distrubuted in Urumqi.
- The energy retrofit of an agricultural education centre in the Nanshan area into the first zero-emission building of Urumqi was accomplished; the heat energy demand was reduced by 85%.
- Planning and completion of the first passive house in Western China adapted to very cold winters. Many challenges regarding design, components (windows, heat recovery) and building quality were overcome.
- A stricter energy effciency standard for new buildings was adopted in Urumqi, effective 2014.
- An energy and mass flow model at the coal-based PVC production was implemented at ZhongTai Chemical Co. A total of 68 economically feasible improvements were identified and have been partly implemented.
- The initiation of energy education in schools in Urumqi by way of establishing a student/teacher exchange and a Sino-German website.
- The evaluation of low-carbon options for Xinjiang shows the potential to increase the use of renewable energy sources (wind, solar, biomass) and potentially detrimental options such as massive SNG (coal gasification) projects.

Adjustments to the original plan were necessary due to changes in circumstances and to address the wishes of the cooperation partners:

- As a consequence of the riots that took place in Urumqi at the beginning of July 2009, communication via international phone calls and direct exchange of emails was impossible until the end of 2009. Contacts continued via letters or indirectly (phone calls /emails to cooperation partners in Beijing, transfer via phone/fax/letter to Urumqi and back). This resulted in a delay of the project work flow which was addressed by a change in the work schedule and by intensifying face-to-face work (additional presence in Urumqi in December 2009); the plan to support an energy conservation event in Urumqi in the fall of 2009 had to be abandoned.
- The project focus with respect to the development of a master plan was changed because the City of Urumqi had already provide the baseline data by spending three million RMB for

a consultant report, the *Integrated Heating and Building Energy Efficiency Master Plan*. Therefore, the modelling focus was redirected to support a long-term strategic plan that identifies the options to increase energy efficiency and the share of renewable energy by 2050 in the province (see chapter 2.6).

- Originally, 5 lighthouse projects were envisioned: *(1) Increasing energy efficiency in existing buildings, (2) Low energy high-rise apartment building, (3) Enhancing renewable energy use, (4) Improving CHP generation and distribution und (5) Developing energy efficient transportation systems*. Lighthouse project (4) was changed to *Mass and energy flow assessment in the PVC industry*, lighthouse project (2) was rephrased as *Passive house project Xingfubao*. Achievements in these four projects exceeded our expectations and required more work than originally estimated, especially for the passive house project. In order to ensure adequate completion of the work, it was decided not to pursue the transportation project and utilize the resources for the others.

The impact of the RECAST Urumqi sub-project *Energy efficiency* is long-lasting: the City of Urumqi has tightened the energy efficiency standard for new buildings and increases support of the construction of more passive house buildings; a China-wide passive house network was established. The German company REHAU is producin more passive house windows; the demand is growing due to the success of the *Xingfuao* demonstration project. The improvements at ZhongTai's PVC production will continue. The method of life-cycle assessment (LCA) in industry is increasingly applied in Urumqi and beyond. The debate about low-carbon options for Xinjiang is ongoing. These achievements were all made possible with the support of the City of Urumqi, the Xinjiang DEP, the Xinjiang Academy of Environmental Protection Sciences and many other stakeholders including those from the private sector. The local stakeholders in Urumqi continue their activities, actively pursue the objectives of RECAST Urumqi and are spreading the word about the achievements.

2.11 Achievements in terms of avoided GHG emissions

The RECAST Urumqi project has resulted in significant direct and indirect avoided CO_2 emissions. A summary is provided in Table 2-14, for details of the calculation see document 28. The direct effects from the lighthouse projects were largest in the PVC production with 150,000 tonnes per year and are an indication of the relative inefficiency of the process that could easily be remedied. It is more difficult to reduce GHG emissions in the building sector. The savings in the Nanshan retrofit (88 tonnes per year) were relatively large despite its small size because avoided emissions of the inefficient coal-based district heating are quite large. In the case of the Xingfubao passive house, abated GHG emission (210 tonnes per year) were calculated using the specific CO_2 emission values after the district heating system in Urumqi's center city was converted to natural gas. The RECAST Urumqi project significantly contributed to the revised energy efficiency standard for new buildings that will lead to avoided CO_2 emissions more than 250,000 tonnes per year. The largest potential impact would result from a feedstock change for the future PVC production to petroleum-to-ethylene instead of coal-based carbide process. Given the economic situation (chapter 2.5.3), this is unlikely to happen.

