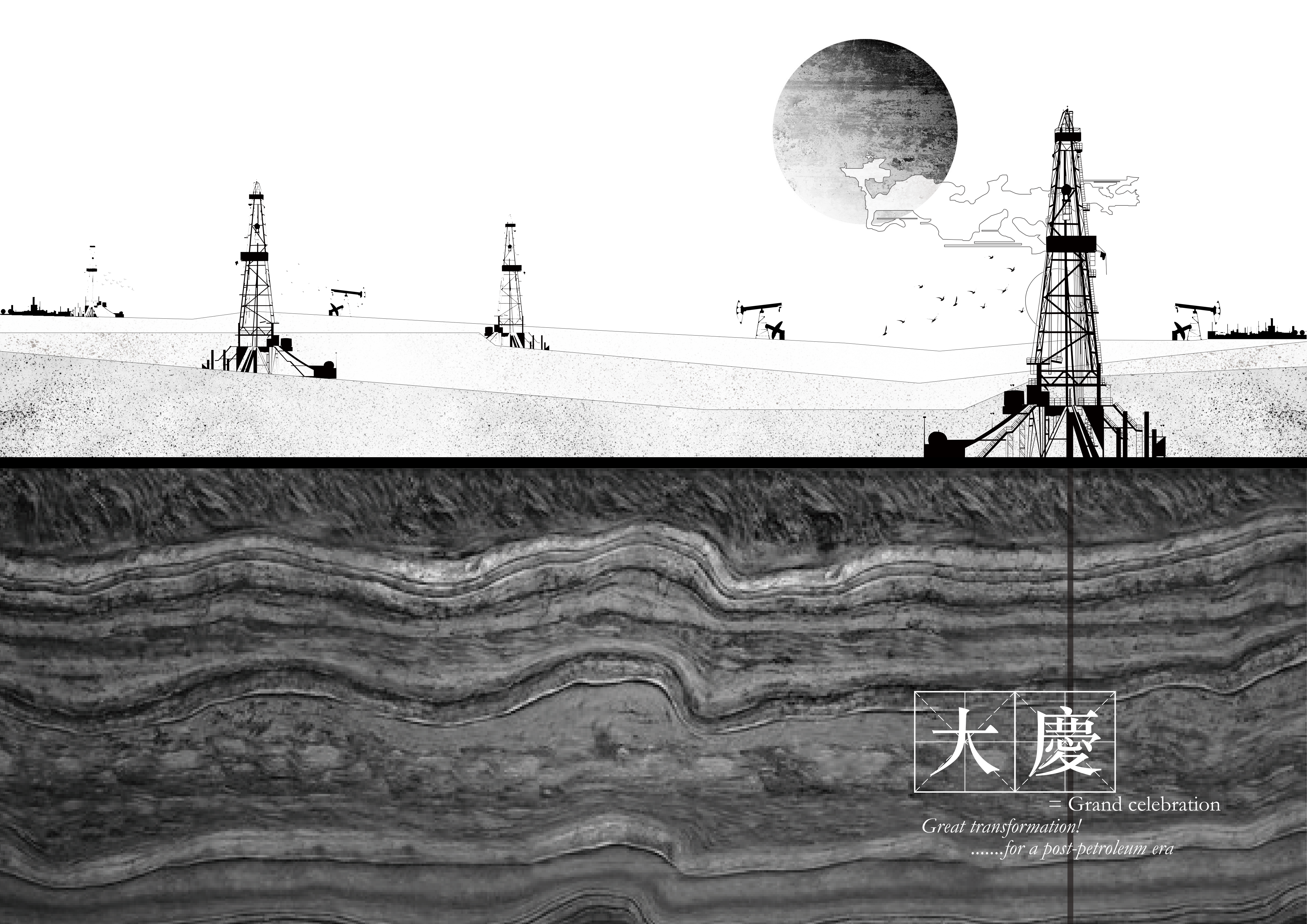
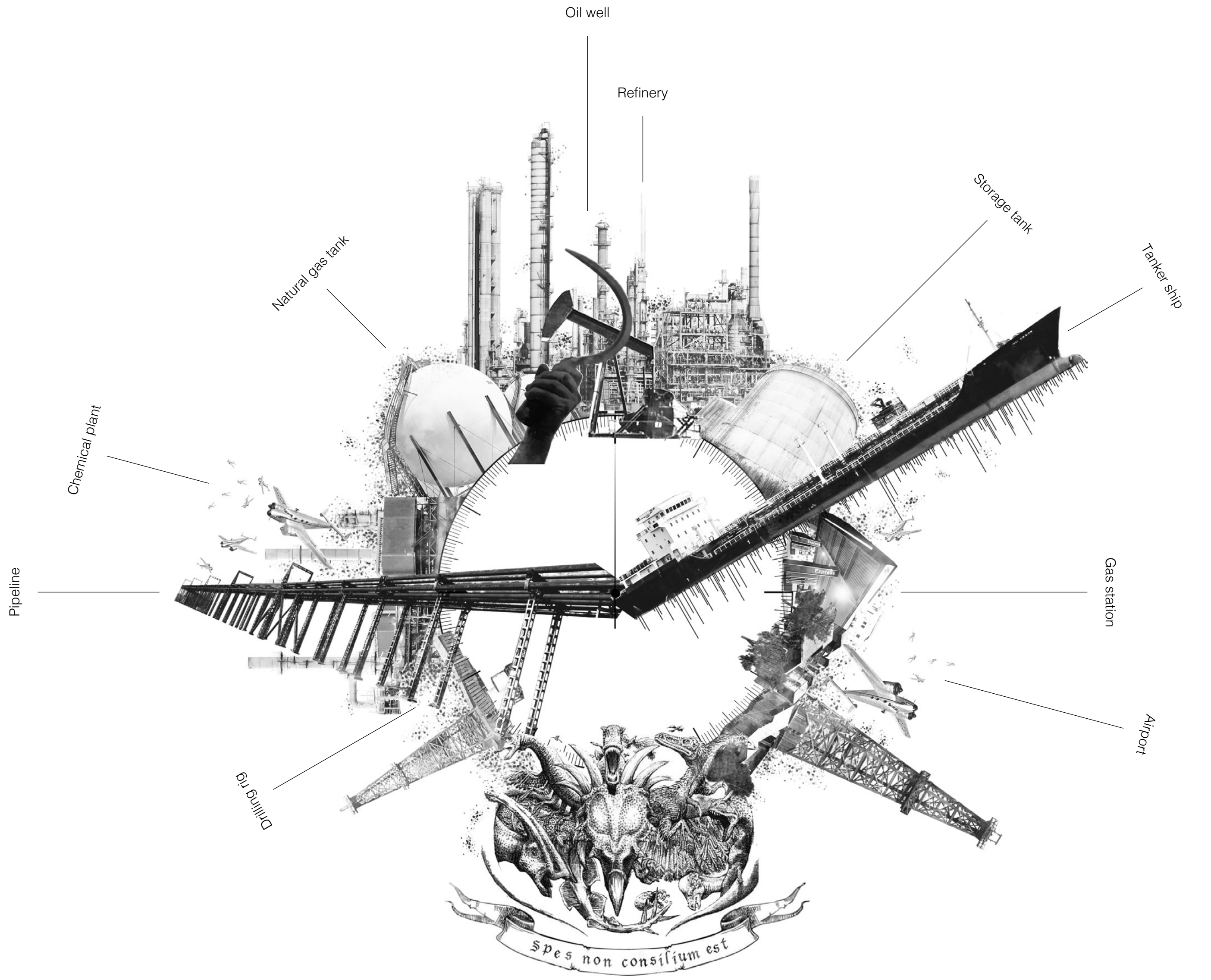

大慶
= Grand celebration
Great transformation!
......for a post-petroleum era

‘Repower the Petroleumscape of Daqing’

Combining Energy Landscape Theory and Scenario Planning in a Post-petroleum Planning of Daqing

First mentor: Alexander Wandl
Second mentor: Nico Tillie
P3 presentation of Xue Cui

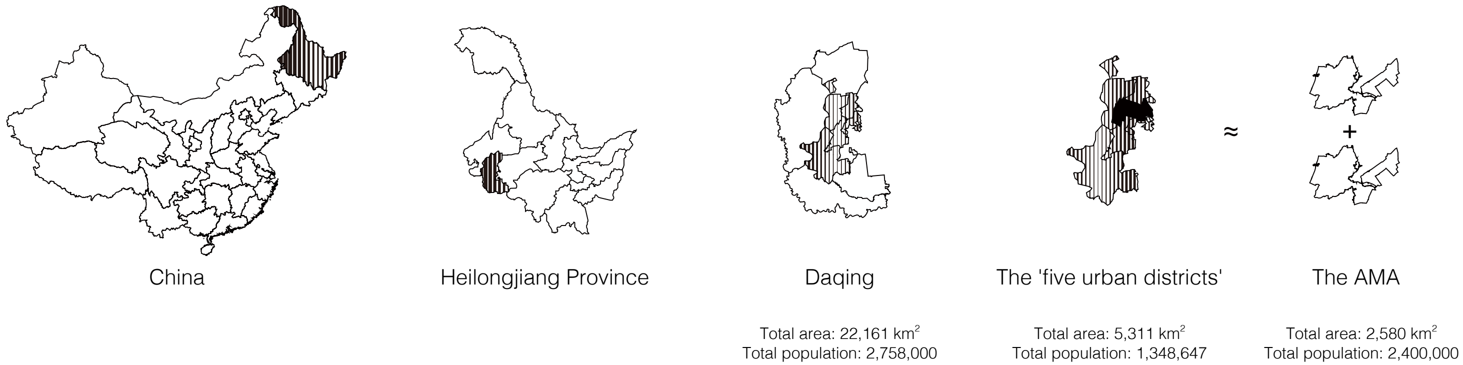
October 4th, 2018



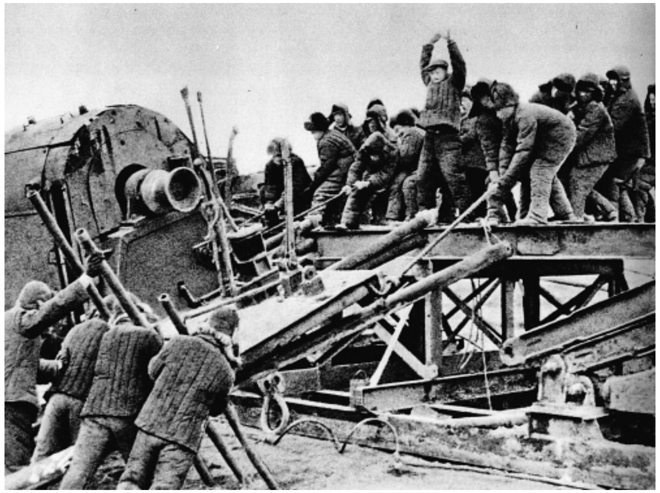
Collage of ‘petroleumscape’, a term borrowed from Carola Hein (2015)’s work. Image made by the author.

Hein, C. M. (2015). Exploring architectural history through the Petroleumscapes of the Randstad to imagine new fossil-free futures. Bulletin Vereniging van Nederlandse Kunsthistorici, 26 (3) 2015.
image source: https://www.flickr.com/; http://www.dinozaury.com;

I Problem Statement

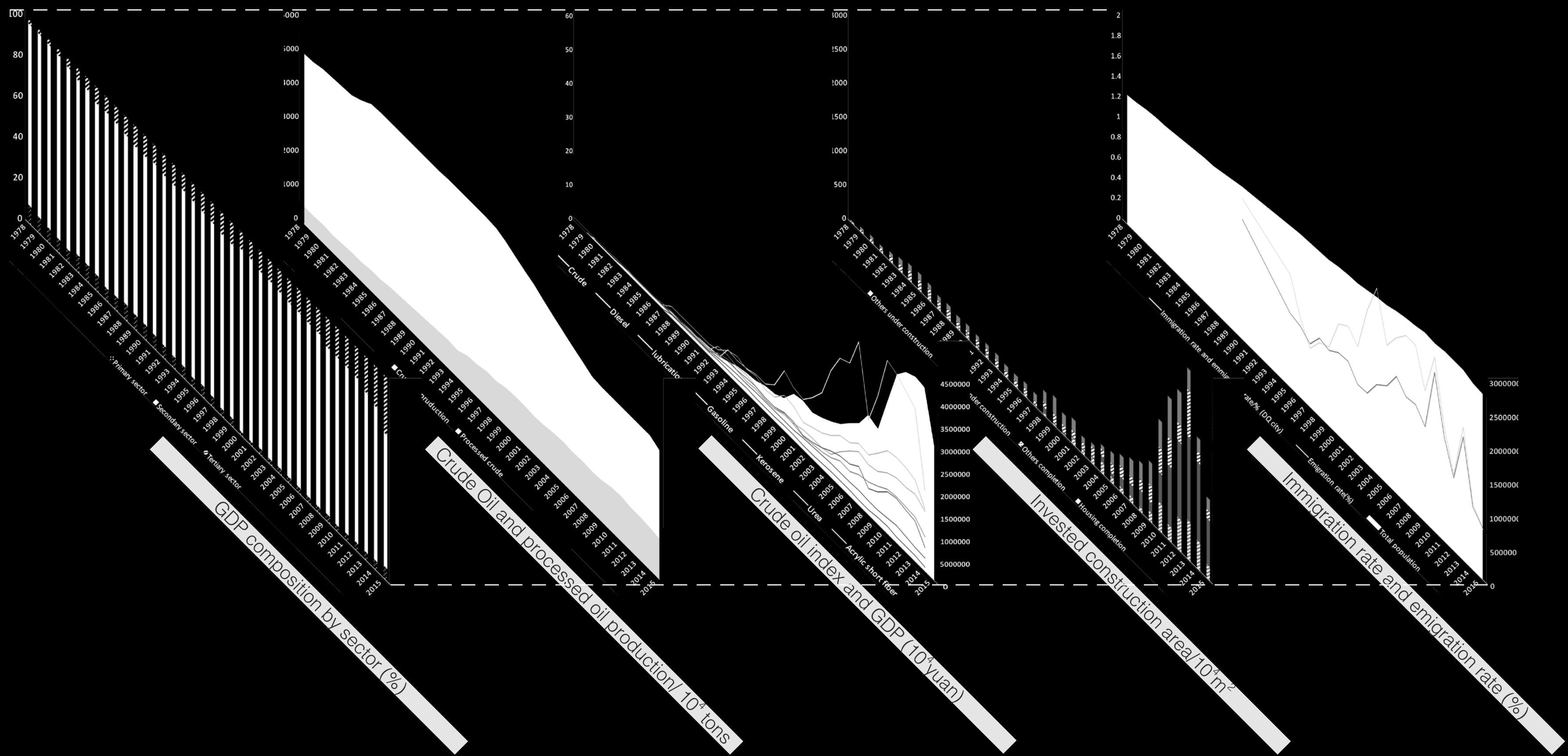


I Problem Statement



Source: http://www.npopss-cn.gov.cn/BIG5/n/2014/1103/c373410-25964012.html

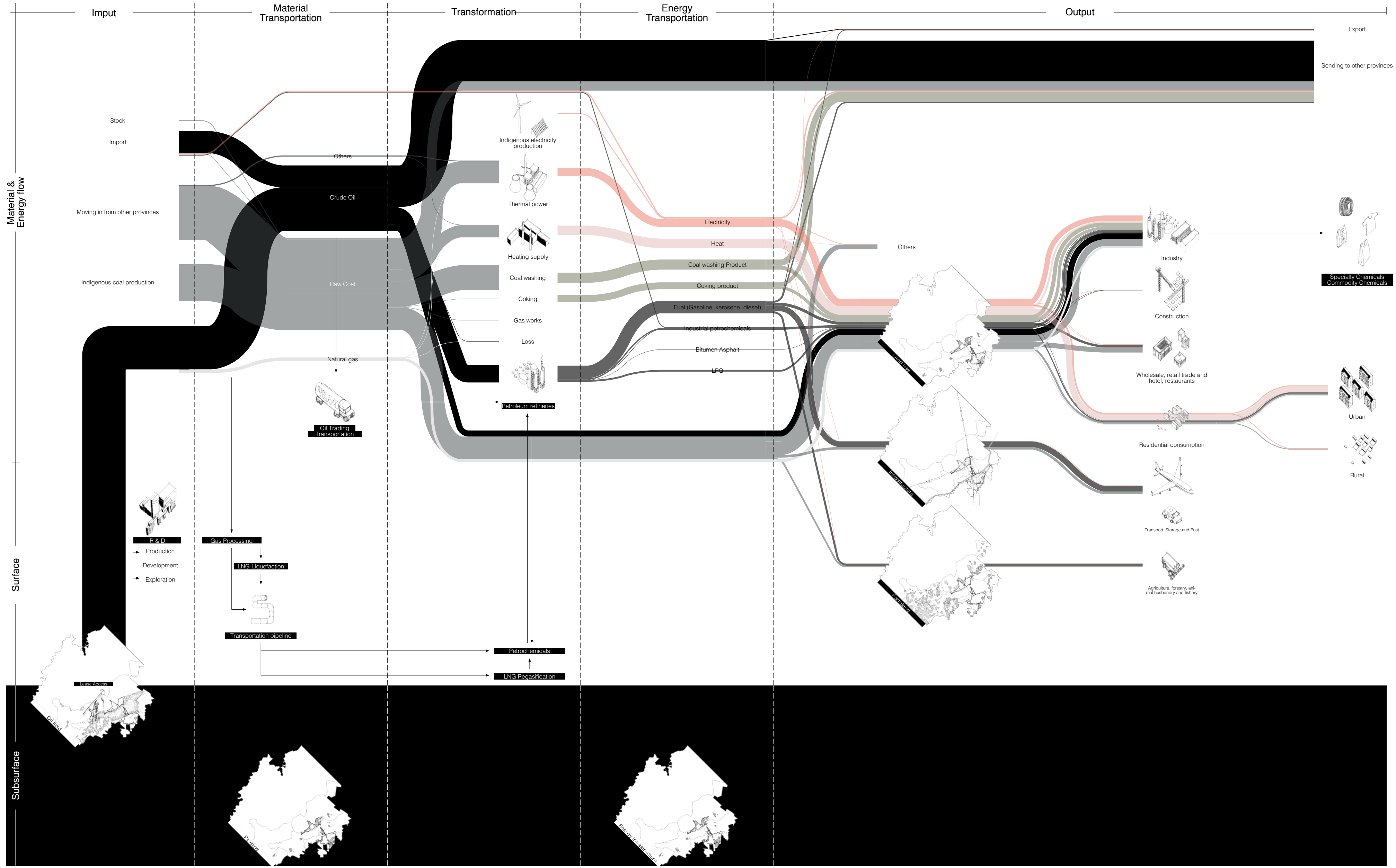
I Problem Statement



The reducing annual oil production and the falling international oil price, have seriously affected the city's economy.

