LOW CARBON ECONOMY IN CITIES OF CHINA
POSSIBILITIES TO ESTIMATE THE POTENTIAL OF CO2-EMISSIONS

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ZUSAMMENFASSUNG

Die zunehmende Urbanisierung und der Klimawandel sind eine der größten Herausforderungen im 21. Jahrhundert. In vielen Regionen der Welt, besonders in den Städten, gibt es bereits negative Auswirkungen durch die immer zunehmender Umweltverschmutzung wie Smog, feste und flüssige Abfälle, Verkehrsstaus und Lärm, etc.. Der wachsende Verbrauch fossiler Brennstoffe und der Verkehr in den Städten führen hierbei zu deutlich steigenden CO2-Emissionen, die den Klimawandel beschleunigen. Weltweit, auch in China, versuchen so die Städte ihren Kohlendioxid-Ausstoß zu reduzieren. So werden die genannten "Low Carbon Cities" gefördert. Derzeit sind es 79 Städte in China die als "Low Carbon City" geplant werden. Eine "Low Carbon City" Stadt zu planen und zu bauen ist keine einfache Aufgabe, da unterschiedlichste Problemstellungen beachtet und überwunden werden müssen. Besonders hindern hier eingeschränkte finanzielle Investitionen sowie traditionelle und institutionelle Beschränkungen die Umsetzung. Die Bauindustrie gehört zu den traditionell wenig innovativen Bereichen der Industrie, die jedoch nun aufgefordert ist, Lösungen für unterschiedliche Klimazonen zu finden. Da diese Lösungen in den verschiedenen Bereichen durch unterschiedlichste Unternehmen zu erarbeiten sind, ist ein ganzheitlicher Ansatz oftmals nur schwer zu realisieren. Ein Ansatz die CO2 Emissionen in den Städten zu berechnen und Möglichkeiten der Reduzierung im Bezug auf den Gebäudesektor aufzuzeigen, war Gegenstand dieses Forschungsvorhabens.

SUMMARY

Increasing urbanisation and climate change are one of the greatest challenges in the 21st Century. Many regions already face different negative impacts on cities such as growing local pollution, solid and liquid waste, traffic congestion and noise. A growing consumption of fossil fuels in cities and the traffic leads to increasing CO2-emissions accelerating climate change. All over the world and also in China, cities are trying to reduce their carbon footprint. In that context, the concept of so called “low carbon cities” is promoted. Currently, 79 cities in China are considering low carbon concepts. To build a low carbon city is not an easy task as there are various barriers to be removed, such as financial, traditional and institutional barriers. Building belong to the most traditional and slow-changing innovative areas in industry. Further solutions are different for hot and warm climates than for cold climates. Due to a very fragmented and divided structure in smaller enterprises and in different areas, a holistic approach is hardly to get. Subject of this research project was to describe possibilities in the building sector how to estimate the potential of CO2 emissions in cities as well the reduction potential.

INTRODUCTION[1]

The Chinese government decided to reduce the domestic emission reduction goals in the 12th Five Year Plan (2011-2015) according to the goals of international emission reduction. The reduction of carbon intensity per unit of GDP (Gross Domestic Product) in China is supposed to be reduced by 40-45% in 2020 against the intensity of 2005 levels.
The implementation of CDM[2] in the United Nations is in the beginning; therefore China has the chance to implement these systems as the first and the most important Nation worldwide in the building sector for LOW Carbon Cities. Germany, as one of the leaders in Low Carbon projects, has the chance, in collaboration with China, to increase the leadership in this working field and to become the master in the implementation of CDM projects in buildings worldwide. An excellent possibility to reach this goal

is therefore the implementation on financial incentives by pCDM (Programmatic CDM) or other advanced methods with this project. In consequence of the development of the city planning in china during the next years and the increasing building industry, the Chinese government needs a set of guideline and reliable prediction methods for the regional LOW Carbon potentials and their application. This project offers China the possibility to receive a forecast of the Low Carbon potentials for their NEW LOW CARBON CITIES. With these tools China can influence and lead the market under the aim of LOW CARBON reduction during the next years to full fill the domestic emission reduction goals. The project will provide the methodology for the implementation of pCDM for the different climate regions in China as well as the guideline during the planning and realisation phase of Low Carbon Cities. Only with both approaches it will be possible to find solutions for the practical implementation for different climate situations (heating, cooling, heating and cooling) and for suitable requirements.