Table 2-14 RECAST Urumqi, Task Group Energy Efficiency: avoided CO_2 emissions

Activity	Avoided CO_2 emissions [tonnes per year]
Direct effects from lighthouse projects	
Lighthouse project 1: Retrofit of Nanshan building to extra-low energy consumption (85% energy savings standard), measured	88
Lighthouse project 2: First passive house in West China (95% energy savings standard) after completion according to design	210
Lighthouse project 3: Improved energy efficiency of PVC production at ZhongTai Chemical Co. (as of 2011) *Source: cleaner production audit by XJAEPS, IFEU, and IUWA*	150,000
Immediate implementation	
Revision of energy efficiency standard for new buildings: 75% energy savings standard for 65% of new buildings effective 2014 and 100% of all buildings effective 2015 (compared to existing 65% energy savings standard), for a total of 28 million m^2 gross floor area until 2018	250,000
Additional energy efficiency improvements at ZhongTai Chemical Co.: Additional 4% savings of carbide input from acetylene loss reduction at PVC production capacity of 500,000 tonnes per year	150,000
Indirect effects due to recommended policy changes	
Recommended policy 1: 1 million m^2 of new construction in Urumqi in passive house standard (compared to existing 65% energy savings standard)	27,000
Recommended policy 2: Retrofit of 10 million m^2 of existing buildings to 65% energy savings standard (compared to existing 50% energy savings standard for retrofits)	130,000
Recommended policy 3: Feedstock change for planned expansion of PVC production of 5 million tonnes per year (petroleum-to-ethylene instead of coal-based carbide process)	44,000,000

Note: Details of the calculation can be found in document 28

3 Project staff

The following staff persons were part of the IFEU team:

- Bernd Franke, senior scientist, project coordinator, 2008-2014
- Hans Hertle, senior scientist, energy efficiency of buildings, 2008-2013
- Andreas Detzel, senior scientist, mass flow analysis of industrial systems, 2011-2014
- Jianfeng Chen, PhD candidate, low-energy housing, translation, 2008-2010
- Nicola Räth, architect, 2008
- Cassandra Derreza-Greeven, project scientist, 2012-2014
- Sybille Kunze, project scientist, 2012
- Stefan Trojek, project scientist, 2012
- Mirjam Busch, project scientist, 2013

External contracting involved the following organizations:

- Culturebridge Architects, Grünstadt *(architectural low-energy concepts adapted to conditions of Urumqi, design, training)*
- Passivhaus-Institut, Darmstadt *(passive house assessment, training, certification)*
- Ifu-Institut für Umweltinformatik, Hamburg *(workshop and training in umberto® mass flow assessment software)*
- Ing. Büro Meyer-Olbersleben, Lüneburg (*workshop for air tightness testing*)
- Kompetenzzentrum für Nachhaltiges Bauen Cottbus *(training on quality control of passive house components)*
- Kompetenzpunkt Berufsbildung Berlin *(workshop on quality control of heating and ventilation systems, preparation of instruction materials)*
- Berufsbildungswerk Osnabrück *(workshop on quality control of heating and ventilation systems, preparation of instruction materials)*

The following DAAD scholarship recipients were part of the task group team:

- Li Niu (PhD student), August 2009 – July 2012
- Dr. Keke Wei (post-doc scholar), March 2010 - February 2012
- Mr. Ming Liu (senior expert, Xinjiang Architectural Design and Research Institute, Urumqi) September 2009 - November 2009

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List of activities, RECAST Urumqi Energy Efficiency Group, 2007 – 2014

