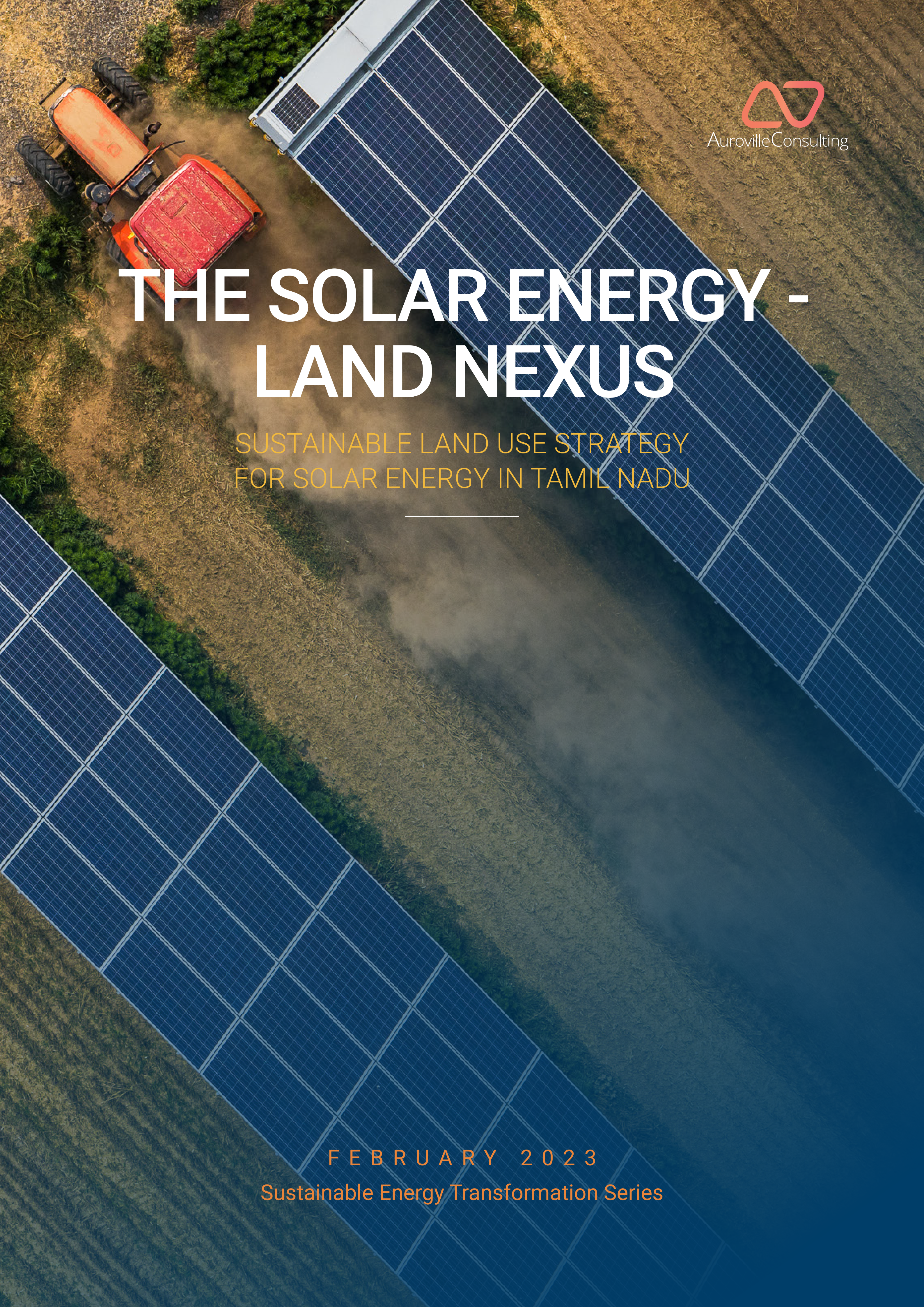

AurovilleConsulting

THE SOLAR ENERGY - LAND NEXUS

SUSTAINABLE LAND USE STRATEGY FOR SOLAR ENERGY IN TAMIL NADU

FEBRUARY 2023

Sustainable Energy Transformation Series

The Solar Energy - Land Nexus

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Acknowledgment

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Abbreviations

APV	Agrovoltaic
BAPV	Building Applied Photovoltaics
BIPV	Building Integrated PV
CCS	Carbon Capture and Storage
CdTe	Cadmium telluride
CIGS	Cadmium telluride and copper indium gallium
CO2	Carbon dioxide
CSP	Concentrated solar power
GW	Gigawatt
IGCC	Integrated gasification combined cycle
IIPV	Infrastructure Integrated PV
km2	Square kilometre
kW	Kilowatt
MU	Million units
MW	Megawatt
NGCC	Natural gas combined cycle
NoC	No objection certificate
PC	Pulverized coal
Poly-si	Polycrystalline silicon
PV	Photovoltaic
RPO	Renewable Energy Purchase Obligation
TCPD	Town and Country Planning Department
TCPO	Town and Country Planning Office
TGA	Total geographical area

Executive Summary

Tamil Nadu has set a target of adding a 20 GW of solar energy by 2030. If this target is to be primarily met by ground-mounted solar plants a 405 km2 land area will be required. Considering the projected annual electrical energy demand of 4,89,395 MU by 2050 (Auroville Consulting 2022) the need to decarbonise the state's power sector and the fact that solar is among the most cost -efficient energy sources today, the potential land-impact of solar is substantial. Meeting 50% of the projected electricity demand for 2050 would require 133 GW[1] of solar capacity, and 2,691 km2 of land resources, which equals the total geographical area of Chengalpattu District or 2.07% of the state's geographical area..

There are competing and often conflicting demands for land for economic, ecological and social needs in the development sector. It will be critical to limit the conversion of agricultural lands for solar energy development.

In this context land-neutral and low land-impact solar energy developments need to be prioritized. The concept of land-neutral solar project refers to the integration of solar project into existing building and infrastructure assets such as building-integrated or infrastructure-integrated solar energy systems. Floating solar energy on water bodies, can be considered as a land-neutral solar energy option as well. Low land-impact solar energy also includes agrovoltaic projects that facilitate the co-location of agriculture and solar energy generation or wind-solar hybrids. Developing energy on lands degraded by human activities is another option to reduce cumulative impacts and minimize land use conflicts.

