GEO GRAP HIES *of* POWER

Spatial strategies for a 'just' energy transition in Tamil Nadu

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Graduation Project
MSc. Urbanism, TU Delft

GEOGRAPHIES OF POWER

Spatial strategies for a ‘just’ energy transition in Tamil Nadu

Colophon.

Geographies of power: Spatial Strategies for a 'just' Energy Transition in Tamil Nadu

Masters Thesis P5 Report
M.Sc. Architecture, Urbanism and the Building Sciences
Department of Urbanism
Faculty of Architecture and the Built Environment, TU Delft

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July, 2019
Delft, Netherlands

Acknowledgments.

I want to thank my mentors, Marcin Dabrowski and Ulf Hackauf for their unwavering support and constructive feedback that helped develop the graduation project with constant critical self-reflection. Their belief in my research and design methods, thoughts and way of working was invaluable to my project. I'm grateful to Verena Balz, Coordinator of Complex Cities studio, for her guidance and the enriching studio experience. I would also like to thank my colleagues at PosadMaxwan and Generation. Energy for sharing their knowledge and inputs on spatial energy transition with me. I also acknowledge the valuable assistance I received from officials of the Tamil Nadu Electricity Board during my field trip. Without the team from Archipress, I would not have been able to organise a workshop on spatial energy transition in Chennai; for this I am immensely thankful to them.

I am also grateful to my fellow Urbanism graduates for their helpful comments, reviews and teachings throughout these two years. I express my gratitude and love to Sarantis Georgiou, Leonardo Cannizzo, and Felipe Chaves Gonzalez, in particular, for the many discussions, jokes and memories. I am also eternally grateful for the support and love of my family.

Thank you all.

“Enter geography.
Where do these materials come from?
Who do they belong to?
Under whose jurisdiction?
How are they moved and removed?
Where do they go?
Who processes them?
What energies are required?
What do they leave behind?”

(Belanger, 2018)

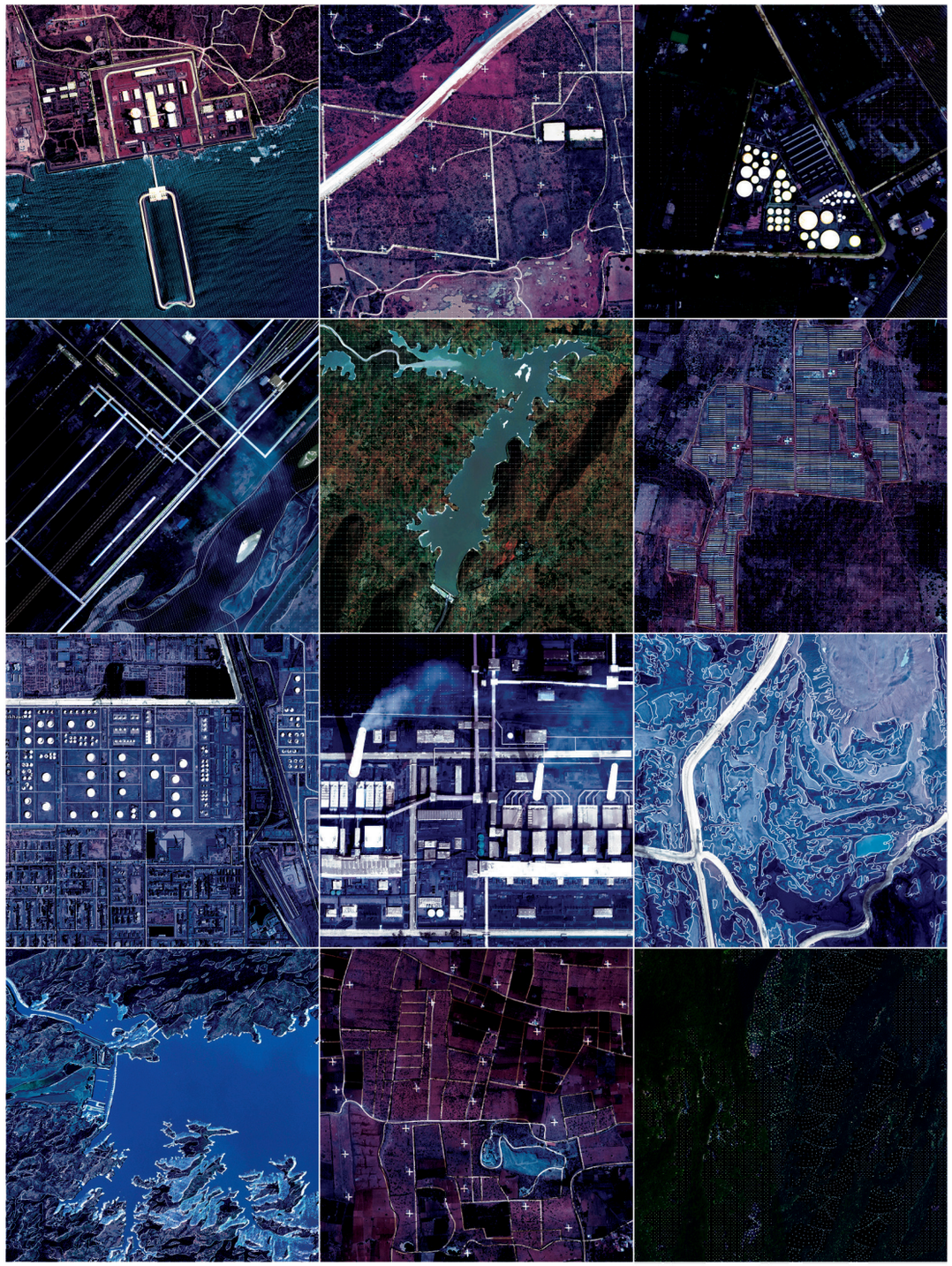

Fig 1.1: Energy Geographies of India (Author's diagram. Satellite images from Google Earth (Digital Globe, 2018)

Abstract.

The era of energy transition has brought to the front, the incredible potential of designing the reciprocal relationship between energy and space. The transition to renewable sources of energy like wind, solar and geothermal energy, uses space in a different way- its altered spatial qualities have blurred the boundaries between technical space (shunned by planners) and 'non-technical' space (coveted by planners). This spatial dimension of energy transition is the focus of the graduation project. Taking the case of Tamil Nadu, India, the project proposes a re-imagination of emerging energy geographies through regional design and spatial strategies, to create a framework for a humanised energy transition.

Keywords: energy transition, spatial governance, energy landscape, energy justice, regional energy design, Tamil Nadu,

Research Question: How can regional design of emerging energy geographies create a framework for a just energy transition in Tamil Nadu?

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1

Introduction

Overview:

Chapter 1 introduces the graduation project, ‘Geographies of Power- Spatial strategies for a just energy transition in Tamil Nadu‘, and presents an overview of individual chapters of the book, pertaining to the research and design phases of the project. The problem, the research motivation, aim, goals, research methodology, and design outcomes are discussed briefly to illustrate how regional design and spatial strategies for the development of energy production landscapes can create a framework for a ‘just’ energy transition in Tamil Nadu, India.

Introduction

Energy and Space have a **reciprocal relationship** (Sijmons, 2014). This relationship between energy and space has historically been driven by necessity and the drive for development (Fig 1.2). The extraction of fossils fuels like coal, oil and gas, and energy infrastructures like minefields, power plants, dictated the perception of energy-space, its use and qualities. However, the drive towards energy transition, and the advent of renewable sources of energy like wind, solar and geothermal energy, uses space **in a different way**- its altered spatial qualities have blurred the boundaries between technical space and 'non-technical' space.

The era of energy transition has brought to the front, the incredible potential of designing this altered relationship between energy and space. This graduation project, called **'Geographies of Power- Spatial Strategies for a 'just' energy transition in Tamil Nadu'** aims to explore the spatial dimension of

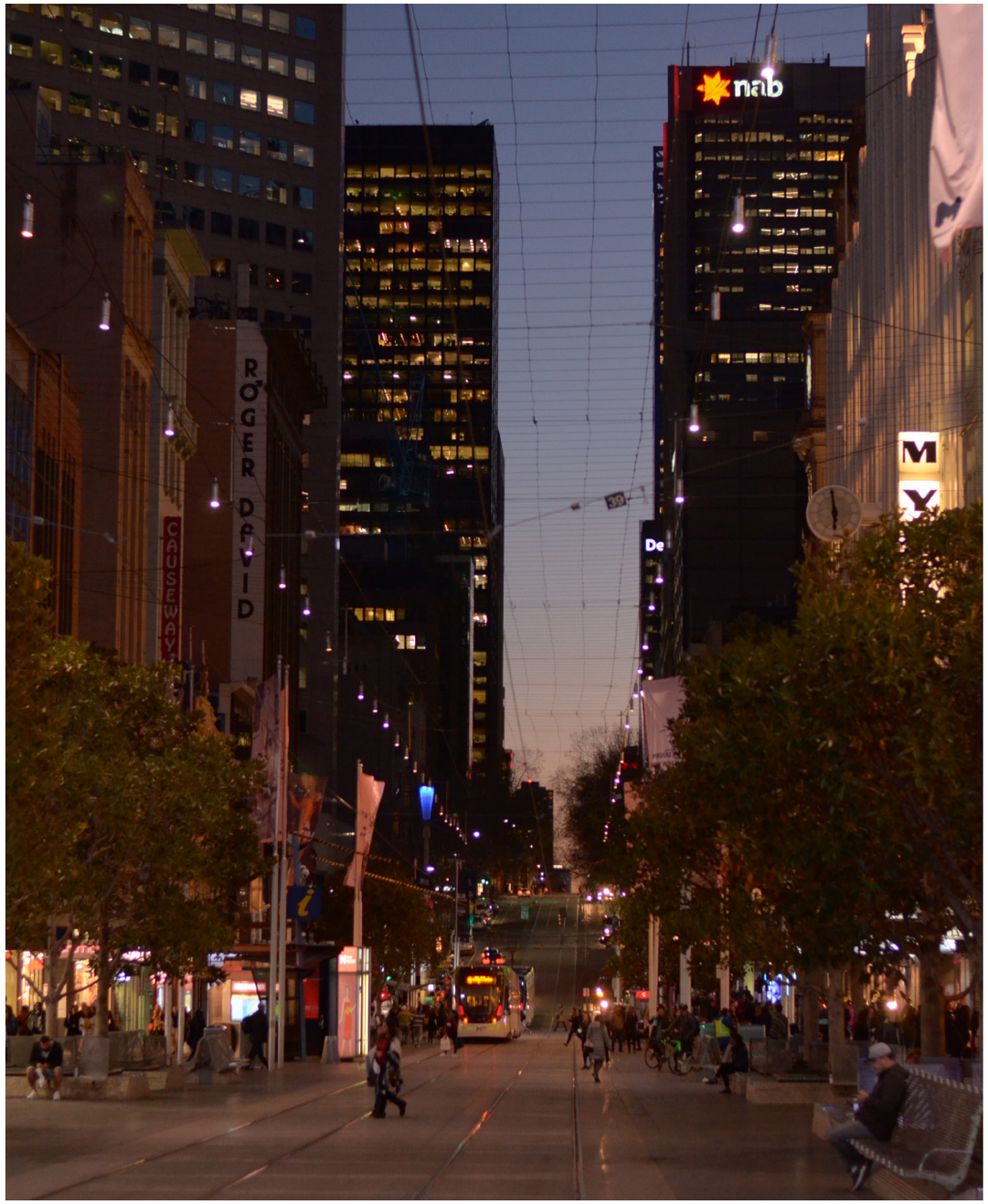

Fig 1.2: Civilisation- a product of energy extraction (Muthusamy, 2017).

energy transition in Tamil Nadu, India. By studying, mapping and analysing existing energy landscapes of the state, a framework for transitioning to renewable energy (R.E.) sources is presented. A regional design, comprising of a set of spatial strategies and a Strategic Plan for the state provides pathways for an ***adaptive, inclusive and collaborative energy transition*** in Tamil Nadu (Fig 1.3).

The following paragraphs present a brief overview of the project and the narrative of the report. In Chapter 2, the report introduces the ***problem field*** of exploring the spatial dimension of energy transition and the notion of 'energy-space' as a spatial typology by itself. Through the analysis of global energy status quo, energy trends, projected energy scenarios and the impact of energy extraction on the ground, a case for pursuing a 'spatial' energy transition is made. This potential of integrating energy transition and spatial planning is still in its nascent stage. The two fields of study largely remain separate with very little interdisciplinary collaborations. The project aims to integrate the fields of spatial planning and energy development to mediate the opportunities and conflicts that will mould the emerging energy-spaces of the future.

In Chapter 3, the conceptual framework adopted for the project and the theories that support the development of the project are elaborated. The project aims to embed the different means of energy in space with respect to the various ***socio-political structures inherent in the system, across geographic scales.*** In other words, the project looks to specifically focus on the spatial, political and social impacts of emerging energy geographies. By relating concepts of energy landscapes (spatial), energy access (social), and energy governance (political), the project aims to create a theoretical framework for a 'just' and humanised energy transition.

In Chapter 4, this aim is further explored by taking the case of Tamil Nadu in India, a state that is making tremendous progress in transitioning to renewable energy systems (Fig 1.4). This chapter elaborates in detail on Tamil Nadu, and highlights the peculiarities of the energy narrative in the region. The problem analysis is streamlined through three branches of research- ***space, politics, society***- and conclusions are presented in the form of specific problem focuses that the project explores in the analysis and design. Briefly, the problem focus identified by the project is the ***lack of regional integration and consideration of spatial conditions in R.E. development***, which continues to operate under extractivist, capitalist energy systems of the fossil fuel era, monopolized by private energy companies and supported by a rigid top-down governance system. This has lead to ***acute regional inequalities in energy access and distribution of benefits of the transition***. The shift to R.E. needs to be accompanied by a transformation of the spatial, socio-political structures that ensure energy development happens hand-in-hand with spatial planning. Tamil Nadu needs to include new actors and stakeholders

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1 GEOGRAPHIES OF 2 POWER

Spatial strategies 3 for a 'just' 4 energy transition 5 in Tamil Nadu 6

1 GEOGRAPHIES

The term 'geographies' of energy transition refers to the distribution of energy related activities, infrastructure, and process that yield geographic patterns, and geographical connections and interactions between that space and other spaces (Bouzarowkski and Simcock, 2017)

2 POWER

Energy is conceptualised as power- power as in 'energy' and power as a relational socio-political structure.

3 SPATIAL STRATEGIES

The project aims to create a regional design and supporting spatial strategies for energy transiiton in Tamil Nadu.

4 'JUST'

The access to and distribution of energy resources and benefits of energy transition in an equitable manner.

5 ENERGY TRANSITION

The spatial, societal, technical, political and geographic shift from non-renewable sources of energy like coal, oil, gas, nuclear, to renewable energy sources of energy like wind, solar, geothermal, biomass, etc.

6 TAMIL NADU

Tamil Nadu is the one of the southern states of India. It is the leader in energy transition in India and has a population of over 68 million.

Fig 1.3: Breakdown of the terms used in the title and subtitle.

Note: *Energy, which is generated from various sources (non-renewable and renewable), takes the form of usable electricity, heat and raw fuels to power various aspects of life. This project will only focus on 'electricity' and its sources, within the energy transition paradigm.*

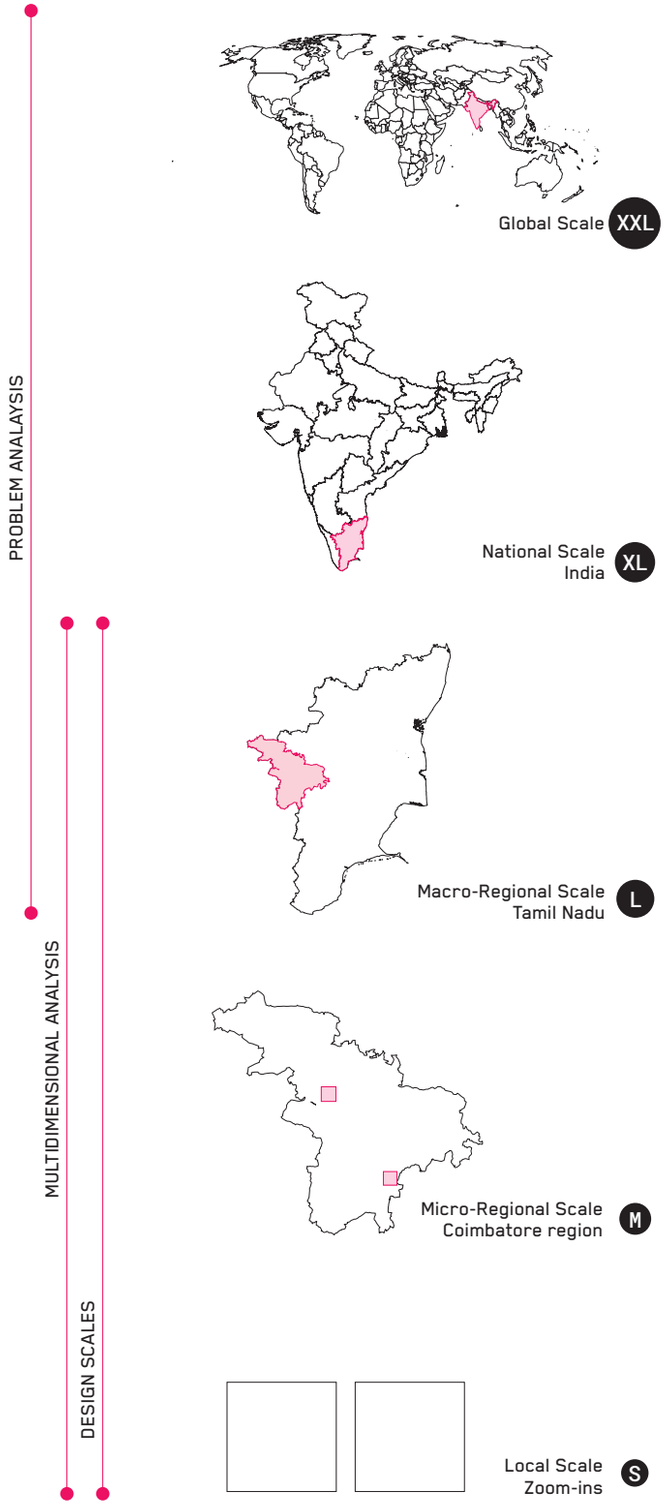


Fig 1.4: Geographic scales broached through research and design.

from local communities of the region, to catalyse social empowerment and place identity through the energy transition. The main research question of the project to tackle the problem- ***How can regional design of emerging energy geographies create a framework for a 'just' energy transition in Tamil Nadu?-*** emphasises the significance of the regional approach to designing for the transition, because of the dispersion of energy landscapes across territories and geographic scale in the state.

Chapter 5 lays out the research methodology and methods for data collection and analysis used in the project. It is important to note that the graduation project is primarily an ***explorative research***, to find new ways to study, analyse, map and design for the emerging energy geographies of the future. Chapter 6 presents the multidimensional analysis conducted to understand the opportunities and potentials for design. A methodology especially suited to the context of Tamil Nadu was crafted to identify the energy hotspots of the state by calculating their energy and spatial potential and social vulnerability in relation to each other. The outcomes of this stage were crucial in deriving the regional energy strategy and design for Tamil Nadu and its districts, of which Coimbatore region (comprising of three administrative districts) was chosen for further design exploration.

The Vision for Tamil Nadu 2050 is presented in Chapter 7, where a spatial vision for energy transition is elaborated. The chapter also presents principles and goals for implementing the ***vision for an energy future that is adaptive, inclusive and collaborative.*** Chapter 8 and 9 present the regional design and spatial strategies that provide pathways to implement the energy vision for Tamil Nadu. Chapter 10 tests the translation of the regional design and spatial strategies on the chosen micro-region of Coimbatore and two strategic zoom-ins in the micro-region. The testing of the design shows the workability of the regional strategies and an understanding of 'what needs to be done' on a local scale in reality.

Chapter 11 concludes the design phase of the project by providing a phase-wise implementation timeline till 2050 and key project milestones. The report concludes with Chapter 12, that reflects on the project, the ethical dilemmas faced during the development of research and design, the scientific and societal relevance of the project and recommendations for further research. It is important to note the project's contribution to the knowledge gap between energy studies and spatial planning. By taking the case of Tamil Nadu, India, the project also ***contributed to the body of knowledge on spatial energy transition in a developing context like India,*** where it is important to include the challenges to energy justice and equality in the discourse. The potential transferability of the concepts, research methodology and design process for use in under-represented geographies of the Global South, that face similar challenges in spatial energy transition is an important outcome of the project.

2

The Problem Field

Overview:

This chapter presents the ‘problem’, i.e., energy transition and its deeply spatial impact. The spatial dimension of energy transition is analysed to understand its significance, necessity and relevance in energy development. The typology of ‘energy-space’ is introduced and methods to study energy-space are identified. Finally, the project makes an argument to approach energy transition as a geographic process in relation to the social, political and spatial settings of a place.

Sections:

2.1. Energy and the World
2.2. Journey towards Energy Transition
2.3. Spatial Dimension of Energy Transition

2.1 Energy and the World

Energy is the only **universal currency** (Smil, 2017). All of the human race's advancements from cultivating crops, forming human settlements with complex societies and specialization of work, to making scientific and societal innovations, has been possible through the consumption and exploitation of various forms of energy resources. The consumption of energy to support increasing human endeavours has reached unprecedented levels, with over 80% of the energy produced from fossil fuels like coal, oil and gas.

The destructive environmental impacts of fossil fuel extraction, climate change, and the depletion of fossil fuel reserves have catalyzed the urgent need to transition to renewable sources of energy like wind, solar, geothermal, biomass or hydro-power (Fig 2.3, Fig 2.4). Renewable energy is fast emerging as a viable alternative to fossil fuels, with the prices of solar panels and wind turbines going down every day.



Fig 2.1: Changing lights from 2012-2016.Note the concentration of purple (new) lights in the Global South (NASA's Goddard Space Flight Center, 2017)

The immediacy of the need is more in developing countries in the Global South, whose consumption patterns are exploding with the drive for development (Fig 2.1). Fig 2.1 shows the increase in our energy consumption as seen from outer space. The map which was generated by comparing night views of the Earth taken in 2012 and 2016, plots the differences in light output. The lights in purple are the 'new' lights and lit areas of land which have come up in the last four years. The emergence of new lights in purple is distinctly visible in parts of South Asia, and India, in particular. The unprecedented increase in energy consumption and output has put the drive for energy transition at the battle foreground in India.

In this Chapter, the project explores the relationship of the world with energy, current production and consumption patterns, future scenarios of energy, the unavoidable shift to renewable sources of energy, and its global impact on India, as a country. First, a history of world energy is presented, followed by an analysis of global energy trends in energy. Then, the journey towards transition and the implications of renewable energy transition is explored. The Chapter ends with making a case for 'spatial dimension' of energy transition and why it is of utmost important to plan this energy-space.

Energy Timeline of the World.

In human history, energy transitions have underpinned broad social, economic and geographic change (Bridge, et al., 2012). In his book 'Energy and Civilisation' (2017), Vaclav Smil theorises that all of humanity's advancements from cultivating crops, forming human settlements with complex societies and specialisation of work, to making scientific and societal innovations, has been possible through the consumption and exploitation of new forms energy resources.

The transition to renewable energy is not the first instance of energy transition in history (Fig 2.2). The discovery and extraction of coal in the mid 18th century was an important milestone in human history. The transition from wood-based energy systems to coal enabled the Industrial Revolution to transform production, economy and society. Then came the transition from coal to oil, natural gas, and subsequent advancements in the automobile industry, have shortened distances and made the world closer. In this millennium, we are on the brink of another worldwide transition to renewable energy sources, which is going to have an immense impact on life as we know it. The transition from wood to fossil fuels (coal, oil, gas) took more than a century; this precedent and the current extreme dependency on this precedent indicates that renewable energy transition will be extremely slow unless we make drastic changes to the way we approach this shift.

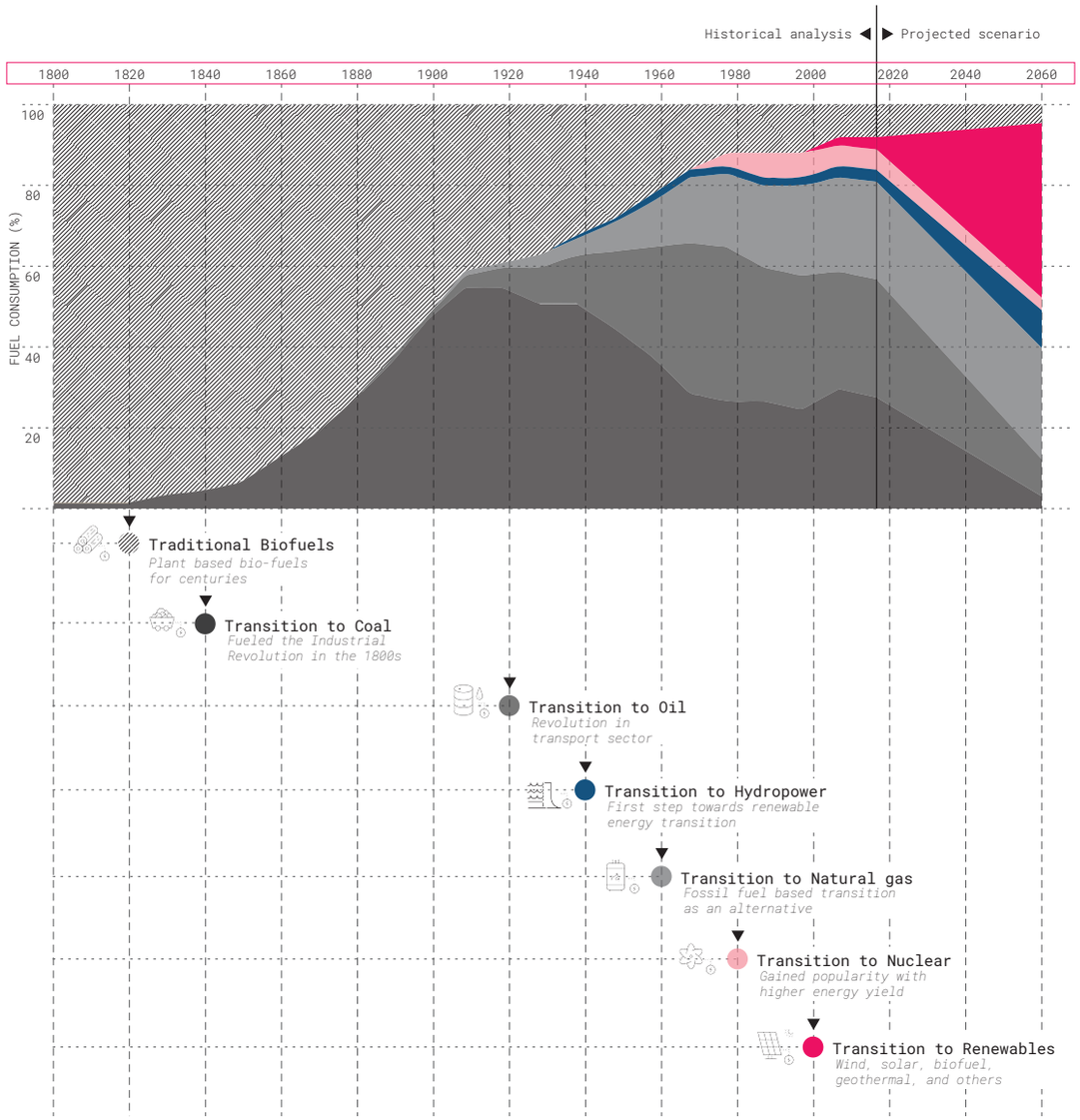


Fig 2.2: Energy timeline of the world. Data from Smil (2017)



Fig 2.3: Windfarms in Idaho, USA. (U.S. Department of Energy, 2012)



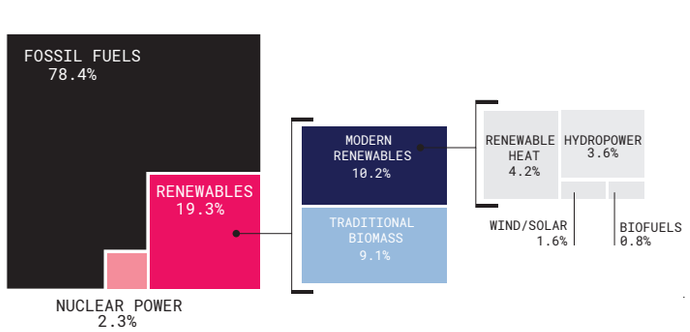
Fig 2.4: Oil fields in California, USA. (Burtynsky, 2003)

Global energy trends.

The next two pages outline global energy trends of production, and its consumption (Fig 2.5, Fig 2.7) and global energy mix by source (Fig 2.6). This gives a gist of global energy-related patterns and the position of India in it. The currency energy mix by source clearly shows an over-dependency on fossil fuels, and also a slow rise in renewable sources of energy. In Fig 2.7, the maps showing global energy production and consumption also indicate countries that face an energy deficit and surplus. This deficit and surplus conditions determine global trade in energy, one of the most powerful commodity trade across the globe. It is important to notice that India faces an energy deficit of 336 Mtoe (Million tons of oil equivalent), which is met by importing energy raw materials (fossil fuels) from other countries. This reinforces the need to achieve energy self-sufficiency within India by the development of renewable energy generation.

GLOBAL ENERGY CONSUMPTION BY SOURCE

Global primary energy consumption expressed by source (energy mix), and its growth, showing the dependency on specific energy sources over time.



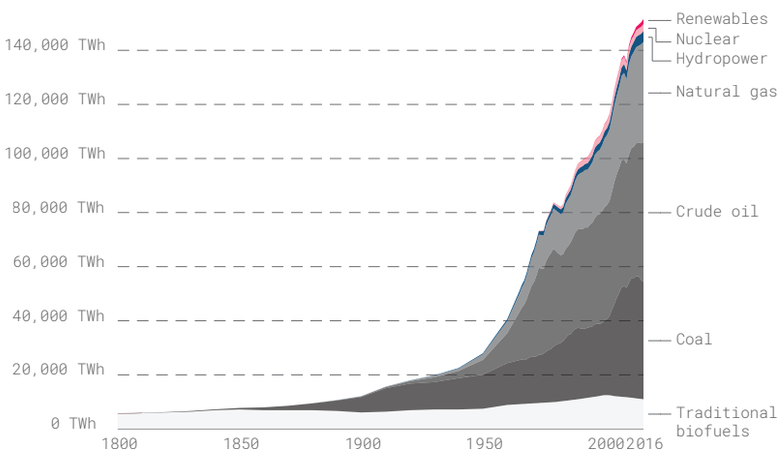


Fig 2.5: (left top) Global energy trends (REN21, 2017)

Fig 2.6: (left bottom) Global trends in energy mix by source (Our World in Data, 2018). Data from Smil (2017) and BP (2016)

Fig 2.7: (right) Three maps showing the global energy production, consumption and energy balance of trade. (Sources indicated in-figure text)

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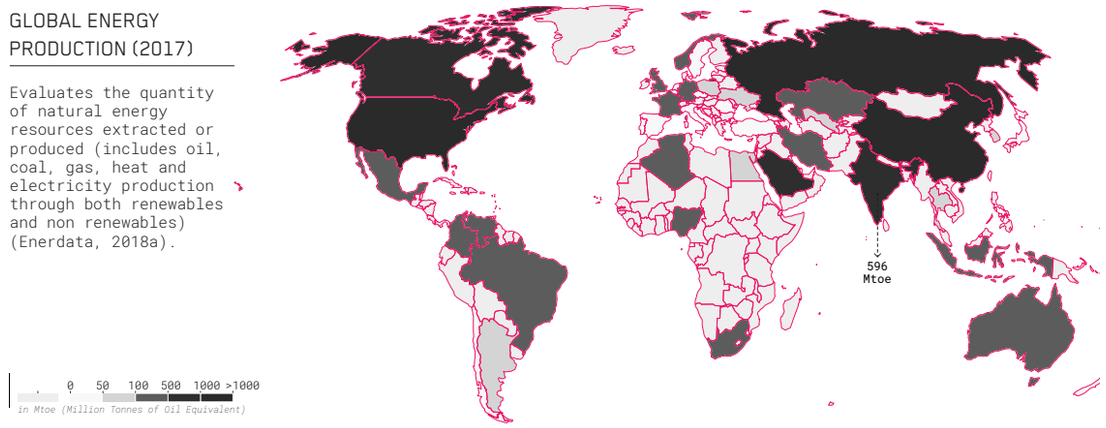
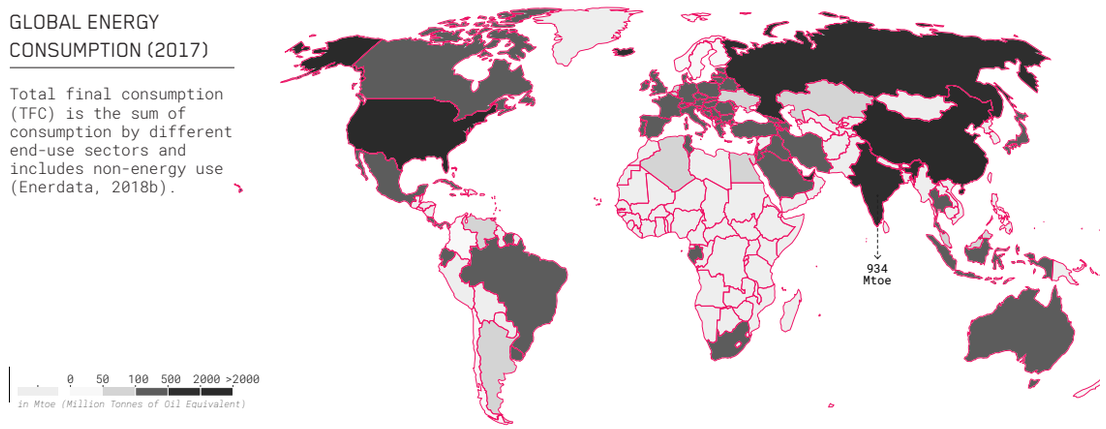
GLOBAL ENERGY PRODUCTION (2017)

Evaluates the quantity of natural energy resources extracted or produced (includes oil, coal, gas, heat and electricity production through both renewables and non renewables) (Enerdata, 2018a).



GLOBAL ENERGY CONSUMPTION (2017)

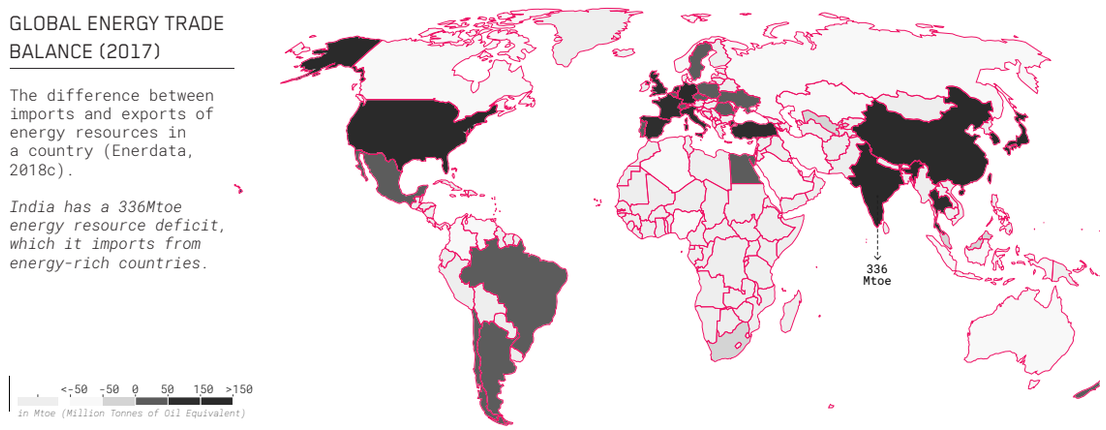
Total final consumption (TFC) is the sum of consumption by different end-use sectors and includes non-energy use (Enerdata, 2018b).



GLOBAL ENERGY TRADE BALANCE (2017)

The difference between imports and exports of energy resources in a country (Enerdata, 2018c).

India has a 336Mtoe energy resource deficit, which it imports from energy-rich countries.





YEARS OF FOSSIL FUELS LEFT

Years of global coal, oil and natural gas left, reported as the reserves-to-product (R/P) ratio which measures the number of years of production left based on known reserves and annual production levels in 2015.

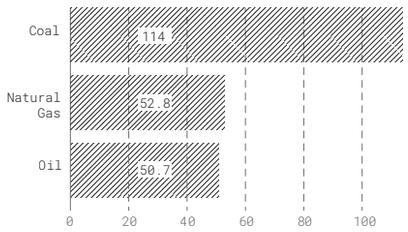


Fig 2.8: Oil fields in California, USA. (Burtynsky, 2003)

Fig 2.9: Years of fossil fuels left (BP, 2016)

Fig 2.10: What powers the world? (GoCompare, 2018; IEA, 2018)

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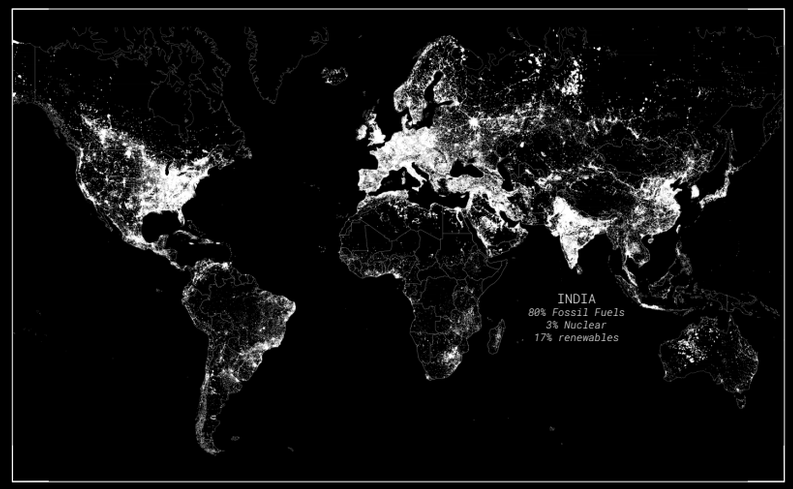
What powers the world?

● ON ○ OFF

CURRENT SCENARIO

The set of maps show the Night Lights visible as indicator of energy use in the world. The first map shows the global lights powered, if all three sources of energy (fossil fuels, nuclear and renewables) are ON.

● Fossil fuels
● Nuclear energy
● Renewable energy



WITHOUT FOSSIL FUELS

The second map shows the regions that will lose power if fossil fuels and nuclear energy (80% of world's energy source) are OFF.

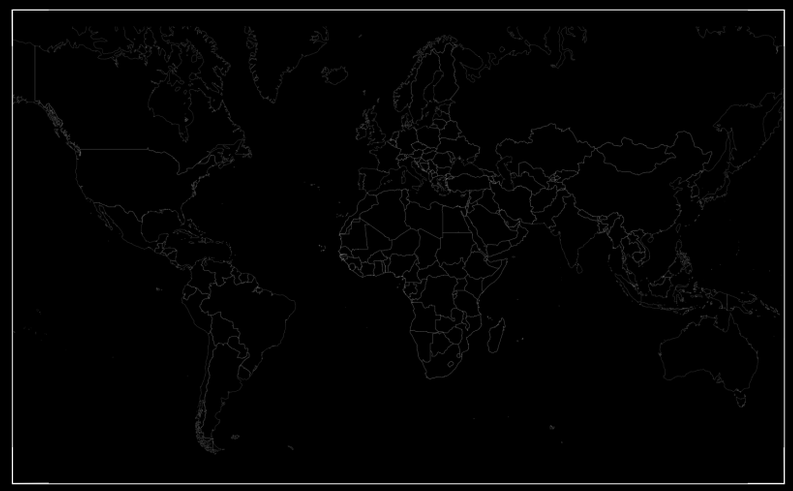
○ Fossil fuels
○ Nuclear energy
● Renewable energy



WITHOUT ALL ENERGY

The third map imagines a powerless world, when all three sources are OFF.

○ Fossil fuels
○ Nuclear energy
○ Renewable energy



To secure the future of the Earth, it is a race against time to shift to renewable sources before fossil fuels run out. Balancing the global over-dependency on fossil fuels is one of the main drivers of energy transition.

2.2 Journey towards Energy Transition

The International Renewable Energy Agency (IRENA) defines energy transition as 'pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century', mainly to reduce energy-related CO2 emissions to limit climate change (IRENA, 2019). It is significant that the agency estimates that renewable energy and energy efficiency measures alone can potentially achieve 90% of the required carbon reductions. It is one of the grand challenges of this century, driven mainly by the fact that there are less than 114 years of fossil fuel reserves left on Earth (BP, 2016).

The radical reduction in carbon emissions will require large scale spatial, societal, technical, political and ultimately a **geographic** shift from non-renewable sources of energy like coal, oil, gas, nuclear, to renewable energy (RE) sources like wind, solar,

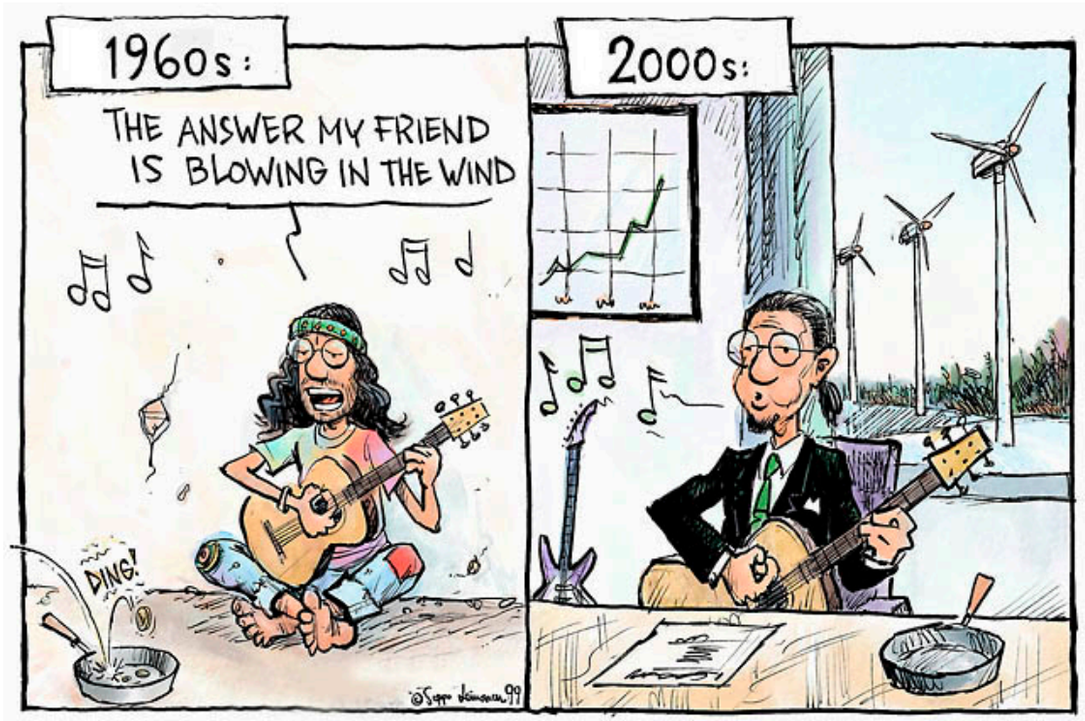


Fig 2.11: Cartoon heralding the wind-energy future (Leinonen, 1999)

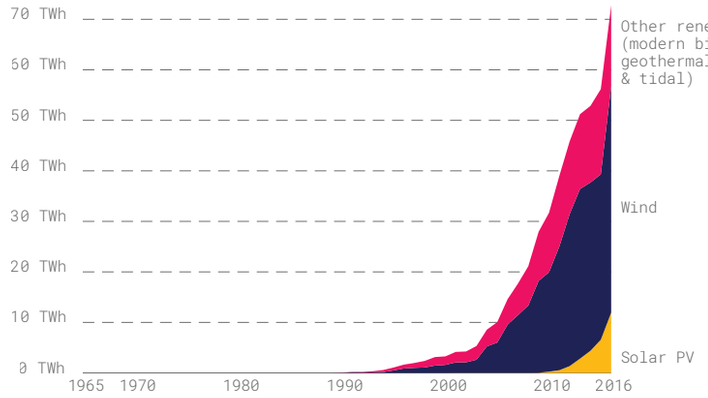
geothermal, biomass, etc. This following pages will argue for the urgent need for energy transition and its multidimensional impacts on various facets of society, from a global perspective by presenting statistics on renewable energy development. The project limits the scope of study to three types of RE: solar, wind, biomass; and the post-transition low carbon energy.

Global trends in renewable energy.

With the increasing urgency for the shift, and growing popularity of RE (Fig 2.12), countries are striving to achieve a higher share of RE sources in their total energy consumption (Fig 2.14). Here, the report also specifically mentions the position of India in the global RE status quo. Additionally, it is important to note that many developing countries in Africa and Latin America have a higher share of RE due to their consumption of traditional bio-based fuels (with the exception of Brazil, which has a high share of hydropower energy). Policies that help in the realisation of this goal are of utmost importance, which in turn will lead to the generation of millions of jobs worldwide in sustainable, clean energy (Fig 2.13).

RENEWABLE ENERGY PRODUCTION, BY SOURCE

Global renewable energy mix and growth over time.



JOBS GENERATED BY RENEWABLE ENERGY

More than 8.1 million jobs were created world-wide in renewable energy generation, directly and indirectly in 2016, and the number has grown to more than 10.5 million in 2018.



Fig 2.12: Renewable energy production by source (Our World in Data, 2018). Data from BP, 2016

Fig 2.13: Jobs generated by renewable energies (REN21, 2017)

Fig 2.14: (right) Three maps showing the global renewable energy share, countries with renewable energy targets and policies, and annual global CO2 emissions (Sources indicated in-figure text)

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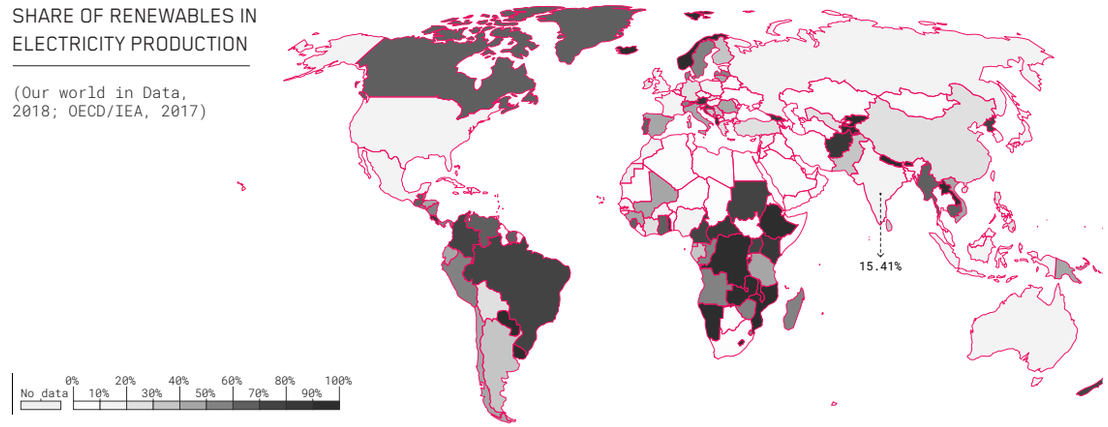
SHARE OF RENEWABLES IN ELECTRICITY PRODUCTION

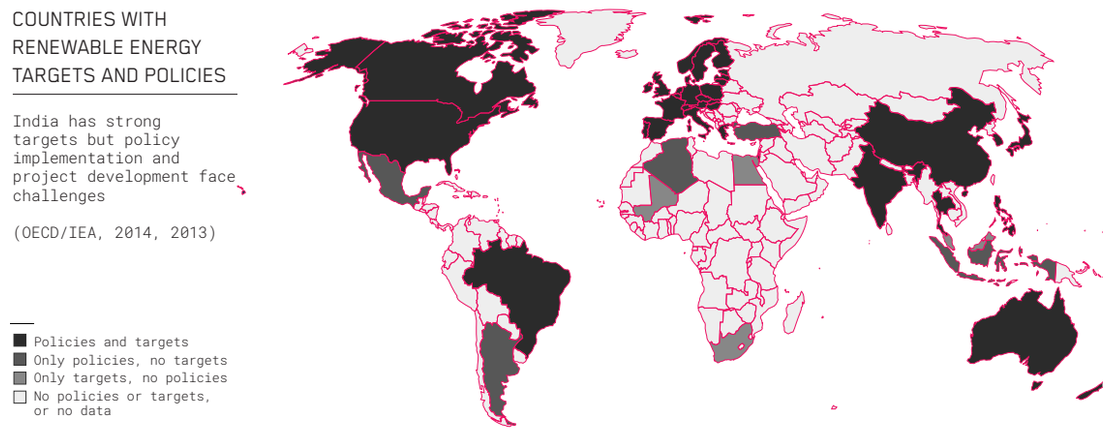
(Our world in Data, 2018; OECD/IEA, 2017)



COUNTRIES WITH RENEWABLE ENERGY TARGETS AND POLICIES

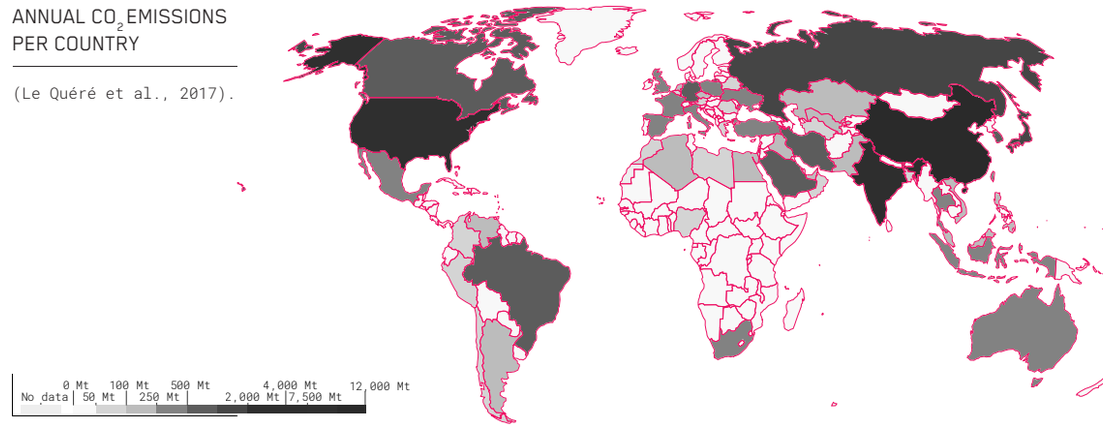
India has strong targets but policy implementation and project development face challenges

(OECD/IEA, 2014, 2013)



ANNUAL CO_2 EMISSIONS PER COUNTRY

(Le Quéré et al., 2017).



2.3 Spatial Dimension of Energy transition

Over the past decade, increasing attention has been drawn to the spatial dimension of energy transition. The human development of energy resources occurs at the **intersection of energy and space,** leaving distinct, permanent marks and spatial patterns on the land (Fig 2.15, Fig 2.16). The resulting landscapes of energy production, networks of distribution and territories of consumption together constitute a distinct spatial typology called **'energy-space'**. This energy-space is under constant development, transformation and exponential expansion, due to the increasing global demand for energy and shifts in energy outlook.

The project argues that there is an urgent need to approach **energy as a spatial phenomenon**, to fully understand the conflicts and opportunities of energy-space. In other words, the 'spatial dimension of energy transition' is the **'problem field'** of the project (Fig 2.17)

Fig 2.15: Westar Open Pit Coal Mine, Sparwood, Canada. (Burtynsky, 1985)





11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

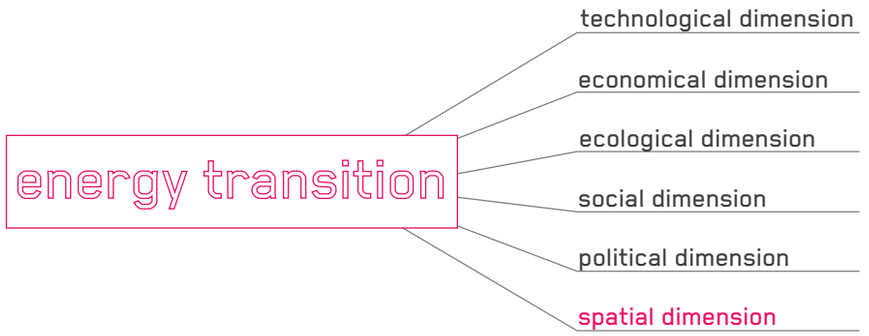
11.1271° N, 78.6569° E

Why spatial dimension?

The spatial dimension is extremely important in the context of energy transition since renewable sources of energy use and produce space in a different way than non-renewable sources. Renewable energy needs 100 to 1000 times more space to be produced than non-renewable energy sources (Smil, 2015), which reinforces the necessity of spatial planning in energy development. There is an urgent need to integrate the fields of spatial planning and energy development to mediate the opportunities and conflicts that will mould the energy-space of the future.

This section outlines the various ways in which development of energy resources has an impact on space and vise versa, to support its identification as the problem field of the project. Energy-space is analysed based on its form, function, spatial quality and embeddedness in space. Photographs of energy-space in India, taken during the field trip are also presented in this section to understand the intersection between energy and space.

Fig 2.16: Photograph showing the qualities of energy-space. (Tamil Nadu, India)



Energy transition has a spatial dimension.

Typology: "Energy-space"

*The human development of energy resources occurs at the intersection of energy and space, leaving distinct, permanent marks and spatial patterns on the land. The resulting landscapes of energy production, networks of distribution and territories of consumption together constitute **'energy-space'.***

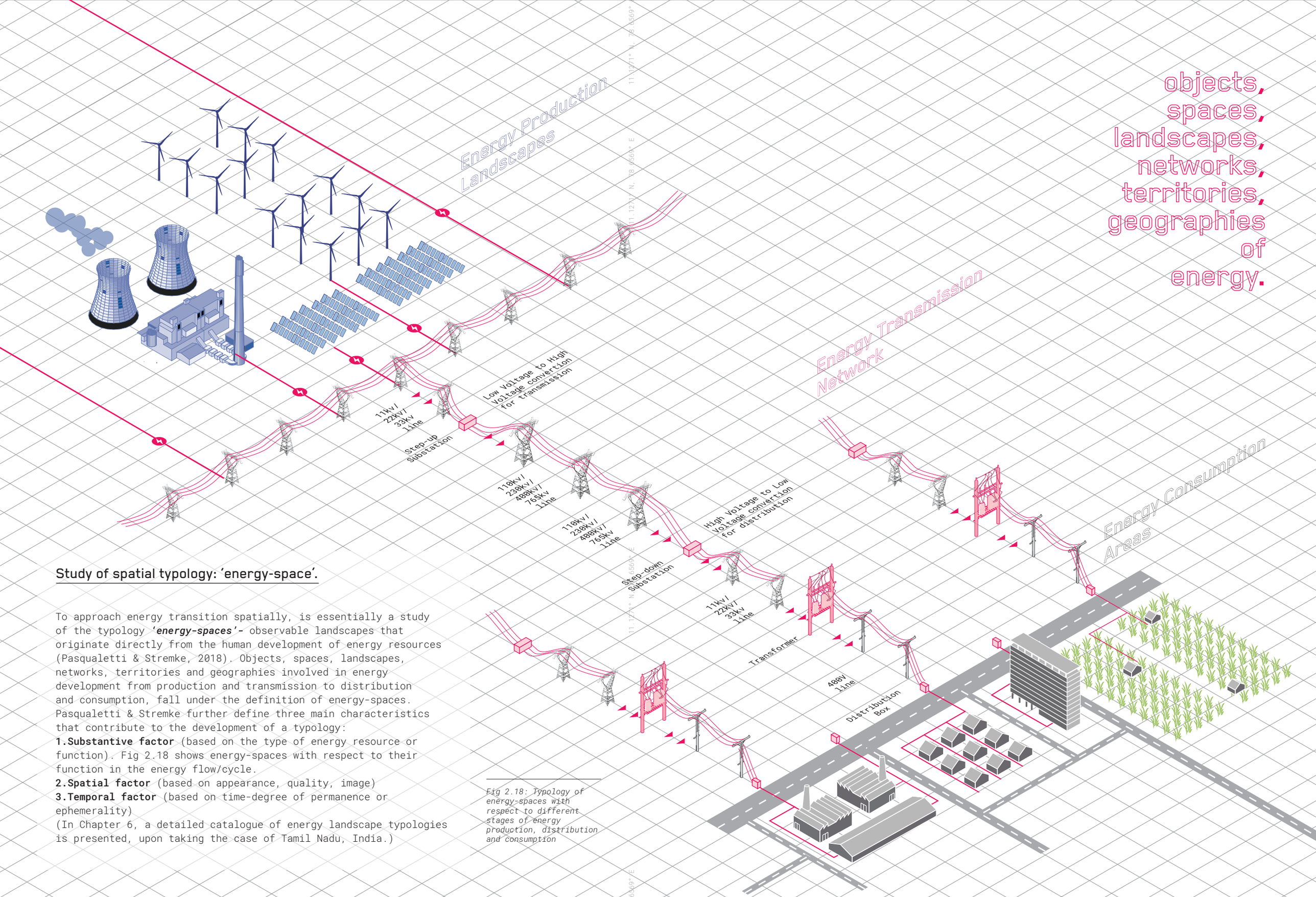
*The spatial dimension of energy transition is especially important in the era of energy transition since renewable energy systems use space in a **different, temporal way** than fossil fuel systems.*

Problem Field

There is an urgent need to integrate the fields of spatial planing and energy development to mediate the opportunities and conflicts that will mould the emerging energy-spaces of the future.

The project is situated in the problem field of investigating the spatial dimension of energy and creating methodologies to study, analyse and design for energy-spaces.

Fig 2.17: Scheme showing the rationale behind the problem field of the project



objects,
spaces,
landscapes,
networks,
territories,
geographies
of
energy.

Study of spatial typology: 'energy-space'.

To approach energy transition spatially, is essentially a study of the typology ***'energy-spaces'***- observable landscapes that originate directly from the human development of energy resources (Pasqualetti & Stremke, 2018). Objects, spaces, landscapes, networks, territories and geographies involved in energy development from production and transmission to distribution and consumption, fall under the definition of energy-spaces. Pasqualetti & Stremke further define three main characteristics that contribute to the development of a typology:

1.Substantive factor (based on the type of energy resource or function). Fig 2.18 shows energy-spaces with respect to their function in the energy flow/cycle.

2.Spatial factor (based on appearance, quality, image)

3.Temporal factor (based on time-degree of permanence or ephemerality)

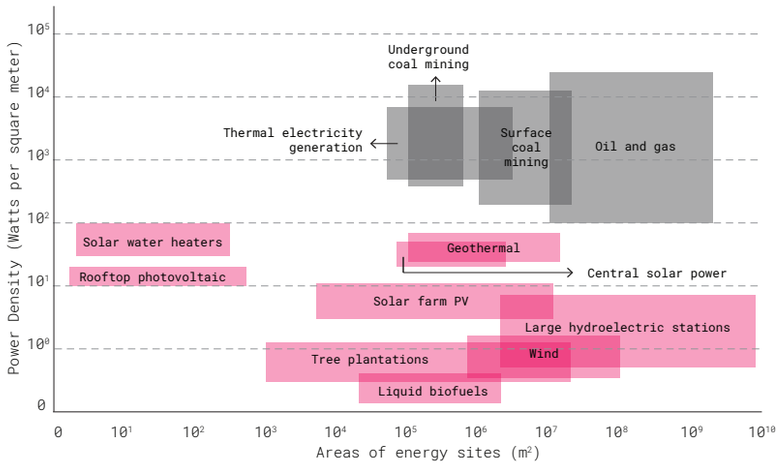
(In Chapter 6, a detailed catalogue of energy landscape typologies is presented, upon taking the case of Tamil Nadu, India.)

Fig 2.18: Typology of energy-spaces with respect to different stages of energy production, distribution and consumption

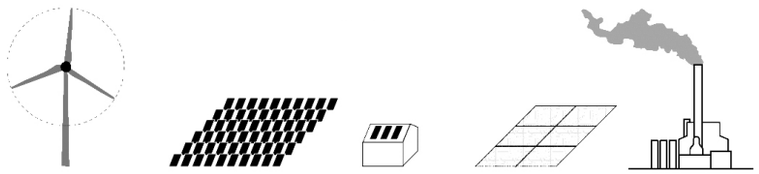
Spatial requirement of renewable energy.

The production of renewable energy will take 100-1000 times more space than NRE production, since RE has a significantly lower ***power density*** than fossil fuels (Smil, 2015)(Fig 2.19, Fig 2.20). Power density is the amount of energy produced per square meter of land utilised for its production (W/m^2). By comparing the spatial footprint that each type of energy would have for producing the same amount of energy, we find that, for example, coal extraction, with the layers of mined earth and tracks of access roads, permanently alters the nature of land formation, but comparatively takes up lesser area than what a hydropower plant or solar plant would use to produce the same quantity of energy (Fig 2.21). This means that the transition will exponentially increase the footprint of energy production, and have huge negative impacts on agricultural lands, ecological systems and overall quality of space- a compelling reason to integrate spatial planning with energy development.

POWER DENSITY- WHY R.E. CONSUMES MORE SPACE.



1PJ (277GWh) =



29-40	300-500	100000	4750	1/8
Windturbines (3MW)	Hectares of solar fields	Solar panels on rooftops of houses	Hectares of biomass fields	1000T/hr coal powerplant

Fig 2.19: Power density diagram. (Adapted from Smil, 2015)

Fig 2.20: Energy expressed in terms of footprint of each energy source. (Adapted from Posad, 2018)

11.1271° N, 78.6569° E

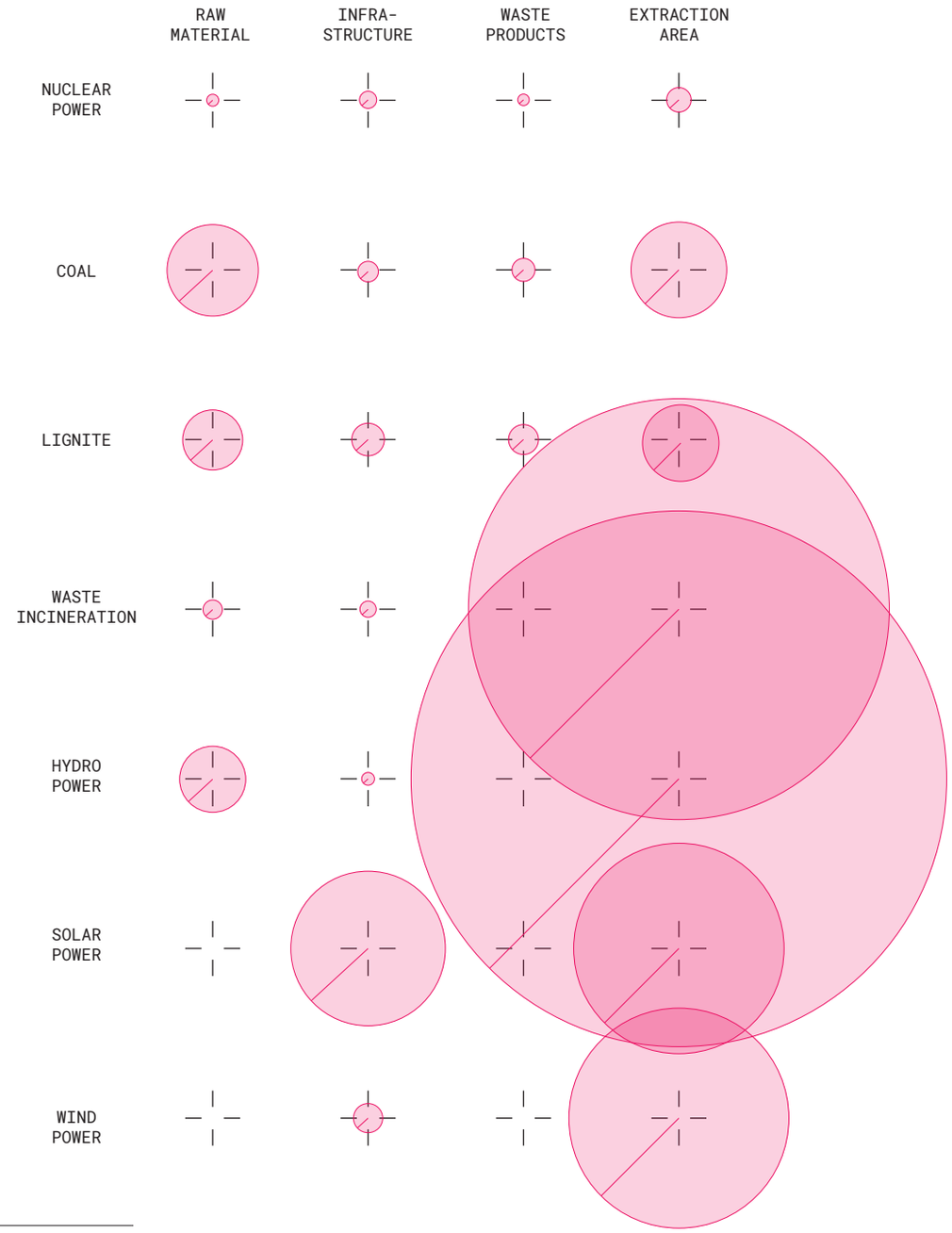


Fig 2.21: Footprints of various process of energy extraction and generation, to produce a common energy target, plotted in relative terms to each type of energy. Adapted from Sijmons, 2014

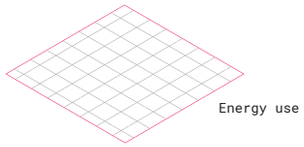
Spatial differences in renewable energy.

The spatial patterns, size, shape, quality of space, footprints, permanence on the land, spatial embeddedness of RE infrastructure are different from conventional energy production. Fig 2.22 and Fig 2.23 highlight some of the fundamental differences in the nature of two types of energy spaces.

SPATIAL PATTERNS OF NON RENEWABLE ENERGY

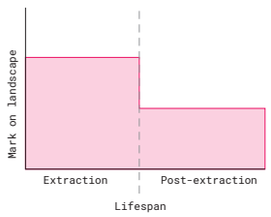
MONO-FUNCTIONAL LAND USE

The extraction of fossil fuels (coal mines, oil drilling, gas extraction), its conversion to usable electricity utilises land in a monofunctional way and doesnot allow other use of land to flourish on the same area.



PERMANENT LANDSCAPE

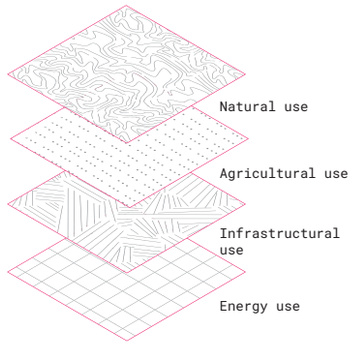
The extraction of fossil fuels (coal mines, oil drilling, gas extraction), its conversion to usable electricity leaves a more permanent mark on the landscape. (marks that can not be reversed sometimes)



SPATIAL PATTERNS OF RENEWABLE ENERGY

MULTI-FUNCTIONAL LAND USE

Sustainable Renewable energy production allows multiple uses of land to flourish on the same area. (with some exceptions)



DYNAMIC LANDSCAPE

Renewable energy production from solar or wind energy happens through point infrastructure that can be dismantled and land restored to its original condition. It doesnt leave a permanent mark on the landscape.

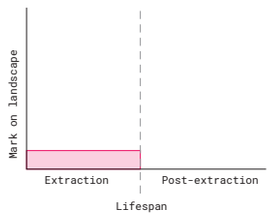
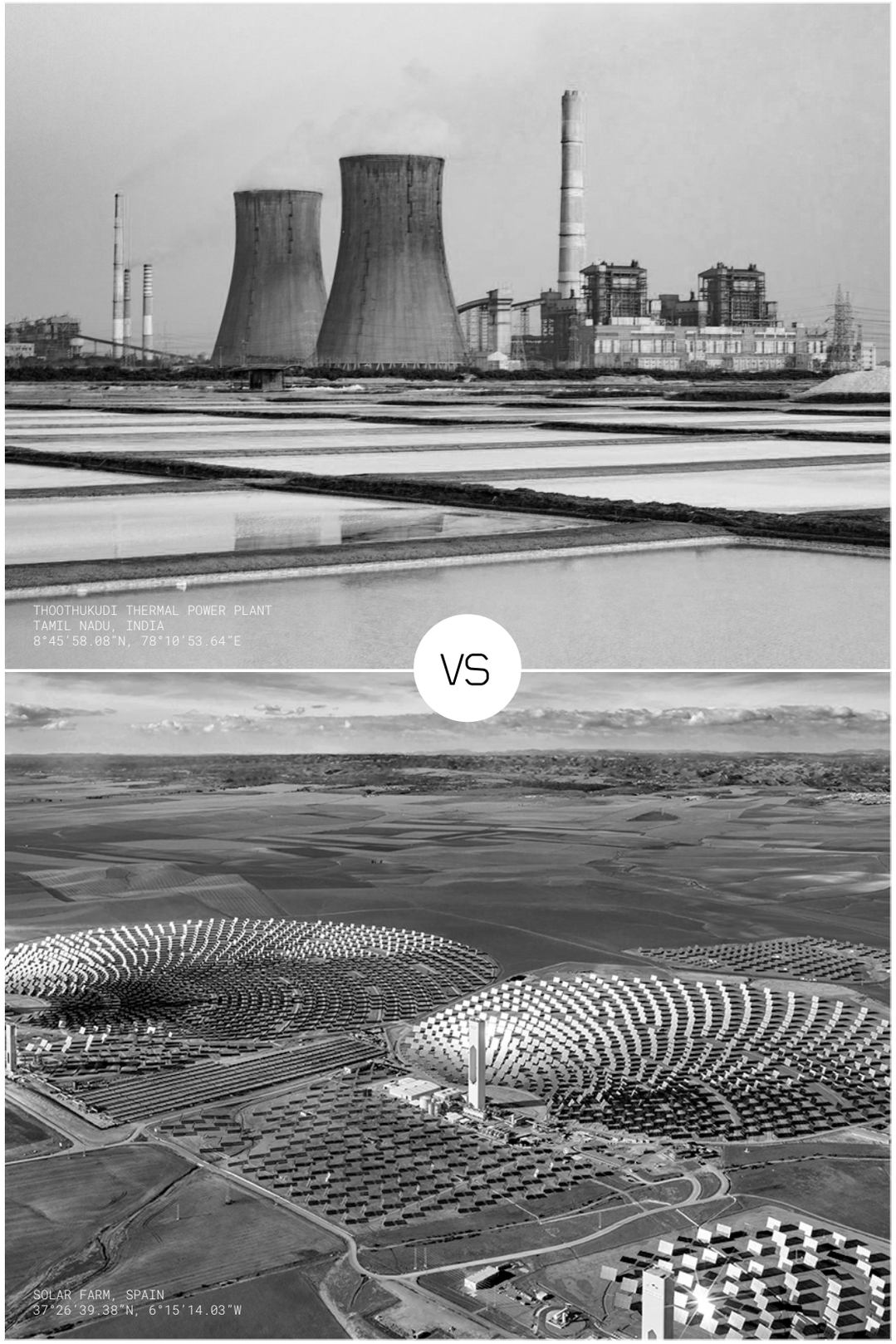


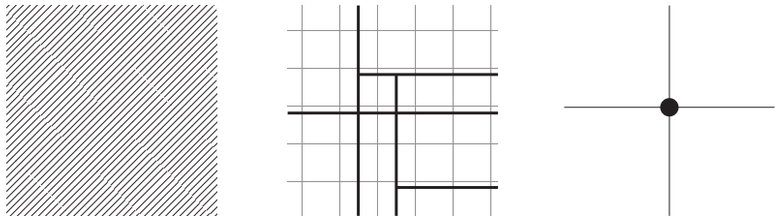
Fig 2.22: Differences in spatial patterns of non-renewable and renewable energies.

Fig 2.23: Two photographs that reveal the contrasting spatial patterns of non-renewable and renewable energy. Right top: Thoothukudi Thermal Power Plant, Tamil Nadu, India (Circle of Blue, 2017). Right bottom: PS10 Solar Power Plant, Seville, Spain (Burtynsky, 2013)



Spatial footprints of energy development.

What kind of spatial footprints do energy spaces leave behind? Each type of energy source has a distinct spatial footprint, both in terms of the ‘quantity’ of space, ‘form’ of the footprint. To understand the ‘form’ of the footprint in relation to the function (type of resource), Fig 2.25 highlights the different shapes of this footprint and their impacts on the surrounding environment. Each satellite image shows the geographic formations of different areas of energy extraction in India. This is then used as the base to draw an inverted ‘Nolli diagram’ to clearly show the morphology of the energy footprints and the spatial quality that they exhibit (Fig 2.27) The footprint, in its essence, is a ‘shape’ (larger areas of space, like thermal power plants) or a ‘point’ (component or entity, like windmills) or a ‘network’ (networks of distribution systems) (Fig 2.24, Fig 2.26).



1. KUDANKULAM NUCLEAR POWER PLANT, TAMIL NADU, INDIA
   8° 9’56.21”N, 77°42’48.84”E
2. MUPPANDAL WINDFARMS, TAMIL NADU, INDIA
   8°15’22.56”N, 77°33’36.95”E
3. MUMBAI COAL BUNDAR, MAHARASHTRA, INDIA
   18°58’56.00”N, 72°51’27.09”E
4. ENNORE COAL TRANSPORT LINES, TAMIL NADU, INDIA
   13°14’49.46”N, 80°19’46.47”E
5. METTUR HYDROPOWER DAM, TAMIL NADU, INDIA
   11°51’19.19”N, 77°49’20.81”E
6. JAMNAGAR OIL REFINERIES, GUJARAT, INDIA
   22°20’50.29”N, 69°51’50.31”E
7. KAMUTHI SOLAR FARMS, TAMIL NADU, INDIA
   9°24’57.49”N, 78°14’52.97”E
8. JAMNAGAR OIL REFINERIES, GUJARAT, INDIA
   22°20’50.29”N, 69°51’50.31”E
9. VINDHYANCHAL THERMAL POWER PLANT, MADHYA PRADESH, INDIA
   24° 6’0.22”N, 82°40’30.35”E
10. NEYVELI LIGNITE MINE, TAMIL NADU, INDIA
    11°33’28.76”N, 79°29’13.77”E
11. PRIVATE WIND FARMS, TAMIL NADU, INDIA
    10°41’14.45”N, 77°24’47.08”E
12. FOREST BIOMASS RESERVES, TAMIL NADU, INDIA
    9°33’34.62”N, 77°20’22.84”E

Fig 2.24: Types of energy footprints- shape, lines/networks, points.

Fig 2.25: Grid of satellite images showing various energy geographies across India (Google Earth/Digital Globe, 2018)

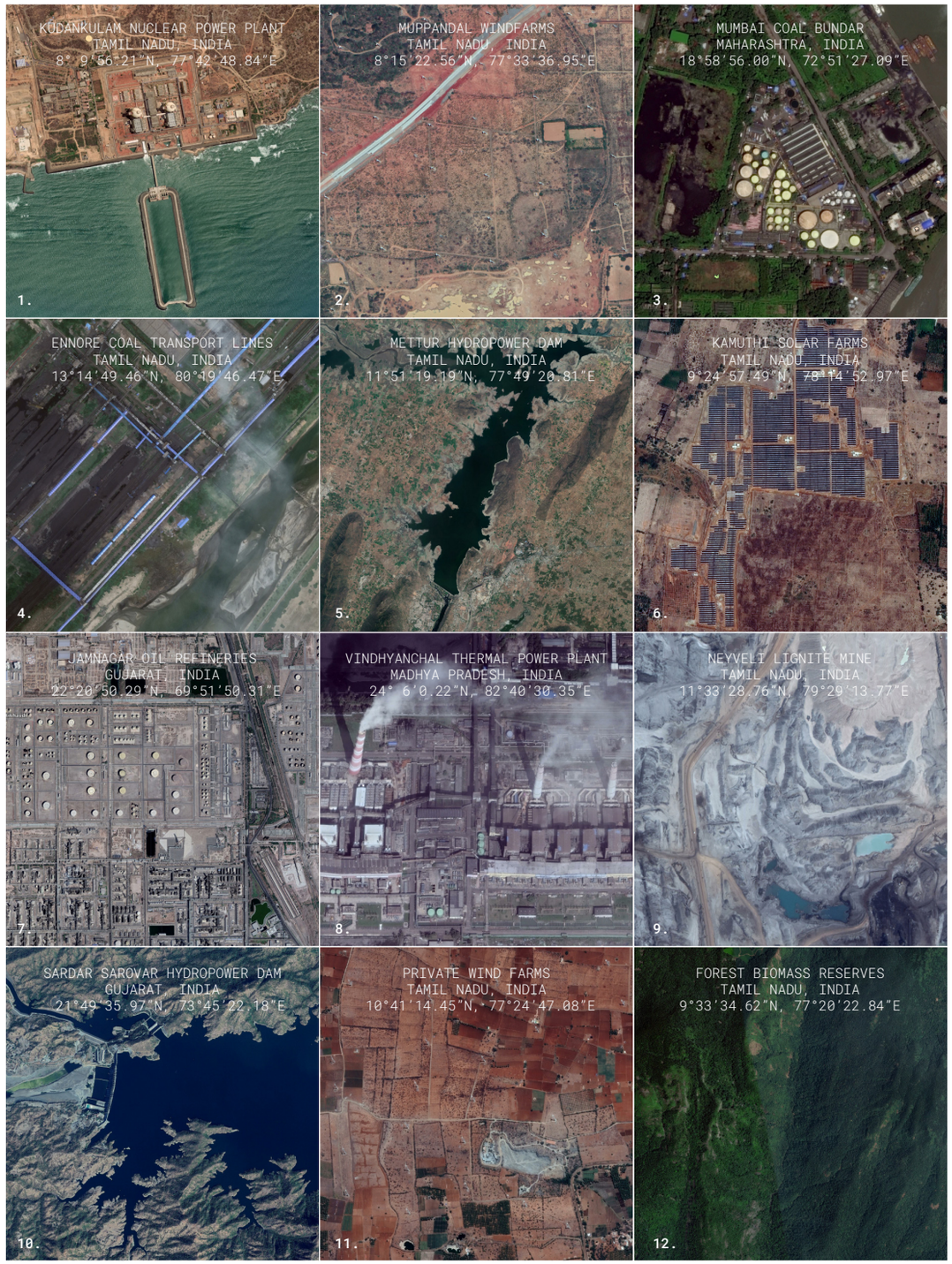
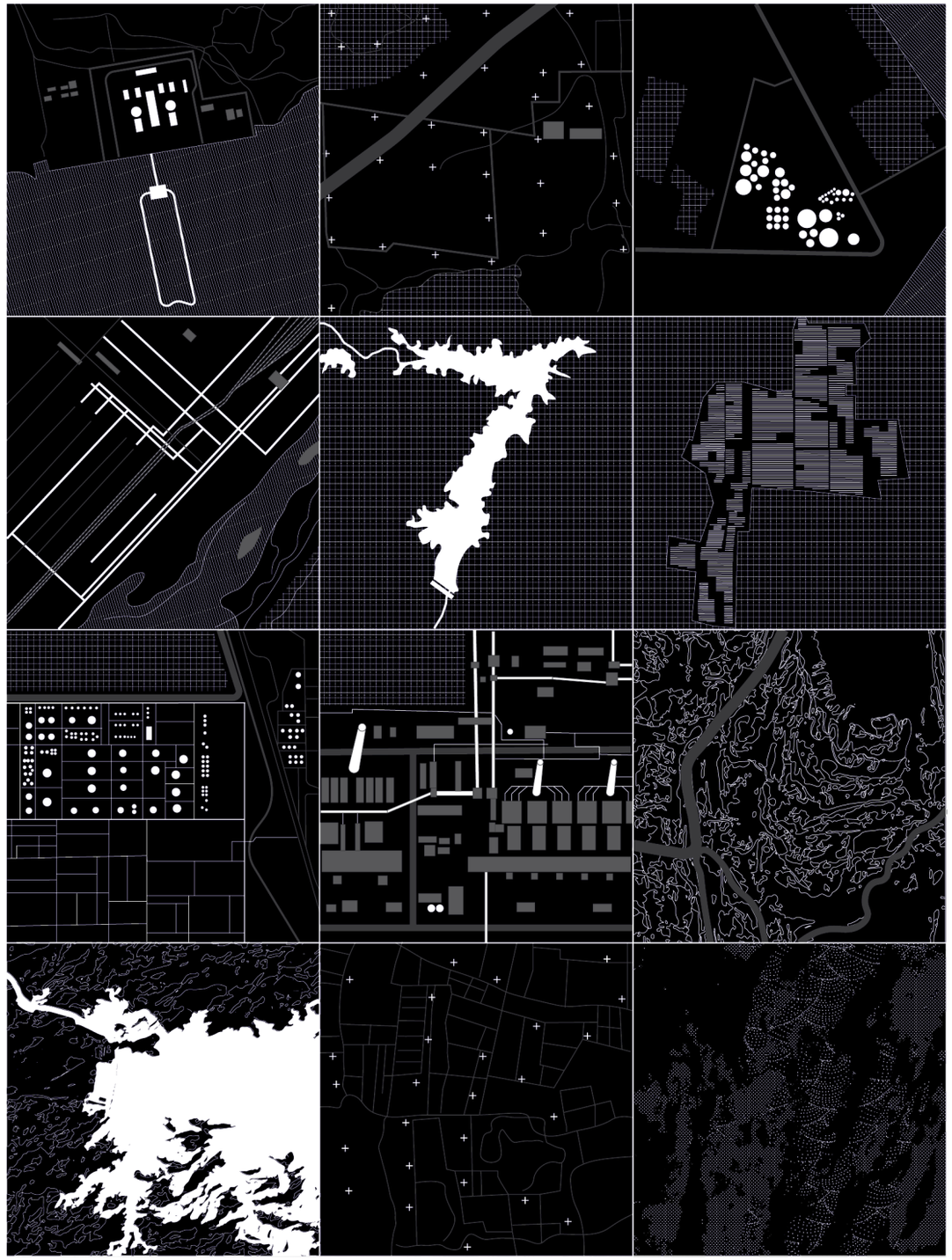




Fig 2.26: Photograph of wind farms situated within coconut groves in Tamil Nadu, India.

Fig 2.27: Grid of inverted 'Nolli diagram' for energy geographies, overlaid on satellite images of Fig 2.25



From a spatial to a geographic approach.

Finally, the conceptualisation of energy as a spatial phenomenon requires a review of current literature on energy-spaces. Various scholars offer different definitions based on their academic background and school of thought. Energy-space, energy landscape (Pasqualetti & Stremke, 2018), energy geographies (Bridge, et al., 2012), energy-scape are some of the terminologies used to define spaces of energy development.

> **Energy landscapes:** The notion of energy landscapes defines it as observable landscapes that originate directly from the human development of energy resources (Pasqualetti & Stremke, 2018). The authors further state that 'combining the term energy with landscape produces a useful unifying label for the marks, structures, excavations, creations, and supplements that energy developments produce,(…) and all the principal elements that appear at the confluence of energy and technology – i.e. technical, visual, social, ecological and political.'
>
> **Energy geographies:** A parallel movement that emerged from the research in energy-space is its conception as energy geographies, which approaches the production of energy as a fundamentally geographic process. This stems from an elementary shift in the understanding of space itself. Informed by the theories of critical geography (Harvey, 2001) and relational space (Massey, 2004; Lefebvre, 1991), this movement understands space not as a neutral container within which various social, political and economic processes happen, but as 'product of interrelations' (Massey, 2005) that is continually made and re-made by these processes. Space, in turn, constitutes the said processes and actively produces and maintains them (Bouzarovski & Simcock, 2017; Dikeç, 2001; Soja, 2010). This geographic approach to energy-space (and energy transition) firmly situates it within the nexus of spatial, social, governance dimensions of transition.

The geographic approach to energy transition will give insights on spatial differentiation and territorialisation of energy networks, relational socio-political structures, patterns and scales of organisation of energy infrastructure. This geographic approach to energy transition has the potential to bridge the epistemological and methodological rift between energy studies and spatial planning, by viewing space as a product of interrelations. By adopting a geographic approach to energy transition, the project will also focus on the social and political dimensions shaping the transition apart from the spatial dimension. Thus, the three dimensions- ***space, society and governance are the three branches of research that the project will focus on henceforth***. The following chapter will introduce the case of Tamil Nadu, India and analyse the region with respect to the three branches of research-space, society and governance.

THREE BRANCHES OF RESEARCH FROM THE GEOGRAPHIC APPROACH

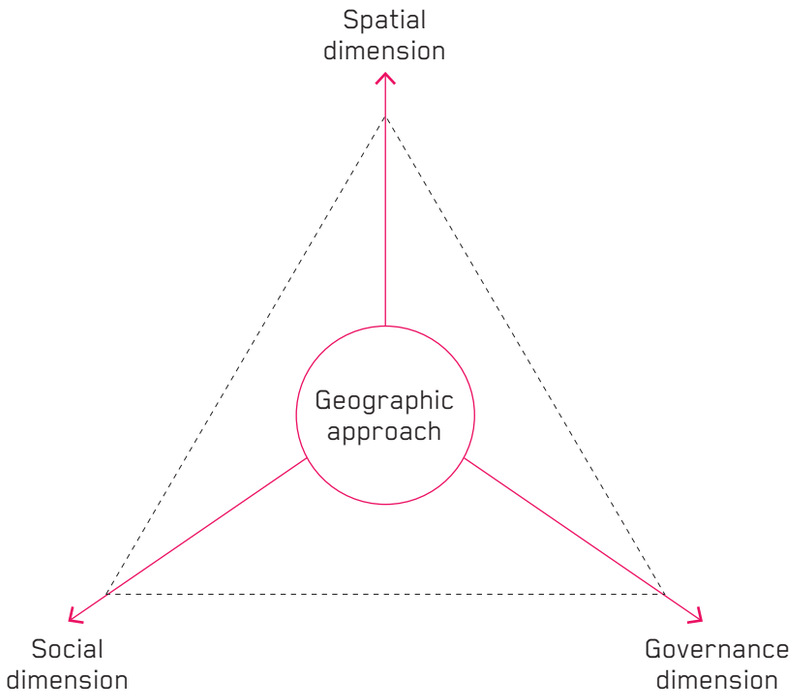


Fig 2.28: Diagram showing the geographic approach and the three branches of research.

Conclusions.

This chapter elaborated on the problem field of the research- spatial dimension of energy transition, to contribute to the knowledge gap between energy development and spatial planning. While Sections 2.1. and 2.2. presented global trends on energy development and transition potentials, Section 2.3. established the project's focus on the spatial dimension of transition. Furthermore, the section elaborated on what exactly it means to approach it 'spatially', and why the study of the typology 'energy-space' is essential to the project (Fig 2.29, Fig 2.30). The section also specified the three branches of research that the project conducts, with respect to energy development- energy-space, energy-society and energy-governance.

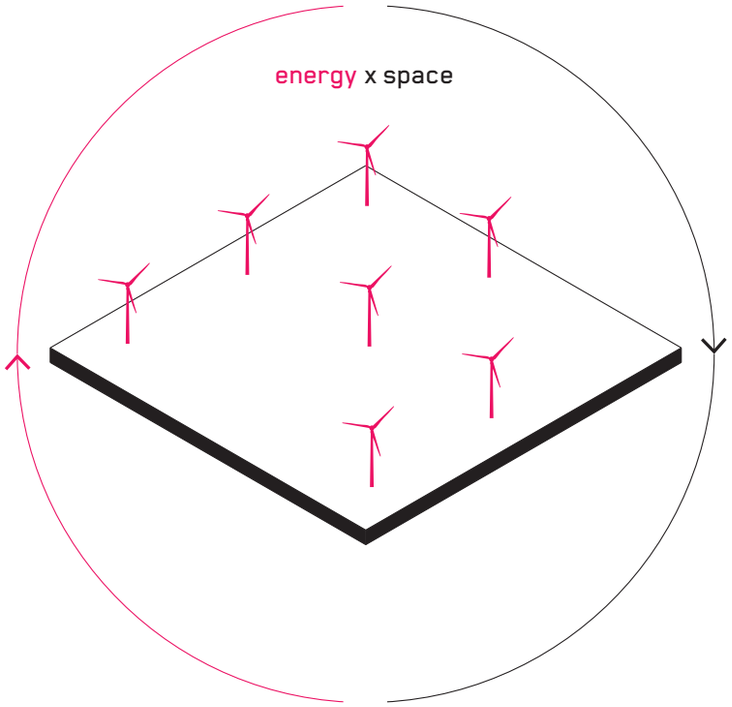


Fig 2.29: Diagram summarizing the Chapter



Fig 2.30: Photograph showing vast infrastructural landscapes in the inter-stitial space between urban and rural areas.

3

The Problem Focus

Overview:

This Chapter introduces the state of Tamil Nadu, India, as the case for the exploration of the geographic approach to energy transition. The spatial, social, and governance dimensions of energy transition in Tamil Nadu are analysed to identify the problem focuses and the main research question of the project: How can regional design of emerging energy geographies create a framework for a just energy transition in Tamil Nadu?

Sections:

3.1. Energy transition in Tamil Nadu, India
3.2. Energy x Space
3.3. Energy x Society
3.4. Energy x Governance
3.5. Problem Focus and Research Questions

3.1 Energy transition in Tamil Nadu, India

13 years ago, India launched plans to develop 16 Ultra Mega Power Plants (UMPP) of 4000MW capacity each to meet the country's growing energy demand. Powered by tons of local and imported coal, these UMPPs was an environmental disaster in the making, and would have reinforced India's dependency on fossil fuels even more. But, in a span of 10 years, India's energy outlook had a significant change. In alignment with the Paris Climate Agreement, India has pledged to increase its renewable energy capacity to 40% reduce the carbon intensity of its economy by 33-35% by 2030 (Mohan and Topp, 2018). By 2027, India is estimated to have installed 275 GW of RE capacity, which would be more than a four-fold increase on current levels (CEA, 2018). India was also one of the first countries to set up a separate ministry for called the Ministry of Non-Conventional Energy Sources, way back in 1992 (now renamed the Ministry of New and Renewable Energy-MNRE) (Nesamalar, et.al., 2017).

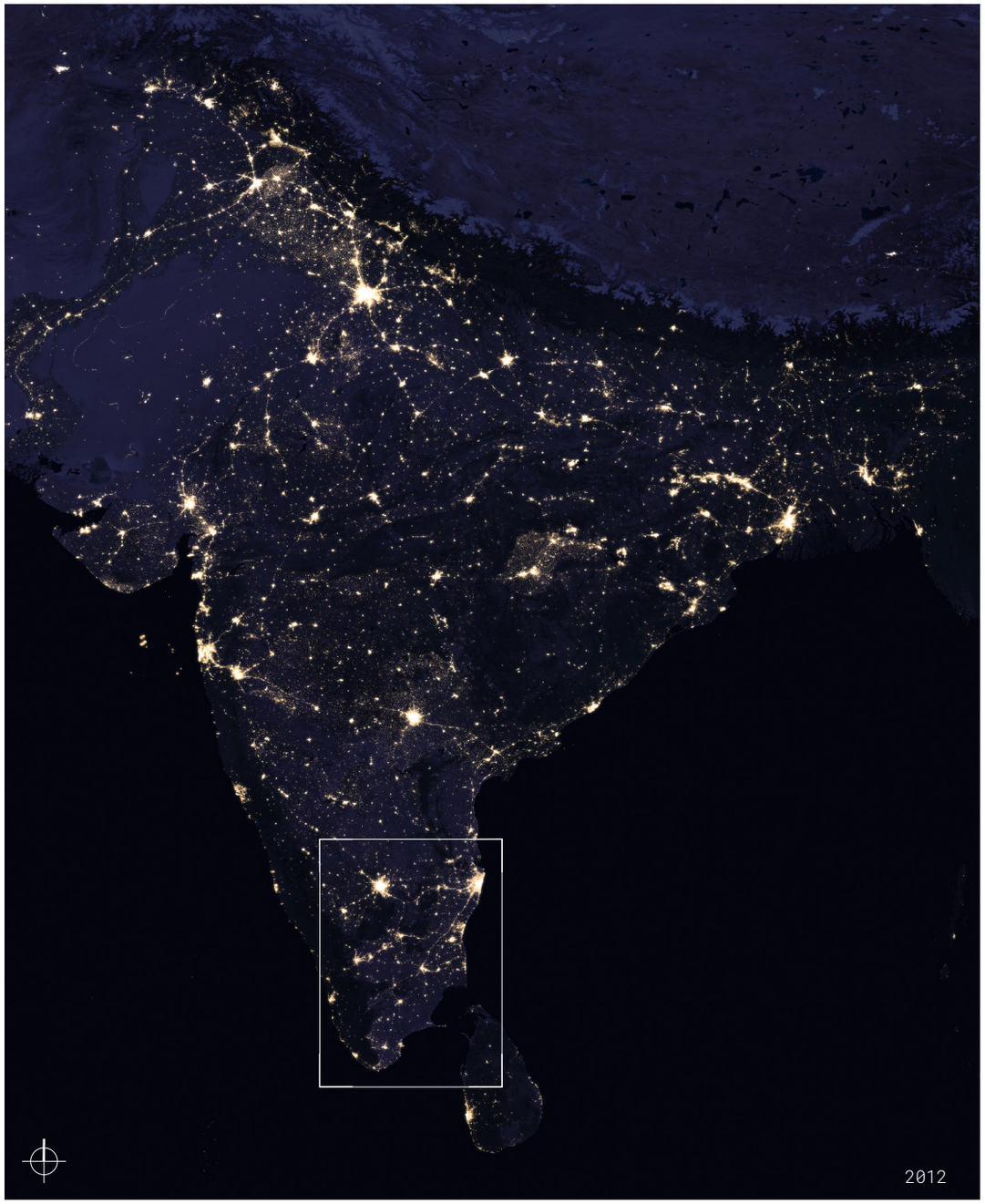
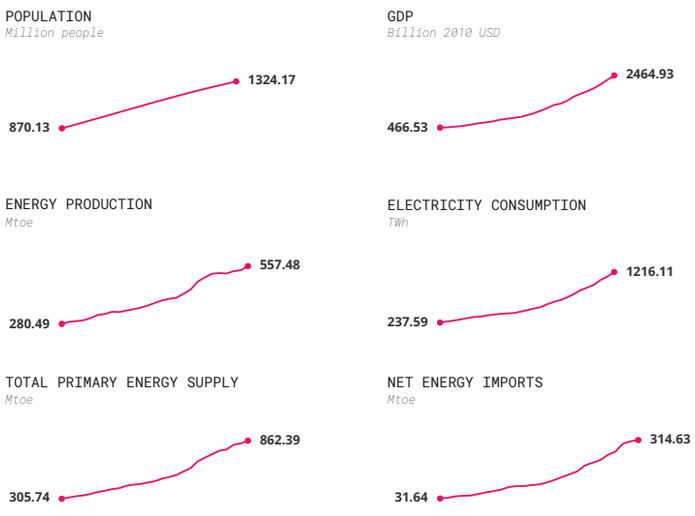


Fig 3.1: View of India at night from outer space showing intensity of light (energy use) in 2012 (NASA Worldview, 2012). Note that the white box indicates the region of focus of the project.

Additionally, India, which was one of the largest energy access deficit countries in the world, is on its way to achieving universal electricity access by the end of 2018. The country faces the huge challenge of providing uninterrupted, affordable and equitable energy to support the pace of growth and development (See Fig 3.1 and Fig 3.4). Despite commendable technical advancements in electricity generation and capacity, India continues to be a power deficit country. The current energy scenario in India is a 'contested narrative of change' (Mohan and Topp, 2018). While the economic and social opportunities of renewable energy are starting to be tapped, the country continues to be swayed by players with vested interests in fossil fuel domination. These contested narratives will determine India's energy scenario of the future. This section explores the energy status quo of India, trends in consumption and generation of energy (Fig 3.2 and Fig 3.3) and raises the following question:

> **How will energy transition change the future of the second most populated country in the world? And importantly, how can this transition be driven by the notion of energy justice?**



INSTALLED CAPACITY OF ELECTRICITY BY SOURCE AND OWNERSHIP (2017)

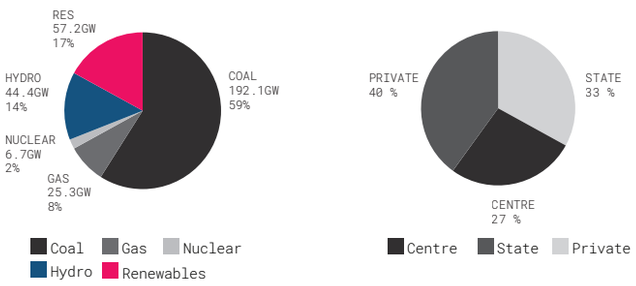


Fig 3.2: Key energy trends in India (1990-2016) (IEA, 2018)

Fig 3.3: Total installed capacity of electricity in India (CEA, 2018)

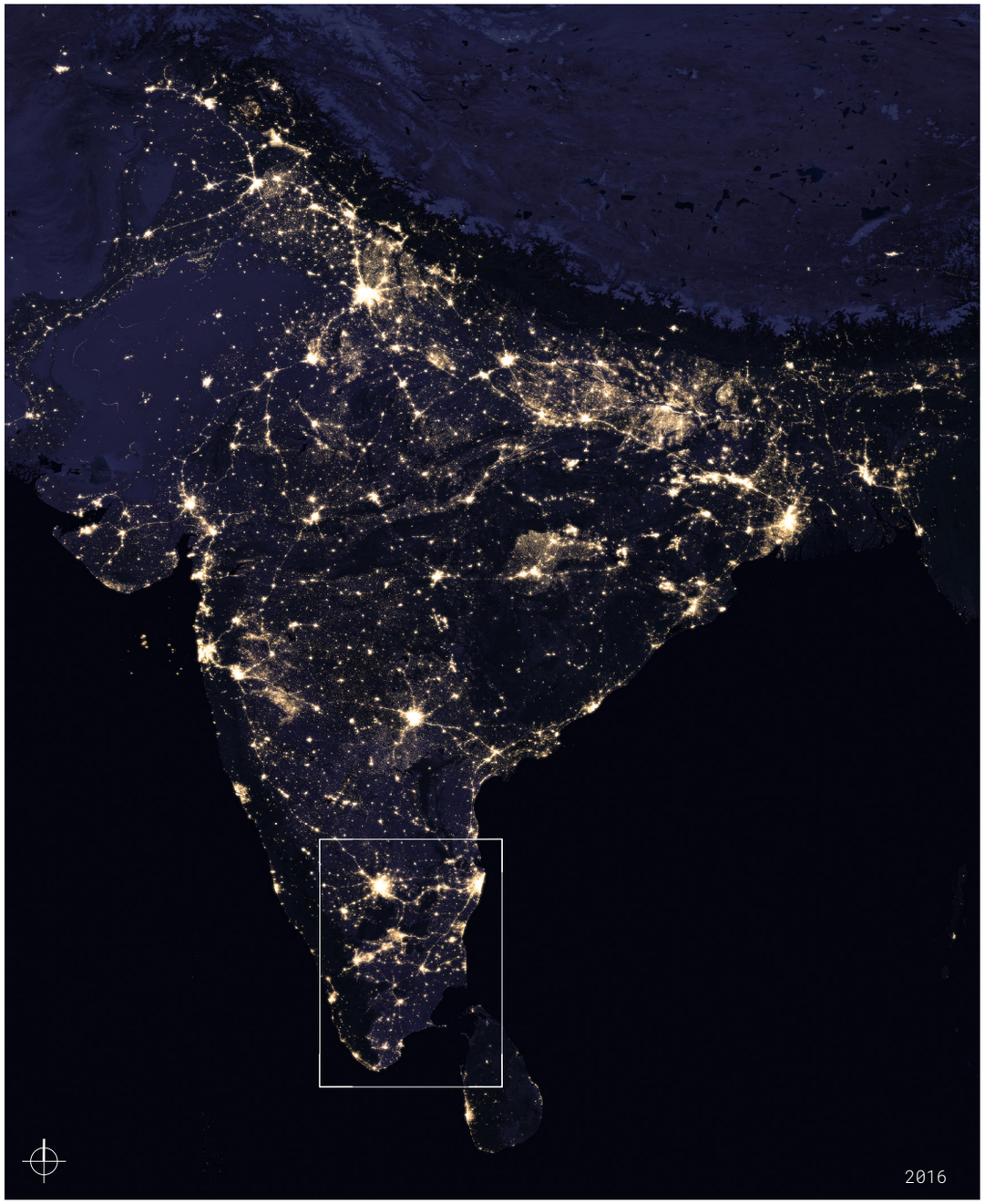


Fig 3.4: View of India at night from outer space showing intensity of light (energy use) in 2016 (NASA Worldview, 2016). Note that the white box indicates the region of focus of the project.

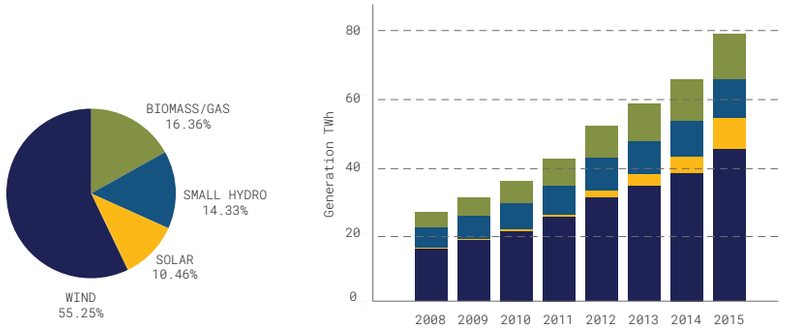
Renewable energy in India.

India now competes with China, the United States, Japan, and Germany as a world-leading developer of electricity from wind, solar, biomass, and small hydropower plants. India has the fourth largest generating capacity from wind power, at more than 30 GW. Most parts of the country (especially the western and southern regions) are also blessed with sunny skies for more than 300 days/ year, which makes it highly suitable for the development of solar energy as well. Key statistics in renewable energy scenario of India (Fig 3.5), the employment opportunities created by renewable energy directly and indirectly (Fig 3.7) are presented below. The estimated state-wise renewable energy potential (Fig 3.8), and the estimated total renewable energy potential of the country (Fig 3.9) indicate that energy transition could be the most favourable pathway for India's energy future.

36%
Share of renewables in total final energy consumption

16%
Share of renewables in total final electricity consumption

56%
of total renewable energy generation is from wind energy



JOBS GENERATED BY THE RENEWABLE ENERGY SECTOR IN INDIA

Renewable energy generation provides more than 621000 jobs currently, and with the expansion of RE, this number is likely to grow exponentially.

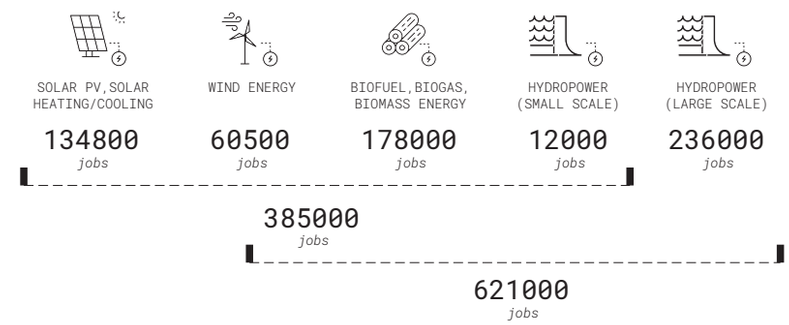


Fig 3.5: Key stats on renewable energy in India (India Energy Data, 2018).

Fig 3.6: Share of types of renewable sources of energy over the years in India (India Energy Data, 2018)

Fig 3.7: Jobs generated by Renewable energy sector in India (REN21, 2017)

STATE-WISE RENEWABLE ENERGY POTENTIAL IN INDIA

Estimated renewable energy potential of India. Note that Tamil Nadu has a high cumulative RE potential in comparison to other states.

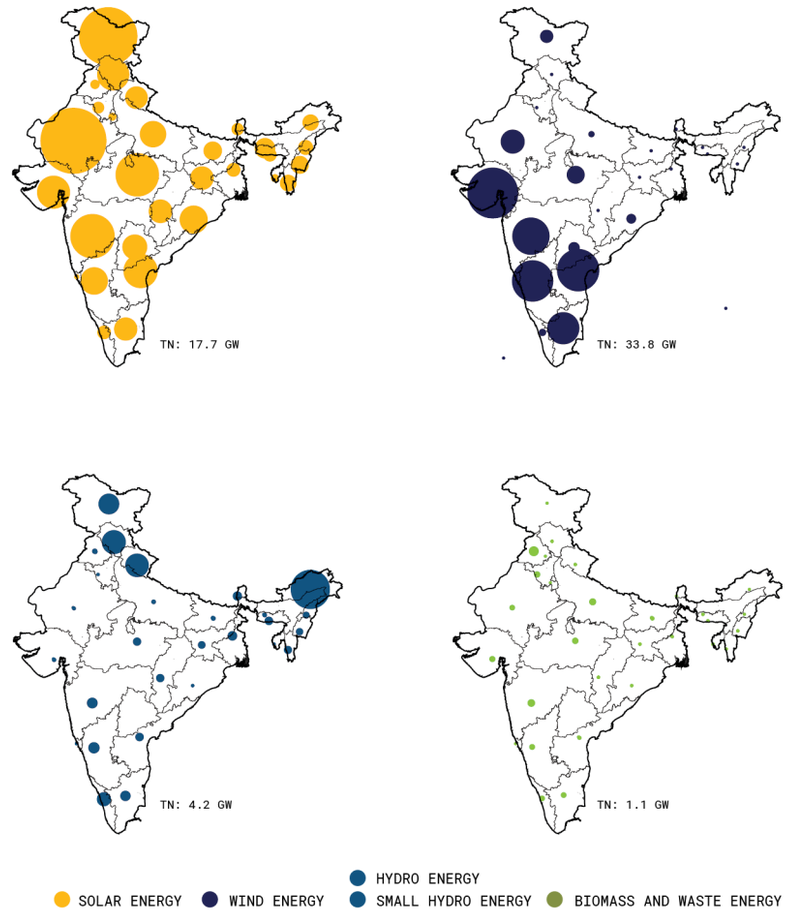


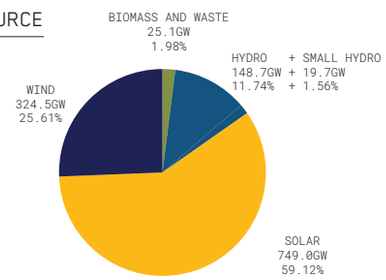
Fig 3.8: State-wise renewable energy potential in India (India Energy Data, 2018).

Fig 3.9: Share of renewable energy potential in India (India Energy Data, 2018).

RENEWABLE ENERGY POTENTIAL BY SOURCE

Estimated total renewable energy potential by source in India. Since India is located in the tropical zone, the high solar intensity means that the country has tremendous solar energy potential upto 750GW.

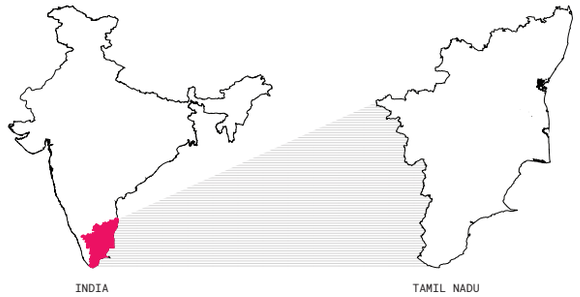
By comparison, only 28GW has been tapped in terms of installed energy infrastructure (India Energy Data, 2018).



Renewable energy in Tamil Nadu.

The southern state of Tamil Nadu in India (Fig 3.10), with a population of over 68 million, is powered by diverse energy sources- thermal power plants (43%), renewables (31%), nuclear (5%) and hydroelectricity (8%) (India Energy Data, 2018) (Fig 3.11, Fig 3.12). Tamil Nadu has been a pioneer in renewable energy development in the country since 1985, when it set up a separate ministry for research into renewable sources, called the Tamil Nadu Energy Development Agency (TEDA). At around 11650MW of renewable energy generation, Tamil Nadu accounts for nearly 32% of India's total RE installed capacity and 35% of India's total wind energy installed capacity. (Nesamalar, et.al., 2017).

WHERE IS TAMIL NADU?



The state's electricity generation, transmission and distribution is managed by the Tamil Nadu Electricity Board (state-owned enterprise) and its subsidiary companies- TANTRANSCO (Tamil Nadu Transmission Company) undertakes transmission, TANGEDCO (Tamil Nadu Generation and Distribution Company) undertakes the generation and distribution of energy to the consumers. The state-owned TANTRANSCO and TANGEDCO solely hold the transmission and distribution licenses, which means that all energy producers must rely on the state utility for its transmission. This strong presence of the state in this service-providing sector and its socialist welfare-based political regime helps to keep the influence of private market forces at a distance. However, the state utility but has been facing huge losses in the past decade due to increasing energy demand, unregulated energy use, heavy state subsidies for agriculture and the monopoly of private sector over renewable energy production.

Nevertheless, the state has ambitious plans to continue harvesting the estimated 720 GW of R.E. potential (60 times the current R.E installed capacity), with proposals to add 21.9GW of wind and solar energy by 2022. To echo Belanger (2018), ***who will produce this energy? Who will benefit from it? Where will the new energy landscapes be built? How will it be governed? What will they leave behind? Will the new renewable energy geographies operate under the extractivist, capitalist systems of the fossil fuel era?***

Fig 3.10: Map showing the geographic location of Tamil Nadu within India.

