SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

TASK 69
Solar Hot Water For 2030

Solar Hot Water for 2030, Subtask B:

Initial results of failure modes and GHG reduction on thermosyphon systems

Li Bojia (China Academy of Building Research, CN)

Solar Academy, Sep 25, 2024

Background

- Thermosyphon systems represent the majority of installed SHW systems

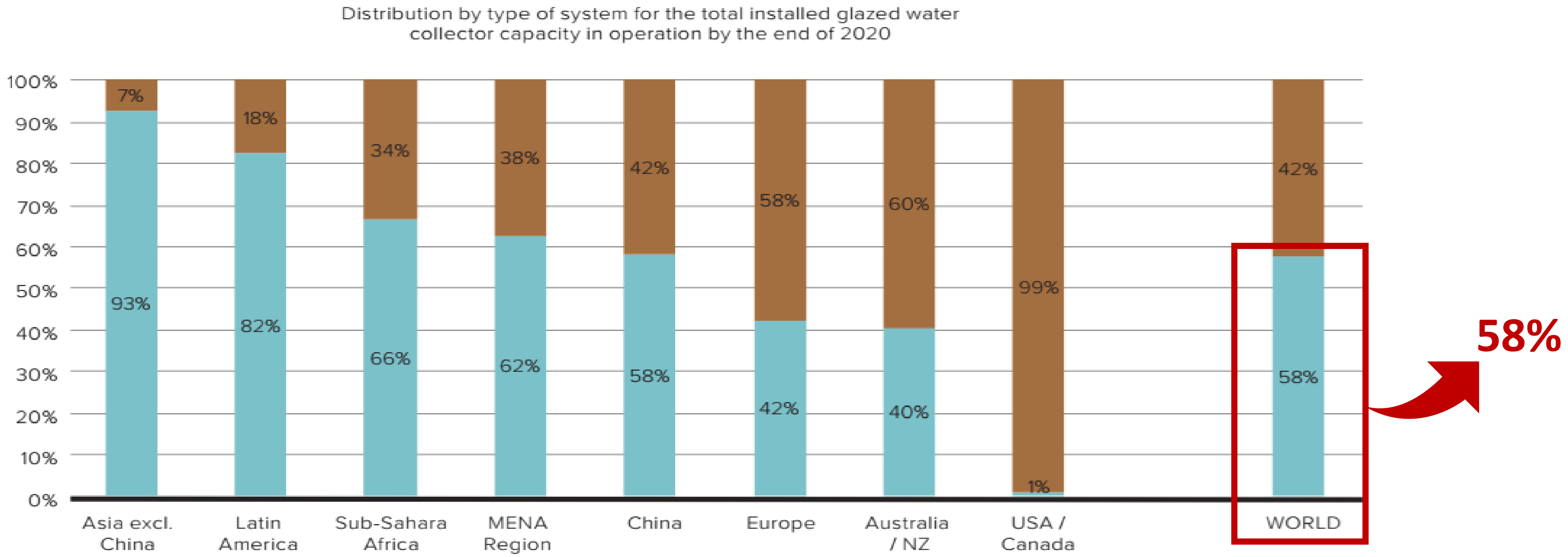


Figure 48: Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2020

Source: *Solar Heat Worldwide 2023,* Werner Weiss, Monika Spörk-Dür

Solar Hot Water for 2030, Subtask B:

To promote thermosyphon hot water systems by

- Improving convenience and performance
  better design and management tech.

- Improving durability and reliability
  failure modes survey and suggestions in different regior

- Investigate the Energy-saving & GHG reduction performance in different region

  how the thermosyphon systems contribute to carbon peak & carbon neutral (latest data, evaluation metho & experiments)

Durability and Reliability

Failure Modes
- mainly from GNSEC & South Africa

#	Name
Design and installation	
1	**Incorrect mounting** support for components
2	**Wrong positioning** of pipes and components
3	**Wrong positioning** of vacuum breaker
4	**Missing insulation**
5	**Deterioration of insulation** due to missing protection
6	Missing and wrong positioning **safety devices**
Operation	
7	**Leakage** due to missing or wrong concentration of antifreeze liquid
8	Wrong response pressure for **safety valve**
9	Missing inspection of **antifreeze liquid**
10	**Unsuitable control** of back-up heating device
11	**Corrosion** phenomena solar thermal equipment
12	**Poor water quality** especially for direct solar water heating systems