Integrated spatial land use planning can facilitate sustainable development that finds the right balance between socio-economic aspirations and environmental considerations. Policy guidelines that address the solar energy - land nexus and provide an effective hierarchical spatial planning framework for solar energy, could ensure the judicious use of land while meeting the state's solar energy needs.

[1]This assumes a capacity utilization factor (CUF) of 21% and an average land area requirement of 5 acres per MW of solar PV. Potential efficiency gains through technology innovation have not been considered in this estimate.

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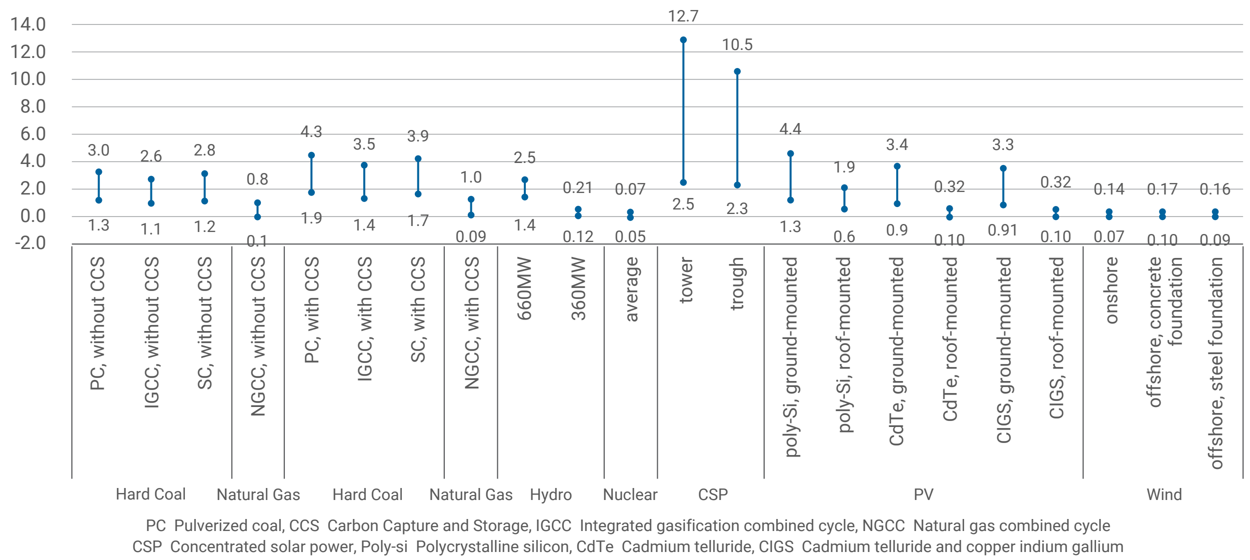
01
Introduction

Energy generation can have intensive or extensive land use requirements, causing habitat and biodiversity loss in sensitive and diverse ecosystems globally or competing with other land use such as agriculture.

As a direct consequence of the Paris Climate Agreement, which requires global decarbonization, renewable energy sources will continue to expand, in particular solar and wind. The increasing land use for renewable energy generation systems and related infrastructure will become more relevant in the future. The extent to which the overall land use balance will be more favourable than for non-renewable sources depends on the mix of renewables, their siting and centralized or decentralized mode of deployment (UNEP, 2016). Innovative deployment of renewables can reduce land use pressures, as well as avoid landscape disturbances caused by fossil fuels and nuclear energy (Lovins, 2011).

While the use of fossil fuels is limited by the size of the resource (including future cost and the carbon dioxide (CO_2) budget), renewable energy and in particular solar energy, is mostly restricted by land use allocation and by the availability or solar irradiation or adequate windspeeds. A life cycle land occupation assessment for various energy generation technologies by UNECE (2021) indicates that Concentrated Solar Energy has the highest land occupation need. This is followed by coal power (hard coal) and ground-mounted photovoltaics. Lifecycle land occupation is minimal for fossil gas, nuclear and wind. For coal power, land occupation occurs mostly at the extraction phase, either through the mining infrastructure itself and the use of timber props in underground mines, which entails land use impacts from forestry (UNECE 2021).

Figure 1: Land occupation by energy technology



Source: UNECE 2021

Land or sea occupancy is one of the most visible impacts for any energy development. The relatively large land requirement for solar energy highlights the importance of good mitigation practices to help facilitate the transition into a renewable energy future. Fortunately, the abundance of solar energy means that, unlike other energy sources, there is often flexibility in project siting, allowing the integration of solar energy systems with buildings and infrastructure assets or the co-location of solar energy systems with agricultural practices or the use of wastelands.

02
INDIA

Both the developmental targets and the social, cultural and environmental aspects of India require land resources and competing demands may lead to land use conflicts.

With 2.40% of the total world geographical area, India supports about 17% of the global population. The already high population density of 464 persons per square kilometre (Worldometer 2023) and the expected future population growth makes strategic and sustainable land resource management exceedingly important. This brings home the urgent need of comprehensive land utilization policies at both the central level and the state level.

Lands classified as wastelands are typically considered as the first-go to option for solar energy development. The Department of Land Resources, under the Ministry of Rural Development, regularly publishes the Wasteland Atlas of India. This Wasteland Atlas provides the states' wasteland-wise land profile. Wastelands are categorized under 23 different types. An estimated 46.70 million hectares, accounting for 14.75% of the total geographical area of the country, has been mapped as wastelands during the period 2008-09 (Department of Land Resources 2011). As per the Wasteland Atlas, the share of wasteland as a percentage of total land area has decreased from 14.91% in the year 2005 to 14.75% during the year 2009. The National Institute of Solar Energy (NISE) estimated the solar potential of India at 750 GW based on 3% of the suitable wasteland area available.

