GEO GRAPHIES *of* POWER

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

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P5 Presentation . Graduation Thesis . M.Sc. Urbanism . 2019

Structure of the Presentation

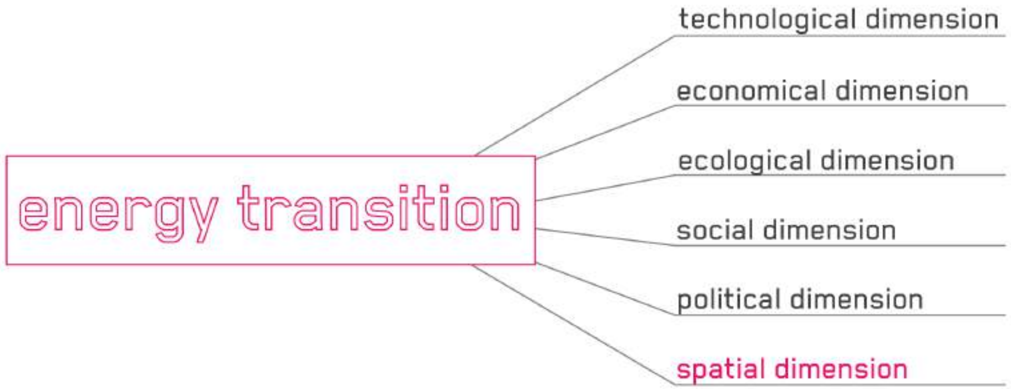
1

The Problem

energy transition has an impact on *space*

Problem field: ***Need for spatial planning*** in energy transition.

Knowledge Gap

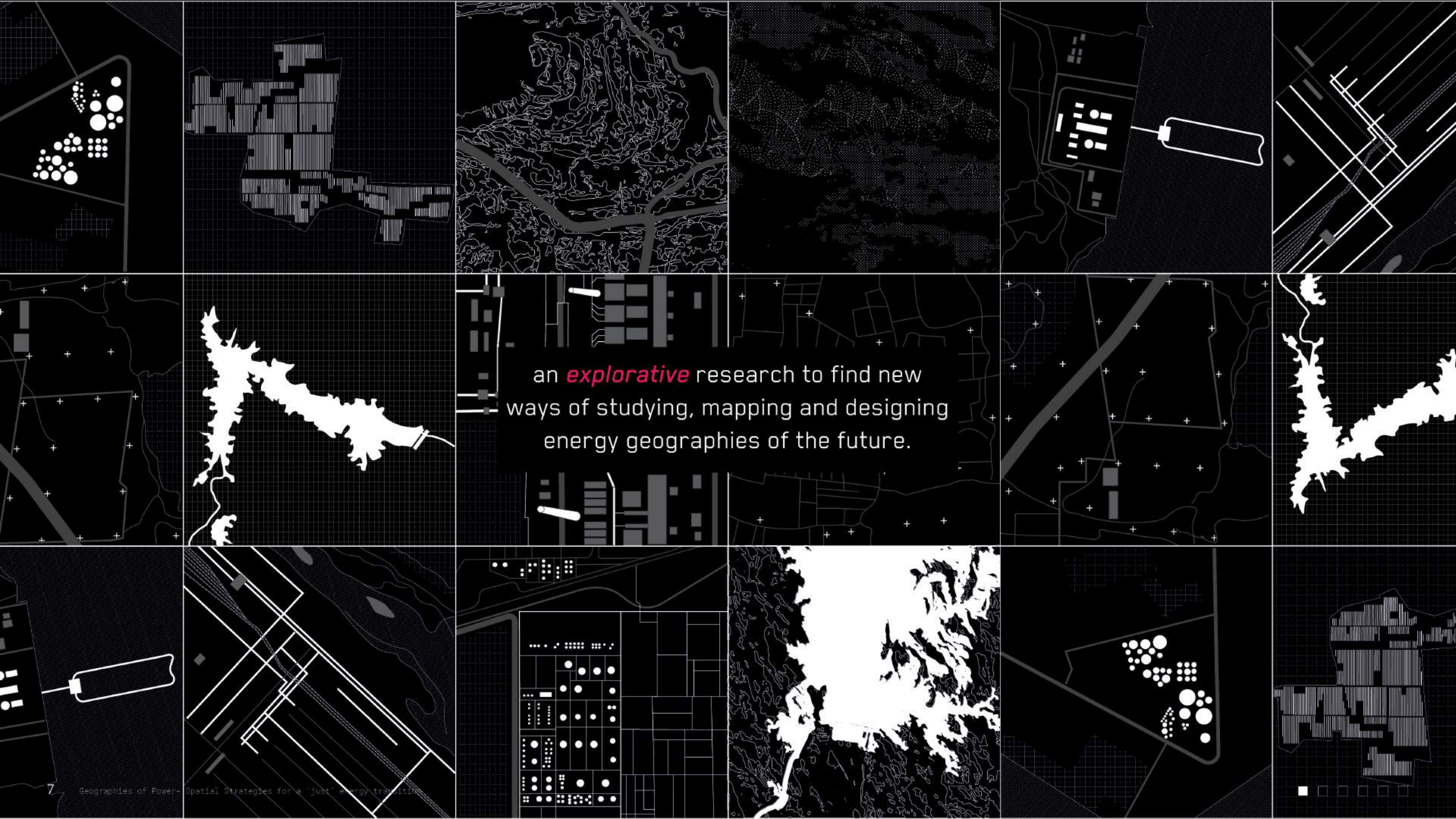


Energy transition has a spatial dimension.

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'.***

KAMUTHI SOLAR FARMS
TAMIL NADU, INDIA
9°24'57.49"N, 78°14'52.97"E
NEYVELI LIGNITE MINE
TAMIL NADU, INDIA
11°33'38.76"N, 79°29'13.77"E
FOREST BIOMASS RESERVES
TAMIL NADU, INDIA
9°33'34.62"N, 77°20'22.84"E
TAMIL NADU, INDIA
ENNORE COAL TRANSPORT LINE
TAMIL NADU, INDIA
METTUR HYDROPOWER DAM
TAMIL NADU, INDIA
11°51'19.19"N, 77°49'20.81"E
MADHYA PRADESH, INDIA
PRIVATE WIND FARMS
TAMIL NADU, INDIA
10°41'14.45"N, 77°24'47.08"E
MUPPANDAL WINDFARMS
TAMIL NADU, INDIA
8°15'22.56"N, 77°33'36.95"E
Typology: "energy-space"
ENNORE COAL TRANSPORT LINES
TAMIL NADU, INDIA
13°14'49.46"N, 80°19'46.47"E
GUJARAT, INDIA
SARDAR SAROVAR HYDROPOWER DAM
GUJARAT, INDIA
21°49'35.97"N, 73°45'22.18"E
MUMBAI COAL BUNDAR
MAHARASHTRA, INDIA
18°58'56.00"N, 72°51'27.09"E



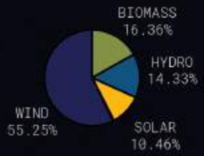
an *explorative* research to find new ways of studying, mapping and designing energy geographies of the future.

Case study: Tamil Nadu, India.

Energy trends

32% of India's total RE installed capacity

35% of India's total installed wind energy capacity.



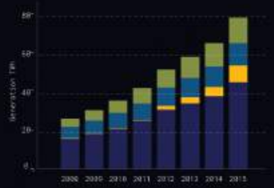
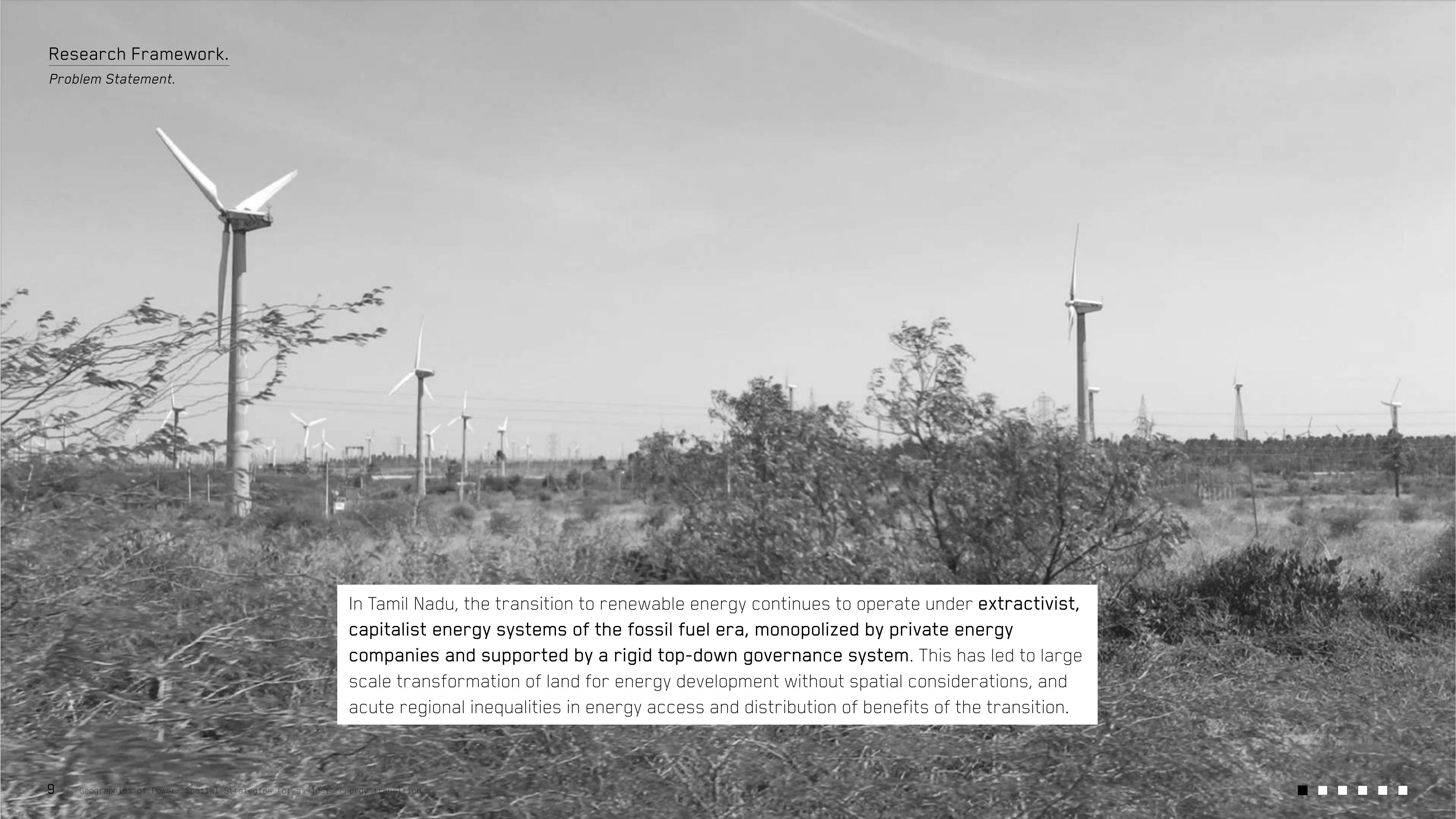


Fig 1: (NASA Worldview, 2016)

Problem Statement.



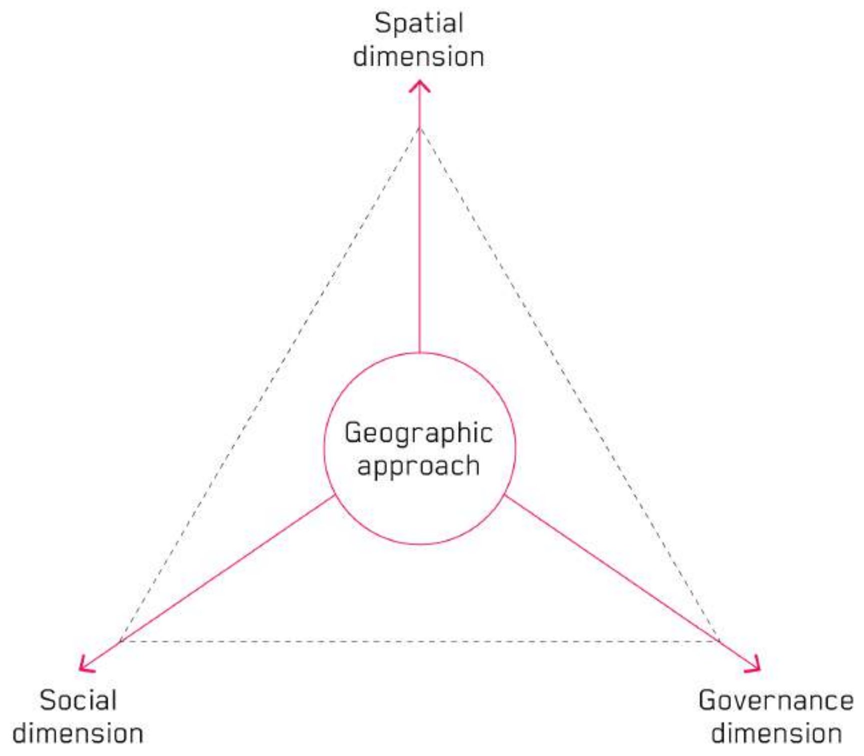
In Tamil Nadu, the transition to renewable energy continues to operate under **extractivist, capitalist energy systems of the fossil fuel era, monopolized by private energy companies and supported by a rigid top-down governance system**. This has led to large scale transformation of land for energy development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

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

Research Framework.

Theoretical foundation

THREE BRANCHES OF RESEARCH FROM THE GEOGRAPHIC APPROACH



Literature references:

Spatial dimension:
Pasqualetti & Stremke, 2018; Belanger, 2016; Sijmons, 2014;

Social dimension:
Jenkins et al, 2016; Soja, 2010; Bouzarovski & Simcock, 2017; Ghanem, 2018

Governance dimension:
Hess, 2018; Kim & Carver, 2015; Sijmons & Von Dorst, 2012;

Geographic approach:
Harvey, 2001,2006; Massey, 2004; Lefebvre, 199; Bridge, 2018; Hui, & Walker, 2018;

2

Multidimensional Analysis

Energy geographies of Tamil Nadu

energy x space

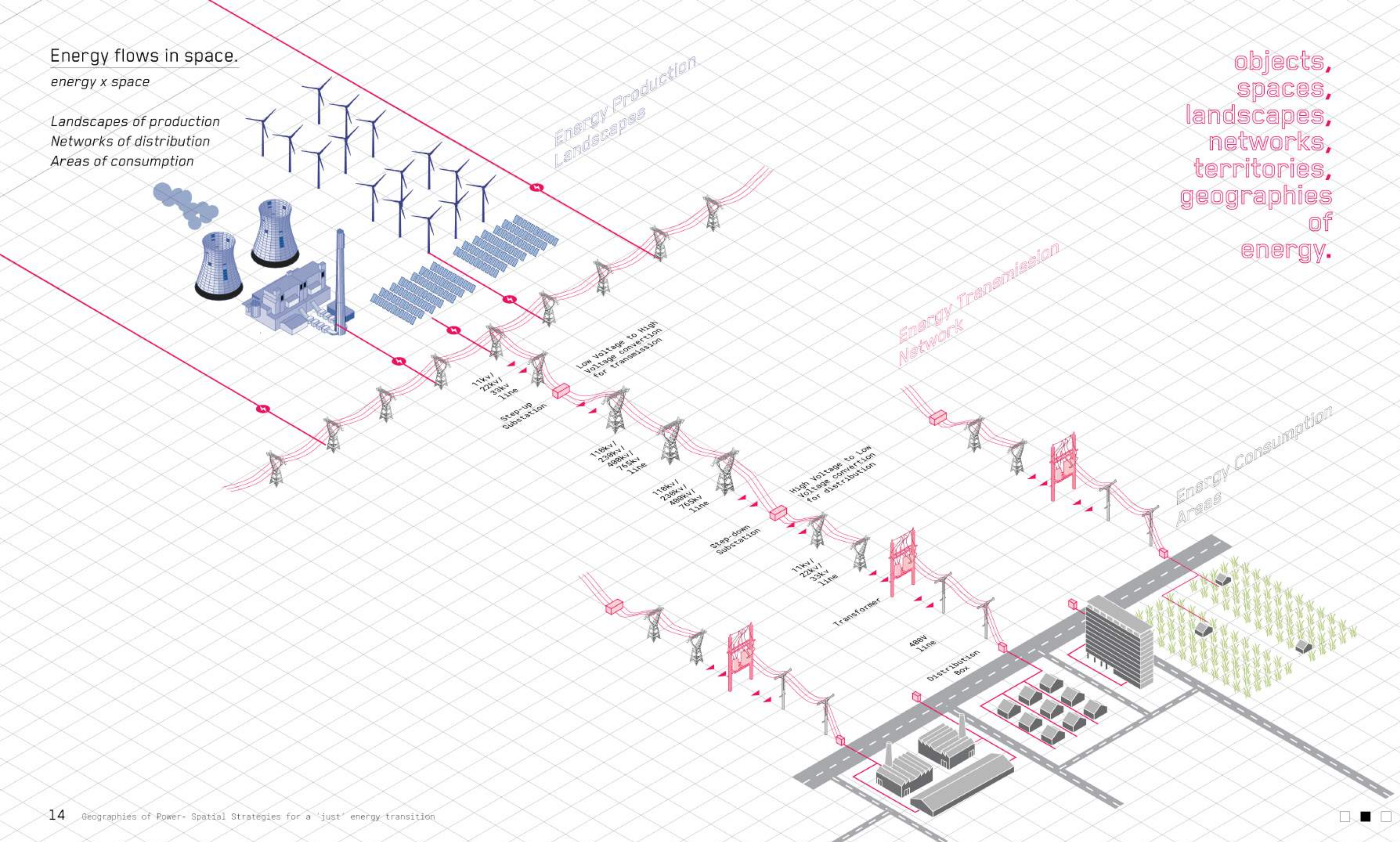
Landscapes of production
Networks of distribution
Areas of consumption

Energy flows in space.

energy x space

Landscapes of production
Networks of distribution
Areas of consumption

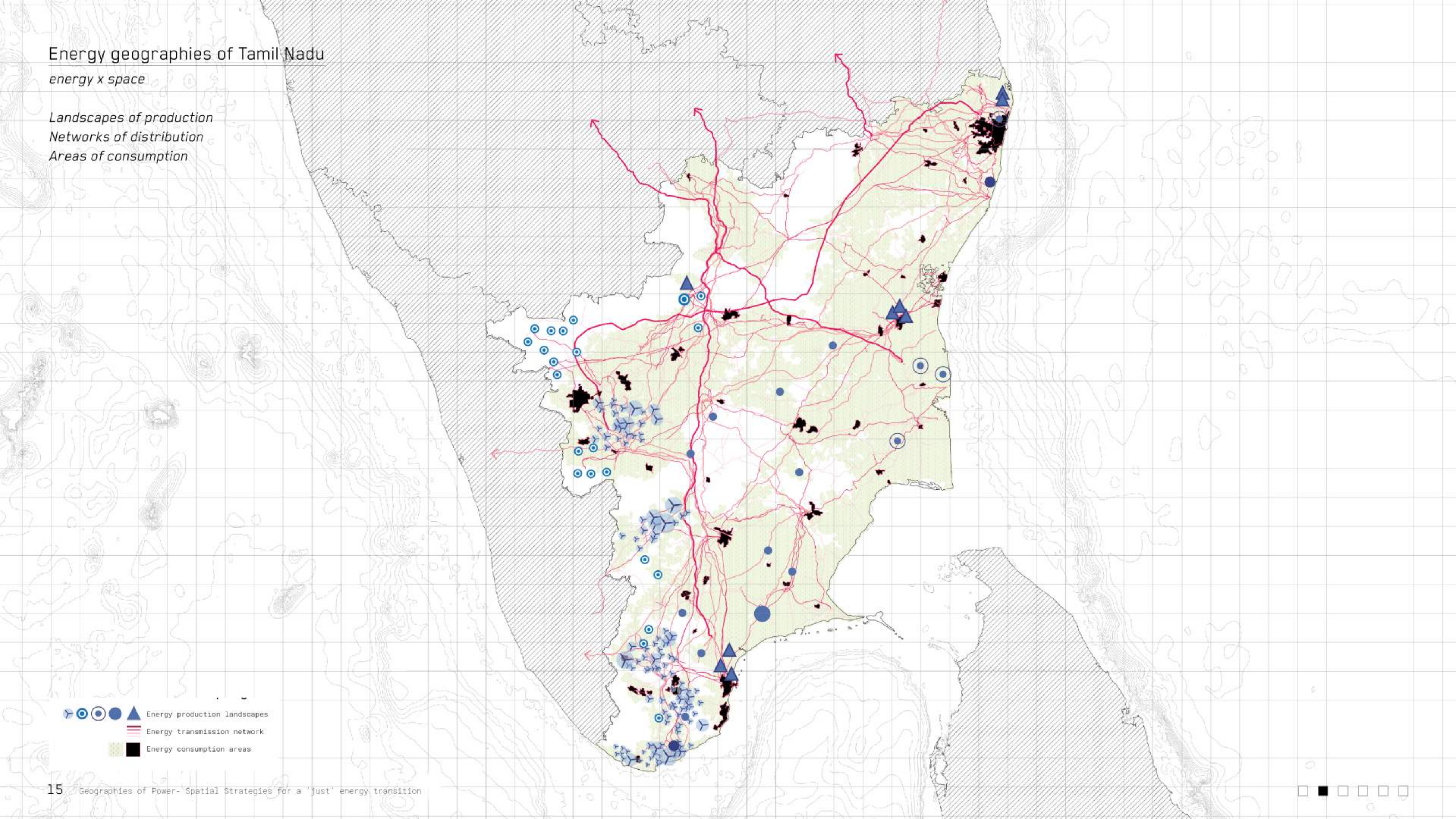
objects,
spaces,
landscapes,
networks,
territories,
geographies
of
energy.



Energy geographies of Tamil Nadu

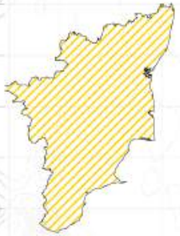
energy x space

Landscapes of production
Networks of distribution
Areas of consumption



Solar energy landscapes.

energy x space



POTENTIAL
17700 MW

INSTALLED CAPACITY
1800 MW

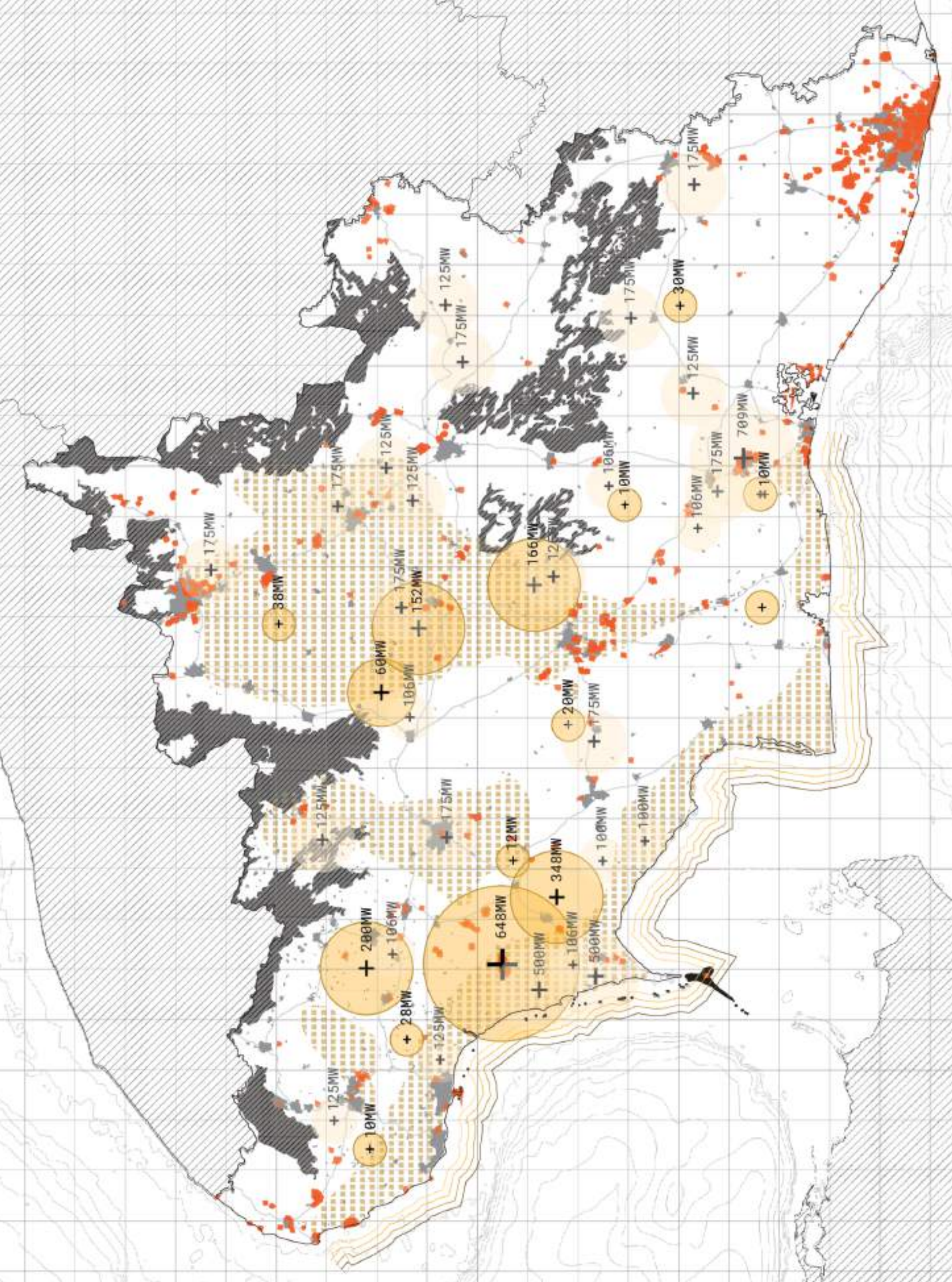
PROPOSED
1000 MW

* as of December 2017

SHARE IN TOTAL R.E INSTALLED CAPACITY

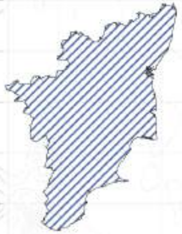
Existing installed cpacity of large scale solar farms

- Industrial areas- Large scale Solar Rooftop
- High solar intensity area
- Existing large Solar farms
- Proposed solar farms
- Urban and infrastructure network
- Western Ghats mountain range



Wind energy landscapes.

energy x space



POTENTIAL

33800 MW

INSTALLED CAPACITY

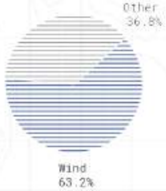
8594 MW

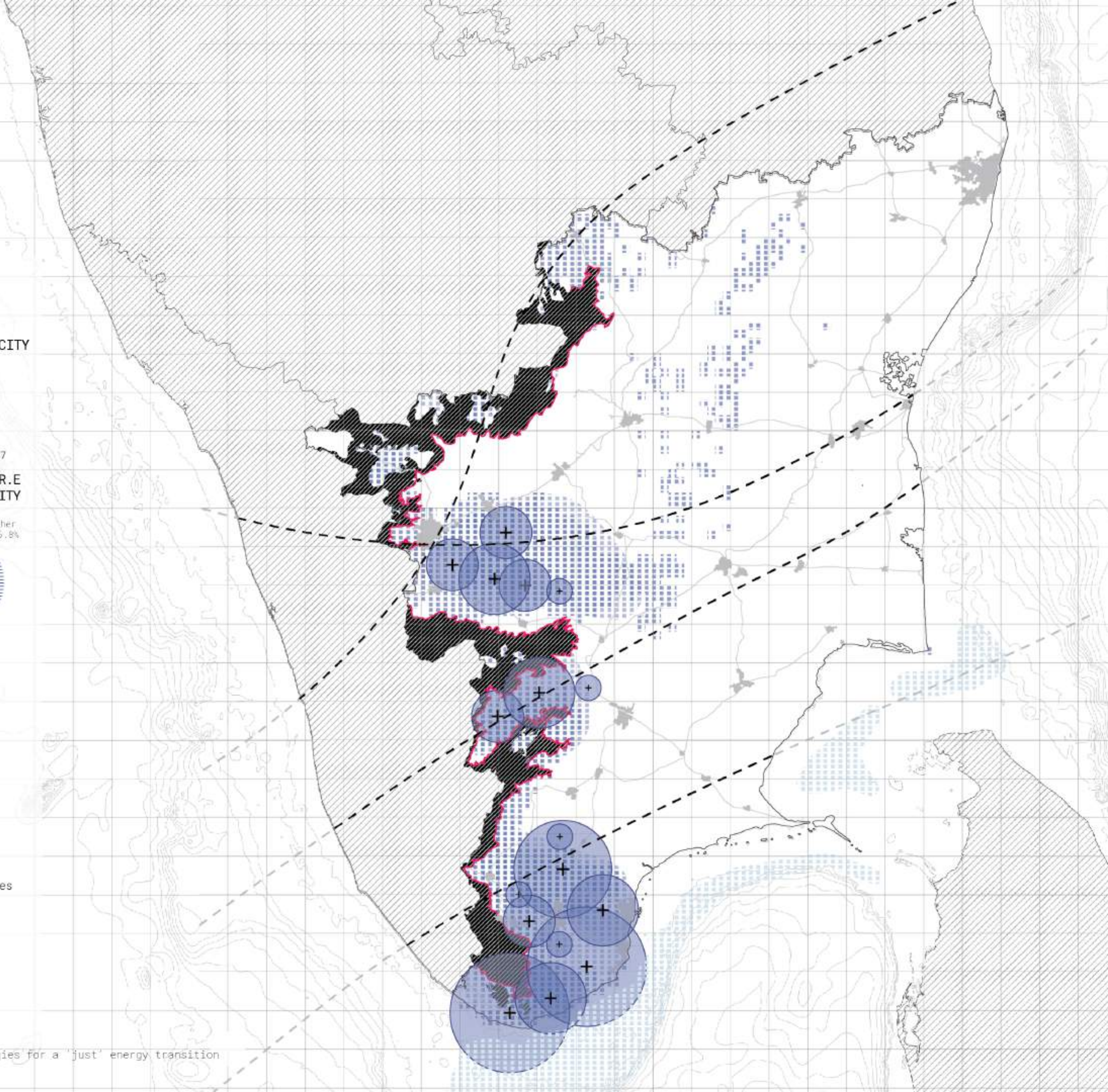
PROPOSED

12400 MW

* as of December 2017

SHARE IN TOTAL R.E INSTALLED CAPACITY





Biomass energy landscapes.

energy x space

POTENTIAL
1589 MW

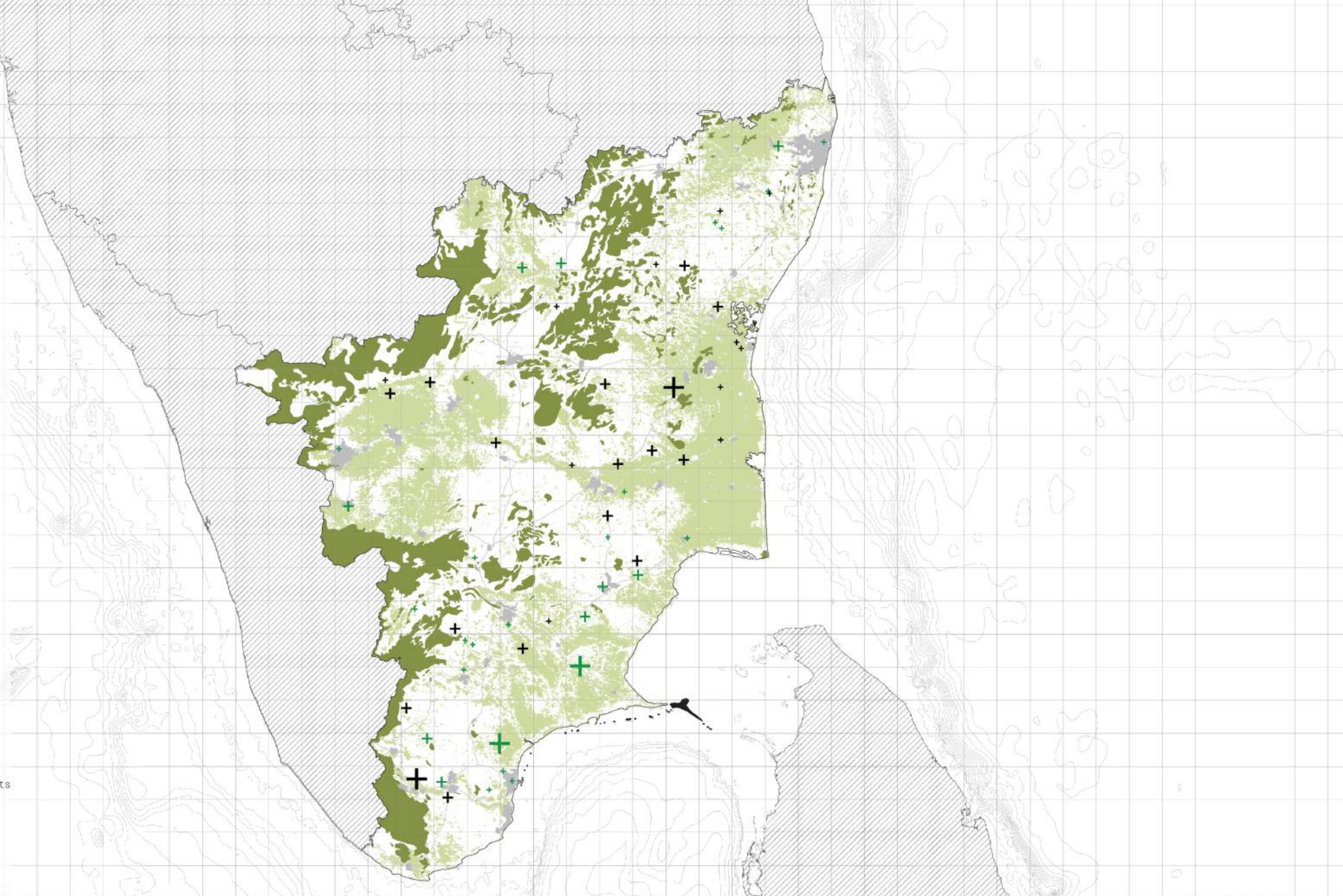
INSTALLED CAPACITY
890 MW

PROPOSED
-

* as of December 2017

SHARE IN TOTAL R.E INSTALLED CAPACITY

- Fertile agricultural land- Crop residue
- Moderate agricultural land- Crop residue
- Western Ghats mountains- forest byproducts
- Concentration of bio-based power plants
- Biomass Power plants
- Baggase Cogeneration Power plants
- Main infrastructure network



