SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

GHG Emissions Reductions Testing for Thermosyphon Systems in China

LI Bojia, China Academy of Building Research
IEA SHC Solar Academy Webinar

Content

Subtask B - Background

- Thermosyphon systems represent the majority of installed SHW systems

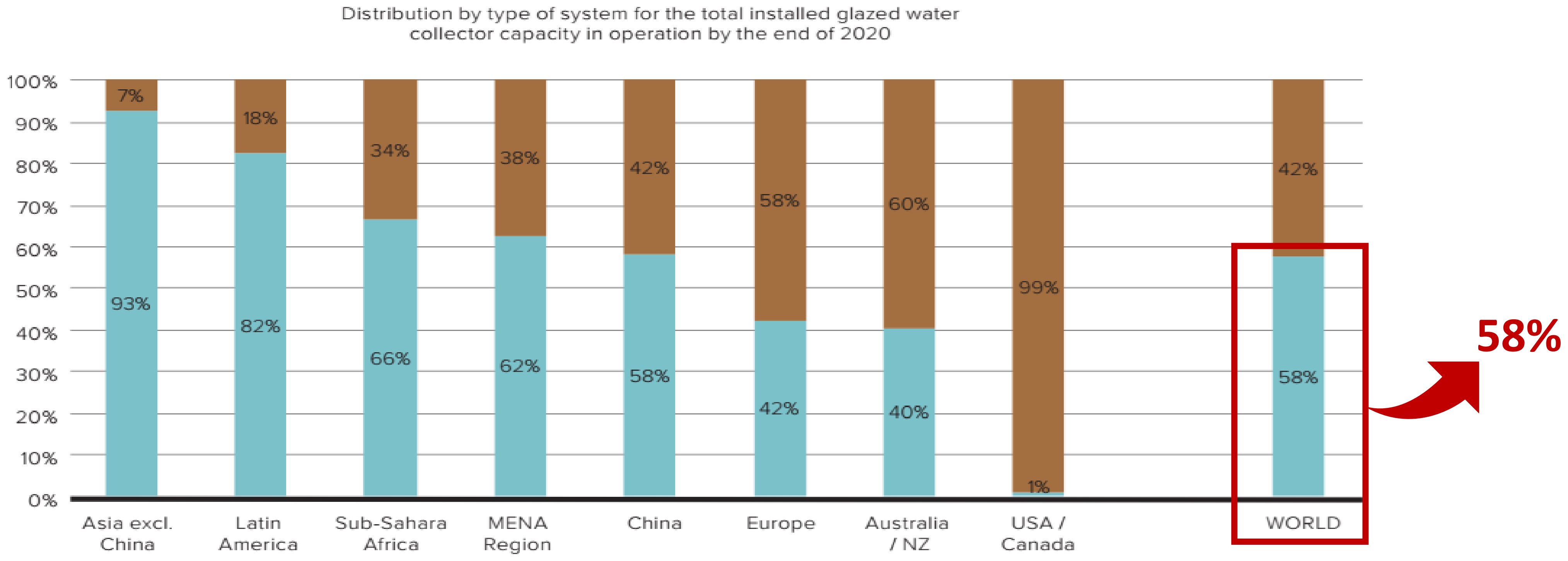

Figure 48: Distribution by type of system for the total installed glazed water collector capacity in operation by the end of 2020

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

Subtask B - Goal

To promote thermosyphon hot water systems by

- Improving convenience and performance

  better design and management tech

- Improving durability and reliability

  failure modes and effects in different region

- **Investigate the Energy-saving & GHG reduction performance**

  how thermosyphon systems contribute to carbon peak & carbon neutral

  to attract more attention from society

Photos by CABR

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Background

- According IEA SHC, China accounts for 72.8% of world’s total installed solar collectors.
- SHW systems is making significant contributions to energy saving and carbon reduction.
- It’s hard to calculate SHW systems’ contributions to carbon neutral goal.