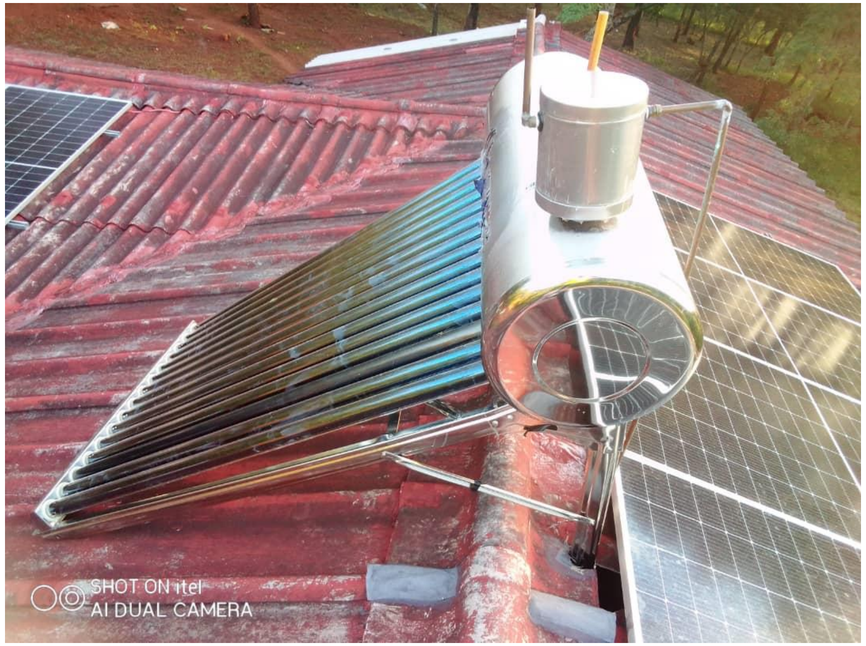
Failure Modes

Incorrect mounting support for components

Fact: Wrong way of installation of solar system would lead to roof breaking.

Effect: The roof would break and damage or lead to water leaks in the roof.

Example: Figure shows below the examples of wrongly installed solar collector that has the roof not inspected.



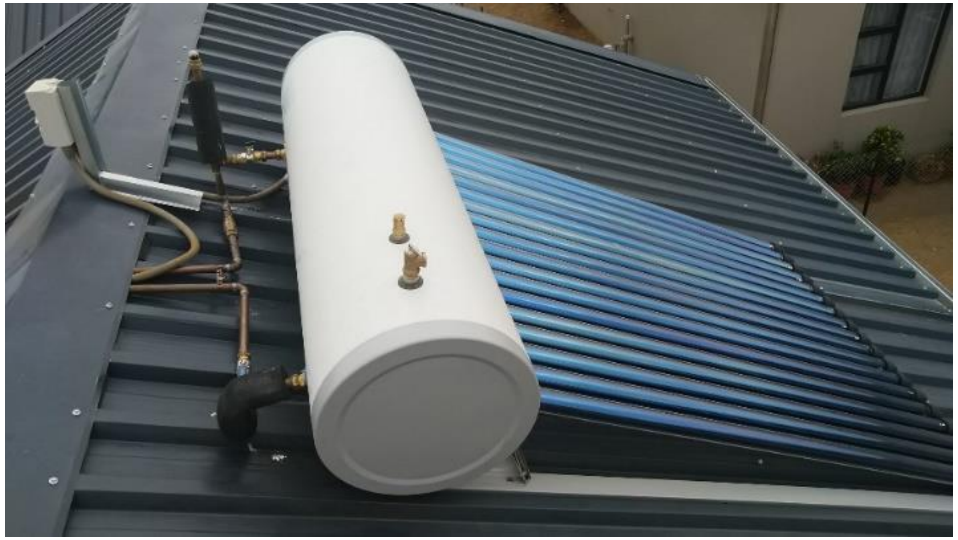
Source: Samson Mhlanga

Failure Modes

Wrong positioning / installation of vacuum breaker

Fact: There is no thermosyphon loop in place to prevent back flow out of the tank in case there is not sufficient cold-water supply.

Effect: in case having not enough water supply, the tank will be drained by leaving the taps open, which are positioned lower as the tank. Having an empty tank, this phenomenon can easily destroy the electrical heating element in the tank.