Data source: Daqing Bureau of Statistics. (2016). Daqing statistical yearbook 2016. Daqing: Chinese Statistic Press.

I Problem Statement



I Problem Statement

Dependent on imported oil

Small proportion of energy comes from renewable energy production, while the electricity and heat supply is currently dependent on coal

Large amount of crude oil sent to other part of China (from the ports of Qinhuangdao, Dalian)

Industry consumes most energy of all the urban functions; Trade and service dependent on coal (to supply heat in boiling houses) and fuel

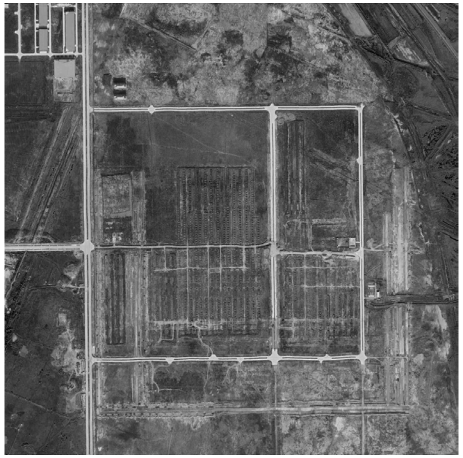
Energy demand of urban residential area is much higher than rural settlements, the possible reason is that rural houses burn biomass for heating their ‘kang’ during winter

Transportation consume most fuel of all the listed urban functions, thus it will suffer the greatest impact from oil depletion

Automated agriculture dependent on fuel, while its heating dependent on coal

I Problem Statement

'Spring of the North Realm, A Dream City': A Jurassic theme park, the construction expected to be completed in 2016, the developer turned out to be a dummy company



'China Zhongwang': An Aluminum processing industry projected by the municipality, project terminated due to protesting

Source: https://www.google.nl/

I Problem Statement

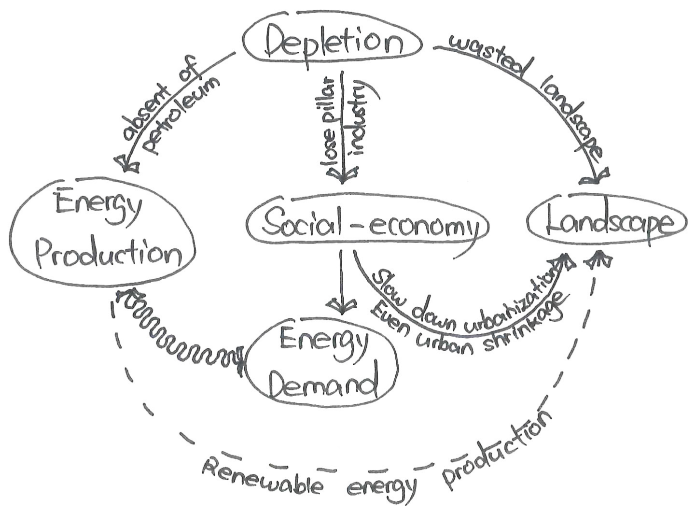
Awareness:

‘Resource Exhausted City’, a term addressed by Chinese government
Li, Long & Chen, 2013; Li, 2002; Wang & Guo, 2012; We, Wang & Li, 2011

(National) Energy Development Strategic Action Plan (2014-2020):
by 2020, 85% of energy use be self-sufficient, for dominant energy safety
Non-fossil fuel energy/ Indigenous energy production= 0.15
Natural gas > 10%
Coal < 62%

Li, H., Long, R., & Chen, H. (2013). Economic transition policies in Chinese resource-based cities: an overview of government efforts. Energy Policy, 55, 251-260.
Li. L. (2002). De-industrialization and development of industrial heritage tourism: the actual process and development model of Ruhr in Germany [J]. World Regional Studies, 3, 008.
Wang, S. Y., & Guo, S. Q. (2012). Study on Countermeasures for sustainable development of Resource-Exhausted Cities. China Soft Science, 1(8), 1-13.
Wei, Q., Wang, C. B., & Li, H. J. (2011). The adjustment of resource-exhausted city based on Houston’s experience: taking Baiyin city of Gansu province for example. Ecol Econ, 9, 71-5.

I Problem Statement

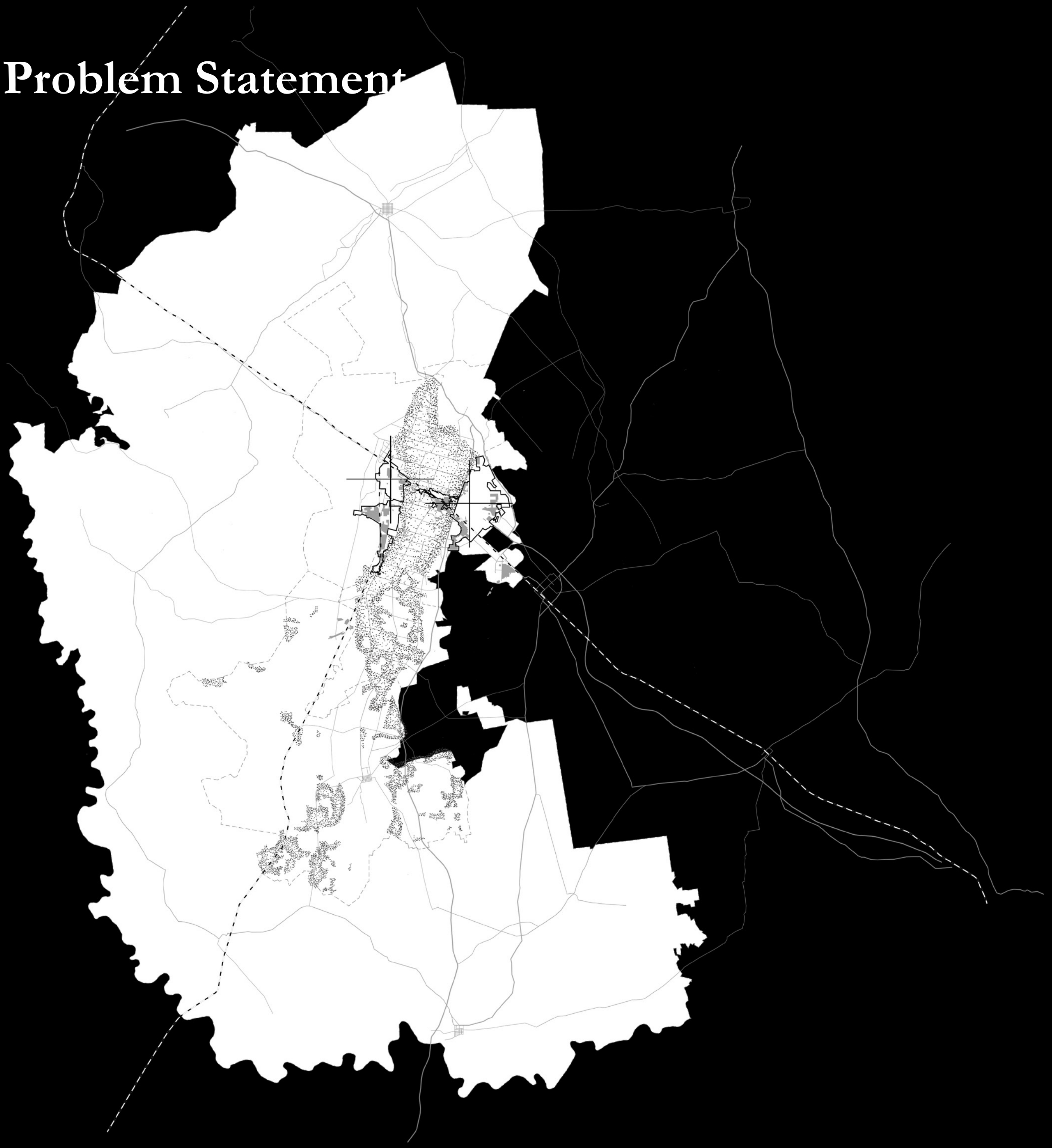


Smarter economic and energy solutions for Daqing as a 'future post-petroleum city'

Renewable energy 'appropriates disproportional amounts of space' (Sijmons et al., 2014), and will consequently squeeze the landscape and the built environment.

Sijmons, D., Hugtenburg, J., Hoorn, A., & Feddes, F. (Eds.). (2014). Landscape and energy: Designing transition. Rotterdam: Nai010.

I Problem Statement



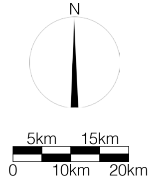
Petroleumscape

Oil field
Petroleum industries

Data Source:
Yu, G. Reseach on space development pattern of resource based city (2013). Northeast Petroleum University.
https://www.google.nl/maps
http://www.dqghj.gov.cn/

Legend

- Waters
- Wetland
- Waters with oil well
- Trees
- Reserved area
- Severe salinization
- Moderate salinization
- Slight salinization
- Green
- Urban residential area
- Rural residential area
- Prime farmland
- Ordinary farmland
- Wind turbine
- Oil extraction area
- Petroleum industries
- Urbanized area
- Railway
- National road
- Main road



I Problem Statement

Oil extraction land

Source: http://dp.pconline.com.cn

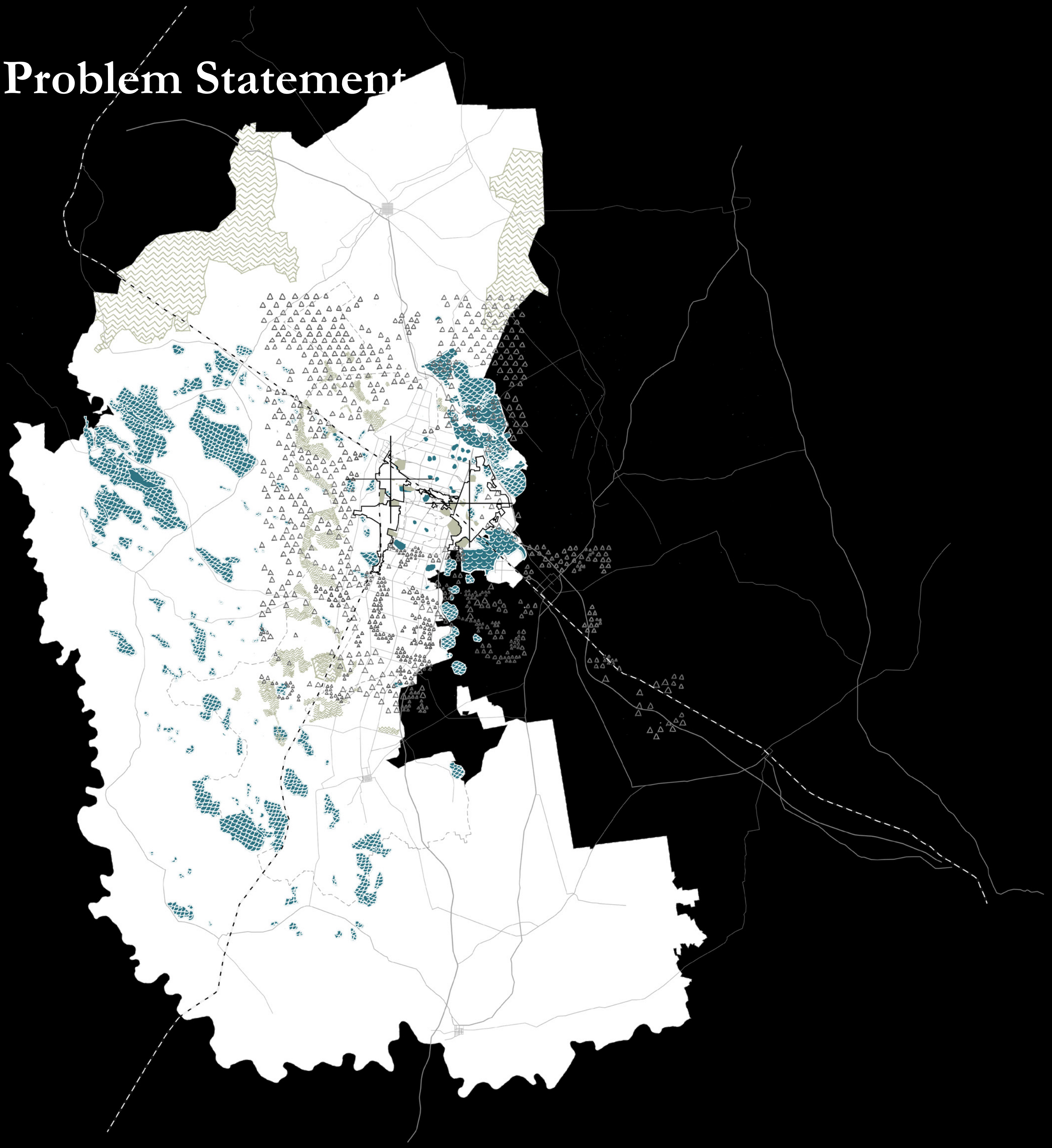
Petroleum industries

Source:http://www.bf150.com/keyanjishu/wsdpjishu/424.html

Oil transfering station

Source: http://www.huitu.com

I Problem Statement



Natural landscape

Green and blue structure
Soil salinization
Trees
Reserved areas

Data Source:
Yu, G. Reseach on space development pattern of resource based city (2013). Northeast Petroleum University.
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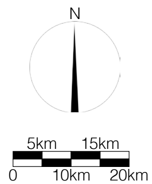
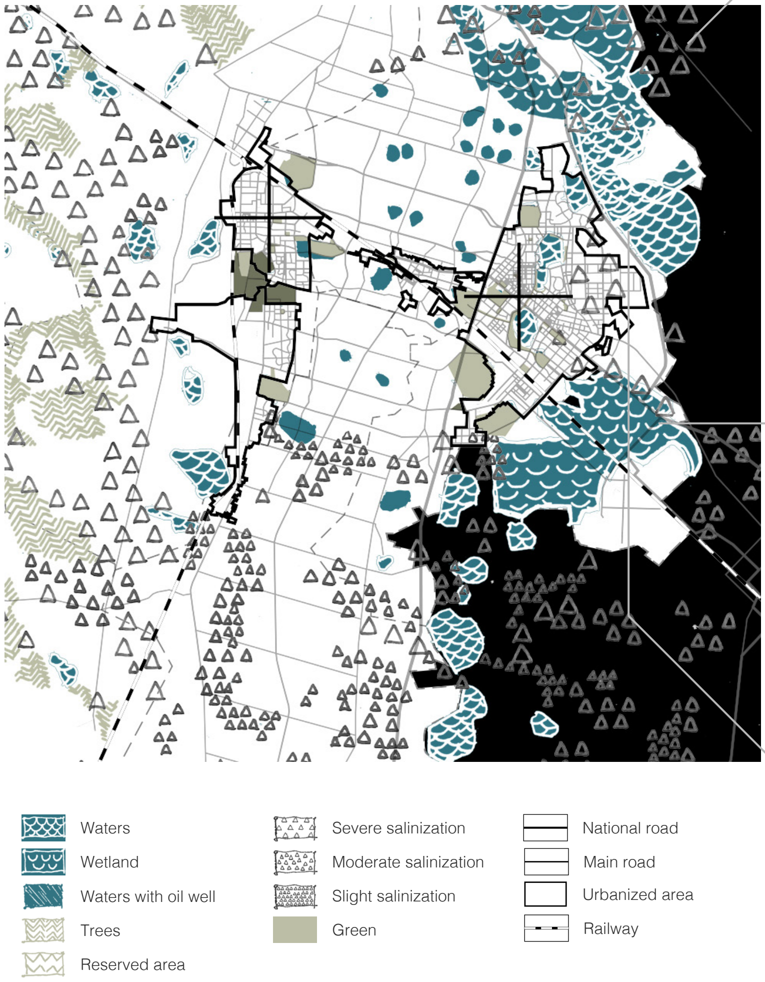


