- Project is a partnership between the Hopi Tribe and the Native Peoples Design Coalition (NPDC) at the University of Arizona.

- Solar Decathlon Studio was asked by NPDC to help in providing design solutions for the Hopi for a new community that has been decades in the making.

- Throughout the semester, we have been in close contact with the Tribe, by visiting their Tribal Council and inviting them to Tucson for feedback.

- All design work will be provided pro bono to the Hopi Tribe for future development and funding opportunities.

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**ARCHITECTURE ENGINEERING ENVELOPE EFFICIENCY GRID-INTERACTIVITY LIFE-CYCLE HEALTH MARKET COMMUNITY**
THE HOPI / culture

History.
- The Hopi have been settled in the region since 1100 AD
- Old Oraibi is the oldest continuously inhabited village in the country
- Hopi trace their ancestry to pueblo civilizations, including Mesa-Verde in Colorado.

Culture.
- Dry Farming - only using rainfall to irrigate their crops
- Matrilineal Society - Land is owned by the women in the tribe, men cannot hold land
- Religious Traditions - center around harvest and rainfall, which is the basis of their society
- Clan Identities - Hopi people identify strongly with extended families or Clans, land is distributed by clan

Values.
- Stewardship to the land
- Sustainability
- Respectful of resources
- Durability and resilience
DEMographics / on the hopi Reservation

14,000 registered tribe members

1/2 registered tribe members live on the reservation

35/100+ clans (lineages) remaining
STATE OF HOUSING

35% don’t have access to electricity + running water making it difficult for younger families to establish livelihoods on the reservation.
STRENGTHS, WEAKNESSES, OPPORTUNITIES, THREATS.

**STRENGTHS**
- strong culture and history
- sovereignty
- need for economic development

**WEAKNESSES**
- coal economic dependence
- lack of housing
- lack of employment opportunities
- difficult land issues
- lack of infrastructure

**OPPORTUNITIES**
- growth
- grant eligibility
- low-risk internal project opportunities

**THREATS**
- loss of coal revenue
- limited water resources

SWOT Analysis conducted by Hopi Tribe CEDS
Plan 2023
VISION / statement

Hopi should be a place where:

Hopi culture and religion are strong;
Sacred sites are protected;
Culturally and environmentally sensitive development occurs;
The land is looked after;
There are jobs and businesses;
Quality infrastructure serves everyone;
Everyone has their own quality house;
Public service facilities serve all needs.

"Hopit Tunaty'aat 2000" - Hopit Tunaty'aat 2000

The mission of this project is to address the drastic housing need on the Hopi reservation by providing affordable, energy independent, and sustainable housing to foster a comfortable and stable lifestyle within a vibrant close-knit community while celebrating and being true to Hopi Values.
ASHRAE Climate Zone
Cool, dry winters. Warm, dry summers. Heating dominated.

5B
TAWA’OVI / master plan for a new Hopi village

Present.
- Site is remote, and virtually undeveloped.
- Some progress started on Solar Farm since 2019.
TAWA’OVI /master plan for a new Hopi village

In progress.

- Design for attached housing development
- Design for multi-family complex
- Design for CTE School

Education CTE
Attached Housing
Multi-family Housing
Looking forward...

- Fully master planned community with multiple housing developments scaled from current designs.
- Thriving community with modern amenities staying true to culture.

- Education CTE
- Attached Housing
- Multi-family Housing
From Coal to Clean Power: Hopi Tribe’s Vision to Rewrite Its Energy Story Starts With Hopi Utilities Corporation, Economic Development Administration Funding

For Immediate Release

Kykotsmovi Village, Ariz. - December 27, 2021 (Newswire) - On December 13, 2021 the Economic Development Administration awarded funding to Hopi Utilities Corporation to support the Tribe's transition to a clean energy economy focused on workforce development and quality jobs on Reservation.

When the Navajo Generating Station (NGS) closed in 2019, it left the Hopi Tribe in incredible economic distress. The Tribe received payments for supplying coal to the NGS, representing 85% of Hopi’s revenue. When these payments and jobs vanished, it left the Tribe in dire need for economic development.