Source: Rudi Moschik

Failure Modes

Missing insulation

Fact: Insufficient hot water in the morning provision by the system and over sizing of systems to compensate for heat loss.

Effect: Over sizing of systems and poor performance of the systems.

Example: examples of uninsulated solar collector outlet pipes.

Source: Samson Mhlanga, Joseph Shigwedha, Helvi IILeka

Failure Modes

Corrosion

Fact: Frequent deterioration phenomenon that has been detected, in equipment that fails prematurely, is stress corrosion cracking (SCC), which manifests itself as cracks

Image taken from internet

Failure Modes

Deterioration of insulation due to missing protection

Wrong positioning of pipes and components

Missing safety devices

Wrong response pressure for safety valve

Missing inspection of antifreeze liquid

Unsuitable control of back-up heating device

Poor water quality especially for direct solar water heating systems

Suggestions on Reliability and Durability

Standards and Guidelines: Better Design & Basic Performance

Testing and Certification: Product Quality

Training and Qualification: Incorrect mounting & operation

Smart detecting: Future thoughts for operation

Energy-saving & GHG reduction of thermosyphons

Background

- Difference between IEA and China's statistics that is hard to ignore

IEA SHC Solar Heat Worldwide 2023：

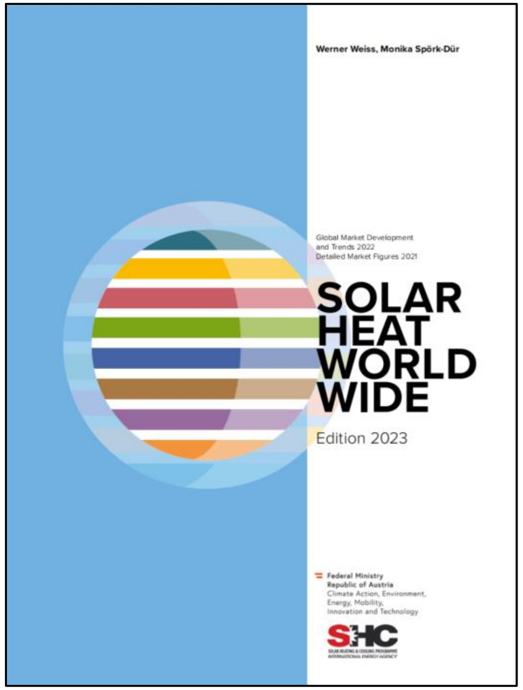
✓ Global solar thermal capacity in 2021: **522 GW_{th} (746 million m^2)**

✓ GHG reduction: **147.5 million tons of CO_2**

China Solar Thermal Industry Federation：

✓ China solar thermal capacity in 2021: **337 GW_{th} (482 million m^2)**

✓ GHG reduction: **186 million tons of CO_2**



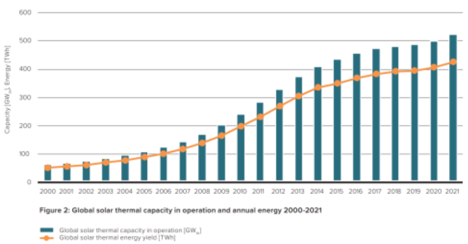


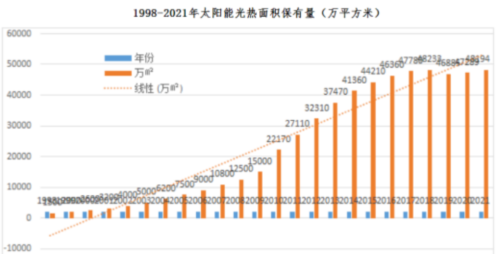
Figure 2: Global solar thermal capacity in operation and annual energy 2000-2021

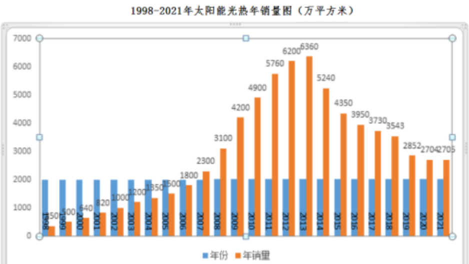
As shown in the figure below, the global solar thermal capacity of unglazed and glazed water collectors in operation grew from 62 GW_{th} (89 million m^2) in 2000 to 522 GW_{th} (746 million m^2) in 2021. The corresponding annual solar thermal energy yields amounted to 51 TWh in 2000 and 425 TWh in 2021 (Figure 2).