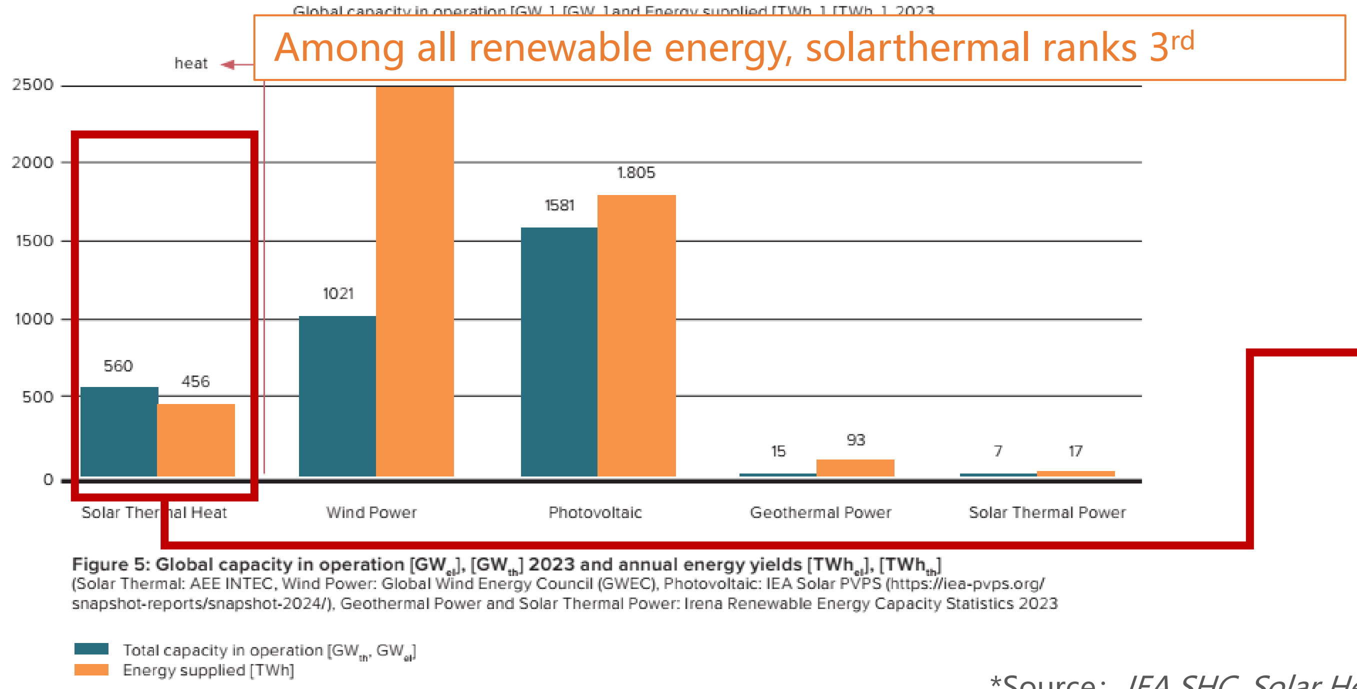
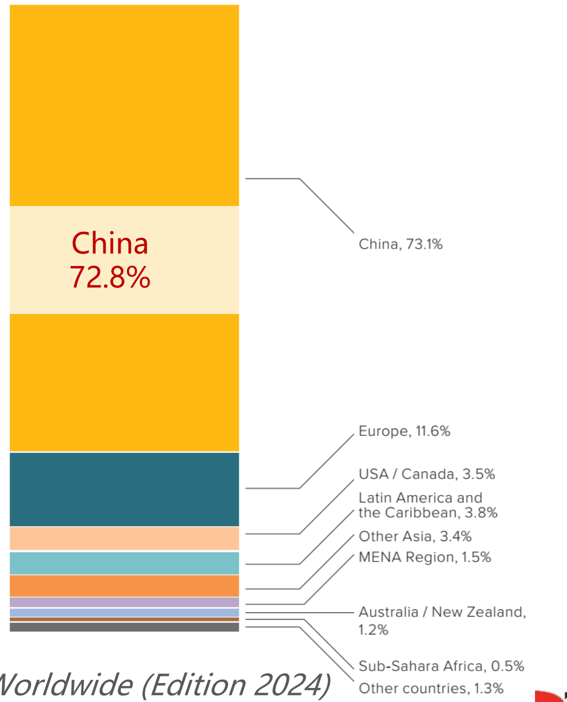


Figure 5: Global capacity in operation [GW_{el}], [GW_{th}] 2023 and annual energy yields [TWh_{el}], [TWh_{th}]
(Solar Thermal: AEE INTEC, Wind Power: Global Wind Energy Council (GWEC), Photovoltaic: IEA Solar PVPS (https://iea-pvps.org/snapshot-reports/snapshot-2024/), Geothermal Power and Solar Thermal Power: Irena Renewable Energy Capacity Statistics 2023



*Source: *IEA SHC, Solar Heat Worldwide (Edition 2024)*

Current standard

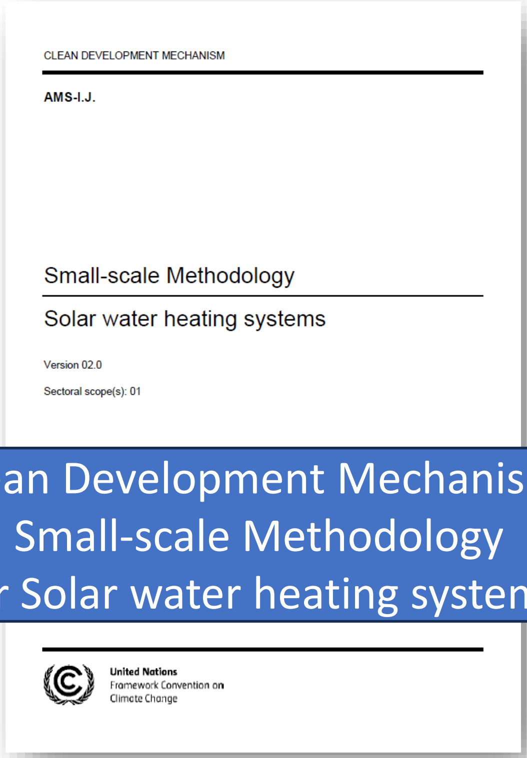
GHG reduction = **Total collector area** × **Annual reduction per m² collector**