I Problem Statement



Soil salinization

Photograph by the author

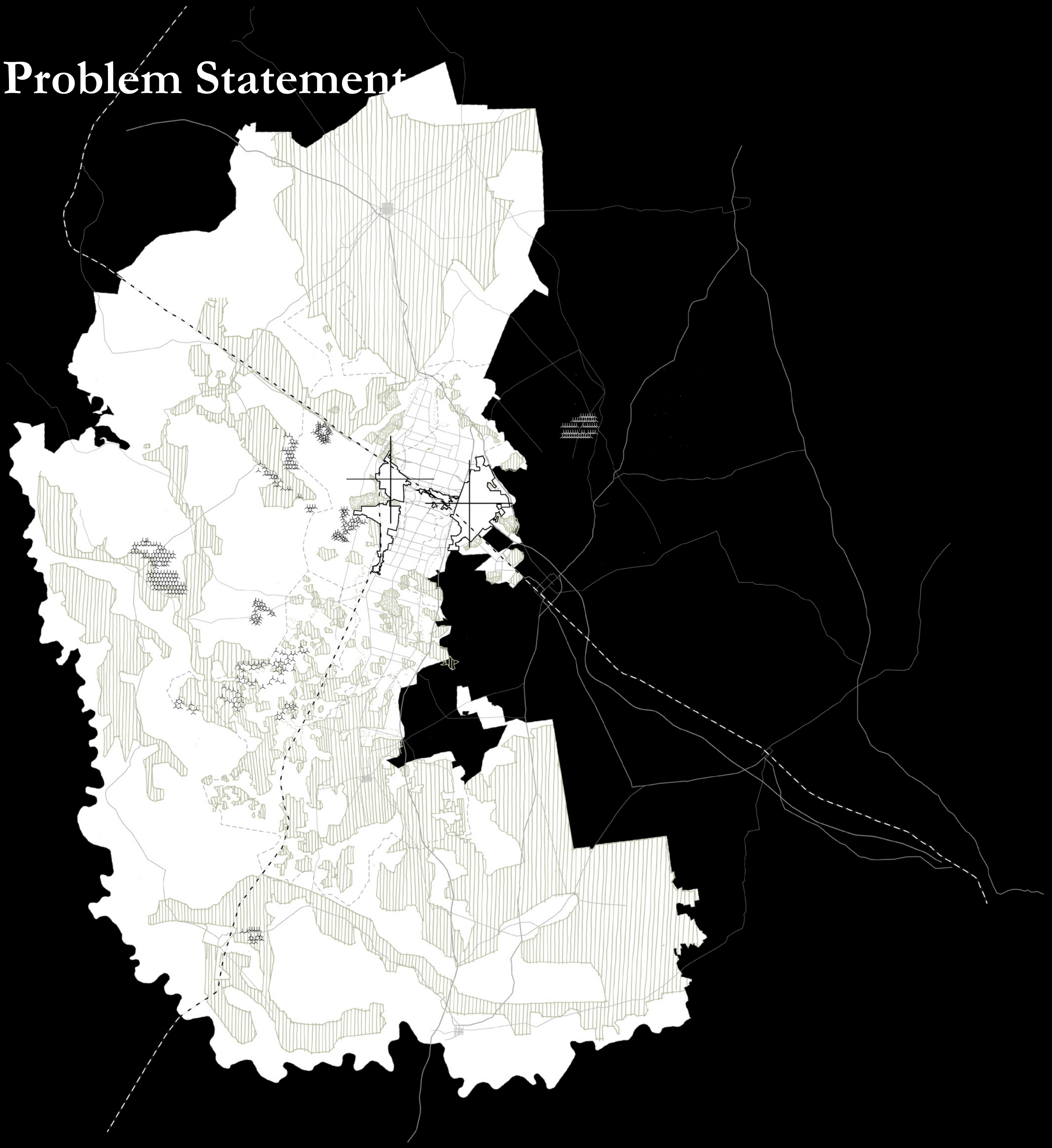
Green & blue structure

Source: http://dp.pconline.com.cn

Reserved areas: Longfeng wetland

Photograph by the author

I Problem Statement



Renewable energy landscape

Wind farm
Geothermal
Biomass

Data Source:
Yu, G. Reseach on space development pattern of resource based city (2013). Northeast Petroleum University.
https://www.google.nl/maps
http://www.dqghj.gov.cn/

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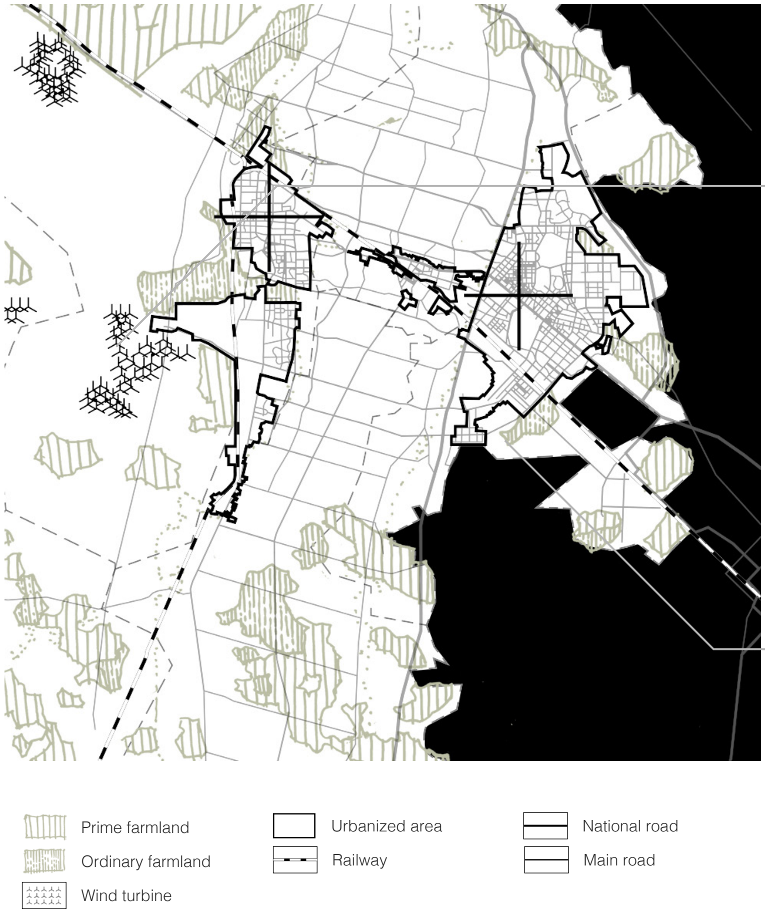


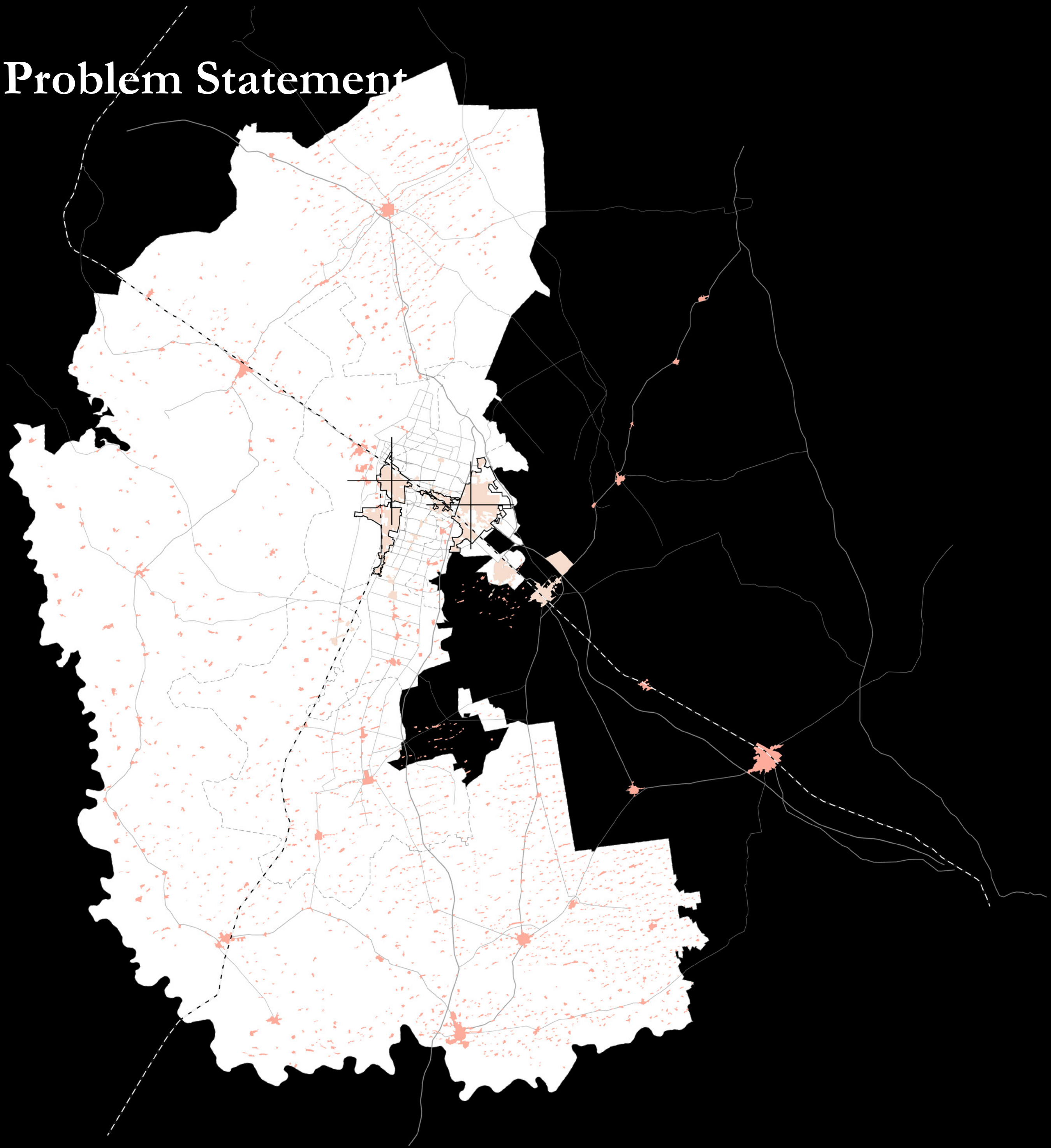
Wind farm

Photograph by the author

Biomass

Photograph by the author

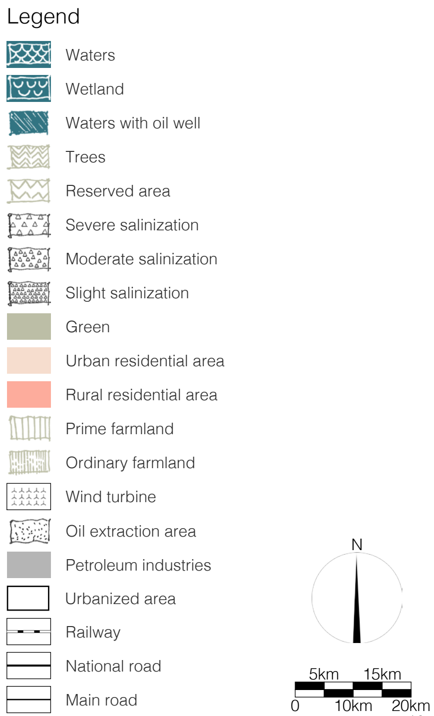
I Problem Statement



Human settlement

Rural residential area
Urban residential area

Data Source:
Yu, G. Reseach on space development pattern of resource based city (2013). Northeast Petroleum University.
https://www.google.nl/maps
http://www.dqghj.gov.cn/



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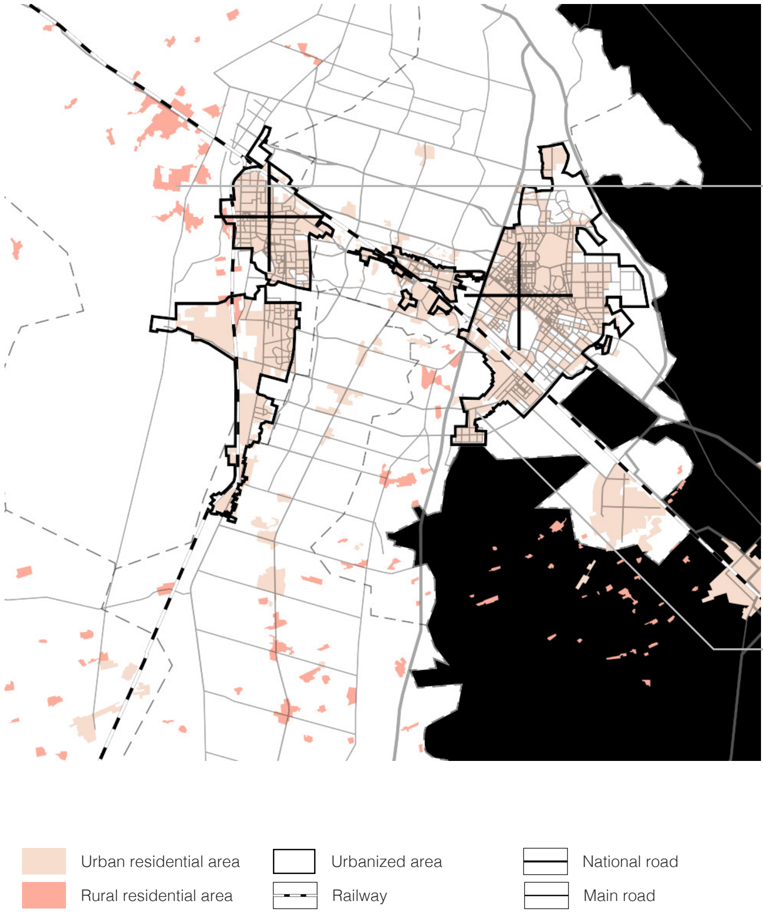


Rural residential area

Photograph by the author

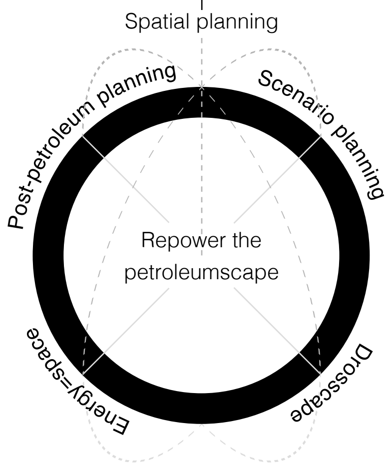
Urban residential area

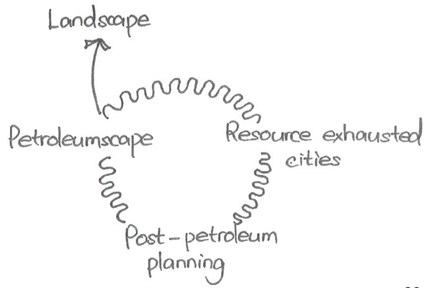
Photograph by the author

II

Theoretical Framework

Hein, 2015	Petroleumscape
Monte, 1978 Cooke, 2017 Smirnova & Rusanova, 2008 Tang, Wang & Yao, 2008	Landscape impacted by petroleumscape
Li, Long & Chen, 2013 Wang & Guo, 2012 Li, 2002 We, Wang & Li, 2011	Resource-exhausted city transformation
Newman, 2007 Beatley, 2007 Aftabuzzaman & Mazloumi, 2011 Geels, 2012 Thayer, 2008	Post-petroleum visions and scenarios





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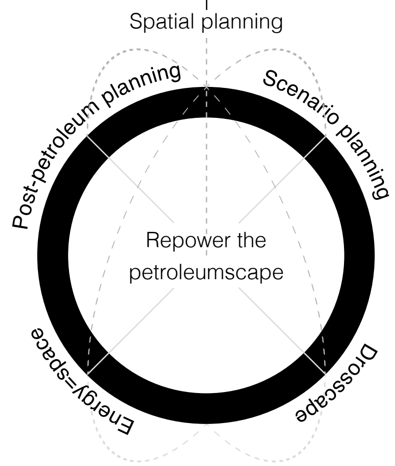

