AI and Blockchain Abetted Energy Access for E-Cooking and Post-Harvest Management

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Rationale

A Million Dying & A Billion Hungry

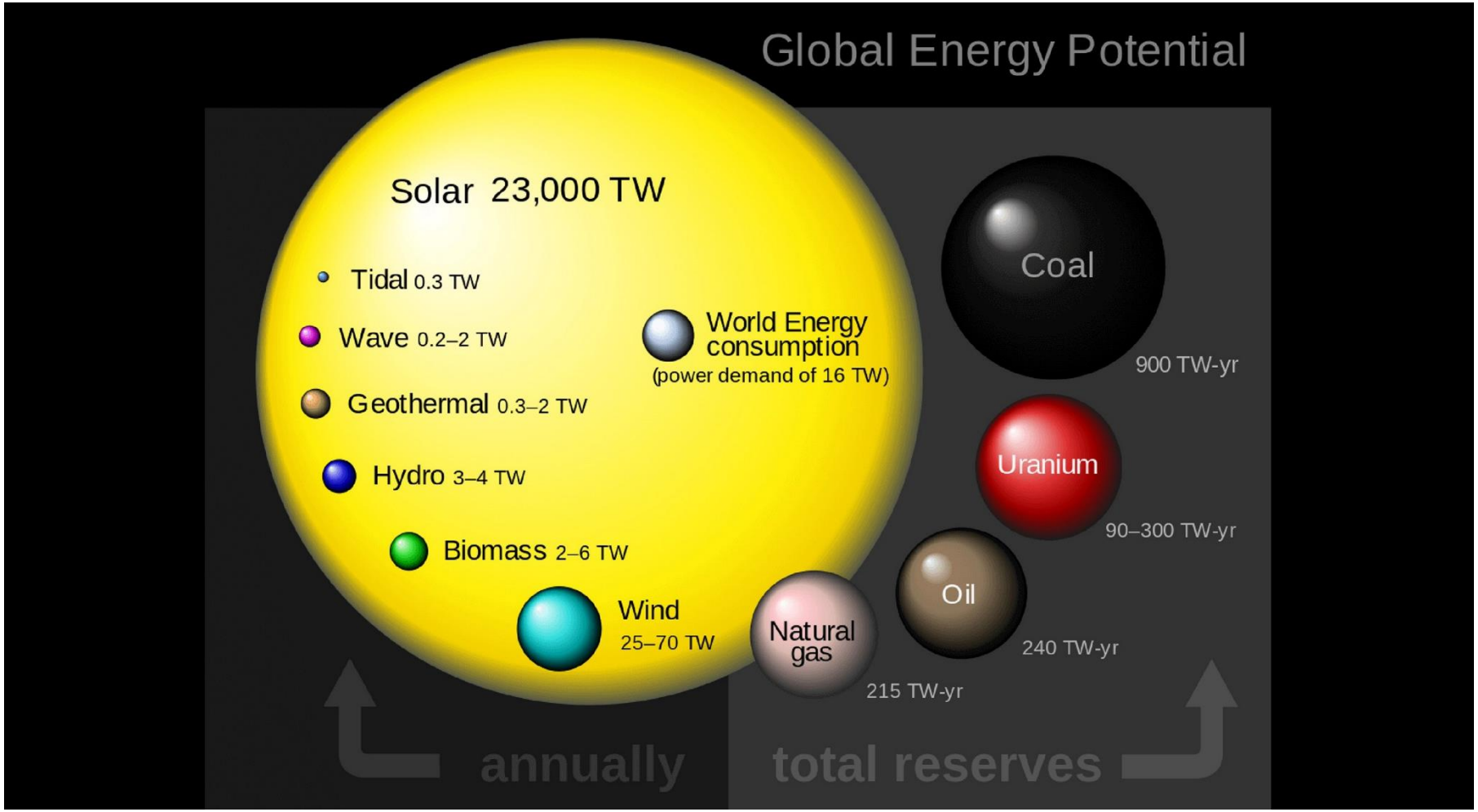
- A billion hungry people can be fed
  - Over one seventh of food produced lost in field
  - Additional one seventh wasted in retail and consumption
  - Cold chains can impart material difference in loss prevention
  - Limited cold chain in hot countries amid rising temperature
  - Distributed and optimized cold chain can be beneficial
- A million dying children can be saved
  - Acute respiratory infection claims a million each year
  - Unhealthy indoor pollution is the primary cause of infection
  - Polluting cooking fuel in closed space exterminates precious life
  - Active women and children below five are the worst affected
  - Transition to pollution free electric cooking can help

Food and Nutrition Security with Clean Energy

- Food and nutrition security
  - Population, income, preference are basic drivers of food demand
  - Global demand may stretch by more than a quarter in a quarter century
  - More crop land, pasture, usable water, clean energy and productivity in demand
  - Robot farmer, blockchain, climate control, innovative technology promising
  - Growing yield and cutting food loss may lead to the path of food security
- Affordable reliable sustainable modern energy
  - Fossil fuel largest contributor to global climate change
  - Agri-food system consumes about a third of global energy
  - Energy aids food production, post-harvest and consumption
  - Solar irrigation, grain milling, ice making, refrigeration growing
  - Yet to extend electricity access to about 0.7 billion people globally

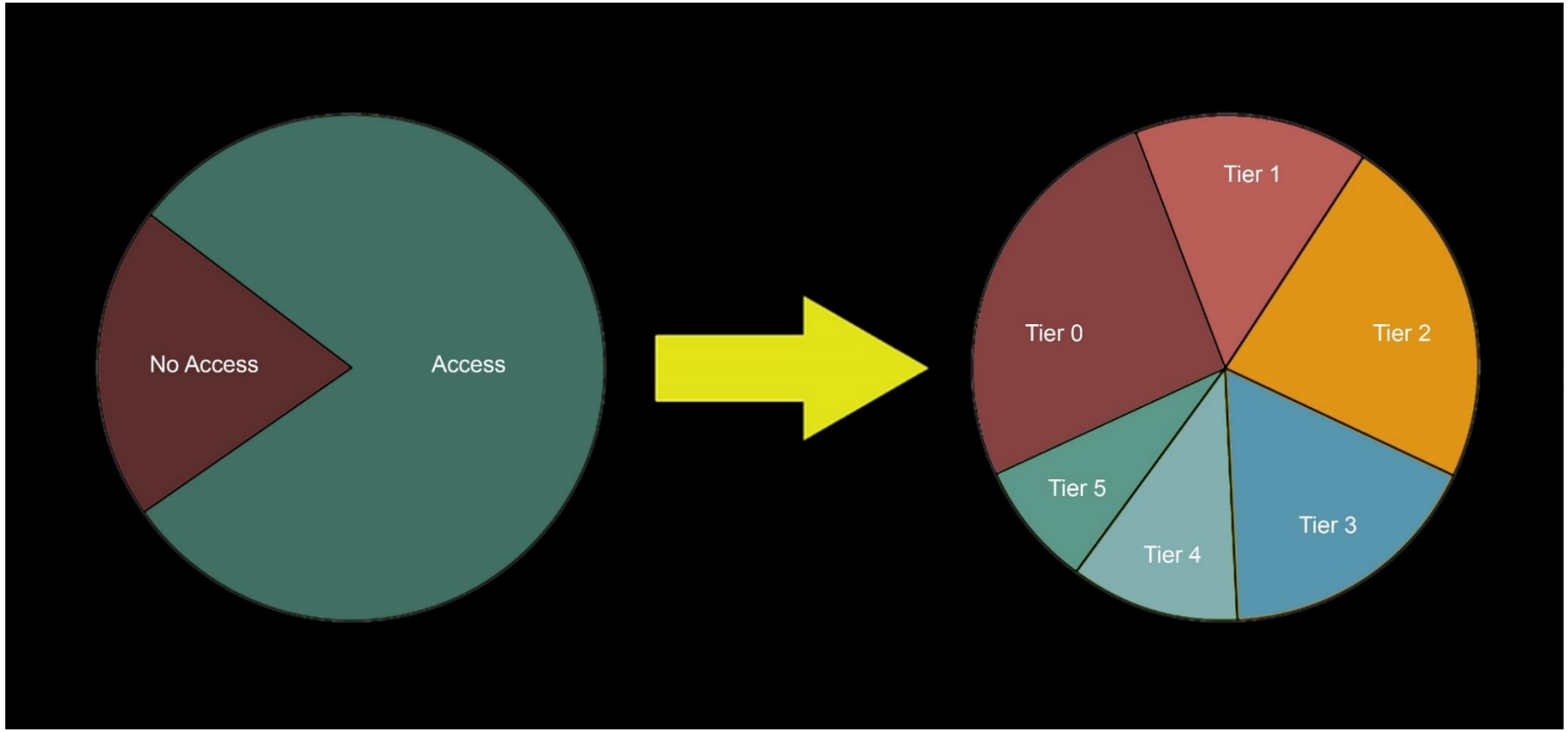
Abundant Solar Energy

- Solar energy abundant
- Solar PV application increasing
- Solar thermal use case specific
- Increasing electrification



Measure to Treasure

- Traditional
  - Two access levels
    - Access
    - No access
- Modern
  - Six access tiers
    - T1 phone charging
    - T2 television
    - T3 medium power
    - T4 high power
    - T5 very high power



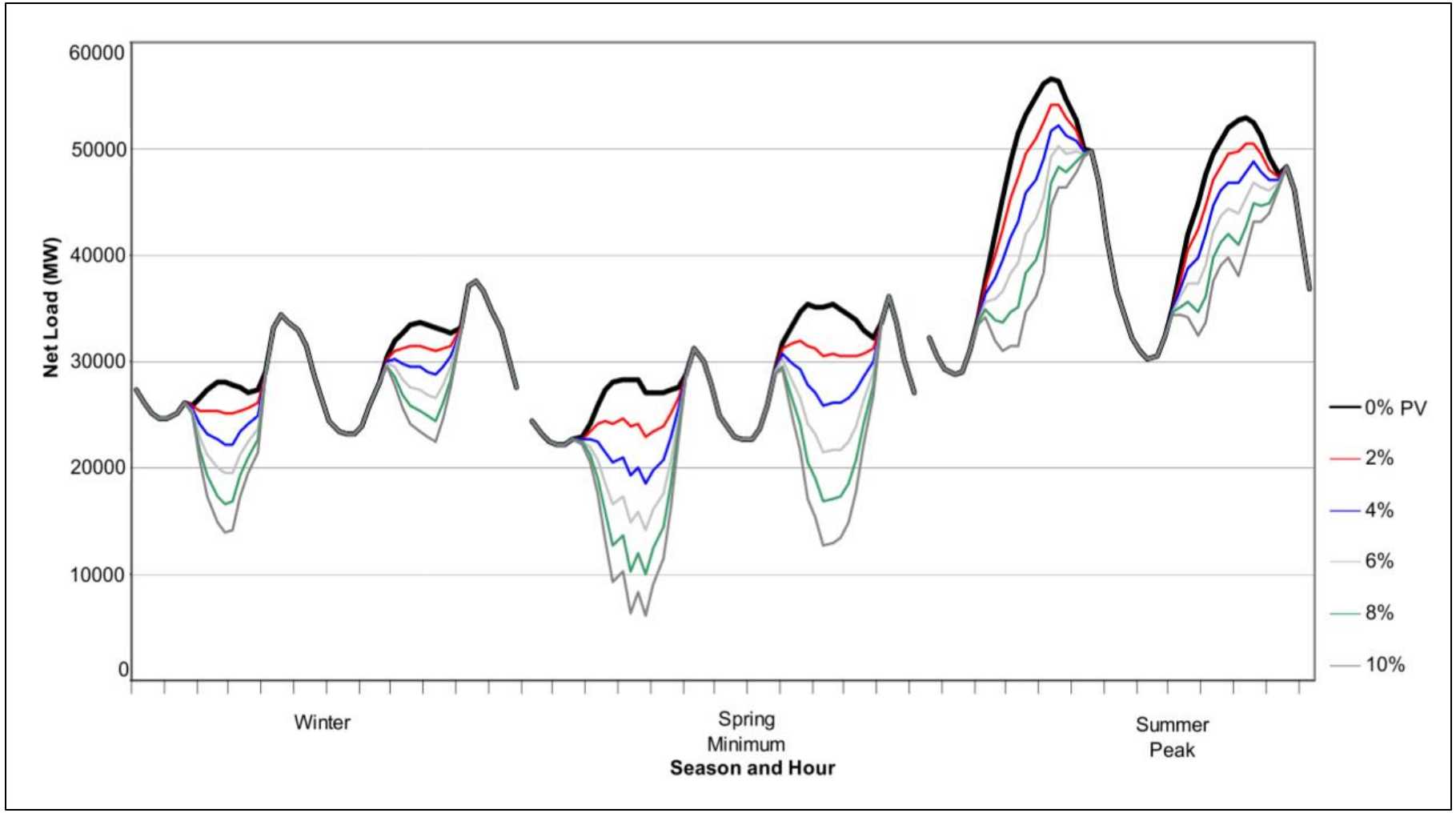
Multi-tier Framework

- Capacity
- Duration
- Reliability
- Quality
- Affordability
- Legality
- Safety

Attribute	Indicator	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	Minimum Power Requirement (W)		3	50	200	800	2000
	Minimum Energy Available per Day (Wh)		12	200	1000	3400	8200
Duration	Minimum Supply Per Day (Hours)		4	4	8	16	23
	Minimum Supply Per Evening (Hours)		1	2	3	4	4
Reliability	Maximum Disruptions Per Week (No)					14	3
	Maximum Total Duration of Disruption (Hours)						2
Quality	Desired Appliance Use Not Affected by Voltage					Yes	Yes
Affordability	365 kWh Energy Costs 5% or Less of Annual Income				Yes	Yes	Yes
Legality	Bill Paid to Utility or Other Legitimate Entities					Yes	Yes
Health & Safety	Absence of Past Accidents & Perceived High Risk					Yes	Yes

