AUROVILLE

RENEWABLE ENERGY SOURCING PLAN

2020-2030

January 2021

A U R O V I L L E

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Auroville Tdc L'avenir d'Auroville Auroville Town Development Council

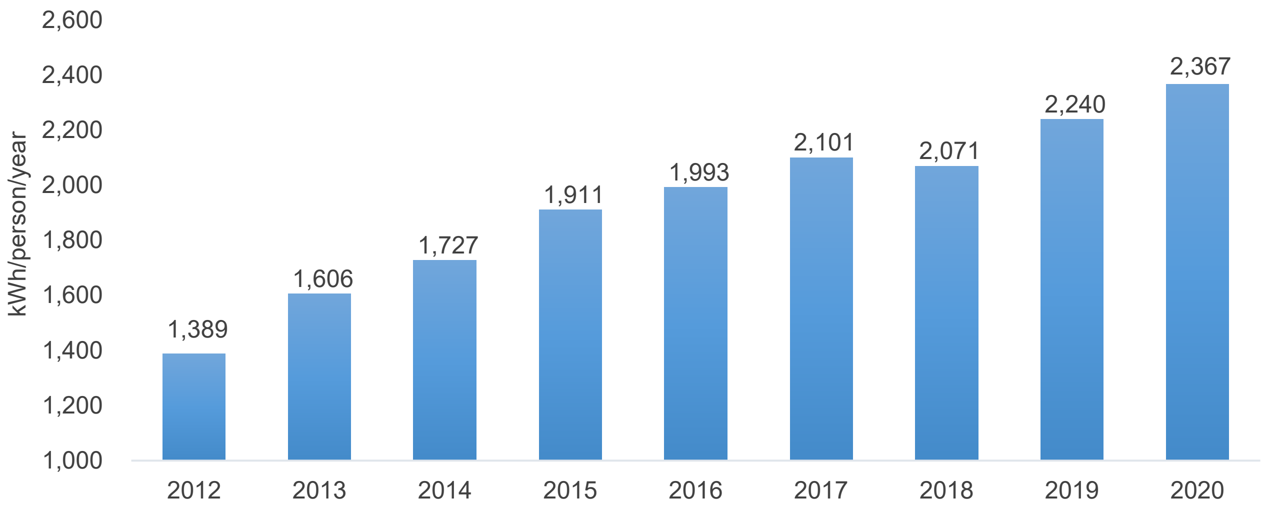
AurovilleConsulting

SUMMARY

Increased Electricity Consumption

Auroville's overall electricity demand has increased by a factor of 2 from 2012 to 2020. The annual per capita consumption increased by 47% during the same time period.

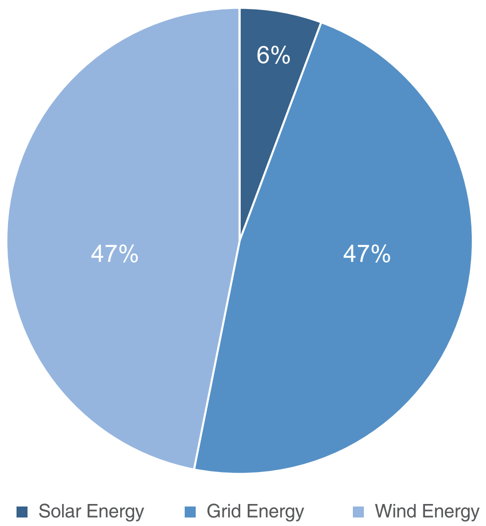
Figure 1 Per capita electricity consumption (kWh/person/year)



Sourced From Renewables

As of 2020 approximately 6% of Auroville's electricity consumption is sourced from renewables. Considering wheeling of wind energy, 47% of Auroville's electricity consumption in 2020 is sourced from the TANGEDCO (Tamil Nadu Generation and Distribution Corporation) grid. Electricity supplied from TANGEDCO is largely sourced from thermal energy sources (~ 70% is from coal power plants).