- Current method: China lacks GHG emission reduction assessment methods for SHW, only 4 methods applied in CCER(China Certified Emission Reductions):
  - CCER method for solar thermal power generation
  - CCER method for carbon sink of forests
  - CCER method for grid connected offshore wind power generation
  - CCER method for mangrove forest construction
- International method： CDM(Clean Development Mechanism)

AMS-I.J.: Solar water heating systems (SWH)-Version 2.0

- System simulation (by RET Screen)
- System metering (monthly)
- Stipulated energy saving：

Annually：450 kWh/(a·m²)；Not annually：300 kWh/(a·m²)


CLEAN DEVELOPMENT MECHANISM

AMS-I.J.

Small-scale Methodology

Solar water heating systems

Version 02.0

Sectoral scope(s): 01

United Nations Framework Convention on Climate Change

Clean Development Mechanism: Small-scale Methodology for Solar water heating systems

*Source：*AMS-I.J.: Solar water heating systems (SWH)-Version 2.0*

Differences

- A big difference between China and Europe causes differences in GHG reduction
  - Solar resource: 4 different regions
  - System type: evacuated tube collectors
  - Hot water demand: High rise department building
- Therefore, other countries' experience is not quite suitable for GHG reduction in China

Compact system with evacuated tube collector & Closed system with flat plate collector are dominated solar hot water market

High rise department buildings are more popular than single family houses

*Photos: Sunrain

Content

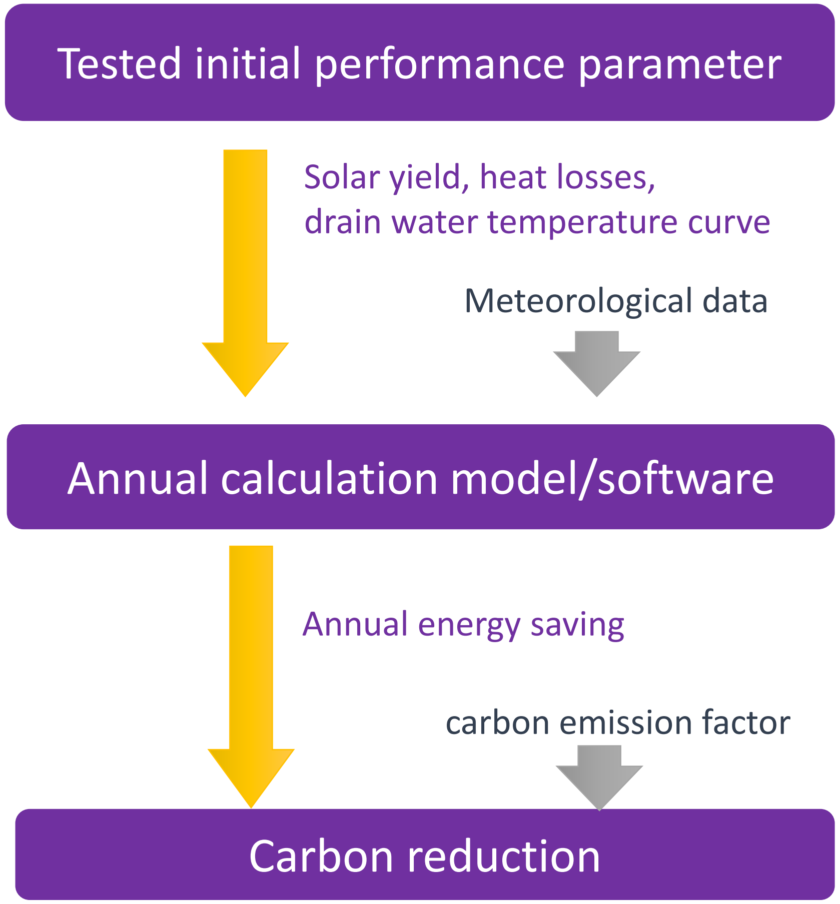
Approach

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

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

- **General procedure:**
  Generate a procedure to evaluate long-term GHG reduction performance of SHW systems
  Initial Parameters were determined by testing according to ISO 9459-2 and GB/T 18708-2002
- **Long-term modelling:**
  A model for annual energy saving and carbon reduction by daily calculation was developed
- **Long-term verification:**
  A long-term testing field has been established
  Samples were tested to verify the model with long-term operation data
- **Performance in different locations:**
  Simulation of the GHG reduction of SHW systems in different cities
  Reach total GHG reduction for SHW systems in China

General procedure



1. **Get initial performance parameter with lab testing**
   ISO 9459-2 & GB/T 18708-2002 are the main reference
   For compact systems, drain water temperature remains the 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.
   Software was developed to make it easier.

