Energy Demand and Emissions in Building in China: Scenarios and Policy Options

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Abstract: Recent rapid growth of energy use in China exerts great pressure on the energy supply and environment. This study provides scenarios of future energy development in buildings, including urban residential, rural residential and service sectors (not including transport), taking into account the most up-to-date data and recent policy discussions that will affect future economic, population, and energy supply trends. To understand the role of policy options including technology options and countermeasures, two scenarios were defined, which represent the range of plausible futures for energy development in buildings. This is also part of an energy and emission scenario study for the IPAC (Integrated Policy Assessment Model for China) modeling team. The results from quantitative analysis show that energy demand in buildings in China could increase quickly, as high as 666 million in 2030. However, policies and technologies could contribute a lot to energy demand savings, which could be 28% energy savings compared with the baseline scenario. There is still space for further energy savings if more advanced technologies could be fully diffused.

Key words: energy, building, modeling, scenario, China

1. BACKGROUND

In China, due to rapid economic growth, total primary energy consumption increased from 400 Mtoe in 1978 to nearly 1320 Mtoe in 2004, with an annual average rate of increase of 4.7% (see Figure 1)[1][2]. Coal is the major energy source, providing 70.7% in 1978 and 69% in 2004 of total primary energy use (see Figure 2). Recent years have witnessed a dramatic surge in the rate of increase of energy use in China and widespread energy shortages.

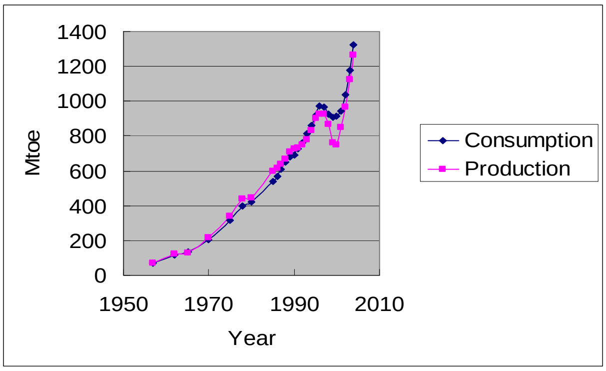

Fig. 1 Energy production and consumption in China

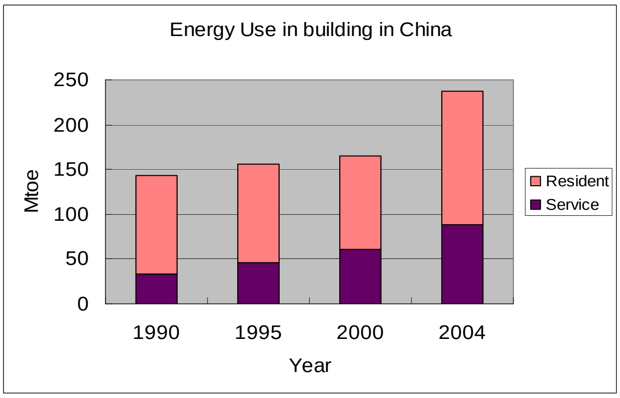

Fig. 2 Energy use in building in China

Increase of energy use in building(including urban residential, rural residential and service sector) is one of major driving force for energy increase in China in most recent years(see figure 2). During 1990 to 2000 energy use in building increase only a little bit due to replacement of coal by natural gas in urban area. However significant energy demand increase was seen after 2000. Major reason for this is energy service demand such as air cooling, electric appliance increase a lot, and they are becoming a key factor for power shortage in China

Energy future in building therefore is an important concerning for policy making and energy supply. This paper tries to explore future path of energy use in building, by giving different scenarios. Policy options to reduce energy demand also simulated in policy scenario. This study is part of energy demand and emission scenario study for China, conducted in IPAC modeling team in Energy Research Institute[3][4].

2. METHODOLOGY

IPAC-AIM/Technology model – components of the Integrated Policy Assessment Model for China (IPAC) – was used to perform the quantitative scenario and policy option analysis. The models project future energy and pollutant emissions.

The IPAC-AIM/Technology model is a single region model for China, developed based on AIM/enduse model [5][6][7][8]. This model includes three modules (i.e., energy service demand projection, energy efficiency estimation and technology selection). The demand is divided among the industrial, agricultural, service, residential, and transportation sectors, and these sectors are further divided into sub-sectors. For both demand and supply side, more than 400 technologies are considered, including existing as well as advanced technologies that may be used in the future. The model searches for the least-cost technology mix to meet the given energy service demand. The most up-to-date information on these technologies were collected from large number of printed sources, as well as by consulting experts directly.