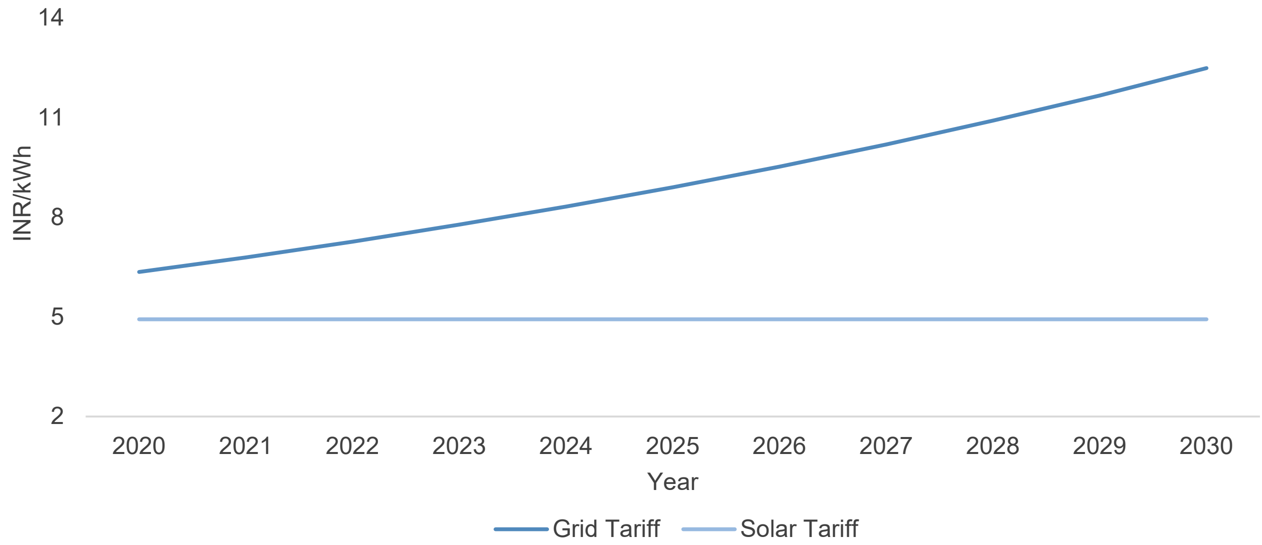
Figure 2 Energy share by source 2020



Renewable Energy is Affordable

The electricity tariff of Auroville's HT connection (tariff II-A) stands at INR 6.35 per kWh as of 2020. This tariff is expected to increase in the future by at least the rate of inflation. Distributed renewable energy sources, such as solar energy, are lower than the cost of grid supply. The cost of energy storage has seen dramatic reductions in the past years. Further cost reduction on energy storage is expected in the near future thereby making the combination of solar plus energy storage both a financially attractive and environmentally sound proposition to Auroville.

Figure 3 Projected tariff evolution



Towards a Resilient Energy Future

The deployment of distributed renewable energy generation and energy storage solutions paired with effective demand response strategies and smart technologies will allow Auroville to develop a resilient and robust mini-grid. Such a mini grid will be capable of operating in 'grid-islanding' mode in the case of grid outages, providing uninterrupted, clean and affordable power supply even during extreme events such as cyclonic storms.

1 THE GLOBAL NEED

The Special Report on Global Warming of 1.5°C (SR 15, October 2018) by the Intergovernmental Panel for Climate Change (IPCC) estimates the impacts of global warming of 1.5 °C above pre-industrial levels. One of the key messages that comes out strongly from this report is that the world is already seeing the consequences of 1.0°C of global warming through more extreme weather, rising sea levels and diminishing Arctic sea ice, among other changes. The report states that emissions in line with current pledges under the Paris Agreement (known as Nationally-Determined Contributions or NDCs), global warming is expected to surpass 1.5°C, even if they are supplemented with very challenging increases in the scale and ambition of mitigation after 2030.

The report also states that limiting warming to 1.5°C implies reaching net zero CO2 emissions globally around 2050 and concurrent deep reductions in emissions of non-CO2 climate forcers, particularly methane. Risks to natural and human systems are lower at 1.5oC than at 2oC. The impacts at 2oC are particularly catastrophic for developing nations like India. Human-induced global warming has already reached 1oC.

Drastically decarbonising existing energy systems by investing in renewable energy systems, including solar, at an unprecedented scale and pace is required to address global warming. Increasing penetration of renewable energy systems in the distribution network of utilities comes with its own set of challenges. Renewable energy is not always available (“infirm power”) and even when available there are fluctuations in output. Therefore an increase in renewable energy generation needs to go hand-in-hand with other measures including energy storage and smart grid management (including demand-side management).

2 AUROVILLE’S RE HISTORY

Auroville has been active in renewable energy since the early years, starting with windmills for water pumping and stand-alone solar PV systems with battery banks. In 2012 Auroville pioneered rooftop grid-connected solar energy by proposing to the Tamil Nadu Government that pilot projects may be undertaken in Auroville with grid-connectivity. The pilot projects implemented in Auroville in close cooperation with the Tamil Nadu Government and the Tamil Nadu Generation and Distribution Corporation (TANGEDCO) contributed to the finalisation and notification of the Tamil Nadu Solar Energy Policy 2012 in which rooftop solar energy was given an important role.

In 2020 Auroville Consulting in cooperation with Auroville units Sunlit Future, Auroville Electrical Service and Cynergy realised the first phase of a Smart Mini Grid project in Auroville. The project includes distributed solar energy generation and storage systems, smart energy metering, demand-side management and other components that contribute to transitioning to a sustainable energy future. The Smart Mini Grid project includes solar PV energy systems with a total capacity of 700 kW of which 122 kW has already been installed after a corporate CSR grant was received for the first phase of the project. The avoided cost of TANGEDCO grid power is being used to maintain the solar energy generation and storage systems and to create additional solar energy generation and energy storage capacity. Even a 700 kW will not cover Auroville’s current electricity demand. Therefore, this long term (10-year) electricity sourcing plan has been prepared.

3 AUROVILLE’S RE FUTURE

To transition Auroville towards a net zero carbon electrical energy future will require accelerating deployment of renewable energy sources and implementing comprehensive energy efficiency programs. Distributed, locally installed renewable generation capacity, energy storage solutions, demand side management programs and an IoT integrated electrical distribution infrastructure are needed to facilitate this transition. The deployment of distributed , locally installed, renewable energy systems has the potential to reduce Auroville’s overall electricity cost, improve supply quality and reliability and contribute to a more resilient energy system. A 100% sourcing of Auroville’s electricity demand from renewable sources can be achieved by 2030.