Today, Hopi is rebuilding its economy with renewable energy.
Each building will be a PHIUS GEB or Grid-Interactive Efficient Building.

- A solar micro-grid provides the energy to power these highly efficient buildings.

- Excess solar energy can be shared across many building clusters or neighborhoods in a BlockLoop, with 19% more efficiency than traditional grids.

- A central solar farm stores reserve energy for later use, when individual buildings may not be able to generate all of their own energy.
**Prioritize Efficiency**
- optimized for resources
- designed for the climate
- responsible to the land
- easy to construct
- designed to meet Phius ZERO standards
- prefabricated construction
- incorporation of passive design strategies
- high efficiency, low cost mechanical systems

**Promote Well-being**
- implementing an architecture that fulfills a comfortable and healthy standard of life amid a harsh desert environment
- use of berms and entry wall to block dust
- incorporation of native vegetation in landscape
- ERV to maintain indoor air quality

**Requests of the Hopi**
- familiar housing typologies
- reinterpreting traditional motifs
- tiered form
- accessible roofs for drying crops
- use of traditional materials and techniques

**Celebrate Culture**
- familiar housing typologies
- reinterpreting traditional motifs
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Requests of the Hopi

Responses

Celebrate Culture
- familiar housing typologies
- reinterpreting traditional motifs
- tiered form
- accessible roofs for drying crops
- use of traditional materials and techniques

Cultivate Community
- provide spaces for community gatherings
- connection to local resources and community
- community outdoor spaces
- paths connecting to education and services
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### Design Goals

<table>
<thead>
<tr>
<th>Celebrate Culture</th>
<th>Cultivate Community</th>
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**Requests of the Hopi**

- familiar housing typologies  
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**Responses**

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- use of traditional materials and techniques

---

**ARCHITECTURE** | **ENGINEERING** | **ENVELOPE** | **EFFICIENCY** | **GRID-INTERACTIVITY** | **LIFE-CYCLE** | **HEALTH** | **MARKET** | **COMMUNITY**
**Phius ZERO / passive house standards**

**Thermal Control.**

Thermal control helps keep the inside warmer when it’s cold outside, and cooler when it’s hot outside — to maximize comfort and energy efficiency.

**Air Control.**

Passive buildings achieve air control by air sealing the enclosure and then providing balanced, mechanical ventilation to achieve superior indoor air quality.

**Radiation Control.**

Phius-optimized buildings balance solar radiation — taking advantage of it when needed and shading when not to lighten the cooling load and maximize energy efficiency.

**Moisture Control.**

Passive buildings require special attention to moisture control both in proper vapor and moisture control design for the enclosure as well as the mechanical systems needed to maintain appropriate moisture levels in the space.
Site Intentions.

- Orient housing clusters on North-South Axis for optimal solar control.
- Create communal greenbelts to encourage socialization, physical activity, and gardening.
- Create berms to deflect wind and create outdoor privacy.

Site Plan Key:
1. Unit Clusters
2. Communal Gathering Space
3. Solar Farm
4. Roasting Pits
5. Education Site
6. Multi-Family Site

The circulation of the site plan was design around the solstice lines. These being important in Hopi culture, it was important to use them as a guiding perimeter throughout design.
COMMUNITY PLAZA

- Outdoor Kitchen
- Roasting Pits

Central Gathering Plaza
For community celebrations

ARCHITECTURE  ENGINEERING  ENVELOPE  EFFICIENCY  GRID-INTERACTIVITY  LIFE-CYCLE  HEALTH  MARKET  COMMUNITY
Site
The location of the berms and walls creates a physical obstruction that prevents wind from blowing dust particles into the interior of the units.

Entrance
The vegetation outside of the units promotes health by absorbing pollutants and contributing to a calming environment that supports mental well-being.

Interior
While the ERV exchanges stale indoor air with fresh outdoor air, ensuring efficient ventilation, the use of low VOC materials and finishes removes the potential of formaldehyde in the air, both of which contribute to healthy indoor air quality.