Carbon energy landscapes.

energy x space

POTENTIAL

98 MT of CO_2/yr

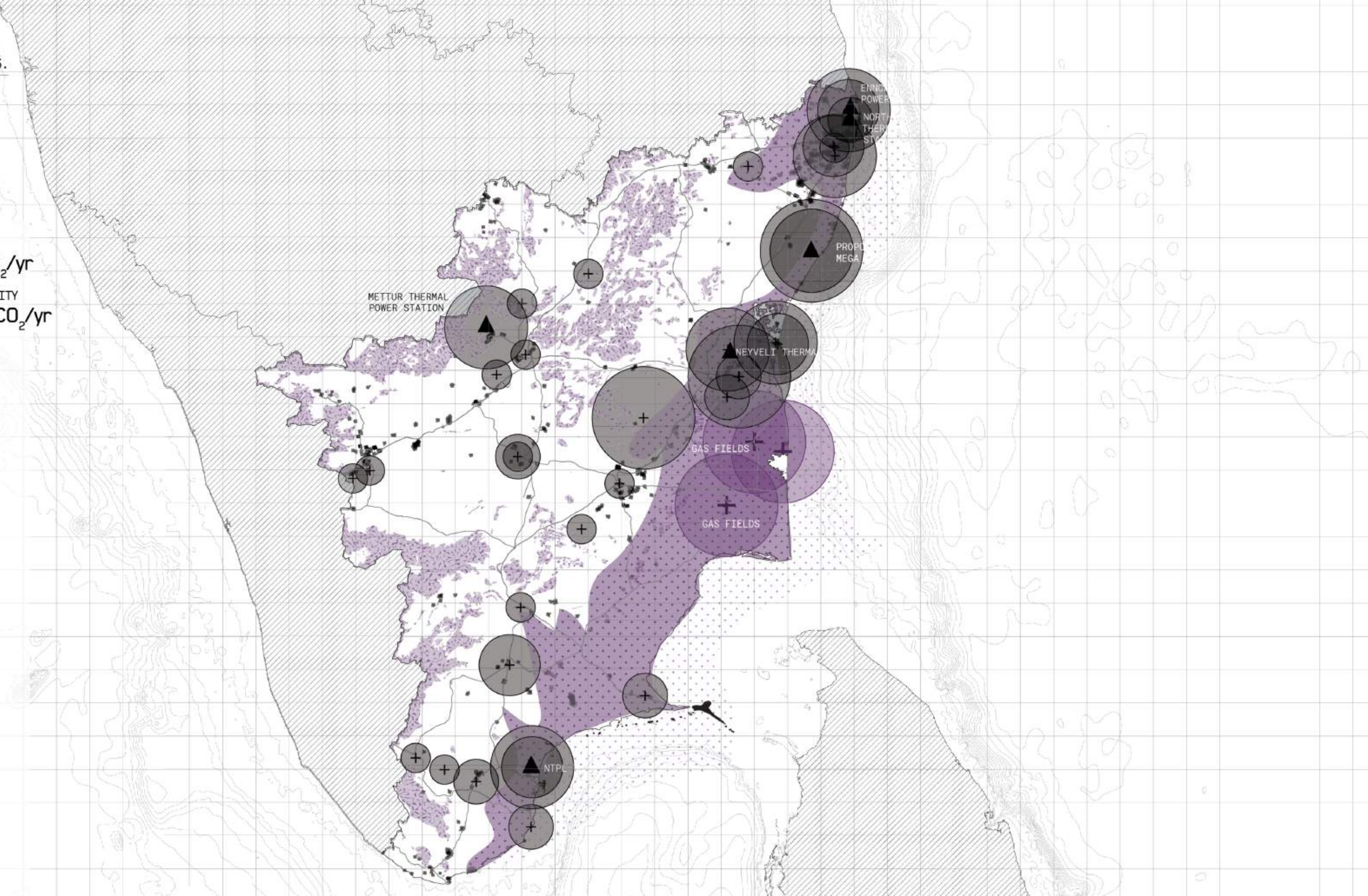
INSTALLED CAPACITY

70000 T of CO_2/yr

PROPOSED

-

* as of December 2017
MT- million tons



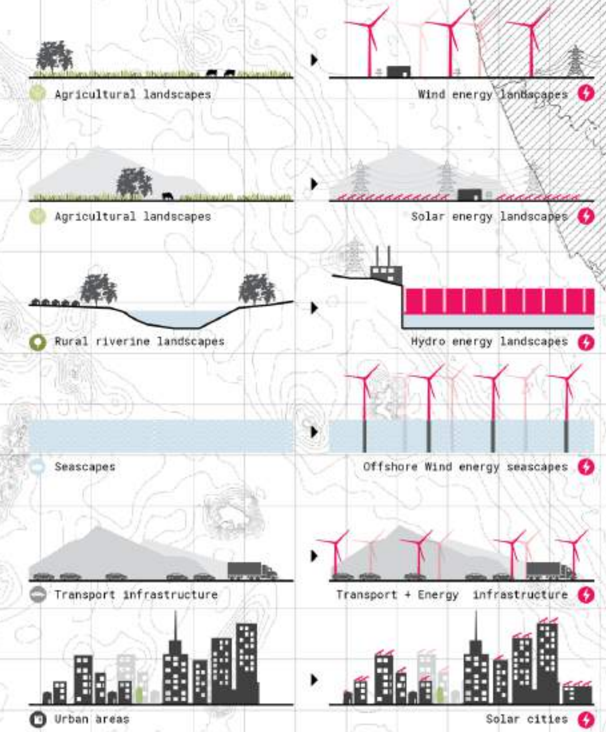
6000-15000kT
3000-6000kT
1500-3000kT
500-1500kT
100-500kT

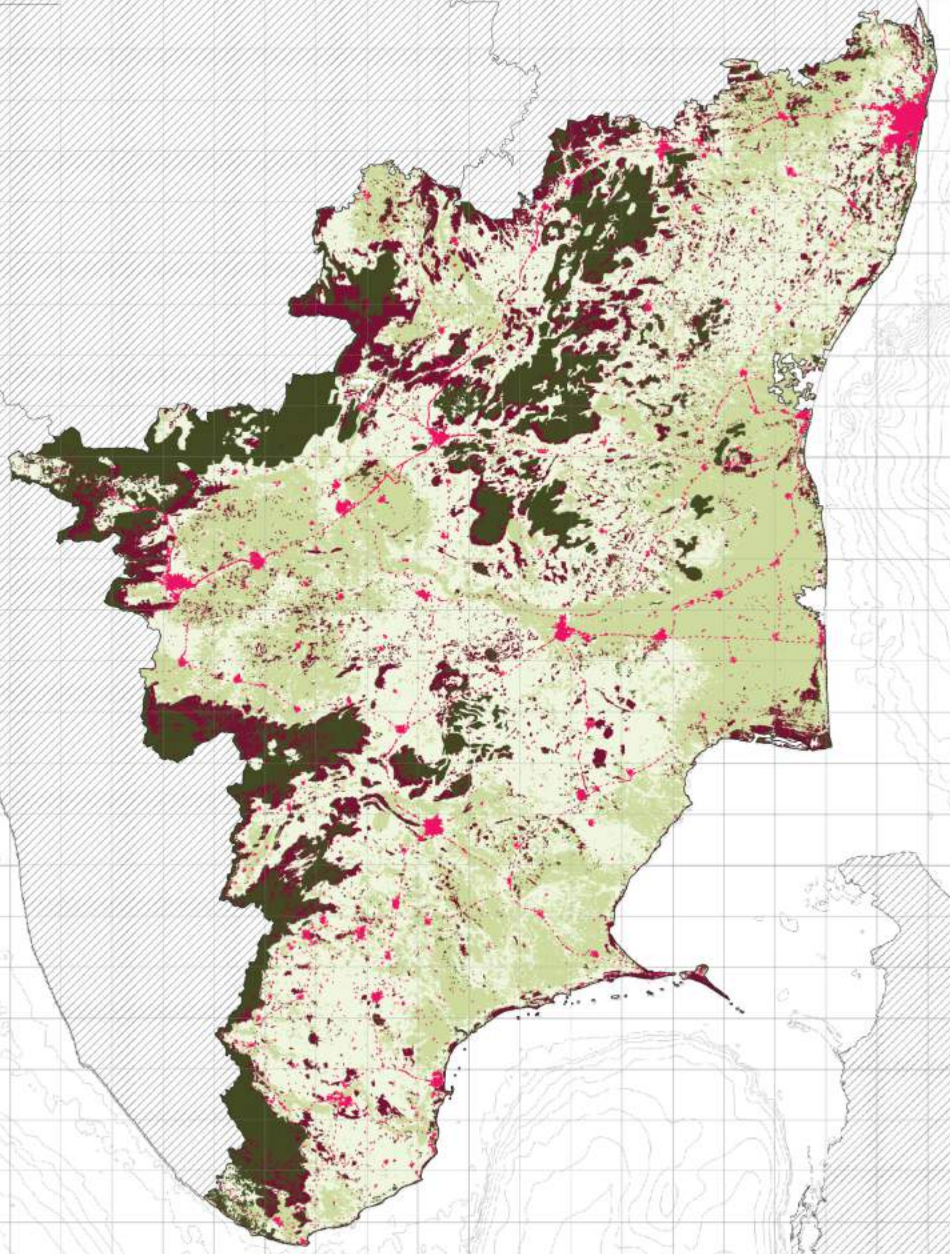
Carbon emissions from Thermal power plants and industries

- 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

Evaluating ***suitability of landuse*** for energy development.

energy x space



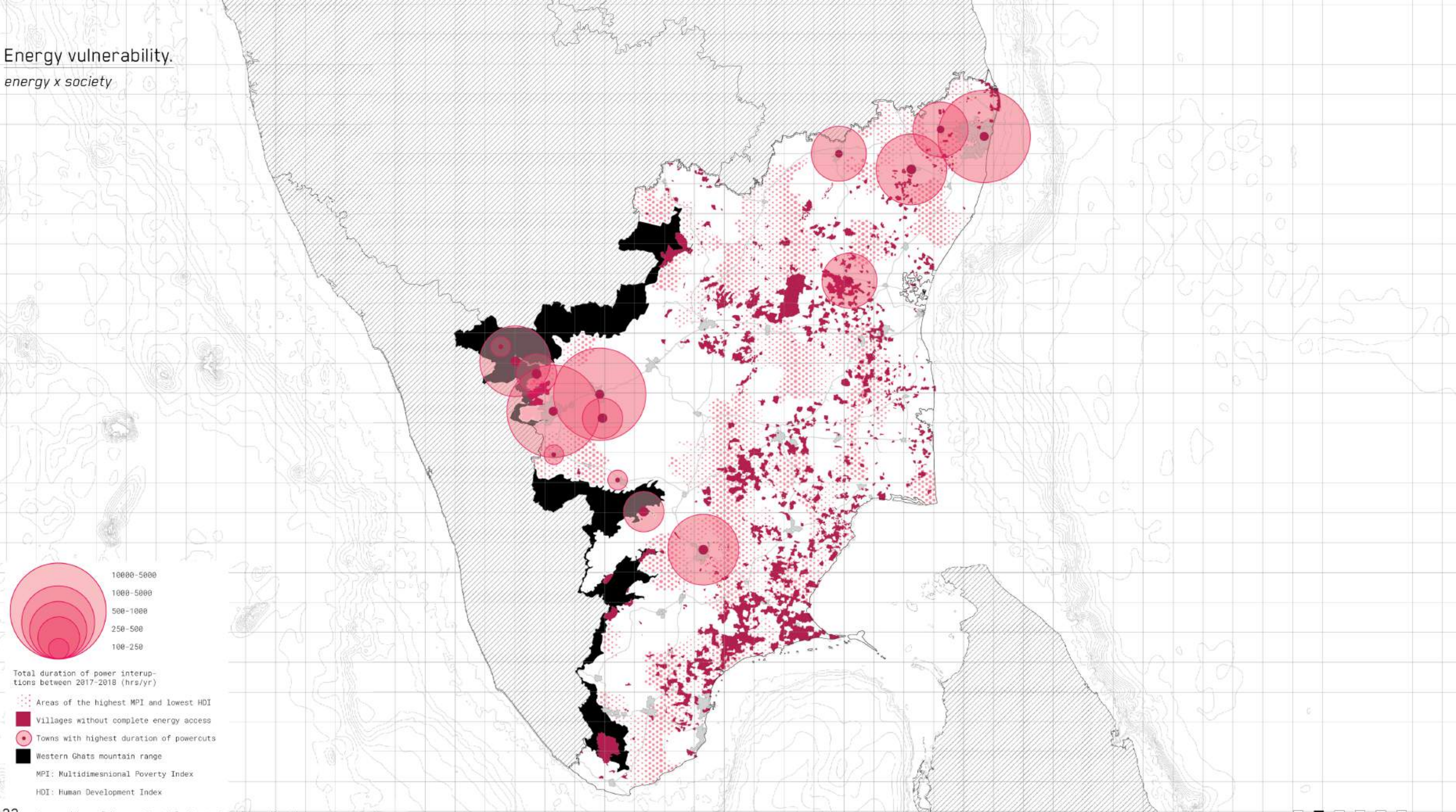


Energy access and vulnerability.

energy x society

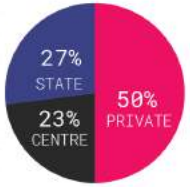
Energy vulnerability.

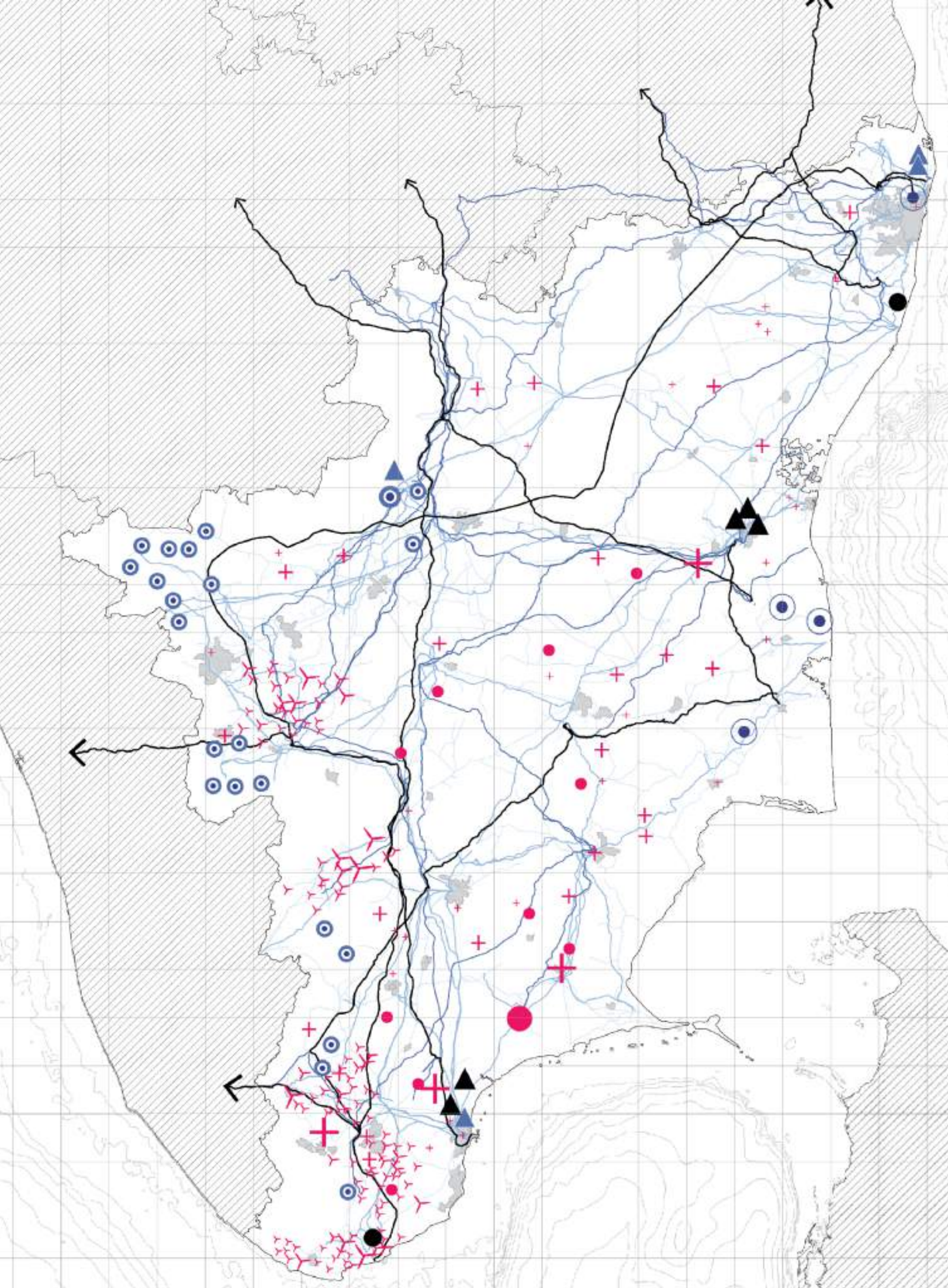
energy x society



Monopoly in energy ownership.

energy x society





Ownership:

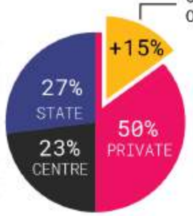
Centre owned (26%)

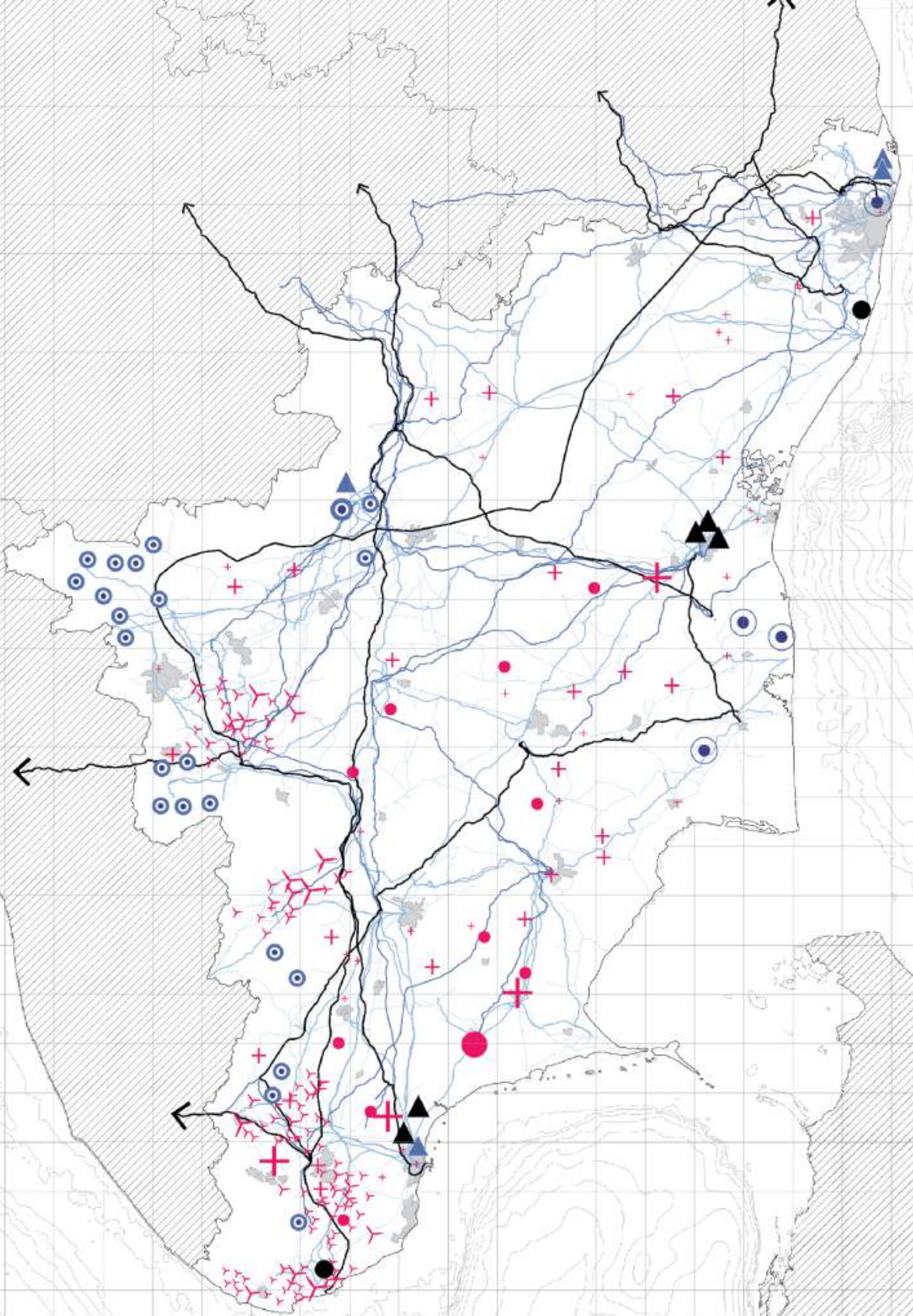
State owned (29%)

Private owned (45%)

Potential to coproduce energy.

energy x society





Ownership:

Centre owned (26%)

State owned (29%)

Private owned (45%)

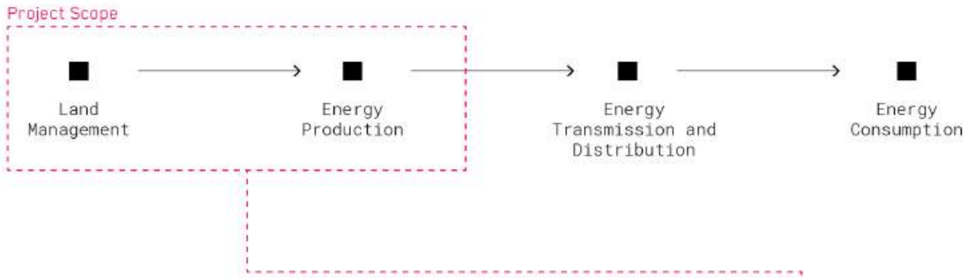
Governance of energy transition in Tamil Nadu.

energy x governance

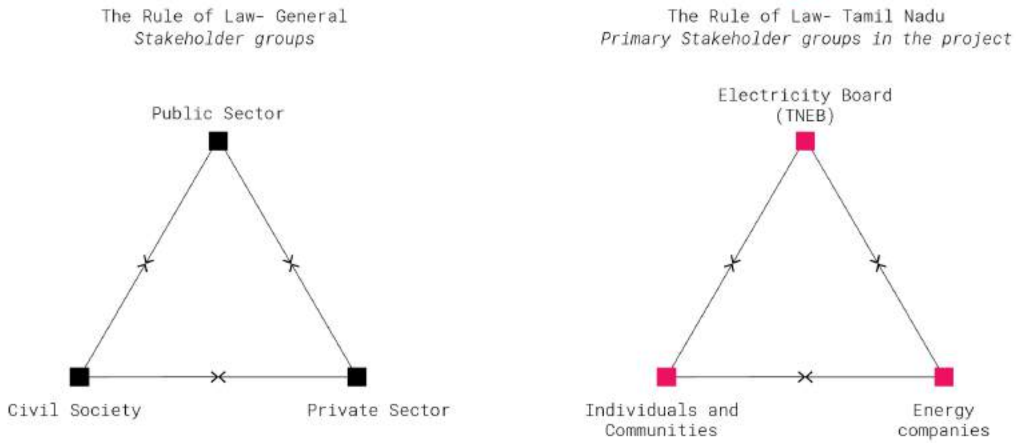
Identifying the stakeholders of energy transition.

energy x governance

1. Base: Defining the project scope in transition governance

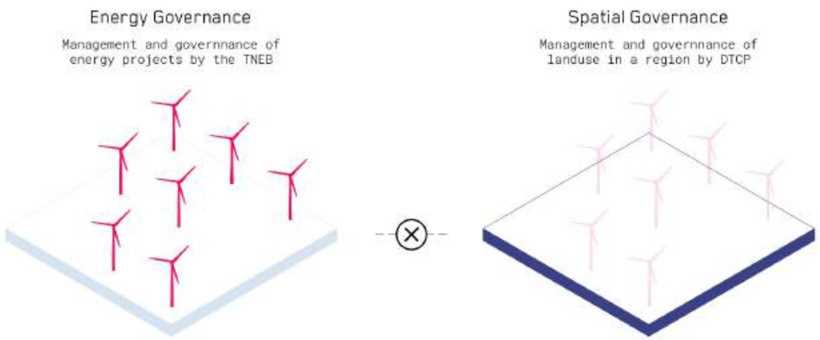


2. Identifying the primary stakeholders relevant to the project



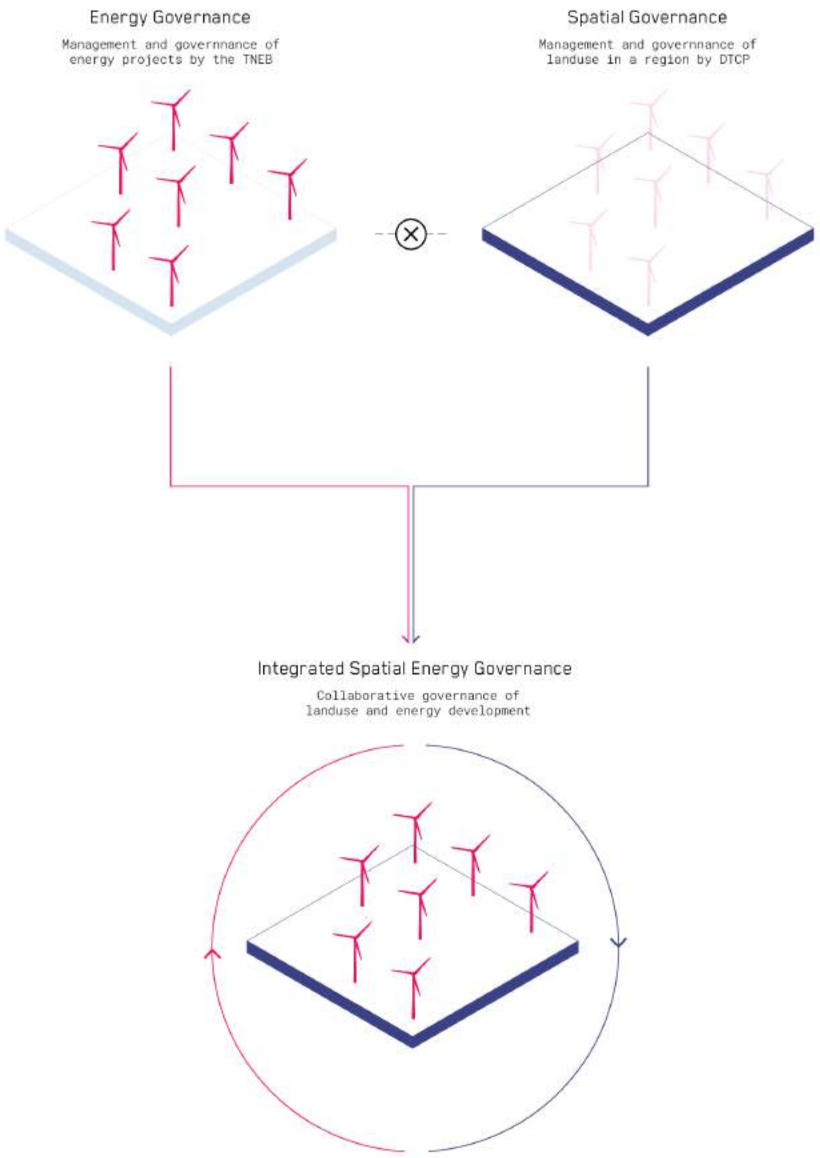
Gap between energy governance and spatial governance.

energy x governance



Gap between energy governance and spatial governance.

energy x governance



Workshop discussion on stakeholders.

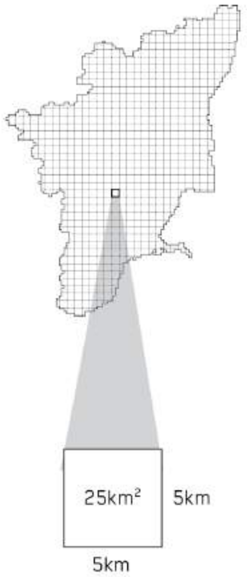
energy x governance

Conclusion: Multi-criteria Analysis.

energy x space
energy x society
energy x governance

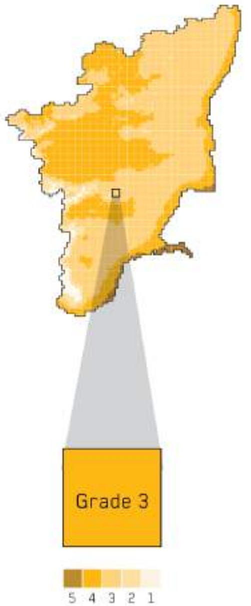
Step 1:
Creatng a Spatial Grid

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



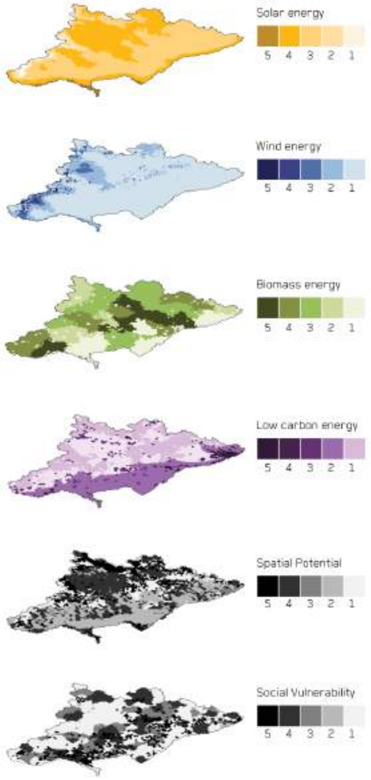
Step 2:
Evaluating the Grid

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

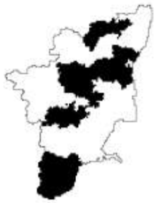


Step 4:
Outputs- Strategic areas for Regional Design

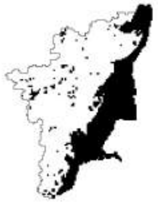
Different outputs showing strategic areas for intervention can be generated based on the choice of the input parameters. One example pathway is shown, where areas of high energy potential are crossed with areas of high social vulnerability to identify regions that are viable for 'coproduction' initiatives.

