Division presentation
Kindergarten in Sangga Village

Team Solar Ark
Southeast University
Tibet University
Sangga Village, Shannan, Tibet Autonomous Region, China

Tibet Plateau
AMSL 3000-5000m
PROJECT GOALS

Alterations and additions
Misused public building

Target occupant
Kindergarten

30 local students / 3 classes
10 kindergarten staff

Required functions
3 classrooms
3 restrooms with lavatories for each class
Indoor and outdoor recreational spaces
Specialized classrooms for art
A classroom shared with local community
Food services for both students and staff
Offices for kindergarten staff
Storages

Climate Zone
5C

Lot size
0.695 acre
PROBLEMS
Lack of kindergartens  Demand of revitalization
Lack of kindergartens

Low kindergarten attendance rate in 2011

- Kindergarten students
- Overall Tibet villages, 5056

2011

Kindergarten education included in 15 YEARS of free education

2012

480 kindergartens across Tibet

2023

2199 kindergartens across Tibet

Overall 5256 villages in Tibet

OVER 50% of villages in Tibet don’t have their own kindergartens
Increasing Tibetan villages in government’s revitalization plan, calling for retrofit of misused public buildings.
CHALLENGES
Challenges

01 How can we construct kindergartens efficiently and economically?

02 How to preserve the nature of children?

03 How can we take advantage of the existing building?

04 How to address resource scarcity and pollution?
CONCEPT
How can we construct kindergartens efficiently and economically?

How to preserve the nature of children?

How can we take advantage of the existing building?

How to address resource scarcity and pollution?
STRATEGIES
Innovation

Preservation & Renovation

- Maintain the layout of the existing building and its surroundings
- Preserve existing building facades and materials
- Expand the space inward without destroying the original building
- Fusion of new technology image and Tibetan style
Form and function

**Solar Corridor**
Safe and comfortable communal space for children

**Unit classroom and restroom**
Safe teaching area for children

**Open courtyard**
Outdoor activity areas for each class
View of Courtyard
View of Classroom Module
Product Mode

Classroom for 5 students

Classroom for 10 students

Classroom for 15 students

Kindergarten in Sangga-Education Division

Architecture  Engineering  Envelope  Efficiency  Grid-Interactivity  Life-Cycle  Health  Community  Market
Engineering system

Structure system

Plumbing & Sewage treatment system

Renewable energy & Mechanical systems

- Photovoltaic Array
- Inverter
  - AC
  - DC
- Load
- Electric Utility Grid
- Energy Storage System
- HVAC
- Lighting
- Plug load

Architecture  Engineering  Envelope  Efficiency  Grid-Interactivity  Life-Cycle  Health  Community  Market
Structure system

Structure Retrofit

1. Foundation construction
2. Pillars construction
3. Beams construction
4. Removing part of the wall
5. Reinforcement components construction
6. Components connection

Structure expansion

- Frames for on-site assembly
- Modulus with higher flexibility
- All-bolt connections
**Innovation**

**Standardized prefabrication**

Safety of components during transportation

Higher **efficiency** of on-site assembly

Support **upgrading** in the future

- Frames for on-site assembly
- Modulus with higher flexibility
- All-bolt connections

**Sewage treatment**
## Monthly energy consumption composition

<table>
<thead>
<tr>
<th></th>
<th>Lighting [kBTU]</th>
<th>Plug loads [kBTU]</th>
<th>HVAC[kBTU]</th>
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<td>Septembe r</td>
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</table>

### Load calculation

- **Air sourced heat pump**
  - 220 V/1-180 VA

- **Underfloor heating loop**
  - KD-66N1/BP

- **Radiator**

- **Bidirectional full heat purification fresh air system**
  - 250 m³/h
  - 150w

- **Mini electric Water Heater**
  - for instant hot water
  - Q=86kw
  - P=5500w

- **LED Spotlight**
  - P=16w

- **LED Lawn lamp**
  - P=10w

- **LED Ceiling light**
  - P=10w

- **LED Spotlight**
  - P=16w
Existing condition of envelope

- **Broken Structure**
- **Lack of Insulated**
- **Lack of Air Sealing**
- **Poor Waterproofing**
- **No Interior Finishing**

**Existing building wall**

- R-2.2 \( \text{ft}^2 \cdot \text{hr} \cdot \text{°F}/\text{BTU} \)

**Existing building windows**

- U-2.7 \( \text{W/m}^2 \cdot \text{K} \)

**Existing building roof**

- R-2.3 \( \text{ft}^2 \cdot \text{hr} \cdot \text{°F}/\text{BTU} \)

**Existing building floor**

- R-1.9 \( \text{ft}^2 \cdot \text{hr} \cdot \text{°F}/\text{BTU} \)
Response to climate risk

Climate Zone: Cool (5C)

- **Low Temperature**
  - Average maximum temperature: 84.2°F
  - Average minimum temperature: -13°F

- **Low Rainfall**
  - July is the most rainfall with an average rainfall of 78mm,
  - January is the driest month with an average rainfall of 0mm.