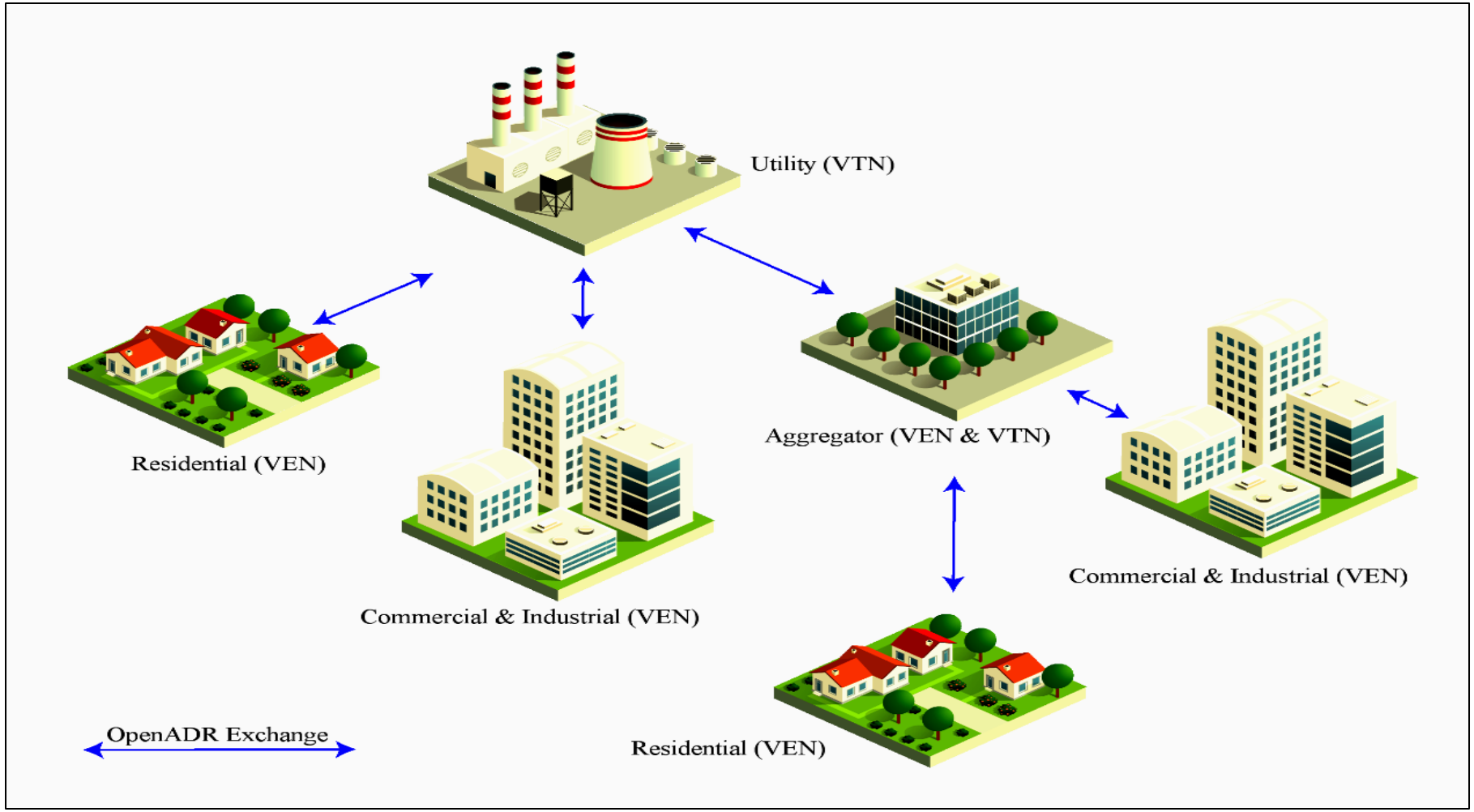
Supply Stability

- Impact of increasing solar penetration
- Load dispatch effort complex
- Variation over different seasons



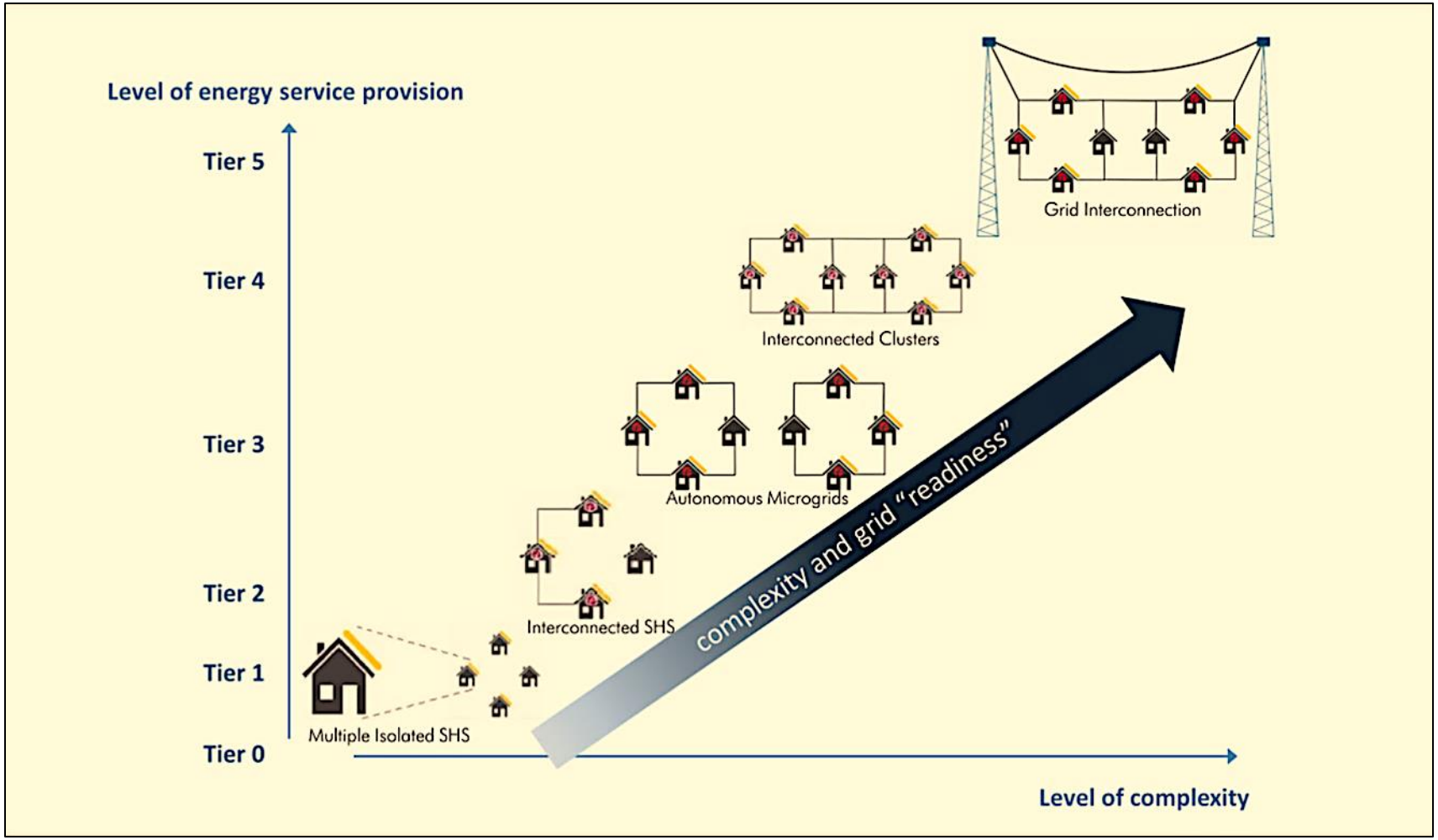
Demand Response

- Virtual top node
- Virtual end node
- Dual role aggregator



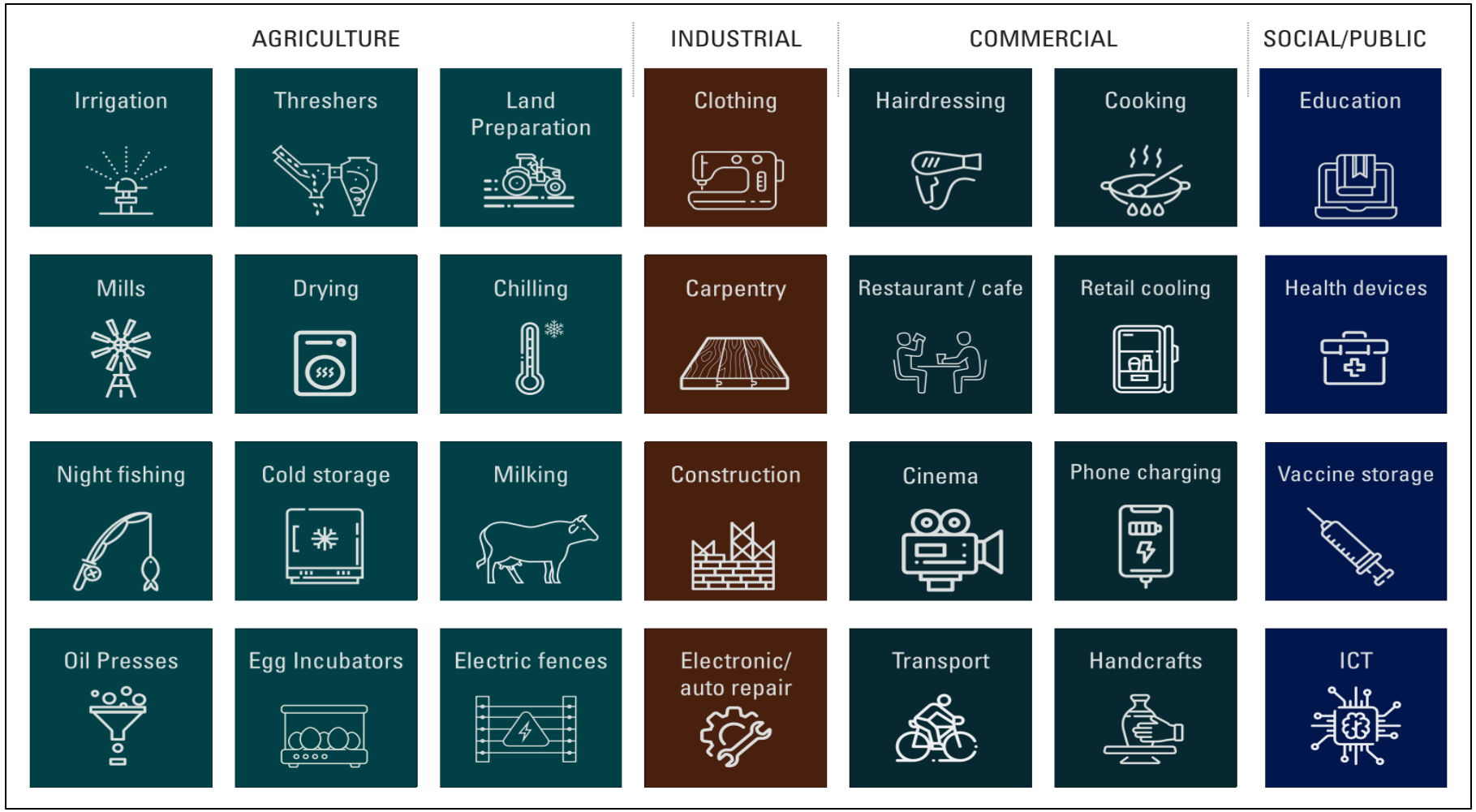
Cluster Supports Higher Tier

- Improving energy delivery service tier
- Increasing system operating complexity



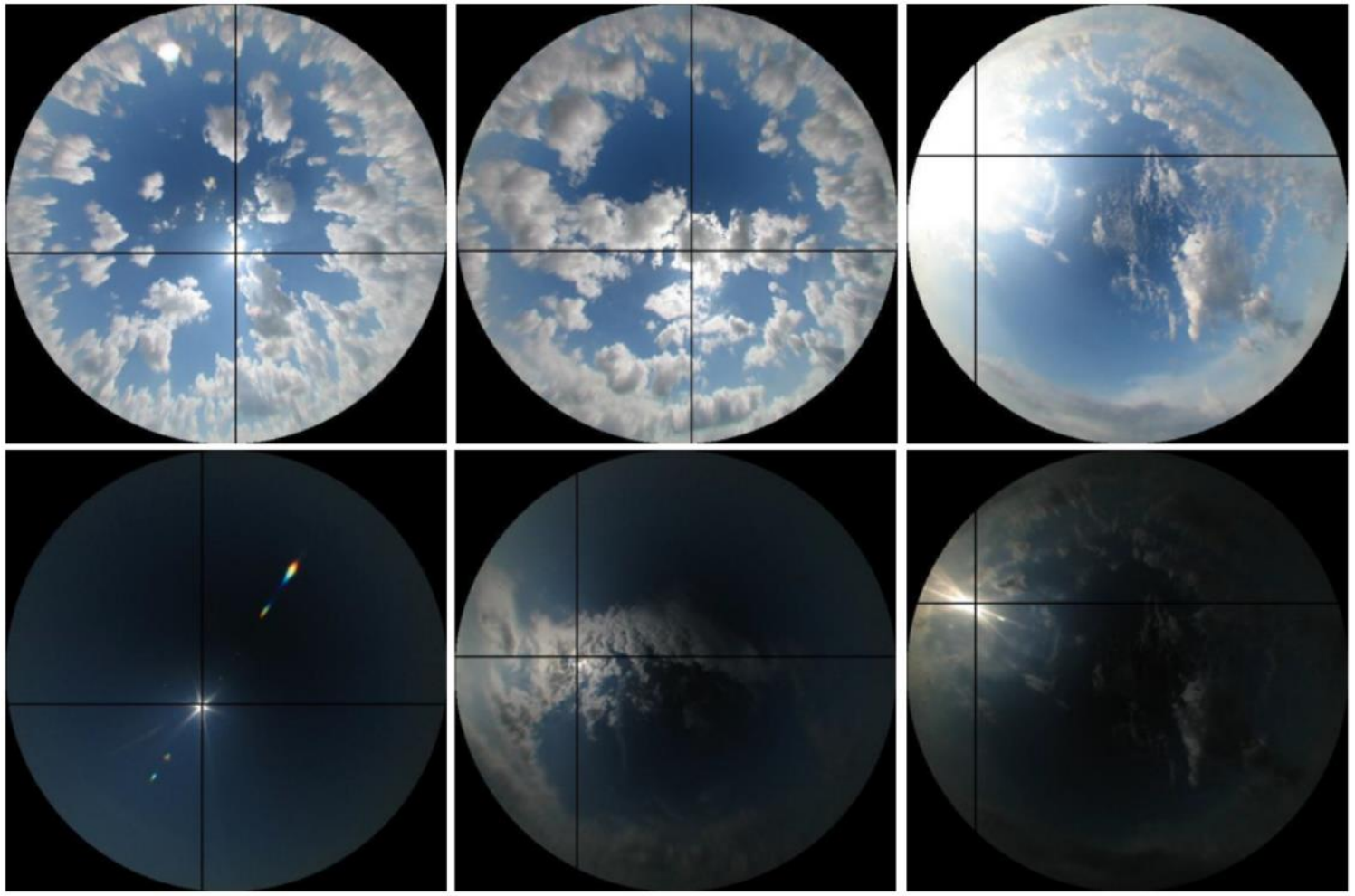
Productive Decentralized Use

- Agriculture
  - Irrigation
  - Fishing
  - Milking
  - Incubation
  - Milling
  - Cold storage
- Commercial
  - Retail cooling
  - Cooking