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

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

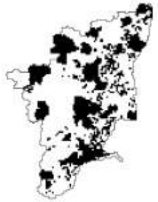


Output 2: Areas of highest biomass energy potential (Grade 4,5)

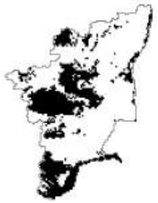


Output 4: Areas of highest carbon capture potential (Grade 4,5)

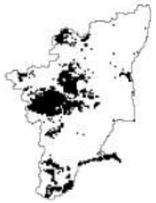
Output 5: Areas of highest spatial development potential, i.e. regions with wasteland concentrations



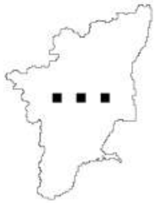
Output 6: Areas of highest social vulnerability and energy potential



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



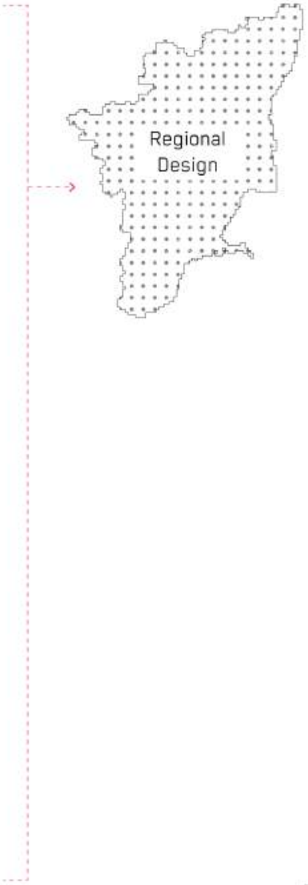
Output 8: Areas of highest energy potential and spatial potential (Derived from Outputs 5,6)



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

Step 5:
Inputs for design

The ouput iterations provide valuble insights on where and how regional design strategies can be implement-ed



Conclusion: Multi-criteria Analysis.

energy x space
energy x society
energy x governance

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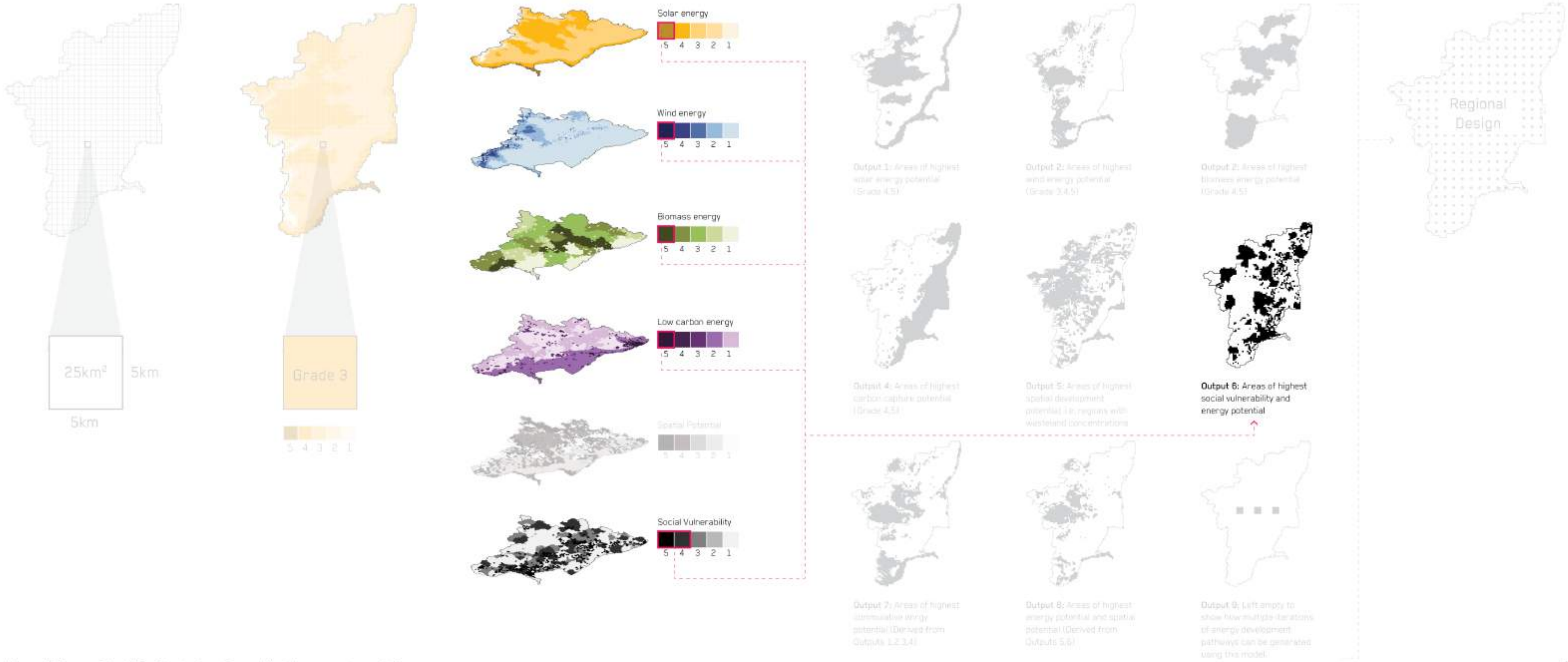
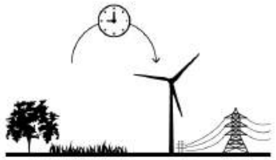


Conclusions: Factors for design.

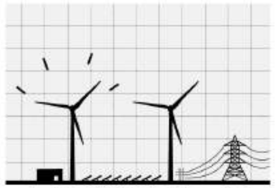
energy x space
energy x society
energy x governance

Energy X Space

1. Need for adaptive energy production landscapes.

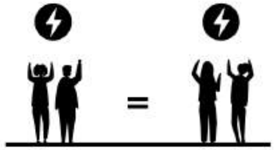


2. Need for consideration of local conditions and spatial embeddedness of energy infrastructure.

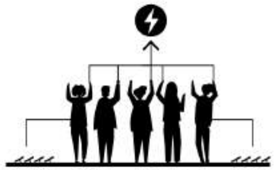


Energy X Society

1. Need for equitable access to renewable energy.

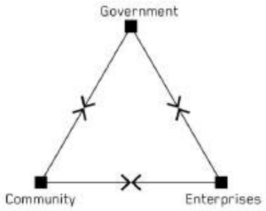


2. Need for empowerment of energy vulnerable communities.

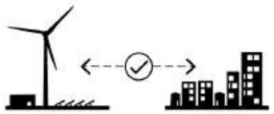


Energy X Governance

1. Need for collaborative bottom up governance structure



2. Need for integrated spatial energy governance



Conclusions: Factors for design.

energy x space
energy x society
energy x governance

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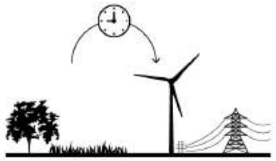

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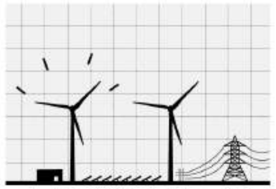
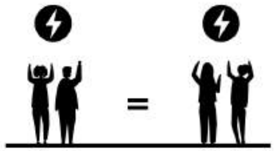


adaptive
energy landscapes

Energy X Society

1. Need for equitable access to renewable energy.



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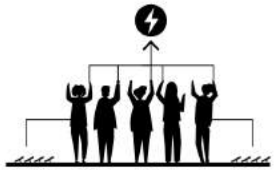
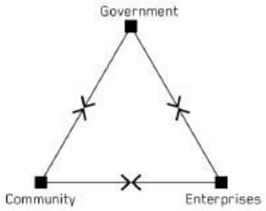


inclusive
energy transition

Energy X Governance

1. Need for collaborative bottom up governance structure

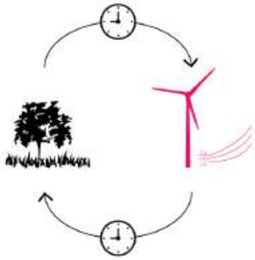
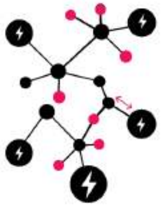
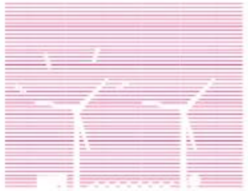
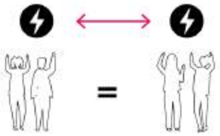
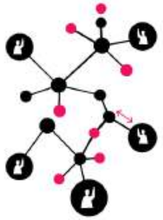
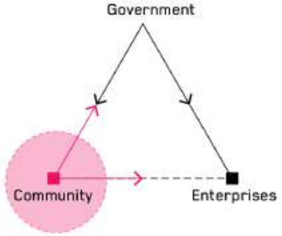
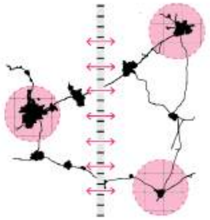


2. Need for integrated spatial energy governance

collaborative
energy governance

3

Vision 2050

Goals and Values	Principles of the Vision		
Adaptive Energy x Space	On flexibility and reversibility of energy landscapes 	On scaling and decentralisation of energy systems 	On spatial embeddedness of energy infrastructure 
Inclusive Energy x Society	On energy justice and equity 	On coproduction and the commons 	On social acceptance of energy transition 
Collaborative Energy x Governance	On decentralisation of power 	On collaborative governance 	On soft counter planning 

Existing situation

Vision 2050 - Tamil Nadu.

Energy landscape of the future

..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.**

Defining the energy future.

Scenario Construction

Transition timeline.

Energy demand Projections.

2018*

36%

Renewable energy share in total energy demand in 2018

11650MW

Renewable energy share in total energy demand in 2018

2050**

60%

Renewable energy share in total energy demand in 2050

52000MW

Renewable energy share in total energy demand in 2050

* 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.

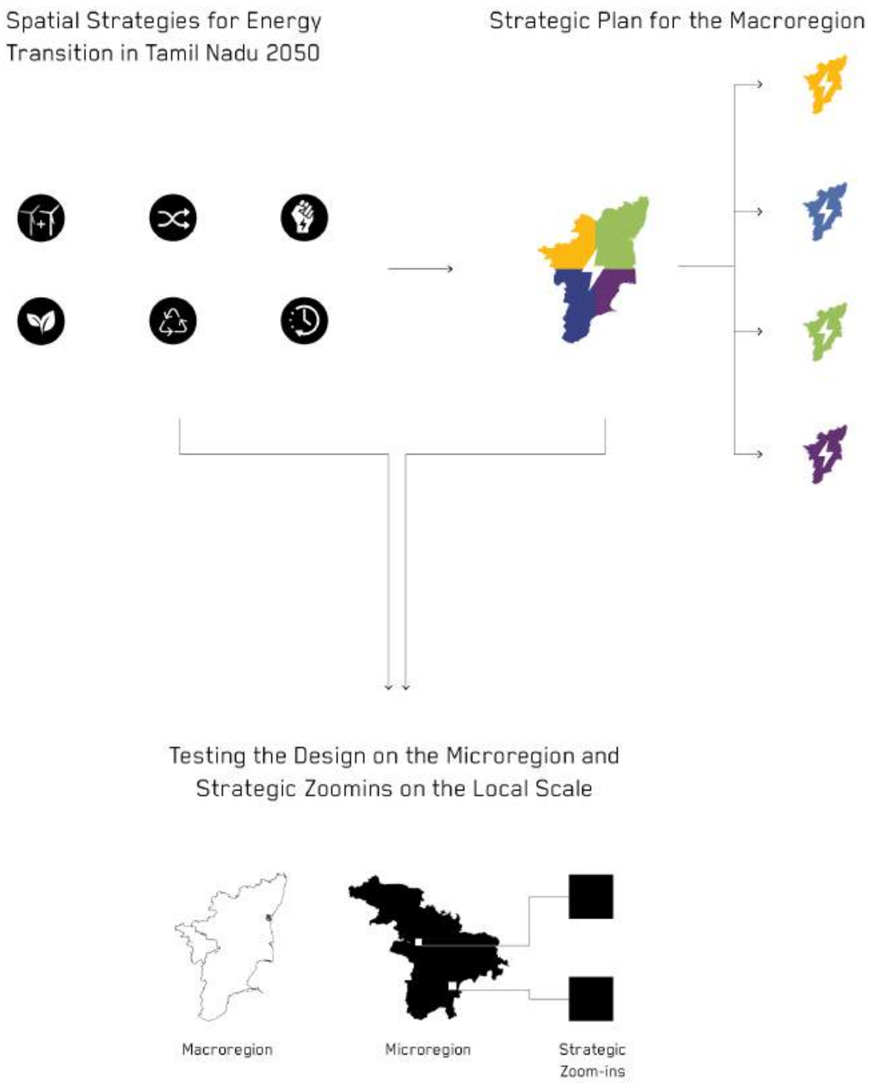
4

Regional Design and Spatial Strategies

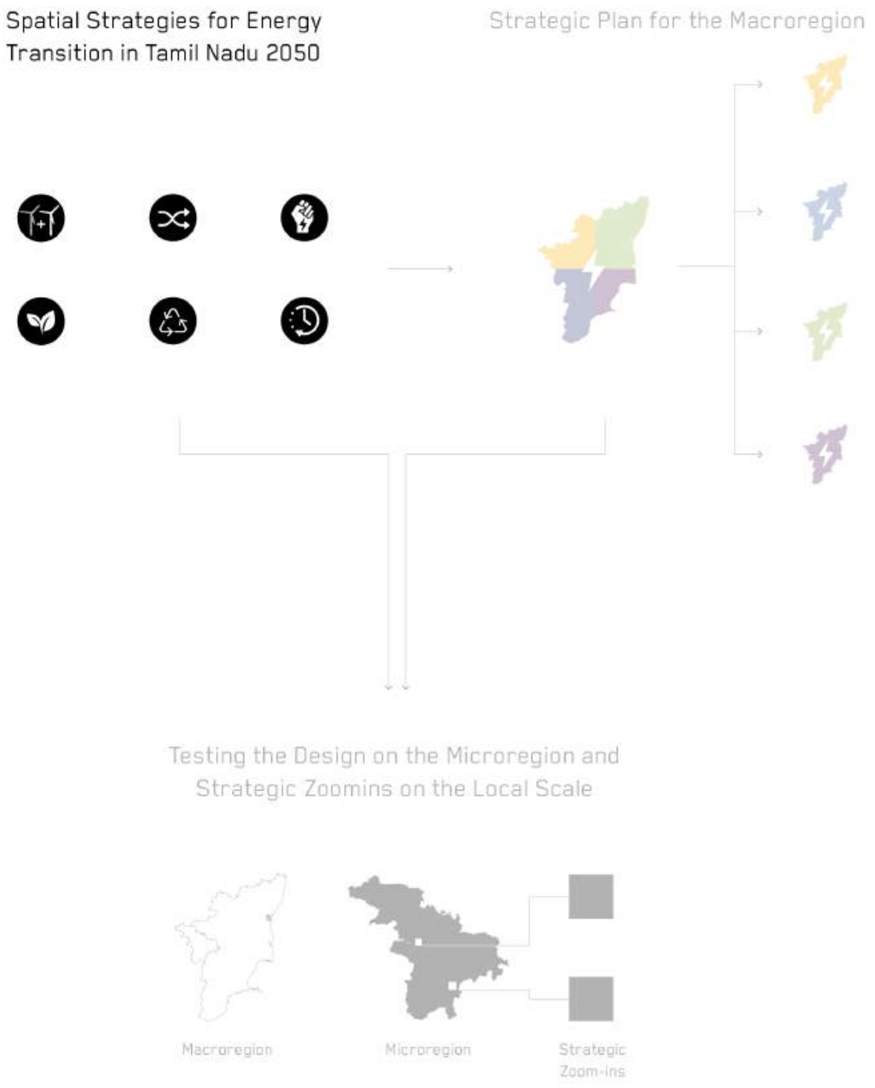
Research Question.

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

Components of the Regional Design.

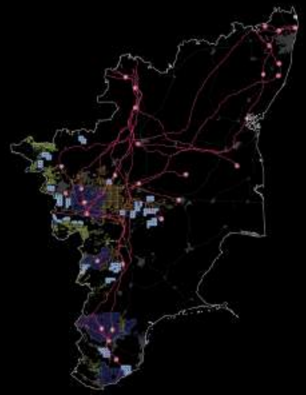


Spatial strategies for energy transition in Tamil Nadu.



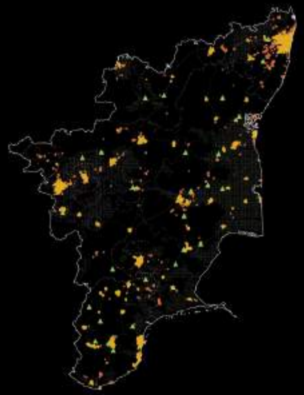
Spatial strategies for energy transition in Tamil Nadu.

Densify around existing energy production sites.



Create multifunctional energy landscapes through cross programming

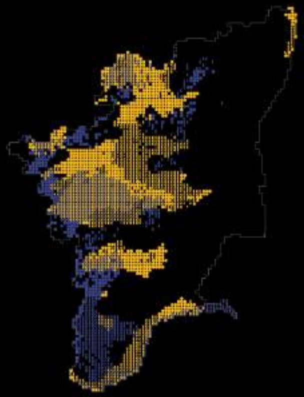
Coproduce energy with the community in urban and rural areas.



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.



Spatial strategies for energy transition in Tamil Nadu.

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

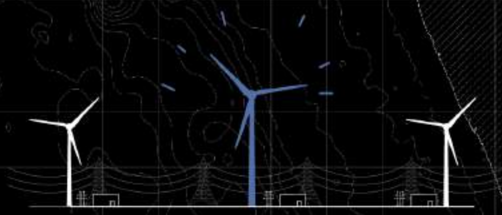
Repower and Reconfigure the post-carbon energy landscapes.

Increase flexibility through seasonal activation of energy landscapes.

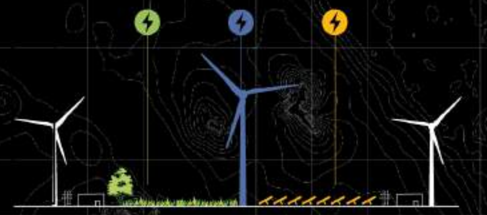
elaborated in the presentation

elaborated in the report

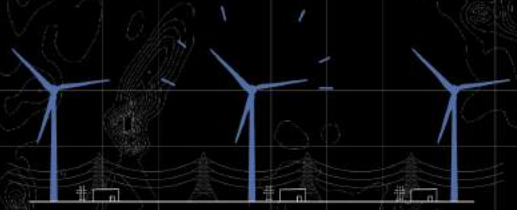
Strategy 1: ***Densify*** around existing energy production sites.



A. Densification of energy sites.

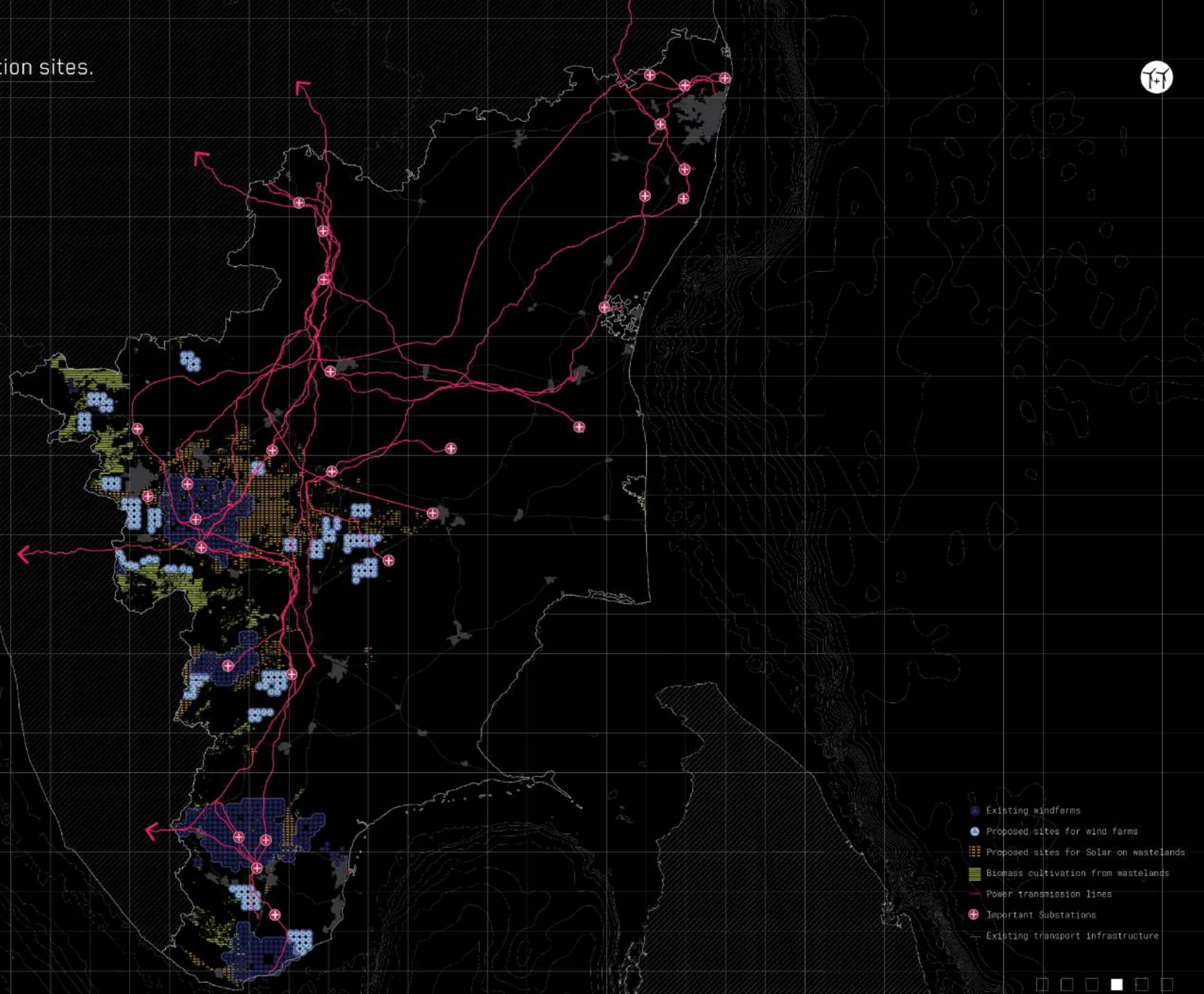


B. Diversify energy development.

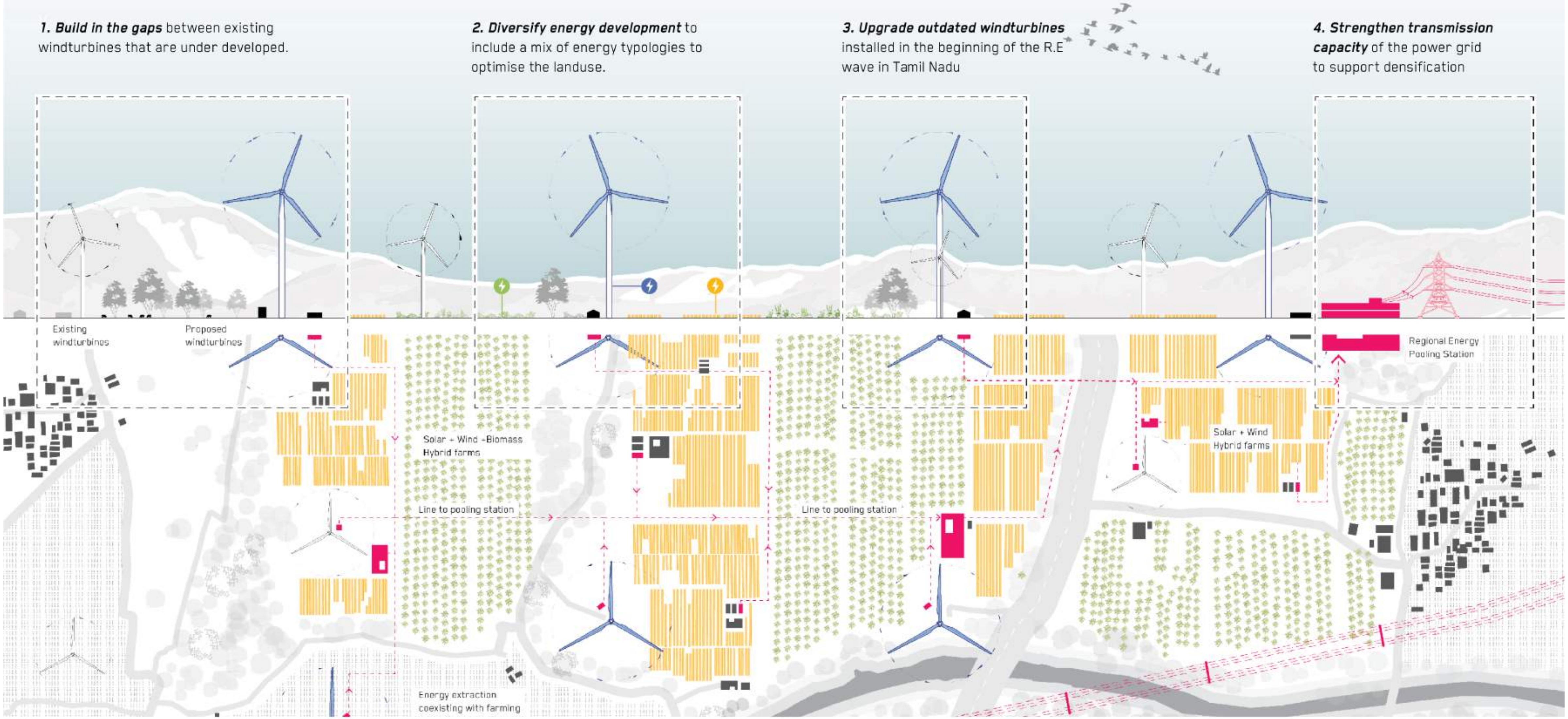


C. Upgrade outdated energy infrastructure.

D. Strengthen transmission capacity.



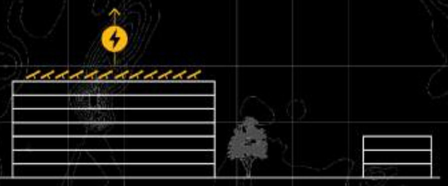
Spatial implications of the ***densified*** energy landscape.



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

A. Energy x Mobility

B. Energy x Waste Management



C. Energy x Public infrastructure.

Spatial implications of the ***crossprogrammed*** energy landscape.

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

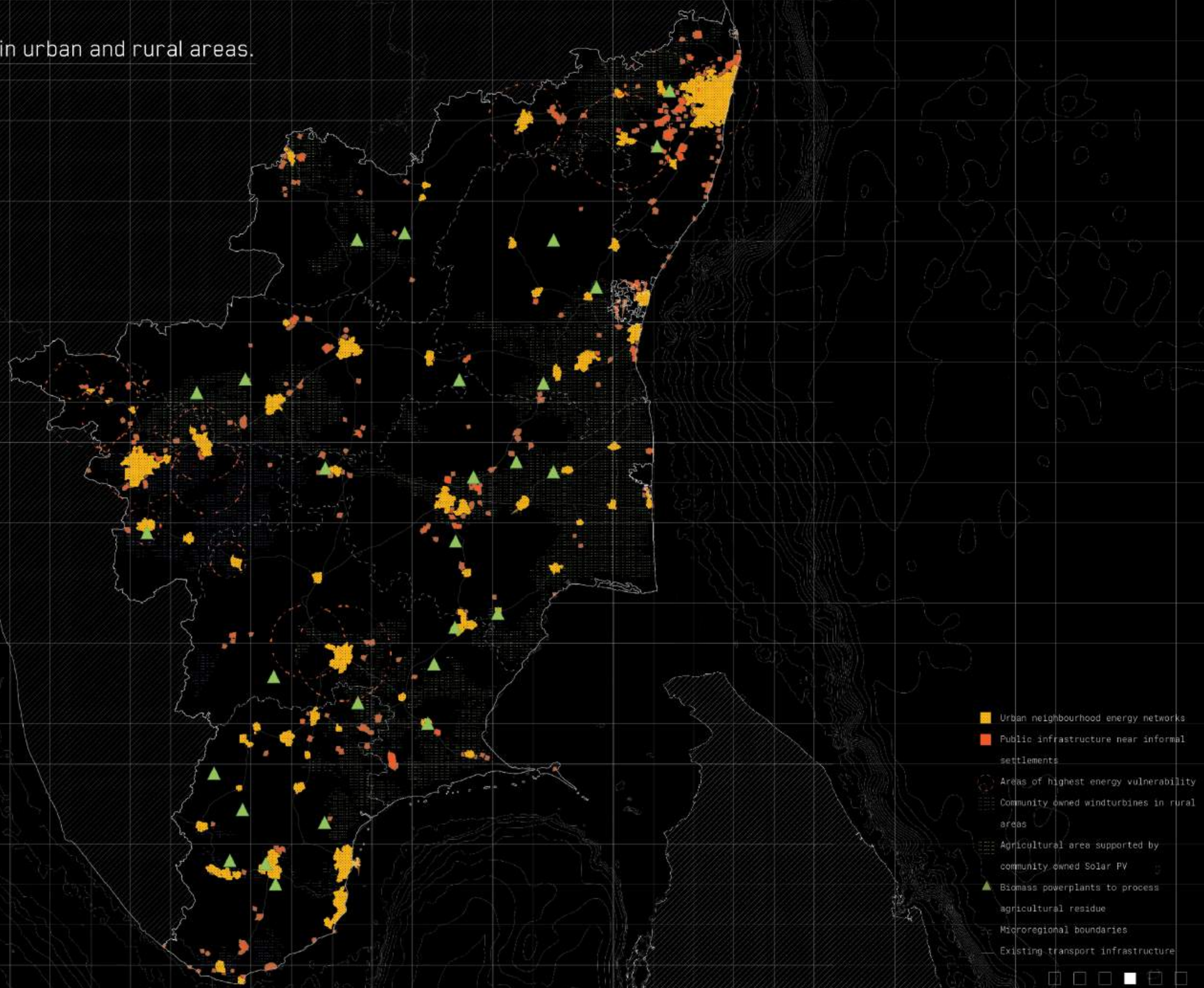
Strategy 3: ***Coproduce*** energy with the community in urban and rural areas.

A. Densification of energy sites.

B. Diversify energy development.

C. Upgrade outdated energy infrastructure.

D. Strengthen transmission capacity.



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

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

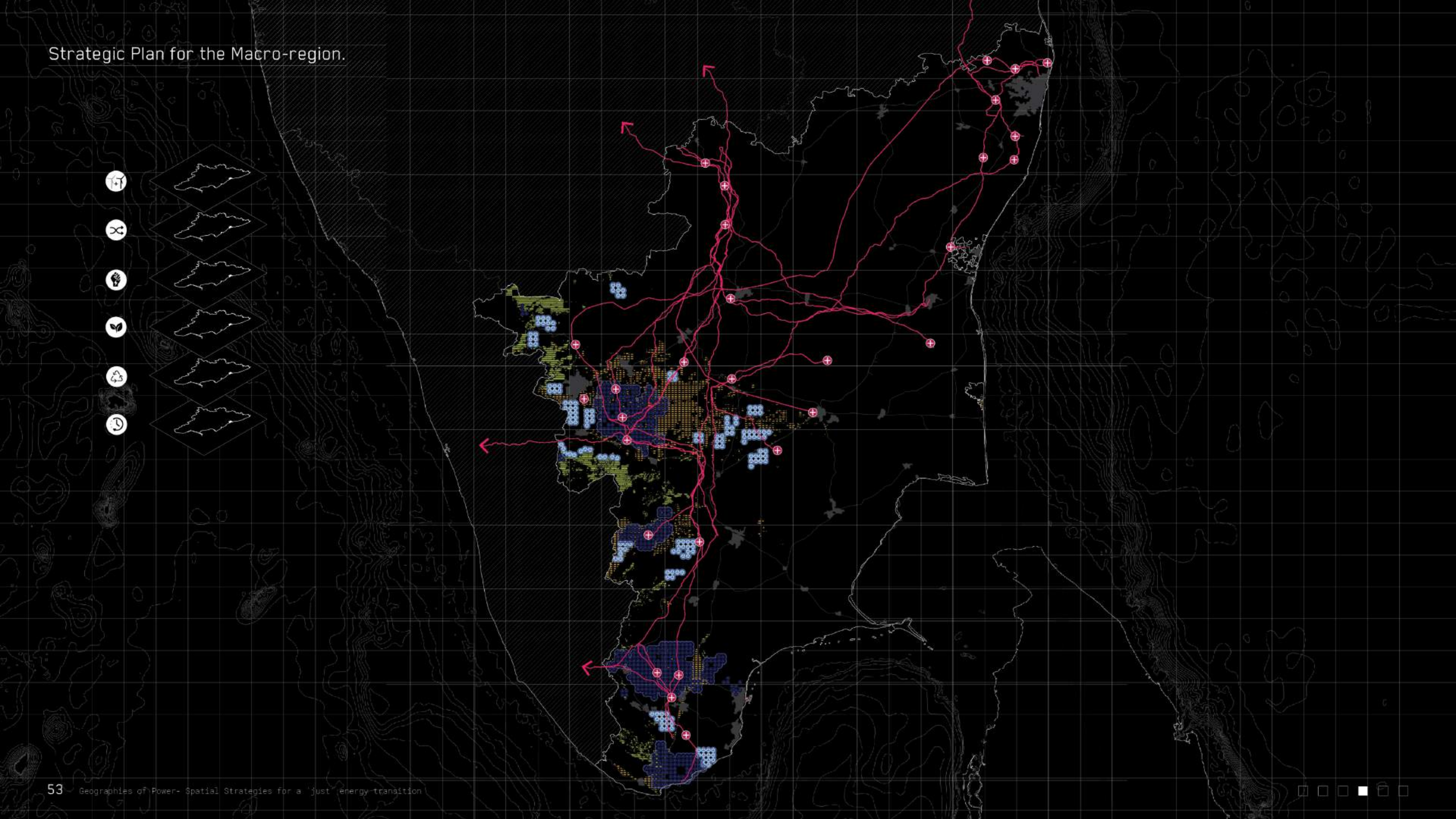
2. Connect informal settlements with energy vulnerability to the nearest public or commercial building with large rooftops that can be used to ***coproduce energy along with the vulnerable communities .***

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

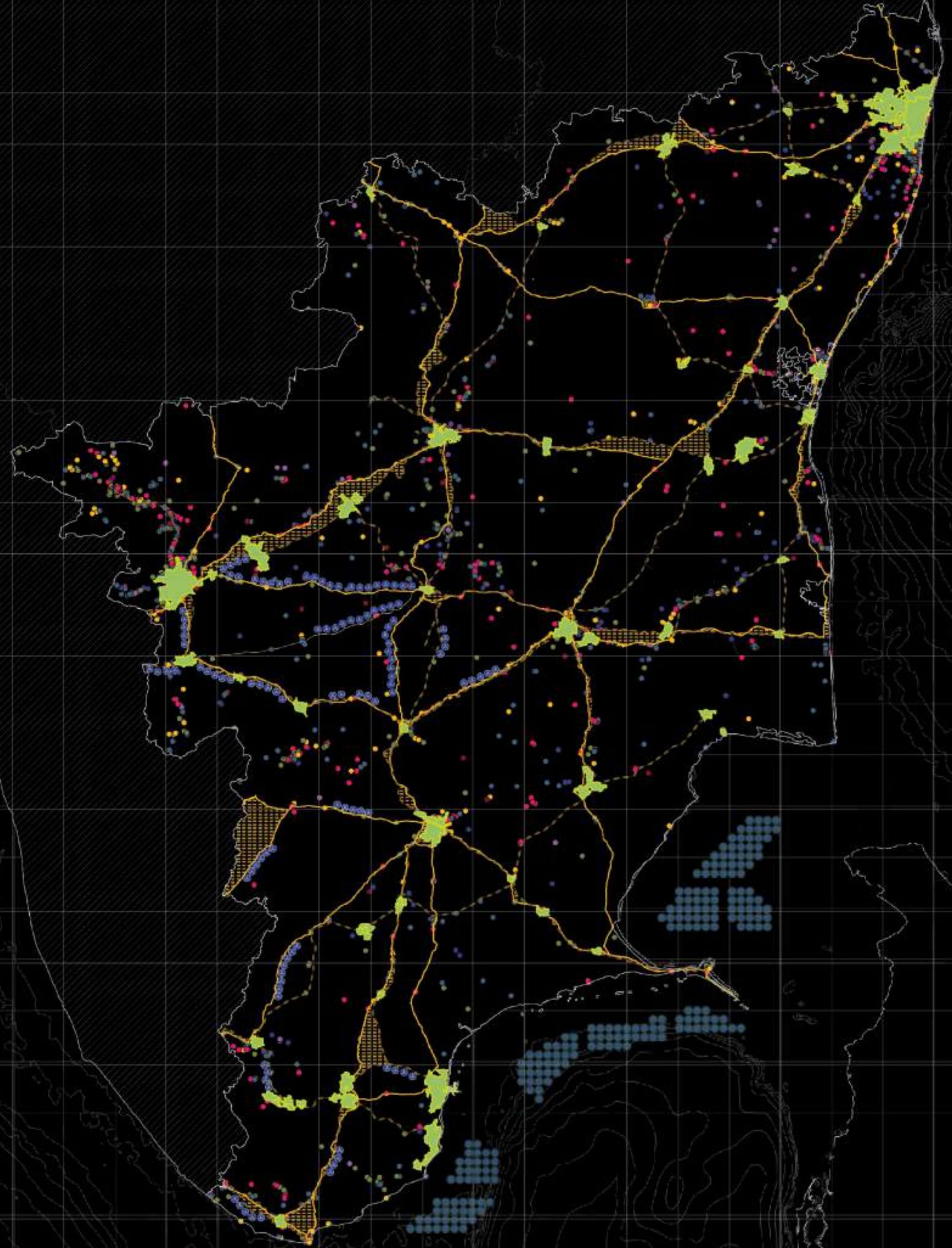
4. Build Capacitatiion Centres in every Taluk (administrative division) for sharing knowledge and support rural coproduction initiatives

Strategic Plan for the Macro-region.