4 ABOUT THIS REPORT

The Auroville Renewable Energy Sourcing plan explores different 10-year scenarios to accelerate Auroville’s progress towards a renewable energy future. Its objective is to estimate future electricity demand based on population and electricity consumption growth assumptions and energy efficiency load reduction strategies and to present 6 different sourcing strategies. This plan considers only the ‘on-campus’ electricity consumption, which is the load currently connected - or expected to be connected in future - to Auroville’s internal distribution network. Load centres outside the Auroville masterplan area or in the green belt of Auroville are not part of this exercise.

The 6 scenarios considered are:

1. Business as Usual (BAU) – no increase in distributed renewable energy generation and storage and primarily supply from grid.
2. Solar - Best Economic Case
3. Solar plus Energy Efficiency – Best Economic Case
4. Solar Plus Energy Storage - Best Economic Case
5. Solar Plus Energy Storage & Energy Efficiency – Best Economic Case
6. Multiple distributed RE sources & Energy Efficiency – Grid islanding capability, deployment of solar, energy storage and bio-energy systems.

1. Business as Usual (BAU)

Determines Auroville’s electricity expenses from 2020 to 2030 assuming that no additional solar energy capacity or other distributed renewable energy sources are deployed. Electricity will be sourced from the TANGEDCO grid at prevailing tariff rates.

2. Solar – Best Economic Case

Determines the annual solar energy capacity addition required to maximise economic gains to Auroville. This considers the financial savings to Auroville on account of the lower cost of solar energy generation in comparison to the prevailing grid tariff payable to TANGEDCO (bill management). As per current Tamil Nadu Solar Energy, HT consumers are not eligible to receive payment for surplus solar energy exported to the grid. Therefore under this scenario surplus solar energy export to the grid has been minimized to meet the overall objectives of achieving the highest savings on Auroville’s electricity bill.

3. Solar & Energy Efficiency – Best Economic Case

Same as Case 2 Solar- Best Economic Case assuming a reduction on electricity consumption compared to the Business as Usual case on account of an aggressive energy efficient target of 30% by 2030.

4. Solar Plus Energy Storage – Best Economic Case

In addition to solar energy generation lithium-ion energy storage systems are being considered in order to optimize the financial returns to Auroville (bill management).

5. Solar Plus Energy Storage & Energy Efficiency– Best Economic Case

Same as Case 4 Solar Plus Energy Storage – Best Economic case assuming a reduction on electricity consumption on account of an aggressive energy efficient target of 30% by 2030.

6. Multiple distributed RE sources – Grid Islanding Capability

Unlike the early two scenarios economic returns are not the key criteria for the sizing and planning of distributed renewable energy generation and storage capacities. The objective is to be able to operate the entire Auroville campus on grid-islanding mode if and when necessary. In addition to solar plus energy storage capacity, bio-energy systems are deployed. Wind energy currently wheeled is assumed to be sold to TANGEDCO or third parties and wheeling to Auroville will be stopped. A reduction in energy consumption as compared to the Business as Usual scenario of 30% by 2030 on account of energy efficiency is assumed. Bio-energy systems have the additional advantage of providing base load, having a load following capability and a fairly fast response rate to power demand fluctuations.

5 METHODOLOGY

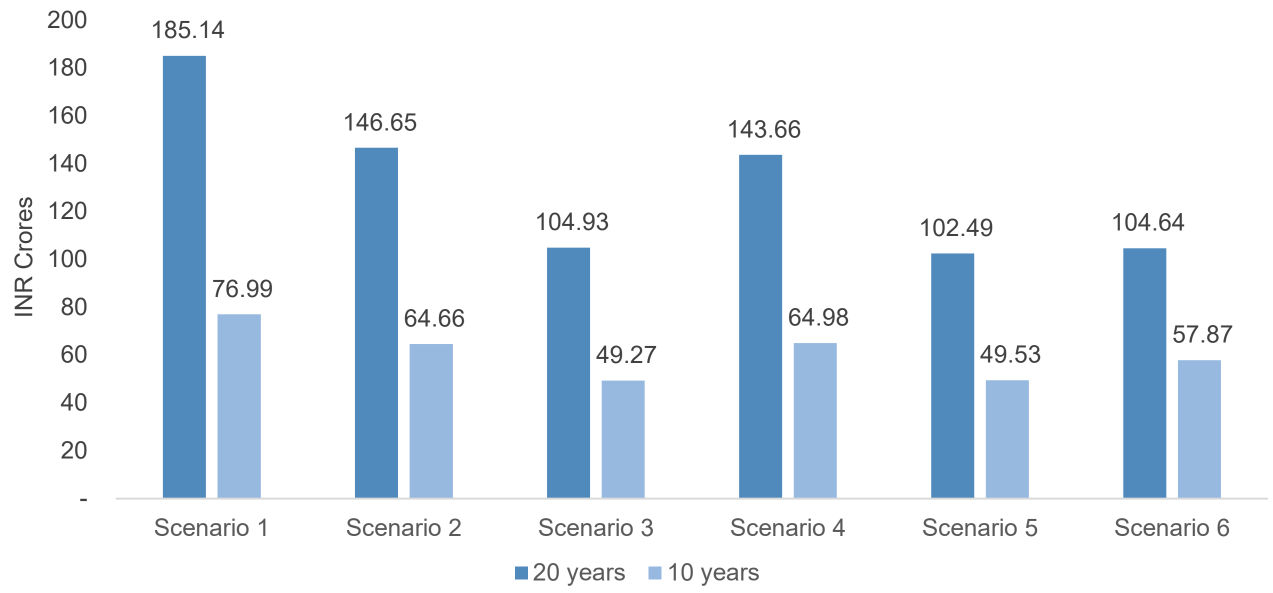
The sourcing tool was developed in Microsoft Excel. Generalized Reduced Gradient (GRG) nonlinear method of solver plug-in of excel is used to do the optimization of different energy sources. For each scenario, the solver will optimize the capacity of different energy sources in order to minimize the net present value (NPV) of 10 years. For scenario 4 and 5, the constraint for optimization is on surplus solar energy export to the grid which is assumed as 10% of the total surplus solar energy generated. For scenario 6, the constraint for optimization includes (a) energy export to grid with an upper limit of 20% of the surplus solar energy generated and (b) import from grid with an upper limit of 3% of the total consumption. Limitations on contracted demand with the utility are not considered in this analysis.