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

Initial parameters

Solar yield parameters, heat loss coefficient, and drain water temperature curve of SHW system sample should be tested in laboratory according to ISO 9459-2.

If the sample is a compact system, it should be tested according to GB/T 18708-2002, and get drain water temperature curve with same output temperature vs 1 time of tank volume.

INTERNATIONAL STANDARD

ISO 9459-2

First edition 1995-08-15

Solar heating — Domestic water heating systems —

Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems

Chauffage solaire — Systèmes de chauffage de l'eau sanitaire —

Partie 2: Méthode d'essai en extérieur pour la caractérisation de la performance des systèmes "tout solaire" et la prédiction de leur performance annuelle

ISO

Reference number ISO 9459-2:1995(E)

ICS 27.160
F 12

GB

中华人民共和国国家标准

GB/T 18708—2002

家用太阳热水系统热性能试验方法

Test methods for thermal performance of domestic solar water heating systems

2002-04-28 发布 2002-10-01 实施

中华人民共和国国家质量监督检验检疫总局 发布

Standard testing (6 days) → **Coefficient: a_1 a_2 a_3 f_v g_v**

$$Q = a_1 H + a_2 \left[t_{a(day)} - t_{(main)} \right] + a_3$$

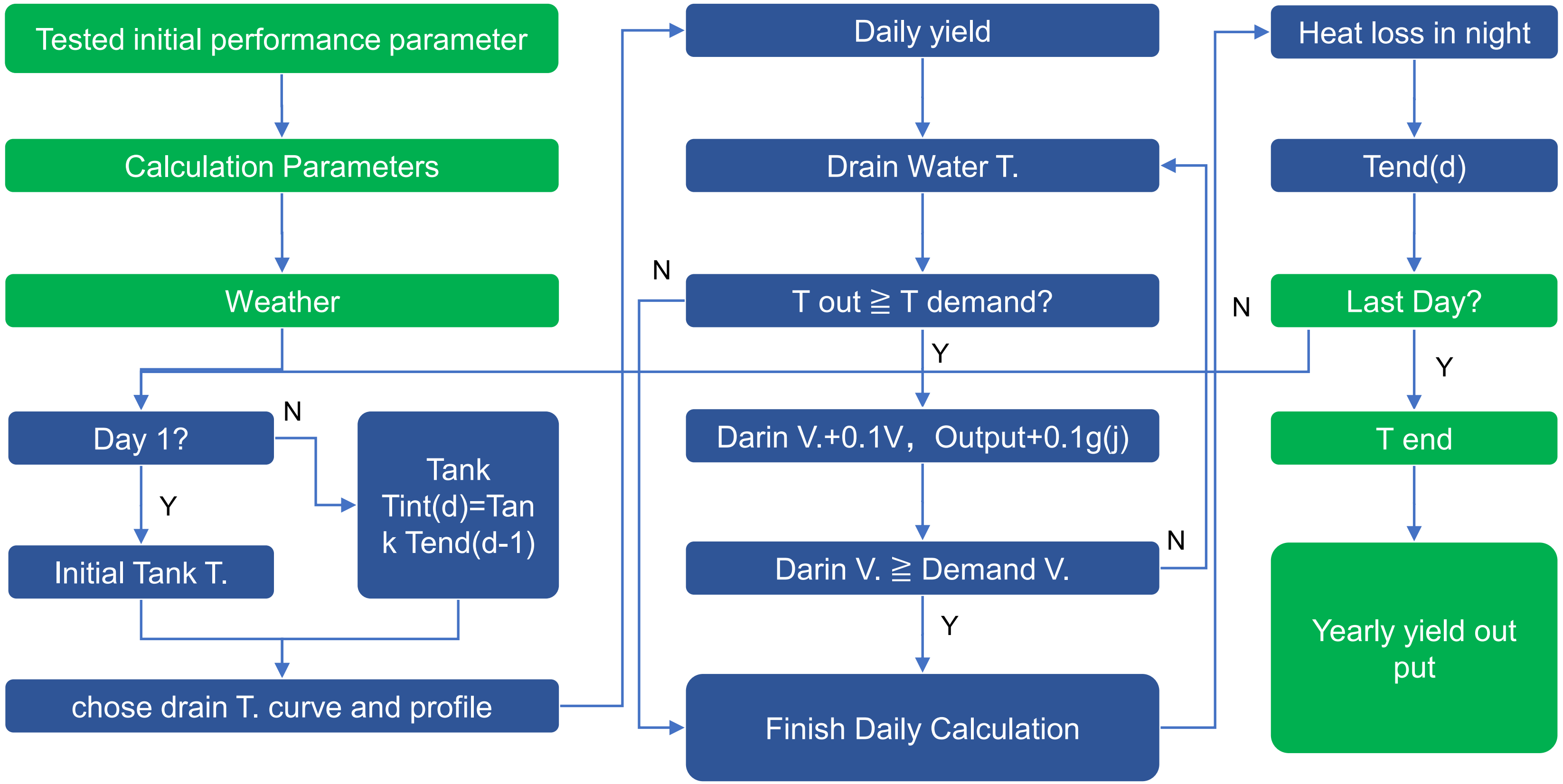
Tank heat loss testing → **Heat loss coefficient U_s**