No	Date	Activity
1	January 2007	A Sino-German workshop on the energy efficiency of buildings was organized in Urumqi with presentations from 12 German & Chinese experts, the participation of many Urumqi stakeholders, and resulted in local media coverage
2	December 2008	A one-day workshop in Heidelberg for a delegation of Chinese specialists (including representatives from Urumqi) on low energy buildings as part of a GTZ sponsored tour of projects in Germany and Poland.
3	02.03.-06.03.2009	A five-day workshop in Heidelberg on the planning of low-energy houses with a focus on passive house design, policy development and excursions to objects in Heidelberg and Frankfurt
4	April 2009	Publication of a 108-page booklet Sustainable Elements for the Development for the Dryland Megacity Urumqi in collaboration with Culturbridge Architects Grünstadt/Germany and Beijing/PR China; with lectures given at the Construction Committee, the Xinjiang Architectural Design Institute and the Dacheng International Center.
5	April 2009	Energy efficiency review of the Dacheng International Center in Urumqi; recommendations to improve energy efficiency and indoor climate in Dacheng International Center on the basis of the current planning status, in collaboration with Culturbridge Architects. Workshop in Urumqi on Energy and City Planning
6	April 2009	Preparation of a concept to improve energy efficiency in the planning for the Dacheng International Center high-rise building
7	May 2009	Evaluation of the results of a household survey regarding energy use that was carried out by project team IUWA/Xinjiang Academy for Environmental Protection Sciences, Urumqi
8	May 2009 and July 2009	Support of a thematic German/Chinese student and teacher exchange (Internationale Gesamtschule Heidelberg und No. 8 Middle School, Urumqi), by preparation of curricula and materials with respect to energy conservation and climate protection, conducting seminars and by providing logistical support
9	June 2009	Preparation of a proposal for an energy efficiency campaign in connection with the Department for energy efficiency of the Construction Committee of the City of Urumqi
10	June 2009	Participation in a workshop with excursions in Heidelberg and surroundings for high-ranking politicians as well as experts from Urumqi
11	September 2009	Presentation of the project RECAST Urumqi, sub-project energy efficiency, at the international conference Megacities: Risk, Vulnerability and Sustainable Development, Leipzig
12	November 2009	Participation in a workshop of the entire project with politicians and experts in Urumqi

No	Date	Activity
13	November/ December 2009	Preparation of a concept for the new construction of a multi-story extra-low energy building at Xingfu Rd., Urumqi in collaboration with Dacheng International Center, Xinjiang Architectural Design Institute, Urumqi
14	05.12.-15.12.2009	A one-week planning session for the renovation of the agricultural training center in the Nanshan area near Urumqi in collaboration with Culturbridge Architects.
15	December 2009	Preparation for the in-depth study of material and energy flow management of Xinjiang Zhongtai Chemical Co., Ltd., Urumqi in the Midong district in collaboration with the Xinjiang Academy for Environmental Protection Sciences, Urumqi
16	December 2009	Information exchange and collaboration with DAAD scholar Chen Ping, Xinjiang Academy for Environmental Protection Sciences, Urumqi
17	January 2010	Preparation of a design plan for the renovation of the agricultural training center in the Nanshan area near Urumqi in collaboration with Culturbridge Architects and Prof. Wang, University of Xinjiang.
18	January 2010	Preparation of a preliminary design plan for the new construction of a passive house in Xingfu Rd. in collaboration with Culturbridge Architects and the Xinjiang Architectural Design Institute. Partial funding for this planning was provided by Dacheng Industries directly to Culturbridge Architects.
19	30 January to 10 February 2010	Workshop on environmental reporting and eco-profiling of companies in Heidelberg with excursions, (including company visits) with representatives of the Xinjiang Zhongtai Chemical Co., Ltd., the Xinjiang Academy of Environmental Protection Science and the Urumqi Environmental Protection Agency.
20	25 February 2010	Preparation of a report entitled Guidelines for implementing the Passive House concept in the city and the surroundings of Urumqi, Xinjiang, China by the Passive House Institute, Darmstadt, with a translation into Chinese
21	04 March 2010	Preparation of a report entitled Thermal analysis of a retrofit project in Nanshan, Xinjiang, China by the Passive House Institute, Darmstadt, with a translation into Chinese
22	04 March 2010	Preparation of a report entitled Construction project: Xingfulu Mixed Use Building, Urumqi / China Interim report about the energy performance by the Passive House Institute, Darmstadt, with a translation into Chinese
23	06.03.-23.03.2010	Finalization of design details on the Nanshan renovation project with a review of energy consumption for various options provided by the Passive House Institute in Darmstadt/Germany.
24	March 2010	Negotiations, for the Nanshan renovation project, with the department for city planning and construction licensing of the City of Urumqi.
25	15.03.-10.04.2010	On-site training to conduct a material and energy flow management assessment using Umberto® and field research at the Xishan factory of Xinjiang ZhongTai Chemical Co., Ltd., Urumqi