3. MODEL ASSUMPTION AND SCENARIO DEFINITION

3.1 Model assumptions

The major assumptions used in this study (including population, GDP growth and mix) are given in the following tables. The assumptions for population come from other studies by reviewing papers and reports. The assumed GDP growth rate is consistent with government targets and research by the different research teams[9][10][11][12][13].

Beside GDP growth and population in China, there are several other important factors to be considered in the scenario study. Table 3 presents these key factors.

Tab. 1 Population assumption, million

	2000	2010	2020	2030
Population	1284	1380	1460	1530
Urban	465	665	846	994
Rural	819	724	613	535

Note: Assumptions by authors, based on review of relevant studies

Tab. 2 GDP growth in China

	2000-2010	2010-2020	2020-2030
Annual GDP Growth Rate	8.9%	7.5%	6%

In the scenario study, three sectors included, they are urban residential, rural residential and service sector(tertiary sector not including transport). Then major factors for these sectors including number of household, living area in residential sector, and total building area in service sector are major factor to decide energy services. Assumptions for residential are given in table 4.

As mentioned in methodology session, this model considers technology used in these sectors, by providing desired energy service. These energy service are decided by giving assumption for service ownership, intensity change and utilization time change. In order to easy to understand, we take energy service in year 2000 to be the standard one. Service assumption and factors for service change for urban and rural are given from table 5 to 10.

Energy service demand and key factor in service sector are given in table 11 to 13. In table 11 building area in service sector is given. Different type of building area is considered and reflected in ownership of energy service.

The model calculates energy demand based on technology use for each energy service. All together more than one hungry energy technologies are listed in the model. Table 14 gives technology used in these sectors.

3.2. Scenarios

In order to analyze future energy demand in building in China, we consider two scenarios.
The two scenarios are defined as follows:

Baseline scenario: This scenario gives a basic trend to describe future energy use based on moderate energy efficiency improvement.

Policy scenario: mainly include higher efficiency building and equipment.

Policy options to be considered in the policy scenario are given in Table 15.

Tab. 3 Factors influenced by key driving forces

Driving forces	Factors	Policies to promote the Change
Social Efficiency change	Energy activity change within the sector(such as change of use of heating, cooling; use of more efficient electric appliances etc.)	Public education, price policies
Technology progress	Efficiency progress for technology(unit energy use improvement)	Technology R&D promotion, market oriented policies, international collaboration
	Technology mix change(, more advanced technologies)	Market oriented policies, environmental regulation
	Fuel mix change(more renewable energy and nuclear)	National energy industry policies, import & export policies, tax system

Tab. 4 Assumptions for residential

	2000	2010	2020	2030
Household in Urban , million	139	205	273	326
Number of people per household in urban	3.30	3.20	3.10	3.05
Living area per person in urban, m^2	19.70	30.00	34.84	36.72
Household in Rural, million	227	196	175	158
Number of people per household in rural	3.84	3.70	3.5	3.4
Living area per person in rural, m^2	24.7	31.1	36.0	38.8

Tab. 5 Service assumption for urban resident

	2000	2010	2020	2030
Cooking	139	205	273	326
Electric cooking	115	225	462	639
Hot water	85	197	516	815
Space heating	51	133	234	329
Air Conditioner	51	247	681	1096
Fan	209	297	546	685
Lighting: Incandescence lamp	100	148	280	632
Lighting: Fluorescent lamp	40	148	315	843
Refrigerator	94	154	363	489
Color TV	109	207	455	665
Black TV	56	71	31	0
Washing Machine	167	286	721	1552
Other appliance	76	141	254	310

Tab. 6 Intensity change of service in urban resident

		2000	2010	2020	2030
Cooking	Cooking time	1.05	1.05	1.05	1
Electric cooking	Use times per week, (1990 2 hours)	1.1	1.2	1.3	1.4
Hot water	Heating time	1.5	1.8	2.1	2.5
Space heating	Heating time	1.25	1.3	1.33	1.36
Air Conditioner	Cooling time	1.2	1.36	1.5	1.5
Fan	Lighting time, (1990, 3.5 hours)	1.10	1.22	1.22	1.22
Lighting: Incandescence lamp	Lighting time	1.14	1.29	1.29	2.50
Lighting: Fluorescent lamp	Capacity change	1.14	1.29	1.29	2.50
Refrigerator	Capacity change	1.05	1.2	1.4	1.5
Color TV	Capacity change	1.1	1.3	1.4	1.5
Washing Machine	Capacity change	1.05	1.1	1.2	1.7
Other appliance	Capacity change	1.5	2.5	3.5	4.5