Strategic Plan for the Macro-region.



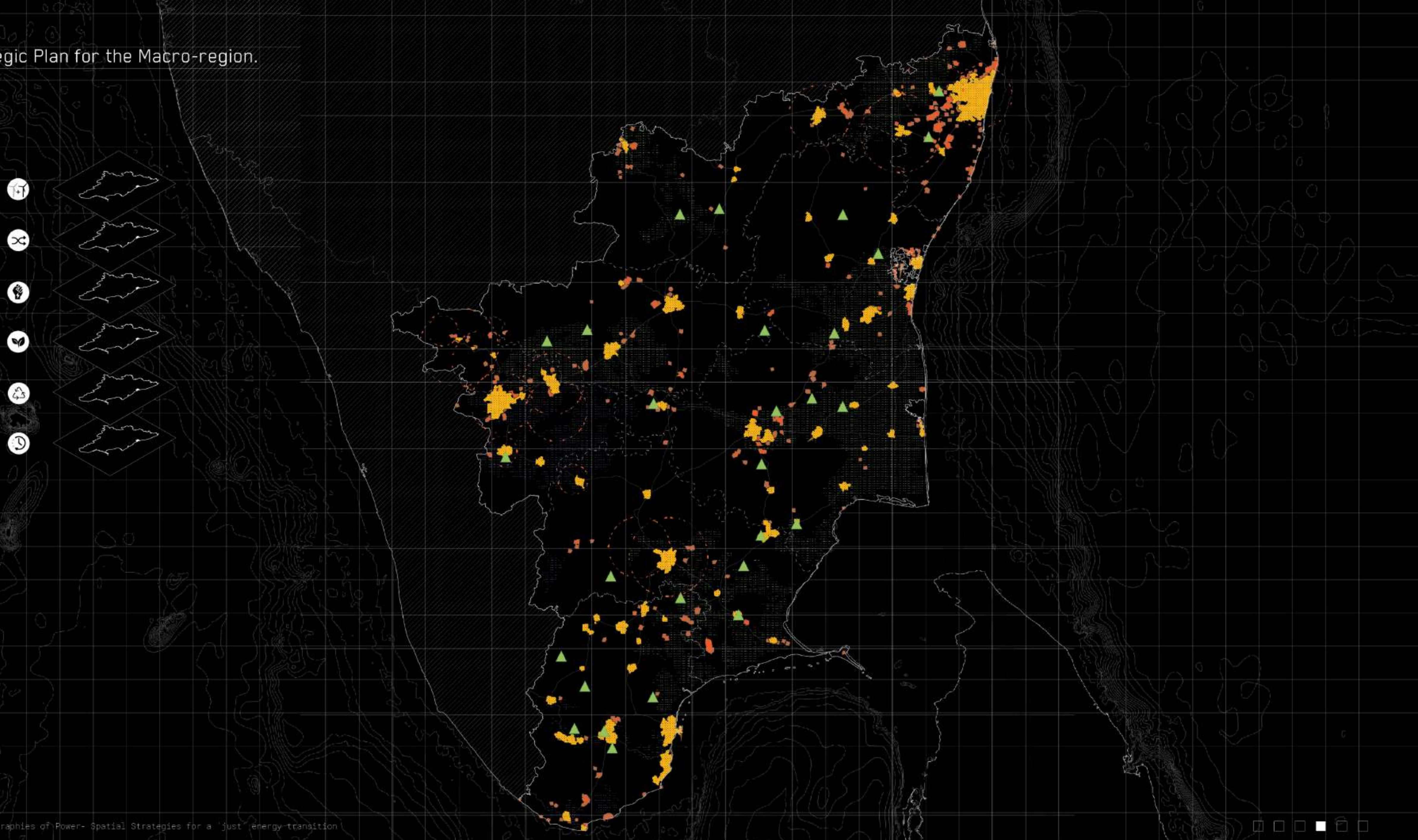
Strategic Plan for the Macro-region.



PROPOSED ENERGY PRODUCTION LANSCAPE	189750 Gwh
Solar PV on urban rooftops	11000 Gwh
Solar PV on wastelands	21500 Gwh
Solar PV along infrastructure (road,rail)	6000 Gwh
Windfarms on passive farmlands *	70000 Gwh
Offshore windfarms *	15000 Gwh
Windturbines along infrastructure *	23000 Gwh
Biomass cultivation from wastelands	4000 Gwh
Biomass from agricultural residue	2200 Gwh
Biomass power plants	
CCS Pipelines	
Undersea CCS Storage Points	
TOTAL ENERGY PRODUCTION	**300000 Gwh**

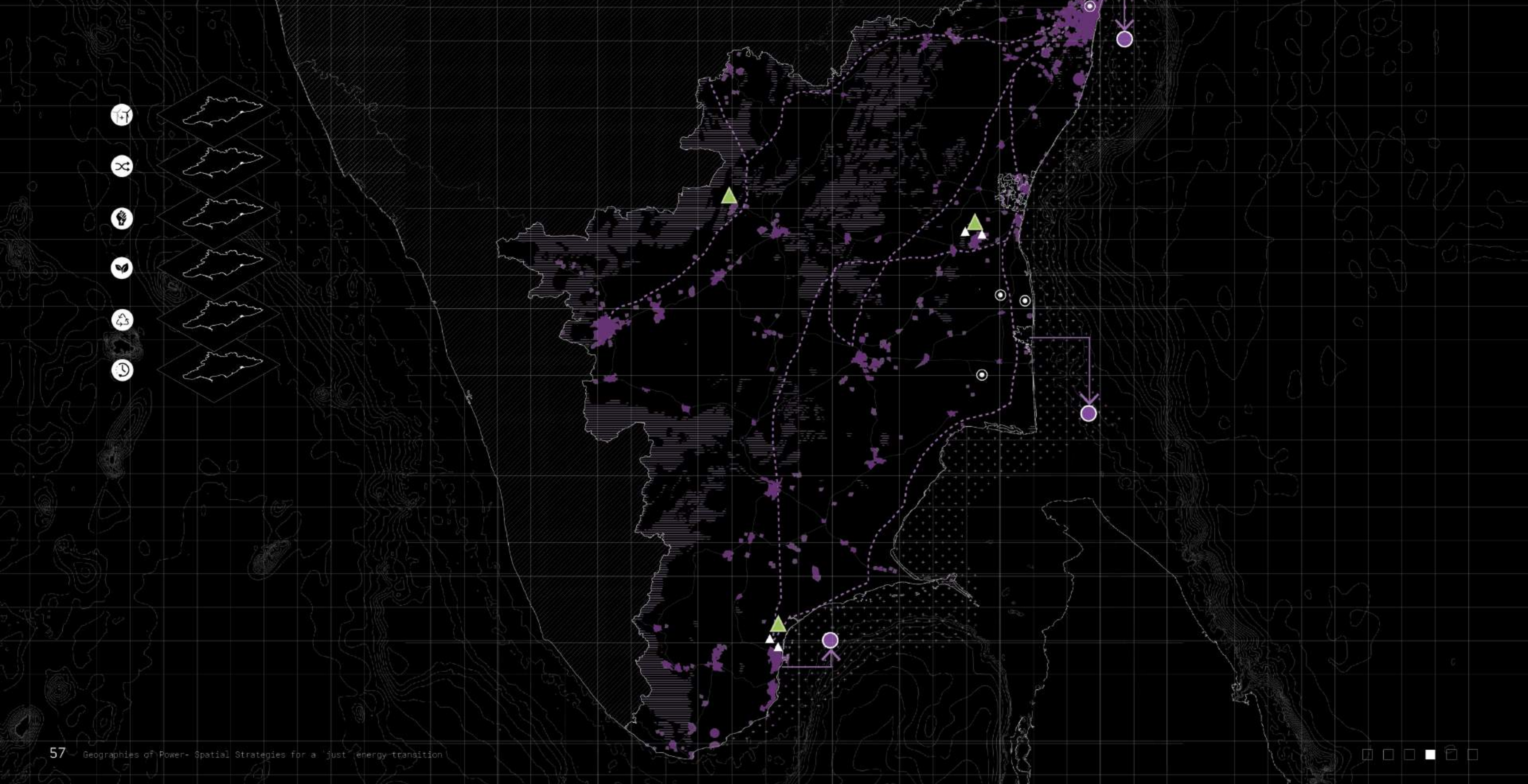
EXISTING ENERGY PRODUCTION LANSCAPE	110250 Gwh
Thermal Power Plant	82000 Gwh
Nuclear Power Plant	20000 Gwh
Gas extraction fields	6000 Gwh
Hydro power projects	4500 Gwh
Solar farms	2500 Gwh
Wind farms *	12000 Gwh
Biomass power plants	1000 Gwh
Power transmission lines	
Important Substations	
Western ghats mountains	

Strategic Plan for the Macro-region.

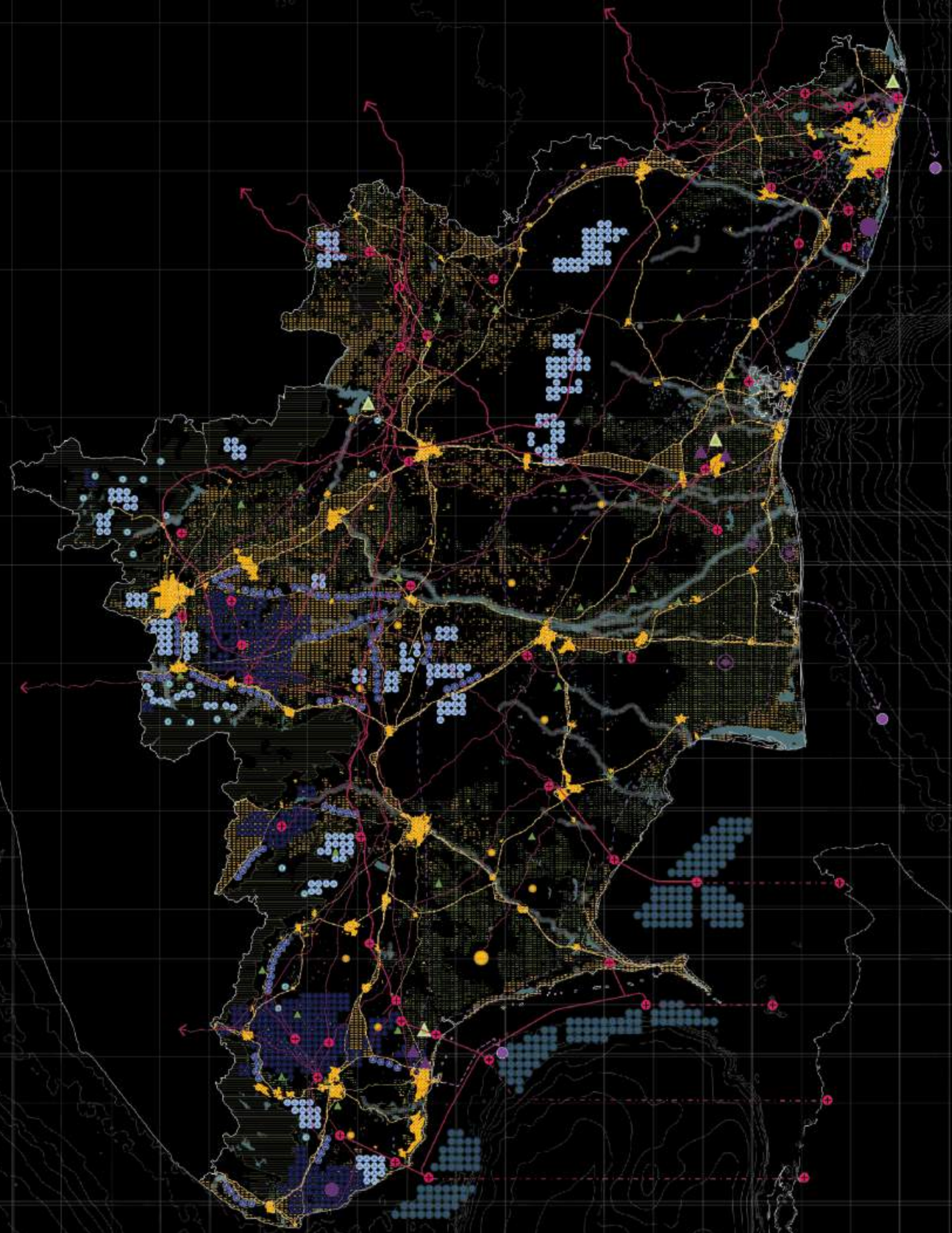


Strategic Plan for the Macro-region.

Strategic Plan for the Macro-region.



Strategic Plan for the Macro-region.



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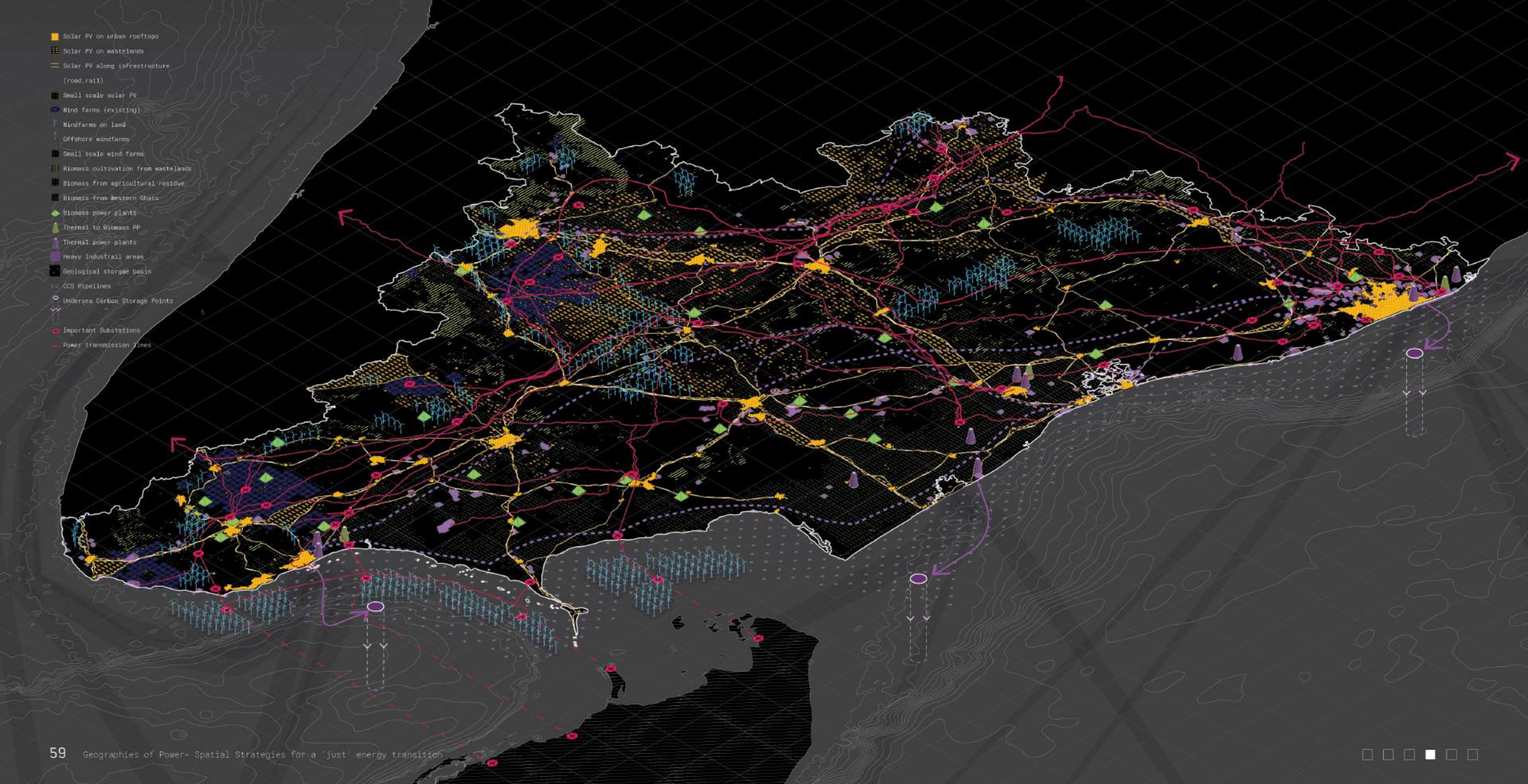
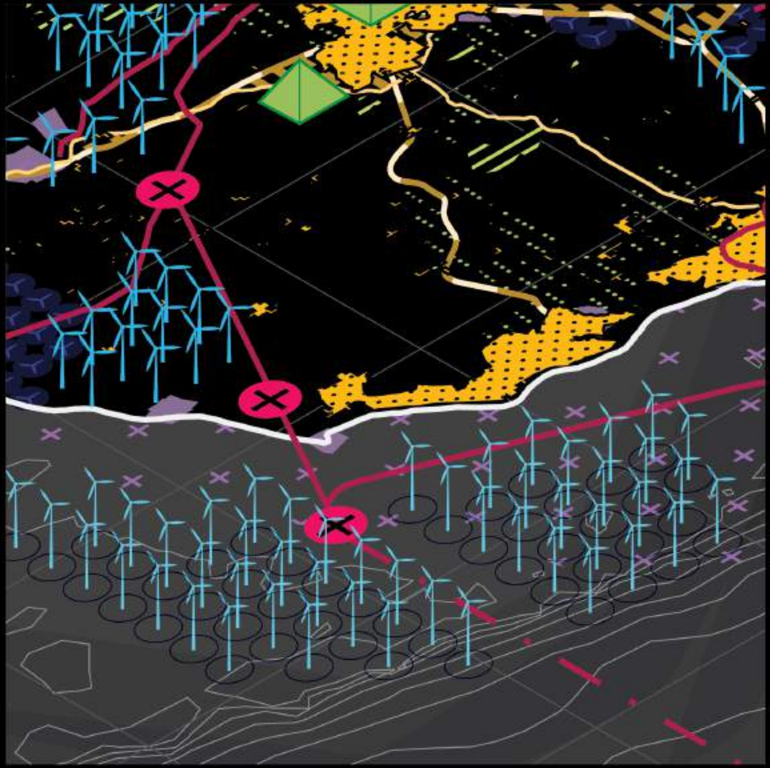
Wind farms *	12000 Gwh
Biomass power plants	1800 Gwh
Power transmission lines	
Important Substations	
Western ghats mountains	

3D view of the Strategic Plan.

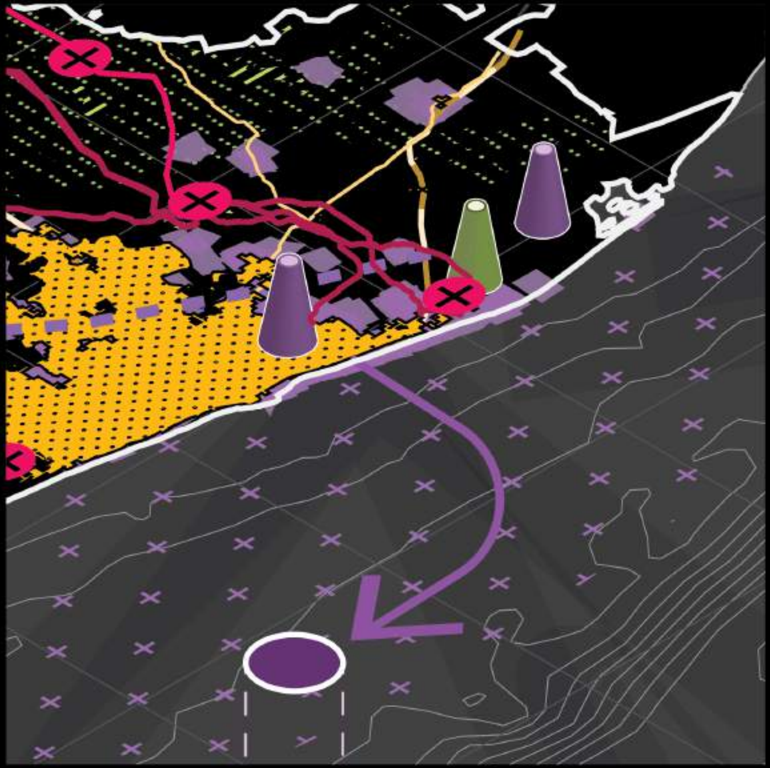


Impacts of the regional design on the local scale.

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.

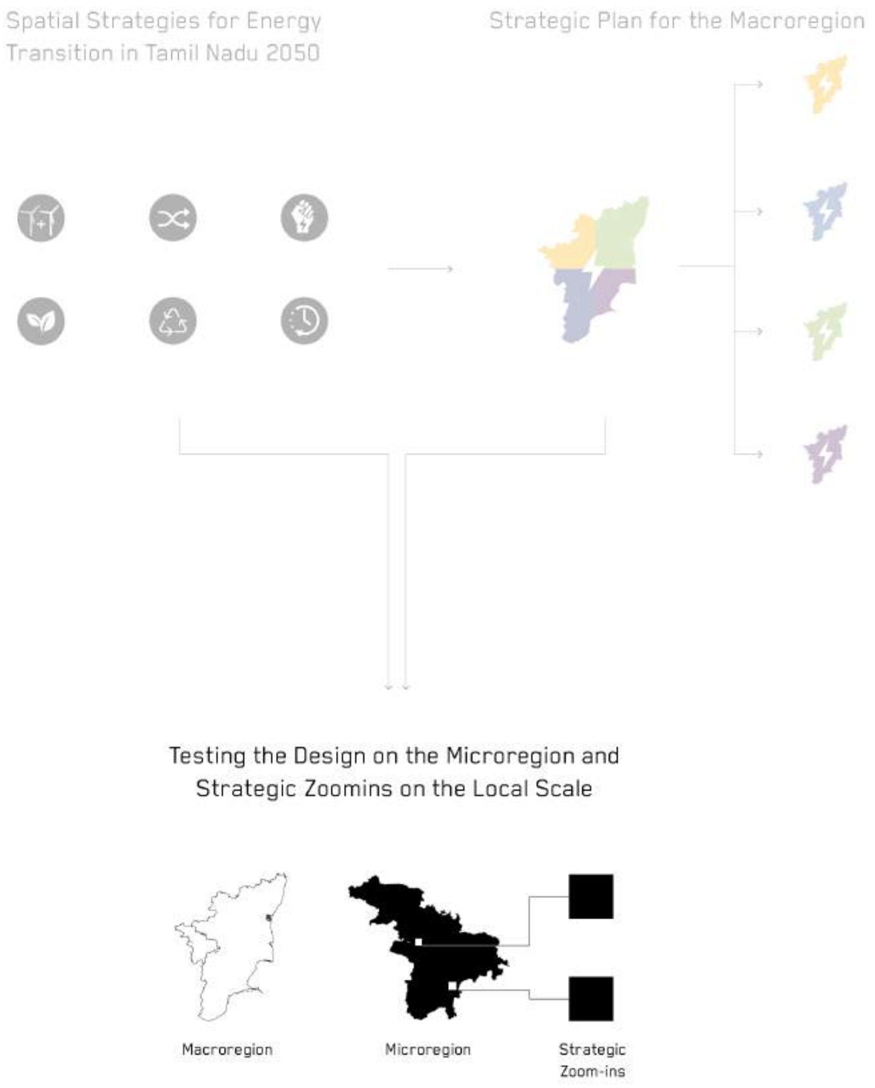


Detail 3: Post carbon energy landscape around Chennai, the capital city of the state. Part of the Ennore Thermal Power Plant is converted to biomass based TPP. Heavy industries near the energy sites that benefit from the development are also seen in the detail.

5

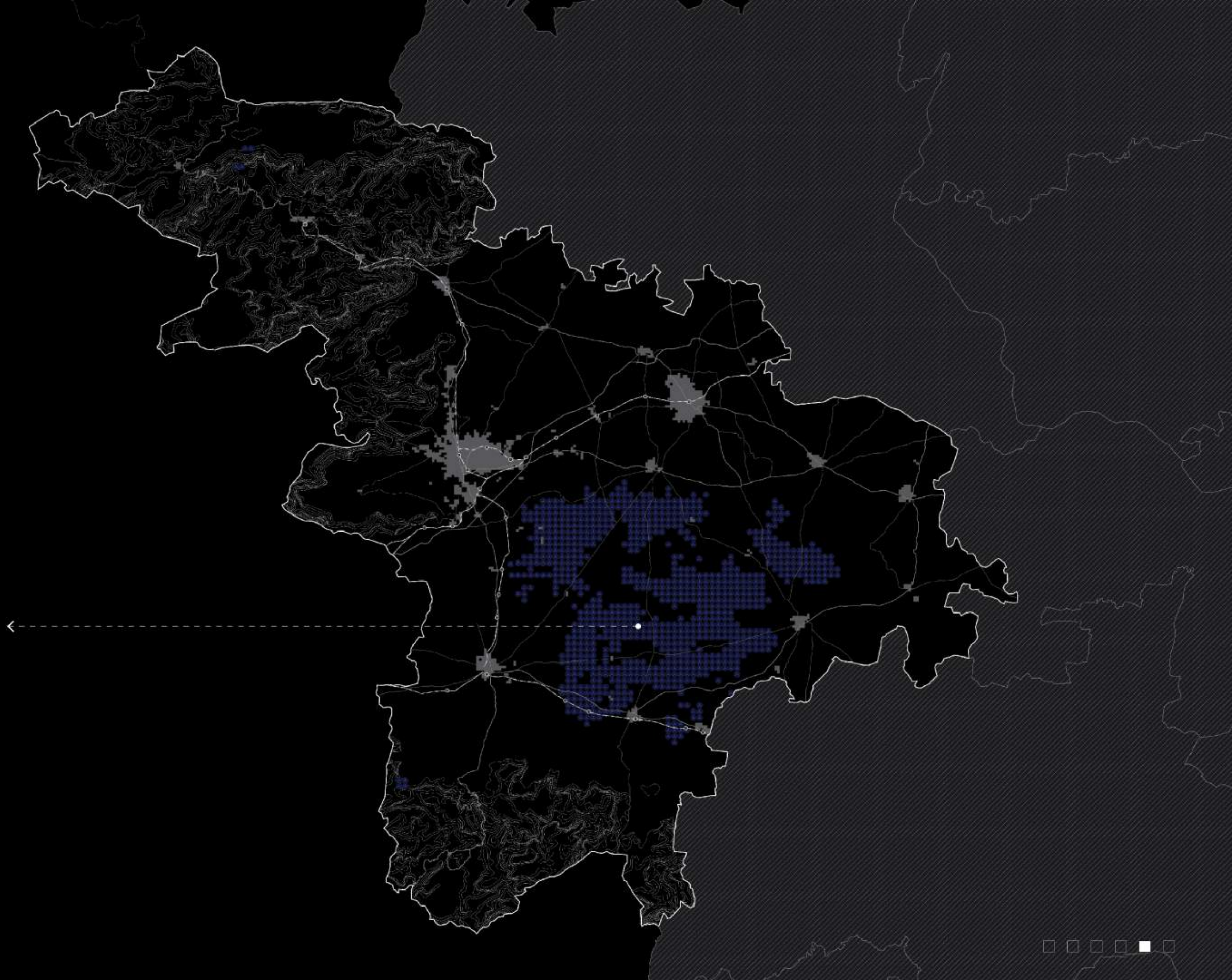
Testing the Design

Testing the Design on the Micro-region and Zoom-ins

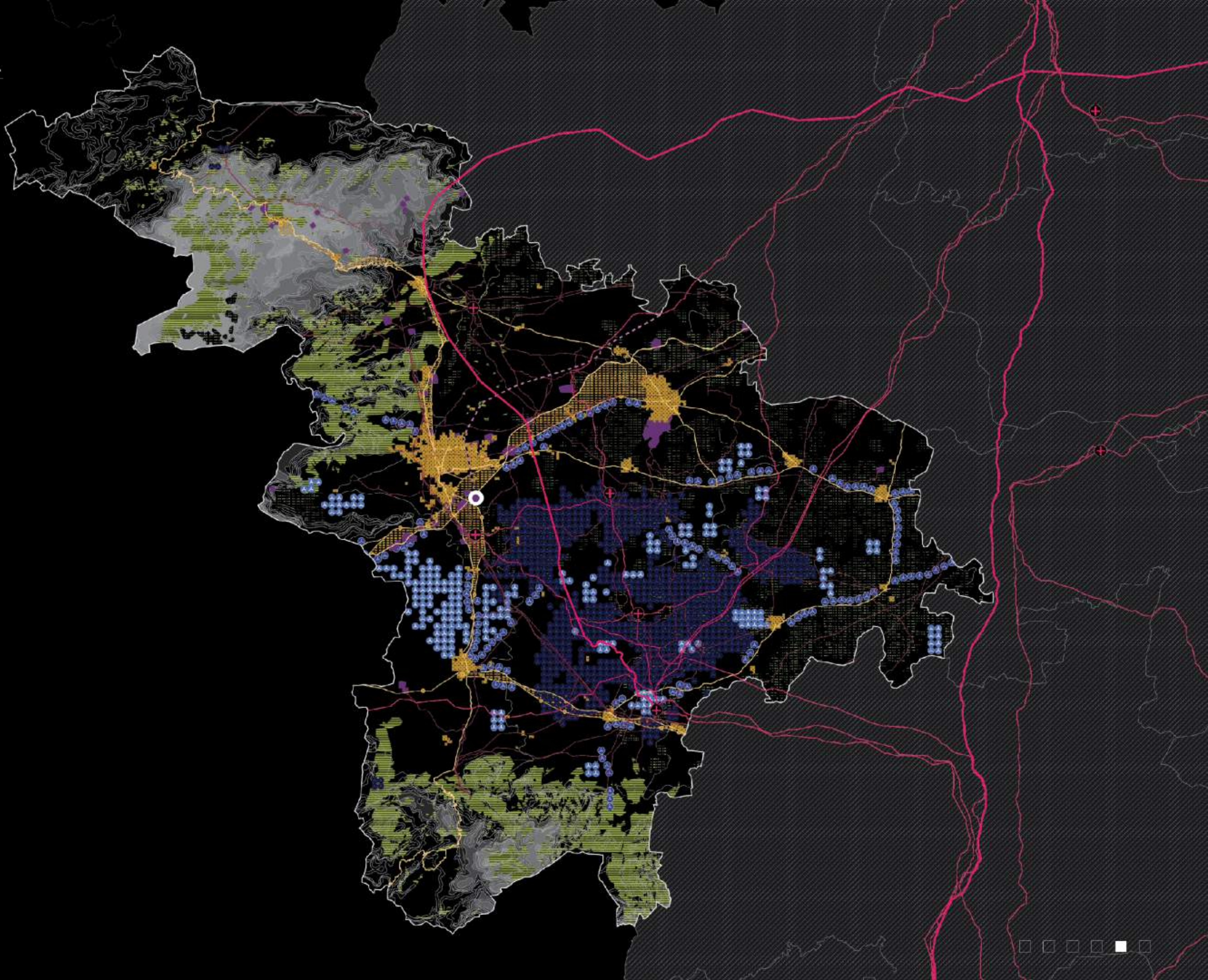


Coimbatore micro-region.