**Climate Risk**

- **Drought**
  - The longest drought lasts for 7.5 months
  - 60% of the total disaster in April

- **Frost**
  - Snowfall is concentrated from December to February

- **Snow**

**Section View**

- **Roof Section View R-31**
- **Wall Section View R-21**
- **Floor Section View R-25**

**Existing**

- Air Barrier
- Thermal Barrier
- Moisture Barrier

**Architecture**  **Engineering**  **Envelope**  **Efficiency**  **Grid-Interactivity**  **Life-Cycle**  **Health**  **Community**  **Market**
Materials

Strategies of Local Straw Cycle

The wheat yield is 12167 tons and the barley yield is 12100 tons in 2022.

Seasonal Edible Envelope

Autumn & Summer, Wall R-21
Polyurethane vapor barrier membrane
8x8 Lightweight square steel column, embedded with straw
4/5”Cement fiberboard
2”Furring channel &Insulation layer
Waterproof breathable membrane
Existing earth and granite wall

Spring & Winter, Wall R-42

Architecture  Engineering  Envelope  Efficiency  Grid-Interactivity  Life-Cycle  Health  Community  Market
Passive Design

Multi-cavity windows & Climate Sun Corridor

Existing U-Factor
2.7 W/m²·k
0.48 BTU/ft²·hr·°F

Proposed U-Factor
0.6 W/m²·k
0.11 BTU/ft²·hr·°F

Polymer optical shading energy-saving insulated glass

Optical components

Tempered glass

Polymer optical heat shielding film

Performance of Light Shield Film

Direct beneficiary window | Passive solar corridor | Courtyard--Microclimate improvement | Direct beneficiary window | Passive solar corridor | Cold front from the north

Architecture | Engineering | Envelope | Efficiency | Grid-Interactivity | Life-Cycle | Health | Community | Market
Strategy

- Climate Consideration
- Resource Consideration with Less Environmental Impact
- Current Situation of buildings
- Architecture Function
- Local Economy

Passive Technology
- Passive Technology Strategy
- Building Envelop Design

HVAC System
- HVAC System
- Energy Use Intensity

Solar Panel System
- PV System Calculation
- PV System Energy Storage

Active Technology

Architecture         Engineering         Envelope         Efficiency         Grid-Interactivity         Life-Cycle         Health         Community         Market
Operation savings

Kindergarten in Sangga - Education Division

R-31
ft²·hr·°F/ BTU
Roof Assembly
R-value

R-25
ft²·hr·°F/ BTU
Floor Assembly
R-value

R-21
ft²·hr·°F/ BTU
Wall Assembly
R-value

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<th></th>
<th>Existing R-Value</th>
<th>Proposed R-Value</th>
<th>Existing U-factor</th>
<th>Proposed U-factor</th>
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<td>Wall</td>
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<td>Floor</td>
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<td>Window</td>
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<td>0.48</td>
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Energy consumption (kBTU)

Existing
- 94.12 kBTU/ft²/Year
- EUI

Proposed
- 85.47 kBTU/ft²/Year
- EUI

<table>
<thead>
<tr>
<th>Energy consumption (kBTU)</th>
<th>HVAC</th>
<th>Lighting</th>
<th>Plug loads</th>
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<td>October</td>
<td>352,239</td>
<td>256,707</td>
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Architecture  Engineering  Envelope  Efficiency  Grid-Interactivity  Life-Cycle  Health  Community  Market
**Maintenance and operability**

**Air heat pump**
- The high-efficiency coupled heating system of gas boiler and air source heat pump
- Zonal regulation

**Ventilation system**
- Heat recovery
- Zonal regulation

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**Kindergarten in Sangga-Education Division**

