



switchasia



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# Sustainable energy consumption solutions for rural households

Technology solutions  
applied in the pilots

# INTRODUCTION

Switch Asia RurEnergy is dedicated to facilitating the widespread adoption of cost-effective sustainable energy consumption solutions for rural households. These solutions comprehensively enhance thermal efficiency and introduce sustainable renewable heating and cooking measures in two Chinese Provinces (Henan and Gansu).

One pivotal component within RurEnergy is the systematic implementation of demonstration pilots across 25 villages in these provinces, aimed at catalyzing the adoption of sustainable energy consumption solutions. This booklet introduces six types of technology solutions deployed within these demonstration pilots, encompassing both new and existing rural family houses. These solutions have been carefully crafted to align with the specific circumstances prevalent in the area, with particular consideration given to the relatively limited financial resources available to rural families. They span energy retrofits, biomass centralized and decentralized heating, and heat pumps. In addition to detailing the technologies, we also present their associated economic benefits, energy savings, and carbon emissions reductions.



# CASE 1 SINGLE-STORY FLAT ROOF HOUSE



## Building basics

- **Location:** Cold climate zone in Henan Province
- **Building envelops:**
  - 17m\*7m, a brick-concrete structure with external walls made of 240mm thick red bricks and no external wall insulation (heat transfer coefficient:  $1.96 \text{ W}/(\text{m}^2\cdot\text{K})$ ),
  - Roof constructed with 100mm reinforced concrete roof panels and topped with a 20mm thick slag layer (heat transfer coefficient of  $3.25 \text{ W}/(\text{m}^2\cdot\text{K})$ )
  - Windows made of plastic steel with a standard 5mm single glazing (heat transfer coefficient is  $4.9 \text{ W}/(\text{m}^2\cdot\text{K})$ )
- **Energy consumption** (simulated):  $93.29 \text{ W}/\text{m}^2$

## Technologies

- **Insulation:** A **50mm extruded polystyrene(XPS)** insulation inverted insulation layer installed on the **roof** of the building.
- **Heating system:** **Air-source heat pump**

## Costs

### Energy retrofit:

Inverted roof construction:  $100\text{-}150 \text{ yuan}/\text{m}^2$  (approx. EUR 13-19)

### Air-source heat pump:

- Installation cost: In rural areas, each household requires 2-3 units of 3kW equipment, with an initial investment of around 10,000 yuan per household. (approx. EUR 1,276)
- Operating cost (a heating season of 120 days ):  $18 \text{ yuan}/\text{m}^2$  (approx. EUR 2.4)



## Technology Performance & Benefits

### Technical Performance

- Insulation: With insulation, electricity used for heating decreases from  $0.88\text{-}1 \text{ kWh}$  to  $0.66\text{-}0.75 \text{ kWh}$ .
- Heating system: COP: 3.10, operating for more than 16 hours a day with an indoor temperature set at  $16 \text{ }^\circ\text{C}$  (outdoor temperatures average  $1.87 \text{ }^\circ\text{C}$ )



**Energy savings due to insulation:** 34%, 14 GJ/year

**Life cycle CO2 emission reduction:** 72.3 tons in total

**Annual cost saving:** energy retrofit  $9 \text{ yuan}/\text{m}^2/\text{year}$  (approx. EUR 1.2); low-carbon heating:  $9 \text{ yuan}/\text{m}^2/\text{year}$

# CASE 2 ONE-STORY SLOPED-ROOF HOUSE



## Building basics

- **Location:** Cold climate zone in Henan Province
- **Building envelops:**
  - 13m\*7.5m a single-story farmhouse with external walls made of 240mm thick red bricks and no thermal insulation (heat transfer coefficient of  $1.77\text{W}/(\text{m}^2\cdot\text{K})$ ),
  - Roof covered with 20mm thick clay-fired green tiles (heat transfer coefficient of  $3.66\text{W}/(\text{m}^2\cdot\text{K})$ ),
  - The windows with wooden frames and fitted with ordinary 5mm single-layer glass (heat transfer coefficient of  $4.4\text{W}/(\text{m}^2\cdot\text{K})$ )
- **Energy consumption** (simulated):  $101.9\text{W}/\text{m}^2$

## Costs

### Energy retrofit:

- Exterior wall construction cost:  $150\text{-}200\text{ yuan}/\text{m}^2$  (approx. EUR 19-25)
- Window replacement cost:  $200\text{-}250\text{ yuan}/\text{m}^2$  (approx. EUR 25-32)