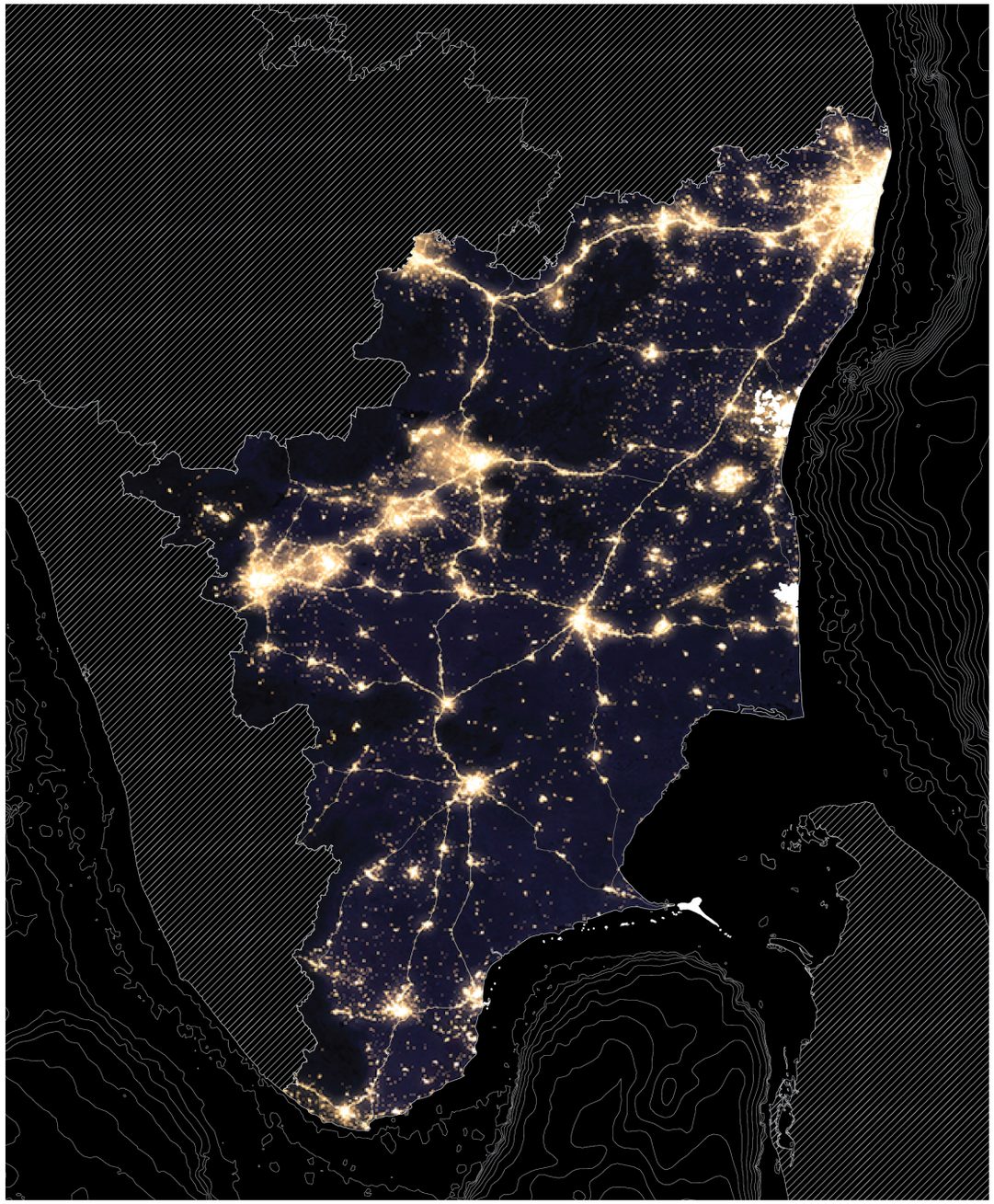


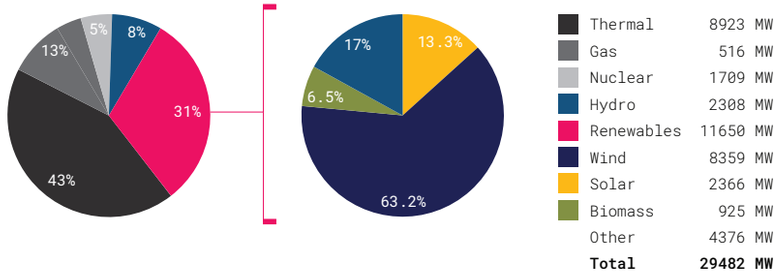
Fig 3.11: View of Tamil Nadu at night from outer space showing intensity of light (energy use). (NASA Worldview, 2016)

Tamil Nadu not only faces the challenge of transitioning to renewable energy, but also the challenge of improving energy access to energy vulnerable communities in both rural and urban areas, who do not have equitable access to energy. The state is at a crossroad, to define its energy future, one that can benefit immensely from the integration of spatial planning and strategies. There is an urgent need for regional integration and planning of emerging energy landscapes, that can ensure that future energy development happens with the consideration of regional long term vision, local spatial conditions, the inclusion of local stakeholders and grass-root initiatives in the energy transition process.

The following sections will elaborate in detail, on the spatial, social and political dimensions energy transition through study, analysis and mapping of the region. The Chapter concludes with the identification of specific problem focuses identified in the three branches of research. Furthermore, the overall project aim, problem statement and overarching research question of the project are explained in Section 3.5.

INSTALLED CAPACITY OF ELECTRICITY IN TAMIL NADU BY SOURCE

Tamil Nadu's installed electricity capacity by source. 1/3rd of the state's electricity is from renewable sources, of which wind energy contributes 63.2%. It is important to note that, the state's's renewable energy potential is close to 680000 MW, 85 times its current installed capacity.



9TH IN THE WORLD IN TERMS OF WIND AND SOLAR ENERGY SHARE

Tamil Nadu's installed energy capacity in wind and solar energy is now the 9th largest in the world, after Denmark, South Australia, Uruguay, Germany, Ireland, Spain, Texas (USA) and California (USA).

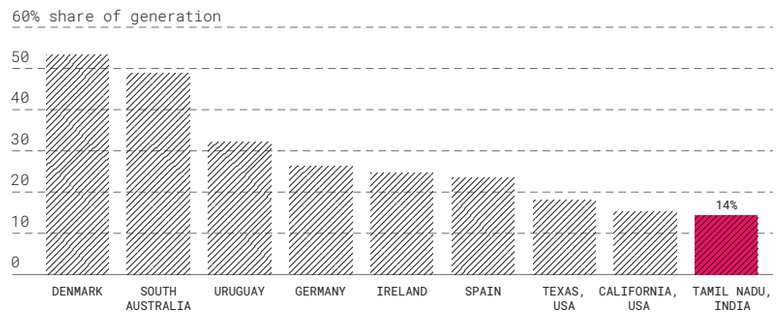


Fig 3.12: Installed capacity of electricity in Tamil Nadu by source and ownership (India Energy Data, 2018)

Fig 3.13: Tamil Nadu is 9th in the world in terms of wind and solar energy share (Buckley & Shah, 2018)

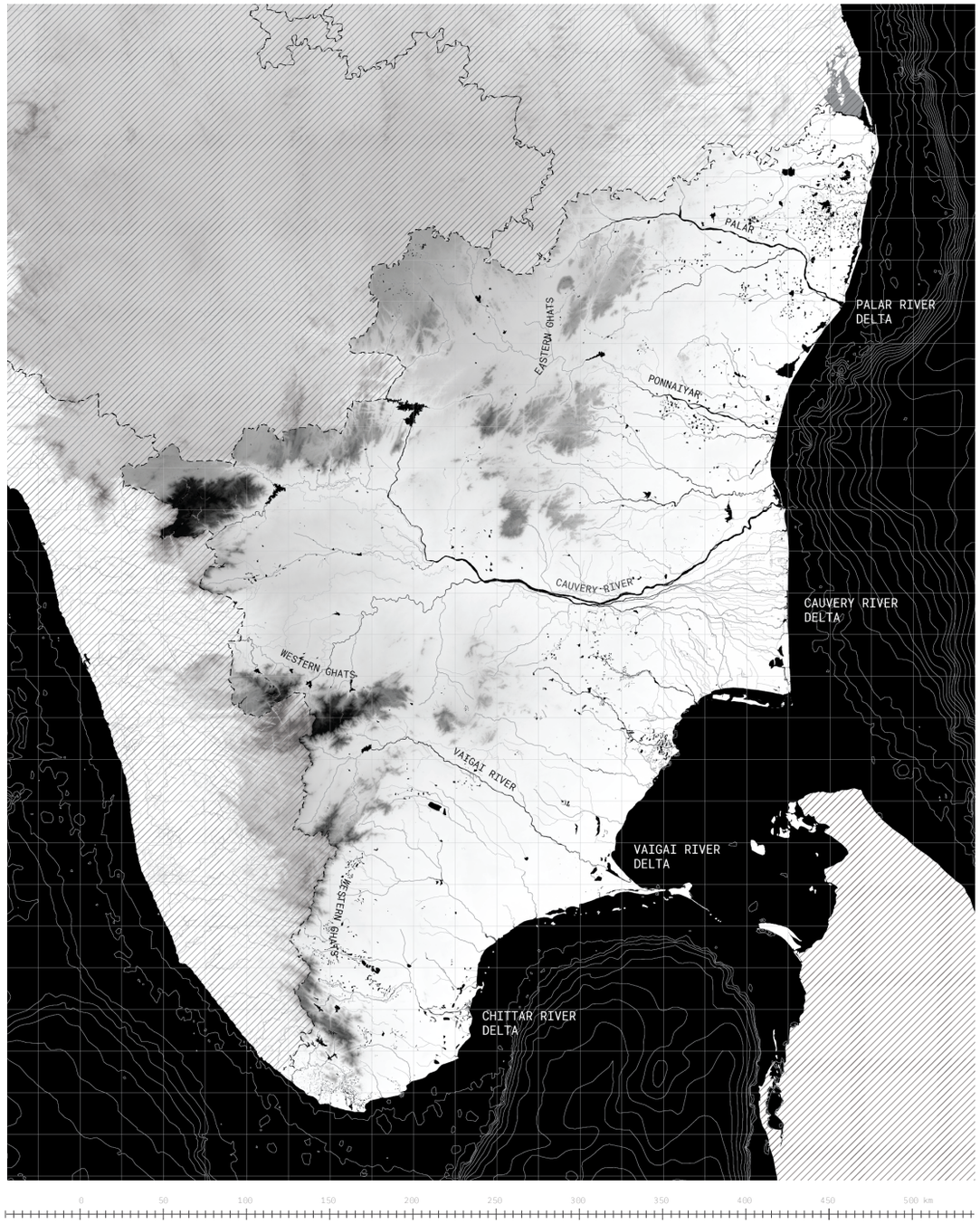


Fig 3.14: Hydrology and physiology of Tamil Nadu



Fig 3.15: Administrative districts of Tamil Nadu and major cities

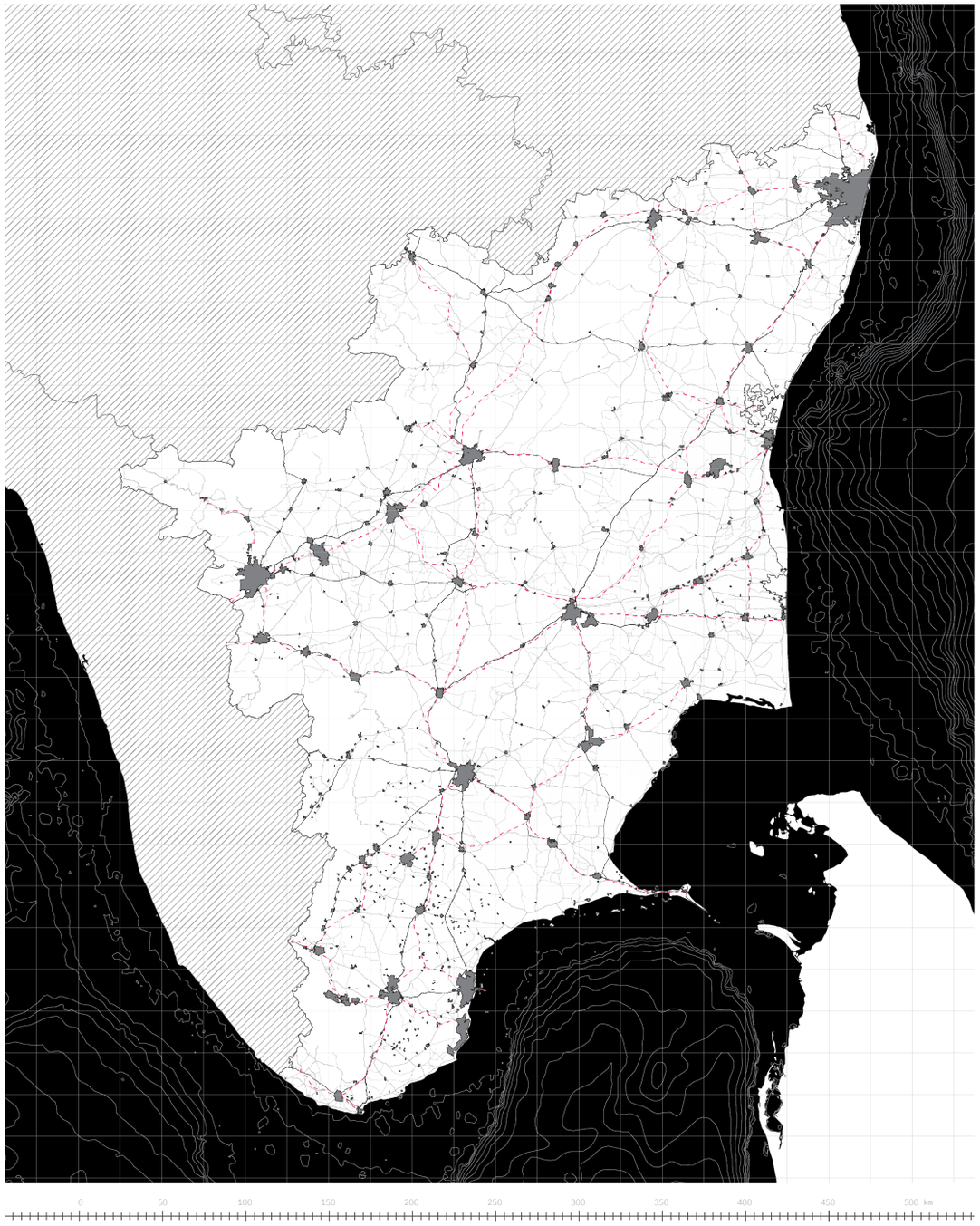


Fig 3.16: Urban and infrastructure network in Tamil Nadu

3.2 Energy x Space

Exploring the spatial dimension of energy transition in Tamil Nadu

The development of new RE projects in Tamil Nadu like the Kamuthi Solar Power Project, spread over an area of 2,500 acres (10 km2) in Kamuthi (648 MW), and new tenders for large scale wind farms in western Tamil Nadu (Fig 3.17) have led to the emergence of new energy geographies that span vast tracks of rural land, traditionally meant for agriculture. This section identifies the existing energy geographies of the state, their relationship with the environment and analyses the impacts of emerging renewable energy landscapes on existing landuse. The mapping of energy geographies- energy production landscapes, energy transmission networks and the energy consumption areas is crucial in identifying the **spatial concentration of energy development and landuse transformation** or 'energy hotspots' in the state. Finally, a photo essay developed from the photo-documentation of the region, during the field trip is presented to show the spatial qualities of the energy geographies of Tamil Nadu.

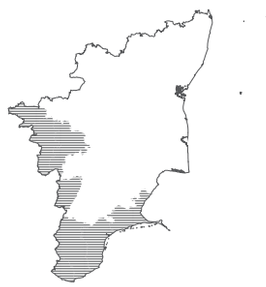


Fig 3.17: Wind energy landscapes in western regions of Tamil Nadu, near Udumelpet. (Photo by author)

Energy production landscapes of Tamil Nadu.

The existing and emerging energy geographies are mapped in the energy map of Tamil Nadu (Fig 3.19). There is a concentration of fossil fuel based power plants and nuclear power plants in the coastal regions of the country, with hydropower plants concentrated in the west, along the mountain ranges. The state has extensive wind farms spread over the wind-belt in the western and south-western part of the state, along the Eastern Ghats mountain range. The breaks in the continuous mountain range create wind passes (TN has four main wind passes: Kambam, Palghat, Aralvaimozhi and Shencottah) that are extremely favourable for wind energy development. Muppandal Wind Farm in the southern tip of the state is the largest operational, onshore wind farm in India with a capacity of 1500MW. Moreover, the hot and arid climate in the landlocked central part of the state is highly favourable for the development of solar energy. The state has a total installed capacity of almost ***30000MW*** from all its energy production sites.

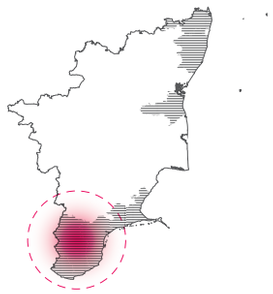
However, the oversaturation of energy development in the southern district of the state and the rapidly transforming western region has resulted in an unplanned, sprawling energy landscape with varied densities and scale (Fig 3.18). The lack of integrated macro-regional planning of energy production landscapes, and long term vision in its development has adversely impacted the spatial integrity and identity of various geographies of the state.



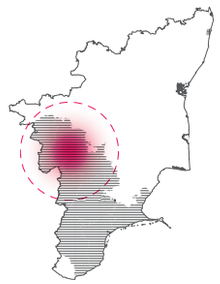
Districts that produce 85% of Tamil Nadu's renewable energy (wind, solar, biomass, hydro)



Districts that produce 90% of Tamil Nadu's non-renewable energy (coal and nuclear)



Districts over-saturated with energy infrastructure and major landuse transformation since 1990s



Districts projected to have major renewable energy development and landuse transformation in the next 10 years

Fig 3.18: Regional differences in energy production landscapes of Tamil Nadu

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

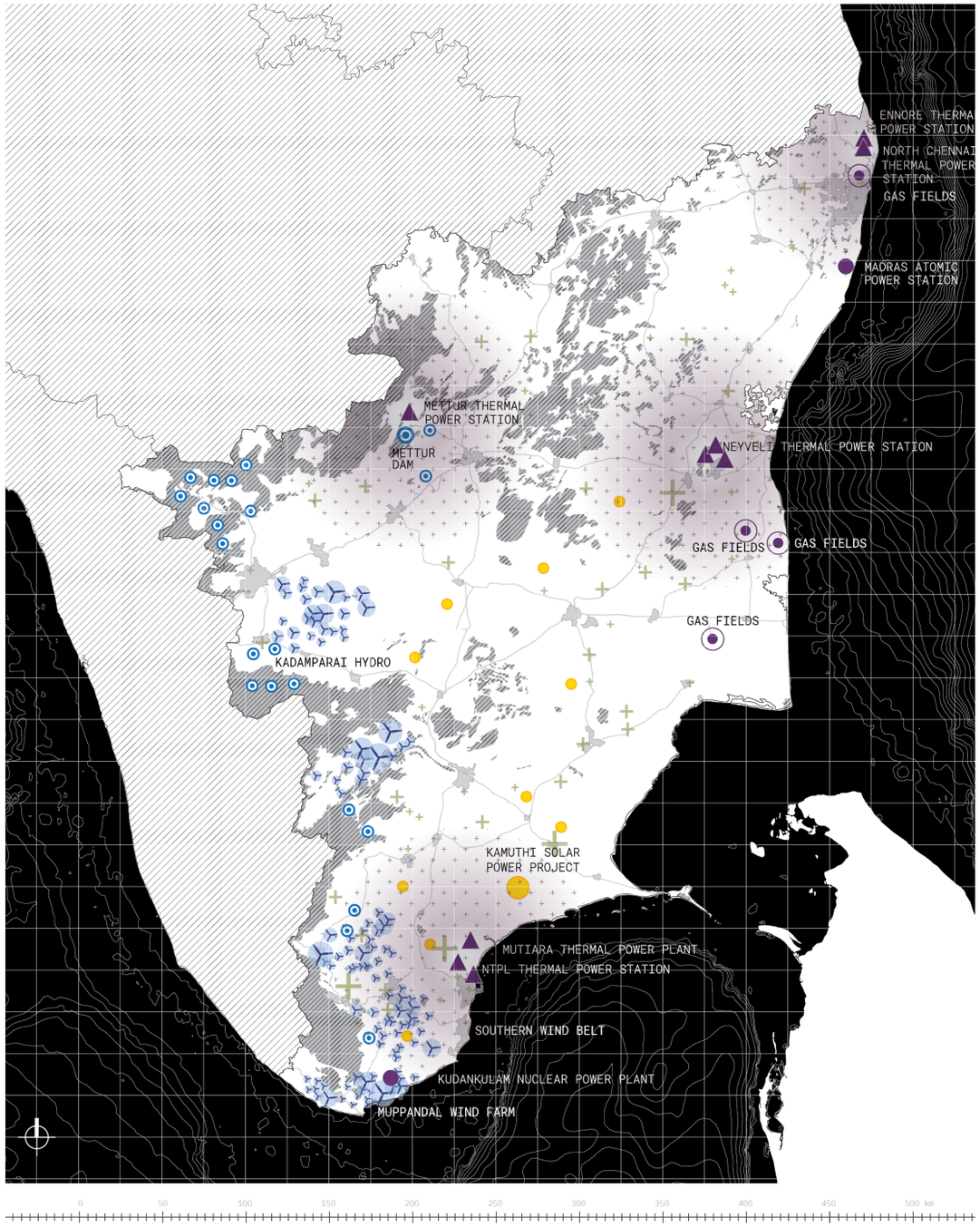
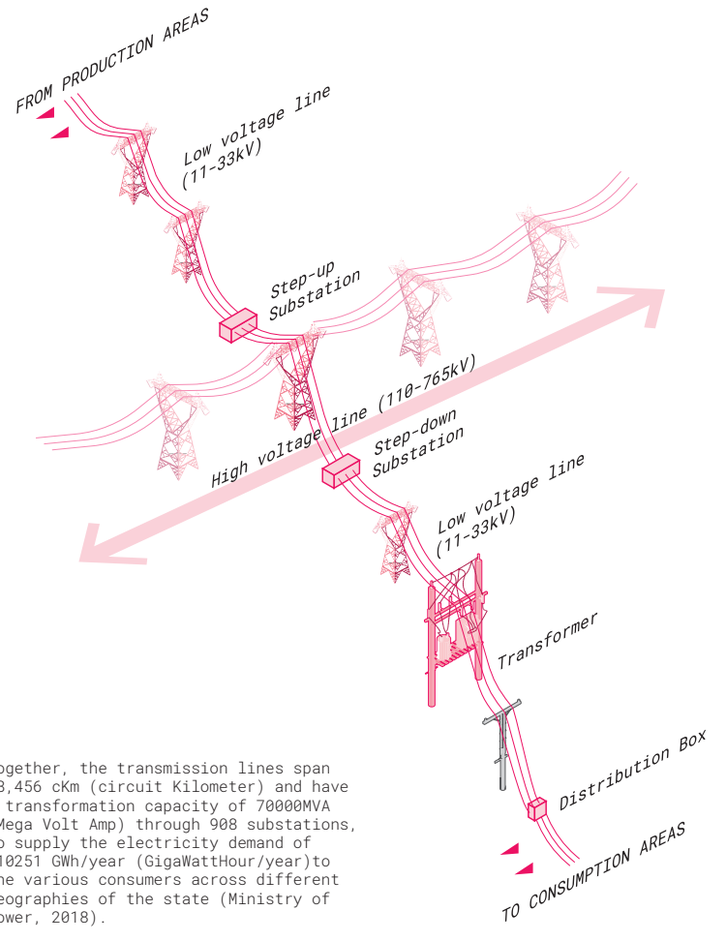


Fig 3.19: Existing energy production landscapes of Tamil Nadu. Adapted from TNGIS, 2018

Energy transmission network in Tamil Nadu.

The energy produced by the production sites is carried to the consumption areas through high voltage power transmission network operated by the TANTRANSCO (Tamil Nadu Transmission Company) within the state, and by PGCIL (Power Grid Corporation of India) for the inter-state networks. Fig 3.21 shows the regional distribution and variations in density of the power transmission lines across the state, based on the location of the energy hotspots. Fig 3.20 gives an overview of the objects, lines and spaces that populate the vast territories of infrastructural landscapes and the schematic representation of its functioning. The existing transmission capacity needs to be strengthened significantly to meet the projected energy demand in the coming decades, along with the provision of renewable energy corridors dedicated to the evacuation of R.E. supply. (Ministry of Power, 2018)



Together, the transmission lines span 38,456 cKm (circuit Kilometer) and have a transformation capacity of 70000MVA (Mega Volt Amp) through 908 substations, to supply the electricity demand of 110251 GWh/year (GigaWattHour/year)to the various consumers across different geographies of the state (Ministry of Power, 2018).

Fig 3.20: Schematic diagram showing how the transmission system operates.

11.1271° N, 78.6569° E

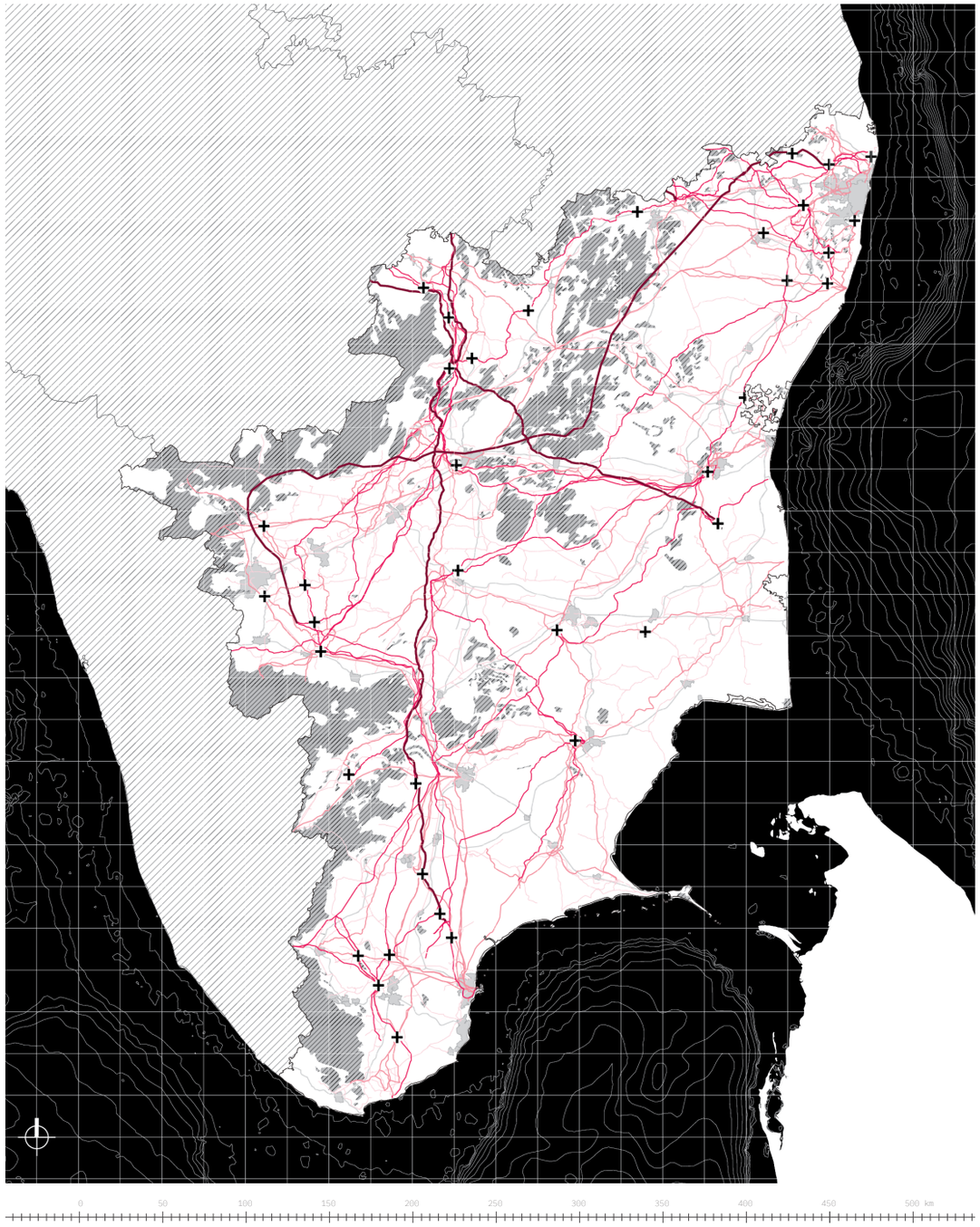


Fig 3.21: Energy transmission network in Tamil Nadu Adapted from TNGIS, 2018.

*This map shows only the *transmission network*, i.e. power lines of high voltage (756kV-66kV) used for transmission of energy from production sites to consumption areas. However, the *distribution network*, i.e. power lines of low voltage present within consumption areas to connect individual units (residences, industries, etc) to the power grid are not shown in this map due to unavailability of data.

Energy consumption areas in Tamil Nadu.

Tamil Nadu is the 3rd largest consumer of electricity accounting for nearly 9% of total energy consumption in India in 2016, with an energy demand of 110,251 GWh/year for a population of 68 million with per-capita energy consumption of 1,280 kWh (Ministry of Power, 2018). To put this in relative terms, the energy demand of the Netherlands is 875,000 GWh/year for a population of 17 million with per-capita energy consumption of 6351 kWh (CBS, 2019). The industrial sector is the largest consumer of energy in Tamil Nadu (35%), and along with the commercial sector (11%) form the major revenue making consumers for the state utility (Fig 3.22). Energy for agricultural use is unmetered and therefore, free, while energy for domestic use is heavily subsidised as well.

Fig 3.23 shows the regional, spatial distribution of energy consumption areas in Tamil Nadu. Urban areas and associated infrastructures consume 85% of the energy in the state, and 15% in rural agricultural areas. On the contrary, energy production sites are wholly located in rural areas, barring the microgeneration from solar rooftops in cities. The planning of future energy production landscapes needs to consider the energy interdependencies between urban areas and the surrounding rural landscape.

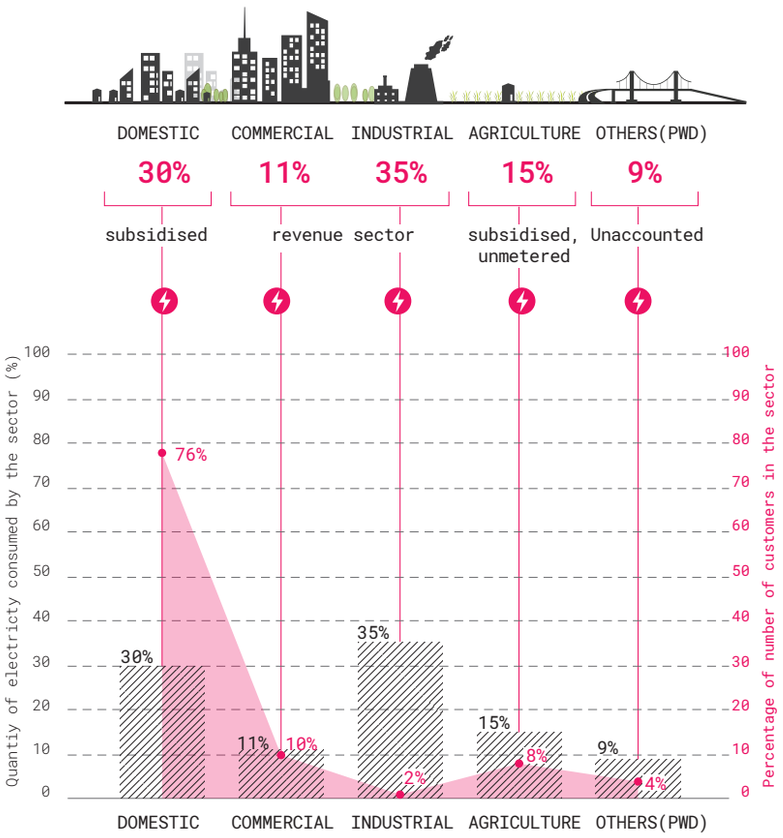


Fig 3.22: Schematic diagram showing the sectoral classification of energy consumers in Tamil Nadu

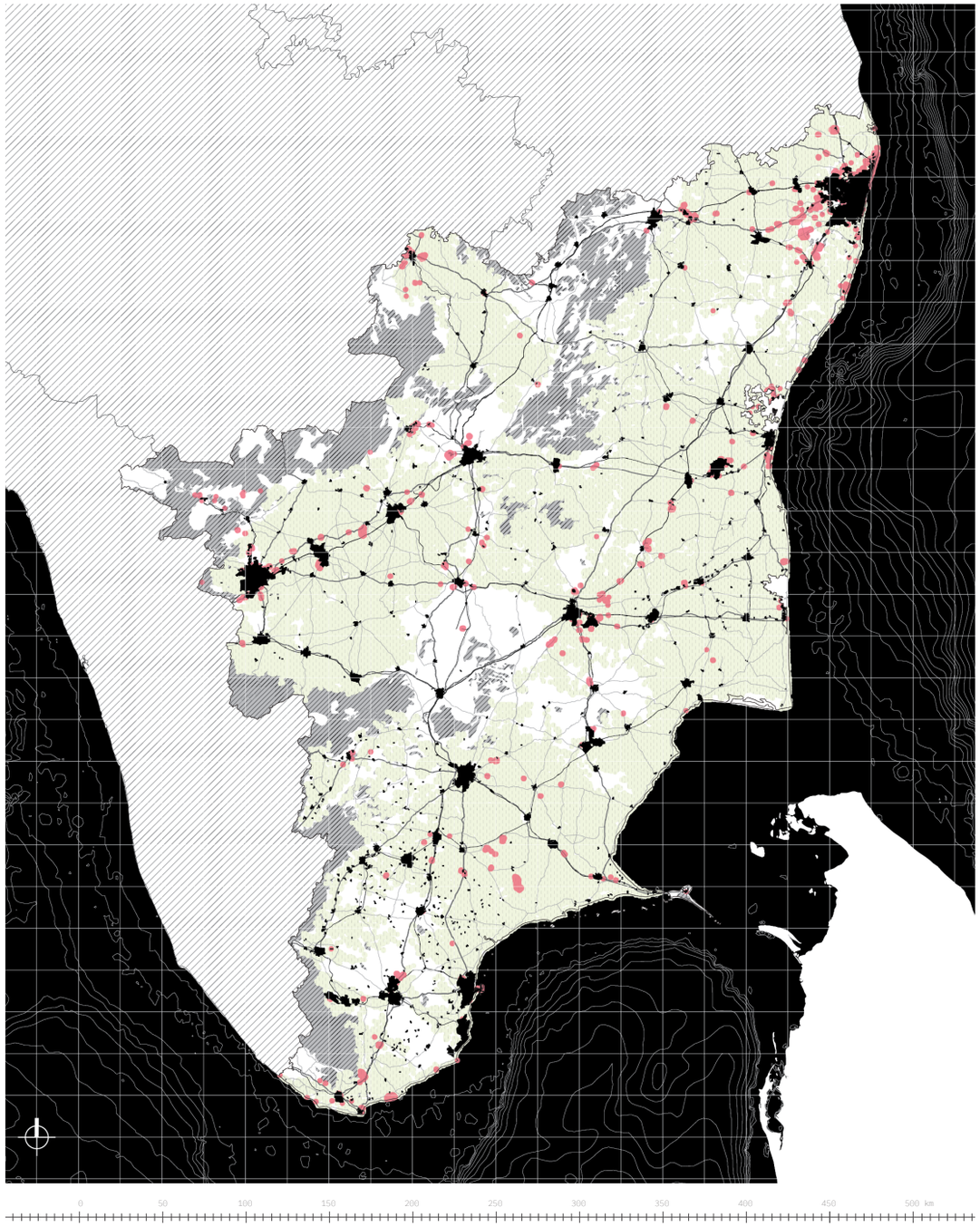


Fig 3.23: Areas of energy consumption in Tamil Nadu. Adapted from TNGIS, 2018

Layered energy landscapes of Tamil Nadu.

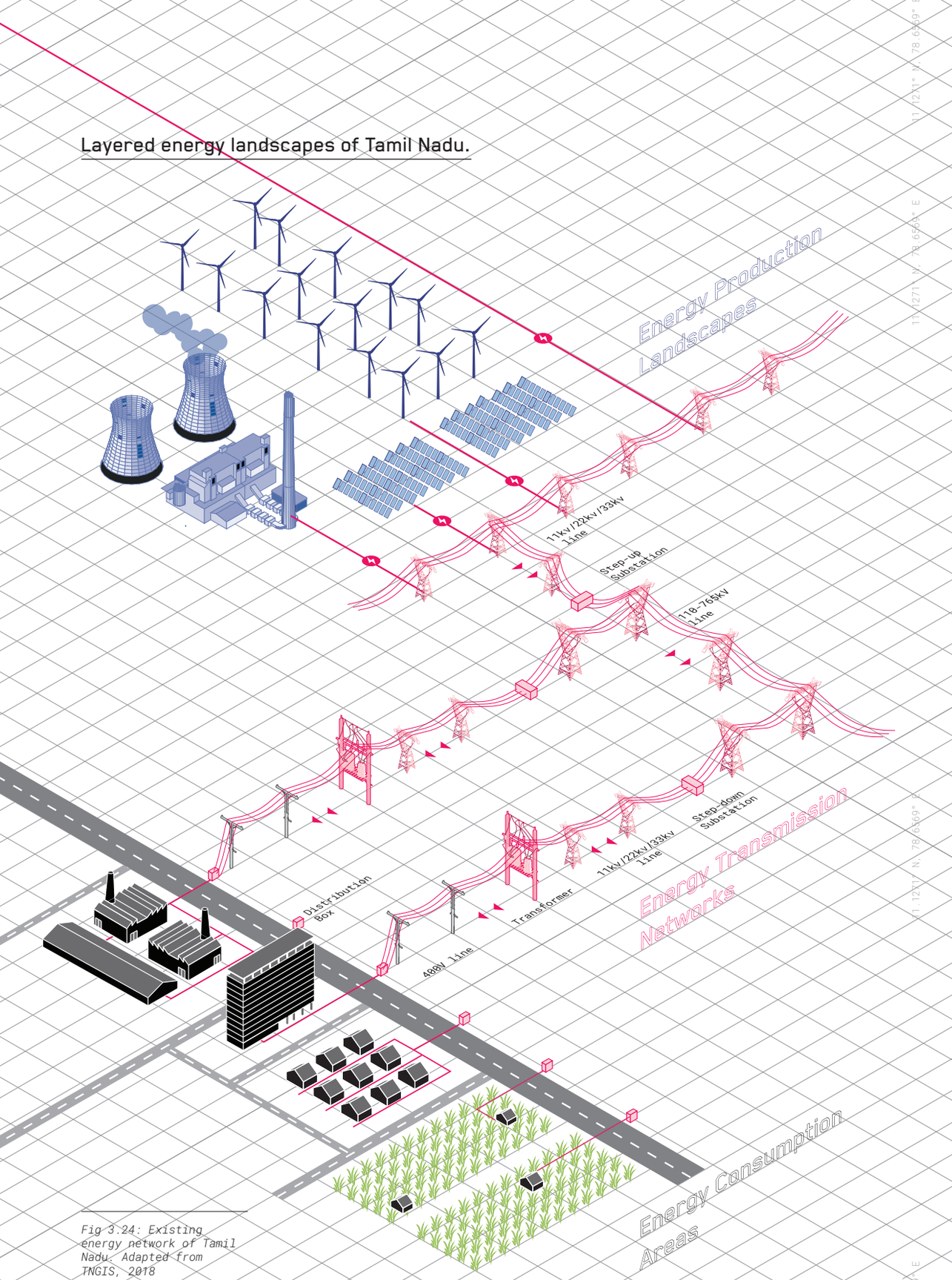
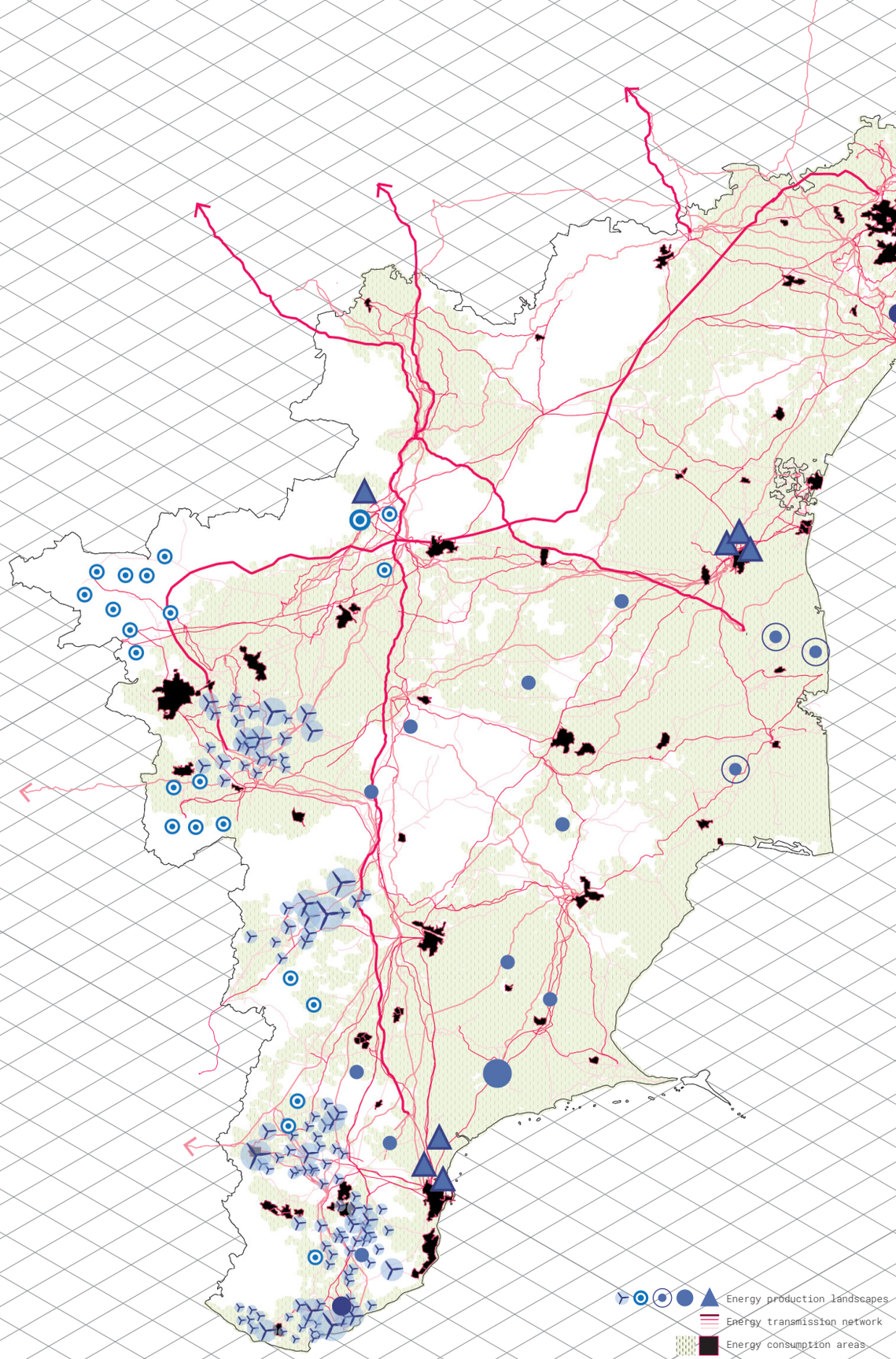
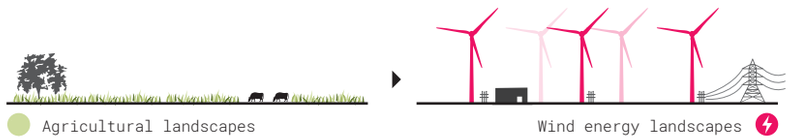


Fig 3.24: Existing energy network of Tamil Nadu. Adapted from TNGIS, 2018



Unchecked energy sprawl and transformation of landuse.

The harvesting of renewable energy requires an exponentially higher amount of land than conventional energy production. The lower power density of R.E means that there is a slow but massive 'sprawl' of energy infrastructure across the rural landscapes of Tamil Nadu (See Fig 3.24 and Fig 3.25). This ***'energy sprawl'***, defined as the product of the total quantity of energy produced annually (e.g., TWhr/yr) and the land-use intensity of production (e.g. km2of habitat per TWhr/yr) (McDonald, et.al., 2009), has lead to regional transformation of territories and social practices in the state. The constant buy out of land by energy companies in the south and south-western part of the state can be seen in the considerable decline of agricultural land. ***How can the transition to R.E respect the boundaries of energy development and sustain local landuse practices?***



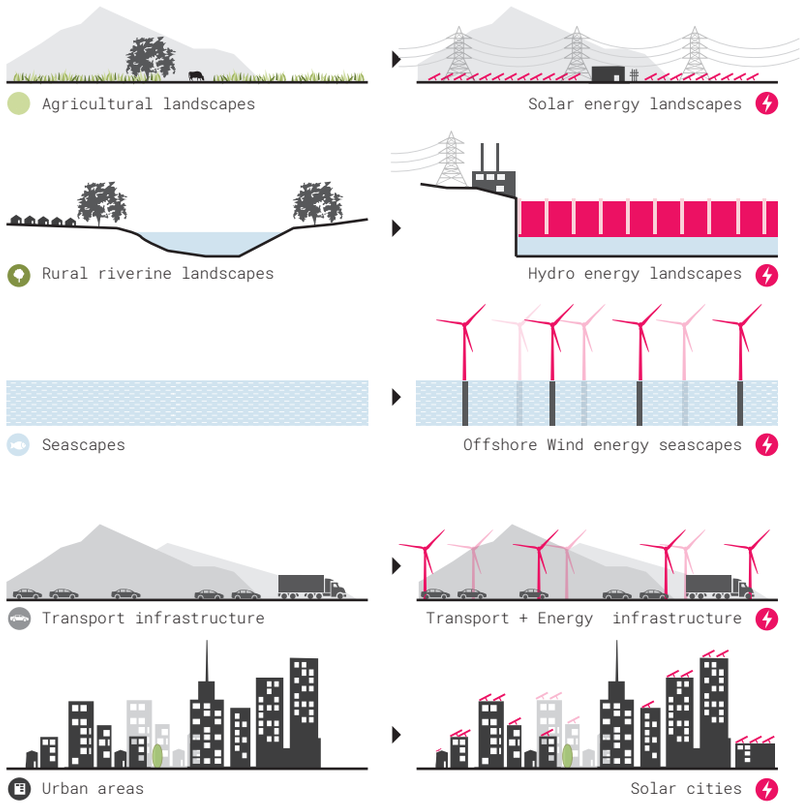
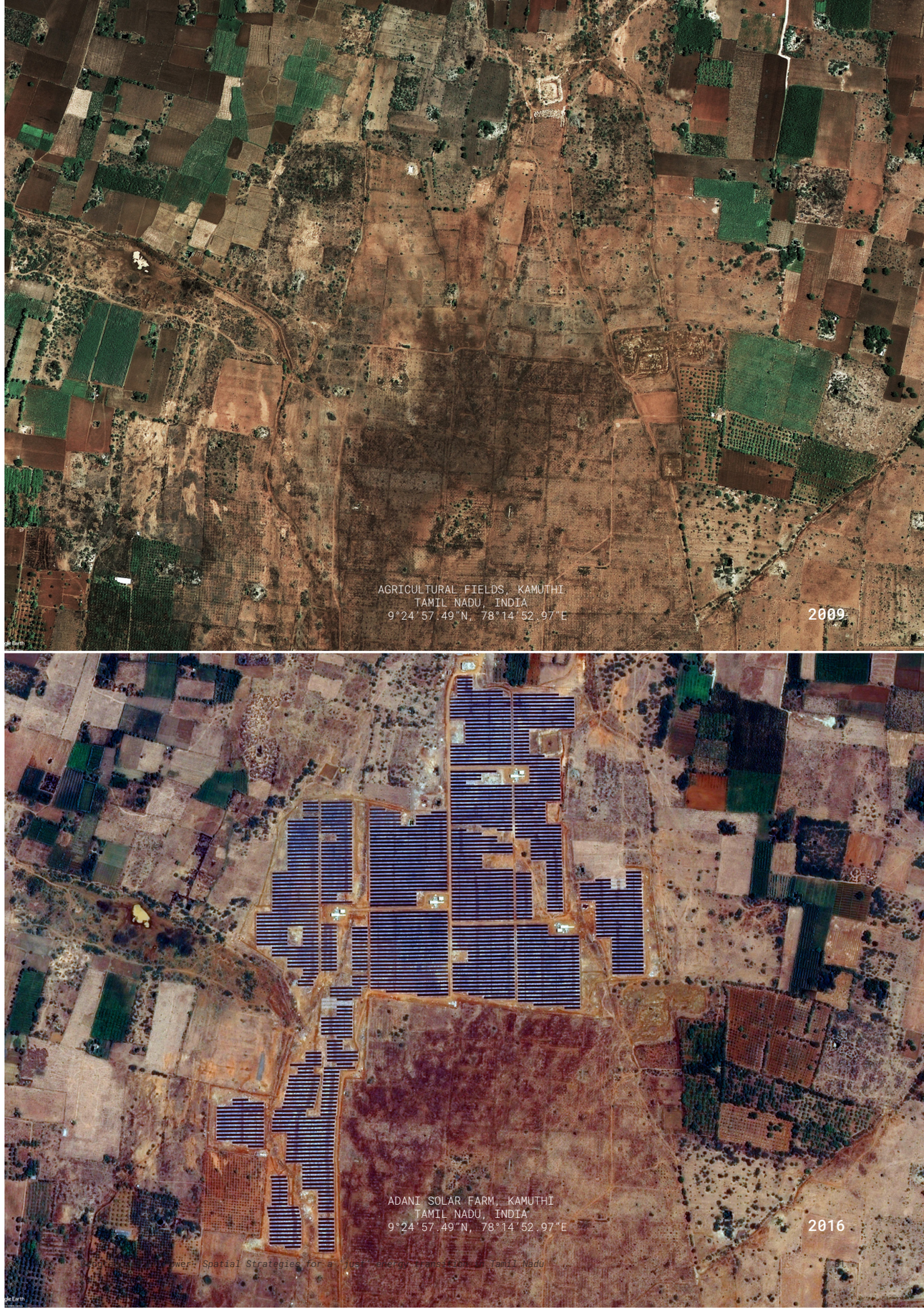


Fig 3.25: Transformation of urban and rural landscapes to energy geographies.

Fig 3.26: Satellite image of agricultural land around Kamuthi village in Tamil Nadu taken in 2009. In five years, the agricultural fields have transformed into solar fields. (Google Earth)



Disconnect from the productive landscape.

A photo essay on the energy geographies of Tamil Nadu

Energy infrastructures have a distinct spatial quality and image with respect to the surrounding space. The existing energy landscapes in Tamil Nadu, spanning urban and rural areas have a distinct spatial quality, which shapes human relationships and interaction with the energy 'objects' (Fig 3.27). The qualitative impact of energy infrastructures or the ***sense of place*** of energy landscapes contributes to the collective memory, symbolism and meaning derived from the energy objects and associated spaces. The energy production sites in Tamil Nadu are harsh, infrastructural terrains, interspersed with the local landscape- an image that has not contributed to the building of a connection between the people and the landscape. The following pages present selected photographs from the photo-documentation of the region, undertaken during the field trip (February 2019). This photo essay is a visual account or ***image*** of the energy geographies of the region.



Fig 3.27: Degree of embeddedness, and nature of human-interaction with energy objects/ infrastructure in space





Fig 3.28: (left) Wind farms in the Udumelpet region, and their associated energy infrastructures

Fig 3.29: (right) Wind farms in Tamil Nadu are privately owned, and usually fenced off, preventing other forms of landuse coexisting in the space

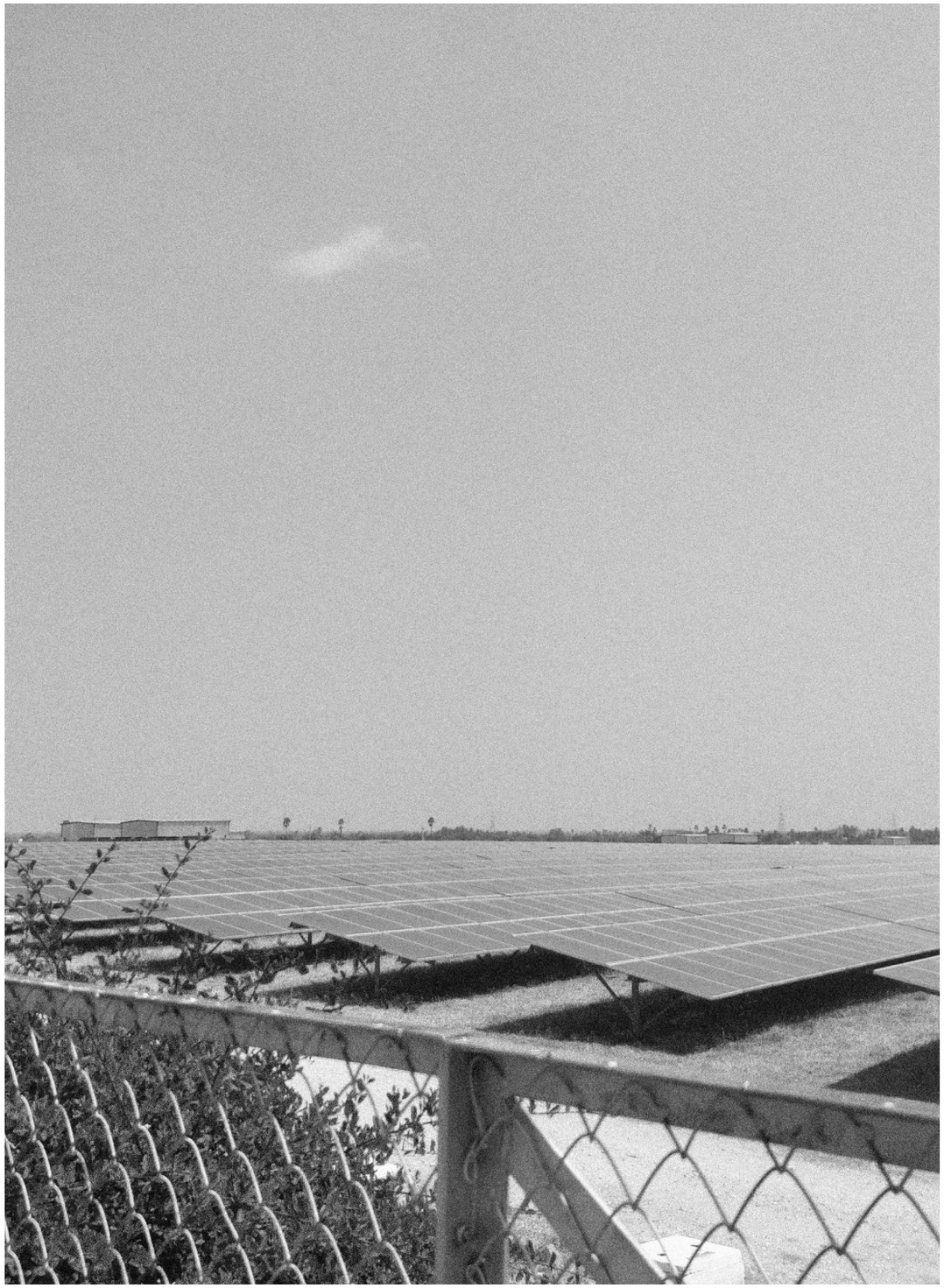




Fig 3.30: (left) Solar farms in Coimbatore region stretching till the horizon, like the one pictured in the photograph, have transformed vast areas of agricultural land to privately owned energy production sites

Fig 3.31: (right) Spatial quality of solar energy landscapes. Note the pattern of shadows on the ground below

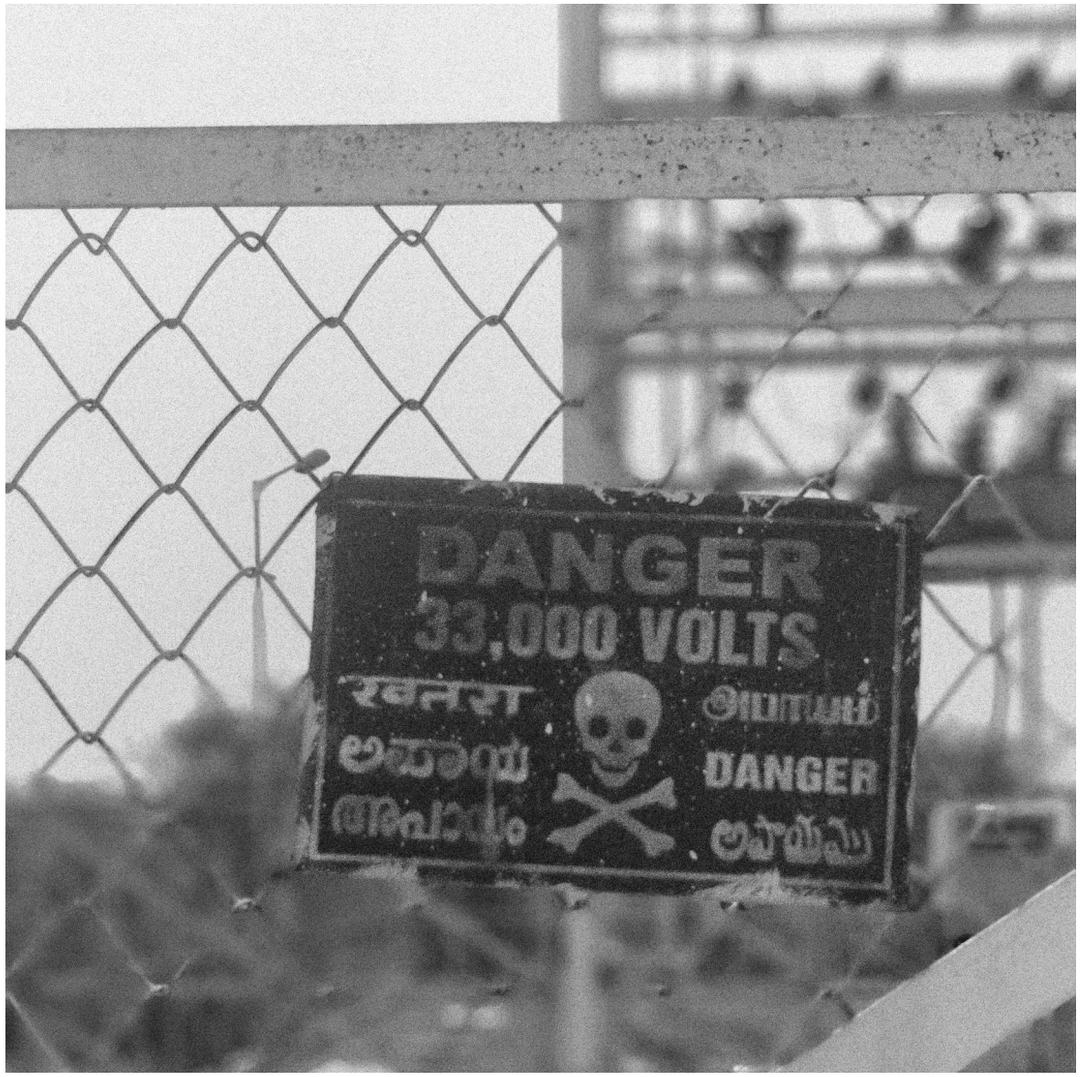


Fig 3.32: (left) Signboard warning people of the high voltage infrastructural landscapes

Fig 3.33: (right) The hard technocratic spaces necessary for the energy landscape to function are a dominant part of the landscape aesthetics.





Fig 3.34: Networks of energy transmission lines stretching across the rural landscape

Fig 3.35: Chaotic complexity of energy infrastructure in a typical Indian city.



11.1271° N, 78.6569° E

Problem Focus - Energy x Space.

This section presented an analysis of the spatial dimension of energy transition in Tamil Nadu, that is, the mapping and study of existing energy production landscapes, transmission networks and consumption areas in the state, to identify the regions undergoing rapid transformation and energy concentration, their territorial distribution and spatial qualities. Through the analysis, the project identified how lack of spatial planning and landuse consideration in energy development has resulted in **monofunctional, sprawling energy landscapes, that do not contribute to the landscape integrity of the region.**

From this understanding, the project identifies four main problem focuses that the design needs to address:

1. Need for adaptive energy production landscapes that are flexible, multi-functional and responsive to the transitional territories of energy production.

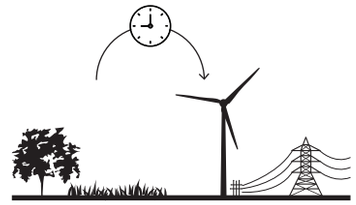
2. Need for consideration of local conditions and spatial embeddedness of energy infrastructure.

3. Need for integrated regional planning and design of energy production landscapes, that consolidates the fragmented energy sites under a common regional vision.

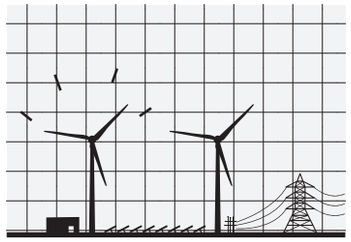
4. Need for tools, instruments and spatial strategies that provide guidelines, regulations and context-specific restrictions for development of energy-spaces.

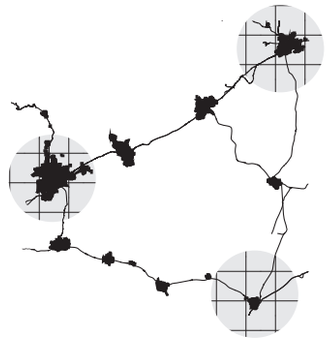
Note: This project limits its research and design scope of the 'spatial dimension' to the energy production stage of the transition process- that is, the planning and design of energy production landscapes and associated spaces. Energy transmission, distribution and consumption stages of the energy cycle will be addressed only when relevant to the analysis and design of energy production landscapes.

1. Need for adaptive energy production landscapes.

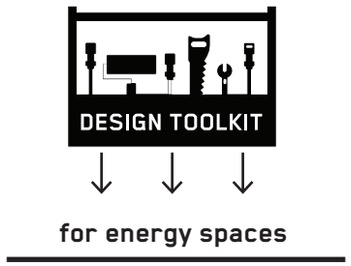


2. Need for consideration of local conditions and spatial embeddedness of energy infrastructure.





3. Need for integrated regional planning and design of energy production landscapes.



4. Lack of tools, instruments and spatial strategies to guide development of energy landscapes

Fig 3.36: The key problem focuses identified through the analysis of the spatial dimension of energy transition in Tamil Nadu

3.3 Energy x Society

Exploring the social dimension of energy transition in Tamil Nadu

Energy transition has an inexplicable social dimension. The integration of renewable energy systems into our spatial and socio-economic landscapes is a challenge, in terms of ensuring that the societal impacts, distribution and access to the renewable energy is 'just' (Sareen & Haarstad, 2017). In a developing context like India, where the fight for equitable access to energy is still ongoing, the transition to renewable energy must be accompanied by **measures to ensure equitable access to energy as well.**

The following pages explore the social dimension of energy transition in India, in terms of the access to energy, ownership of energy and barriers to social empowerment of energy vulnerable communities in the region. The section concludes by highlighting the potential of **energy coproduction** in improving energy access while simultaneously contributing to renewable energy development in the state.

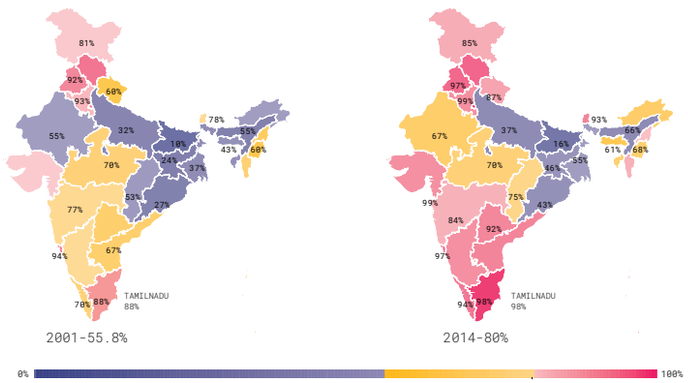


Fig 3.37: Photograph of a village in Tamil Nadu, showing the relationship between people and the energy infrastructure of the place.

Inequitable energy access and energy vulnerability.

India is the largest access deficit country in the world in terms of the number of people without access to energy (21% of those without access to energy are in India). 'About 311 million people still live without electricity, and they mostly reside in poor rural areas. Among these, 200 million live in villages that already have electricity. Less than half of all households in the poorest income group have electricity. Even among households that have electric service, hundreds of millions lack reliable supply, experiencing power cuts almost daily.' (Banerjee et.al., 2015). India's has made rapid strides in providing universal access to energy since 2000, when less than 56% of the people had access to energy (Fig 3.38, Fig 3.39). The government deems a village "electrified" if power cables from the grid reach a transformer in each village and 10% of its households, as well as public places such as schools and health centers, are connected, a definition that has evolved over the years (Fig 3.40). While India is expected to reach the goal of 100% basic electrification by the end of 2018, how will the renewable energy systems perform in terms of equitable energy access?

ELECTRIFICATION RATES IN INDIA



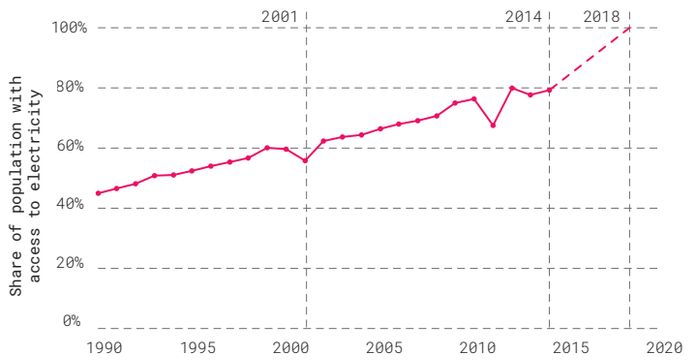


Fig 3.38: Rate of access to electricity in 2001 and 2014. Note that by 2018, the GoI claims to have achieved 100% electrification in the country (India Energy Data, 2018)

Fig 3.39: Access to electricity in India (Our World in Data, 2018; The World Bank, 2018)

CHANGING DEFINITIONS OF ENERGY ACCESS (ELECTRIFICATION) IN INDIA

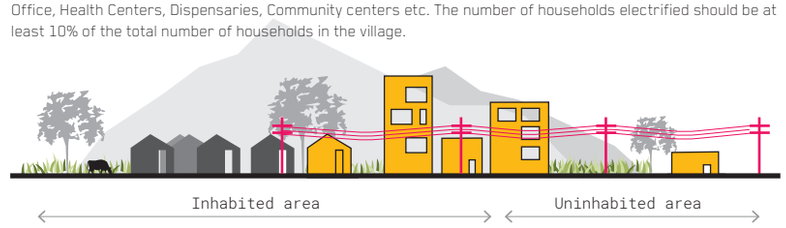
Before 1997:
A Village is deemed to be electrified if electricity is being used within its revenue area for any purpose whatsoever.



After 1997:
A village is deemed to be electrified if the electricity is used in the inhabited locality, within the revenue boundary of the village for any purpose whatsoever.



After 2004:
A village is deemed to be electrified if basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality, and if electricity is provided to public places like Schools, Panchayat Office, Health Centers, Dispensaries, Community centers etc. The number of households electrified should be at least 10% of the total number of households in the village.



2018:
A village is deemed to be electrified if 2004 requirements are satisfied and household electrificationn is 100%



Fig 3.40: Changing definitions of electricity access in India.(DDUGJY, MoP, 2018)

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Relationship between energy access and social empowerment.

The drive towards equitabel access to energy is particularly important in the era of energy transition since R.E systems have the unique potential to penetrate remote areas and improve the quality of energy access (IEA, 2017) (Fig 3.41). The means that the drive towards energy transition can be used as the vehicle to spearhead measures and policies to improve energy access and break the vicious cycle energy vulnerability and socio-economic vulnerability (Fig 3.42). Improving energy access will have a cascading impact on the educational outcomes and longer-term income-earning potential, decreased risk of respiratory disease related to burning kerosene in rural areas (Fig 3.43). Banerjee et al., further state that

> *'With electric lighting, household businesses can extend their hours of operation to generate more income, and farm households can switch from manual to electric tools and machinery to increase their productivity and profits. Family members, particularly women, will read, watch television, and listen to the radio, thus gaining valuable access to knowledge that can help with their decision making power within the household. Additional benefits of electrification include a greater sense of public security and more time in the evenings for socialization and entertainment. The cumulative impact of all these benefits is an improved quality of life.'*

PEOPLE GAINING ELECTRICITY ACCESS BY FUEL TYPE IN DEVELOPING COUNTRIES

Electricity access is accelerating and increasingly coming from renewable sources of energy. Decentralised Renewables, in particular, have the potential to penetrate rural areas more effectively than conventional fossil fuels.

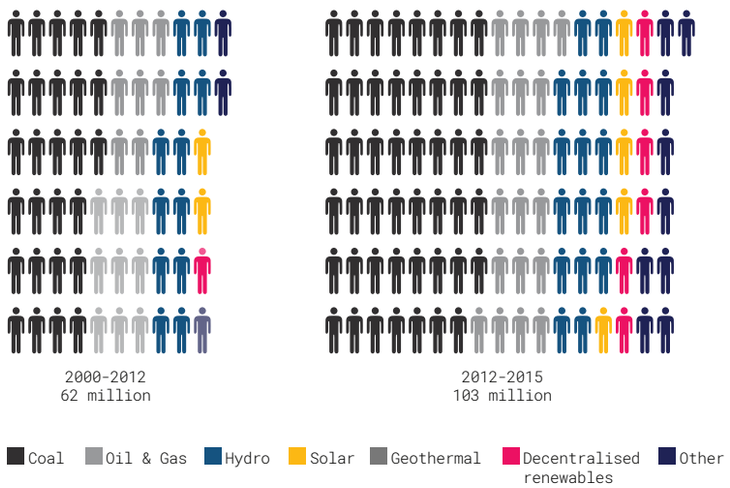
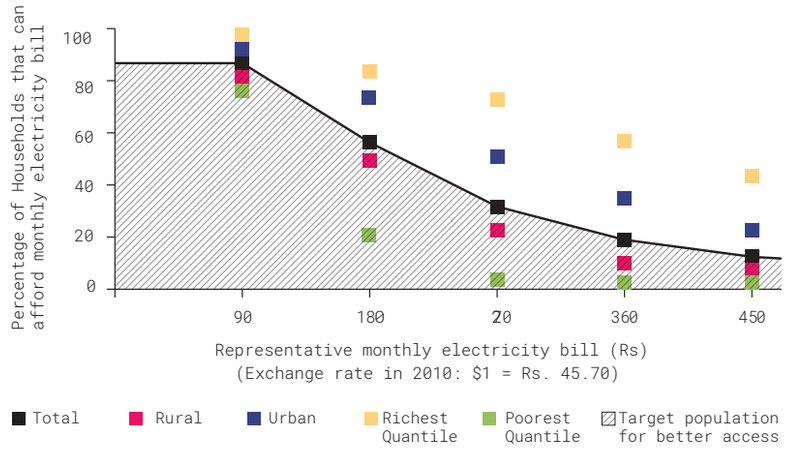


Fig 3.41: Annual number of people gaining access by fuel type in developing countries. (IEA, 2017)

VICIOUS CYCLE OF SOCIO-ECONOMIC VULNERABILITY AND ENERGY VULNERABILITY

The graph showing the percentage of households that can afford the monthly electricity bill in relation to the socio-economic status shows the dependency of energy vulnerability on socio-economic vulnerability and visa versa. Communities who cannot afford energy access mostly belong to the poorest quantile of the population in India (Banerjee et.al, 2015)



SOCIO-ECONOMIC BENEFITS OF ELECTRIFICATION.

Studies show that increased access to renewable energy has profound socio-economic impacts, like higher income, improved health and better education-factors that contribute to overall standard of living (Banerjee et.al, 2015)

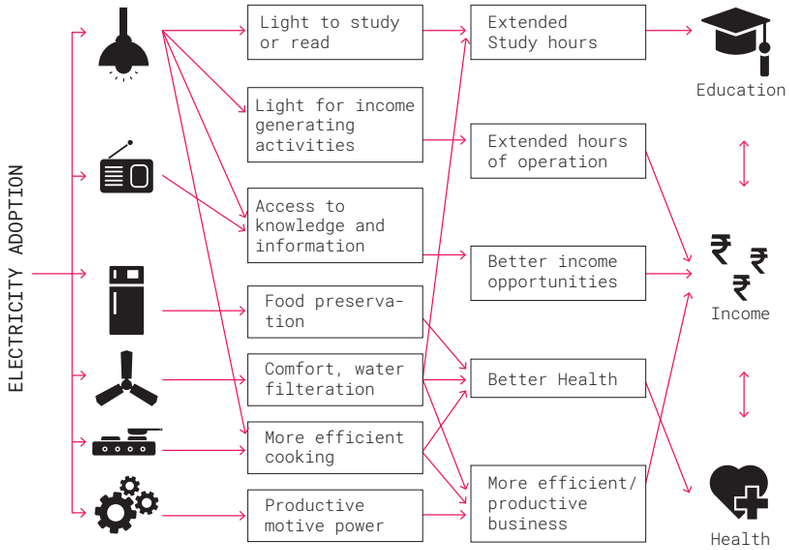


Fig 3.42: Graph showing the vicious cycle of socio-economic vulnerability and energy vulnerability (Banerjee et.al, 2015)

Fig 3.43: Socio-economic benefits of electrification (Banerjee et.al, 2015)

Lack of institutional support for 'coproduction' of energy.

With the understanding gained from the theoretical and empirical study on energy access and energy vulnerability in India, and by extension, Tamil Nadu, the project now presents an analysis of the relationship between energy ownership and energy access. As shown previously, small renewable energy infrastructure has the potential to connect millions of energy vulnerable people to reliable energy. Furthermore, it is widely acknowledged that community owned renewable energy (CRE) projects have the potential to have a wide range of environmental and social benefits (Berka & Creamer, 2017).[1]

The provision of state subsidies to ***invest in and own*** renewable energy production can benefit individuals and communities and involve a diverse set of actors and stakeholders in the energy transition process in Tamil Nadu. Specifically, the promotion and incentivisation of ***'coproduction'*** of energy by communities and individuals in partnership with the state and/or private enterprises can pave the way for an inclusive energy transition, where the benefits trickle down to grassroots.

However, the mapping of energy production landscapes in terms of their ownership shows that all renewable energy production in the state is undertaken and owned by private enterprises (Fig 3.45). The extractive energy production system, perpetuated by the monopoly of the private sector in energy production and supported by a top-down governance system makes it difficult for new players from the civil society (individuals and communities) to enter the production market. While coproduction of energy with local communities can improve energy access and civic engagement with the energy transition process, the coproduction agenda ***needs to be part of the long term vision and strategic planning to ensure that the skills, technical knowledge, social networks, economic partnerships are easily available to the communities.***

INSTALLED ENERGY INFRASTRUCTURE BY OWNERSHIP

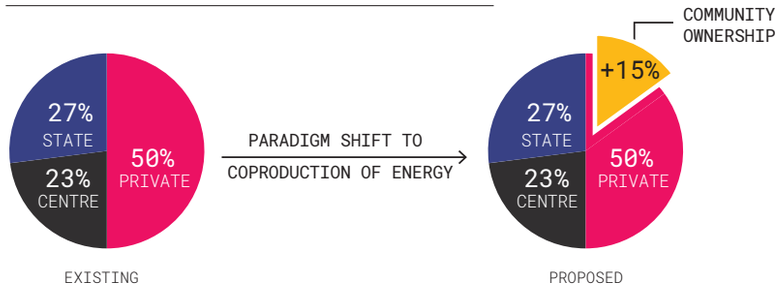


Fig 3.44: Existing and proposed ownership of energy infrastructure. (Source for existing values- India Energy Data, 2018)

Note: *Precedents in literature that discuss the coproduction of energy and the socio-economic impact of CRE are elaborated in Chapter 4.*

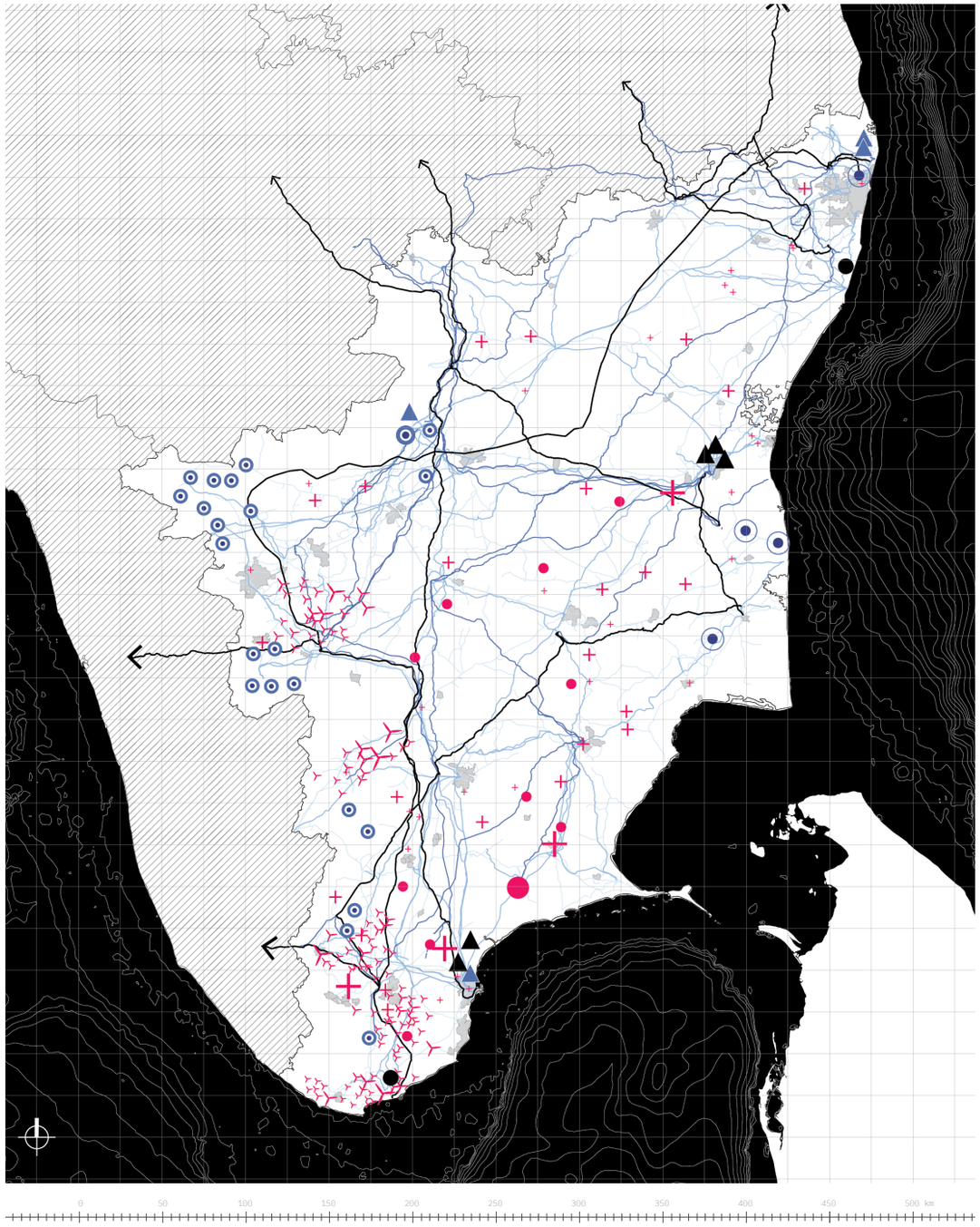


Fig 3.45: Map showing the spatial distribution of energy infrastrtcure based on ownership Adapted from India Energy Data, 2018.

Problem Focus - Energy x Society.

This section presented an analysis of the social dimension of energy transition in Tamil Nadu, that is, the mapping and study of quality of energy access, relationship between socio-economic and energy vulnerability, and the role of community owned renewable energy and coproduction in improving energy access and social capital. Through the analysis, the project identified how lack of institutional support for coproduction and CRE has resulted in the **monopoly of renewable energy production by private enterprises, leading to an exclusive, capitalist energy system.**

From this understanding, the project identifies four main problem focuses that the design needs to address:

1. Need for equitable access to renewable energy, where the benefits of energy transition are distributed in a fair manner.

2. Need for empowerment of energy vulnerable communities through incentivisation of coproduction and community owned renewable energy.

3. Need for integrated regional understanding of energy vulnerability distribution to consolidate actions, measures based on regional variations and similarities.

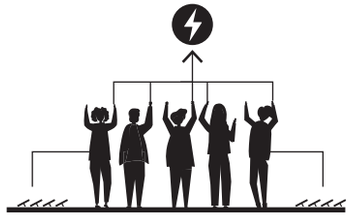
4. Need for tools, instruments and spatial strategies that provide guidelines, regulations and context-specific restrictions for development of community owned renewable energy.

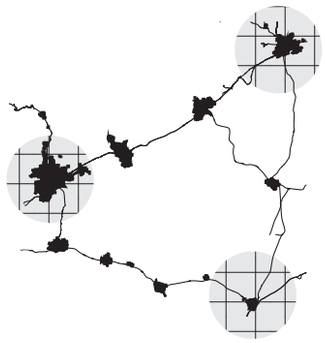
Note: The project limits the research and design scope of the 'social dimension' of what is relevant to the energy production stage, as specified in the previous section. Here, it means that the project will explore the potential for community owned renewable energy production as a pathway for improving energy access and social empowerment.

1. Need for equitable access to renewable energy.



2. Need for empowerment of energy vulnerable communities.







3. Need for integrated regional understanding of energy vulnerability distribution.

4. Need for tools, intruments and spatial strategies to guide development of CRE.

Fig 3.46: The key problem focuses identified through the analysis of the social dimension of energy transition in Tamil Nadu

3.4 Energy x Governance

Exploring the political dimension of energy transition in Tamil Nadu

Energy is a politically sensitive subject, and the governance of its development is a complex choreography of alliances, decisions and political agendas that have far-reaching consequences. In Tamil Nadu, energy is an important political agenda, that carries a lot of weight in political manifestos of governments. The powerful influence of private enterprises that drive capital investment, and the centralisation of power in energy governance with the state, **does not give room for collaborative, decentralized, bottom-up decision making.**

In order to address the challenges identified in spatial and social dimensions of energy transition, radical reform in the governance sector is of paramount importance. This section will discuss the **governance dimension** of energy transition in Tamil Nadu, the main stakeholders involved, and the relationship between spatial governance and energy governance.



Fig 3.47: Photograph of showing the headquarters of the Tamil Nadu Electricity Board, one of the main stakeholders in Tamil Nadu's energy transition. (TNEB, 2011)

Top-down governance of energy transition.

The primary stakeholders in the energy transition process (specifically in the land management and energy production stage, as specified in the project scope) are identified below:

Public Sector:
In Tamil Nadu, energy production, transmission and distribution to consumers is managed, undertaken and governed by the Tamil Nadu Electricity Board (TNEB), a state owned enterprise under the state government's Department of Energy. TNEB was divided into two subsidiary companies-TANTRANSCO (Tamil Nadu Transmission Company) undertakes transmission, TANGEDCO (Tamil Nadu Generation and Distribution Company) undertakes the generation and distribution of energy to the consumers.

Private Sector:
In the private sector, the primary stakeholders in energy production are the energy companies, who have huge investments and stake in the renewable energy market. In Tamil Nadu, all R.E production is owned and operated by private energy companies, who sell the energy to the TNEB at a rate fixed by the TNERC (Tamil Nadu Electricity Regulatory Commission).

Civil Society:
Individuals, communities, cooperatives from the civil society who produce energy on a small scale are the primary stakeholders targeted in the project.

The transmission and distribution licenses are solely held by the state owned TANTRANSCO and TANGEDCO, which has resulted in centralisation of power that inhibits community participation in the governance process. Furthermore, the monopoly of private energy companies in renewable energy market further hinders the participation of individuals and communities. ***The political (TNEB) and economic (energy companies) centralization of power produces a top-down energy governance model***, where the interests of the state and private companies dictate the pathway to transition. In order for community owned renewable energy and coproduction of R.E to happen in the state, there needs to be a ***radical governance reform*** that allows bottom-up initiatives to be part of the transition process. By including citizens, communities and grassroot initiatives in energy transition, Tamil Nadu has the opportunity to facilitate a 'humanised' energy transition. For this, the project proposes a systemic shift to a ***collaborative form of governance*** where individuals and communities activate participate in the decision making process along with the state and private enterprises. Fig 3.48 shows an analysis of the existing governance structure and the proposed governance model that the project intends to explore. Here, a brief introduction to the primary stakeholders and their relationships are presented to understand the 'problem'; in Chapter 6, detailed stakeholder analysis is presented to identify stakeholder networks for design development.

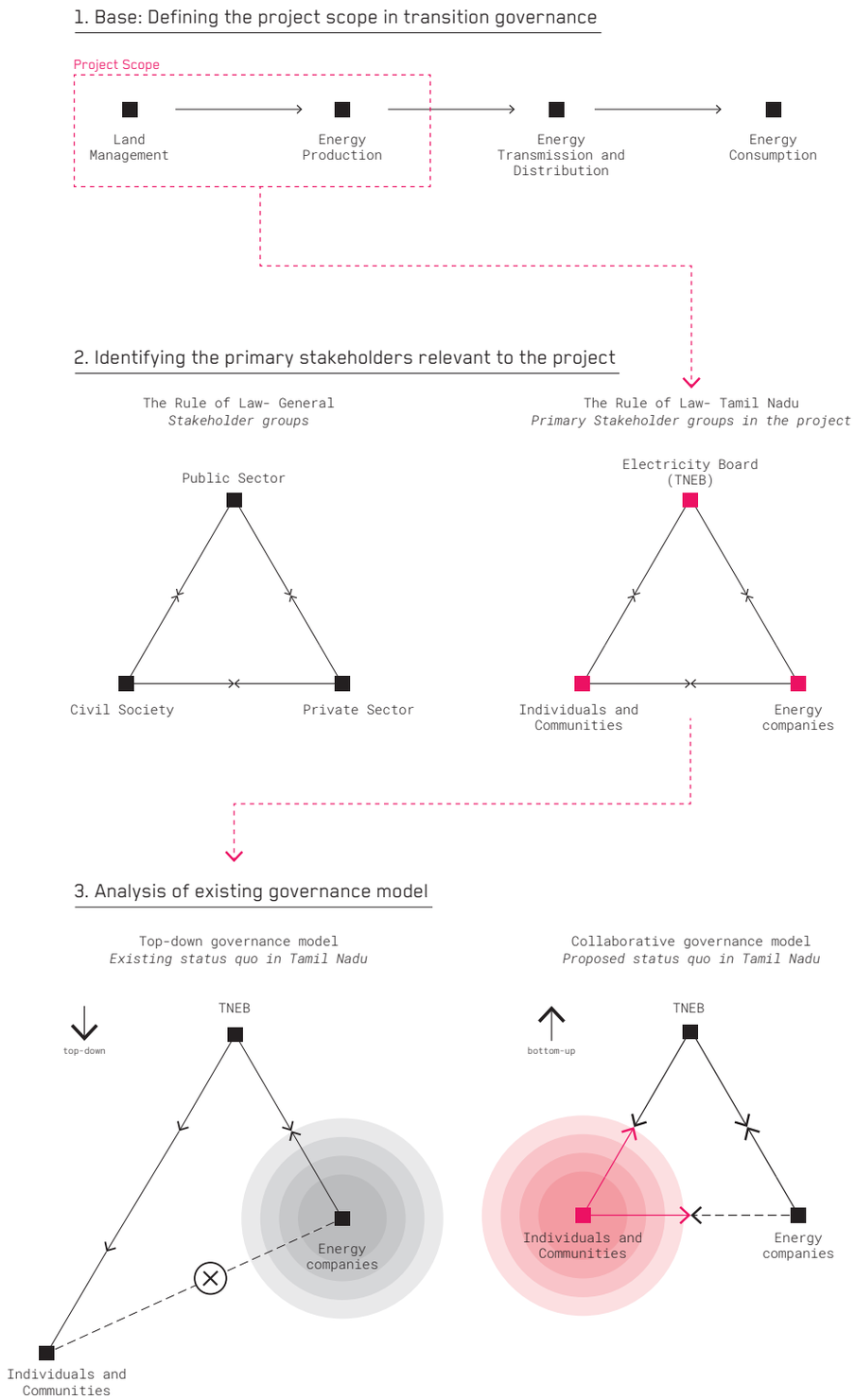


Fig 3.48: Analysis of the transition governance model in Tamil Nadu

Lack of integration between energy and spatial governance.

Apart from a governance reform that increases collaboration between stakeholders, a 'spatial' energy transition requires collaboration between energy and spatial governance structures. In Tamil Nadu, governing bodies related to energy development and landuse management are separated in function, without any mechanisms for collaboration. However, as elaborated earlier, energy transition is a process that primarily results in large scale transformation of land. ***The impact on landuse brings the transition process under the purview of not just the TNEB, but also the DTCP (Directorate of Town and Country Planning, responsible for landuse management and spatial planning).*** An integrated spatial energy governance that acknowledges the complex interdependency between energy development and spatial planning is necessary for spatial energy transition in Tamil Nadu. (Fig 3.49).

To understand where and how the interrelated governance can transpire, Fig 3.50 and Fig 3.51 present a ***comparison of energy and spatial governance structure*** in terms of the hierarchy and interrelations between different governmental departments, non-governmental organizations, energy research institutions across national and federal geopolitical scales. This gives a parallel overview of vertical and horizontal organization of both energy and spatial governance, independently.

Following this understanding, a ***comparison of scales of territory and scales of jurisdiction was made*** (Fig 3.52). In other words, energy governance structure was studied to see how energy development is managed across geographic scales, ranging from area covered by macro-regional grid to area covered by a single distribution box. This was viewed in comparison to spatial governance structure to see how landuse planning is managed across geographic scales, ranging from the macro-region to a single street. The scales of territories for energy and spatial governance are similar in terms of size, but vary in terms of administrative boundaries. ***The mismatch of interest and action between the energy and spatial governance across territories needs to be resolved through a soft planning approach that transcends administrative borders and jurisdictions.***

This is important because, in Tamil Nadu energy planning is, for the most part, a *regional* undertaking, whereas spatial planning is carried out only at the *local* scale (urban areas, villages). The pre-existing lack of (macro)regional spatial planning in Tamil Nadu further hinders the conception of a ***regional spatial plan specifically for energy development.*** An integrated spatial energy governance is essential to the conception of a regional spatial plan for energy development, a joint effort of both energy and spatial governing bodies.

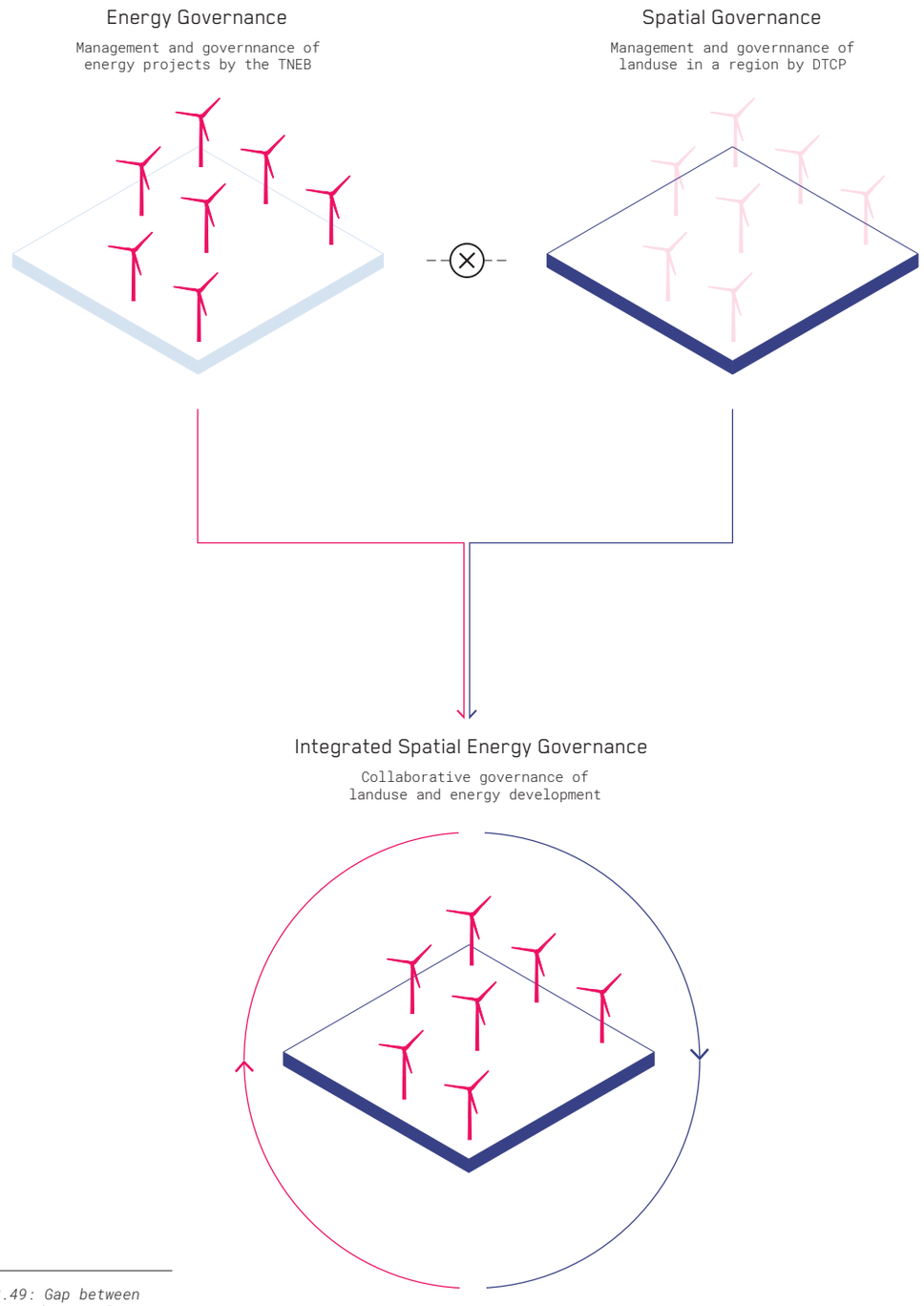
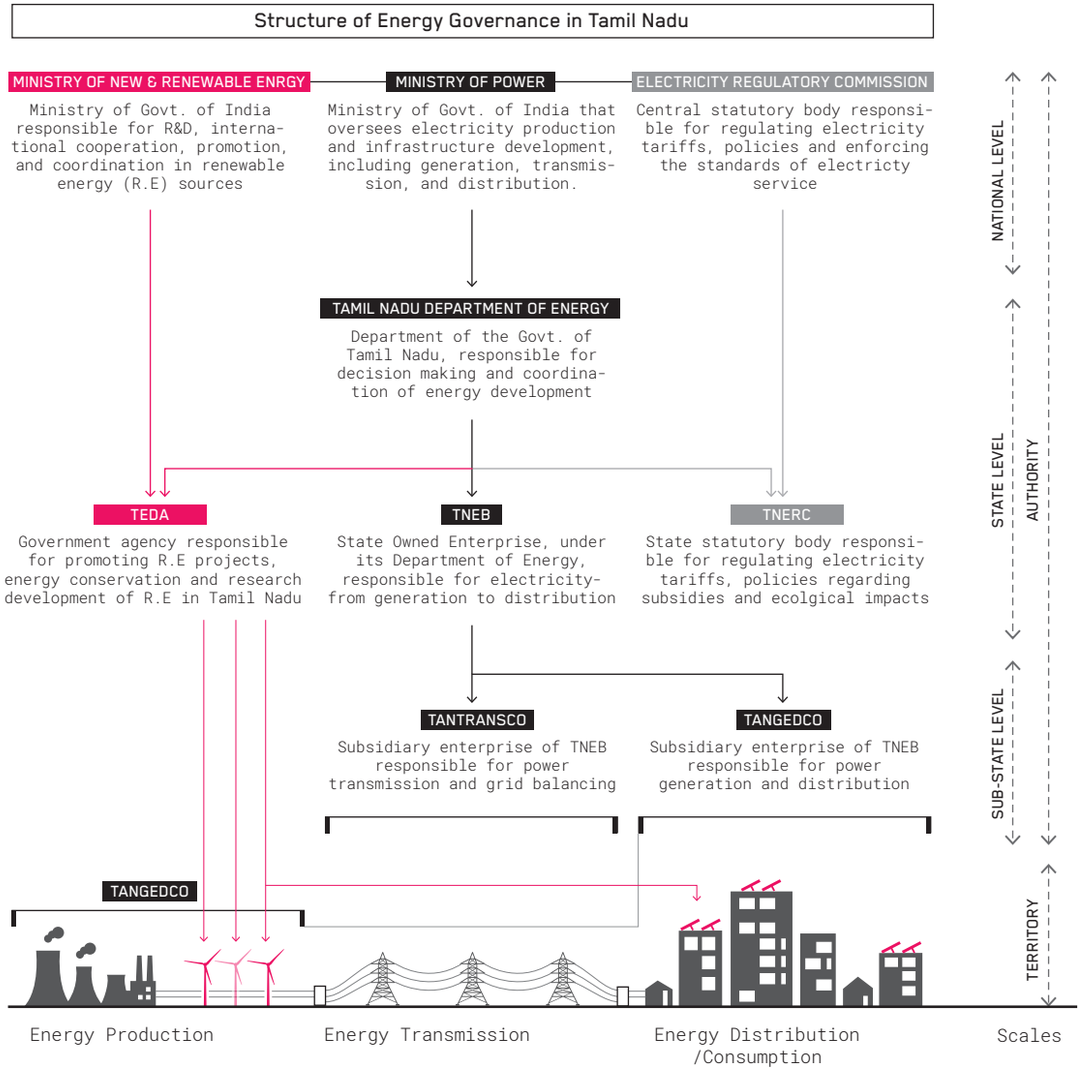


Fig 3.49: Gap between energy and spatial governance.

Comparison of energy and spatial governance.



TNEB - Tamil Nadu Electricity Board
TANGEDCO - Tamil Nadu Generation and Distribution Corporation Limited
TANTRANSCO - Tamil Nadu Transmission Corporation Limited
TEDA - Tamil Nadu Energy Development Agency
TNERC - Tamil Nadu Electricity Regulatory Commission

Renewable energy related bodies
Regulatory bodies

Fig 3.50: Energy governance system in Tamil Nadu

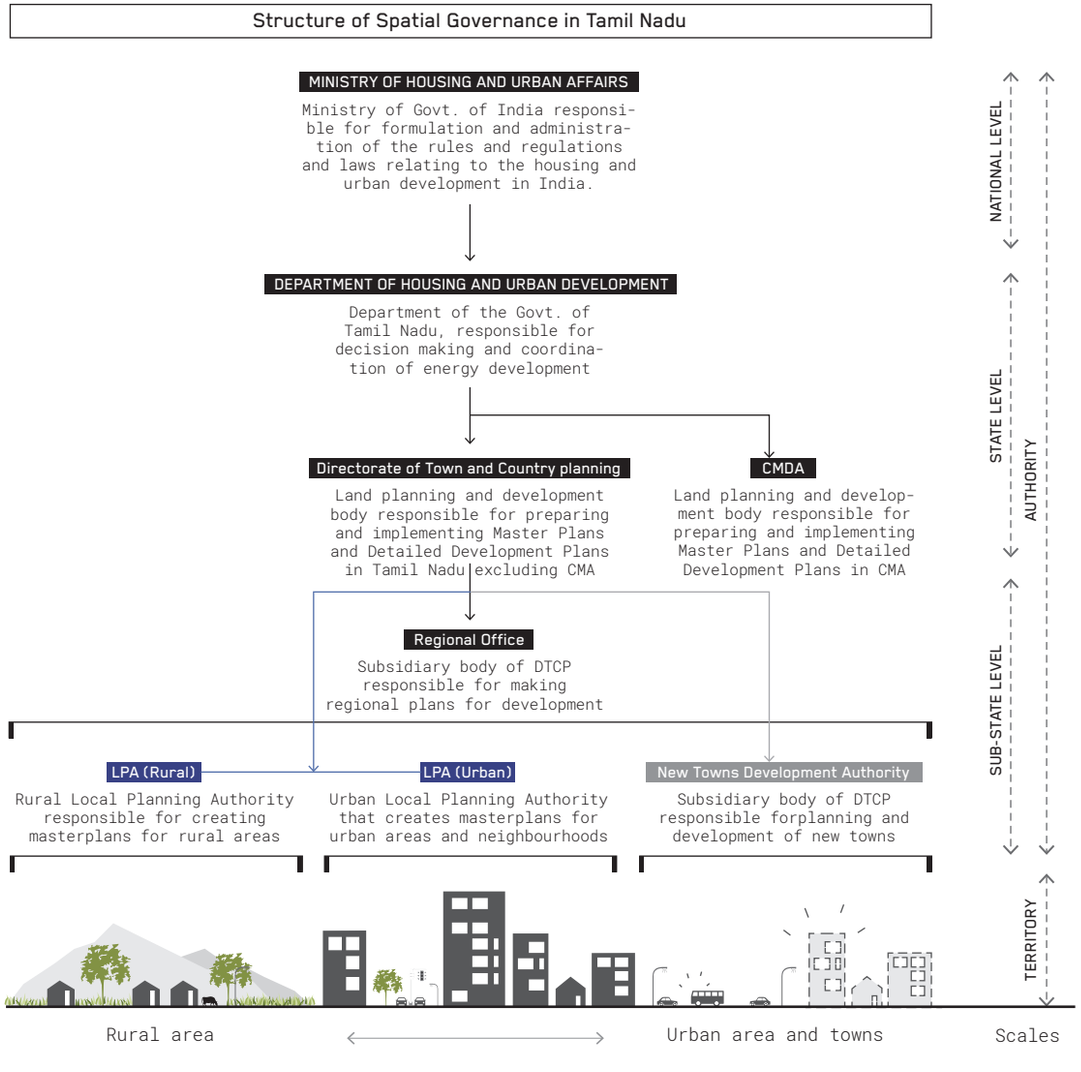
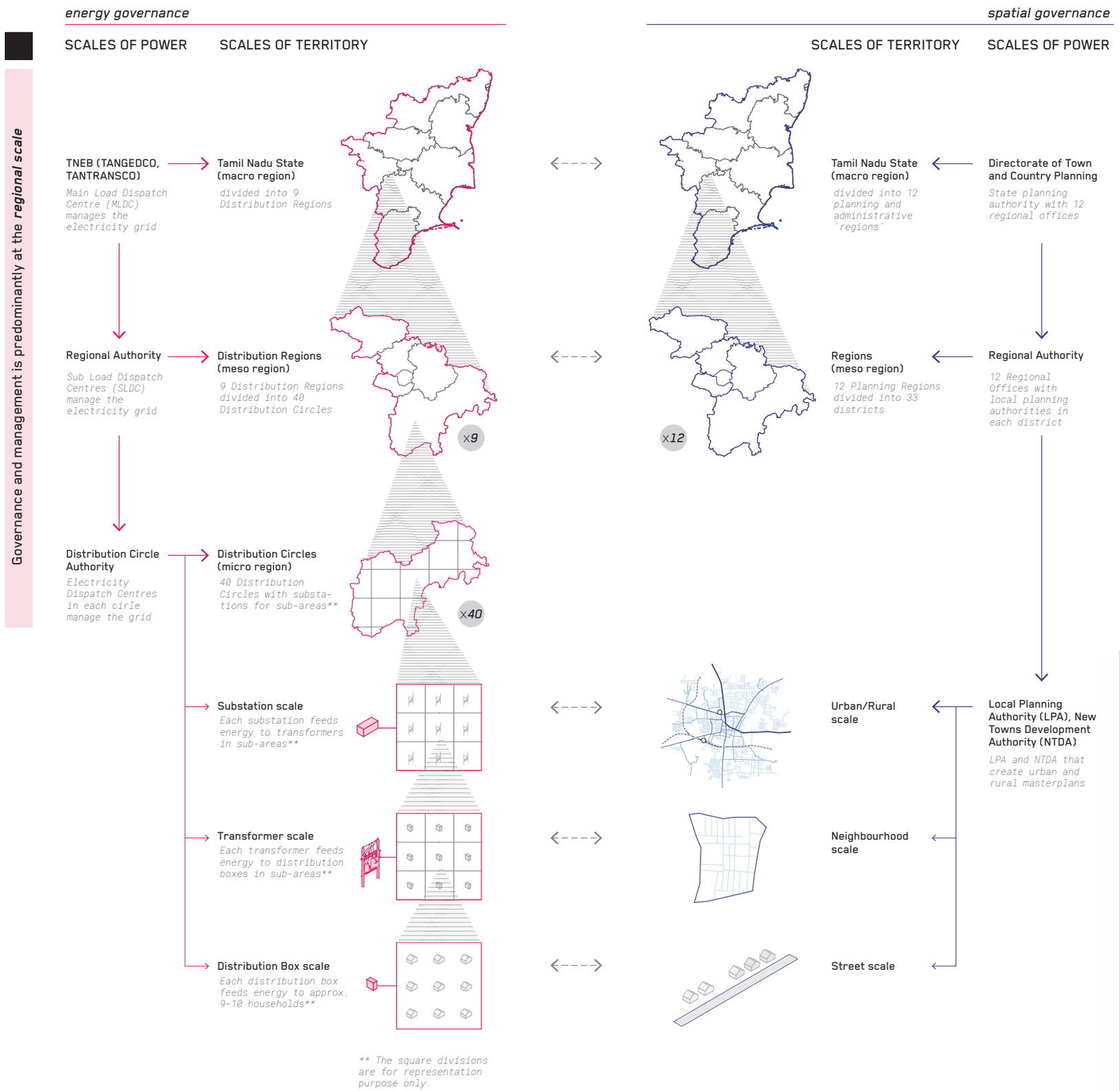


Fig 3.51: Spatial governance system in Tamil Nadu

... governance, coordination and planning of energy is, for most part, a regional undertaking, whereas spatial governance and creation of masterplans is carried out only at the local scale. There is an urgent need for **regional spatial planning** for energy development in the state of Tamil Nadu.



Governance and management is predominantly at the *local scale*

... the mismatch of boundaries and territories between energy and spatial governance demands **softer planning approach** that extends beyond boundaries, and **integrates spatial planning and energy planning.**

Fig 3.52: Mismatch between energy and spatial governance

Problem Focus - Energy x Governance.

This section presented an analysis of the governance dimension of energy transition in Tamil Nadu, that is, the mapping and study of the main stakeholders involved in the public sector, private sector and civil society; and the relationship between spatial governance and energy governance. Through the analysis, the project identified how the centralisation of power and lack of interdepartmental relationships in Tamil Nadu has resulted in a top-down governance structure that legitimises the gap between energy and spatial governance.

From this understanding, the project identifies four main problem focuses that the design needs to address:

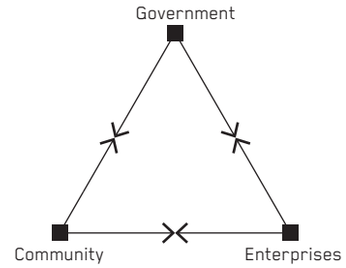
1. Need for collaborative bottom-up governance structure, that supports community participation and grassroot initiatives in energy transition.

2. Need for integrated spatial energy governance that promotes interdepartmental collaboration in energy transition.

3. Need for regional governance networks that can facilitate the regional integration of energy production landscapes and long term spatial vision.

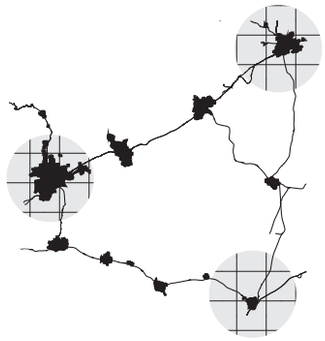
4. Need for tools, instruments and spatial strategies that provide guidelines, regulations and context-specific restrictions collaborative governance and participatory decision making.

1. Need for collaborative bottom up governance structure

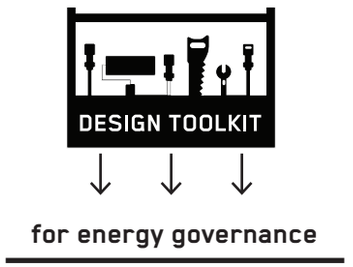


2. Need for integrated spatial energy governance





3. Need for regional governance networks



4. Need for tools, intruments and spatial strategies to guide participatory decision making.

Fig 3.53: The key problem focuses identified through the analysis of the political dimension of energy transition in Tamil Nadu

3.5 Problem Focus and Research Questions

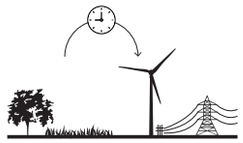
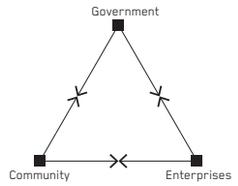
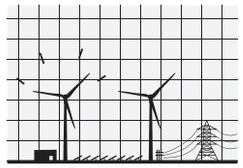
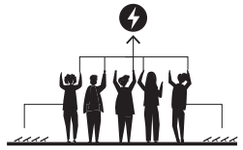
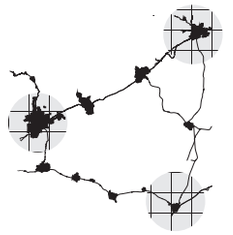
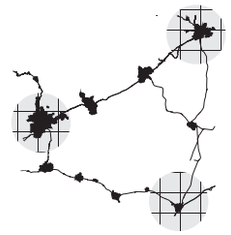
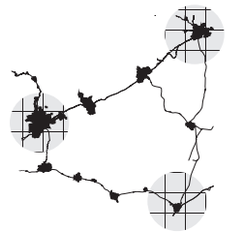
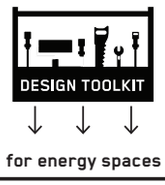
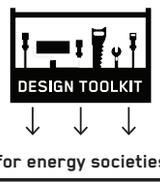
From the problem analysis through three branches of research (space, society and governance), specific problem focuses were identified (Fig 3.54):

A. Energy x Space: Lack of spatial consideration and regional integration of energy production landscapes in Tamil Nadu
B. Energy x Society: Inequitable access to energy and exclusion of individuals and communities from the energy transition process
C. Energy x Governance: Rigid, top-down governance model and gap between energy and spatial governance.

Taking the three points as the problem focus, this section presents the problem statement, project aim, main research question and sub-research questions of the project. These research foundations will be the starting point for the analysis and design stages of the project.

Fig 3.54: Consolidation of problem focuses explored through the three branches of research.

PROBLEM FOCUS- FACTORS FOR DESIGN

Energy x Space	Energy x Society	Energy x Governance
		
1. Need for adaptive energy production landscapes.	1. Need for equitable access to renewable energy.	1. Need for collaborative bottom up governance structure
		
2. Need for consideration of local conditions and spatial embeddedness of energy infrastructure.	2. Need for empowerment of energy vulnerable communities.	2. Need for integrated spatial energy governance
		
3. Need for integrated regional planning and design of energy production landscapes.	3. Need for integrated regional understanding of energy vulnerability distribution.	3. Need for regional governance networks
		
4. Lack of tools, instruments and spatial strategies to guide development of energy landscapes	4. Need for tools, intruments and spatial strategies to guide development of CRE.	4. Need for tools, intruments and spatial strategies to guide participatory decision making.