Tab. 7 Ownership of service in urban resident, %

	2000	2010	2020	2030
Cooking	100	100	100	100
Electric cooking	90	120	130	140
Hot water	49	70	90	100
Space heating	37	40	43	45
Air Conditioner	30.8	60	100	130
Fan	180	190	200	210
Lighting: Incandescence lamp	75	50	48	45
Lighting: Fluorescent lamp	30	50	54	60
Refrigerator	77	82	95	100
Color TV	80	90	105	120
Washing Machine	91	98	100	100
Other appliance	65	90	93	95

Tab. 8 Service assumption for rural resident

	2000	2010	2020	2030
Cooking	272.40	254.55	245.28	236.25
Electric cooking	27.24	58.74	96.36	110.25
Hot water	13.62	48.95	87.60	126.00
Space heating	80.02	142.22	204.95	279.02
Air Conditioner	2.95	44.33	418.27	1066.86
Fan	159.35	180.15	227.76	236.25
Lighting: Incandescence lamp	147.10	136.29	135.94	131.31
Lighting: Fluorescent lamp	74.91	142.22	188.22	227.60
Refrigerator	22.70	39.16	70.08	141.75
Color TV	79.45	97.91	147.17	209.48
Black TV	158.90	137.07	134.90	86.63
Washing machine	62.43	70.49	122.64	240.98

Other Appliance	204.30	274.14	350.40	401.63

Tab. 9 Service intensity change in rural resident

	2000	2010	2020	2030
Cooking	1.2	1.3	1.4	1.5
Electric cooking	1.2	1.3	1.4	1.5
Hot water	1.2	1.3	1.4	1.5
Space heating	1	1.5	2.1	2.55
Air Conditioner	1	1.87	3	3.9
Fan	1.08	1.15	1.3	1.5
Lighting: Incandescence lamp	1.08	1.15	1.3	1.5
Lighting: Fluorescent lamp	1.1	1.2	1.35	1.6
Refrigerator	1	1	1	1
Color TV	1	1	1.2	1.4
Black TV	1	1	1.1	1.1
Washing machine	1.1	1.2	1.4	1.8
Other Appliance	1.5	2	2.5	3

Tab. 10 Ownership of service in rural resident, per 100 household

Cooking	100	100	100	100
Electric cooking	10	30	55	70
Hot water	5	20	50	80
Space heating	38	40	42	50
Air Conditioner	1.4	1	4	125
Fan	65	80	100	100
Lighting: Incandescence lamp	60	50	45	40
Lighting: Fluorescent lamp	30	50	60	65
Refrigerator	10	20	40	90
Color TV	35	50	70	95
Black TV	70	70	70	50
Washing machine	25	30	50	85
Other Appliance	60	70	80	85

Tab. 11 Energy service demand in service sector

	2000	2010	2020	2030
Service building area(million m2)	9000	16000	23000	28000
Cooling	44.9	38.0	88.9	157.2
Space Heating	71.5	110.3	153.3	210.6
Lighting	209.0	312.0	429.0	560.0
Duplicating machine	13.2	24.2	42.8	63.0
Computer	22.6	61.8	123.6	211.7
Elevator	21.5	36.0	52.3	71.3
Other electric appliance	76.6	114.3	157.1	205.1
Hot water	48.9	89.9	139.0	194.4
Cooking	13.6	23.5	26.8	49.6

Tab. 12 Service ownership change in service sector

	2000	2010	2020	2030
Cooling	21.0%	24.0%	26.0%	28.0%
Space Heating	38.0%	41.0%	43.0%	45.0%
Lighting	100.0%	100.0%	100.0%	100.0%
Duplicating machine	7.0%	9.0%	12.0%	14.0%
Computer	12.0%	22.0%	32.0%	42.0%
Elevator	12.0%	14.0%	16.0%	18.0%
Other electric appliance	40.7%	40.7%	40.7%	40.7%
Hot water	26.0%	32.0%	36.0%	40.0%
Cooking	100.0%	100.0%	100.0%	100.0%