Currently however there is no land use policy in place that optimizes the use of wastelands for solar energy projects. Additionally, in needs to be recognized that wastelands provide essential biodiversity and ecosystem services or are often of essential value to local communities. As of 2023, solar and wind energy projects are not required to undertake an environmental impact assessment. The Ministry of Environment, Forests and Climate Change (MoEFCC 2006), Government of India, has placed wind and solar PV projects under the 'white category' industries, which are exempted from obtaining 'Consent to Operate' from the concerned State Pollution Control Board (SPCB). Mandating an environmental impact assessment could contribute to a more responsible land-use management.

More than two-thirds of India's population depends, directly or indirectly, on agricultural activities. Most of the agriculture farms are of very moderate size, with a large number of small and marginal farmers having a land holding of 2 hectares. With the high dependency of a large population on agriculture and the small average farm size make many farming households vulnerable to large infrastructure developments, including solar energy (TERI 2017).

Consider that projected population growth in India from 1.40 billion in 2022 to 1.66 billion by 2050 (UN 2022), and India's Green India Mission aims at increasing the countries forest cover by 5 million hectares by 2030 (MoEFCC 2015). Simultaneously meeting renewable energy development goals, increasing forest cover, and devoting land to support a growing population (e.g., food production, housing, industries) will require proactive land use planning in order to avoid dire land use conflicts (Kiesecker, J. et al. 2019).

03

Tamil Nadu

Land use pattern in Tamil Nadu has undergone tremendous transformation over the past few decades due to the impact of urbanization and industrialization.

Land Cover maps for Tamil Nadu on a scale of 1:250,000, are available on the National Remote Sensing Centre's Bhuvan portal. A simplified comparison for the years 2005-06 and 2016-17, indicates that land use for agriculture increased by 1.20% from 62.85% to 64.05%, it is the predominant land use in the state. The second land cover that saw an increase during this time period is land under built-up including all settlements – urban or rural, industrial, infrastructure including roads, railways, ports canals etc. These land uses increased from 2.82% to 4.02%, an increase by 1.20%. The third and last land cover category that shows an increase is wastelands. 8.39% of the state's total geographical areas has been classified as wasteland (refer to Table 1).

While not all wasteland types are suitable for solar energy development, some of them are, and provided that these wastelands fulfil other suitability criteria for solar energy developments such lands could be prioritized for solar energy initiatives. The National Institute for Solar Energy (NISE) estimated the Solar potential on wastelands in Tamil Nadu at 17.67 GW (NISE 2014).

Water and forest land cover in Tamil Nadu decreased by 1.12% and 1.22% respectively, grasslands and littoral swamps saw some moderate decreases as well.

Table 1: Landcover share Tamil Nad

Land Use	2005-06	2016-17	Change
Built Up	2.82%	4.02%	1.20%
Water	6.40%	5.28%	-1.12%
Forest	18.71%	17.49%	-1.22%
Grasslands	0.84%	0.69%	-0.15%
Littoral Swamps	0.09%	0.07%	-0.02%
Agri	62.85%	64.05%	1.20%
Wasteland	8.30%	8.39%	0.09%
Total	100%	100%	

Source: Adapted from. Bhuvan Portal

There are competing and often conflicting demands for land for economic and social needs in the development sector. Changes in the land use pattern are associated with ecological and socio-economic changes and it will be imperative that these changes align with the state's long term social, economic and environmental policy objectives.

04

Land Use Regulations

Policy guidelines pertaining to land use for solar energy project can support the optimal use of land resources, while at the same time accelerating the pace to unlock land for solar development.

Land falls under the legislative and administrative competence of the states. The Tamil Nadu Town and Country Planning Act 1971 (Act 35 of 1972), provides for preparation of Master Plans, Zonal Plans, Local Area Plans, and Detailed Development Plan. Such plans will be statutory plans that can be enforced at the local level.

Planning is steered by guidelines issued by the Town and Country Planning Office (TCPO) at the national level. The regional master plans are prepared by the Town and Country Planning Department (TCPD) at the state level and include land use and transportation aspects.

As per India's constitutions two self-governing bodies at the local level are defined. These are (i) Gram Panchayat for rural areas and the (ii) Municipalities for urban areas. Most Gram Panchayats have not undertaken and spatial planning exercise whereas many municipalities have developed master plans.

As per the provisions of law, fertile land can only be used for agricultural purposes. In the case of solar energy development on agricultural land the end use classification needs to be changed to the non-agricultural (industrial) category for which the project developer submits a letter requesting the district administration for land use conversion of the proposed land along with the land purchase documents, NoC from village Panchayat, recommendation from local Sub-Divisional Magistrate /Tehsildar as well as the respective State Nodal Agency. Obtaining the required approval for land conversion permission therefore can be time consuming. It is estimated that it takes over 6-9 months to procure land for setting up solar projects (TERI 2017).

Agriculture and related activities are of significant importance for the states socio-economic development and welfare. Large-scale land use and possibly land-ownership changes brought in by solar energy projects may impact the lives of the local farming communities. While the state will need to find answers to sustainably integrate energy generation into its long-term land use strategy it will also need to find sound solutions to accelerate the pace to unlock land for solar energy development, while reducing the impact on the farming communities.

Settlement level land use plans or zoning and other land use regulations can play an important role in enabling renewable energy projects that are cost effective while at the same time reducing land use conflicts. Zoning allows a region to align its solar energy target with other development plans and priorities such as economic development and job creation, environmental sustainability and climate resilience, food and water security, watershed and aquifer functions or urban growth areas.

Developing policy guidelines to inform spatial planning on solar land use, and mandates incorporating solar energy into local land use zoning and planning exercises could support in realising the state's renewable energy targets without compromising responsible land resource management.

Such policy guidelines may need to be capacity specific, context specific and type specific. For example, the guidelines can exempt Agrovoltaic (APV) projects from the land conversion requirement as long as a set of criteria are fulfilled. Ground-mounted solar energy systems beyond a certain capacity may only be permitted on wastelands. The objective should be to minimize the need of agricultural land-conversion for solar energy, protect forest, lands under tree cover, sites of cultural and natural heritage, while at the same time providing attractive and implementable alternatives for solar energy generation.