Problem Statement.

Tamil Nadu's energy transition legacy, beginning from 1984, has built a vast renewable energy production capacity that contributes to 35% of India's R.E. share, despite being only 4% of the country's geographic extent.

However, the transition to renewable energy continues to operate under extractivist, capitalist energy systems of the fossil fuel era, monopolized by private energy companies and supported by a rigid top-down governance system. This has led to ***large scale transformation of land for energy development without spatial considerations, and acute regional inequalities in energy access and distribution of benefits of the transition.*** Furthermore, the systemic barriers to the participation of individuals, communities and other members of civil society in energy transition impede long term societal acceptance and adoption of transition values.

Research aim.

The project argues that there is an urgent need to rethink existing systems of resource extraction and their implications on space, place and people. The project challenges existing extractivist, national R.E planning motives that perpetuate the cycle of reckless landuse transformation and energy vulnerability, under the guise of 'progressive' energy transition. The project argues that the shift to R.E needs to be accompanied by a transformation of the spatial, societal and political structures to create an ***adaptive, inclusive and collaborative energy transition in Tamil Nadu.*** The project makes three crucial contributions to achieve this goal (adapted from Balz, 2018):

1. Analytical contribution: The project is an explorative research to define methodologies to study, analyse and map emerging energy geographies in the region, to gain scientific knowledge about existing material spatial settings and socio-political structures that define the transition.

2. Normative contribution: Upon gaining analytical knowledge on the context, the project proposes and imagines a desired planning outcome- a spatial vision- for a 'just' energy transition, with a set of strategies, know-hows, actions to achieve the goals of the vision.

3. Organisational contribution: The project then critically evaluates the organisational logic and regional implications of planning policies, and how specific local territories are affected by the regional strategies (Schön, 2005; Balz, 2018). This deals with the testing of the feasibility and spatial implications of regional design on local territories.

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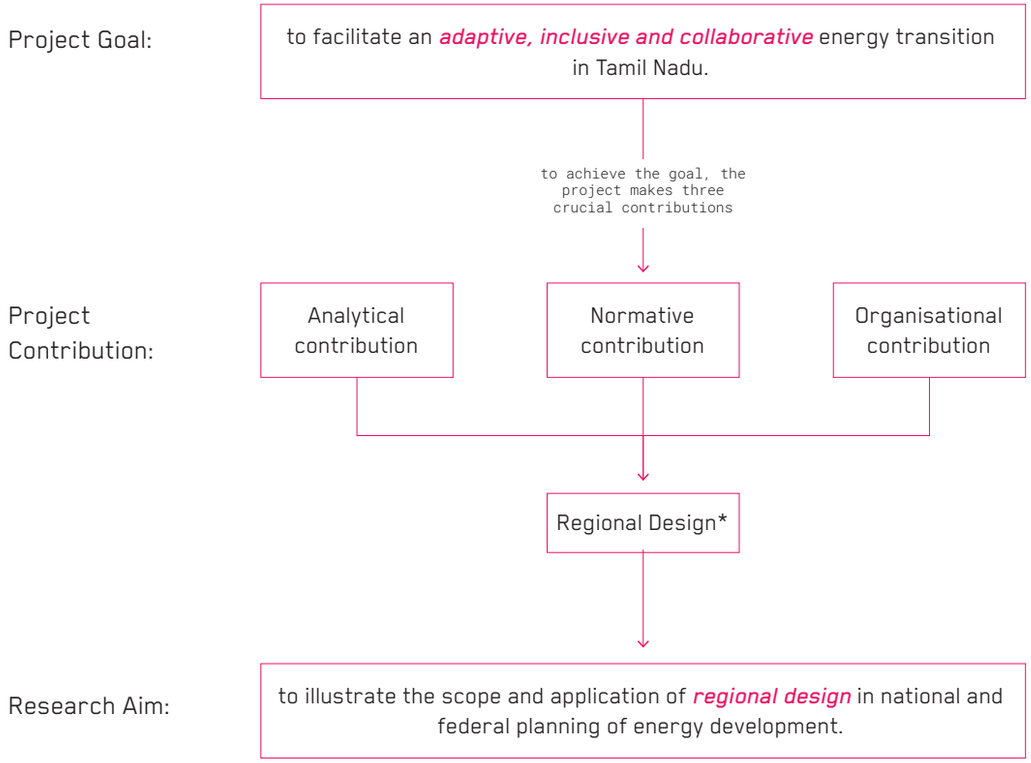
RESEARCH FOUNDATIONS



* Balz (2018) argues that this exploration and explicit identification of 'analytical knowledge, normative convictions and territorial interests when developing solutions for the built environment' can be seen as 'regional design'. The project argues that regional design, through its analytical and normative goals for energy production landscapes and governance of spatial development, can create the framework for a 'just' energy transition in Tamil Nadu.

Fig 3.55: Diagram summarizing the project foundations.

Balz (2018) argues that this exploration and explicit identification of 'analytical knowledge, normative convictions and territorial interests when developing solutions for the built environment' can be seen as 'regional design'. The analytical, normative and organisational dimensions of regional design contribute to not only the creation of design solutions but also to the formation of governance around projects.

The project argues that regional design, through its analytical and normative goals for energy production landscapes and governance of spatial development, can create the framework for a 'just' energy transition in Tamil Nadu. Thus, the main research aim of the project is to ***illustrate the scope and application of regional design in national and federal planning of energy development*** (Fig 3.55).

Research Questions.

The research aim of the project gave rise to the main research question of the project:

> ***How can regional design of emerging geographies of energy create a framework for a 'just' energy transition in Tamil Nadu?***

In other words, the project aims to illustrate how regional design of emerging energy geographies in Tamil Nadu can create a framework for a just (adaptive, inclusive and collaborative) energy transition in Tamil Nadu, by exploring and building ***analytical*** knowledge on

a. the spatial implications of energy transition on urban and rural landscapes in Tamil Nadu,

b. the systemic deficiencies in energy governance that create barriers to equitable ownership and access to energy,

and ***normative*** directions for

c. the territorial transformation of energy production landscapes into resilient infrastructural systems,

d. a collaborative governance structure to bridge the gap between top-down and bottom-up initiatives in energy transition,

e. creating conditions for energy justice, while offering higher social, economic and ecological returns.

The project takes the analytical and normative aim of the project as the base for defining the sub-research questions (Fig 3.56). The analytically and normatively oriented sub-research questions guide the project through the analysis and design phases.

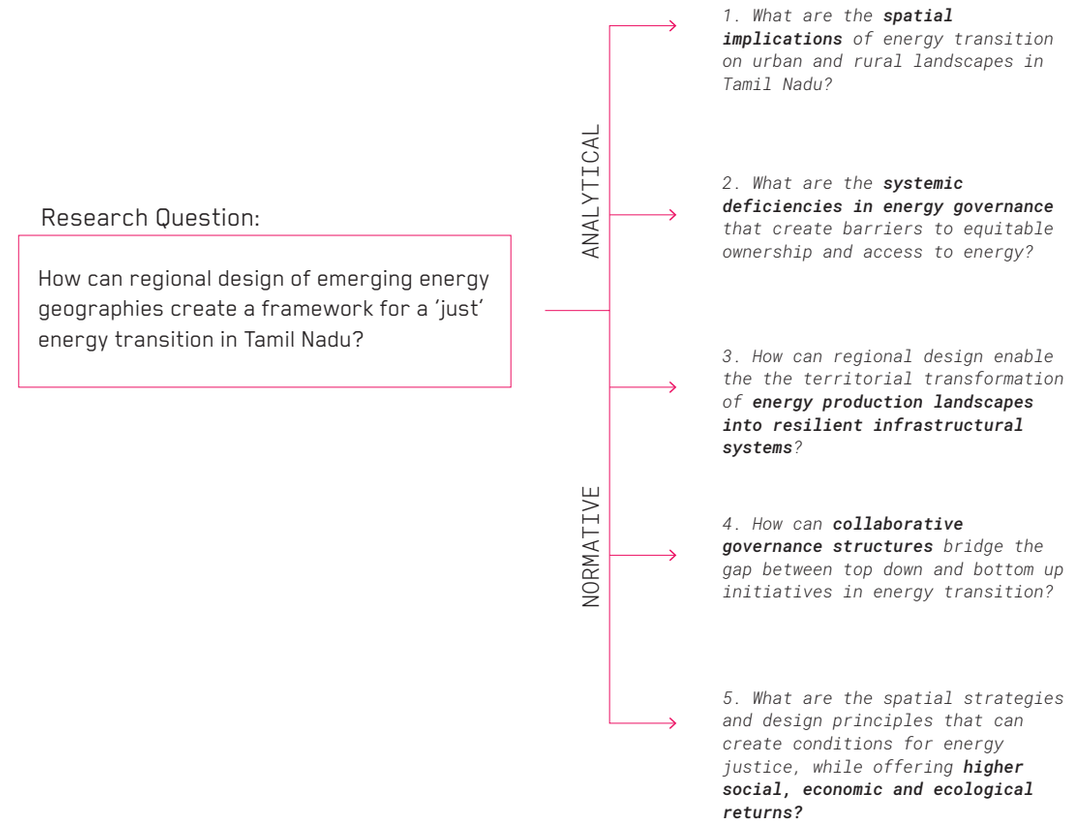


Fig 3.56: Diagram summarizing the research questions of the project

Conclusions.

This chapter introduced the case study- Tamil Nadu, India, through which the spatial, social and political dimensions of energy transition were explored (Sections 3.2, 3.3, 3.4). Through the problem analysis, specific problem focuses for energy transition in Tamil Nadu were identified to provide directions for detailed analysis and design phases of the project. Section 3.5 outlined the overall aim, contribution and research questions of the project. The significance of regional design in theory and for the case was highlighted, along with identifying the scope of the project. The following chapter will elaborate on the theoretical framework of the project to support the analysis and design.

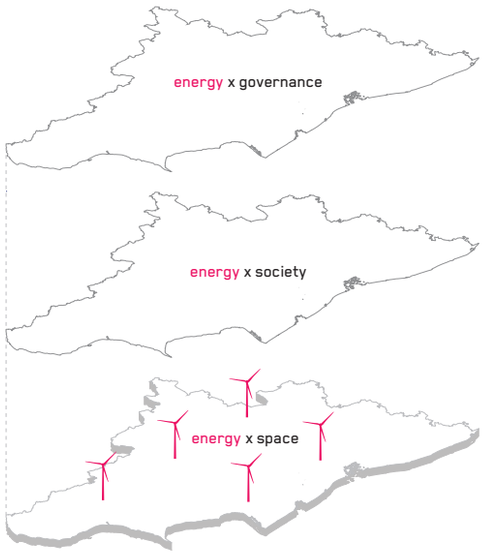


Fig 3.58: Diagram summarizing the Chapter

Fig 3.57: Satellite view of windfarm in Tamil Nadu, where the remnants of discarded energy objects can be seen dispersed through space.

4

Theoretical Framework

Overview:

This Chapter presents the theoretical framework of the project and selected precendents in literature on the nexus between energy, space, society and governance. The theoretical framework supports the project's focus on these three dimensions of energy transition and attempts to define what exactly creates 'good' energy geographies.

Sections:

4.1. The Argument
4.2. The Equation

4.1 The Argument

Over the past decade, increasing attention has been drawn to the spatial dimension of energy transition. The project argues that there is an urgent need to approach energy as a spatial phenomenon in relation to the inherent socio-political structures, which is outlined in this chapter by reviewing precedents in literature. The literature review is streamlined through the three branches of research (energy-space, energy-society and energy-governance) to derive a normative direction for analysis and design. Through the literature reviews, a theoretical understanding of what constitutes **'good' energy geographies** is gained. Then, using the literature reviews as the base, a conceptual equation is created to be the theoretical backbone of the project. The three branches of research are taken as the variables of the equation. This chapter will make the theoretical and philosophical stand of the project explicit in order to guide the design in later stages.

Energy x Space.
From a spatial to *geographic* approach to energy transition.

Energy and Space have a reciprocal relationship where they 'change each other and have changed together throughout the course of history' (Sijmons, 2014). In fact, energy is the driving force in land use (Smil, 2017; Pasqualetti & Stremke, 2018). The transformation of land for the extraction of energy resources was a crucial impact of the era of 'fossil fuel expressionism' (Sloterdijk, 2014). This resulting energy landscape spanned territories, changed socio-political relationships and created distinct, often permanent geographic patterns. This can be explicitly seen in the deforestation of entire regions for wood, excavation of mines for coal, fracking and drilling of oil rich lands, and nuclear disaster zones. Similarly, the era of energy transition saw the transformation of agricultural fields into solar fields, erection of wind farms spanning territories and the construction of hydropower dams that altered the morphological features of the landscape itself.

The human development of energy resources occurs at the intersection of energy and space, leaving distinct, permanent marks and spatial patterns on the land. The resulting landscapes of energy production, networks of distribution and territories of consumption together constitute 'energy-space'. This energy-space is under constant development, transformation and exponential expansion, due to the increasing global demand for energy and shifts in energy outlook. In other words, the space produces energy and energy, in turn, produces space (Lefebvre, 1991).

Particularly in the era of energy transition, the spatial dimension of energy transition ***must be considered*** while planning for the new, emerging renewable energy-space of the future, because spaces of renewable energy (RE) production are distinctly different from those of non-renewable energy (NRE). They differ in terms of ***size, form, spatial embeddedness, scale and degree of permanence,*** to name a few. One way of quantifying the difference between RE space and NRE space and spatialise their impacts is to quantify energy units in terms of the amount of space/area they utilise for energy generation. This is called ***'power density'*** (Smil, 2015). Smil further states in his book Power density : a key to understanding energy sources and uses, that RE production will take 100-1000 times more space than NRE production since RE has a significantly lower power density than fossil fuels (See Fig 3). This means that the transition will ***exponentially increase the footprint of energy production***, and have huge negative impacts on agricultural lands, ecological systems and overall quality of space.

However, the conceptualisation of energy as a spatial phenomenon first requires an understanding of what an 'energy-space' actually is. Various scholars offer different definitions based on their

academic background and school of thought. Energy-space, energy landscape (Pasqualetti & Stremke, 2018), energy geographies (Bridge, et al., 2012), energy-scape are some of the terminologies used to define spaces of energy development.

Energy landscapes: The notion of energy landscapes defines it as observable landscapes that originate directly from the human development of energy resources (Pasqualetti & Stremke, 2018). The authors further state that 'combining the term energy with landscape produces a useful unifying label for the marks, structures, excavations, creations, and supplements that energy developments produce,(…) and all the principal elements that appear at the confluence of energy and technology – i.e. technical, visual, social, ecological and political.' In Landscape and Energy (2014), Sijmons states that landscape is the battleground of energy transition, which emphasises the importance of the word 'landscape' in the conception of energy landscapes.

Energy geographies: A parallel movement that emerged from the research in energy-space is its conception as energy geographies, which approaches the production of energy as a fundamentally geographic process. This stems from an elementary shift in the understanding of space itself. Informed by the theories of critical geography (Harvey, 2001) and relational space (Massey, 2004; Lefebvre, 1991), this movement understands space not as a neutral container within which various social, political and economic processes happen, but as 'product of interrelations' (Massey, 2005) that is continually made and re-made by these processes. Space, in turn, constitutes the said processes and actively produces and maintains them (Bouzarovski & Simcock, 2017; Dikeç, 2001; Soja, 2010). This geographic approach to energy-space (and energy transition) firmly situates it within the nexus of social, political and economic dimensions of transition.

Hui and Walker (2018) describe the geographic approach as one that brings 'the full range of conceptual resources now running through human geography and its subfields to bear on energy questions – in all of their diversity and complexity' (Calvert, 2016; Huber, 2015; Zimmerer, 2011; Bridge, et.al., 2012). Calvert (2016) uses the term energy geographies to 'signify the various geographical imaginaries, spatial identities, and connections to place that are co-productive with particular systems of energy provision'. Bridge, et al.,

Note: *The project argues that the term 'energy geography(ies)' provides a more comprehensive and relational understanding of energy-space and its constituents, than the term 'energy landscape'. From this point onward, the project will adopt the term energy geographies to describe all types of energy-space.*

THREE BRANCHES OF RESEARCH FROM THE GEOGRAPHIC APPROACH

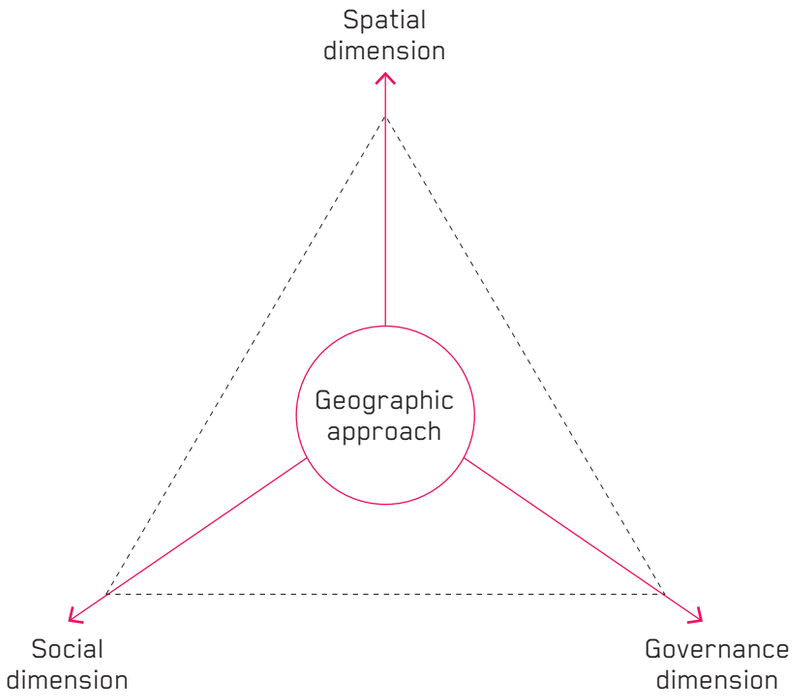


Fig 4.1: Diagram showing the geographic approach and the three branches of research.

(2012) posit that the geographic approach will give insights on spatial differentiation and territorialisation of energy networks, relational socio-political structures, patterns and scales of organisation of energy infrastructure. This geographic approach to energy transition has the potential to bridge the epistemological and methodological rift between energy studies and spatial planning, by viewing space as a product of interrelations.

Thus, the project conceptualises energy geographies as a product of the interrelations between the 'spatial dimension' and the socio- political dimensions of energy transition. The geographic approach provides the framework to synthesize these multiple dimensions of transition in relation to each other and energy, by using space as the common denominator. The following paragraphs will outline the second and third branch of research (energy x society and energy x governance)

Energy x Society.

The relationship between energy and society is co-productive; on one hand, energy availability and consumption establishes the parameters around the types of lifestyles that are possible, while on the other hand, cultural and political-economic value systems guide the resources from which, and end-uses toward which, energy is expended (Shove and Walker, 2010). The degree of access to energy influences our lifestyles, social behaviour, ability to afford goods that use energy (cars, appliances), improvement of living standards and status in society. Consequently, the lack of access to energy limits certain populations from achieving a higher quality of life. This is called 'energy poverty', or 'the inability to attain a socially and materially necessitated level of domestic energy services' (Bouzarovski & Petrova, 2015). Countries with lower levels of energy consumption, and by extension, energy access, have a lower human development index.

Energy poverty is turn underpinned by and reproduces distinct forms of spatial inequality. A socio-technical transition that aims to achieve energy justice must first address the concept of spatial justice (Soja, 2010; Yenneti et al., 2016). This can be interpreted as a call for the right to services, stemming from Lefebvre's 'right to the city (1991), which intends to improve spatial living conditions and break vicious cycles of energy poverty and vulnerability, perpetuated by structures of spatial inequality.

The project argues that future energy geographies should create the framework for ***energy justice*** (Bouzarovski & Simcock, 2017) that enhances the equitable access to, and distribution of its benefits to the disadvantaged, socio-spatially segregated

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Fig 4.2: Community as stakeholders in energy transition (urban areas) (Soneji, 2018)



Fig 4.3: Community as stakeholders in energy transition (rural areas) (Soneji, 2018)

communities (Fig 4.2, Fig 4.3). The future energy geographies must dissolve the geographies of difference, inequality and injustice, so that 'the prospects of the least advantaged territory are as great as they can be' (Harvey, 1973). Since energy justice is driven by spatial justice, broader interventions to address the geographic process that (re)produce spatial inequalities must be prioritized (Dikeç, 2001; Harvey, 1996). Spatial energy justice should be a key factor in determining 'where resources should be focused, whose needs should be recognized and prioritized in relation to geographical difference, and how democratic legitimacy might be achieved' (Bouzarovski & Simcock, 2017; McCauley, et al., 2013).

In addition to addressing spatial energy justice, future energy geographies should create social narratives of change and trigger an alternative way of life that redefines social practice and relations with energy. They should create spaces, places, territories and cities that foster an emotional transition- ***the social acceptance of energy transition*** and the emerging energy geographies, its spatiality, image- which is crucial to the long term assimilation and integration of any spatial energy plan (Sijmons & van Dorst, 2012).

Energy x Governance.

In the energy sector, the past few decades have pushed for territorialisation, i.e, integration or scaling up of national and continental grid systems (Platt, 1991, Nye, 1998), which has resulted in 'different scales and arenas of political action that govern energy systems because of the way they are spatially constituted' (Hughes, 1993). Since energy systems are constituted spatially, the components and the networked nature of the system itself produces geographies of connection, dependency and control (Bridge, et.al., 2012).

Energy infrastructure is primarily funded, built and operated by a niche group of players like the government, private banks, private business, individuals who can afford the high capital investment. They are powerful and influential players in decision making and governance of energy resources. The spatial and political centralization of power that makes decisions in a top-down manner that does not give room for collaborative, decentralized, bottom-up approach to decision making.

We need a collaborative form of governance 'where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs or assets' (Ansell & Gash, 2008). Collaborative governance 'brings public and private stakeholders together in collective forums with public agencies to engage in consensus-oriented decision making' (Ansell & Gash, 2008). The collaborative governance approach should be flexible and adopt both formal and informal tools of governance that includes face-to-face dialogue, trust building, and the development of commitment and shared understanding (Ansell & Gash, 2008) between the multiple stakeholders of energy transition. Political reform of the power sector is crucial for a smooth energy transition.

To enable the collaborative model of governance, power relations that underpin the production of energy geographies must be restructured, fundamentally shifting control away from the capital and the state, towards inhabitants and stakeholders of the energy geographies (Purcell, 2002). Decentralization of power will reduce dependency and exploitation across regions and scales and create a 'stronger sense of local and regional identity, authenticity and meaning (Jacobs & Appleyard, 1987).

In addition, a collaborative model of governance is absolutely necessary for the creation and sustenance of an alternative economic model that adapts to this socio-technical transition. The project argues that the future renewable energy geographies should reject the extractivist systems of the capitalocene (Moore, 2017) and fossil fuel expressionism (Sloterdijk, 2014). The current extractivist energy economy should be replaced by a new economic model that respects the limits of the natural environment and creates room for alternative practices and forms of extraction without exploitation. The post extractivist economy promises a 'different kind of imaging and imagination, action and retro-action, forms of representation and reclamation', to undermine neoliberal strategies of land dispossession to produce energy and the resulting uneven forms of development. (Belanger, 2018)

The alternate economic model should be built on the idea of the commons and co-production of energy and energy geographies (Ostrom, 1990; Cahn, 2008; Wolf & Mahaffey, 2016) to increase citizen participation and social entrepreneurship in renewable energy transition. Co-production should be a strong driving force especially in energy transition, since renewable energy infrastructure does not need to be large scale and centralised. The co-production of renewable energy with the help of local communities must be supported by interventions from the state, to reduce the dependency on large energy corporations.

The knowledge gained from precedents in literature on the spatial, social and political dimensions of energy transition was crucial in defining the importance of a relational, geographic approach to energy transition that respects values of the place, people and territory. The following section summarises the argument presented here for applying the lens of geography to energy transition, in the form of a conceptual equation (Fig 4.4).

4.2 The Conceptual Framework

The geographic approach to energy transition can redraw the map of social and economic activity in different ways with new potentials and opportunities. The project summarizes the theoretical foundation elaborated earlier by combining the three branches of research in the form of a **conceptual equation (Fig 4.4).** The equation will act as the backbone of research and design methodology of the project. The nexus between space, society and governance, and their interrelations are critical to the successful transition to renewable energy sources. The equation explicitly sees the spatial, societal and governance dimensions of energy transition in relational terms by adopting a geographic lens. This interdisciplinary research also adds to the body of knowledge on spatial planning for energy, and points towards a new paradigm of conception and perception of energy geographies, which integrates the multidimensional facets of energy transition.

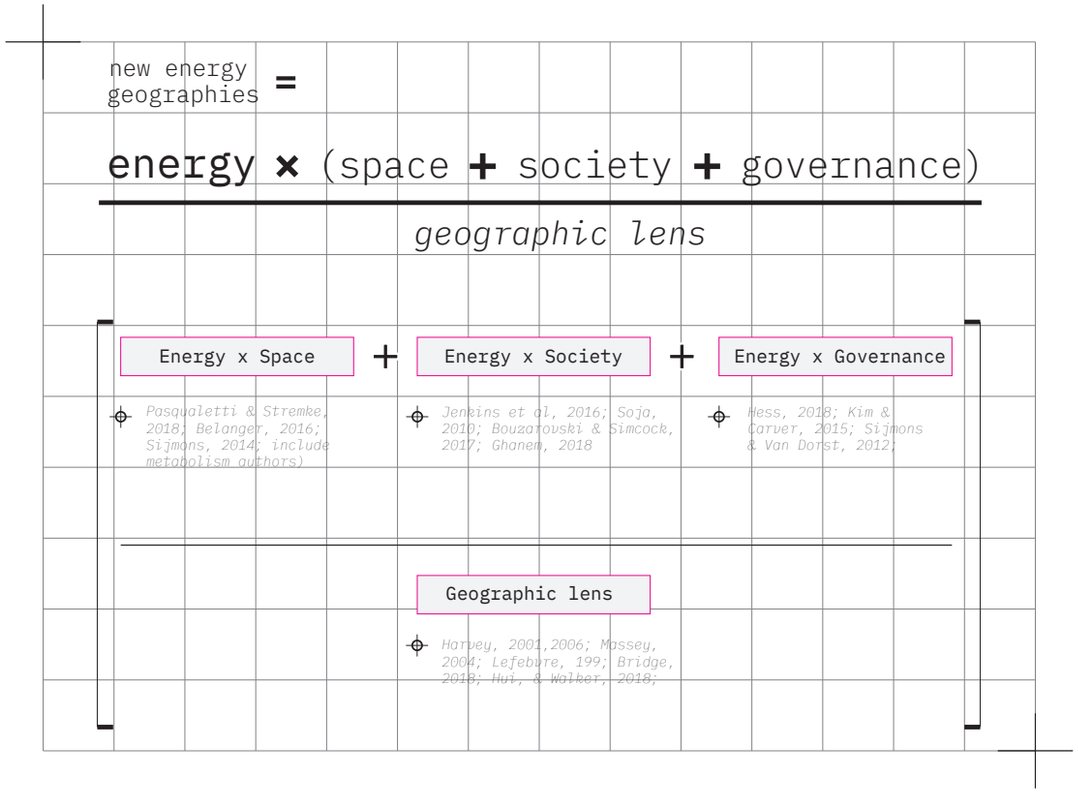

Fig 4.4: Conceptual framework diagram/ equation

Conclusions.

This chapter reviewed precedents in literature related to the three branches of research of the project:; space, society and governance of energy transition. The knowledge gained from the literature reviews helped in the development of the project's conceptual framework. The theoretical elaboration of the three dimensions of energy transition also reinforced the relevance of the geographic approach to energy transition in Tamil Nadu. The following chapter will present the research and design methodology defined by the project.

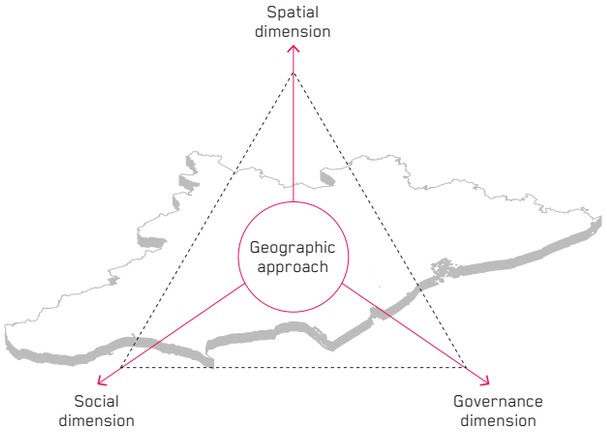

Fig 3.6: Diagram summarizing the Chapter

Fig 3.5: Satellite view of windfarm in Tamil Nadu, where the remnants of discarded energy objects can be seen dispersed through space.



5

Methodology

Overview:

This chapter presents the research and design methodology that was chosen to address the problem field and context of study, analysis and design phases of the graduation project. First, an overall research framework chart was developed to lay out the steps of research and design of the graduation project, following which, the methods for theoretical, analytical and normative undertsanding of the problem are presented.

Sections:

5.1. Introduction
5.2. The ‘What’- Project Foundations
5.3. The ‘How’- Frameworks
5.4. Methods Used
5.5. Design Development and Outcomes
5.6. Conclusions

5.1 Introduction

The intersection of energy and space sets a challenging premise for the project, in terms of identifying suitable research and design methods. The spatial implications of the human development of energy resources have been largely ignored in energy studies. Scholarly research in the spatial dimension of energy transition is relatively new; an endeavor of the past decade. The reciprocal relationship (Sijmons, 2014) between energy and space has since then caught the attention of academia, due to the increasing relevance of energy transition in our daily, societal life. However, there exists a knowledge gap between the fields of energy studies and spatial planning, despite the fact that the altered spatial qualities of renewable energy space have **blurred the boundaries between technical space and 'non-technical' space** (coveted. This project primarily aims to contribute to bridging the epistemological and methodological rift between energy studies and spatial planning.

Fig 5.1: Overall research framework chart

RESEARCH FRAMEWORK

Problem Field: Spatial Dimension of Energy Transition

Key words: *energy transition, spatial governance, energy landscape, Tamil Nadu, spatial justice, regional energy design*

Where?: Tamil Nadu (TN), India

Problem Statement: In Tamil Nadu, the transition to renewable energy continues to operate under extractivist, capitalist energy systems of the fossil fuel era, monopolized by private energy companies and supported by a rigid top down governance system. This has lead to ***large scale transformation of land for energy development without spatial considerations, and acute regional inequalities in energy access and distribution of benefits*** of the transition.

Research Aim: To illustrate the ***scope and application of regional design*** in national and federal planning of energy development, to facilitate an ***adaptive, inclusive and collaborative energy transition*** in Tamil Nadu.

Research Questions: **How can regional design of emerging energy geographies create a framework for a 'just' energy transition in Tamil Nadu?**

1. *What are the **spatial implications** of energy transition on urban and rural landscapes in Tamil Nadu?*
2. *What are the **systemic deficiencies in energy governance** that create barriers to equitable ownership and access to energy?*
3. *How can regional design enable the the territorial transformation of **energy production landscapes into resilient infrastructural systems**?*
4. *How can **collaborative governance structures** bridge the gap between top down and bottom up initiatives in energy transition?*
5. *What are the spatial strategies and design principles that can create conditions for energy justice, while offering **higher social, economic and ecological returns?***

Research Approach: Exploratory Research

Conceptual Framework *+ key literature*: Here, the implications of 'Energy-space' on different socio-political relationships are viewed through a geographic medium. Critical relational geography is a way of bridging the epistemological and methodological rift between energy studies and social sciences.

$$\textit{new energy geographies} = \frac{\text{energy} \times (\text{space} + \text{governance} + \text{society})}{\textit{geographic lens}}$$

Inductive / Deductive

Methods Used *(methods for data collection and analysis)*:
- Literature Review
- Documentary Research
- Field work
- Transcalar Mapping
- Scenario Potential Calculations
- Stakeholder Analysis

Analysis: Multi-criteria anaysis

Design Outcomes:

L **Macroregional Scale**
- Regional Design and spatial strategies for energy transition in Tamil Nadu

M **Microregional Scale**
- Designing Urban-Rural energy relationships

S **Local Scale**
- Pilot projects in various neighbourhood typologies, from urban to rural.

- Design rules/ Toolkit that can be applied to interventions across the scales
- Design of governance system based on scales of relationsl power and territoriality

Conclusion: Impact Assessment Indicators

The spatial dimension of energy transition is explored in the state of Tamil Nadu, India. Tamil Nadu is one of the leaders in renewable energy in India, accounting for nearly 32% of India's total RE installed capacity and 35% of India's total wind energy installed capacity (Nesamalar, et.al., 2017). The state is at a crucial crossroad in determining what kind of energy future it needs, with new energy geographies emerging at a rapid pace (See Chapter 3 for detailed analysis). There is an urgent need for an integrated, state-wide ***regional design*** (Balz, 2017; Balz & Zonneveld, 2015) for energy transition, that takes into account its spatial dimension. Thus, ***'spatial energy transition'*** is the problem field and ***'Tamil Nadu, India'*** is the context of study.

This chapter presents the research and design methodology that was chosen to address the problem field and context of study, analysis and design phases of the graduation project. First, an overall research framework chart was developed to lay out the steps of research and design of the graduation project (Fig 5.1). The research framework acts as a guiding principle to orient the individual components of the research framework to be in alignment with one another. The research philosophy, research approach, methodology for research and design were carefully chosen based on the theoretical (deductive) and contextual (inductive) foundations of the project.

> **The three branches of the problem focus, namely 'energy-space', 'energy-governance' and 'energy-society', and their intersections gave rise to the overarching aim of the project, which is to enable a 'humanised', socio-technical energy transition in Tamil Nadu.**

Section 5.2, *'The 'What'- Project Foundation'*, is essentially the articulation of the argument that lead to the research questions and research approach. To do this, a careful analysis of the spatial dimension of energy transition (problem field) and the challenges of addressing this problem field within a developing country like India (context of study). Once the problem field and context of study were defined, a problem focus was developed to streamline the project and define its scope. Specifically, the project focuses on the relationship between energy, space and various socio-political relationships across various geographic scales, in the state of Tamil Nadu, India. The three branches of the problem focus, namely 'energy-space', 'energy-governance' and 'energy-society', and their intersections gave rise to the overarching aim of the project, which is to enable a 'humanised', socio-technical transition to renewable energy in Tamil Nadu. The section further outlines the hypothesis, research questions and the research approach that guides the project.

Following this, Section 5.3, *'The 'How'- Methods Used'* elaborates in detail the theoretical foundation, analytical framework and methods used for research development. First, three streams of theory pertaining to 'energy-space', 'energy-governance' and 'energy-society' were researched and elaborated, through careful literature reviews. This theoretical foundation gave rise to the project's conceptual framework, which seeks to juxtapose a geographic lens on the three streams of theory. ***Application of a geographic lens*** is the project's key argument to bridge the gap between energy studies and spatial planning. From this conceptual standpoint, a framework for the analysis of the context was created. This section also elaborates in detail, the methods used for gaining a conceptual understanding, data collection and analysis on national, regional, and local scales. The methods are indicative of the process of research/design and the outcomes of this process are presented throughout the report. The section concludes with the relevance of methods described in the report and the inferences for design development.

Section 5.4, *'Design Development and Outcomes'*, presents the various steps undertaken to evolve the design component of the graduation project. The design outcomes of the project include a Manifesto for the Design of Energy Geographies, development of scenarios to imagine potential energy futures for Tamil Nadu, an Energy Vision for Tamil Nadu 2050, Regional Design for energy transition in Tamil Nadu wrt the energy scenarios, a toolkit prescribing spatial, socio-political conditions for a humanised energy transition, and an assemblage of spatial interventions in strategic locations to manifest the regional design. Furthermore, the project also describes indicators for impact assessment, should the design proposal come into fruition. The section concludes by describing the development of the User-Interface (name to be given)- an online platform for knowledge on the spatial dimension of energy transition. Establishment of this digital resource would be a significant contribution to create awareness on the intersection of energy and space in a developing context like India.

Finally, the conclusions from adopting this methodology for research and design, scope and limitations, ethical considerations of the project are elaborated in Section 5.5. 'Conclusions'.

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5.2 The ‘What’ - Project Foundation

Energy is the only **universal currency** (Smil, 2017). All of the human race’s advancements from cultivating crops, forming human settlements with complex societies and specialization of work, to making scientific and societal innovations, has been possible through the consumption and exploitation of various forms of energy resources.

In human history, energy transitions have **underpinned broad social, economic and geographic change** (Bridge, et al., 2012). It was the transition from wood to coal in the mid 19th century that fueled the industrial revolution, and the transition from coal to oil and gas that triggered the developments in the automobile and transportation industry. These historic precedents show that energy transitions influence the nature of industrialisation, urbanisation, the growth of consumer society, economic prosperity, geographic structure and international relations (Bridge et al., 2012). Similarly,

Problem Statement

In Tamil Nadu, the transition to renewable energy continues to operate under extractivist, capitalist energy systems of the fossil fuel era, monopolized by private energy companies and supported by a rigid top down governance system. This has lead to ***large scale transformation of land for energy development without spatial considerations, and acute regional inequalities in energy access and distribution of benefits*** of the transition.

Research Aim

To illustrate the ***scope and application of regional design*** in national and federal planning of energy development, to facilitate an **adaptive, inclusive and collaborative energy transition** in Tamil Nadu.

Research Questions

How can ***regional design*** of emerging energy geographies create a framework for a ‘just’ energy transition in Tamil Nadu?

ANALYTICAL

1. *What are the **spatial implications** of energy transition on urban and rural landscapes in Tamil Nadu?*

2. *What are the **systemic deficiencies in energy governance** that create barriers to equitable ownership and access to energy?*

NORMATIVE

3. *How can regional design enable the the territorial transformation of **energy production landscapes into resilient infrastructural systems**?*

4. *How can **collaborative governance structures** bridge the gap between top down and bottom up initiatives in energy transition?*

5. *What are the spatial strategies and design principles that can create conditions for energy justice, while offering **higher social, economic and ecological returns?***

Fig 5.2: Diagram summarizing the project foundations- problem statement, hypothesis, research question.

the current transition to renewable energy also has extensive impacts on geographies of power, economy, ecology, space and place.

Over the past decade, increasing attention has been drawn to the ***spatial dimension of energy transition.*** The human development of energy resources occurs at the intersection of energy and space, leaving distinct, permanent marks and spatial patterns on the land (Fig 5.3). The resulting landscapes of energy production, networks of distribution and territories of consumption together constitute ***'energy-space'***. This energy-space is under constant development, transformation and exponential expansion, due to the increasing global demand for energy and shifts in energy outlook. The projects begins with the premise that there is an ***urgent need to approach energy as a spatial phenomenon,*** to fully understand the conflicts and opportunities of energy-space. This is extremely important in the context of energy transition, since renewable sources of energy uses space and produces space in a *different way*- its altered spatial qualities have blurred the boundaries between technical space (shunned by planners) and 'non-technical' space (coveted by planners).

The deficiencies and gaps in knowledge at the intersection of energy and space is the 'problem field' of the project.

This problem field was further investigated in the context of Tamil Nadu, India. As elaborated previously, Tamil Nadu is a national leader in the transition to R.E., where new energy spaces are emerging rapidly. However, the lack of integration between the fields of energy studies and spatial planning has resulted in negligence of the spatial component of energy transition when planning for it. In addition to the spatial perspective, there is crucial need to conceptualise energy-space as a ***product of interrelations*** (Lefebvre, 1991; Massey, 2004; 2005) between the spatial dimension and the social, political, economic dimensions of energy transition. This multidimensional outlook is particularly significant in a developing country like India, where ***systemic deficiencies in governance and socio-spatial inequalities in the access to energy*** are major barriers in transition.

The analysis of the problem field, combined with study of the context gave rise to the 'problem focus' of the project. Specifically, the project focuses on the relationship between energy, space and various socio-political relationships across various geographic scales, in the state of Tamil Nadu, India. Thus, the three branches of the problem focus, namely ***'energy-space', 'energy-governance' and 'energy-society'***, and their intersections gave rise to the overarching ***'aim'*** of the project, which is to illustrate the scope and application of regional

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Fig 5.3: Westar Open Pit Coal Mine, Sparwood, Canada. (Burtynsky, 1985)

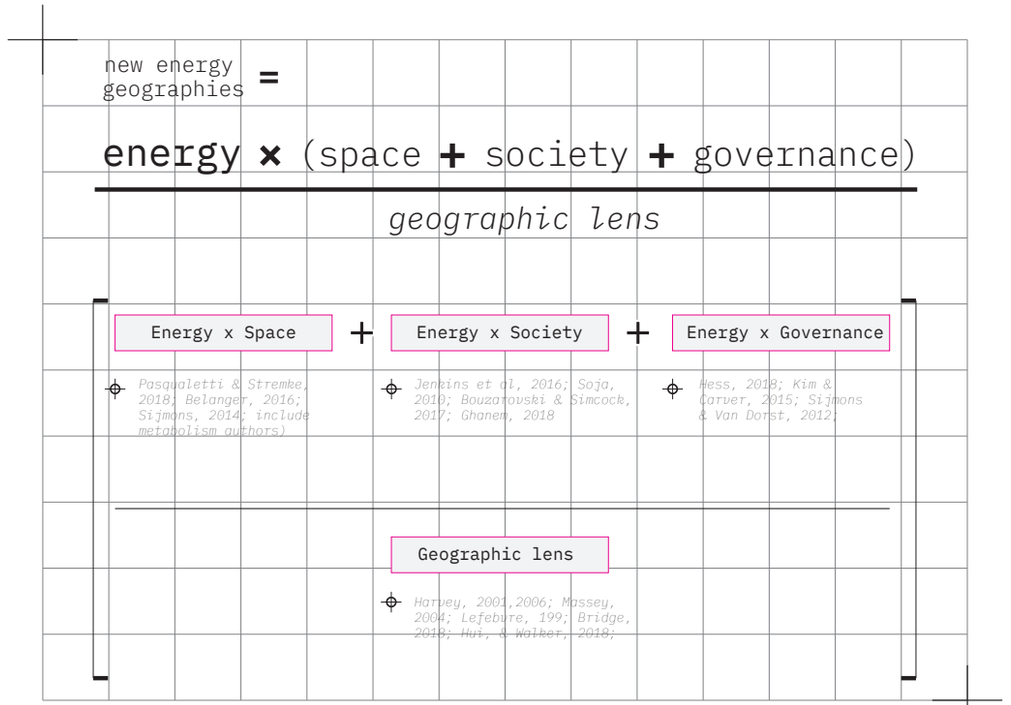
design in national and federal planning of energy development, to facilitate an adaptive, inclusive and collaborative energy transition in Tamil Nadu.With the articulation of the problem statement and the aim, the project presents the research question, which is ***'How can regional design of new geographies of energy create a framework for a 'humanised' energy transition in Tamil Nadu?'***. The use integrated, state-wide regional design (Balz, 2017; Balz & Zonneveld, 2015) as a planning tool to address emerging energy geographies is the main research enquiry of the project. The main research question is broken down into five sub research questions that each asks either a descriptive or prescriptive question (Fig 5.2). The descriptive questions guide the analysis, while the prescriptive question guide the design phase of the project. In other words, the sub-questions first try to understand the spatial and socio-political implications of energy transition, and then to propose methods and approaches to tackle them in the design of energy geographies.

To answer these research questions, ***an exploratory and predictive research approach*** is adopted to shed light on a subject that has had limited explorations in the past. This research approach is supplemented by the development of appropriate theoretical and analytical frameworks. These frameworks, elaborated in the following section, give a structure to the enquiry into the three branches of research identified.

5.3 The ‘How’ - Frameworks

The complex nature of relationships between energy, space, governance and society demands a new way of approaching this intersection that can address the complexities. The project proposes to adopt a geographic lens to approach the intersection of the three branches of research, to serve as the theoretical underpinning of the project. This approach to energy transition still in its nascent stages, and the geographic implications of energy transition are not yet defined or anticipated in academia and practice within the spatial planning paradigm. The project aims to contribute to bridging this knowledge gap in conceptualising **’energy geographies’** through the articulation of an appropriate conceptual framework and analytical framework to structure the analysis.

In other words, this section elaborates on the **’How’ component of the project**, as opposed to the ’What’ component elaborated in the previous section.



Conceptual framework.

The articulation of the three branches of research (space, governance and society) was the guiding principle in the creation of the conceptual framework (Fig 5.4) to explicitly tie them together. The conceptual framework ties the three branches of research by adopting a geographic lens to view them. Approaching energy transition as a ‘geographic process’, which reconfigures existing spatial patterns and scales of economic and social activity, gives a relational meaning to energy, space, governance and society. This relationship is expressed as an equation, where the three branches of research and the geographic lens are the variables of the equation. The conceptual framework posits that ***for the creation of new energy geographies, energy must be embedded in space and various socio-political relationships across geographic territories and scales.*** Understanding energy transition as a geographically-constituted process, rather than as a process that simply affects places, has a number of significant implications in all realms of life.

Each variable of the equation is substantiated by a normative theory that is the backbone of design ideology. The equation and the supporting theories inform the analytical framework, strategies and components of design, in later stages of the project.

Fig 5.4: Equation diagram showing the conceptual framework

5.4 Methods Used

Choosing the appropriate methods for research and design was a challenge, due to limited scholarly exploration in the intersection of energy studies and spatial planning. These methods are applied in different stages of the project, separately and together, often to investigate themes or topics that need multiple lines/ methods of enquiry (Fig 5.5). The project primarily utilizes **six methods** in the development of research and analysis of the context, which are listed below (in no particular order):

1. **Literature review**
2. **Documentary research**
3. **Field work**
4. **Transcalar mapping**
5. **Scenario Potential calculations**
6. **Stakeholder analysis**

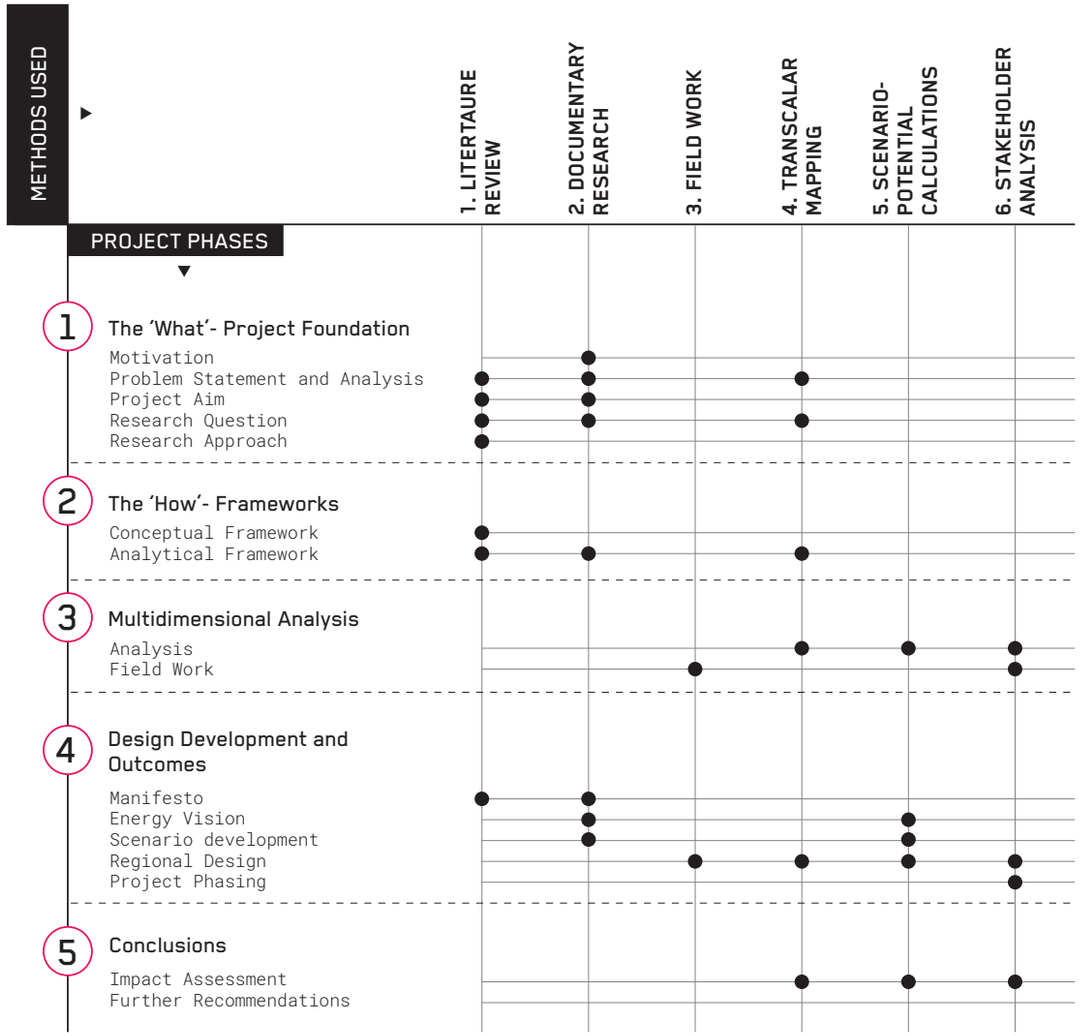


Fig 5.5: Diagram showing the methods for data collection and analysis used in the project and its area of application

At the start of the project, intuitive research from various sources like online websites, digital media and reports from global energy institutions provided the base for a broad, thematic understanding of 'energy space'. Additionally, first hand participation in energy projects of Posad Spatial Strategies (an urban design and spatial strategies studio, based in the Netherlands) and Generation.Energy (design studio specializing in spatial planning for energy transition), during the author's employment at the studio from April 2018-present, shaped the project's design methodology and approach.

The theoretical foundation of the project was developed from a careful assessment of literature precedents and ***literature reviews*** of key works in each branch of research. This was conducted in parallel to ***documentary research*** (governmental and non-governmental reports, publications, websites and newspapers) to understand the problem field of energy transition and its implications on space and socio-political structures, on three geopolitical scales- global, national and state of Tamil Nadu. The thematic knowledge gained from documentary research and theoretical understanding gained from literature reviews were supplemented by empirical knowledge gained from intensive ***field work*** spanning three weeks in the months of January-February 2019.

As described in earlier sections, the project's cardinal aim is to facilitate a 'humanised', socio-technical energy transition, by considering its spatial and socio-political implications. The purpose of the analysis phase of the project was to extract the contextual conditions that contribute to, or cause barriers to achieving this aim. A combination of several analytical methods like ***transcalar mapping*** across global, national and federal geopolitical scales, documentary research on the context, ***and stakeholder analysis*** to understand governance structures, and empirical field work was applied to understand the spatial and socio-political implications of energy transition in Tamil Nadu, India.

The inferences from the analysis (See Chapter 6) formed the preliminary parameters for formulating the future scenarios for spatial energy transition in Tamil Nadu. Scenario planning is a crucial step in design development for the project, for which the IESS 2047 (India Energy Security Scenarios, 2047), an energy scenario building webtool launched by the Planning Commission of India (now NITI Aayog) was taken as the base model for calculations. Using the assumptions, development models, projected energy targets of the IESS 2047, the project evolved three scenarios for Tamil Nadu's energy future.

In the following pages, the eight methods applied in research and analysis are elaborated in detail along with preliminary aim, process of applying the method and resulting outcomes. The next section elaborates how the inferences from the research and analysis phase of project lead to the development of design and its outcomes.

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1. Literature Review.

Aim: To develop a theoretical (deductive) and contextual (inductive) understanding of the three branches of research - 'energy-space', 'energy-governance' and 'energy-society', to develop the project foundations and conceptual framework, and to identify critical gaps in knowledge.

Keywords: energy transition, energy landscape, energy geography, energy justice, spatial justice, transition governance

Primary Databases: Science direct, JSTOR: Journal Storage, Taylor & Francis, SpringerLink and published books- Accessed through Google Scholar search engine

Process: A keyword search using the keywords and combination of keywords was conducted through Google Scholar search engine to access relevant databases (specified above). From the results obtained, specific peer-reviewed literature related to the three branches of research (energy-space, energy-governance and energy-society) were included in the review. Following this, a detailed review of selected academic work in each branch of research was made to gain theoretical and contextual understanding of spatial energy transition. To supplement this process, a keyword analysis was conducted on Google Ngram Viewer to identify the popularity of each keyword between 1900-2018 (Fig 5.6). In other words, the graph plots how many times a keyword has occurred in a corpus of books between 1900-2018. The keyword analysis was important in identifying the gaps in knowledge in three research branches. This method was important in developing the project foundations, conceptual and analytical frameworks, and in the development of the 'Manifesto for Design of Energy Geographies'.

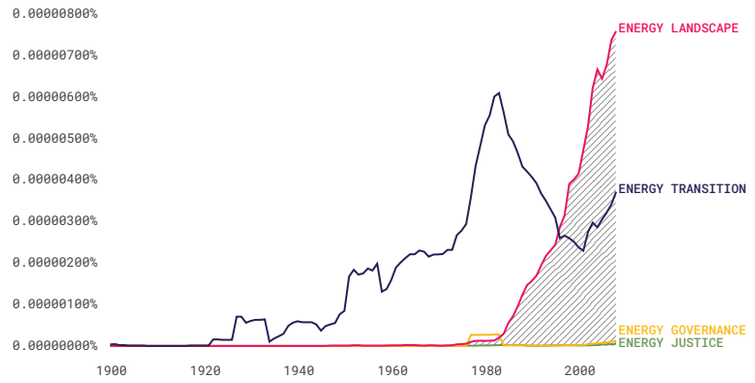


Fig 5.6: Results of the keyword analysis done using Google Ngram Viewer to identify the popularity of each keyword between 1900-2018.

2. Documentary Research.

Aim:

To collect quantitative data from external sources from government records and publications, global and national energy research institutions, websites, newspapers, and other media to gain an understanding of real-world conditions in the field of energy transition.

Primary Databases:

1. Reports and online data from global and national energy research institutions like IEA, REN21, BP, Enerdata, The World Bank and United Nations.
2. Government records, publications and online data from energy ministries of Govt. of India (Ministry of Power, Ministry of New and Renewable Energy (MNRE), Ministry of Coal, Ministry of Petroleum and Natural Gas and energy organizations of state government of Tamil Nadu (TNEB, TANGEDCO, TANTRANSCO, TEDA)
3. Forms of media like national newspapers, photographs, videos, films, etc.

Process:

The documentary research was part of the process to understand the global and context specific situation related to energy transition. The reports gave ***practical, quantitative insights*** on scope of energy transition, data related to energy production, consumption and trade, progress in renewable energy development and level of energy access. The energy ministries of Govt. of India, specifically the MNRE, have several ***online energy dashboards*** that provide live data on the energy production, distribution, shortages, national electrification status, various government schemes, initiatives, and policies. The India Energy Dashboard, an initiative of the NITI Aayog, was a comprehensive source for national and local energy data.

The social implications of energy extraction and use is a subject that is covered very little in mainstream literature or documents. Often intangible and hard to quantify, these social and phenomenological aspects sometimes ***find expression in art and culture***. One such medium is cinema, where several filmmakers in India have addressed the socio-politically sensitive energy issue. For example, the Tamil language movie 'Merku Thodarchi Malai' (Sethupathi & Bharathi, 2018), whose story revolved around the rampant land grabbing of agricultural land by private renewable energy energy companies, shed light on the illegal and unethical practices that occur even within the 'clean' energy paradigm (Fig 5.7)

IEA- International Energy Agency, BP- British Petroleum, NITI Aayog- National Institution for Transforming India.



Fig 5.7: Stills from the Tamil movie 'Merku Thodarchi Malai', on rampant land grabbing of agricultural land by energy companies. (Sethupathi & Bharathi, 2018)

3. Field work.

Aim: To conduct an empirical study on the context of study, i.e., Tamil Nadu to gain first-hand information on the status and potential for energy transition in the state, by using a combination of sub-methods.

Duration of fieldwork: January 21st 2019- February 10th 2019, at various locations in the state of Tamil Nadu.

Process: Fieldwork was conducted for a period of three weeks in Tamil Nadu, where interviews, surveys, extensive photographic and video documentation of potential sites was made (Fig 5.8), elaborated below:

a. Interviews: Interviews with the officials from the Tamil Nadu state department for energy (TNEB, TANGEDCO, TANTRANSCO, TEDA), and stakeholders in the nergy transition. These interviews provided valuable insights in the practical barriers to implementing policies and initiatives for energy transition.

c. Workshop: A presentation and workshop of the spatial implications of energy transition in Tamil Nadu was organised in collaboration with Archipress, a Chennai based design think-tank (Fig 5.9). The event was attended by 35 people, mostly from the design community, and the discussions were useful in identifying key challenges of energy transition.

c. Site observations: During the site visit, a notebook with all site observations on people-environment relationships, spatial conditions, etc was maintained for documentation.

d. Documentation: Throughout the duration of the field work, photographs and videos of interrelations between energy and space and society were taken to visually document the intersection.

Selected transcripts and notes can be found in the Appendix.

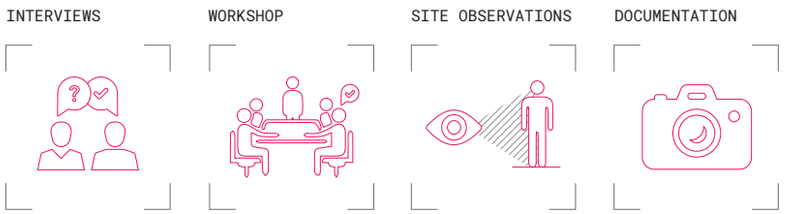
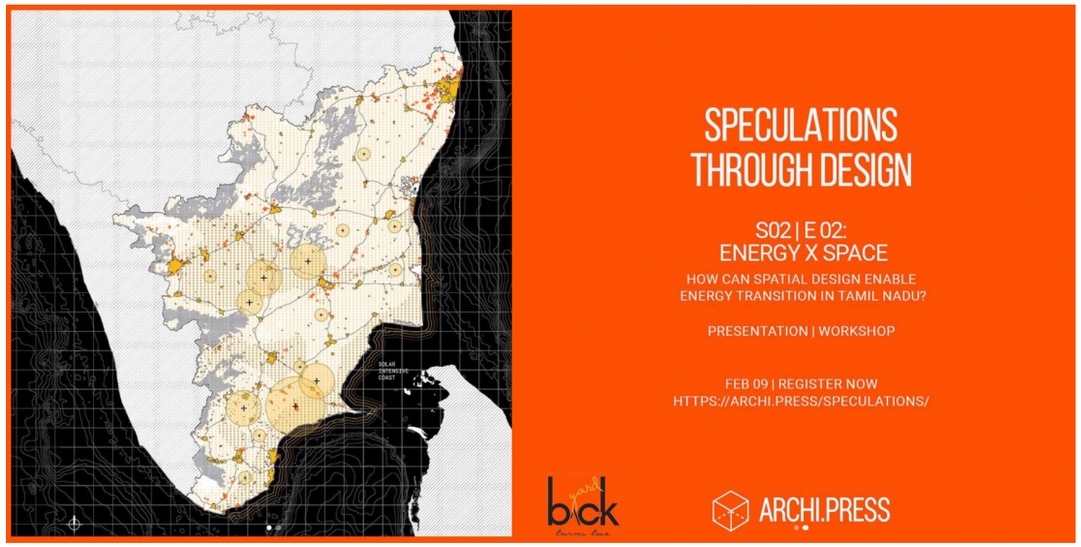


Fig 5.8: Types of fieldwork conducted in the project

Fig 5.9: Images from the workshop conducted in Chennai.

WORKSHOP ON SPATIAL DIMENSION OF ENERGY TRANSITION





4. Transcalar Mapping.

Aim: To gain a spatial understanding of the three branches of research (energy-space, energy-governance, and energy-society) through transcalar mapping of energy geographies across global, national and federal geopolitical scales.

Scales:: Global (XXL), National (XL), Macro-regional (L), Micro-regional (M), Local (S)

Process: The transcalar mapping was done in three stages of the project; this method is explained below based on its relevance in each project stage:

a. Problem analysis: Mapping of global, national and regional production of energy its consumption, trade deficits, renewable energy potentials, socio-economic and political dimensions of energy transition was important to understand the spatial implications of energy transition on various geo-political scales. The method of mapping gave key insights that contributed in framing the problem statement, aims, hypothesis and research questions of the project. This was also important in identifying critical energy hotspots, especially at the regional (L) scale, in Tamil Nadu.

b. Multidimensional Analysis: The mapping done at this stage of the project was part of the spatial analysis across Macro-regional (L), micro-regional (M) and local (S) scales. The subject (topics) of the mapping were derived from the analytical framework, elaborated in the previous section. These topics range across spatial, social and political dimensions of energy transition to understand the inter-relationships between them. The conclusions from the transcalar mapping gave insights on strength, weaknesses, opportunities and threats for emerging energy geographies in Tamil Nadu and parameters for design. The overlays of these maps were also used to select sites for design interventions and spatial strategies.

c. Design Scale: The mapping done in the design stage of the project was done to identify and evaluate the opportunities for design in regional (L), microregional (M), and local (S) scales. This was useful to locate the assemblage of design interventions in relation to each other.

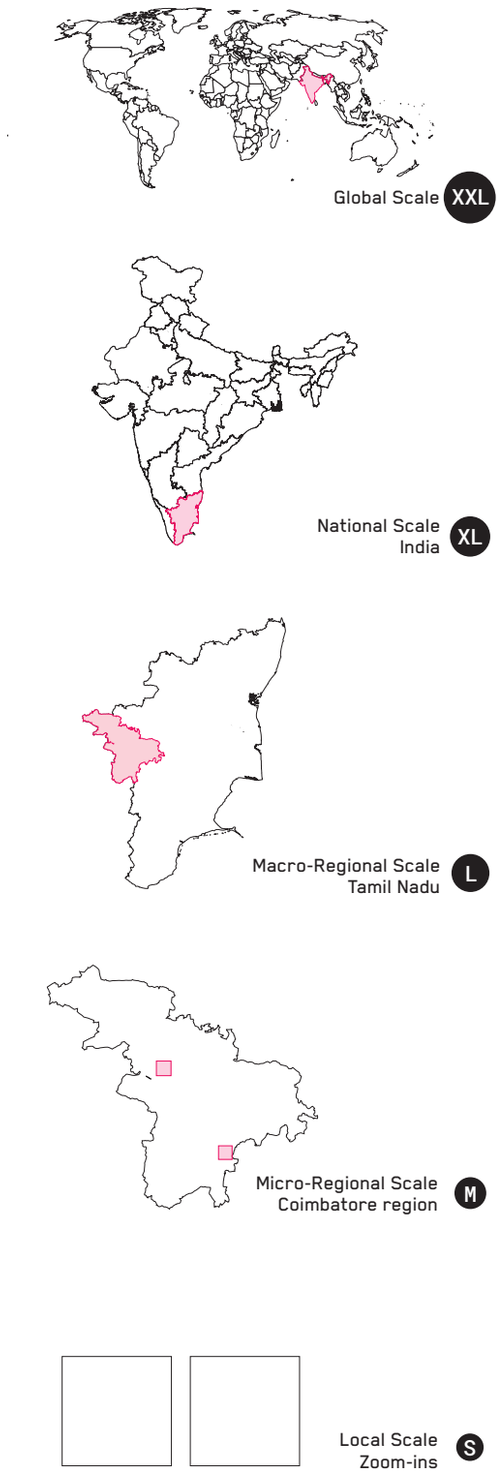


Fig 5.10: Diagram showing the structure of transcalar mapping method

5. Energy Scenario - Potential Calculations

Aim: To formulate a basis for calculation of project energy demand of Tamil Nadu, and create possible scenarios for spatial energy transition that can meet this demand.

Process: The scenario planning method is used as a tool to imagine different possibilities for Tamil Nadu's energy future and then develop regional design strategies to address these possibilities. This strategic planning method is especially relevant in creating flexible long-term plans, as in the case of energy transition. The first step in creating the scenarios was to set the time frame for development of the scenario. Here, the energy scenarios are projected for the year 2050.

Following this, the projected energy demand for Tamil Nadu in the year 2050 was calculated using two energy scenario models. The first model is the ***IESS 2047 (India Energy Security Scenarios 2047)***, an energy scenario building webtool launched by the Planning Commission of India (now NITI Aayog). In this webtool, based on the assumed economic growth of the country and chosen energy pathway (fossil fuel based or renewable energy based), the energy demand (target) for 2050 is calculated. Apart from the energy target for India, the energy mix and space required to meet the target can also be obtained.

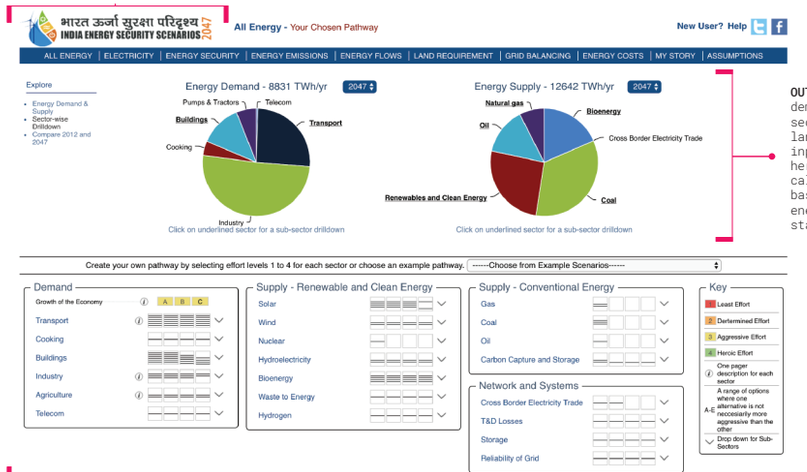
The second model used is the online R.E scenario building tool developed by ***'Greening the Grid'***, a platform for the development of R.E in developing countries. Implemented by the NREL (National Renewable Energy Laboratory, U.S Department of Energy, this platform allows users to calculate the renewable energy potential or every state in India, the energy mix that can generate this potential, day-night energy flow balances and territorial energy flows across states at different times of the year. The results from the scenario development within the two online models were used to identify Tamil Nadu's ***energy demand in 2050, energy mix needed to achieve it and the estimated renewable energy potential of the state***. The energy target for Tamil Nadu in 2050 was fixed at 300,000GW (Refer Chapter 7)

The next question is, what are the possible scenarios or pathways through which this energy target be achieved? To answer this, the two key

Fig 5.11: Digram showing how the two energy calculation models work (IESS 2047, 2018; Greening the Grid, 2018)

MODEL 1

OUTPUTS: All-India energy potential and land requirement



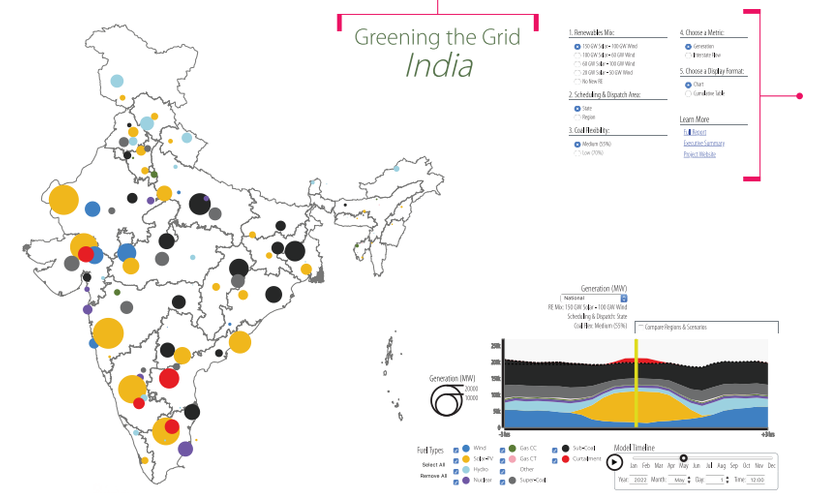
OUTPUT: The outputs (Energy demand, supply, energy security, emissions and flows, land requirement, etc) of the input scenario is generated here. This all-India energy calculation is then used as a base for calculating the energy outputs for Tamil Nadu state.

INPUT: Variables like the rate of sectoral growth of the economy, energy mix and status of infrastructure are choosen from the available options, to generate output energy calculations.

MODEL 2

OUTPUTS: State-wise energy potential and flows

Greening the Grid is a platform for the development of R.E in developing countries, implemented by NREL, United States Department of Energy. Their online scenario building tool is the second model used in this project.



INPUT: The target R.E mix for India and the degree of relience on coal are input as variables to calculate statewise R.E potential.

OUTPUT: The energy mix at various times of the day, grid balancing with R.E, statewise potential R.E output, interborder energy flows are generated for the input scenario

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determinants of energy pathways- ***energy mix (fossil fuel or renewables) and model of organization (centralized or decentralized)***- were identified. The combination of the two determinants (Fig 5.12) gave rise to two polar scenarios- ***centralized-non-renewables*** (Scenario 1) and ***decentralized-renewables*** (Scenario 2). These two polar scenarios represent the negative and positive extremes possible, respectively. A third ***'optimum renewables'*** scenario (Scenario 3) was developed as a middle ground between the two extremes that combines the strength of Scenario 1 (energy security) and Scenario 2 (clean energy).

The scenarios were further defined based on nine parameters, which were used to compare and evaluate the scenarios. The parameters are resource based (energy mix from fossil fuel to renewables), spatial (spatial organization from centralized to decentralized, land requirement from low to high, landuse from monofunctional to multifunctional, ecological impacts from low to high, and degree of spatial permanence from low to high), political (governance model from top-down to bottom-up), social (range of societal changes from low to high), economic (model of energy production from extractivist to co-productive). These parameters are used as the base to determine the opportunities and threats to each scenario and the multidimensional factors that need to be considered while planning for the preferred scenario (Scenario 3).

Outcomes: The spatial implications of the preferred scenario is visualized through maps and impressions that imagine that possible futures. The conditions for the realization for the preferred scenario for energy transition in Tamil Nadu provide a normative direction for the project in its design stage. The preferred energy scenario, combined with guidelines for design prescribed in the 'Manifesto for the Design of Energy Geographies' gave rise to the 'Energy Vision for Tamil Nadu 2050' (Refer Section 5.5).

Fig 5.12: Diagram showing the process of scenario development.

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ENERGY SCENARIO POTENTIAL CALCULATIONS.

Defining the energy target

MODEL 1
IESS 2047

+

MODEL 2
Greening the Grid

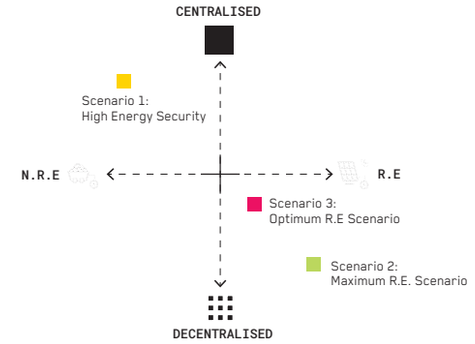
=

300000 GWh
energy target

Research question

What are the possible scenarios or pathways through which this energy target be achieved?

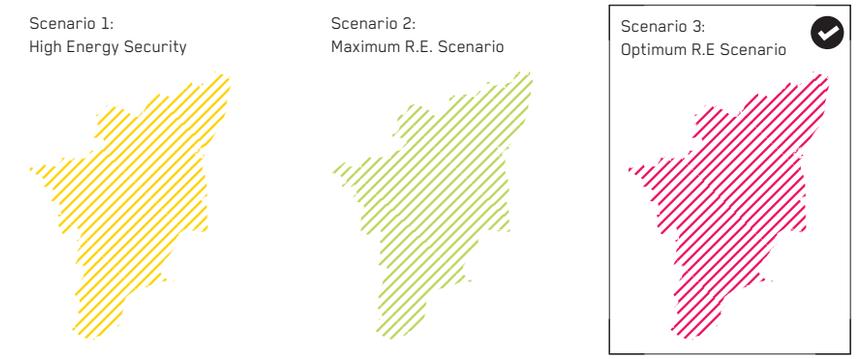
Determinants of the scenarios



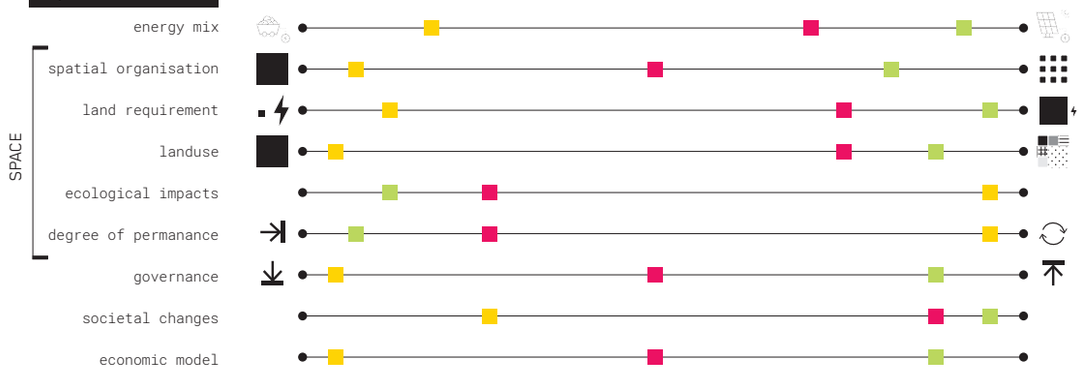
Two key determinants of energy pathways- energy mix (fossil fuel or renewables) and model of organization (centralized or decentralized)- were identified.

The combination of the two determinants gave rise to two polar scenarios- centralized-non-renewables (Scenario 1) and decentralized-renewables (Scenario 2). A third 'optimum renewables' scenario (Scenario 3) was developed as a middle ground between the two extremes that combines the strength of Scenario 1 (energy security) and Scenario 2 (clean energy).

Selecting the prefered scenario



Parameters for impact assessment



6. Stakeholder Analysis

Aim: To create alternative strategies and tactics for engaging various actors and stakeholders in energy transition by mapping their power and interests, common grounds, shared fundamental values and points of conflict or collaboration.

Process: The stakeholder analysis is a form of actor analysis where the various actors and actor configurations in energy transition are mapped to identify the best combination of connections between stakeholders that can maximize their cooperative potential and minimize threats of obstruction. First an inventory of actors and stakeholders was made to determine their interest, objectives, and the resources they bring to the table. Then the formal and informal relations and interdependencies between actors was reconstructed using an actor network diagram and power-interest matrix. This step was also used ***'to identify coalitions and alliances that need to be established, encouraged or discouraged'*** (Koppenjan, 1993), in design of future energy geographies in Tamil Nadu.

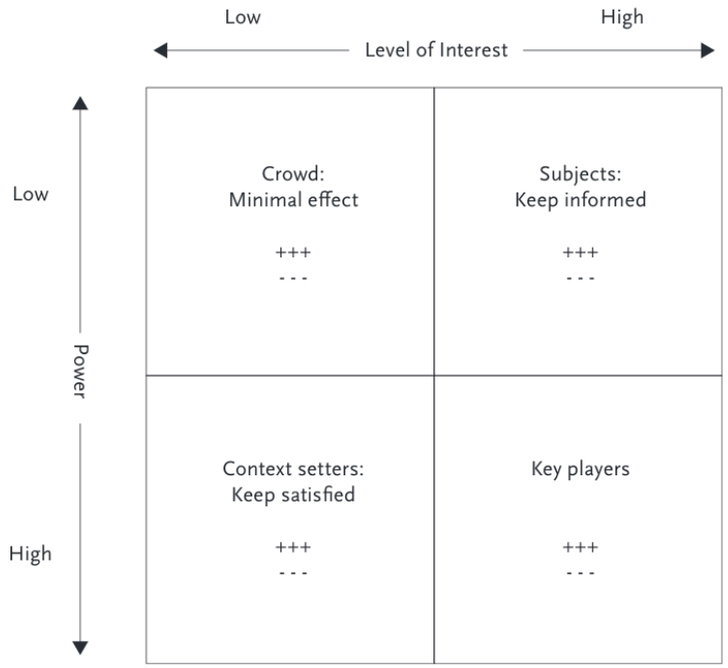
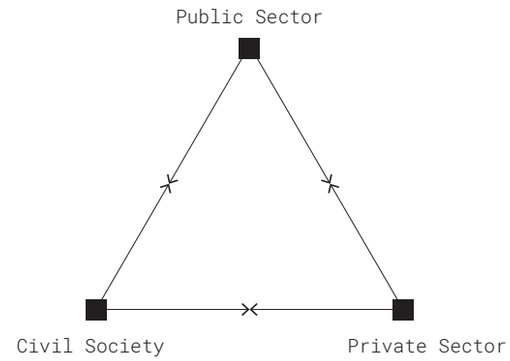


Fig 5.13: Diagram showing the method for analysing the interests of the stakeholders involved in energy transition in Tamil Nadu, India

The Rule of Law- General
Stakeholder groups



The Rule of Law- Tamil Nadu
Primary Stakeholder groups in the project

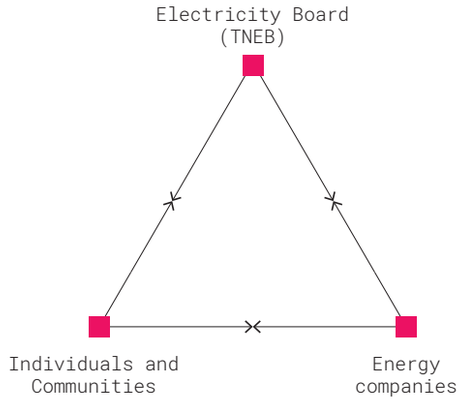


Fig 5.14: Diagram showing the stakeholders involved in energy transition in Tamil Nadu, India

5.5 Design Development and Outcomes

The project proposes a **five-step design process** to facilitate a spatial energy transition in Tamil Nadu. (Fig 5.15)

1. **Manifesto for the Design of Energy Geographies**
2. **Scenarios Planning and development**
3. **Energy Vision for Tamil Nadu 2050**
4. **Regional Design for Energy Transition**
5. **Project Phasing**

The design phase begins with a declaration- a **Manifesto for the Design of Energy Geographies** that defines what 'good' energy geographies should be like and acts as the theoretical underpinning of the design process. The manifesto is a call for an integrated geographic approach to energy production and consumption, within the paradigm of energy transition. It is an assertion of what energy geographies ought to be and what qualities they should have, which can act

Fig 5.15: Diagram showing the seven-step design process

DESIGN DEVELOPMENT AND OUTCOMES

1 Manifesto for Design of Energy Geographies

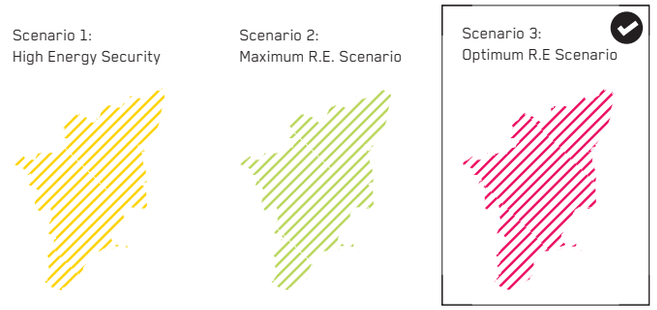
2 Scenario Planning and Development

3 Energy Vision for Tamil nadu 2050

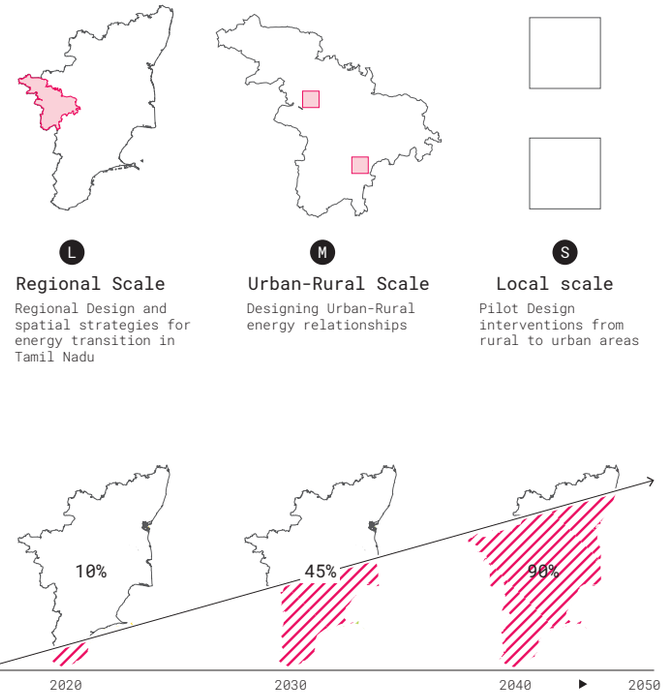
4 Regional Design for Energy Transition

5 Project Phasing

The 'Manifesto for Design of Energy Geographies' is a declaration of intention to consider the spatial dimension in energy development, and integrate the disciplines of energy studies and spatial planning. It is an assertion of what energy geographies ought to be and what qualities they should have. The 11 points of the Manifesto will be the principles and guidelines for the design of emerging energy geographies of the future.



Manifesto + Scenario
=
Energy Vision for Tamil nadu 2050



as principles and guidelines for the design of energy geographies. This was developed by collating ideas and spatial concepts from various theories in spatial planning, infrastructure management, political ecology, critical geography and energy studies. Thus, the manifesto is essentially an aggregation of concepts, intentions and arguments to provide a theoretical normative direction for the project.

Informed by this theoretical standpoint, the conclusions from the multidimensional analysis are taken forward to develop ***energy scenarios*** for Tamil Nadu in the year 2050. The scenarios re-imagine different possibilities for the state's energy future, and the spatial impact of each scenario is mapped and analysed. This step is crucial, especially in an infrastructure development project like energy transition, to create flexible, long term plans. The spatial implications of the preferred scenario is visualized through maps and impressions that imagine that possible futures. The conditions for the realization for the preferred scenario for energy transition in Tamil Nadu provide a contextual normative direction for the project in its design stage.

The contextual insights from this stage, combined with the principles of the manifesto lead to the creation of an ***Energy Vision for Tamil Nadu 2050.*** The vision projects a spatial energy transition in Tamil Nadu, where emerging energy geographies are resilient, sustainable and equitable. These energy geographies will tap the potential of decentralised renewable energy sources to enhance the quality of energy access in the state. To achieve this vision, the project evolved a set of spatial strategies, societal and political actions that translate the goal of the vision into tangible codes for development. The set of strategies together form the Strategic Plan for energy transition in Tamil Nadu. The implications of the spatial strategies and macro-regional strategic plan is then tested on the micro-region and strategic zoom-ins at the local scale. The assemblage of design interventions together create the conditions for a humanized energy transition in Tamil Nadu. Finally, detailed pathways for phase wise development of the project and indicators for ***impact assessment*** are created to measure the impacts of the regional design.

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COMPONENTS OF THE REGIONAL DESIGN.

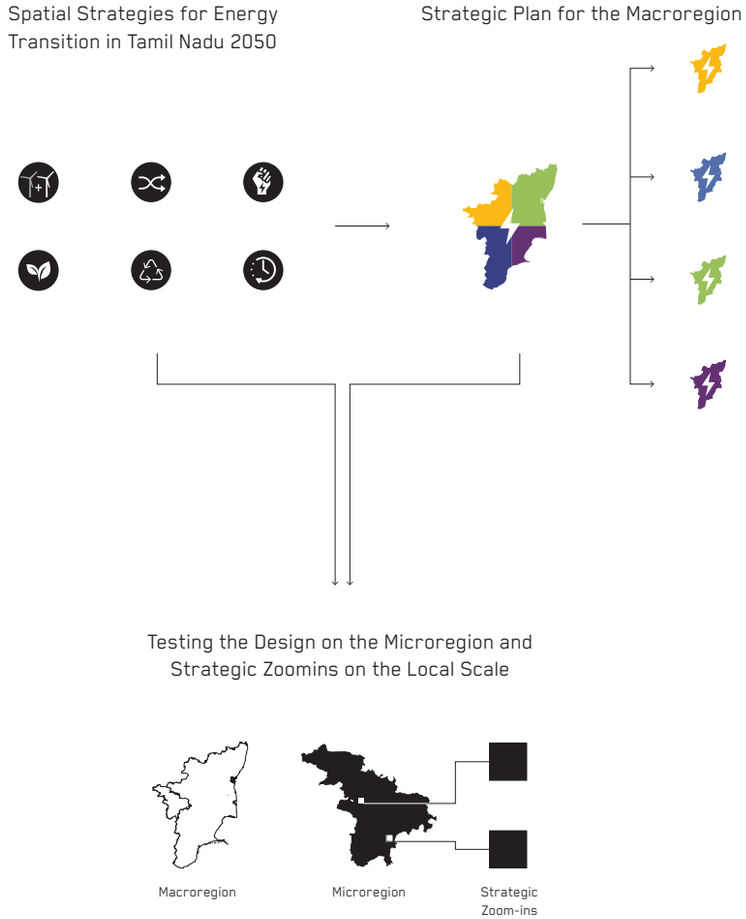


Fig 5.16: Diagram showing the components of the regional design and scales of application.

5.6 Conclusions

The idea of looking at energy transition as a geographical process requires a reconfiguration of (Bridge et.al, 2012) current social, cultural, economic and technocratic processes. It requires the development of new ways of producing, living and working with energy. This challenge is intensified in a developing context like Tamil Nadu, where exploration in the field of energy and space is limited, to say the least. The gaps in theoretical and contextual knowledge on spatial energy transition necessitated the development of a research and design methodology that is **tuned to the challenges faced by this project.** This chapter presented the overall research framework, which is the fundamental core of the project, and provided a comprehensive account of the research and design methodology, and methods used for data collection and analysis. The phase-wise development of the project with respect to the evaluation periods is illustrated in Fig 5.17. The following pages will elaborate on the limitations of the project, and aspects of energy transition that fall outside the scope of the project. Furthermore, the scientific and societal relevance of the project and its methodology is also highlighted, to position the project's contribution. The chapter concludes with the ethical considerations of the project, especially in the discussion on equality and justice. The political sensitivity of the topic of energy transition is also notable, since the interests of powerful individuals and energy companies greatly influence national and global energy outlooks.

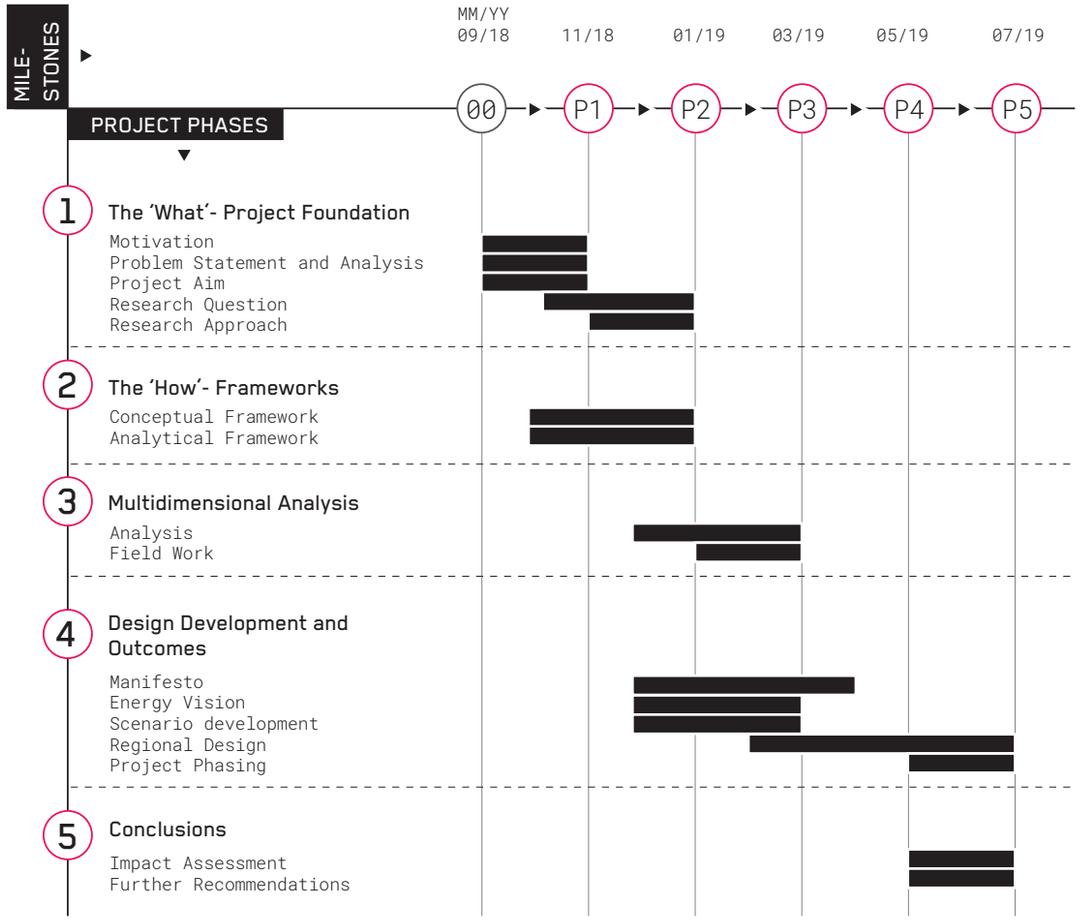


Fig 5.17: Diagram showing the timeline of the graduation project

Limitations.

1. Energy, which is generated from various sources (non-renewable and renewable), takes the form of usable electricity, heat and raw fuels to power various aspects of life. This project limits its focus to 'electricity' and its sources, within the energy transition paradigm.

2. As elaborated in previous chapters, energy transition has multidimensional impacts on space, society, politics, economy. Here, the project limits its focus to studying the spatial and socio-political implications of energy transition in alignment with the main aim of the project, which is to facilitate a humanised socio-technical transition.

3. Energy justice is intrinsically tied to the idea of spatial justice (Bouzarovski & Simcock, 2017), a concept that emphasises the geographic dimensions of inequality and inequity (Soja, 2010; Yenneti et al., 2016). Equitable access to energy, thus, is not just a socio-economic or political issue but has a spatial dimension. Here, it is important to note that the physical boundaries and problems that delineate locations of energy poor communities have evolved due to years of negligence and systemic inequality in all socio-spatial fields. Energy poverty is ***only one of the many*** social issues faced by the energy poor. Faced with this reality, it is crucial to acknowledge that the outcome of this project can create conditions for equitable energy access to exist, but the systemic inequality in other fields falls outside the scope of this project.

Scientific and societal relevance.

This project will add to the body of knowledge on spatial energy transition, and the proposed geographic approach has the potential to bridge the gap between energy studies and spatial planning. Although notable literature has emerged in the field of energy geographies in the past decade, the research is predominantly limited to European or North American contexts. Moreover, the current literature on energy studies in Tamil Nadu limits itself to descriptive studies on energy status and energy potential calculations; and shies away from delving deeper into the spatial consequences of energy transition and its impacts on the socio-political economy. This project on spatial energy transition in Tamil Nadu, will thus ***contribute both to the theoretical knowledge gap and context-specific knowledge gap*** in this field.

Moreover, the Dutch approach to spatial energy transitiont can have world-wide applications, if adapted to the local context. The potential ***transferability of the concepts, research methodology and design process*** for use in developing countries that face the challenge of spatial energy transition highlights the scientific and societal relevance of the project.

Additionally, the contribution of energy transition to the ***UN Sustainability Development Goals (UN SDGs)*** is an important marker of the societal relevance of this project (Fig 5.18). The strong focus of the project on socio-political relationships with energy and the notion of spatial energy justice is an asset to furthering the debate and discussion on 'equality' in society.



Fig 5.18: Relevance of the project with UNSDG7 (UN, 2018)

Ethical considerations.

Energy transition, but at what cost?

Energy is a politically sensitive topic. Like all infrastructure projects, energy transition too comes at the cost of sacrificing the interests of certain communities who are 'in the way' of the realizing development, in the name of the 'greater good'. The concept of 'energy justice' (Jenkins et al, 2016) directly ties the techno-dominant field of energy transition with the social vulnerabilities of marginalized communities. Specifically, in the context of Tamil Nadu, energy transition may affect these communities in two ways- firstly, the lack of access to the renewable sources of energy, whose benefits filter down only to privileged social groups, and secondly, the ecological side effects and pollution caused by investment and development of fossil fuels in the region.

For example, the development of the Kudankulam Nuclear power plant in Tamil Nadu has spawned social unrests and protests against the displacement of marginalized fishing communities who have traditionally lived there. The dangers of living close to the nuclear power plant is compounded by the resentment that the electricity generated doesn't benefit the local communities that live with the risks, but is diverted for the use of the industrial sector of the state. Another example to illustrate the burden of energy transition on communities without voice or means of dissent, is the illegal practice of land grabbing by private renewable energy companies that arm-twist farmers to sell agricultural land for the development of wind or solar farms (Sethupathi & Bhrathi, 2018).

Faced with the legal system that gives room for enforced inequality in energy access, ***what then, is the role of the planner/ designer in contributing to energy justice,*** in the drive to achieve transition? Can a regional energy design overcome political measures designed to prioritise the lives of certain communities over others?

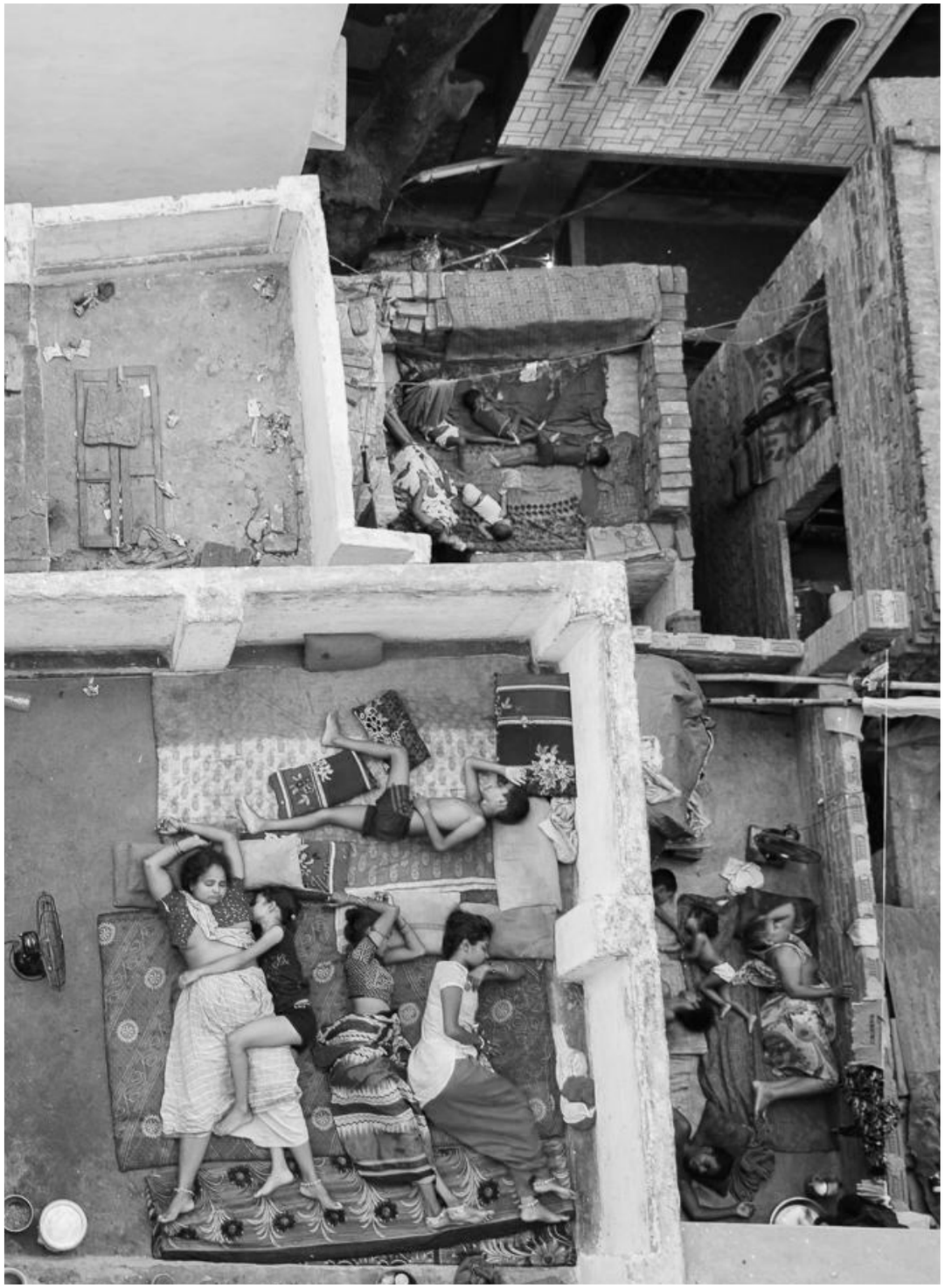


Fig 5.19: Rooftop Dreams. (People sleeping on the rooftop in summer due to lack of air conditioning in their homes) (Mund, 2015)

6

Multidimensional Analysis

Overview:

This chapter presents in detail multidimensional anlysis, based on the problem focuses identified through the problem analysis. The emerging renewable energy production landscapes and resulting spatial typologies are elaborated, along with an evaluation of energy potential, spatial suitability and social vulnerability, across three geographic scales: the macro-region (Tamil Nadu), the micro-region (Coimabtore region) and two strategic zoomins (urban and rural).

Sections:

6.1. Introduction
6.2. The Productive Landscape
6.3. Mapping Potentials and Vulnerabilities
6.4. The Microregion
6.5. Strategic Zoom-ins
6.6. Stakeholder analysis

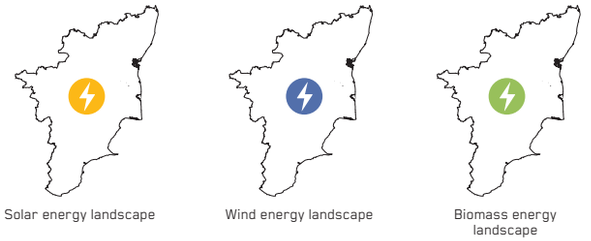
6.1 Introduction

The project aim to illustrate the scope and application of regional design in energy planning to facilitate just energy transition is considered the base for crafting a methodology for detauiled analysis. First, the 'productive landscape', i.e. the energy production landscapes of Tamil Nadu are mapped to identify territorial variations in **energy potential, spatial suitability** (landuse) for energy development and concentrations of **social vulnerability**. Based on these criterias, a methodology for grading spatial units is created to find critical areas of intersection between them. The analysis is repeated across the micro-region, and strategic zoom-ins chosen for detailed study. The chapter concludes with the analysis of the **actors and stakeholders** involved in Tamil Nadu's energy transtion. The inferences and knowledge gained from the multidimensional analysis provide valuble insights for design, specifically related to space, society and governance.

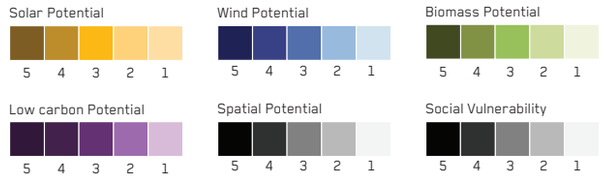
Fig 6.1: Diagram showing the various components of the multidimensional analysis

SECTIONS OF THE ANALYSIS - BASIS FOR DESIGN DEVELOPMENT

Mapping the 'Productive Landscape'- Section 6.2.



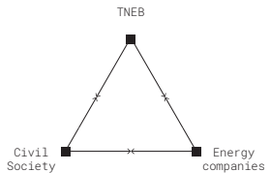
Potentials vs Vulnerability- Multi-criteria analysis'- Section 6.3.



Analysis of the Microregion and Strategic Zoomins'- Section 6.6, 6.5.



Staekholder analysis '- Section 6.6.



6.2 The ‘Productive Landscape’

This section maps the various energy production landscapes in Tamil Nadu based the energy source: **solar energy, wind energy, biomass energy and carbon-based (conventional) energy.** The spatial distribution, morphological differentiation, spatial typologies, conflicts and opportunities for each type of energy are presented. The spatial analysis of energy infrastructure gave key insights on **energy dense regions, territorial interdependencies, and future trajectories of development** planned by the state. Following this, the regional spatial distribution of energy development is compared with the landuse of the region to evaluate the suitability of space for development. Apart from mapping existing energy production landscapes and landuse of the macro-region, concentrations of social vulnerability, and by extension, energy vulnerability are mapped. The knowledge gained in this section forms the base for the multi-criteria analysis presented in Section 6.3.

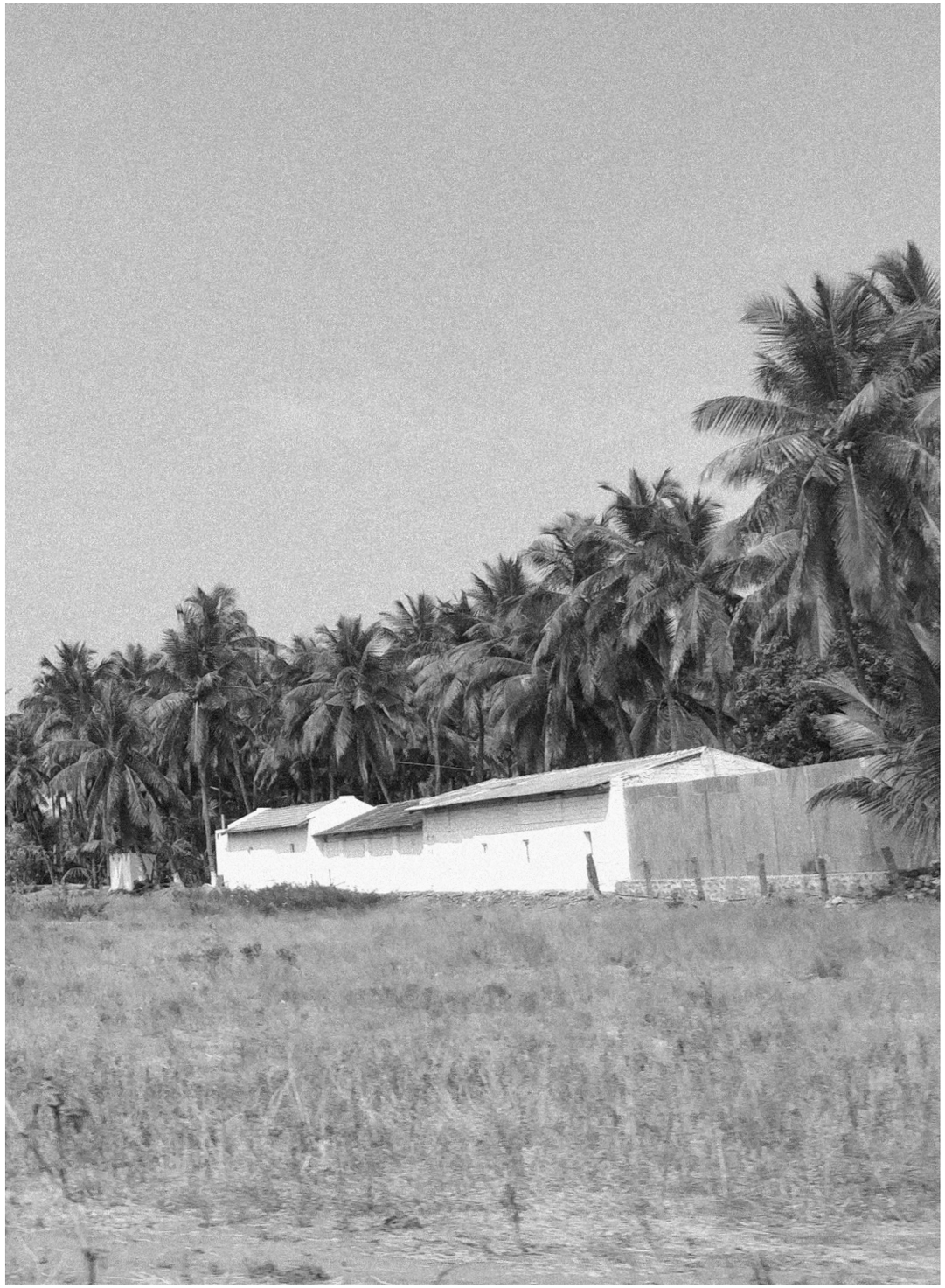


Fig 6.1: Photograph showing the critical areas of landuse transformation for energy development in Tamil Nadu.

Solar Energy Landscapes.

With over 300 days of sunny skies per year, Tamil Nadu has one of the highest solar energy potentials in the country. Solar energy is developing fast, supported by government incentives for commercial and non-commercial installation of solar energy infrastructure. The Adani power plant set up in Kamuthi in Southwestern Tamil Nadu, with an installed capacity of 648MW is the 2nd largest single site power plant in the country. The National Solar City mission as part of the Smart Cities programme and the state level Solar Energy Policy have accelerated the development of solar energy plants and off grid PV panel installations. The following pages outline the solar energy sector in the state of Tamil Nadu and the spatial distribution of solar energy typologies.

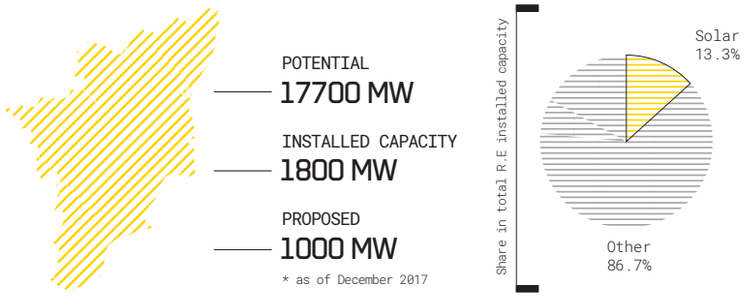




Fig 6.2: Solar energy statistics (TEDA, 2018)

Fig 6.3: Solar PV installation on industrial rooftops, Chennai. (TEDA, 2018)

Fig 6.4: Solar energy landscapes in Tamil Nadu (Google Earth Satellite images)

11.1271° N, 78.6569° E



Spatial Typologies and Distribution.

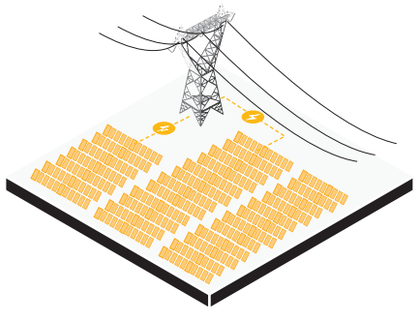
1. Solar Farms- Large Scale

Single site, on-ground solar power plants with capacity of over 1MW fall under this category. Tamil Nadu has one of the largest single site solar power plants in the world at Kamuthi with a capacity of 648MW. The electricity output from the solar power plant is converted and fed into the regional grid. The state has plans to add more than 3000MW of solar energy by setting up large scale farms, mostly in land that is currently used for agriculture.

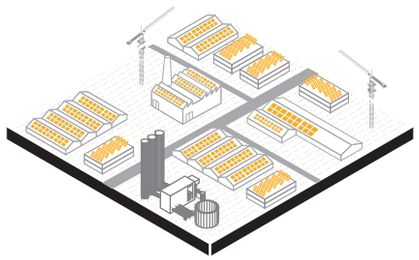
2. Solar Rooftops- Large and Small scale

Large and small scale rooftop solar PV installations in urban areas on roofs of houses, apartments and small offices fall under this category. These off grid installations partially or fully meet the energy requirement of the house based on the roof space available. In Tamil Nadu, policies and subsidies to increase the adoption of solar PV panels is slowly bearing fruit. Since most roofs in urban areas are flat, there is immense potential for the development of rooftop solar energy production through the involvement of individuals and communities.