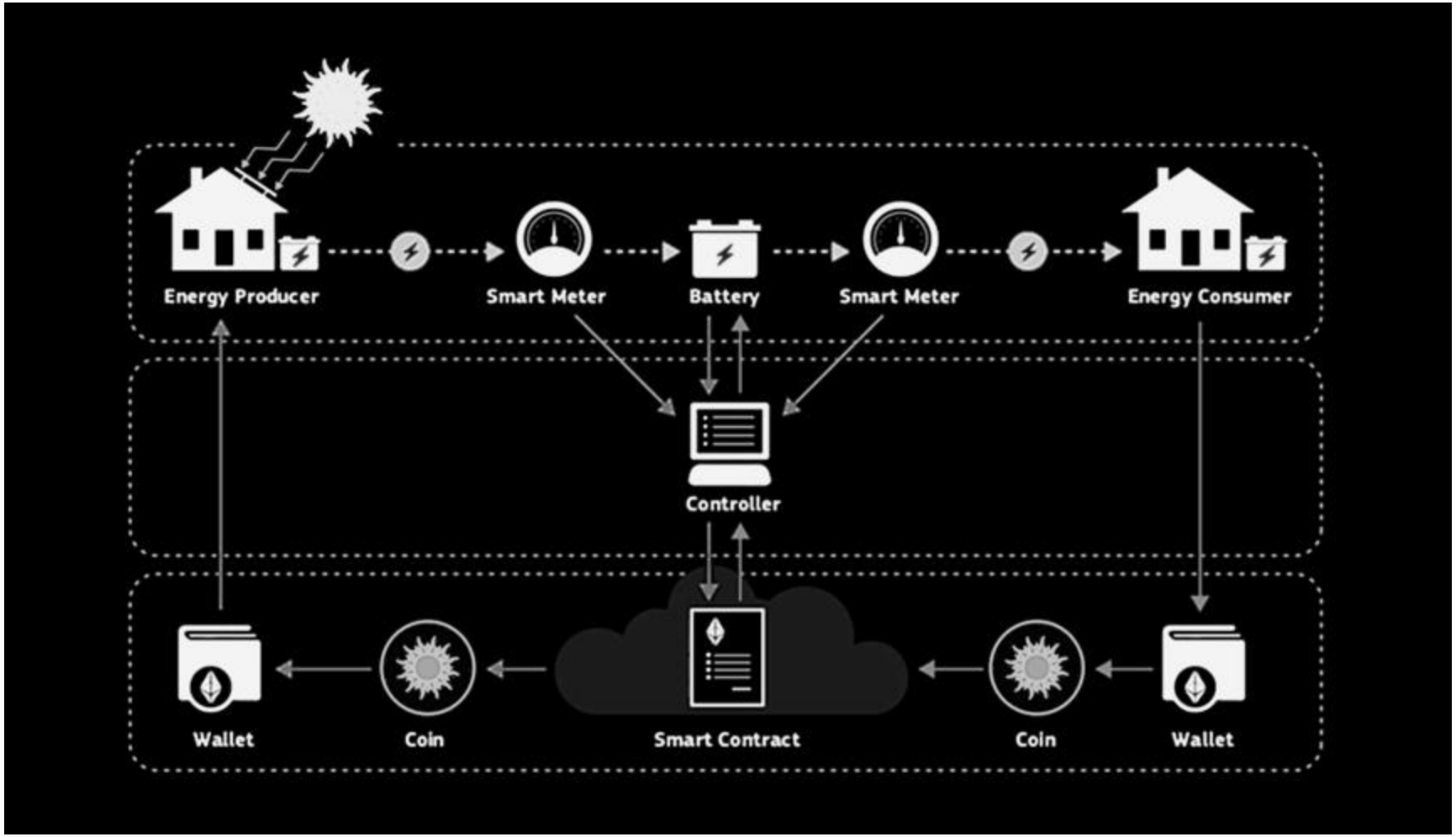
Artificial Intelligence

- Generation forecast
- Demand forecast
- Optimal storage use
- Smart energy trade
- Predictive upkeep
- Energy management



Blockchain

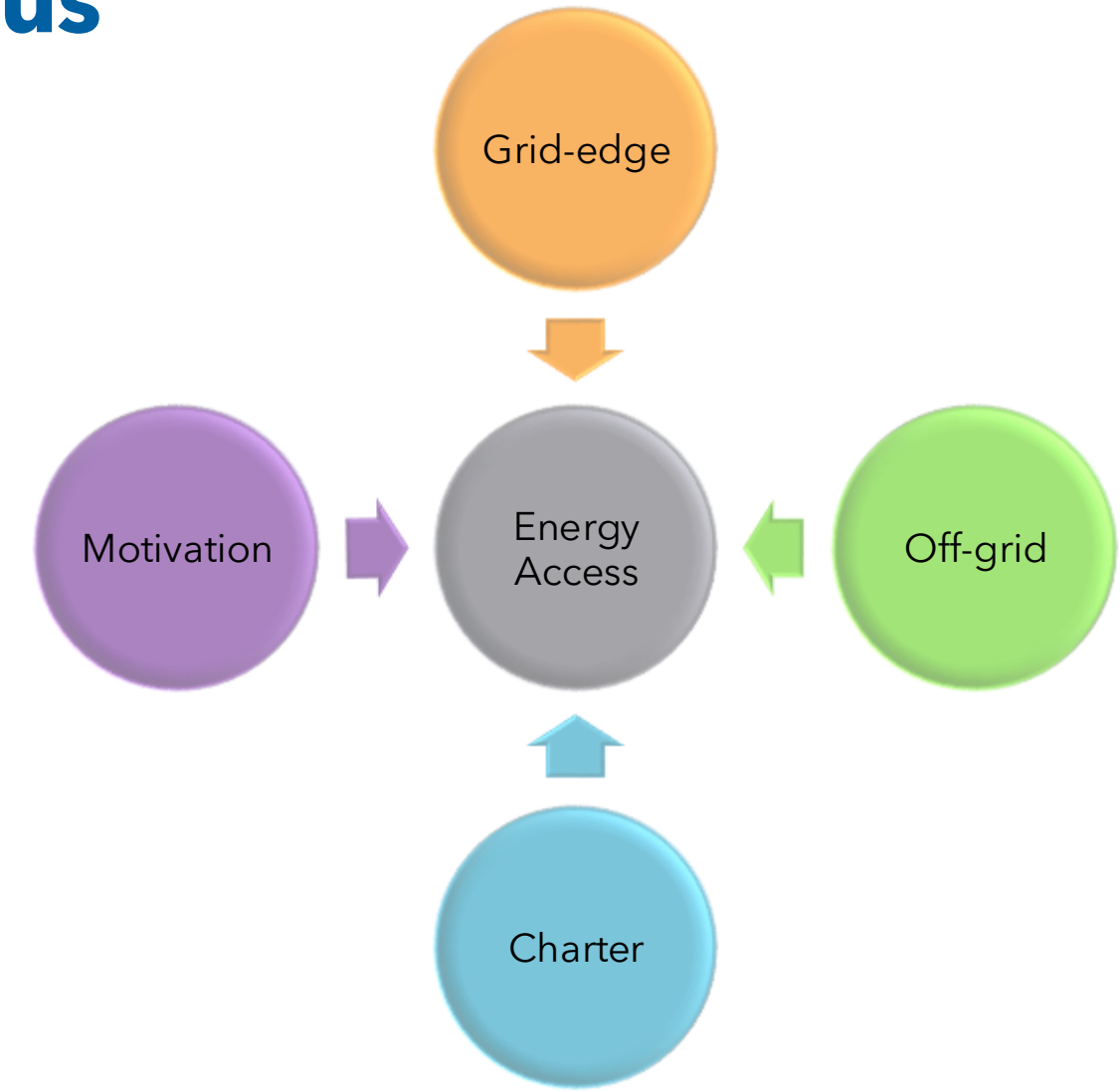
- Peer-to-peer trading
- Renewable certificate
- Automatic settlement
- Virtual power plant
- Demand response
- Secure smart meter



Evolving Grid

Characteristic	Traditional Grid	Early Smart Grid	Evolving Smart Grid
Role of ***information technology***	**Gradually expanding** in diverse ways	**Bidirectional control & monitoring** communication	One-way **monitoring but no central control**
Consumer engagement in system regulation	**Passive consumer** without engagement	Binary **ON/OFF demand response**	Continuous, **autonomous demand response**
Generation mix and distributed sources	**Central generation** led system	**Centrally controlled** distributed generation	**Distributed generation dominated** system
Cascading ***system-wide failures***	Systemic **intrinsic design defect**	**Reduced incidence** but still cataclysmic	Locally-contained and **effect-limited flaw**

Research Focus



Research Questions

- Grid-edge - Can multi-tier framework impact access at the grid-edge
- Grid-edge - Is there collaborative opportunity in the multi-tier framework
- Off-grid - Can essential anchor loads influence off-grid resource efficiency
- Off-grid - Will affordability improve with cooperative use of anchor load
- Charter - Can responsible consumption impact solar PV community
- Charter - Will costs reduce with optimal resource transaction structure
- Motivation - Can message framing induce temporal shift in consumption
- Motivation - Is there predictability of temporal shift in consumer motivation

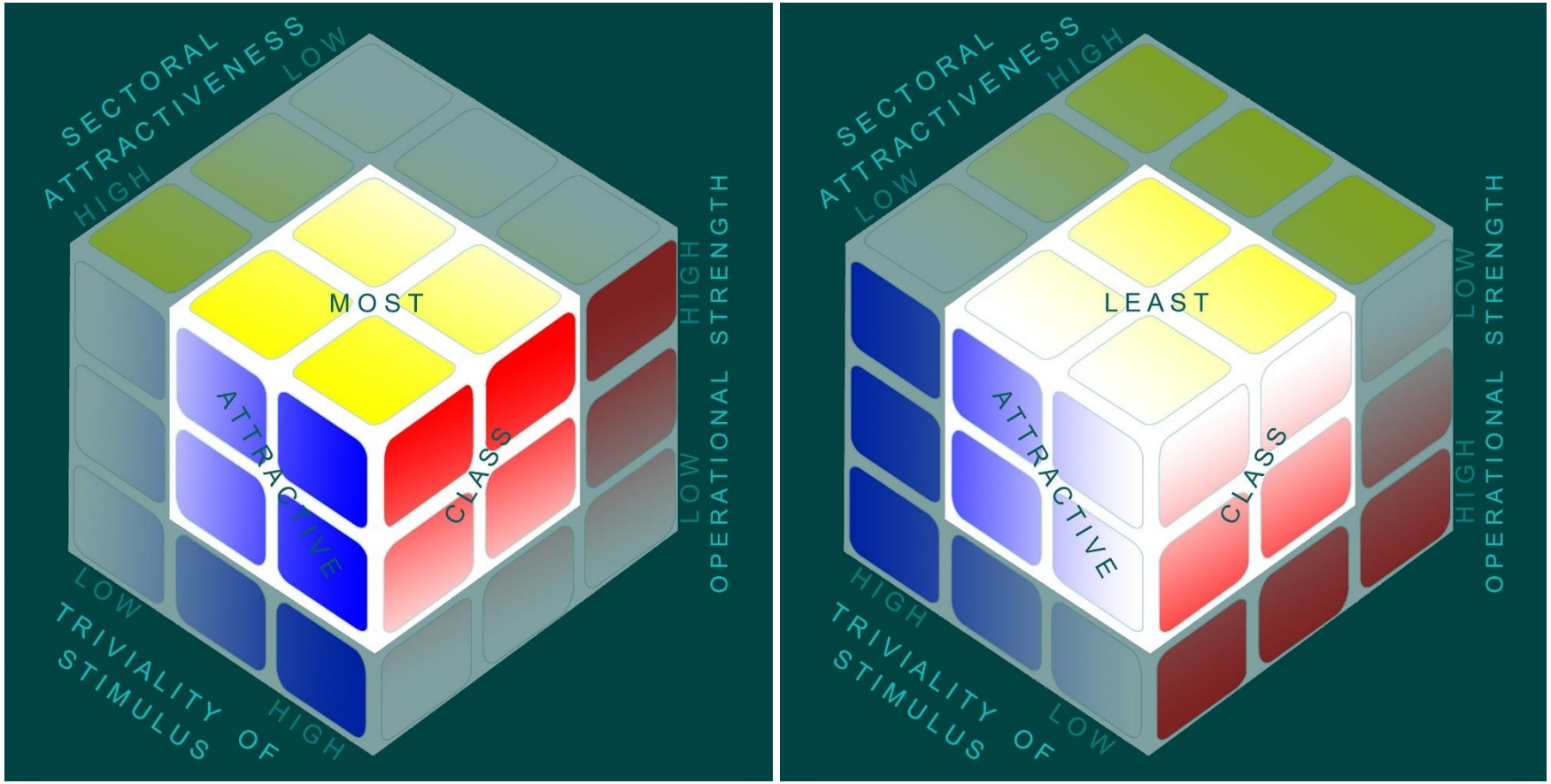
Methods

Member Selection Strategy

Operational strength – value creation ability of the target for fulfilling a delineated necessity

Sectoral attractiveness – craving of the ecosystem for having the delineated necessity fulfilled

Triviality of stimulus – dispensability of external stimuli without disrupting exchange between target and environment