6 ANALYSIS

10-year discounted cost of supply by scenario

All alternative scenarios compared to the BAU case indicate a substantial reduction in Auroville's electricity sourcing cost. Scenario 3 and 5 are expected to result in the lowest 10-year electricity sourcing costs. The reduction of electricity consumption on account of energy efficiency interventions is a major contributor to the cost reduction. It may be highlighted that even scenario 6 promises to be a financially attractive opportunity to be considered. Additional a 20-year electricity cost projection by scenario was undertaken in order to evaluate the long-time financial benefits in comparison to the capital investments. This projection assumes no increase in electricity demand from 2030 onwards (refer to Figure 4).

Figure 4: Net present value of electricity cost for 10 and 20 years



10-year energy balance by source

Scenario 6 is close to achieving a 100% or electricity sourced from locally generated renewable energy generation and storage. Less than 1% of Auroville's expected 10-year electricity demand will be source from the TANGEDCO grid. All other alternative scenarios will rely on close to 50% electricity supply from the grid (refer to Figure 5).

Export of surplus energy to the grid by scenario

Scenario 4 and 5, both have zero export of surplus solar energy to the TANGEDCO grid. All solar energy will either be consumed at the time of generation or stored for consumption during non-solar energy generation hours. Export of surplus energy is highest in scenario 2 and 3.

Currently surplus solar energy exported to the grid for behind-the-meter systems is not credited by TANGEDCO to Auroville. Scenario 4 and 5 indicate zero export of surplus RE to the TANGEDCO grid on account of the introduction of energy storage. Scenario 6 results in moderate export to the TANGEDCO grid over the 10 year time period (refer to Figure 6).