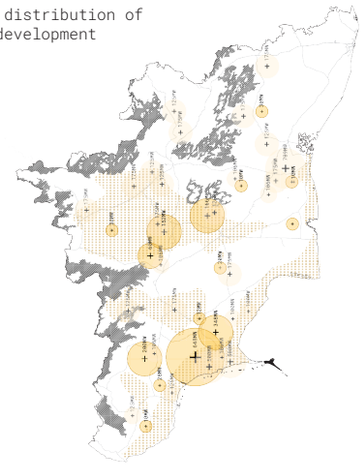
Morphology of energy infrastructure



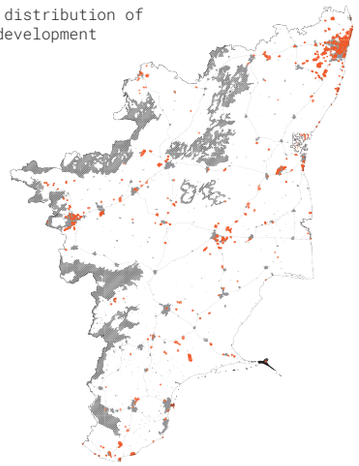
Morphology of energy infrastructure



Spatial distribution of energy development



Spatial distribution of energy development



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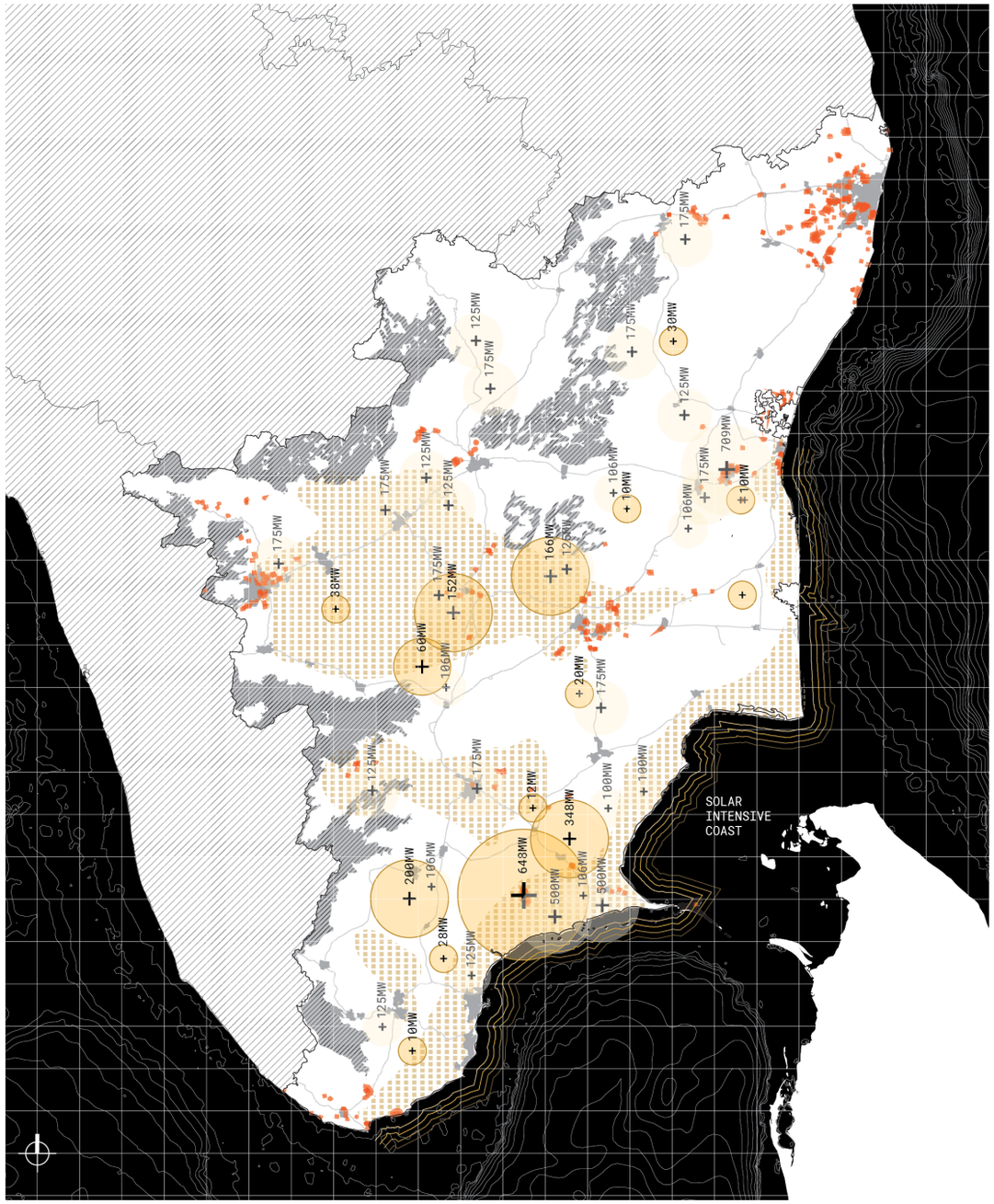
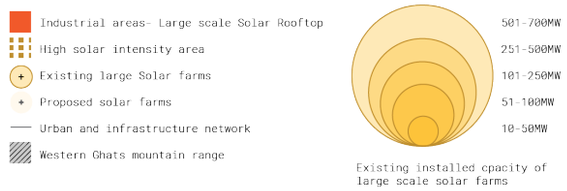


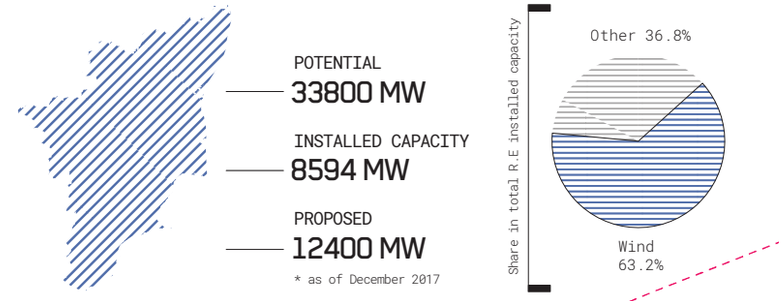
Fig 6.5: (left) Diagrams showing the morphology and spatial distribution of solar energy typologies

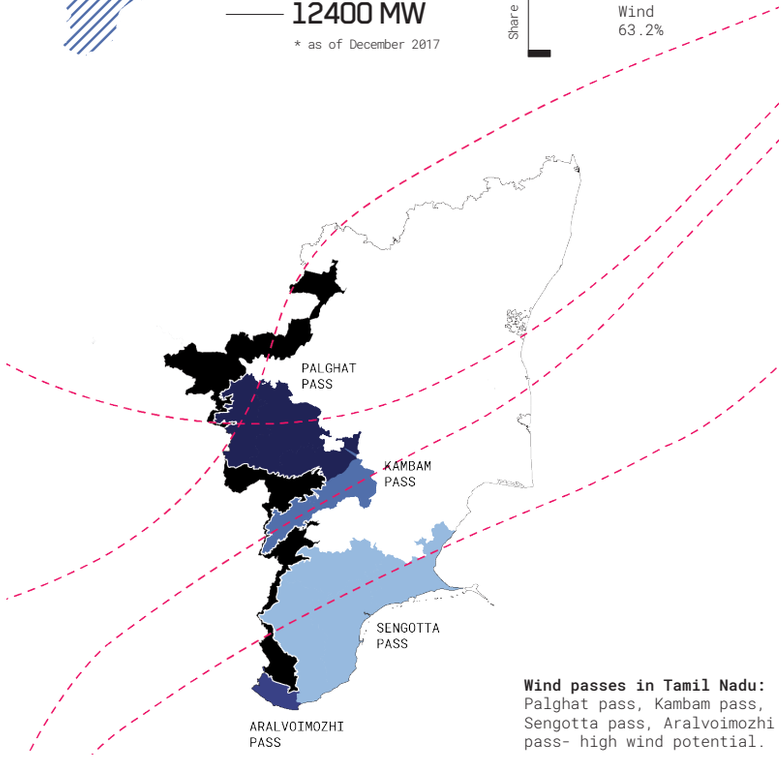
Fig 6.6: (right) Spatial distribution of solar energy typologies



Wind Energy Landscapes.

Tamil Nadu leads India's wind energy sector with over 8594MW (Fig 6.7) of installed wind energy capacity. Tamil Nadu's four prominent wind passes (Palghat pass, Kambam pass, Sengotta pass, Aralvoimozhi pass) have high wind energy potential, due to the tunneling effect during South West Monsoon (Fig 6.8). The wind passes occur in the breaks between the Western Ghats mountain ranges that bound the western edge of the state. The availability of rich wind energy resources for more than 10 months in a year, a wide gap between power demand and supply during the industrialisation drive of the 1980s, and incentivised government policies helped Tamil Nadu develop its wind energy sector. Now, with most of the energy infrastructure at the end of life stagee, the state is at an important crossroad to reassess its wind energy future and plan energy development in areas that are still largely untapped, like the Palghat and Kamban wind pass areas.





Wind passes in Tamil Nadu:
Palghat pass, Kambam pass, Sengotta pass, Aralvoimozhi pass- high wind potential.

Fig 6.7: Wind energy statistics (TEDA, 2018)

Fig 6.8: Wind passes in Tamil Nadu (TEDA, 2018)

11.1271° N, 78.6569° E
11.1271° N, 78.6569° E
11.1271° N, 78.6569° E
11.1271° N, 78.6569° E



Spatial Typologies and Distribution.

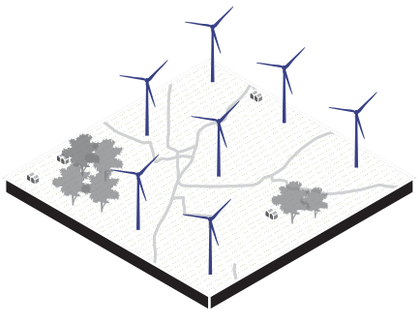
1. Wind Farms- Large Scale

Most of Tamil Nadu's wind energy development is owned by the private sector, in the form of large wind farms spread over rural farmlands in the wind pass regions in the South West. Large scale wind farms like the Muppandal wind farm with a capacity of 1500MW are located in the Aralvoimozhi pass. The textile industry alone owns over 3000MW of wind farms (40% of total capacity). However, with the first wind farm set up in 1986, energy infrastructure is over 25 years old and at their end-of-life stage.

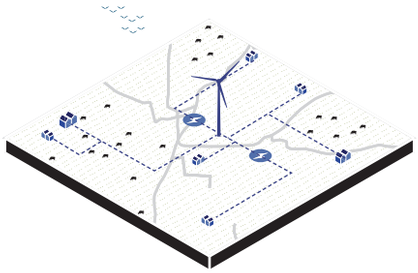
2.Wind Installation- Small Scale

Certain small and large industries have set up their small wind installations and turbines to support their industrial activity. There is also huge potential to establish small, off-grid wind installations in urban areas and public buildings that can mitigate the huge energy demand in developing urban centres. In addition to this, local small wind turbines in every village can sustain agriculture and the energy requirements of the rural settlement.

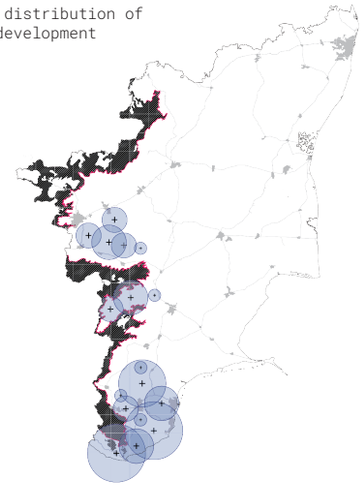
Morphology of energy infrastructure



Morphology of energy infrastructure



Spatial distribution of energy development



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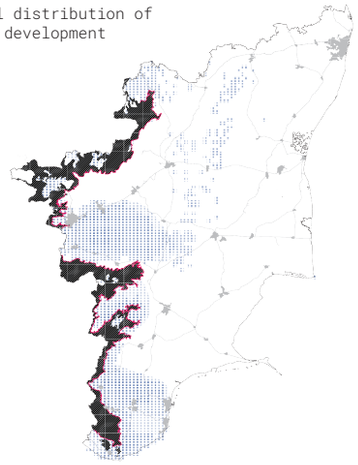

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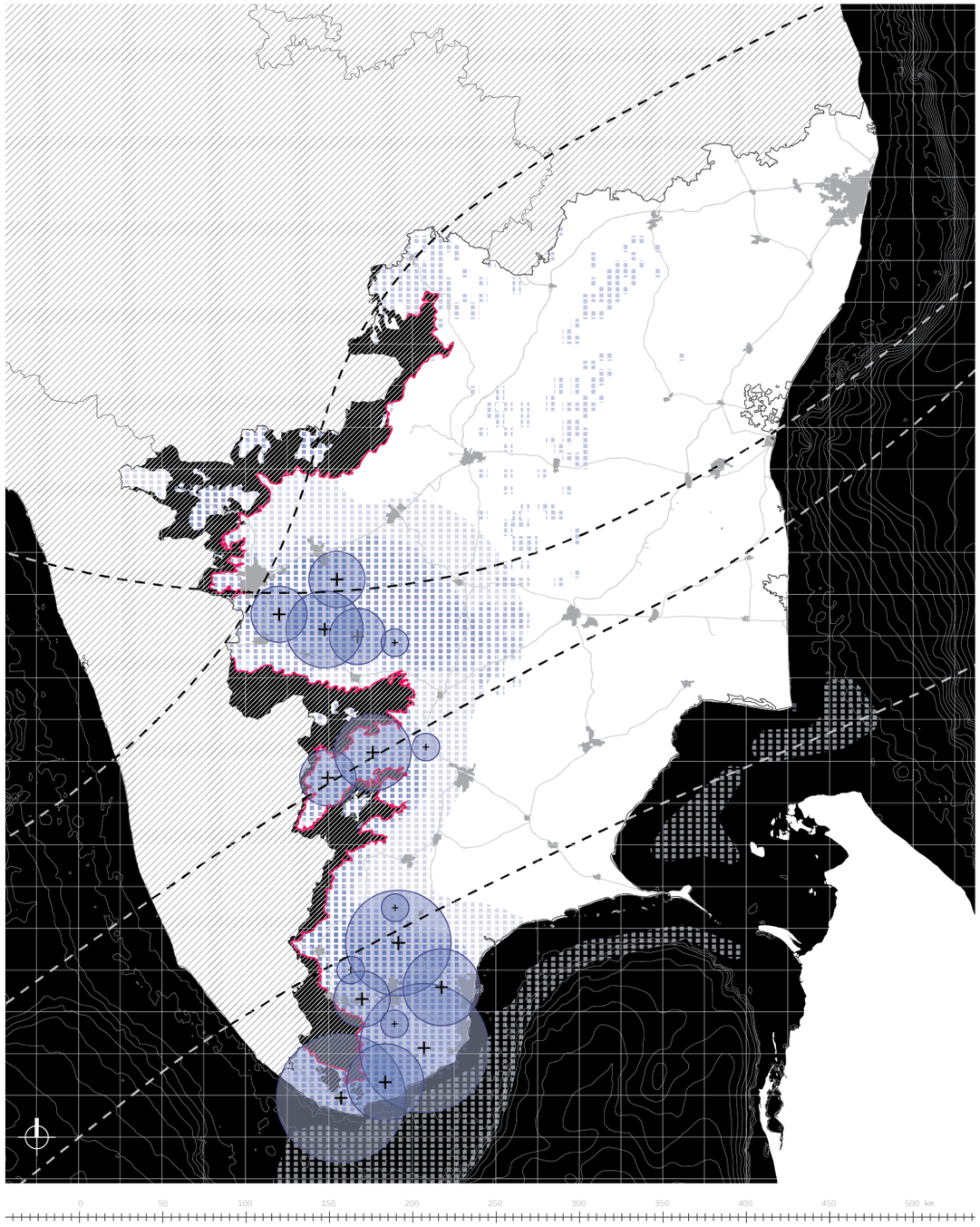


Fig 6.9: (left) Diagrams showing the morphology and spatial distribution of wind energy typologies

Fig 6.10: (right) Spatial distribution of wind energy typologies

Biomass Energy Landscapes.

Tradition sources of biomass for cooking accounts for nearly 75% of rural energy needs, which itself constitutes 70% of the total population of India. Apart from this, modern forms of bio-energy which involves thermal processing of the residue from agricultural crops and forests by-products to generate electricity. Tamil Nadu has over 340MW installed capacity of biomass power plants and cogeneration plants that convert field based and process based agricultural residue to grid connected electricity. The following pages outline the biomass energy sector in the state of Tamil Nadu and the spatial distribution of biomass energy typologies.

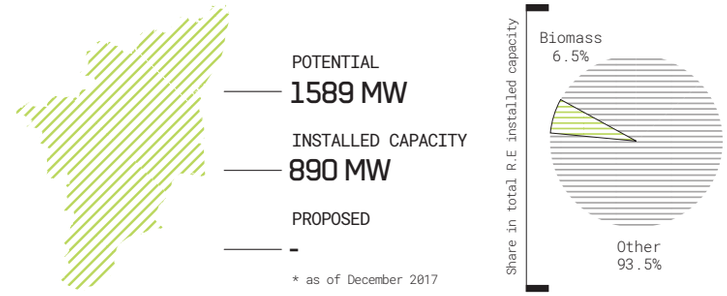




Fig 6.11: Biomass energy statistics (TEDA, 2018)

Fig 6.12: Satellite view of agricultural fields in Tanjore, Tamil Nadu (Google Earth, 2018)



Spatial Typologies and Distribution.

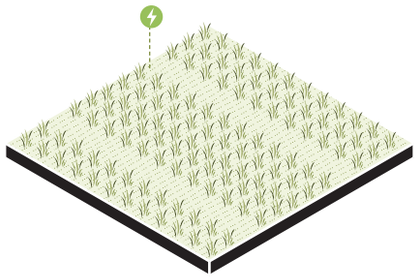
1. Source: Agricultural Residue

The residue from agricultural crops after harvest, like the husk, stem, and other non-edible parts are burnt in a Biomass power plant or baggase cogeneration plant (for sugarcane baggase) to generate grid connected electricity. Tamil Nadu has bio-power potential of 790MW from agricultural residue alone. Apart from this, local power generation in off-grid biomass power plants is also carried out.

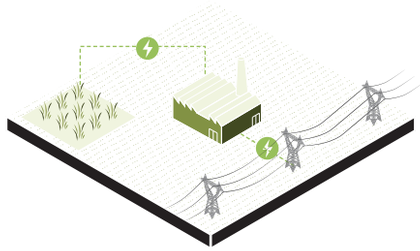
2. Generation: Cogen or Biomass Power Plants

Thermal combustion plants and gasifiers that burn the biomass from forest and agricultural residue to generate electricity fall under this category. Sugarcane baggase is generally processed in a Baggase Cogen plant, while other forms of biomass is burnt in Biomass power plant. Cogen plants 'co-generate' both heat and electricity, which can have multiple industrial applications as well.

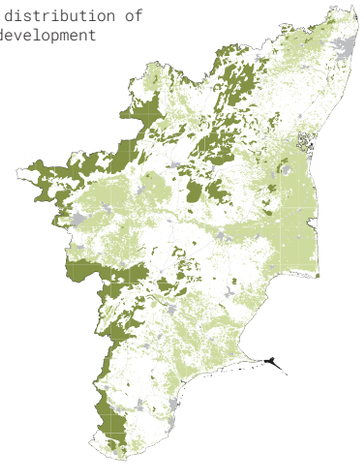
Morphology of energy infrastructure



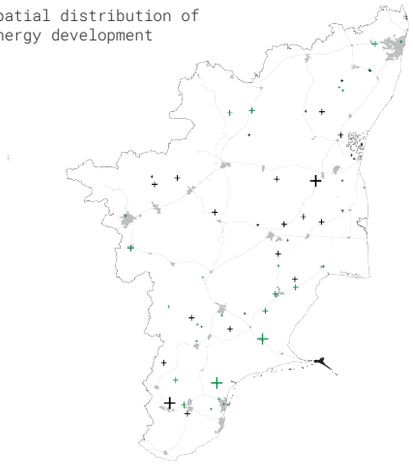
Morphology of energy infrastructure



Spatial distribution of energy development



Spatial distribution of energy development



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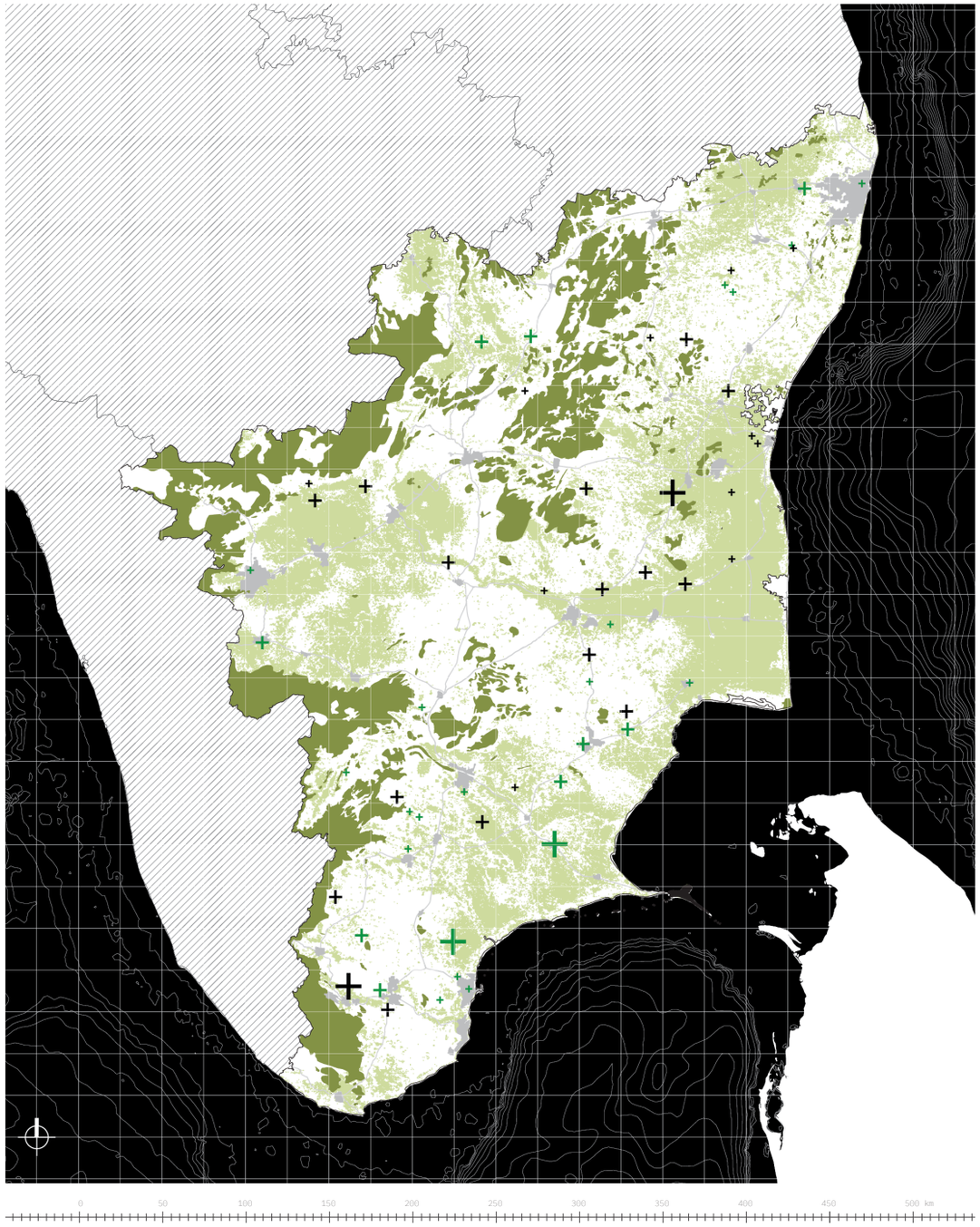


Fig 6.13: (left) Diagrams showing the morphology and spatial distribution of biomass energy typologies

Fig 6.14: (right) Spatial distribution of biomass energy typologies

Carbon Production Landscapes.

Apart from mapping and planning for R.E production landscapes, it is also important to understand how the existing carbon-based energy landscape will adapt to the new energy paradigm. For this, existing carbon landscapes, their spatial typologies were mapped to understand the opportunities and barriers for carbon emission reduction. With total capacity of 12479MW, Tamil Nadu's thermal power plants emit 34.2 million tons of CO_2 every year (Guttikunda & Jawahar, 2014). Tamil Nadu's industrial sector, with 800000MT of carbon emissions from cement industries alone (Ghoshal & Bhattacharyya, 2008), has a huge role to play in reducing carbon emissions in the future. Retrofitting carbon capture technology* onto existing power plants and heavy industries can reduce emissions upto 80%. The following pages outline the CCS sector in the state of Tamil Nadu and the spatial distribution of carbon source and sinks.



POTENTIAL
98 MT of CO_2/yr

INSTALLED CAPACITY
70000 T of CO_2/yr

PROPOSED
-

* as of December 2017
MT- million tons



* Carbon Capture and Sequestration or Storage (CCS) is a way to mitigate the effect of greenhouse gas emissions by capturing the emitted CO2 from carbon emission sources like thermal power plants and industries, and storing them artificially in deep geological basins, gas fields and oceans.

Fig 6.15: CCS statistics (India Energy Data, 2018)

Fig 6.16: Thermal power plants: Sources of carbon emissions (Seen in the image is the Tuticorin Thermal Power Plant, Tamil Nadu)

11.1271° N, 78.6569° E



Spatial Typologies and Distribution.

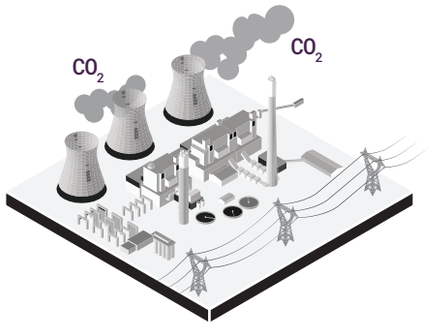
1. Carbon Source: Thermal Power Plants

To catalyse the shift to renewable sources, existing thermal power plants (TPP) and industries that emit large quantities of carbon are mapped to identify sites for capturing CO_2. Carbon carpture has gained increasing attention in the country, with 8 pilot projects for in Tamil Nadu alone (Global CCS Institute, 2019). Apart from this, existing power plants that can be converted to biomass based TPPs to curtail fossil fuel extraction and production. Retrofitting CCS technology to existing sites can have a significannt impact on climate change, one of the main drivers of energy transition.

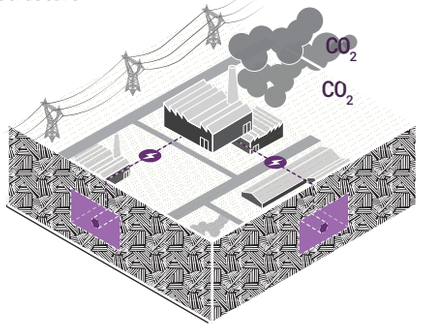
2. Carbon Sink: Geological basins (potential)

The captured CO_2 from thermal power plants and industries then needs to be transported through pipelines to be stored underground in geological basins. The Cauvery river basin in the coastal region of Tamil Nadu has good carbon storage potential, due to the natural geological formations and the presense of old gas and oil fields, where carbon can be stored (Viebahn et al., 2011). The proximity of the basin to existing carbon emission sites like TPPs, is an important factor that Tamil Nadu can use to its advantage in furthering research on CCS.

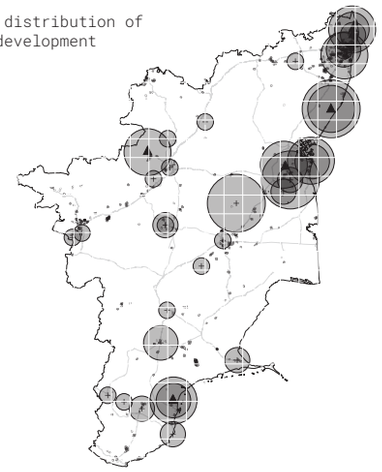
Morphology of energy infrastructure



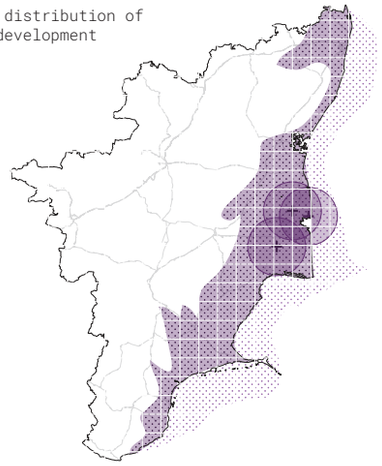
Morphology of energy infrastructure



Spatial distribution of energy development



Spatial distribution of energy development



11.1271° N, 78.6569° E

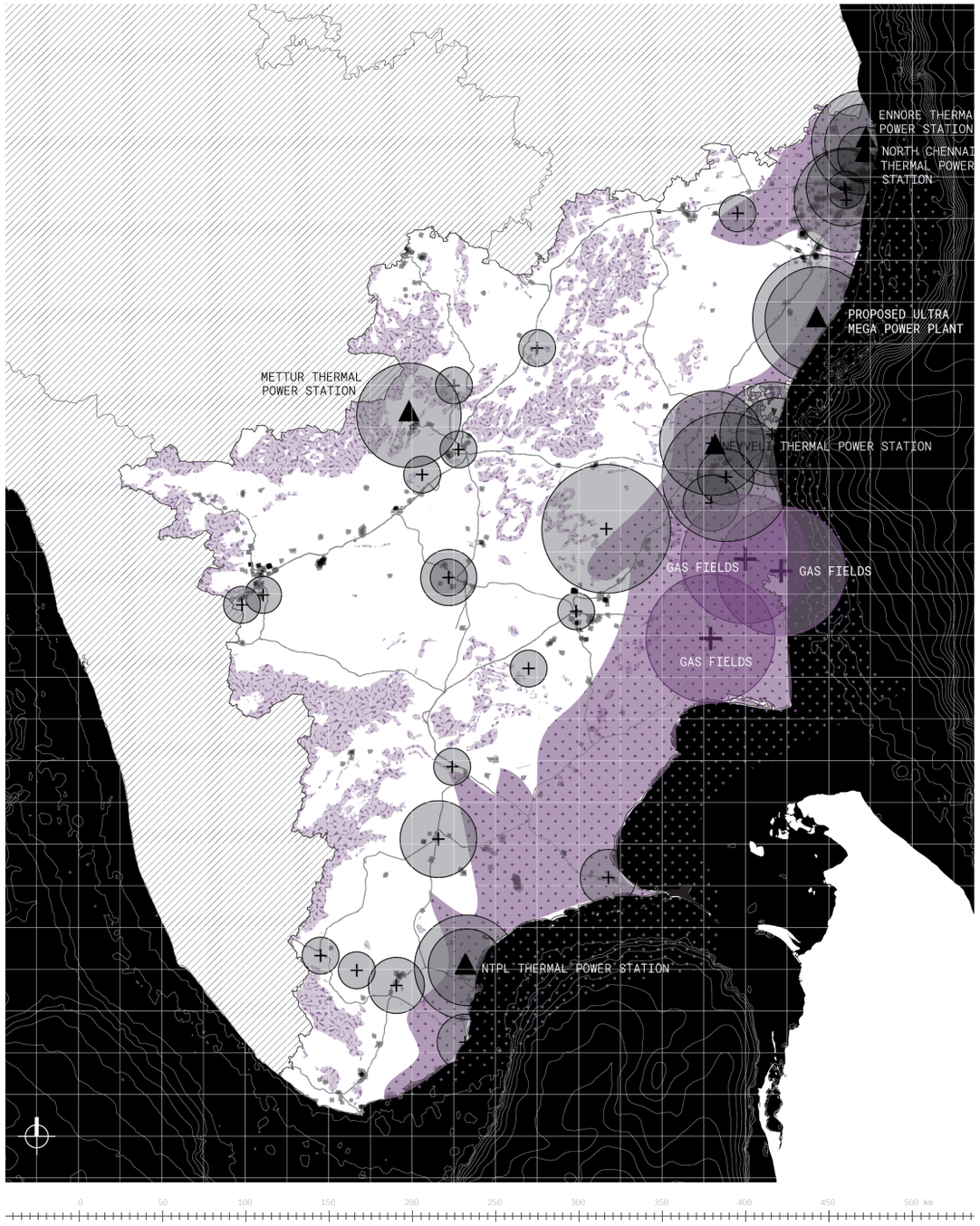


Fig 6.17: (left) Diagrams showing the morphology and spatial distribution of carbon energy typologies

Fig 6.18: (right) Spatial distribution of carbon energy typologies

Carbon source: Thermal Power plant
Carbon source: Industries
Carbon emssions level
Carbon sink: Gas fields
Carbon sink: Geological basin
Carbon sink: Nature reserves
Main infrastructure network

6000-15000kT
3000-6000kT
1500-3000kT
500-1500kT
100-500kT
Carbon emissions from Thermal power plants and industries

Spatial suitability for energy development.

The analysis of existing energy infrastructure in Tamil Nadu is then compared with landuse patterns across the macro-region to determine what type of energy development is best suited for the local use of land. The macro-region was mapped and classfied into five types of prominant landuse patterns: built up area, moderately fertile agricultural land, very good agricultural land, ecological sensitive areas and barren wastelands. Each landuse type was given a grade from 1-5 (5 being most suited) to prioritse areas for energy development. For example, Fig 6.19 shows how the project focuses on the potential of utilising wastelands for energy development, over fertile agricultural land.

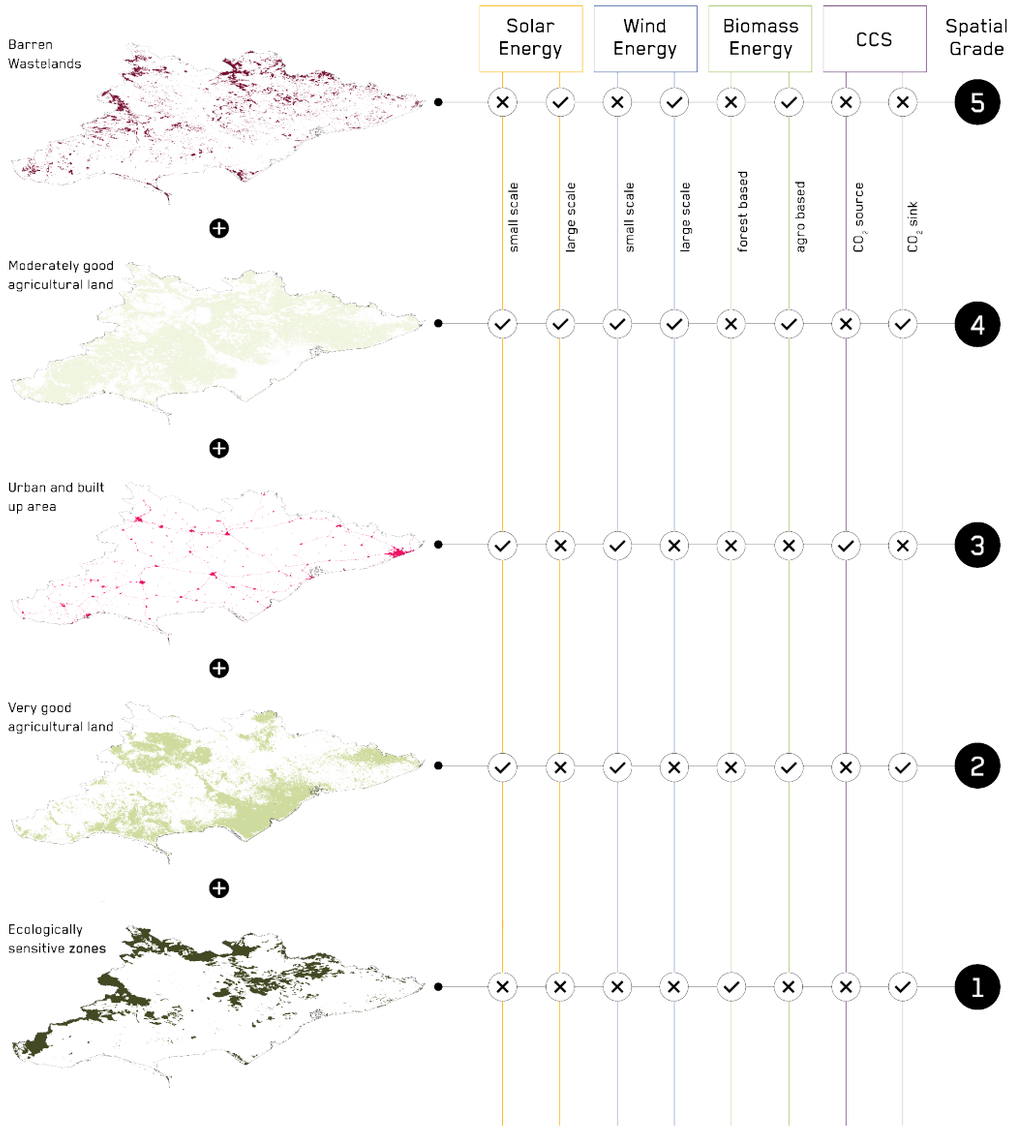
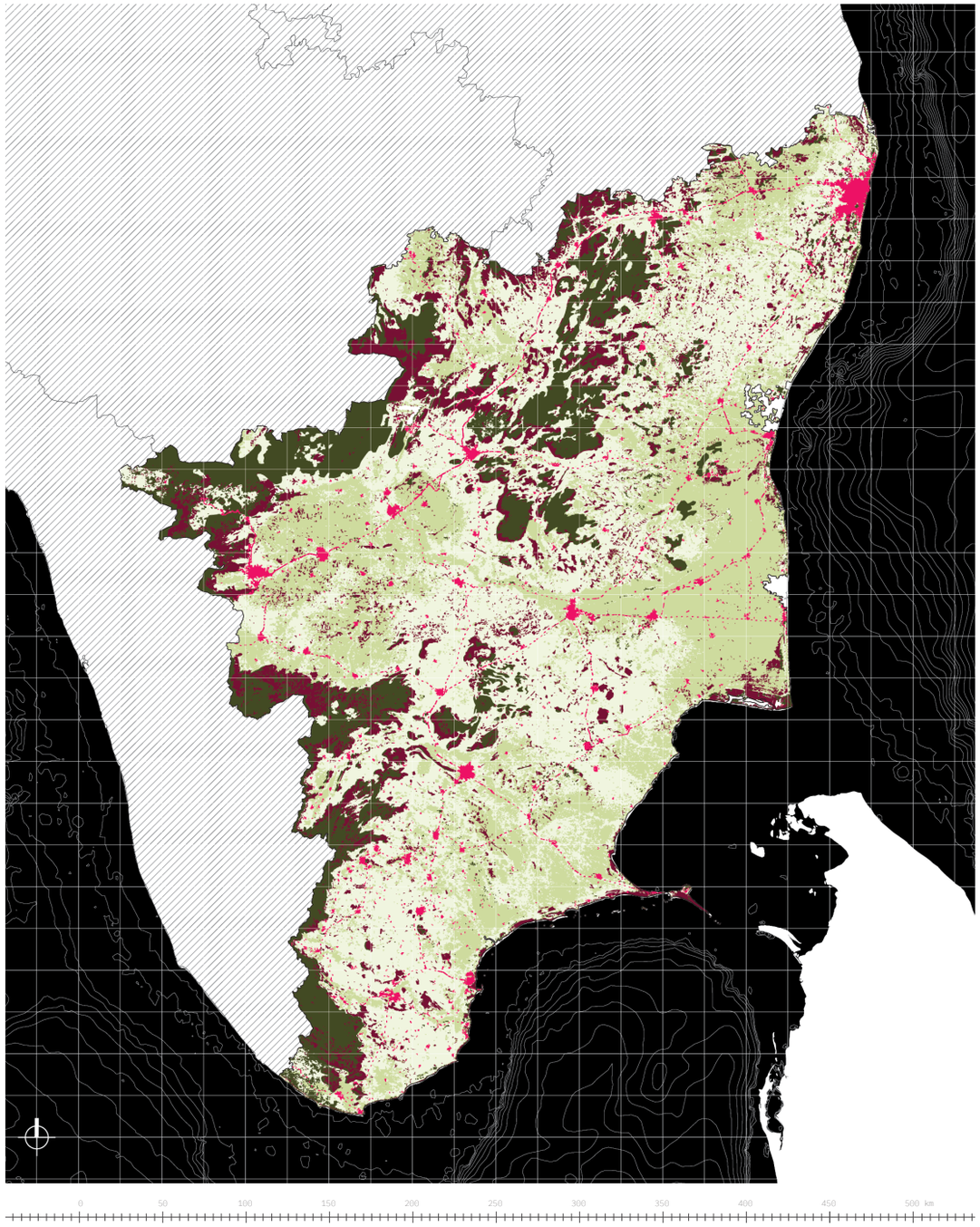


Fig 6.19: (left) Diagram evaluating the spatial suitability of energy development wrt landuse patterns.

Fig 6.20: (right) Landuse map of Tamil Nadu (Data from NRSA, 2011)



Evaluating Social Vulnerability.

As elaborated in previous sections, there exits a strong relationship between energy vulnerability and socio-spatial vulnerability. Energy inequality is essentially perpetuated by structures of spatial inequality and segregation. In this light, the project attempted to map the macro-regional concentrations of energy vulnerability by using three factors, listed below:

1. Indicators for social vulnerability:

Human Development Index (HDI)- Composite index that measures people and their capabilities- a long and healthy life, being knowledgeable and having a decent standard of living (UNDP, 2019)
Multidimensional Poverty Index (MPI)- Composite index that measures the multiple and simultaneous ways in which people experience poverty across three key dimensions: health, education and standard of living, comprising of 10 indicators. 'People who experience deprivation in at least one third of these weighted indicators fall into the category of multidimensionally poor.' (UNDP, 2019)

These two indicators were taken as the standard for measuring energy poverty in Tamil Nadu, since both the composite indexes measure energy access (one of the indicators). The districts with highest MPI and lowest HDI (Tamil Nadu Human Development Report, 2017) are mapped in Fig 6.21 to understand macro-regional concentration of social (and energy) vulnerability.

2. Level of energy access in rural areas:

Rural areas in Tamil Nadu, while 100% 'electrified' (Refer Fig 3.40 for the evolution of the definition of electrification by the Govt. of India), the level or quality of energy access is still very poor. Rural areas benefit from the unmetered energy supply for agricultural use, but bear the impact of regular load shedding, more than in urban areas. Here, the project acknowledges lack of knowledge and data on quality of energy access in Tamil Nadu as a limitation to mapping this factor accurately. Values from the 2001 National Population Census, measuring energy access was taken as the base to identify villages that lacked access in the beginning of the millennium. The project assumes these values temporarily for mapping inequalities in energy access.

3. Number of power interruptions in urban areas:

By mapping the highest recording number of power interruptions in urban areas in a year, measured in urban areas (Ministry of Power, 2019), urban areas with energy shoratges were identified. Here, the shortages do not result from a planned inequality, but from the systemic inadequacy in meeting the energy demand.

To sum up, the mapping of social vulnerability was crucial in identifying regions to channel the social benefits of energy transition.

11.1271° N, 78.6569° E

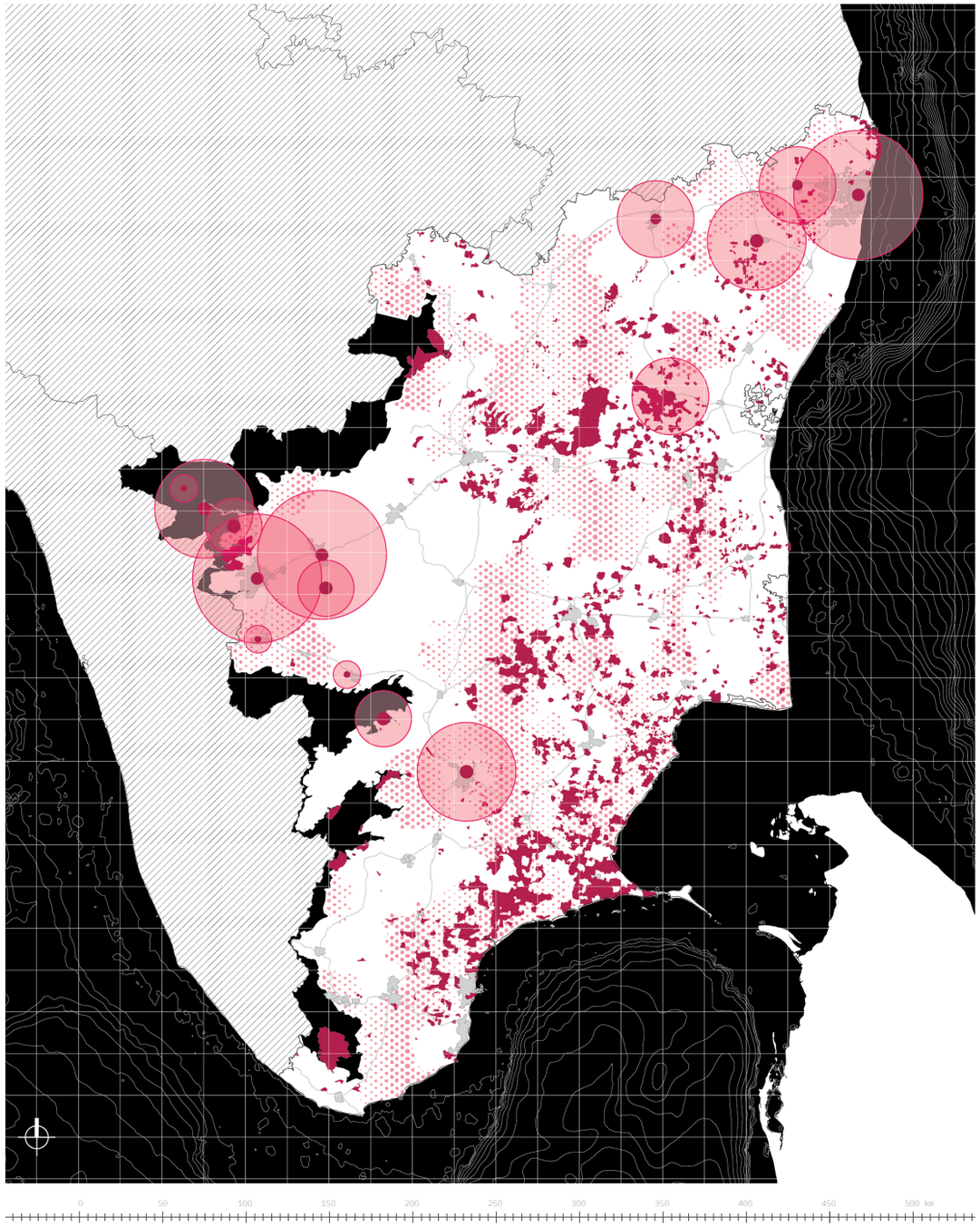


Fig 6.21: Map showing concentrations of social vulnerability and energy vulnerbability.

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

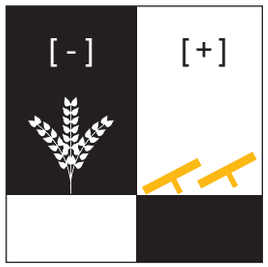
Barriers and Opportunities for energy transition in Tamil Nadu.

Barriers

Solar energy



1. Water intensive during maintenance and cleaning of the panels on site.

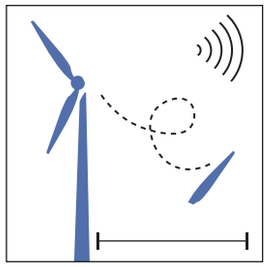


2. Rapid landuse transformation to solar farms affects food security

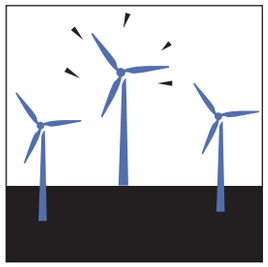




Wind energy



1. Causes noise pollution and needs safely buffer around windturbines



2. Aesthetic and visual dominance of windturbines lacks social acceptance

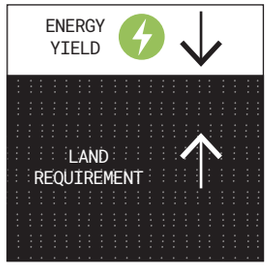


3. Seasonal availability of wind during the monsoon seasons

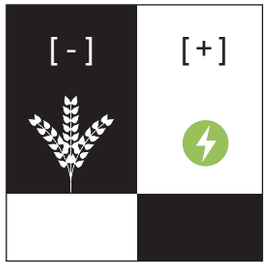


4. Moving rotor blades are ecological hazards to migratory birds

Biomass energy



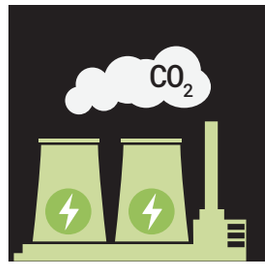
1. Lower energy yield compared to other types of R.E.



2. Rapid landuse transformation affects food security



3. Seasonal availability of agricultural residue after the harvest season

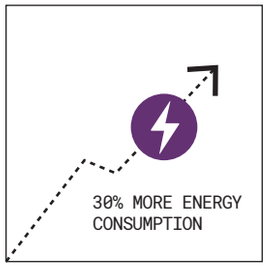


4. Biomass power plants spew carbon emissions as well

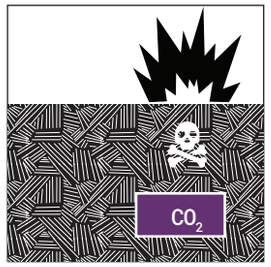
Carbon Capture Storage



1. Technical and financial barriers



2. Consumes 30% more energy to function

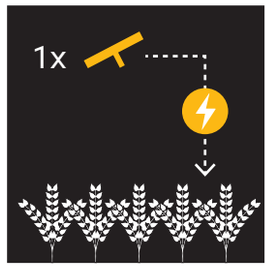


3. Safety hazard due to leakage of stored carbon

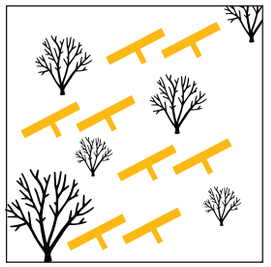


Opportunities

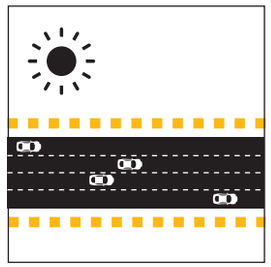
Solar energy



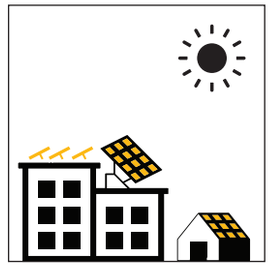
1. Small scale solar panels to support agriculture



2. Productive use of wastelands through wind energy production

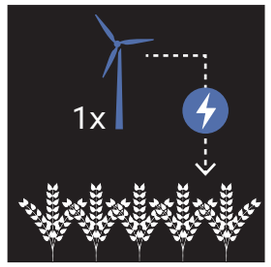


3. Creation of infrastructural energy landscapes along highways, etc

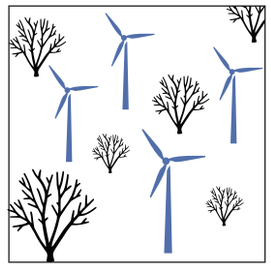


3. Urban areas to become solar rooftop zones to create urban mini grids

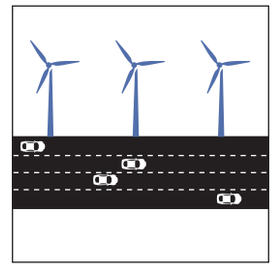
Wind energy



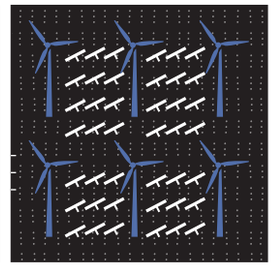
1. Small scale windturbine to support agriculture



2. Productive use of wastelands through wind energy production

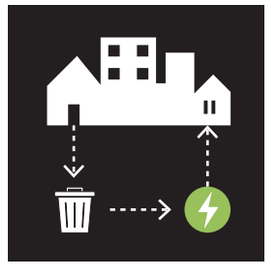


3. Creation of infrastructural energy landscapes along highways, etc

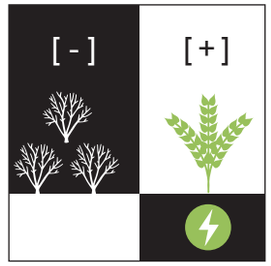


4. Hybrid solar + wind energy programming to increase productivity

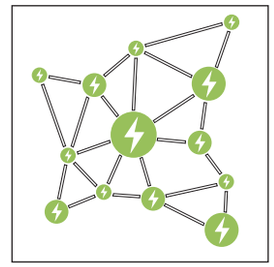
Biomass energy



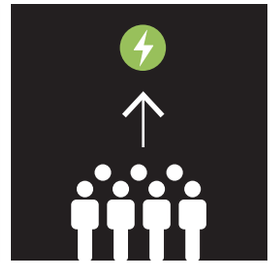
1. Waste to energy initiatives for urban areas that feeds back to the city



2. Productive use of wastelands for growing biomass suited crops

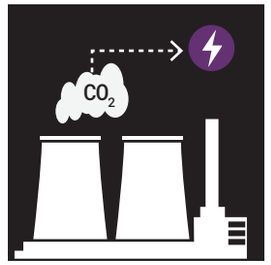


3. Decentralised Bio-energy production through self-sustaining networks

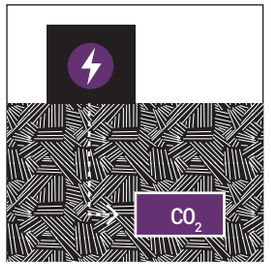


4. Coproduction of bio-energy by involving local communities

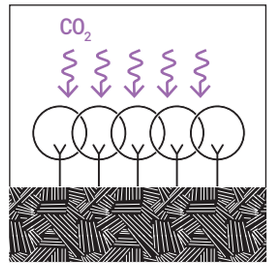
Carbon Capture Storage



1. Can be retrofitted to existing thermal power plants and industries



2. Presence of good geological basins for carbon storage.



3. Use of natural carbon sinks like forests and croplands



4. Can reduce pollution and increase livability of urban areas

6.3 Mapping Potentials and Vulnerabilities

The knowledge gained from spatial analysis of energy production landscapes, landuse and energy access was taken as the base for the multi-criteria analysis to calculate the energy potential, spatial potential and social vulnerability in Tamil Nadu. In order to do this, a methodology using GIS was evolved (Fig 6.22), wherein a 5kmx5km spatial gridwas overlaid on the map of the state, and each square was graded (from 1-5, 5 being the highest relative potential) based on the criterias. Fig 6.23 elaborates in detail the methodology used for the multicriteria analysis. The potentials and vulnerabilities of each 5kmx5km square were taken as the input criterias to **iterate combinations of energy use, landuse, and social conditions of the place.** This methodology was used to run various simulations corresponding to specific energy pathways to test their spatial impacts. The outcomes of this analysis gave insights for design on **where energy landscapes should be built and who they should benefit.**

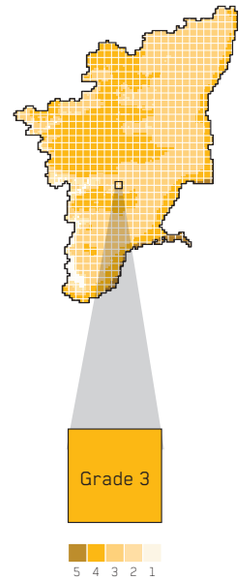


Fig 6.22: Graphic showing the aim of the multicriteria analysis

This section presents the mapping and evaluation of different regions in Tamil Nadu based on the input criteria elaborated in the previous section. The individual maps showing the methodology of grading the 5km x 5km squares are presented in the following pages- solar, wind, biomass, carbon energy potentials, spatial potential and social vulnerability are the six criterias used to grade the squares. These input criterias were overlapped to identify critical areas of intervention: ***for example, areas of high solar potential and social vulnerability, can targeted for stimulating for bottom-up solar energy cooperatives to improve energy access through R.E. production.***

This section concludes with few example outputs generated from this methodology to highlight the opportunities for design, and implementation of specific interventions based on the material and social settings of a place.

Methodology for Multi Criteria Analysis.

Step 1:

Creatng a Spatial Grid

5x5km grid is overlaid to have a common spatial unit for analysis

Step 2:

Evaluating the Grid

Each square is graded from 1-5, 5 being thhe highest, based on certain input parameters (energy potentials, spatial potentials, etc)

Step 3:

Input Parameters

Input parameters for each square are overlaid to obtain various outputs to determine areas of potentiality and vulnerability

Step 4:

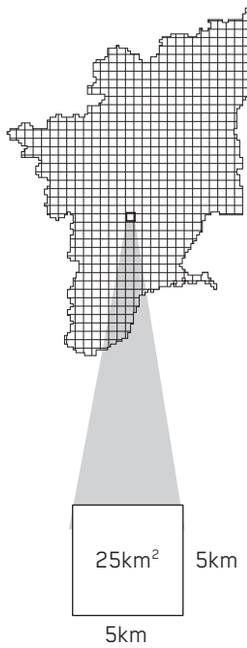
Outputs- Strategic areas for Regional Design

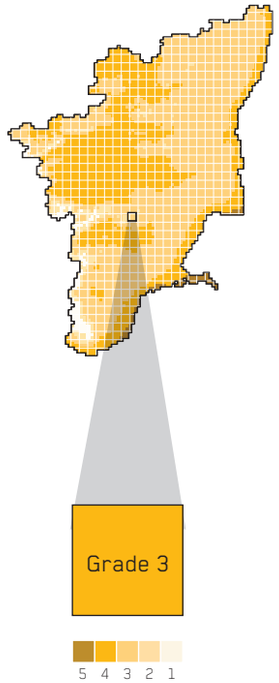
Different outputs showing strategic areas for intervention can be generated based on the choice of the input parameters. One example pathway is shown, where areas of high energy potential are crossed with areas of high social vulnerability to identify regions that are viable for 'coproduction' initiatives.

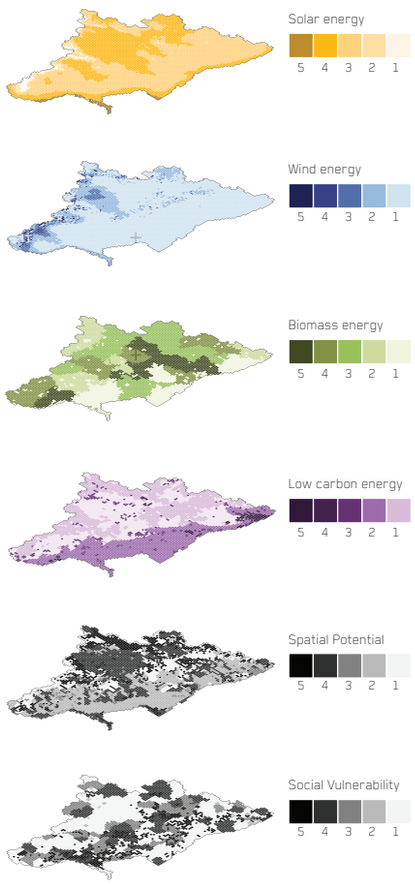
Step 5:

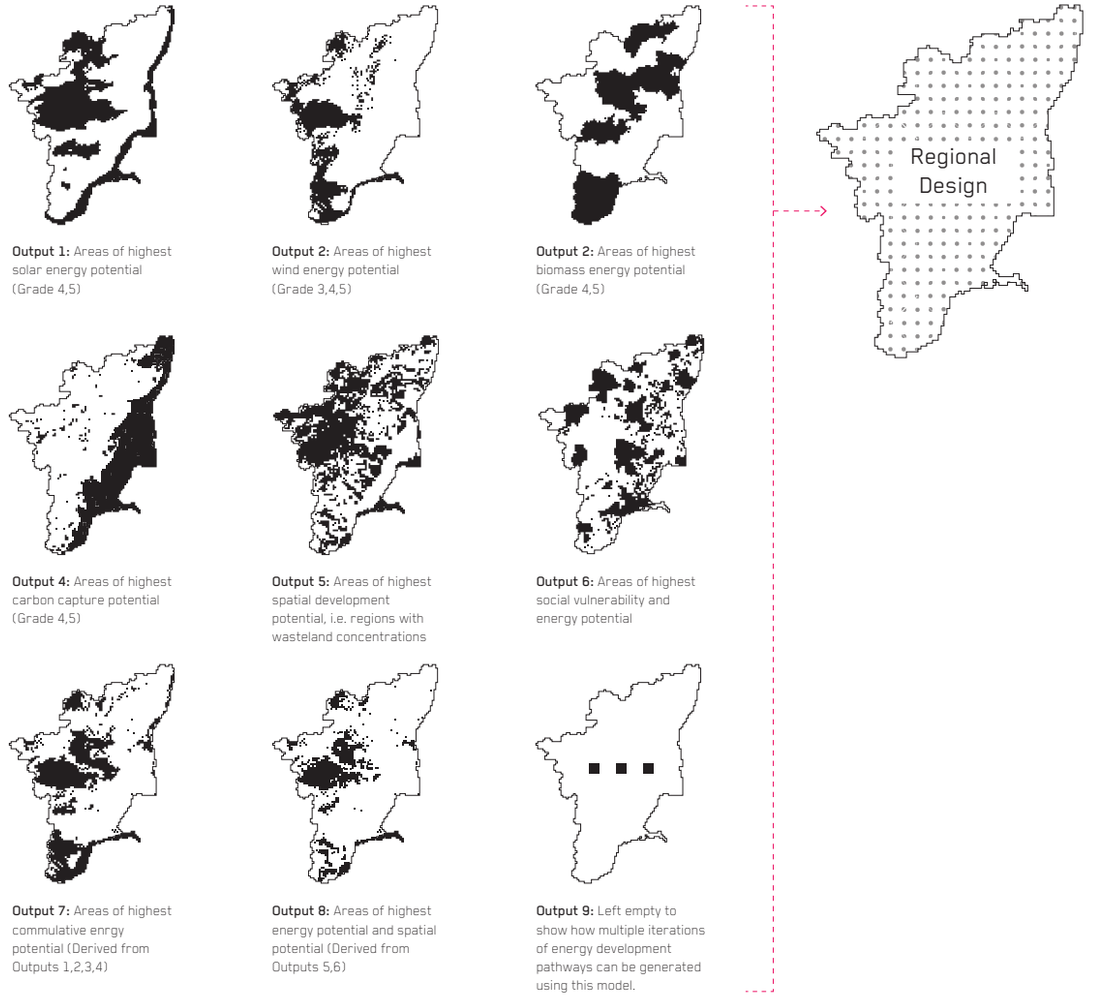
Inputs for design

The ouput iterations provide valuble insights on where and how regional design strategies can be implemented









Output 1: Areas of highest solar energy potential (Grade 4,5)

Output 2: Areas of highest wind energy potential (Grade 3,4,5)

Output 2: Areas of highest biomass energy potential (Grade 4,5)

Output 4: Areas of highest carbon capture potential (Grade 4,5)

Output 5: Areas of highest spatial development potential, i.e. regions with wasteland concentrations

Output 6: Areas of highest social vulnerability and energy potential

Output 7: Areas of highest commulative enrgy potential (Derived from Outputs 1,2,3,4)

Output 8: Areas of highest energy potential and spatial potential (Derived from Outputs 5,6)

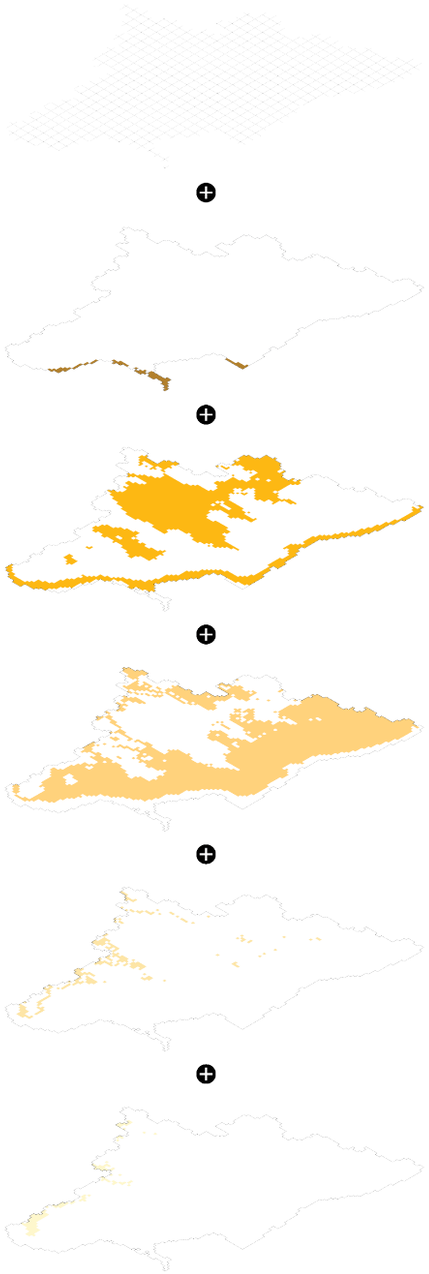
Output 9: Left empty to show how multiple iterations of energy development pathways can be generated using this model.

Fig 6.23: Methodology for the evaluation of regional potentiality and vulnerability

11.1271° N, 78.6569° E

1. Energy Potential - Solar.

Rationale for the grading of 5km x 5km squares



5km x 5km Grid: Based on the intensity of solar radiation (Global Solar Atlas, 2018), each 5km x 5km was graded from 1-5, 5 being the highest potential possible.

Grade 5: Barren land near the tip of the Rameshwaram coast, along the Gulf of Mannar receives highest amount of solar radiation in Tamil Nadu. Hot and dry climatic conditions

Grade 4: Coastal and mid-western parts of the state have a hot and arid climate that is extremely conducive to solar energy production

Grade 3: Most regions of the state enjoy high temperatures for most part of the year.

Grade 2: Protected natural reserve areas and tropical forests along the Western Ghats in the South West.

Grade 1: High altitude mountain regions that receive low sun radiation and low temperatures.

Fig 6.24: Individual layers of the solar potential map

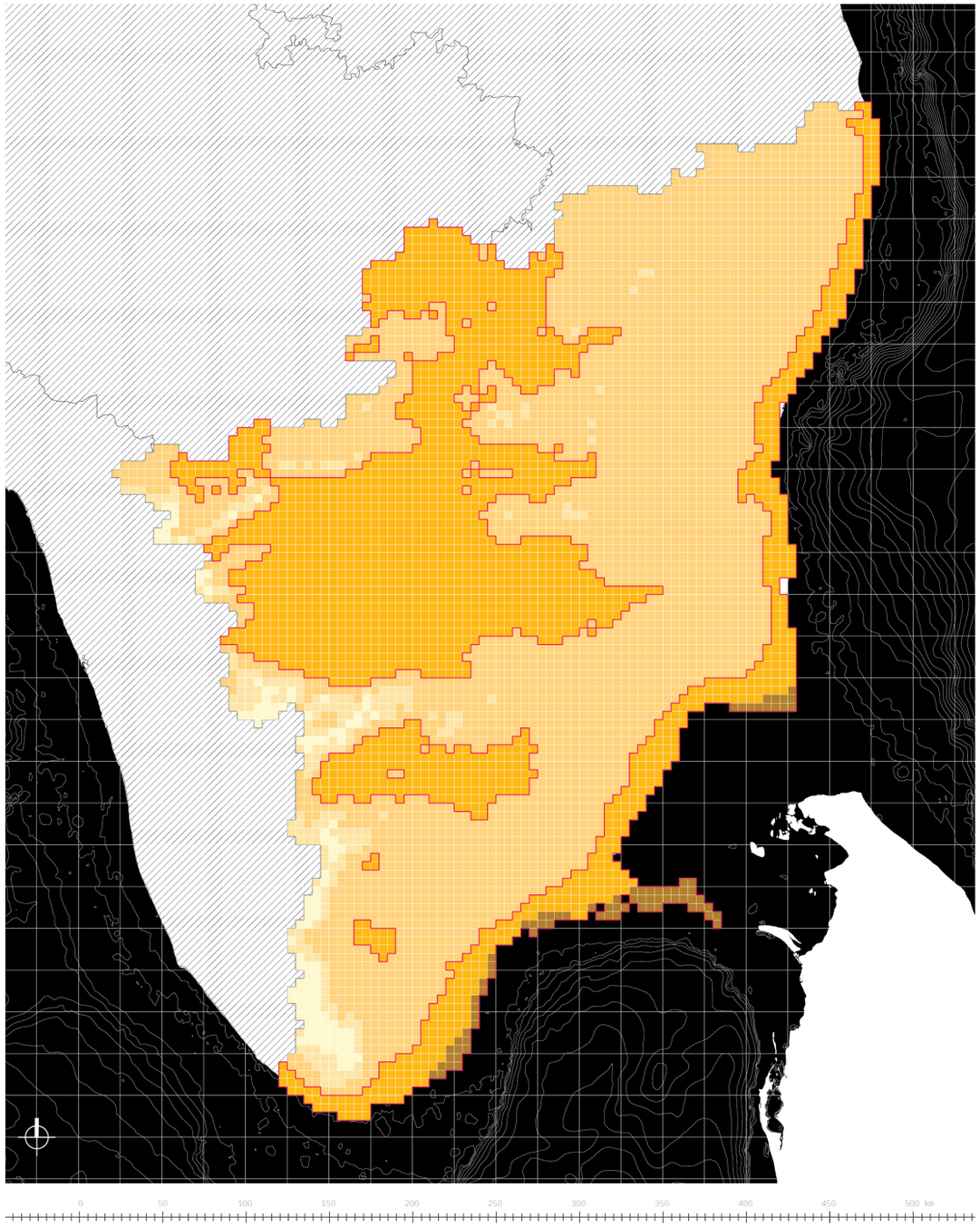
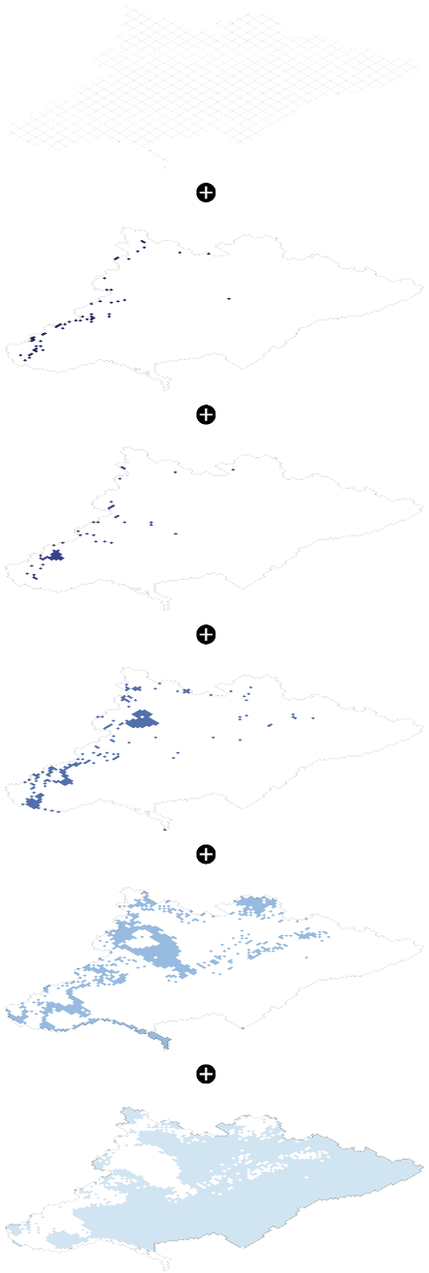


Fig 6.25: Solar potential map of Tamil Nadu (Global Solar Atlas, 2018)

11.1271° N, 78.6569° E

2. Energy Potential - Wind.

Rationale for the grading of 5km x 5km squares



5km x 5km Grid: 5km x 5km Grid: Based on average wind speed and wind power density (Global Wind Atlas, 2018), each 5km x 5km was graded from 1-5, 5 being the highest potential possible.

Grade 5: Higher altitude mountain slopes with wind speed over 13km/hr

Grade 4: Mountainous region with wind speed between 10-13km/hr.

Grade 3: Foothills of the western ghats with wind speed between 7-10km/hr

Grade 2: Wind pass region in the breaks between mountain ranges that produces a tunneling effect. Wind speed 4-7km/hr.

Grade 1: Flat agricultural area with wind speed between 1-4km/hr.

Fig 6.26: Individual layers of the wind potential map

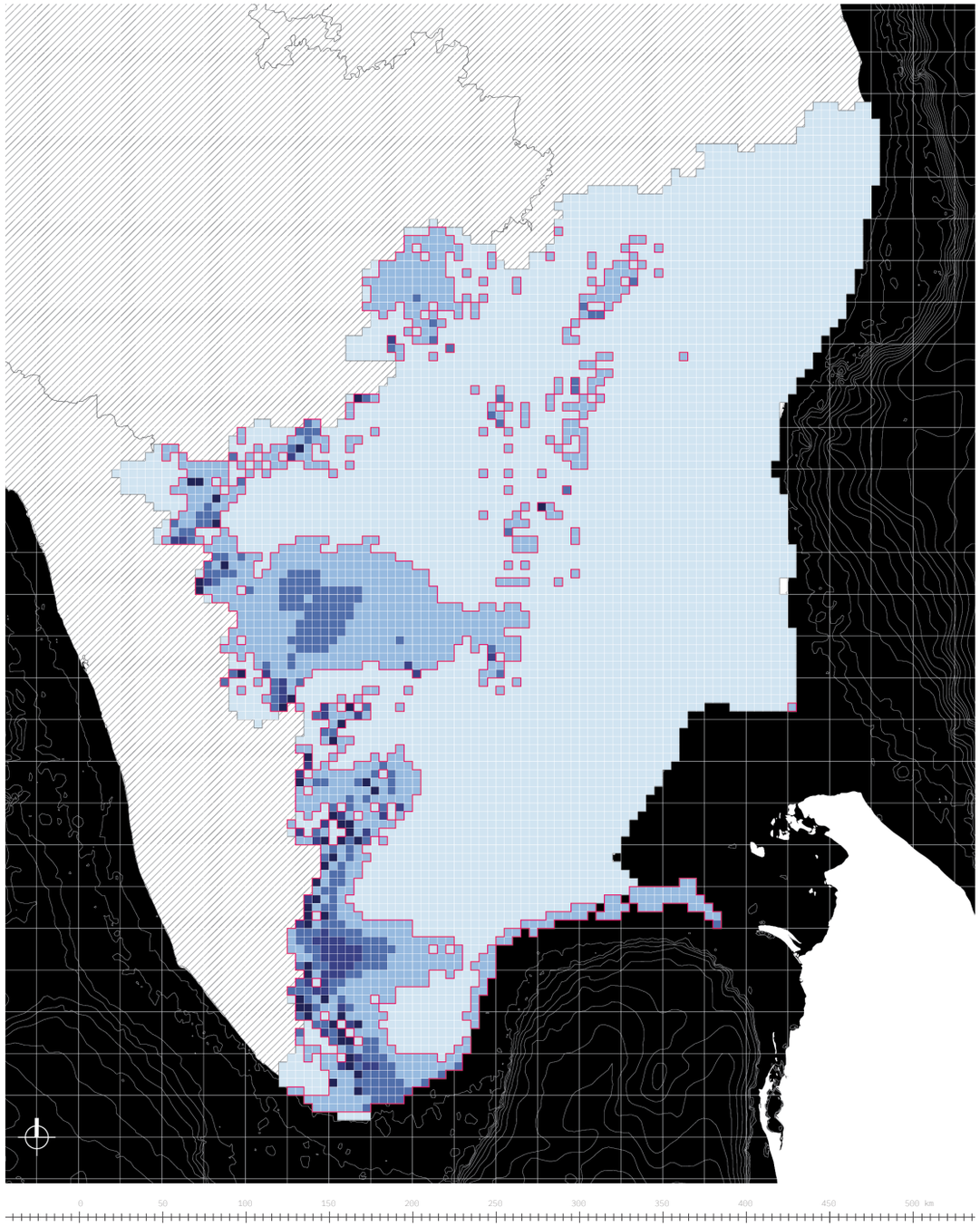
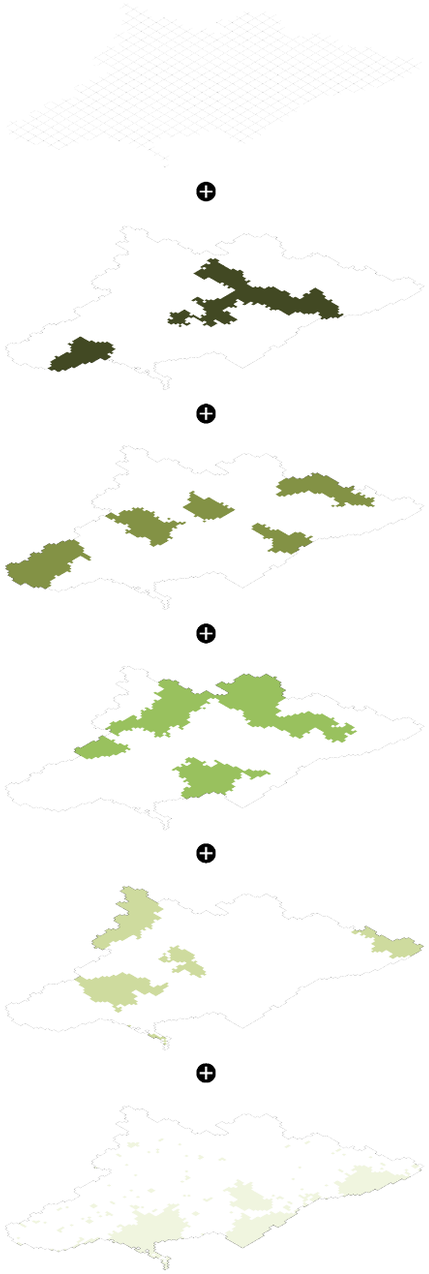


Fig 6.27: Wind potential map of Tamil Nadu (Global Wind Atlas, 2018)

11.1271° N, 78.6569° E
11.1271° N, 78.6569° E
11.1271° N, 78.6569° E
11.1271° N, 78.6569° E

3. Energy Potential - Biomass.

Rationale for the grading of 5km x 5km squares



5km x 5km Grid: Based on average biomass power potential (MNRE, 2018), each 5km x 5km was graded from 1-5, 5 being the highest potential possible.

Grade 5: Fertile agricultural regions with power potential between 80-100MW from both crop and forest residue

Grade 4: Regions with power potential between 60-80MW from both crop and forest residue

Grade 3: Regions with power potential between 40-60MW from both crop and forest residue

Grade 2: Regions with power potential between 20-40MW from both crop and forest residue

Grade 1: Urban areas and regions with low power potential between 0-20MW from both crop and forest residue

Fig 6.28: Individual layers of the biomass potential map

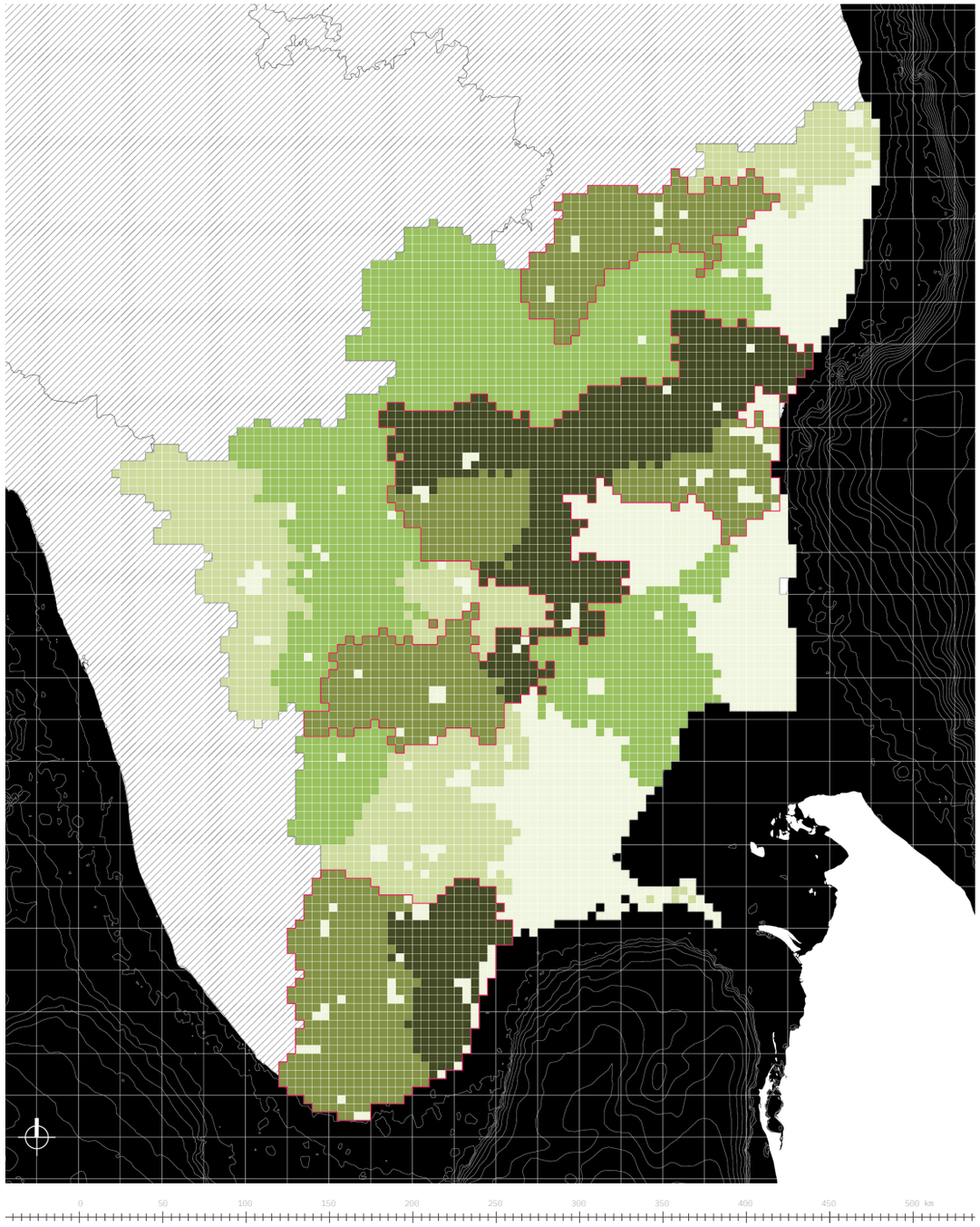
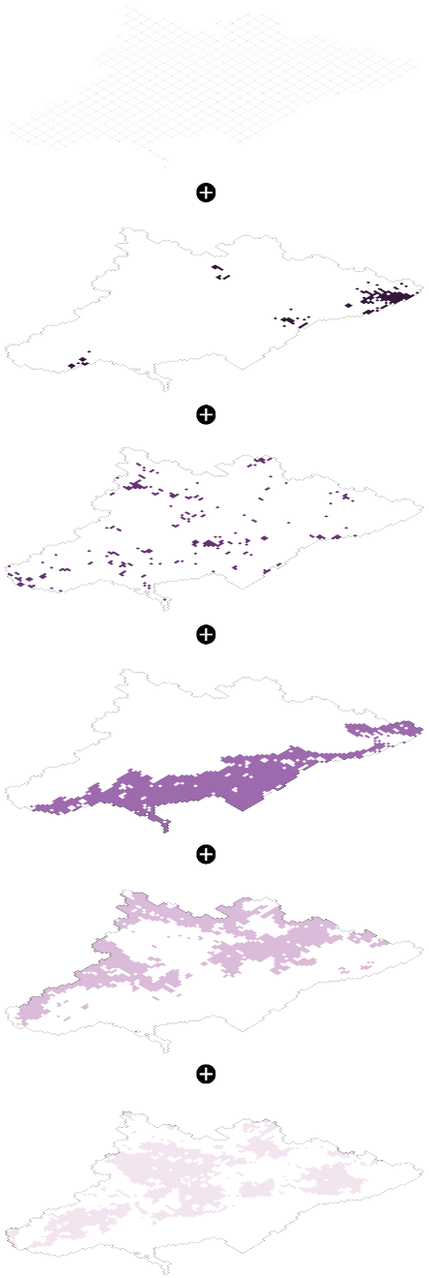


Fig 6.29: Biomass potential map (TEDA, 2018)

4. Energy Potential - Carbon Capture and Storage.

Rationale for the grading of 5km x 5km squares



5km x 5km Grid: Based on composite factors related to carbon emissions and CCS potential, each 5km x 5km was graded from 1-5, 5 being the highest potential possible.

Grade 5: Thermal power plants with extremely high carbon emissions- carbon source

Grade 4: Industries with high carbon emissions- carbon source

Grade 3: Geological basin which can be used for underground carbon storage- carbon sink

Grade 2: Natural forest reserves that can sustain passive carbon capture from the atmosphere- carbon sink

Grade 1: Regions with low carbon source and carbon sink potential

Fig 6.30: Individual layers of the carbon potential map

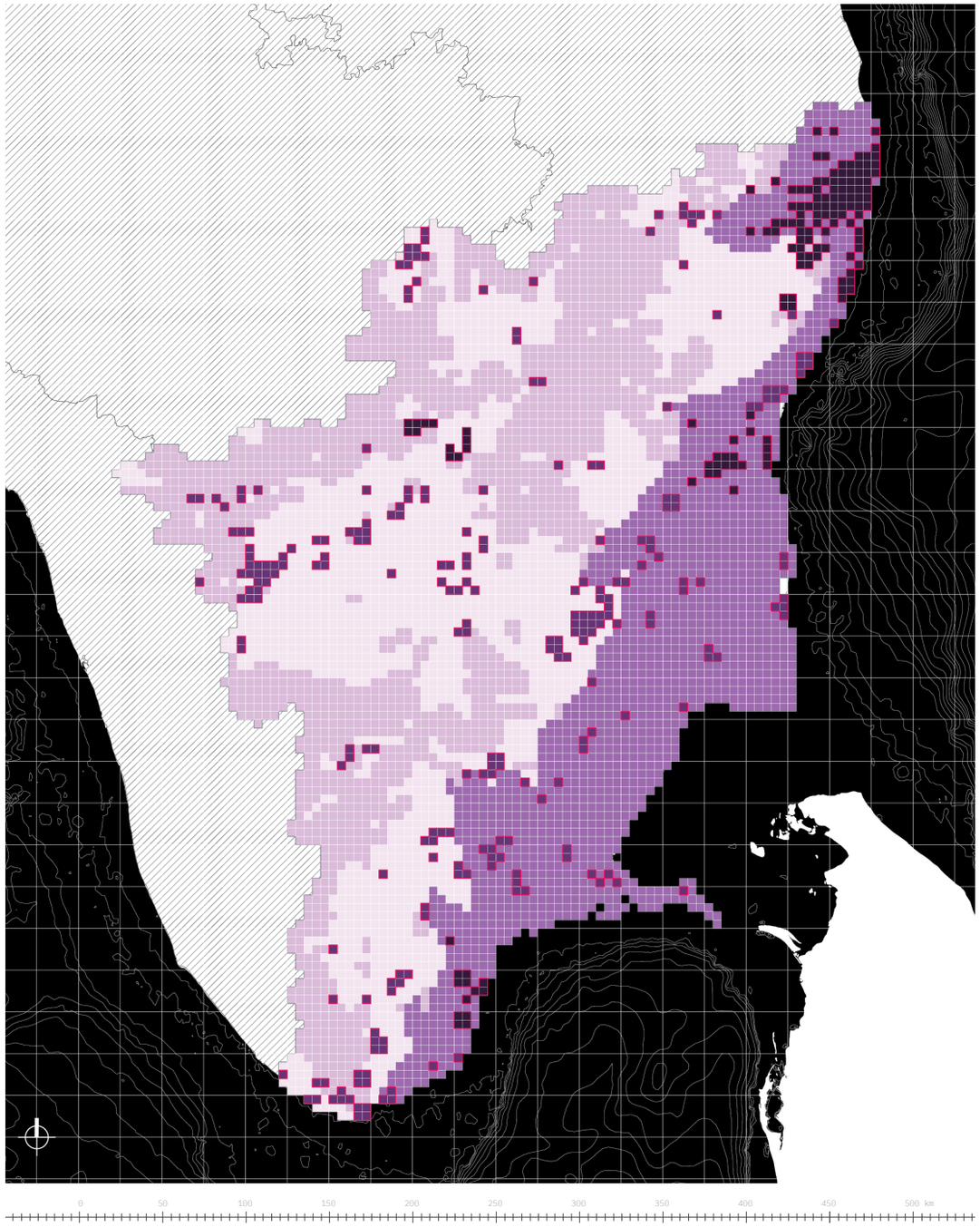


Fig 6.31: Carbon potential map (Viebahn et al., 2011)

5. Spatial Potential for energy development*.

Rationale for the grading of 5km x 5km squares



5km x 5km Grid: Based on landuse patterns and their suitability for energy development, each 5km x 5km was graded from 1-5, 5 being the highest potential possible.

Grade 1: Barren Wastelands: Non- productive land, degraded land that is not used for agriculture or human habitation

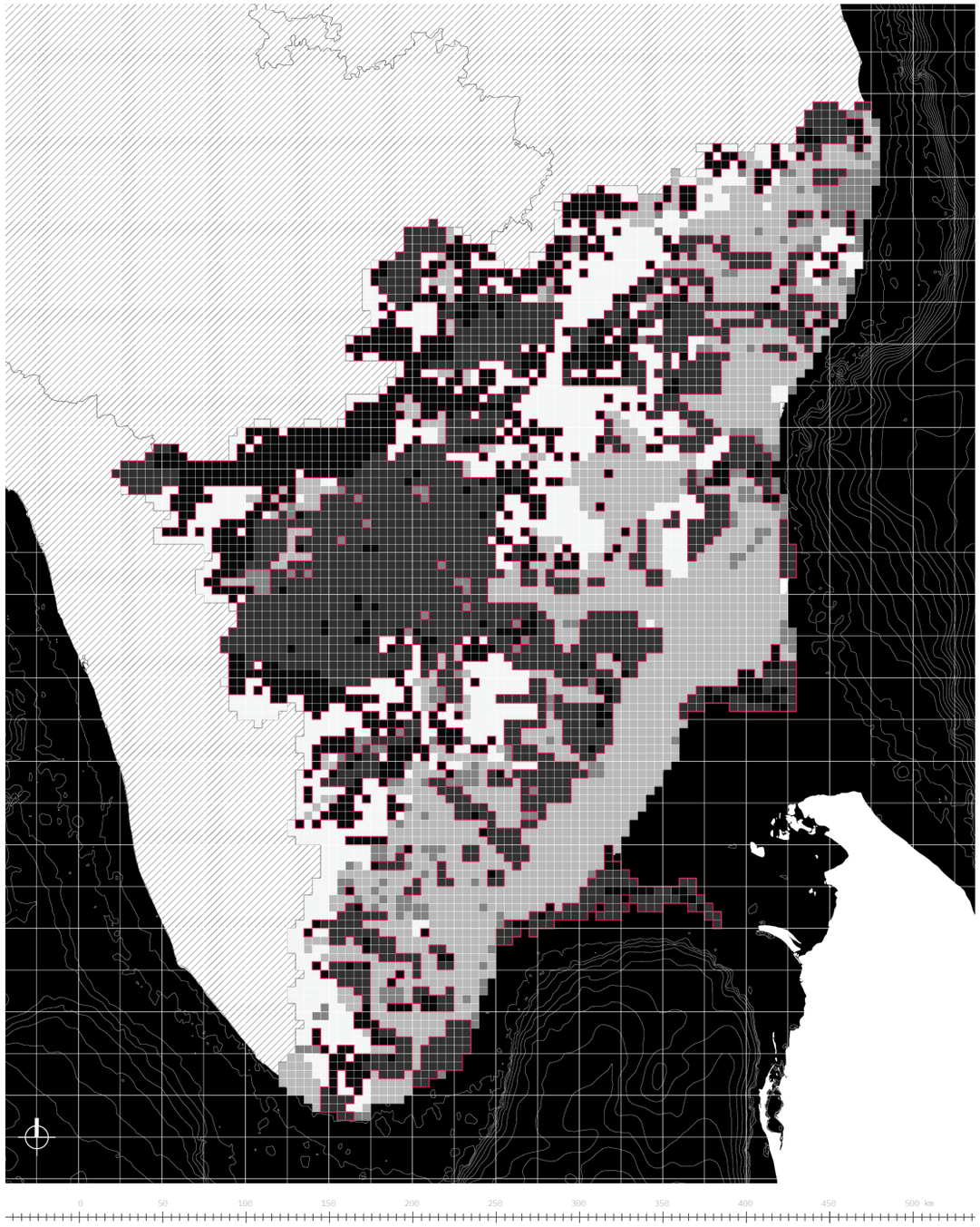
Grade 2: Moderately good agricultural land: Cropland or areas of natural vegetation that is moderately fertile.

Grade 3: Urban and built-up area: Built up area including infrastructure lines

Grade 4: Very good agricultural land: Extremely fertile cropland that is found around river basins.

Grade 5: Ecologically sensitive zones: Natural reserves, marshlands and hilly areas fall in thhis category.

Fig 6.32: Individual layers of the spatial potential map



** graded based on the square's spatial potential derived from landuse types*

Fig 6.33: Spatial potential of Tamil Nadu

6. Social Vulnerability.

Rationale for the grading of 5km x 5km squares



5km x 5km Grid: Based on composite indicators for measuring social vulnerability, each 5km x 5km was graded from 1-5, 5 being the highest potential possible.

Grade 1: Villages without complete, uninterrupted energy access

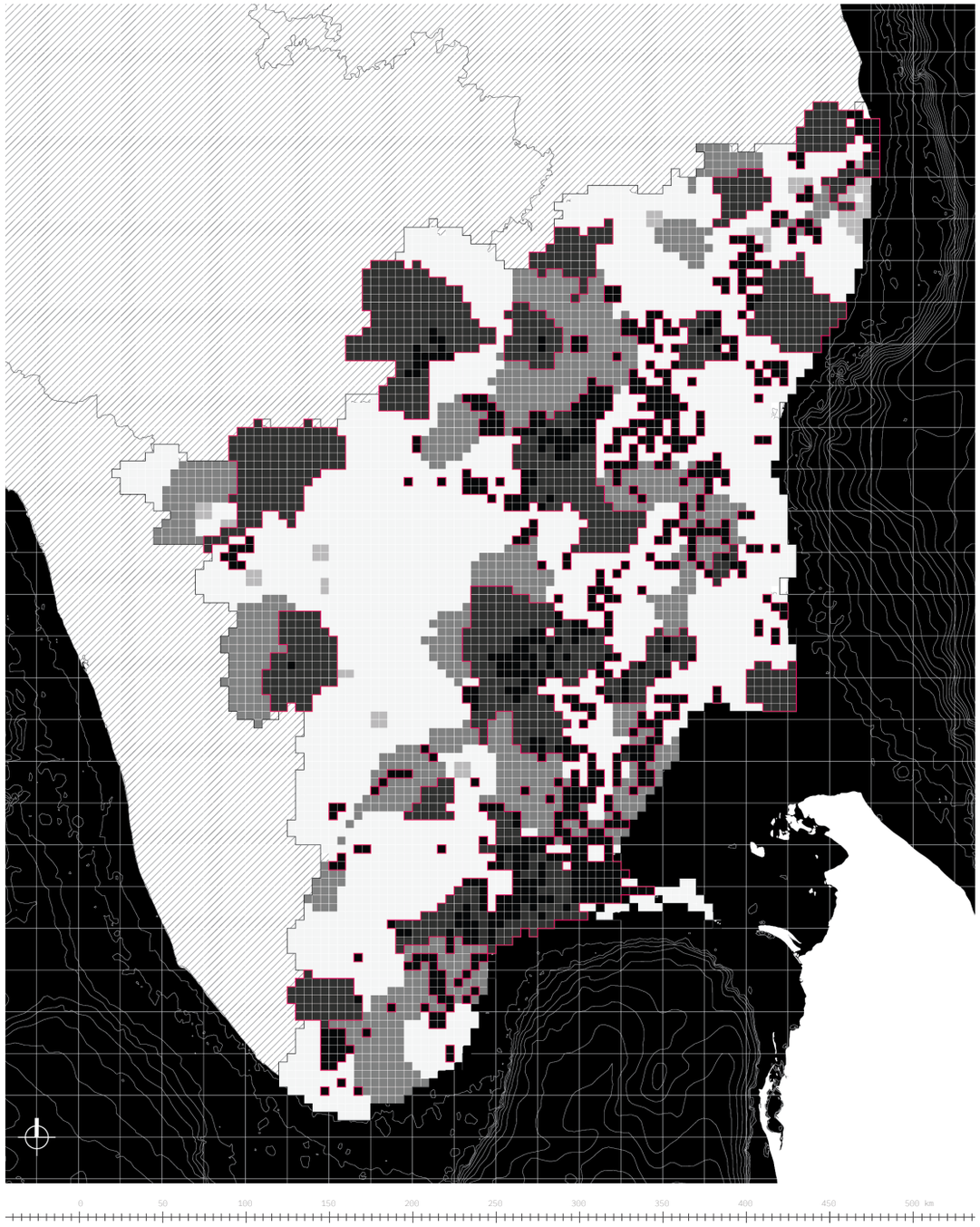
Grade 2: Districts with highest levels of MPI and lowest level of HDI (Tamil Nadu Human Development Report, 2017)

Grade 3: Districts with average levels of MPI and lowest level of HDI (Tamil Nadu Human Development Report, 2017)

Grade 4: Urban areas with highest number of power shortages and interruptions (Ministry of Power, 2019)

Grade 5: Areas with good level of energy access in the state.

Fig 6.34: Individual layers of the total energy potential map

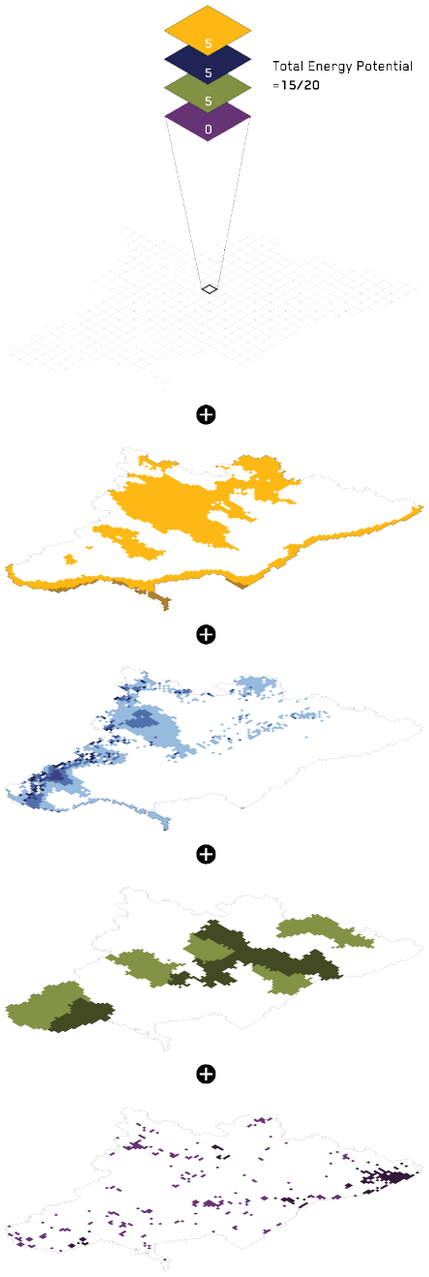


** graded based on the square's social vulnerability index derived from multiple factors explained in the previous page.*

Fig 6.35: Spatial potential of Tamil Nadu

Example Output: Combined Energy Potential

Rationale for the grading of 5km x 5km squares



The total energy potential of each square was crucial in identifying the energy dense regions of the state. The hybrid multi-potentiality of each square is represented in map.

5km x 5km Grid: The cumulative energy potential of each square was derived from the mapping of individual energy potentials. The energy potential hotspots in the state are identified

Solar: Regions with grade 4,5 with high solar intensity and dry climate were chosen for their potential

Wind: Regions with grade 2,3.4,5 were chosen for their potential (Wind energy can successfully operate from Grade 2)

Biomass: Regions with grade 4,5 were chosen for their potential. They also form the major agricultural region of the state

Carbon: Regions with grade 4,5 (carbon source from industries and power plants) were chosen for their potential

Fig 6.36: Individual layers of the total energy potential map

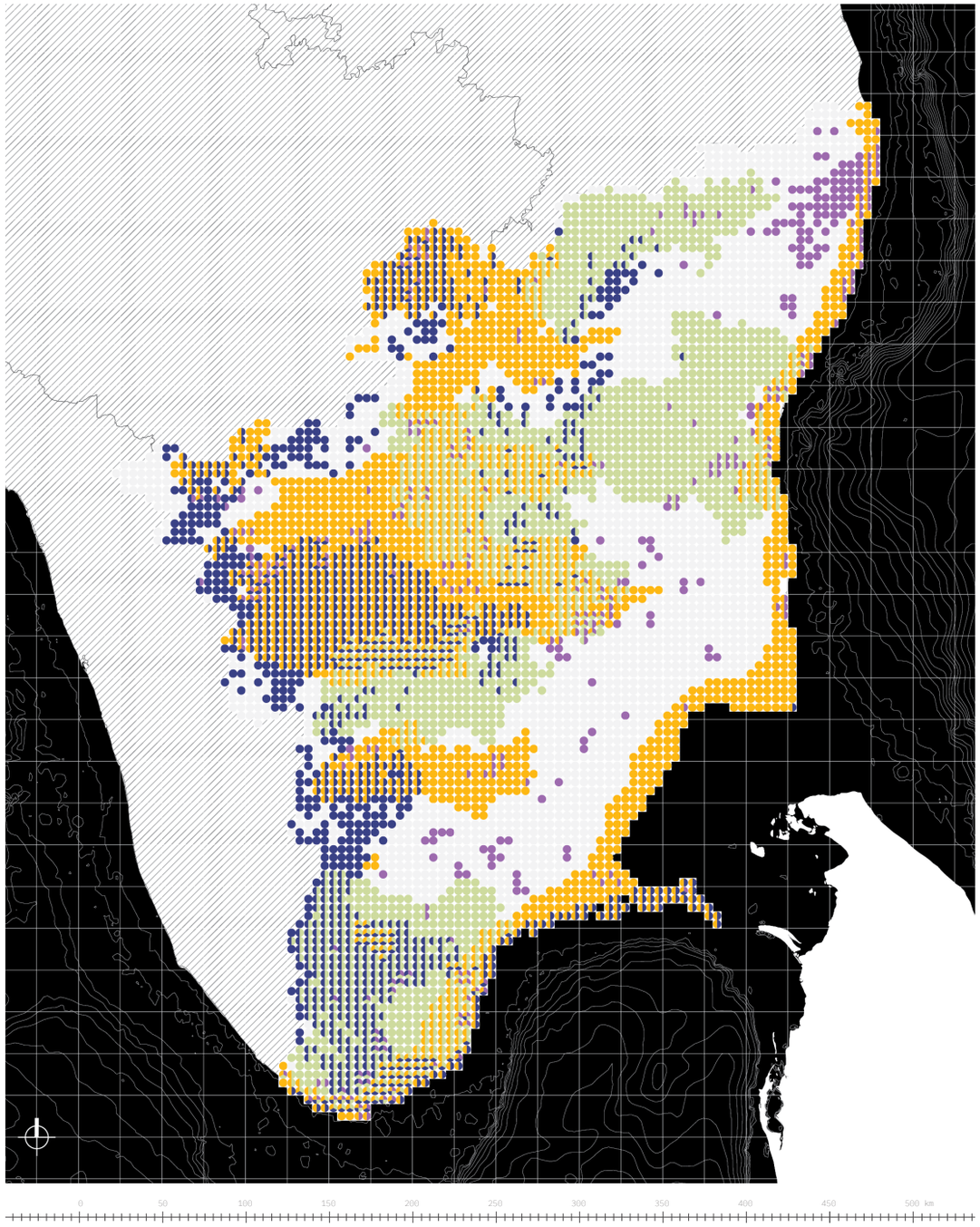


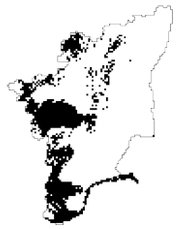
Fig 6.37: Hybrid energy potential of Tamil Nadu

Conclusions/Iterations.

The grading of the macro-region based on the six criteria elaborated before was then used as the input parameters to derive critical areas of overlap between potentials. In the example shown in the previous page, the multipotentialty of each square in terms of supporting energy development from multiple sources can be seen. Here, other iterations that were derived to identify areas for design are shown in Fig 6.38, and the detailed version of Output 7 is shown in Fig 6.39. This output was generated by overlapping the solar, wind, biomass and carbon energy potentials of each square. The output shows ***the concentration of energy potential in the south and western regions of the state.*** Of the two, the western region, falling mainly within the boundaries of *Coimbatore*, was chosen for detailed analysis.



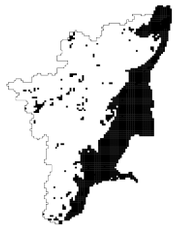
Output 1: Areas of highest solar energy potential (Grade 4,5)



Output 2: Areas of highest wind energy potential (Grade 3,4,5)



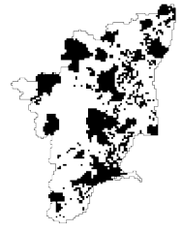
Output 2: Areas of highest biomass energy potential (Grade 4,5)



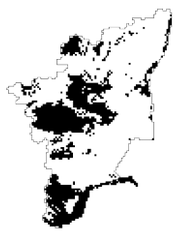
Output 4: Areas of highest carbon capture potential (Grade 4,5)



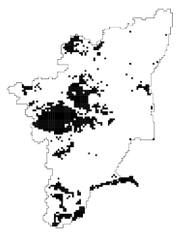
Output 5: Areas of highest spatial development potential, i.e. regions with wasteland concentrations



Output 6: Areas of highest social vulnerability and energy potential



Output 7: Areas of highest commulative enrgy potential (Derived from Outputs 1,2,3,4)



Output 8: Areas of highest energy potential and spatial potential (Derived from Outputs 5,6)



Output 9: Left empty to show how multiple iterations of energy development pathways can be generated using this model.

Fig 6.38: Outputs of the multi-criteria analysis

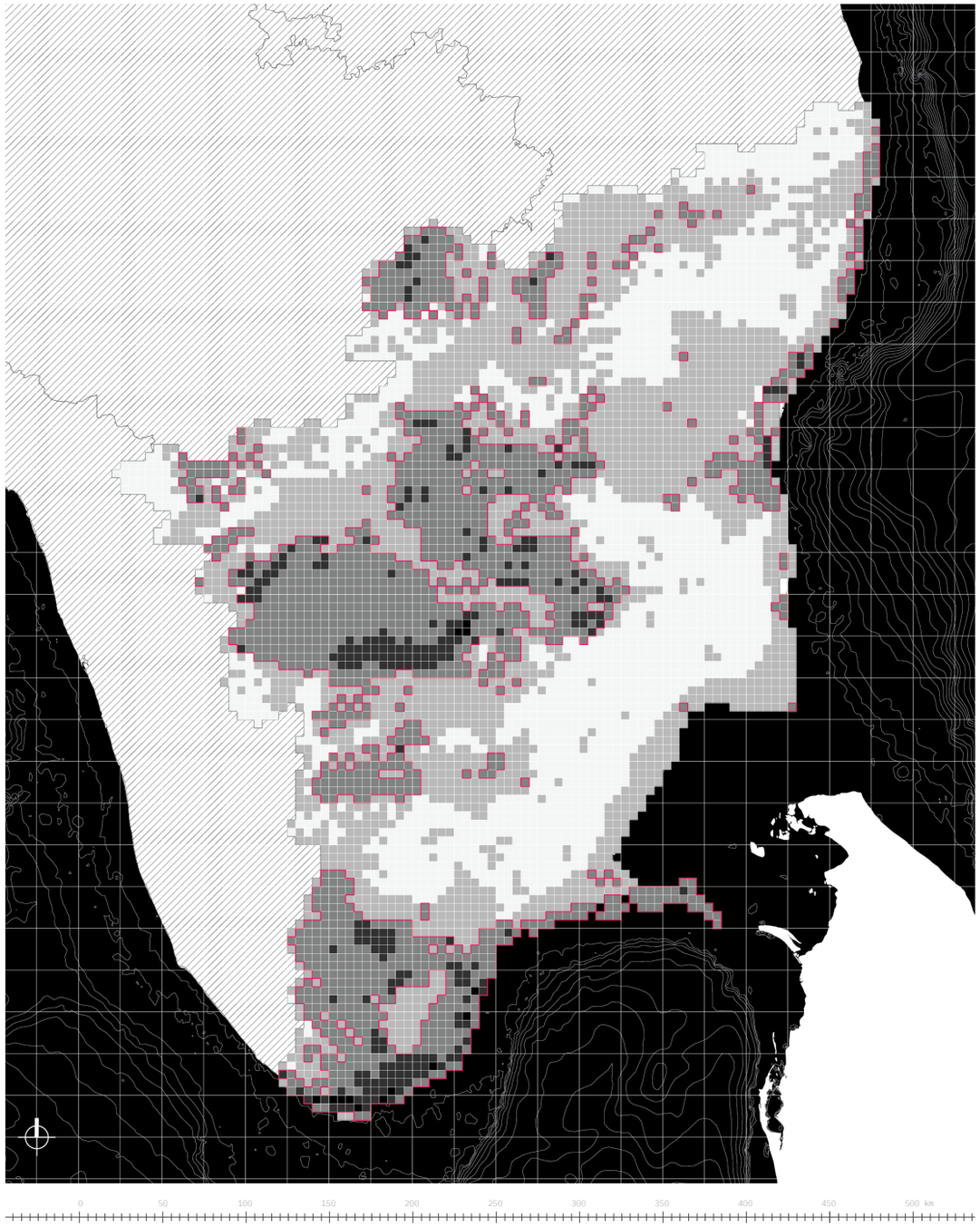


Fig 6.39: Detailed version of Output 7- the cumulative energy potential of the state

6.4 The Microregion

Evaluating spatial energy potential in Coimbatore microregion

Based on the macro-regional analysis of energy production landscapes, landuse patterns and energy access, and the initial findings from the problem analysis, **Coimbatore region in western Tamil Nadu** was chosen for further analysis. A prominent **industrial region with high energy demands**, diverse socio-economic groups, and high concentration of areas with both energy and spatial potential, Coimbatore is a promising region for further design experimentation. The region has been a testing ground for R.E. production since 1990s, with the earliest wind farms set up in Udumelpet area. The dispersed sites of existing R.E. extraction and its surroundings have been undergoing **rapid transformation for the last two decades**. In this light, the following pages present a brief spatial analysis of the micro-region and results of the multi-criteria analysis conducted at this scale. Based on these insights, two smaller areas were chosen for local spatial analysis.

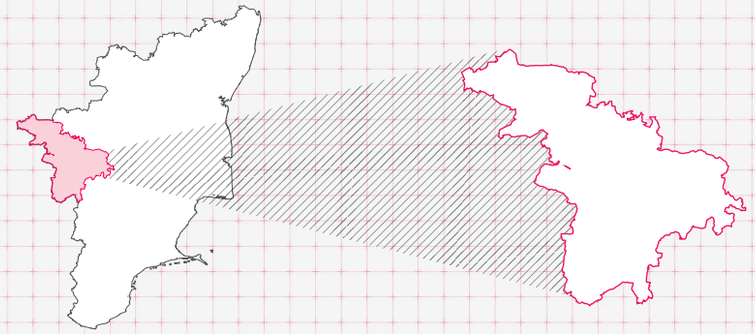


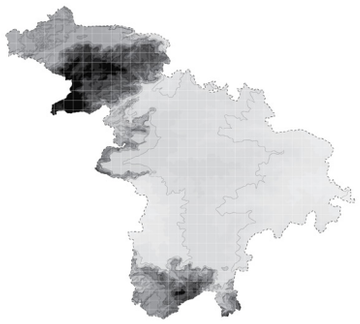
Fig 6.40: Aerial view of northern part of Coimbatore region, overlooking Coimbatore city and the Western Ghats mountain ranges behind.

Spatial analysis of the Micro-region.

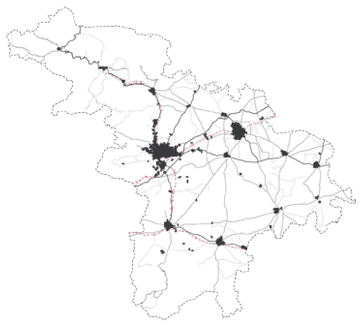
The territories created by division of the state into 12 distribution regions for energy governance, and a similar division of the state into 9 regions for spatial governance was carefully studied to delineate the area of study, i.e., Coimbatore region. Comprised of three administrative districts- Coimbatore, Tiruppur and Nilgiris- Coimbatore region is the fourth largest economy in the state, with the industrial (secondary) sector contributing to over 40% of the economy. The region serves as a major education, textile and software hub, along with a thriving poultry industry. Coimbatore city is the second largest city by area and population in Tamil Nadu after Chennai, the capital city. Fig 6.41 and Fig 6.42 present the spatial analysis of the micro-region, identifying major infrastructure networks, urbanised areas, agricultural lands, natural ecological networks.



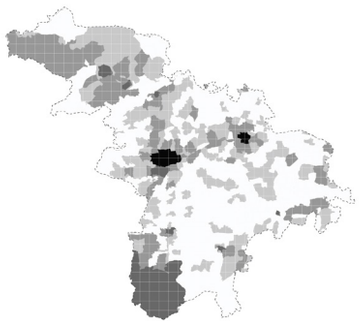
Administrative boundaries



Topography



Mobility Infrastructure



Population Density

Fig 6.41: Maps showing the spatial analysis of the region.