–05

Estimating Future Solar Energy Land Use

To meet Tamil Nadu's projected electricity demand in 2050 exclusively from ground mounted solar plants, a cumulative solar energy capacity of 266 GW and a land area of 5,383 km2 will be needed.

Tamil Nadu is a renewable energy leader among the Indian states. As of November 2022, the state has a cumulative solar energy capacity of 6,333 MW. The majority of this, a 5,905 MW or 93%, is utility-scale solar PV (ground mounted). The remaining capacity is on account of grid interactive rooftop solar, with a total capacity of 369 MW, and off-grid solar systems with a capacity of 60 MW (MNRE 2022).

The Tamil Nadu Government has set a target to deploy an additional 20 GW of solar energy capacity by the year 2030. Combined with other renewable energy resources, such as wind and hydro, the 20 GW solar capacity addition target will help the state to meets its Renewable Energy Purchase Obligations (RPO). The RPO for the year 2029 aims at sourcing 43% of the state's total energy demand from renewable energy sources (MoP 2022).

While other renewable energy technologies such as onshore wind or hydro require land resources as well, this paper focuses exclusively on the land resources required for solar energy in Tamil Nadu. To meet the 20 GW solar capacity addition target by 2030 through conventional ground mounted systems, an estimate land area of 405 km2 is required. However, it may be useful to look beyond the year 2030 and take a long-term perspective for the reasons listed below:

(i) Tamil Nadu's electricity demand is expected to increase sharply in the coming decades,

(ii) Solar energy today is among the cheapest sources of energy available,

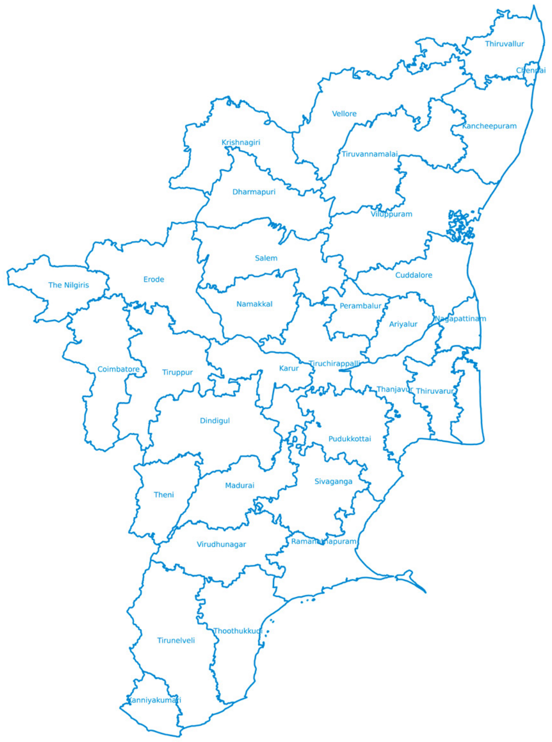
(iii) Decarbonizing the power sectors has become a global imperative and,

(iv) More renewable energy capacity and therefore more solar energy capacity will need to be deployed in the coming decades.

The state's energy generation is expected to increase from 1,05,146 MU in 2020 to 4,89,395 MU in 2050 (CEA 2022, Auroville Consulting 2022). This is an increase of 365% over the 2020 number.

Furthermore, if the state were to meet all its projected electricity demand in the year 2050 from (ground-mounted) solar energy plants, a cumulative solar energy capacity of 266 GW will be needed (refer to Table 2).

Table 2: Land resource requirement for different solar energy penetration scenarios by 2050



Solar energy share on total demand (%)	Solar PV capacity (GW)	Land area (km2)	Share on TGA (%)
100%	266	5,383	4.14%
75%	200	4,037	3.10%
50%	133	2,691	2.07%
25%	67	1,346	1.03%

Assumptions: 5 acres per MWp of Solar Energy, CUF of 21% Assuming a CUF of 30% on account of technology advances the 100% scenario would require a 186 GW of solar and a 3,768 km2 of land.

For the 100% solar energy penetration scenario, a total land area of 5,383 km2 or 4.14% of total geographical area (TGA) is required. This is about the area of Erode District (5,722 km2). Or to use another comparison, this is similar to the total build-up area in the state as of 2016, which was 5,228 km2 or 4.02% of TGA. Water bodies or lands under dense forest account for a similar land area too (refer to Table 3 below).

While a 100% solar energy scenario is rather unlikely, a 50% scenario may be more plausible. This would require 2,975km2 or 2.07% of the state's TGA. Chengalpattu district for example accounts for an area of 2,691 km2. Considering these high level land requirement assessments, it will be critical, whether the state embarks on a 25%, 50% or a 100% solar energy penetration scenario, to ensure a responsible use of land resources for solar energy developments.

Table 3: Comparing land requirement for the 100% solar scenario with current land cover

Landcover	%	km2
% of Agri	64.05%	83,303
% of build up	4.02%	5,228
% water (post monsoon)	5.28%	6,867
% waste land	8.39%	10,912
% dense forest	4.42%	5,749
100% solar by 2050	4.57%	5,950