$$U_s = \frac{\rho_w c_{pw} V_s}{\Delta\tau} \ln \left[\frac{t_i - t_{as(av)}}{t_f - t_{as(av)}} \right]$$

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Calculate annual energy output and saving with a software

The annual energy-saving of SHW system should be determined by daily calculation
Calculation procedure is similar with that in ISO 9459-2.



Convert annual energy output to carbon reduction

- GHG reduction of SWH system could be calculated with following equation:

Annual GHG reduction = Baseline Emission - Project Emission

= Total Energy-Saving (yield) × Baseline CO_2 Factor ÷ Baseline Efficiency

- **Baseline could be electric water heater/boiler or gas fired boiler**
- **According to National Standards, energy efficiency for electric water heater/boiler: 0.95**

  for gas fired boiler: 0.86
- **CO_2 emission factor for electricity: 0.5 kg/kWh; for gas: 0.2 kg/kWh**

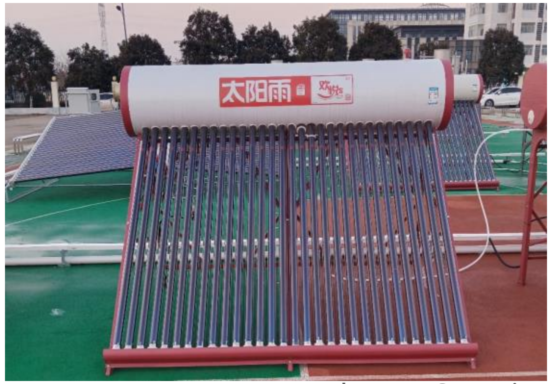
Long-term testing

- For verification, a carbon reduction testing field was established in Jiangsu province
- 25 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

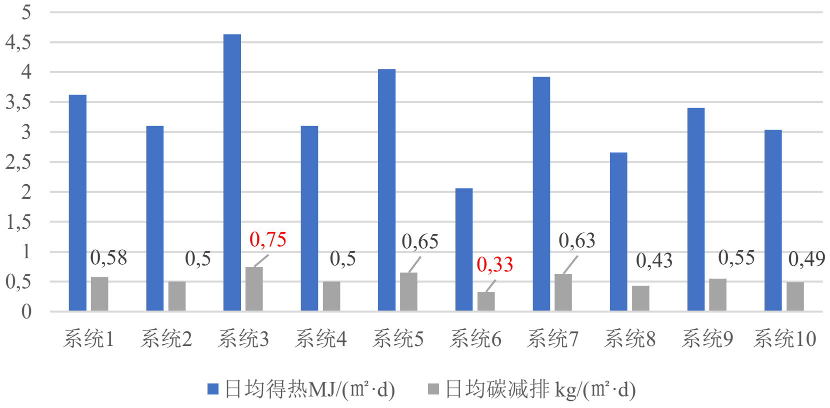
Photo: Solareast

Long-term testing results

Compact (open) system



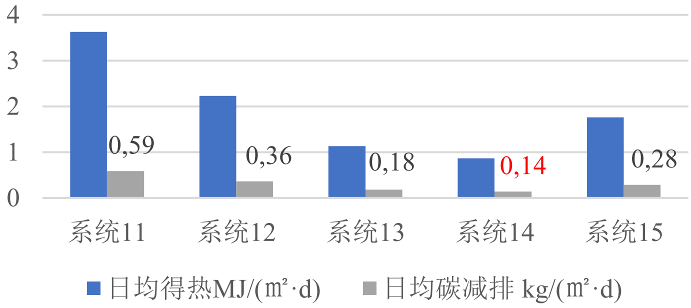
*Photos: Sunrain



Avg. daily energy-saving: 2.0 to 4.7 MJ/m²
Avg. daily GHG reduction: 0.33 to 0.75 kg/m²

Pressured (closed) system

*Photos: Sunrain



Avg. daily energy-saving: 0.8 to 2.3 MJ/m²
Avg. daily GHG reduction: 0.14 to 0.50 kg/m²

Verification

2 compact systems and 2 pressurized systems have been chosen to conduct the laboratory testing according to ISO 9459-2 and GB/T 18708 for long-term performance calculations and verification.
By comparing the calculated and tested average daily solar yield, the deviation is within 12%, verifying the accuracy of software calculations.