CALCULATION OF THE CO_2 – EMISSION REDUCTION FOR THE MOST IMPORTANT BUILDING TYPES

Example for Xiamen - China

This chapter describes the basic approach to evaluate the energetic behaviour of buildings as well as to provide a calculation methodology for the CO_2-emission reductions in the PoADDs (Program of Activities Design Documents). In order to detect and to investigate the CO_2 saving potential in the different building types, the following steps of work are necessary:

Numeric simulation of the range of the energy demand from the selected building types for heating, cooling and dehumidification

Setting a baseline for each building type

Calculation of the energy saving-/ CO_2 emissions saving potential of each building type

Forecast of the CO_2 emissions saving potential for a whole pilot-region

In scope of this investigation, the available values from measurements of buildings/building categories will be compared to numeric calculations of energy requirement.

IDENTIFICATION OF THE BASELINES

The detection of the CO_2 saving potential is based on baselines, which are set by the energy standard of national requirements and/or regulations.

THERMAL ENERGETIC SIMULATION OF BUILDINGS (TES)

In this project, three simulation computer models are used:

- TRNSYS
- LEC
- China GB-50189-2005 by the computer program BEED developed by MoHURD

TRNSYS delivers the calculation of the final energy demand of each building type, LEC will deliver an easy method to estimate the primary energy demand taking into account the primary energy and CO_2-emissions used to produce and transmit the final energy for the use in buildings.

TRNSYS is a complete and extensible simulation environment for the transient simulation of thermal systems including multi-zone buildings.
It is used by engineers and researchers around the world to validate new energy concepts, from simple solar domestic hot water systems to the design and simulation of buildings and their equipment, including control strategies, occupant behaviour, alternative energy systems (wind, solar, photovoltaics, hydrogen systems), etc. Throughout its thirty year history, TRNSYS has been under continual enhancement by an international group. TRNSYS is based on a model developed by the Solar Energy Laboratory at University of Wisconsin-Madison, USA, 1992.

LEC (Low Energy Certificate) is the result of two years of research to develop a planning tool to evaluate the energy performance of buildings. Thanks to the evaluation programme it is possible to evaluate nearly all building types and parts of a building with regard to their energetic quality separately after the heating period and after the cooling period. The examination of the buildings with regard to the regional climate conditions is based on a pure physical basis. In this context it is important to mention that the calculations are exclusively based on results of analysis of the thermal equations.
The basis for the evaluation of the heating period is a comparison with similar buildings (Reference–building) which is in accordance with a building according the standard of the 80ies. As far as the cooling periods are concerned, the evaluation is based on comparisons with an “optimal” envelope of a building. The evaluation of the energy for cooling and heating are re-evaluated, classified and shown with regard to certain criteria. The result of the energetic verification is presented with a simple star system. An increase of stars clearly shows the energetic quality of the building, which means that

the user can immediately recognize the energetic quality of the building thanks to a simple illustration.

BEED Building Energy Efficiency Design, Calculation and Economy Analysis Software was developed by the Centre of Science & Technology of Construction Minister of Construction; P.R. China cooperates with Beijing E-house building science and technology development Co. Ltd. to finish the task of the World Bank "economy analysis about building energy efficiency measures and stimulation calculation module in BEED". The result has passed the MOC evaluation and the level is in the top in China. BEED was designed according as "Thermal design code for civil building" and "Energy conservation design standard for new heating residential building.

Calculation results

The simulation by TRNSYS delivers the Energy demand (kWh/m²) and the Maximum energy load (kW/m²) for heating, cooling and dehumidification.
LEC calculates the energy level considering the outer surface only. Other methods such as China GB-50189-2005 calculate a more general use of energy, based not only on the building surface, but also on system engineering and on political conversion factors. The evaluation tool offers the possibility to evaluate almost every building and construction part regarding to its energetic quality, separated by cooling period and heating period. The evaluation of the buildings under consideration of regional climatic circumstances is strictly based on fundamentals of physics. The calculations are based on results of thermo technical equations.

CALCULATIONS OF THE CO2-EMISSIONS OF BUILDINGS

Basis of the classification are the 18 types of buildings according to the MoHURD-Ministry of Housing and Urban-Rural Development typology. For these types of buildings the energy demand and other relevant data are available in 23 cities of China. For the Xiamen project, however, the analysis of 18 building types is too detailed. Therefore, there was made a first selection of 7 main categories divided in

- Residential Buildings
- Non Residential Buildings

For residential buildings, a classification of the buildings was made on the basis of the building geometry. Here, the ratio of outer wall and roof to volume (A/V ratio) will be taken and the
residential buildings will be differentiated in
a) single family houses up to 3 stories;
b) multi-storage houses for multiple families.
Non-residential buildings will be differentiated in
c) office buildings;
d) Shopping centres;
e) Hotels;
f) Buildings for trade and fair;
g) Schools and other buildings.