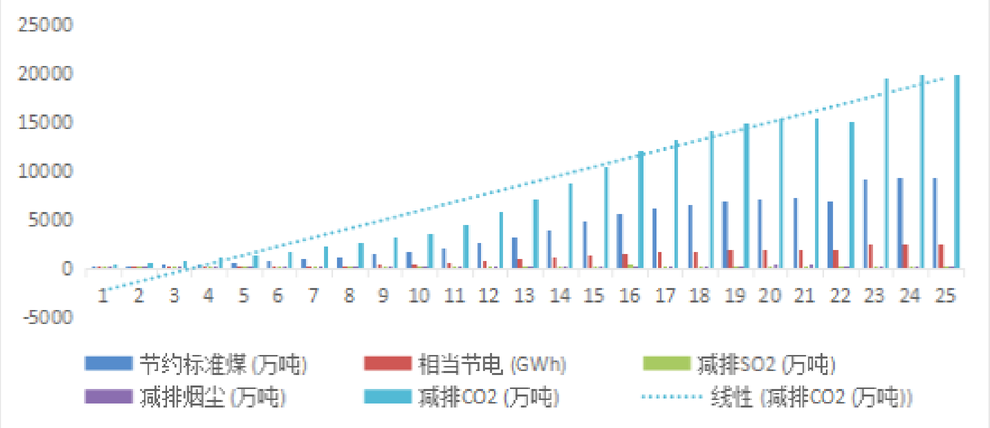
Environmental effects and contribution to climate goals

The global solar thermal energy yields of all installed solar thermal systems in 2021 correspond to a savings of 45.7 million tons of oil and 147.5 million tons of CO_2. This shows the significant contribution of solar thermal in reducing global greenhouse gas emissions.

Source: Solar Heat Worldwide 2023







Source: CSTIF

Difference

- A lot difference between China and Europe causes difference in GHG reduction
  - **System type:** In China, systems with evacuated tube collector are more popular.
  - **Hot water demand:** High rise department building is more popular than single house.
- That causes other countries' experience not quite suitable for GHG reduction in China

Compact system with ETC & Closed system with FPC are dominated solar hot water system

Goal

Together with Solareast and Sunrain, CABR start a research on this topic

- To give a GHG reduction evaluation method for Solar hot water system.
- Achieve the general GHG reduction in different cities in China, as a reference for quick review.

中国建研院 环境能源研究院
Institute of Building Environment and Energy

EET 环能科技

日出东方

sunrain太阳雨

Approach

To ensure the reliability of method, the research includes these activities:

General procedure → Initial parameter → Long-term modelling → Long-term verification → Different location

- **General procedure:**

  Generate a procedure to evaluate long-term GHG reduction performance of solar hot water system
- **Initial parameters:**

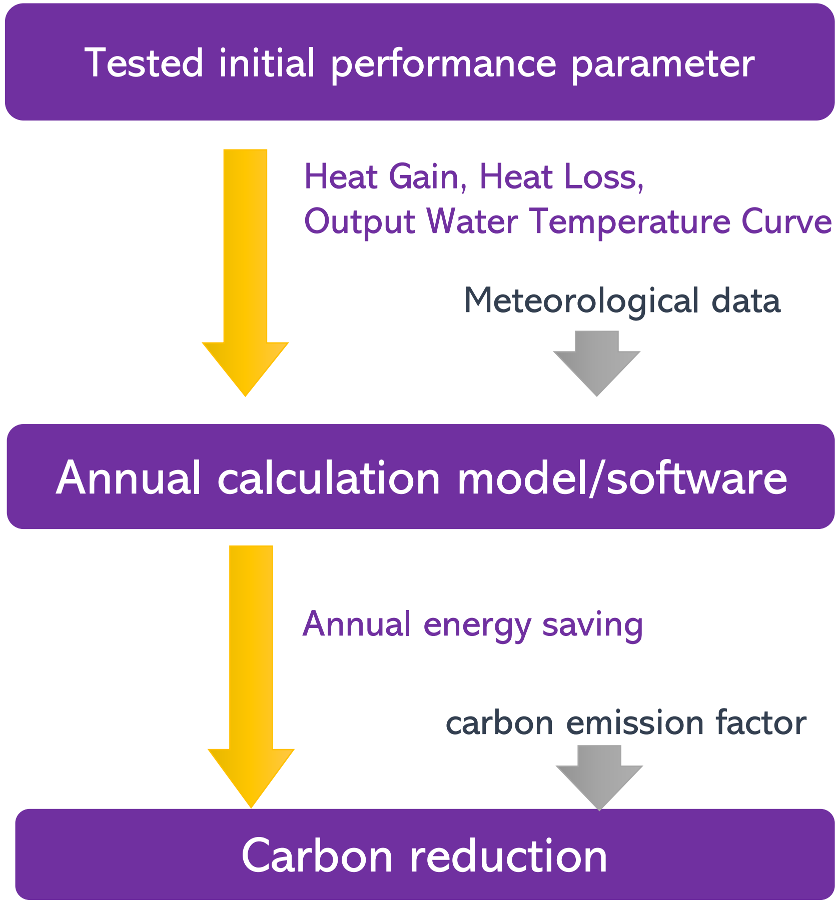
  According ISO and Chinese standard, give a method to get initial parameters
- **Long-term modelling:**