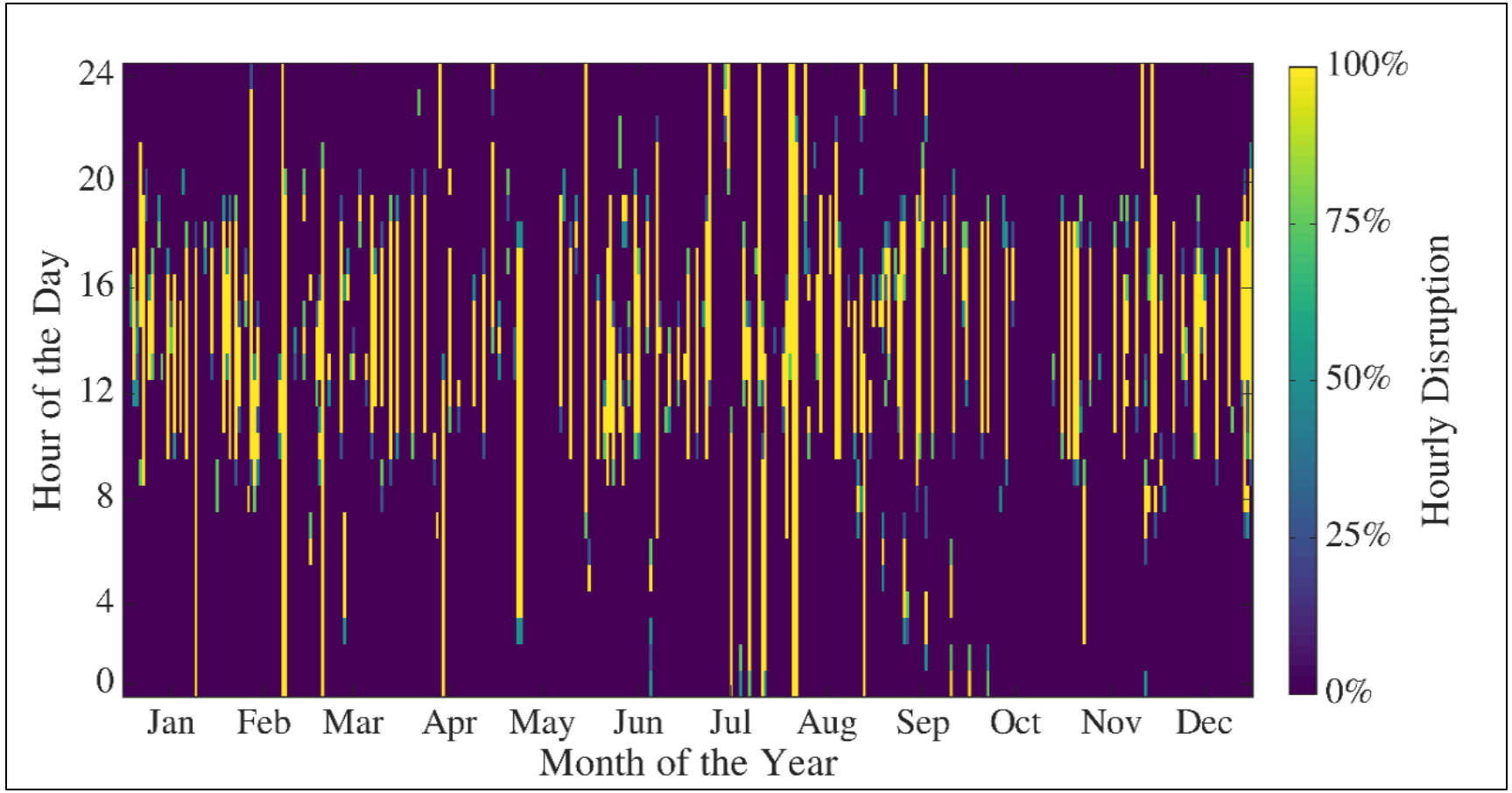


Brief Methods

- Grid-edge
  - Multi-tier framework analysis
  - Grid-edge supply analysis
  - Demand assessment for cooking
  - Demand assessment for cold storage
  - Optimal energy supply framework
- Off-grid
  - Standalone system analysis
  - Cluster-based supply analysis
  - Demand assessment for cooking
  - Demand assessment for cold storage
  - Optimal energy supply framework

Grid-edge Supply Reliability

- Grid supply
  - One year data
  - 15 minute interval
  - Color coded supply disruption
  - More disruptions in later part of day
  - Sustained failure signifies technical interruption



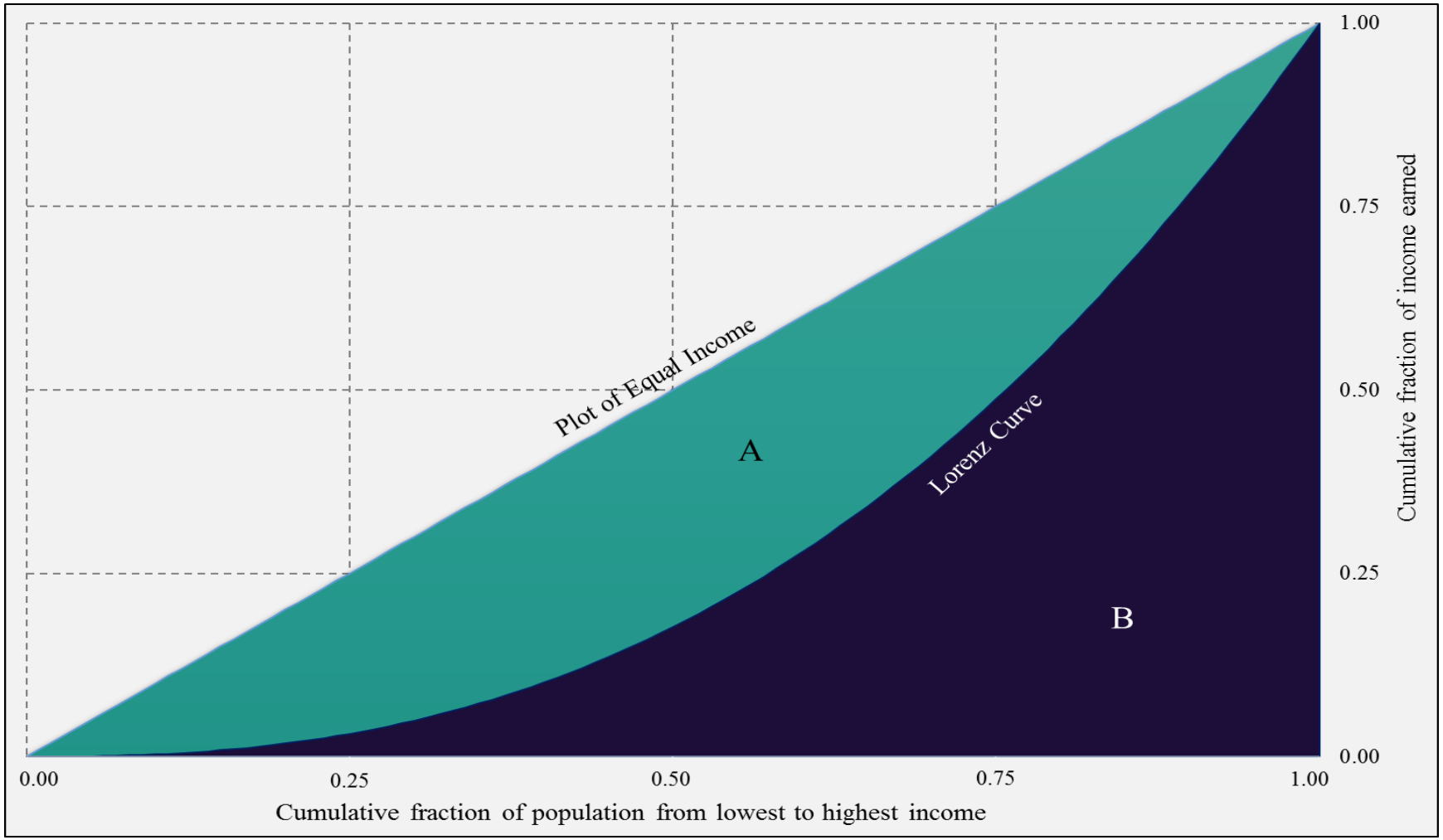
Off-grid Shared Consumption

- Demand following
  - No control effort
  - Abrupt failure
  - Complete blackout
  - Balancing disruption
  - Technical disruption
- Demand response
  - Intricate control effort
  - Generally predictable
  - Design load criticality
  - Load priority defined
  - Technical disruption

Energy Supply	Demand Response	Consumer Awareness	Load Following
Control Scheme	**Collaborative** Control	Manual Control	No Control
Supply Certainty	High **Certainty**	Medium Certainty	No Certainty
Supply Failure	**Measured** & Gradual	Human Frailty - Sudden	Abrupt Failure

Income Distribution

- Lorenz curve
- Kumaraswami double bounded distribution
- Country gini coefficient



Brief Methods

- Structure
  - Solar PPA structure analysis
  - Supply-following framework
  - Demand assessment for cooking
  - Demand assessment for cold storage
  - Optimal energy supply structure
- Motivation
  - Regulatory focus framework
  - Determining consumption impact
  - Temporal choice message framing
  - Message induced consumption shift
  - Identifying regulatory fit of a subject
  - Predictability of consumption shift

Message Framing for Temporal Shift

- Regulatory focus
  - Fit
  - Non-fit
  - Control
- Consumption impact
  - Fit
  - Non-fit
  - Control

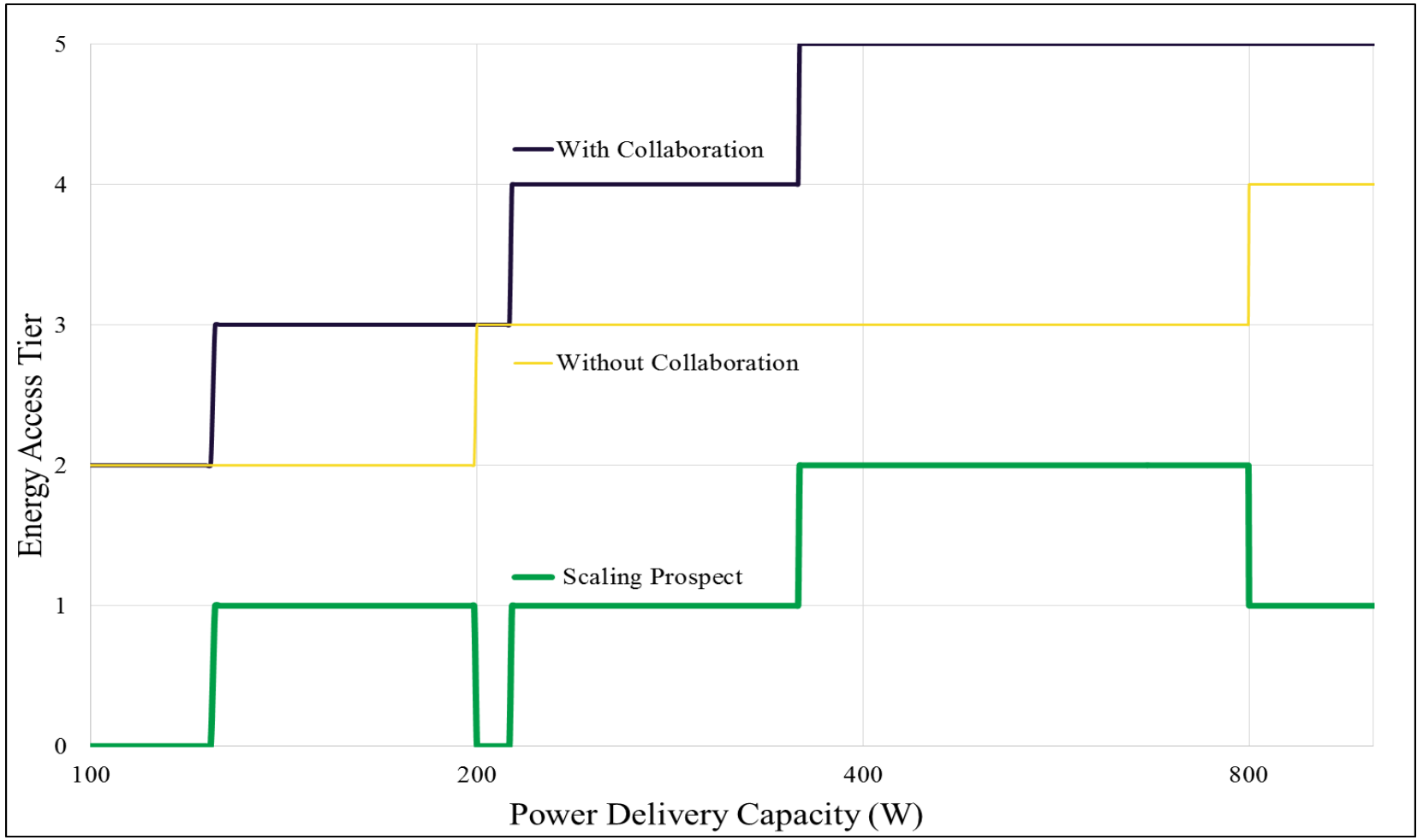
Temporal choice affecting message		Consumption Impact (CI)		
		Fit	Non-fit	Control
Regulatory Focus (RF)	Fit	Hypothesis 1: RF Fit - CI Fit	Hypothesis 1: RF Fit - CI Non-fit	Not used
	Non-fit	Hypothesis 1: RF Non-fit - CI Fit	Hypothesis 1: RF Non-fit - CI Non-fit	Not used
	Control	Not used	Not used	Hypothesis 2: Control Condition