The simulation of energy demand is calculated by TRNSYS and based on a single-zone-model according to the standard room. Therefore, the standard room is calculated with different building components, different window to wall ratio and different utilization. Furthermore, the orientation and position of the room is varied.
The properties of the building parts fulfil the minimal requirement of the GB 50189-2005 and JGJ 75-2003. At this, the window to wall ratio fits the classification of the current Chinese requirements. Different user profiles have been provided for the utilization in accordance with the applicable standards in China.
Based on the determination of the final energy demand for cooling in Xiamen, CO_2-emissions of primary energy demand will be calculated by taking into account the primary energy structure, energy efficiency of energy transformation and the losses during transmission of electricity. For the PoA, to be conservative, additional reductions may be taken into account for user behaviour, planning and construction quality.
pCDM are based on the real energy consumption / real CO2-emissions of a building or a side area. The problem is, that at the beginning of a Low Carbon building City planning phase (town planning phase) no detailed values of the CO2-emissions are existent. In this phase, pCDM can be based on a calculation of the energy consumption / CO_2-emissions. Calculation methods offer the following advantages:
considering the energetic behaviour of the building under repeatable boundary conditions
provide the possibility to directly compare buildings (under the same boundary conditions)
provide a forecast on the savings potential for CO_2 during the planning period
Summing up, they provide the possibility to compare the economical savings potentials from pCDM plus the saved amount of energy to the costs of the investment. Based on the variety investigation, an economical investigation is herewith possible.

ENERGY DEMAND OF THE 7 DIFFERENT BUILDING TYPES

The aim was the calculation of the energy consumption and the CO_2 emissions of the 7 characteristic building types for new buildings in Xiamen, China under the climate conditions according to GB50189 for the region “hot summers and warm winters” by implementing a building energy efficiency simulation.

Table 1. *End Energy Demand of building types (a-g)*

No.	Building type	**Simulated energy demand** (mean value) for cooling, heating, dehumidification current Energy Standard China	
		kWh/m²	kg CO_2/m²
a	Single family houses	43.10	36,59
b	Multi-storage/families houses	54.28	46,64
c	Office buildings	101.29	87,03
d	Shopping centres	114.02	97,97
e	Hotels	164.93	141,71
f.	Congress/Fair buildings	112.60	96,74
g	Schools	76.37	65,61

In this case, the possible variables, including building type, size, height, orientation according to azimuth of the buildings, the different ratios of the wall-/window areas of the facades, different uses and quality standards of the building services installations for energy distribution and energy production, are taken into account. Furthermore, the range of influence on planning- / arithmetic errors and execution mistakes had to be described.

APPLICATION OF THE MODELS FOR THE CALCULATION OF THE CO_2-POTENTIAL FOR XIAMEN amen

The Chinese government decided the domestic emission reduction goals in the 12th Five Year Plan (2011-2015) according the international emission reduction goals the reduction of carbon intensity per unit of GDP in China by 40-45% in 2020 against 2005 levels. To fulfil these requirements the CO_2-potential for China has to be known. One of the parts in this research project is to know well the energy demand of buildings according to the CDM standard. With this information it will be possible, to get a forecast of the CO_2-potential for new buildings for whole China. To get this forecast based on the level of the baseline CDM the following information has to put into account in a bottom-up calculation process (see Figure 1):

The transfer of the results of the single buildings to complex new LOW Carbon Cities was reviewed by the city of Xiamen/Jimei.

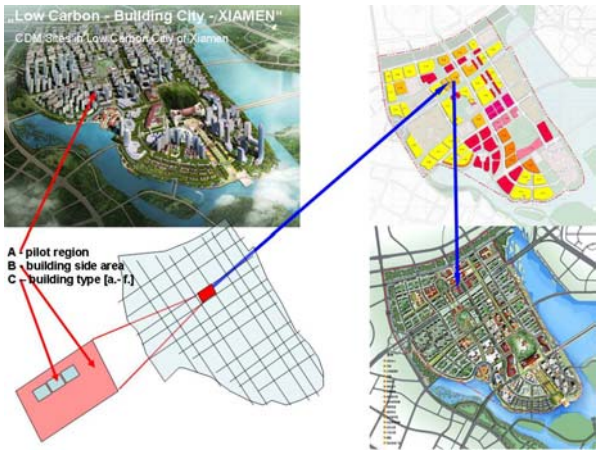

Figure 1. *Calculation of the CO_2 emissions' potential for the new LOW Carbon Building City Xiamen/Jimei*

Table 2. *– CO_2 emissions Jimei, different building standards according to the building standard LEC*