  Build up a model to calculated annual energy saving and carbon reduction
- **Long-term verification:**

  Verify the model & improve methods with different types systems’ long-term operation data
- **Different location:**

  Simulate GHG reduction of solar hot water systems in different cities in China

General procedure



1. **Get initial performance parameter with lab testing**
   ISO 9459-2 & GB/T 18708-2002 are main reference
   For compact system, drain water temperature remains same as no cold water added.

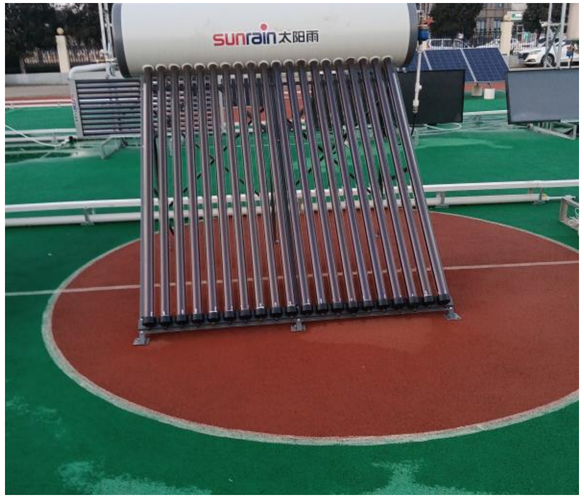
2. **Calculate annual energy output and saving with a software**
   Through daily calculation, method is similar to ISO 9459-2. A software developed to make it easier.

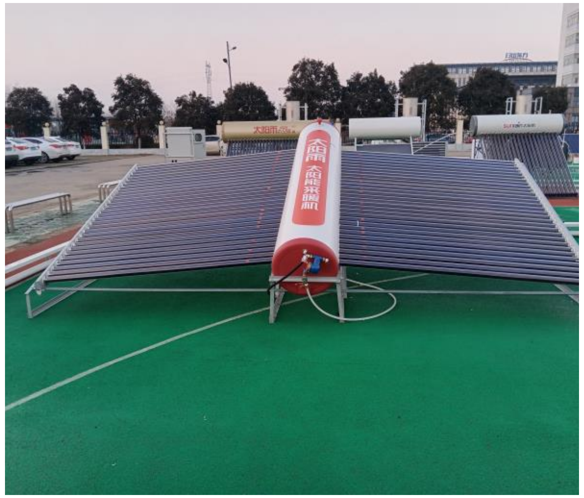
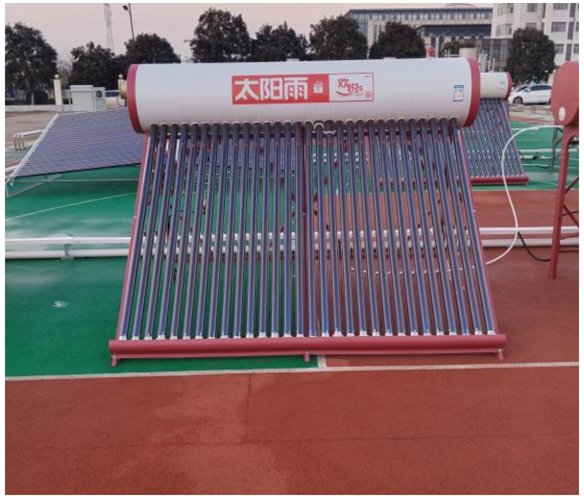
3. **Convert annual energy output to carbon reduction**
   Electricity water heater is used as reference system, so carbon emission factor of electricity power is used to calculate the carbon reduction.