Source: Bhuvan Portal Analysis 2016-17

06

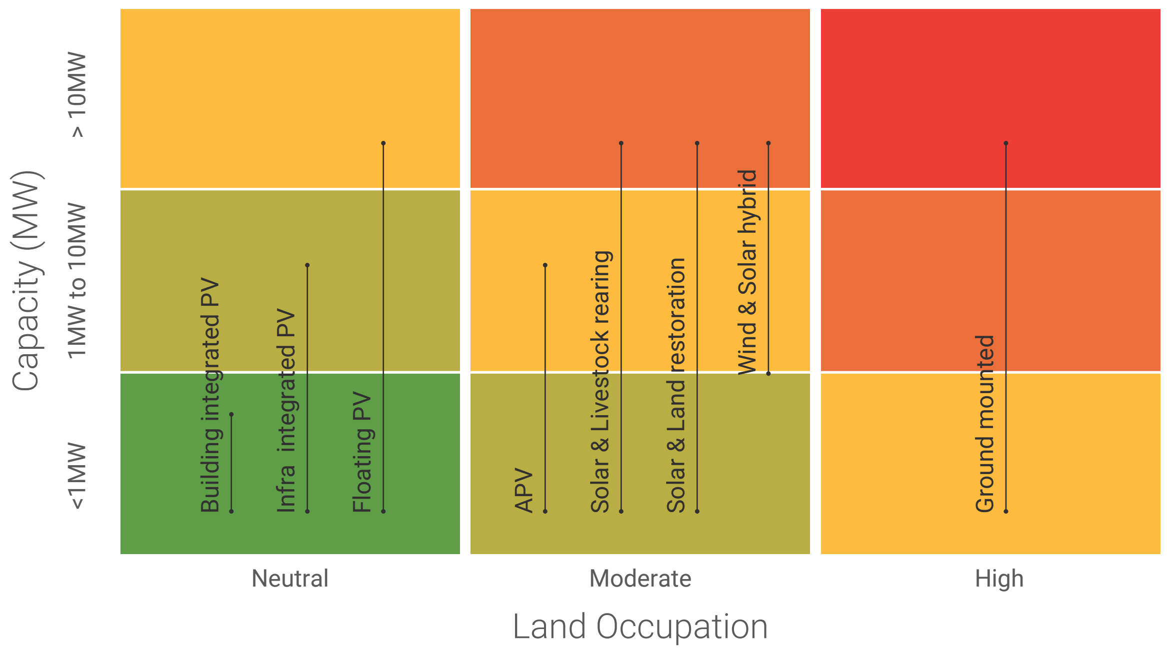
Examples of Low Land Use Impact Solar Energy Development

Low impact solar energy development minimizes land occupation and the local land use impact, while promoting agriculture or ecosystem and biodiversity services whenever possible.

While solar parks cover a small land area relative to the world's land surface, project developments still need to be strategically implemented to safeguard ecological processes and principles. This chapter presents low land-impact solar energy deployment options.

Solar PV projects can be classified by their direct land-occupation impact and by their impact on local land use. The direct land-occupation impact refers to the land area required to install 1 MW of solar PV, whereas the local land use impact is the degree to which the solar project modifies the existing level land use at the local level. Larger solar capacities require more land and therefore have a higher impact of local land use.

Figure 2: Solar Photovoltaic Systems land use and capacity



Building integrated PV examples:
rooftop solar systems, solar tiles and shingles, photovoltaic facades, photovoltaic windows etc.

Infrastructure integrated solar examples include:
solar roadways, solar canals, road integrated solar, solar parking etc.

In this case conventional ground mounted solar energy systems have the highest land impact. These systems do not consciously facilitate any type of co-location (agriculture, wind hybrid, biodiversity etc) neither do they integrate with existing building or infrastructure assets. Additionally, their local land use impact can be significant, especially larger solar energy projects (>10 MW) will dominate the local land use significantly.

Solar development projects that fall within the green and yellow fields as per Figure 4 above are having the least impact on land use management and could therefore be made a strategic policy priority. This includes solar project on existing building and infrastructure assets, such a Building Applied Solar (BAP), Building Integrated Solar (BIPV), Infrastructure Integrated Solar (IIPV), floating PV, Agrovoltaic (APV), Solar grazing and wind solar hybrids.

BUILDING-APPLIED & INTEGRATED SOLAR PV

Building Applied Photovoltaics (BAPV) and Building Integrated PV (BIPV) systems are retrofitted (e.g. rooftop solar) or integrated into the building envelope, such as the roof or the facade. These solar systems are considered land-neutral options as no additional land surface area is needed. BAPV and BIPV systems have the advantages of producing clean energy close to, or at the point, where this energy is needed. They reduce transmission and distribution losses and contribute to grid resilience on account of its distributed nature. Examples of BAPV include rooftop solar, while BIPV includes solar tiles and shingles, photovoltaic facades, photovoltaic windows etc.

Vertical solar PV louvres

Image: Fraunhofer Institute

Photovoltaic facades

Image: Sunrator

Photovoltaic windows

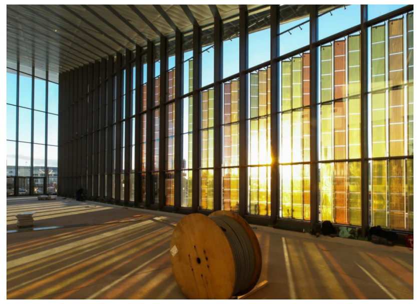


Image: Alain Herzog & EPFL

INFRASTRUCTURE-INTEGRATED SOLAR PV

Infrastructure Integrated PV (IIPV) is an approach that co-locates or integrates solar PV system with built infrastructure facilities. IIPV is a land-neutral solar PV deployment option and has the same technical benefits as BAPV and BIPV systems. Examples include solar roadways, canal top PV, highway solar roof, road integrated solar, solar parking etc.

Canal-top PV

Image: Solar AquaGrid

Solar parking

Image: Shubhankar Gautam

Highway solar roof

Image: Sonnenkraft

FLOATING SOLAR PV

Formally known as floating photovoltaic systems, or "floatovoltaics", they are solar panels mounted on a structure that floats on a body of water, typically a reservoir or a lake. The main advantage of floating PV plants is that they do not take up any land, except the limited surfaces necessary for electric cabinet and grid connections. Their price is comparable with land-based plants, but avoids land consumption. The partial coverage of the water body can reduce water evaporation. In warm and hot climates this is an important advantage. Another advantage is an Increased panel efficiency due the cooling effect of the water on the solar panels, this may lead to an energy gain from 5% to 15% (Choi, Y.-K. and N.-H. Lee (2013).

Floating solar

Image: The Agility Effect

WIND-SOLAR HYBRID SYSTEMS

A wind-solar hybrid system is a combination and the co-location of wind and solar power generation systems. This is done to provide a more consistent and reliable source of electricity, better utilize the power evacuation infrastructure and to optimize landuse.