No	Date	Activity
26	18 March 2010	Lecture *Climate Protection Policy in Germany and China* by Bernd Franke (IFEU) at the *Ministry of Environmental Protection of Xinjiang*, with discussion attended by about 60 senior staff members of the ministry
27	6 to 12 May 2010	RECAST Urumqi Status Workshop, workshops and excursions, Urumqi
28	26 to 30 May 2010	Support for a pCDM project application by the City of Urumqi / workshop on low-energy-houses and pCDM
29	27 May 2010	Ribbon-cutting ceremony for the Nanshan renovation project
30	30.05.-18.06.2010	Field research on low-energy-house project, pCDM and Zhongtai Chemical Co.
31	June 2010	Preparation of booklet Nanshan Training Center, with a translation into Chinese, in collaboration with Culturebridge Architects
32	June 2010	Preparation of booklet Xingfu Road Mixed-Use Building Urumqi, with a translation into Chinese, in collaboration with Dacheng Industry Ltd. Urumqi and Culturebridge Architects
33	06 June 2010	Presentation of the BMBF Megacities Programme as well as a topical lecture "Planning of Passive Houses in Urumqi" at the workshop Nachhaltige Stadtbausteine – Architektur, Stadtform und Mobilität (Elements of a Sustainable City – Architecture, Urban Form and Mobility), Shanghai
34	11 to 17 July 2010	Preparation for and participation in RECAST Urumqi Status Conference Resource-efficient economic activities in China / Urumqi / Xinjiang in Heidelberg, including a visit of EnerKey project workshop in Stuttgart
35	July 2010	Finalization of design for the Xingfu Rd. construction project with a review of energy consumption for various options provided by the Passive House Institute in Darmstadt/Germany.
36	30 August 2010	Preparation of the interim report Ökoprofil der ZhongTai Chemical Company, Urumqi (Ecoprofile of the ZhongTai Chemical Company)
37	30 August 2010	Preparation of the report *Deregulation, Environmental Protection and China's Electric Power Industry*
38	September/October 2010	Contributions to a joint methodology to compare key parameters (GDP, CO_2 etc.) between Megacities project cities for the Essen conference
39	September 2010	German/Chinese student and teacher exchange (Internationale Gesamtschule Heidelberg and No. 8 Middle School, urumqi)
40	9th to 10th of October 2010	Presentation of scientific results of the RECAST Urumqi TG Energy Efficiency by Dr. Keke Wei (IFEU) within the DAAD Future Megacities Young Researchers' Symposium in Essen, entitled Deregulation and environmental protection in China's electric power industry
41	11.10.-13.10. 2010	"Future Megacities in Balance - New Alliances for Energy- and Climate-Efficient Solutions"
42	11 to 17 December 2010	Initiation of a new low-energy high-rise project (Dacheng Tower B) and a low-energy hotel in Burqin/Xinjiang during a visit to Urumqi, together with *Dacheng Industry Ltd. Urumqi* and *Culturebridge Architects*
43	December 2010	Contribution to the pCDM methodology for the determination of CO2 emission dactor for CHP heat in the Guang Hui zone