### Biomass stove:

- Installation cost: Each household bears a cost of 1000 yuan for biomass stove (approx. EUR 127); the rest is covered by subsidies.
- Operating cost:  $700\text{-}1150\text{ yuan}/\text{year}$  (approx. EUR 89-146)

## Technology Performance & Benefits

### Technical Performance

- Indoor temperature above  $20\text{ }^\circ\text{C}$  (outdoor temperatures average  $1.87\text{ }^\circ\text{C}$ )

**Energy savings due to insulation:** 40%, 15.9 GJ/year

**Life cycle CO2 emission reduction:** 41.7 tons in total

**Annual cost saving:** energy retrofit  $13\text{ yuan}/\text{m}^2/\text{year}$  (approx. EUR 1.7); low-carbon heating:  $5\text{ yuan}/\text{m}^2/\text{year}$  (approx. EUR 0.7)

## Technologies

- **Insulation:** *60mm of expanded polystyrene (EPS)* insulation to all *four external walls*, the original windows replaced with *double-glazed PVC windows (5+9A+5)*, and foam polyurethane sealing to enhance air tightness and insulation performance
- **Heat system:** *Decentralized smart biomass-based heating and cooking* with a single stove: Due to abundant biomass resources, a processing factory was established by the village. The processed pellets were made available for purchase by farmers.



# CASE 3 TWO-STORY FLAT-ROOF HOUSE



## Building basics

- **Location:** Cold climate zone in Henan Province
- **Building envelops:**
  - 16m\*9m a single-story flat-roof farmhouse with exterior walls made of cement mortar (20.0mm), solid clay bricks (240.0mm) and cement mortar (20.0mm) (heat transfer coefficient: 2.17 W/ (m<sup>2</sup>·K))
  - Roof constructed with 80 mm concrete (heat transfer coefficient of 3.75 W/ (m<sup>2</sup>·K))
  - Windows with wooden frame single glazing (heat transfer coefficient of 3.5 W/ (m<sup>2</sup>·K))
- **Energy consumption** (simulated): 96.93 W/m<sup>2</sup>

## Costs

**Energy retrofit:** 275-295 yuan/m<sup>2</sup> (approx. EUR 35-38)

**Heating system:** Each household invested 9,000 yuan (approx. EUR 1,150)

## Technology Performance & Benefits

### Technical Performance

- Indoor temperature above 20 °C (outdoor temperatures average 1.87°C)

**Energy savings due to insulation:** 33.4%, 13.7 GJ/year

**Life cycle CO2 emission reduction:** 41.5 tons in total

**Annual cost saving:** energy retrofit 7 yuan/m<sup>2</sup>/year (approx. EUR 0.9); low-carbon heating: 8 yuan/m<sup>2</sup>/year (approx. EUR 1)

In the pilot village, a favorable tariff of 0.44 yuan/kWh during off-peak hours was additionally offered through a time-of-use electricity pricing model tailored for individual households.

A preferential tariff policy for clean heating: contributing further to cost savings, reducing rates by approximately 0.1 yuan/kWh.

Payback period for households: approximately 6 years, considering subsidies for initial equipment costs and electricity tariffs.

## Technologies

- **Insulation:** 60mm expanded polystyrene (EPS) board insulation structures on the **east, west, and north sides** (without altering the south side) and the original windows replaced with **double-glazed windows (5+12A+5)**
- **Heat System:** **Decentralized phase change energy storage system** offering three power levels with a maximum capacity of 9 kW.



# CASE 4 TWO-STORY SLOPED-ROOF HOUSE



## Building basics

- **Location:** Cold climate zone in Henan Province
- **Building envelops:**
  - 14m\*8m, a sloped-roof farmhouse with exterior walls made of 240mm red bricks without external insulation (heat transfer coefficient:  $2.29 \text{ W}/(\text{m}^2\cdot\text{K})$ ),
  - Roof constructed with 20 mm clay-fired red tiles (heat transfer coefficient of  $5.53 \text{ W}/(\text{m}^2\cdot\text{K})$ )
  - Regular single-glazed windows 5mm with wooden frames (heat transfer coefficient is  $4.4 \text{ W}/(\text{m}^2\cdot\text{K})$ )
- **Energy consumption (simulated):**  $127.12 \text{ W}/\text{m}^2$

## Costs

**Energy retrofit:** 85 yuan/ $\text{m}^2$  (approx. EUR 11)

### Air source heat pump

- Upfront cost: 3,000-4,000 yuan per household (approx. EUR 384-512)
- Operating costs: 18.55 yuan/ $\text{m}^2$  (approx. EUR 2.4)