Wind-solar hybrid

Image: The Hindu

AGRO-PHOTOVOLTAIC (APV)

APV describes a method for the simultaneous use of agricultural land for food production and solar power generation. The technology enables an efficient dual use of agricultural land and is a land neutral or low-land-use impact option. The crop yields can be optimized through targeted light management. APV projects are predestined to be managed in a decentralized mode by farmers, communities and small and medium-sized enterprises and could substantially contribute to the economic development of rural areas and in particular of small holder farmers.

APV fruit orchards

Image: KU Leuven

APV rice fields

Image: New York Times

APV horticulture

Image: Kirk Siegler/NPR

SOLAR ENERGY & LIVESTOCK REARING

Solar energy and livestock refers to the dual use of spaces for solar energy generation and livestock rearing and is in fact another type of APV. Animal species that with their natural activities contribute to some extend the maintenance of the solar plant are selected. Livestock farmers can obtain a double benefit from the space during the life of the solar plant by adding a rental or compensation to its traditional use. Additionally, the solar plant provides an excellent shelter in the middle of nature, allowing the grazing animals to be protected from the sun or from bad weather. Examples of combining solar energy and livestock rearing includes solar grazing with sheep, goats, cows, poultry and bees.

Solar grazing

Image: Array Technologies

Solar chicken farming

Image: Lynn Freehill-Maye

Solar beekeeping

Image: Connexus Energy

SOLAR ENERGY & LAND REGENERATION

Co-location of solar energy generation and regenerative, nature-based practices is a new approach to solar land management. Recognizing that land and vegetation are valuable ecological and biological assets rather than liabilities. After the solar plant is installed, the land typically goes idle and it's usually mowed, and pesticides are applied. An alternative land management is one that pro-actively aims at using vegetation to improve soil health, increase biodiversity, sequester carbon, and improve water quality. With such an approach waste lands can, over the lifetime of a solar plant, be regenerated and made into fertile lands. Alternatively solar plants placed in modified habitat can provide biodiversity enhancement opportunities when well designed and managed (Montag et al. 2016). Alongside biodiversity enhancement there are also opportunities for solar parks to play a role in alleviating water scarcity by facilitating active and passive rainwater harvesting and by replenishing the local aquifers.

Solar as biodiversity corridor

Image: Ecological Landscape Alliance

Solar and landfill remediation

Image: BQ Energy Development

Solar parks on abandoned mines

Image: TBEA

07

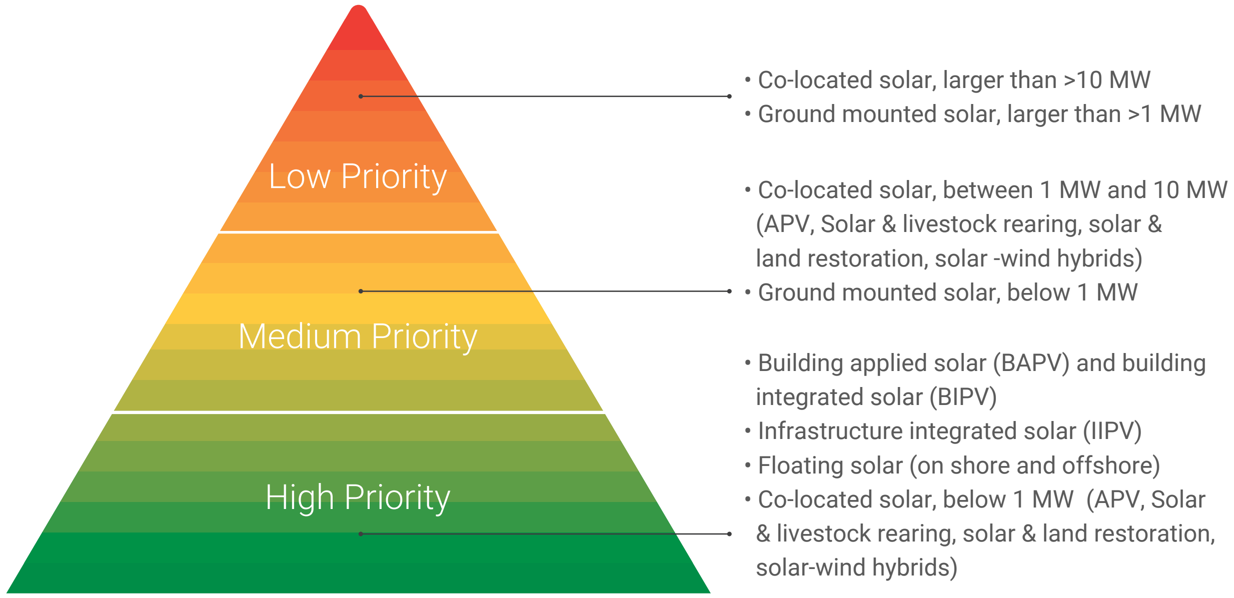
Policy Recommendations

Maximising land-neutral solar energy deployment options and promoting dual-land use wherever possible can make a significant contribution to a sustainable land resource management.

Combining energy production with buildings and infrastructure, with agricultural activities, with biodiversity habitats or with rain water management presents viable options for scaling up solar energy generation while mitigating its land impact. From a land use management perspective, Tamil Nadu would be well advised to develop a long-term policy strategy that facilitates meeting its renewable energy needs while minimizing the land impact.

The hierarchy of priorities would first maximize land-neutral renewable energy, in this context solar projects. Secondly it would promote dual-use solar developments. Conventional ground-mounted utility scale solar development would focus on waste land and degraded lands while its' land impact could be mitigated by mandating sustainable landscaping practices and biodiversity enhancements.

Figure 3: Priorities solar-land nexus



A spatial strategy at the state-level for the solar and land- nexus could emphasis the following 6 strategies:

(i) Maximize the development of land-neutral solar projects.

(ii) Create mechanisms to promote and accelerate APV.

(iii) Promote the co-location of solar energy and wind energy generation.

(iv) Develop mechanisms to maximize solar energy development on suitable waste lands and unused lands.

(v) Limit agricultural land-conversion for solar energy development.

(vi) Mandate sustainable landscaping practices for conventional ground mounted solar energy systems.