Nadaï & Van Der Horst, 2010	Renewable energy 'renaissance'
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Dobbelsteen & Tillie, 2011	Energetic urbanism
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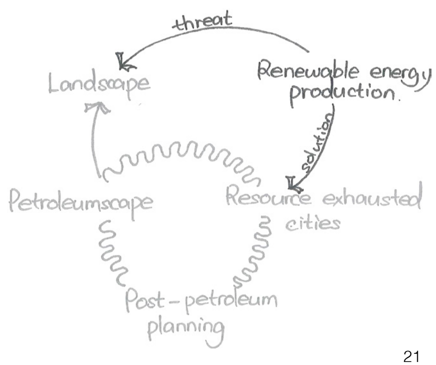
Beatley, 2007	Initiatives



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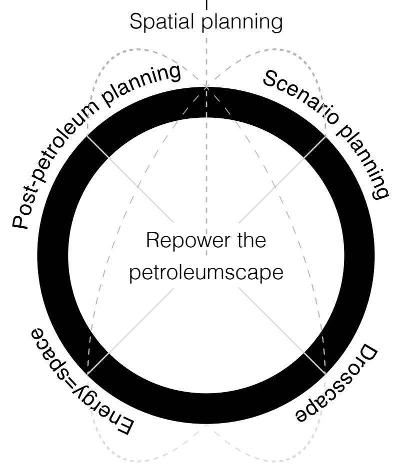

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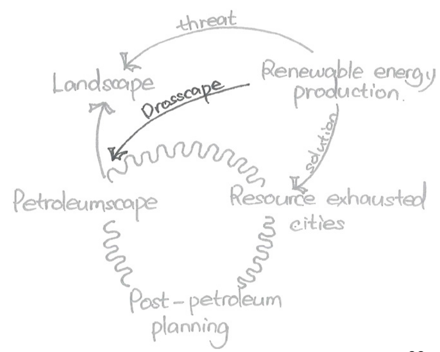
Wasted landscapes should be seen as opportunities instead of threats to the city	Berger, 2006



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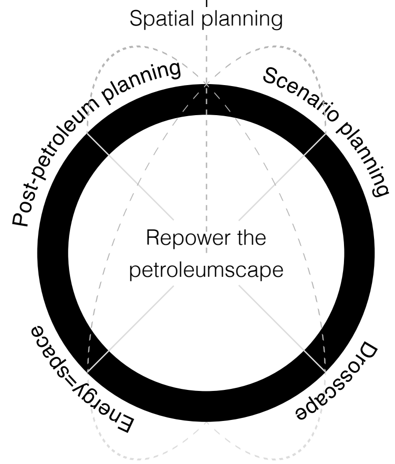
Future uncertainties	Secchi, 2010 Salewski & Paine, 2012)
Complexity Theories of Cities (CTC)	Batty & Xie,1994 Portugali, 1997 Portugali, 2011a Portugali, 2011b
Scenario planning	Kahn & Wiener, 1967 Amer, Daim & Jet- ter, 2013 Salewski & Paine, 2012 Khakee, A, 1991 Kosow & Gaßner, 2008 UNEP, 2002
Principles of scenario building	Durance and Godet, 2010 Greeuw et al., 2000 Kosow & Gaßner, 2008



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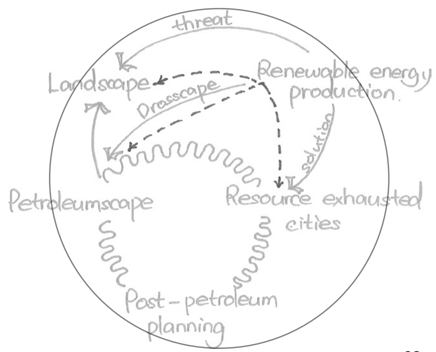
Scenario planning



II

Theoretical Framework

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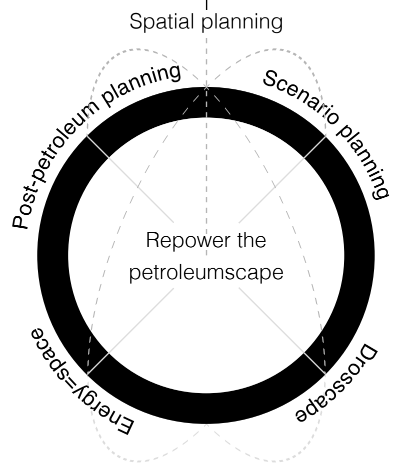

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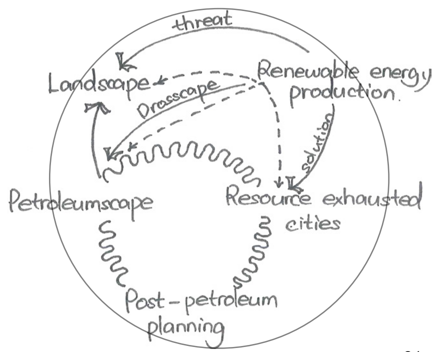
Scenario planning



II Theoretical Framework

Main research question:

How can Daqing's urban landscape facilitate renewable energy production and contribute to neutralise the energy and economic crisis of the post-petroleum era, while extending its own sustainability?

Design goals:

Spatial strategies of making use of Daqing's urban landscape for renewable energy production while extending its own sustainability

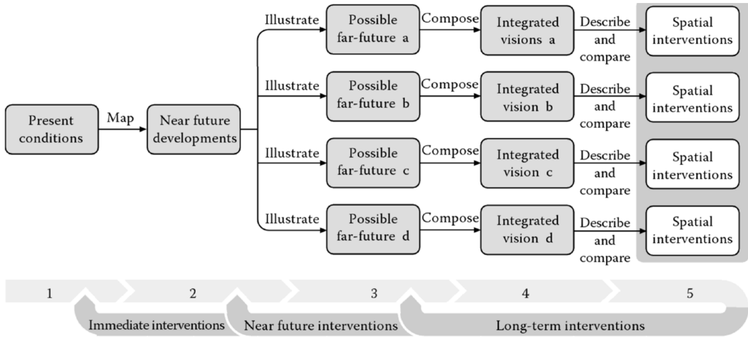
Sub-research questions:

1 How is the present landscape, economy, and energy demand & production of Daqing shaped by petroleum industries?
2 How will the current landscape, economy and energy demand & production of Daqing change in the near future, when the depletion becomes evident?
3 How will post-petroleum era (and the possible introduction of renewable energy) reshape the socio-economy and energy demand & production of Daqing in the far future?
4 What will be the spatial consequences on the landscape of powering Daqing with renewable energy in the post-petroleum era?
5 How will the spatial changes affect the sustainability of the landscape?

'So, providing we are on the verge of a new era, what will this era's new Janus faces look like?'

Sijmons, D., Hugtenburg, J., Hoorn, A., & Feddes, F. (Eds.). (2014). Landscape and energy : Designing transition. Rotterdam: Nai010.

III Methodology Framework



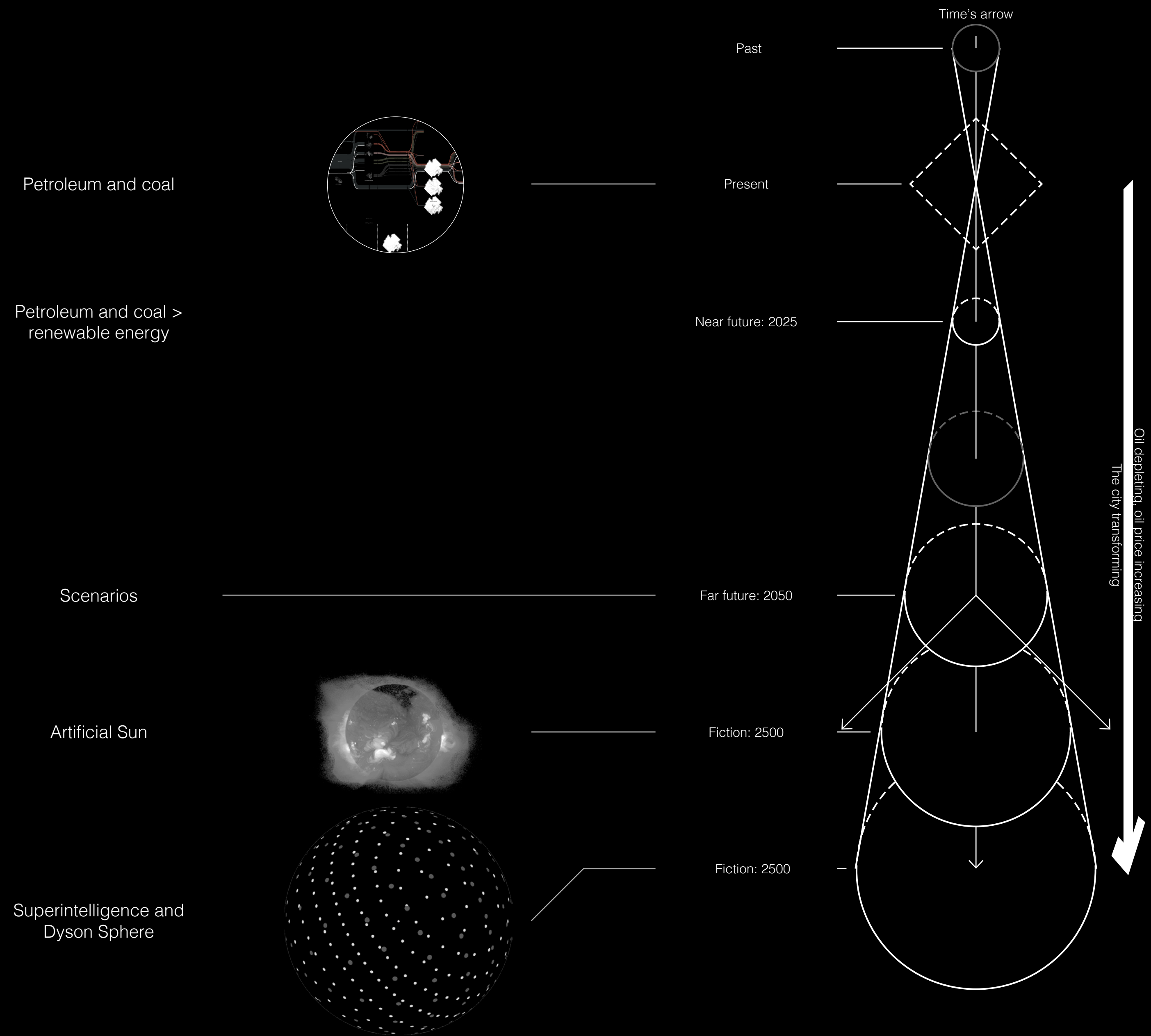
The 'five-steped approach'

(1) Analysing present conditions
(2) Mapping near-future development
(3) Illustrating possible far-futures
~~(4) Composing integrated visions~~
(5) Identifying energy-conscious spatial interventions

Stremke, S., & Van Den Dobbelsteen, A. (2012). Sustainable energy landscapes : Designing, planning, and development (Applied ecology and environmental management). Boca Raton, FL: Taylor & Francis.

III Methodology Framework

A Metaphor: Light Cone



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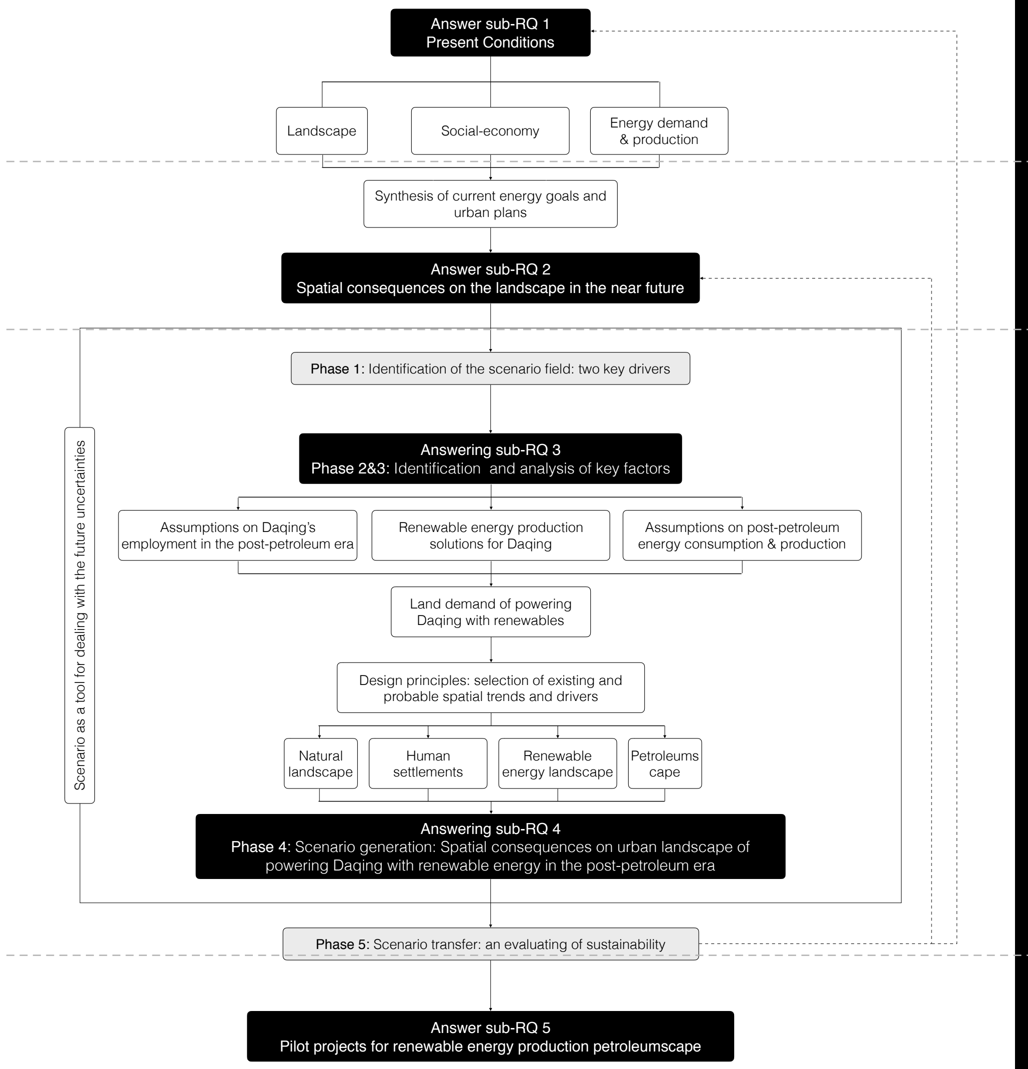
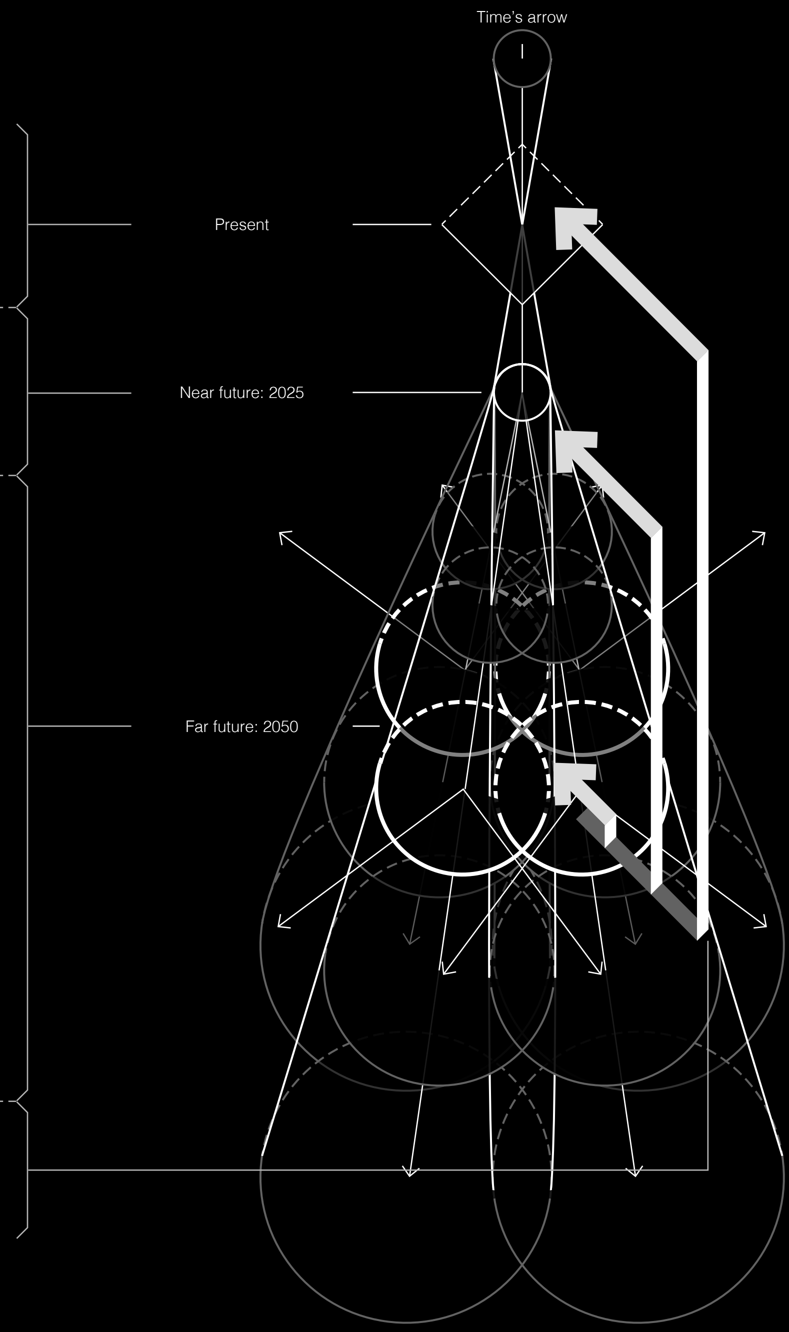
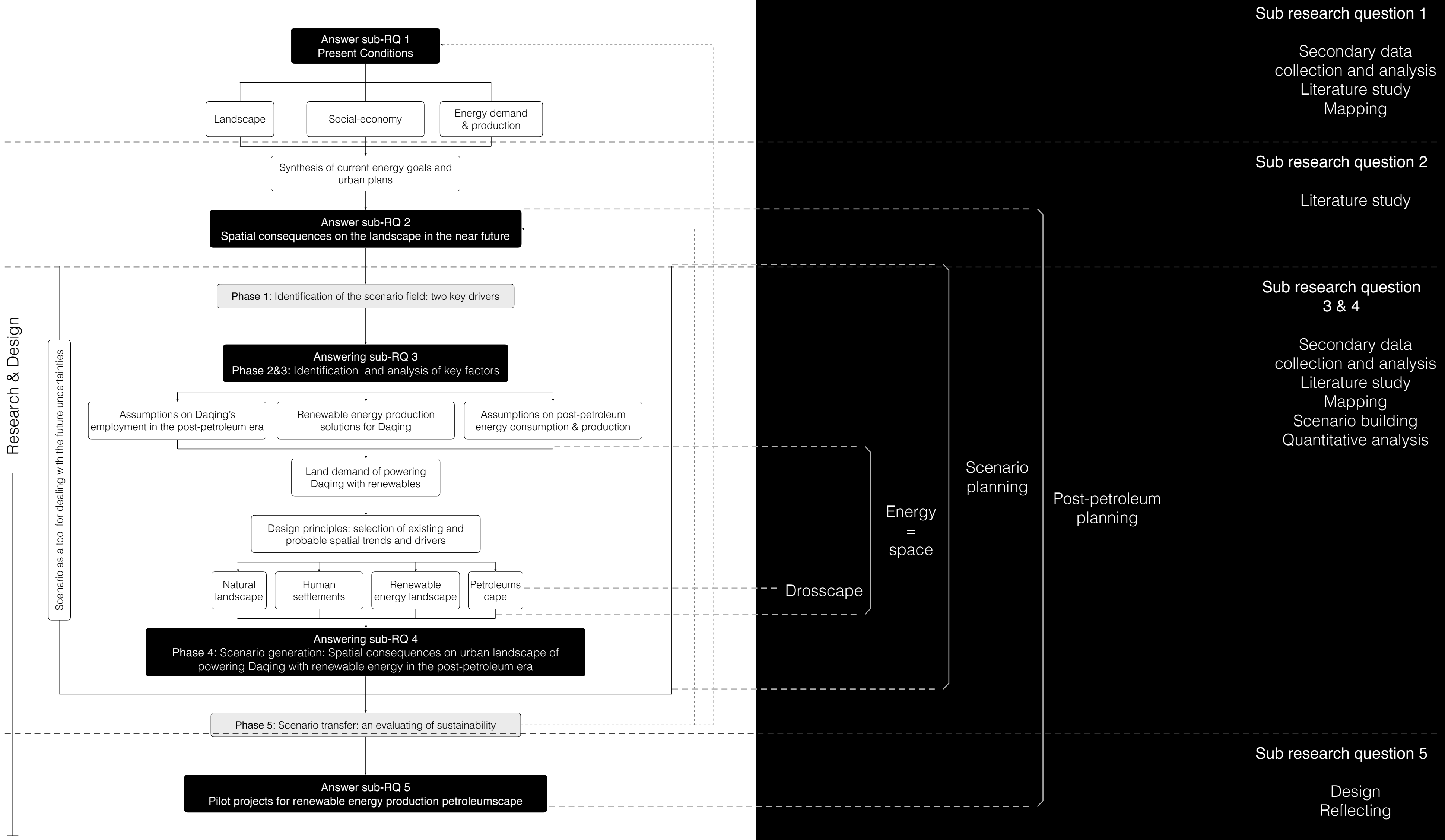