Existing energy sites



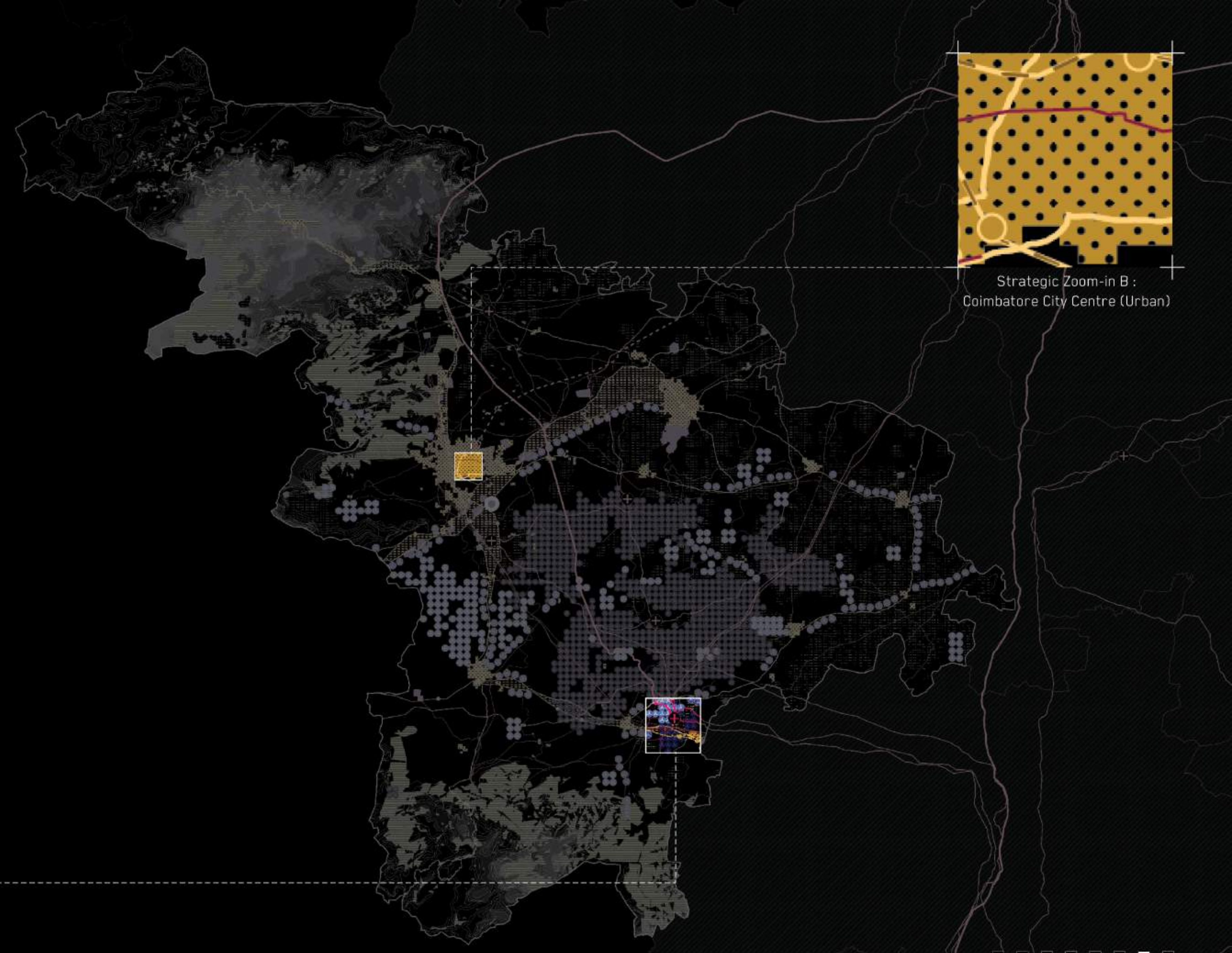
Translation of the strategies in the micro-region.



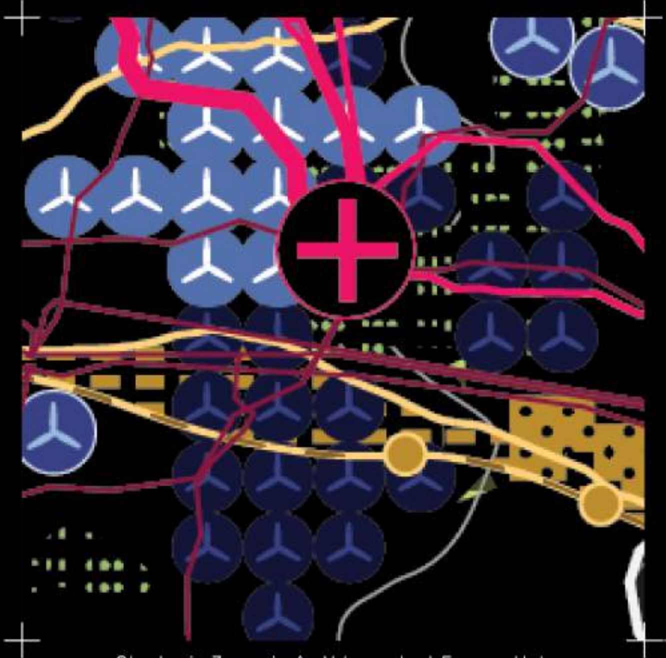
Existing windfarms
Proposed sites for wind farms
Proposed sites for Solar on wastelands
Biomass cultivation from wastelands
Power transmission lines
Important Substations
Existing transport infrastructure

Micro region to Strategic Zoom-ins.

Udumelpet Energy Hub
Coimbatore City Centre



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

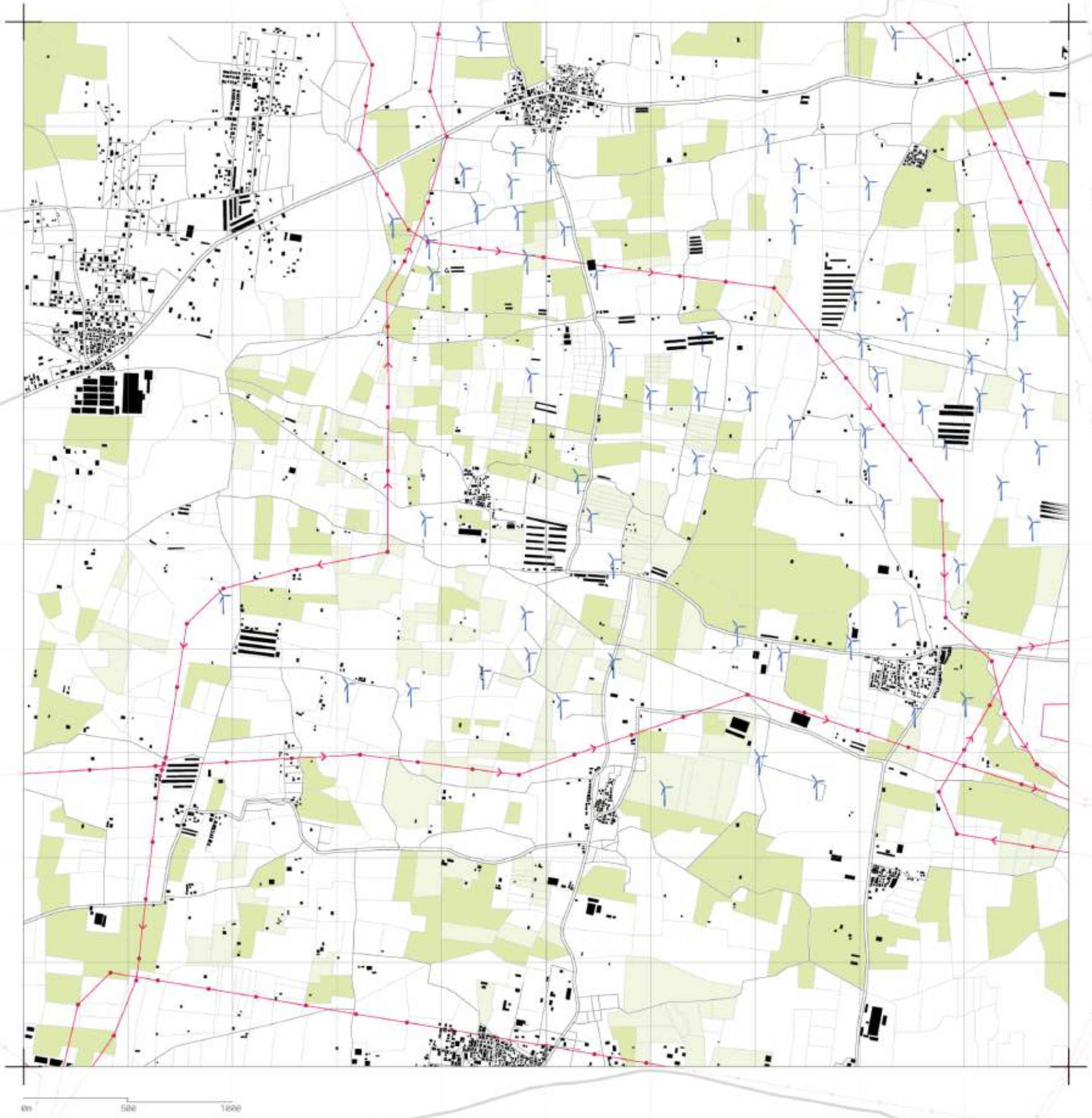


Strategic Zoom-in A : Udumenlpet Energy Hub
(Rural)

Strategic Zoom-in A: Udumelpet energy hub

Existing situation.

Udumelpet energy hub

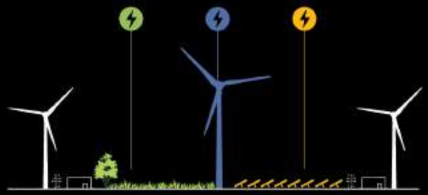


- Rural built up area
- Important roads
- Agricultural fields
- Coconut farms
- Existing wind farms
- Power transmission lines

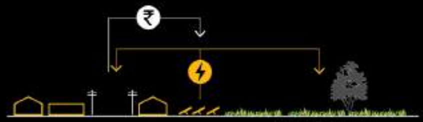
Design interventions.

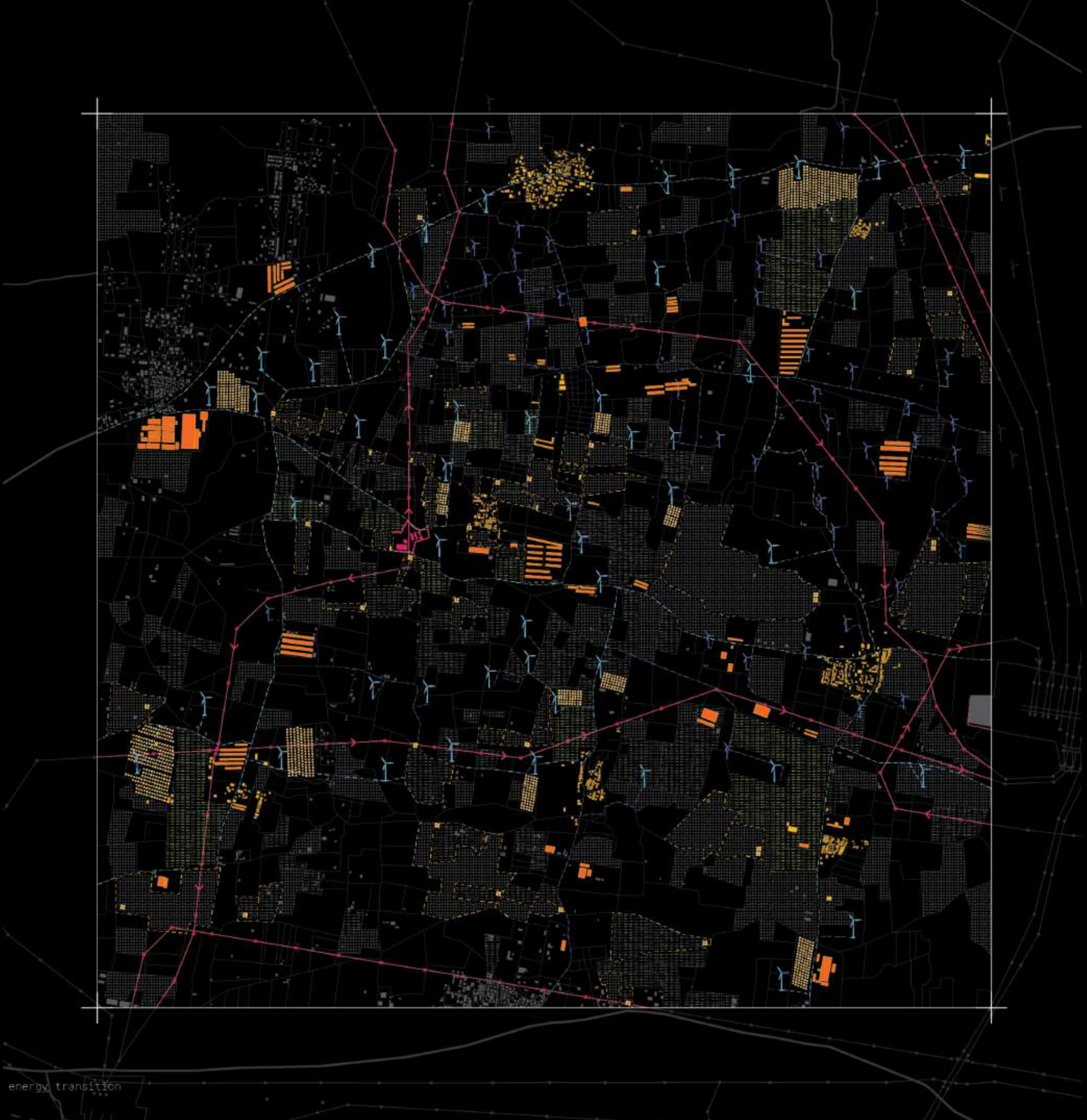
Udumelpet energy hub

S1: Densification.



S3:; Coproduction.





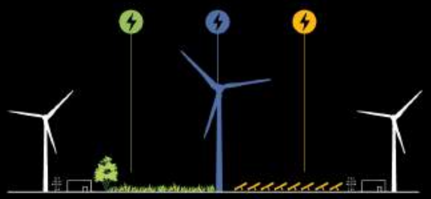
Existing end of life wind turbines
Repowered wind turbines
New wind turbines
Existing connections to pooling station
New connections to the pooling station
Solar energy plants
Biomass cultivation areas
Proposed R.E pooling station
Transmission lines

Households powered by mini grid
Agriculture fields powered by mini grid
Poultry farms in the area
Mini grid between micro-enterprises

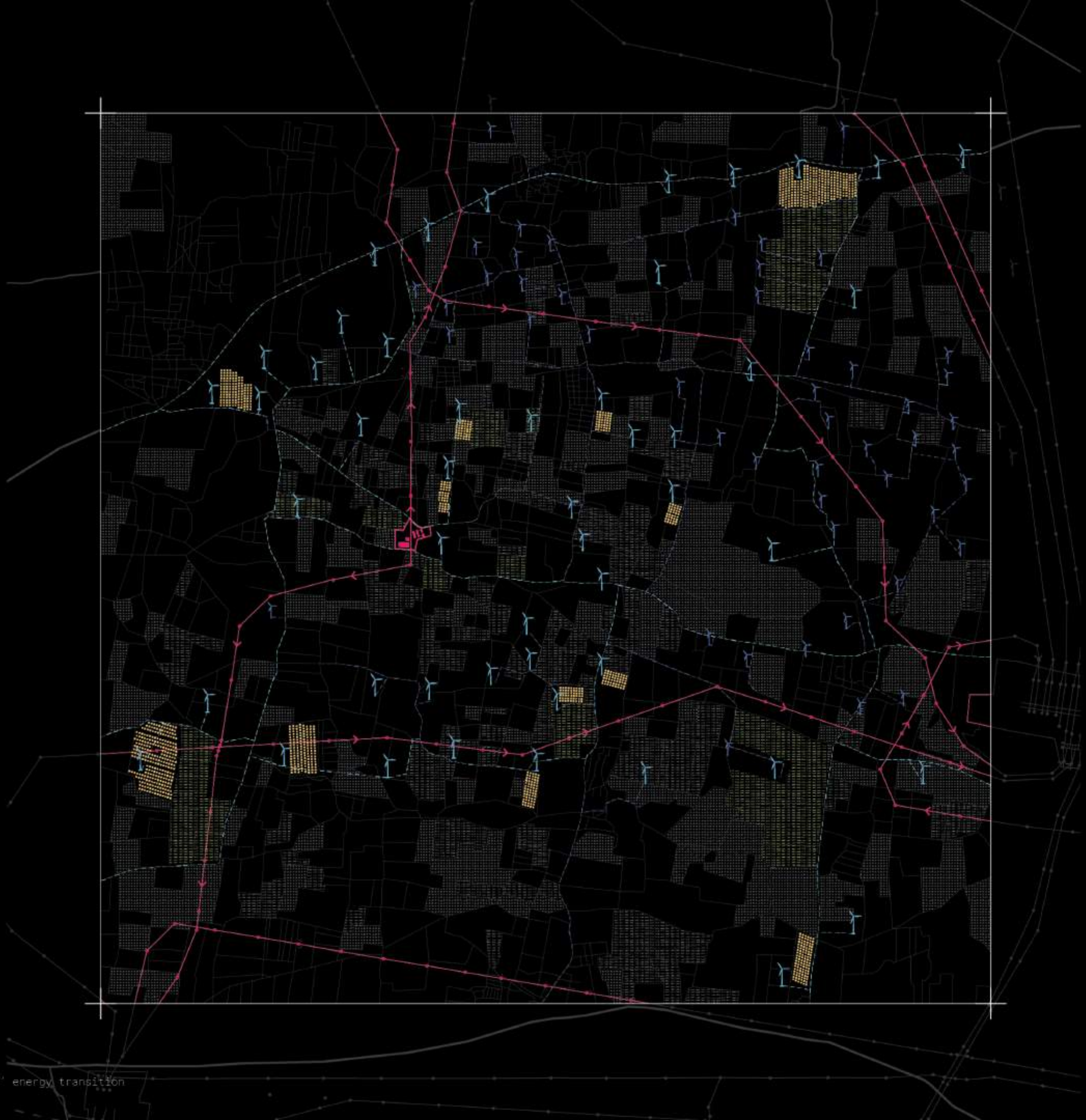
Design interventions.

Udumelpet energy hub

S1: Densification.



S3: Coproduction.



- Existing end of life wind turbines
- Repowered wind turbines
- New wind turbines
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- New connections to the pooling station
- Solar energy plants
- Biomass cultivation areas
- Proposed R.E pooling station
- Transmission lines

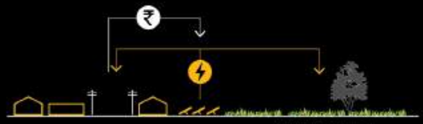
- Households powered by mini grid
- Agriculture fields powered by mini grid
- Poultry farms in the area

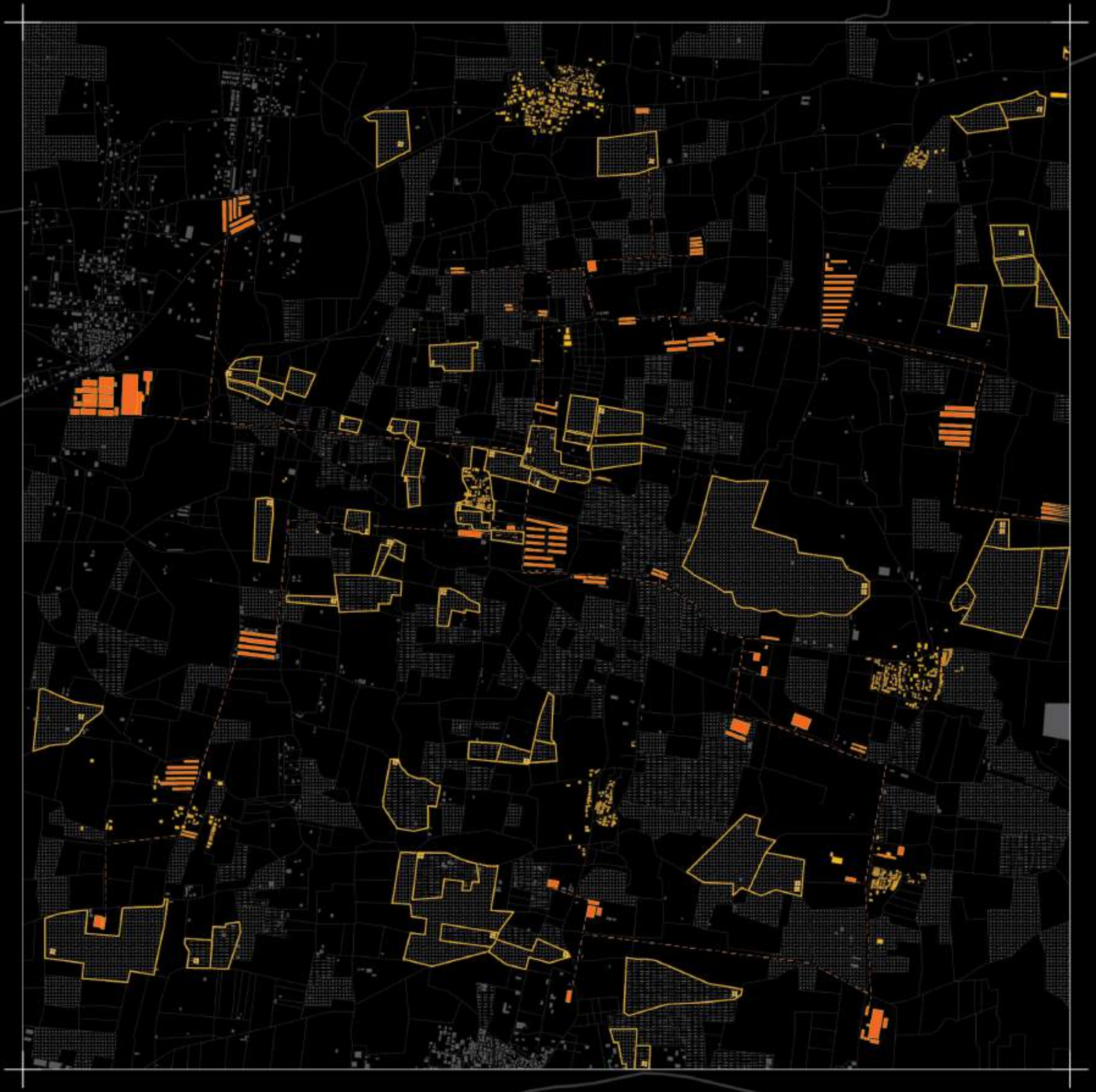
Design interventions.

Udumelpet energy hub

S1: Densification.

S3:; Coproduction.





Sites for EV charging stations

Important transit points powered by R.E

Railway network

Energy x Mobility Network

Public buildings with solar PV on rooftops

Industries with solar PV

Connection to the Public Energy Network

Public Energy Network

Urban Energy Park for Coimbatore

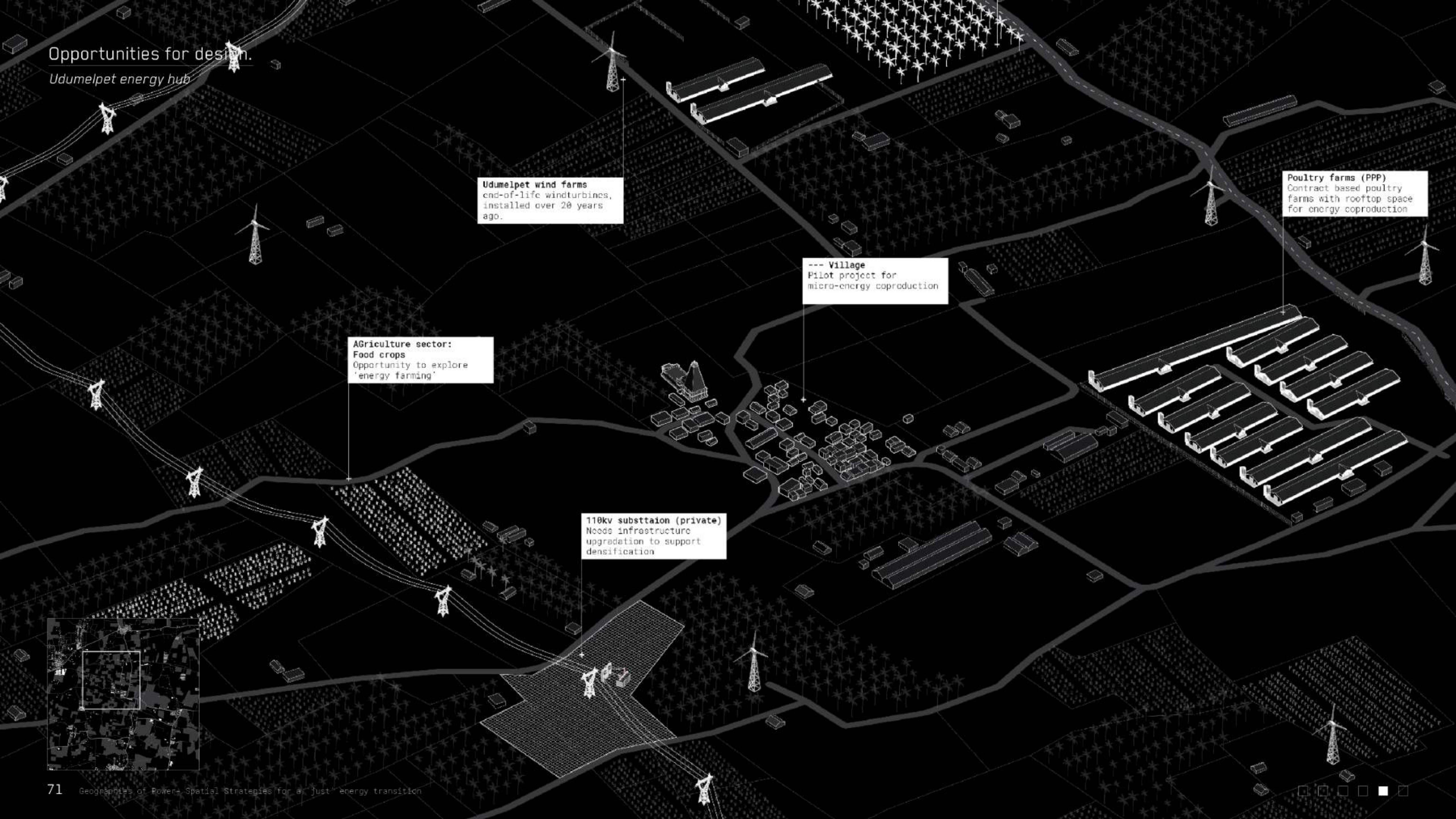
Residences with solar Pv on rooftops forming the neighbouhood energy netwroks

Schools and educational instituions near energy vulnerable communities

Informal settlements and energy vulnerable communities

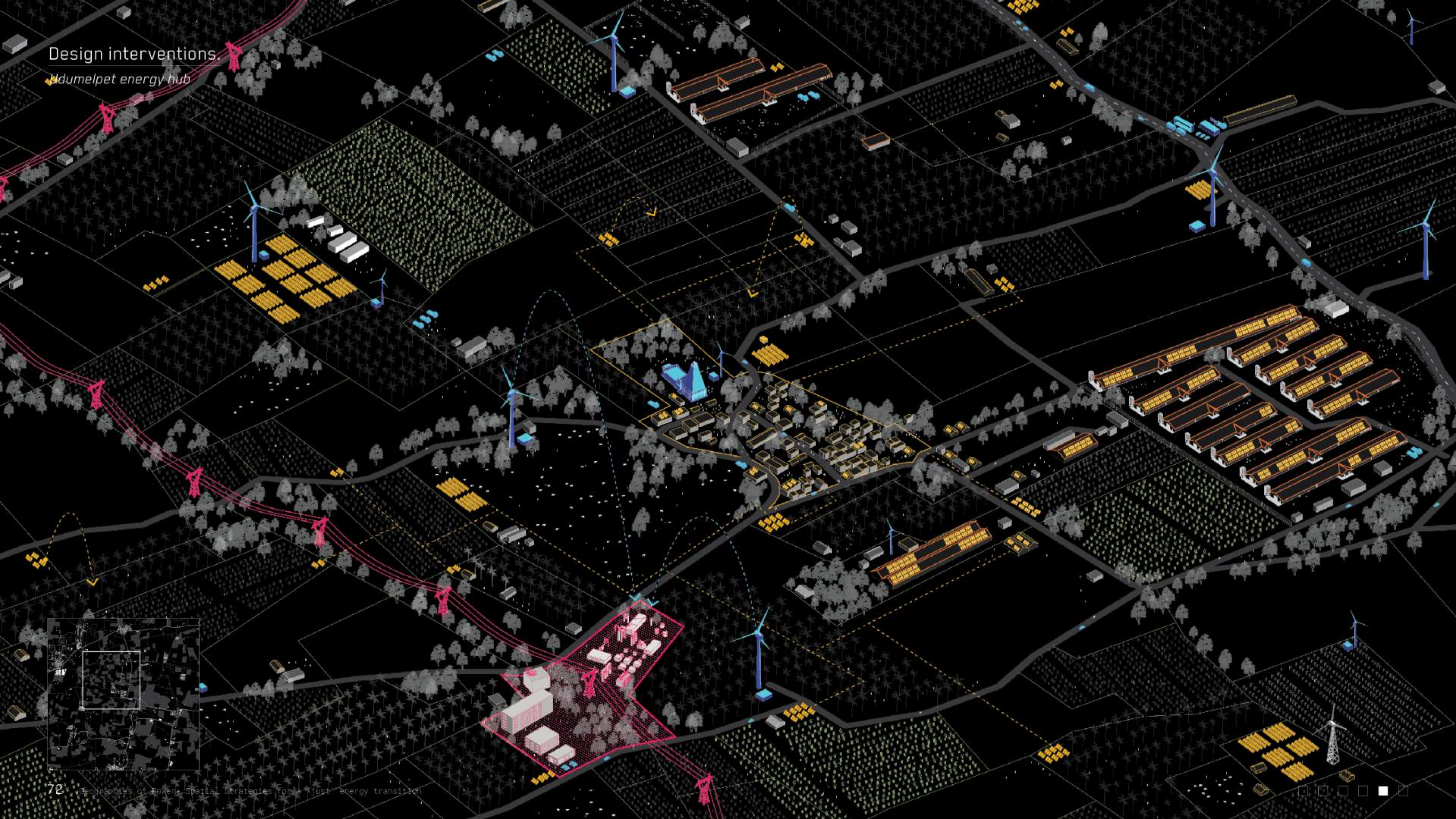
Opportunities for design.

Udumelpet energy hub



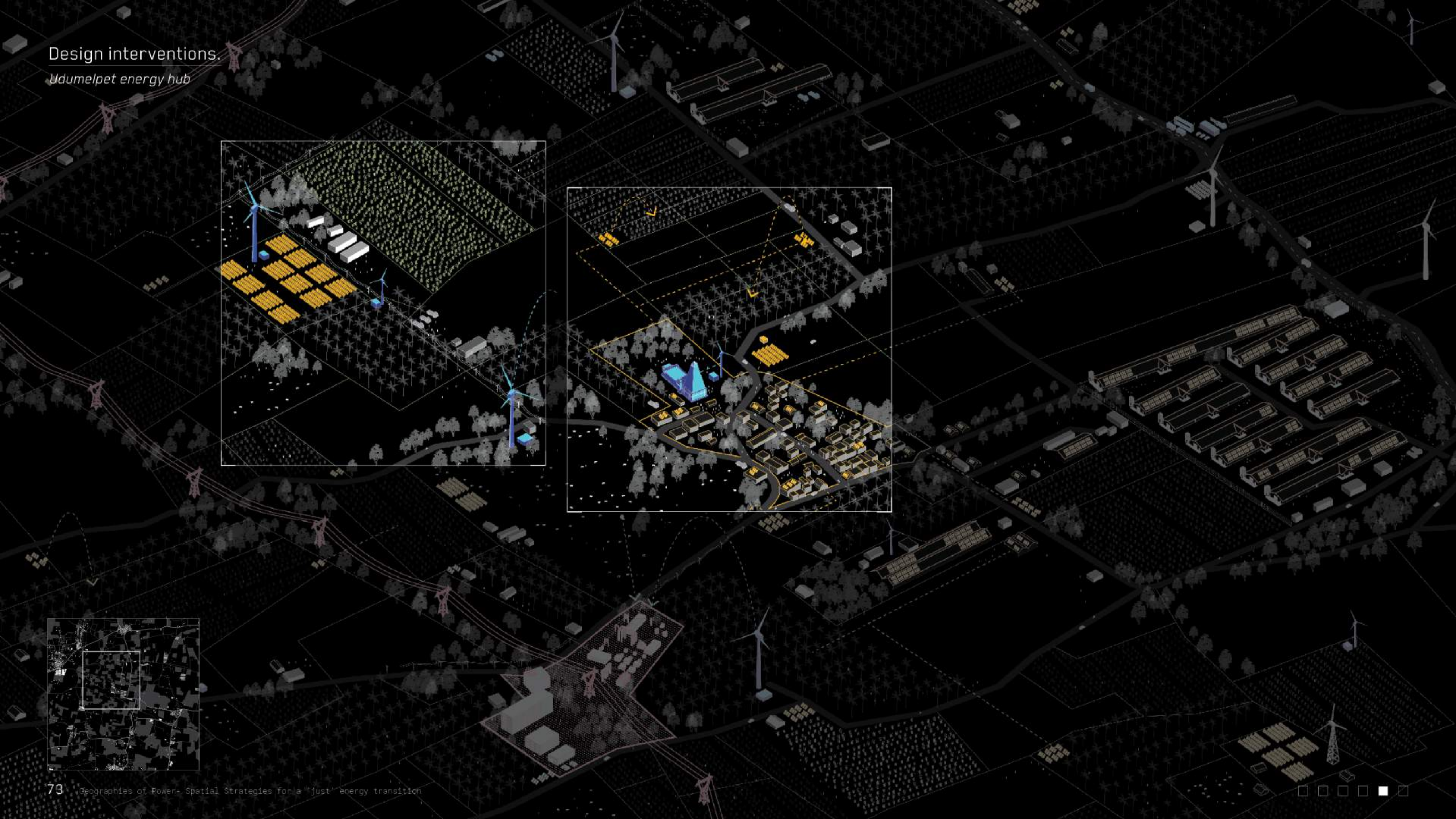
Design interventions.