MAXIMIZE THE DEVELOPMENT OF LAND-NEUTRAL SOLAR PROJECTS

Creating a driving environment for land-neutral solar energy projects can make a significant contribution to meeting the state's solar energy ambitions without the requirement of dedicated lands. Land-neutral solar energy projects include BAP, BIPV, IIPV and Floating PV. Policy instruments available include:

- Target setting
- Building codes and solar mandates
- Feed-in tariffs
- Capital subsidy
- Interconnection process
- Demand aggregation models
- Property tax rebates
- Access to low-cost credit lines
- Solar capacity potential mapping

With the exception of canal-top solar and solar parking, there is currently little experience in India with IIPV initiatives. Therefore demonstration projects and pilots may need to be encouraged. For floating PV the government will need to develop policy guidelines.

Box 1: Examples of policy interventions for land neutral solar

Rooftop solar mandates, European Union
The Commission of the European Union is proposing a solar rooftop requirement for commercial and public buildings starting from 2027, and for new residential buildings starting from 2029. By doing so the Commission recognises the immense potential of rooftop solar to address the EU's energy supply security and to create green jobs. It is expected that up to 1.1 million solar jobs will be created in Europe by 2030.

Rooftop Mandate for Parking Lots, France
France is a pioneer in the development of solar parking lots. Since the inception of solar energy development in the country, solar parking projects have been quite prominent. In 2022, the French Parliament has passed a legislation that mandates the integration of solar PV with parking slots of surface area of greater than 1,500 square meters (PV Magazine 2022).

Solar-Ready Building Codes, City of St. Louis, Missouri, USA
The City of St. Louis requires all new buildings to be made solar-ready. All new structures—commercial and residential—must reserve rooftop sections for solar panels to be easily installed. The ordinance does not mandate that rooftop solar be installed. The solar-ready zone must be at least 40% of the roof area. The solar-ready area cannot be obstructed by pipes, vents, HVAC equipment, or other shadow-casting elements. Construction documents must outline pathways for routing of piping from the solar-ready zone to the building's electrical service panel or service hot water system. The electrical panel must also have reserved space for a dual-pole circuit breaker to support future solar installations. Solar-ready building codes for new construction can help make future solar installations easier and more cost effective (ProBuilder 2020).

CREATE MECHANISMS TO PROMOTE AND ACCELERATE APV

APV creates a symbiotic relationship between food production and energy generation, allowing farmers to make full use of the available land, while also producing clean energy. Considering that the average farm size in India is 2.67 acres (Ministry of Agriculture and Farmers Welfare 2016) the promotion of APV may focus on solar plans of moderate power capacity (< 1 MW). Such APV systems could provide a second income for smallholder farmers. The farmer may lease the land to a developer or operate a solar plant herself. Policy instruments available include:

- Exempt APV systems from the land conversion mandate
- Feed-in tariffs
- Interconnection processes
- Standardised land-lease agreements
- Access to low-cost credit lines for farmers
- Demand aggregation models

Box 2: Examples of policy interventions for co-location of solar and agriculture

APV Legislation, Italy
In June 2022 Italy's Ministry of Ecological Transition released its "Guidelines for the Design, Construction and Operation of Agrovoltaic Plants." The guideline document specifies the minimum characteristics and requirements a photovoltaic system must have in order to be considered "Agrovoltaic." The guidelines also introduces incentives for agrovoltaics. Permissible activities under 'Agrovoltaic are agricultural cultivation, floriculture and livestock grazing. A requirement is that at least 70% of the surface area is dedicated to agricultural activity (PV Magazine 2018).

APV, Massachusetts, USA
In 2018, the Massachusetts Department of Energy Resources established the Solar Massachusetts Renewable Target (SMART) program, which regulates incentives associated with new solar PV development. APV is included in the SMART program. Systems qualifying as APV receive an additional $0.06 per kWh feed-in tariff. SMART Program system parameters required for APV includes:

- System Size: The capacity (rated electricity production) of the system must be no more than 2 MW AC.
- Height: The lowest edge of the panel must be at least 8 feet above the ground for a fixed tilt panel system, or 10 feet at horizontal position for tracking systems.
- Shading: During the growing season, the maximum sunlight reduction due to shading from the panels on any square foot of land under the dual-use system may be no more than 50%.
- Agricultural use: The system should be designed to optimize a balance between electrical generation and agricultural production, and the land must be under continuous agricultural production over the 20-year SMART program period (DOE 2022).

PROMOTE THE CO-LOCATION OF SOLAR ENERGY AND WIND ENERGY GENERATION

Land utilized within a wind farm often lies unutilized. The average land requirement for windfarms is 1.5 hectares per MW (TERI 2017). However, the direct physical footprint of the wind turbine is much lower at about 3% of the area of the wind farm. It makes economic sense to open wind-farm land up for solar development. Solar-wind hybrid systems combine two of the fastest growing and most affordable renewable energy technologies. The two technologies offer a certain degree of complementarity. Solar PV produce power only during sunshine hours whereas wind turbines, on the other hand, typically generates more energy during late evenings and reaches its peak during the nights. As of January 2022, Tamil Nadu has not yet formulated a wind-solar hybrid policy.

Policy instruments available include:

- Provision of adequate power evacuation infrastructure.

Box 3: Examples of policy interventions for solar and wind hybrids

Wind-Solar-Hybrid Policy, India
The Ministry of New and Renewable Energy (MNRE) adopted the National Wind-Solar Hybrid Policy on 14th May 2018. The objective of the policy is to provide a framework for the promotion of large grid-connected wind-solar PV hybrid system for efficient utilization of transmission infrastructure and land. The Policy also provides for flexibility in share of wind and solar components in hybrid project, subject to the condition that, rated power capacity of one resource be at least 25% of the rated power capacity of other resource for it to be recognised hybrid project.

The Policy seeks to promote new hybrid projects as well as hybridisation of existing wind/solar projects. The existing wind/solar projects can be hybridised with higher transmission capacity than the sanctioned one, subject to availability of margin in the existing transmission capacity (IEA 2021).