No	Date	Activity
44	January 2011	Developing of detailed energy demand calculations for a new low-energy high-rise project (Dacheng Tower B) together with Dacheng Industry Ltd. Urumqi and Culturebridge Architects
45	January to March 2011	On-site training of ZhongTai and XJAEPS staff to conduct a material and energy flow management assessment using Umberto® and field research at the Midong factory of Xinjiang ZhongTai Chemical Co., Ltd., Urumqi
46	07.03.-12.03.2011	Participation in workshops and conferences in Johannesburg together with the EnerKey Megacities Project, enhancing the collaboration on issues such as energy scenario modeling, the assessment of CSP (concentrated solar power) and PV (photovoltaic) potential in Xinjiang/China and Gauteng/South Africa, and energy conservation in buildings
47	29 March 2011	Presentation of a topical lecture "Planning of Passive Houses in Urumqi" at the annual conference of Energy Efficient Cities of Ukraine, Vinnitsa, Ukraine, discussing possibilities to transfer the results to Ukraine
48	26-28 May 2011	Support of the China Council for International Cooperation on Environment and Development (CCICED) “Special Policy Study of Mercury Management in China”. For this, a visit of ZhongTai was prepared and conducted together with CCICED member Prof. Uwe Lahl, University of Darmstadt. Process data were provided by ZhongTai Chemical Co. and reviewed with respect to use of mercury catalyst in coal-based PVC production, ADSD
49	25 May 2011	Establishing a collaboration with the Xinjiang Normal University, Urumqi where a Centre for Energy and Environmental Research will be established
50	16 to 22 July 2011	Preparation for and participation in the trade delegation visit and associated RECAST Urumqi Status Workshop, with workshops and excursions, Urumqi
51	17 July 2011	Official inauguration of Urumqi’s first zero-emission building, the retrofit of the Nanshan agricultural education center. IFEU contributed to the energy retrofit in which an agricultural education center with a net heated area of 769 m² was transformed into the first zero-emission house in the province. The heating energy demand was reduced by more than 85 % by a variety of measures. The remaining heat demand of 64 kWh/(m²*a) in the very cold winters is supplied by solar heating with an innovative seasonal storage; the entire demand of electricity is provided by a photovoltaic system.
52	17 July 2011	Official inauguration of the Research Base for the Sino-German cooperative Industry Energy Efficiency & Wastes Recycling at the Zhong-Tai chemical plant, Urumqi

No	Date	Activity
53	September 2011	Collaboration with Xinjiang Academy of Environmental Protection Science to prepare the study “Assessment of next generation biofuel pro-duction in the Xinjiang Uyghur Autonomous Region, P.R. China”. The study was funded by the UN Global Environment Facility (GEF) and prepared by cooperation with RECAST Urumqi, providing a value-added product
54	September 2011 to March 2012	Ongoing refinement of the detailed planning for Xingfubao, the first passive house building in Urumqi, in collaboration with Culturebridge Architects, Grünstadt/Beijing, the Passive House Institute Darmstadt, Dacheng Industry Ltd. Urumqi, the Urumqi Construction Committee and the Xinjiang Architectural Design and Research Institute, Urumqi. Possibilities of a joint venture to produce passive house windows in China were negotiated with Aluplast GmbH Karlsruhe and representa-tives of the Urumqi Construction Committee.
55	30 November 2011	Preparation for and participation in the 17th Conference of the Parties (COP17) to the United Nations Framework Convention on Climate Change (UNFCCC): presentation of the RECAST Urumqi’s achievements at a COP17 side event in Durban, South Africa “Governance for Sustainable Development in Cities”
56	20 October 2011	Establishing a cooperation between the Megacities projects RECAST Urumqi and Young Cities Tehran/Iran on quality control and capacity building in construction of low-energy buildings
57	October to December 2011	On-going continued support of a thematic German/Chinese student and teacher exchange (Internationale Gesamtschule Heidelberg and No. 8 Middle School, Urumqi), update of the website in Chinese
58	November 2011	Comparison of district heating networks in Germany and Urumqi, together with DAAD scholar Liu Ming
59	September to November 2011	Providing day-to-day support for DAAD scholars Jiarheng Ahati (Xin-jiang Academy of Environmental Protection Science), Liu Ming (Xinjiang Architectural Design and Research Institute) and Xiaoyan Peng (Urumqi Construction Committee) during their research stay in Germany from September to November 2011: preparation of workshops (e.g. on energy retrofit in buildings), training (e.g. PHPP tool for passive house planning), excursions (e.g. City planning in Essen, Passive House Days), joint participation in conferences (e.g. GIZ conference of Chinese Mayors in Berlin/Bonn) and visit of exhibition (UrbanTec, Cologne)
60	22 November 2011	Signing of a cooperation agreement between IFEU and the Xinjiang Academy of Environmental Protection Science (XJAEPS) for continued collaboration after the completion of the RECAST Urumqi project with the main focus on joint life cycle assessment (LCA) projects
59	29 - 30 March 2012	Preparation for and participation in the status conference of the Future Megacities research programme, Berlin
60	05 April 2012	Presentation of RECAST Urumqi project in a panel discussion forum organized by the Future Megacities Project at the Hannover Messe