## Technology Performance & Benefits

### Technical Performance

- Insulation: With insulation, electricity used for heating decreases to 0.66-0.75 kWh from 0.88-1 kWh.
- Heating system: COP: 3.10, operating for more than 16 hours a day with an indoor temperature set at  $16^\circ\text{C}$  (outdoor temperatures average  $1.87^\circ\text{C}$ )

**Energy savings due to insulation:** 32.8 %, 13.4 GJ/year

**Life cycle CO2 emission reduction:** 67.9 tons in total

**Annual cost saving:** energy retrofit 8 yuan/ $\text{m}^2$ /year (approx. EUR 1); low-carbon heating: 9 yuan/ $\text{m}^2$ /year (approx. EUR 1.2)

## Technologies

- **Insulation:** *60mm extruded polystyrene(XPS) board insulation structures* on the **east, west, and north** side. To improve the airtightness of the doors, windows, and openings, foam polyurethane sealing or improved insulation curtains was used. Besides, **insulation curtains with reflective insulating materials** was used, which reduce the heating load by 10-15%.
- **Heat System:** *Low-temperature air source heat pump*



# CASE 5 NEW ENERGY EFFICIENT HOUSE



## Building basics

- **Location:** Temperate continental arid climate in Gansu Province (The average annual temperature: 7.3°C, the average length of frost-free period: 165 days per year)
- **Building features:**
  - Energy-efficient resident buildings with a total area of 5,360 m<sup>2</sup>;
  - Newly constructed one-story dwellings with a ceiling height of approximately 3.5 m;
- **Heating demand:** A total of 67 households, each with an approximate building area of 80m<sup>2</sup>

## Costs

**Air source heat pump installation cost** for the whole village: 1,300,000 yuan (approx. EUR 167,533)

**Operating costs:** around 106,000 yuan (approx. EUR 13,660) during heating season, calculated based on the heating area of 5,360 m<sup>2</sup>, 151 days of heat supply per year: 19.85 Yuan/m<sup>2</sup> (approx. EUR 2.5)

## Technology Performance & Benefits

### Technical Performance

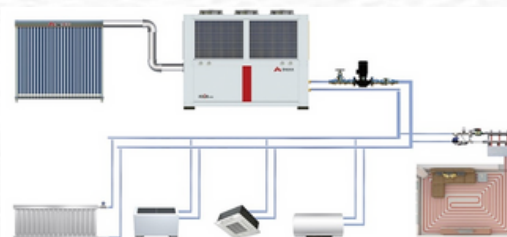
- Average daily heating supply: 728.75 kWh/day
- Heating system: indoor temperature: 20~24°C

**CO2 emission reduction** 312 tons annually

**Annual cost saving:** 8.3 yuan/m<sup>2</sup>/year (approx. EUR 1) compared with using centralized heating with coal boilers )

## Technologies

- **Insulation:** Brick and concrete structure with **70-mm extruded polystyrene(XPS) insulation** boards on the exterior walls and roof and **double-glazed insulated windows** with a thermal break aluminum frame.
- **Heat system:** **Multi-household centralized** distributed clean heating stations (with **5 units of PV and air source heat pump**), a **floor radiant heating system**



# CASE 6 CENTRALIZED HEATING WITH BIOMASS



## Building basics

- **Location:** Temperate continental arid climate in Gansu Province (The average annual temperature: 7.1°C, the average length of frost-free period: 147 days per year)
- **Building envelops:**
  - Buildings constructed with a concrete frame structure and indoor areas ranging from 80 to 200 m<sup>2</sup>
- **Heating demand:** A total of approximately 612 households with a heating area of around 123,900m<sup>2</sup>

## Costs

**Installation cost** of the biomass heating plant: 7-8 million yuan (EUR 904,158-1,030,910)

**Operational costs:** 25 yuan/m<sup>2</sup> (approx. EUR 3.2) during the heating season

## Technology Performance & Benefits

### Technical Performance

- Annual heat supply: 37,690 GJ
- Indoor temperature: 19~24°C

**CO<sub>2</sub> emission reduction** 3,369 tons annually

**Economic:** Cost saving: 10-15% compared to coal-fired heating used previously

## Technologies

**Heat System:** One 12-ton and one 15-ton **biomass boiler** replacing the previous 4-ton and 6-ton coal-fired steam boilers





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