Verification

- For verification, a carbon reduction testing field was established in Jiangsu province
- 15 types of solar thermal system have been installed for a long-term testing:
  - ✓ Compact solar water heating system
  - ✓ Closed loop solar water heating system
  - ✓ Solar heat pump water heater
  - ✓ Air source heat pump water heater
  - ✓ PV water heater
  - ✓ PV direct-driven air-conditioner

Verification


Verification

INPUT

- **Measured** solar irradiation, etc.
- **System parameters:** collector area, heat storage tank volume, etc.

OUTPUT

- Simulated thermal **energy collecting**

Type	Sample	Collector Area (㎡)	Tank Volume (L)	Testing Results		Calculated Result		
				Avg. Daily Heat Gain MJ/(㎡·d)	Avg. Daily GHG Reduction kg/(㎡·d)	Daily Heat Gain MJ/(㎡·d)	Avg. Daily GHG Reduction kg/(㎡·d)	Deviation
Compact (open) system	1	2.25	140	3.62	0.58	3.19	0.52	**11.9%**
	2	3.75	225	3.18	0.51	2.97	0.48	**6.6%**
Pressured (closed) system	14	1.73	80	0.86	0.14	0.84	0.14	**1.2%**
	15	1.73	80	1.76	0.28	1.71	0.28	**2.8%**

Average GHG Reduction

- GHG reduction have great difference in different cities
- 14 cities with different solar energy resource have been used

Cities	Classification of solar energy resource	Slope	Total horizontal radiation (MJ/m²)	Solar irradiation on title surface (MJ/m²)	Annual Heat Gain (MJ/m²)	Annual Heat Gain (kWh/m²)	Annual GHG Reduction (kg/m²)
Lhasa	Ⅰ	30°	7163.27	8166.28	2820.31	783.42	455.17
Golmud		35°	6957.09	8274.42	2832.39	786.78	457.12
LinZhi	Ⅱ	30°	6269.81	7073.97	2298.25	638.40	370.91
Hohhot		40°	5757.01	7242.03	2384.43	662.34	384.82
Xining		35°	5668.91	6574.27	1835.39	509.83	296.21
Guangzhou	Ⅲ	25°	4995.84	5222.79	1944.07	540.02	313.75
Luoyang		35°	4823.47	5181.20	1700.17	472.27	274.39
Shanghai		30°	4728.68	5011.88	1627.61	452.11	262.68
Harbin		45°	4695.60	5793.23	1380.66	383.52	222.82
Beijing		40°	4663.48	5460.16	1655.48	459.86	267.18
Nanjing		30°	4377.84	4585.11	1510.15	419.49	243.72
Chengdu		30°	4087.70	4127.17	1200.59	333.50	193.76
Guiyang	IV	25°	3648.35	3662.26	864.43	240.12	139.51
Chongqing		30°	3186.10	3089.59	872.24	242.29	140.77

Average GHG Reduction

- **Average GHG Reduction is weighted according to the POPULATION of each region**
- **Average Heat Gain: 489.72 kWh/m²**
- **Average GHG Reduction: 284.53 kg/m²**

- **According *Solar Heat Worldwide 2024*, Total installed collector in China is 545 million m²**
- **If all Solar hot water systems: Annual GHG Reduction: 155 million ton**

- **Initial Results, Further Analysis on going.**

Sustainable Solar Building & Industry (SSBI) 2024
IEA SHC Task meeting

- **Goal:**
  - Enhance the exchange of development trends between international and China.
  - Enhance the exchange of new technology innovation between academic and industry.
  - Promote the application of both Solar thermal and PV in Building & Industry sector.
- **Solar Energy Application Center of CABR initiated this conference**
- **Date:** Oct 11 to Oct 13
- **Location:** Lianyungang, Jiangsu Province

- **Contact:**

  SSBIconference@outlook.com

Contact us

Bojia Li

China Academy of Building Research

E-Mail: libojia@outlook.com

Tao He

China Academy of Building Research

E-Mail: iac@vip.sina.com

Thanks!

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(group 4230381)