Results

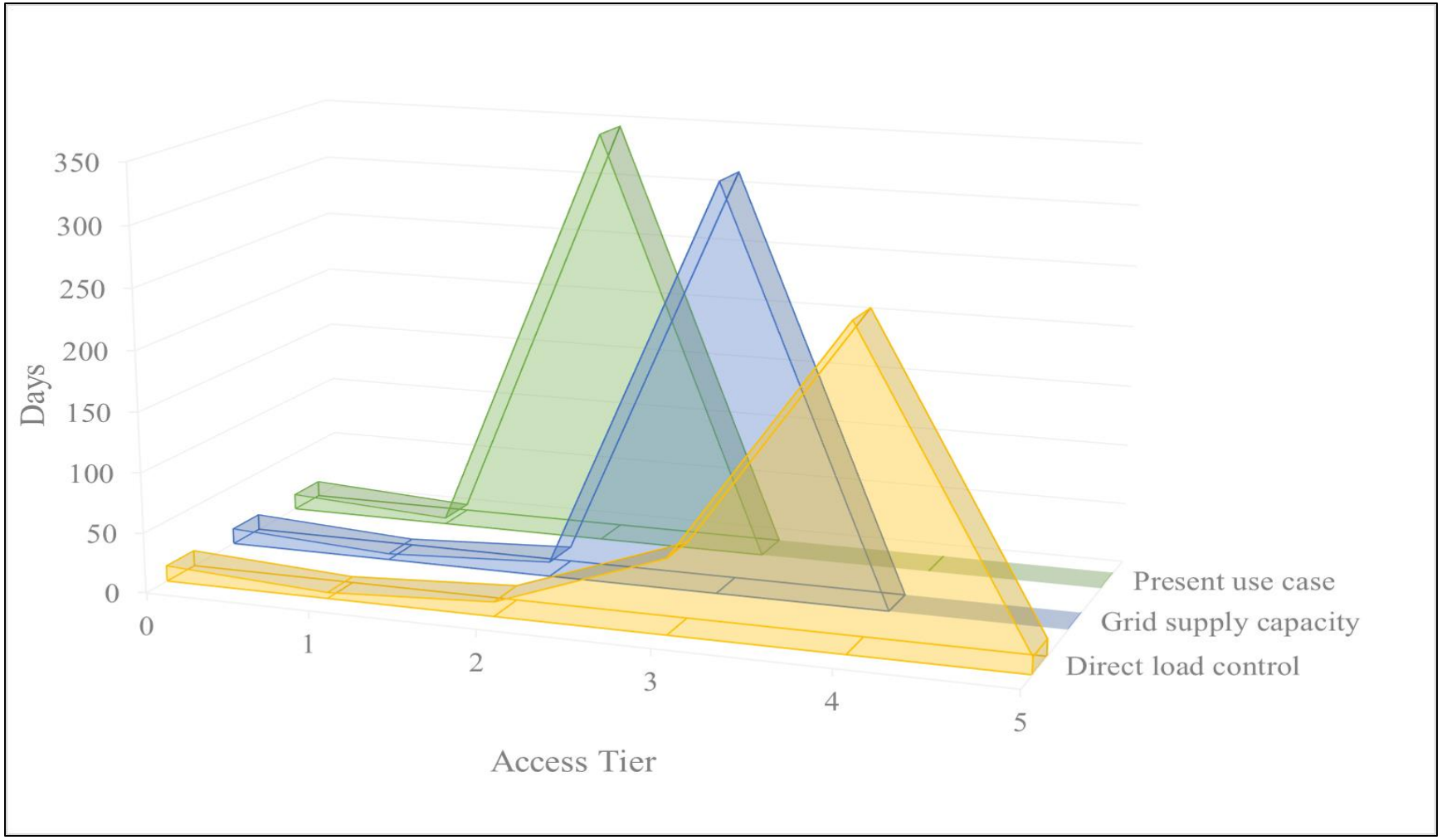
Multi-tier Framework

Access tier requirement vis-à-vis potential	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Access tier peak power required (W)	3	50	200	800	2000
Daily supply duration required (Hrs)	4	4	8	16	23
Daily energy supply potential at peak power (Wh)	12	200	1600	12800	46000
Actual energy supply capacity required (Wh)	12	200	1000	3400	8200
Share of time required with peak power (%)	100	100	62.5	26.6	17.8
Maximum collaboration potential for powering loads	1:1	1:1	1.6:1	3.7:1	5.6:1
Peak power supply provision per consumer (W)	3	50	125	212.5	356.5

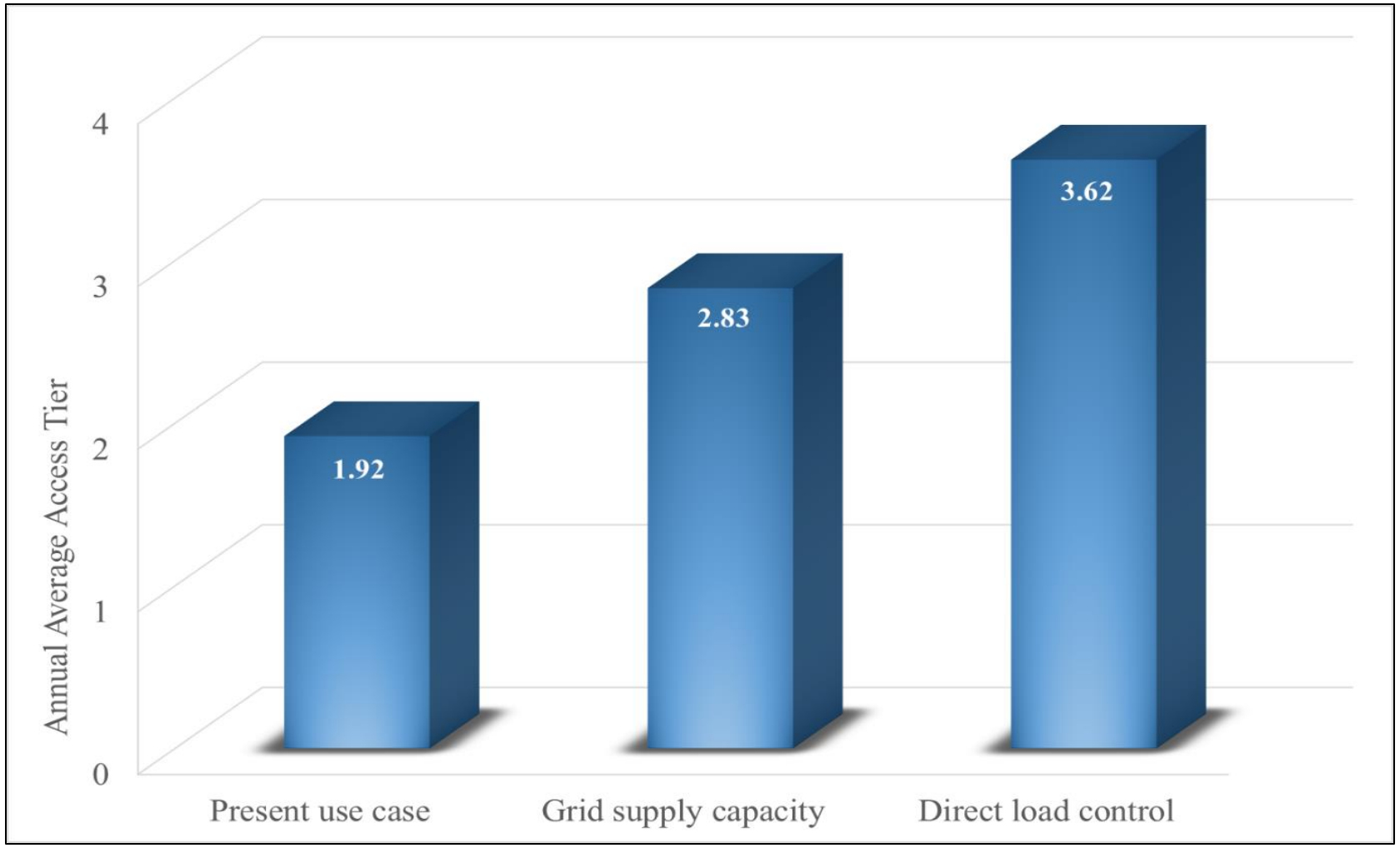
Collaborative Access Tier Gain



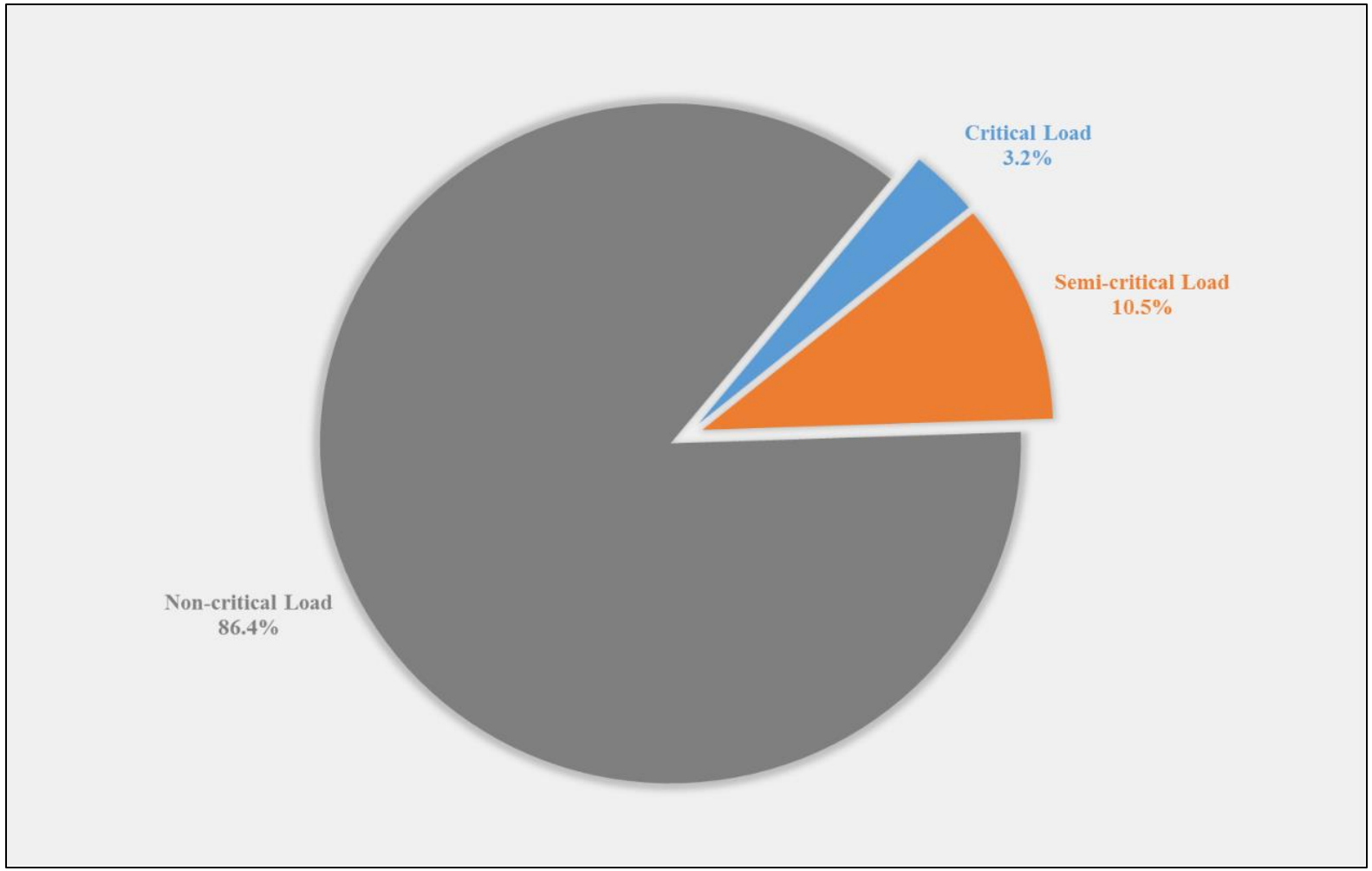
Access Tier Spread at the Grid-edge



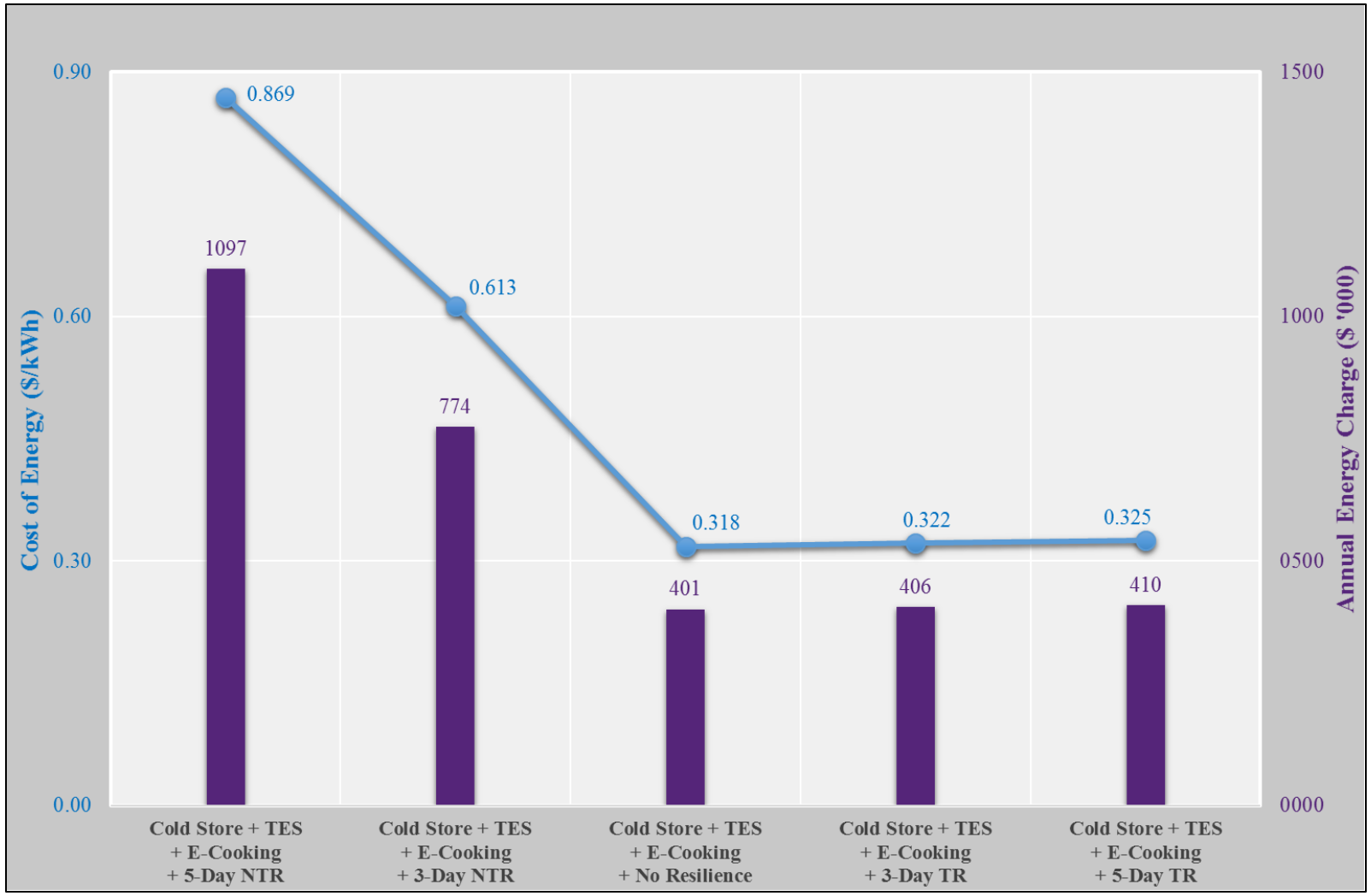
Effective Annual Access Tier at the Grid-edge