Tab. 13 Service intensity change

	2000	2010	2020	2030
Cooling	1.25	1.28	1.34	1.38
Space Heating	1.1	1.15	1.2	1.3
Lighting	1.1	1.2	1.3	1.4
Duplicating machine	1.1	1.15	1.2	1.25
Computer	1.1	1.2	1.3	1.4
Elevator	1.05	1.1	1.1	1.1
Other electric appliance	1.1	1.2	1.3	1.4
Hot water	1.1	1.2	1.3	1.35
Cooking	1.1	1.2	1.3	1.35

Tab. 14 Technology used in the sectors

Energy Service	Technologies	Sectors
Energy Saving Building	Normal Building 50% Energy Saving building 60% Energy Saving building 75% Energy Saving building	Urban residential, rural residential, service sector
Space Heating	Co-Generation heat supply CENTERAL HEAT SUPPLY SMALL COAL STOVE ELECTRIC HEATER Space Heating by gas Gas boiler Air conditioner for space heating Air conditioner for cooling Air conditioner for heating Air conditioner for cooling	
Cooking	GAS STOVE(FOR COOKING) Coal STOVE(FOR COOKING) BRIQUET STOVE	

	LPG Stove	
	Work Gas Stove	
	Biomass stove	
	Efficient biomass stove	Rural Residential
	Bio-gas stove	
Electric Cooking	ELECTRIC POT 1	
	ELECTRIC POT 2	
	Incandescent Light	
Incandescent Light	Incandescent Light: 8% efficiency higher	
	Incandescent Light: 20% energy efficiency higher	
	Fluorescent Light: normal	Urban residential, rural residential, service sector
Fluorescent Light	Fluorescent Light: 20% energy saving	
	compact Fluorescent Light: 75% energy saving	
	ring Fluorescent Light: 20% energy saving	
	Electric Air Conditioner	
Space cooling	Electric Air Conditioner	
	Super air Con	
	Central air cooling	Service sector
Fun	FUN	
Washing machine	WASHING	
	New WASHING	
Refrigerator	Electric Refrigerator	
	New Electric Refrigerator	
Color TV	Color TV	
Black TV	Black TV	Urban residential, rural residential
Other electric Appliance	Other electric	
	Other electric: Advanced	
	Solar Heater	
Hot water	Gas heater	
	LPG heater	
	Eli heater	
Computer	Computer	
	Energy efficient computer	
Duplicator	Duplicator	
	Energy saving duplicator	Service sector
Elevator	Elevator	
	Energy saving elevator	
Other office appliance	Office appliance	
	Energy saving office appliance	

Tab. 15 Policy options used in the modeling study

Area	Options, in 2030
Cooking	Natural gas cooking in urban, LPG and biogas in rural
Space heating	Central heating, energy saving building: 70% in urban, 65% in rural, use of heat pump

Space cooling	Ultra high efficiency air conditioner: 60%, energy efficiency building for cooling:80%
Electric appliance	Refrigerator: fully use of high efficiency refrigerator, washing machine: 45% higher efficiency
Lighting	Fully use of compact lighting with 80% higher efficiency
Hot water	Solar heater
Office electric equipment	30% higher efficiency higher computer, duplicator

4. RESULTS

Energy demand is calculated using the IPAC-AIM/technology model, Baseline scenario results are given in Figures 3 to 6.

Final energy demand in building in the baseline scenario could go to 417million toe in 2020 and 666million toe in 2030. The annual growth rate from 2000 to 2030 is 6.2%. By 2020 share of urban resident, rural resident and service will be 39%, 27% and 34%, and 38%, 28%, 34% in 2020 respectively. Electricity will be the major energy used in building, taking share of 42% in 2020, 48% in 2030. Coal use also increase due to cooking and space heating demand(see figure 3 and 4).

