COST ANALYSIS

Per Node Hardware Cost (Sensors + Controller + Power)

Component	**Model / Type**	**Qty**	**Approx. Price (₹)**	**Total (₹)**
ESP32 Dev Board	DOIT ESP32 / NodeMCU-32S	1	800	800
LoRa Module	SX1278 / RFM95	1	900	900
Soil Moisture Sensor	Capacitive v1.2	1	700	700
Soil Temp Sensor	DS18B20 Waterproof	1	300	300
Air Temp & Humidity	DHT22	1	500	500
pH Sensor Kit	Gravity pH (DFRobot)	1	1,800	1,800
EC Sensor Kit	Gravity EC (DFRobot)	1	2,000	2,000
Water Level Sensor	Ultrasonic / Pressure	1	600	600
Flow Sensor	YF-S201	1	800	800
Light + Rain Sensor	BH1750 + Rain Module	2	600	600
Solar Panel + Battery + Charge Ctrl.	10W panel + 3.7V Li-ion	1 set	3,000	3,000
Enclosure, PCB, wiring	Waterproof IP65 box	1 set	1,000	1,000

2) **Per Node Hardware Cost (Sensors + Controller + Power)**

Component	**Qty**	**Price (₹)**	**Total (₹)**
Solenoid Valve (12V DC, 1”)	1	1,500	1,500
DC Pump (12V/AC small farm pump)	1	4,000	4,000

Component	Qty	Price (₹)	Total (₹)
Relay / MOSFET Driver Circuit	1	700	700
Pipes & Fittings (HDPE/Drip lines)	set	2,000	2,000

3) **LoRa Gateway (Village / Cluster Level)**

Component	Qty	Price (₹)	Total (₹)
LoRa Gateway Board (RAK / Dragino / DIY RPi)	1	8,000	8,000
4G Dongle / Wi-Fi Backhaul	1	2,000	2,000
Solar + Battery for Gateway	1 set	3,000	3,000
Antenna + Mounting Kit	1	1,000	1,000

4) **Pilot Budget (Example: 5 Farms Cluster)**

Item	Cost / Saving (₹)
Annualized Hardware (Node + Actuator)	~7,000
Annual O&M (Battery, Sensor Calib, SMS, Cloud)	~4,000
Total Annual Cost	**~11,000**
Annual Benefits (Water + Yield + Input Savings)	**~20,000**
Net Annual Gain per Farmer	**~9,000**
Payback Period	**~2.4 years**

This tabular breakdown shows **Indian market pricing** (based on Amazon India, Robu.in, DFRobot India distributors, and typical agri IoT BOM costs).At scale (100+ units, bulk purchase), costs can drop by **20–25%**.

POWER CONSUMPTION ANALYSIS

1. Node Energy Consumption

Component	**Current**	**Duration**	**Cycles/day**	**Energy/day (Wh)**	**Notes**
ESP32 Active	80 mA	10 s	144	0.27	Processing
LoRa TX	120 mA	5 s	144	0.20	Data TX
Sensors	20 mA	10 s	144	0.07	Moisture, Temp, etc.
Deep Sleep	0.15 mA	rest of day	—	0.27	Very low
Total Electronics	—	—	—	**0.9 Wh/day**	From 12 V battery

2. Pump Energy Consumption (Example Pump)

Pump Spec	**Current**	**Voltage**	**Runtime**	**Energy/day**
Small DC Pump	3 A	12 V	0.5 h/day	**18 Wh/day**

3. Total Energy Per Farm

Load	**Daily Energy (Wh)**
Node electronics	0.9
Pump	18

Load	Daily Energy (Wh)
Total	**18.9 Wh/day**

4. Battery Sizing (per farm)

Requirement	Value
Energy needed (2 days autonomy)	37.8 Wh
At 12 V → Ah required	3.15 Ah
With 80% DoD ($LiFePO_4$)	3.9 Ah
Practical Choice	**12 V, 7–12 Ah battery**

5. Solar Panel Sizing (per node)

Parameter	Value
Daily Wh load	18.9 Wh
Peak Sun Hours	4 h/day
System Efficiency	70%
Panel size needed	6.75 W
Practical Choice	**10–20 W panel per node**

6. Gateway Power Requirement

Load	Avg Power (W)	Daily Energy (Wh)
Raspberry Pi (MCU)	2	48
LoRa concentrator	1	24

Load	Avg Power (W)	Daily Energy (Wh)
4G Dongle	2	48
Total	**5 W**	**120 Wh/day**

7. Gateway Battery Sizing

Requirement	Value
Energy for 2 days	240 Wh
At 12 V → Ah required	20 Ah
With 80% DoD	25 Ah
Practical Choice	**12 V, 25–40 Ah battery**

8. Gateway Solar Panel

Requirement	Value
Daily Energy	120 Wh
Peak Sun Hours	4 h/day
Efficiency	70%
Panel size needed	43 W
Practical Choice	**50 W panel**

9. Cost Additions (Indian Market, 2025)

Item	Components	Approx. Cost (₹)
Node Power Kit	10–20 W solar panel + 7 Ah SLA/$LiFePO_4$ + charge controller + wiring	2,500–4,000

Item	Components	Approx. Cost (₹)
Gateway Power Kit	50 W panel + 25–40 Ah battery + MPPT controller + mounting	15,000–21,000

10. Updated Pilot Cost (5 Farms)

Item	Qty	Cost (₹)
Full Node (with power kit)	5 × 16,000	80,000
Actuator Systems	5 × 8,200	41,000
Gateway (with power kit)	1 × 30,000	30,000
Cloud Hosting + SMS (1 yr)	—	8,000
Training & Installation	—	10,000
Contingency (10%)	—	16,400
Total Pilot (5 farms)	—	**₹1,85,400 ≈ 1.85 Lakh**

SUMMARY

Power & Energy Summary

- **Node electronics (ESP32 + LoRa + sensors):** only ~0.9 Wh/day (negligible).
- **Pump load dominates:** ~18 Wh/day for a small 12 V, 3 A pump running 30 min/day.
- **Total farm energy need:** ~18.9 Wh/day.
- **Battery sizing (per farm):** 12 V, 7–12 Ah → gives 2 days autonomy.

- **Solar panel sizing (per node):** 10–20 W → ensures recharge even in cloudy weather.
- **Gateway needs more power:** ~5 W continuous → ~120 Wh/day.
- **Gateway battery:** 12 V, 25–40 Ah with 2 days autonomy.
- **Gateway solar panel:** 50 W recommended.

Cost Additions

- **Node power kit (solar + battery + controller):** ₹2,500–4,000 each.
- **Gateway power kit (solar + battery + MPPT):** ₹15,000–21,000.

Pilot Cost (5 Farms Cluster)

- **Full Nodes (with power kits):** ₹80,000.
- **Actuator systems (valve + pump + fittings):** ₹41,000.
- **Gateway (with power kit):** ₹30,000.
- **Cloud + SMS (1 year):** ₹8,000.
- **Training & installation:** ₹10,000.
- **Contingency (10%):** ₹16,400.
- **Total Pilot Cost: ~₹1.85 Lakh**.

Key Insights

- Pump is the **biggest energy consumer** → optimizing irrigation schedules saves both power & water.
- Using **solar + battery kits** makes system **independent of unreliable grid power** in hilly Sikkim.
- Cost per farm (~₹37,000 capex incl. power) pays back in **≈3 years** via higher yields & water savings.
- Gateway reliability is critical → must be oversized with robust solar/battery.