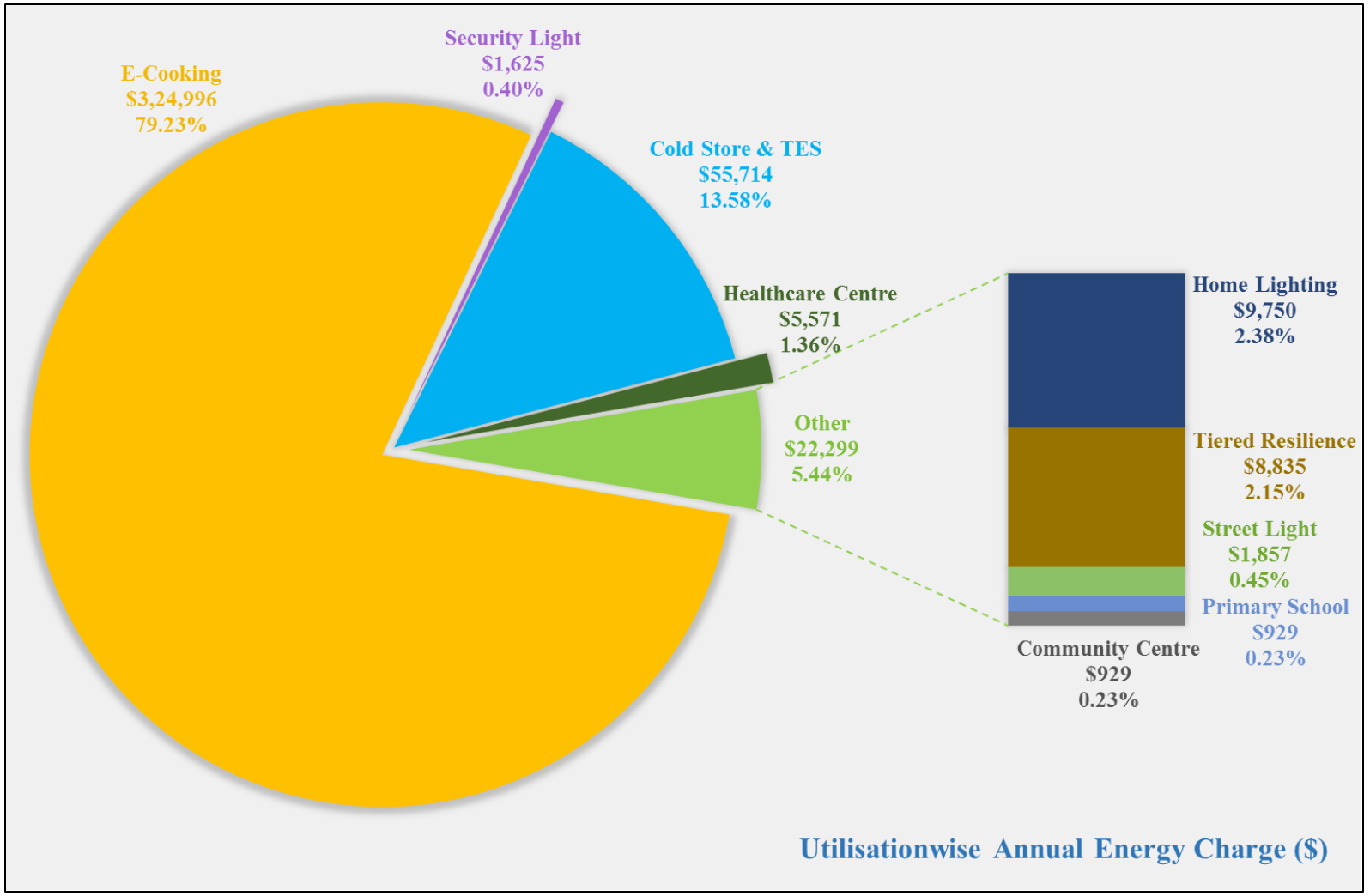
Criticality-tiered Resilience Charter



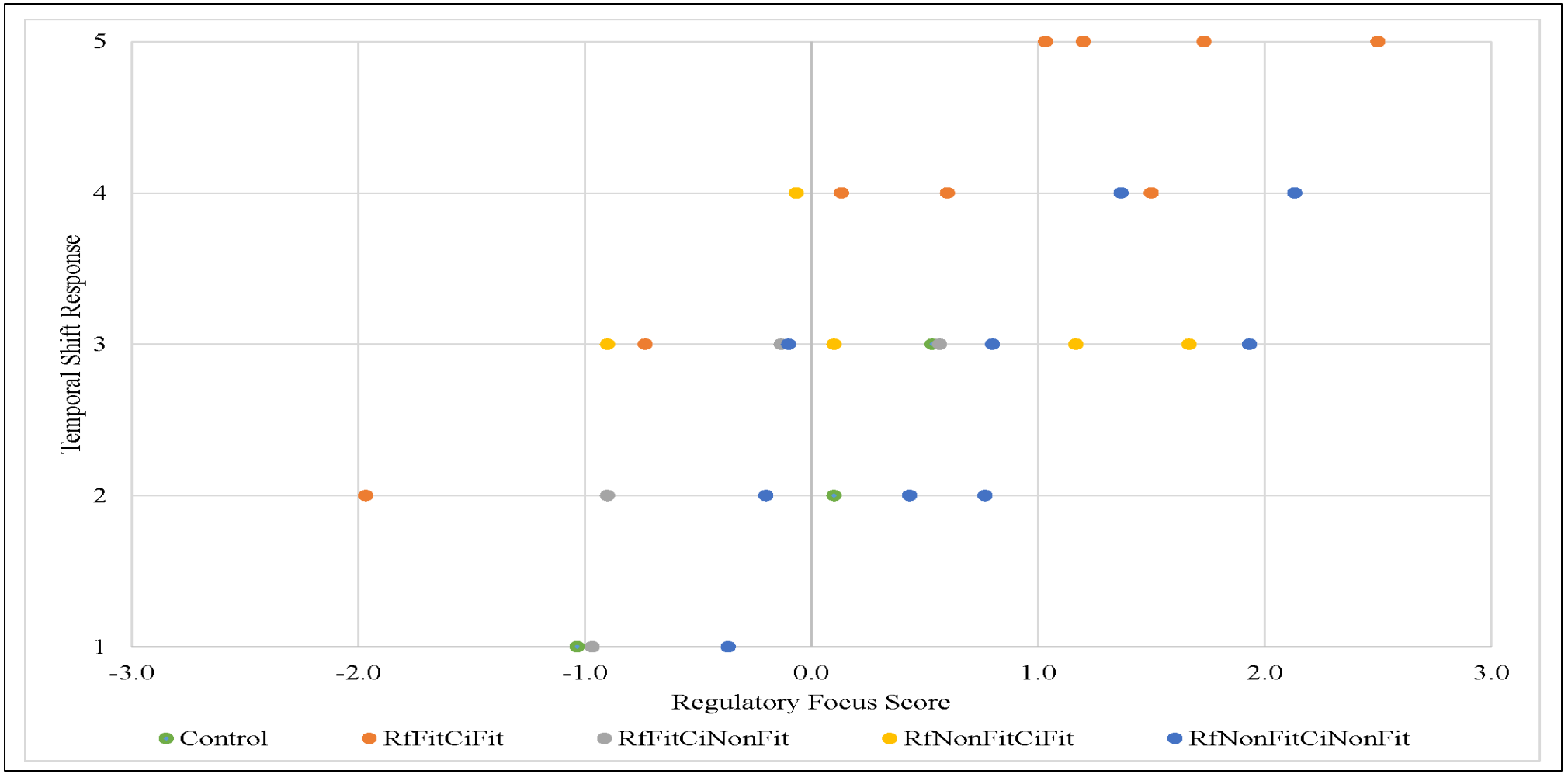
Cost of Energy with Sharing Charter



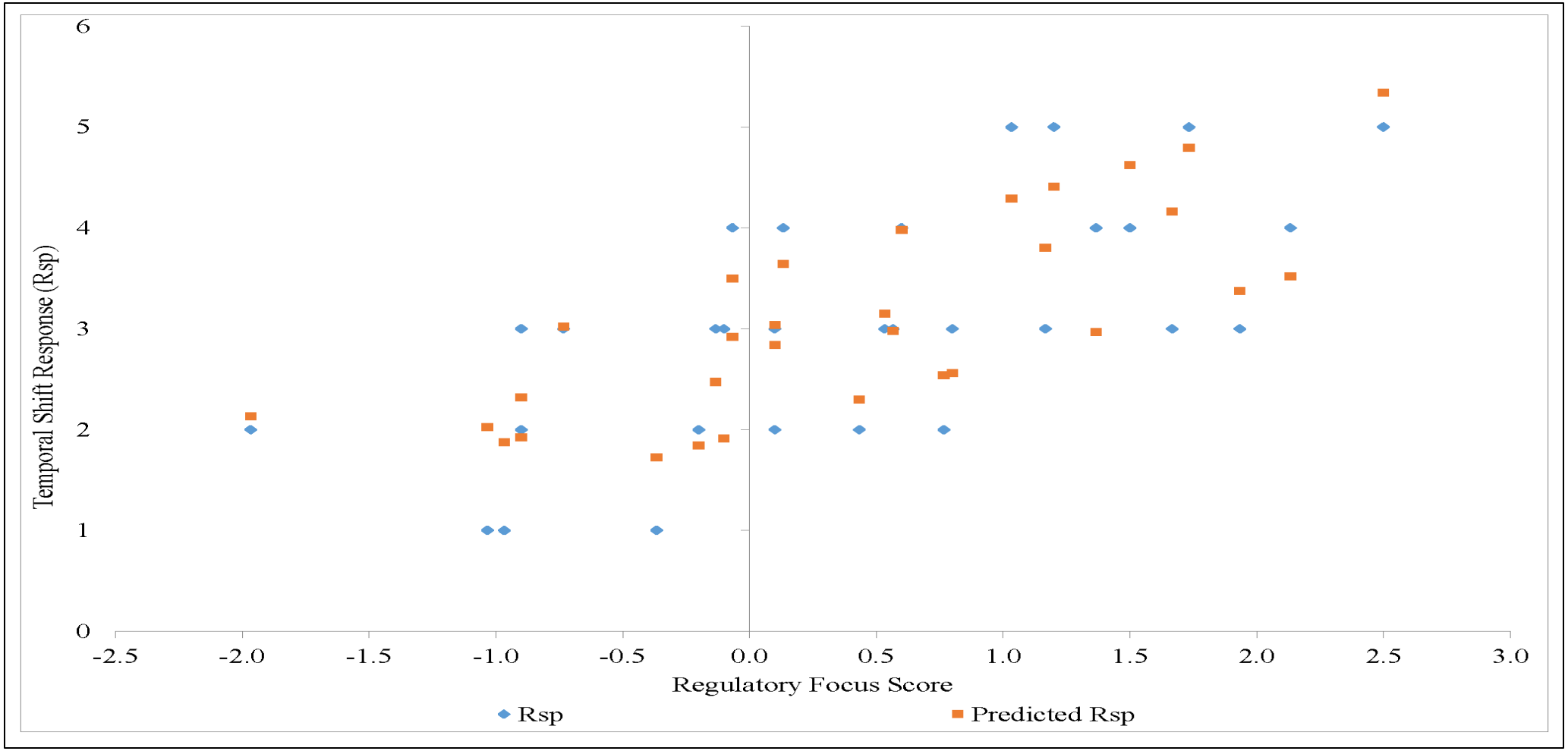
Annual Energy Charge with Sharing Charter