A Metaphor: Light Cone

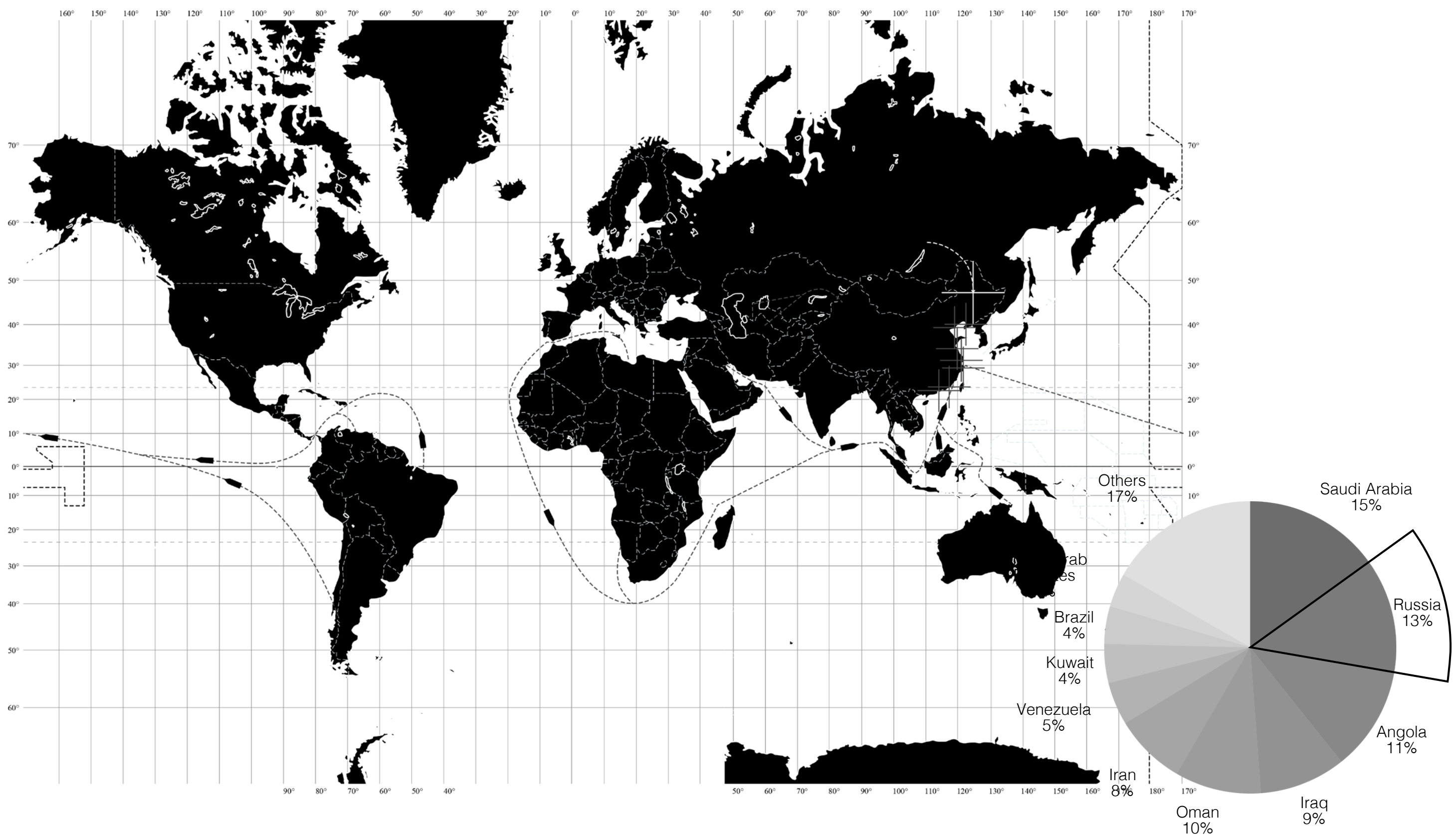


III Methodology Framework

Research method



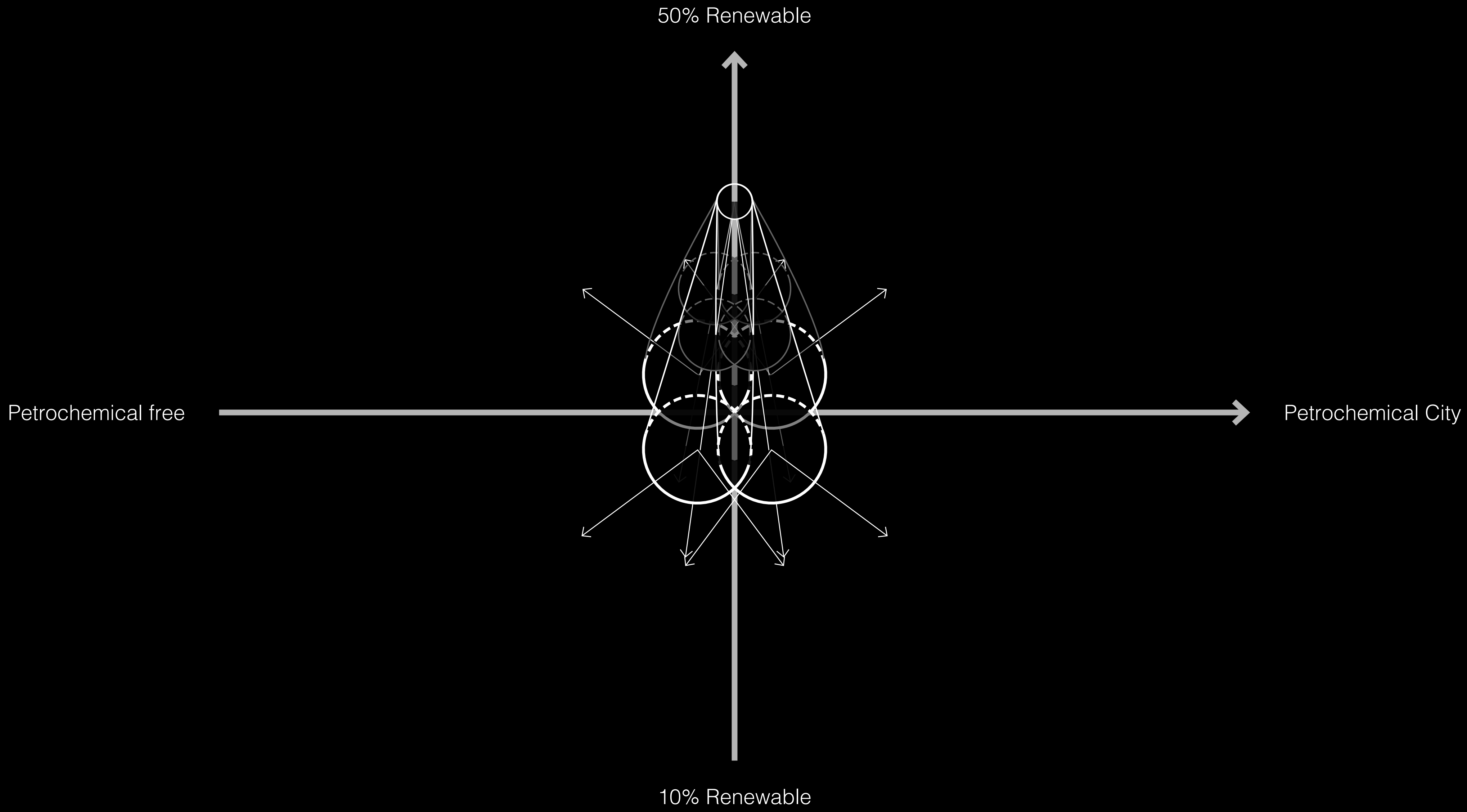
IV Scenario building



1) identification of the scenario field; 2) & 3) identification and analysis of key factors; 4) scenario generation; 5) scenario transfer

Source of the base map: https://english.freemap.jp/

IV Scenario building



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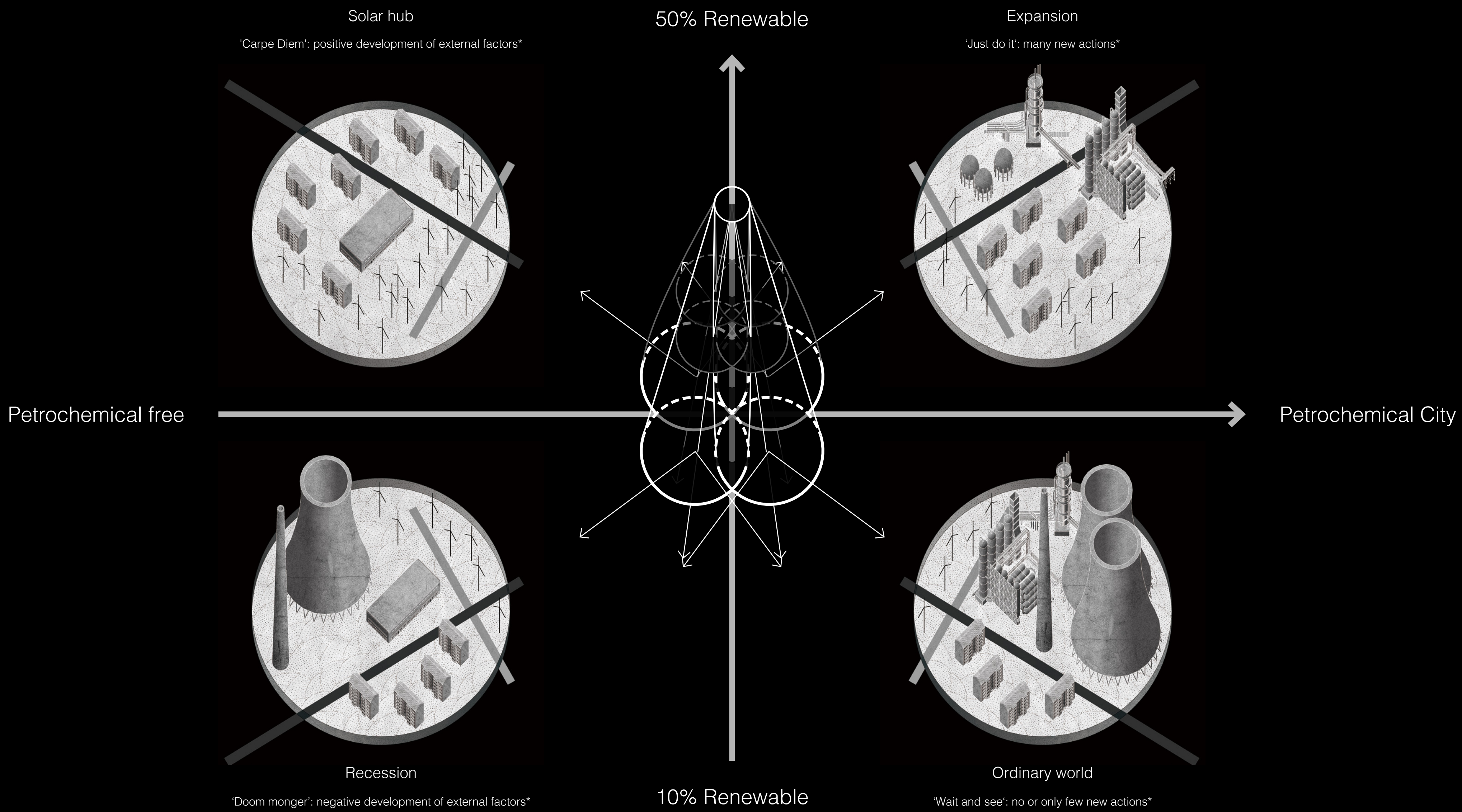

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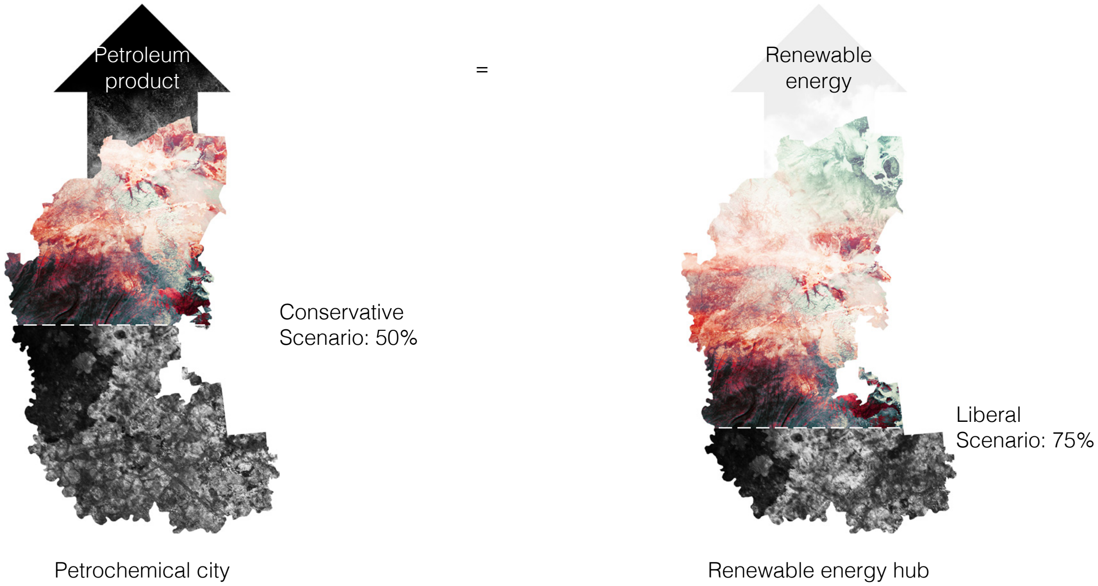
Kosow, H., & Gaßner, R. (2008). Methods of future and scenario analysis: overview, assessment, and selection criteria.