Udumelpet energy hub



Design interventions.

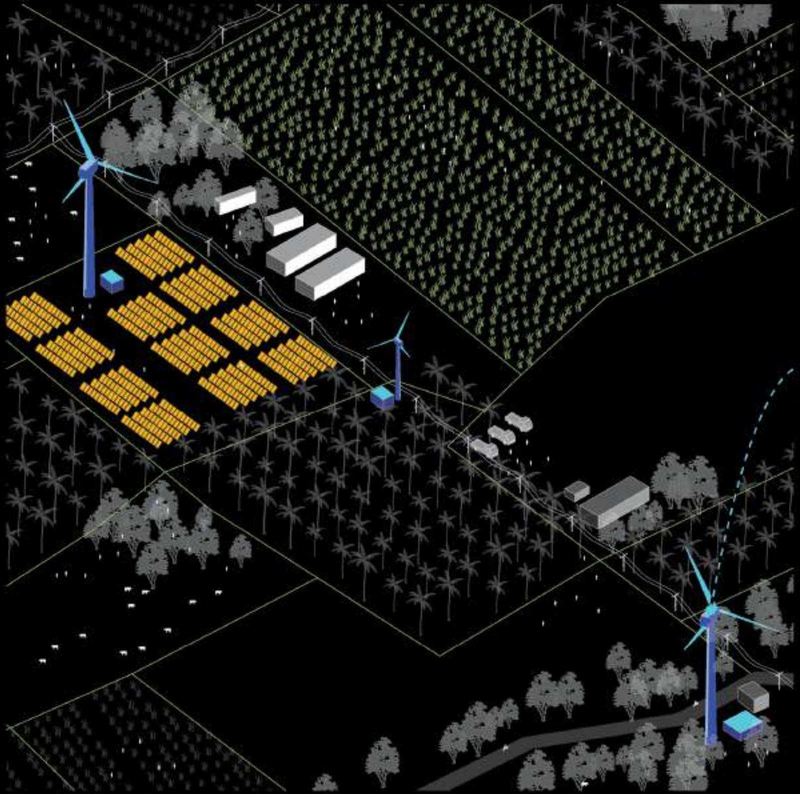
Udumelpet energy hub



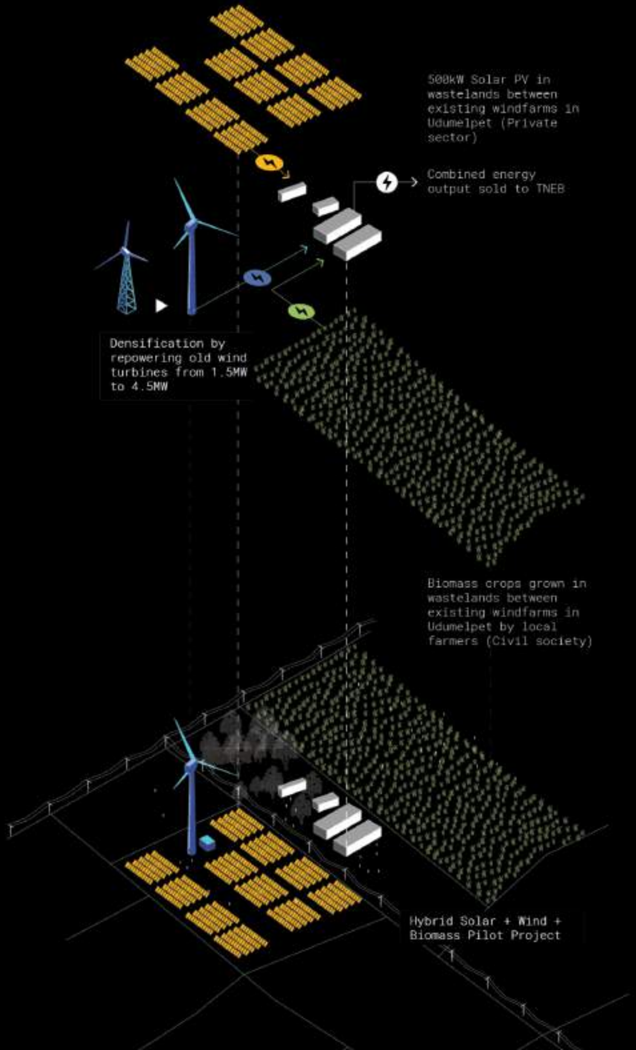
Detail: Hybrid S + W+ B Pilot Project.

S1: Densification

A,B,C: Densify, diversify, repower



Key plan



Detail: Hybrid S + W+ B Pilot Project.

Existing situation

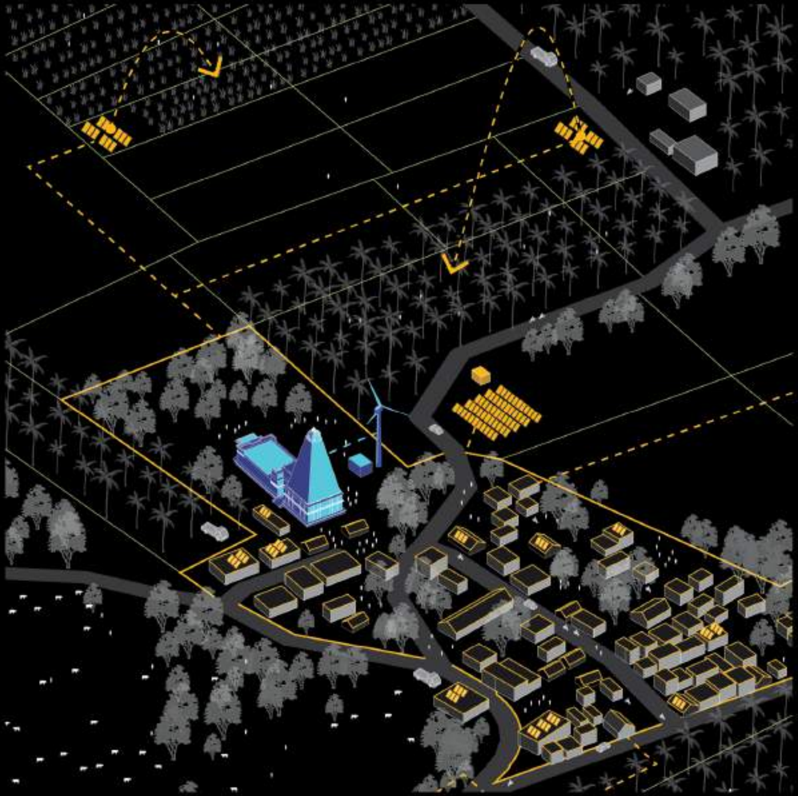
Detail: Hybrid S + W+ B Pilot Project.

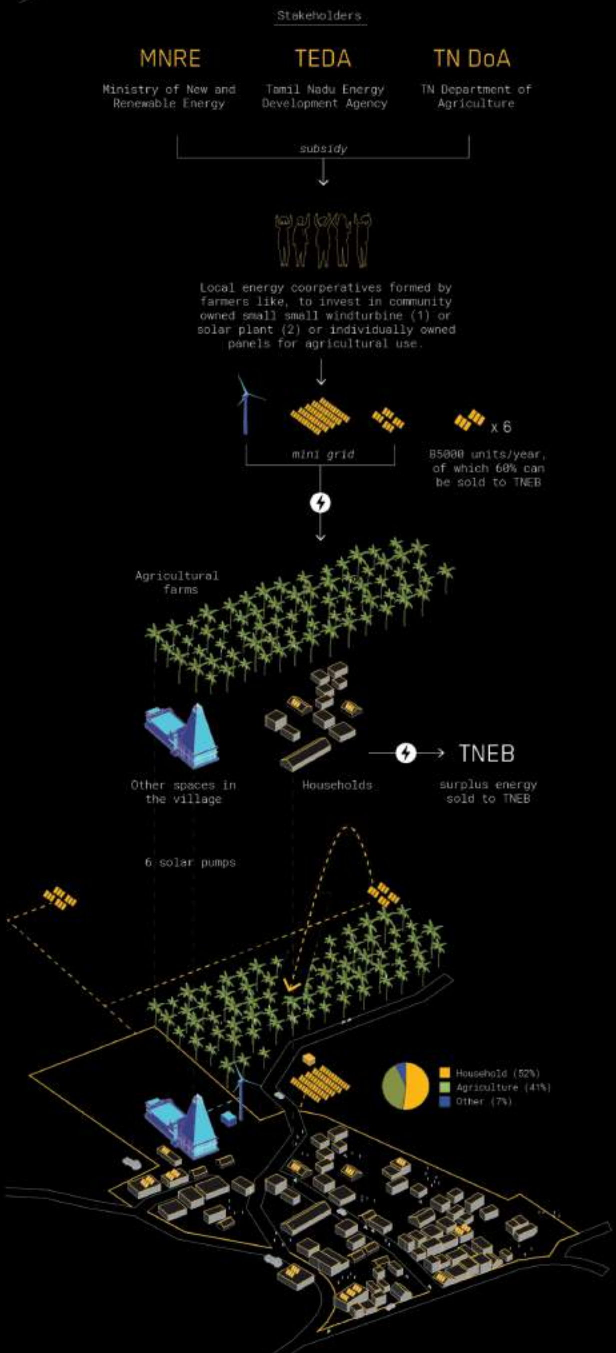
Proposed situation

Detail: Solar Village Pilot Project.

S3: Coproduction

C. Rural mini-grids- agriculture





Detail: Solar Village Pilot Project.

Existing situation

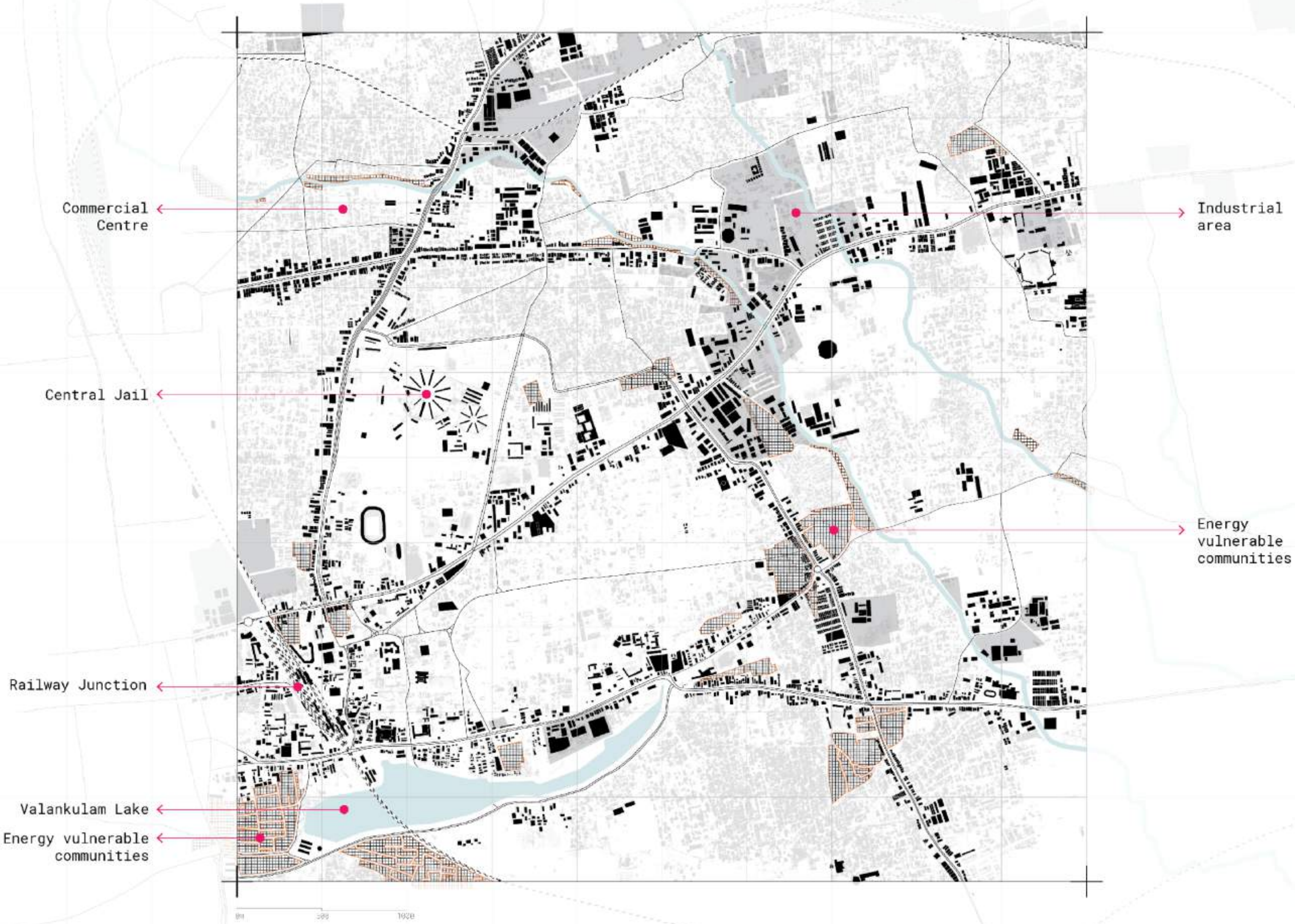
Detail: Solar Village Pilot Project.

Proposed situation

Strategic Zoom-in B: Coimbatore city centre.

Existing situation.

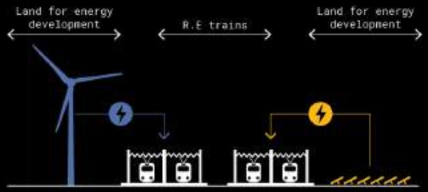
Coimbatore city centre



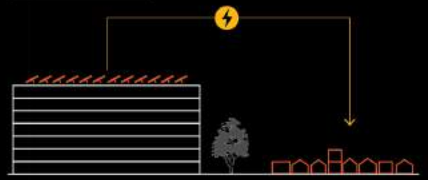
Design interventions.

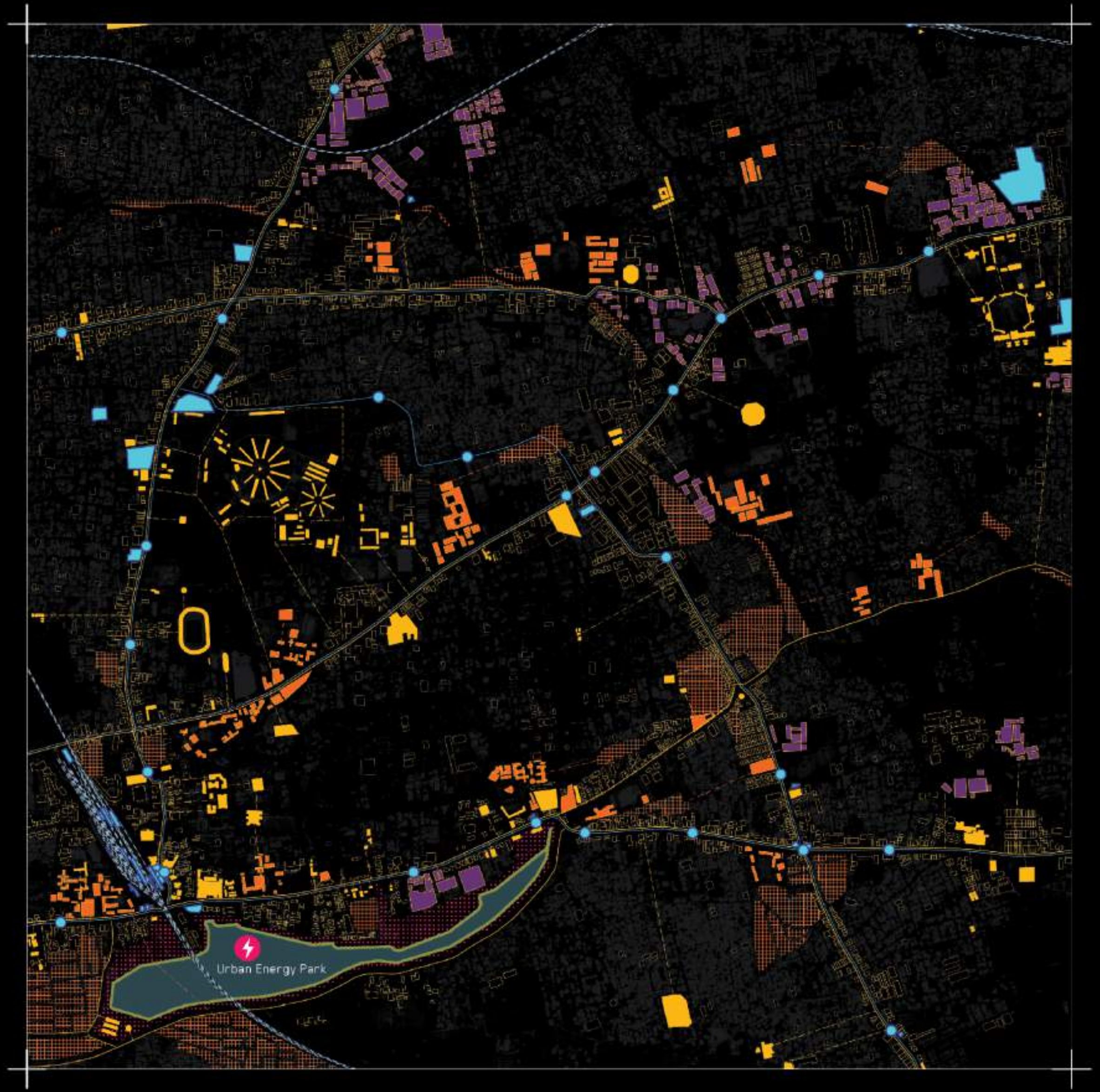
Coimbatore city centre

S2: Crrossprogramming.



S3:; Coproduction.





- Sites for EV charging stations
- Important transit points powered by R.E
- Railway network
- Energy x Mobility Network
- Public buildings with solar PV on roofttops
- Industries with solar PV
- Connection to the Public Energy Network
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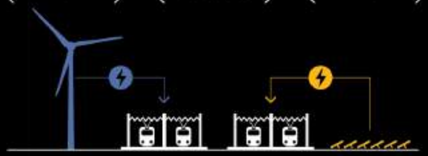
- Schools and educational instituions near energy vulnerable communities
- Informal settlements and energy vulnerable communities

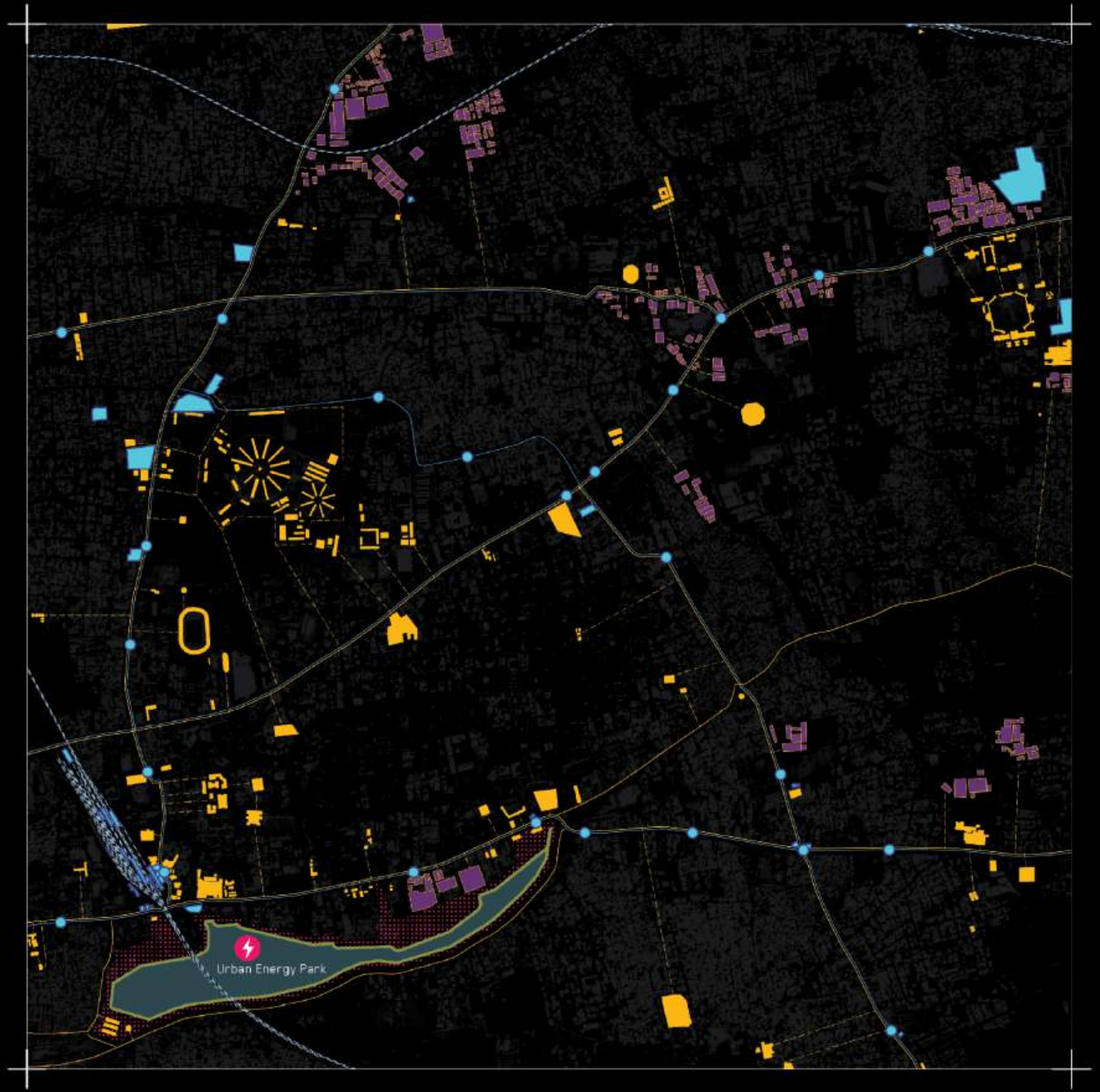
Design interventions.

Coimbatore city centre

S2: Crrossprogramming.



S3: Coproduction.



- Sites for EV charging stations
- Important transit points powered by R.E
- Railway network
- Energy x Mobility Network
- Public buildings with solar PV on roofttops
- Industries with solar PV
- Connection to the Public Energy Network
- Public Energy Network
- Urban Energy Park for Coimbatore

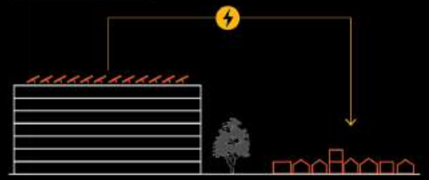
- Residences with solar PV on rooftops forming the neighbourhood energy networks
- Schools and educational institutions near energy vulnerable communities
- Informal settlements and energy vulnerable communities

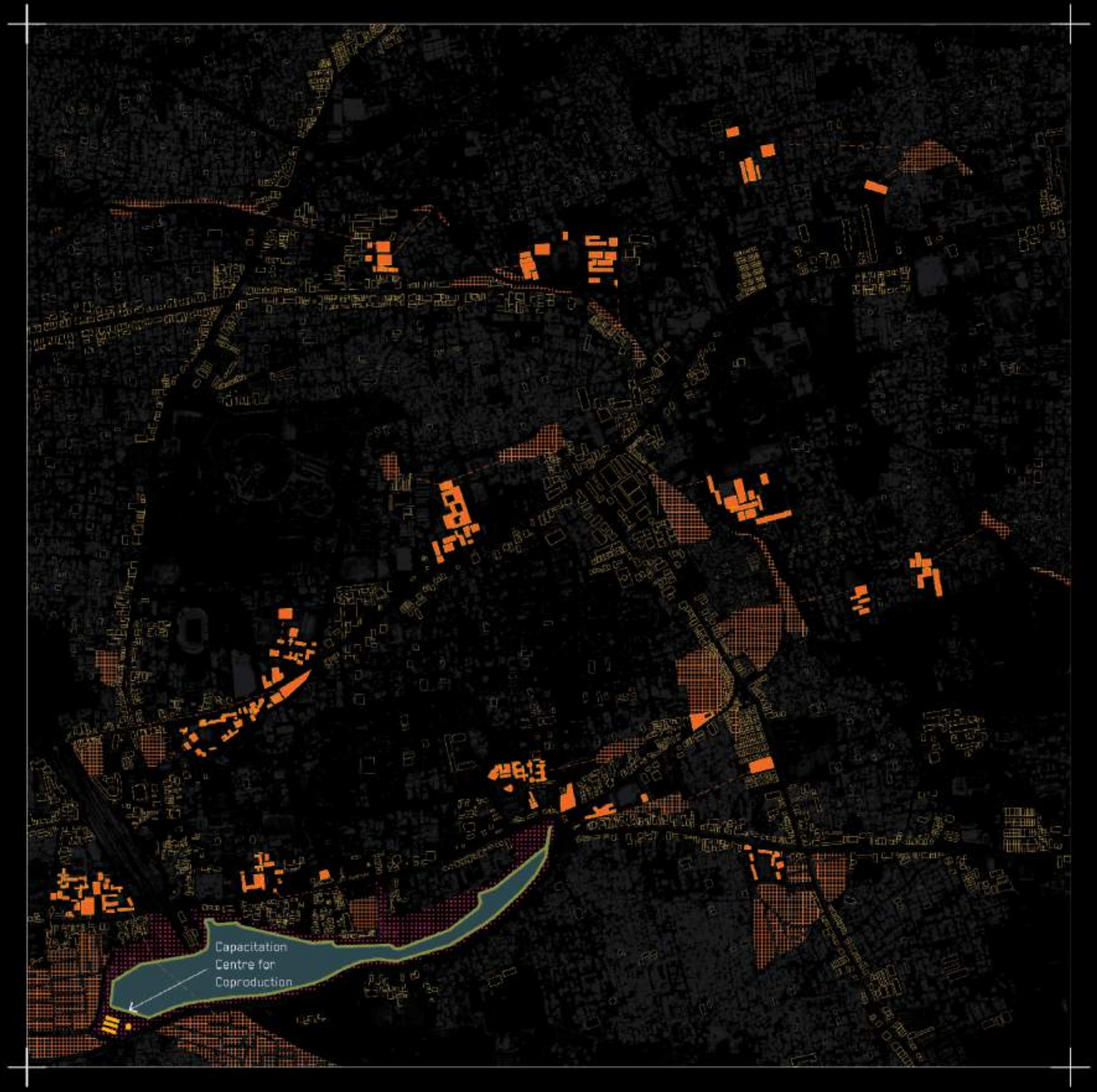
Design interventions.

Coimbatore city centre

S2: Crrossprogramming.

S3:; Coproduction.



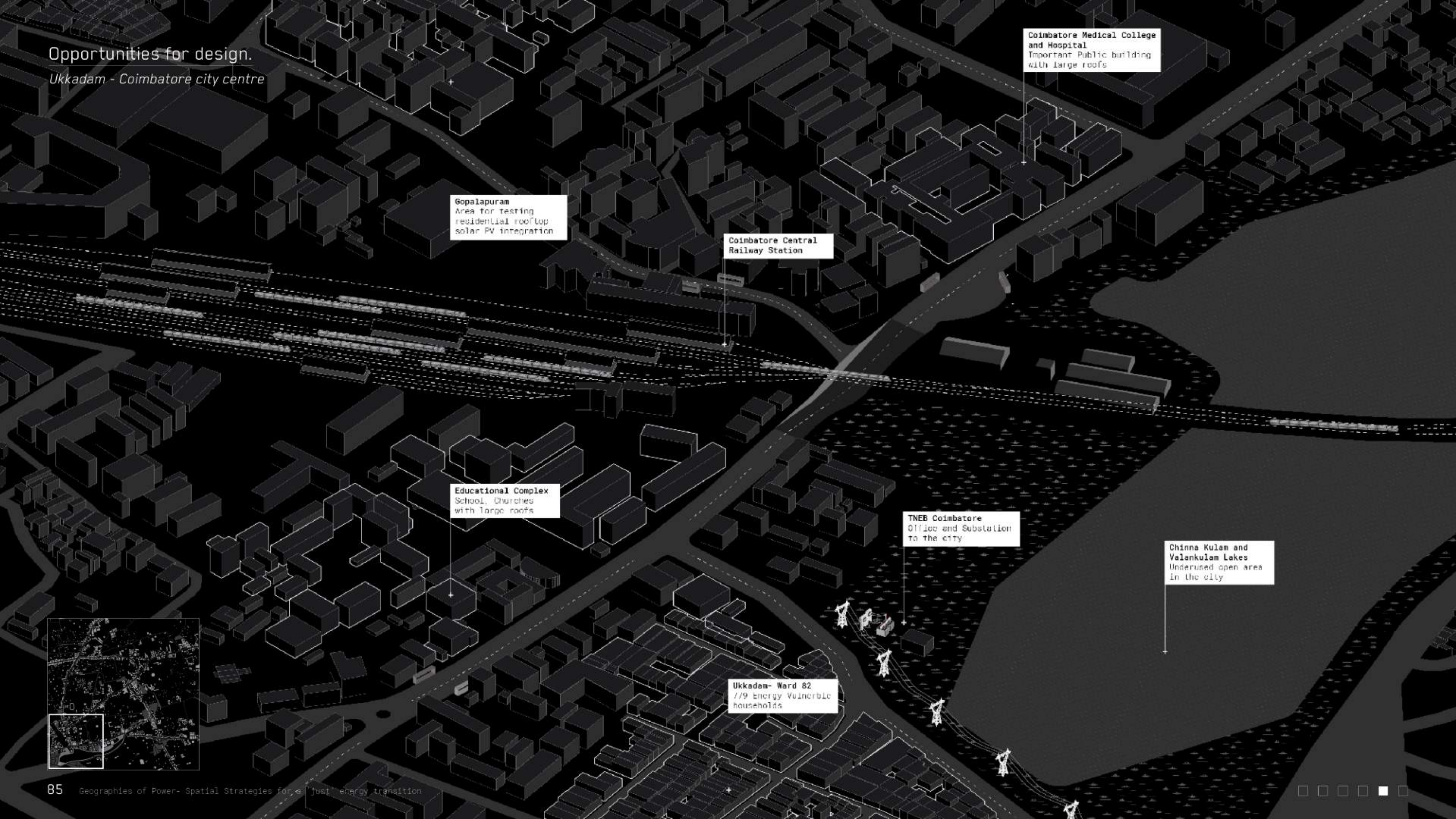


Sites for EV charging stations
Important transit points powered by R.E
Railway network
Energy x Mobility Network
Public buildings with solar PV on rooftops
Industries with solar PV
Connection to the Public Energy Network
Public Energy Network
Urban Energy Park for Coimbatore

Residences with solar Pv on rooftops forming the neighbouhood energy netwroks
Schools and educational instituions near energy vulnerable communities
Informal settlements and energy vulnerable communities

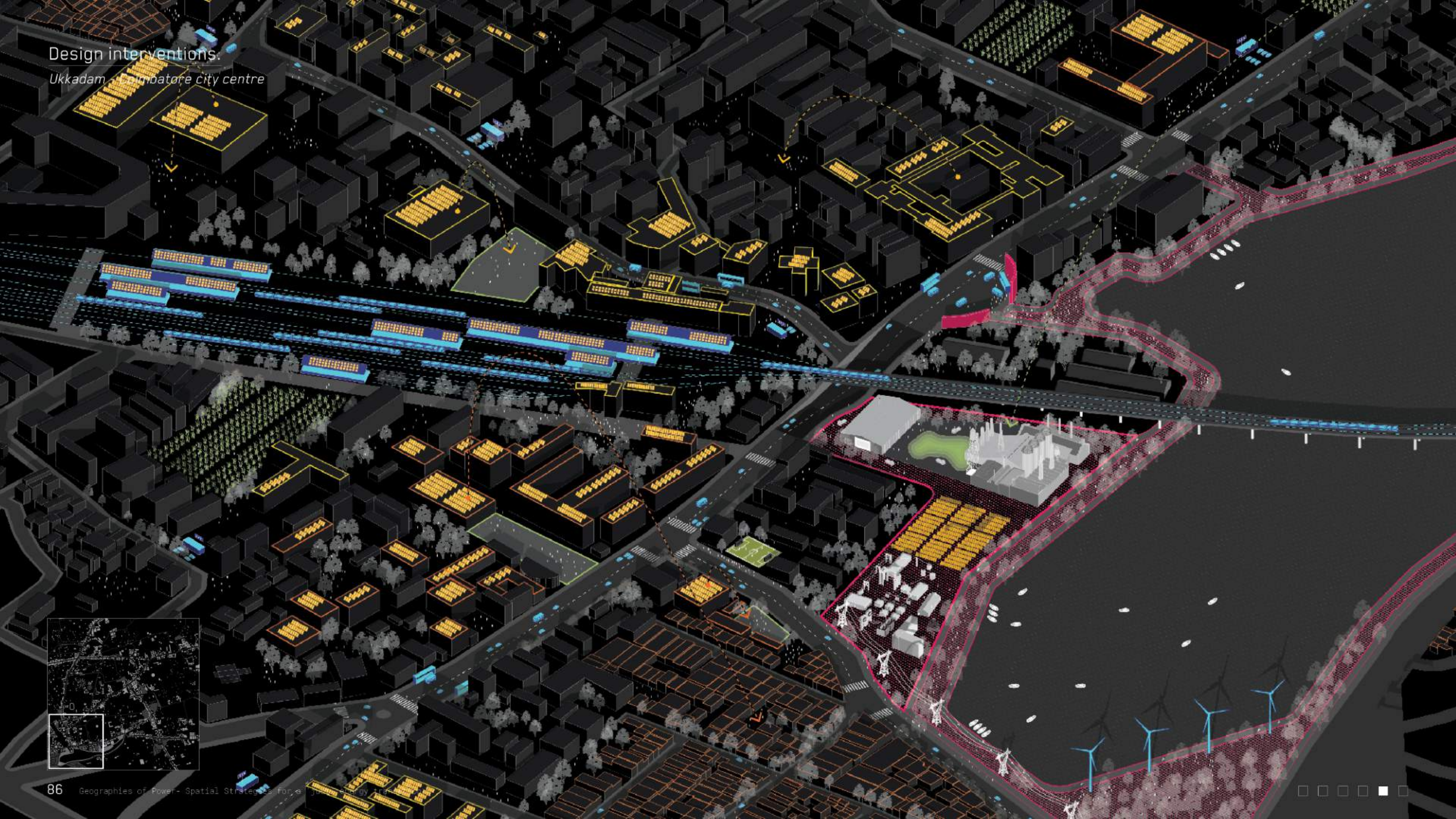
Opportunities for design.