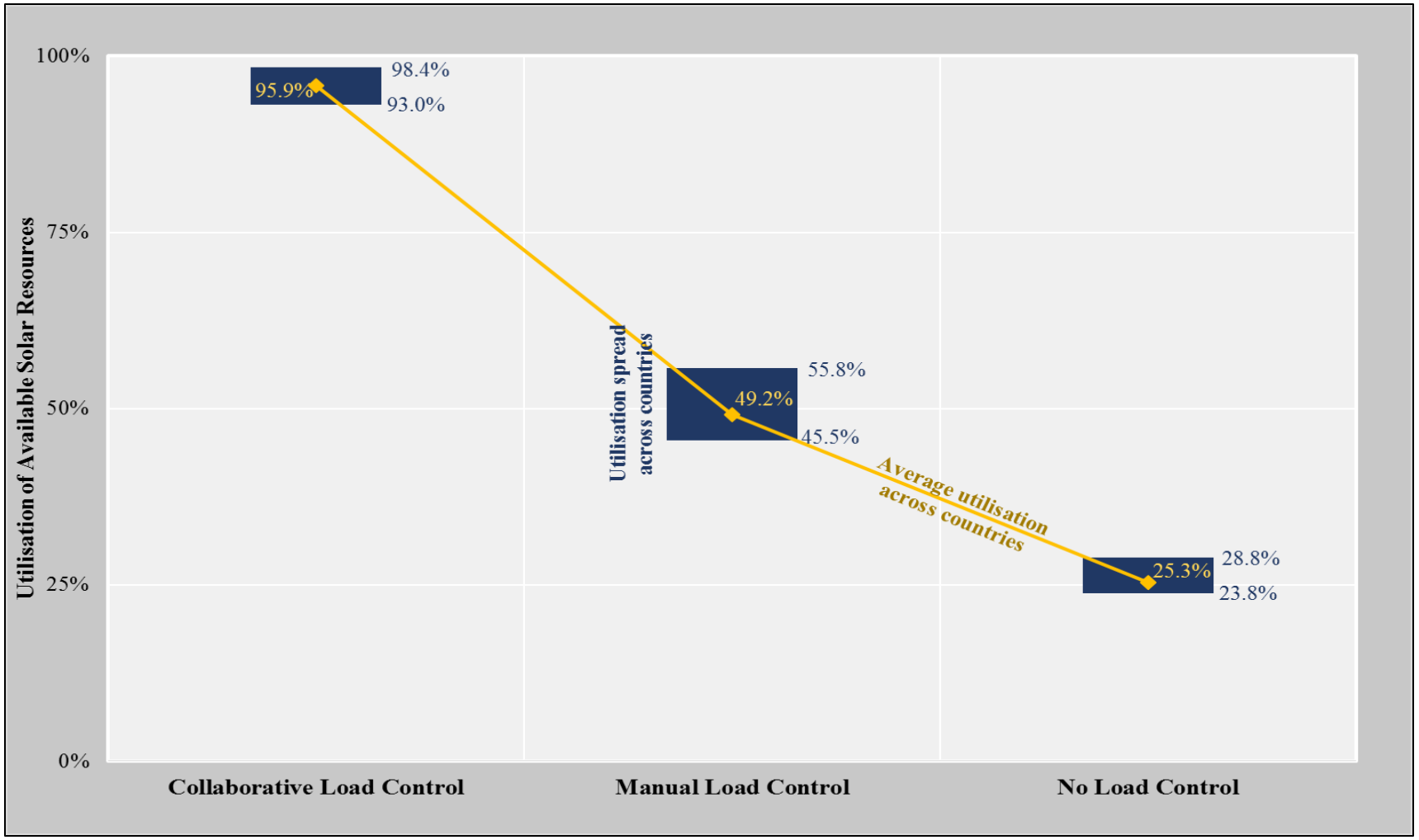
Temporal Shift Response



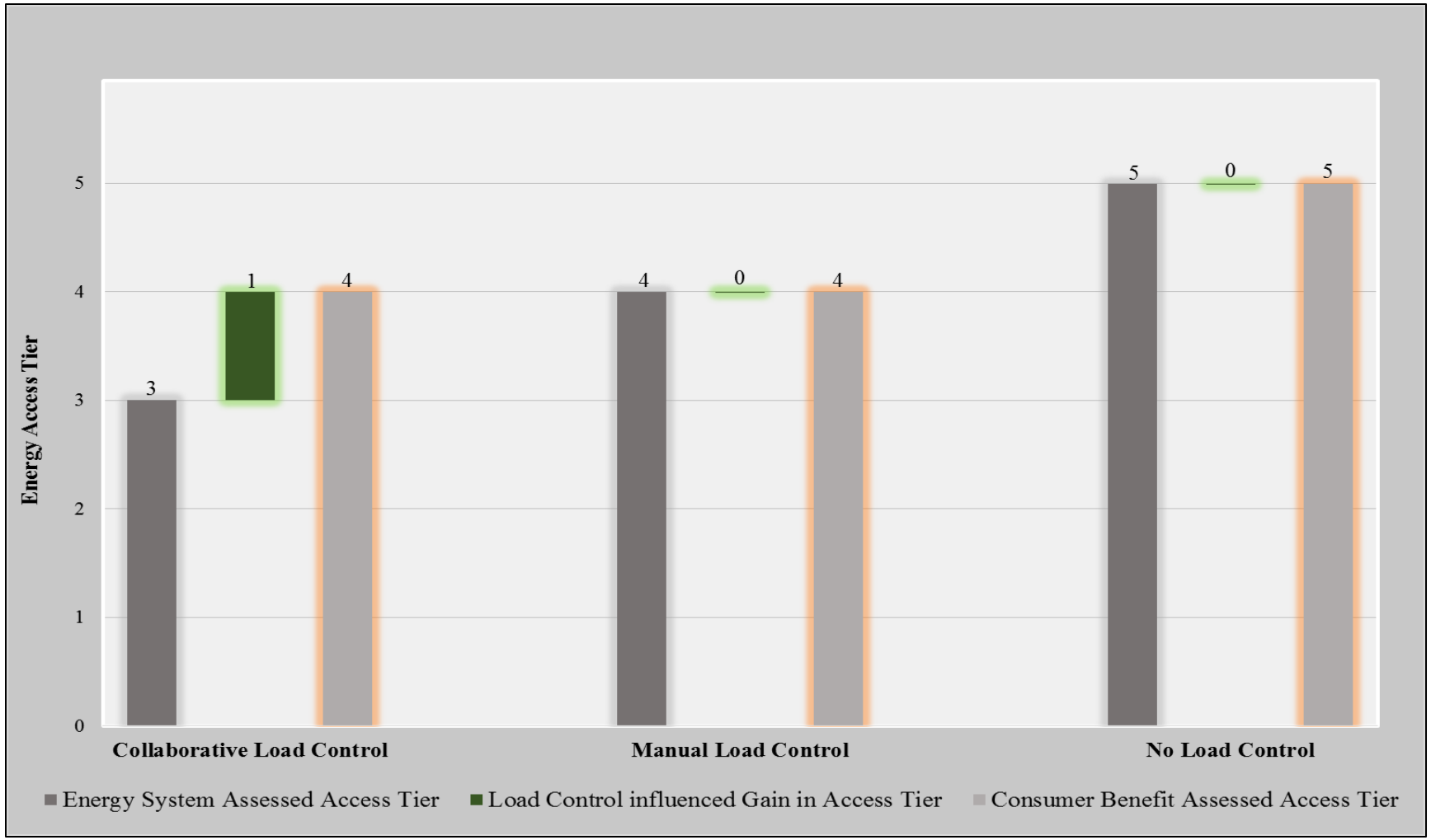
Temporal Shift Prediction



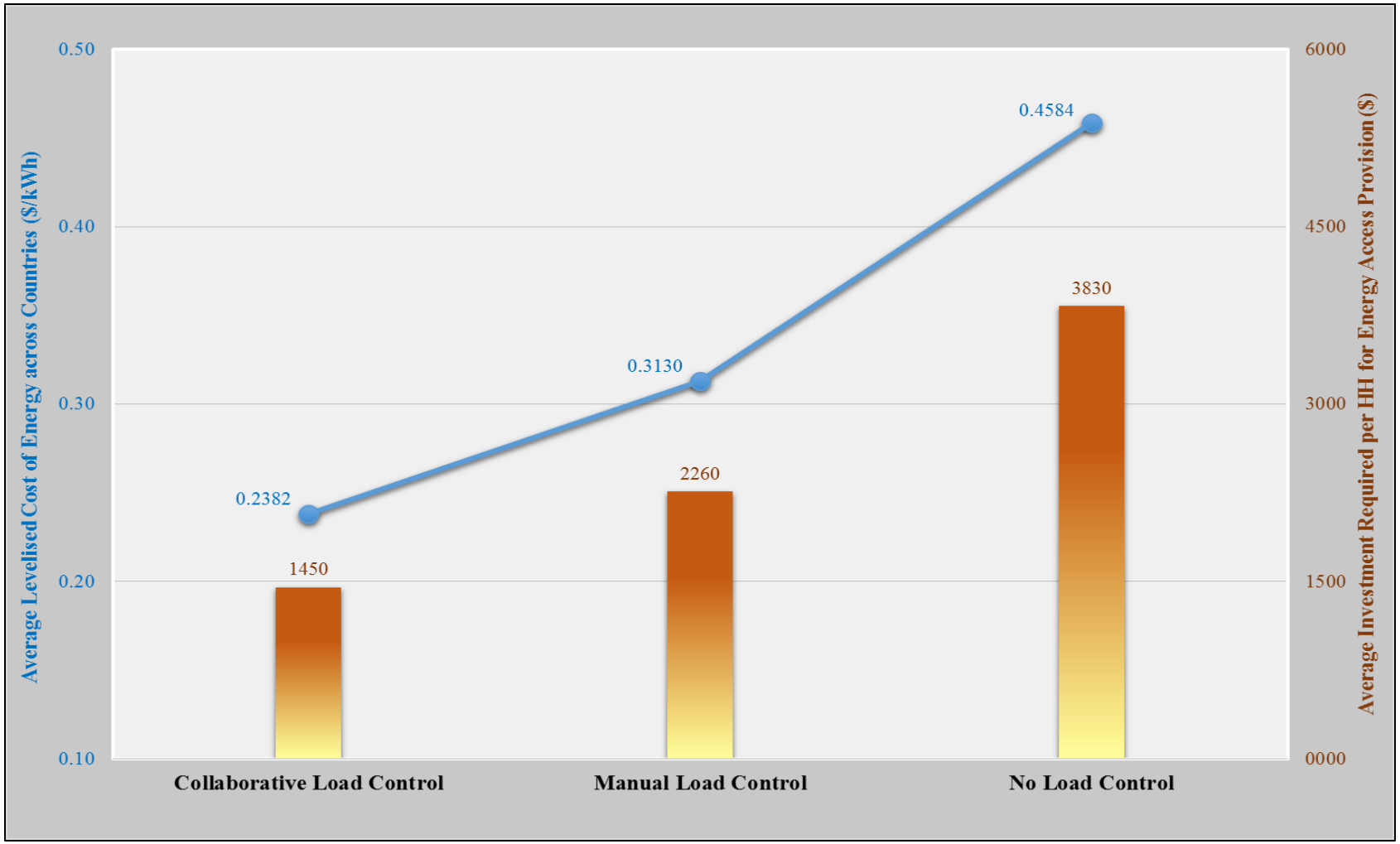
Resource Utilization in Off-grid



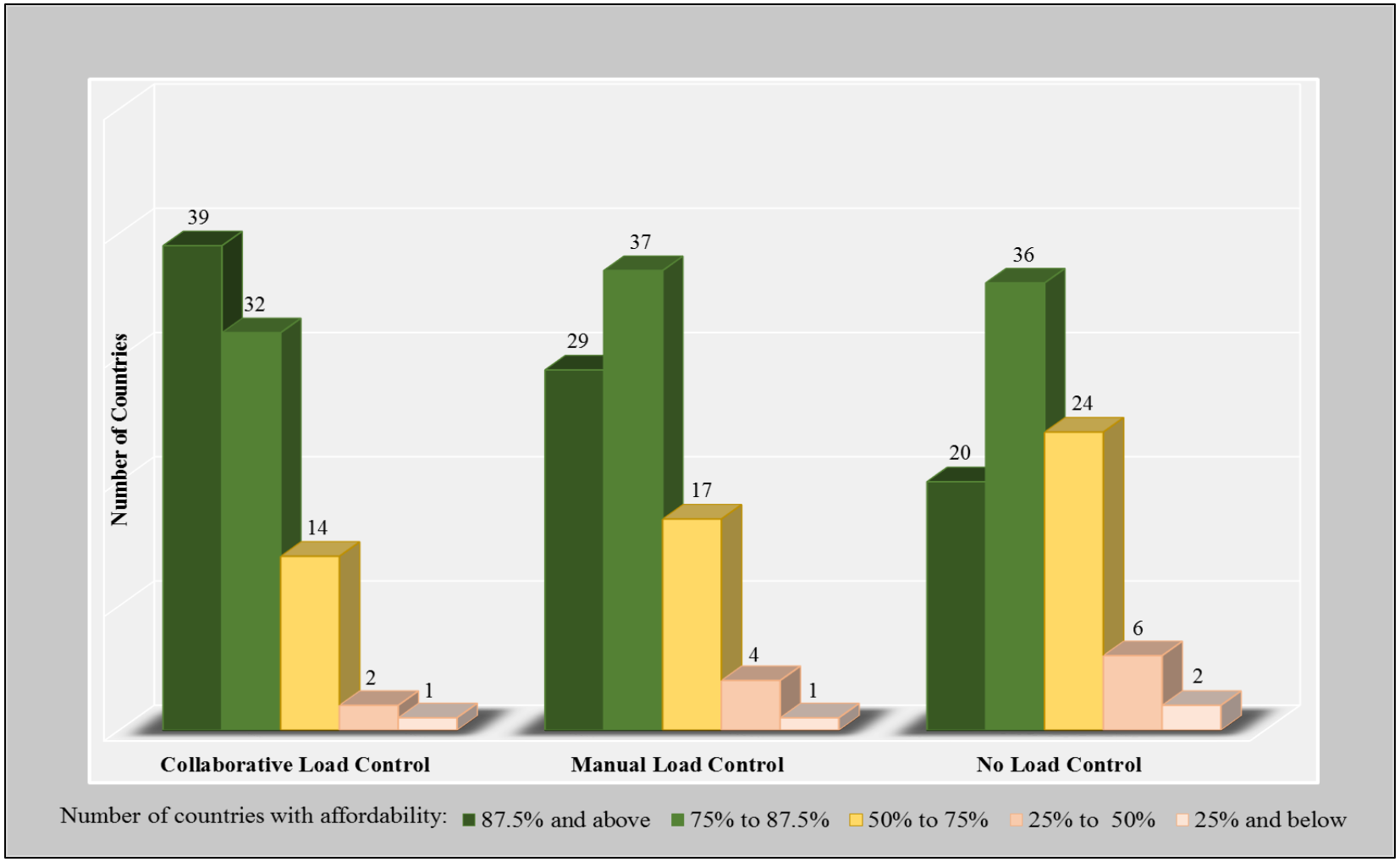
Collaborative Access Tier Gain in Off-grid



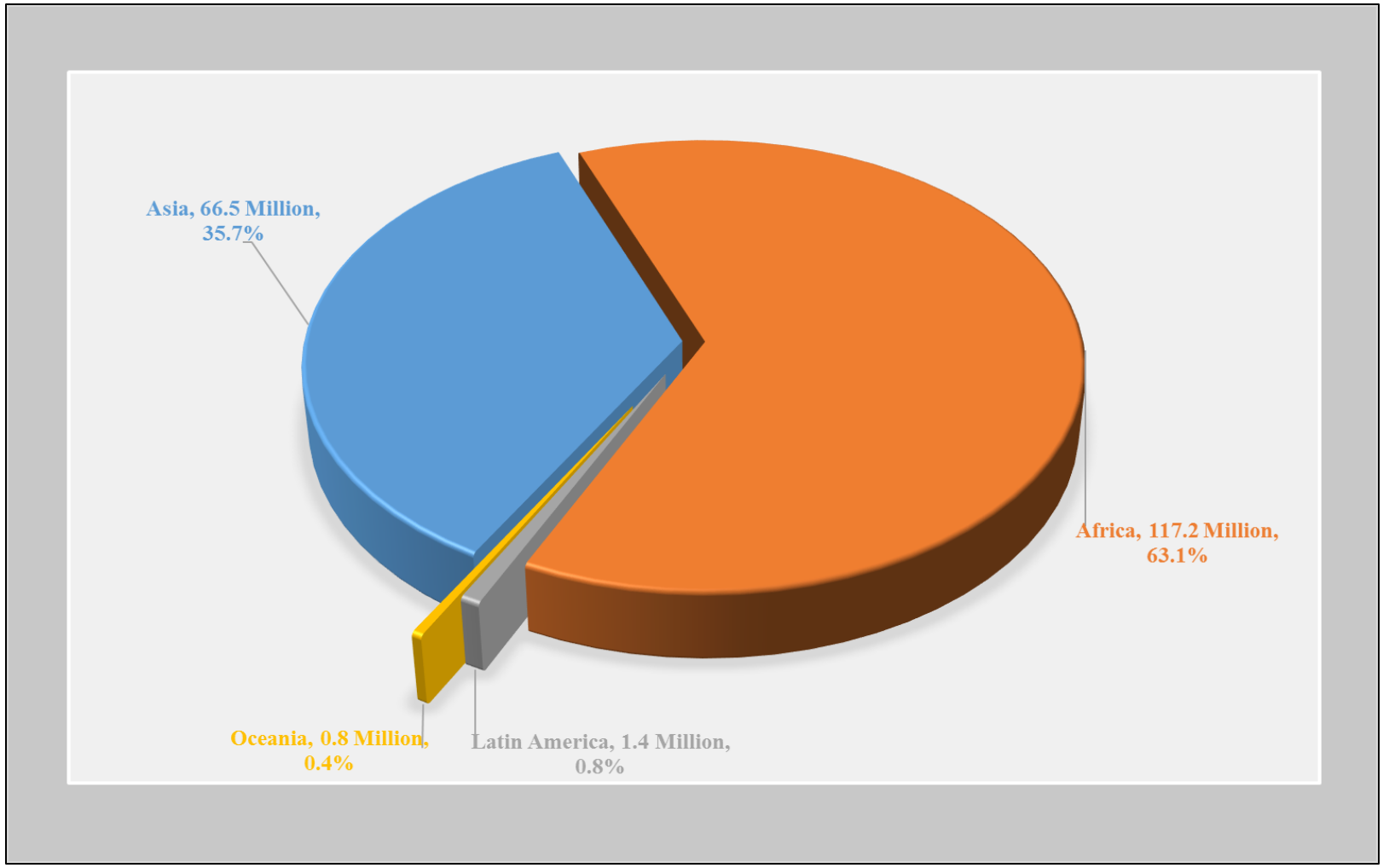
Investment and Cost of Energy in Off-grid