IV Scenario building



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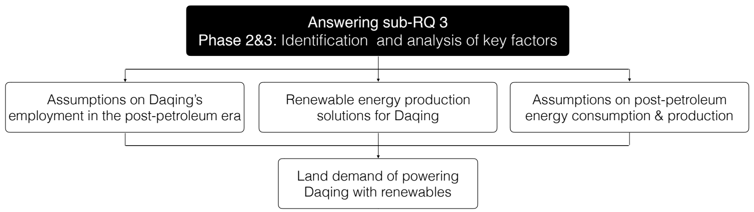
IV Scenario building

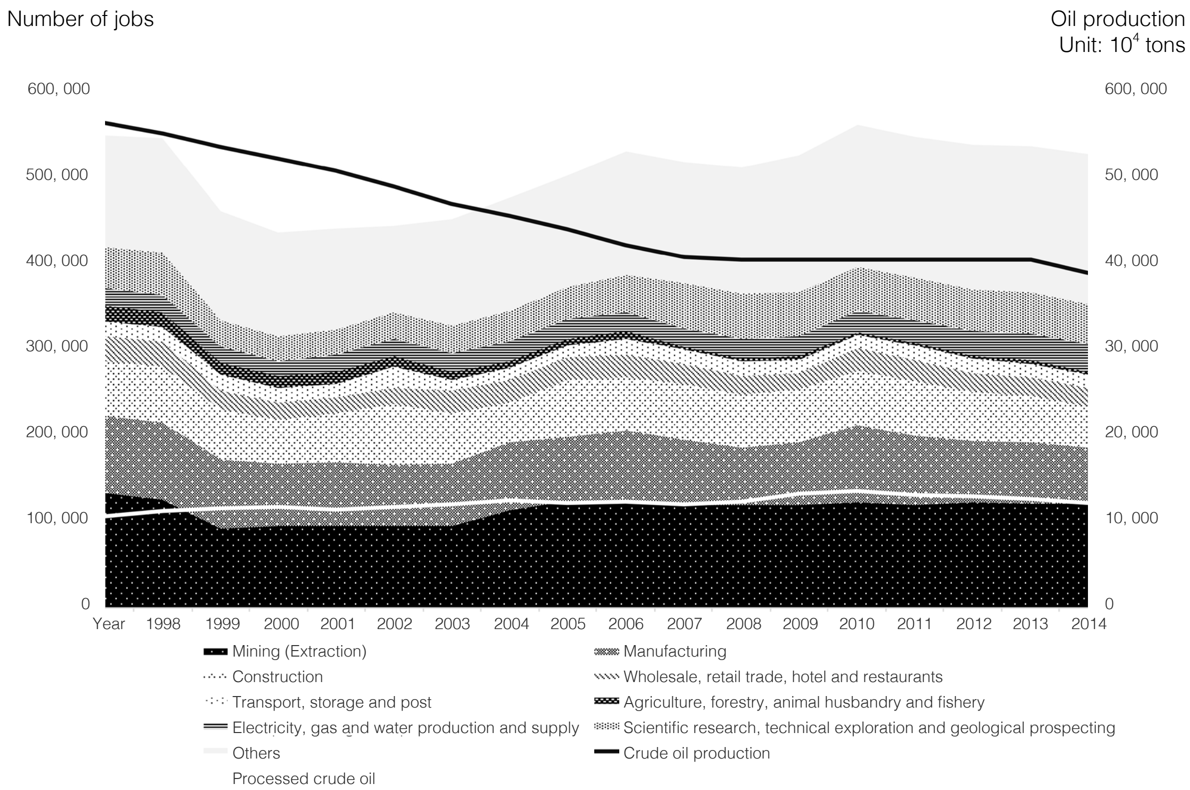


$$\frac{\text{Green jobs}}{\text{Employment multipliers}} = \textbf{Renewable energy production} =$$

$$[(\text{Reduced) initial population} + \text{green jobs}] \times \text{renewable energy production per capita}$$
$$+ \text{Renewable energy consumption} + \text{Renewable energy exports}$$

1) identification of the scenario field; 2) & 3) identification and analysis of key factors; 4) scenario generation; 5) scenario transfer

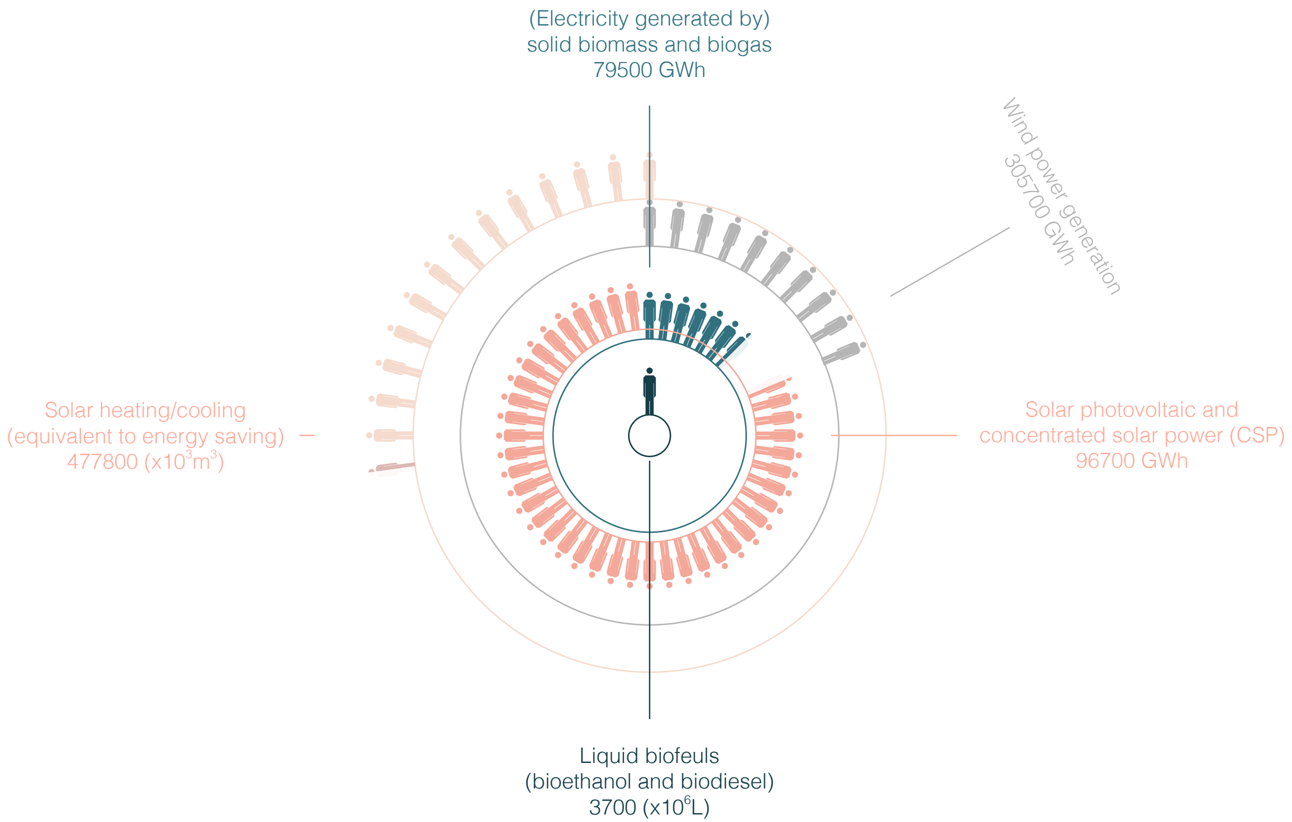
IV Scenario building: Employment impact of the post-petroleum era



1) identification of the scenario field; 2) & 3) identification and analysis of key factors; 4) scenario generation; 5) scenario transfer

Image made by the author. Data source: Daqing Bureau of Statistics (2016)

IV Scenario building: Employment impact of the post-petroleum era



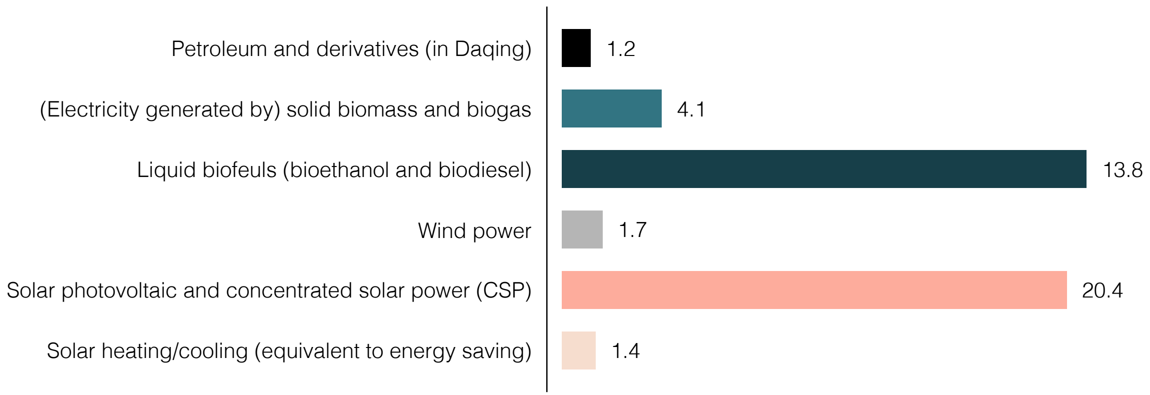
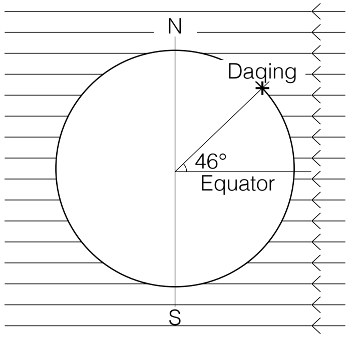


Image made by the author.
Data source: IRENA, 2017; National Bureau of Statistics; National Energy Administration; USDA, 2017

IV Scenario building: Renewable energy production solutions



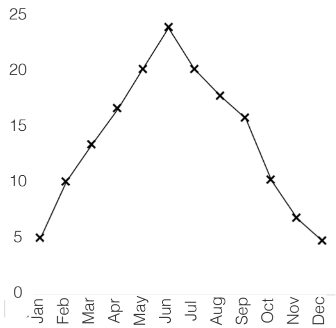


Image made by the author.Data source: Ma, Li & Zhang, 2016

Wind velocity
6 m/s
6.2 m/s
6.4 m/s
6.6 m/s
6.8 m/s

Image made by the author.
Data source: http://fd.bjx.com.cn/

Solar energy
5040 MJ/m²
5400 MJ/m²

Image made by the author.
Data source: https://news.solar-be.com/201603/24/97015_1.html

Biomass

Image made by the author.
Data Source: Yu, 2013.

Geothermal -1,000m
50 C
42 C
37 C
31 C

Image modified by the author.
Data source: Li, 2017.

Geothermal -3,000m
146 C
119 C
93 C
66 C

Image modified by the author.
Data source: Li, 2017.

IV Scenario building: Renewable energy production solutions

Solar thermal collectors

A 60 L solar water heater with a heating power of 3000 W is sufficient to meet the daily hot water demand of a single household.

Photovoltaic cells

Fundamental physical laws limit the maximum efficiency of photovoltaic systems with hypothetical perfect concentrating mirrors or lenses to 60%, and 45% without any concentration (MacKay, 2008).

An ambitious research group has designed a GaSb-based photovoltaic cell with a photoelectric conversion efficiency of 44.5%

In the 2050 scenarios, the average efficiency of commercial PV systems (during their effective working hours) is postulated to reach 30%.

$4.73 \times 10^6 / (3.6 \times 10^6) \times 30\%$ = **0.4 kWh/d in December**
$23.49 \times 10^6 / (3.6 \times 10^6) \times 30\%$ = **2 kWh/d in June,**
and **411.9 kWh** annually.

Photovoltaic thermal hybrid solar collectors (PVT)

In the 2050 scenarios, the average photoelectric conversion efficiency of commercial PVT systems is postulated to be 15%, while the thermal efficiency reaches 80%.

Thermal energy: $4.73 \times 10^6 / (3.6 \times 10^6) \times 80\%$ = **1.1 kWh/d in December**
$23.49 \times 10^6 / (3.6 \times 10^6) \times 80\%$ = **5.2 kWh/d in June,**
and **1098.3 kWh** annually.

Electrical energy: 4.73×10^6 J $/ (3.6 \times 10^6) \times 15\%$ = **0.2 kWh/d in December**
23.49×10^6 J $/ (3.6 \times 10^6) \times 15\%$ = **1 kWh/d in June**
and **205.9 kWh** annually.

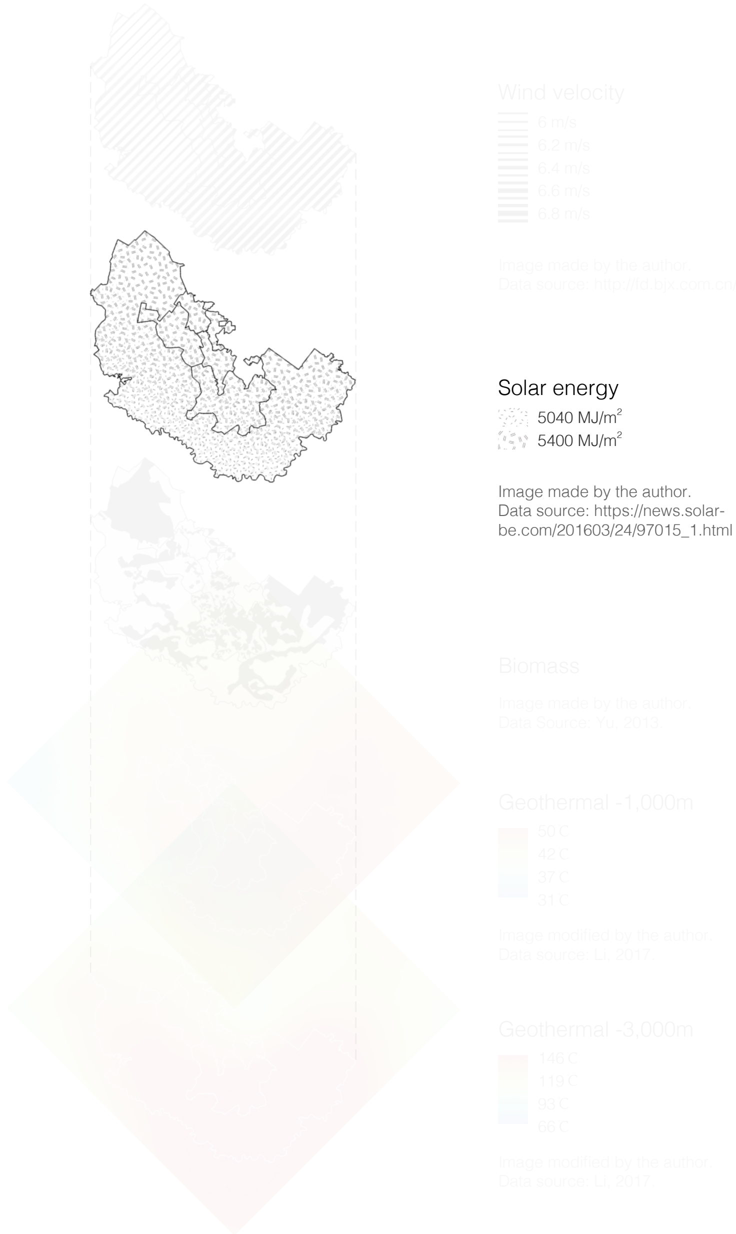


Image made by the author.
Data source: https://news.solar-be.com/201603/24/97015_1.html

IV Scenario building: Renewable energy production solutions

Photograph by the author's mother, Shuzhi Liu.
Modified by the author.