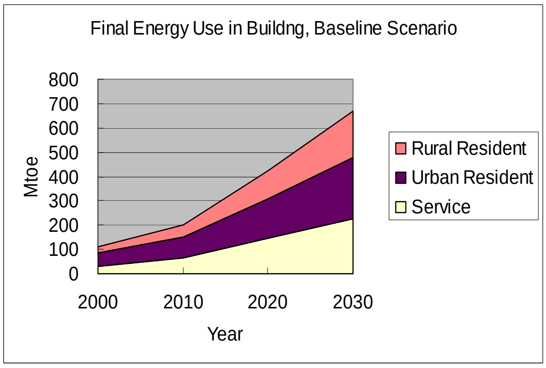

Fig.3 Final energy use in building by sectors, baseline scenario

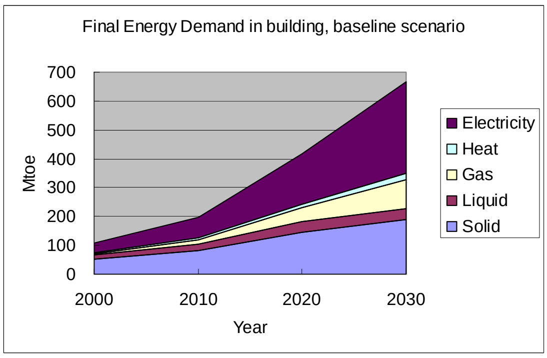

Fig. 4 Final energy use in building by energy, baseline scenario

For the policy scenario, final energy demand in building could go to 347million toe in 2020 and 479million toe in 2030. The annual growth rate from 2000 to 2030 is 6.2%. By 2020 share of urban resident, rural resident and service will be 37%, 30% and 33%, and 36%, 32%, 32% in 2030 respectively(see figure). Electricity will be the major energy used in building, taking share of 38% in 2020, 42% in 2030 (see figure 5 and 6).

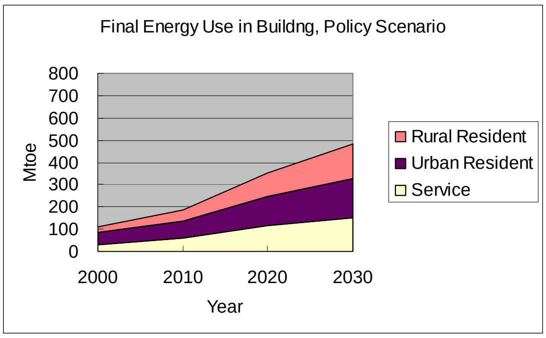

Fig. 5 Final energy use in building by sectors, policy scenario

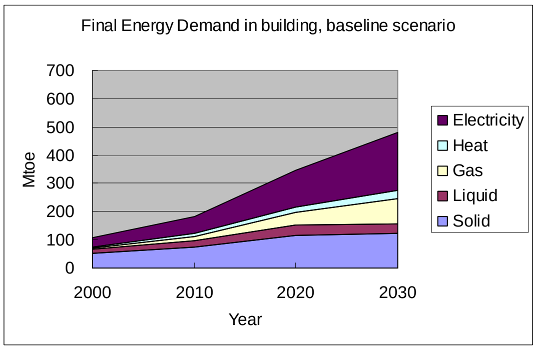

Fig. 6 Final energy use in building by energy, policy scenario

5. CONCLUSION

This scenarios study shows energy demand in building in China will have significant increase. The energy demand in building in 2020 could range from 347 and 417 million toe, 479 to 666 million toe in 2030. This depends on technology progress, and polices applied etc.

Policy and widely use of new technology could reduce largely energy demand in building in China. Even with existing technology with lower cost, such energy efficient building, solar heater, high efficiency refrigerator and air conditioner, energy demand could be much lower. Energy saving in buildings have very good potential and low cost, only strong policies are urgently needed right now for further implementation of new energy saving technologies and change of consumption in building. Policies on regulation on energy efficient building with strong government enforcement, fiscal policies to reduce payment of space heating for users of energy efficient building, much more higher energy efficiency standard for electric appliance, promotion for solar heater, geothermal for space heating, heat pump, should be implemented as soon as possible, to avoid long time technology lock-in effects. There are already lot of good practice for energy saving in building in other countries. Efforts should be made at early time to reduce rapid increase energy use in building to China, in the sake of energy security, local environment and global environment issues. In the meantime, study in IPAC modeling team also found progress of technology could contribute to local economy activities[14].

One more things should be mentioned here. This study considering many technologies for building, and policy options, which can contribute the more than 28% energy saving in building compare with baseline scenario. However there are some advanced technology available now which not yet considered in this study, such as distribute heating, cooling and power generation system, super high energy saving building, and countermeasures such as energy saving campaign etc. If those technologies will also be implemented, there will more energy saving potential.

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