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**Efficiency**

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**Architecture**

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**Engineering**

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**Envelope**

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**Grid-Interactivity**

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**Life-Cycle**

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**Health**

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**Community**

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**Market**

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Operational carbon emission

Solar energy utilization potential

https://globalsolaratlas.info/

Photovoltaic Power Potential in Tibet

East-west solar photovoltaic panel layout

- **01** Flat-Southward
  - AC Energy: 1125777.12kBTU

- **02** Tilt 20°-Southward
  - AC Energy: 1271908.98kBTU

- **03** Tilt 20°-Eastward&Westward
  - AC Energy: 1457115.07kBTU

Tilt 20°-Southward

- AC Energy: 1125777.12kBTU

- AC Energy: 1271908.98kBTU

- AC Energy: 1457115.07kBTU

Roof mounted PV

- **160 PANELS**

- **590W**

- **635W**

- **635W**

- **590W**

1457115.07 kBTU per year
Operational carbon emission

Kindergarten in Sangga-Education Division

- HVAC
- Lighting

Existing

94.1 \( \frac{kBTU}{ft^2/Year} \)

EUI

Zonal regulation

Energy-saving lamps

Envelope

Air source heat pump

85.4 \( \frac{kBTU}{ft^2/Year} \)

EUI

37.66 \( \frac{kBTU}{ft^2/Year} \)

EUI

PV

63.4 \( \frac{kBTU}{ft^2/Year} \)

EUI

= -

25.74 \( \frac{kBTU}{ft^2/Year} \)

Architectural Verb

Efficiency

Grid-Interactivity

Life-Cycle

Health

Community

Market
Resilience

Snow Disaster

Solar panels have independent east-west mounts to prevent snow buildup. Energy storage batteries provide prompt response. Light steel frame structure reinforced to support loads.
Energy supply and demand

Kindergarten in Sangga-Education Division

<table>
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<th>Month</th>
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<td>November</td>
<td>130,000</td>
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<tr>
<td>December</td>
<td>140,000</td>
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- PV
- Energy consumption

Architecture Engineering Envelope Efficiency Grid-Interactivity Life-Cycle Health Community Market
Innovative energy management solutions

01 Generation power = Load power
No charge or discharge the battery

02 Generation power > Load power
Excess power is stored in the battery
If the battery is full, the remaining power is sent to the grid

03 Generation power < Load power
Battery discharge to power loads

04 PV power + Battery power < Load power
Purchasing power from the grid to feed the load
Material selections and design decisions

Retrofitting
Reduce carbon emissions from **new material production and transportation**

Local straw are used as insulation layer
Improve the **thermal performance** of the building and avoid the **long-distance transportation of materials**

Prefabricated light steel system
Reduce the embodied carbon emissions of **on-site construction**
Reduce the need for **new materials** due to their dismantling and recycling at the end of the building’s useful life

Inorganic straw boards are used for the interior finishes
Reduces the large amount of carbon emissions generated by the cement mortar construction layer

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**Kindergarten in Sangga-Education Division**

- **Architecture**
- **Engineering**
- **Envelope**
- **Efficiency**
- **Grid-Interactivity**
- **Life-Cycle**
- **Health**
- **Community**
- **Market**
**Life cycle assessment**

- **Embodied carbon emission**
  
  $391 \text{ kgCO}_2\text{e/m}^2 < 450 \text{ kgCO}_2\text{e/m}^2$

- **Life-cycle carbon emission**
  
  $112.53 \text{ kgCO}_2\text{e/m}^2/\text{Year}$

**Carbon Heroes benchmark**

- **level A**
  
  By Cradle to Grave

---

**STAGE**

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<tr>
<th>PRODUCT</th>
<th>CONSTRUCTION</th>
<th>MAINTAIN AND USE</th>
<th>END OF LIFE</th>
<th>BEYOND THE LIFECYCLE</th>
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**MODULE**

- Architecture
- Engineering
- Envelope
- Efficiency
- Grid-Interactivity
- **Life-Cycle**
- Health
- Community
- Market

---

- Embodied
- Embodied
- Operational
- Embodied
Carbon neutral calculation

Zero Carbon Building
-121.7 t/Year
achieve Carbon Neutrality 7 Year
Comfort

**Light Control**

Intense noon sunlight poses risks to children's vision health.

Excessive exposure to ultraviolet radiation presents health hazard.

- Utilization of two layers of polymer heat-insulating film in the middle of the quadruple-pane triple-cavity glass at the solar corridor.
- As the ultraviolet radiation intensifies in the noon sunlight, the glass adjusts its transparency accordingly.

**Acoustic Control**

The main sources of noise: the inner courtyard / teaching activities / the solar corridor.

Material performance considered in decoration and enclosure structure design.

Sound insulation materials chosen:

- Quadruple-glazed triple-cavity glass
- Straw decorative panels
- Hanging sound-absorbing bodies
- Sound-absorbing curtains

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Excessive exposure to ultraviolet radiation presents health hazard.