Gradient of Strategies.
- Strategies are implemented in a layered approach from the site to interior to maintain healthy environments for our occupants.
**ARCHITECTURE** / rendering

- **Drainage Canales** - deliver water to gardens and provide visual connection to water.
- **Tiered Massing** - familiar architectural typology giving a sense of home to the community.
- **Sandstone Walls** - incorporates traditional and local building materials.
- **Accessible Roof Top** - for communal living.

**Notes:**
- Drainage Canales deliver water to gardens and provide visual connection to water.
- Tiered Massing is a familiar architectural typology giving a sense of home to the community.
- Sandstone Walls incorporate traditional and local building materials.
- Accessible Roof Top is designed for communal living.
ACCESSIBLE ROOFTOP / rendering

Outdoor Gathering
Provide outdoor gathering spaces for individual residents that can be opened up to other residents for impromptu gatherings.

Ramada
Place for drying Hopi corn.
Prefabricated Wall and Roof Panels

- Panels include all envelope control layers

- Panel structured from CLT panels helps sustainable forest management by using beetle infested Ponderosa Pine logs.

- Prefabrication allows rapid installation onsite by tribal members in this extremely remote area.
The prefabricated panels from Timber Age are centered around 3-inch CLT panels as the structure for the building. An air barrier membrane is attached to the exterior of the panel ensuring a tight seal, and includes I-joists with dense-packed cellulose insulation. The exterior features Oriented Strand Board, a weather-tight membrane, and a stucco finish. The roof assembly is topped with EPDM and exterior insulation, completed with a raised wooden deck above to make it usable for residents. This gives us an R-value of R-54 for the walls and R-68 for the roof, meeting Phius guidelines for climate zone 5B.

**Total Wall Assembly = R-54.75**

**Diagram:**
- Drainage Plane
- Vapor Control Layer
- Thermal Envelope
- Air Barrier

- CLT 3", R-3.75
- 11-3/4" Dense-pack Cellulose, R-47
- Synthetic Stucco Coats, R-4

**Acknowledgments:**
- Andrew Gashwazra - Hopi Tribe Liaison
- David Brubaker - Team Lead + Professor
- Laura Carr - Native Peoples Design Coalition Founder
- Greg Veitch - Drachmann Institute Research Coordinator
UA Attached Housing / Harvest Mesa 2024 Solar Decathlon Design Competition

**ARCHITECTURE**

**EFFICIENCY**

**GRID-INTERACTIVITY**

**LIFE-CYCLE**

**HEALTH**

**MARKET**

**COMMUNITY**

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**CLIMATE ZONE 5B**

- **Maximum Window U-value (Btu/hr.sf.F)**: 0.19
- **Minimum Wall R-value**: 33
- **Minimum Roof R-value**: 64
- **Minimum Unconditioned Basement / Crawlspace Ceiling R-value**: 21
- **Minimum Below-grade walls / floors R-value**: 16

**WOOD FRAMING**

- 1/2" OSB
- Tyvek StuccoWrap WRB
- Fiber Glass Mesh Set In Base Coat
- Stucco Finish Coat
- BCI Joist fastened to CLT every 2' O.C.

**Adhered Air Barrier Membrane**

- CLT Panel 3", R-3.75
- 11-3/4" Dense-pack Cellulose, R-53

**Total Wall Assembly = R-54.75**

**Roof Assembly**

- EPDM Roofing on Tapered Insulation
- Pedestal
- Wooden Raised Deck

**Drainage Plane**

- Vapor Control Layer
- Thermal Envelope
- Air Barrier

---

**ARCHITECTURE / wall section**

**Stone Cape w/ Drip Edge**

**Wood Framing**

**Stucco Finish Coat**

**Fiber Glass Mesh Set In Base Coat**

**Tyvek StuccoWrap WRB**

- 1/2" OSB
- CLT Panel 3", R-3.75
- Adhered Air Barrier Membrane
- BCI Joist fastened to CLT every 2' O.C.