Ukkadam - Coimbatore city centre



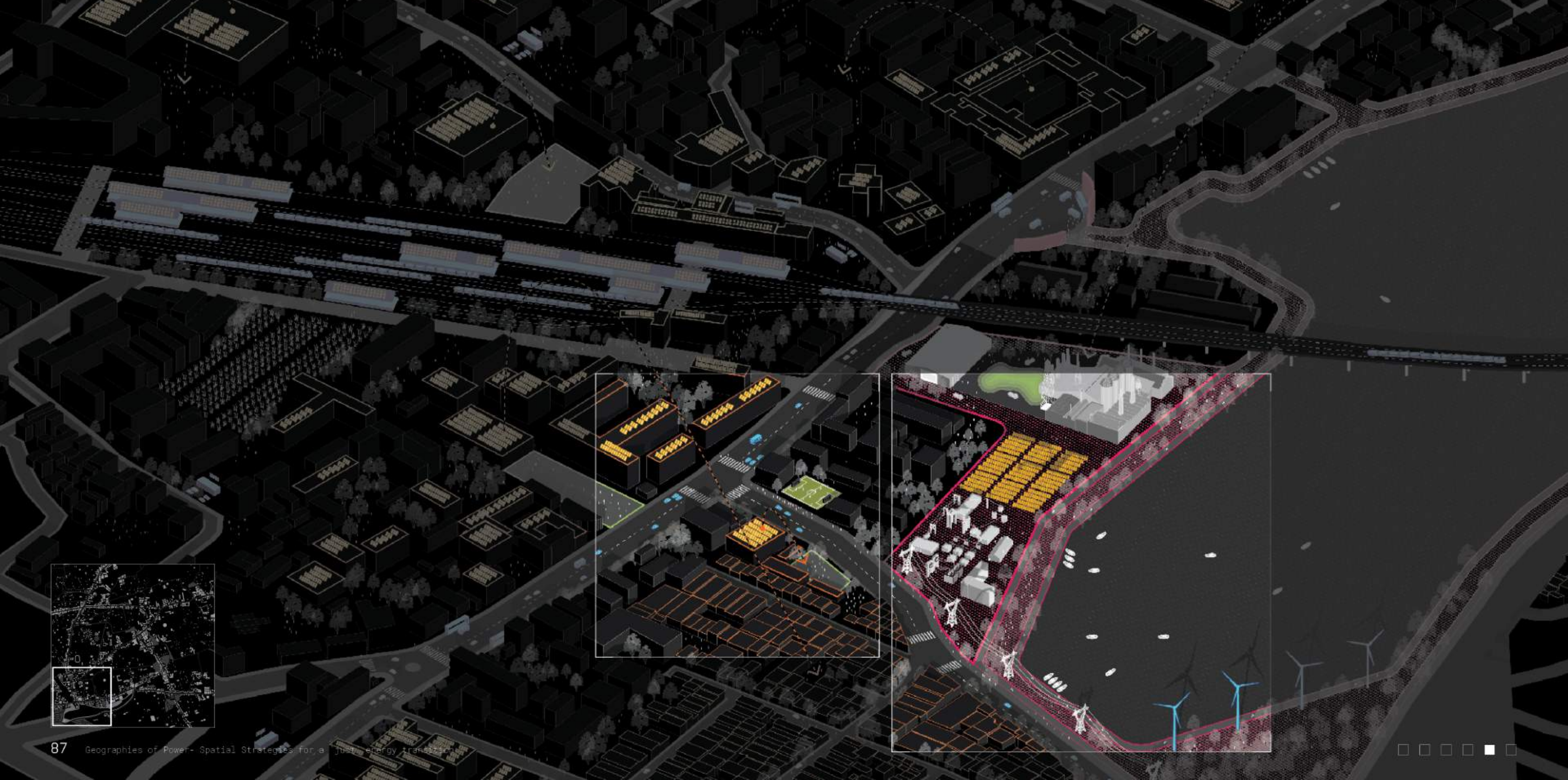
Design interventions:

Ukkadam - Coimbatore city centre



Design interventions.

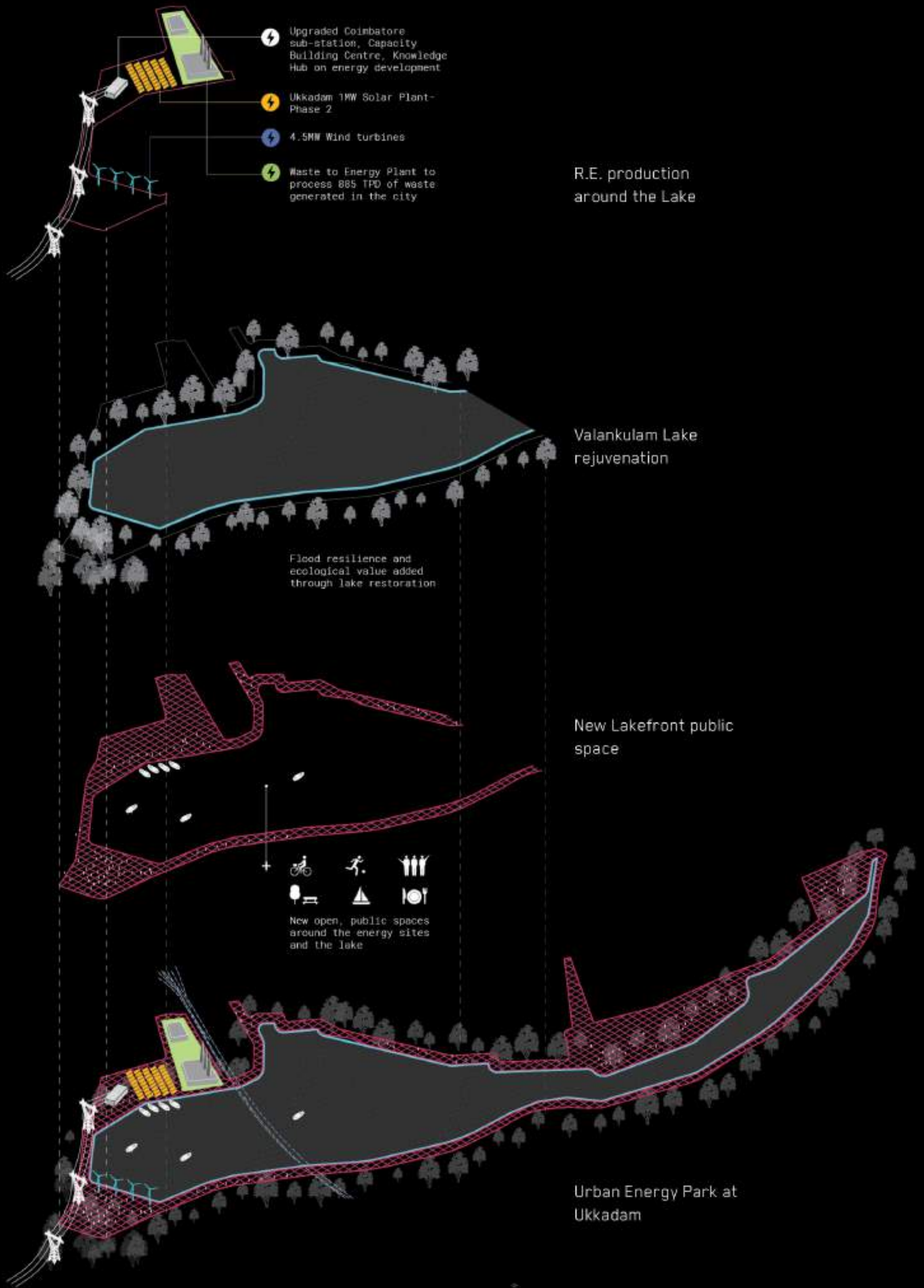
Ukkadam - Coimbatore city centre

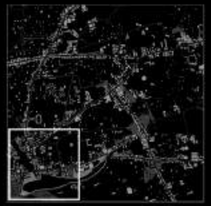


Detail: Urban Energy Park

S2 : Cross program.

C. Energy x Public Infrastructure



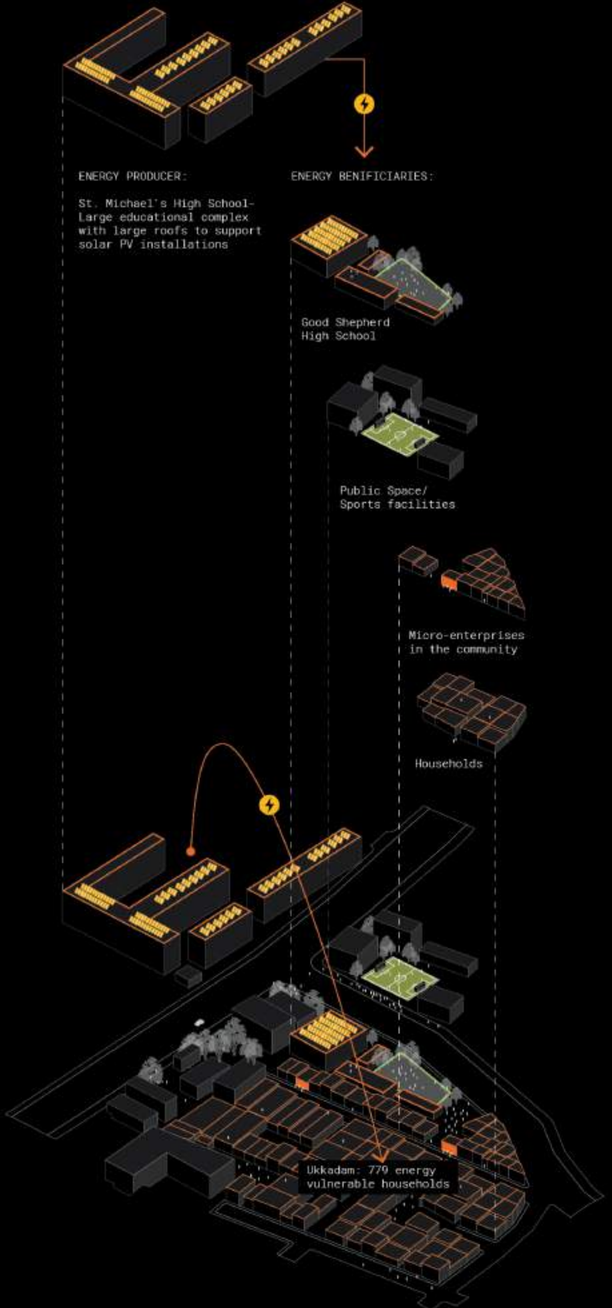


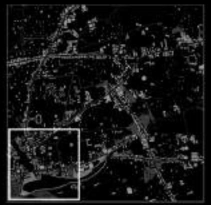
Key plan

Detail: Ukkadam energy sharing Pilot Project

S3: Coproduction

B. Energy sharing with vulnerable communities





Key plan

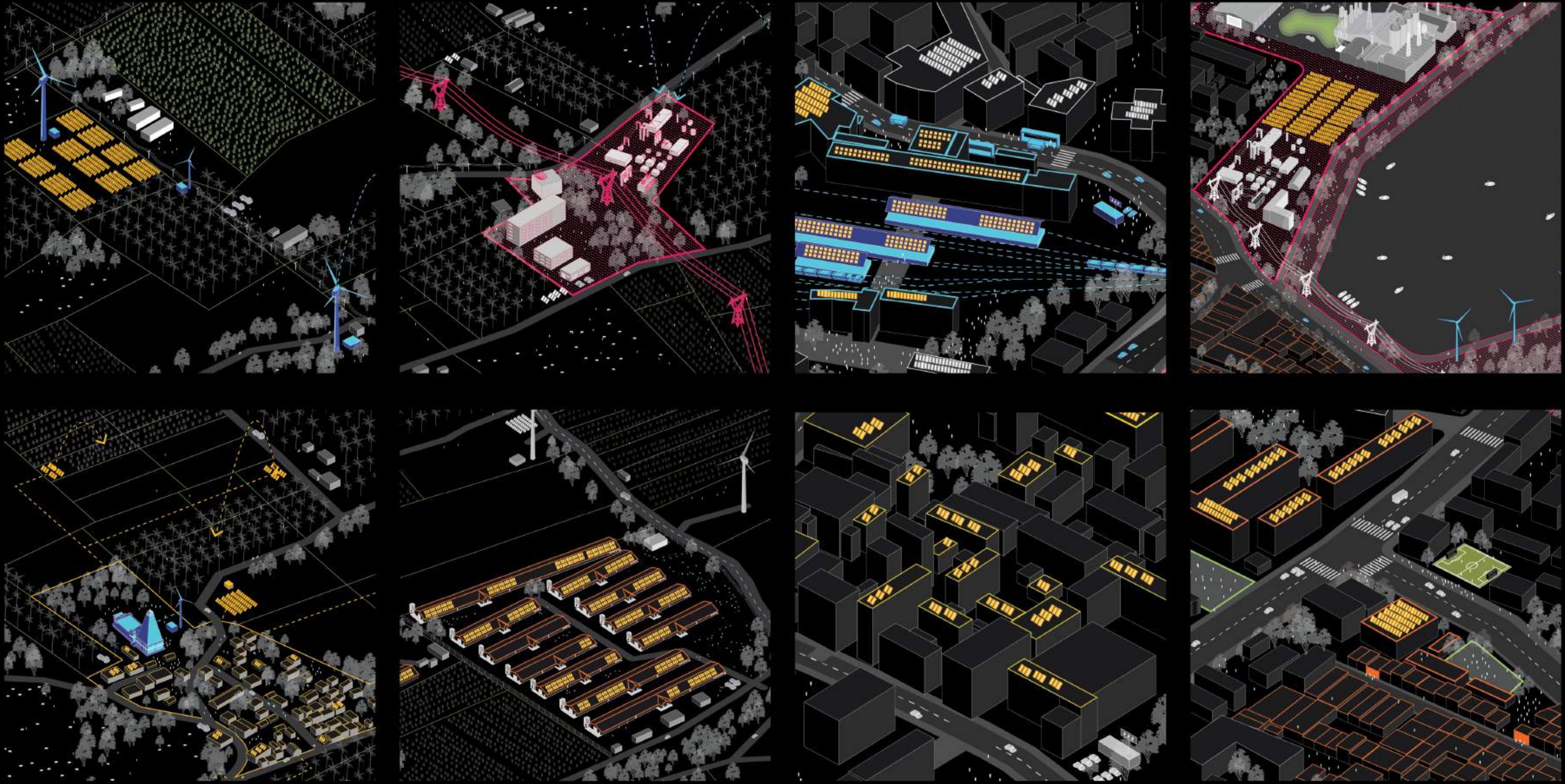
Design interventions.

Existing situation

Design interventions.

Proposed situation

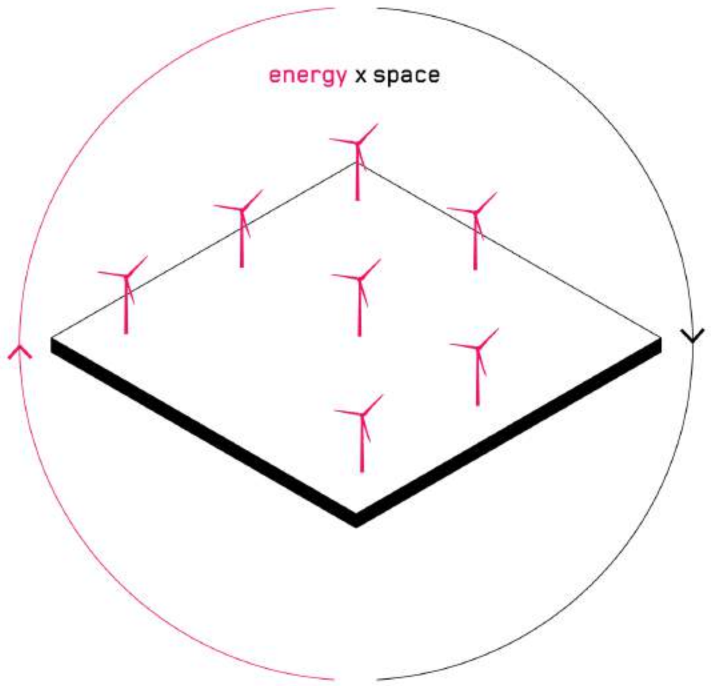
Outcomes of the Testing.



8

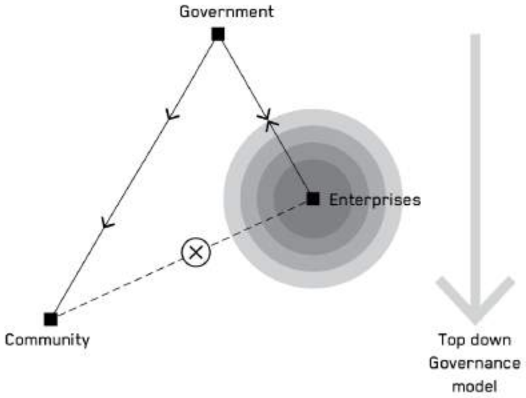
Conclusions

To conclude,

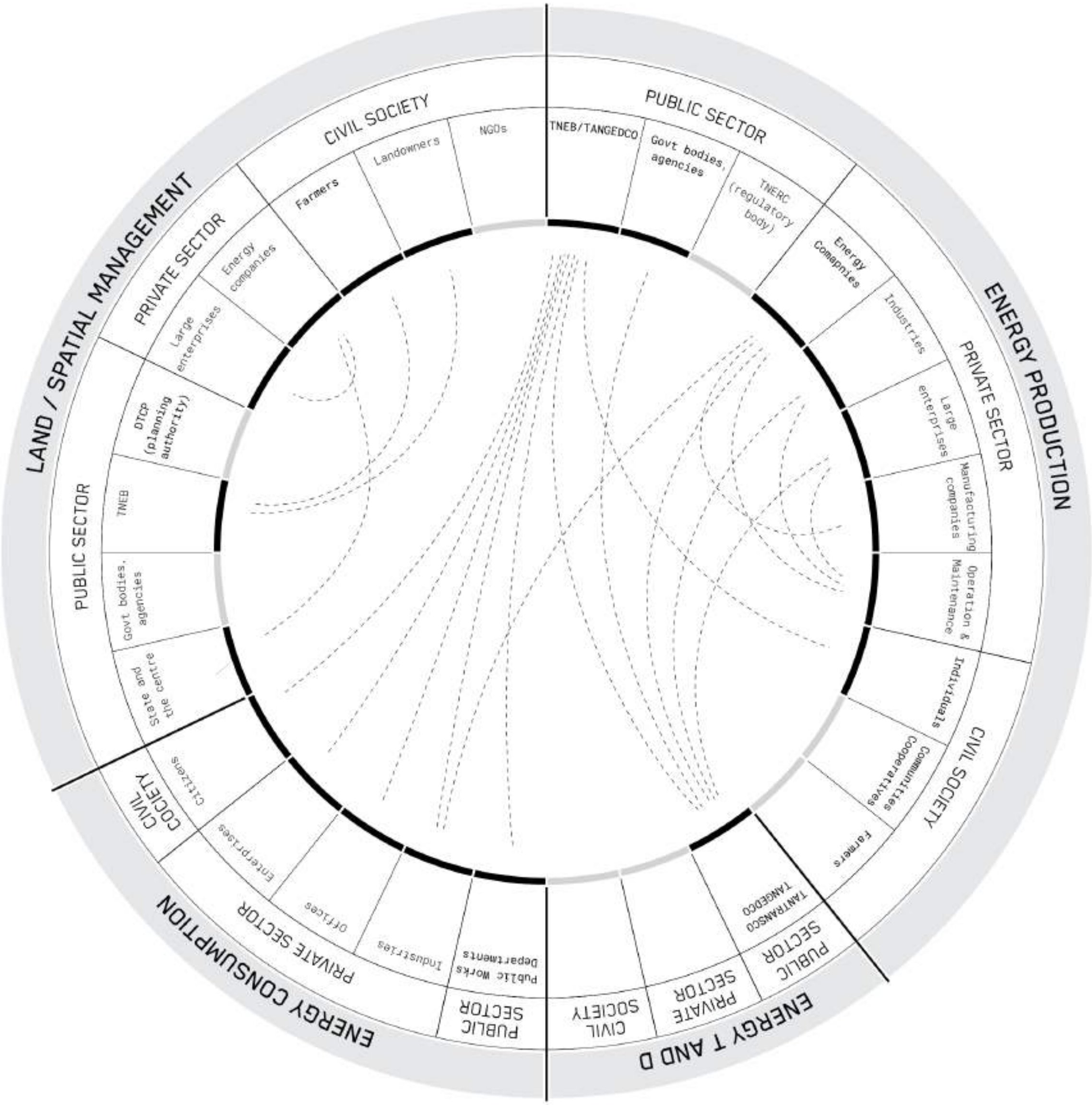


1. Transformations in transition governance.

Existing stakeholder relationships

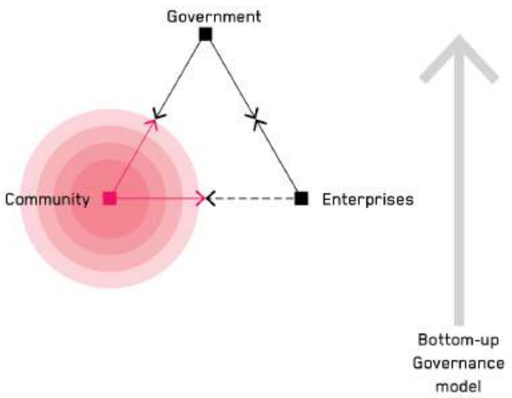


Current governance model

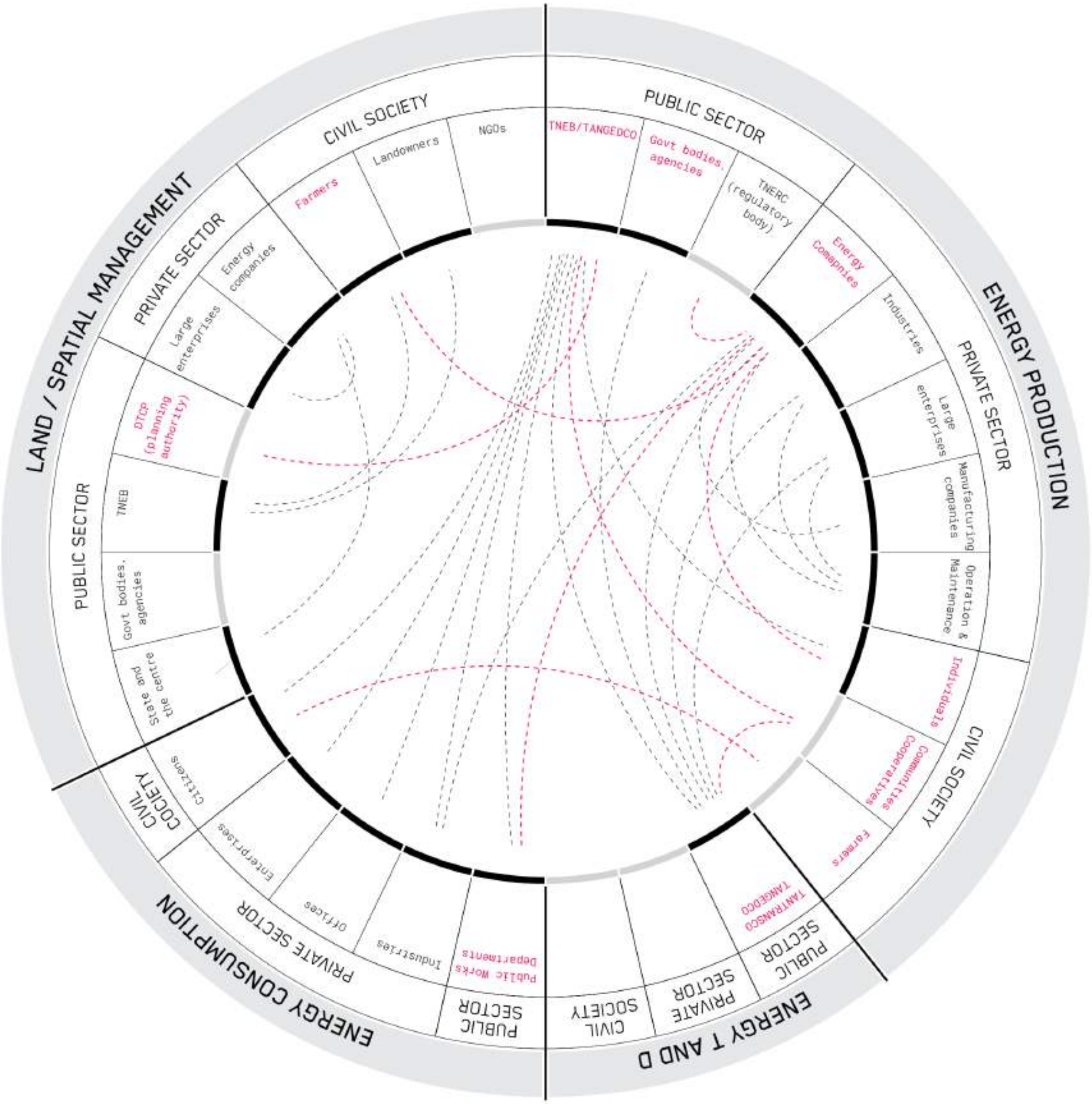


1. Transformations in transition governance.

New stakeholder relationships

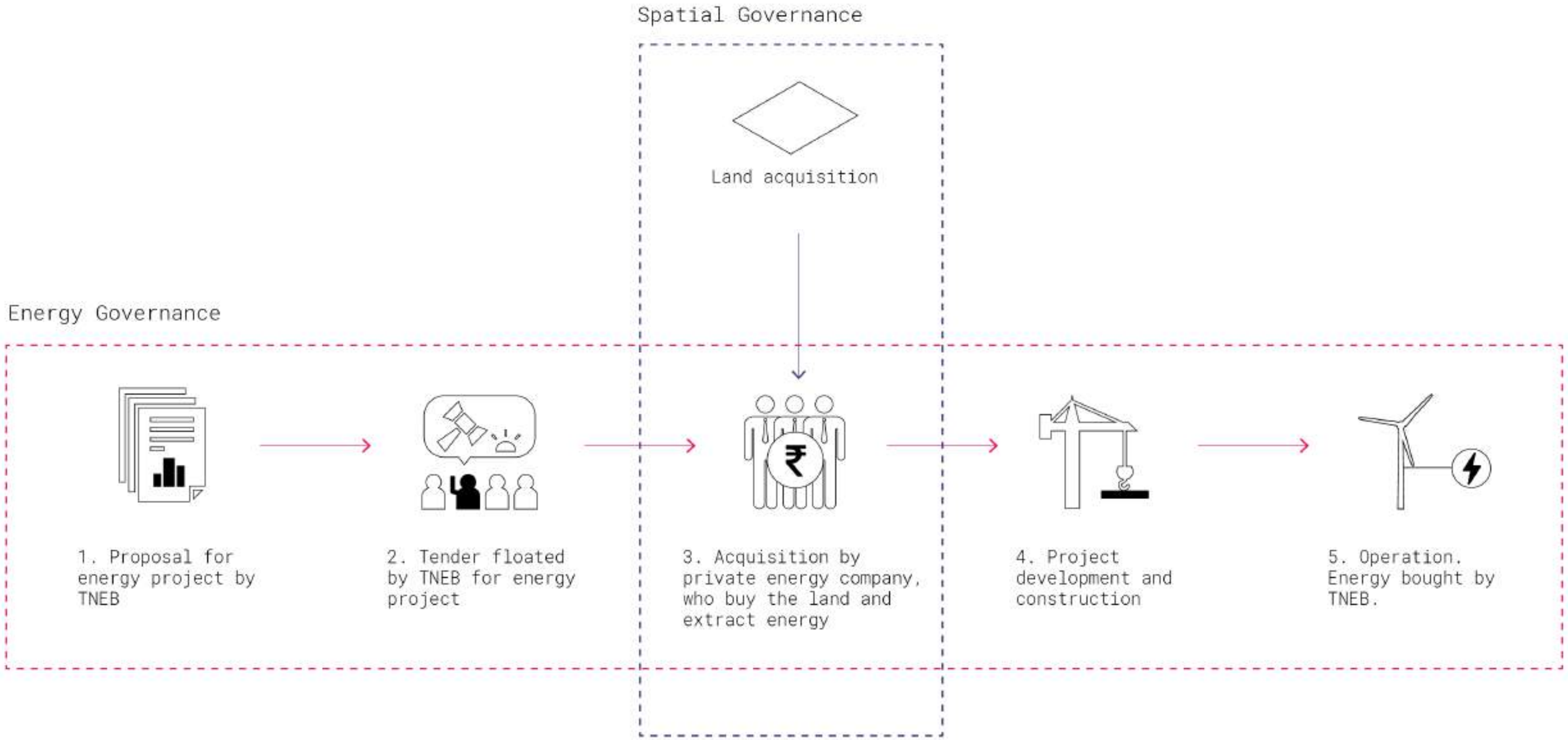


Desired governance model



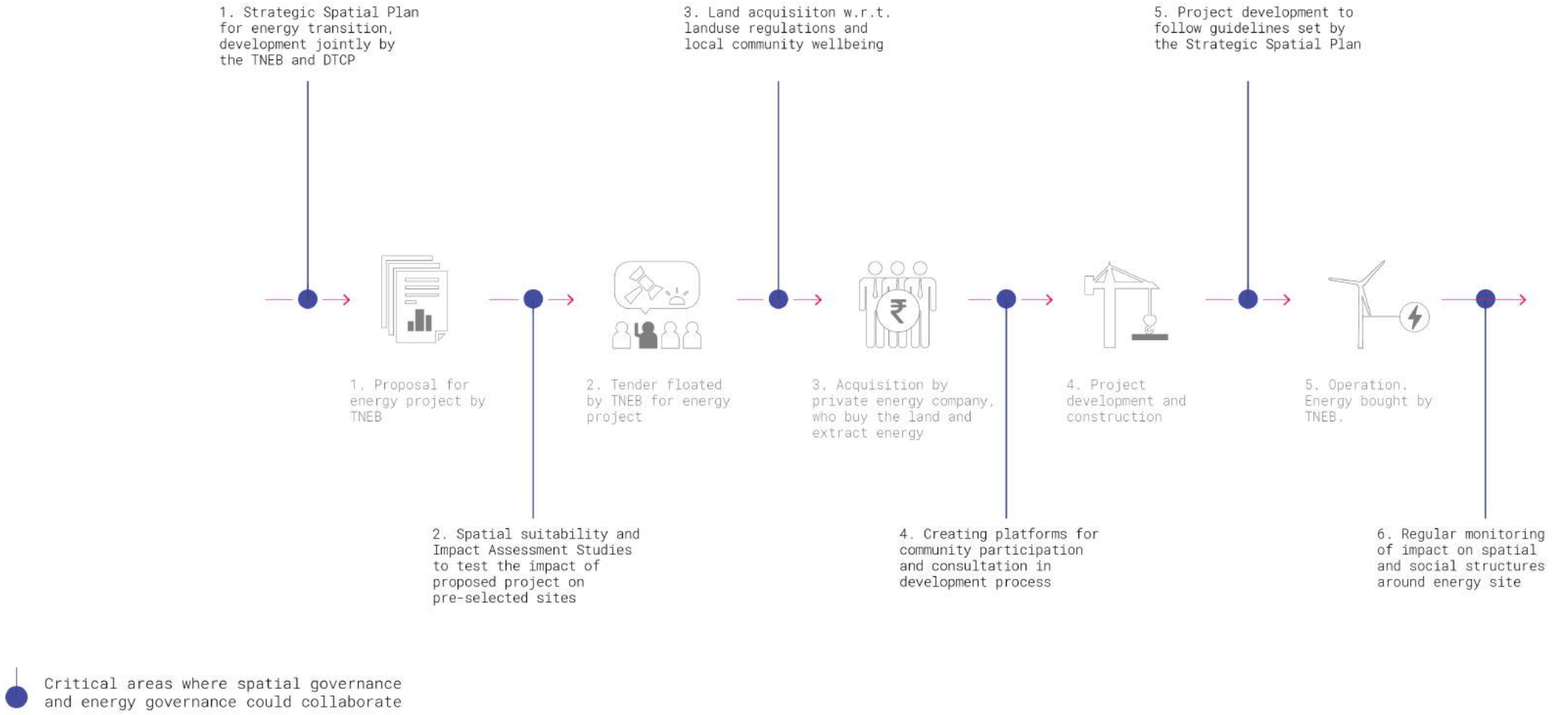
2. Critical areas of collaboration between energy and spatial governance

Existing model of development



2. Critical areas of collaboration between energy and spatial governance

New model of development



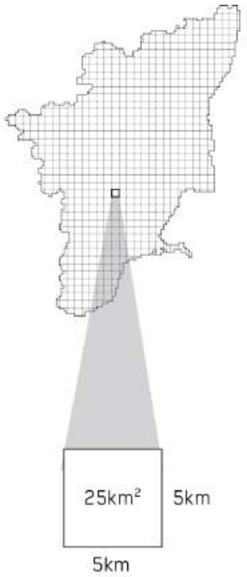
3. Transferability of the methodology.

in developing countries

Step 1:

Creatng a Spatial Grid

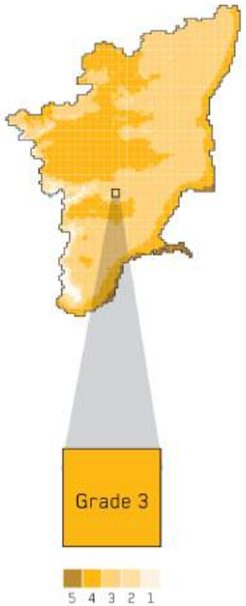
5x5km grid is overlaid to have a common spatial unit for analysis



Step 2:

Evaluating the Grid

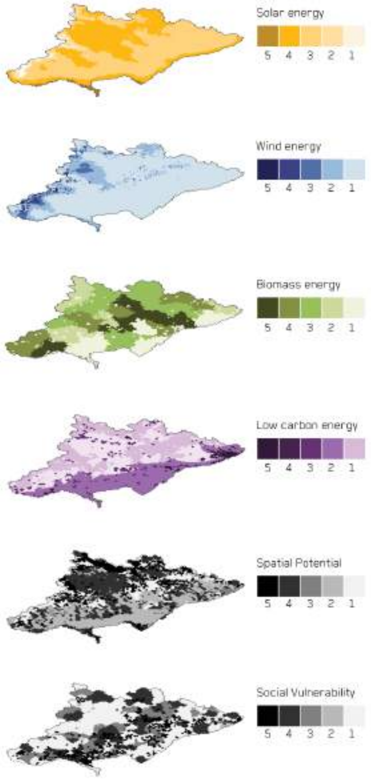
Each square is graded from 1-5, 5 being thhe highest, based on certain input parameters (energy potentials, spatial potentials, etc)



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.