11.1271° N, 78.6569° E

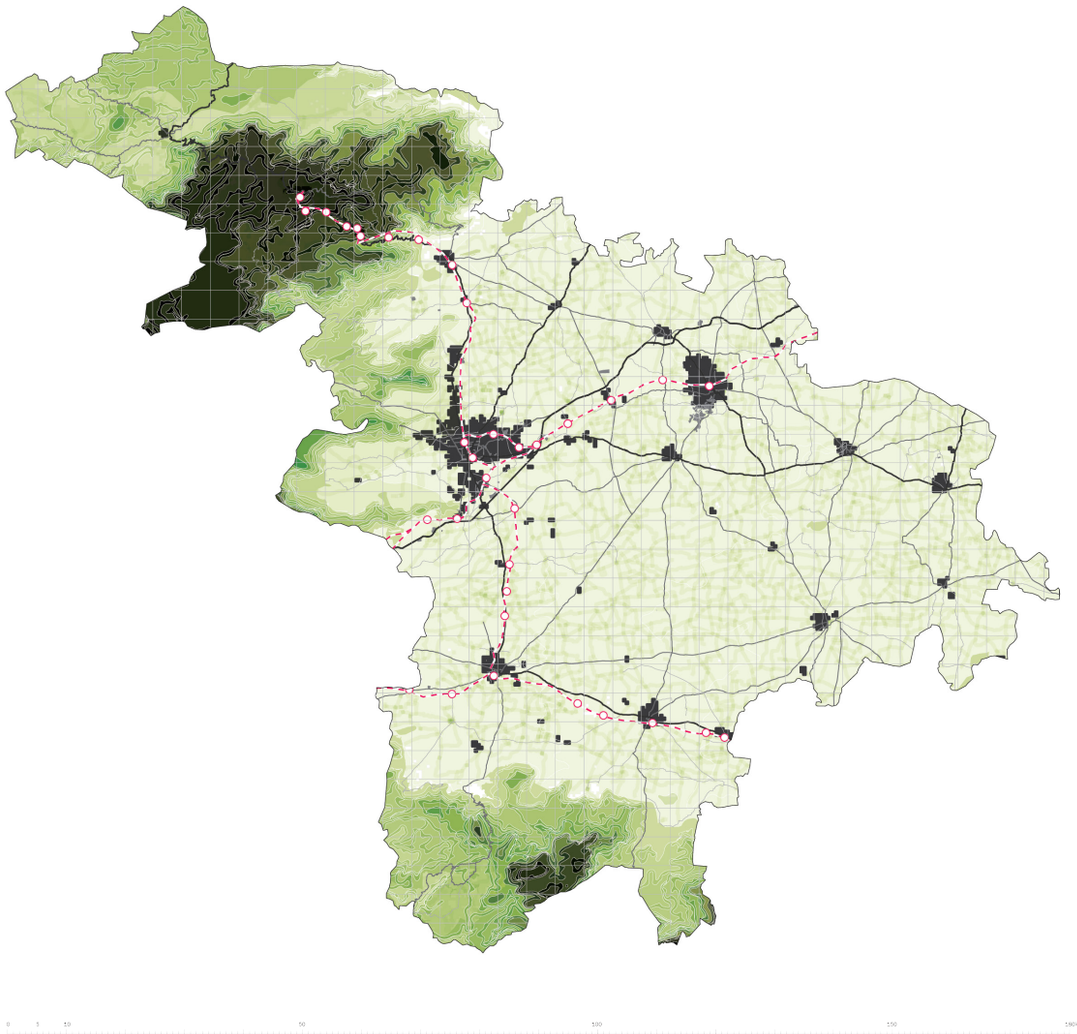
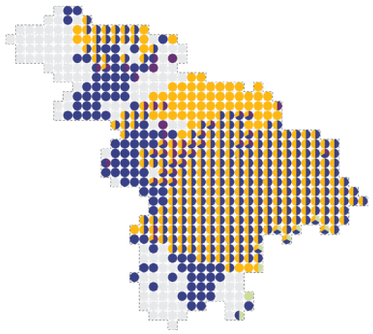
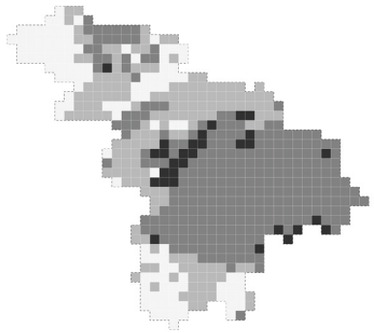


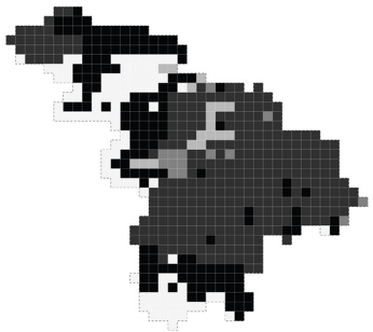
Fig 6.42: Map showing the landuse, infrastructure networks and built up area in the region.

Existing energy infrastructure in the Microregion.

The multicriteria analysis elaborated in Section 6.3, was repeated for the micro-region, to map opportunities for design. This gave insights on how the intensive agricultural and industrial practices in the micro-region have a high energy demand, partly met by the vast network of existing hydropower plants in the Western ghats mountains and wind farms in the east and south-eastern regions. Fig 6.44 shows the concentration of existing energy infrastructure, mostly large scale wind farms in the south eastern parts of the region. these farms set up over 20 years ago, are in need for upgradation. Moreover, the mono functional energy landscapes in the region have 'gentrified' the land, pushing out local farmers or causing occupational shifts in the local communities. The transition to renewable energy in Coimbatore region has to coexist with existing energy infrastructure, without disrupting local socio-economic practices. There is a urgent need to curb further energy sprawl in the region, one that can tap the potential of underused wastelands in the region for energy development, instead of agricultural lands.







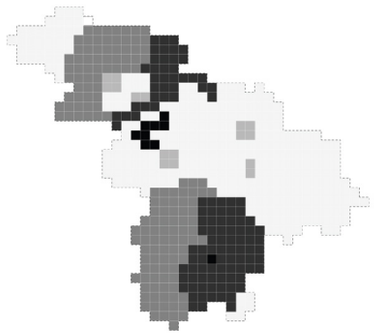


Fig 6.43: Maps showing the energy potential, spatial potential and social vulnerability in different areas of the micro-region

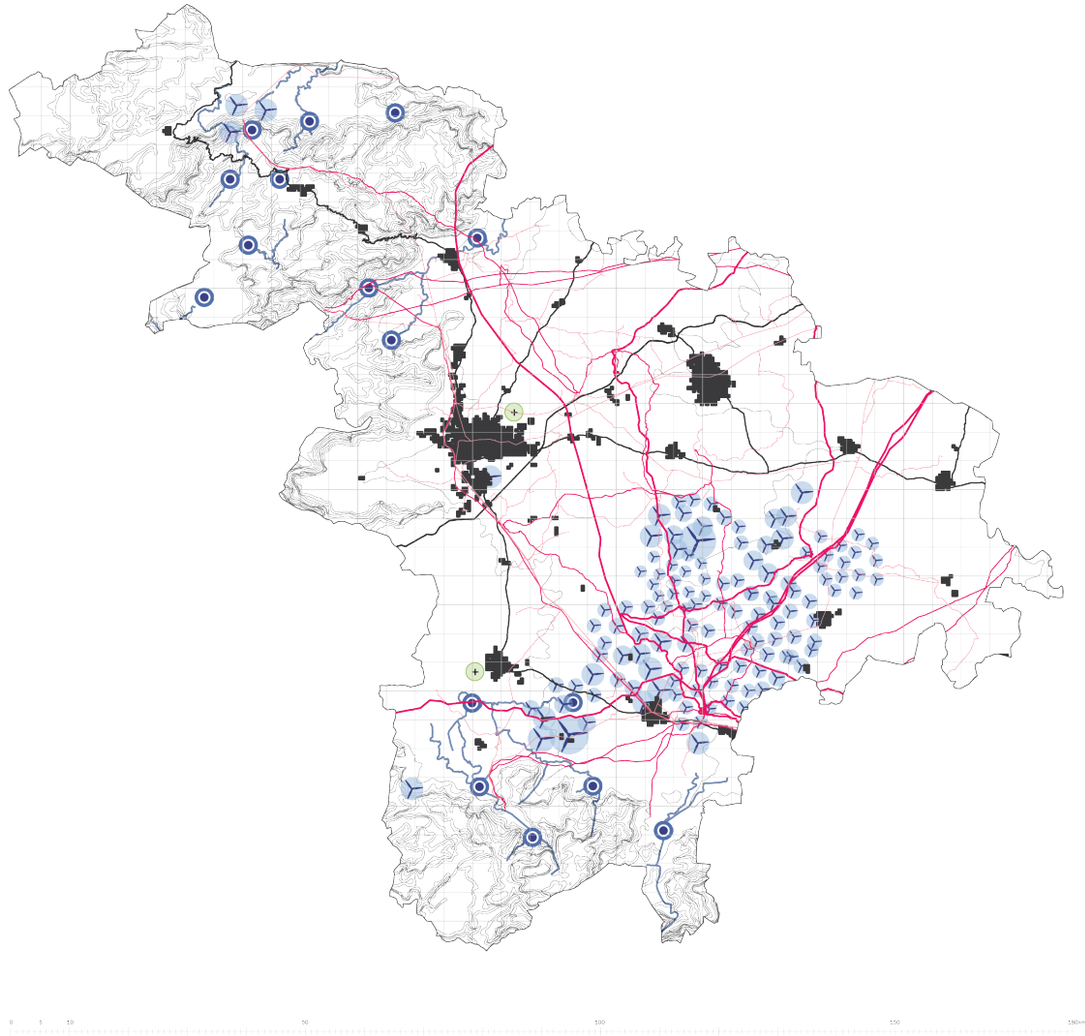


Fig 6.44: Map showing existing energy infrastructure in the region. Note the concentration of wind farms in the south east



Fig 6.45: Photograph showing the spatial quality of energy landscapes in Coimbatore region



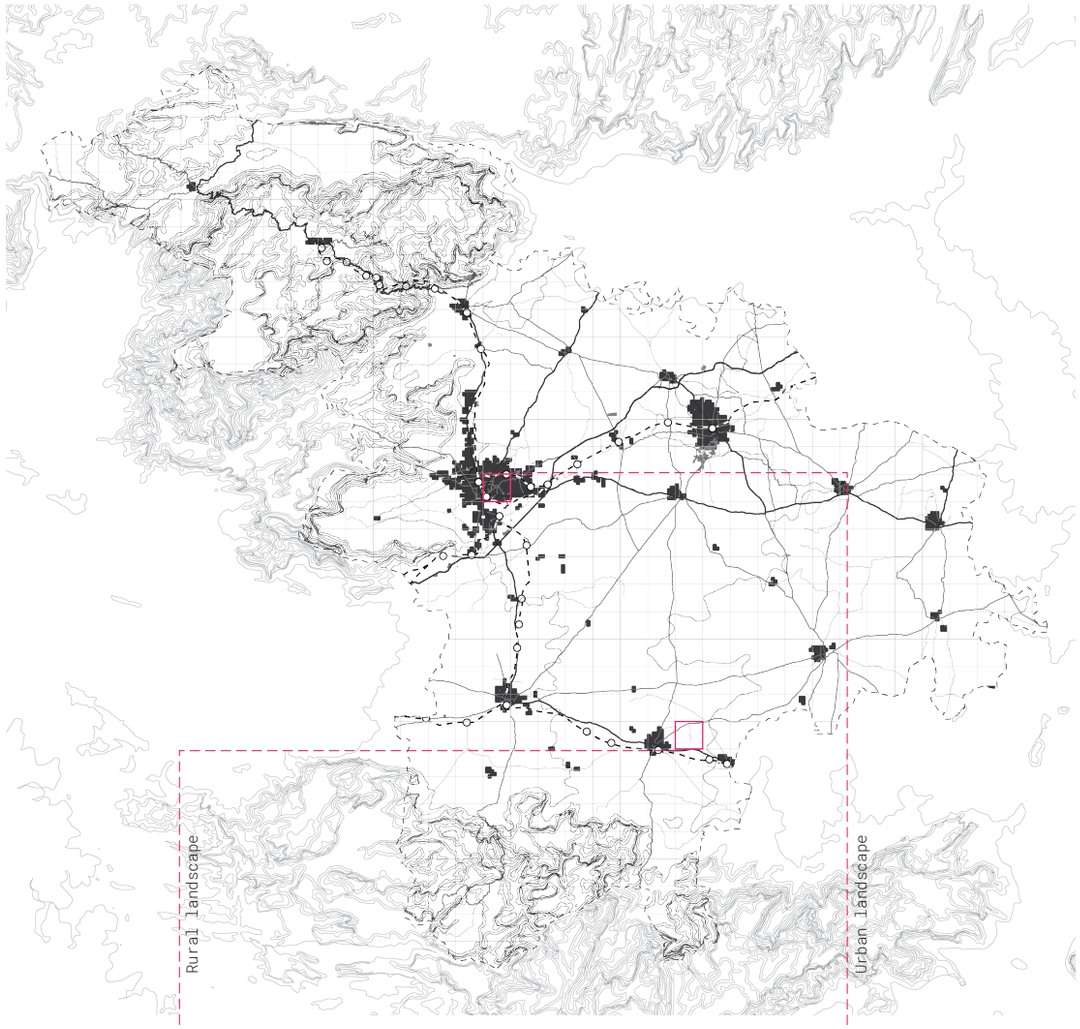
Fig 6.46: Photograph showing the spatial quality of energy landscapes in Coimbatore region

6.5 Strategic Zoom-ins

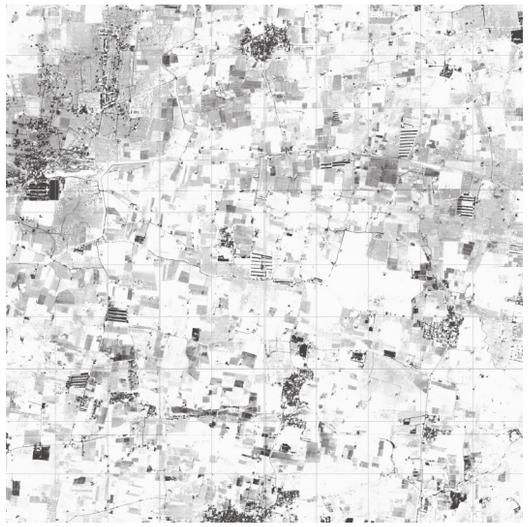
Based on the micro-regional analysis, two areas for strategic zoom-in were chosen within Coimbatore region. Strategic Zoomin A is in **Udumelpet area**, a primarily rural landscape. Strategic Zoomin B is in **Coimbatore city centre**, a dense urban area. The analysis of the contrasting areas provide a broad understanding of the contextual specificities that will aid or hinder the design implementation. The regional design and spatial strategies for energy transition in Tamil Nadu and its micro-regional translation will be tested in the zoom-ins. Each zoom-in is a 5km x 5km square which is maintained from the previous scale of analysis. The local spatial settings, social conditions, energy networks are mapped to derive opportunities for testing the design. The zoomins are illustrative of spatial conditions that exist in Tamil Nadu. The inferences learned at this stage can be used to guide interventions in other similar locations. The following pages present the spatial analysis of the two zoom-ins.

Fig 6.47: Maps showing the location of the strategic Zoomins

Micro-region: Coimbatore Region



Strategic Zoom-in A: Udumelpet Energy Hub



Strategic Zoom-in B: Coimbatore City Centre



Strategic Zoom-in A : Udumelpet Energy Hub ***(Rural)****

The first area of local analysis, Udumelpet Energy Hub, is located in the south-eastern part of the region in the foothills of the Western Ghats, and is the site of numerous wind farms, some set up over 20 years ago. The 5km x 5km area has fragmented coconut groves, and agricultural fields cultivating paddy, maize, etc (Fig 6.48). Vast areas of land owned by private wind energy companies (60 wind turbines of 1.5-2MW each are located within the 5km5km area) lie uncultivated, and have transformed into dry, infrastructural wastelands. Adjacent to the area is the Udumelpet 440kV substation, a major high-voltage substation that pools energy from various energy sites in the region and feeds to the macro-regional grid. Several 230kV, and 110kV power lines traverse the 5kmx5km area, to converge at Udumelpet substation. The area also has several micro-enterprises, poultry farms, and small scale industries with warehouses in the rural areas.

The area has ample **opportunities for bottom-up, community owned renewable energy**, apart from **densification** of existing wind farms. For example, the energy demand of the agricultural sector for irrigation, and operational energy demand of small industries and micro enterprises can be met through community owned R.E. The project presents a brief spatial analysis of the zoom-in, to identify opportunities for design in the following page. The inferences gained can be used as starting points for similar studies in other regions of the state.

* Based on observations from the field trip to the area, conducted in February 2019.





Fig 6.48: Photograph showing the spatial settings around energy infrastructure in Udumelpet.

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

Spatial analysis of the rural landscape.

From the spatial analysis of the area (Fig 6.49, Fig 6.50), the following inferences were gained:

1. Unused land occupied by wind turbines that require buffer spaces can be densified to include other forms of energy production within the same site.
2. Scope for upgrading transmission capacity for increased energy production in the future, to supplement the existing Udumelpet 440kv substation near the site.
3. Pilot projects for rural energy cooperatives for community owned R.E. can be initiated to support agriculture and coconut farming in the area.
4. Micro-enterprises and poultry farms that have large rooftop space can be incentivised to house solar panels on their rooftops.

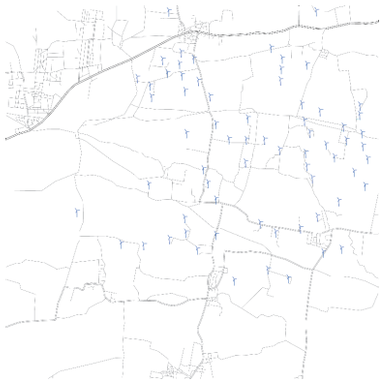
These opportunities will be explored in the translation and testing of the regional design and spatial strategies on the local areas.



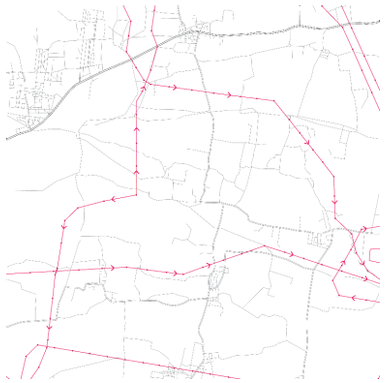
Built up area and infrastructure network



Agricultural fields



Existing energy sites- wind farms



Power transmission lines in the area

Fig 6.49: (left) Analytical layers used to map the opportunities for design

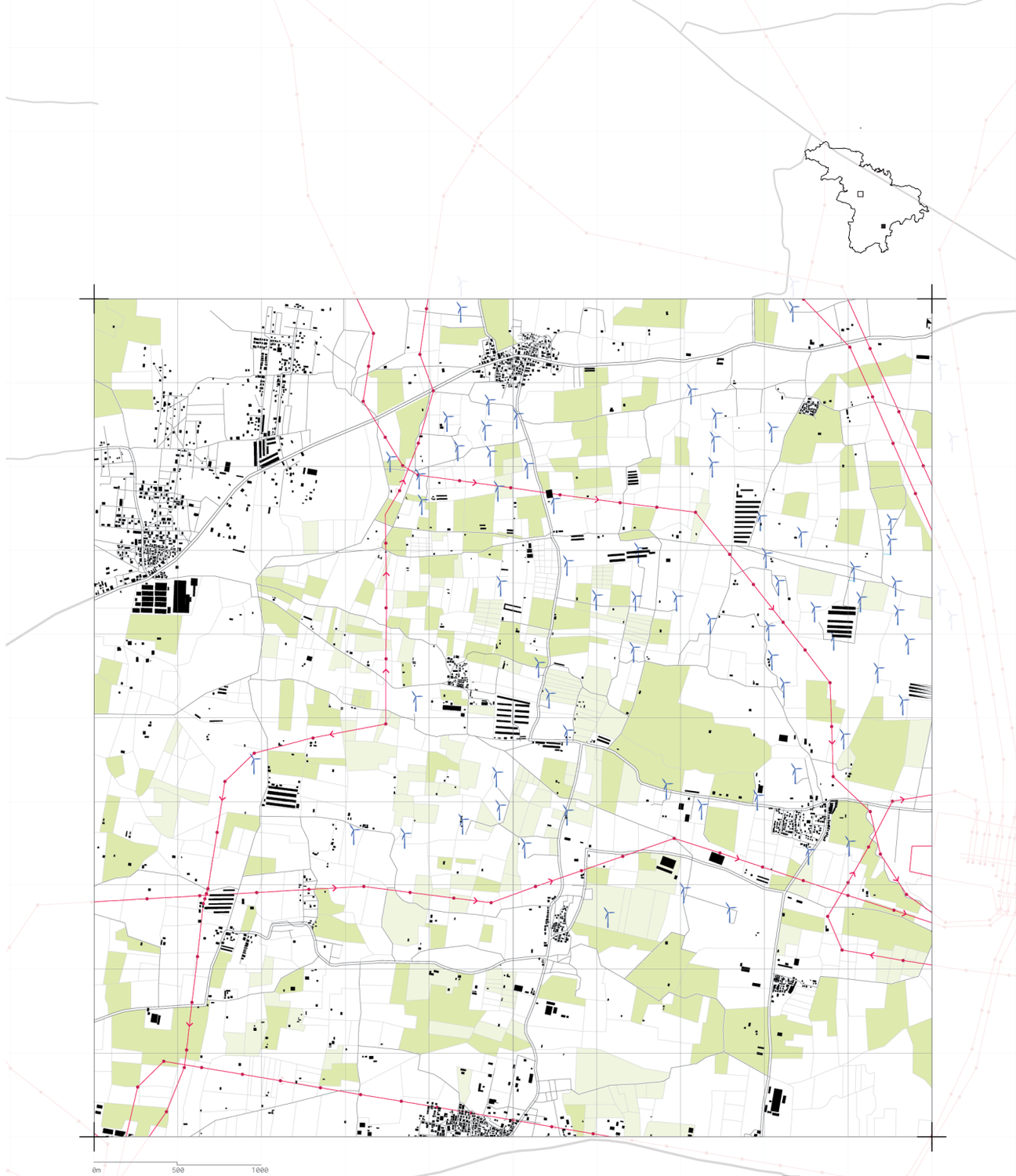


Fig 6.50: (right) Analysis of Udumelpet area showing the key elements of the landscape.

Strategic Zoom-in B : Coimbatore City Centre ***(Urban)***

The second area for local analysis is a 5kmx5km area of the central zone of Coimbatore city. With a population of 1.7 million, Coimbatore is the second largest city in the state. The city has an energy demand of 615MW per day, of which currently only 2% is from solar energy, and the rest from wind and fossil fuels. 12 substations in and around the city feed electricity to the consumers who are mainly domestic, commercial and institutional (CMC, 2012). Coimbatore is the only city chosen in Tamil nadu to be a part of the Solar City Mission*. Under the masterplan created under this scheme, the city has extensive plans for promoting renewables, and improving energy efficiency.

The project presents a brief spatial analysis of the zoom-in, to identify opportunities for design in the following page. The Solar City Masterplan has the potential to catalyse urban R.E production by extending governmental support to individuals and communities to produce their own energy. This planning momentum should be tapped to investigate all the ways in which **energy can be integrated with existing functions and spaces in the city**. The inferences gained at this stage can be used as a starting point for a similar study in other regions in the state, to tap the opportunities for a just energy transition.

* The Solar Cities Mission, launched by the Ministry of New and Renewable Energy (MNRE) brings 60 cities in the country under development as "Solar/ Green Cities" during the 11th Plan period. "The program aims at minimum 10% reduction in projected demand of conventional energy at the end of five years,(...) achieved through a combination of energy efficiency measures (5%) and enhancing supply from renewable energy sources (5%)." In Tamil Nadu, Coimbatore is the only city chosen to be developed as a Solar City. A Masterplan to implement the Solar Cities Mission was prepared for Coimbatore by TN's Department of Urban Development & Poverty Alleviation and the Coimbatore Municipal Corporation with financial support from the MNRE (CMC, 2012). The analysis and design proposal for Strategic Zoom-in B in this project will work under the framework of the Solar Cities Mission.





Fig 6.51: Photograph showing the spatial quality of Coimbatore City Centre

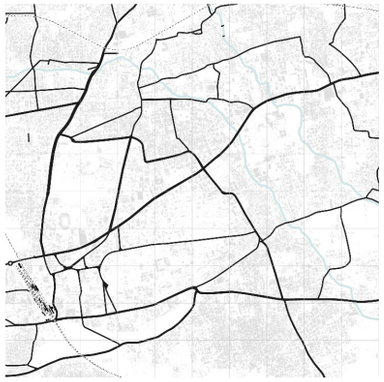
11.1271° N, 78.6569° E

Spatial analysis of the urban centre.

From the spatial analysis of the area (Fig 6.52, Fig 6.53) the following inferences were gained:

1. The Coimbatore Central Railway Station in the dense urban centre with major infrastructure networks converging there. Opportunity to explore how R.E. can support urban mobility.
2. Area has many large public and private instituional buildings with large rooftops that can bbe used for solar energy production. The underused area around Valankulam and Chinnakulam lakes in the south, also the site of the TNEB headquarters of Coimbatore region, shows potential for development.
3. Individuals and communities can be encouraged to install solar on their rooftops, promoting ciitzen participation.
4. Energy sharing projects and coproduction initiatives can be explored with energy vulnerable areas in the city (informal settlements and low income households).

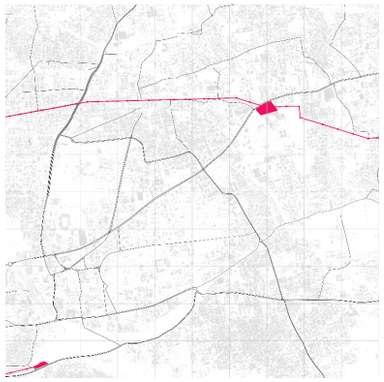
These opportunities will be explored in the translation and testing of the regional design and spatial strategies on the local areas.



Transport infrastructure lines



Urban blocks



Transmission lines and substations



Energy vulnerable communities

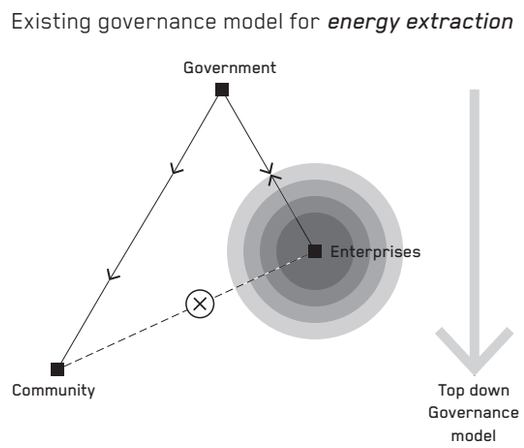
Fig 6.52: Analytical layers used to map the opportunities for design

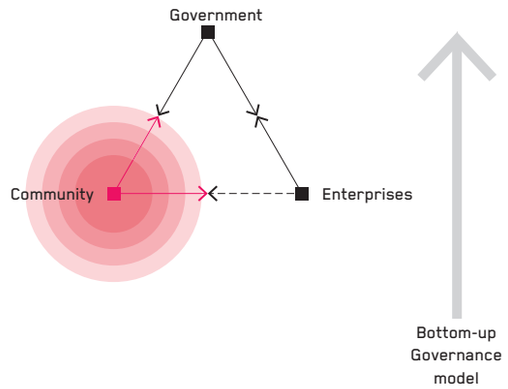


Fig 6.53: Analysis of Coimbatore city centre area showing the key elements of the landscape.

6.6 Stakeholder Analysis

The successful implementation of energy transition initiatives in the region largely depends on the degree of participation of diverse set of stakeholders and the coordination of their activities and interests through **consensus oriented decision making** (Ansell & Gash, 2008). To create the mechanisms for a collaborative governance model that supports bottom up initiatives, the existing model of energy governance is analysed in this section. The attitude, power and interests of various stakeholders from the public sector, private sector and civil society are identified, to align the design interventions with respect to their interests. Existing dependences, collaborations and conflicts between the stakeholders are also identified. The knowledge gained is then used to **foster new connections between them, and reinforce existing relationships** that create common benefits for those involved. The inferences from this analysis is used to develop the governance pathways for regional design.





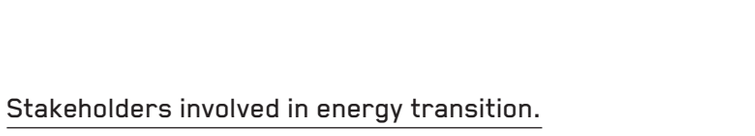
Target governance model for ***energy transition***

Fig 6.54: (left) Analytical layers used to map the opportunities for design

Stakeholders involved in energy transition.

As elaborated in Chapter 3, the primary stakeholders that the project address are the TNEB (Tamil Nadu Electricity Board), private energy companies and individuals or communities from the civil society. The role played by these three primary stakeholder groups and other secondary or tertiary stakeholders, with respect to the energy flow is elaborated in Fig 6.55. The actors involved in the four stages of energy flow- land management, energy production, energy transmission and energy consumption- are identified in Fig 6.56. Based on the identification of distinct stakeholder groups across sectors, is used as the base to analyse the influence and interests of the stakeholders.

1. Base: Defining the project scope in transition governance



2. Identifying the primary stakeholders relevant to the project

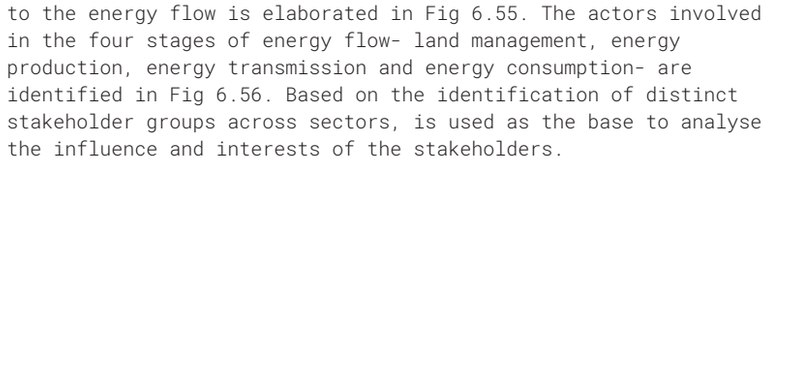


Fig 6.55: Methodology for arriving at the stakeholders

Steps in the energy flow	Stakeholders	Stakeholder Group
1. Land/Space Management Actors and stakeholders involved in the process of land/space acquisition and management for renewable energy development	**State and Centre** (land owners) **Govt bodies, agencies** (land owners) **TNEB/TANGEDCO** (land acquisitors) **DTCP** (landuse regulator)	Public Sector/ Government
	Large enterprises (land owners) Energy companies (land acquisitors)	Private Sector/ Enterprises
	Farmers **Landowners** (Individual, collective) **NGOs** (Environmental groups)	Civil Society/ Community
2. Energy Production Actors and stakeholders involved in the process of energy production, operation and maintanance from large scale and centralised to small scale and decentralised.	**TNEB/TANGEDCO** (investor/supporter) Governmental **agencies** **TNERC** (energy regulator)	Public Sector/ Government
	Energy companies **Industries** **Large enterprises** **Manufacturing industries** (of solar panels, windturbines,etc) **O&M companies**	Private Sector/ Enterprises
	Individuals Communities/Cooperatives Farmers	Civil Society/ Community
3. Energy Transmission and Distribution Actors and stakeholders involved in the process of energy distribution to end use consumers.	**TANTRANSCO**- Transmission **TANGEDCO**- Distribution	Public Sector/ Government
		Private Sector/ Enterprises
		Civil Society/ Community
4. Energy Consumption End users ofthe energy produced	Public Works Department (and other govt publicsector needs)	Public Sector/ Government
	Industries Offices Enterprises	Private Sector/ Enterprises
	Citizens	Civil Society/ Community

Fig 6.56: Stakeholders in Tamil Nadu's energy transition

Stakeholders involved in energy transition.

Here, the interests and influence (power) of the stakeholders are analysed to identify specific interventions based on the motives of the stakeholder group (Fig 6.57). Existing relationships, connections between the actors is mapped in Fig 6.58. Using this and the base, desired future connections are mapped over it to identify areas of collaboration. For example, the proposed collaboration between communities and the TNEB stresses the need for the involvement of public sector in aiding the coproduction of energy. The inferences gained from the stakeholder analysis is crucial for the development of mechanisms for the implementation of the regional design.

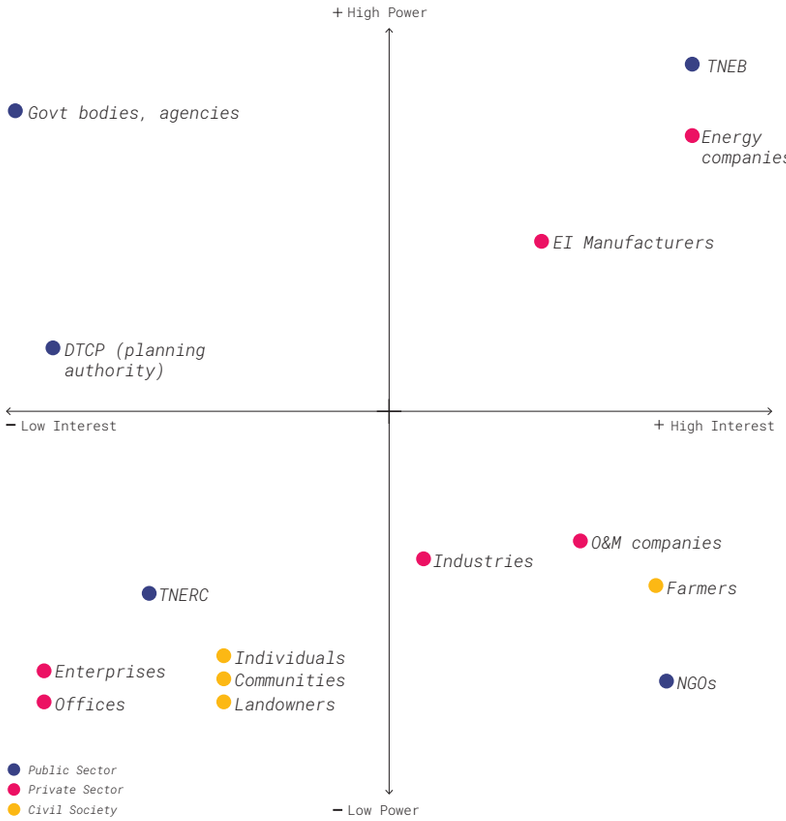


Fig 6.57: Stakeholders located in the power-interest diagram

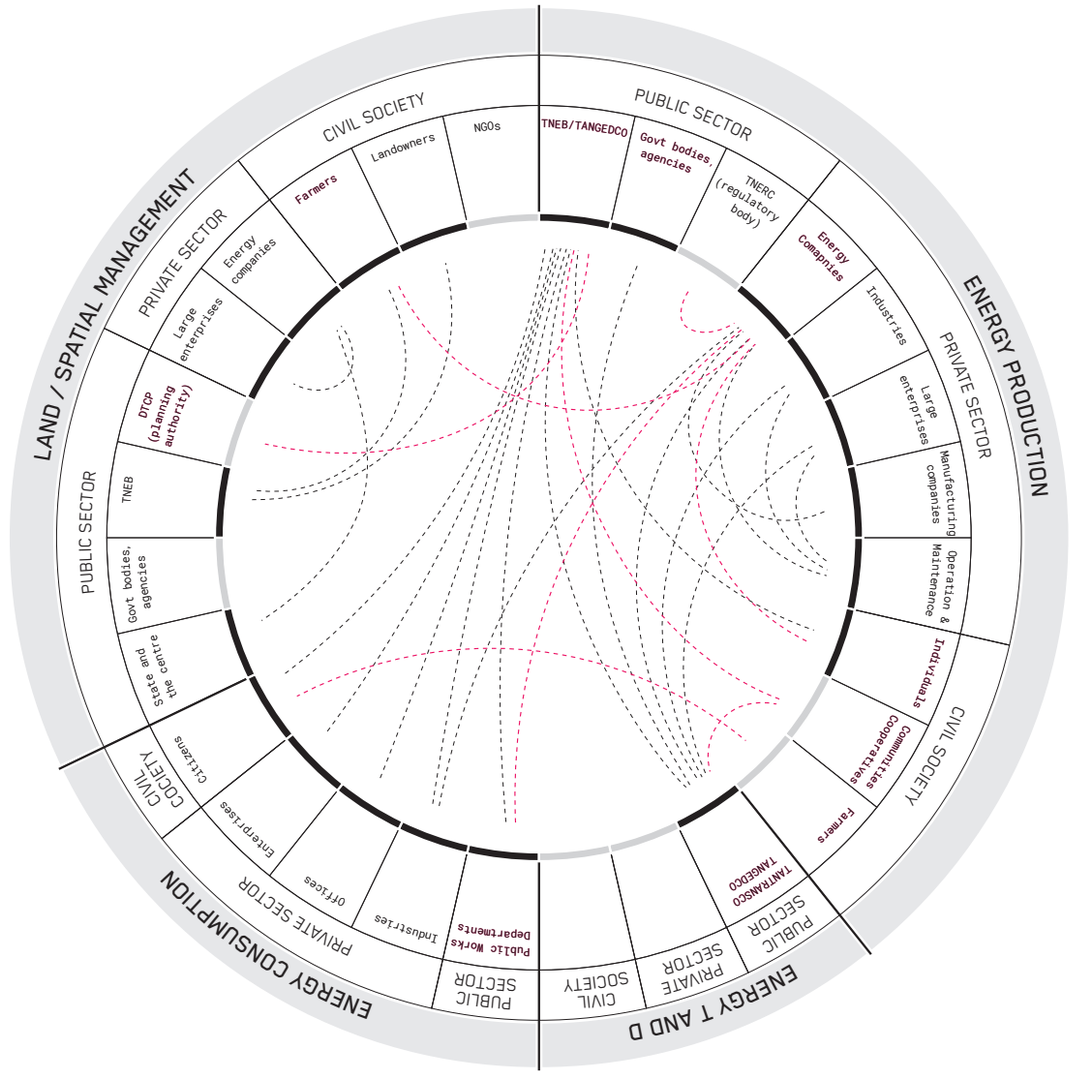


Fig 6.58: Existing and proposed connections between stakeholders

------ Existing stakeholder relationships

------ Desired stakeholder relationships in the project

Conclusions.

This chapter presented the multidimensional analysis of energy production landscapes in Tamil Nadu, and the methodology for the assessment of energy potentials, spatial suitability and social vulnerability in the macro-region. This chapter also introduced second and third scales of analysis- the Micro-region and the Strategic Zoom-ins. The macro regional analysis was supplemented by local spatial analysis of the Coimbatore (micro region), Udumelpet Energy Hub and Coimbatore City Centre (strategic zoomins). The analysis conducted across the three scales, highlighted the context specific challenges and opportunities for energy transition in Tamil Nadu. The opportunities for design inferred from the multidimensional analysis and the problem analysis (Chapter 3) are taken as the base for the development of a spatial vision and regional design for the state (Fig 6.60), elaborated in the following chapter.



Fig 6.59: Diagram summarizing the Chapter

Fig 6.60: Graphic showing the roadmap to design development.

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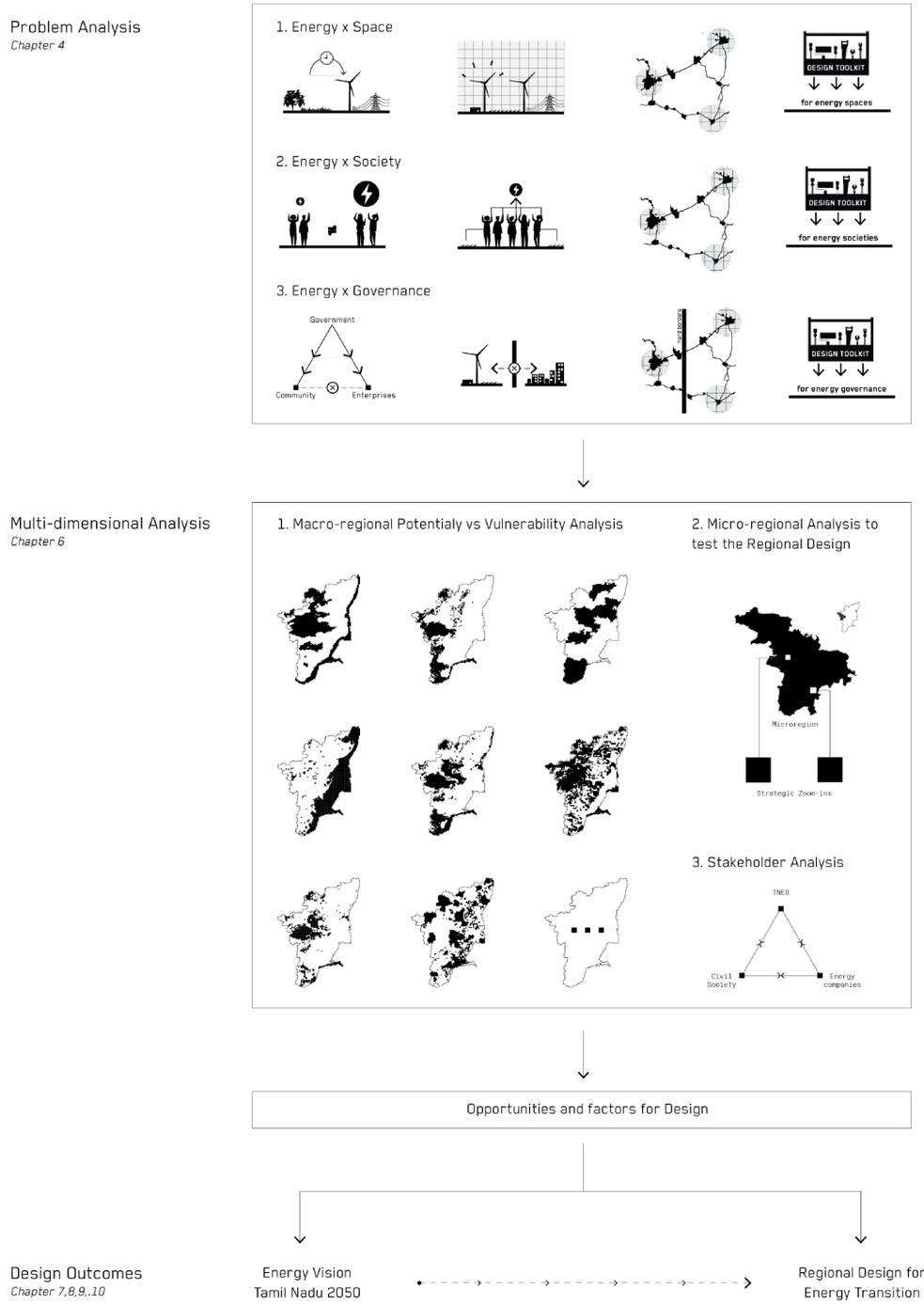
ROADMAP TO DESIGN DEVELOPMENT



7

Vision for Tamil Nadu 2050

Overview:

The research and analysis on the scope for energy transition in Tamil Nadu was processed to develop the Vision for Tamil Nadu 2050, a ‘spatial imagination’ and set of value systems to guide development of energy production landscapes in the region. This chapter elaborates on the vision for the state and the energy scenario for 2050 that sets the conditions and requirements for regional design.

Sections:

7.1. Energy Vision 2050
7.2. Scenario Definition

7.1 Energy Vision 2050

for an adaptive, inclusive and collaborative energy transition in Tamil Nadu.

The Vision for Tamil Nadu 2050 is a 'spatial' imagination to guide the transition to renewable energy. It defines **goals and values** for the emerging energy geographies in Tamil Nadu, and **principles** to guide the development of energy production landscapes in the state. These principles define standards for energy development, spatial qualities, social relationships, and political support systems that emerging energy landscapes in Tamil Nadu should have, to facilitate a 'just' energy transition. In other words,

> ..in 2050, the project envisions a holistic energy transition in Tamil Nadu, where constructed energy landscapes are **flexible, adaptive and coproduced in an inclusive and collaborative manner.**

The following pages will elaborate on the principles of the vision, proposed energy targets and the impacts that the chosen energy pathway has on society.



Fig 7.1: Image illustrating the values of the vision- adaptivity, inclusivity and collaboration.

Foundations of the Vision.

The project envisions a energy system that respects the limits of the natural environment and creates room for alternative practices and forms of extraction without exploitation. This post extractivist economy requires a 'different kind of imaging and imagination, action and retro-action, forms of representation and reclamation', to undermine neoliberal strategies of land dispossession to produce energy and the resulting uneven forms of development (Belanger, 2018).

By building a roadmap till 2050, the Vision sets the course for long term planning with foresight and acumen. The Spatial Energy Vision for Tamil Nadu 2050 borrows its values from the 'Manifesto for the Design of Energy Geographies', developed in the course of the project (Refer Appendix). The Manifesto is an assertion of what energy geographies ought to be and what qualities they should have, to guide for the design of energy geographies. Here, the vision for the state was developed by adapting the theoretical knowledge and normative values of the Manifesto the region, resulting in nine principles to define the development of energy landscapes (Refer Appendix for detailed elaboration).

Goals and Values of the Vision:

Adaptive energy landscapes:
Energy geographies should have a high degree of flexibility and dynamism to adapt for future energy transitions. The multitude of energy infrastructures, that intersect and overlap across various geographic scales must be integrated to form a transcalar network of future energy geographies, that reinforce each other. Apart from the systemic adaptability, the future energy geographies must create a sense of place, and manifest spatial cues for deriving memory, meaning and symbolism from energy 'objects' and associated spaces.

Inclusive energy transition:
The future energy geographies should create the framework for energy justice (Bouzarovski & Simcock, 2017) that enhances the equitable access to, and distribution of its benefits to the disadvantaged, socio-spatially segregated communities. The alternate economic model should support coproduction of R.E to increase citizen participation and social entrepreneurship in renewable energy transition.

Collaborative spatial energy governance:
A collaborative spatial energy governance that involves the community and private sector in decision making at local and regional geopolitical scales should be formed to stakeholders from the civil society. By using both formal and informal tools of governance, mutually reinforcing relationships should be fostered between the multiple stakeholders of energy transition.

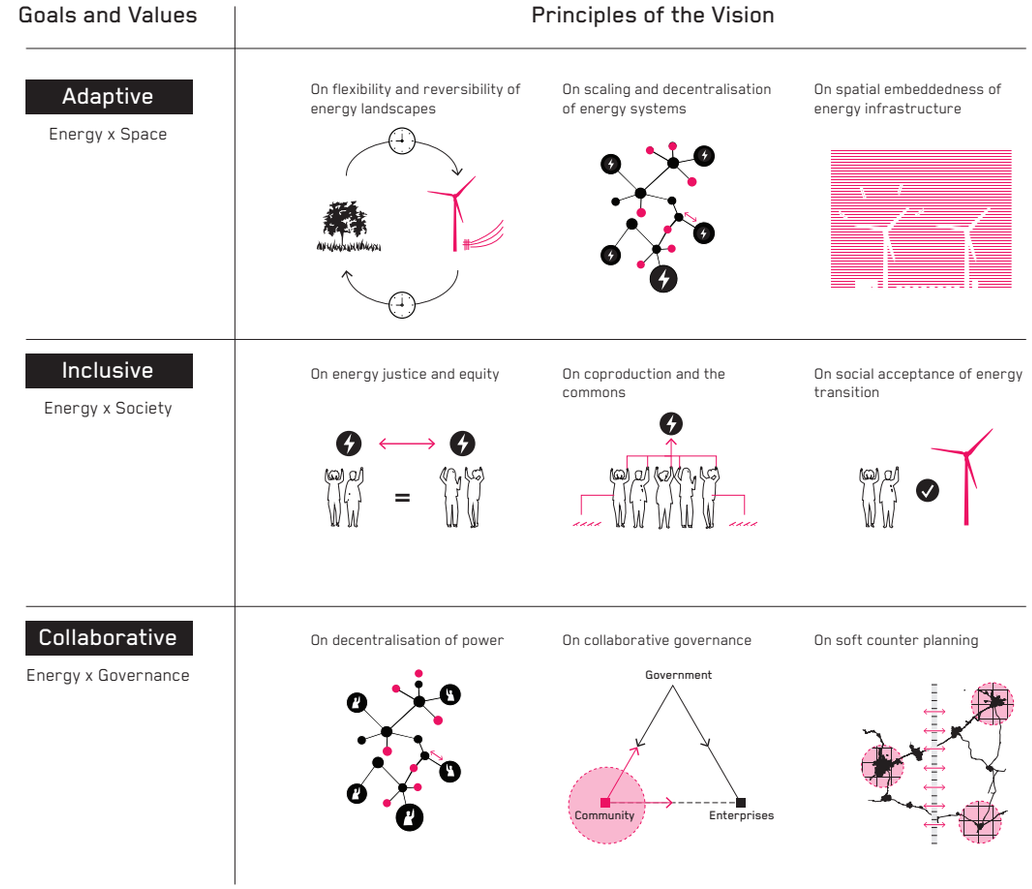


Fig 7.2: Diagram showing the goals, values and principles of the vision

Principles of the Vision:

1. On flexibility and reversibility of energy landscapes
2. On scaling and decentralisation of energy systems
3. On spatial embeddedness of energy infrastructure
4. On energy justice and equity
5. On co-production and the commons
6. On social acceptance
7. On decentralisation of power
8. On collaborative governance
9. On counter-planning

Here, the goals, values and principles defined in the project will act as normative guidelines for the development of the regional design. The Vision also plays an important role in ensuring that the values of adaptivity, inclusivity and collaboration are added at every stage of energy development. In this way, the transition to renewable energy can be harnessed as the vehicle for overall spatial and socio-economic development of the region.

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7.2 Scenario Definition

Since energy transition is a long term process, the Vision sets the course for the year 2050, and defines energy targets, desired R.E. mix and estimates the amount of land that will be transformed in the process. Fig 7.3 defines in detail the energy scenario and demand that the design will work to meet. The project sets the **desired renewable energy share in 2050 at 60%,** which can be met through a combination of energy sources and landscape typologies. The regional design will take these values as the base for guiding decisions regarding the scale, location and regional distribution of energy production landscapes. The target values set to achieved by specific energy types, like small solar rooftop PV, also ensures that citizen participation in energy production is written into the strategic plan. With the successful implementation of the Energy Vision through regional design and spatial strategies, Tamil Nadu can benefit from a **five fold increase in R.E installed capacity.**

Transition timeline.



Energy demand Projections.

2018*		2050**
2500 Gwh	**Solar**	**41000 Gwh**
N/A	Solar PV on urban rooftops	11000 Gwh
2500 Gwh	Large scale solar farms	24000 Gwh
N/A	Solar PV along infrastructure (road,rail)	6000 Gwh
12000 Gwh	**Wind**	**120000 Gwh**
12000 Gwh	Windfarms on passive farmlands *	82000 Gwh
N/A	Offshore windfarms *	15000 Gwh
N/A	Windturbines along infrastructure *	23000 Gwh
1800 Gwh	**Biomass**	**8000 Gwh**
N/A	Biomass cultivation from wastelands	4000 Gwh
1800 Gwh	Biomass from agricultural residue	4000 Gwh
85950 Gwh	**Carbon-based**	**118000 Gwh**
57950 Gwh	Thermal Power Plant	82000 Gwh
21000 Gwh	Nuclear Power Plant	30000 Gwh
4000 Gwh	Gas fields	6000 Gwh
8000 Gwh	**Other (Hydro, IPP)**	**15900 Gwh**
110250 Gwh	**Total energy production/year**	**302900 Gwh**

Installed infrastructure capacity.

In 2018*

36%
Renewable energy share in total energy demand in 2018

11650MW
Renewable energy share in total energy demand in 2018

In 2050**

60%
Renewable energy share in total energy demand in 2050

52000MW
Renewable energy share in total energy demand in 2050

Fig 7.3: Diagram defining the scenario that the design will work towards.

* Values based on current energy demand and energy mix in the production (India Energy Data, 2018)
** Values based on the IESS 2017 (India Energy Security Scenarios 2047) online dashboard (IESS 2047, 2018)
The methodology used to make the energy projections is explained in Chapter 5.

Conclusions.

This chapter presented the project's Vision for Tamil Nadu 2050, a spatial imagination to guide the design of emerging energy geographies in Tamil Nadu (Fig 7.5). The Vision also set tangible energy targets to work towards, and presented the set of goals, values and principles to ensure that energy development respects the contextual conditions and spatial restrictions, prevents ecological degradation and generates socio-economic capital for the stakeholders of the transition. The calculation of energy targets was based on the spatial analysis that identified the potentials and vulnerabilities of different regions in the state (Section 6.3).

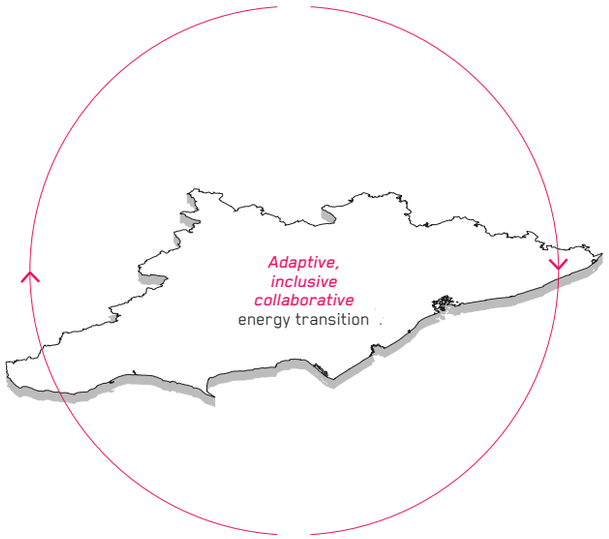

Fig 7.4: Diagram summarizing the chapter





Fig 7.5: Image showing the spatial and socio-economic impacts of implementing the vision

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8

Regional Design and Spatial Strategies

Overview:

This chapter introduces the regional design for energy transition proposed by the project. The regional design for energy transition in Tamil Nadu is a layered assemblage of spatial strategies and design solutions, brought together by the overall Strategic Plan for the region. This chapter elaborates in detail, the six spatial strategies for the macro-region to implement Vision 2050. Finally, a toolbox of solutions derived from the strategies is presented. The toolbox is a 'pattern language' (Alexander, 1977) for the design of energy geographies in developing contexts like Tamil nadu, India.

Sections:

8.1. Components of the Regional Design
8.2. The 6 Strategies

8.1 Components of the Regional Design

The ‘regional design’ for energy transition in Tamil Nadu aims to create a framework for development of adaptive energy production landscapes that add socio-economic capital to the place and local communities around energy development sites. It is a layered assemblage of **spatial strategies** and design solutions, brought together by the overall **Strategic Plan** for the macro-region (Fig 8.1). The spatial strategies and the Strategic Plan for the macro region are then translated to suit the spatial conditions and social settings in the micro-region, to **test the feasibility and local implications of the regional design**. To organize the implementation of the design, **governance of energy development and phase wise development** plans are also elaborated. The inferences gained from the multidimensional analysis and the goals set by the Vision 2050 were the basis for the development of the regional design. In this Chapter, the first component- the six spatial strategies- is presented.

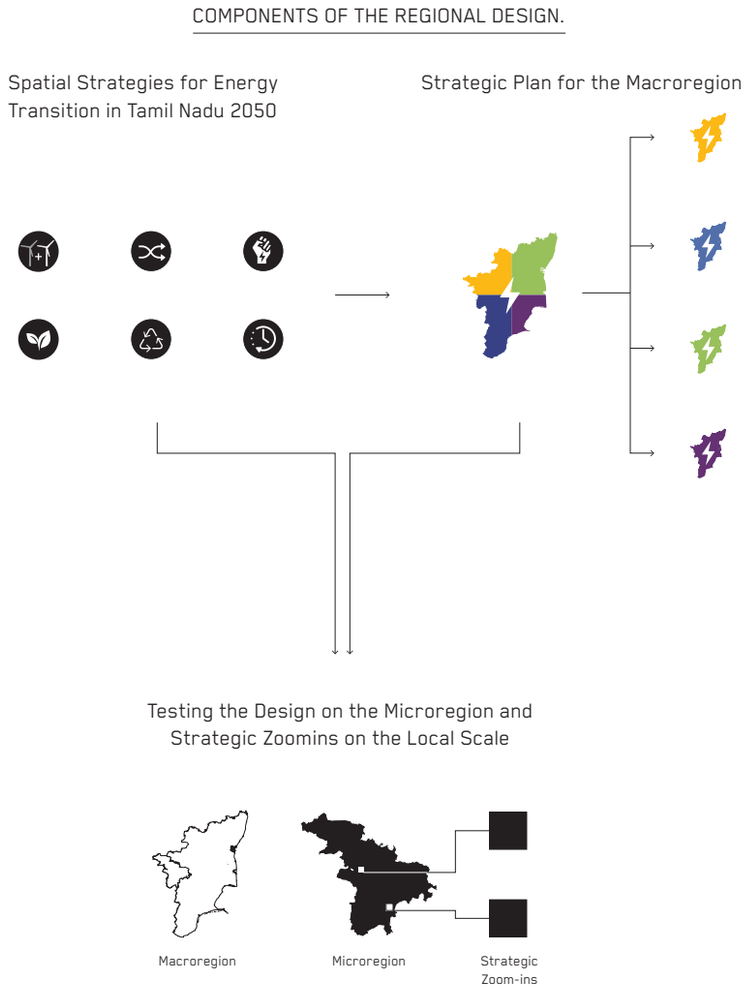

Fig 8.1: Diagram showing the components of the regional design and scales of application.

8.2 The 6 Strategies

The regional design is assemblage of **six context specific spatial strategies** that act as guidelines for energy development in Tamil Nadu. The spatial strategies range from actions to densify existing energy landscapes to policies regarding energy efficiency measures, and provide pathways for the implementation of Energy Vision for Tamil Nadu 2050. The strategies drive the macro-regional integration of the transition to renewables and inform long term local visions and development plans that transcend administrative borders. The following pages explain each strategy in detail- **the aim, spatial translation of the strategy on the macro-region, the set of tangible design solutions to implement the strategy, the spatial interpretation of the transformed landscape and the stakeholders** involved in its realisation. The development of the strategies was informed by the region-specific opportunities and issues, and diversity of existing energy landscapes across the territory.

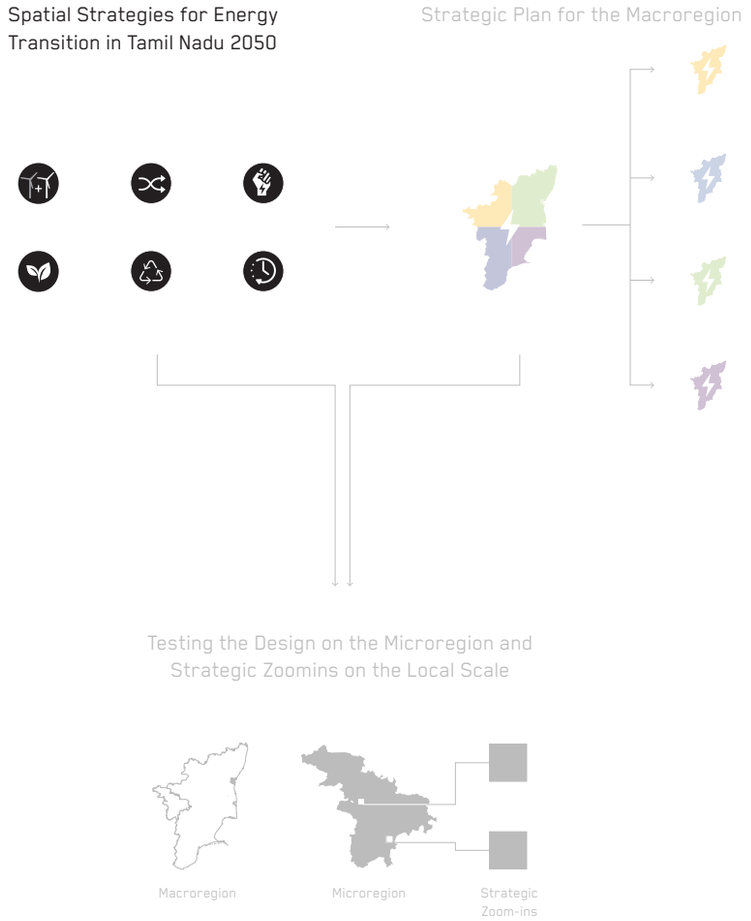

Fig 8.2: Diagram showing the components of the regional design and scales of application.

Spatial strategies for creating energy geographies of the future in Tamil Nadu, India.

Densify around existing energy production sites.

Concentrate energy development around existing windpasses and sun-intense regions that have existing energy sites to prevent energy sprawl. Ensure that the densified energy landscape is heterogenous to maximise power density.

Create multi-functional energy landscapes through cross programming.

Combine energy production with other functions like mobility, urban waste management, public services, etc to create mutually benefiting and reinforcing relationships across sectors

Coproduce energy with the community in urban and rural areas.

Democratise energy transition by involving individuals, communities and cooperatives through co-production of renwable energy along with private or state owned energy enterprises to support livelihoods and improve access.

Add ecological value through landscape integration in energy development.

Enforce policies to supplement any energy development with the creation of landscape integration measures to add ecological value and resilience through energy development. Wasteland regeneration is a key component of this strategy.

Repower and Reconfigure the post-carbon energy landscapes.

Reconfigure the existing fossil fuel based energy landscapes to adapt to the renewable energy paradigm. This involves ecological remediation and downsizing of resource extraction zones and Carbon Capture and Storage.

Increase flexibility through seasonal activation of energy landscapes.

The new renewable energy landscape is temporal, dynamic and constantly fluctuating. This strategy provides pathways to enable seasonal activation of energy landscapes and opportunities for utilisation during the off-seasons.

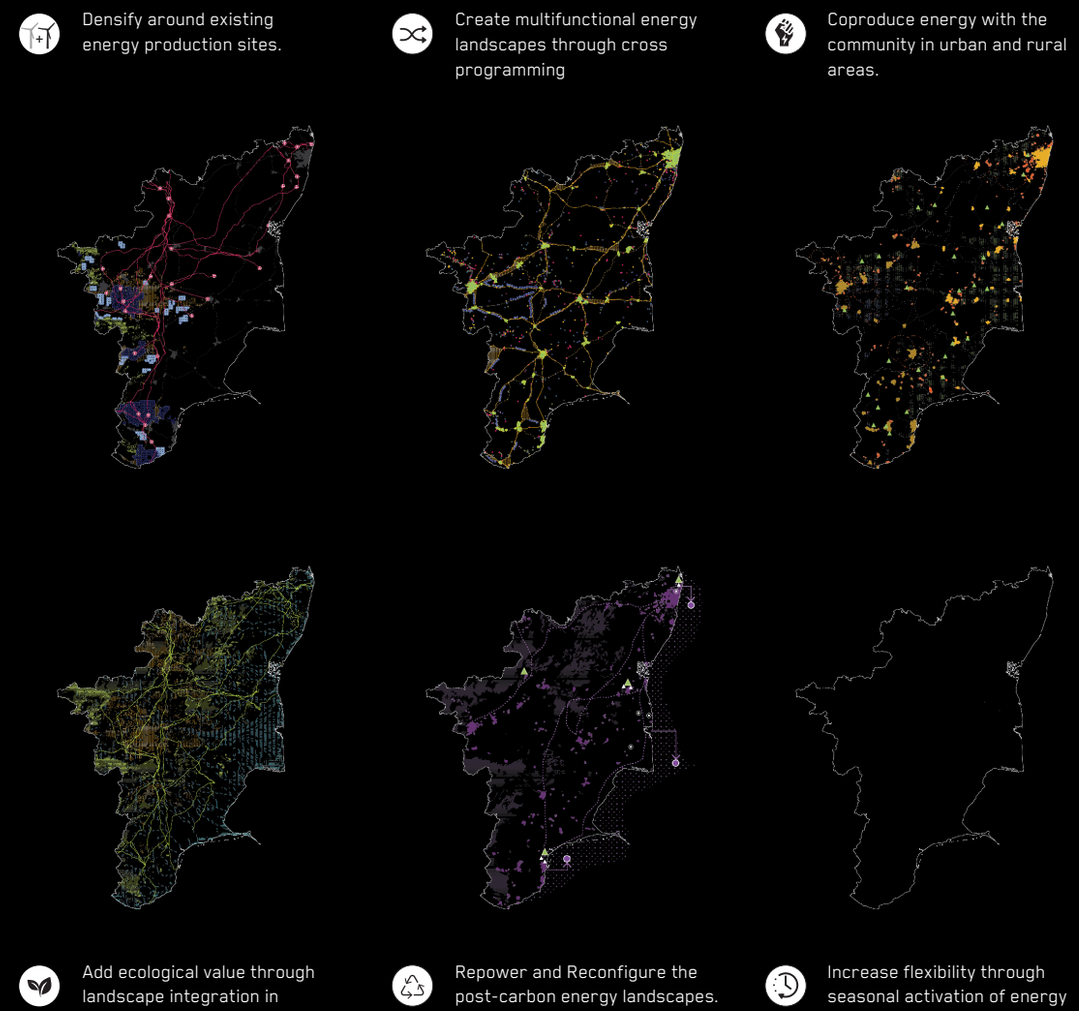

Fig 8.3: Spatial strategies for energy transition in Tamil Nadu 2050

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Strategy 1 - ***Densify*** around existing energy production sites.

One of the overarching issues addressed through the research and design is the rapid transformation fo landuse patterns and reorganisation of territories through extractive energy development. This strategy aims to **prevent 'energy sprawl' by incentivsing the densiification of existing energy production areas** (See Fig 8.4). The strategy will ensure minimal transformation of agricultural land and maximise the efficiency of the energy system by making use of the preexisting power transmission networks in the region. It comes into play primarily in the south and south-western regions of the state that have considerable wind and solar energy farms, some in operation since 1984.

A key component of this strategy is to identify and upgrade old energy sites with run down infrastructure in areas of high energy potential, and strengthen transmission capacity of the power grid to support densification. Apart from this, the strategy also promotes the inclusion of diverse energy types to create heterogenous energy landscapes that mutually reinforce one another. The following pages elaborate on the key actions that translate the strategy into design interventions, the spatial interpretation of the strategy and the stakeholders involved in its implementation.

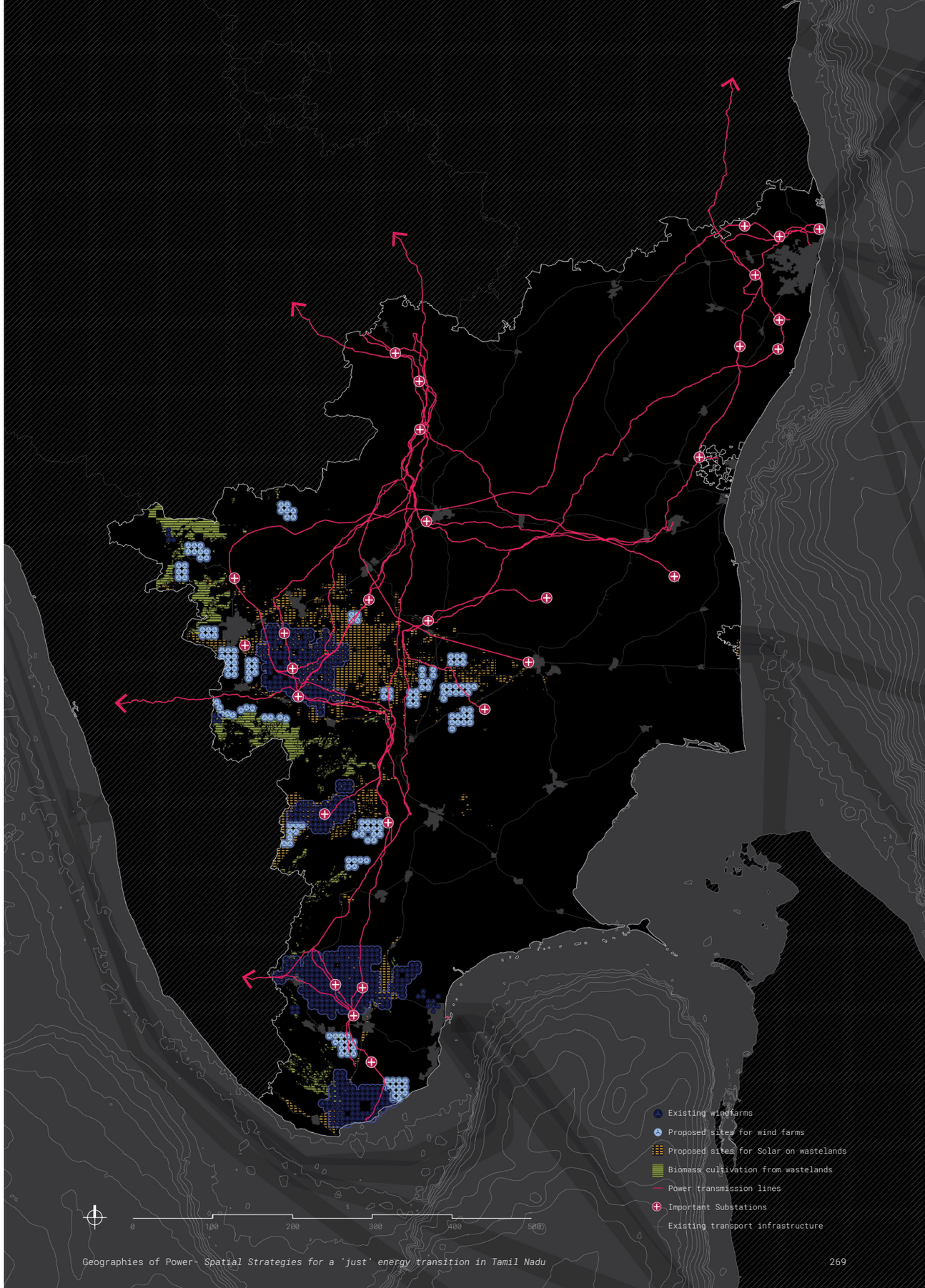


Fig 8.4: Macro-Regional distribution of densification strategies.

S1: Design interventions/Actions.

1. Densification of energy sites.

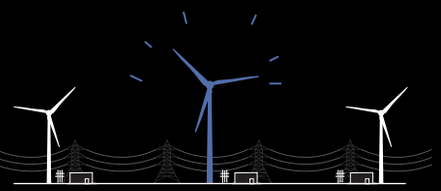
Build in the gaps between existing wind turbines that are under developed. Akin to urban densification, energy densification taps the potential of underutilized spaces within existing energy sites that are well connected to the grid. By finding gaps between existing energy sites, and densifying it, rapid transformation of land can be avoided.



Macro-Regional Plan



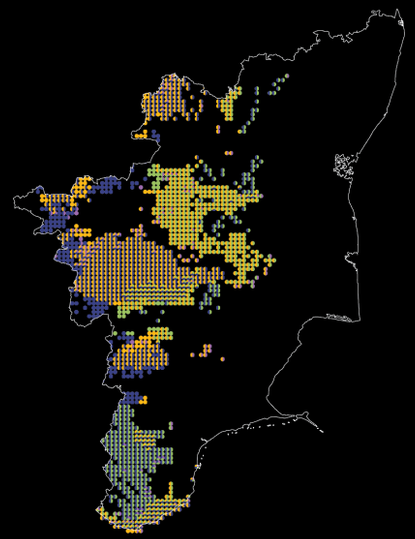
Existing situation



Proposed situation

2. Diversify energy development.

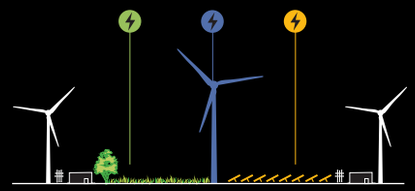
Diversify energy development to include a mix of energy typologies to optimise the landuse. For example wind energy development can be supplemented with solar PV or biomass cultivation in the underutilized space around the turbines to increase the power density of the site. This hybrid energy development controls energy sprawl in the region.



Macro-Regional Plan



Existing situation



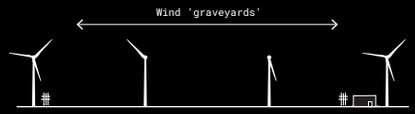
Proposed situation

3. Upgrade outdated energy infrastructure.

Upgrade outdated wind turbines installed in the beginning of the R.E wave in Tamil Nadu Akin to urban redevelopment to support urban densification, redevelopment of old energy sites will give better long term returns in the transition.



Macro-Regional Plan



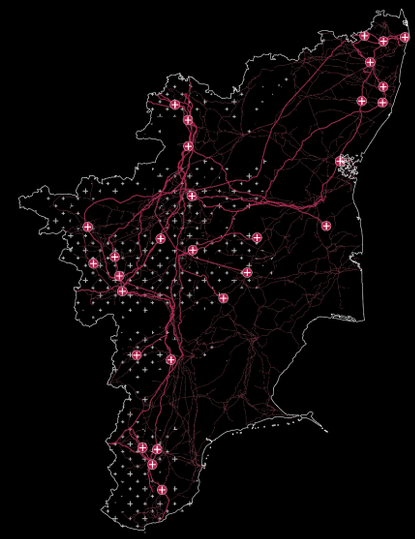
Existing situation



Proposed situation

4. Strengthen transmission capacity.

Strengthen transmission capacity of the power grid to support densification of energy production landscapes. Here, the corridors for increasing transmission capacity were identified based on the areas chosen for densification. Based on the local energy output, the transmission capacity can be decided by the TANTRANCO.



Macro-Regional Plan



Existing situation



Proposed situation

Fig 8.5: Design interventions for energy densification in Tamil Nadu 2050

Spatial interpretation of the ***densified*** energy landscape.

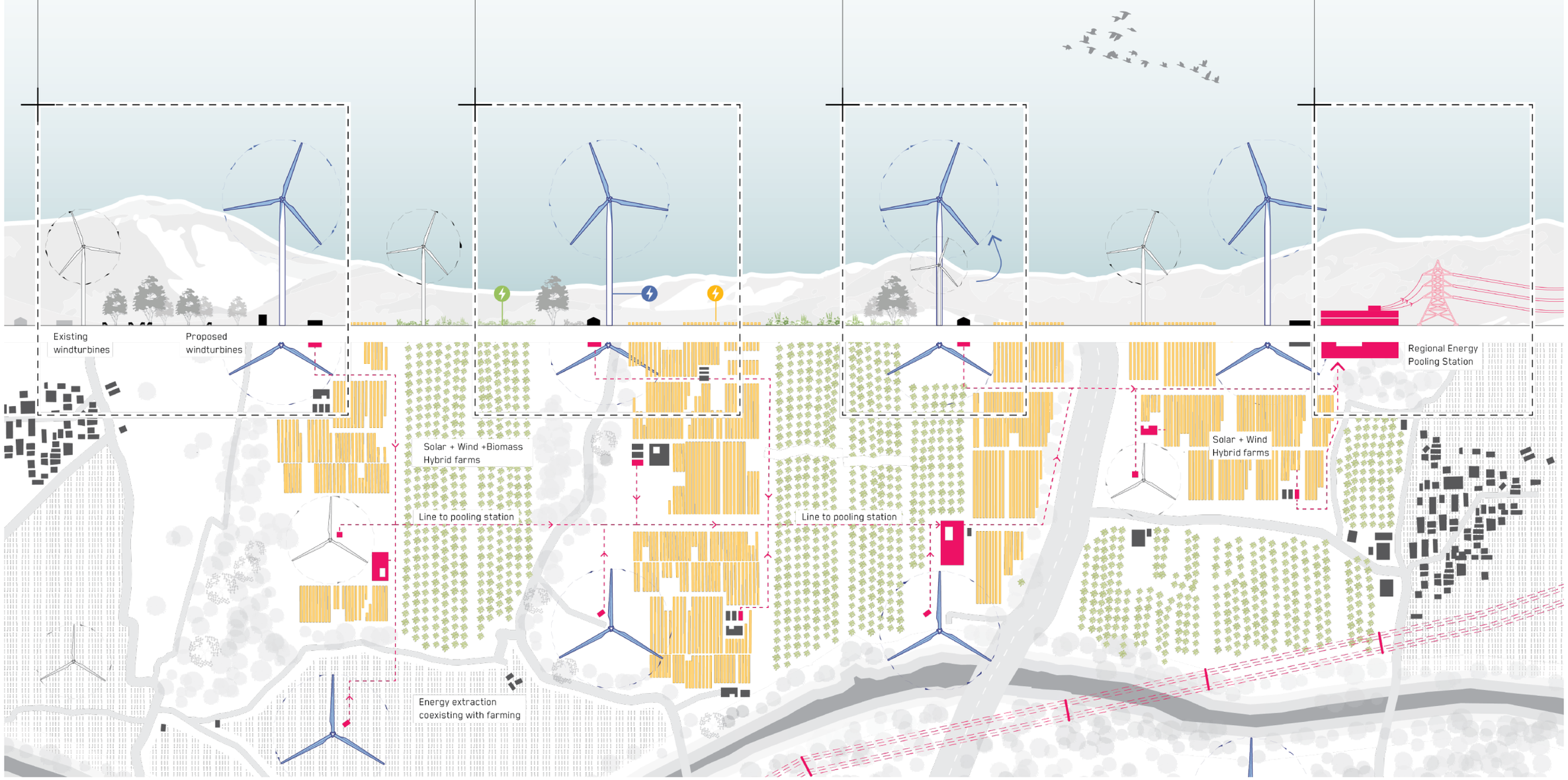
Fig 8.6: Composite section showing the spatial interpretation of the strategy

1. Build in the gaps between existing windturbines that are under developed.

2. Diversify energy development to include a mix of energy typologies to optimise the landuse.

3. Upgrade outdated windturbines installed in the beginning of the R.E wave in Tamil Nadu

4. Strengthen transmission capacity of the power grid to support densification



Stakeholders of the ***densified*** energy landscape.

Public Sector
Private Sector
Civil Society

- TNEB/TANTRANSCO (Tamil Nadu Tansmission Company)

- Wind energy companies of existing sites
- Operation and maintanance (O&M) companies around existing sites

- Rural land owners

- Wind, Solar and Biomasss energy Companies
- O & M companies

- Rural land owners
- Farmers involved in biomass cultivation

- Wind energy companies of existing sites
- O & M companies

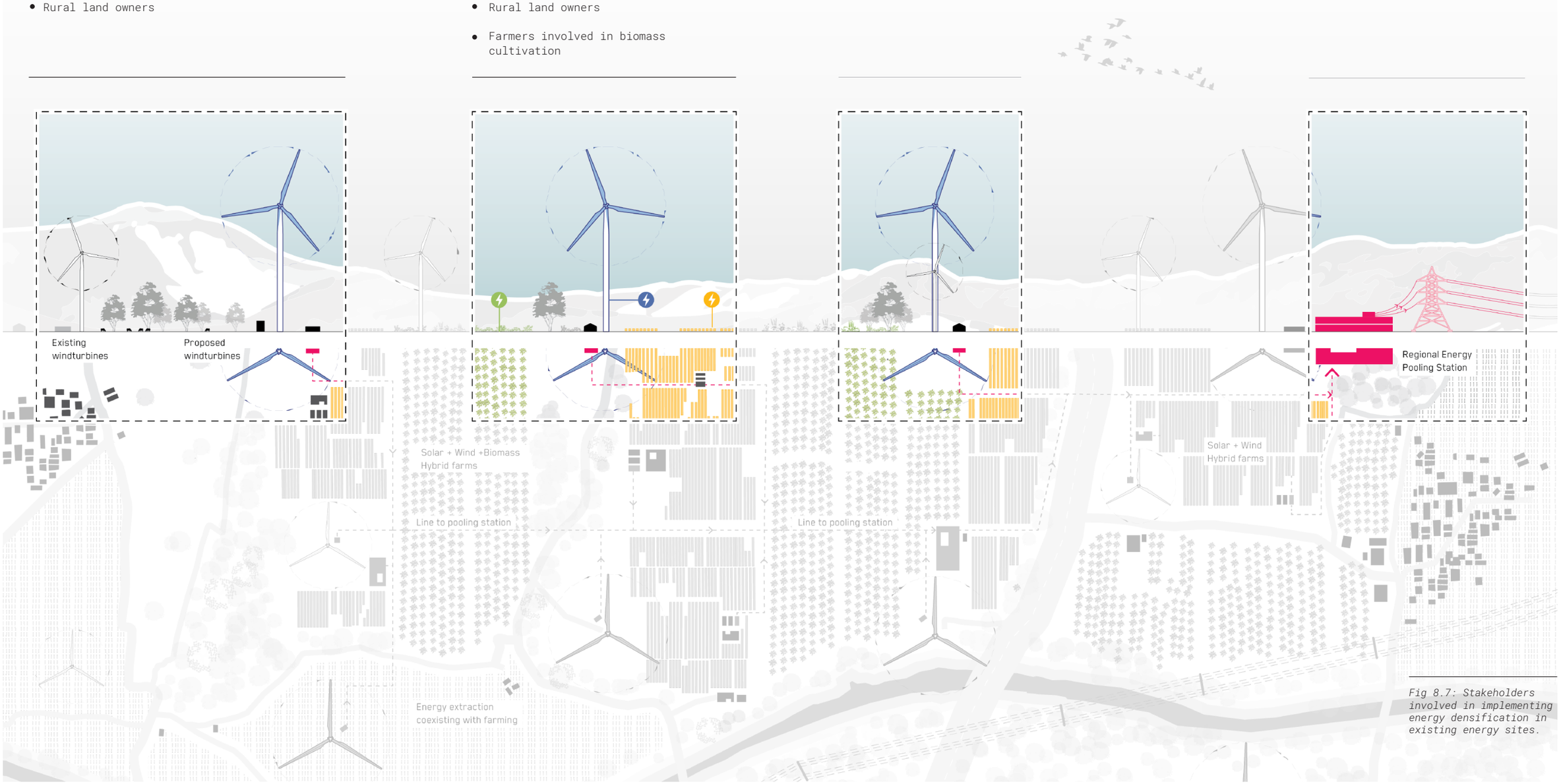


Fig 8.7: Stakeholders involved in implementing energy densification in existing energy sites.

Strategy 2 - Create multifunctional energy landscapes through ***cross programming.***

The alternate, non-extractivist form of energy development imagined in the Vision needs a conscious shift from large scale, mono-functional energy extraction sites to **multi-functional, decentralised energy extraction system, that coexists with other forms of spatial use.** To enable this shift, this strategy defines pathways and solutions for combining energy production with other functions like mobility, urban waste management and infrastructures to create mutually benefiting and reinforcing relationships across the sectors. The heterogeneity of the energy production landscapes creates accordances for various functions to manifest across the same space, thus increasing the overall value of the land. Here, Fig 8.8 shows the macro-regional distribution of cross-programming strategies.

The collaboration between energy sector and mobility, urban waste management or public infrastructure **shows how energy production can be integrated in urban areas**. For example, combining energy with waste management through Waste to Energy plants in urban areas produces R.E, while simultaneously treating the waste generated in the city. The following pages present the key solutions derived from the strategy, its spatial interpretation and the stakeholders involved in its implementation.

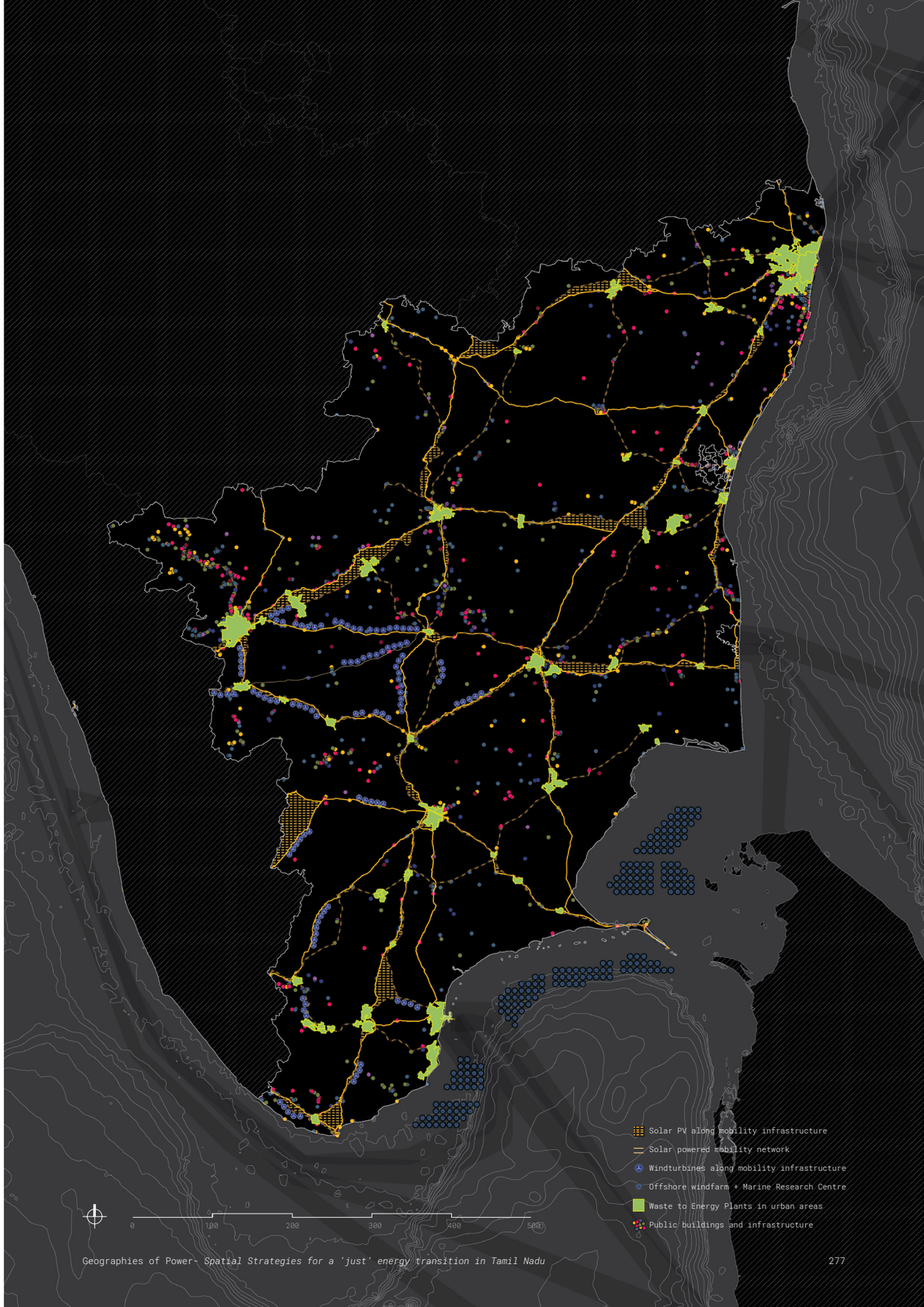


Fig 8.8: Macro-Regional distribution of cross-programming strategies.

S2: Design interventions/Actions.

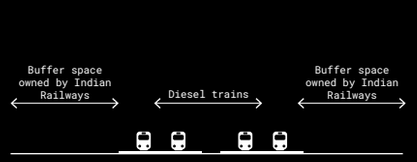
A. Energy x Mobility*

Cross program energy with mobility where R.E can power urban mobility in return for space along transport infrastructure to install R.E like winnd turbines, solar roads, solar road dividers, etc. The map below shows areas where there are this strategy is implemented in the macroregion.

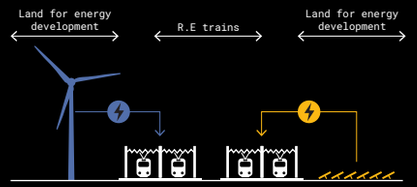


Solar PV and windturbines along mobility infrastructure

Macro-Regional Plan



Existing situation



Proposed situation

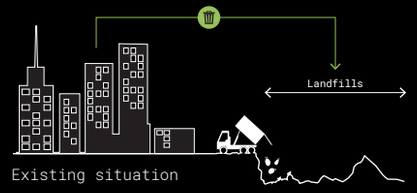
B. Energy x Waste Management

Cross program energy with waste management where household waste can be converted to electricity within urban areas, by constructing Waste to Energy Plants in urban areas of the state. The energy generated powers the city, while contributing to urban waste management.

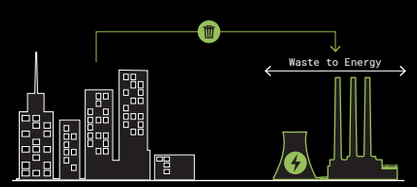


Waste to Energy plants in cities

Macro-Regional Plan



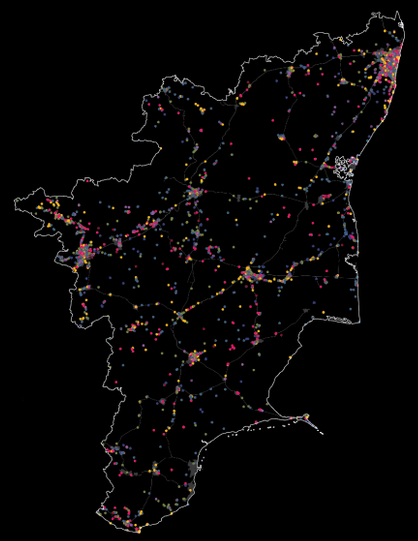
Existing situation



Proposed situation

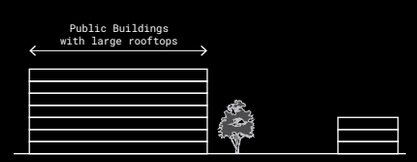
C. Energy x Public Infrastructure

Cross program energy with public infrastructure where large rooftops of public buildings and public utilities like street lights, bus stops, etc are utilised for the production of renewable energy, mainly solar. Here, the Solar Cities Mission of the Govt. of India, is a important policy framework that can support the implementation of the strategy.



R.E integration in public spaces, instituitions & buildings

Macro-Regional Plan



Existing situation



Proposed situation

* Note:

The Indian Railways is the single largest consumer of electricity in India, (2% of total energy consumption of India) and began efforts to produce R.E. (specifically solar energy) through rooftop PV and large scale plants in 2018. ***Solar Mission of the Indian Railways*** programme, launched in 2016 in partnership with the UNDP (United Nations Development Programme) sets an ambitious target of 5GW by 2022 and to become a net-zero carbon emitter by 2030 (mercom,lifegate). Under this proposal, 98% of India's railway stations will be powered by solar energy. Furthermore, in 2018, the Union cabinet passed the bill to electrify all broad guage tracks by 2022, which is a key step towards replacing 2.6 billion litres of diesel consumed per year, to R.E.

The proposal to utilise the vast infrastructure and land owned by the Indian Railways to this end, is taken as the base policy to execute S2 A. Energy x Mobility.

It is important to note that this strategy specifically requires a healthy collaboration and building of relationships between different sectors for its implmentation.

Fig 8.9: Design interventions for crossprogrammning in Tamil Nadu 2050

Spatial interpretation of the ***cross-programmed*** energy landscape.

Fig 8.10: Composite section showing the spatial interpretation of the strategy

1. Cross program ***Energy with Mobility*** where R.E can power urban mobility in return for space along transport infrastructure to install R.E.

2. Cross program ***Energy with Urban Waste Management***, where household waste can be converted to electricity- within urban areas.

3. Cross program ***Energy with Public Spaces,*** where large rooftops of public buildings and public utilities like street lights, bus stops, etc produce R.E



Stakeholders of the ***cross-programmed*** energy landscape.

Public Sector

Private Sector

Civil Society

- Indian Railways, Southern Railways, Airport Authority of India, and Roadway Departments
- Ministry of Infrastructure

- Urban Waste Management Department
- Local municipalities

- TNEB/TANGEDCO (Tamil Nadu Generation and Distribution Company)
- Public buildings- with large rooftops

- Wind and Solar energy companies
- Electric Vehicle companies

- Waste to Energy Companies
- Waste Management Companies

- Privately owned public buildings, semi-public buildings, private services, industrial areas- with large rooftops

- Electric Vehicle Owners

- Urban residents, restaurants, large hotels and organic waste generators
- Actors in the informal waste economy



Fig 8.11: Stakeholders involved in implementing crossprogramming strategies in urban areas

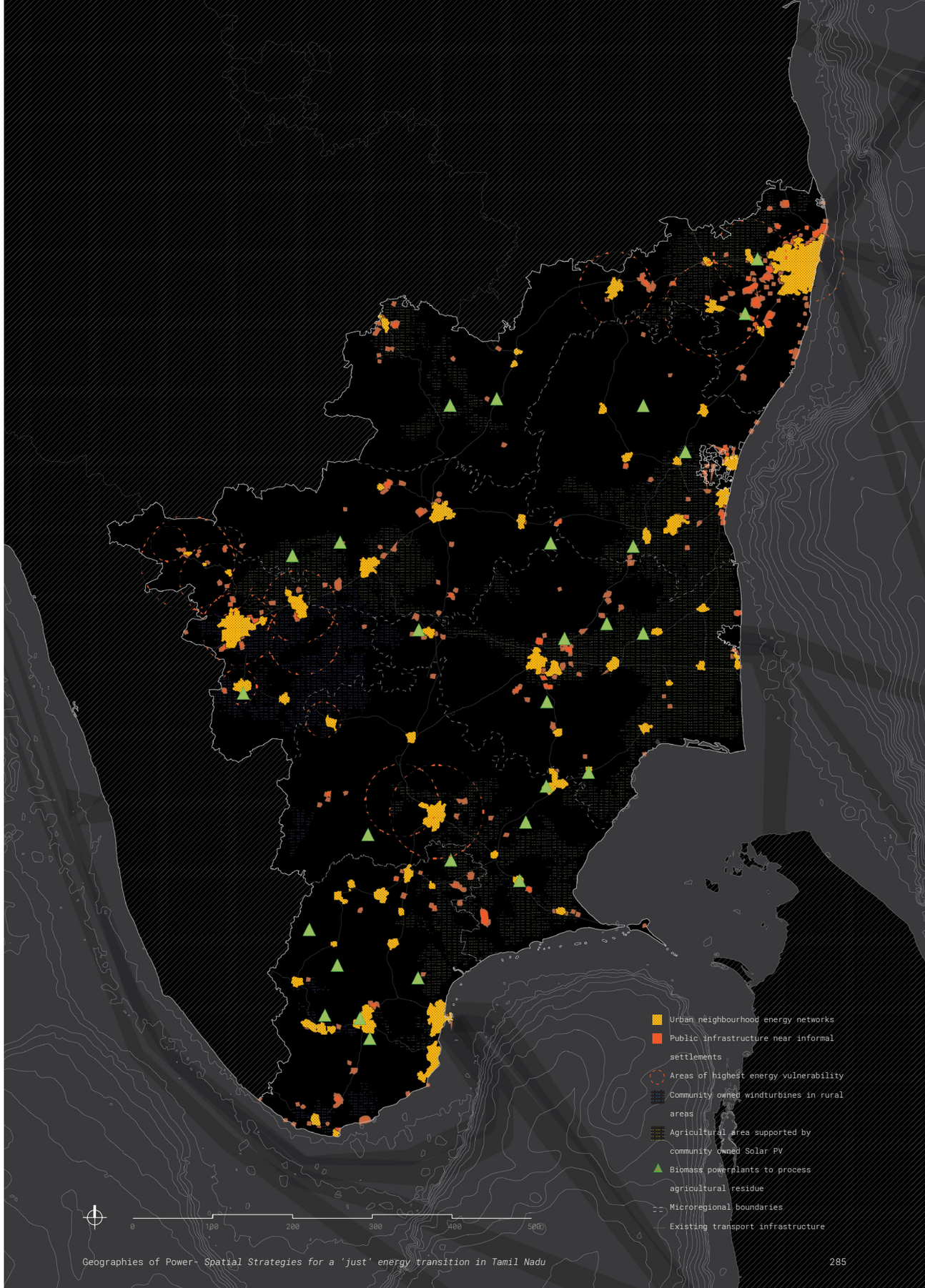
° N, 78.6569° E

Strategy 3 - ***Coproduce*** energy with the community in urban and rural areas.

This strategy aims at dissolving the monopoly of private energy companies in energy production by catalyzing the **inclusion and participation of individuals and communities in energy transition**. This is achieved by defining pathways and solutions for involving individuals, communities and cooperatives in the **co-production of renewable energy** along with private or state owned energy enterprises. This coproduction of energy involving local stakeholders improves the degree energy access and adds socio-economic capital to the communities. The development of urban and rural mini grids to support local energy demands empowers energy vulnerable populations, and positively contributes to their overall human development. Here, Fig 8.12 shows the macro-regional distribution of coproduction strategies.

In this strategy, design interventions like the formation of neighbourhood or village level energy cooperatives, energy sharing with vulnerable communities and establishment of capacitation centres to support citizen in energy production ventures are elaborated in detail. **The democratization of energy development** is an important outcome of this strategy. The following pages present the design interventions derived from the strategy, its spatial interpretation and the stakeholders involved in its implementation.

Fig 8.12: Macro-Regional distribution of coproduction strategies.



S3: Design interventions/Actions.

A. Neighbourhood Energy Networks

Catalyse micro-energy generation through solar PV on residential rooftops to create neighbourhood energy networks in urban areas of Tamil Nadu. The surplus energy produced is fed back to the grid, thus becoming an additional income for the coproducers.

B. Energy sharing with energy vulnerable communities

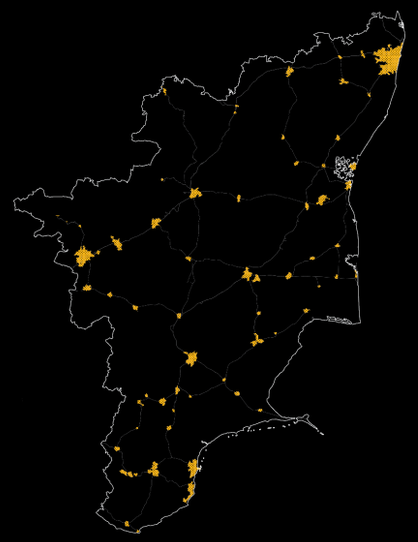
Connect informal settlements with energy vulnerability to the nearest public or commercial building with large rooftops that can be used to coproduce energy along with the vulnerable communities .

C. Rural mini grids

Subsidise rural micro energy generation by local communities. With the support of public and private sectors, energy cooperatives in rural areas could produce cheap R.E to support agriculture, household activities in the rural areas pf the region.

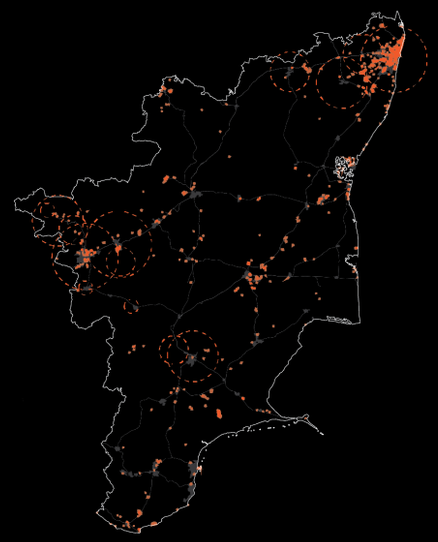
D. Establish capacitation centres

Build Capacitation Centres in every Taluk (administrative division) for sharing knowledge and support rural coproduction initiatives. The capacitation centres enhance citizen awareness on micro energy systems and socio-economic benefits of coproduction.



Neighbourhood networks of solar rooftop installations

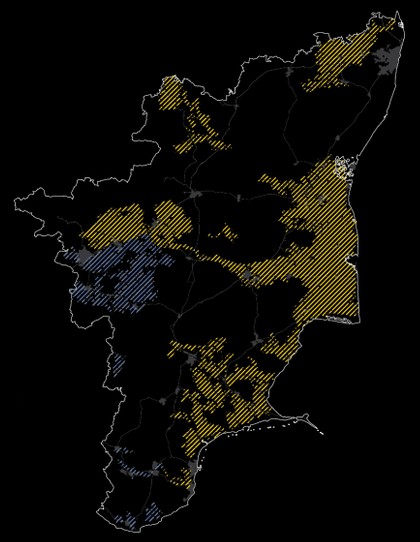
Macro-Regional Plan



Public buildings near informal settlements

Areas of highest power shortages

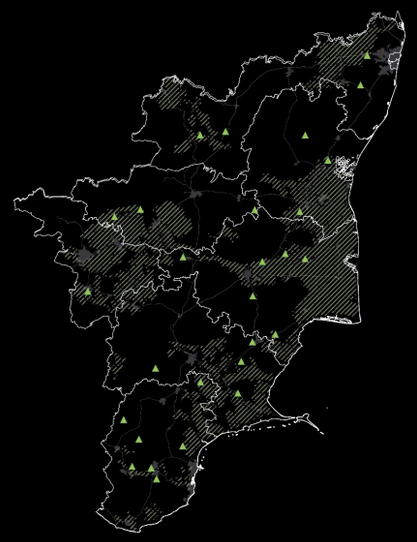
Macro-Regional Plan



Solar PV to support farming

Small winturbines (>500kV)

Macro-Regional Plan

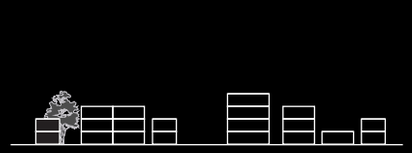


Taluk boundaries

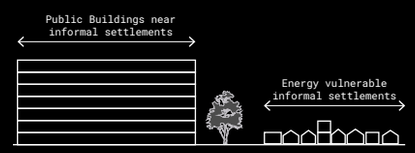
Agricultural area

Biomass Power Plant

Macro-Regional Plan



Existing situation



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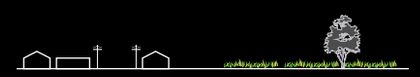

Existing situation



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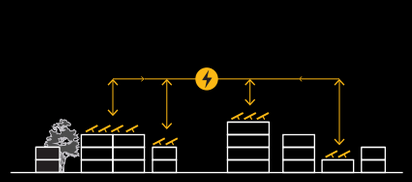
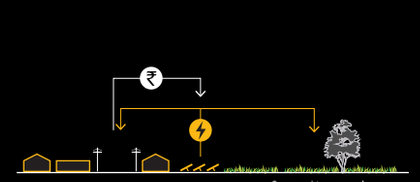


Proposed situation



Proposed situation



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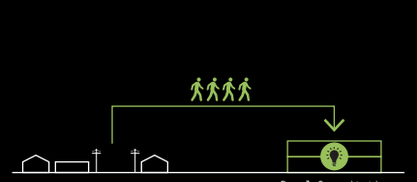


Proposed situation

Fig 8.13: Design interventions for coproduction in Tamil Nadu 2050

Spatial interpretation of the ***coproduced*** energy landscape.

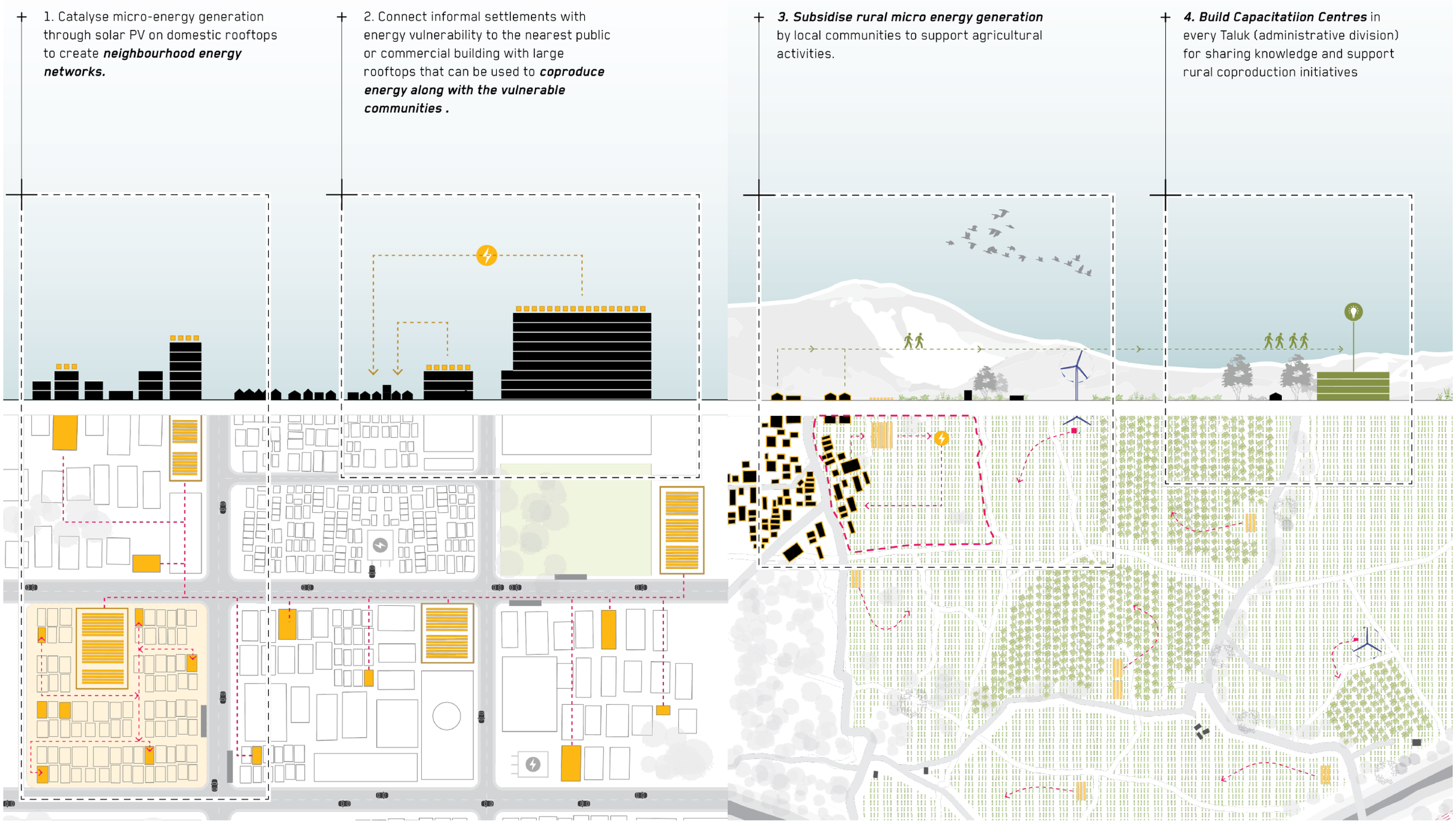
Fig 8.14: Composite section showing the spatial interpretation of the strategy

1. Catalyse micro-energy generation through solar PV on domestic rooftops to create ***neighbourhood energy networks.***

2. Connect informal settlements with energy vulnerability to the nearest public or commercial building with large rooftops that can be used to ***coproduce energy along with the vulnerable communities .***

3. Subsidise rural micro energy generation by local communities to support agricultural activities.

4. Build Capacitatiion Centres in every Taluk (administrative division) for sharing knowledge and support rural coproduction initiatives



Stakeholders of the ***coproduced*** energy landscape.

Public Sector

Private Sector

Civil Society

	• TNEB/TANGEDCO (Tamil Nadu Generation and Distribution Company) • Tamil Nadu Slum Clearance Board, • Public Schools and other services	• TNEB/TANGEDCO (Tamil Nadu Generation and Distribution Company), TEDA (Tamil Nadu Energy Development Agency) • State and Central Governments	• TNEB/TANGEDCO (Tamil Nadu Generation and Distribution Company), TEDA (Tamil Nadu Energy Development Agency) • State Govt, and Local municipalities
	• Privately owned public buildings, semi-public buildings, private services, industrial areas- with large rooftops ***AND near informal settlements***	• Energy companies (large and small), in case of co-venture with rural communities	
• Urban residents • Apartment/Block/Neighbourhood level energy cooperatives	• Inhabitants of informal settlements with low energy access • Other energy vulnerable communities	• Rural inhabitants, farmers • Rural energy cooperatives	• Rural inhabitants, farmers • Rural energy cooperatives



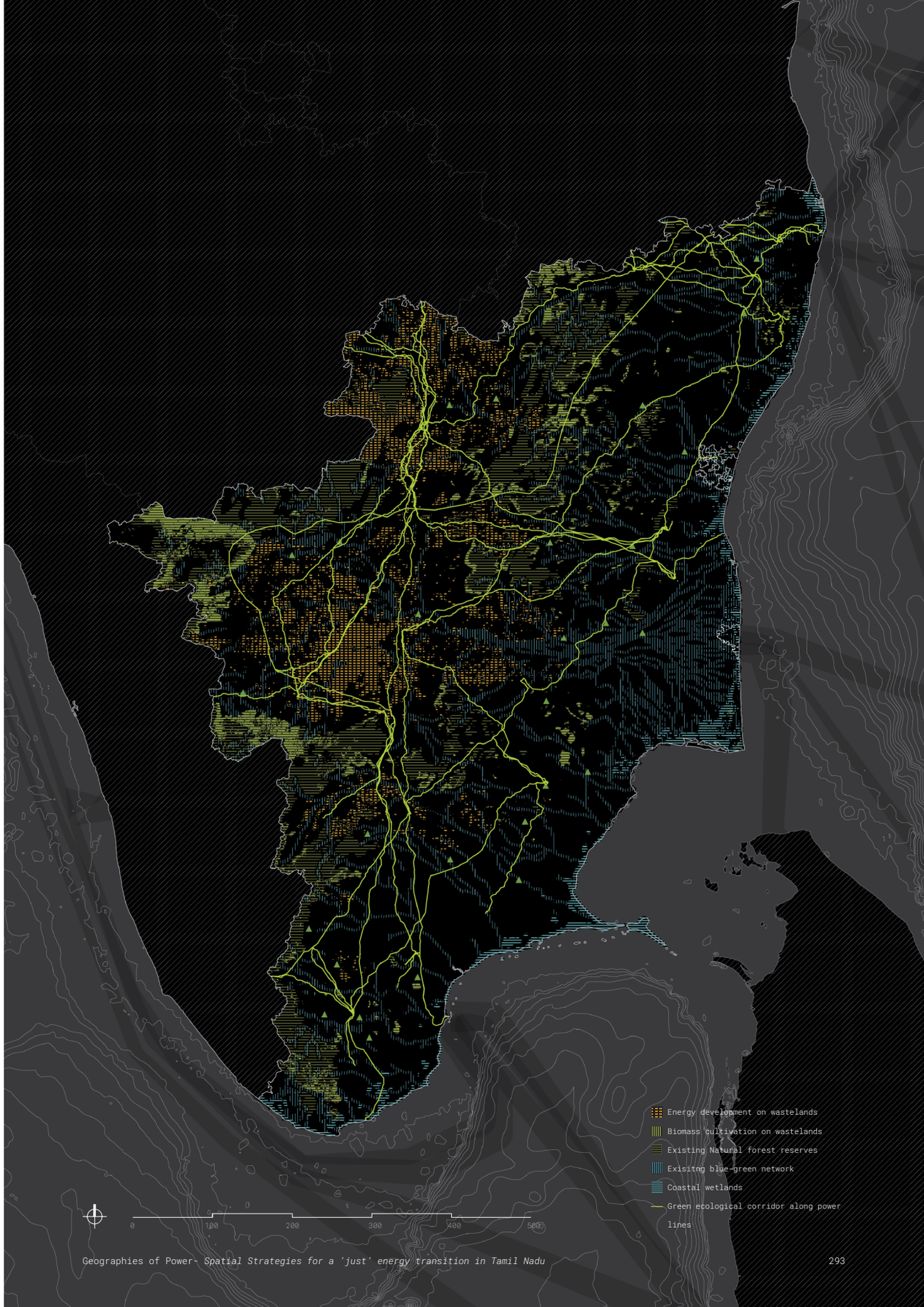
Fig 8.15: Stakeholders involved in coproducing energy in urban and rural areas

Strategy 4 - Add ecological value through ***landscape integration*** in energy development.