**11-3/4" Dense-pack Cellulose, R-53**

**Concrete Raft Foundation**

**Cement Board**

**Glulam Beam**

---

**[CABANILLAS. MOODA Y. NELSON. PEREA. WEST]**

**[UA ATTACHED HOUSING TEAM / solar decathlon 2024]**
Healthy Forests

Ponderosa Pine forests have been overgrown and face the issue of the Colorado Mountain Pine beetle attacking and killing trees.

Sickly Forest

When mismanaged, the rotting wood decomposes and creates excess carbon emissions leading to a high chance of forest fires.

Forest Fires

Timber Age CLT Panels uses modern, low-impact equipment in order to log unhealthy trees that are harming the natural environment.

Timber Aged Modular Systems

This panelized wall system is 126% better than the IECC 2021 standards. These wall panels are packed and shipped saving air, and reducing build times.

Building Timber Age CLT Panels

How Much Carbon is Really Being Used?

Over the lifetime of the building, it is estimated that 138 kg CO2 e/m² over its lifetime. The high efficiency panels are Passive House Certified.

Assembly

Using Timber Age CLT Panels for assembly, along with reducing other loads, yearly energy consumption can be reduced 91%.
**WINDOW / details**

**Alpen Tyrol TR-6 Series**
phius certified, triple pane, low-e.

0.106  /window-to-wall ratio

0.35    /SGHC

0.16    /whole window U-value
$2 million / kickstart budget

With funding provided by the CARES Act of 2020

$1.48 million / project cost

+ $500,000

under budget

Phius studies have shown a 3.3% decrease in construction costs compared to conventional methods after 4 years.
PASSIVE STRATEGIES / section

- summer solar radiation
- spring/autumn solar radiation
- winter solar radiation
- time lag heat radiation from thermal mass
- fresh, cool airflow
- hot, exhausted air
- heated zinc surface, heating air in chimney

Hopi men assembling a sandstone wall.

Hopi woman applying plaster to sandstone wall.
Hopi sandstone on the trombe wall seamlessly blends into the interior, creating a **space that resonates** with the occupants. It contributes both to the **aesthetic** and **thermal comfort** of the interior.
**Passive Wall Operation**

**Solar Gain Mode** (winter-spring-autumn)

**Insulation Mode** (winter-nights, summer-extremes)

**Passive Wall Legend**

- A - Sandstone Thermal Mass Wall
- B - Retractable Radiant Barrier
- C - Double Paned Glazing
- D - Air Chamber
- E - Rotating Louvers
- F - Larsen Truss
- G - External Stucco Cladding
- H - Zinc Panels
- I - Insect Screen
- J - Vent
- K - Flagstone Cap

**Radiation Analysis** (shading effectiveness)

- December (fully lit)
- June (fully shaded)

---

**Architecture**

**Engineering**

**Envelope**

**Efficiency**

**Grid-Interactivity**

**Life-Cycle**

**Health**

**Market**

**Community**
Exterior Stucco Finish w/ Beige Paint

1/2" Brown Coat
1/4" Scratch Coat w/ Lath
Zinc Backing Panel, for Increased Thermal Conduction
2" x 6" Larsen Truss
1/2" Plywood

Zinc Backing Panel, for Increased Thermal Conduction
2" x 6" Larsen Truss
1/2" Plywood

3" Polysio Foam Insulation

1/2" Plywood w/ Waterproof Finish
3" Polysio Foam Insulation
1/2" Plywood w/ Waterproof Finish
3" Polysio Insulation
Steel Rotation Axle
Dual Paned, Clear Storefront Glazing for Trombe Wall Assembly

3.5" Air Gap for Trombe Assembly

Operable Alpen Tyrol High Performance PHIUS Certified Window Acting as Vent
Mechanical Arm
Motor for Automatic Window Operation
Fascia Support Framing
Decorative Vent Fasica/Cover - 1/2" Plywood Mitered, Sanded and Finished in Natural Oil
Removable Stone Veneer for Retractable Barrier Access
CLT Panel with Access Channel
Retractable Radiant R-4 Radiant Barrier for Night Time Insulation of Trombe Wall
J-Bolt w/ Steel Angle to Fasten CLT to Stone Wall
Traditional Load Bearing Sandstone Masonry Thermal Mass/Bearing Wall