Figure 5: 10-year energy balance by source for different scenarios

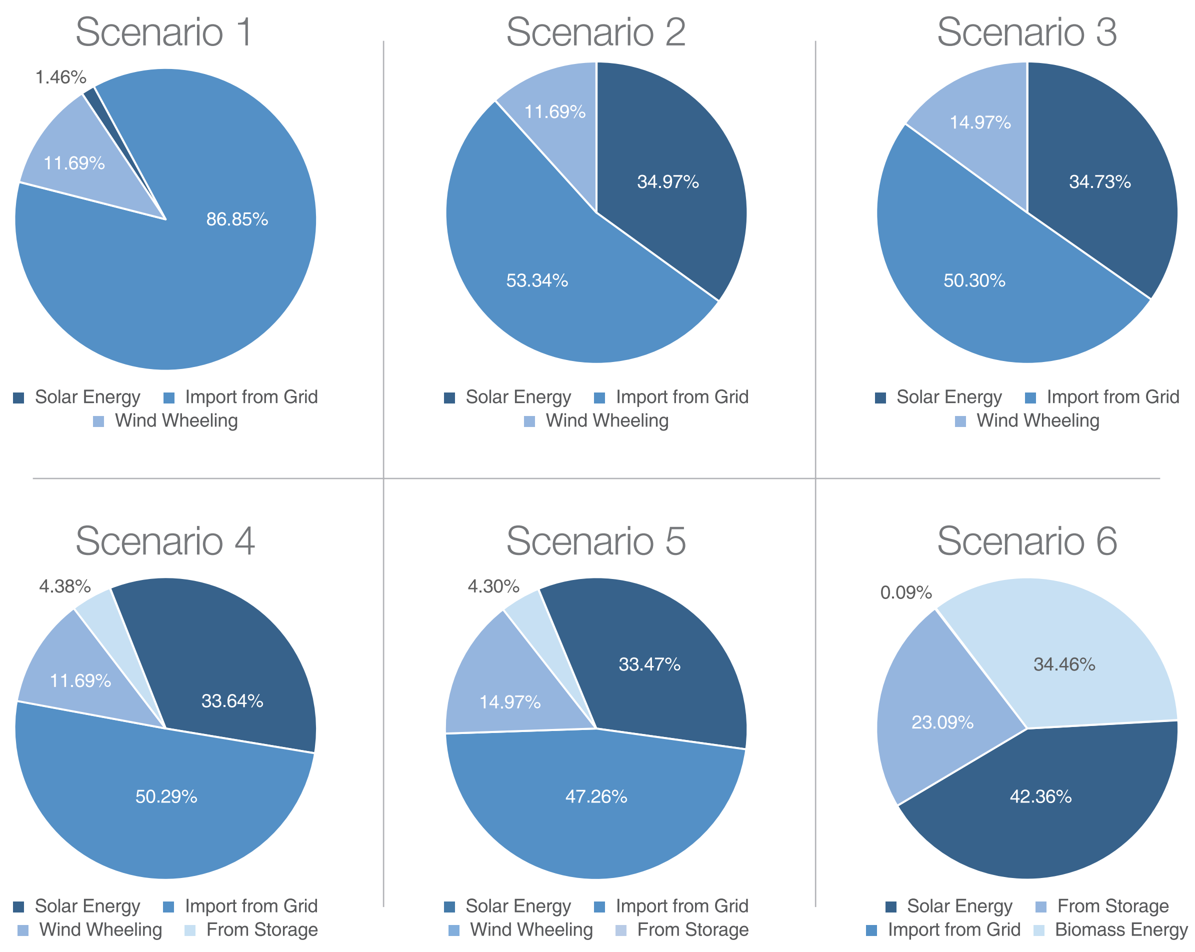
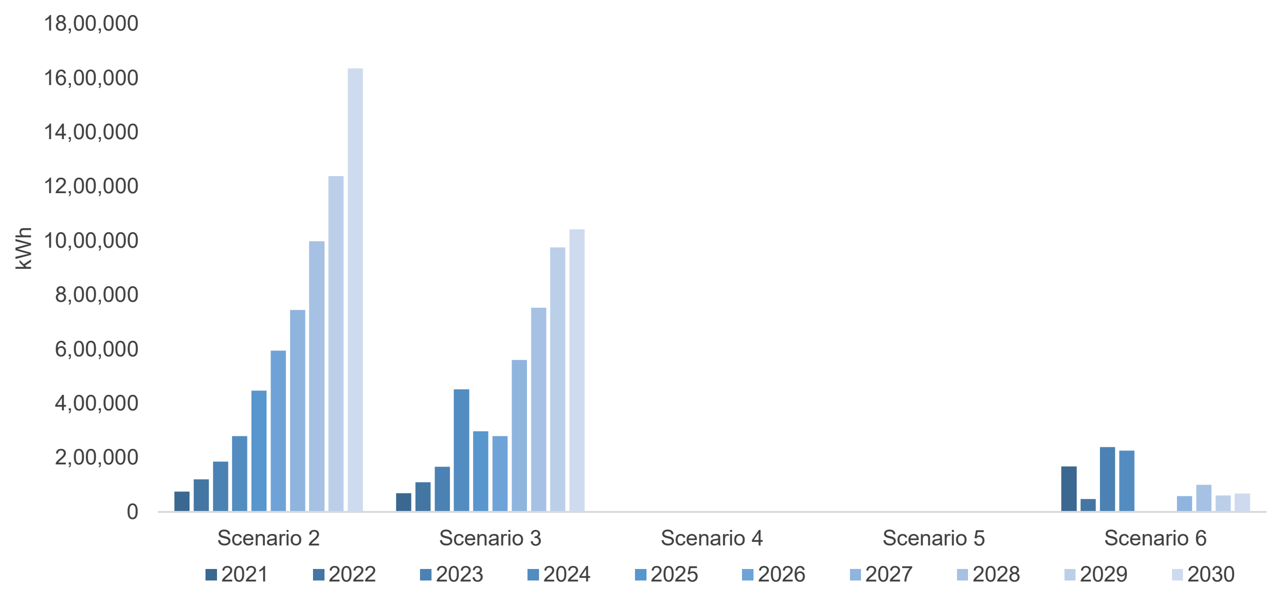


Figure 6: Energy export to grid for different scenarios



Cumulative distributed energy generation and storage capacity addition by scenario

Scenario 4 requires the highest energy storage capacity due the absence of energy efficiency interventions. Scenario 6 on the other hand results in the highest capacity addition of solar and bio-energy capacities (refer to Figure 7). Estimated annual capacity addition by scenario and technology is provided in Table 1.

Cumulative capital investment requirement by scenario

Scenario 6 requires the highest capital investment with an estimated INR 82.93 Crores over 10 years. Though investment cost is higher for scenario 6, almost 99% of Auroville's projected electricity demand is met by distributed energy resources, this provides energy security and partial grid independence. Scenarios 2 and 3 are low investment scenarios as they exclude energy storage and bio-energy generation. However only 34% of total electricity demand will be met from distributed renewable energy generation on site (refer to Figure 8). Estimated annual investment requirements by scenario and technology is listed in Table 2. All scenarios, except scenario 4, show a positive net benefit in terms of return over investment (refer to Figure 11).