This strategy aims to create mechanisms for the reinforcement of ecological structures impacted by energy development through landscape integration. This is achieved by defining pathways and solutions for integrating the surrounding landscape within energy production, such that **ecological value and resilience of the landscape is increased**. Here, Fig 8.16 shows the macro-regional distribution of landscape integration strategies.

In order to preserve the visual and spatial integrity of the landscape, policies that make it mandatory for energy production to be accompanied by landscape remediation measures are presented. Specifically, the project proposes the **use of wastelands for energy development** to prevent the transformation of pristine agricultural fields into energy landscapes. Existing blue-green networks are identified to observe areas of intersection between local energy development and regional ecological corridors. The strategy also proposes the creation of a 'Green Energy Corridor' where the transmission network is taken as the **backbone for building macro-regional ecological structures**. The following pages present the design interventions derived from the strategy, its spatial interpretation and the stakeholders involved in its implementation.

Fig 8.16: Macro-Regional distribution of ecological strategies.



S4: Design interventions/Actions.

A. Prioritise wastelands for energy development.

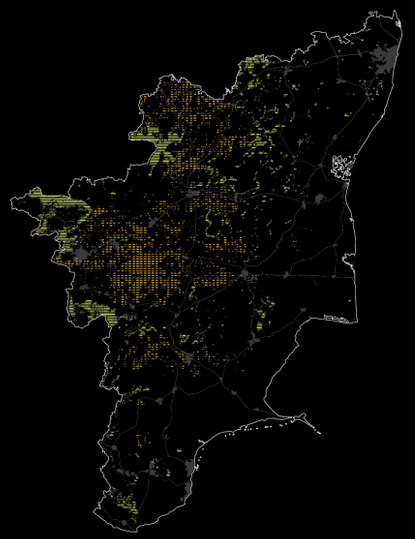
Prioritise wastelands over fertile agri-cultural land for energy development, so that transformation of landuse is kept to a minimum. In addtion to energy production like solar farms, wind farms or biomass cultivation, the wasteland is also remediated to offset the negative impacts of energy development.

B. Create landscape buffers

Create landscape buffers around energy infrastructure to preserve the aesthetics and integrity of the landscape. The landscape buffer is made relevant to the larger territory by connecting it to existing green blue networks in the region.

C. Build a 'green energy corridor'

Build regional ecological energy networks by using the buffer space around power transmission networks as the backbone for creating ecological structures around energy development.



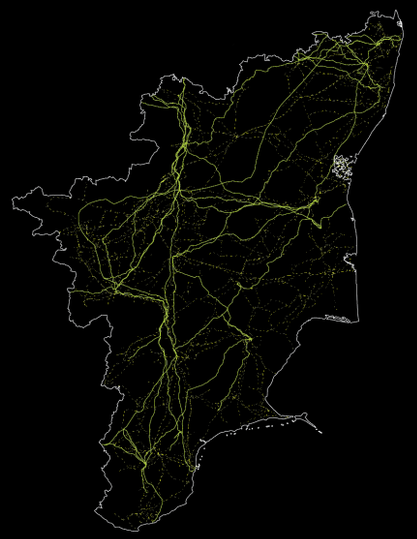
Solar PV on wastelands Biomass production on barren land

Macro-Regional Plan



Green network Blue network Coastal wetlands

Macro-Regional Plan

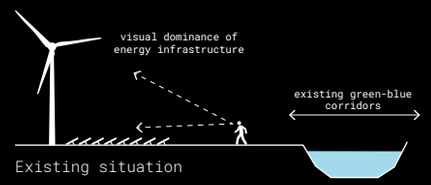


Transmission network as the green-blue backbone

Macro-Regional Plan



Existing situation



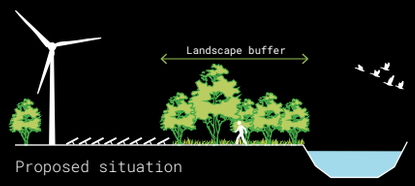
Existing situation



Existing situation



Proposed situation



Proposed situation



Proposed situation

Fig 8.17: Design interventions for landscape integration in Tamil Nadu 2050

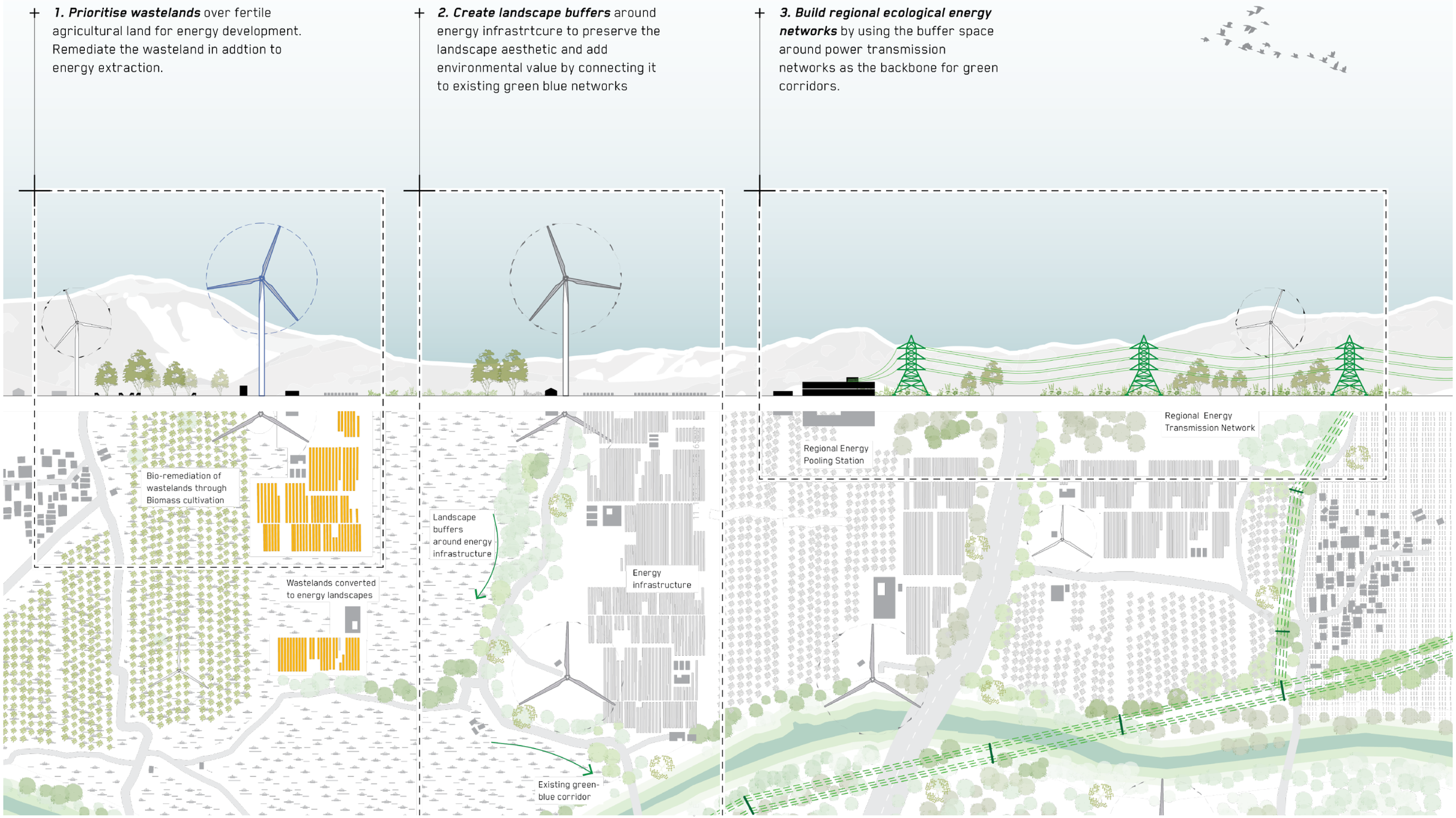
Spatial interpretation of ***landscape integration.***

Fig 8.18: Composite section showing the spatial interpretation of the strategy

+ ***1. Prioritise wastelands*** over fertile agricultural land for energy development. Remediate the wasteland in addtion to energy extraction.

+ ***2. Create landscape buffers*** around energy infrastrtcure to preserve the landscape aesthetic and add environmental value by connecting it to existing green blue networks

+ ***3. Build regional ecological energy networks*** by using the buffer space around power transmission networks as the backbone for green corridors.



Stakeholders in ***landscape integration.***

- Directorate of Town and Country Planning (DTCP), TNEB/TANGEDCO, Ministry of Environment
- Wind, Solar and Biomass energy companies

- Directorate of Town and Country Planning (DTCP), TNEB/TANGEDCO, Ministry of Environment
- Wind, Solar and Biomass energy companies
- Inhabitants of the area who benifit from the ecological value addition

- TNEB/TANGEDCO (Tamil Nadu Generation and Distribution Company)
- Public buildings- with large rooftops
- Privately owned public buildings, semi-public buildings, private services, industrial areas- with large rooftops

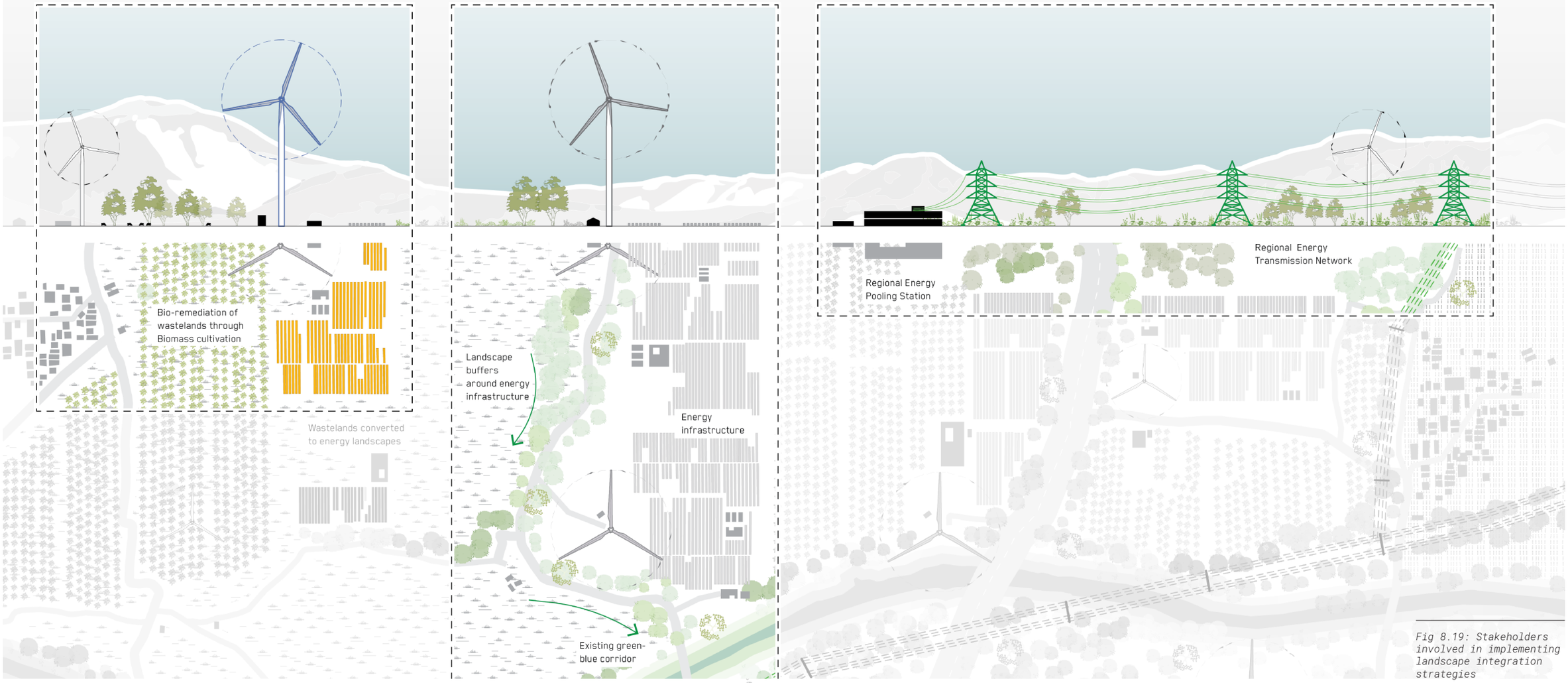


Fig 8.19: Stakeholders involved in implementing landscape integration strategies

Strategy 5 - ***Repower and reconfigure*** the post-carbon energy landscapes.

While the first four strategies focused on the production of renewable energy, this strategy aims to repower and reinforce the existing carbon based energy landscape for it to adapt to the R.E. paradigm in the future. This is achieved through a combination of actions, chief being the **carbon capture and storage** measures to reduce carbon emissions into the atmosphere, **conversion of selected thermal power plants to biomass power plants, and encouraging energy efficiency measures** in urban areas. Here, Fig 8.20 shows the macro-regional distribution of post-carbon strategies.

Existing areas of carbon emission like heavy industries, thermal power plants and gas fields are identified to retrofit CCS technology and capture the released carbon. Pipelines to transport the captured carbon to geological basin in the eastern coast are constructed along with local intermediary storage points. The pipelines for transporting carbon also makes use of existing natural gas pipelines in the state. The carbon is then stored deep under the sea in carbon storage points in the Bay of Bengal.

The following pages present the design interventions derived from the strategy, its spatial interpretation and the stakeholders involved in its implementation.

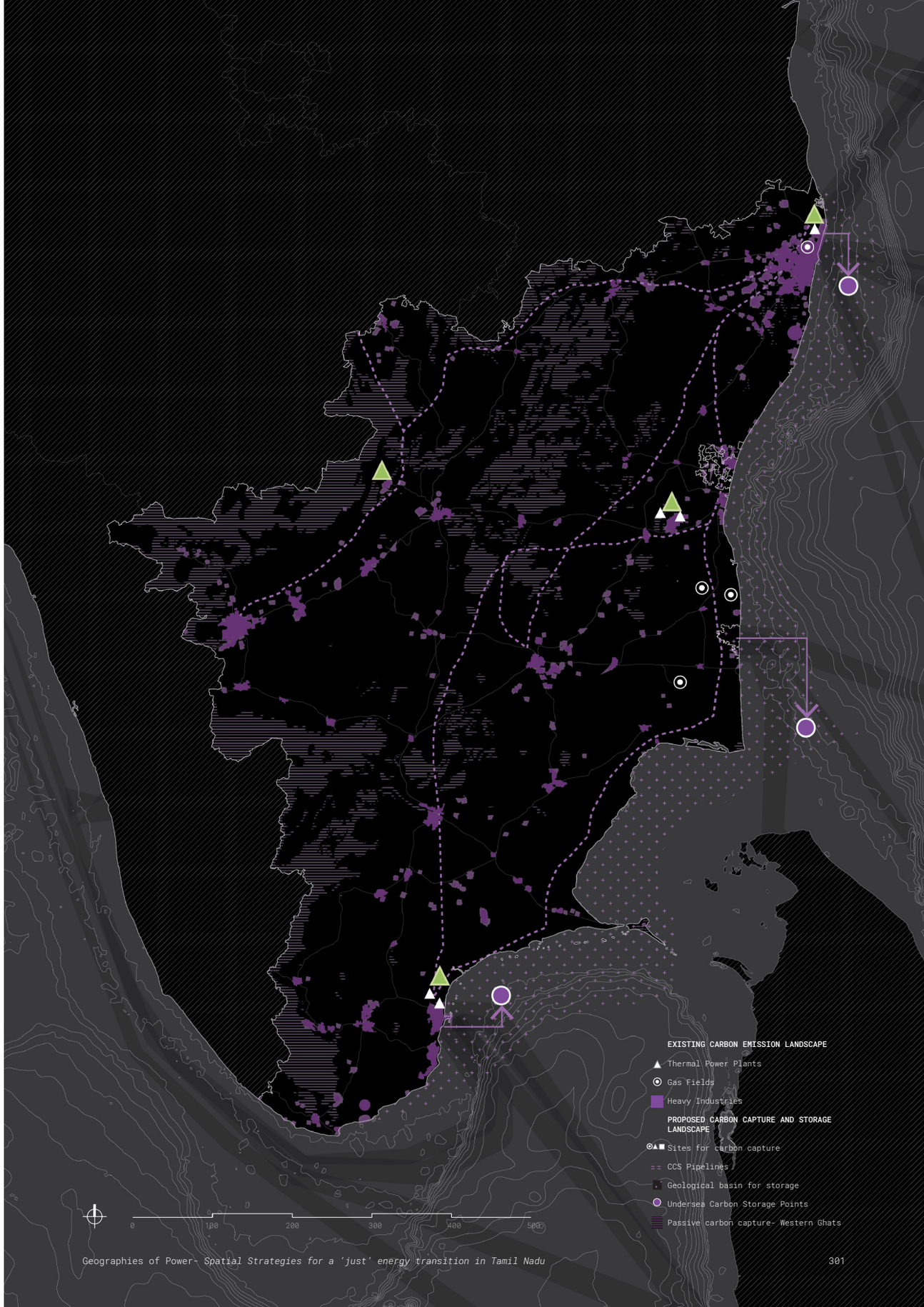


Fig 8.20: Macro-Regional distribution of post-carbon strategies.

S5: Design interventions/Actions.

A. Increase energy efficiency in urban areas.

Measures to increase energy efficiency in urban areas is integral to the reduction of energy demand in 2050. The energy projection made for 2050 assumes 50% reduction in current demand, to be realised by the implementation of this strategy. Solutions range from green energy certification of buildings to upgradation of outdated energy in

B. Adaptive reuse of TPPs

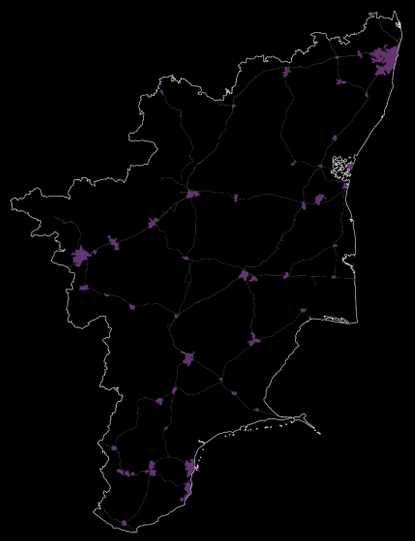
The shift to renewable energy is accompanied by the remediation of existing carbon energy landscapes. This is done partly by decommissioning thermal power plants that are not needed anymore, or converting them into biomass based TPPs. This significantly reduces carbon emissions in the region.

C. Enhance passive carbon capture

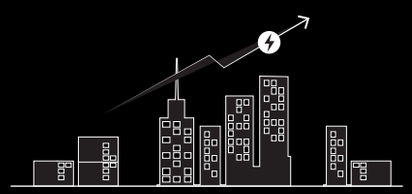
Enhance passive carbon capture by nurturing natural carbon sinks like forests (Western Ghats mountain ranges, Gingee forest etc), agricultural fields, etc, through afforestation of the degraded landscape.

D. Retrofit CCS to TPPs

Carbon capture technology is retrofitted to existing functional thermal power plants to capture the carbon. The captured carbon is then stored in geological basins in the Bay of Bengal. This, although expensive, significantly reduces the amount of carbon emissions, one of the primary goals of the global energy transition.



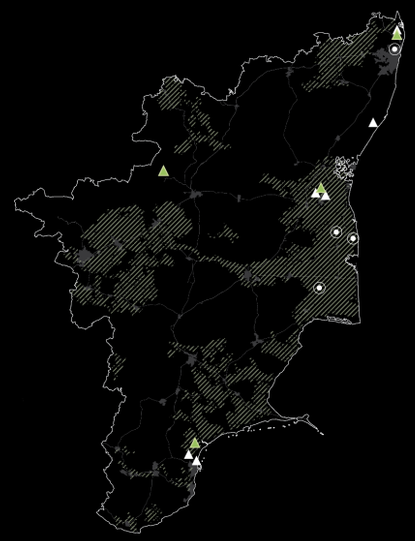
Macro-Regional Plan



Existing situation



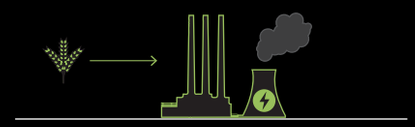
Proposed situation



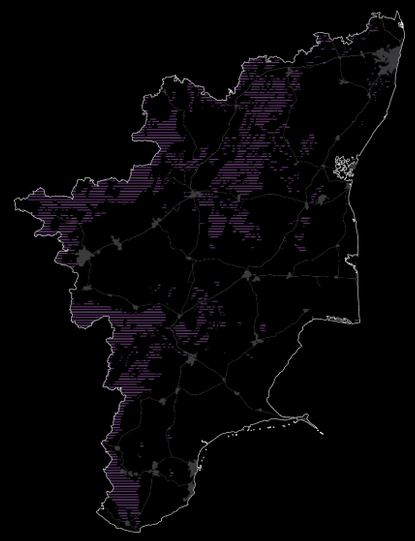
Macro-Regional Plan



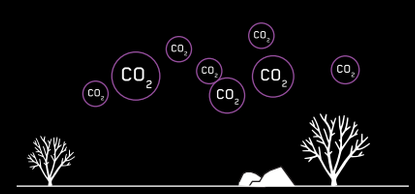
Existing situation



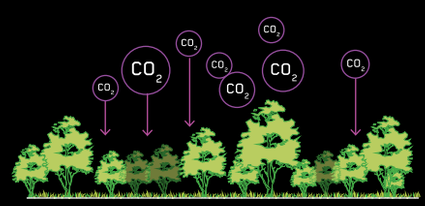
Proposed situation



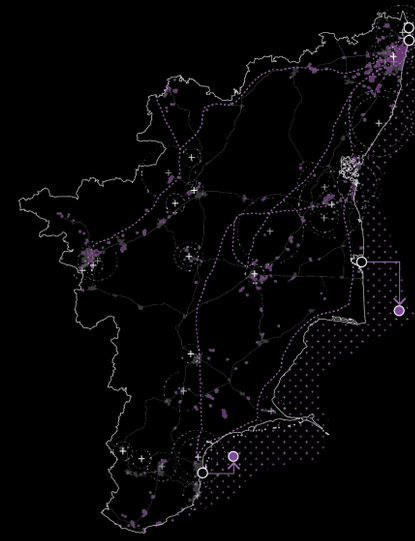
Macro-Regional Plan



Existing situation



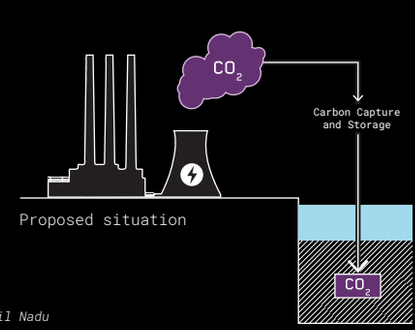
Proposed situation



Macro-Regional Plan



Existing situation

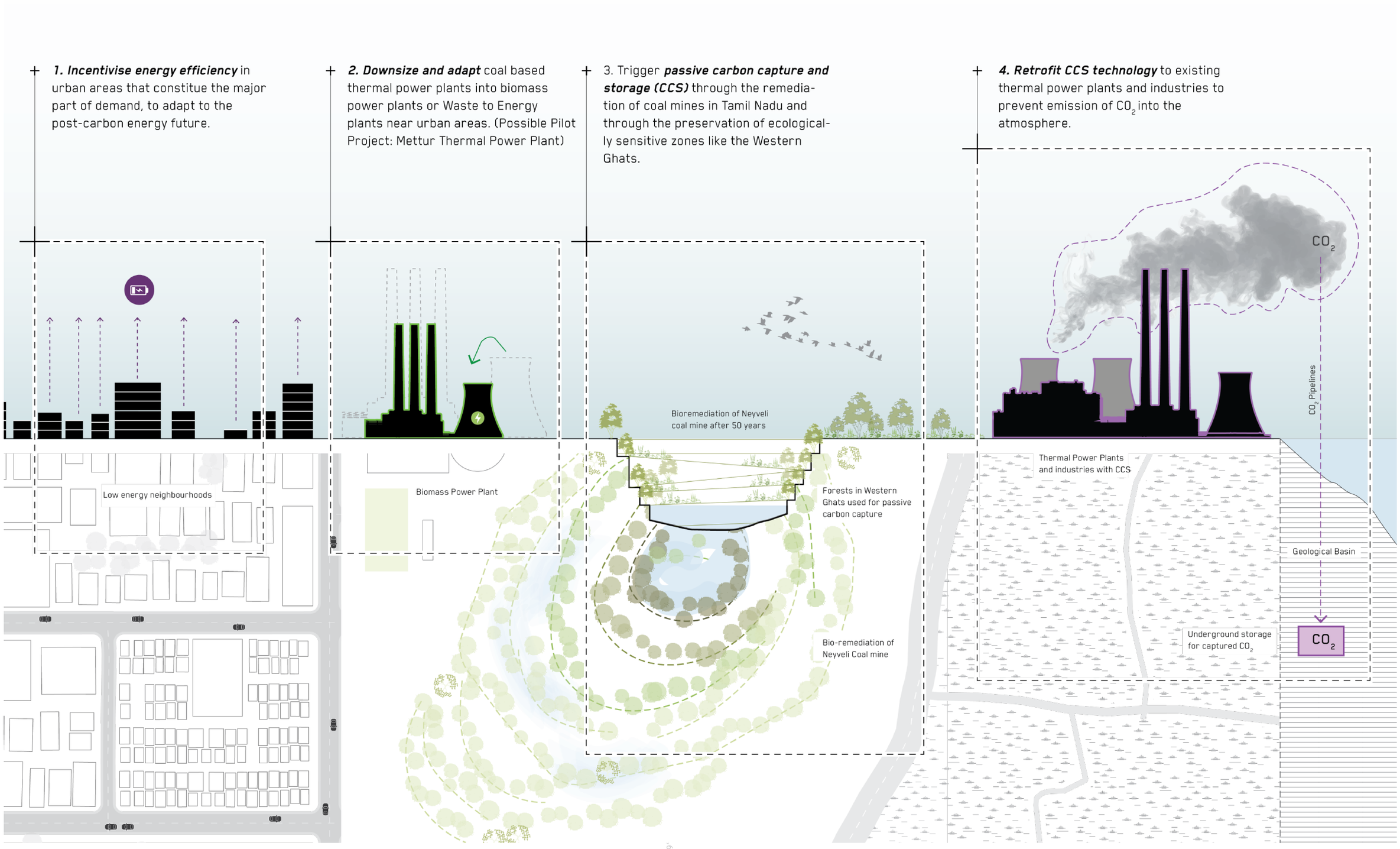


Proposed situation

Fig 8.21: Design interventions for post-carbon Tamil Nadu 2050

Spatial interpretation of ***post-carbon energy landscapes.***

Fig 8.22: Composite section showing the spatial interpretation of the strategy



Public Sector
Private Sector
Civil Society

Stakeholders of ***post-carbon energy landscapes.***

- Private enterprises, offices, industries with high energy needs
- Urban residents, Neighbourhood associations

- Thermal energy companies
- Biomass energy companies

- Tamil Nadu Forest Department, Ministry of Environment
- Thermal energy companies, coal mining companies,

- State agency to spearhead and refulate CCS in Tamil Nadu
- Institutions and Research departments for technology exploration
- Thermal energy companies, industries with high carbon emissions
- Carbon Capture and Storage related companies

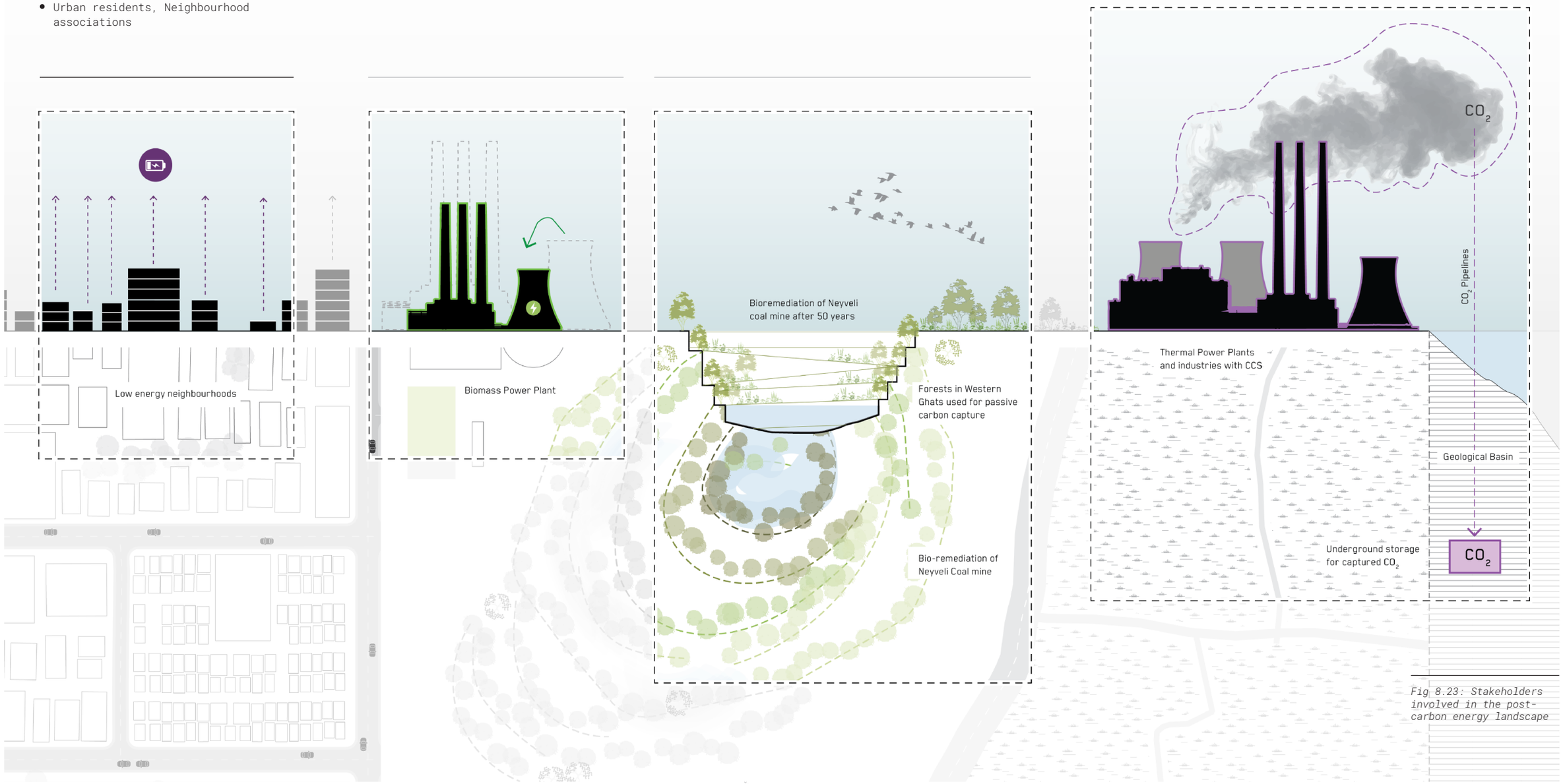


Fig 8.23: Stakeholders involved in the post-carbon energy landscape

Strategy 6 - ***Increase flexibility*** through seasonal activation of energy landscapes.

The flexibility and adaptability of the energy system is increased through infrastructural, systemic and policy level solutions to adapt to the diurnal and seasonal* fluctuations in R.E. generation in Tamil Nadu. This is achieved through a combination of actions, like increasing the diversity and multi-functionality of energy production landscapes, developing **infrastructure for inter-state energy exchanges and energy forecasting, building energy storage facilities and altering energy consumption patterns** to suit peak production periods.

Fig 8.24 compares two extreme energy situations that arises in a year- Highest R.E. production day and lowest R.E. production day, to highlight the changes in total energy mix and the seasonal activation of energy landscapes that correspond to the energy source. This strategy has the potential to balance the variations in energy supply by staggering the peak and off-peak periods of different energy types and activating the corresponding energy landscape. The following pages present the key actions and design interventions derived from the strategy.

* Solar energy is produced only during the day, causing an energy deficit during the nights. Wind energy generation in Tamil Nadu is high during the high wind season (May-September) and fall during the low wind season. Biomass energy depends on the growing and harvesting seasons of agricultural crops, although biomass can be stored before it is converted to energy.

Fig 8.24: Comparing two extreme energy situations in 2050.

11.1271° N, 78.6569° E

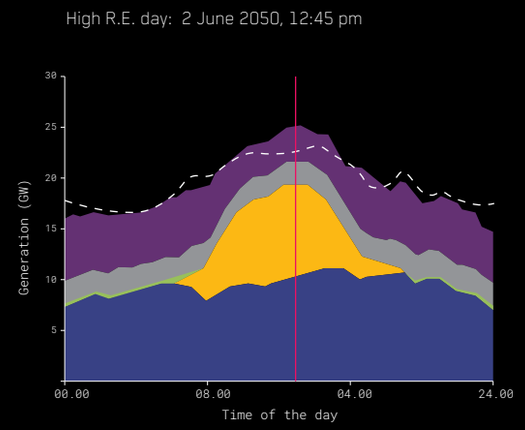
11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

11.1271° N, 78.6569° E

High R.E. day: 2nd June 2050, 12.45pm *

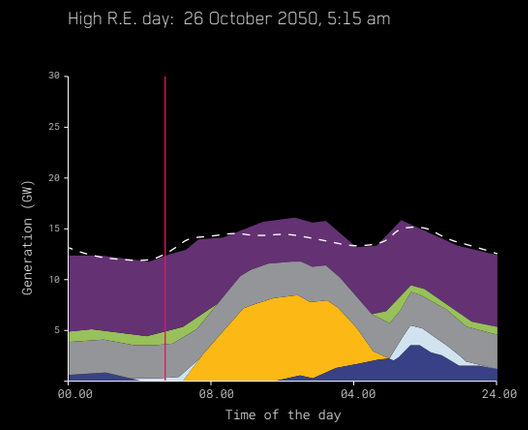
The graph below shows the overall energy production at different times of the day on 2nd June, 2050. Since it is high R.E. production day in the middle of Tamil Nadu's wind season, more than 85% of energy is from solar and wind energy sources. The values are based on the energy mix at the point of measurement- 12.45pm. The map below shows the energy landscapes that are active at the point of measurement.

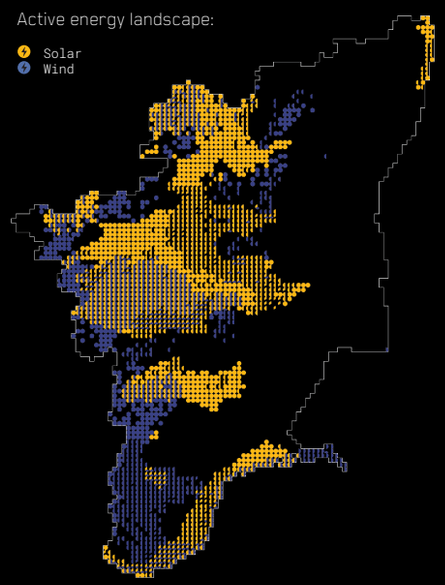


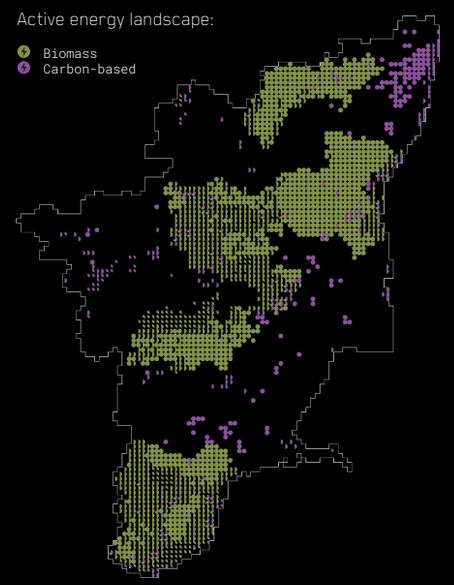
* The values shown in the graph were assumed for 2050 based on the projections for Tamil Nadu in 2022 made by Greening the Grid, a research platform that supports countries in power system transformation and grid modernization (Greening the Grid, 2018)

Low R.E. day: 26th October 2050, 05.15pm *

The graph below shows the overall energy production at different times of the day on 26th October, 2050. Since it is low R.E. production day, only 0.2% of energy is from solar and wind energy sources. The values are based on the energy mix at the point of measurement- 05.15am. The map below shows the energy landscapes that are active at the point of measurement.







S6: Design interventions/Actions.

A. Increase the diversity and multi-functionality

By increasing the diversity and multi-functionality of energy landscapes through Strategy 1 and Strategy 2, the fluctuations in energy supply is reduced.

The diversification of energy production landscapes to generate multiple (solar, wind and biomass) creates the flexibility to stagger energy production to suit the fluctuations. Moreover, by creating opportunities for multiple uses of land to coexist (like mobility, agriculture, waste management), the project ensures that the reduction in energy yield does not affect the overall productivity of the land during the off-peak season.

B. Develop cross-border energy exchanges

By developing the infrastructure for inter-regional and inter-state energy exchanges, variations in R.E. generation is balanced on a national scale. This involves increasing inter-state high voltage transmission capacity, constructing metering points for energy flow at the borders, and policy changes to ensure that the all imported energy is from renewable energy sources.

This solution not only generates better profits for TNEB, but also ensures that the penetration of R.E in total energy mix remains high even during the low R.E periods. For example, studies have shown that the high-wind, low-demand situation in Tamil Nadu coincides with the high-demand, low-supply situation in the northern grid during the high R.E periods (WISE, 2012). This means that instead of curtailing the surplus R.E. generated, it can be exported at a profit to states with energy deficits during the peak season. Similarly, energy can be imported from a larger northern seller base at a more reasonable price during off-peak season.

C. Store and Release

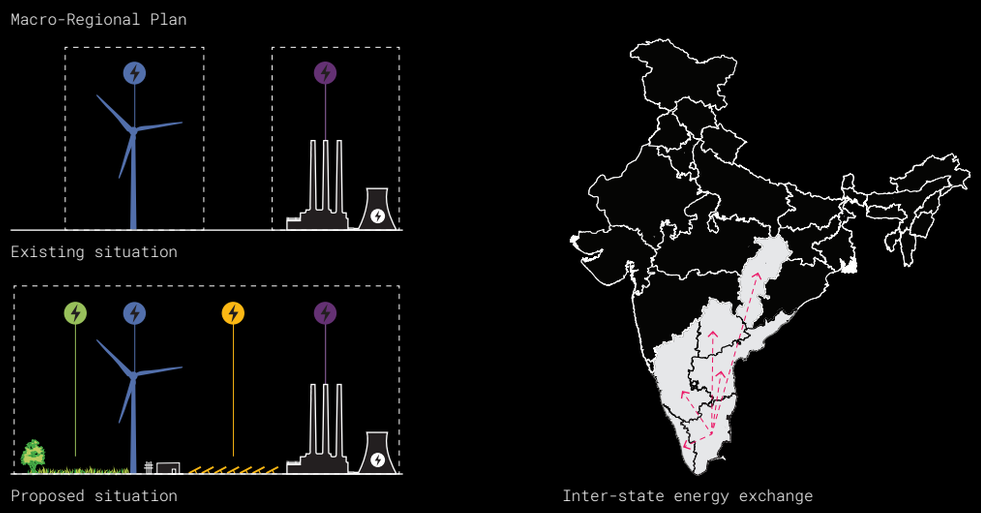
Investing in energy storage infrastructure is one of the solutions to overcome the diurnal (solar) and seasonal (wind) fluctuations in renewable energy supply. By storing surplus R.E. during the peak season in energy storage points, and releasing it for use during the off-peak season, energy deficit due to fluctuations is balanced.

However, the project acknowledges that although energy storage technology is becoming more commonplace, it is still very expensive and also negatively impacts the environment due to its chemical composition. The project, while noting it as a relevant solution to grid variations, does not elaborate on this in the design.

D. Enforce demand-side management

While technological solutions like the ones explained in A, B and C, this solution takes a softer approach to addressing the fluctuations in R.E. supply. By altering energy demand and consumption patterns to align with R.E. generation period (6am to 6pm typically), the dependency on coal powered energy is minimised.

This is enforced by careful demand-side management like increasing tariffs during the off peak periods to shift high energy loads to peak generation periods. This policy level change can trigger changes even in the domestic sector, like using energy intensive appliances during the low tariff period and using only essential appliances during the high tariff period.



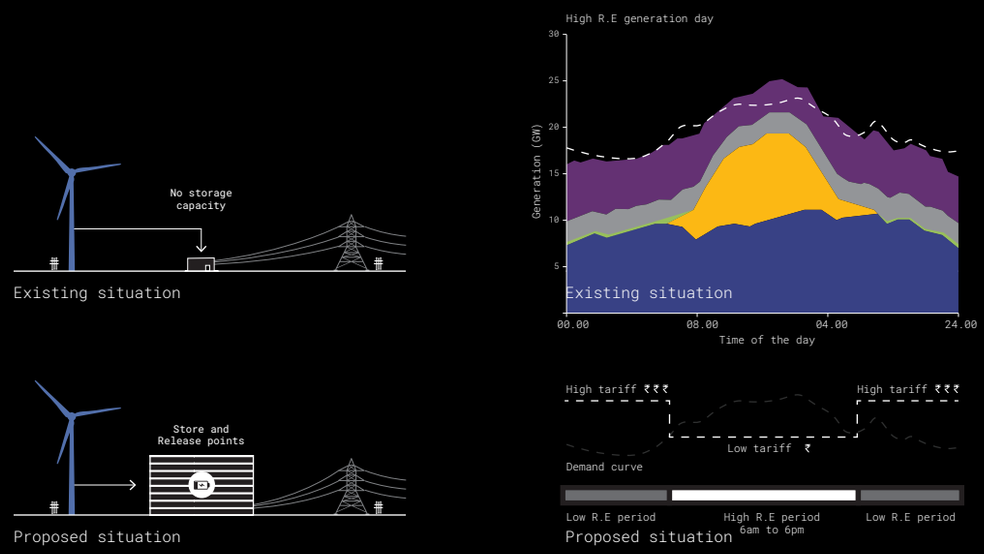


Fig 8.25: Design interventions for flexibility of energy network

Conclusions.

This chapter presented the set of spatial strategies proposed by the project for achieving the Energy Vision 2050 for Tamil Nadu. The set of six spatial strategies and the (expandable) toolbox of design interventions, solutions, policies, and regulations act as guiding principles to create an adaptive, inclusive and collaborative energy transition in Tamil Nadu.

The set of strategies (Fig 8.27) aimed at increasing R.E production by densifying existing energy production landscapes, finding unique opportunities for combining energy production with other sectors, and coproducing energy through bottom-up initiatives. These ***alternatives to extractivist, sprawling, large scale energy development*** depend on building mutually beneficial relationships between the network of actors and stakeholders involved. Furthermore, the strategies addressed the lack of ecological sensitivity in energy development by proposing regulations for landscape integration in energy development and mitigating the post-carbon landscape. Finally, by reinforcing mechanisms for efficient and flexible utilisation of energy, the adaptability of the energy landscapes was increased to manage the fluctuating renewable energy supply.

The toolbox of design interventions can each be independently implemented by the group of stakeholders identified for each action, with respect to the local conditions in the site of implementation. While change in policy and law is required for the execution of some solutions, certain bottom-up initiatives are open for adoption and interpretation by the individuals and communities participating in Tamil Nadu's transition to renewable energy. The ***flexibility and accessibility of the bottom-up solutions*** ensures that the individuals and communities can independently initiate the shift to renewables and achieve self sufficiency in energy use. Therefore, project stresses on the need for democratic, consensus oriented decision making through the inclusion of key stakeholders identified for each action.

The following chapter presents how the set of strategies were juxtaposed to find overlaps, conflicts and opportunities. The outcome of this process was the ***Strategic Plan for the state- a proposal for the development of energy production landscapes in the Tamil Nadu.***



Fig 8.26: Diagram summarizing the chapter

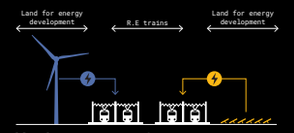
Fig 8.27: Toolbox of spatial strategies for energy transition

11.1271° N, 78.6569° E

TOOLBOX OF STRATEGIES FOR ENERGY TRANSITION IN TAMIL NADU



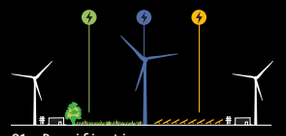
S1- Densification
A: Build in the gaps



S2- Crossprogramming
A: Energy x Mobility



S3- Coproduction
A: Neighbourhood Energy Networks



S1- Densification
B: Diversify-heterogenous landscapes



S2- Crossprogramming
B: Energy x Waste management



S3- Coproduction
B: Energy sharing with energy vulnerbale communities



S1- Densification
C: Repower old energy sites



S3- Crossprogramming
C: Energy x Public Infra-structure



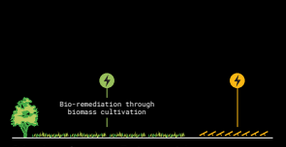
S3- Coproduction
C: Rural mini grids



S1- Densification
D: Build R.E transmission capacity



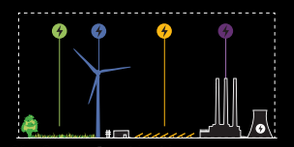
S3- Coproduction
D: Citizen Capacitation Centres



S4- Landscape Integration
A: Prioritize wastelands for energy development



S5- Post-carbon landscapes
A: Energy saving in cities



S6- Seasonal activation
A. Increase the diversity and multi-functionality



S4- Landscape Integration
B: Create landscape buffers around energy development



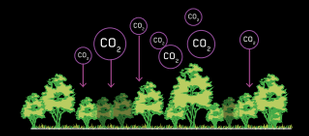
S5- Post-carbon landscapes
B: Coal to biomass power plants



S6- Seasonal activation
B. Develop cross-border energy exchanges



S4- Landscape Integration
C: Create 'green-energy' networks

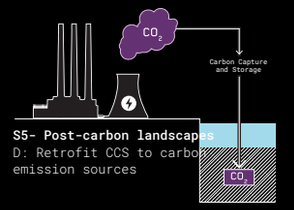


S5- Post-carbon landscapes
C: Enhance passive carbon capture

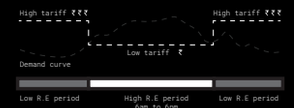


S6- Seasonal activation
C. Store and Release

The set of six spatial strategies and the (expandable) toolbox of design interventions, solutions, policies, and regulations act as guiding principles to create an adaptive, inclusive and collaborative energy transition in Tamil Nadu. The strategies are meant to be adjusted based on the conditions of the local context.



S5- Post-carbon landscapes
D: Retrofit CCS to carbon emission sources



S6- Seasonal activation
D. Enforce demand-side management

11.1271° N, 78.6569° E

9

Strategic Plan for the Macro-region

Overview:

This chapter presents the Strategic Plan for the macro-region, the assemblage of spatial strategies defined in the previous chapter. The plan showing the locations for energy development is supplmented with calculations to assess the contribution of the area to the macro-region. Finally, a catalogue of spatial energy typologies resulting from the implmentation of the strategic is presented.

Sections:

9.1. Strategic Plan for the Macro-region
9.2. Typologies of Energy Landscapes

9.1 Strategic Plan for the Macro-region

The Strategic plan for the macro region is a combination of the six spatial strategies defined in the previous chapter (Fig 9.1, Fig 9.2, Fig 9.3). The Strategic Plan determines **where to build renewable energy infrastructure in order to meet the energy demand of 2050**, by taking the spatial strategies as the guiding principles for development. It includes estimations on the total energy that can be produced by each typology of energy landscape in the macro-region.

The Strategic Plan is further delineated into the four energy types explored in this project- **solar, wind, biomass and post-carbon energy landscapes**, to cluster and understand energy-specific spatial opportunities and solutions afforded by the design. The following pages will elaborate on the macro-regional Strategic Plan for Tamil Nadu's energy transition, along with the catalogue of distinct energy landscapes that are sustained by the implementation of the design.

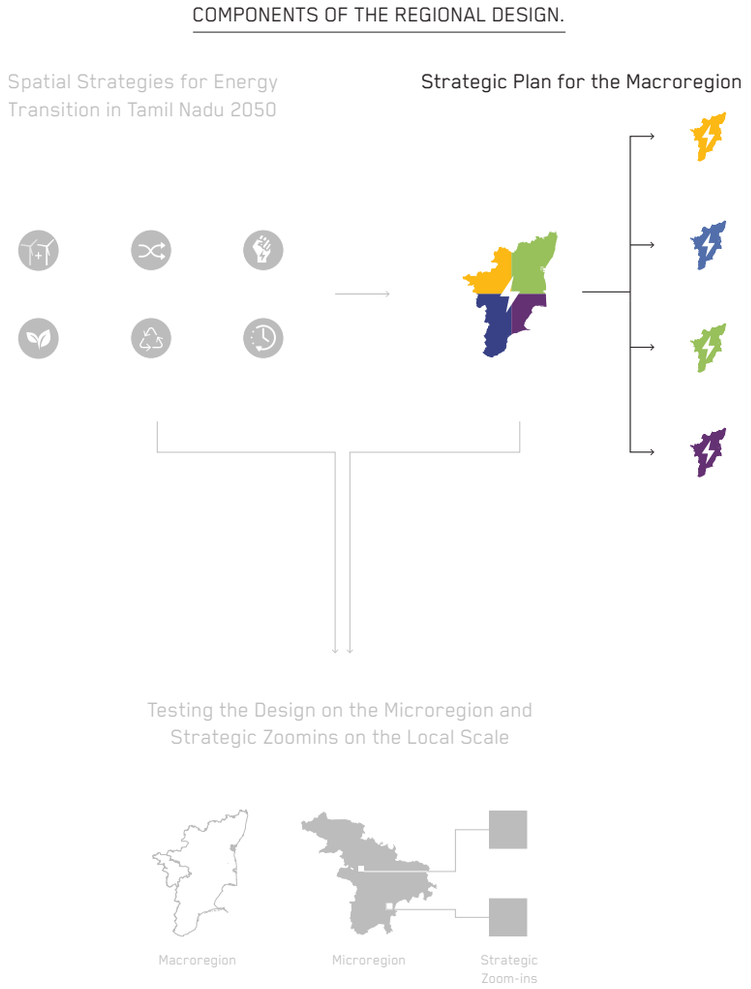
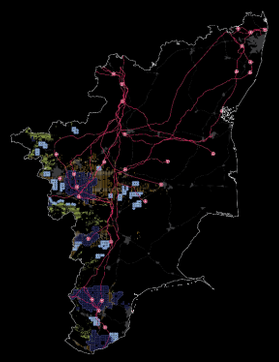


Fig 9.1: Diagram showing the components of the regional design and scales of application.

Layering the Strategies.

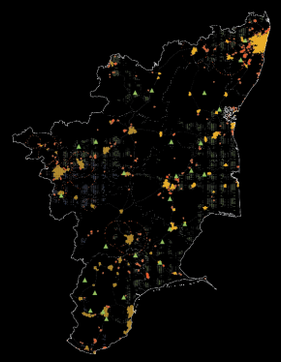
Densify around existing energy production sites.



Create multifunctional energy landscapes through cross programming



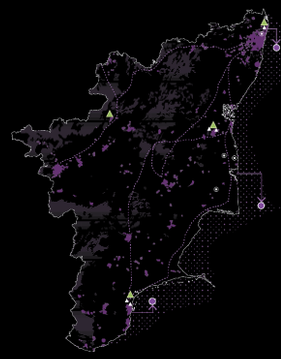
Coproduce energy with the community in urban and rural areas.



Add ecological value through landscape integration in energy development



Repower and Reconfigure the post-carbon energy landscapes.



Increase flexibility through seasonal activation of energy landscapes.



Fig 9.2: The six strategies that were taken into consideration to generate the strategic plan for the macro-region

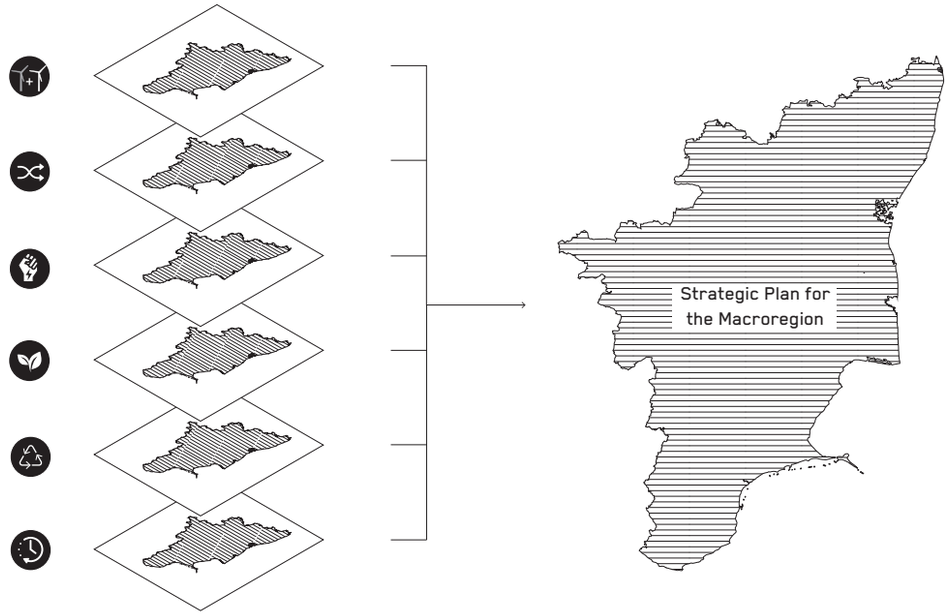


Fig 9.3: Layers of the strategic plan

Strategic Plan for Energy Transition in Tamil Nadu 2050

The map shows the Strategic Plan for the development of energy production landscapes in Tamil Nadu. The plan defines where to build specific R.E. types like solar, wind, biomass and carbon. Refer the legend for target energy outputs proposed for each typology of energy landscape.

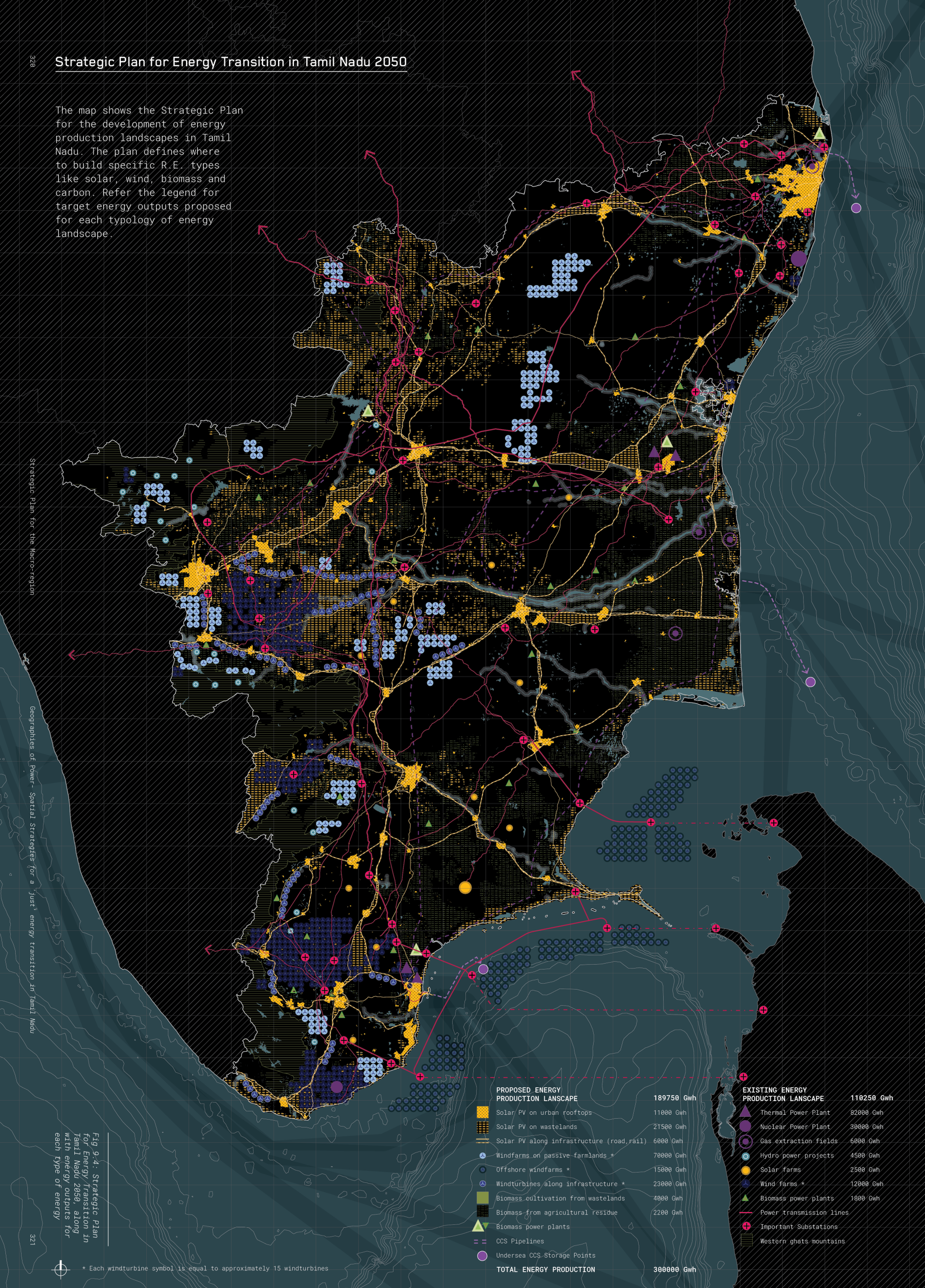


Fig 9.4: Strategic Plan for Energy Transition in Tamil Nadu 2050, along with energy outputs for each type of energy

Strategic Plan for Solar Energy Development in Tamil Nadu 2050

Proposed Solar energy landscapes

This map shows the regional distribution of solar energy production areas in Tamil Nadu. Refer the legend for target energy outputs proposed for each typology of energy landscape and scale of development.

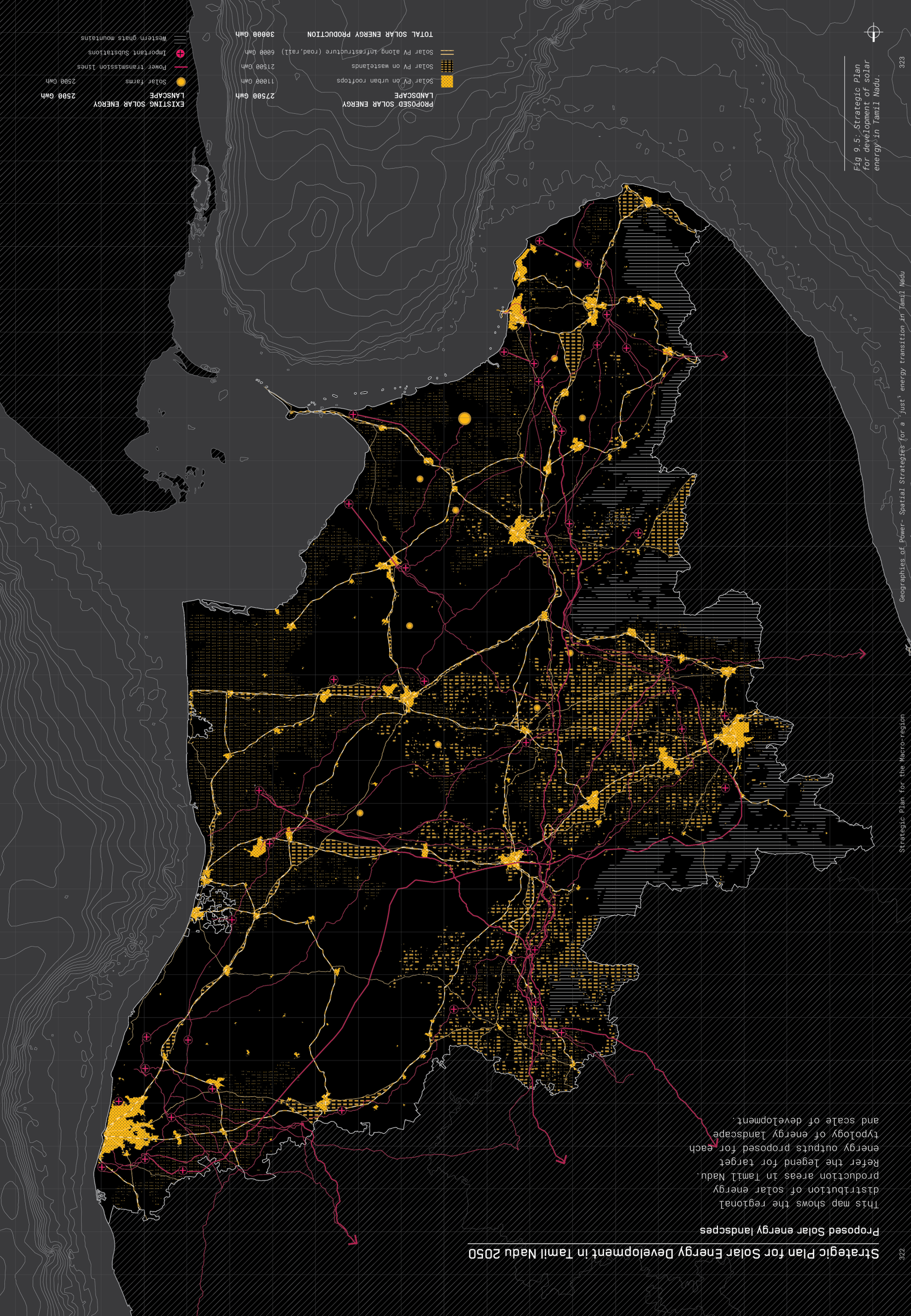


Fig 9.5: Strategic Plan for development of solar energy in Tamil Nadu.

Strategic Plan for WindrEnergy Development in Tamil Nadu 2050

Proposed Wind energy landscpes

This map shows the regional distribution of wind energy production areas in Tamil Nadu. Refer the legend for target energy outputs proposed for each typology of energy landscape and scale of development.

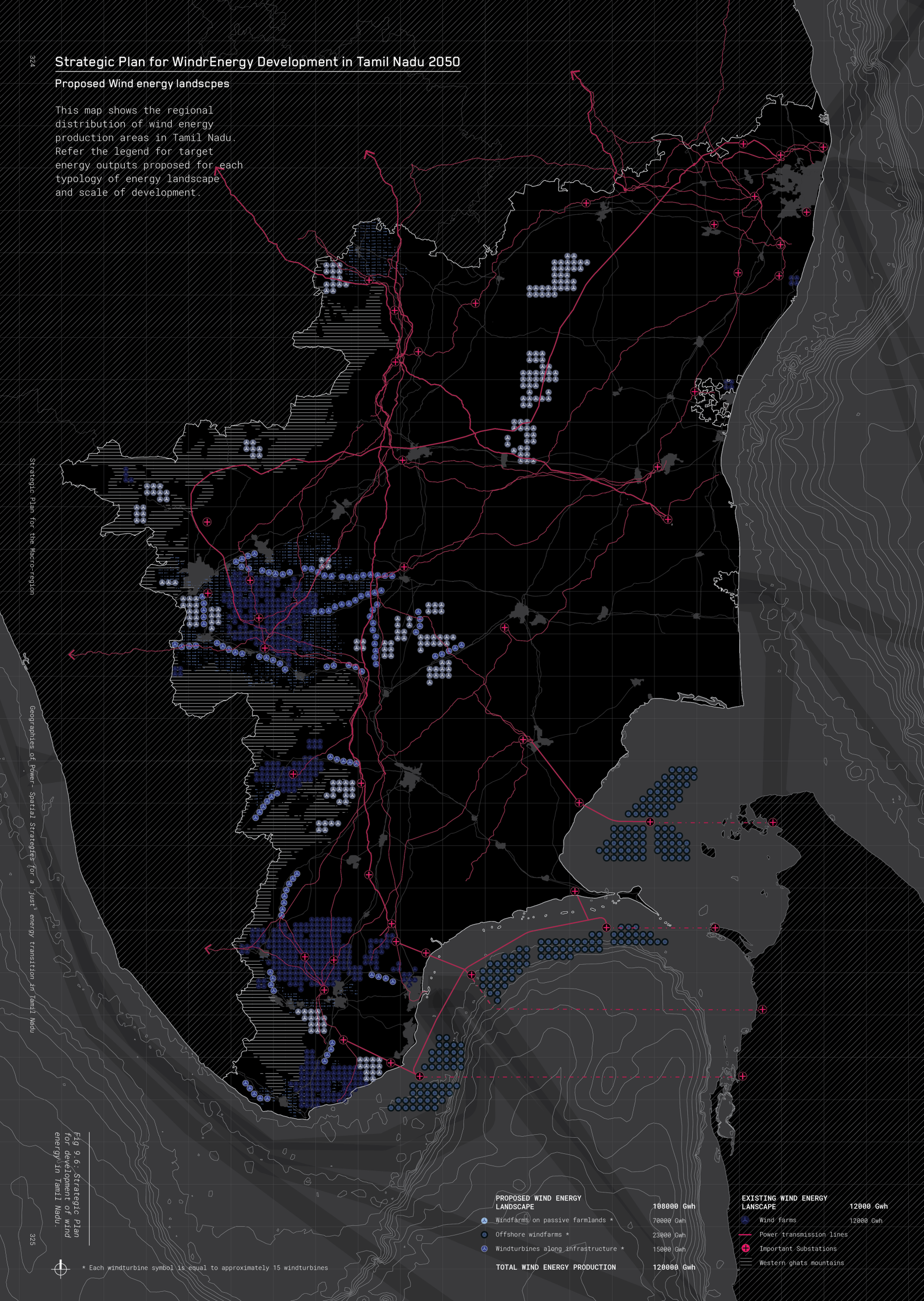


Fig 9.6: Strategic Plan for development of wind energy in Tamil Nadu.

Strategic Plan for Biomass Energy Development in Tamil Nadu 2050

Proposed Biomass energy landscpes

This map shows the regional distribution of biomass energy production areas in Tamil Nadu. Refer the legend for target energy outputs proposed for each typology of energy landscape and scale of development.

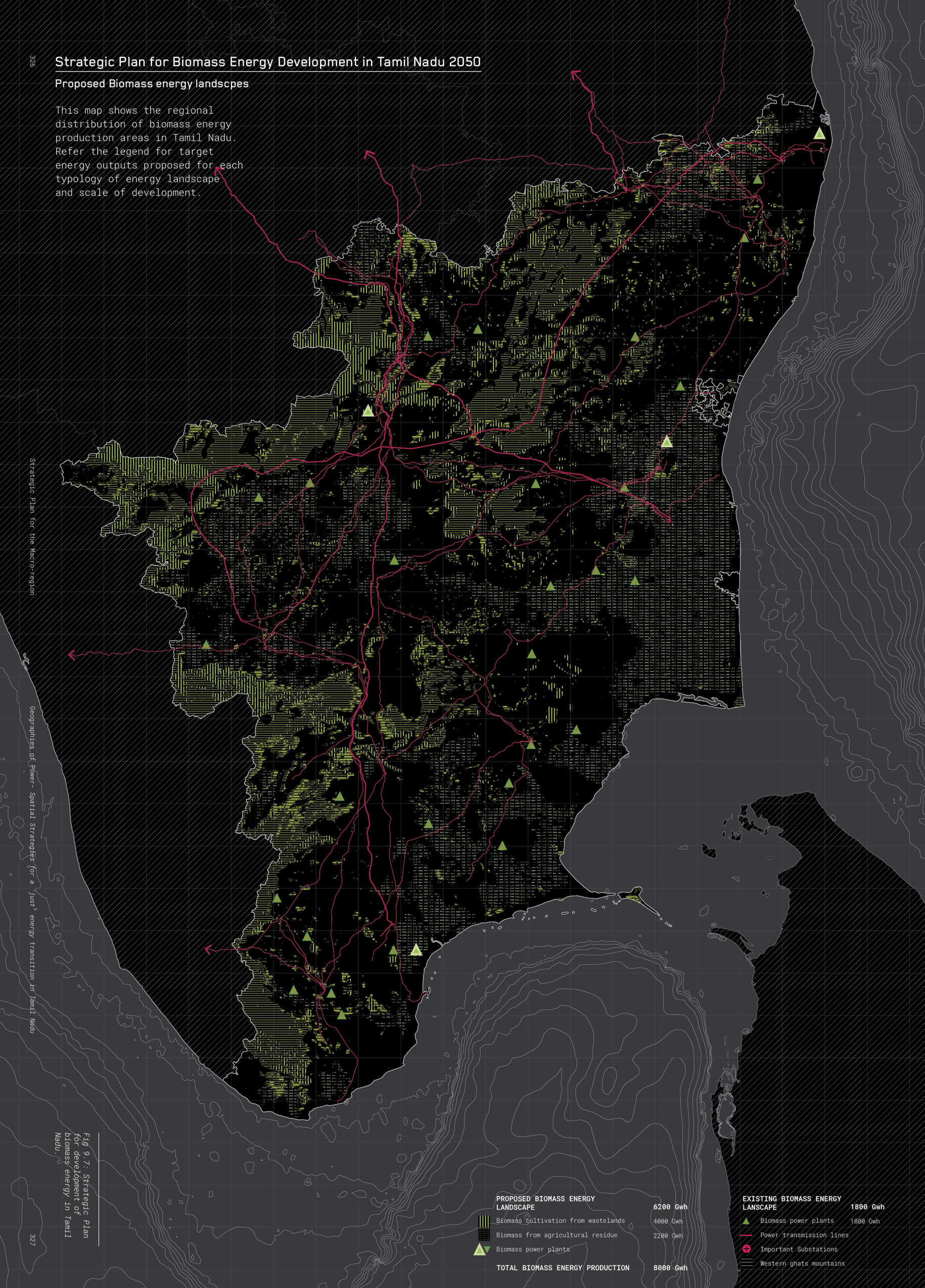


Fig 9.7: Strategic Plan for development of biomass energy in Tamil Nadu.

Strategic Plan for Post-Carbon Energy Development in Tamil Nadu 2050

Proposed Post-carbon energy landscpes

This map shows the regional distribution of carbon-based energy production areas in Tamil Nadu. Refer the legend for target energy outputs proposed for each typology of energy landscape and scale of development.

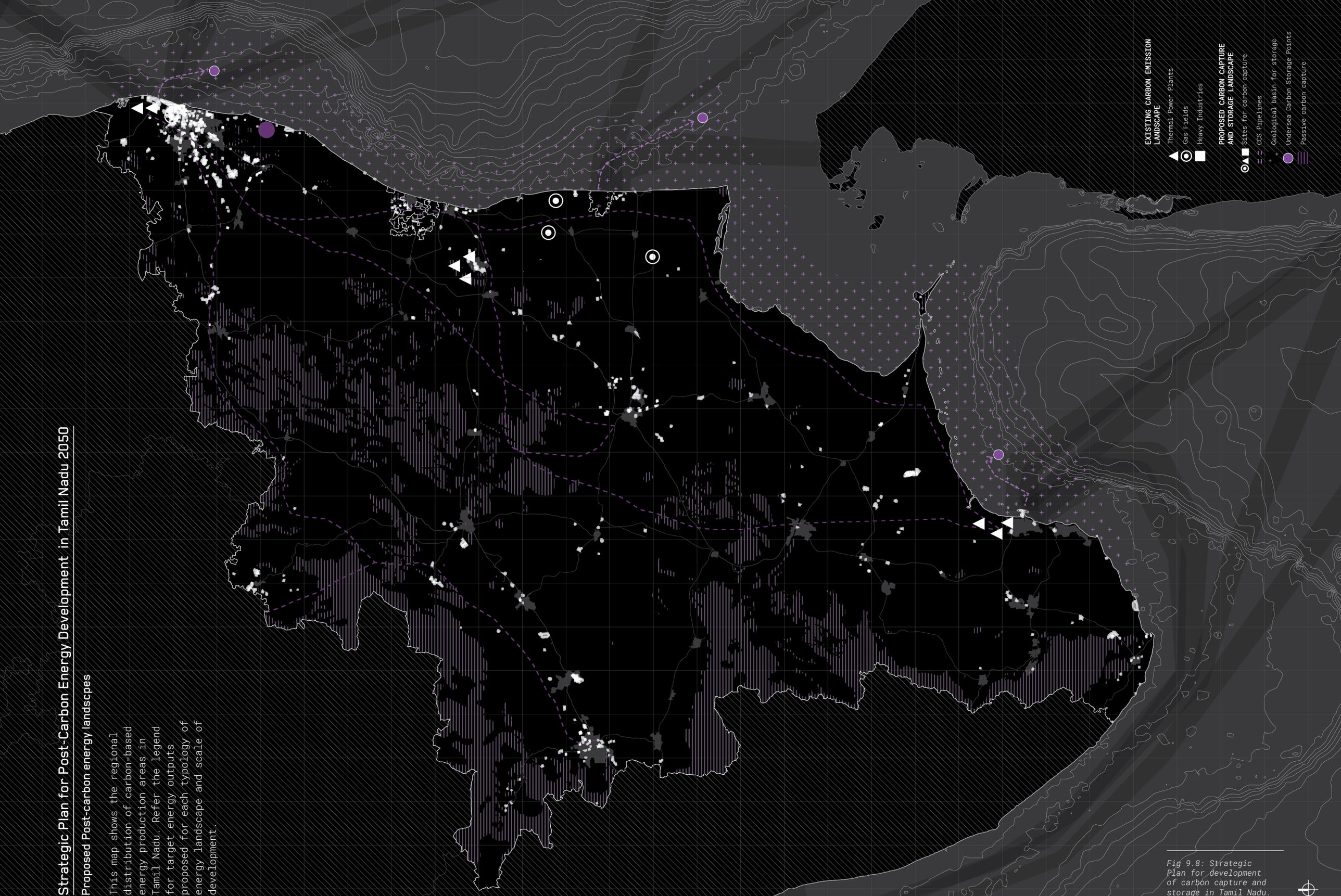


Fig 9.8: Strategic Plan for development of carbon capture and storage in Tamil Nadu.

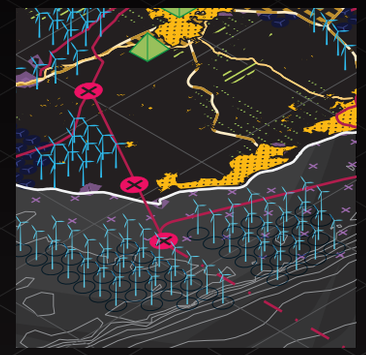
3D view of the Strategic Plan.

The strategic plan envisions an integrated energy production network in the state that prevents energy sprawl through densification of existing energy production sites, improves intersectoral collaboration through crossprogramming and increases citizen participation through coproduction of energy. The plan also defines regulations for the mitigation of the post carbon energy landscape, and the cyclic, seasonal activation of energy production sites. Fig 9.9 shows the 3D representation of the strategic plan, where the confluence of the six strategies create interesting

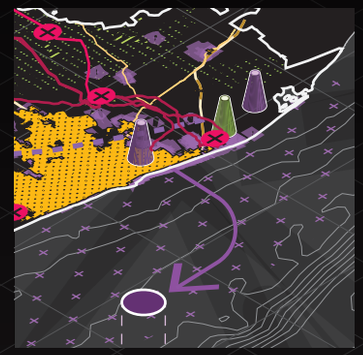
- Solar PV on urban rooftops
- Solar PV on wastelands
- Solar PV along infrastructure (road,rail)
- Small scale solar PV
- Wind farms (existing)
- Windfarms on land
- Offshore windfarms
- Small scale wind farms
- Biomass cultivation from wastelands
- Biomass from agricultural residue
- Biomass from Western Ghats
- Biomass power plants
- Thermal to Biomass PP
- Thermal power plants
- Heavy Industrail areas
- Geological storage basin
- CCS Pipelines
- Undersea Carbon Storage Points
- Important Substations
- Power transmission lines



Detail 1: Concentration of wind energy development in the north western border regions of the state. Transmission lines to carry the energy produced to other regions of the state are also seen in the detail.



Detail 2: Offshore wind energy farms in the Gulf of Mannar. The marine energy landscape has the potential to add 2300MW of R.E to the grid in Tamil Nadu.



Detail 3: Post carbon energy landscape around Chennai, the capital city of the state. Part of the Ennore Thermal Power Plant is converted to biomass based TPP. Heavy industries near the energy sites that benefit from the development are also seen in the detail.

Detail 1

Detail 2

Detail 3

Fig 9.9: 3D view of the strategic plan with zoom-in details at stratgic points in the design.

9.2 Typologies of energy landscapes

The multitude of energy landscapes that are nurtured by the project are clustered in this section to view them as a spatial 'type' that is distributed across the entire region. This dual understanding of energy landscapes as a **repeated 'type'**, (where the spatial quality, elements, embeddedness, and needs of the energy landscape can be observed), and in terms of its **territorial distribution** is an important contribution of this project. This helps in identifying and coordinating actions, design interventions and decision making that is specific to the typology of energy landscape. Fig 9.10 shows the consolidation of the proposed typologies of energy landscapes. The following pages individually present the four types of energy production landscapes explored in the project- solar, wind, biomass and post-carbon energy landscapes. The idolation of design strategies based on energy type also helps in channeling relationships between stakeholders, who are different for each energy type.

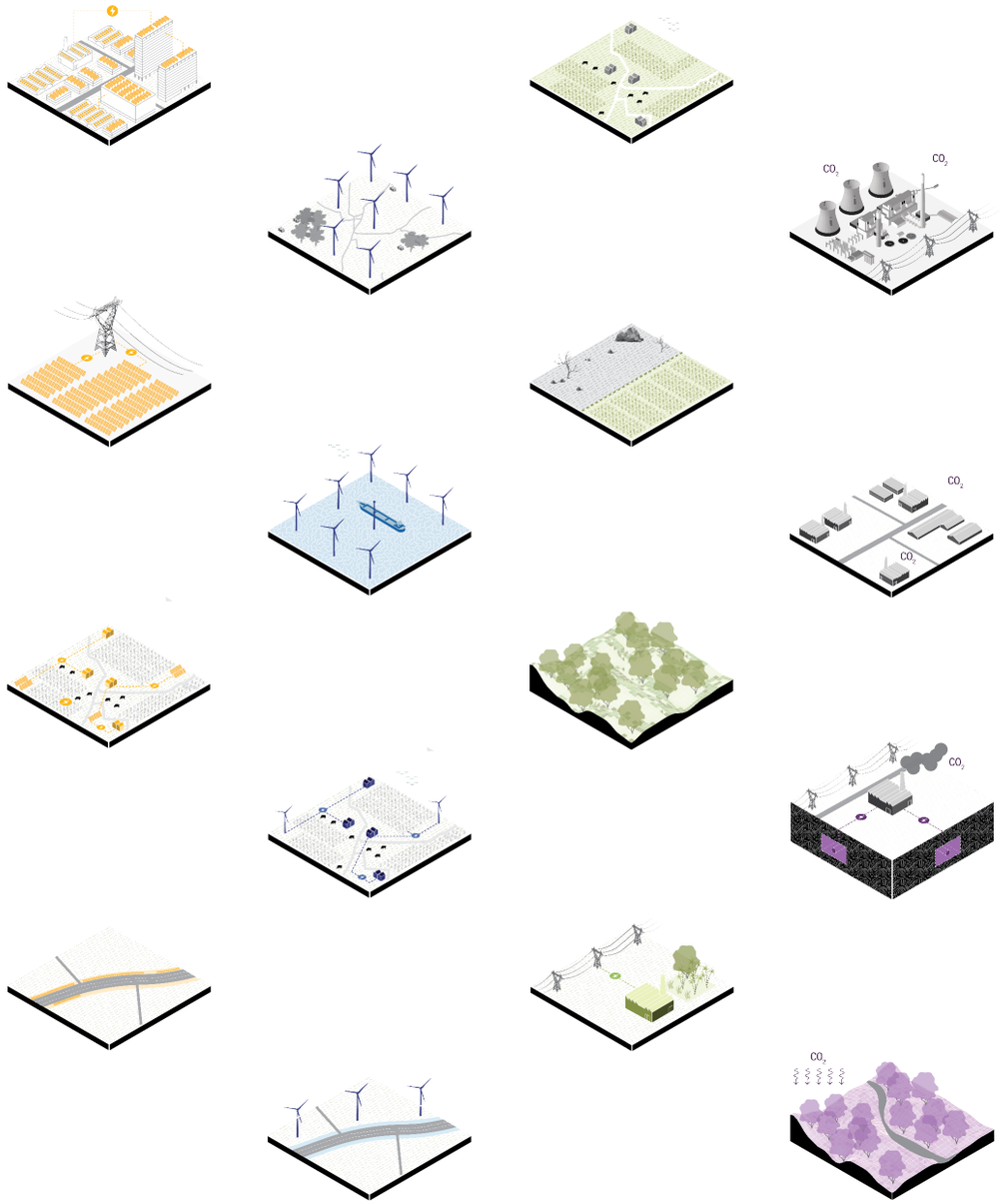
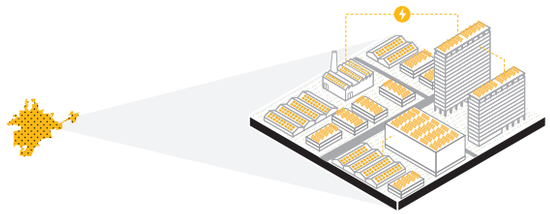


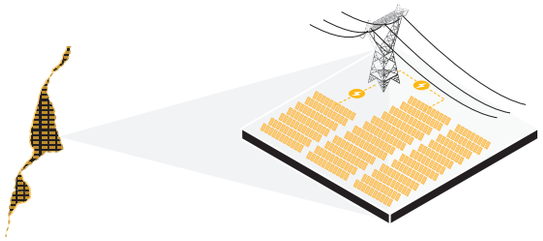
Fig 9.10: Catalogue of energy landscapes derived from the Strategic Plan

Design Typologies - Solar Energy Landscapes.

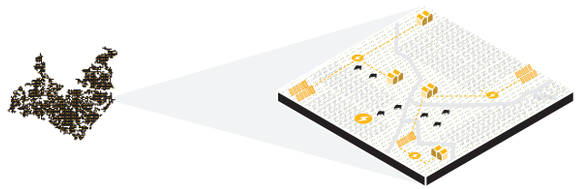
1. Rooftop solar PV



2. Large sclae
solar power plants



3. Small scale
solar PV



4. Solar PV along
infrastructure

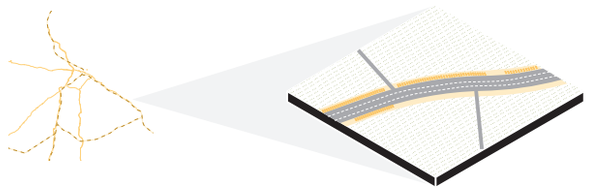
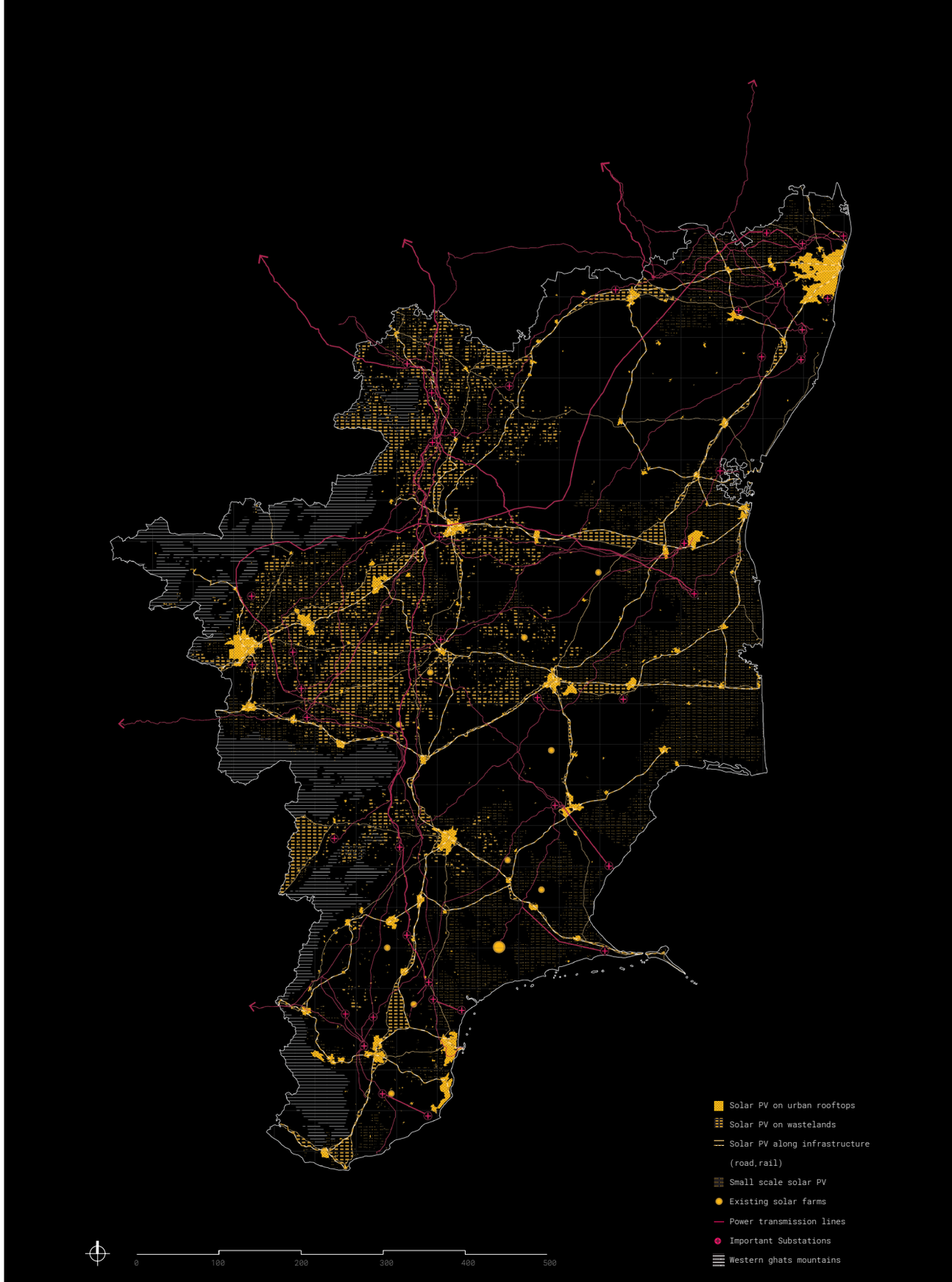


Fig 9.11: Typologies of solar energy landscape

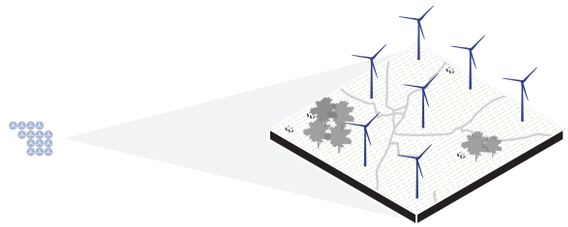
Fig 9.12: The regional distribution of solar energy landscapes.

11.1271° N, 78.6569° E

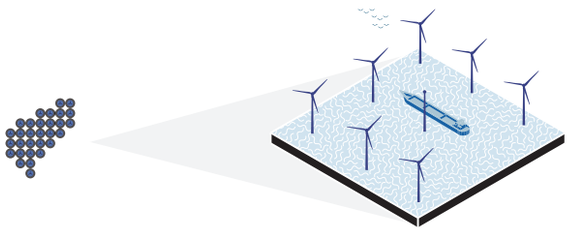


Spatial Typologies - Wind Energy Landscapes.

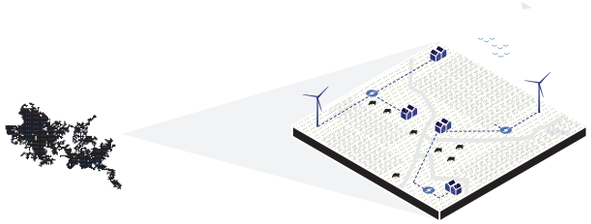
1. Large scale wind farms



2. Offshore wind farms



3. Small scale wind turbines



4. Windturbines along infrastructure

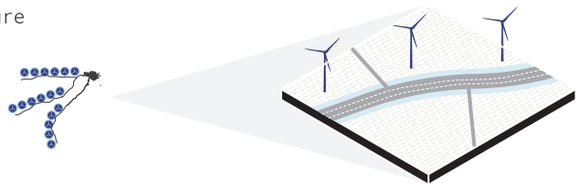
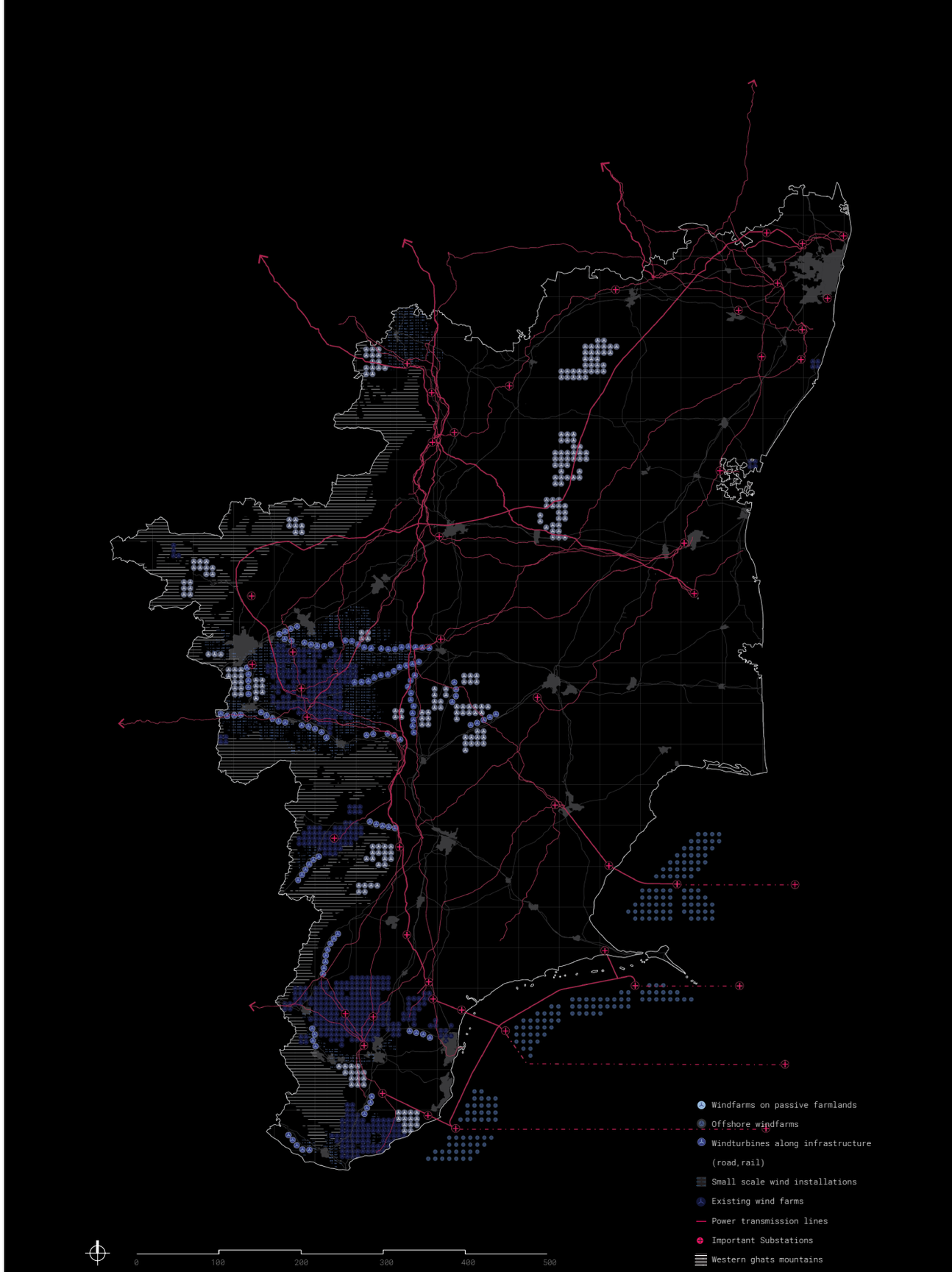


Fig 9.13: Typologies of wind energy landscape

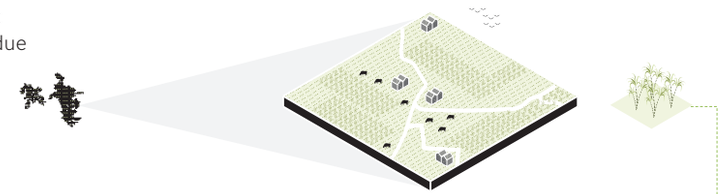
Fig 9.14: The regional distribution of wind energy landscapes.

11.1271° N, 78.6569° E

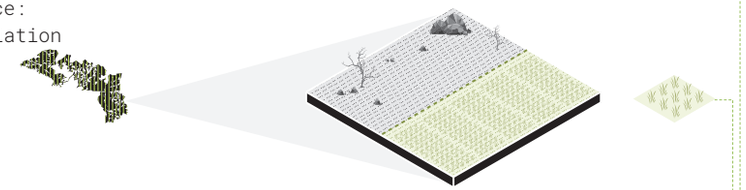


Design Typologies - Biomass Energy Landscapes.

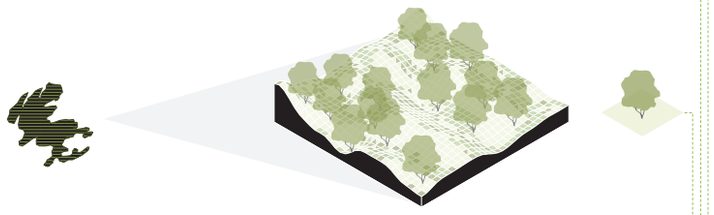
1. Biomass Source:
Agricultural residue



2. Biomass Source:
Wasteland remediation



3. Biomass Source:
Forest byproducts



4. Biomass Power plant

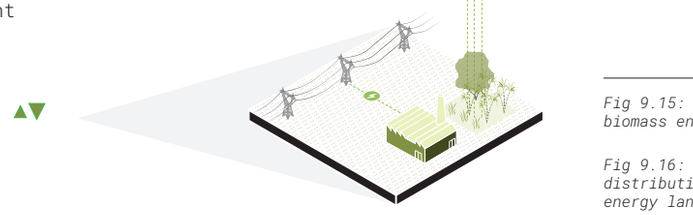


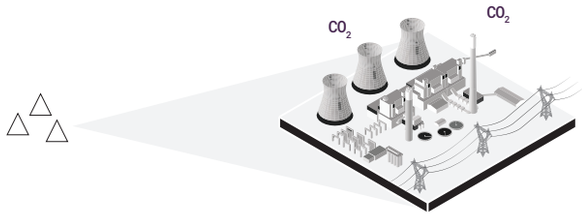
Fig 9.15: Typologies of biomass energy landscape

Fig 9.16: The regional distribution of biomass energy landscapes.

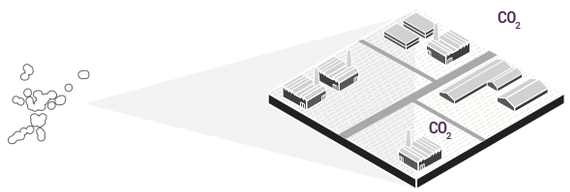


Design Typologies - Post Carbon Landscapes.

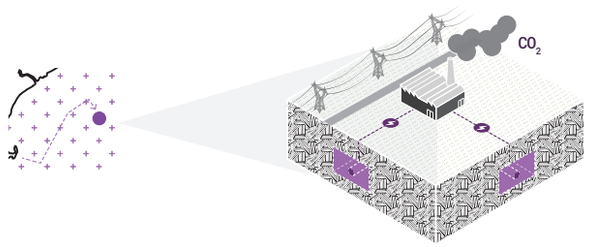
1. Carbon emission landscape: Thermal power plants



2. Carbon emission landscape: heavy industries



3. Carbon capture and storage sites



4. Passive carbon capture on natural ecological reserves

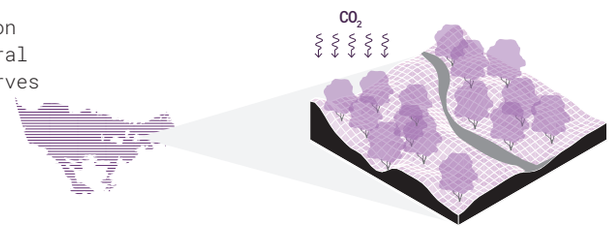
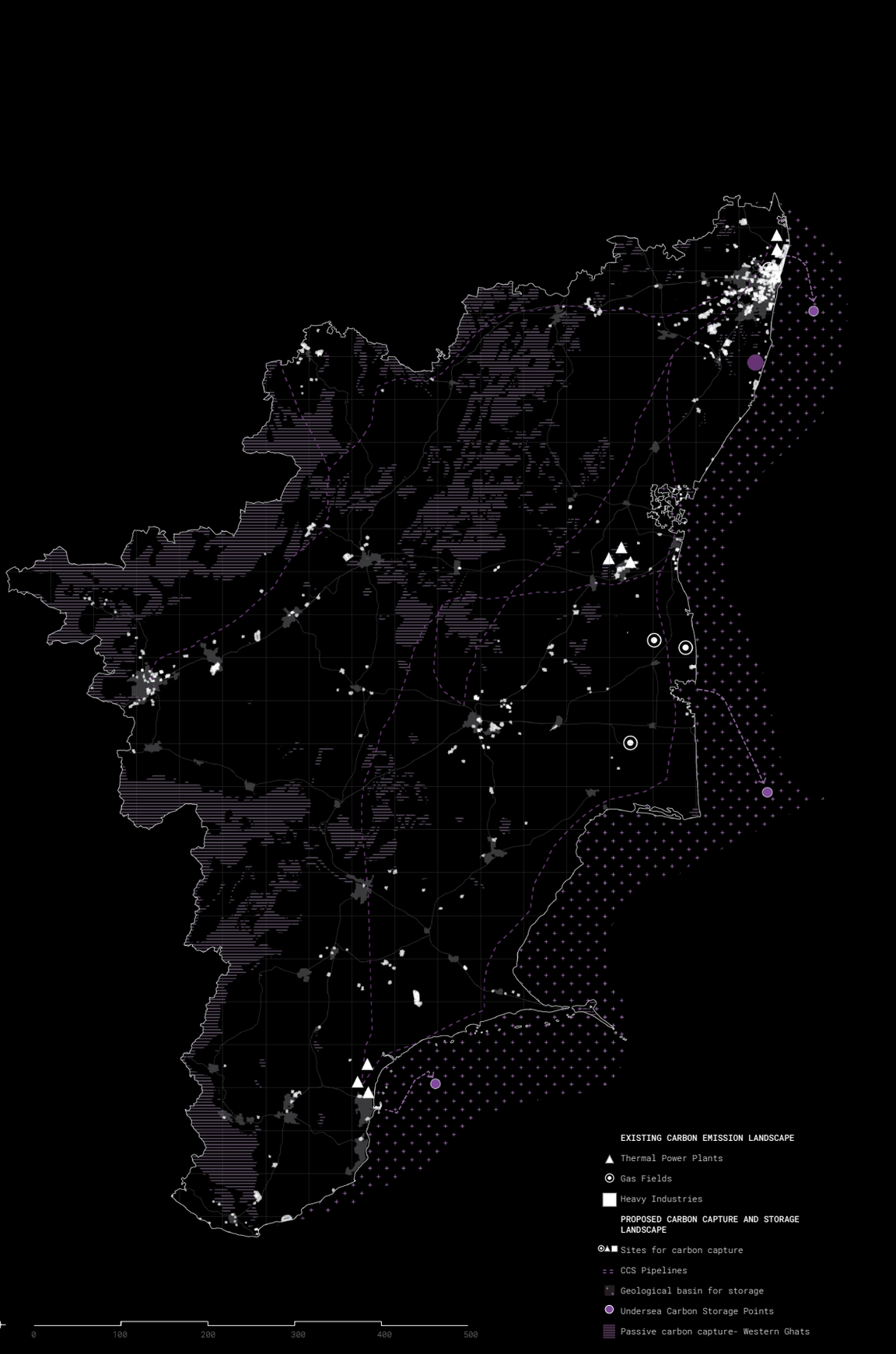


Fig 9.17: Typologies of post carbon landscape

Fig 9.18: The regional distribution of post carbon landscapes.

11.1271° N, 78.6569° E



Conclusions.

This chapter presented the Strategic Plan for the macro-region by layering the spatial strategies elaborated in the previous chapter. The Strategic Plan acts as the planning document to guide the development of energy production landscapes in Tamil Nadu. The elaboration of the Strategic Plan with respect to the type of energy and typology of energy landscapes also enables the coordination of activities, actions and stakeholders based on their energy specialization. The following chapter will test the implications of the spatial strategic and the Strategic Plan in the local scale through design explorations in the two zoom-ins chosen.



Fig 9.19: Diagram summarising the Chapter

Fig 9.20: The layered energy networks of the strategic plan

10

Testing the Design

Overview:

The performance of the macro-regional spatial strategies and the resulting Strategic Plan is tested by applying them to the selected micro-region- Coimbatore, and two Strategic Zoom-ins at the rural (Udumelpet Energy Hub) and urban scale (Coimbatore City Centre), to identify context specific opportunities and challenges.

Sections:

10.1. Methodology for testing the Design
10.2. Strategies in the Micro-region
10.3. Interventions in the Strategic Zoom-ins

10.1 Methodology for testing the Design

The performance of the macro-regional spatial strategies and the resulting Strategic Plan is tested by applying them to the selected micro-region- Coimbatore, and two Strategic zoom-ins at the urban and rural scale. The normative values defined in the Vision and the Strategic Plan, and the inferences gained from the spatial analysis of the micro-region drive the translation of the regional design in this scale. This process of macro-regional spatial planning and subsequent local translation and evaluation of the plan **reveals context specific opportunities and challenges,** that may aid or hinder its implementation. First, the six spatial strategies are adapted in the micro-region to form a comprehensive Strategic Plan for Coimbatore region. Based on the outcome of this process, specific design interventions for the Strategic Zoom-ins are derived. The translation of the design across the two geographic scales illustrates the role regional design can play in R.E. development.

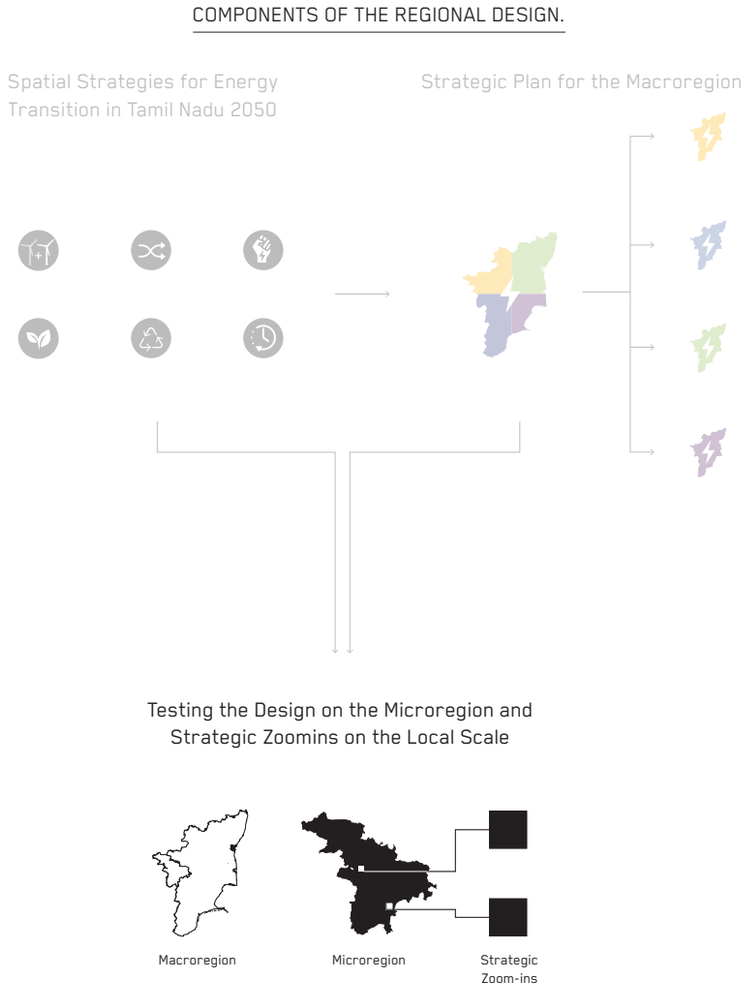
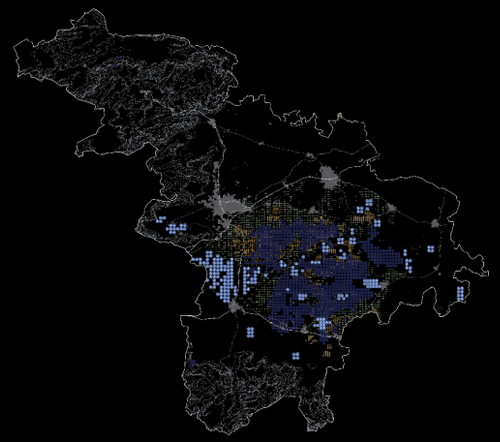


Fig 10.1: Diagram showing the components of the regional design and scales of application.

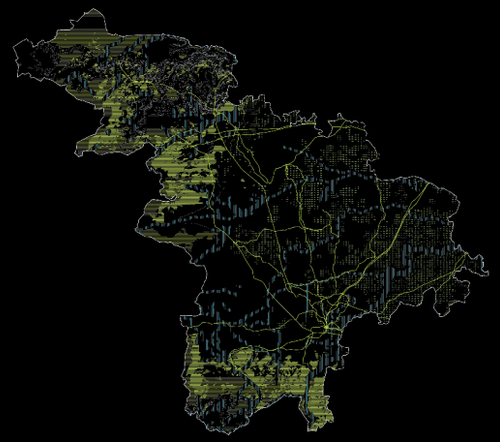
10.2 Strategies in the Micro-region

Coimbatore region, with considerable concentration of existing energy sites, was an challenging territory to translate the Strategic Plan. The spatial strategies and solutions were adapted to the local spatial conditions and social settings in the micro-region (Fig 10.2).
The new energy infrastructure is planned based on **local agricultural landuse patterns to preserve its visual and landscape integrity.** The new network of energy landscapes in the region densify and surround the existing energy sites in the central zone of the region, and enable the transition to low-energy Coimbatore, with surplus renewable energy to transfer to the rest of the macro-regional grid. The regional design for energy transition in Tamil Nadu must be **supplemented by local adaptions in 9 administrative regions of the state** to reinforce it. The chosen case of Coimbatore is illustartive of the research and design process that can be adapted to suit the spatial condiitons in other regions of the state.

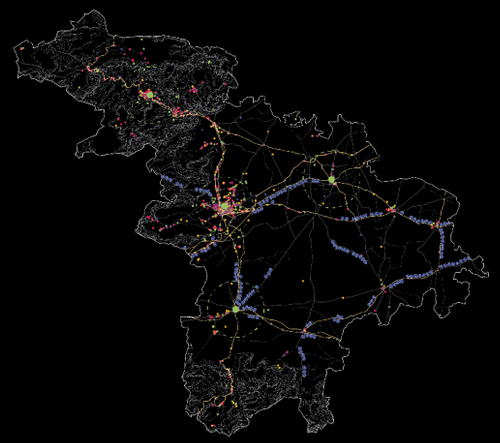
1.Densify around existing energy production sites.



4. Add ecological value through landscape integration in energy development.



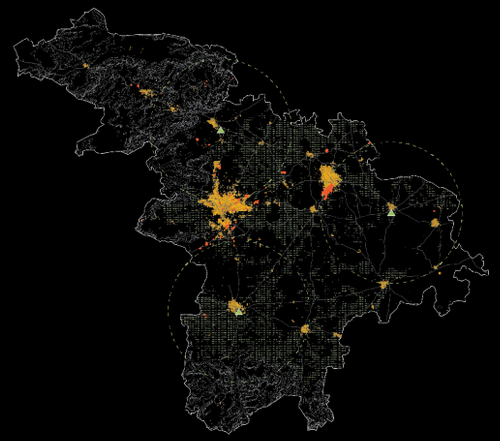
2. Create multi-functional energy landscapes through cross programming.



5. Repower and Reconfigure the post-carbon energy landscapes.



3. Coproduce energy with the community in urban and rural areas.



6. Increase flexibility through seasonal activation of energy landscapes.

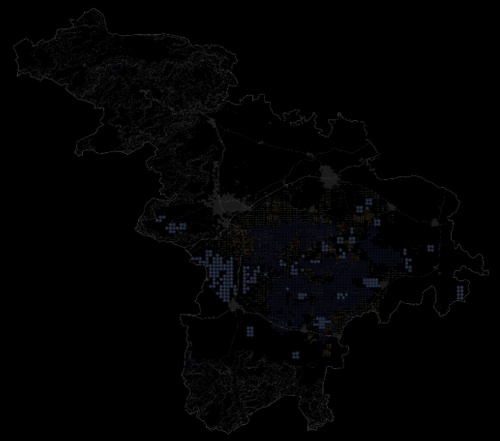


Fig 10.2: Maps showing the translation of the six spatial strategies on Coimbatore micro-region

Macro region to Micro region.