DEVELOP MECHANISMS TO MAXIMIZE SOLAR ENERGY DEVELOPMENT ON SUITABLE WASTE LANDS AND UNUSED LANDS

Studies on wasteland distribution for India and Tamil Nadu indicate that there are abundant wastelands that are potentially suitable for solar energy developments (Department for Land Resources 2016). A policy could emphasise the use of waste lands, degraded lands and brownfield site for solar parks. If the development of such lands results in additional capital and operational investments to the operator policy regulations and interventions to mitigate these will be required. Policy instruments available include:

- Publish maps that list wastelands, brownfield sites and unused lands that are suitable for solar energy development
- Acquire suitable wastelands and unused lands and lease/transfer to solar developers.
- Include specific clauses in bid documents.
- Provide power evacuation infrastructure for large wasteland tracks.
- Mandate an environmental impact assessment for ground mounted solar.
- Formulate decommissioning and site restoration regulations.

Box 4: Examples of policy interventions for developing waste lands and unused lands

Mapping tool to for contaminated lands, USA
EPA's RE-Powering America's Land Initiative encourages the redevelopment of contaminated and potentially contaminated sites for renewable energy projects. It provides an online toolkit for project developers, which includes an interactive mapping of about 130,000 potentially contaminated land sites for renewable energy development that have been pre-screened by the EPA. The program also provides trainings and other "best practices" guides for prospective developers. In addition to the programmatic support provided by the RE-Powering America's Land Initiative, financial incentives are available for these types of projects through the EPA's brownfields program, certain grants and loans offered by the U.S. Department of Agriculture and tax credits for renewable energy development in the Internal Revenue Service's opportunity zones (EPA 2016).

Mapping unused lands suitable for solar, India
Lila mapping tool identifies unused lands in any geographical area of interest and evaluates these lands for its suitability for climate action, including reforestation, surface water management and distributed solar energy. This can inform local land use and zoning regulations and planning and accelerate land-identification and acquisition process for solar developers.

LIMIT AGRICULTURAL LAND-CONVERSION FOR SOLAR ENERGY DEVELOPMENT

Solar energy development, if not managed well, could be a major contributor to farmland loss. The state may consider more stringent land-conversion and solar energy application processes. Prime agricultural land could be mapped with a ban on land conversion. Policy instruments available include:

- Promote APV systems
- Set capacity limit for conventional ground- mounted solar energy (e.g. max 10 MW)
- Use zoning instruments and incorporate solar into local land use plans
- Increase land conversion fees

Box 5: Examples of policy interventions for using zoning and information instruments to limit the conversion of agricultural land

Solar-Go-To-Areas Italy
The Italian government intends to publish a decree outlining the guidelines for the definition of suitable areas for the development of renewable energy projects. Suitable areas will then be defined by regional laws. In the meantime, the government has identified different types of “go-to areas” along with simplified permitting procedures, for instance:

- Land within a radius of 500 m from industrial or commercial areas
- Areas secluded within a radius of max. 500 m from industrial plants
- Buffer zones within a radius of max. 300 m from highways
- Areas in the vicinity of railways
- Ceased mines and quarries
- Sites subjected to remediation (Solar Power Europe 2022)

Zoning for Solar Energy Guidelines, Michigan, USA
Michigan University developed a guide on planning and zoning for solar energy. The guide is meant to assist communities in meeting the challenge of becoming solar ready by addressing the requirements of solar energy systems within their planning policies and zoning regulations. The document illustrates how various scales and configurations of solar energy systems fit into landscape patterns ranging between rural, suburban, and urban (Michigan University 2021). It also includes a model zoning that can be adapted by local authorities. This model zoning is quite comprehensive and addresses ground-mounted solar energy, building integrated solar, dual use (AVP) solar applications. It further includes standards for repowering and decommissioning of solar systems.

ENSURE SUSTAINABLE LANDSCAPING PRACTICES FOR CONVENTIONAL GROUND-MOUNTED SOLAR ENERGY SYSTEMS

Solar farms could be leveraged to provide additional ecosystem services or benefits beyond the solar power generation itself. This could include planting of a certain vegetation to create pollinator habitats, prevent soil erosion, increase soil carbon, and manage storm water. Solar farms can also provide essential biodiversity spots. With regard to sustainable vegetation, soil and water management associated with solar farms, Tamil Nadu currently does not have solar plant -specific guidelines.

Policy instruments available include::

- Guidelines to minimize construction-related soil compaction
- Mandate sustainable vegetation management and soil erosion control
- Set biodiversity net gain requirements
- Introduce guidelines for good storm water management practices
- Include specific clauses in bid documents

Box 6: Examples of policy interventions to integrate biodiversity into solar developments

Biodiversity Net Gain, UK
Under Part 6 of the Environment Act (2021) new developments in the UK are required to show a minimum net gain in biodiversity of 10%. Biodiversity Net Gain (BNG) applies to all new developments - including solar farms - and is designed so that a project ‘leaves biodiversity in a better state than before’. BNG is calculated by a qualified ecologist by comparing the baseline biodiversity units - measured in its pre-development state - with the results that would be expected after construction is complete and all the ecological enhancements have been implemented. local authorities. This model zoning is quite comprehensive and addresses ground-mounted solar energy, building integrated solar, dual use (AVP) solar applications. It further includes standards for repowering and decommissioning of solar systems.

08
Summary

To meet the twin objectives of an accelerating energy transition and sustainable land use management, the current prevailing solar energy development of conventional ground-mounted systems with large and very large (ultra-megawatt) capacities will need to be reconsidered. While this type of solar energy development has contributed a great deal in reducing the cost of solar energy and thereby making solar energy an integral part of the state's energy mix, this model may need to be replaced with models that have less land impact.

Promoting a diverse set of solar PV deployment typologies that have a low land-impact such as BAP, BIPV, IIPV, floating solar, APV etc. could make major contributions in meeting the state's solar energy needs. Unlocking suitable wastelands, degraded lands and brownfield sites can complement these low land-impact solar options.

A long-term spatial strategy that considers multiple policy objectives simultaneously - such as climate adaptation and mitigation, food security, biodiversity, soil health, water security, farmers welfare etc. – will be required to meet the twin objectives of accelerated energy transition and sustainable land use.

09
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