- Utilization of two layers of polymer heat-insulating film in the middle of the quadruple-pane triple-cavity glass at the solar corridor.
- As the ultraviolet radiation intensifies in the noon sunlight, the glass adjusts its transparency accordingly.
Safety

- Water quality checkpoints placed at the end of the pipeline network for safety
- Water temperature displayed at taps in children's areas
- Independent small electric water heaters at handwashing sinks for rapid hot water supply
- Emphasis on converting nitrogen and phosphorus in sewage to meet farmland standards in Tibet
Air quality

Source control

- **Platinum-certified paint products** evaluated by the Chinese healthy building product assessment system
- **Environmentally friendly** rubber material
- Solid wood furniture with relatively **low levels of formaldehyde and VOCs**

Pathway control

- Combination of **passive and active** ventilation
- Installation of **PM2.5 filters** on ducts of the fresh air system
Control system

Active system Control

Light Control

Air quality Sensor

Kindergarten in Sangga-Education Division

IP Layer | Data Link Layer | Terminal Equipment

Battery Management System | Air Source Heat Pump | Fresh Air System | Leakage Protector | Audio Equipment | Smart Door Lock

Light Control

Adjustable Light | Common Light

Air quality Sensor

Temperature Sensor | Humidity Sensor | PM2.5 Sensor | CO2 Sensor

Architecture | Engineering | Envelope | Efficiency | Grid-Interactivity | Life-Cycle | Health | Community | Market
Engagement of community

Demand

- Revitalizing the biggest courtyard village in the building
- Transition of low-income traditional agriculture
- Sewage treatment facilities
- Clean energy systems with higher efficiency
Interaction

Shared space with community
Equity Promotion

Natural resource recycling and utilization

Highland Barley Straw cycle

- Highland Barley
- Highland Barley Straw
- Forage
- Fermentation Of Straw And Cow Manure
- Fertilizer
- Straw Brick
- Straw Insulation Board
- Straw Decorative Panel

PV system

427038 kWh per year

More clean energy for community if PV system expanded towards north

Architecture         Engineering         Envelope          Efficiency         Grid-Interactivity         Life-Cycle         Health         Community         Market
Potential risk

01 Noise and cooking fumes

02 Water pollution

Function layout

Shared sewage treatment
Market analysis

OVER 50% of villages in Tibet don’t have their own kindergartens

Lack of kindergartens

Increasing Tibetan villages in government’s revitalization plan, calling for retrofit of misused public buildings.

Demand of village revitalization
Market potential

Kindergarten in Sangga - Education Division

Scalability

Architecture  Engineering  Envelope  Efficiency  Grid-Interactivity  Life-Cycle  Health  Community  Market

replicability

buildability
Applied technology

- Quadruple glazing technology for climate zone 5C
- Technologies of straw board and insulation
- Independent PV system facing west and east
- Reinforcement technology of Tibetan traditional courtyard
- Frame as components for prefabrication and assembly
- Sewage Treatment tailored to Tibet condition

Kindergarten in Sangga-Education Division

Architecture         Engineering         Envelope          Efficiency         Grid-Interactivity         Life-Cycle         Health         Community         Market
Cost estimation

Total Cost:

6,600,900 CNY
912,614 USD

Construction Cost:

5,170,180 CNY
714,808 USD

Retrofit Saved Cost:

3,000,000 CNY
414,768 USD

Operation and Maintenance Cost:

1,430,720 CNY
197,806 USD

Average Utility Cost:

Cost w/o PV: $1430.8/month
Cost w/ PV: $-540.33/month

Project Budget Pie Chart
Engagement of industry

Research Academy+
Cooperative enterprises
Thanks everyone for listening!

You are welcomed to scan the QR code for more information.
## Appendix 1: EUI Calculation

<table>
<thead>
<tr>
<th>Program</th>
<th>Thermal zone</th>
<th>Occupancy density (㎡/p)</th>
<th>Lighting density (W/㎡)</th>
<th>Equipment density (W/㎡)</th>
<th>Heating setpoint (℃)</th>
<th>COP</th>
<th>Max supply air (℃)</th>
<th>Flow rate (m³/s·㎡)</th>
<th>Air change rate (1/hr)</th>
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<td>20</td>
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### Notes
- **EUI:** Energy Use Intensity
- **COP:** Coefficient of Performance
- **Schedule:** Time periods with different cooling strategies.
# Appendix 2: Carbon emission calculation

## Life-Cycle assessment for level(s) in compliancy with EN 15978

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<td>Construction/installation process</td>
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</table>
Appendix 3: Construction drawings
Appendix 3: Construction drawings

1. Renovation Existing Wall Section

2. Prefabricated Wall Section
Appendix 3: Construction drawings