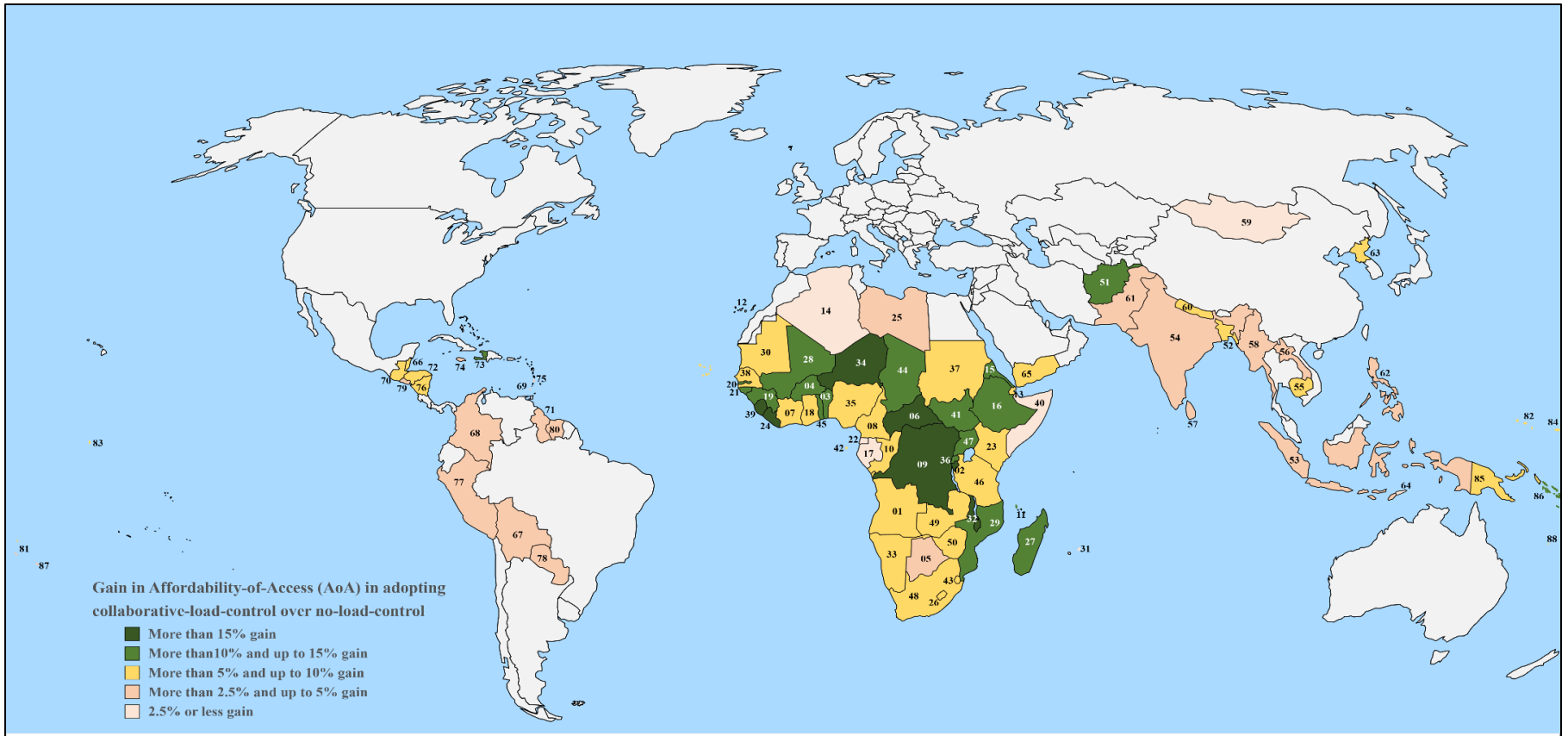
Additional Countries Can Afford Energy



Expanding Population Can Afford Energy



Gain in Affordability-of-Access



No	Country	LCOE ($ / kWh) CC	LCOE ($ / kWh) NC	AoA (%) CC	AoA (%) NC
01	Angola	0.23	0.44	89%	82%
02	Burundi	0.24	0.47	53%	21%
03	Benin	0.24	0.47	74%	62%
04	Burkina Faso	0.23	0.44	83%	69%
05	Botswana	0.23	0.43	88%	84%
06	Central African Republic	0.23	0.44	47%	32%
07	Cote d'Ivoire	0.25	0.48	86%	78%
08	Cameroon	0.24	0.45	80%	72%
09	Congo Democratic	0.24	0.47	58%	33%
10	Congo	0.24	0.47	82%	75%
11	Comoros	0.24	0.47	79%	69%
12	Cape Verde	0.23	0.45	88%	82%
13	Djibouti	0.23	0.43	84%	76%
14	Algeria	0.23	0.44	100%	99%
15	Eritrea	0.23	0.44	88%	76%
16	Ethiopia	0.23	0.44	84%	71%
17	Gabon	0.25	0.49	97%	94%
18	Ghana	0.24	0.47	86%	79%
19	Guinea	0.23	0.45	88%	76%
20	Gambia	0.23	0.44	86%	75%
21	Guinea-Bissau	0.24	0.45	66%	53%
22	Equatorial Guinea	0.25	0.48	96%	93%
23	Kenya	0.23	0.44	86%	77%
24	Liberia	0.25	0.47	75%	55%
25	Libya	0.23	0.43	92%	89%
26	Lesotho	0.24	0.45	72%	64%
27	Madagascar	0.23	0.44	76%	63%
28	Mali	0.23	0.43	87%	74%
29	Mozambique	0.24	0.45	58%	45%
30	Mauritania	0.23	0.44	94%	88%
31	Mauritius	0.25	0.48	98%	96%
32	Malawi	0.24	0.45	65%	48%
33	Namibia	0.22	0.42	78%	73%
34	Niger	0.23	0.43	68%	41%
35	Nigeria	0.24	0.45	88%	81%
36	Rwanda	0.24	0.47	77%	65%
37	Sudan	0.23	0.43	93%	87%
38	Senegal	0.23	0.44	86%	78%
39	Sierra Leone	0.24	0.47	81%	63%
40	Somalia	0.23	0.43	0%	0%
41	South Sudan	0.24	0.45	72%	59%
42	Sao Tome and Principe	0.25	0.49	93%	84%
43	Swaziland	0.25	0.48	85%	80%
44	Chad	0.22	0.42	74%	62%
45	Togo	0.24	0.47	73%	59%
46	Tanzania	0.23	0.45	87%	77%
47	Uganda	0.23	0.44	75%	62%
48	South Africa	0.23	0.44	76%	71%
49	Zambia	0.23	0.44	70%	62%
50	Zimbabwe	0.23	0.44	82%	72%
51	Afghanistan	0.23	0.44	90%	76%
52	Bangladesh	0.25	0.49	95%	89%
53	Indonesia	0.24	0.47	96%	94%
54	India	0.24	0.47	96%	92%
55	Cambodia	0.24	0.47	90%	83%
56	Laos	0.25	0.49	95%	91%
57	Sri Lanka	0.24	0.47	96%	93%
58	Myanmar	0.25	0.48	94%	89%
59	Mongolia	0.25	0.49	98%	97%
60	Nepal	0.25	0.48	92%	84%
61	Pakistan	0.24	0.47	95%	90%
62	Philippines	0.24	0.47	91%	86%
63	North Korea	0.27	0.52	48%	38%
64	Timor	0.24	0.47	98%	96%
65	Yemen	0.22	0.42	87%	77%
66	Belize	0.24	0.47	83%	77%
67	Bolivia	0.23	0.44	91%	86%
68	Colombia	0.24	0.47	90%	86%
69	Grenada	0.24	0.45	91%	88%
70	Guatemala	0.24	0.45	87%	82%
71	Guyana	0.24	0.47	91%	86%
72	Honduras	0.24	0.47	81%	74%
73	Haiti	0.23	0.45	79%	66%
74	Jamaica	0.24	0.47	91%	86%
75	Saint Lucia	0.24	0.45	89%	85%
76	Nicaragua	0.24	0.47	86%	80%
77	Peru	0.23	0.45	94%	91%
78	Paraguay	0.24	0.47	90%	86%
79	El Salvador	0.23	0.43	95%	92%
80	Suriname	0.24	0.45	83%	78%
81	Fiji	0.25	0.48	96%	93%
82	Micronesia	0.25	0.49	87%	79%
83	Kiribati	0.22	0.42	86%	76%
84	Marshall Islands	0.24	0.45	88%	81%
85	Papua New Guinea	0.25	0.48	87%	79%
86	Solomon Islands	0.25	0.48	84%	72%
87	Tonga	0.25	0.48	93%	88%
88	Vanuatu	0.25	0.49	87%	78%

Implications

Decentralization – Architectural and Political

- Energy Security and the Food Chain
  - Possibility
    - Distributed sources enable remote processing
    - Improved efficiency favourably impacts necessity
  - Affordability
    - Temporally diverse sources for conforming usage
    - Technological progress may aid active engagement
  - Desirability
    - Architectural decentralization facilitates resilience

Decentralization – Architectural and Political

- Energy Policy and the Food Chain
  - Possibility
    - Silo-evading focus may kindle climate finance
    - Measured service level progression attainable
  - Affordability
    - Improved reliability may not trade affordability
    - Dynamic community aspiration regulates usage
  - Desirability
    - Political decentralization empowers consumers

Publications and References

Publications

- Grid-edge
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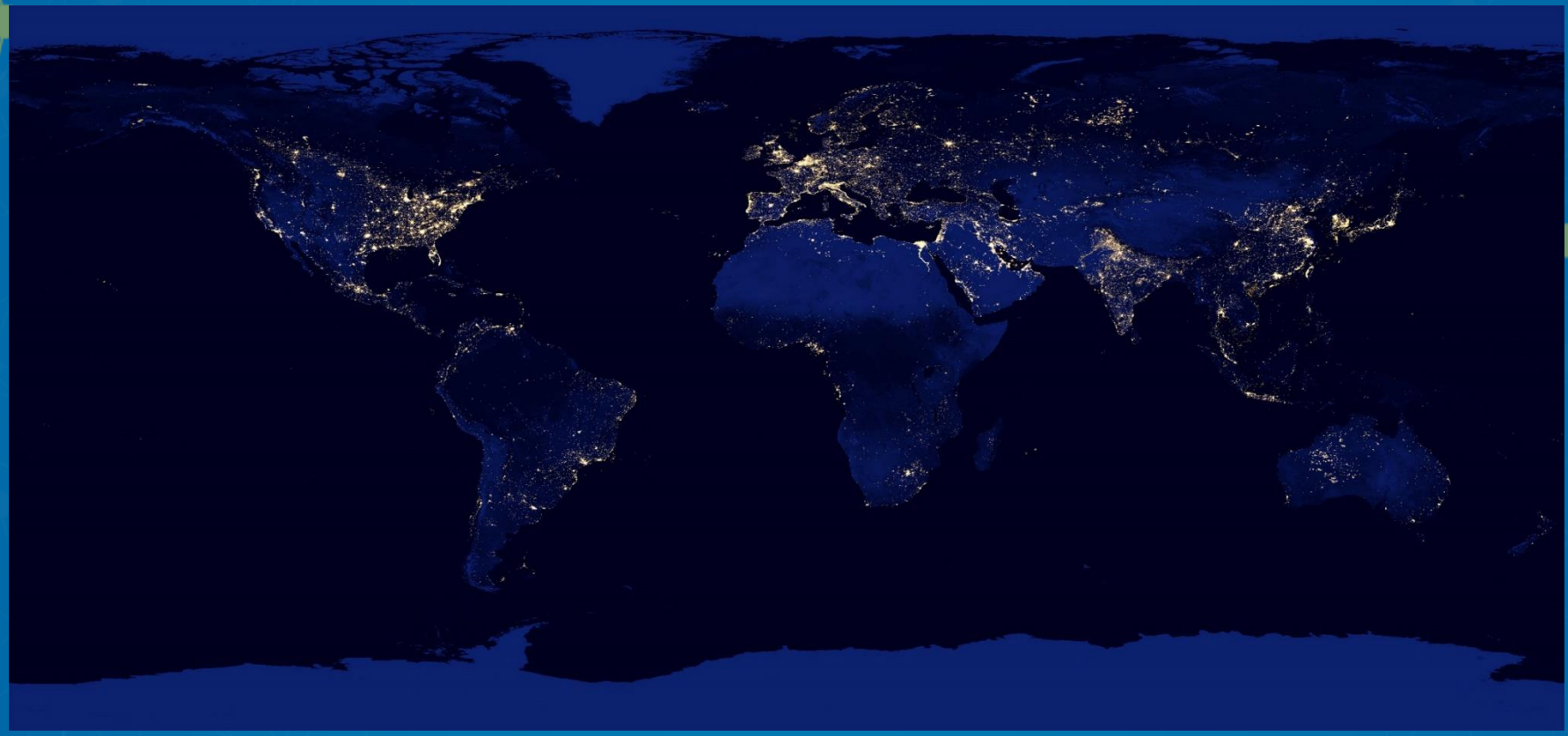

Want to make a difference? Let us join hands to end hunger and ensure food security for all

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