No	Date	Activity
61	12 April 2012	Presentation of the RECAST Urumqi Project in a lecture on Energy Efficient Buildings in Urumqi/China at the 1st International Symposium Sustainability for New Neighbourhoods & Buildings in El Gouna/Egypt
62	20 April 2012	Presentation of of the RECAST Urumqi Project in a lecture on City Energy Strategies: Examples from Germany, China, USA and Japan at the Energy Days in Banja Luka/Bosnia and Herzegovina
63	03 May 2012	Ground-breaking for Xingfubao, the first passive house in West China, Urumqi
64	04 - 05 May 2012	Planning of training for construction personnel and quality control together with Bernd Mahrin (TU Berlin), Dacheng International and Urumqi Construction Committee, Urumqi
65	07 May 2012	Visit of Tianye Chemical Xinjiang Tianye (Group) Co., Ltd. (PVC production of more than 2 million tonnes per year), in Shihezi, Xinjiang, to present findings on the ZhongTai assessment and to evaluate the application of results to the operation at Tianye plant
66	09 May 2012	Presentation of the RECAST Urumqi project and its achievements before representatives of the City of Karamay (pop. 420,000) in the North of Xinjiang. The city government and the real estate investor Youngsun are interested in building the first passive house in this desert city where winters are as cold as in Urumqi but the summers are even hotter.
67	22 May 2012	Preparation for and participation in a review of the Future Megacities support activity group (TU Berlin and TÜV Rheinland), Heidelberg
68	25 - 28 June 2012	Preparation for and participation in a visit of the trade delegation from Urumqi Status Workshop, Heidelberg
69	24-25 July 2012	Preparation for and participation in annual RECAST Urumqi conference, Urumqi
70	04-05 October 2012	Participation in the 13th Climate Technology Initiative (CTI) Workshop in Berlin, with a lecture on RECAST Urumqi: Strategies for an Energy Efficient Building Sector in a Future Chinese Megacity
71	09 October 2012	Cooperation with dena, Deutsche Energieagentur in support of the dena roadshow on energy conservation in buildings in Urumqi
72	07 November 2012	Expert workshop on the question Does the German passive house standard fit to China?, Heidelberg
73	19 to 23 November 2012	Preparation and organization of a tour of senior personnel responsible for the construction of the Xingfubao passive house in Urumqi including a 3-day practical training at the Berufsförderungswerk e.V., Kompetenzzentrum für Nachhaltiges Bauen Cottbus, , Heidelberg and Cottbus
74	14-18 January 2013	Representing the Future Megacities programme at “Future World Energy Summit” in Abu Dhabi, UAE
75	31 January to 05 February 2013	Outreach activities on passive house in the Xinjiang cities of Changji and Karamay
76	15 April 2013	Preparation for and participation in status seminar with Chinese partners in Heidelberg