Figure 7: Cumulative capacity requirement by 2030

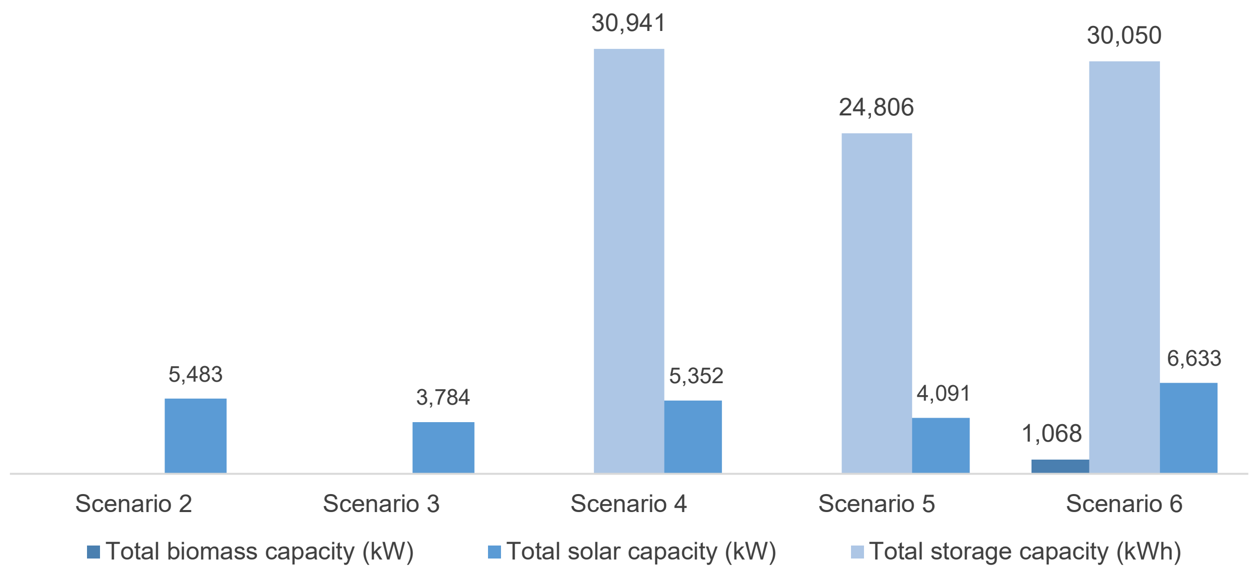


Table 1: Annual capacity addition for different scenarios

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Scenario 2	Solar capacity addition (kW)	888.31	390.55	468.46	562.59	722.76	480.45	508.27	660.46	677.17	885.08	**6,244.10**
Scenario 3	Solar capacity addition (kW)	834.05	307.40	418.05	570.71	-	-	481.11	497.48	551.63	-	**3,660.43**
Scenario 4	Solar capacity addition (kW)	710.21	378.97	514.07	464.96	638.57	397.98	554.96	766.01	802.75	1,334.91	**6,563.39**
	Storage capacity addition (kWh)	2,864.13	3,231.42	3,521.12	3,661.31	3,731.78	3,725.78	3,651.08	3,447.59	3,106.52	2,604.35	**33,545.07**
Scenario 5	Solar capacity addition (kW)	716.41	264.38	460.67	237.20	519.67	304.75	294.43	519.20	650.14	823.47	**4,790.32**
	Storage capacity addition (kWh)	2,547.45	2,684.97	2,779.80	2,845.98	2,870.17	2,866.51	2,833.68	2,754.84	2,622.94	2,428.33	**27,234.66**
Scenario 6	Solar capacity addition (kW)	2,764.79	0.00	0.00	250.01	998.31	620.22	350.03	524.50	1,001.23	240.41	**6,749.51**
	Storage capacity addition (kWh)	12,000.00	1,500.09	3,000.07	2,000.00	2,000.00	2,018.98	2,530.88	2,500.00	2,500.00	-	**30,050.01**
	Biomass capacity addition (kW)	-	357.00	711.04	-	-	-	-	-	-	-	**1,068.05**

Figure 8: 10- year total investment by scenario (discounted cost)