S1- Densification: Unused areas and wastelands around existing wind energy sites in the south-east parts of the region are densified with hybrid energy infrastructure (solr, wind, biomass)

S2- Crossprogramming: The highway and railway network, forming a ring around the heart of the region are taken as the backbone for the development of infrastructure oriented R.E. production.

S3- Coproduction: The strategies for coproduction of energy is manifested in urban residential areas and rural agricultural land with the involvement of local stakeholders.

S4- Landscape Integration: The wastelands in the region, especially near the Western Ghats mountains are remediated through the cultivation of biomass crops.

S5- Carbon Mitigration: Pipelines for the transport of captured Co_2 from heavy industrial areas in the region are constructed, with a intermediate carbon storage point outside Coimbatore City

S6- Seasonal activation: The hybrid, heterogenous nature of energy developed proposed in the project ensures the uninteruped available of R.E even during off-peak season.

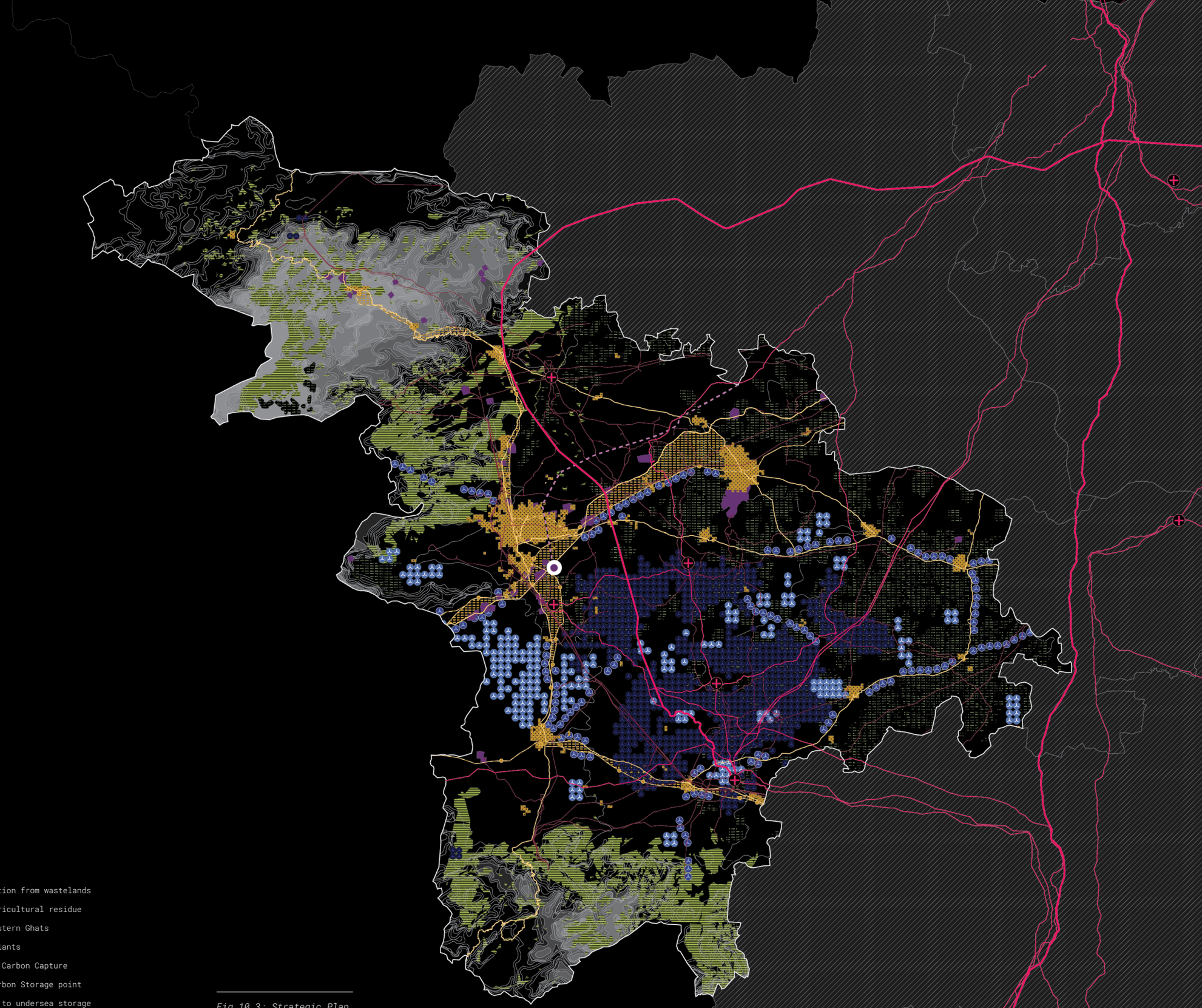


Fig 10.3: Strategic Plan for energy transition in the Coimbatore micro-region.

3D view of the Microregional Design.

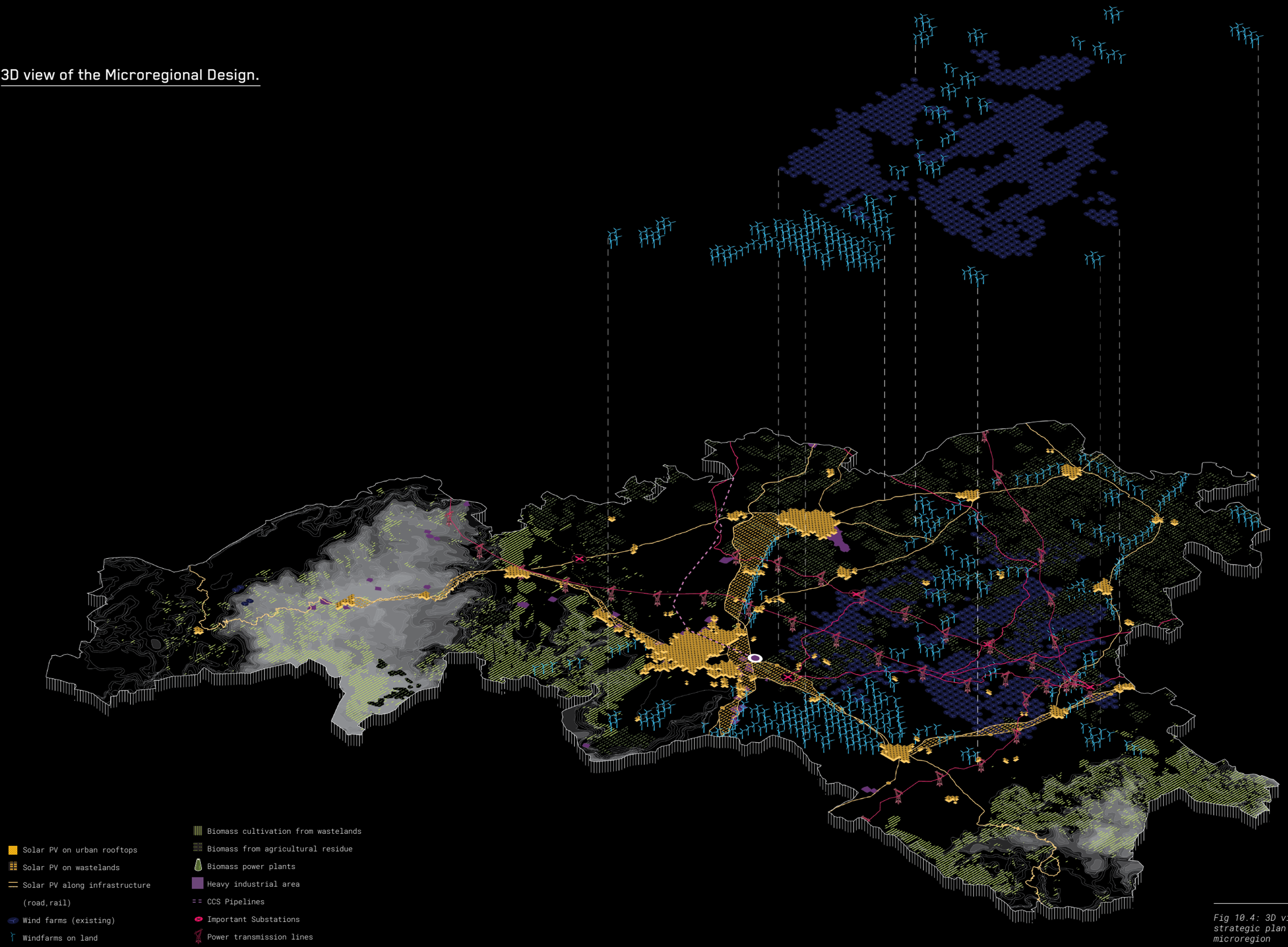


Fig 10.4: 3D view of the strategic plan for the microregion

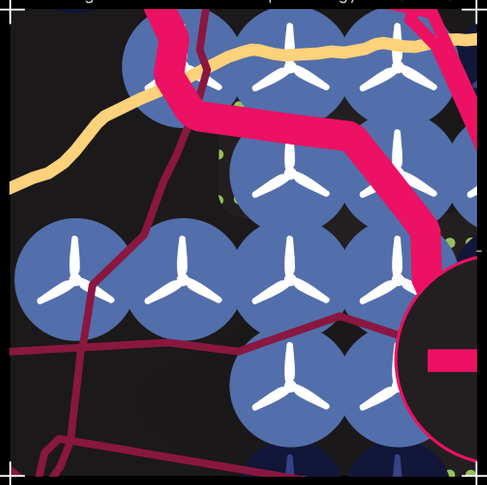
Micro region to Strategic Zoom-ins.

The implications of the manifestation of the micro-regionla design is tested in the two areas chosen for zoom-in- Udumelpet Energy Hub annd Coimbatore City Centre. In the map below, the two factors stand out:

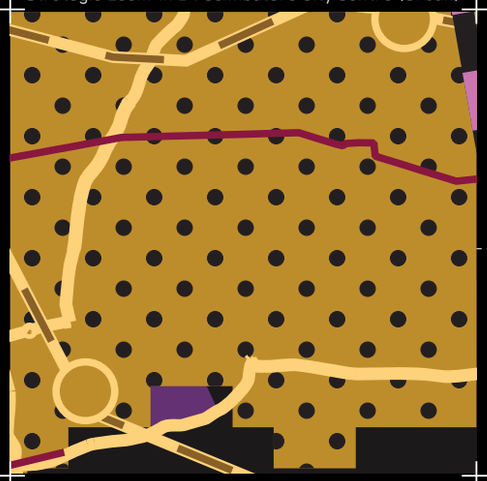
1. The design around existing wind energy sites in Udumelpet (A)
2. The concentration of solar energy based initatives in Coimbatore city (B)

These two factors, among others are explored in detail in the following section.

Strategic Zoom-in A : Udumelpet Energy Hub (Rural)



Strategic Zoom-in B : Coimbatore City Centre (Urban)



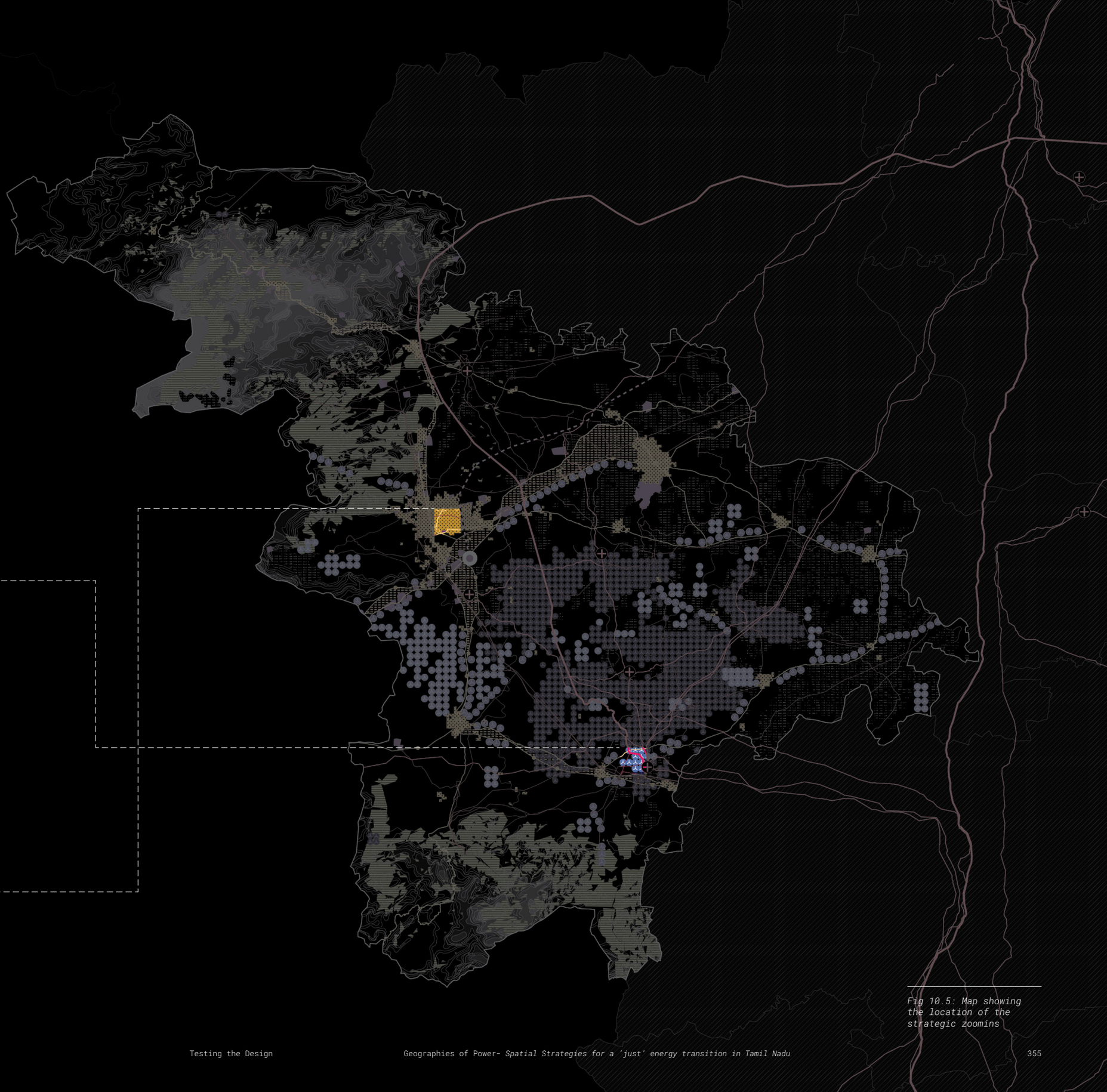


Fig 10.5: Map showing the location of the strategic zoomins

10.3 Interventions in the Strategic Zoom-ins

The degree of success of the macro-regional spatial strategies is tested by conducting design explorations in the Strategic Zoom-ins. Three spatial strategies- densification, crossprogramming and coprodction are chosen for translation in the local scale. For each of the areas, two specific design interventions derived from the strategies are elaborated in detail. In other words, for each zoom-in, four design solutions are discussed in detail with respect to their **spatial manifestations, socio-economic benefits, policy framework under which they operate, and the stakeholders involved in its implementation**. Through this process, the feasibility, scope and limitations of the regional design are identified. These inferences gained from the testing of the design is then used to inform similar kind of energy development in other areas of the macro-region. The testing is also useful in defining the desired spatial qualities in energy development and the image of the energy landscape.

Rationale for design explorations in the Strategic Zoom-ins.

In the strategic zoom-ins, three strategies are chosen for detailed exploration. The strategies for densification, and coproduction are explored in the Udumelpet Energy Hub, while strategies for crossprorgamming and coproduction are explored in Coimbatore City Centre. These strategies were chosen for exploration due to the opportunities in the local scale for its translation. The other strategies, while relevant in the area, do not have many opportunities for implementation.

STRATEGIES EXPLORED IN ZOOM-IN A : UDUMELPET ENERGY HUB

Densify around existing energy production sites.

Add ecological value through **landscape integration** in energy development.

Create multi-functional energy landscapes through **cross programming.**

Repower and Reconfigure the post-carbon energy landscapes.

Coproduce energy with the community in urban and rural areas.

Increase flexibility through **seasonal activation** of energy landscapes.

STRATEGIES EXPLORED IN ZOOM-IN B: COIMBATORE CITY CENTRE

Densify around existing energy production sites.

Add ecological value through **landscape integration** in energy development.

Create multi-functional energy landscapes through **cross programming.**

Repower and Reconfigure the post-carbon energy landscapes.

Coproduce energy with the community in urban and rural areas.

Increase flexibility through **seasonal activation** of energy landscapes.

Strategic Zoom-in A : Udumelpet Energy Hub ***(Rural)***



The design interventions in Udumelpet Energy Hub create frameworks for the integration of energy transition in rural areas, by densifying energy production around existing energy sites, and creating platforms for coproducing energy with the local communities, thereby adding ecological and socio-economic value to in the area. Here, Strategy 1 on 'densification' and Strategy 3 on 'coproduction' are translated into tangible design interventions within the 5km by 5km area (Fig 10.8). To understand the spatial manifestations, actor networks, societal impacts of each strategy (S1, S3), a smaller area is elaborated in detail in the following pages. The design explorations in Udumelpet are illustrative of the feasibility of the strategies in other rural areas of the macro-region.

STRATEGIES EXPLORED IN ZOOM-IN A : UDUMELPET ENERGY HUB

Densify around existing energy production sites.

Add ecological value through **landscape integration** in energy development.

Create multi-functional energy landscapes through **cross programming.**

Repower and Reconfigure the post-carbon energy landscapes.

Coproduce energy with the community in urban and rural areas.

Increase flexibility through **seasonal activation** of energy landscapes.

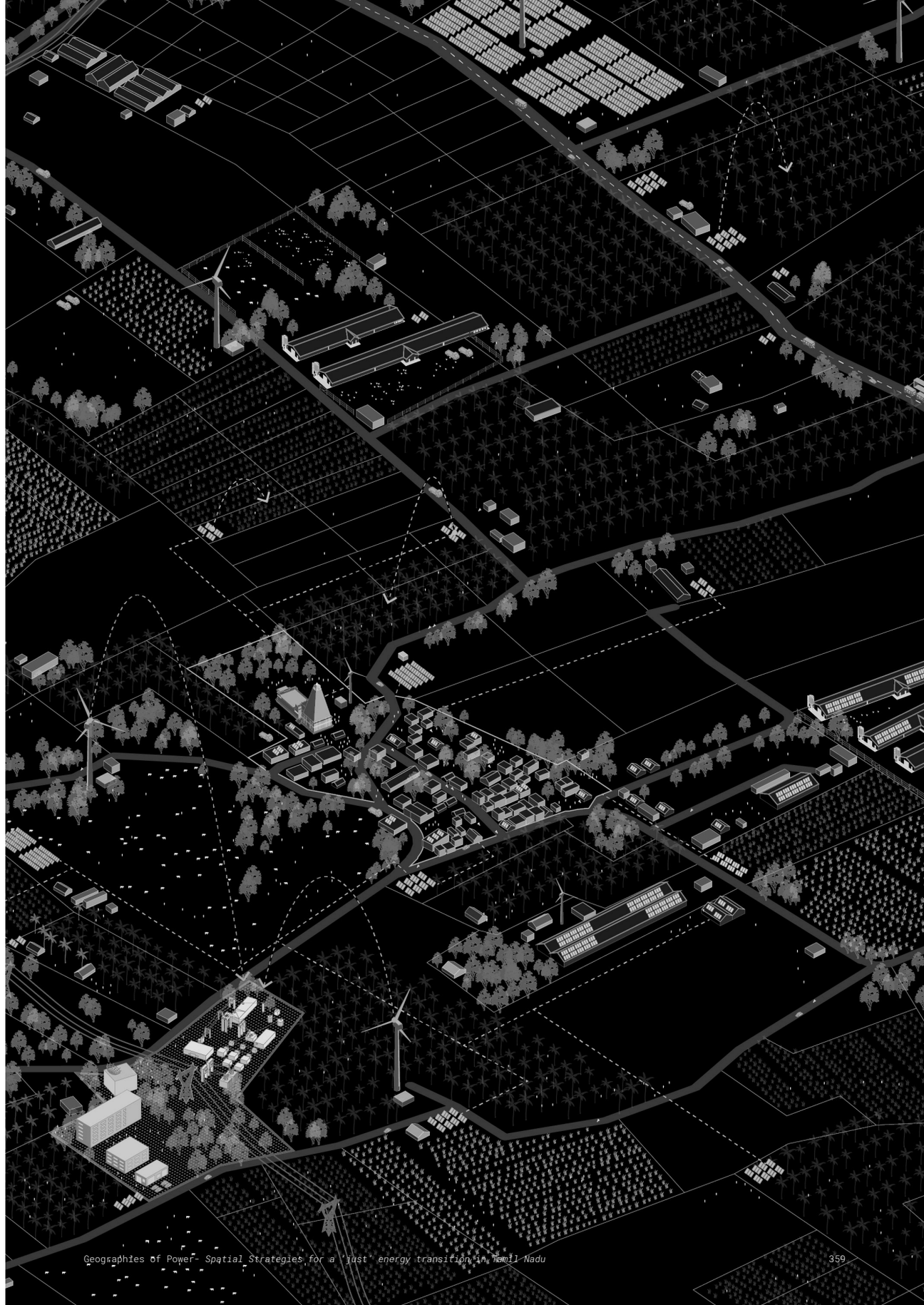


Fig 10.6: Design explorations based on the regional plan and strategies

Design Interventions.

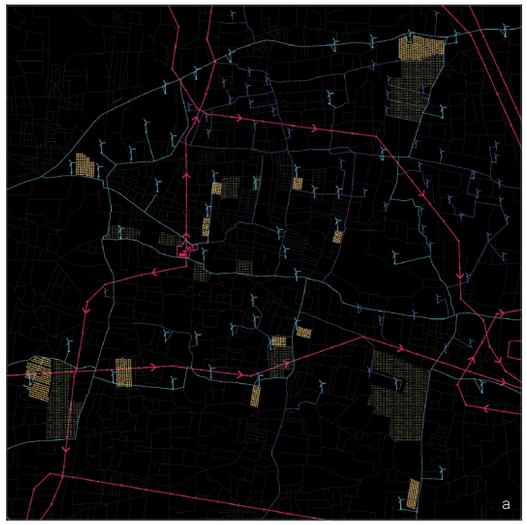
Testing and translating the spatial strategies in Udumelpet Energy Hub



S1: Densification

The existing wind turbines in the area, that are at their end-of-life condition are upgraded to high power turbines to increase the energy yield of the land. The underused wastelands in the area around wind turbines are utilised for the installation of solar panels and biomass cultivation to densify the energy landscape with diverse energy types to increase the richness of the landscape (Fig 10.7a). The presence of high voltage transmission lines in the area is a asset for energy densification. Specifically, two categories of design interventions are elaborated in the area:

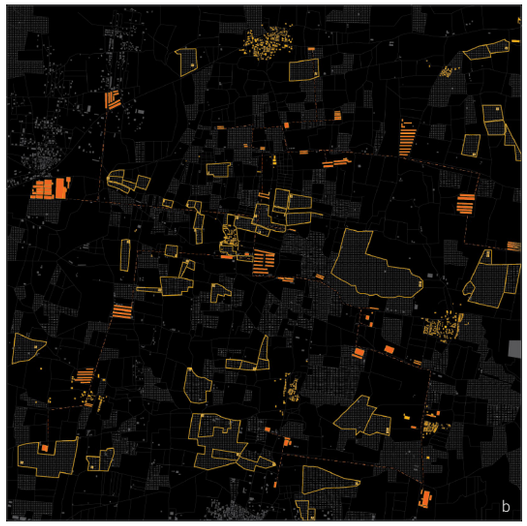
A,B,C. Densify, Diversify and Upgrade
D. Capacity Addition



S3: Coproduction.

The strategy for coproduction is realised in the area through the creation of rural mini-grids powered by decentralized renewable energy systems, and owned by the local communities. Farmers, owners of micro enterprises, landowners in the area are encouraged and supported to create renewable energy cooperatives, by which local communities collectively own and operate the micro R.E. infrastructure like solar powered water pumps, micro-wind turbines (under 500kW) and small solar farms (Fig 10.7b). Specifically, two categories of design interventions are elaborated in the area:

C. Rural mini grids- Agriculture
C*. Rural mini grids- Micro enterprises



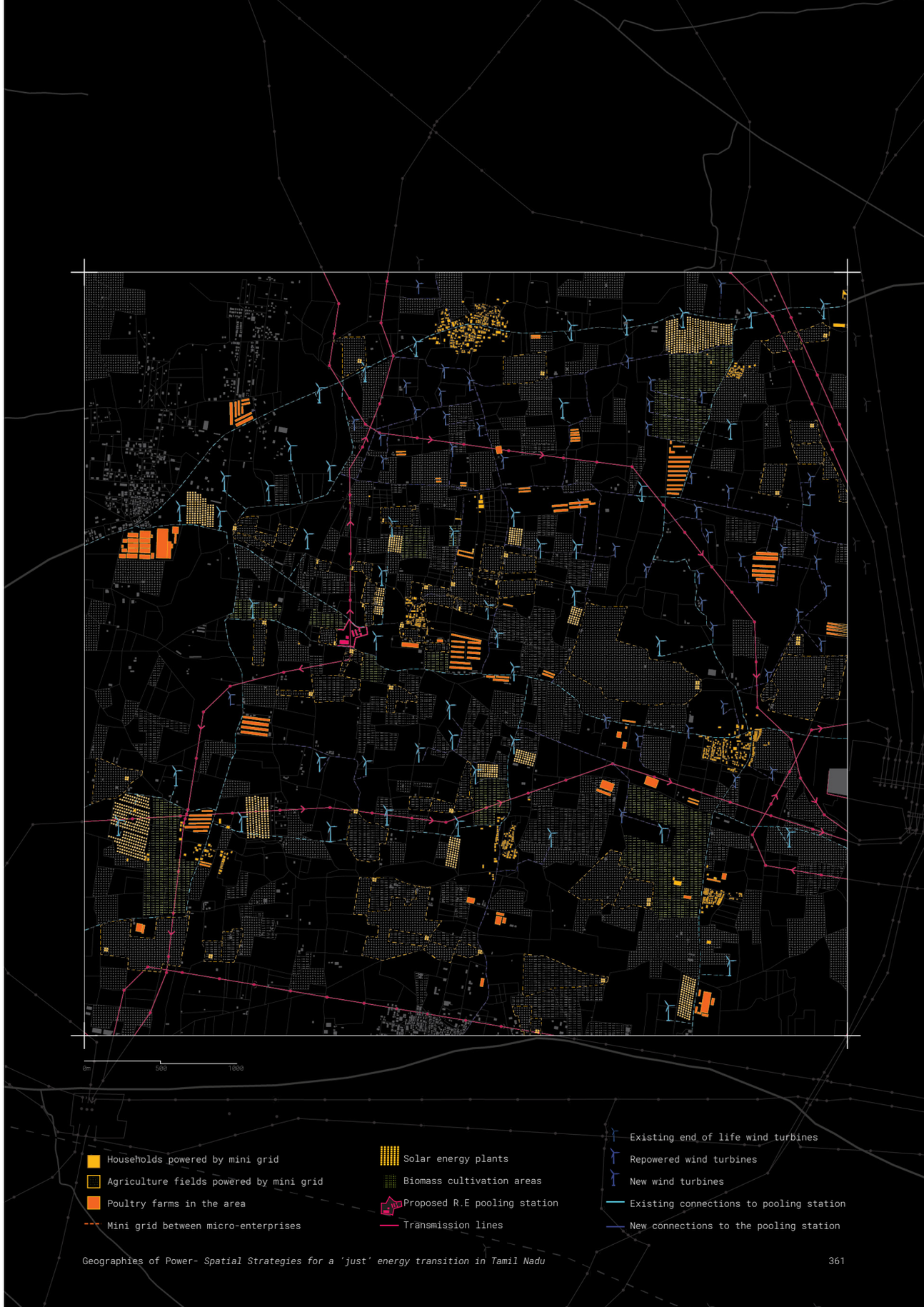
The following pages will elaborate in detail, the two strategies separately, by taking *Kathadi***, a smaller area within the 5kmx5km square for detailed design.

* The repetition 'C' refers to the nomenclature used in the Strategies (Section 8.2)
** No official records for the name of the village could be found, hence the project will refer to it by the pseudonym, 'Kathadi', meaning 'one that sways with the wind'

Fig 10.7: (a, b) Maps showing the design interventions derived from the two strategies

Fig 10.8: (right) Design explorations for energy transition in Udumelpet.

11.1271° N, 78.6569° E



Existing Situation at Udumelpet.

Testing and translating the spatial strategies in Udumelpet Energy Hub

To fully understand the feasibility of the strategies and their spatial manifestations, a smaller area around Kathadi village, was chosen to detail the design interventions. The area has existing wind turbines at their end-of-life state interspersed with coconut groves and farmlands, near Kathadi. Kathadi, a typical Indian village, was chosen to test the feasibility of rural mini grids. The area also has a large number of poultry farms with large rooftops that can be used for solar energy production by the owners. Small pooling station near Kathadi is strategically located near energy production sites and can be upgraded to meet the densified energy output. The following pages will elaborate on the design interventions in the area.

AGriculture sector: Cocunut Farms
60% of farmers in TN grow coconut; Coimbatore is the highest producer in TN.

Udumelpet wind farms
end-of-life windturbines, installed over 20 years ago.

Kathadi Village
Pilot project for micro-energy coproduction

Poultry farms (PPP)
Contract based poultry farms with rooftop space for energy coproduction

AGriculture sector: Food crops
Opportunity to explore 'energy farming'

110kv substtaion (private)
Needs infrastructure upgradation to support densification

Key Map

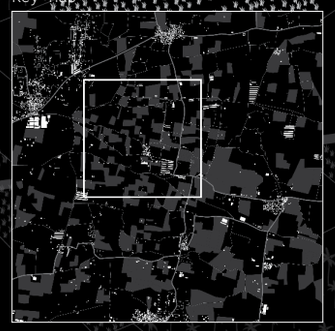


Fig 10.9: Existing situation, barriers and opportunities in Udumelpet.

Proposed Design Interventions.

Testing and translating the spatial strategies in Udumelpet Energy Hub

Key Map

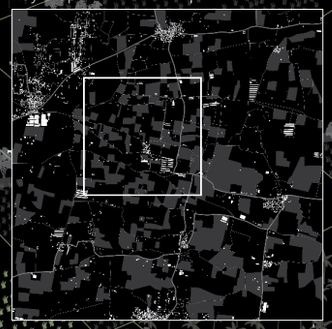
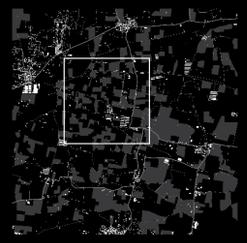
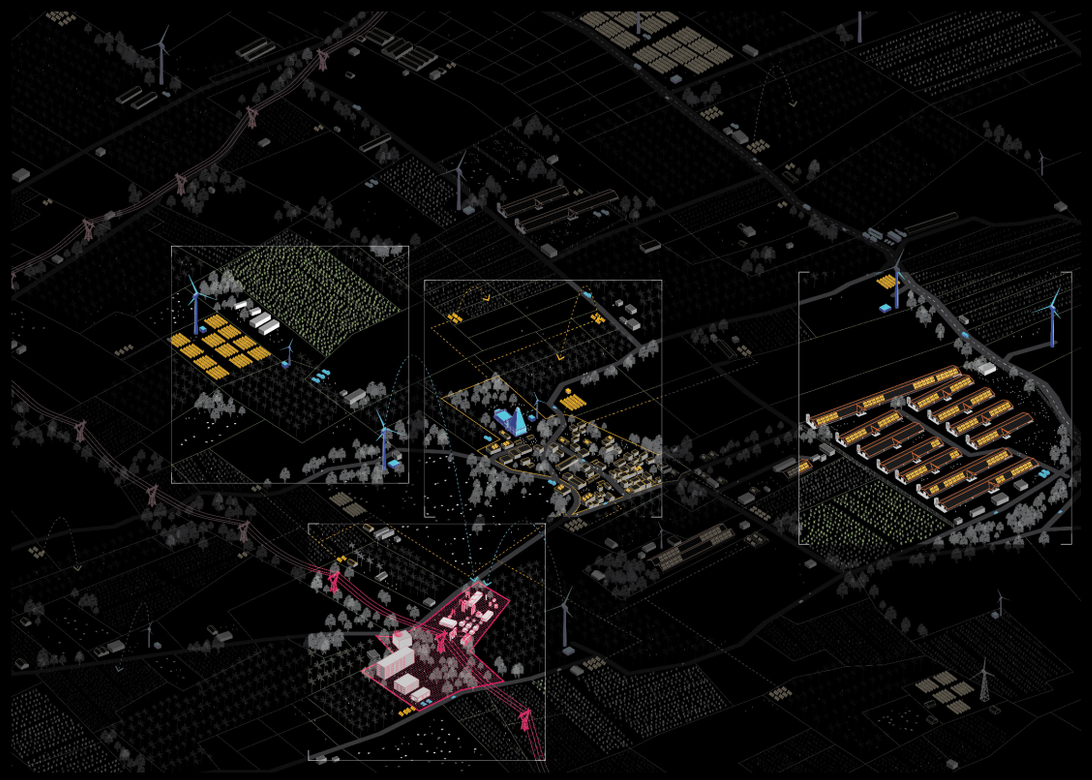


Fig 10.10: Design interventions in Udumelpet area

Proposed Design Interventions.

Testing and translating the spatial strategies in Udumelpet Energy Hub



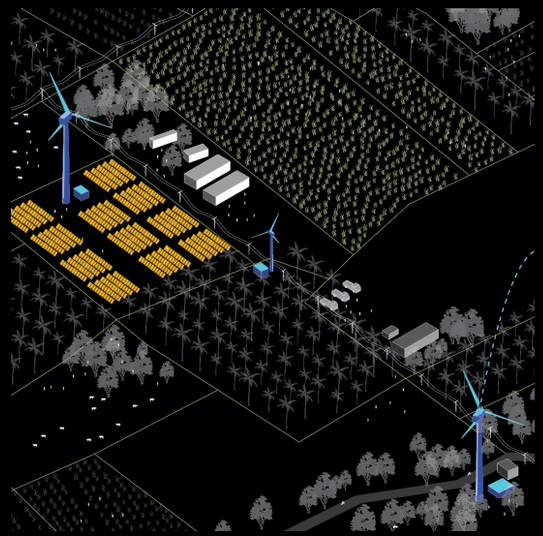


The project will explain the spatial manifestations of the translation of the strategies in Udumelpet area by showing four ***details*** of the design (Fig 10.12). The details are illustrative of design interventions transpiring across the rural landscape, and explain its feasibility, limitations, stakeholders involved in its implementation and the societal impacts that the interventions create in the energy hub.

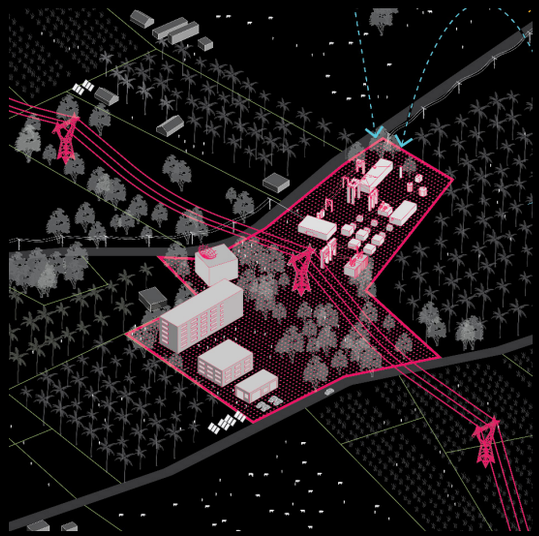
Fig 10.11: (left) Proposed design interventions in Udumelpet.

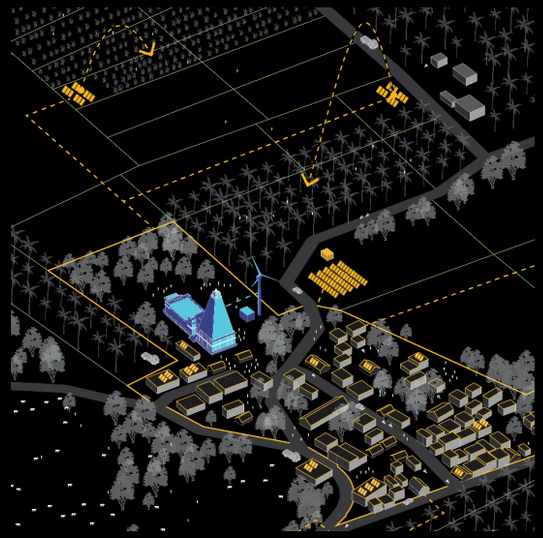
Fig 10.12: (right) Design details elaborated in the project for the two strategies.

S1: Densification
A,B,C. Densify, Diversify and Upgrade
Detail: Hybrid S+W+B Pilot Project



S1: Densification
D. Capacity Addition
Detail: Pooling Station and R.E. Control Centre





S3: Coproduction
C. Rural mini grids- Agriculture
Detail: Rural Energy Cooperatives Pilot Project



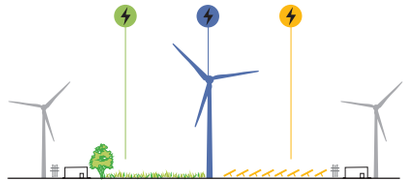
S3: Coproduction
C. Rural mini grids- Micro enterprises
Detail: Solar Poultry Farms Pilot Project

S1: Densification.

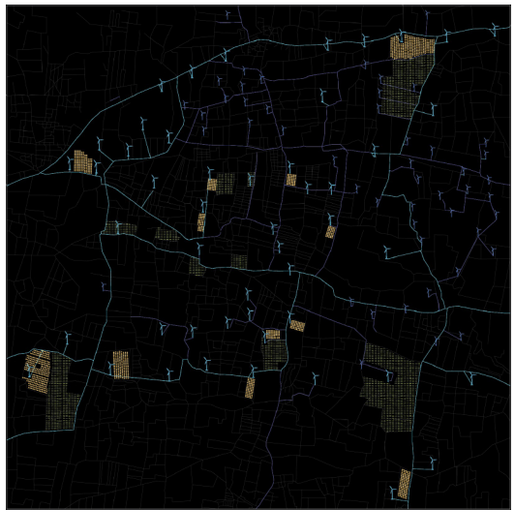
A,B,C. Densify, Diversify and Repower*

Renewable energy produced in the grey areas along transport infrastructure network in the region is used to power long distance trains, buses, cars and bikes in the city, supported by the strategic placement of EV charging stations.

Detail: Hybrid S+W+B Pilot project



Schematic Section



Plan of the design interventions

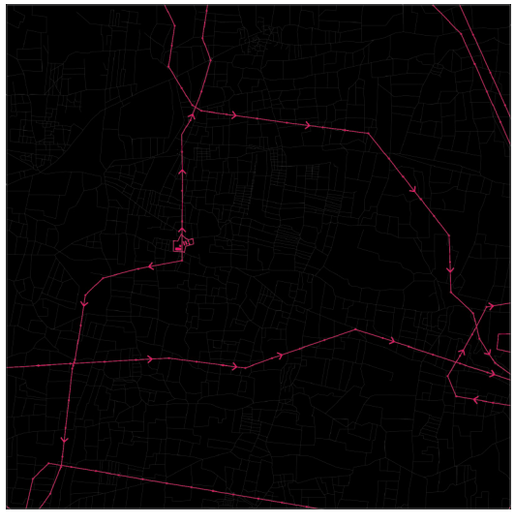
D. Capacity Addition

The existing small pooling station near Kathadi is upgraded into a dedicated renewable energy pooling station for and control centre to coordinate the R.E production in the micro-region with the macro-regional energy demand. The pooling station collects the energy produced nearby, and transmits it to the Udumelpet substation nearby, for it to be fed into the macro-regional grid.

Detail: Substation and R.E. Control Centre



Schematic Section



Plan of the design interventions

* The nomenclature A,B,C refers to the solutions elaborated for S1 in Chapter 8. Here, the three actions are elaborated under a singular intervention for the sake for brevity.

Fig 10.13: Maps showing the design actions to achieve densification.

11.1271° N, 78.6569° E

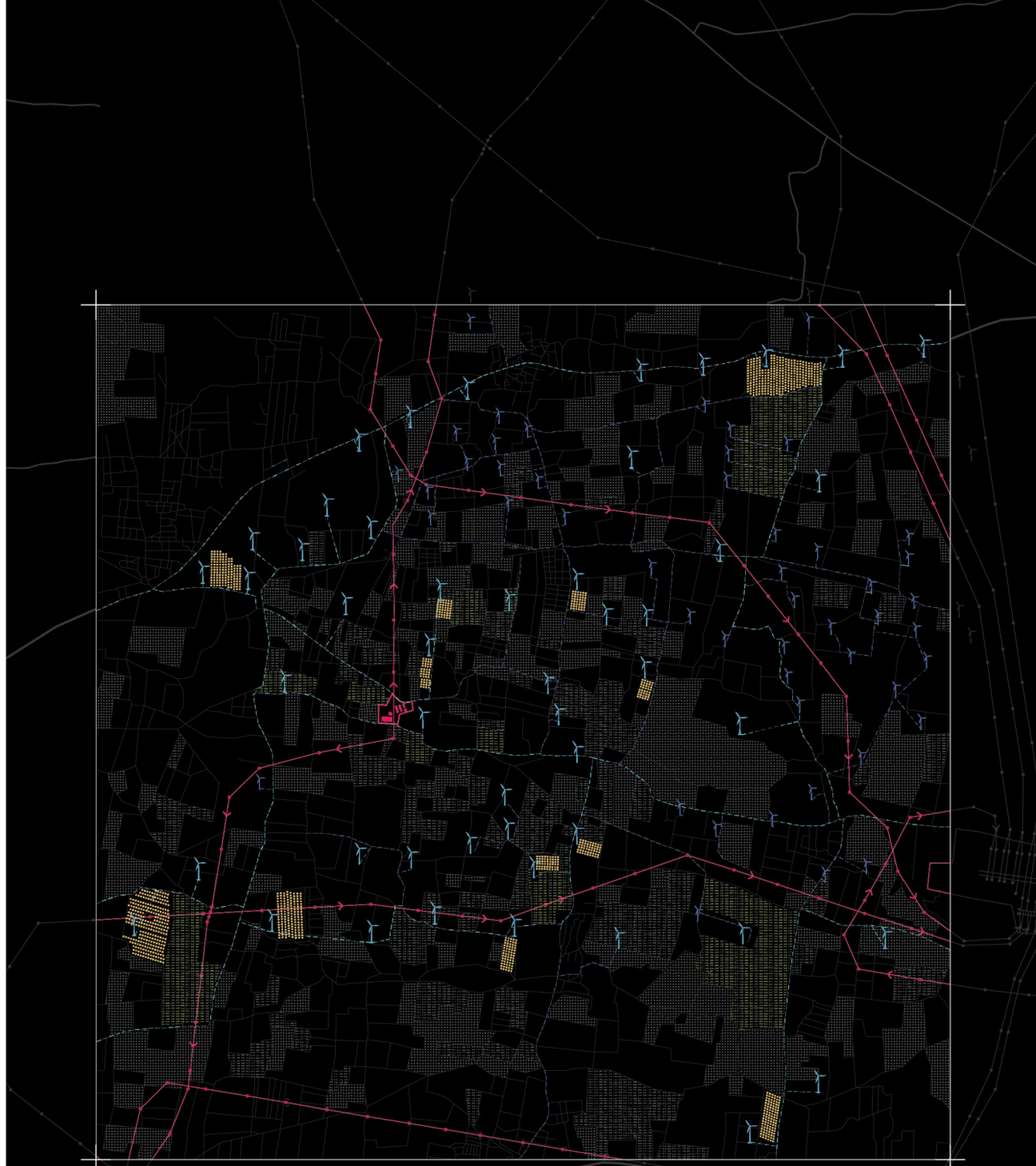
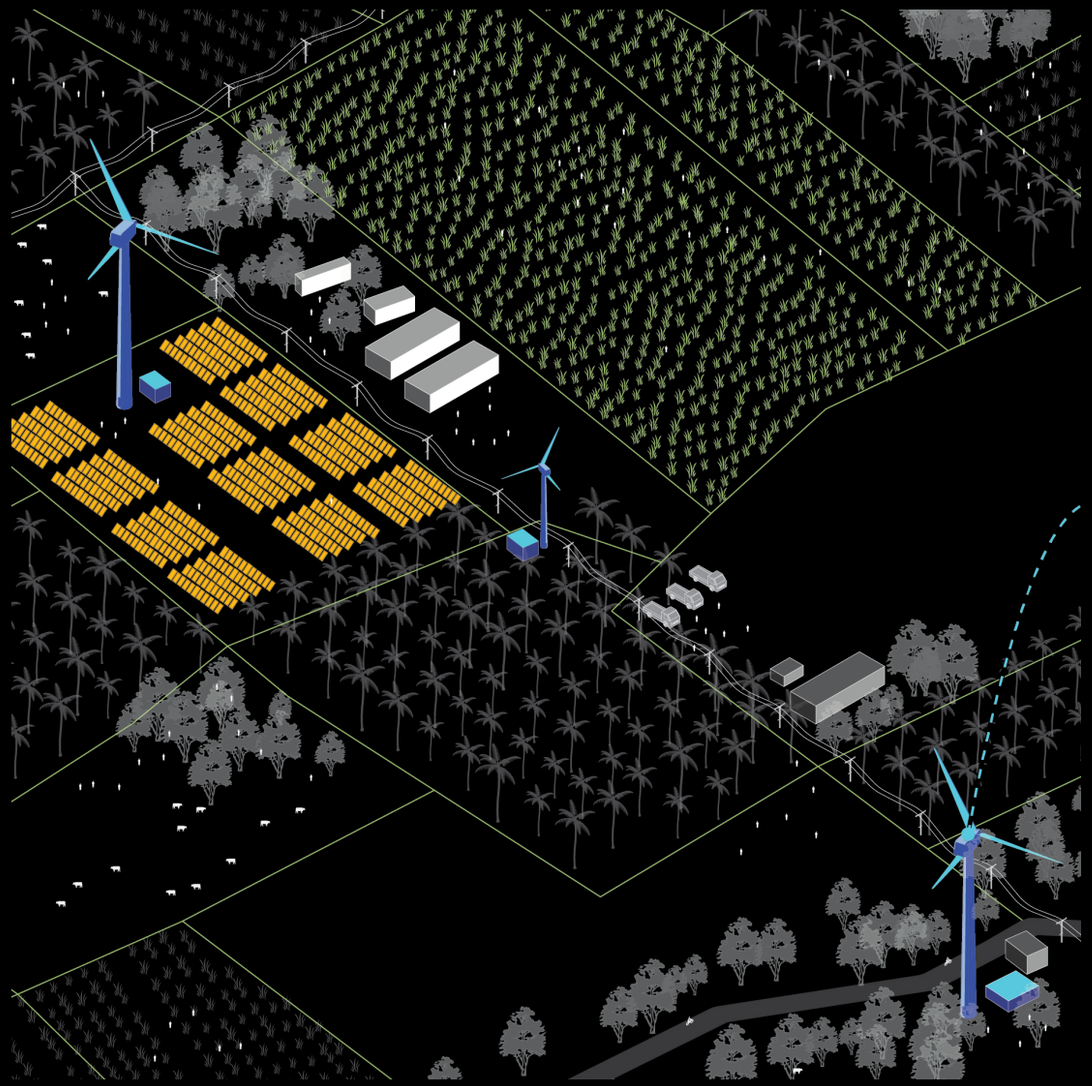


Fig 10.14: Design explorations for cross-programming based on the regional plan and strategies

S1: Densification.

A,B,C. Densify, Diversify and Repower



Detail: Hybrid S+W+B Pilot Project

The underutilized wastelands around existing wind farms are redeveloped into Hybrid energy projects, where wind, solar and biomass energy production occurs simultaneously in the same piece of land, thus increasing the energy yield of the land and making efficient use of the existing infrastructure.

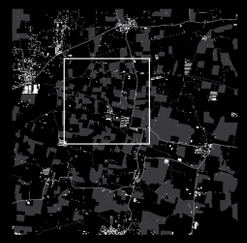
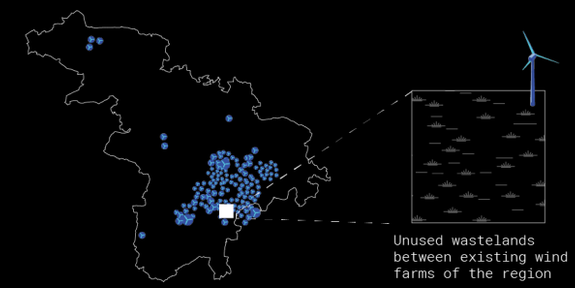
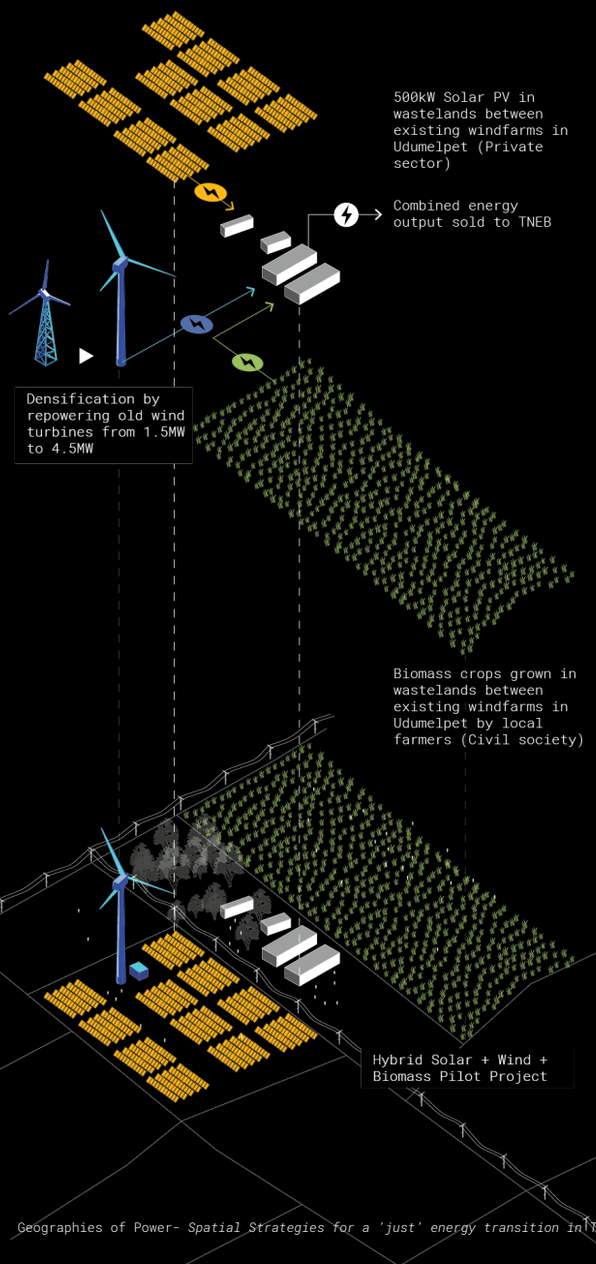


Fig 10.15: Spatial manifestations of the design.

Fig 10.16: Key Map





Solar + Wind + Biomass Hybrid

As seen in the map on the left, the concentration of wind energy sites in Udumelpet presented a unique challenge for design. The energy sprawl is controlled through densification around existing wind turbines in the area.

The strategy is implemented under the framework of the National Wind Solar Hybrid Policy and the Draft Policy for Repowering of the Wind Power Projects issued by the MNRE. Under these policies, existing end-of-life wind turbines are upgraded to increase the energy yield of the land. Nearly 4000MW of old windturbines in Tamil Nadu require upgradation (repowering) in the next ten years (IGEF-SO, 2018). Apart from upgrading old winturbines, the site is also hybridized to produce solar energy or cultivate biomass in the same land. The hybridization of energy landscapes also ensures that there is uninterrupted energy production throughout the day. Solar energy is produced mainly during the day, while wind energy picks up in the afternoon and continues throughout the night in most places.

While the wind solar hybrid plants need investment from the private sector, biomass cultivation can be done in collaboration with local farmers in the area.

Stakeholders:

Public Sector: TNEB, MNRE

Private Sector: Energy company contracted to install and maintain the solar panels and windturbines

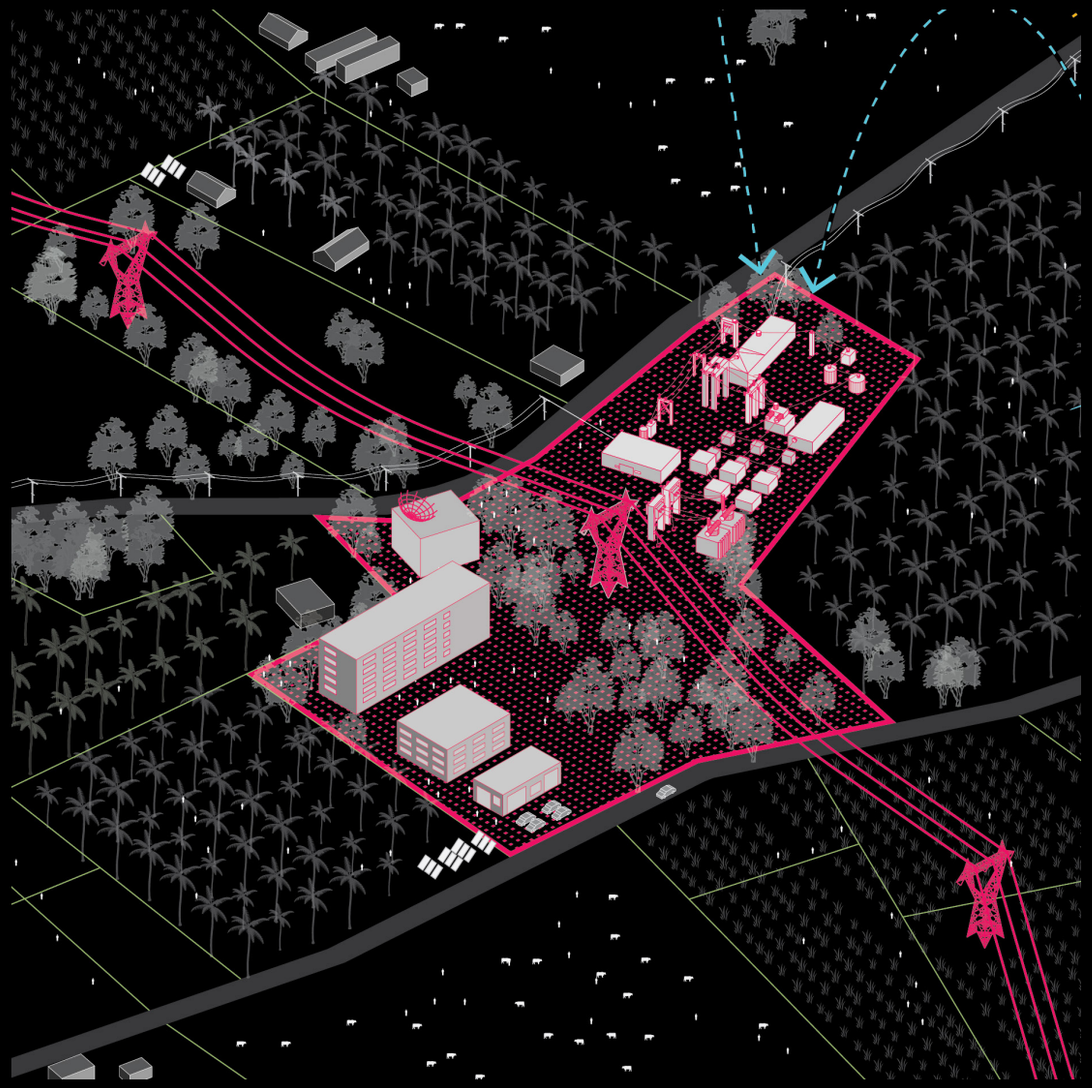
Civil Society: Farmers involved in biomass cultivation

* National Wind Solar Hybrid Policy: 'The main objective of the Policy is to provide a framework for promotion of large grid connected wind-solar hybrid systems for optimal and efficient utilization of transmission infrastructure and land, reducing the variability in renewable power generation and achieving better grid stability.' (MNRE, 2018).

Fig 10.17: Details of the design intervention

S1: Densification.

D. Capacity Addition



Pooling Station and R.E. Control Centre

The existing pooling station near Kathadi village is upgraded into a larger pooling station and RECC (Renewable Energy Control Centre) to coordinate the transmission of R.E to the macro-regional grid. This intervention is elaborated under the framework of the Green Energy Corridor scheme of the central Ministry of Power.

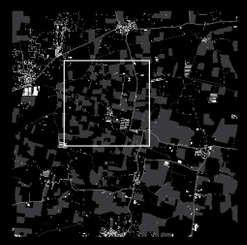


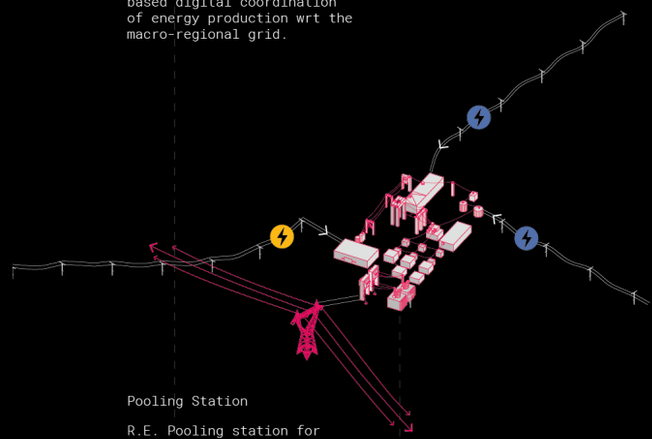
Fig 10.18: Spatial manifestations of the design.

Fig 10.19: Key Map



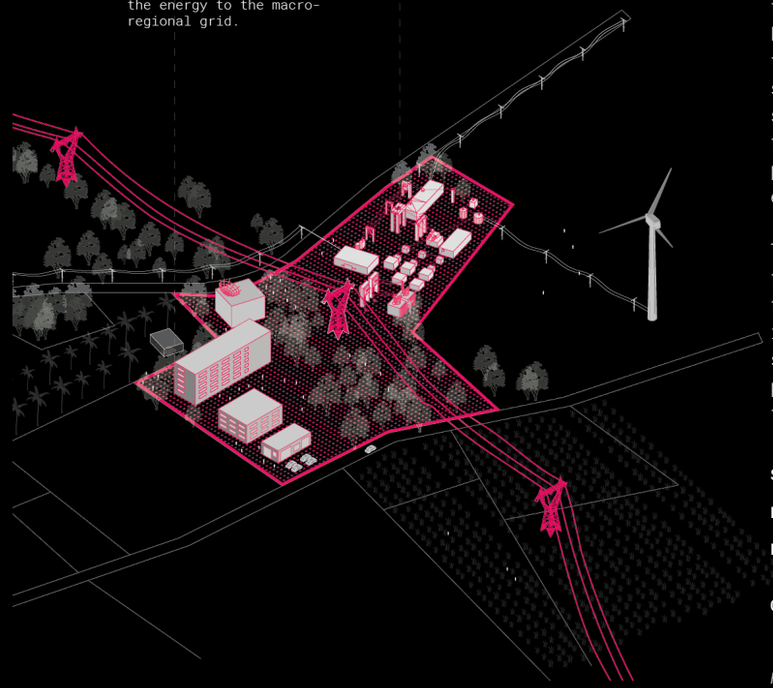
Control Centre

R.E. Control centre for GPS based digital coordination of energy production wrt the macro-regional grid.



Pooling Station

R.E. Pooling station for collecting and transmiting the energy to the macro-regional grid.



Green Energy Corridor Scheme

Under the Green Energy Corrdior scheme from the central Ministry of Power, financial support is given to the states for building dedicated R.E. transmission lines and pooling stations for both inter, and intra-state transmission. Here, the existing small pooling station for the wind farms is expanded to evacuate the increased R.E. produced in the area after densification, along with the establishment of a R.E Control Centre that coordinates the transmission efforts.

Macro-regional relevance

The low voltage R.E.produced in the Hybrid S+W+B Pilot Projects and/or coproduced with local inhabitants is collected in the pooling station, and converted to high voltage current that can be stepped up further in the Udumelpet substation nearby. Dedictaed renewable energy power lines carry it across the rest of the macro-region. The R.E Control Centre manages the digital coordination of R.E. integration and grid balancing, through live updates to the State Load Dispatch Centre (SLDC). Due to the proximity to existing wind energy sites, the R.E Control Centre also serves as a research hub for testing the feasibility of energy pilot projects in the heart of the state's energy landscape.

The state (TNEB/TANTRANCO) and the central Ministry of Power are the main actor involved in the implmentation, along with the private sector. There is little scope for the participation of the civil society in this intervention.

Stakeholders:

Public Sector: TNEB, MoP, TEDA, TANTRANSCO

Private Sector: Transmission infrastructure buildings companies

Civil Society: -

Fig 10.20: Details of the design intervention

Existing situation at Udumelpet.

Testing and translating densification strategies in Udumelpet Energy Hub



Fig 10.21: Photograph of the existing situation in Udumelpet

Proposed situation at Udumelpet.

Testing and translating densification strategies in Udumelpet Energy Hub



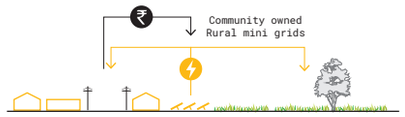
Fig 10.22: Collage showing the proposed situation in Udumelpet

S3 : Coproduction.

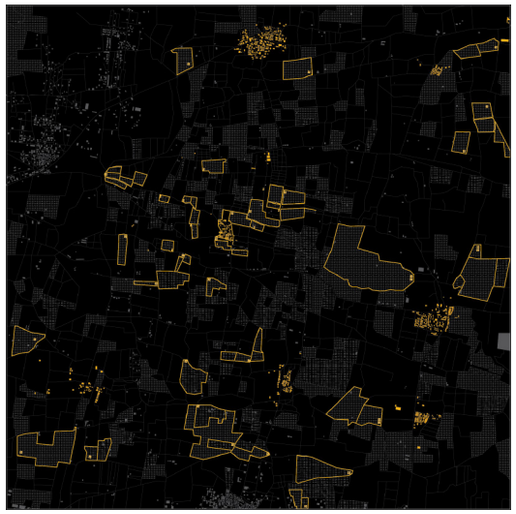
C. Rural mini-grids- Agriculture*

The coproduction of R.E through the installation of rural mini grids, specifically in the agricultural sector, is explored in this intervention. Rural energy coorperatives are encouraged to be formed to invest collectively in R.E. infrastructure like solar PV and <500kV wind turbines. The R.E produced is used to irrigate the agricultural fields and cocunut farms, thus increasing the food security of the region.

Detail: Rural Energy Cooperatives Pilot Project



Schematic Section

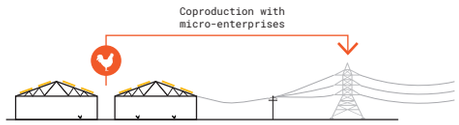


Plan of the design intervention

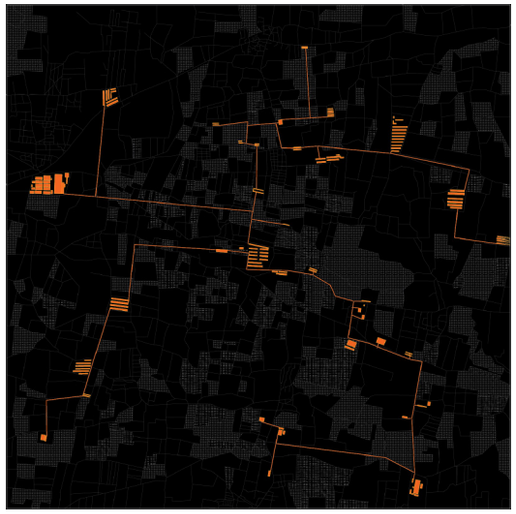
C. Rural mini-grids- Micro enterprises*

In this strategy, the large number of micro enterprises in the area like contarct based poultry farms, which have long (80m long approximately) rooftops suitable for solar energy production. The poultry farmers are incentivised to set up solar PV with the support of the private poultry companies and TEDA (Tamil Nadu Energy Development Agency). The surplus energy generated in the indivdual poultry farms is then sold to the TNEB.

Detail: Solar Poultry Farms Pilot Project



Schematic Section



Plan of the design intervention

* The repetition 'C' refers to the nomenclature used in the Strategies (Section 8.2). 'D. Capacity Addition' is not elaborated in detail in the project, although it is a key part of the regional strategies.

Fig 10.23: Maps showing the design actions to achieve coproduction

11.1271° N, 78.6569° E

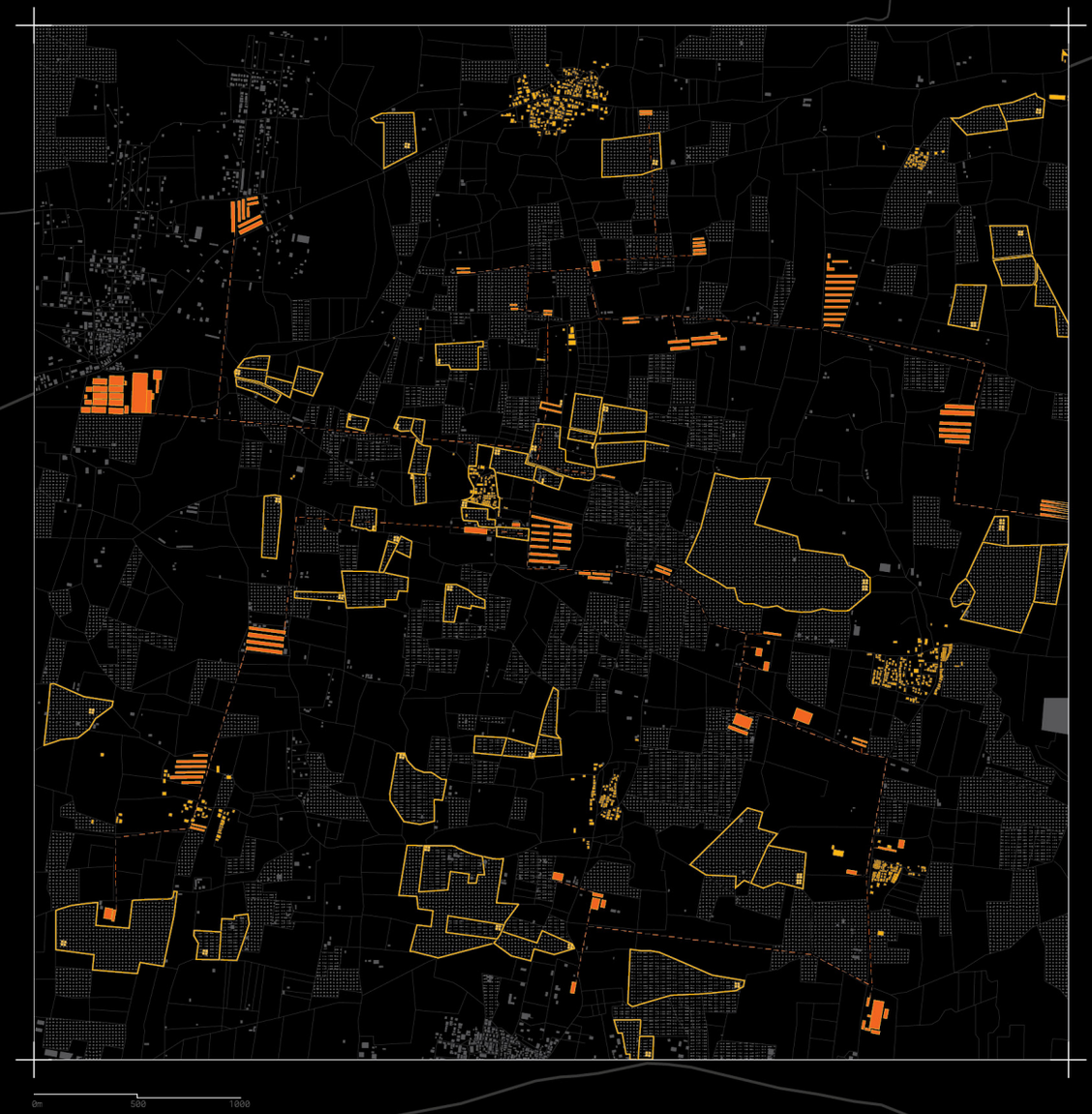
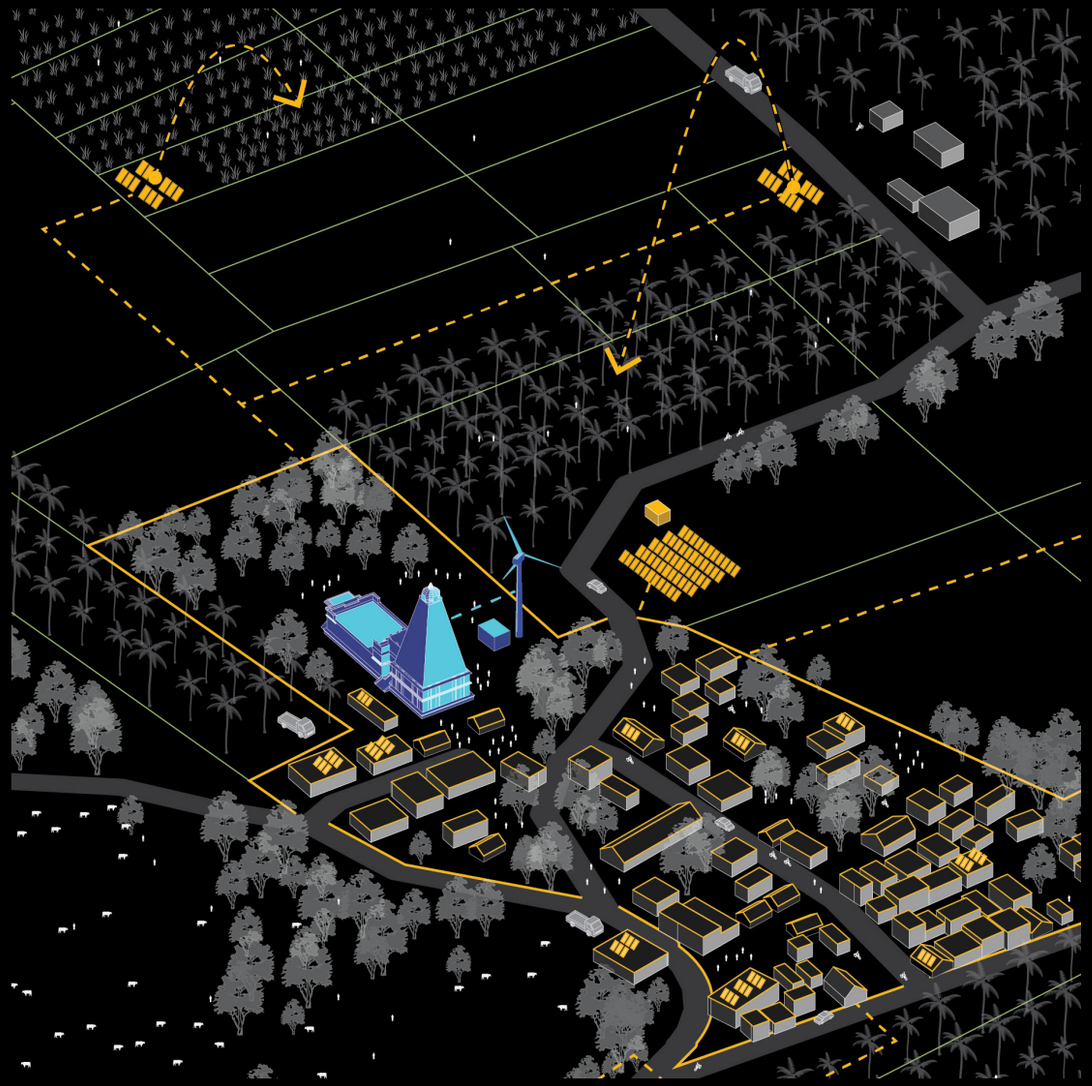


Fig 10.24: Design explorations for co-production based on the regional plan and strategies

S3: Coproduction.

C. Rural mini grids



Detail: Rural Energy Cooperatives Pilot Project

This detail explains the feasibility and spatial manifestation of rural mini grids and creating R.E. powered villages in India. The intervention is based on the success of energy cooperatives in Dhundi*. Here, the village of Kathadi is chosen for implementing the Pilot project.

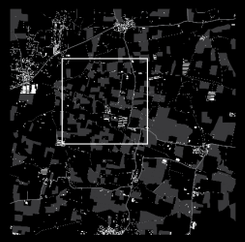
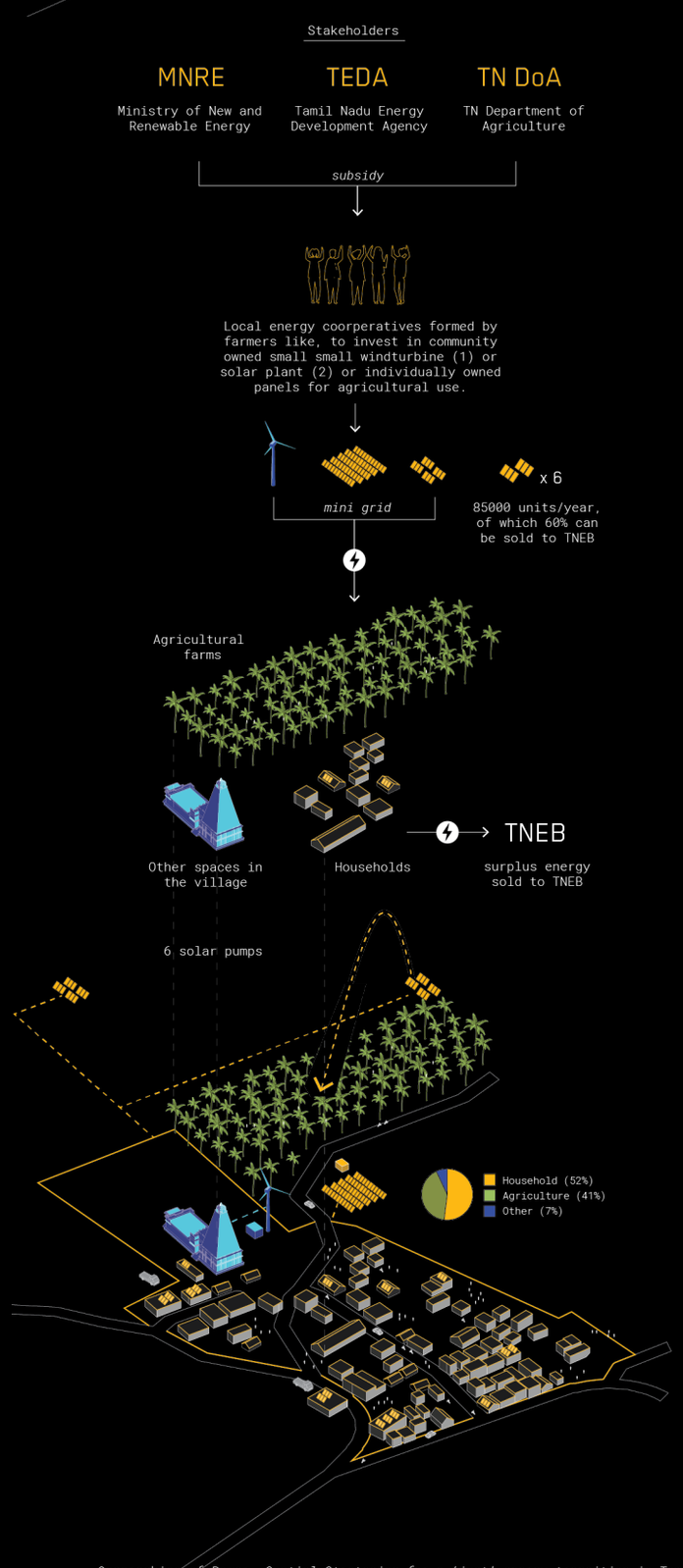


Fig 10.25: Spatial manifestations of the design.

Fig 10.26: Key Map



Solar Villages- Energy farming

In Kathadi, the farmers depend on the unmetered electricity supplied by the TNEB for agriculture, while energy for household use is metered and paid for every month, after the first 100units of energy. But since the energy demand of each household (typically) is 39.3units/month, Kathadi has 'free' but unreliable energy access due to the regular power cuts. In this intervention, the farmers are supported in forming rural energy cooperatives that invests collectively in micro-energy like:

1. **Solar panels** in agricultural fields to pump water and irrigate the water intensive coconut groves,thus reducing the burden on TNEB to supply free electricity for agricultural purposes.
2. **Micro wind turbines** below 200kW to support energy needs of the whole village.
3 .**Small scale solar farm** below 50KW capacity to support energy needs of the village.

The panels or turbines are connected to form a mini grid that supplies energy to the entire village, thus improving the quality of energy access. Excess energy can be sold to the TNEB, thus 'farming' energy along with food crops. The project proposes that the Pilot project is financially supported by the MNRE, TNEB, and the TN Dept of Agriculture to support coproduction of energy.

Stakeholders:

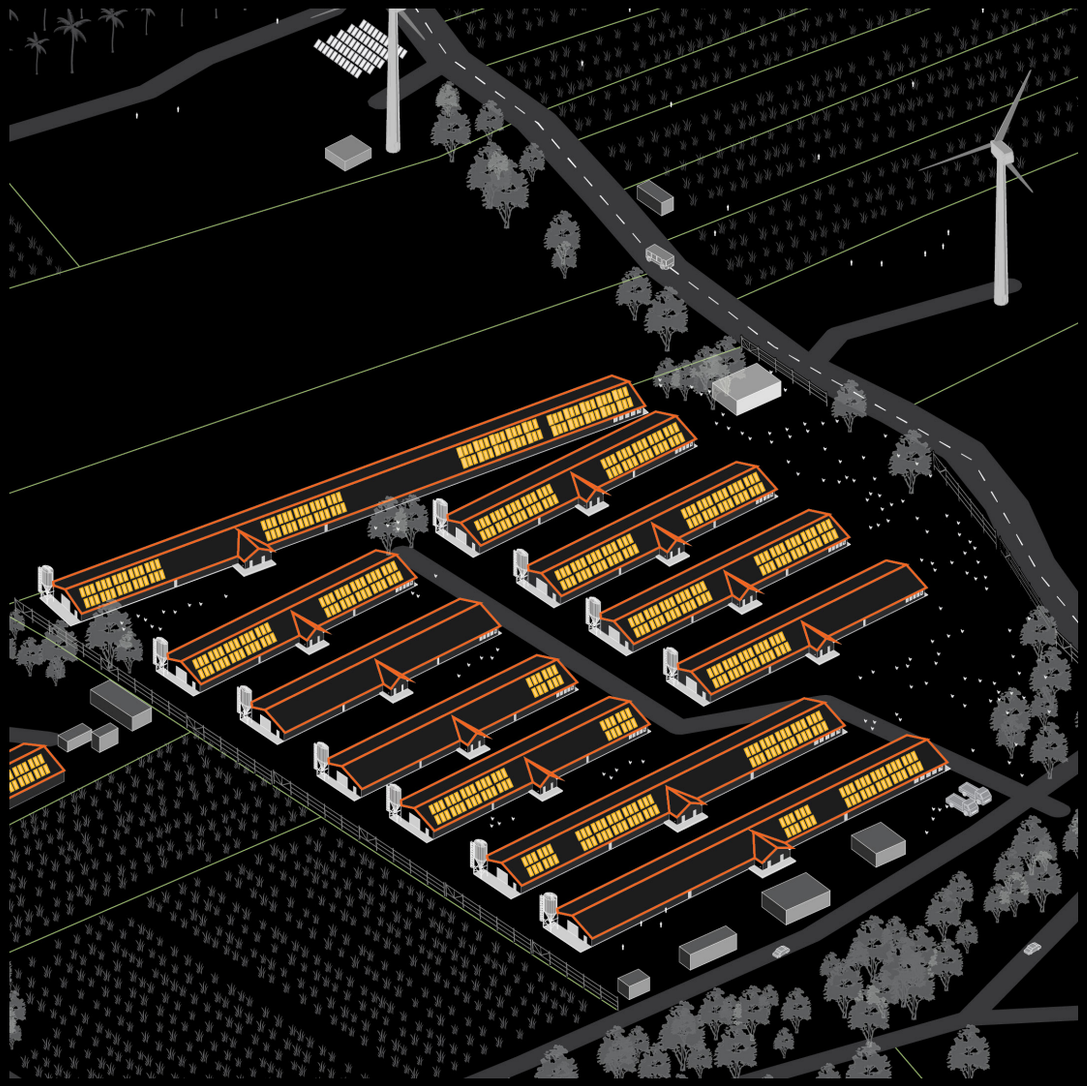
Public Sector:	TNEB, TEDA, MNRE, Department of Agriculture of Govt. of TN, NGOs**
Private Sector:	Energy infrastructure manufacturing companies
Civil Society:	Individuals, rural energy cooperatives

*Dhundi village in State of Gujarat in India is India's first solar energy cooperatives,
** The project acknowledges the efforts of The Solar Village initiative, a NGO based in Tamil Nadu, that has been working with Irumbai village to set up a solar cooperative

Fig 10.27: Details of the design intervention

S3: Coproduction.

C. Rural mini grids



Detail: Solar Poultry Farms Pilot Project

This detail explains the feasibility and spatial manifestation of neighbourhood level coproduction of energy by residential energy cooperatives, under the framework of the Solar City Masterplan for Coimbatore, substantially decreasing the energy footprint of domestic sector in Coimbatore.

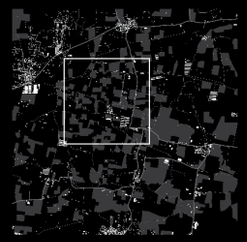
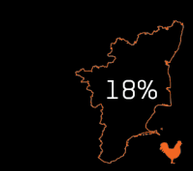
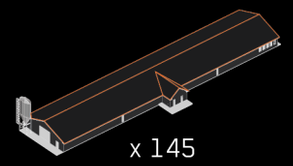


Fig 10.28: Spatial manifestations of the design.

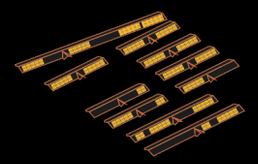
Fig 10.29: Key Map



poultry population of the country is from Tamil Nadu



145 largescale poultry farms in Coimbatore



25kW*

energy capacity for each poultry farm

40000 kWh

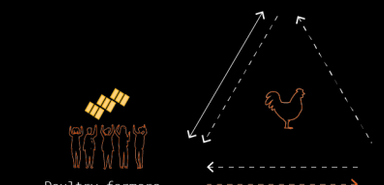
solar energy genrated annually by each farm, of which more than 85% can be sold to the grid

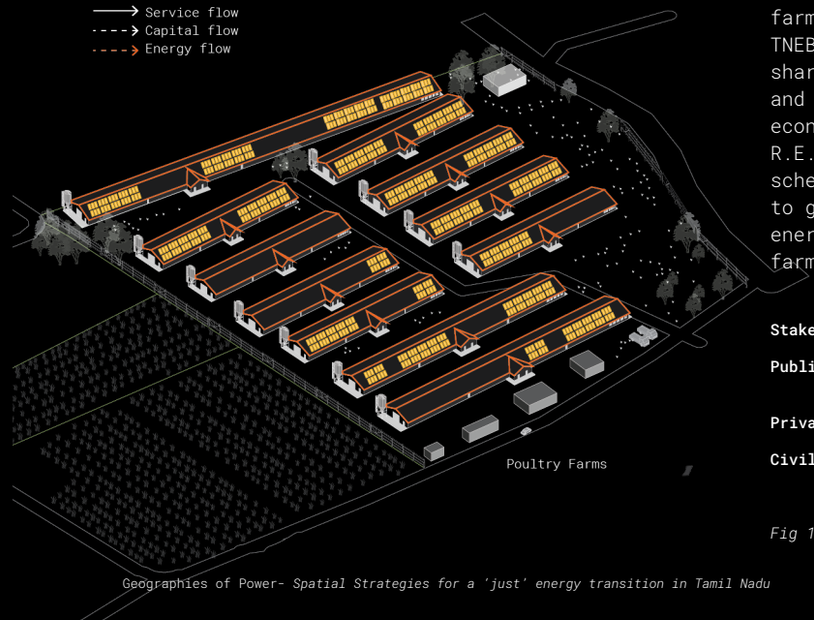
* estimated from avaerge energy output of solar panels and roof area available

Stakeholders

Private

broiler companies who contract the farmers





Coproduction with Poultry Farms

The large number of poultry farms in the area provides an unique opportunity for coproducing energy with micro-enterprises. The long sheds housing the animals can be reinforced to house solar panels on their rooftops.

In Udumelpet, poultry farming happens on a 'contract' basis where large broiler companies supply the animals, feed and services to local farmers who provide the space and rear the chicken to slaughter weight. Here, the partnership between local farmers and private companies can be augumented to include support for energy production in the poultry farms.

Private companies are encouraged to provide financial assistance as part of their CSR (Corporate Social Responsibility) where the policy allowed for funds to be used for bettering rural livelihoods in exchange for tax benifits. The funds from broiler companies, along with support from TNEB and the felt of poultry farming can enable the setting up of solar panels in poultry farms.

The energy output from the sheds can be used for the energy demand of the farm and the excess energy sold to TNEB. The income can gained can be shared between the private company and the farmer, thus adding socio-economic value in the area through R.E. production. Moreover, existing schemes to buy the chicken droppings to generate bio-gas shows multiple energy flows fostered by the poultry farms.

Stakeholders:

Public Sector: TNEB, TEDA, Department of Animal Husbandry and Fisheries

Private Sector: Broiler Comapnies

Civil Society: Contract based poultry farmers

Fig 10.30: Details of the design intervention

Existing situation at Udumelpet.

Testing and translating coproduction strategies in Udumelpet Energy Hub



Fig 10.31: Photograph of the existing situation in Udumelpet

Proposed situation at Udumelpet.

Testing and translating coproduction strategies in Udumelpet Energy Hub



Strategic Zoom-in B : Coimbatore City Centre ***(Urban)***



The design interventions in Coimbatore City Centre create frameworks for the integration of energy transition in urban areas, by combining energy production with urban functions and thereby adding socio-economic and ecological value to urban areas. In this area, Strategy 2 on 'crossprogramming' and Strategy 3 on 'coproduction' are translated into tangible design interventions. The design interventions to realize the strategies within the 5km by 5km area are shown in Fig 10.35. To understand the spatial manifestations, actor networks, societal impacts of each strategy (S2, S3), the area around the Central Railway Station (*Ukkadam*) is elaborated in detail in the following pages. The design explorations in Coimbatore are illustrative of the feasibility of the strategies in other urban areas of the macro-region.

STRATEGIES EXPLORED IN ZOOM-IN B : COIMBATORE CITY CENTRE

Densify around existing energy production sites.

Add ecological value through **landscape integration** in energy development.

Create multi-functional energy landscapes through **cross programming.**

Repower and Reconfigure the post-carbon energy landscapes.

Coproduce energy with the community in urban and rural areas.

Increase flexibility through **seasonal activation** of energy landscapes.

Fig 10.33: Design explorations in Coimbatore City Centre

Design Interventions.

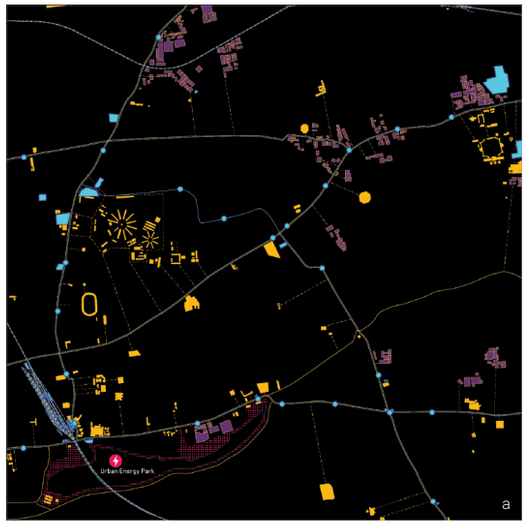
Testing and translating the spatial strategies in Coimbatore City Centre



S2: Cross programming.

The existing mobility network, public buildings, and industries concentrated near the city centre were identified to explore how energy production can be crossprogrammed with it to maximize mutual benefits offered (Fig 10.34a). Specifically, two categories of design interventions are elaborated in the area:

A. Energy x Mobility
B. Energy x Public Infrastructure



S3: Coproduction.

The Solar City Programme of the MNRE (Ministry of New and Renewable Energy) was taken as the instituitional framework for realising coproduction of renewable energy in Coimbatore city centre. Through the design interventions derived from the strategy, urban residents, communities and instituitions are incentivised to produce energy in partnership with the TNEB and other public sector utilities (Fig 10.34b). Specifically, two categories of design interventions are elaborated in the area:

A. Neighbourhood Energy Networks
B. Energy sharing with energy vulnerable communities

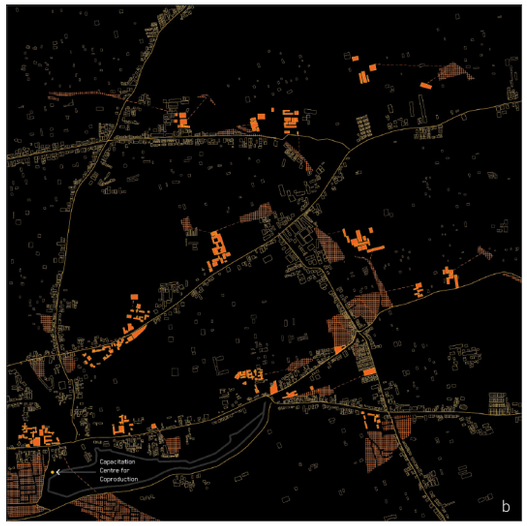
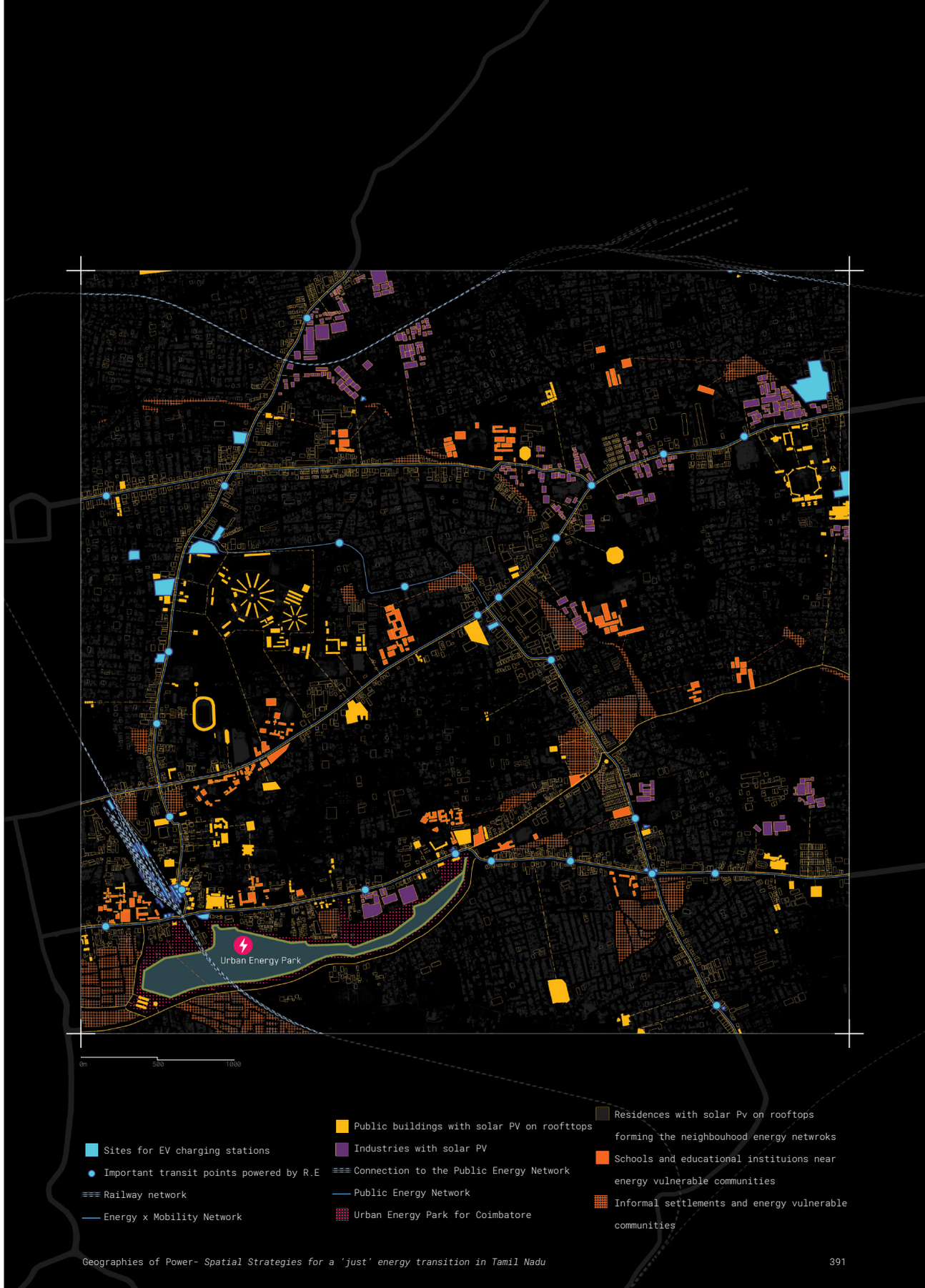


Fig 10.34: (a, b) Maps showing the design interventions derived from the two strategies

Fig 10.35: (right) Design explorations for energy transition in Coimbatore.

The following pages will elaborate in detail, the two strategies separately, by taking Ukkadam area around the Railway Station as the site for detailed design explorations



Existing Situation at Ukkadam.

Testing and translating the spatial strategies in Coimbatore City Centre

To fully understand the feasibility of the strategies and their spatial manifestations, a smaller area around the station, Ukkdadam, was chosen to detail the design interventions. Ukkadam is a highly dense neighbouhood, with a heterogenous urban fabric and connected by important arterial roads of the city. The Valankulam and Chinnakulam lakes, separated by railway infrastrtcture is an neglected waterbody and underused public space in the city, on the banks of which is the head office of TNEB-Coimbatore. A 110kV substation that brings electricity into the city is also located at the edge of Chinnakulam. Ukkadam alone has over 779 energy vulnerable households (). The area also has several high rise (7-10 floors) apartments, and residential colonies with active residents' associations that are vocal about urban issues.

The following pages will elaborate on the design interventions in the area.

Gopalapuram
Area for testing residential rooftop solar PV integration

Coimbatore Medical College and Hospital
Important Public building with large roofs

Coimbatore Central Railway Station

Educational Complex
School, Churches with large roofs

TNEB Coimbatore
Office and Substation to the city

Chinna Kulam and Valankulam Lakes
Underused open area in the city

Ukkadam- Ward 82
779 Energy Vulnerble households

Key Map

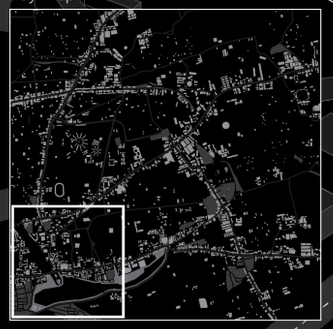


Fig 10.36: Existing situation, barriers and opportunities in Ukkadam.

Proposed Design Interventions.

Testing and translating the spatial strategies in Coimbatore City Centre

Key Map

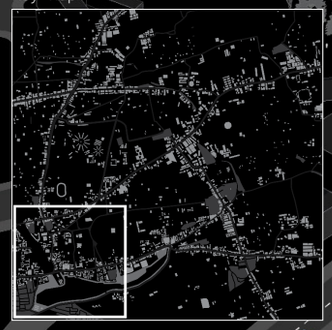
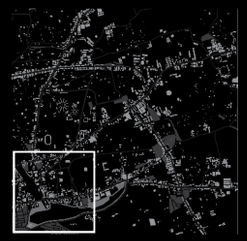


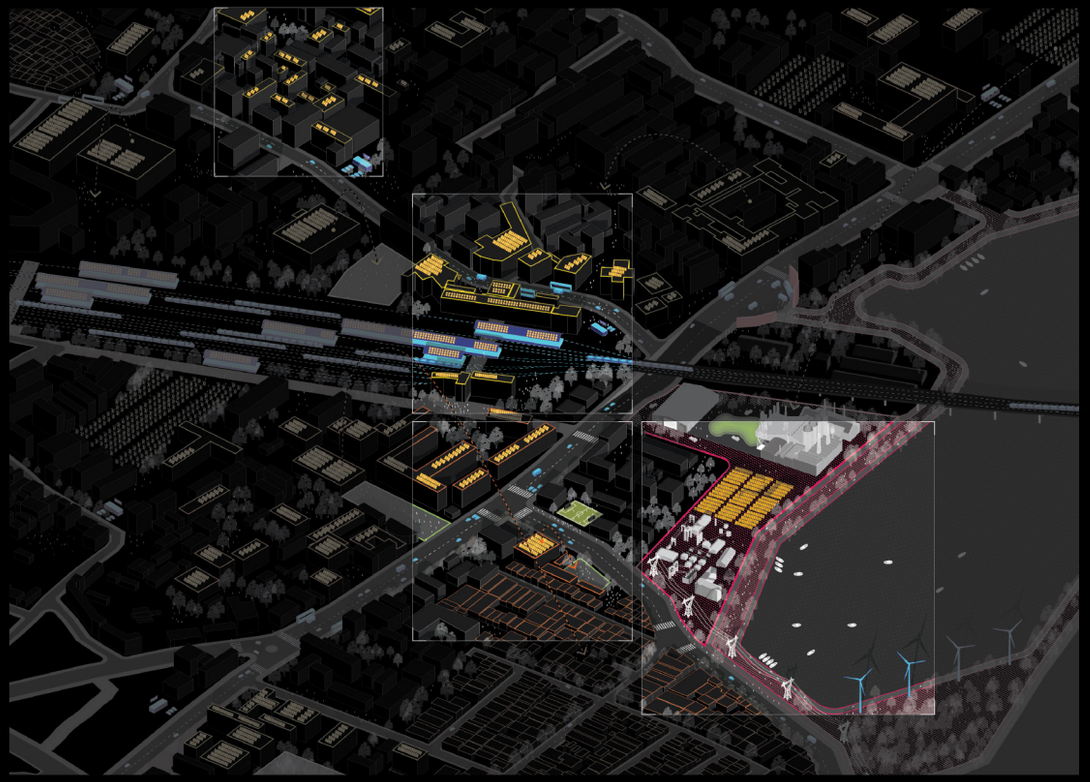
Fig 10.37: Proposed design interventions in Ukkadam

Proposed Design Interventions.

Testing and translating the spatial strategies in Coimbatore City Centre



Key map

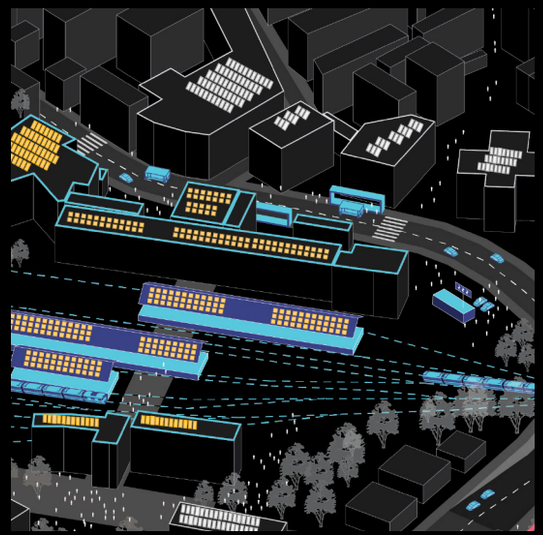


The project will explain the spatial manifestations of the translation of the strategies in Coimbatore City by showing four ***details*** of the design (Fig 10.39). The details are illustrative of design interventions transpiring across the city, and explain its feasibility, limitations, stakeholders involved in its implementation and the societal impacts that the interventions create in the city.

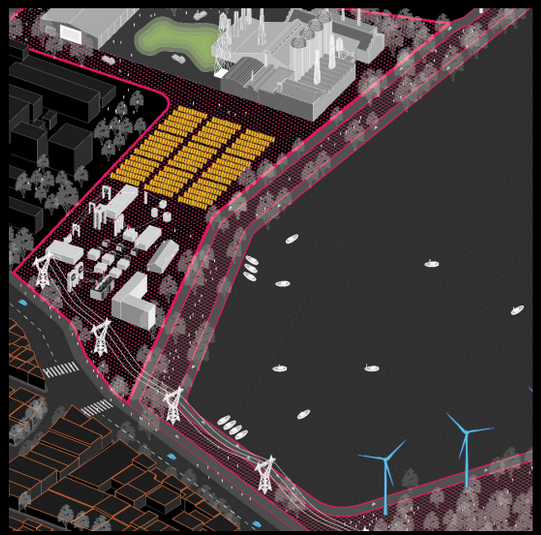
Fig 10.38: (left) Proposed design interventions in Ukkadam.

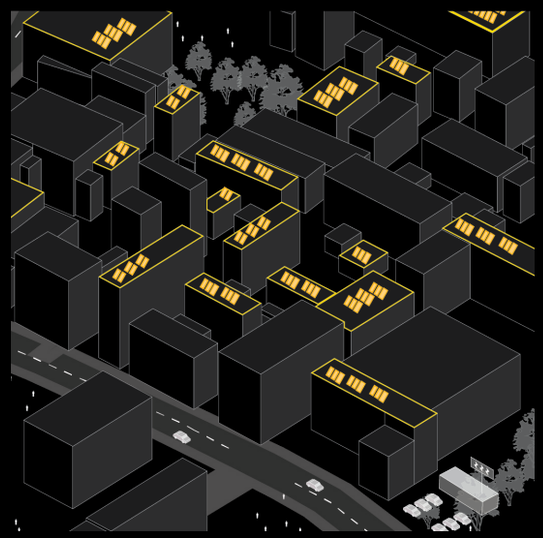
Fig 10.39: (right) Design details elaborated in the project for the two strategies.

S2: Crossprogramming
A. Energy x Mobility
Detail: Coimbatore Smart Mobility

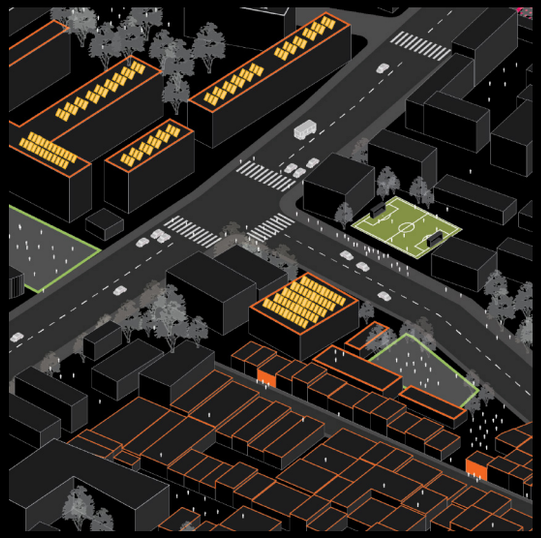


S2: Crossprogramming
A. Energy x Public Infrastructure
Detail: Urban Energy Park





S3: Coproduction
A. Neighbourhood Energy Networks
Detail: Gopalapuram Solar Roofs



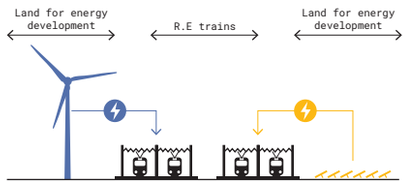
S3: Coproduction
B. Energy sharing with energy vulnerable communities
Detail: Ukkadam-St.Micheal's energy sharing

S2 : Cross programming.

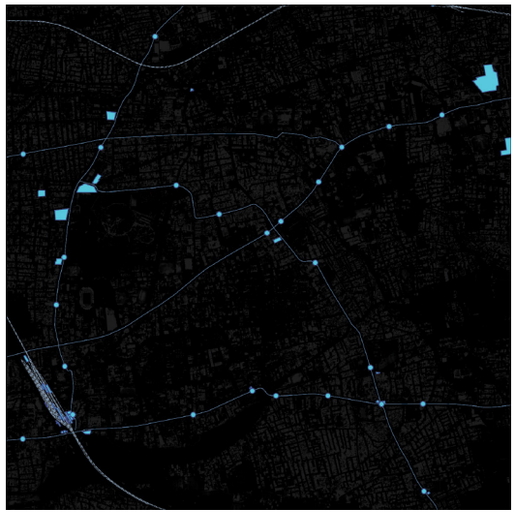
A. Energy x Mobility

Renewable energy produced in the grey areas along transport infrastructure network in the region is used to power long distance trains, buses, cars and bikes in the city, supported by the strategic placement of EV charging stations.

Detail: Coimbatore Smart Mobility.



Schematic Section

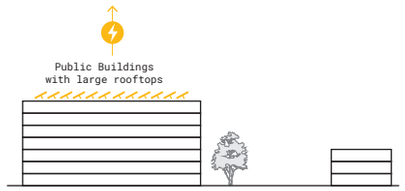


Plan of the design interventions

C. Energy x Public Infrastructure*

Public buildings, public infrastructure privately owned services, industries with large rooftops in the city centre are connected through the 'Public Energy Network', where R.E production is combined with buildings in the public domain, to support maintenance of the city.

Detail: Urban Energy Park.



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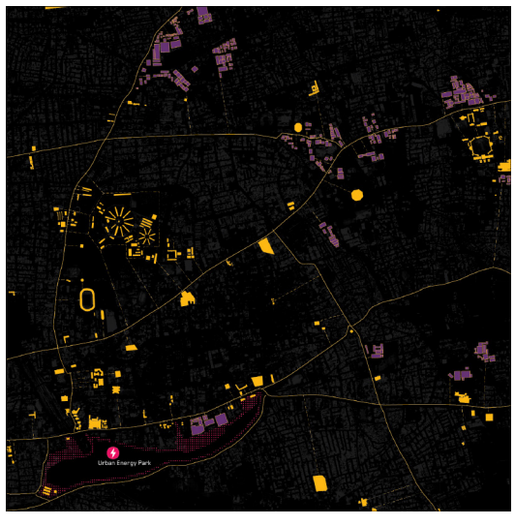


Plan of the design interventions

* B. Energy x Waste Management is not elaborated in detail in the project, although it is a key part of the regional strategies. It is important to note that the Waste to Energy Plant at the Urban Energy park is a envisioned outcome of S2-B.

Fig 10.40: Maps showing the design actions to achieve cross-programming

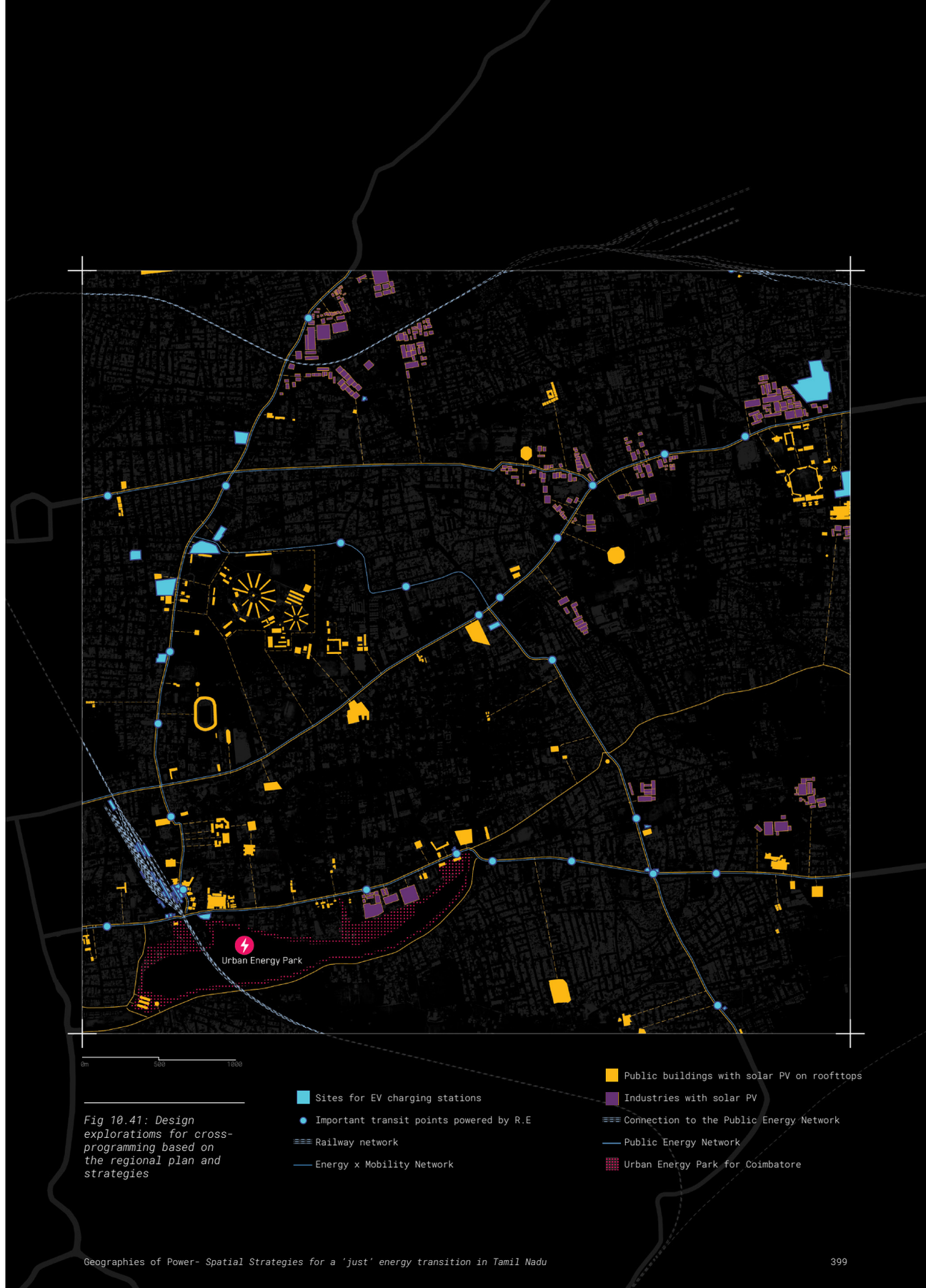
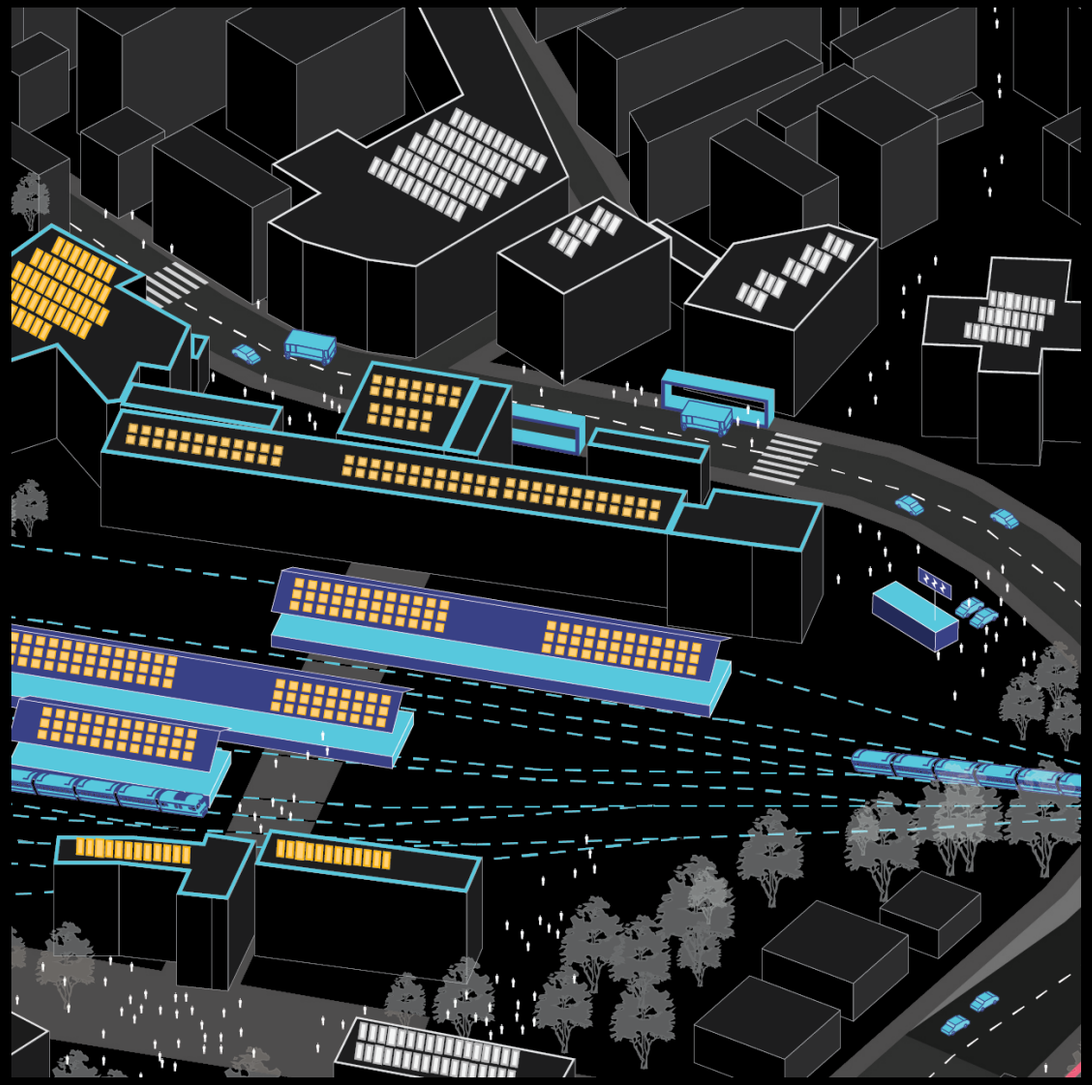


Fig 10.41: Design explorations for cross-programming based on the regional plan and strategies

S2 : Cross program.