		(t CO_2/a)			
Building type	Floor area (m²)	Baseline	3 *	4 *	5 *
Single family houses	125969	4624	3081	2977	2664
Multi storage houses	1142439	47464	29545	27139	25180
Office buildings	946974	68184	61800	54332	46194
Multi storage houses / Office buildings (mix)	1247028	64288	43795	39312	36264
Shopping Centers	647986	52158	43418	40041	37955
Hotels	142016	16831	8503	7854	7083
Congress / Fair	11192	1078	834	772	733
Schools	68966	3493	1476	1249	1187
Other buildings	535384	40473	35351	31715	28292
TOTAL	**4867954**	**298594**	**227805**	**205390**	**191837**
Total (in % of baseline)		**100%**	**76%**	**68%**	**64%**

CO2-emissions for heating, cooling and dehumidification MIN values.
Standards according to: Baseline = applicable Chinese standard
3* acc. Chinese Green Building Standard; 4* German ENEV 2001; 5* German ENEV 2009

Even considering regional characteristics, it is shown that there is a possibility to determine the CO2 potential for new „Low Carbon Cities" of China. The results will deliver the base to make decisions by implementing new CDM-Baselines to limit the energy demand in a special „Low Carbon Standard", a standard quite above the actual energy standard of China.

OUTLOOK / CONCLUSIONS

The possible CO_2 savings potential of the new Low Carbon Cities currently being planned (see Figure 2) shows that an economic and ecological building process in China will be realisable once the requirements of the energetic quality of the buildings are reasonable increasing as well as the requirements for efficient energy distribution and energy production systems. This building process may lead the way to accomplish the global restriction of CO_2 emissions in the construction sector. To establish China as a pioneer for CDM in the building sector, actions have to be done in a short term.

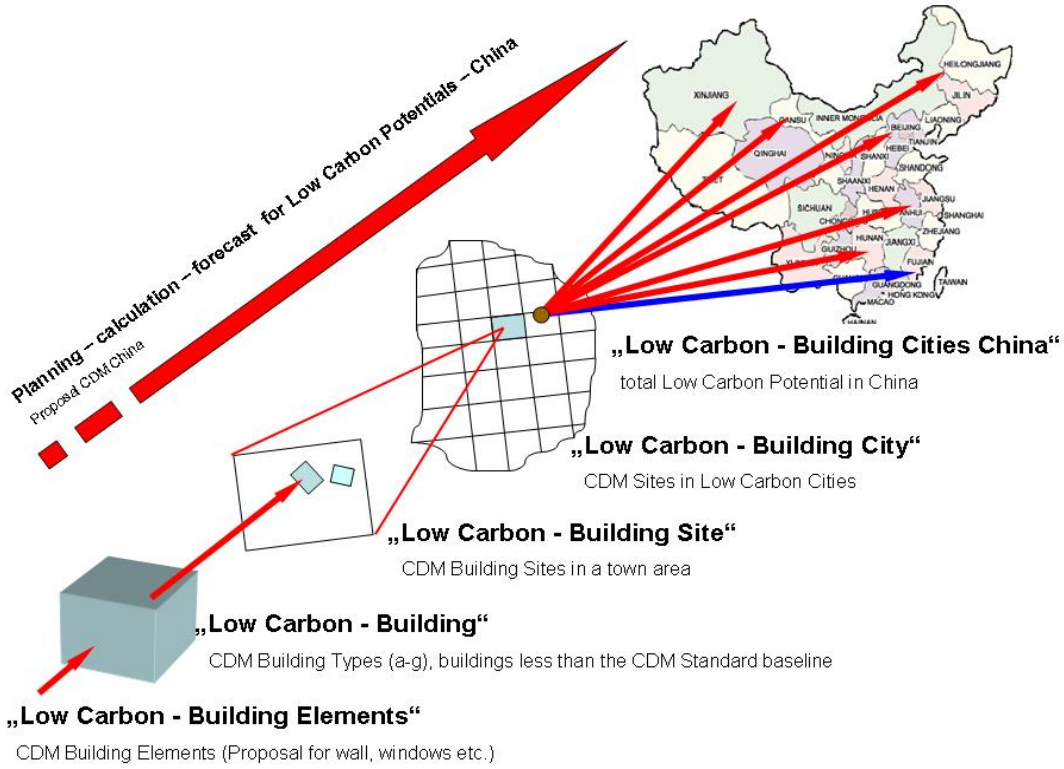

Figure 2. *Bottom-up-Calculation for the expected CO_2-Emissions in China*

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[1] This report is part of the final report of the study for the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Chapter 1602 Title 896 05, 2009 as granted by the notification dated December 3rd, 2009

[2] The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO2, which can be counted towards meeting Kyoto targets. [http://unfccc.int/2860.php]