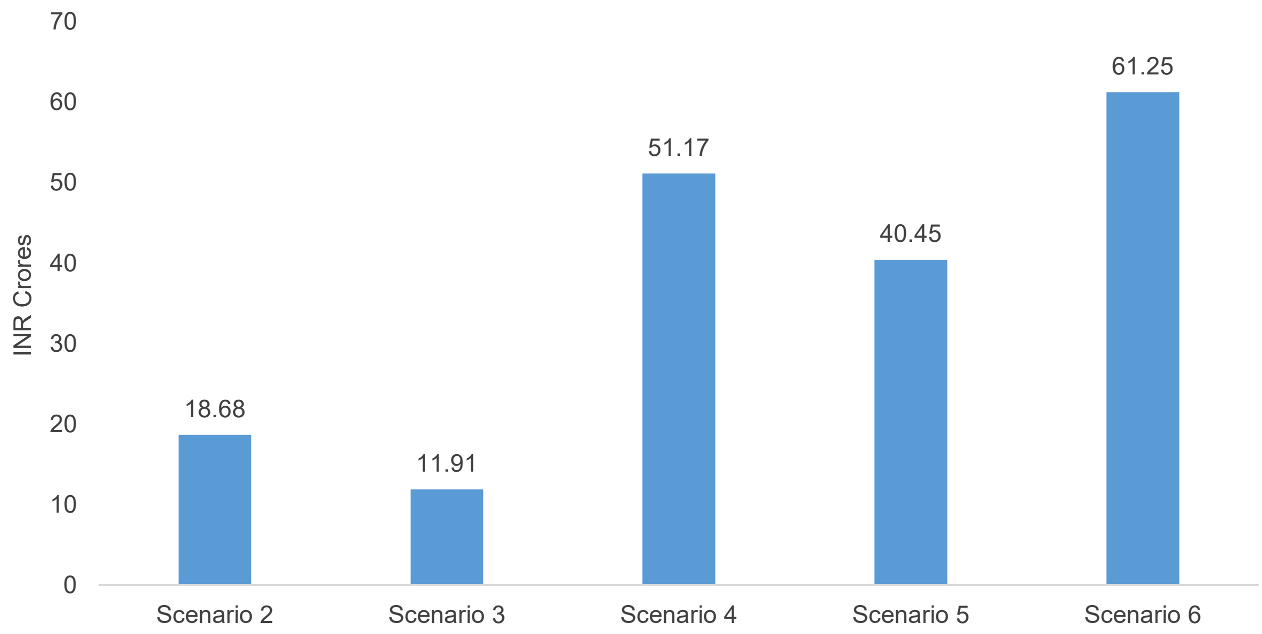


Table 2: Annual capital investment for different scenarios

	Investment cost (INR Crores)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Scenario 2	**Solar capacity addition**	**4.26**	**1.81**	**2.17**	**2.61**	**3.35**	**2.23**	**2.36**	**3.06**	**3.14**	**4.10**	**29.09**
Scenario 3	**Solar capacity addition**	**4.00**	**1.43**	**1.94**	**2.65**	**-**	**-**	**2.23**	**2.31**	**2.56**	**-**	**17.11**
Scenario 4	Solar capacity addition	3.41	1.76	2.38	2.16	2.96	1.84	2.57	3.55	3.72	6.19	30.54
	Storage capacity addition	4.30	4.80	5.23	5.44	5.54	5.53	5.42	5.12	4.61	3.87	49.86
	Total	**7.71**	**6.56**	**7.61**	**7.59**	**8.50**	**7.38**	**7.99**	**8.67**	**8.33**	**10.06**	**80.40**
Scenario 5	Solar capacity addition	3.44	1.23	2.14	1.10	2.41	1.41	1.36	2.41	3.01	3.82	22.32
	Storage capacity addition	3.82	3.99	4.13	4.23	4.26	4.26	4.21	4.09	3.90	3.61	40.48
	Total	**7.26**	**5.21**	**6.26**	**5.33**	**6.67**	**5.67**	**5.57**	**6.50**	**6.91**	**7.42**	**62.81**
Scenario 6	Solar capacity addition	13.27	0.00	0.00	1.16	4.63	2.88	1.62	2.43	4.64	1.11	31.74
	Storage capacity addition	18.00	2.23	4.46	2.97	2.97	3.00	3.76	3.71	3.71	-	44.80
	Biomass capacity addition	-	2.18	4.20	-	-	-	-	-	-	-	6.38
	Total	**31.27**	**4.41**	**8.66**	**4.13**	**7.60**	**5.87**	**5.38**	**6.14**	**8.35**	**1.11**	**82.93**

Figure 9: Total savings on electricity cost for 20 year compared with capital investment requirement by scenario