A. Energy x Mobility



Detail: Coimbatore Smart Mobility

The generation of R.E. along transport infrastructure in the state is used to power Coimbatore's Smart Mobility network. Here, the project explains three main solutions that drives the implementation of the strategy to crossprogram energy with mobility, leading to a faster, cleaner and smarter transport in the city.

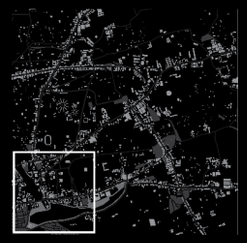
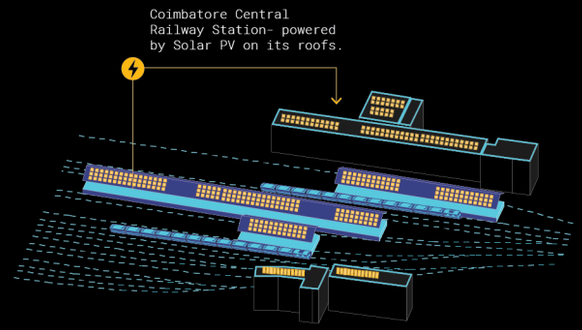
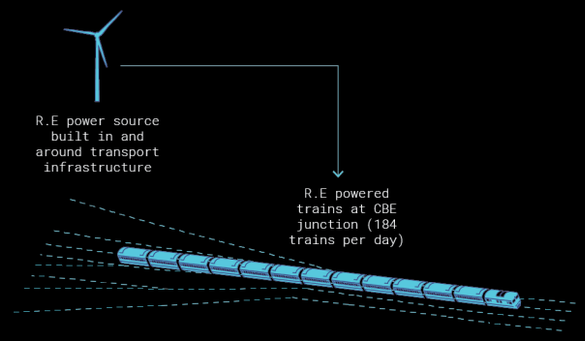
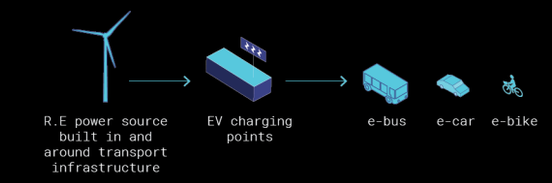


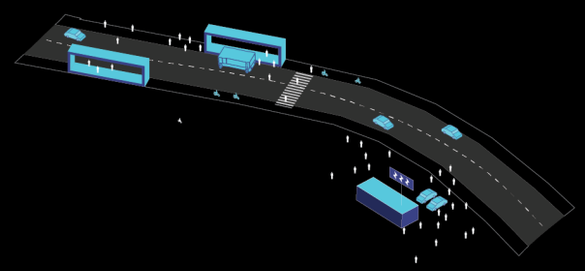
Fig 10.42: Spatial manifestations of the design.

Fig 10.43: Key Map









Zero Energy Coimbatore Railway Station*

Under the Solar Mission of the Indian Railways, solar paneled rooftops of Coimbatore junction currently generate 21% of the station's energy needs. By 2050, efficient space management and technological advancement will lead to the Central Station becoming a zero energy transit complex.

Stakeholders:

Public Sector: TNEB, Southern Railways, Coimbatore Municipal Corporation (CMC)

Private Sector: Energy company contracted to install and maintain the solar panels.

R.E. powered Railway Network*

R.E. powered railways results in faster, cleaner and more efficient train network in the city, where more than 184 national, long distance trains halt everyday (Indian Rail Info, 2019). Profits made from the shift is directed to upgrading transit infrastructure in the city.

Stakeholders:

Public Sector: TNEB, Southern Railways, CMC, Tamil Nadu State Transport Corporation (TNSTC)

Private Sector: Energy company contracted to install and maintain the solar panels.

Coimbatore Electric Mobility

Placement of strategic EV charging stations in the city, paves way for the shift to green, R.E. powered vehicles (privately owned cars, bikes and buses used for public transport). This will reduce GHG emissions in the city by 33%, creating a more liveable, pollution free city.

Stakeholders:

Public Sector: TNEB, CMC, TNSTC, PWD

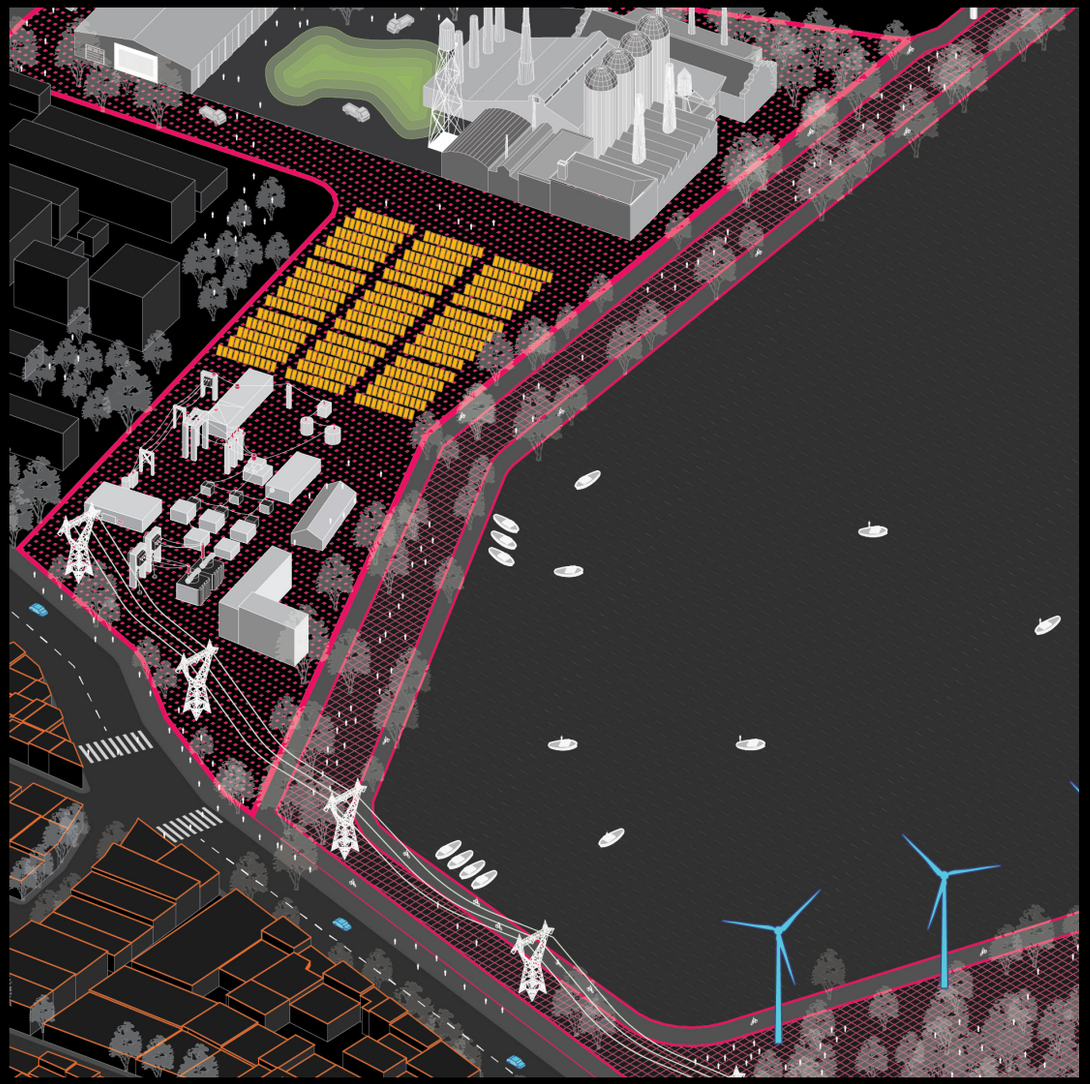
Private Sector: EV and charging point manufacturing companies

Civil Society: Owners of EV.

Fig 10.44: Details of the design intervention

S2 : Cross program.

C. Energy x Public Infrastructure



Detail: Urban Energy Park

In Coimbatore, the existing opportunities at Valankulam Lake is tapped to create an ‘Urban Energy Park’- a new, open, green public space for the city around Valankulam Lake, that combines various types of energy production with the creation of a public space for the city, along with building better flood resilience in the city.

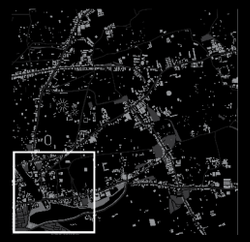
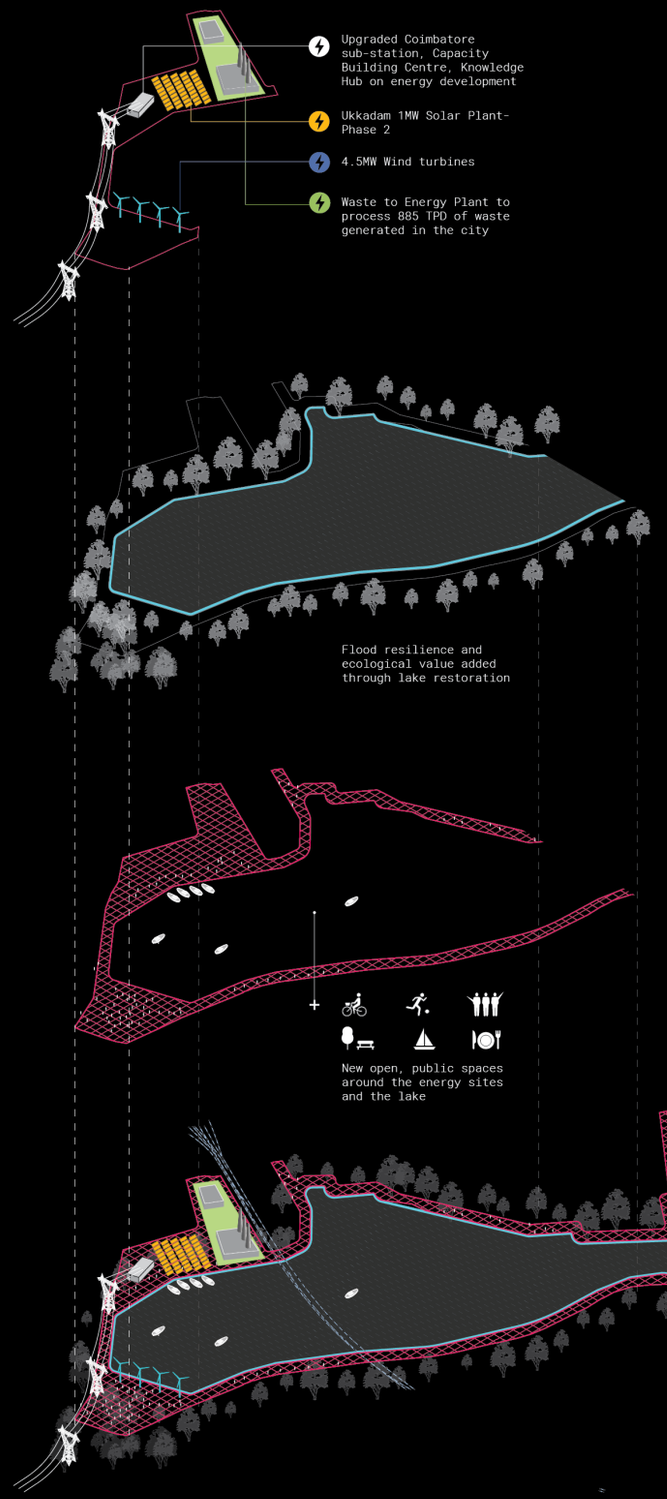


Fig 10.45: Spatial manifestations of the design.

Fig 10.46: Key Map



R.E. production around the Lake

Solar and wind energy production near the existing substation and TNEB office on the banks of the lake, and Waste to Energy plant to treat 885TPD of solid waste generated in the city. The utilitarian importance of the energy production site and the energy identity of the public space reinforces the urgency of the transition among urban citizens.

Valankulam Lake rejuvenation

The development of the Urban Energy Park is accompanied by ecological rejuvenation of the lake itself, leading to increased flood resilience and water storage. The development of a green ring around the lake, integrates the blue-green network to the dense city centre.

New Lakefront public space

Currently, the amount of open spaces in Coimbatore is 1.19m^2/person, much lesser than the national norms of 10-12m^2/person. Creation of the Urban Energy Park, along with public facilities to nurture activities like walking, running, informal events, etc is a step towards adding open public spaces in the city.

Stakeholders:

Public Sector: TNEB, CMC, Directorate of Town and Country Planning (DTCP) Dept of Environment (DoE)

Private Sector: Energy company contracted to install and maintain the energy infrastructure

Civil Society: Citizens, users of the space

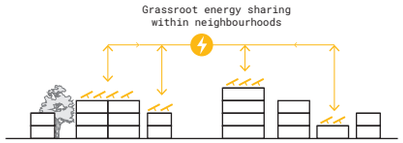
Fig 10.47: Details of the design intervention

S3 : Coproduction.

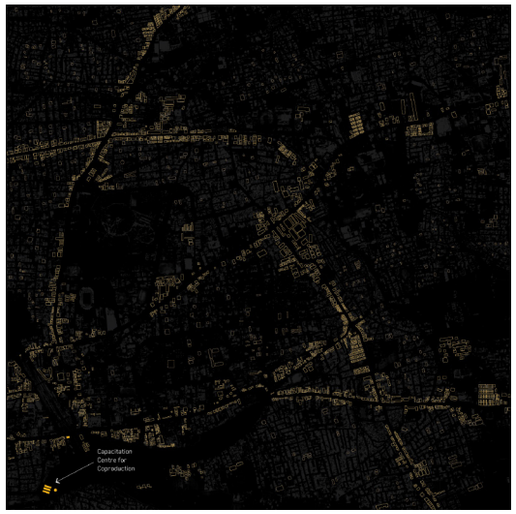
A. Neighbourhood Energy Networks

The coproduction of R.E, specifically through installation of solar PV within neighborhoods and residential colonies in Coimbatore is explored in this intervention. Knowledge centres to facilitate coproduction, energy distribution boxes at the neighbourhood level to balance the grid locally are key supporting interventions.

Detail: Gopalapuram Solar Rooftops



Schematic Section

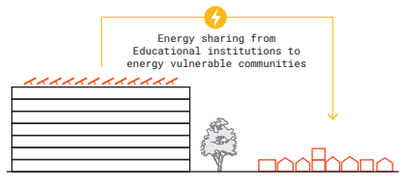


Plan of the design intervention

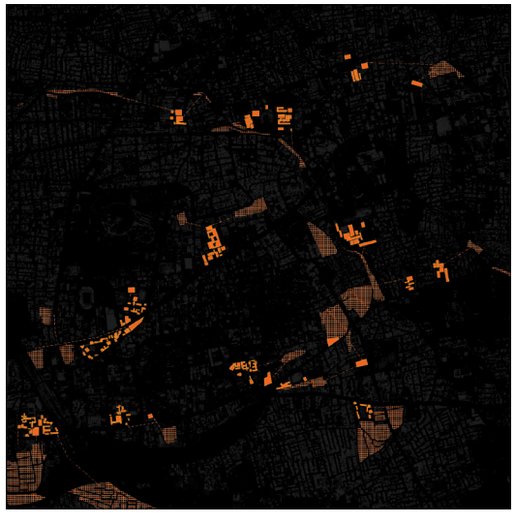
B. Energy sharing with energy vulnerable communities

Energy vulnerable communities in Coimbatore, specifically in informal settlements in the central zone of the city are empowered by connecting them to nearest public institution, like schools, which have the rooftop space to coproduce energy along with the energy vulnerable communities.

Detail: Ukkadam-St.Micheal's energy sharing



Schematic Section



Plan of the design intervention

Fig 10.48: Maps showing the design actions to achieve coproduction

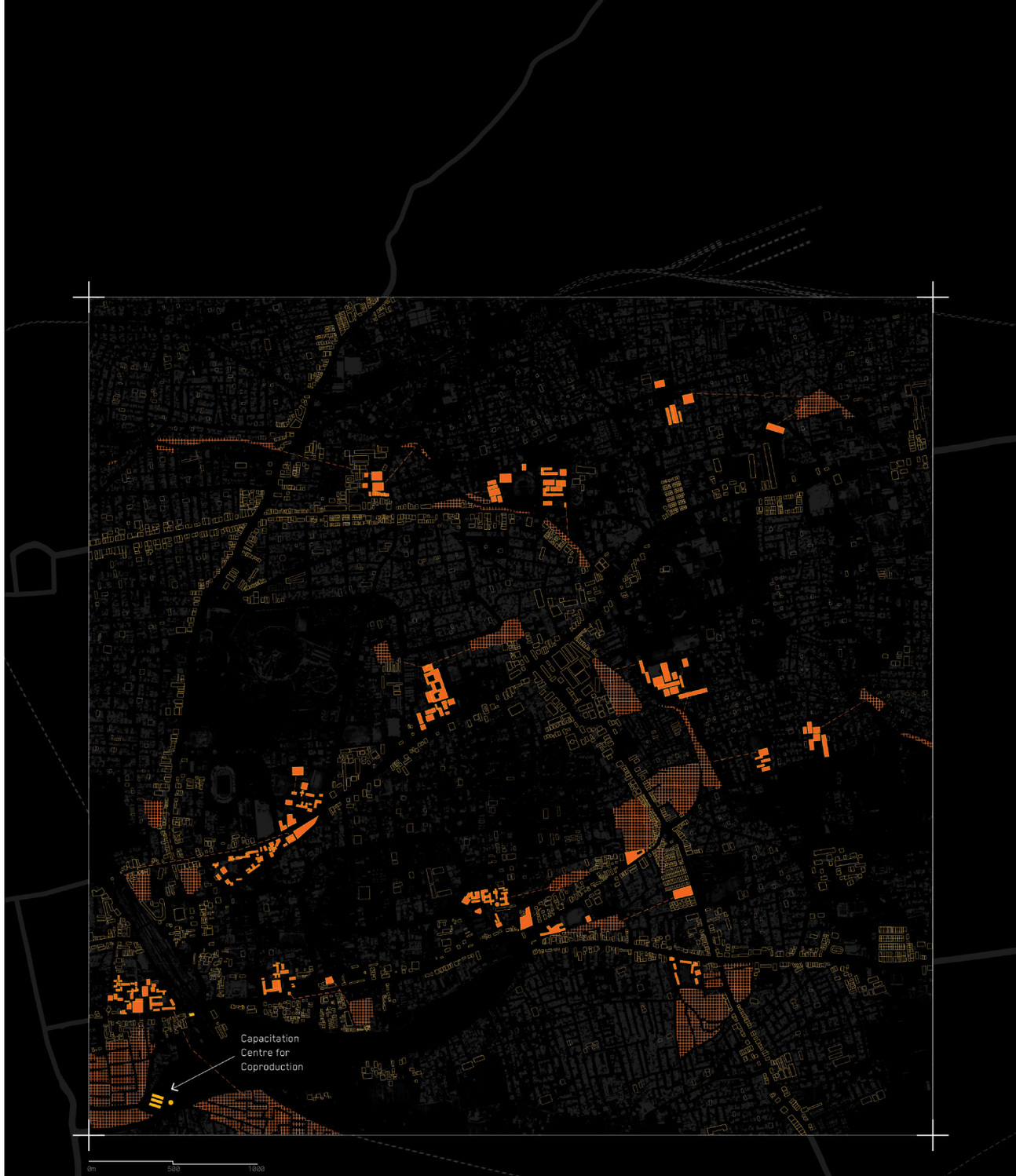
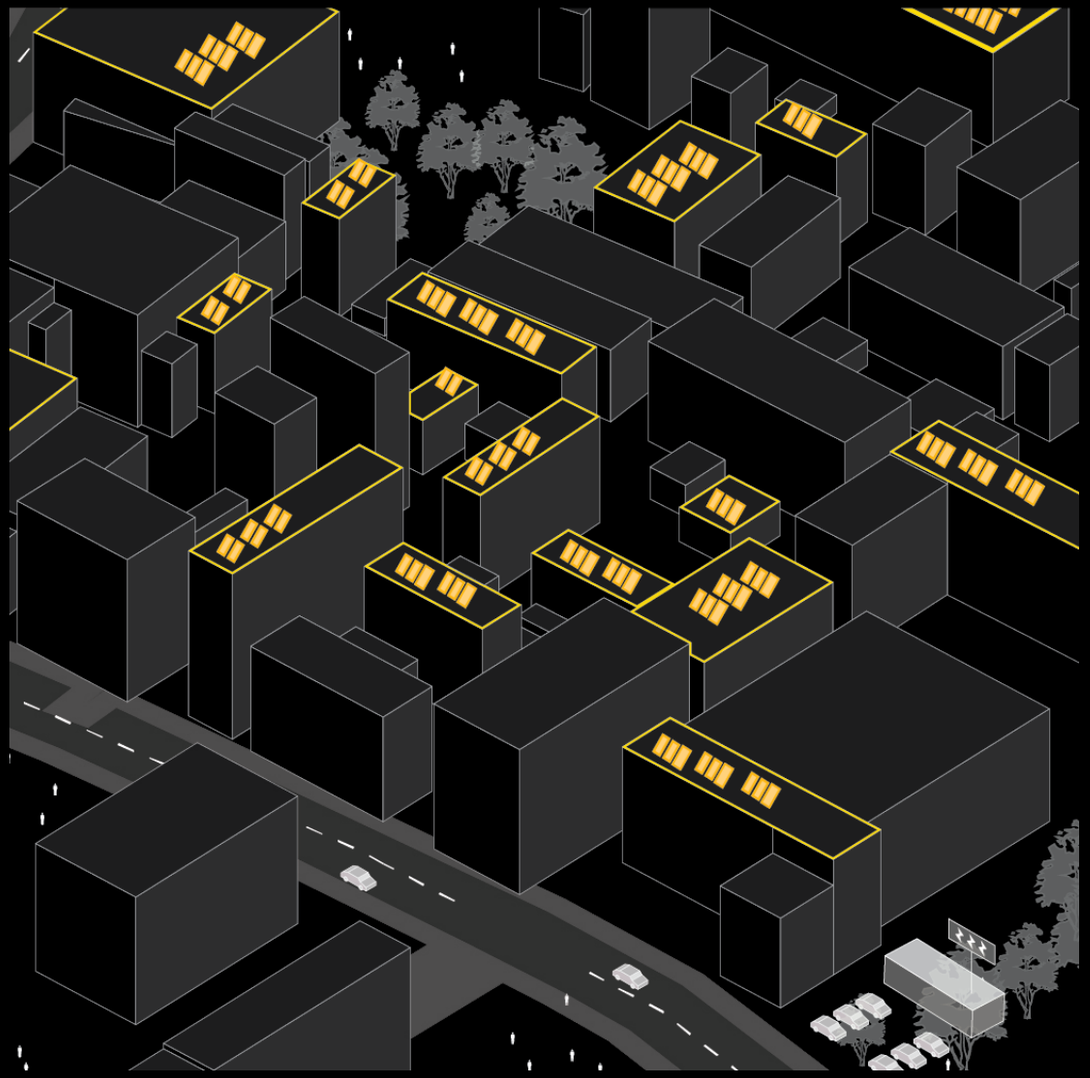


Fig 10.49: Design explorations for co-production based on the regional plan and strategies

S3: Coproduction.

A. Neighbourhood Energy Networks



Detail: Gopalapuram Solar Rooftops

This detail explains the feasibility and spatial manifestation of neighbourhood level coproduction of energy by residential energy cooperatives, under the framework of the Solar City Masterplan for Coimbatore, substantially decreasing the energy footprint of domestic sector in Coimbatore.

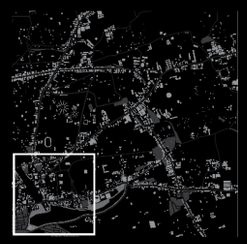
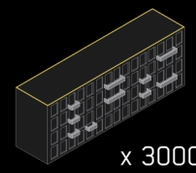


Fig 10.50: Spatial manifestations of the design.

Fig 10.51: Key Map



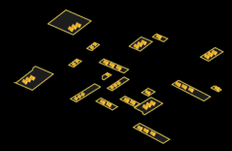
x 3000

In Coimbatore, there are 3000 apartments with 30 units each approx.



15 kW

solar energy capacity of each apartment



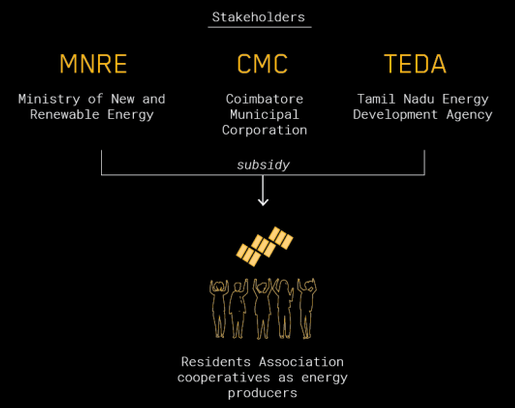
5400 kW

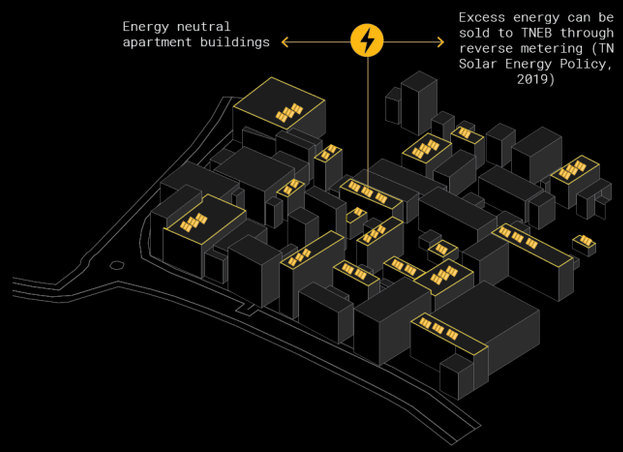
solar energy capacity if just 10% of apartments adopt it.

8.1 Gwh

solar energy generated in 5 years through Solar City programme

Source: Coimbatore Solar City Masterplan, 2012





Solar City Mission- Coimbatore

Coimbatore has over 3000 residential apartments with about 30 units each, 10% of which, when developed, yields over 8.1 GWh in five years. The Solar Cities Masterplan for Coimbatore has specific subsidies, policies and actions directed towards the promoting solar energy generation in the residential sector. Several apartments in Gopalapuram area fall under this category.

The presence of a strong residents' associations in apartments and residential colonies in Coimbatore is an important boost for the implementation of coproduction strategies in Coimbatore. The design proposal involves the mobilisation of residents' association as energy cooperatives, who make a joint investment for the installation of the solar PV. 1/3rd of the capital investment is borne by MNRE as per the Solar City Masterplan, which greatly reduces the burden on the citizens. Apart from meeting the energy needs of the apartment, surplus energy can be fed back into the grid, through 'reverse metering', a move already in motion as per the Solar Cities Masterplan.

Policies that provide more financial support for solar PV installation from the CMC and TEDA, along with better returns for sale of surplus energy back to the TNEB are needed for the successful adoption of R.E. production in residential apartments in Coimbatore.

Stakeholders:

Public Sector: TNEB, TEDA, MRE, CMC, Dept of Urban Development & Poverty Alleviation (Government of Tamil Nadu

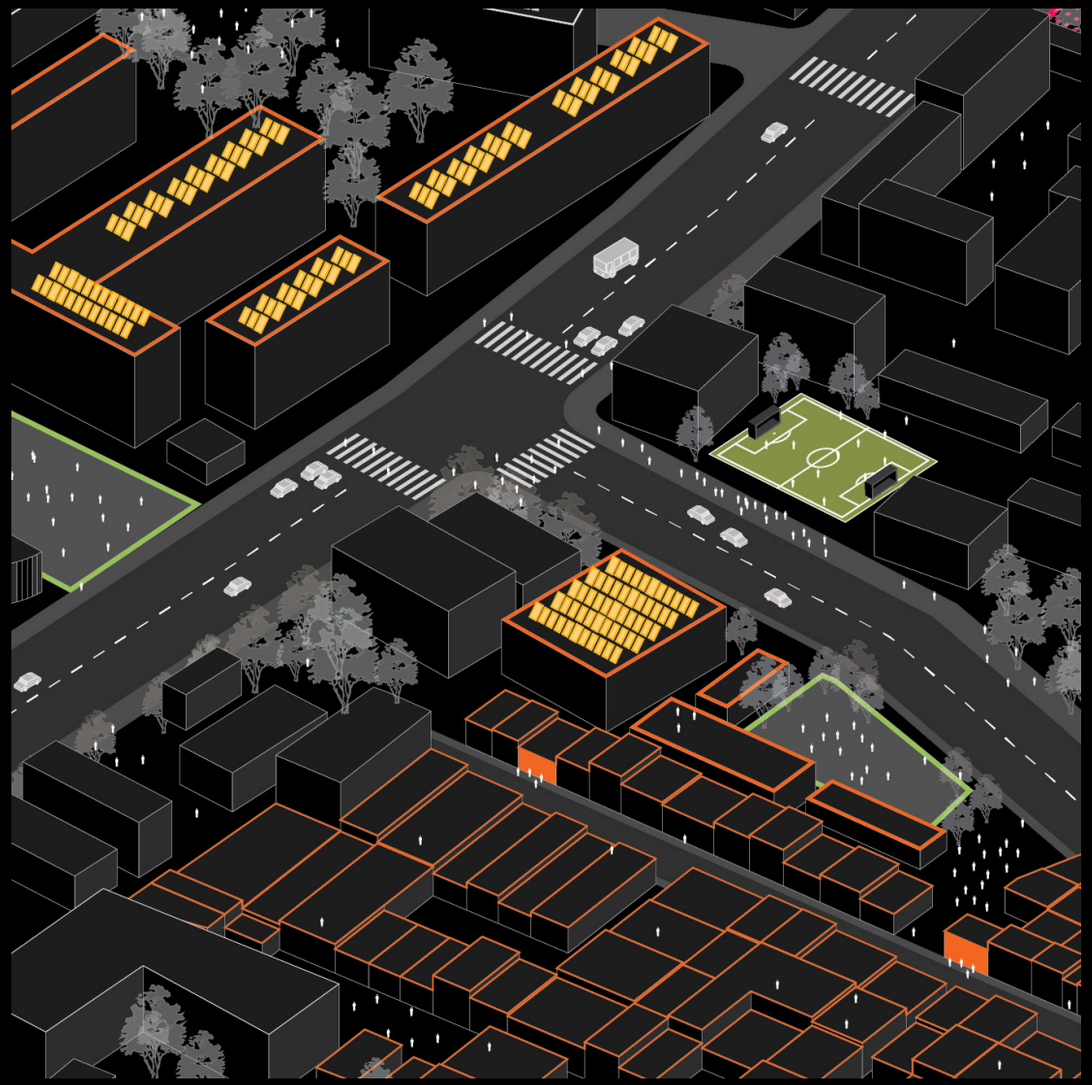
Private Sector: Solar PV manufacturers

Civil Society: Individuals, residents' energy cooperatives

Fig 10.52: Details of the design intervention

S3: Coproduction.

B. Energy sharing with energy vulnerable communities



Detail: Ukkadam-St Micheal's energy sharing

The presence of educational institutions and school in the city centre with large rooftops and near informal settlements is a major boost for the implementation of energy sharing policies in the city. This detail elaborates how energy sharing can be implemented and its socio-economic benefits.

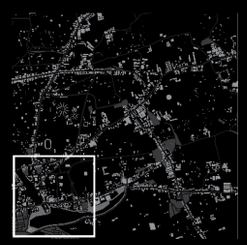
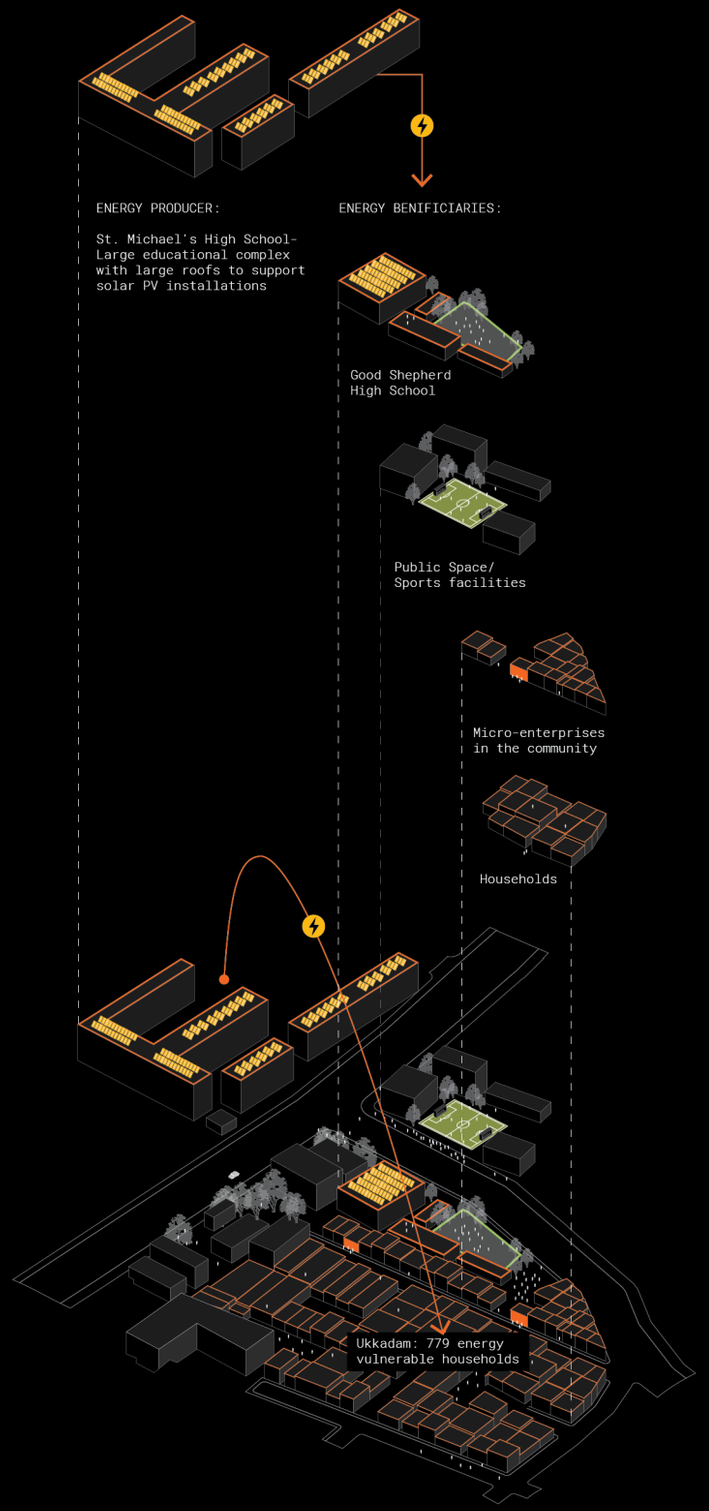


Fig 10.53: Spatial manifestations of the design.

Fig 10.54: Key Map



Energy sharing in urban areas

This intervention proposes that the surplus energy produced on the rooftops of selected educational institutions is connected directly to the nearest energy vulnerable community through TNEB's transmission infrastructure. Policies to ensure that at least 10% of energy generated by large institutions is reserved for the social empowerment of communities nearby, is crucial to the successful implementation of the strategy.

Here, the project recommends that the cost of energy shared with energy vulnerable settlements is borne by the Tamil Nadu Slum Clearance Board (TNSCB)and Department of Urban Development & Poverty Alleviation (DoUDPA), responsible for improving access to services for energy vulnerable communities. In Ukkadam, St. Micheal's institution is proposed to be the energy producer, supplying R.E. to 779 energy vulnerable households nearby, will benefit from the supply of continuous and subsidised R.E.

Socio-economic benefits

The on-site energy generation and supply balances the energy grid locally, preventing power cuts and load shedding in segregated areas in the city. The increased access to services in Ukkadam in turn has positive socio-economic impacts in the neighbourhood, leading to the creation of new public spaces, small scale urban renovation, micro-enterprises and better standard of living in the communities.

Stakeholders:

Public Sector: TNEB, TNSCB, DoUDPA, CMC, public institutions

Private Sector: Private institutions, energy manufacturers

Civil Society: Energy vulnerable individuals and communities

Fig 10.55: Details of the design intervention

Existing situation at Coimbatore.

Testing and translating coproduction strategies in Coimbatore City Centre



Fig 10.56: Photograph of the existing situation in Coimbatore (Google Earth, 2019)

Proposed situation at Coimbatore.

Testing and translating coproduction strategies in Coimbatore City Centre



Fig 10.57: Collage showing the proposed situation in Coimbatore city centre.

Conclusions.

Through the testing and translation of the Strategic Plan in the micro-region and the zoom-ins, context-specific opportunities and limitations of the design were identified (Fig 10.58). The resulting strategic plan for the micro-region is illustrative of planning process that can be applied in other regions of the state. Through the elaboration of specific design interventions in the Zoom-ins (Fig 10.59), the normative values and goals prescribed in the vision are turned into tangible projects that can be easily released for development by the coordinating authorities.

The testing of design interventions in the local scale also shed light on the network of stakeholders that need to be involved in the realization of the project. By studying and identifying existing policies, laws, schemes and proposals by the government, and working under their frameworks, the project showed how the interventions can be implemented in the current political climate. Critical actors networks that need to be fostered were also identified in the design details. The following chapter will discuss the governance and coordination of the energy development and evaluate the project based on its contribution to the project aims set in the beginning of the graduation project.

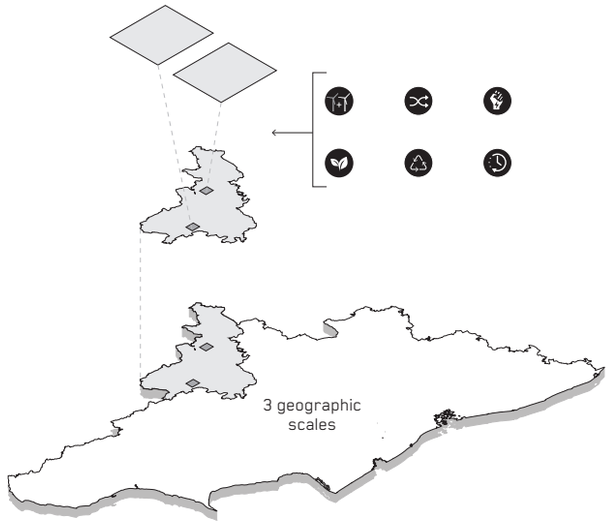


Fig 10.58: Diagram summarizing the Chapter

Fig 10.59: Consolidation of the proposed design manifestations

11

Governance and Evaluation

Overview:

This chapter presents the contribution of the project to governance of energy transition in Tamil Nadu. The pathways for the coordination of actions of multiple stakeholders is elaborated along with the transformations in the relationship before and after the implementation of the regional design. The Chapter concludes with the evaluation of the project in its effort to shed light on the frameworks needed for a ‘just’ energy transition in Tamil Nadu.

Sections:

11.1. Governance and Implementation
11.2. Evaluation and Conclusions

11.1 Governance and Implementation

In Chapter 3, the project identified how the centralisation of power and lack of interdepartmental relationships in Tamil Nadu has resulted in a top-down governance structure that legitimises the gap between energy and spatial governance. Through the regional design the project makes **two main contributions to the energy transition governance** in Tamil Nadu. **Firstly,** by creating opportunities for the mutual benefit of stakeholders from various sectors (energy, mobility, agriculture, etc.) and sections of the society (public sector, private sector and civil society), the project paves way for a **bottom-up governance structure**, that supports community participation and grassroot initiatives in energy transition. **Secondly,** by defining critical areas of **collaboration between energy and spatial governance**, the project bridges the gap between the two and reinforces the mechanisms of 'spatial energy governance'. This section presents these two contributions in the following pages.

Stakeholder relationships after project implementation.

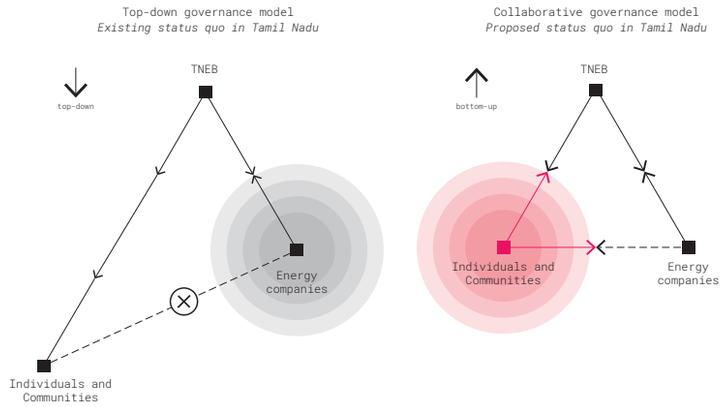


Fig 11.1: Diagram showing transformations in stakeholder relationships after project implementation

The translation and testing of the regional design in the Strategic Zoom-ins showed how stakeholders and actors from the local area can be included in energy production, along with the support of the public and private sectors. Here, the project evaluates the performance of the first contribution of the project- collaborative bottom up governance structure- by highlighting some of the main transformations in relationships between stakeholders after project implementation.

Public Sector:

1. Improved inter-departmental collaboration (energy, mobility, agriculture, waste management) with harvesting of mutual benefits.
2. More support (financial and administrative) for bottom up initiatives from the civil society.
3. Mandatory involvement of spatial governance mechanisms in energy development and decision making.
4. More autonomy for local governments to interpret the regional strategy to suit specific local conditions.

Private Sector:

1. Reduction in the influence of private interests in energy extraction.
2. Incentivisation of the private sector by the government to participate and propel the energy transition in Tamil Nadu.
3. Increased support for bottom-up energy initiatives by way of public-private partnerships.

Civil Society:

1. Increased participation of individuals and communities in energy transition by coproduction of energy
2. More opportunities for participating in decision making process, due to their contribution to energy production.
3. New relationships formed with the public and private sectors increase the energy security of local communities

Critical areas for collaboration.

The second contribution of the project to transition governance is by defining critical areas for collaboration between spatial governance and energy governance. The project prescribes six stages where spatial planning tools, instruments and expertise is integrated in energy governance to ensure that energy development occurs with respect to the values defined in the Vision. Fig 11.2 analyses the existing model of energy development and defines the critical points of intersection between energy and spatial governance. These six points represent ways in which spatial planning knowledge can enrich energy development and improve citizen participation in Tamil Nadu:

1. Development of Strategic Plan:
The Strategic Plan for the macro-region, prepared jointly by the TNEB and the DTCP will be the guiding document for the development of energy production sites and coproduction initiatives.

2. Spatial Suitability and Impact Assessment:
Before the approved projects are tendered for development, preferred sites are chosen by the governing institutions based on macro-regional potential-vulnerability studies, elaborated in Chapter 6. Spatial suitability and impact assessment studies must be conducted before choosing the site for development.

3. Managing land acquisitions:
Tenders for developing the project are released along with preferred sites for development. Strict measures to ensure that the acquisition of land for energy development respects local landuse regulations and livelihoods.

4. Creating Platforms for community participation:
After the contract for development is awarded to private or public sector developers, platforms for constant feedback through community participation in decision making is created to democratize the transition.

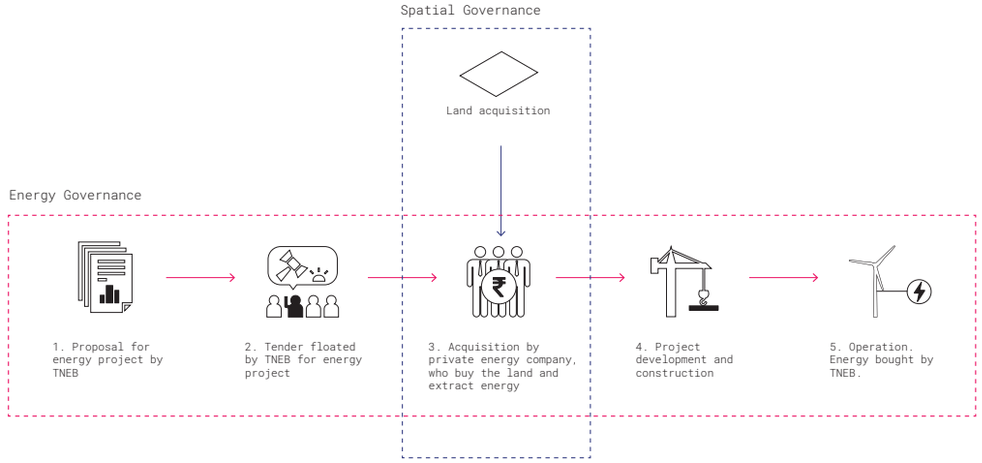
5. Managing the development process:
Constant monitoring of the development process is done by the TNEB and DTPC to ensure that the values of the vision are upheld during its implementation.

6. Post-completion evaluation:
After the completion of the process, regular spatial impact assessment studies are made to inform future projects and improve the quality of performance.

These six tools/areas for the integration of spatial planning in energy development shows how the rift between the two fields can be bridged.

Intersection between energy and spatial governance

Existing energy development process



Critical areas of collaboration between energy and spatial governance

Proposed energy development process

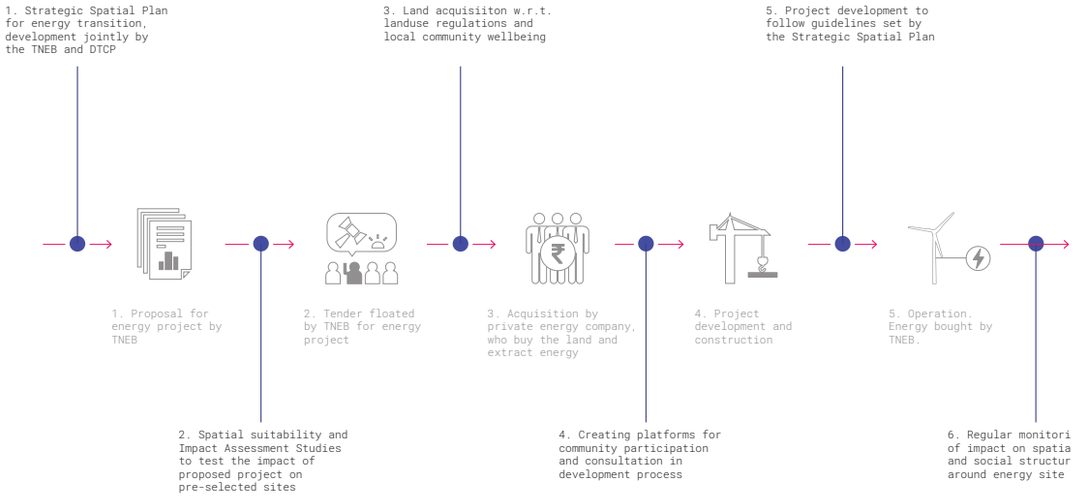
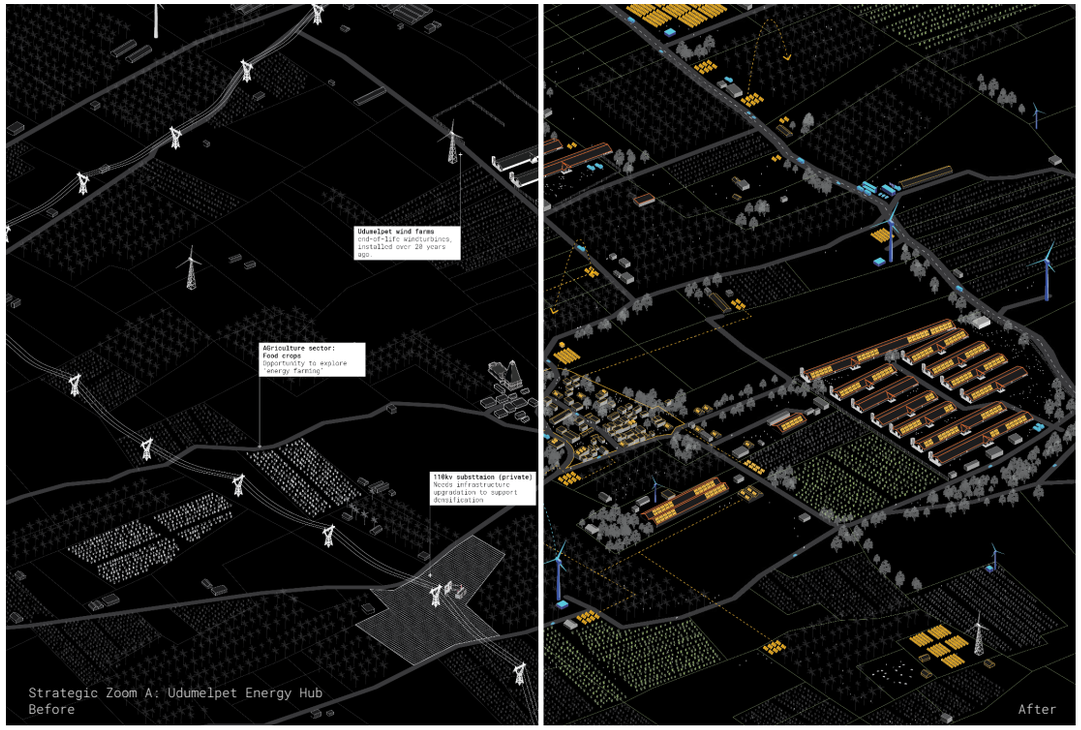


Fig 11.2: Energy governance system in Tamil Nadu

11.2 Evaluation and Conclusions

While the scope and limitations of the design were tested on the local scale in Chapter 10, this section concludes the project by evaluating the impacts of the regional design based on its contribution to the goals of the vision: **adaptivity, inclusiveness and collaboration.** The project illustartes how these three goals have been achieved through specific components of the regional design. With this, the project reviews the **research questions** presented in Chapter 3 to discuss how the project answered them through the prescribed research and design methodology. Finally, the project's **contribution to scientific knowledge** on the topic of spatial energy transition in developing countries is highlighted. Specifically, the project's **geographic approach**, combining the spatial, social and political dimensions of energy transition is a significant contribution to the discourse. The section concludes with **recommendations for further research** on spatial energy transition.



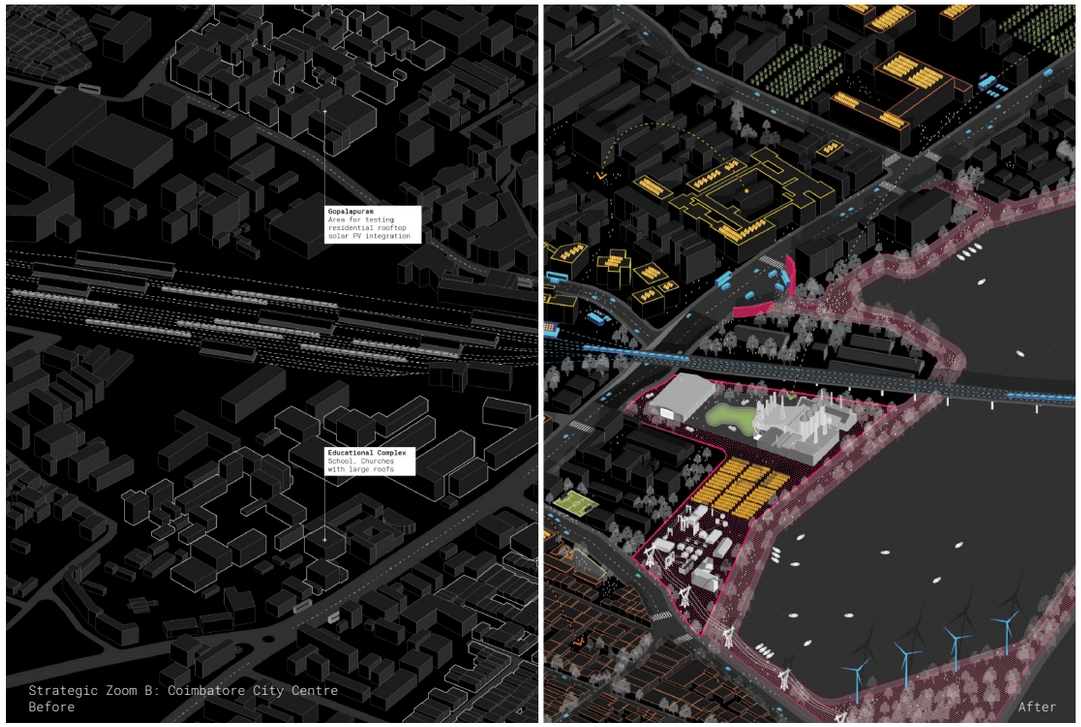


Fig 11.3: Spatial transformation after implementation of the design interventions

Evaluation of project.

The goal of the project was to create a framework for adaptive, inclusive and collaborative energy transition in Tamil Nadu, through regional design of emerging energy geographies, summed up in the research question below:

> *How can regional design of emerging energy geographies create a framework for a 'just' energy transition in Tamil Nadu?*

The scope and application of regional design in achieving the notion of justice is summed up below:

1. Spatial justice through adaptability:
The careful consideration of the potentials, vulnerabilities and uncertainties of a place in the analytical component of the project paved way for the design of energy landscapes that adapts to local spatial settings, addresses regional spatial inequalities, and adds ecological reinforcement to offset the negative impacts of energy development. For example, aim of preserving the integrity of the landscape can be seen in the densification strategy where energy sprawl was contained by building in the gap between existing energy infrastructure.

2. Social justice through inclusiveness:
The design, through cross programming and co-production of energy with the local stakeholders, opened the playing field of energy transition to a wide range of actors stemming from the grassroots. The inclusion and participation of diverse stakeholders in the massive cross-regional effort ensures that the benefits of the development are distributed equally. The in terms of energy access, share in benefits of the transition and inclusion in the energy production process

3. Procedural justice through collaborative governance:
The governance of transition is reconfigured such that coordination of activities, actions, policies and interventions occurs through a collective decision making process that is deliberative and consensus oriented. The development of commitment and shared understanding between multiple stakeholders of the transition is one of the main priorities of the collaborative governance model proposed by the project.

Through these spatial, societal and governance contributions, the project illustrated the scope and application of regional design in national and federal energy planning. The three dimensions stresses the ***relevance of the geographic approach to energy transition in addressing values of justice*** in energy development. The project also presented a comprehensive research and design methodology for the design of energy geographies. Specifically, the development of the 'Manifesto for the Design of Energy Geographies' (Refer Appendix) contributed to the gap in knowledge on normative values and goals for design.

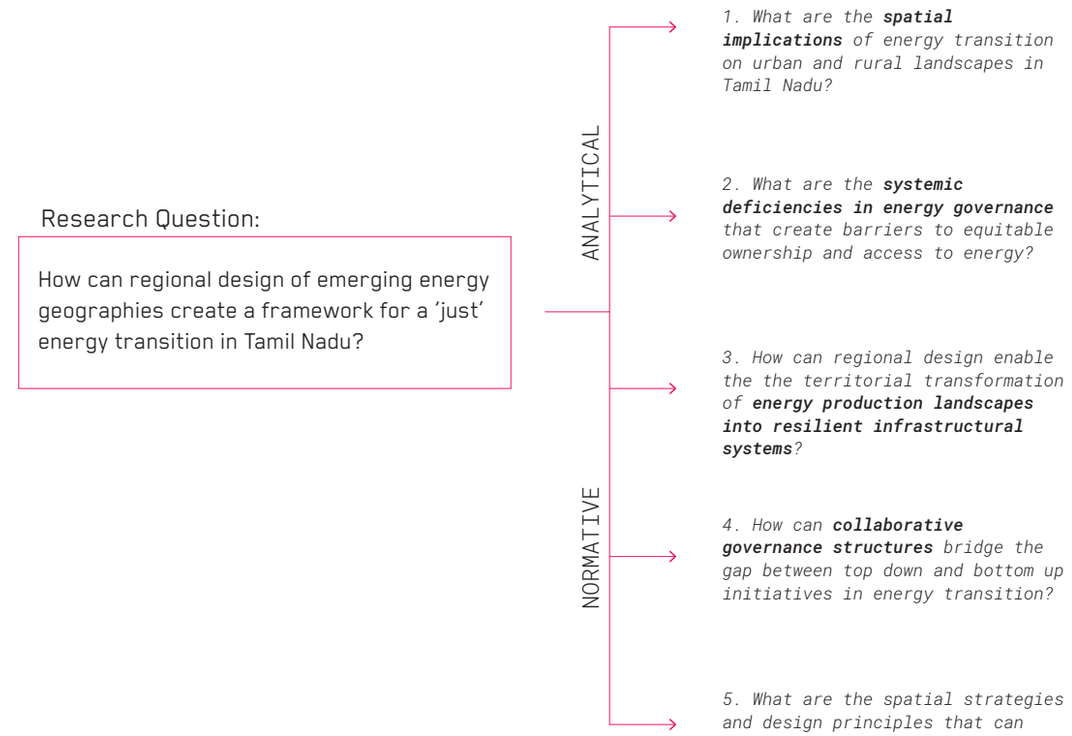


Fig 11.4: Diagram summarizing the research questions of the project

Recommendations for further research.

The project was an explorative research to find new ways of studying, analysing and designing emerging energy geographies in Tamil Nadu. By developing a regional design, with analytical, normative and organizational components, the project presented the know-hows for facilitating a just energy transition. The potential possible governance pathways for the realisation of the project can be developed further using scenario planning tools to see the socio-spatial implications of each strategy. Furthermore, the set of strategies and solutions presented in Chapters 8 has the potential to grow into a handbook for the design of energy landscapes in developing territories in the Global South. The handbook, by no means conclusive will grow with time as new studies on spatial energy transition are published. The challenge of data nonavailability and lack of awareness on the energy-space discourse in praxis, can be addressed through the development of design tools like the handbook and manifesto.

12

Reflection

Overview:

This chapter concludes the project by reflecting on the project, research aim and methodology, design outcomes, limitations and ethical considerations of the project.

On the side of the *katiyabaaz*

It is undeniable that in almost 300 years, since commercial mining of coal, modern society has become increasingly dependent on and accustomed to an extractivist energy system. The human development of energy through continuous mining and burning of fossil fuels and the rapid transformation of territories set the tune for an uneasy relationship between energy and space. Belanger argues that when this ***space*** becomes ***place***, the discussion enters the realm of human geography:

> "Enter geography. Where do these materials come from? Who do they belong to? Under whose jurisdiction? How are they moved and removed? Where do they go? Who processes them? What energies are required? What do they leave behind?" (Belanger, 2018)

These questions point towards a re-examination of extractivist systems of the capitalocene (Moore, 2017) and fossil fuel expressionism (Sloterdijk, 2014), now armed with the concepts of critical geography. This geographic approach to energy extraction/development/transition, where the impacts of energy extraction is examined through the lens of critical geography and infrastructural ecology, is the fundamental school of thought that shaped my graduation project on 'spatial' energy transition in Tamil Nadu. This meant that discussions on energy poverty, post extractivism, right to services, urban political ecology and socio-spatial justice formed the core of my professional and ethical dilemmas when designing for the energy geographies of the future. Consequently the reflection chapter will elaborate in detail on some of the ethical considerations and externalities that gave shape to my project, in addition to reflecting on the course, studio, project methodology , scientific and societal relevance of the project.

Ethics or *The Courage of the Katiyabaaz.*

> ***katiyabaaz***
> n. a Hindi word meaning 'electricity thief'

The relationship between energy and society is co-productive; on one hand, the degree of access to energy influences our lifestyles, social behaviour, ability to afford goods that use energy (cars, appliances), improvement of living standards and status in society. Consequently, the lack of access to energy limits certain populations from achieving a higher quality of life. This 'inability to attain a socially and materially necessitated level of domestic energy services' or 'energy poverty' (Bouzarovski & Petrova, 2015), is underpinned by and produced by spatial inequality. The vicious cycle of energy poverty and spatial injustice ties together energy and space in complex, ethically ambiguous ways.

Take for example, the katiyabaaz, or electricity thief, portrayed in the critically acclaimed documentary, Katiyabaaz (Mustafa & Kakkar, 2013), on the frequent power cuts in Kanpur city, India. The documentary tells the story of Lola Singh and the group of local electricity thieves who stealthily rebel against the state utility to steal electricity for the energy-poor populations in the city. Here, the katiyabaaz is seen as a fearless, almost Robin Hood-esque figure, hauling ladders, climbing electricity poles, and creating connections where there were none. As an urbanist, from a developing context like India, I interpret this as a call for right to services, stemming from Lefebvre's 'right to the city (1991), which intends to break the vicious cycle of energy poverty and energy vulnerability, perpetuated by structures of spatial inequality. *Can energy transition in India really be addressed without tackling the complex challenge of energy poverty and spatial inequality? Will the new energy paradigm of the future continue to operate on the same extractivist systems that create*

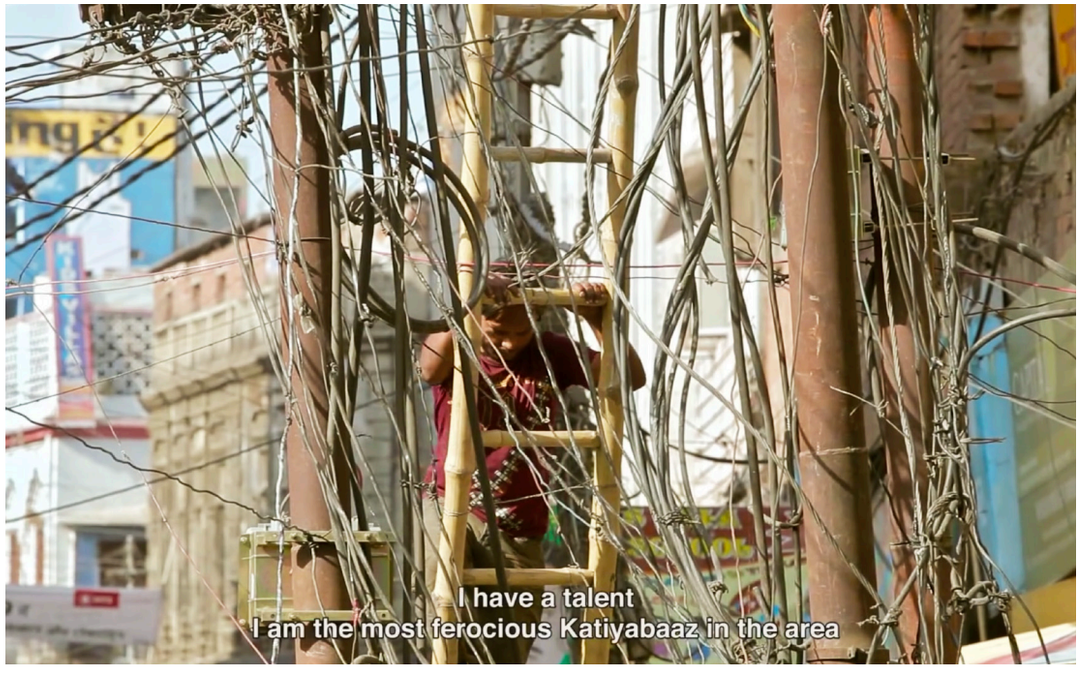


Fig 12.1: Stills from the documentary 'Katiyabaaz' (ELectricity thief), showing the informal networks of electricity in urbanised areas of India. (Mustafa & Kakkar, 2013)

geographies of difference and inequality? The case of illegal land grabbing in southern Tamil Nadu is illustrative of this paradigm, where private renewable energy companies arm-twisted farmers to sell agricultural land for the development of wind or solar farms (Sethupathi & Bharathi, 2018). In both examples, one related to energy access and the other related to energy production, socio-spatial inequality is the crucial denominator. In a hyper renewable, yet extractivist energy future, ***I must disclose that I am on the side of the katiyabaaz.***

These ethical considerations, questions and dilemmas and in time, standpoints that were taken, shaped my graduation project. I focused on justice with respect to energy production by creating a framework for a 'just' energy transition where the production of renewable energy occurs after careful consideration of spatial and social factors that affect, and are affected by, energy development. Through my project, I attempted to design and plan for renewable energy geographies of the future that reject the extractivist systems of the capitalocene (Moore, 2017) and fossil fuel expressionism (Sloterdijk, 2014). The current extractivist energy economy would be transition to a new economic model that respects the limits of the natural environment and creates room for alternative practices and forms of extraction without exploitation. The post extractivist energy system needs a 'different kind of imaging and imagination, action and retro-

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action, forms of representation and reclamation', to undermine neoliberal strategies of land dispossession to produce energy and the resulting uneven forms of development. (Belanger, 2018). This points towards the relevance of the project in society, as it attempts to explore and present a spatial imaging and imagination of the energy future of Tamil Nadu.

One of the outcomes of the project, 'The Manifesto for the Design of Energy Geographies', was an attempt to address the ethical dilemmas that surround energy transition and take a standpoint. The manifesto is call for an integrated geographic approach to energy production and consumption, within the paradigm of energy transition. The 'Manifesto for Design of Energy Geographies' is a declaration of intention to consider the spatial dimension in energy development, and integrate the disciplines of energy studies and spatial planning. It is an assertion of what energy geographies ought to be and what qualities they should have, which can act as principles and guidelines for the design of energy geographies. This was developed by aggregating ideas and spatial concepts from various theories in spatial planning, infrastructure management, political ecology, critical geography and energy studies. Through the manifesto, I defined the philosophical, and scientific foundations of the project as a whole. The manifesto proposes what 'good' energy geographies of the future should be like, who they should benefit, where they should be formed and defines spatial principles to achieve it.

Scientific and Societal Relevance.

The project's position at the intersection of energy and space was important in identifying and contributing to the knowledge gap that exists between energy studies and spatial planning. The spatial patterns and developments across territories due to the human development of energy resources have been largely ignored in energy studies. Scholarly research in the spatial dimension of energy transition is relatively new; an endeavor of the past decade. The reciprocal relationship (Sijmons, 2014) between energy and space has since then caught the attention of academia, due to the increasing relevance of energy transition in our daily, societal life. However, there exists a knowledge gap between the fields of energy studies and spatial planning, despite the fact that the altered spatial qualities of renewable energy space have blurred the boundaries between technical space (shunned by planners) and 'non-technical' space (coveted by planners). This project primarily aims to contribute to bridging the epistemological and methodological rift between energy studies and spatial planning.

By taking the case of Tamil Nadu, India, the project also contributed to the body of knowledge on spatial energy transition in a developing context like India, where it is important to

include the challenges to energy justice and equality in the discourse. Currently, literature on energy studies in Tamil Nadu is limited to descriptive studies on energy status and energy potential calculations; and shies away from delving deeper into the spatial consequences of energy transition and its impacts on the socio-political economy. This project on spatial energy transition in Tamil Nadu, will thus contribute both to the theoretical knowledge gap and context-specific knowledge gap in this field. The design outcomes of the project aim to bridge this knowledge gap by laying down spatial strategies, solutions and policies that enable the creation of adaptive, inclusive and collaborative energy transition in regions of the Global South. The potential transferability of the concepts, research methodology and design process for use in developing countries that face the challenge of spatial energy transition highlights the scientific and societal relevance of the project.

Additionally, the contribution of energy transition to the UN Sustainability Development Goals (UN SDGs) is an important marker of the societal relevance of this project (Fig 5.18). The strong focus of the project on socio-political relationships with energy and the notion of spatial energy justice is an asset to furthering the debate and discussion on 'equality' in society.

Methodology.

Choosing the appropriate methods for research and design was a challenge, due to limited scholarly exploration in the intersection of energy studies and spatial planning. The project was an exploratory research where new methods for the analysis and evaluation of energy landscapes had to be evolved. In the reflection, I would like to highlight two important parts of my research methodology that bears weight. The first is the multicriteria analysis on GIS, (See Chapter 6), where a spatial grid was superimposed on energy potentials to identify areas of potentiality and vulnerability. This process of mapping in Tamil Nadu has not been carried out before, and the project created a valuable set of energy atlases for the region.

In addition to the above, my internship in PosadMaxwan, an urban design office in the Netherlands that specializes in energy transition enabled me gain a practical understanding of the spatial planning approach to energy transition. The energy workshops that the studio held with stakeholders of different Dutch municipalities also helped me understand the value of participatory planning approaches in the long term transition to renewable sources of energy. The knowledge gained from practice was a key reason I organized a presentation and workshop on spatial energy transition during my field trip to Tamil Nadu, India. The workshop was attended by 35 people, mostly from the design community who took part in the workshop with great enthusiasm. During the workshop, the participants discussed debate and pin down key challenges in the spatial, social, and political dimensions of energy transition in Tamil Nadu. Although the workshop could not be organized with on ground stakeholders of the transition, the workshop with fellow urbanists helped raise the question of what the role of an urban designer/planner is, in the energy transition process.

Reflecting on the Studio and Course.

The Complex Cities studio is fueled by the expertise in regionalization, spatial planning and territorial governance. Moreover, the geographical focus on cities of the Global South, faced by disparities and conflicts in the distribution of spatial resources, rapid development and weak governance, brings my graduation under the purview of the studio.
The point of departure that sets apart the Complex Cities studio, is the fact that it critically questions the role of the planner or designer in increasingly complex spatial and societal conditions. This learning, un-learning and deconstruction of historic planning and spatial narratives was crucial to the development of my project. The critical outlook in the Complex Cities studio towards the role (and need) of planning points towards a continuous process of self-introspection, which is relevant to my project. Additionally, my project focus on institutional frameworks and spatial governance systems that are needed to enable an equitable and 'just' energy transition, resonates with the underlying theme of the Complex Cities studio that prioritises a 'governance approach' to planning for the Global South.

The diverse pallete of research groups offered by the Urbanism department at TU Delft, and the Graduation Orientation programme provided a unique opportunity to systematically assess and arrive at a conclusion on the most suitable studio for a graduation project. The 'Dutch approach' to urbanism, that I learnt throughout the two years of the Masters course was crucial to the systematic development of my project, that I attribute to the structure of the Urbanism course.

X

References

Overview:

This chapter consolidates all the references, sources mentioned throughout the report. Sources for photographs used in the report are listed separately. The chapter also contains the complete list of figures shown in the report.

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Appendix

Overview:

The appendix contains the academic paper written for the course, ‘Theories of Urban Planning and Design’, where the theoretical foundations of the graduation project were expanded to develop a Manifesto for the Design of Energy Geographies. The appendix also contains excerpts from the field work conducted during the project duration.

AR3U023 | Theories of Urban Planning and Design

ACADEMIC PAPER

Manifesto for the Design of Energy Geographies

Exploring the spatial dimension of renewable energy transition

Abstract:

The human development of energy resources occurs at the intersection of energy and space. The paper argues that there is an urgent need to approach energy as a spatial phenomenon, to fully understand the conflicts and opportunities of energy-space. This outlook is significant for energy transition, since renewable sources of energy uses and produces space in a different way- its altered spatial qualities have blurred the boundaries between technical space (shunned by planners) and 'non-technical' space (coveted by planners). The resulting energy-space or energy geographies are under constant development, transformation and exponential expansion. This needs to be planned for, through the integration of the fields of energy studies and spatial planning. However, there is a lack of normative understanding and agreement on what energy geographies ought to be like, and a huge epistemological and methodological rift between the fields of energy studies and spatial planning.

The paper is a manifesto, a call for an integrated geographic approach to energy production and consumption, within the paradigm of energy transition. The 'Manifesto for Design of Energy Geographies' is a declaration of intention to consider the spatial dimension in energy development, and integrate the disciplines of energy studies and spatial planning. It is an assertion of what energy geographies ought to be and what qualities they should have, which can act as principles and guidelines for the design of energy geographies. Through the formulation of the 11 points, the manifesto promises a humanized, just outlook towards the energy geographies of the future.

Key words:

spatial dimension of energy transition, geographic approach, energy geographies, energy justice, governance, design manifesto.

Introduction.

Energy is the only universal currency (Smil, 2017). All of the human race's advancements from cultivating crops, forming human settlements with complex societies and specialization of work, to making scientific and societal innovations, has been possible through the consumption and exploitation of various forms of energy resources. The consumption of energy to support increasing human endeavors has reached unprecedented levels, with over 80% of the energy produced from fossil fuels like coal, oil and gas. The destructive environmental impacts of fossil fuel extraction, climate change, and the depletion of fossil fuel reserves have catalyzed the need to transition to renewable sources of energy like wind, solar, geothermal, biomass or hydro-power.

In human history, energy transitions have underpinned broad social, economic and geographic change (Bridge, et al., 2012). It was the transition from wood to coal in the mid 19th century that fueled the industrial revolution, and the transition from coal to oil and gas that triggered the developments in the automobile and transportation industry. These historic precedents show that energy transitions influence the nature of industrialisation, urbanisation, the growth of consumer society, economic prosperity, geographic structure and international relations (Bridge et al., 2012). Similarly, the current transition to renewable energy also has extensive impacts on geographies of power, economy, ecology, space and place.

Over the past decade, increasing attention has been drawn to the spatial dimension of energy transition. The human development of energy resources occurs at the intersection of energy and space, leaving distinct, permanent marks and spatial patterns on the land. The resulting landscapes of energy production, networks of distribution and territories of consumption together constitute 'energy-space'. This energy-space is under constant development, transformation and exponential expansion, due to the increasing global demand for energy and shifts in energy outlook. The paper argues that there is an urgent need to approach energy as a spatial phenomenon, to fully understand the conflicts and opportunities of energy-space. This is extremely important in the context of energy transition, since renewable sources of energy uses and produces space in a different way- its altered spatial qualities have blurred the boundaries between technical space (shunned by planners) and 'non-technical' space (coveted by planners). Consequently, planners are increasingly aware of the potential of considering energy as a crucial factor of spatial development and energy specialists are perceptive to the potential of consulting planners in energy development.

However, there still exists a huge gap and lack of integration between the fields of energy studies and spatial planning, both in academia and practice. Addressing the epistemological

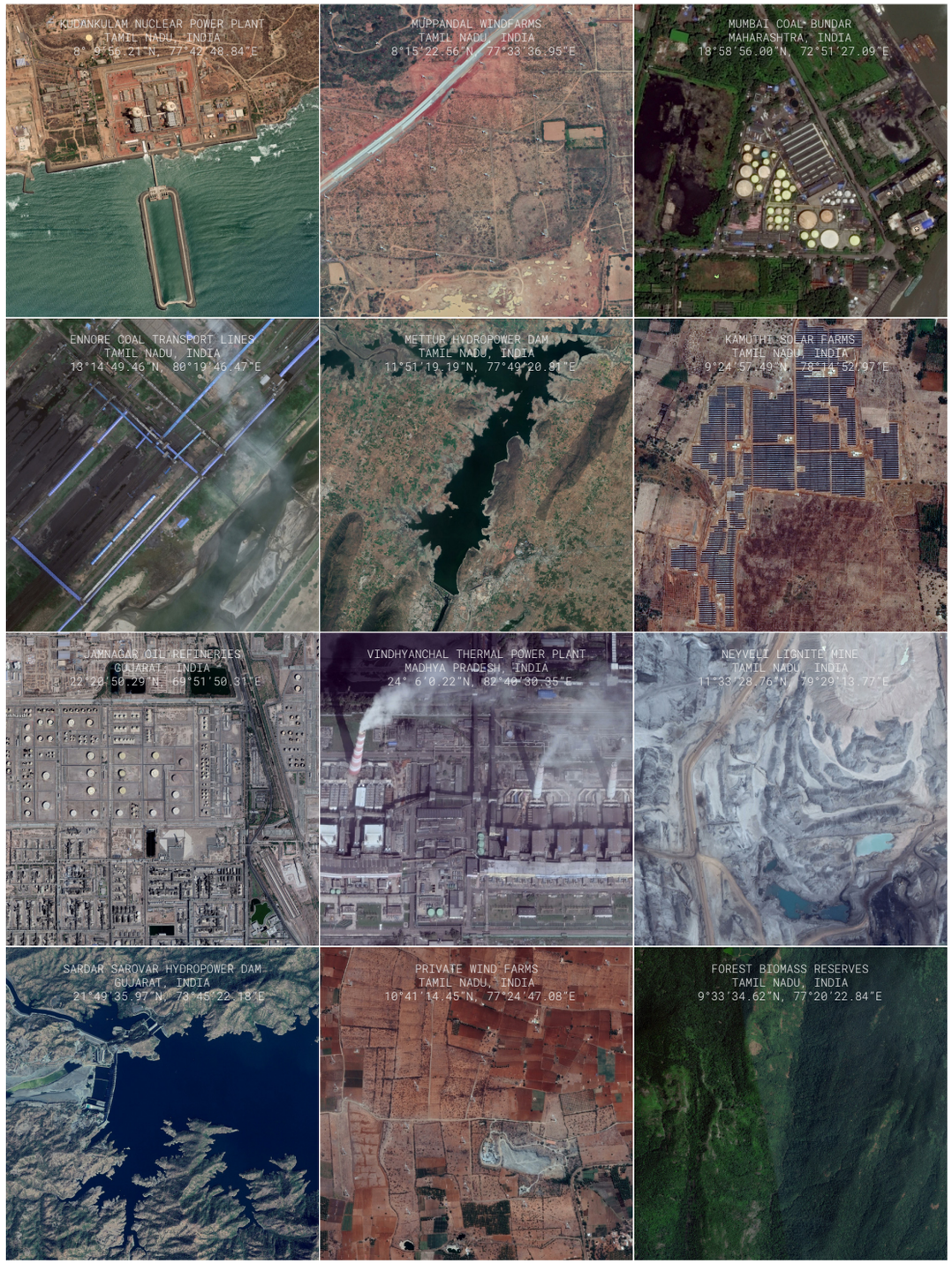

Fig 1: Grid of satellite images showing various energy geographies across India (Google Earth/Digital Globe, 2018)

and methodological rift between energy studies and spatial planning has been the primary endeavour of scholars working in this interdisciplinary field. To bridge this gap, one stream of research proposes to approach energy transition as a fundamentally geographic process that reconfigures current spatial patterns and scales of economic and social activity. (Bridge, et al., 2012). The geographic approach to energy transition, a corollary of the spatial approach to energy transition, positions energy within the nexus of not just space, but also its social-political, economic and ecological dimensions. The geographic approach to energy transition seeks to redefine 'energy-space' as 'energy geographies', which considers the multidimensional impact of energy transition.

While scholars and practitioners have launched investigations to define 'energy geographies', there is a lack of normative understanding and agreement on what energy geographies ought to be like. What are the spatial qualities that create 'good' energy geographies? How can planners approach its design and planning? What are the key methodologies and conceptual frameworks for this approach? While the paper acknowledges the scholarly pursuits to answer these questions, it is important to note that any research into what constitutes good space is 'endless, often without conclusions and always value laden' (Jacobs and Appleyard, 1987). At this moment in history, where spatially insensitive energy development has caused adverse impacts on space, society, and the environment, the paper proposes that it is time to take a leap, and explicitly state the conditions that create 'good' energy geographies of the future.[1]

The paper is a manifesto, a call for an integrated geographic approach to energy production and consumption, within the paradigm of energy transition.

1. Towards an Urban Design Manifesto by Allan Jacobs and Donald Appleyard (1987) proclaimed the need for a new urban design manifesto that articulates what makes good urban places. In the prologue of the manifesto, after acknowledging that 'research into what good places to live will be endless, often without conclusion and always value-laden', the authors stress the importance of taking a leap in research and practice to create specific goals and pathways for achieving it. The Manifesto for the Design of Energy Geographies believes that it is time to take a similar leap, to respond to the urgent need for such a manifesto.

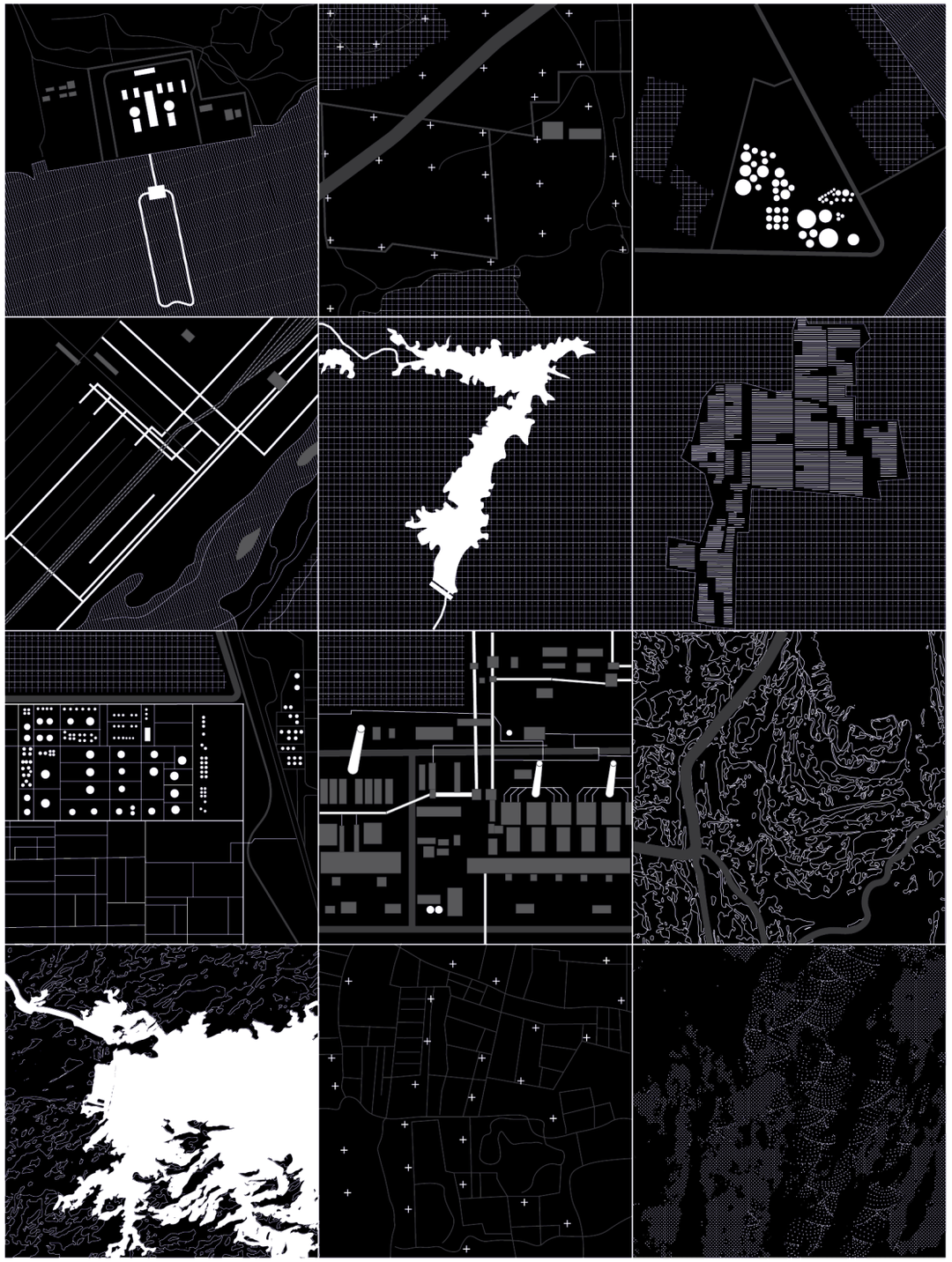

Fig 2: Grid of inverted 'Nolli diagram' for energy geographies, overlaid on satellite images of (insert cross reference) to understand the specific marks and spatial patterns left on the land by various energy extraction processes.

Manifesto for the design of energy geographies.

The ‘Manifesto for Design of Energy Geographies’ is a declaration of intention to consider the spatial dimension in energy development, and integrate the disciplines of energy studies and spatial planning. It is an assertion of what energy geographies ought to be and what qualities they should have, which can act as principles and guidelines for the design of energy geographies. This was developed by aggregating ideas and spatial concepts from various theories in spatial planning, infrastructure management, political ecology, critical geography and energy studies.

The manifesto is divided into two main sections: the first section defines the philosophical, and scientific foundations of the manifesto. The theoretical argument for each foundation is presented by collating relevant precedents in literature. Based on these foundational principles, the manifesto proposes what ‘good’ energy geographies of the future should be like and defines directions to achieve it. The paper concludes by highlighting how the manifesto can be used as a guide for spatial energy development and the specific areas of application, who they should benefit, and where they should be formed.

The Manifesto for the Design of Energy Geographies is an attempt to tackle the multidisciplinary challenges and gaps in addressing the spatial dimension of energy transition. It should act as a set of standards, or guidelines for framing parameters for design of such energy geographies. The manifesto first outlines the foundational arguments of the Manifesto supported by scholarly work at the intersection of energy and space. These foundations were the base for formulating the 11 points of the Manifesto that prescribe spatial, social, political and economic outlooks and goals that the future geographies of energy should aim for.

Foundations of the Manifesto:

1. The ‘Manifesto for the Design of Energy Geographies’ is first and foremost a declaration against the extractivist economy of energy production and consumption.

It is a direct, unveiled and provocative stand against the use of energy for the accumulation of capital- the driving force of the world in the age of the Anthropocene (Altvater, et.al., 2016). However, elaborating on this standpoint falls out of the scope of the paper. The paper limits itself to drafting a manifesto containing principles and guidelines for design of energy geographies. Nevertheless, the manifesto is influenced by the author’s political and philosophical stand against extractivism

2. The personal is political (Hanisch, 1969)

11.1271° N, 78.6569° E

[2] and can be interpreted as a call for a democratic energy transition, where the benefits of technological advancement are not biased against geographies of injustice and inequality.

2. Energy and space have a reciprocal relationship.

Energy and Space have a reciprocal relationship where they ‘change each other and have changed together throughout the course of history’ (Sijmons, 2014). In fact, energy is the driving force in land use (Smil, 2017, Pasqualetti & Stremke, 2018). The transformation of land for the extraction of energy resources was a crucial impact of the era of ‘fossil fuel expressionism’ (Sloterdijk, 2014). This resulting energy landscape spanned territories, changed socio-political relationships and created distinct, often permanent geographic patterns. This can be explicitly seen in the deforestation of entire regions for wood, excavation of mines for coal, fracking and drilling of oil rich lands, and nuclear disaster zones. Similarly, the era of energy transition saw the transformation of agricultural fields into solar fields, erection of wind farms spanning territories and the construction of hydropower dams that altered the morphological features of the landscape itself. In other words, the space produces energy, and energy in turn produces space (Lefebvre, 1991).

3. The spatial dimension of energy transition must be considered while planning for the new, emerging renewable energy-space of the future.

This is because spaces of renewable energy (RE) production are distinctly different from those of non-renewable energy (NRE). They differ in terms of size, form, spatial embeddedness, scale

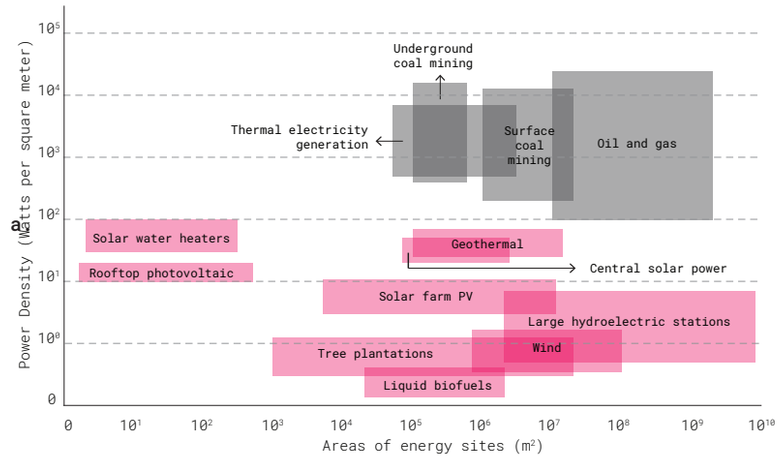

Fig 3: Power density diagram. (Smil, 2015)

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and degree of permanence, to name a few. One way of quantifying the difference between RE space and NRE space and spatialise their impacts, is to quantify energy units in terms of the amount of space/area they utilise for energy generation. This is called 'power density' (Smil, 2015). Smil further states in his book Power density : a key to understanding energy sources and uses, that RE production will take 100-1000 times more space than NRE production, since RE has a significantly lower power density than fossil fuels (See Fig 3). This means that the transition will exponentially increase the footprint of energy production, and have huge negative impacts on agricultural lands, ecological systems and overall quality of space.

4. The conceptualisation of energy as a spatial phenomenon first requires an understanding of what an 'energy-space' actually is.

Various scholars offer different definitions based on their academic background and school of thought. Energy-space, energy landscape (Pasqualetti & Stremke, 2018), energy geographies (Bridge, et al., 2012), energy-scape are some of the terminologies used to define spaces of energy development.

a. **Energy landscapes:** The notion of energy landscapes defines it as observable landscapes that originate directly from the human development of energy resources (Pasqualetti & Stremke, 2018). The authors further state that 'combining the term energy with landscape produces a useful unifying label for the marks, structures, excavations, creations, and supplements that energy developments produce,(…) and all the principal elements that appear at the confluence of energy and technology – i.e. technical, visual, social, ecological and political.' In Landscape and Energy (2014), Sijmons states that landscape is the battleground of energy transition, which emphasises the importance of the word 'landscape' in the conception of energy landscapes.

b. **Energy geographies:** A parallel movement that emerged from the research in energy-space is its conception as energy geographies, which approaches the production of energy as a fundamentally geographic process. This stems from an elementary shift in the understanding of space itself. Informed by the theories of critical geography (Harvey, 2001) and relational space (Massey, 2004; Lefebvre, 1991), this movement understands space not as a neutral container within which various social, political and economic processes happen, but as 'product of interrelations' (Massey, 2005) that is continually made and re-made by these processes. Space, in turn constitutes the said processes and actively produces and maintains them (Bouzarovski & Simcock, 2017; Dikeç, 2001; Soja, 2010). This geographic approach to energy-space (and energy transition) firmly situates it within the nexus of social, political and economic dimensions of transition.

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Hui and Walker (2018) describe the geographic approach as one that brings 'the full range of conceptual resources now running through human geography and its subfields to bear on energy questions – in all of their diversity and complexity' (Calvert, 2016; Huber, 2015; Zimmerer, 2011; Bridge, et.al., 2012). Calvert (2016) uses the term energy geographies to 'signify the various geographical imaginaries, spatial identities, and connections to place that are co-productive with particular systems of energy provision'. Bridge, et al., (2012) posit that the geographic approach will give insights on spatial differentiation and territorialisation of energy networks, relational socio-political structures, patterns and scales of organisation of energy infrastructure. This geographic approach to energy transition has the potential to bridge the epistemological and methodological rift between energy studies and spatial planning, by viewing space as a product of interrelations.

The manifesto argues that the term 'energy geography(ies)' provides a more comprehensive and relational understanding of energy-space and its constituents, than the term 'energy landscape'. From this point onward, the manifesto will adopt the term energy geographies to describe all types of energy-space.

5. Energy geographies are a product of the interrelations between the 'spatial dimension' and the social, political, economic dimensions of energy transition.

The geographic approach provides the framework to synthesize the multiple dimensions of transition in relation to each other and energy, by using space as the common denominator. The manifesto broadly classifies this into three categories: Spatio-Social, Spatio-Political and Spatio-Economic (dimensions). The manifesto will outline scholarly research done with regard to the three categories and use this classification as the structure to organize the normative-prescriptive section of the manifesto.

a. **Spatio-Social (dimension):**

The relationship between energy and society is co-productive; on one hand energy availability and consumption establishes the parameters around the types of lifestyles that are possible, while on the other hand cultural and political-economic value systems guide the resources from which, and end-uses toward which, energy is expended (Shove and Walker, 2010). The degree of access to energy influences our lifestyles, social behaviour, ability to afford goods that use energy (cars, appliances), improvement of living standards and status in society. Consequently, the lack of access to energy limits certain populations from achieving a higher quality of life. This is called 'energy poverty', or 'the inability to attain a socially and materially necessitated level of domestic energy services' (Bouzarovski & Petrova, 2015).

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Countries with is a lower levels of energy consumption, and by extension, energy access, have a lower human development index.

Energy poverty is turn underpinned by and reproduces distinct forms of spatial inequality. A socio-technical transition that aims to achieve energy justice must first address the concept of spatial justice (Soja, 2010; Yenneti et al., 2016). This can be interpreted as a call for right to services, stemming from Lefebvre's 'right to the city (1991), which intends to improve spatial living conditions and break vicious cycles of energy poverty and vulnerability, perpetuated by structures of spatial inequality.

b. Spatio-Political (dimension):

In the energy sector, the past few decades have pushed for territorialisation, i.e, integration or scaling up of national and continental grid systems (Platt, 1991, Nye, 1998), which has resulted in 'different scales and arenas of political action that govern energy systems because of the way they are spatially constituted' (Hughes, 1993). Since energy systems are constituted spatially, the components and the networked nature of the system itself produces geographies of connection, dependency and control (Bridge, et.al., 2012).

Energy infrastructure is primarily funded, built and operated by a niche group of players like the government, private banks, private business, individuals who can afford the high capital investment. They are powerful and influential players in decision making and governance of energy resources. The spatial and political centralization of power that makes decision in a top-down manner that does not give room for collaborative, decentralized, bottom-up approach to decision making.

We need a collaborative form of governance 'where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs or assets' (Ansell & Gash, 2008). Collaborative governance 'brings public and private stakeholders together in collective forums with public agencies to engage in consensus-oriented decision making' (Ansell & Gash, 2008). Political reform of the power sector is crucial for a smooth energy transition.

3. The terminology 'On (topic)' (Example "On' Post-Extractivism) used in the points of the manifesto is influenced by the Exhibition Catalogue of the Canadian Pavilion at the Venice Architecture Biennale 2016, curated by Pierre Bélanger (OPSYS)

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c. Spatio-Economic (dimension):

Energy systems are among the largest human enterprises, comprising 9 of the 12 most heavily capitalized companies in the world (Miller, Iles & Jones, 2013). The current extractivist, economic model that facilitates a high energy society (increasing energy availability with low costs per unit) has given rise to distinctive spatial patterns.

"Seen geographically and understood politically, the process of extraction is a profound and deep-rooted ideology, exercised through forceful penetration, both overtly and covertly, most often felt spatially and temporally downstream, years, decades, and generations later, whose effects are often irreversible and widespread on the intertwined living world of plants, people, soil—ecologically and psychologically." (Bélanger, 2018)

The economic dimension of energy transition, questions the heavily capitalized form of energy production and consumption lifestyle. The past decade has seen the (re)emergence of bottom-up, grass-root initiatives that operate based on values of community participation and co-production of energy, as an alternative.

The foundations of the manifesto are the scientific and philosophical basis for the formulation of the following 11 points of the Manifesto [3]The 11 points collects various calls for change and dissent against the current lack of spatial understanding of energy transition. It gives a directive and overarching principles to formulate methodologies, tools and spatial strategies for the development of energy geographies of the future.

Principles and Guidelines for Design

1. On post-extractivism:

The future renewable energy geographies should reject the extractivist systems of the capitalocene (Moore, 2017) and fossil fuel expressionism (Sloterdijk, 2014). The current extractivist energy economy should be replaced by a new economic model that respects the limits of the natural environment and creates room for alternative practices and forms of extraction without exploitation. The post extractivist economy promises a 'different kind of imaging and imagination, action and retro-action, forms of representation and reclamation', to undermine neoliberal strategies of land dispossession to produce energy and the resulting uneven forms of development. (Belanger, 2018)

2. On co-production and the commons:

The alternate economic model should be built on the idea of the commons and co-production of energy and energy geographies (Ostrom, 1990; Cahn, 2008; Wolf & Mahaffey, 2016) to increase citizen participation and social entrepreneurship in renewable energy transition. Co-production should be a strong driving force specially in energy transition, since renewable energy infrastructure does not need to be large scale and centralised. The co-production of renewable energy with the help of local communities must be supported by interventions from the state, to reduce the dependency on large energy corporations.

3. On decentralisation of power:

Power relations that underpin the production of energy geographies must be restructured, fundamentally shifting control away from capital and the state, towards inhabitants and stakeholders of the energy geographies (Purcell, 2002). Decentralization of power will reduce dependency and exploitation across regions and scales and create a 'stronger sense of local and regional identity, authenticity and meaning (Jacobs & Appleyard, 1987).

4. On collaborative governance:

The decentralisation of power should be built on the model of collaborative governance that involves the community and private sector in decision making at local and regional geopolitical scales. The collaborative governance approach should be flexible and adopt both formal and informal tools of governance that include face-to-face dialogue, trust building, and the development of commitment and shared understanding (Ansell & Gash, 2008) between the multiple stakeholders of energy transition.

5. On energy justice:

The future energy geographies should create the framework for energy justice (Bouzarovski & Simcock, 2017) that enhances the equitable access to, and distribution of its benefits to the disadvantaged, socio-spatially segregated communities. The future energy geographies must dissolve the geographies of difference, inequality and injustice, so that 'the prospects of the least advantaged territory are as great as they can be' (Harvey, 1973).

Since energy justice is driven by spatial justice, broader interventions to address the geographic process that (re) produce spatial inequalities must be prioritized (Dikeç, 2001; Harvey, 1996). Spatial energy justice should be key factor in determining 'where resources should be focused, whose needs should be recognized and prioritized in relation to geographical difference, and how democratic legitimacy might be achieved' (Bouzarovski & Simcock, 2017; McCauley, et al., 2013).

6. On social acceptance:

The future energy geographies should create social narrative of change and trigger an alternative way of life that redefines social practice and relations with energy. They should create spaces, places, territories and cities that foster an emotional transition- the social acceptance of energy transition and the emerging energy geographies, its spatiality, image- which is crucial to the long term assimilation and integration of any spatial energy plan (Sijmons & van Dorst, 2012).

7. On space:

The landscapes of energy production, networks of distribution and territories of consumption must be spatially constituted. In other words, the calculation of renewable energy potential of a place must be made with respect to the. By consequence, calculation of renewable energy potential of a place, the choice of location of energy infrastructures, networked interlinkages and degree of their spatial embeddedness and must be made with respect to the contextual conditions, ecological risks, spatial restrictions, and opportunities offered by the environment.

8. On scaling:

The multitude of energy infrastructures, that intersect and overlap across various geographic scales must be integrated to form a transcalar network of future energy geographies. The relational, spatial dynamics between different scales of energy geographies must be heterarchical (Stephenson, 2009), rather than hierarchical.

9. On sense of place:

The future energy geographies must create a sense of place, and manifest spatial cues for deriving memory, meaning and symbolism from energy 'objects' and associated spaces. This phenomenology of energy geographies must be a crucial factor in its design, planning and execution.

10. On spatial permanence and reversibility

The future energy geographies should have the 'capability to reestablish the original condition (of the landscape) after energy development is completed' (Pasqualetti & Stremke, 2018). Energy geographies should have a high degree of flexibility and dynamism to adapt for future energy transitions. The dominant and soon to be outdated fossil fuel geographies should be recycled or upcycled to meet the new energy outlook or be transformed into productive commons.

11. On counter-planning:

The 'role of the counter planner is to identify and fuel the emergence' of post-extractivist, decentralised, co-productive and socially just energy geographies of the future. Scenario planning, regional design and spatial strategies must be developed in collaboration with the local communities, so that people have a choice in deciding what kind of energy geographies we need to create.

Conclusions.

The use of energy is, without doubt, a spatial phenomenon- the extraction of energy resources (like coal mines, oil fields, wind farms, etc.), the transformation of energy resources into usable electricity, heat or fuels (power plants), the distribution of energy (networks of transmission lines, pipes), and the final places and nature of consumption, ALL happen on and produce space. At the same time, new geographies of energy are emerging at a rapid pace to keep up with the energy demand and infrastructure building. There is a need to map, document and analyse these transforming, emerging geographies. The spatial implications of energy transition can redraw the map of social and economic activity in different ways with new potentials and opportunities.

The geographic approach to energy transition has the potential to fill the gap between the fields of energy studies and spatial planning. This interdisciplinary research also adds to the body of knowledge on spatial planning for energy, and points towards a new paradigm of conception and perception of energy geographies, which integrates the multidimensional facets of energy transition. To do this, it is critical to acknowledge that the integration of renewable energy systems into our spatial and socio-political and economic landscapes is both a necessary and contested process.

However, the continued prioritization of fossil fuel landscapes, the extractivist economic structure and concentration of power in the hands of few, and inequalities in the distribution and access to benefits of energy transition, normalize the existence of major problems even in the era of spatial energy transition.

The future energy geographies need to be better. We need a makeover, an overhaul of existing redundant fossil-fuel based models of economy and governance, that refuses to understand energy transition as a geographic phenomenon, and perpetuates the vicious cycle of energy poverty and spatial inequality. There is a strong need to humanize this largely technical field.

The Manifesto for the Design of Energy Geographies is one such attempt. The manifesto makes the argument for a geographic approach to energy transition and the integration of the multiple dimensions of transition. The final 11 points of the manifesto define what makes good energy geographies and provide normative guidelines for their design. The manifesto acknowledges that there exists certain topics that fell out of the scope of the paper, and that not everyone will agree with the normative directions put forward. The manifesto is not absolute. It is an ongoing investigating into the intersection of energy, space and geography, and posits that the guidelines for design can be defined better with further advancements in academia and practice.

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Fieldwork Compilation.

Fieldwork:

Duration of the field trip: 21st January- 10th February 2019
Location: Chennai, Coimbatore, Udumelpet region.

This is a brief compilation of the data collected during the field trip, the methods used and the results obtained.

1.Interviews
2.Data collection
3.Workshop
4.Photo/video documentation

1. Interviews:

Informal interviews were conducted with various stakeholders and actors involved in energy development and distribution, as well as end users. Questions were directed based on their specific background. The list of interviewees is given below:

i. TNEB: Tamil Nadu Electricity Board:
a. Mallika Bhasker- SE/LD (Load Dispatch)
b. Gomathi K- EE/REMC (Renewable Energy Management Centre)
c. Parameshwar – EE/ Erode Circle SLDC (Sub Load Dispatch Centre, Erode)
d. Karthigeyen -AE/ Erode Circle SLDC (Sub Load Dispatch Centre, Erode)

ii. Industries/Investors:
a. Delphi TVS, Orgadam, Chennai (Industry with on-site 1MW solar rooftop installation, and off-site windturbine installations)
b. Mr. Balasubramanian, ROOTS (Industry with off-site windturbine installations)
c. SUZLON Wind Farm, Nelali (70MW capacity)
d. Swelect Energy systems Ltd, Solar farm, Karukathi (15MW capacity)
e. SUZLON Wind Farm, Boggampatti (70MW capacity)

iii. NGOs
a. R. Raveendran, Secretary, RAAC (Residents Awareness Association Coimbatore)
b. Martin Scherfler, Founder, The Solar Village

iv. Residents in and around Coimbatore (Random survey/talk)

2. Data Collection:

Based on the interviews and on-site observations, the data collected can be organized under the following topics:

i. Governance:
- a. Organizational structure of Tamil Nadu's energy department.
- b. Regional organizational structure based on geographic scales.
- c. Key policies related to energy access

ii. Energy Development:
- a. Up-to-date data on generation and distribution of energy in Tamil Nadu, including proposed projects
- b. Key challenges and opportunities
- c. Stakeholders and actors

iii. On site Observations:
- a. Tests to see if the pre-selected sites work or not.
- b. Observations of spatial conditions in the pre-selected sites

iv. Social dimension and energy access
- a. Data collected on distributed (Decentralised) energy systems and impact on society, along with a case study (www.thesolarvillage.org)
- b. Understanding of business model required for successful community-centric energy development

3. Workshop/Presentation:

A workshop/presentation on the topic of spatial energy transition was organized in collaboration with *Archi.press* (https://archi.press/), a platform for deliberation on design. The event was attended by 35 people, mostly from the design community who took part in the workshop with great enthusiasm. The event was very useful to broaden my understanding on the key challenges and opportunities in addressing the socio-political dimension of energy transition.

A brief description of the event, as promoted by Archipress (https://www.instagram.com/p/Btdn7K1FK3Q/) is given below:

> *ArchiPress invites architects, architectural students, design enthusiasts and curious minds for S02 | E 02 of Speculations through Design – 'Energy X Space - How can spatial design enable energy transition in Tamil Nadu?' by Ar. Preetika Balasubramanian.*
>
> *We will have a presentation, followed by an engaging workshop to introduce the concept of spatial energy transition in Tamil Nadu and come up with creative solutions for a socially*

WORKSHOP ON SPATIAL DIMENSION OF ENERGY TRANSITION

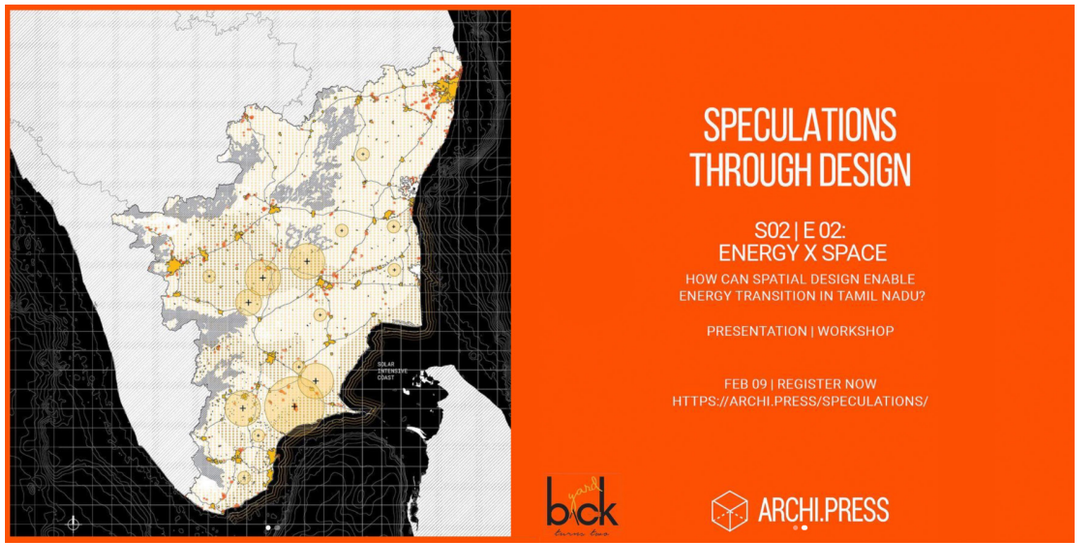



Fig 5.4: Images from the workshop conducted in Chennai.

inclusive and equitable shift to renewable energy sources. The workshop will also speculate on the role of architects and planners in addressing the emerging energy geographies of Tamil Nadu. The presentation will focus on the spatial dimension of energy transition and the workshop session will explore in detail the socio-political dimensions of energy transition.

The workshop was organized in three modules:

Module 1: Wordcloud on what makes 'good' energy-spaces: A live participants' feedback was generated on what qualities make good energy spaces. Qualities, criteria that were not previously considered were brought up (Fig 5)

Module 2: Identifying key issues: The participants were encouraged to debate and put up (post-its) key challenges in the spatial, social, and political dimensions of energy transition in Tamil Nadu

Module 3: Stakeholder analysis: The power-interest diagram was used to discuss about the various stakeholders in the energy transition process and where the lie in the power-interest matrix. Additionally, how design approaches and policies can be targeted based on their position in the matrix was also discussed.



Fig 5: (left) Wordcloud generated by the participants of the workshop to answer the question: what makes good energy geographies?

Fig 5.6: (right) Images from the workshop conducted in Chennai.









Graduation Studio
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