INPUT

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

OUTPUT

- Simulated versus tested Avg. daily solar yield

Sample	System type	Testing Results		Calculated Result		**Deviation**
		Avg. daily solar yield [MJ/(m²·d)]	Avg. daily GHG reduction [kg/(m²·d)]	Daily solar yield [MJ/(m²·d)]	Avg. daily GHG reduction [kg/(m²·d)]	
1	Compact (open) system	3.62	0.58	3.19	0.52	**11.9%**
2	Compact (open) system	3.18	0.51	2.97	0.48	**6.6%**
14	Balcony (closed) system	0.86	0.14	0.84	0.14	**1.2%**
15	Balcony (closed) system	1.76	0.28	1.71	0.28	**2.8%**

Content

Performance Analysis in different region

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

Verified models

↓ Different solar regions

34 cities with different solar energy resource have been used

↓ Sample 1 applied

GHG reduction analysis

Performance Analysis in different regions

Annual heat production and carbon reduction results in different cities in China

Sample	Province	City	Solar energy resources	Horizontal radiation (MJ/m^2)	Annua solar yield (MJ/m^2)	Annua solar yield (kWh/m^2)	Annual carbon reduction (kg/m^2)
1	Tibet	Lhasa	Extremely rich	7163.27	2820.31	783.42	412.33
2	Ningxia	Yinchaun	Abundant	5947.14	2323.00	645.28	339.62
3	Nei Mongolia	Hottot		5757.01	2384.43	662.34	348.60
4	Qinghai	Xining		5668.91	1835.39	509.83	268.33
5	Yunnan	Kunming		5638.01	1991.53	553.20	291.16
6	Xinjiang	Urumqi		5149.22	1739.47	483.19	254.31
7	Gansu	Lanzhou		5069.71	1527.98	424.44	223.39
8	Taiwan	Taibei		5059.38	2029.35	563.71	296.69
9	Hainan	Haikou		5043.01	1976.08	548.91	288.90
10	Jilin	Changchun	Rich	5037.14	1470.26	408.41	214.95
11	Shanxi	Taiyuan		5023.83	1570.52	436.26	229.61
12	Macao	Macao		5017.35	2003.93	556.65	292.97
13	Guangdong	Guangzhou		4995.84	1944.07	540.02	284.22
14	Hebei	Shijiazhuang		4970.02	1649.64	458.23	241.18
15	Hongkong	Hongkong		4926.04	1991.38	553.16	291.14
16	Liaoning	Shenyang		4909.24	1320.54	366.82	193.06
17	Tianjin	Tianjin		4806.00	1524.51	423.48	222.88

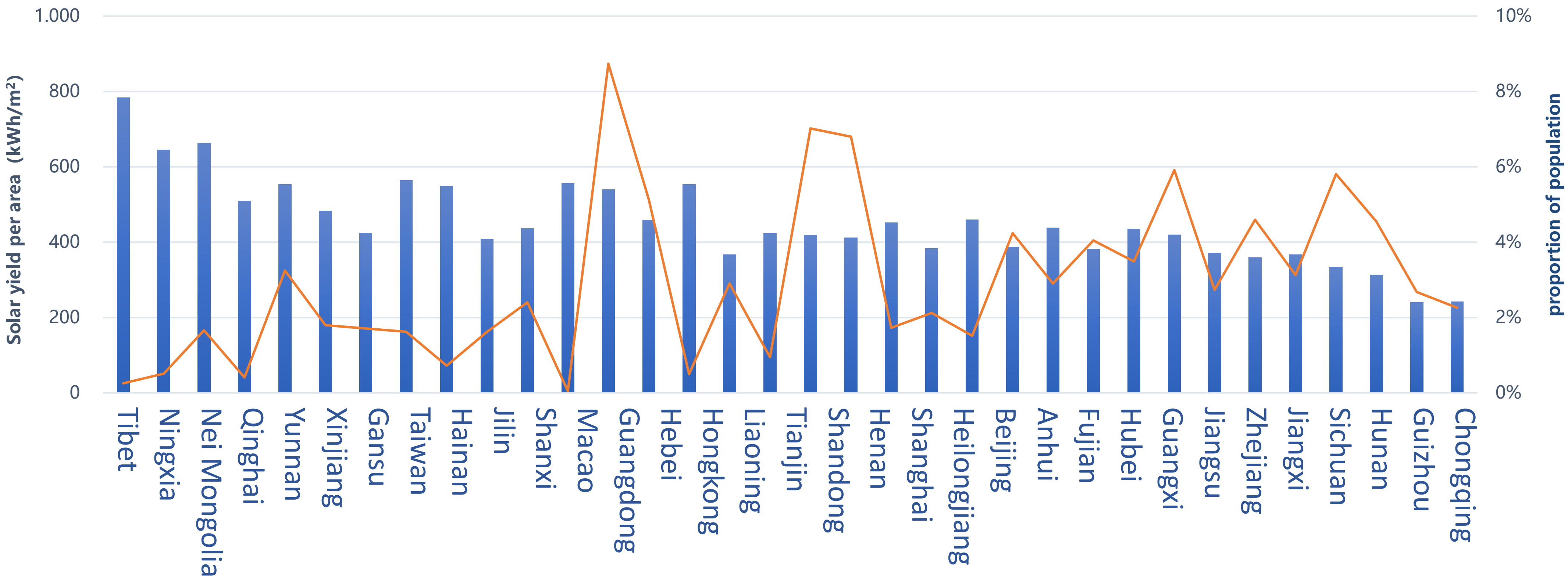
Performance Analysis in different regions