Wind turbines

According to Betz's law, under an ideal condition, the wind energy utilization coefficient (Cp) of a turbine can reach up to 59.3%.

It is assumed that the average distance between wind turbines is 5d. *In the 2050 scenarios, if the same type of wind turbines (C_p = 50%), arranged in grid patterns, were applied in all wind farms, the average power generated by 1 m^2 of a wind farm will be:*

$$\frac{1/2\ \rho\ v^3 \times 1/4\ \pi\ d^2 \times 50\% \times 60 \times 60 \times 24}{3.6 \times 10^6 \times (5d)^2} = \frac{1/2\ \rho\ v^3 \times\ \pi\ \times 24}{25 \times 8 \times 10^3}$$

$$= 0.067\ \text{kWh/d}$$

The number could be even less: for machine protection considerations, turbines will stop working when the wind speed exceeds or falls below their rated value.

0.067 × 49.6% = **0.033 kWh/d**

Wind velocity
6 m/s
6.2 m/s
6.4 m/s
6.6 m/s
6.8 m/s

Image made by the author.
Data source: http://fd.bjx.com.cn/

Source: https://vortexbladeless.com/

Bladeless wind turbines

Bladeless wind turbines are not affected by the downstream wind current, as such can be installed at a higher density.

In 2050, if each household owned a 100 W roof-mounted or ground-mounted bladeless wind turbine, the daily energy generated by the bladeless turbine will be:

(100 × 60 × 60 × 24) / (3.6 × 10^6 × 2.6) = **0.9 kWh/d per capita**

IV Scenario building: Renewable energy production solutions

In order to utilize geothermal energy sustainably, 69 mW/m2 is the theoretical maximum energy that can be extracted from the Earth. If all exploitable geothermal energy is utilized by perfect heat pumps and power stations, the available energy 1 m^2 will be

$(69 \times 10^{-3} \times 60 \times 60 \times 24) / (3.6 \times 10^{6}) = 1.656 \times 10^{-3}$ kWh/d

Direct utilization: geothermal heat pumps (GSHP)

In Daqing, the heating demand during long winters is generally much greater than the cooling demand in summers.

The population density in a typical gated community can reach approximately 0.04 person per square meter, which reduces the local available geothermal energy to:

$1.656 \times 10^{-3} / 0.04 =$ **0.0414 kWh/d per capita**

In order to compensate for the heat loss, GSHPs are combined with the aforementioned PVT systems: the excess heat collected by solar panels in summer can be stored for winter use.

Geothermal power generation: geothermal power plants

Fundamental physical laws limit the conversion efficiency of low-enthalpy geothermal resources to a lower level (21%)

In 2050, if the average efficiency of geothermal power plants reaches 25%, the average available geothermal energy per square meter will be:

$1.656 \times 10^{-3} \times 25\% = 4.14 \times 10^{-4}$ kWh/d

In spite of its invisibility, the extraction area of a 10 MW geothermal power plant will be immense:

$(10 \times 10^{6}) / (69 \times 10^{-3}) = 144927536\ m^2$,
which accounts for approximately 1/153 of Daqing's total area.

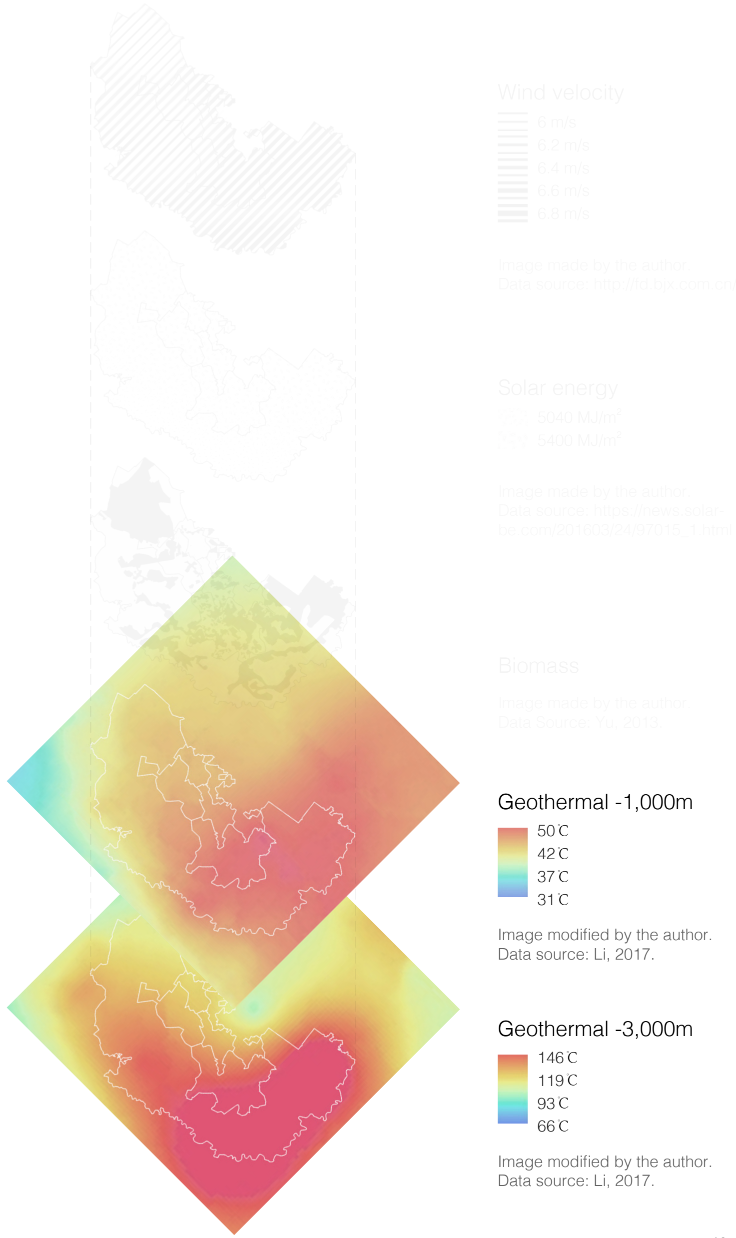


Image modified by the author.
Data source: Li, 2017.

Image modified by the author.
Data source: Li, 2017.

IV Scenario building: Renewable energy production solutions

1st generation biomass (such as corn) compete directly with food production
2nd generations are non-food energy crops like switchgrass (Panicum virgatum) √
Agricultural by-products and waste can be sources of biomass √

‘coal substitution’ (MacKay, 2008): compressed and sent to thermal power stations

‘petroleum substitution’: fermented in biorefineries to produce bioethanol or biodiesel

Biomass

Image made by the author.
Data Source: Yu, 2013.

Non-food energy crops

If the efficiency of photosynthesis of energy crops is around 0.5%, during the time period when the climate allows crops to grow (generally from May 1st to October 31st), the average chemical energy stored in biomass will be 4.5 kWh/m^2

If the conversion efficiency is around 70% in 2050, the available energy stored in bioethanol or biodiesel that made from energy crops will be:

$4.5 \times 70\% =$ **3.2 kWh/m^2**

Waste straw

In 2015, 34% (7478.6 km^2) of the land surface in Daqing is used for crop cultivation (Daqing Bureau of Statistics, 2016).

Presently, 30% of the collected straws go to open-burning, which is not only a waste of energy but also a source of air pollutants (Meng, Yang, Zhou, 2018);

In 2050, It is speculated that 50% of the waste straw collected from farmland is used for renewable energy production.

IV Scenario building: Renewable energy production solutions

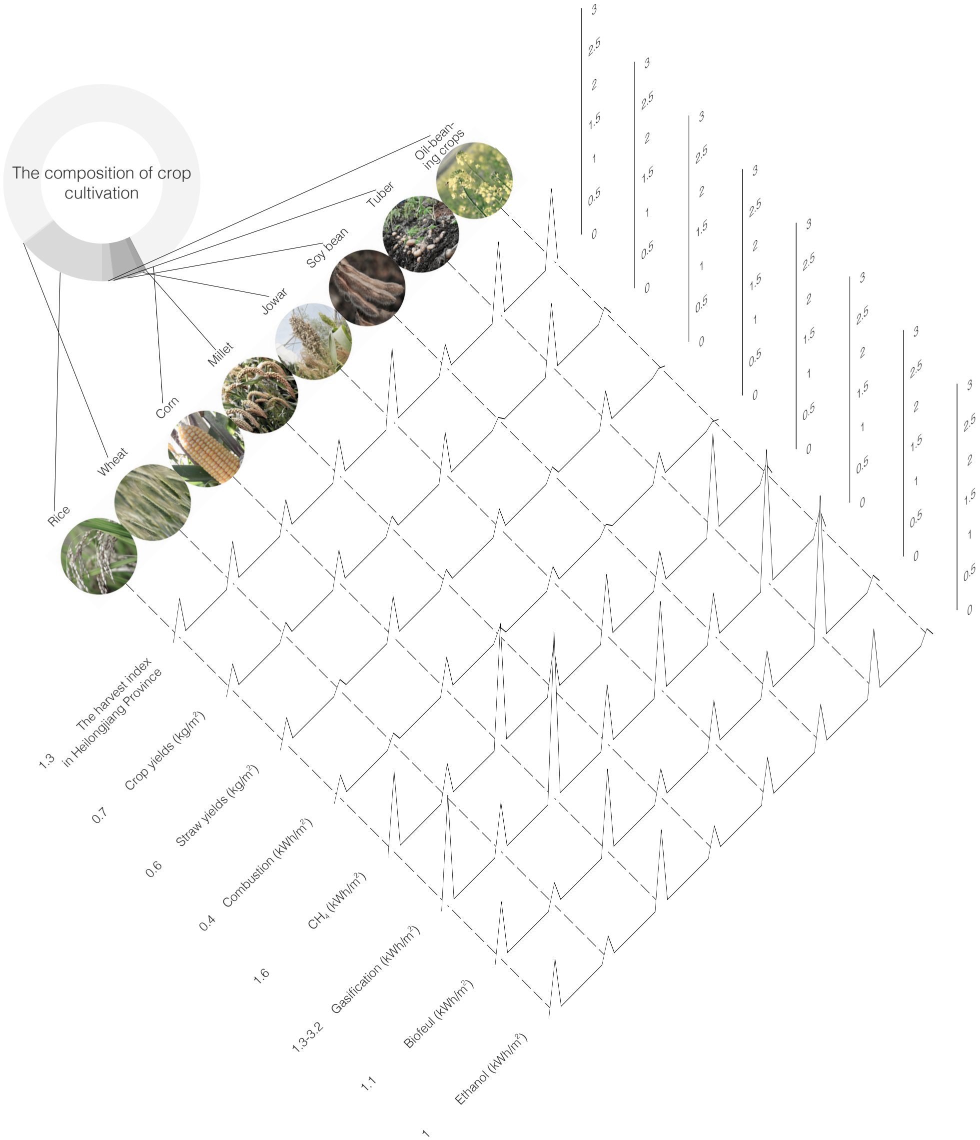


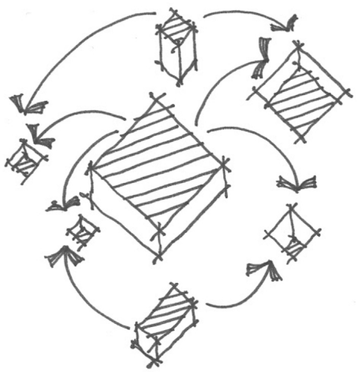
Image made by the author. Data source: Daqing Bureau of Statistics, 2016; Heilongjiang Bureau of Statistics, 2016; Meng, Yang, Zhou, 2018; Dong et al., 2010)

Biomass

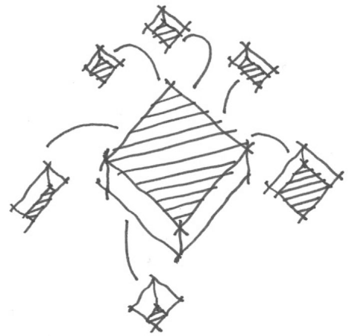
Image made by the author.
Data Source: Yu, 2013.

IV Scenario building: Energy flow in the built environment

Stremke & Koh (2011) has promoted the source-sink thinking:



Build physical connections between source and sink areas that 'lie in close proximity to one another'



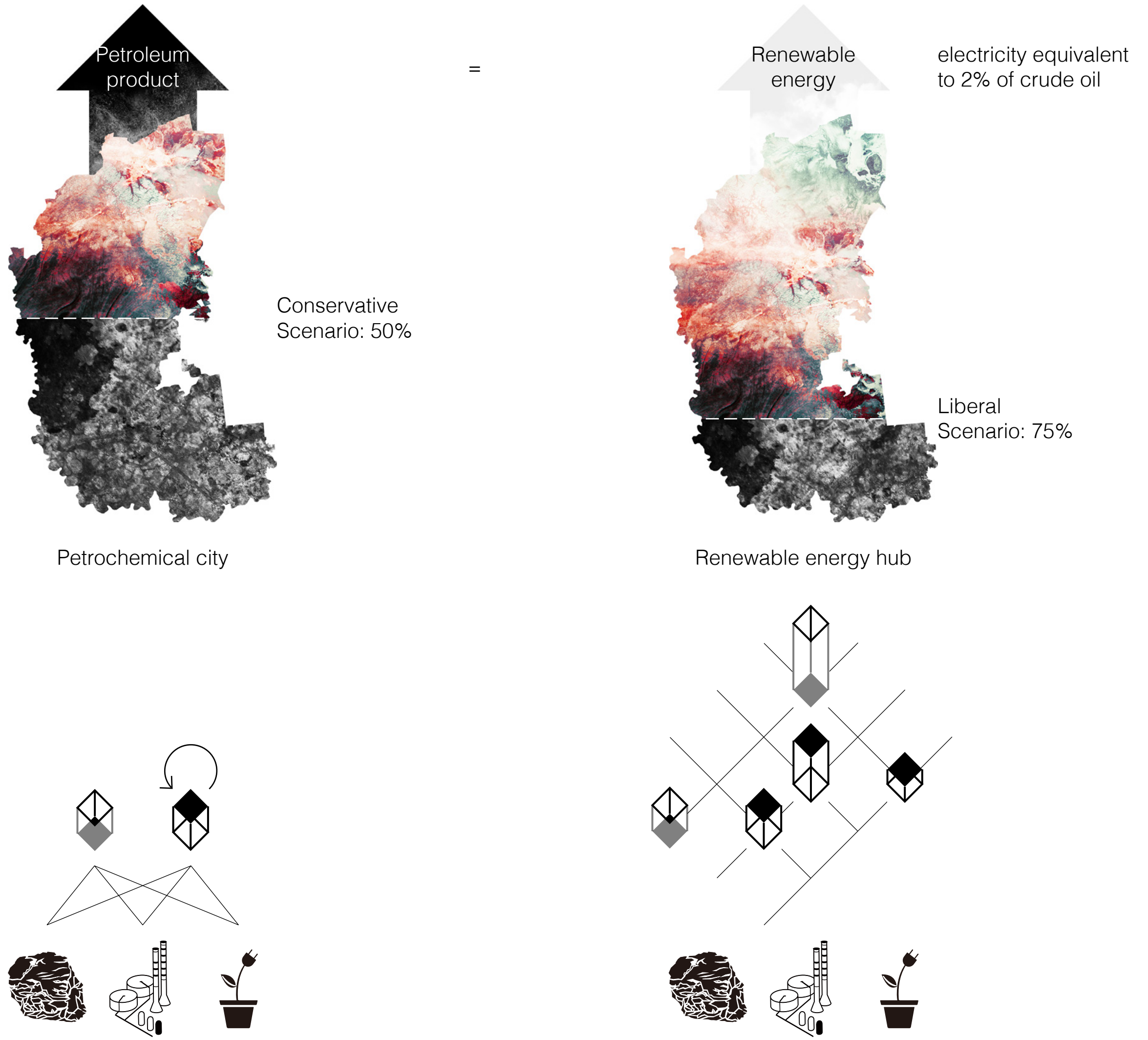
Locate new energy sinks in the proximity of existing source areas

 & 

(1) (rural and urban) residential sector
(2) Service sector: wholesale, retail trade, hotel and restaurants
(4) Industrial sector
(5) Agriculture, forestry, animal husbandry and fishery

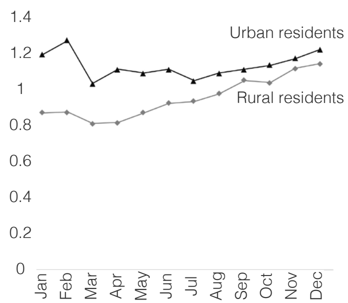
(3) Transportation, storage and post
(6) Construction sector

IV Scenario building: Energy flow in the built environment



Source of icons: Arthur Shlain; Ana María Lora Macias; Stock Image Folio; Bakunetsu Kaito; Marco Livolsi; Olivier Guin; Mahmure Alp from the Noun Project. Modified by the author

IV Scenario building: Energy flow in the built environment - Residential sector



① **Electricity**

1.2 kWh/d per capita > **4.3 kWh/d per capita**, *the average level of the 28 EU member countries in 2016 (Eurostat, 2016)*

② **Water & air heating**

The standard of today's European household - 100L per day per household . The average energy demand for heating water is:
1.5 / 2.6 = 0.6 kWh/d per capita

Most urban dwellings in Daqing are centrally-heated, with a heating season from October 15th to April 15th: 16.2 kWh/d per capita (National Bureau of Statistics, 2016).