Traditional Masonry Thermal Mass Sandstone Wall
Dual Paned Clear Glazing for Trombe Wall Assemble
Insulated Shade Louver Silicon Thermal Break for Continuous Thermal Control
4" Polysio Foam Insulation
Flagstone Concrete Slab Footing

Operable Alpen Tyrol High Performance PHIUS Certified Window Acting as Vent
Chiltrix heat to water air pump

VCT 19 buffer tank

Manifold water distribution

Warmboard radiant tubes

Radiant Heat/Cooling Flow Chart.

Per Cluster

Unit 1

Unit 2

Unit 3

Unit 4

Buffer Tank

Return Air

Fresh Supply Air

Pump

Manifold

DWH

Fresh Air (at parapet)

Return Air (at parapet)

Energy Recovery Ventilation

ERV

Exhaust Air

Fresh Air Intake

Exhaust Air

Fresh Air (at parapet)

Return Air (at parapet)

18.5" 50.5" 31" 23.5" 17.5"
### Systems / Integration

#### Summer
- **Heating:** None
- **Cooling:** Solar chimney open (morning + evening) + radiant cooling (daytime) + closed louvers
- **Ventilation:** Solar chimney (night flushing) + ERV (daytime)

#### Fall
- **Heating:** Trombe wall
- **Cooling:** Solar chimney
- **Ventilation:** Solar chimney + ERV (night time)

#### Winter
- **Heating:** Trombe wall + radiant + closed louvers (night time)
- **Cooling:** None
- **Ventilation:** ERV

#### Spring
- **Heating:** Trombe wall
- **Cooling:** Solar chimney
- **Ventilation:** Solar chimney + ERV (night time)

Legend:
- **Temperature (Deg. F):**
  - 68 - 75
  - 32 - 68
  - 30 - 70
  - <30

- **Relative Humidity (%):**
  - 60%
  - 40%
  - 30%
  - 20%
  - 10%
  - 0%

- **Wind Speed (mph):**
  - 10%
  - 20%
  - 30%
  - 40%
  - 50%
  - 60%
  - 70%
  - 80%
  - 90%
  - 100%

Design Strategies:
- 45% Corridor (1544 hours)
- 17.2% Sun-Shading of Windows (1544 hours)
- 23.2% Trombe Wall (1827 hours)
- 5.1% Natural Ventilation (1404 hours)
- 16.0% Passive Solar Direct Gain Low Mass (9778 hours)
- 1.2% Wind Protection of Outdoor Spaces (972 hours)
- 18.0% Internal Heat Gain (972 hours)
- 7.0% Humidification Only (972 hours)
- 27.0% Heating, add Humidification if needed (972 hours)
- 19.2% Two-Stage Evaporative Cooling (972 hours)
- 19.0% Sun Shading of Windows (972 hours)
- 15.4% Sun Shading of Windows (972 hours)
- 10.0% Comfort (972 hours)

Total Cloud Cover:
- 0% - 10%
- 10% - 20%
- 20% - 30%
- 30% - 40%
- 40% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 80%
- 80% - 90%
- 90% - 100%

Precipitation:
- Jan: 0.18 inches
- Feb: 1.2 inches
- Mar: 0.88 inches
- Apr: 0.53 inches
- May: 0.51 inches
- Jun: 0.8 inches
- Jul: 1.0 inches
- Aug: 1.2 inches
- Sep: 0.3 inches
- Oct: 1.3 inches
- Nov: 0 inch
- Dec: 1 inch

### Architecure Envelope Grid-Interactivity Life-Cycle Health Market Community
WATER CONSCIOUSNESS / + plumbing

Water Efficiency Flow Chart.