Annual heat production and carbon reduction results in different cities in China

Sample	Province	City	Solar energy resources	Horizontal radiation (MJ/m^2)	Annua heat yield (MJ/m^2)	Annua heat yield (kWh/m^2)	Annual carbon reduction (kg/m^2)
18	Shandong	Jinan	Rich	4801.50	1507.62	418.78	220.41
19	Henan	Zhengzhou		4785.55	1481.77	411.60	216.63
20	Shanghai	Shanghai		4728.68	1627.61	452.11	237.95
21	Heilongjiang	Harbin		4695.60	1380.66	383.52	201.85
22	Beijing	Beijing		4663.48	1655.48	459.86	242.03
23	Anhui	Hefei		4499.39	1395.81	387.73	204.07
24	Fujian	Fuzhou		4482.13	1576.56	437.93	230.49
25	Hubei	Wuhan		4466.06	1373.12	381.42	200.75
26	Guangxi	Nanning		4417.63	1568.71	435.75	229.34
27	Jiangsu	Nanjing		4377.84	1510.15	419.49	220.78
28	Shaanxi	Xian		4368.51	1333.86	370.52	195.01
29	Zhejiang	Hangzhou		4333.13	1292.59	359.05	188.98
30	Jiangxi	Nanchang		4151.59	1321.10	366.97	193.14
31	Sichuan	Chengdu		4087.70	1200.59	333.50	175.52
32	Hunan	changsha		3986.47	1128.89	313.58	165.04
33	Guizhou	Guiyang	Normal	3648.35	864.43	240.12	126.38
34	Chongqing	Chongqing		3186.10	872.24	242.29	127.52

Average GHG reduction

- Average GHG reduction is weighted according to the population of each region



Average GHG reduction

Average GHG reduction is weighted according to the POPULATION of each region

- **Average solar yield:** **419.39 kWh/m²**
- **Average GHG reduction:** **97.63 to 220.73 kg/m²**

According *Solar Heat Worldwide 2024*, total installed collector in China is 545 million m^2

- **For all solar hot water systems: Annual GHG reduction is 53 to 120 million tonnes of CO_2**

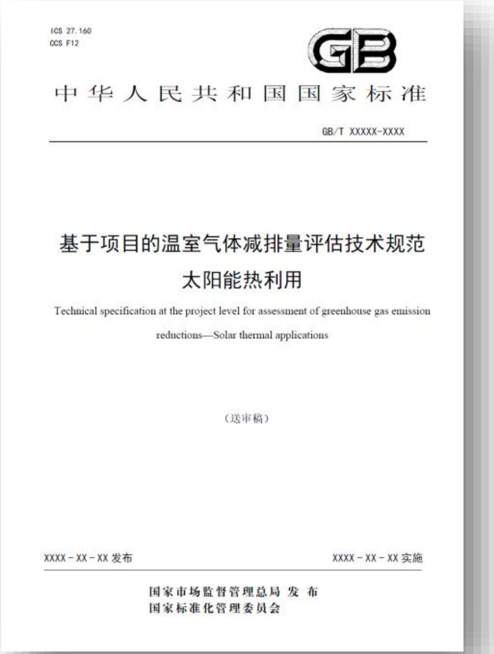
Content

National Standard

- Research results above support a Chinese National Standard

National standard: *Technical specification at the project level for assessment of greenhouse gas emission reductions – Solar thermal applications*

