

## Introduction / Background

### Problem Statement:

Address the need for sustainable, energy-efficient housing that withstands Saudi Arabia's extreme climate while preserving cultural identity.

### Constraints:

- Must withstand ambient temps up to 50°C.
- ≥90% locally sourced materials.
- Budget: < SR10,000 for prototype.
- Max area: 200 m<sup>2</sup> for full-scale, 9 m<sup>2</sup> prototype.
- Net-zero carbon emission.
- Saudi Building Code compliance.

### Specifications:

- Wall insulation R-value: 3.302 m<sup>2</sup>·K/W.
- Green roof R-value: 3.73 m<sup>2</sup>·K/W.
- Window-to-Wall Ratio ≥ 50%, with green space views.
- ≥50% of household wastewater recycled via greywater system.
- ≥10% energy savings enabled by real-time monitoring & automation.
- Cooling system COP: 3.9 (using VRF Hisense system).
- Air exchange rate (ACH): ≥0.6 via passive cross-ventilation.
- ≥20% of the plot dedicated to green spaces

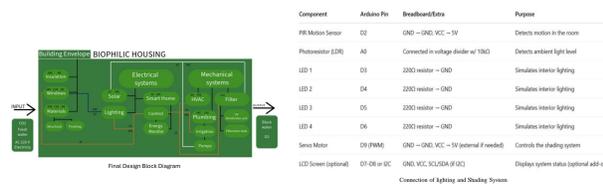
## Prototype Design

### Design Features:

- PCM-insulated ventilated wall.
- Green roof layered with drought-tolerant plants.
- Adaptive shading and window design.
- Modular basement for mechanical/electrical systems.

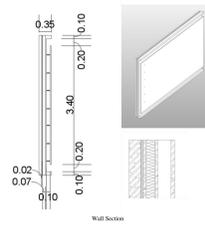
### Smart Systems:

- HVAC: Zoned VRF system
- Smart Lighting & Shading
- Smart Irrigation with ESP32
- Greywater recycling system
- Real-time Energy Monitoring IoT dashboard



LAYER	MATERIAL	THICKNESS	R-VALUE (M <sup>2</sup> ·K/W)
VEGETATION LAYER	Drought-tolerant plants	70 mm	0.05
GROWING MEDIUM	Lightweight soil	150 mm	0.556
FILTER FABRIC	Geotextile fabric	1 mm	-
WATER RETENTION LAYER	Plastic Sheet	20 mm	0.05
DRAINAGE LAYER	gravel	50 mm	0.08
ROOT BARRIER	Polyethylene membrane	1 mm	-
WATERPROOF MEMBRANE	PVC	2 mm	-
INSULATION LAYER	XPS (extruded polystyrene)	70 mm	2.59
STRUCTURAL DECK	Cast-in-place reinforced concrete	200 mm	0.4

TOTAL THICKNESS = 5.9CM  
R-value = 3.73 m<sup>2</sup>·k/w  
U-value = 0.268 w/m<sup>2</sup>·k



## Testing / Validation

### Thermal Tests:

- Wall R-value = 3.302 m<sup>2</sup>·K/W
- Roof R-value = 3.73 m<sup>2</sup>·K/W
- Verified COP = 3.9 with Carrier HAP software

### Ventilation Validation:

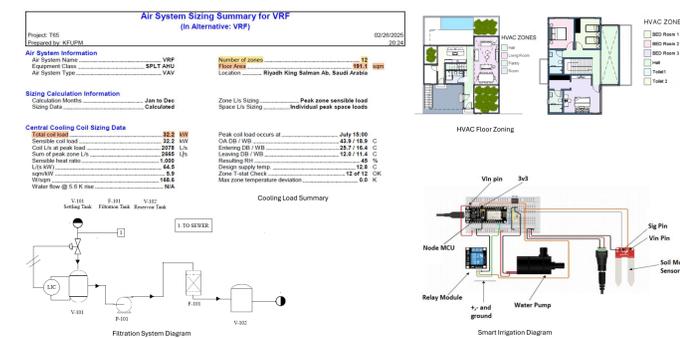
- ACH ≥ 0.6 using automated windows and natural wind

### Water Reuse:

- Greywater system tested to achieve ≥50% reuse rate, Qout = 167.87 L/h.
- Irrigation tested with soil and rain sensors

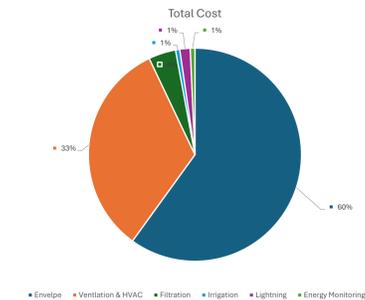
### Smart Control Validation:

- PIR and LDR verified to automate lighting
- Energy dashboard verified energy readings in real-time



## Conclusions

- All specifications were **met or exceeded** within the budget
- The prototype validates a **scalable, culturally-relevant** model for net-zero housing
- Contributes to **Vision 2030** goals in sustainability, localization, and smart cities
- Economic, Environmental, and Social** impact demonstrated through simulation and testing



System	Item	Unit	Estimated Cost per unit (SAR)	Estimated Quantity	Total Cost	System's Total
Envelope	Walls	m <sup>2</sup>	182	160	29120	
	Green Roof	m <sup>2</sup>	186	160	29760	
	Glass	m <sup>2</sup>	300	60	18000	81880
Ventilation & HVAC	Windows and Doors Frames	m <sup>2</sup>	250	20	5000	
	Hisense AAWT-324MHFS1 VR	pc	45000	1	45000	45000
Filtration	HDPPE Tank 500L	pc	500	1	500	
	HDPPE Tank 2000L	pc	1375	2	2750	
	Zenlike	kg	350	1	350	
	Coal Powder	kg	80	1	80	
	Sand	kg	20	1	20	
	Triple-Stage Filtr	pc	400	1	400	
Irrigation	HDPPE Pipes	m	8	5	40	
	the Grundfos SCALA2	pc	2	750	1500	5640
	0.5 hp Alzamil Pump	pc	1	500	500	
	Check Valve	pc	1	40	40	
Lighting	Micro-Sprinkles	pc	6	10	60	
	Moisture Sensors	pc	20	10	200	
	Arduino Controller	pc	1	50	50	
	Electrical Wiring	m	3	10	30	880
	LED Lights	pc	35	25	875	
Energy Monitoring	Motion Sensor	pc	30	8	240	
	Light Switch	pc	15	15	225	
	Wiring	pc	3	170	510	
	Electrical Box and breakers	pc	300	1	300	2150
Energy Monitoring	Energy Monitoring Unit	pc	250	1	250	
	Current Transformer	pc	30	4	120	
	Voltage Sensor	pc	25	1	25	
	Microcontroller	pc	50	2	100	
	Display/Monitoring	pc	150	2	300	
	Wiring	m	3	25	75	
Power Supply Adaptor	pc	25	2	50		
Enclosure Box	pc	50	1	50	970	

Total Systems Cost (SAR) 136520