No	Date	Activity
77	19-20 April 2013	Networking with other passive house projects in China at Passive House Conference in Frankfurt
78	April – October 2013	Finalization of details for Xingfubao passive house
79	02 May 2013	Presentation of the RECAST Urumqi project at *Ressourceneffizienz-Kolloqium*, Hochschule Pforzheim
80	13-15 May 2013	Preparation for and participation in the conference “Future Megacities in Action”, Hamburg
81	16 August 2013	Preparation for and participation in Dena-Workshop „Eco-Index of Cities in China“, Berlin
82	09-11 September 2013	Preparation for and participation in 10th BMBF-FONA Forum, Leipzig
83	23-24 September 2013	Xingfubao construction site quality inspection, Urumqi Improvement of ventilation concept
84	25-26 September 2013	Preparation for and participation in 2-day Passive House Training Seminar in Urumqi construction site quality inspection
85	09 October 2013	Training seminar “Quality control for passive houses”, Urumqi
86	10-12 October 2013	Preparation for and participation in final RECAST Urumqi conference, Urumqi
87	16-17 November 2013	3rd International Symposium on Architecture Heritage Preservation and Sustainable Development, Historic Building Conservation and Green Regeneration Technology, University of Tianjin
88	18 November 2013	Presentation of Xingfubao project at a workshop on passive house technology, at Building Energy Research center, Tsinghua University, Beijing
89	June 2014	Training and quality management of window installation at Xingfubao
90	June 2014	Training and quality management of ventilation and heat recovery unit installation at Xingfubao
91	June 2014	Developing passive house montoring/auditing system for Xingfubao
92	September 2014	Adaptation of TU Berlin training materials to condition in Urumqi
93	18-20 August 2014	Blower door workshop and test at Xingfubao
94	23-24 September 2014	Final inspection for passive house certification at Xingfubao
95	September 2014	Presenting low-carbon plan for Xinjiang
96	25 September 2014	Xingfubao opening ceremony

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1	Action Briefs RECAST Urumqi Energy Efficiency	2014	IFEU
2	Nachhaltiges Bauen von Niedrighäusern in Urumqi	2010	Franke B., Chen J.
3	Xingfubao Zertifizierung Rede Bernd Franke	2014	Franke B.
4	Urumqi Evening Newspaper Sep 2014	2014	
5	Media websites Xingfubao Sep 2014	2014	various
6	Xingfubao ventilation instruction sheets Chinese	2014	Mahrin B., Langer T.
7	Xingfubao ventilation instruction sheets English	2014	Mahrin B., Langer T.
8	Xingfubao blower door testing certificate	2014	Meyer-Olbersleben M.
9	Xingfubao certificate Passive House Institute	2014	Kaufmann B.
10	Xingfubao certificate documentation	2014	Kaufmann B.
11	Xingfubao Dacheng poster	2014	Dacheng Industrial. Co.
12	Xingfubao poster with events series	2014	Dacheng Industrial. Co.
13	Bringing blue skies back to Urumqi	2011	Franke B., Ahati J., Ding X., Peng X., Hennecke C, Hengzhi T.
14	Xingfubao poster Chinese	2014	Liu M., Wang W.
15	Xingfubao To-Do List 12 June 2014	2014	Franke B., Mahrin B., Langer T.
16	Xingfubao ventilation workshop PPT	2014	Mahrin B., Langer T.
17	Structural differences between China's and Germany's large district heating systems	2012	Liu M., Franke B., Peng X.
18	Xingfubao lessons learnt - Chinese & English	2014	various
19	Xingfubao PH certification	2014	Kaufmann B.
20	How applicable are standard Solar Irradiation Maps? Insights from Case Studies	2012	Winkler H., Franke B., Eltrop L., Telsnig T.
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23	Passive House Feasibility Study for Dacheng B Tower in Urumqi/China	2012	Bermich R.
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26	Extra Low Energy Housing: Urumqi as a Model City for Central Asia	2013	Franke B., Hennecke C., Peng X., Liu M., Derreza-Greeven C.
27	Technological and Economic Challenges in Making Urumqi's PVC Industry more Energy Efficient	2013	Franke B., Li N., Ahati J., Detzel A., Derreza-Greeven C., Zhao C., Busch M.
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29	Letter to Urumqi vice-mayor Li Hongbin regarding subsidies for energy efficient houses (English/Chinese)	2013	Franke B.
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31	Sustainable Urban Planning Elements for Urumqi - Booklet (English/Chinese)	2011	Hennecke C.
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34	Passive House Institute- Report Nanshan Retrofit English	2010	Passive House Institute
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37	The Urumqi Passive House Project	2010	Franke, B.
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53	Why would Zhongtai Chemical Co benefit from an Ecoprofile? (Chinese)	2010	Franke B., Li N.
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