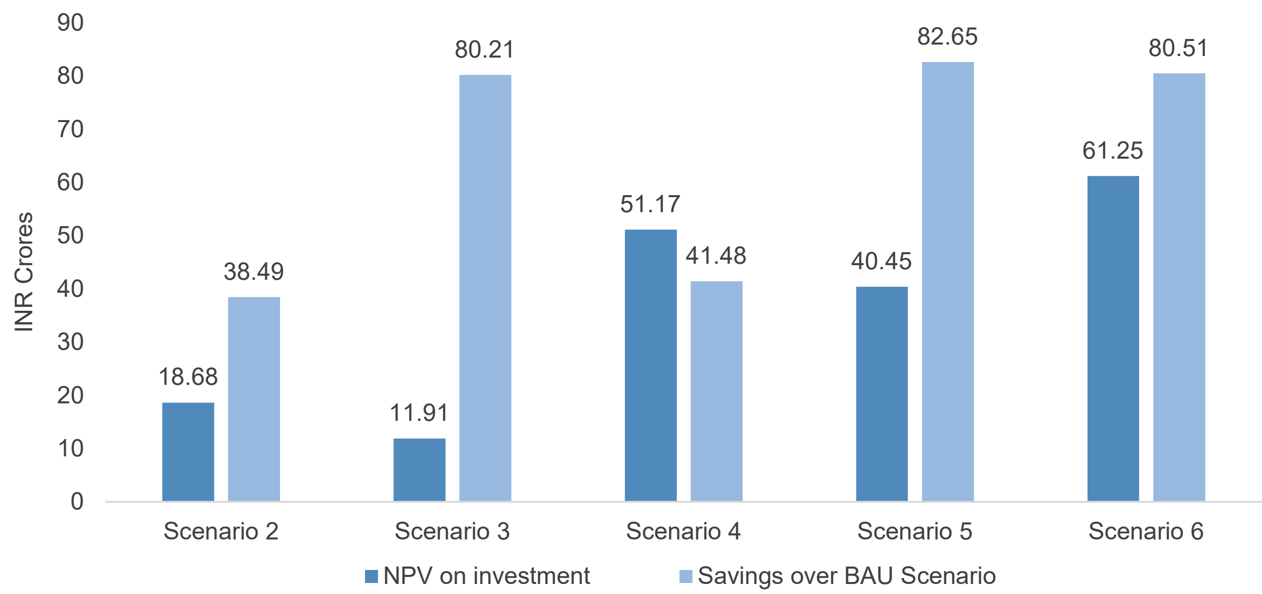
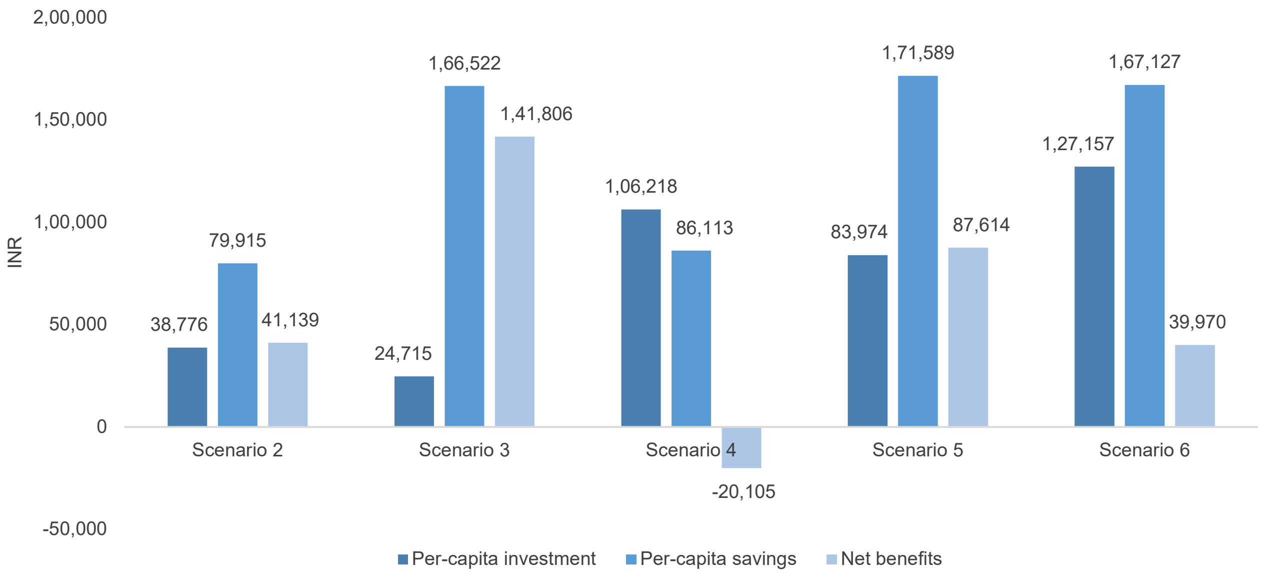


Figure 10: Per capital investment, electricity cost savings and net benefits by scenario



7 WAY FORWARD

Which scenario to go for?

It is recommended that Auroville targets scenario 6 as its energy sourcing strategy. A possible approach could be to start with Scenario 4 and/or 5 and transition to scenario 6 within the first 3-4 years. Annual renewable energy and storage capacity addition may be reviewed on an annual basis. The addition of energy storage capacity may be done keeping in mind expected cost decline on energy storage systems in the future. The analysis clearly showed the benefits of adding bio-energy systems early on.

How to finance it?

Auroville may explore multiple financing and implementation models.

1. Auroville Renewable Energy Generation Service

Auroville may set up and capitalize a dedicated service that plans, implements and operates distributed renewable energy generation and storage systems. Such a service can be made self-supporting by internally debiting for the units of electricity generated.

2. RESCO or lease model

Auroville may enter a partnership with renewable energy services companies to either lease distributed renewable energy systems or enter into a long-term power purchase agreement. In the case of a lease the operation and maintenance will be handled by an Auroville unit.

What else is required?

1. The possibility of sourcing local feedstock for bio-energy generation will have to be assessed. Municipal sludge from Auroville's waste water treatment systems promises to be a viable feedstock as long as it can be complemented with feedstock sources.
2. In order to achieve the energy efficiency target it is recommended that the Auroville Town Development Council develops forward looking energy efficiency guidelines for new developments. Such guidelines shall also include recommendations on designing buildings that can accommodate the maximum amount of solar energy systems. This will be critical in order to reduce the amount of land resources required by Auroville for all explored scenarios.
3. Active demand response programs that remotely control certain loads such as air-conditioners, hot water heaters and water pumps shall be explored. This has the potential to reduce the energy storage capacity required by facilitating higher instantaneous solar energy consumption.
4. Smart metering is recommended as it provides critical data for grid operation and integration of renewable energy and storage systems.

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