Approved in May 2024, an English version is available



ICS 27.160
CCS F12

GB

中 华 人 民 共 和 国 国 家 标 准

GB/T XXXXX-XXXX

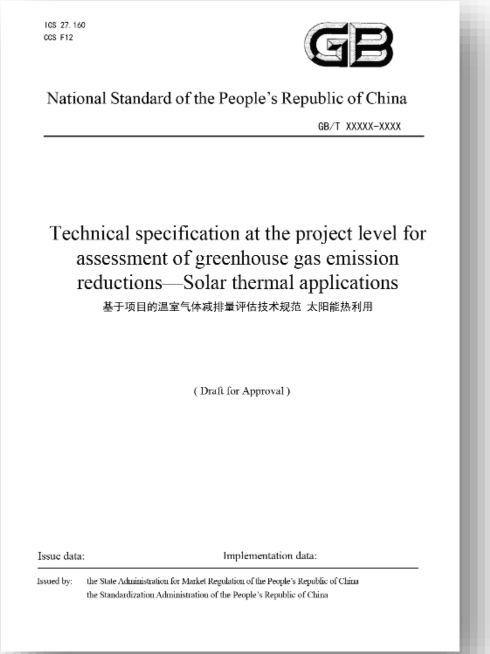
基于项目的温室气体减排量评估技术规范
太阳能热利用

Technical specification at the project level for assessment of greenhouse gas emission reductions—Solar thermal applications

（送审稿）

XXXX－XX－XX 发布　　XXXX－XX－XX 实施

国家市场监督管理总局 发 布
国家标准化管理委员会



ICS 27.160
CCS F12

GB

National Standard of the People's Republic of China

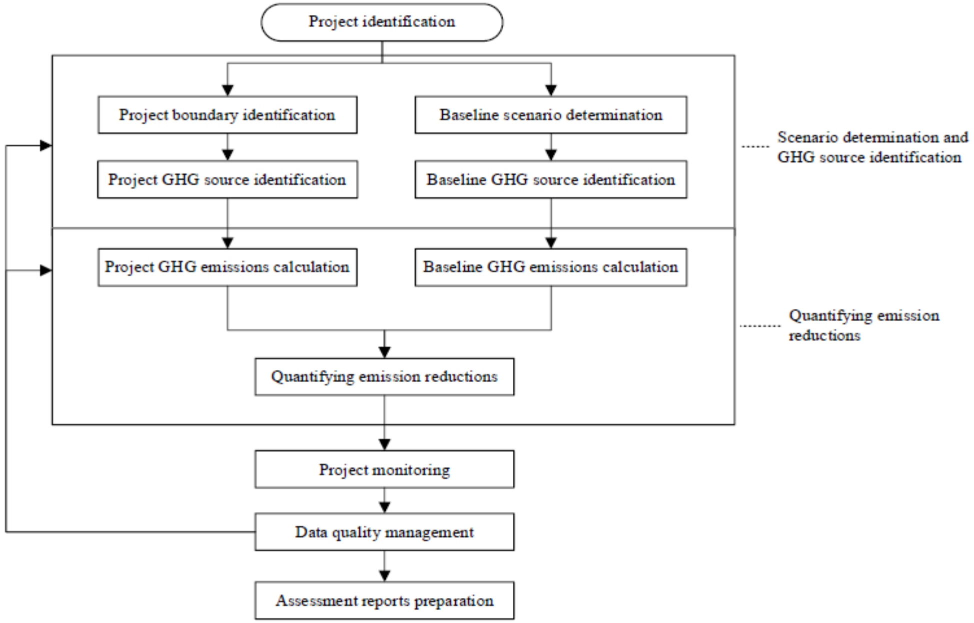
GB/T XXXXX-XXXX

Technical specification at the project level for assessment of greenhouse gas emission reductions—Solar thermal applications
基于项目的温室气体减排量评估技术规范 太阳能热利用

(Draft for Approval)

Issue data:　　Implementation data:

Issued by: the State Administration for Market Regulation of the People's Republic of China
the Standardization Administration of the People's Republic of China



National Standard

- This document specifies the assessment content, assessment procedures, scenario determination, greenhouse gas (GHG) sources identification, quantifying emission reductions, monitoring, data quality management, and assessment reports preparation

  - Based on GB/T 33760-2017
  - For implemented projects,

    monitoring procedures shall be adopted, when not available, use simplified method.
  - For unimplemented projects,

    data from feasibility study reports etc.

Table B.1 Annual heating energy per collector area for projects supplying hot water with solar energy

in megawatt hours per square metre (kWh/m²)

Classification of solar energy resource	Annual heating energy per collector area
Solar energy richest region	735
Solar energy richer region	630
Solar energy rich region	441
Solar energy normal region	350

Table B.4 Annual industrial heating energy per collector area for projects providing industrial heating with solar energy

in megawatt hours per square metre (kWh/m²)

Classification of solar energy resource	Annual industrial heating energy per collector area
Solar energy richest region	525
Solar energy richer region	450
Solar energy rich region	315
Solar energy normal region	250

Summary

- Due to different solar resources, system types and hot water demand profiles, it’s necessary to develop an assessment method for GHG reduction of SHW systems in China.
- An assessment method for the annual energy-saving and GHG reduction of SHW systems based on daily calculation was proposed.
- A testing center has been established, and long-term energy-saving testing was conducted for model verification.
- Reference values for GHG reduction of SHW systems in 34 Chinese cities have been proposed through this assessment method.
- This methodology would provide technical support for GHG reduction assessment in the solar thermal industry and the development of future international standards.

Thanks!

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