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)

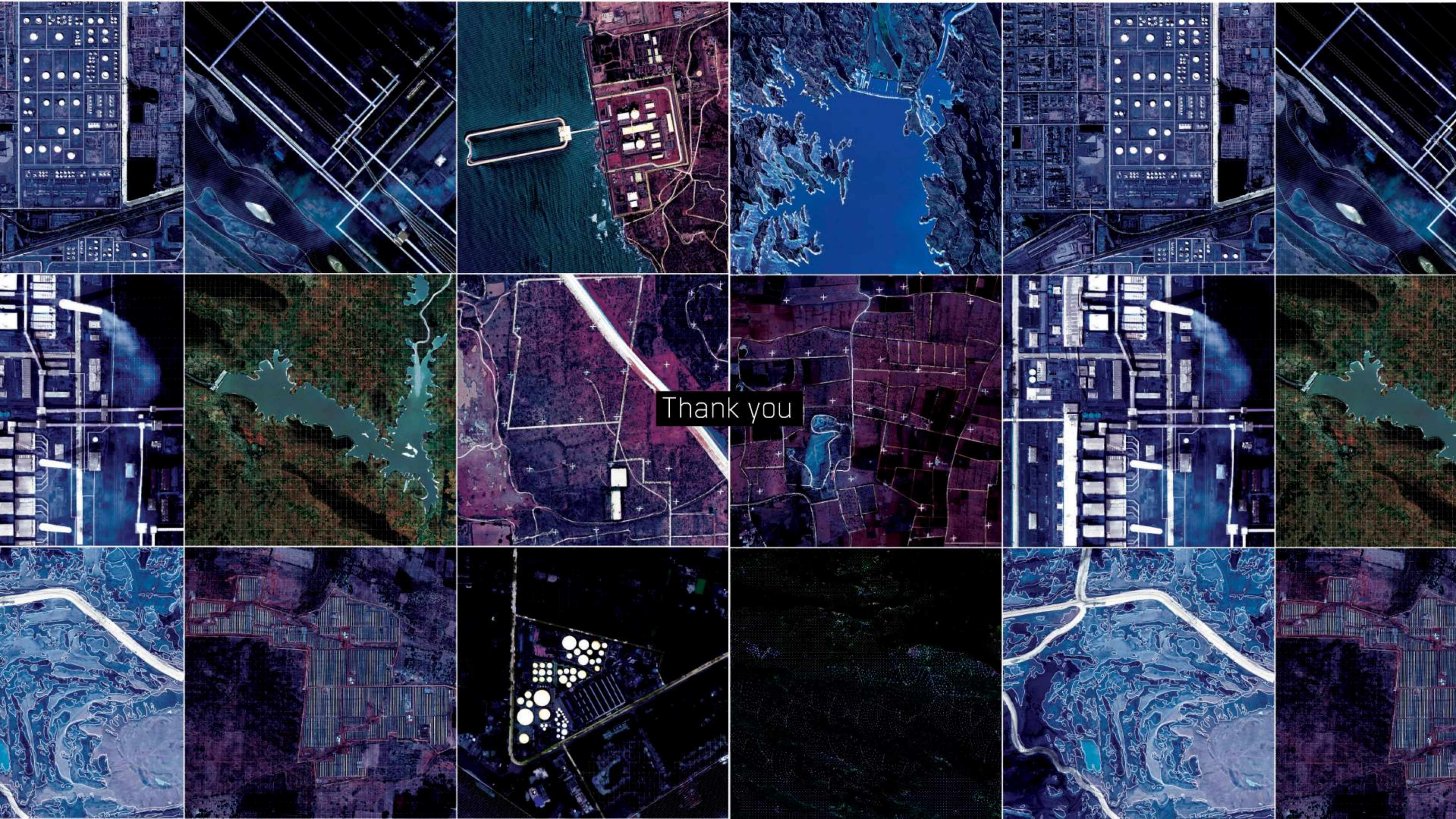
Output 8: Areas of highest energy potential and spatial potential (Derived from Outputs 5,6)

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

Step 5:

Inputs for design

The ouput iterations provide valuble insights on where and how regional design strategies can be implement-ed


Thank you

X

Appendix

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.

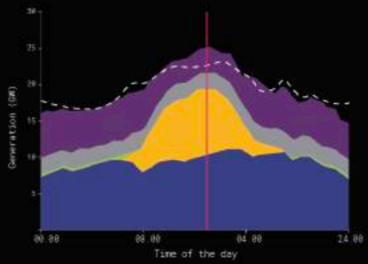
Fig 8.24: Comparing two extreme energy situations in 2050.

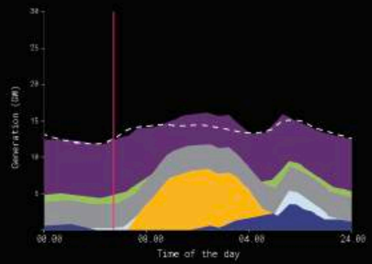
High R.E. day: 2nd June 2050, 12.45pm *

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.

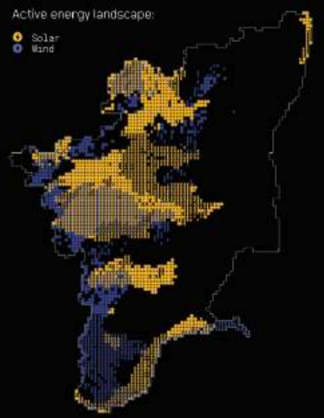
Low R.E. day: 26th October 2050, 05.15pm *

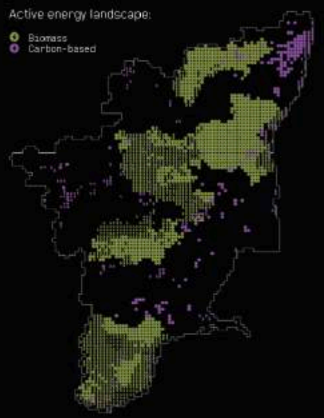
The graph below shows the overall energy production at different times of the day on 26th October, 2050. Since it is low R.E. production day, only 0.2% of energy is from solar and wind energy sources. The values are based on the energy mix at the point of measurement- 05.15am. The map below shows the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





* 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)





S6: Design interventions/Actions.

A. Increase the diversity and multi-functionality

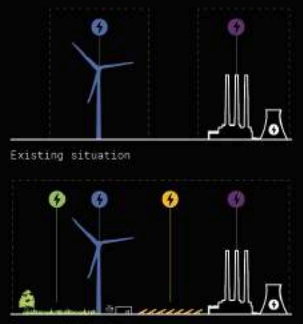
By increasing the diversity and multi-functionality of energy landscapes through Strategy 1 and Strategy 2, the fluctuations in energy supply is reduced.

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.



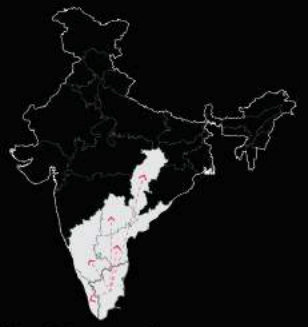


Fig 8.25: Design interventions for flexibility of energy network

C. Store and Release

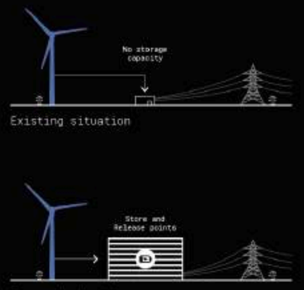
Investing in energy storage infrastructure is one of the solutions to overcome the diurnal (solar) and seasonal (wind) fluctuations in renewable energy supply. By storing surplus R.E. during the peak season in energy storage points, and releasing it for use during the off-peak season, energy deficit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

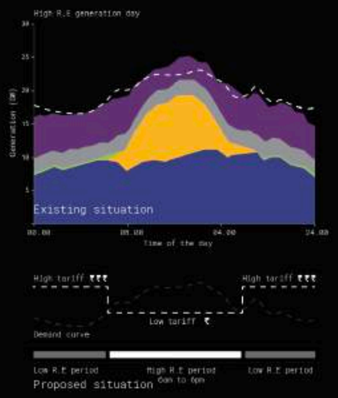
However, the project acknowledges that although energy storage technology is becoming more commonplace, it is still very expensive and also negatively impacts the environment due to its chemical composition. The project, while noting it as a relevant solution to grid variations, does not elaborate on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

D. Enforce demand-side management

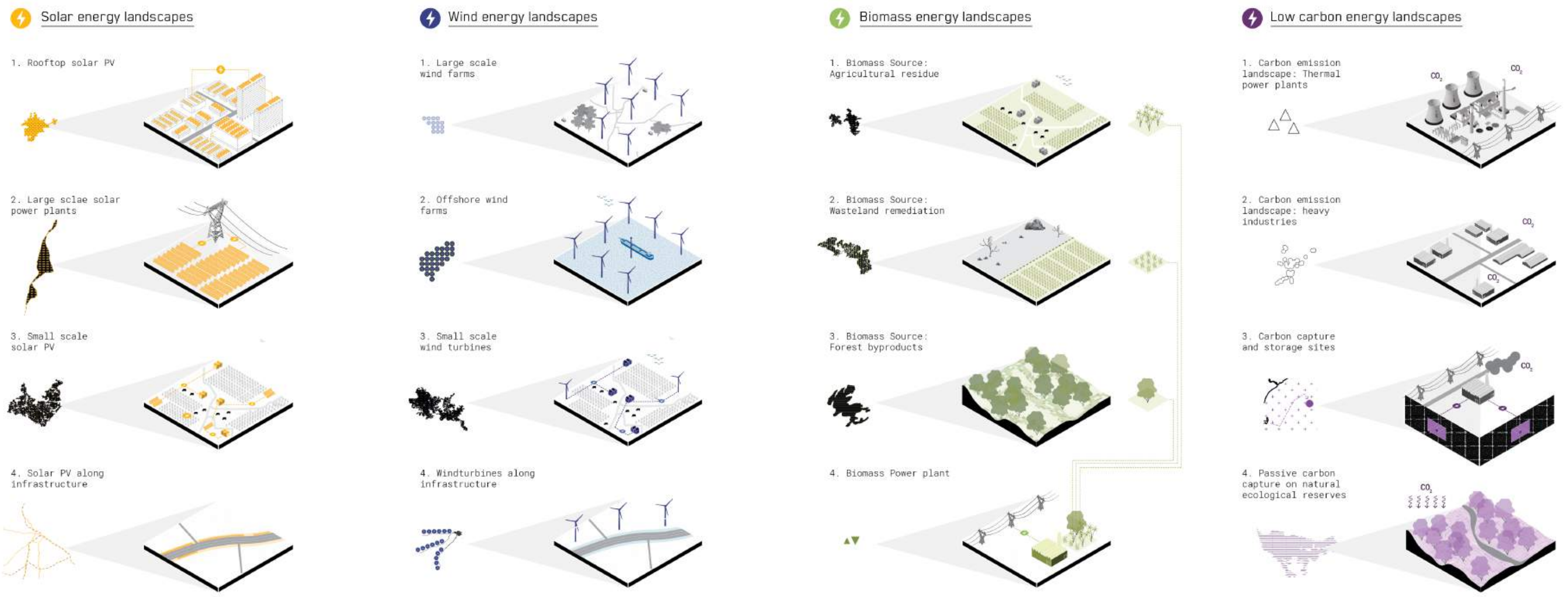
While technological solutions like the ones explained in A, B and C, this solution takes a softer approach to addressing the fluctuations in R.E. supply. By altering energy demand and consumption patterns to align with R.E. generation period (6am to 6pm typically), the dependency on coal powered energy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





Catalogue of energy production landscapes



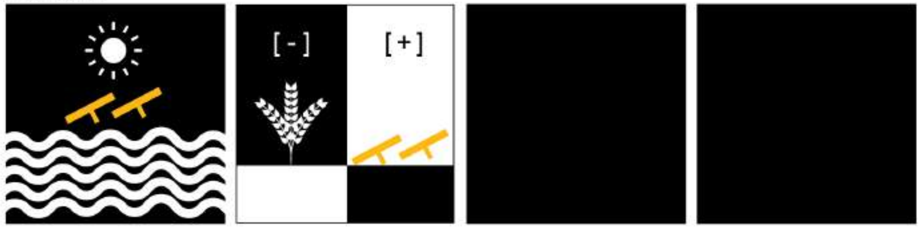
Tamil Nadu Energy Calculations 2050

Total energy installed capacity (MW)								Total energy demand/generation in a year (GWh)					
Energy mix	Ownership	2018	2022	2050	%	2050 (b)	Potential	2018	2022	2050	2050 (b)		Difference from existing
Thermal	State	4320	8500			12000							
Thermal	Centre	4603	5700			6500			59000		76866	82000	
Gas	State	516	1400			2000			4000		5714	6000	
Nuclear	Centre	1709	3400			4800			21000		29647	30000	
Hydro	State	2308	2000			3000			3000		4500	4500	
Wind	Private	8359	11900		53	28000	324282	11048	40000		94117	120000	108000
Solar	Private	2366	8900		42	16000	78505	2458	15000		26966	30000	27500
Solar rooftop	Private		3500			6000	259700		6000		10285	11000	11000
Biomass	Private	925	1200	1560	5	2000	1560		4800		8000	8000	6200
IPP (Thermal)	Private	746	600			1000			2000		3330	3400	
Purchase	Open Access	3630	2000			4000			4000		8000	8000	
Total (Sum)		29482	49100			85300	664047		158800		267425	302900	
Total (Estimate)			49100	55500		83200		110251	154000	200000	300000		
			Greening the Grid	CAGR 4% and 50% energy reduction measures		CAGR 6% and 50% energy reduction measures			Greening the Grid	CAGR 4% and 50% energy reduction measures	CAGR 6% and 50% energy reduction measures		
Just N.R.E						28300						122500	
Just R.E						52000						169000	
Peak demand in April (one day)		15440	26330	35000		55000		355					
Average energy demand per day								306					
Percapita consumption (kWh)		1200											
Sources:													
		TNEB	Sharma, 2016 Greening the Grid	Sharma, 2016				TNEB	Sharma, 201	Sharma, 2016			
Notes:													
				Biomass: Full realisation of Potential									

Analysis of Conflicts and Opportunities.

Conflicts

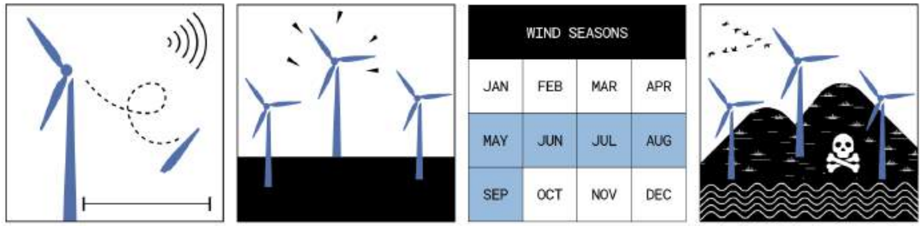
Solar Energy



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

2. Rapid landuse transformation to solar farms affects food security

Wind Energy



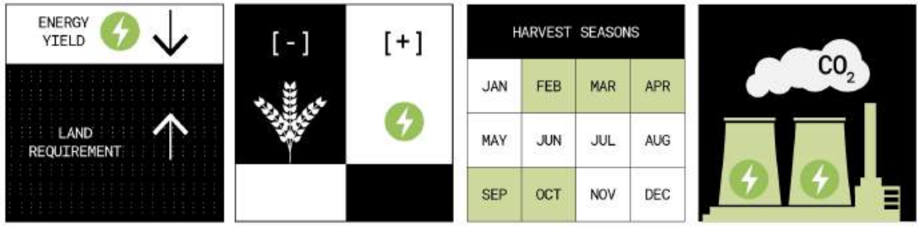
1. Causes noise pollution and needs safely buffer around windturbines

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



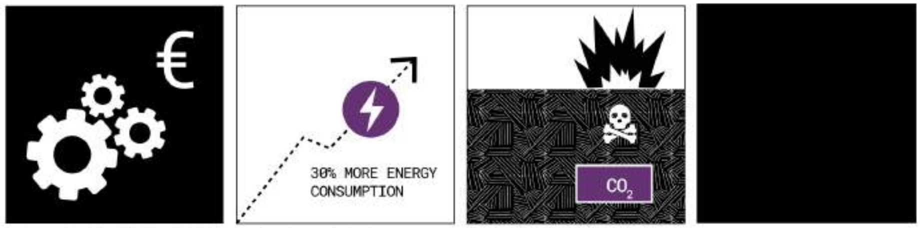
1. Lower energy yield compared to other types of R.E.

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 and Storage



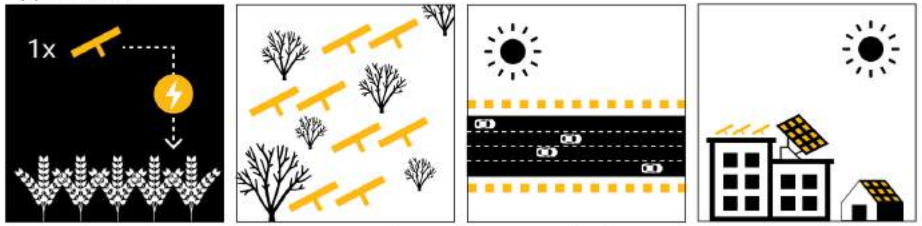
1. Technical and financial barriers

2. Consumes 30% more energy to function

3. Safety hazard due to leakage of stored carbon

Opportunities

Solar Energy



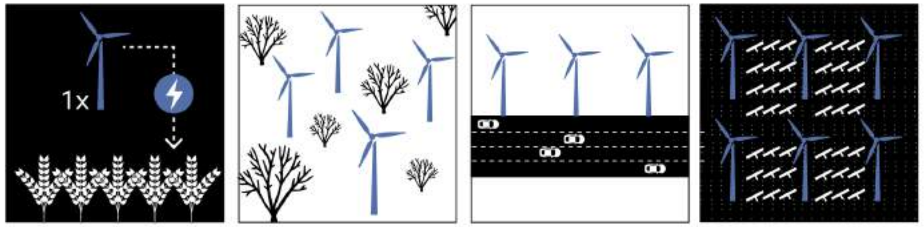
1. Small scale solar panels to support agriculture

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



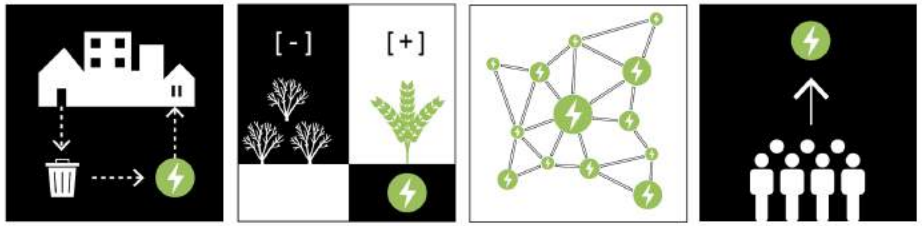
1. Small scale windturbine to support agriculture

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



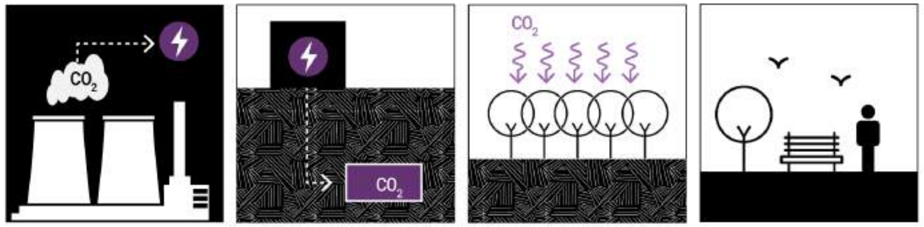
1. Waste to energy initiatives for urban areas that feeds back to the city

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 and Storage



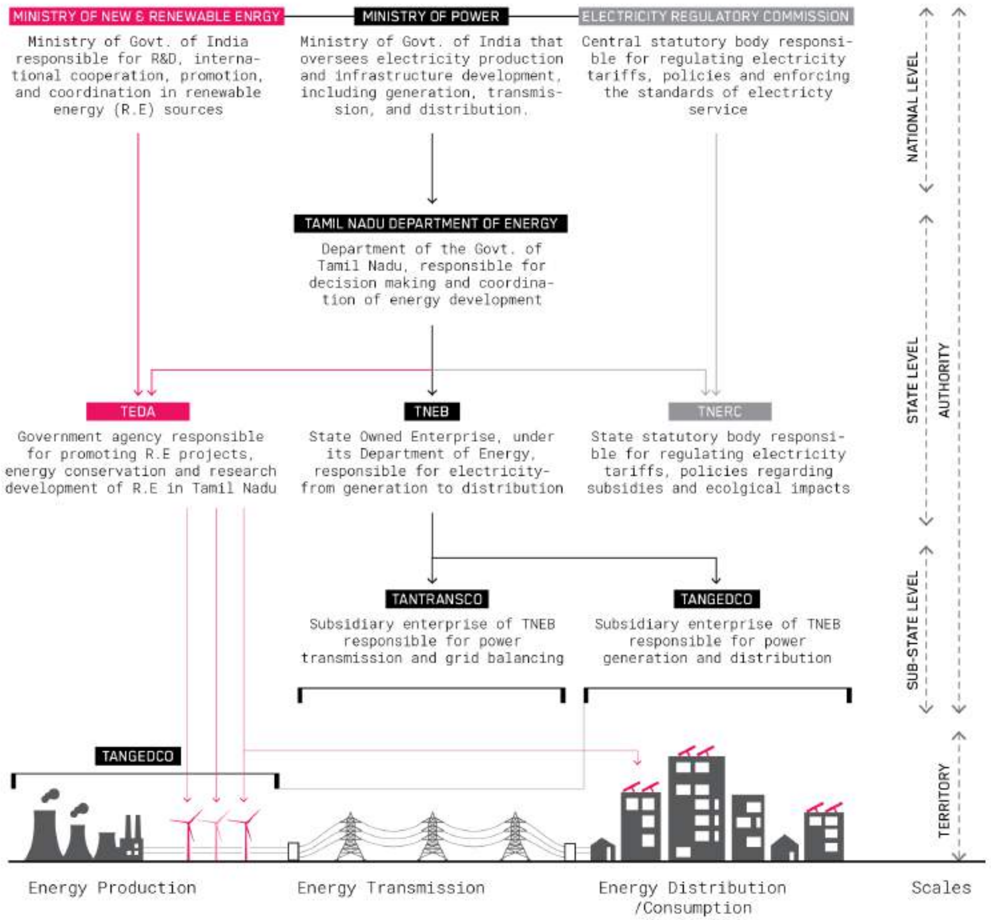
1. Can be retrofitted to existing thermal power plants and industries

2. Presence of good geological basins for carbon storage.

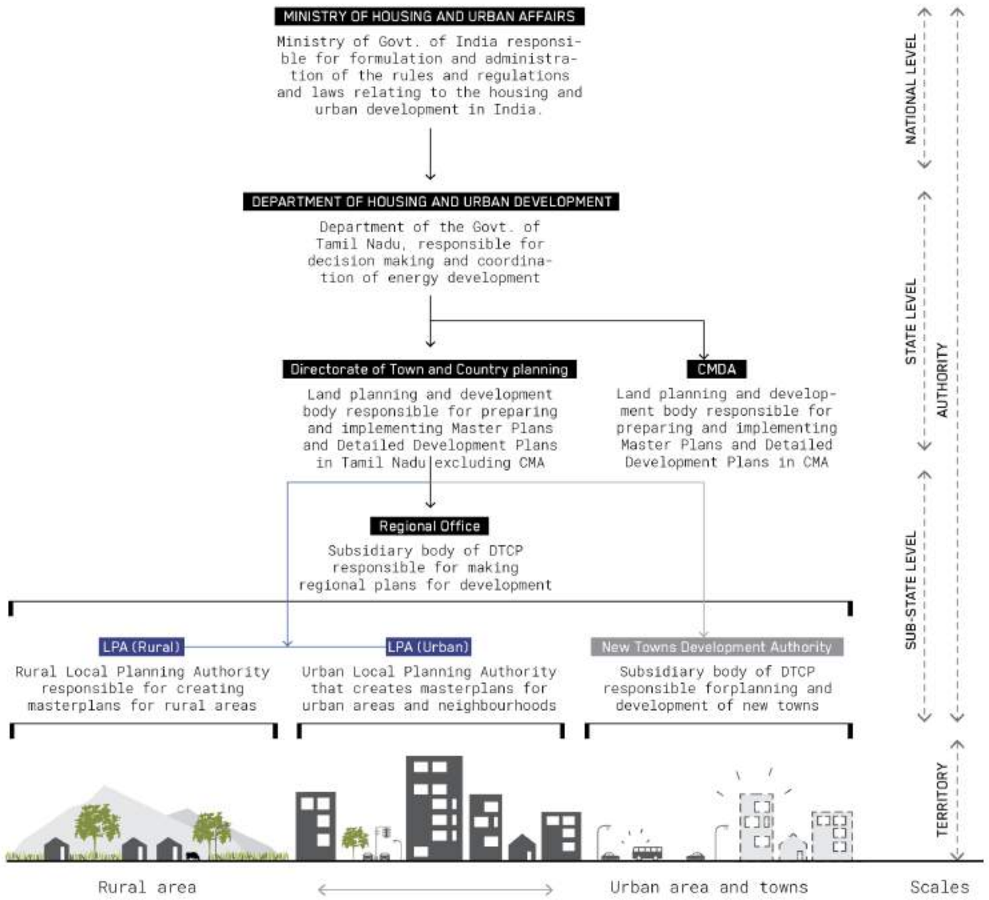
3. Use of natural carbon sinks like forests and croplands

4. Can reduce pollution and increase livability of urban areas

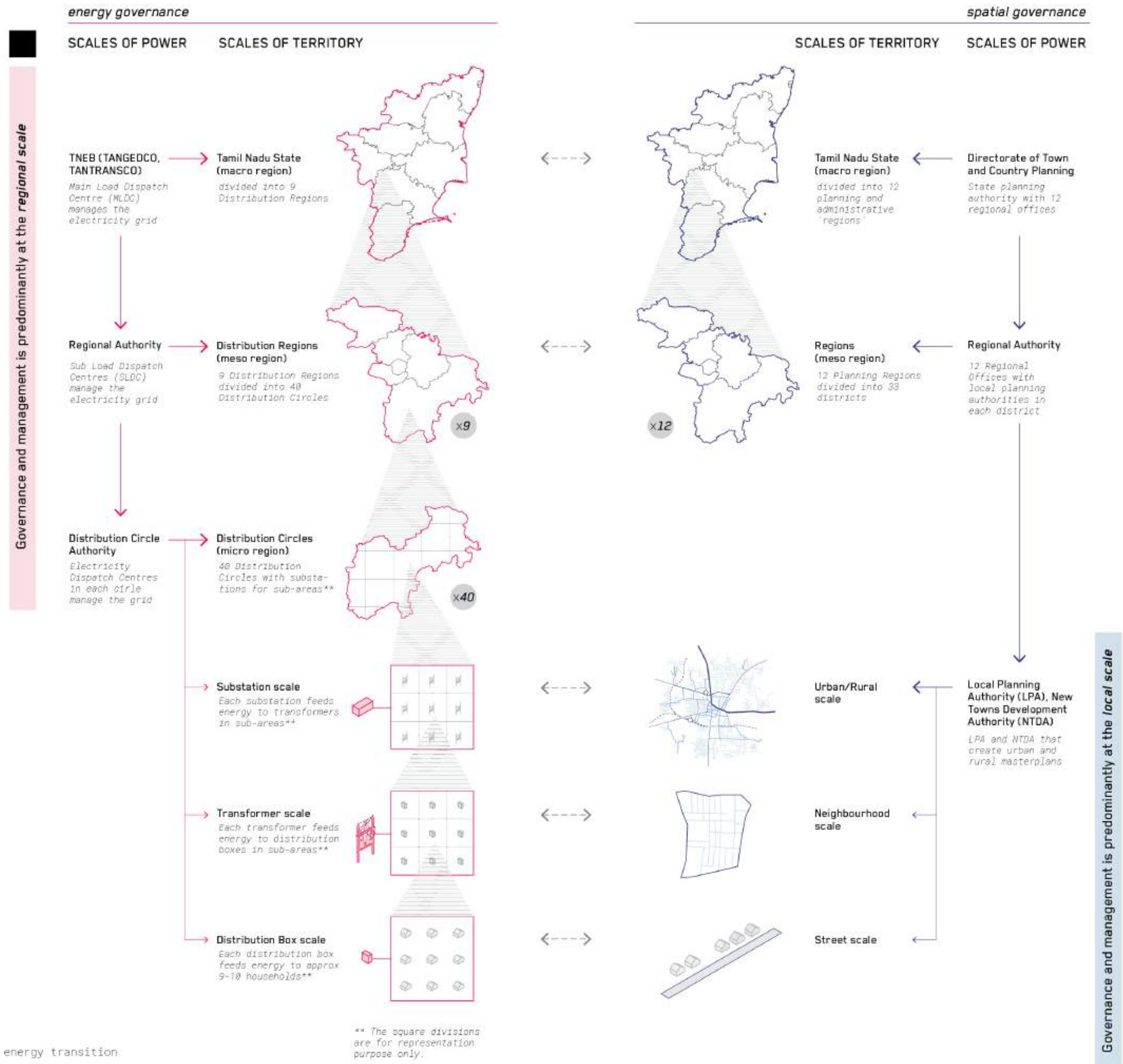
Energy Governance Structure



Spatial Governance Structure



... 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.



... 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.**