RAINWATER
FILTER
WELL WATER
CISTERN
SENSOR
LAUNDRY
SINKS
VEGETATION
TOILET
WATER TREATMENT

6,000 gallons harvested per unit. 23,000 gallons per cluster.
Systems work best when they are in dialogue with each other. A smart hub coordinates all systems together by monitoring the conditions of the house to efficiently and effectively control energy loads.
PHOTOVOLTAICS / energy onsite

Winter Energy Balance

31,566
/kWh/yr of energy generated per cluster (189,396 kWh/yr total)

Summer Energy Balance

9,470
/kWh/yr of energy used in cluster

+22,088
/kWh/yr of energy surplus to be stored per cluster (132,528 kWh/yr total)

Haha
British: an earthen depression used to protect landscape site lines, in this case to hide PV.

Blockbox
**Energy Efficiency / Net-Zero Ready**

- **HERS Score**: 65
- **Annual Energy Savings**: $7,340

**Home Energy Rating System**

- **More Energy**: 150, 140, 130, 120, 110
- **Reference Home**: 100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0
- **Zero Energy Home**: -8

- **WUFI Passive Data - Conventional CMU**
  - Heating Demand: 23.6 kBtu/ft² yr
  - Cooling Demand: 2.12 kBtu/ft² yr
  - Heating Load: 2.67 kBtu/hr ft²
  - Cooling Load: 2.1 kBtu/hr ft²
  - Source Energy: 2,135 kWh/Person yr

- **WUFI Passive Data - Timber Age CLT Panels**
  - Heating Demand: 4.5 kBtu/ft² yr
  - Cooling Demand: 2.33 kBtu/ft² yr
  - Heating Load: 2.67 kBtu/hr ft²
  - Cooling Load: 1.53 kBtu/hr ft²
  - Source Energy: 1,011 kWh/Person yr

- **WUFI Passive Data - CLT Panels + Passive Wall**
  - Heating Demand: 2.8 kBtu/ft² yr
  - Cooling Demand: 2.77 kBtu/ft² yr
  - Heating Load: 1.84 kBtu/hr ft²
  - Cooling Load: 1.4 kBtu/hr ft²
  - Source Energy: 1 kWh/Person yr

**Notes**

- POOR = Phius Zero Criteria for Climate Zone 5B
- BEST = Reference Home
- BETTER = Existing Homes
- Zero Energy Home

**Sources**

[UA ATTACHED HOUSING TEAM / Solar Decathlon 2024]

**Abbreviations**

- HERS: Home Energy Rating System
CONCLUSION

Hopi should be a place where:

Hopi culture and religion are strong;
Sacred sites are protected;
Culturally and environmentally sensitive development occurs;
The land is looked after;
There are jobs and businesses;
Quality infrastructure serves everyone;
Everyone has their own quality house;
Public service facilities serve all needs.

- Remote Location away from Sacred Land
- Inclusion of ceremonial community space

"Hopit Tunatya’at 2000"
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**Culturally and environmentally sensitive development occurs**;
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Everyone has their own quality house;
Public service facilities serve all needs.

- Low impact, sustainable structural wall panels.
- Water conservation and harvesting.
- Clean Energy
- Food Security through Dry Farming

-Hopit Tunatya’at 2000
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Everyone has their own quality house;
Public service facilities serve all needs.

- Re-introducing sandstone walls brings back traditional Hopi masonry jobs.
- Pre-fabricated assemblies allows the Hopi to participate in the construction process.
- Block Energy Micro-grid gives energy sovereignty to the Hopi

-Hopit Tunatya’at 2000
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- Hopi culture and religion are strong;
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-Hopit Tunatya’at 2000
CONCLUSION
ACKNOWLEDGEMENTS

Special thanks to...

Andrew Gashwazra
- Hopi Tribe Liaison
- Director, Hopi Office of Community Planning and Economic Development

David Brubaker
- Team Lead + Professor
- CPHC (Phius Certified Consultant)

Laura Carr
- Native Peoples Design Coalition Founder

Greg Veitch
- Drachmann Institute Research Coordinator

Otterbein Engineering

BLOCK ENERGY™

HOTSPOT ENERGY

TIMBER AGE SYSTEMS

ALPEN HIGH PERFORMANCE PRODUCTS

College of Architecture, Planning & Landscape Architecture

U.S. DEPARTMENT OF ENERGY

Solar Decathlon Design Challenge