The air heating in rural residences often relies on small coal-fired boilers or direct combustion of loose coal and biomass.

In 2050, if rural residences and urban housings shared a same thermal comfort level, and are both equipped with combined PVT and ground coupled heat pump systems
16.2 + 0.6 = **16.8 kWh/d** per capita from October 15th to Aptil 15th
0.6 kWh/d per capita from Aptil 15th to October 15th

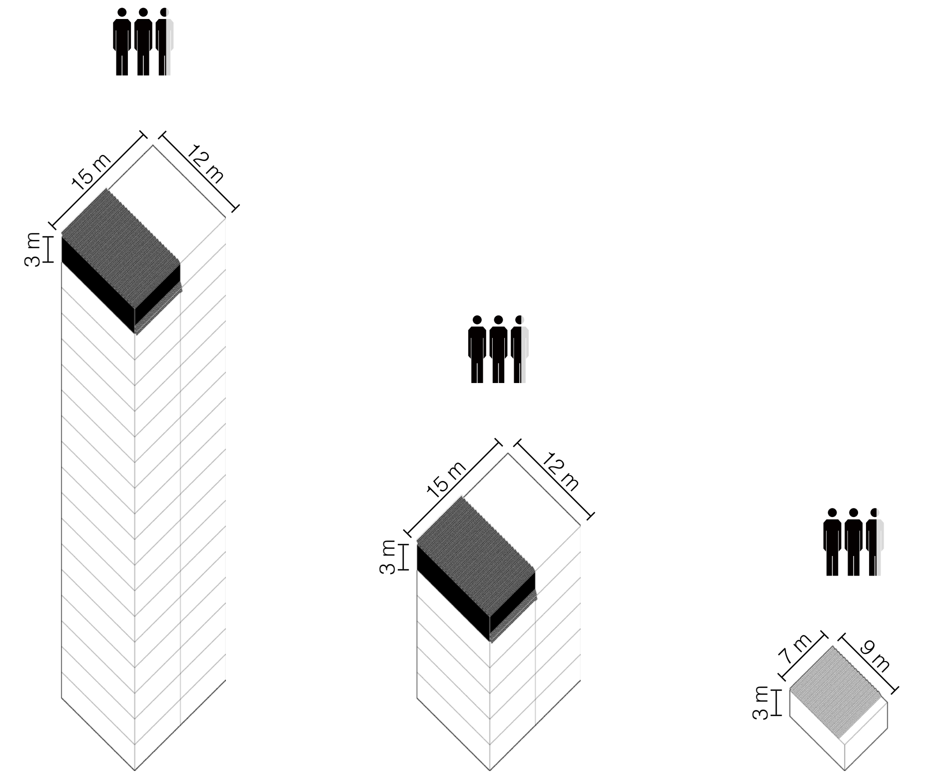
③ **Cooking**

LPG consumption in urban area is 1.4 kWh/d per capita, while the natural gas consumption is about 1.1 kWh/d per capita (National Bureau of Statistics, 2016)

A comprehensive replacement of LPG by natural gas in urban and rural homes.
1.4 + 1.1 = **2.5 kWh/d per capita**, which equals to **0.25 m^3/d per capita**

Data source: Heilongjiang Bureau of Statistics. (2011). Retrieved August 11, 2018, from http://www.hlj.stats.gov.cn/tjsj/ydsj/

IV Scenario building: Energy flow in the built environment - Residential sector



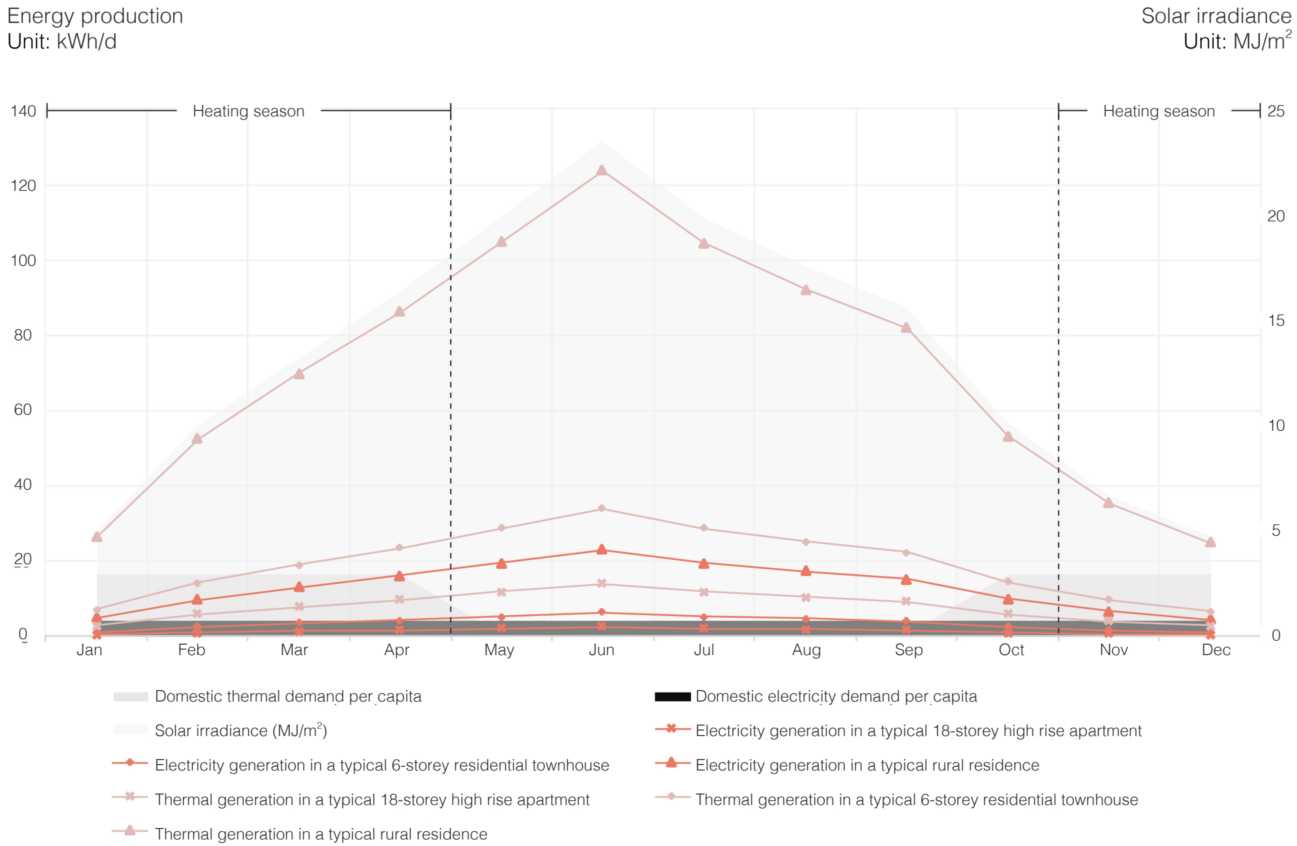
A typical
18-storey high rise apartment

A typical
6-storey residential townhouse

A typical
rural residence

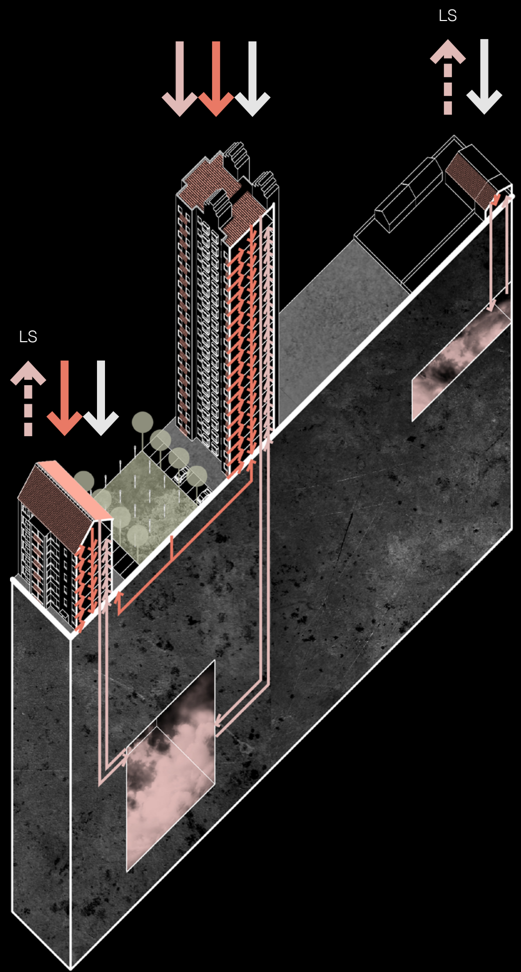
(90 / 18 + 2) / 2.6 = **2.7 m^2 per capita** in a 18-storey high rise apartment
(90 / 6 + 2) / 2.6 = **6.5 m^2 per capita** in a 6-storey residential townhouse
Average GFA of rural residences = 23.7 m^2 per capita

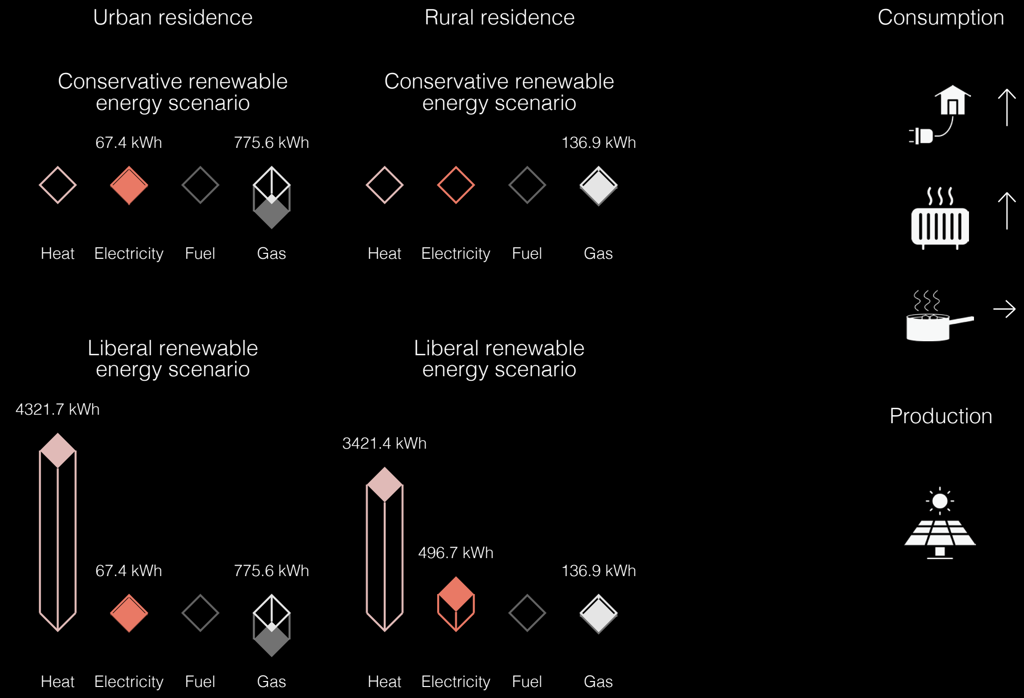
IV Scenario building: Energy flow in the built environment - Residential sector



Data source: Daqing Bureau of Statistics (2016) and other open data sources

IV Scenario building: Energy flow in the built environment - Residential sector



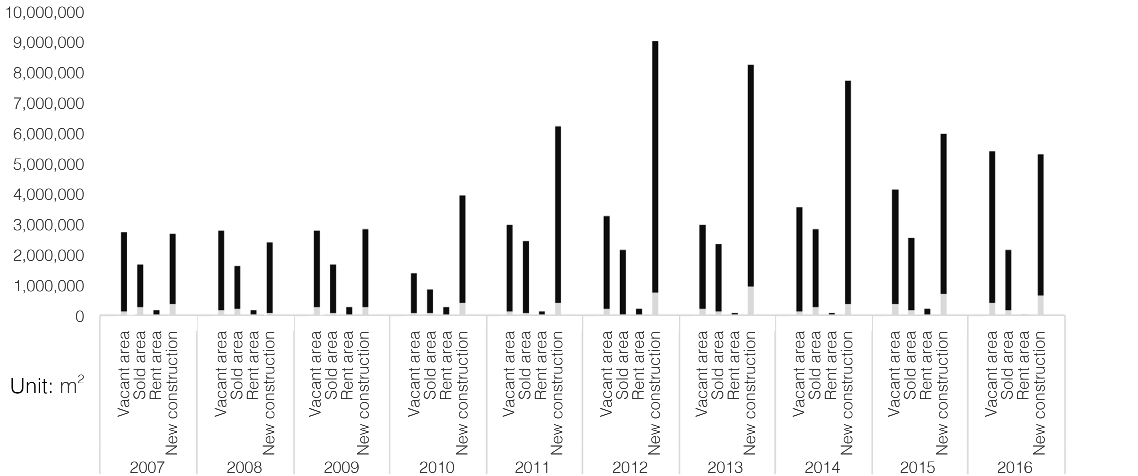


*Unit: per year per capita

Legend

- Heat
- Electricity
- Fuel
- Gas
- Solar energy
- Wind energy
- Geothermal
- Solid biomass
- Liquid biomass

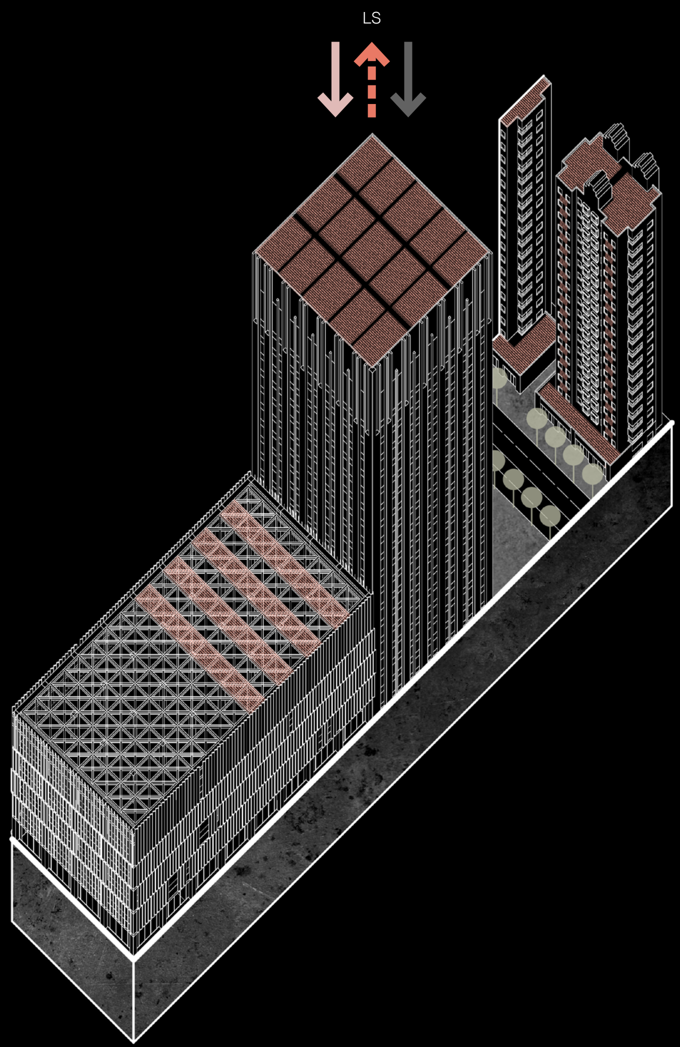
IV Scenario building: Energy flow in the built environment - Service sector



The heat consumption is approximately 4.6 kWh/d per capita (National Bureau of Statistics, 2016). In 2050, this number will fall to:
4.6 × 85% = 3.9 kWh/d per capita
The electricity consumption will reduce to: 0.4 × 85% = 0.3 kWh/d per capita
The traffic fuel consumption will increase to: 2.9 × 120% = 3.5 kWh/d per capita

Data source: Fixed Assets Investment Statistics Division of National Bureau of Statistics, 2016

IV Scenario building: Energy flow in the built environment - Service sector



Conservative renewable energy scenario

Heat	Electricity	Fuel	Gas
713.7 kWh		638.8 kWh	

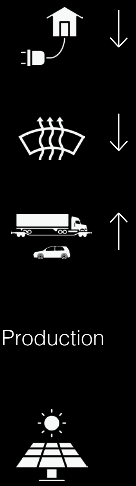
Liberal renewable energy scenario

Heat	Electricity	Fuel	Gas
713.7 kWh	858.1 kWh	638.8 kWh	

*Unit: per year per capita

Consumption

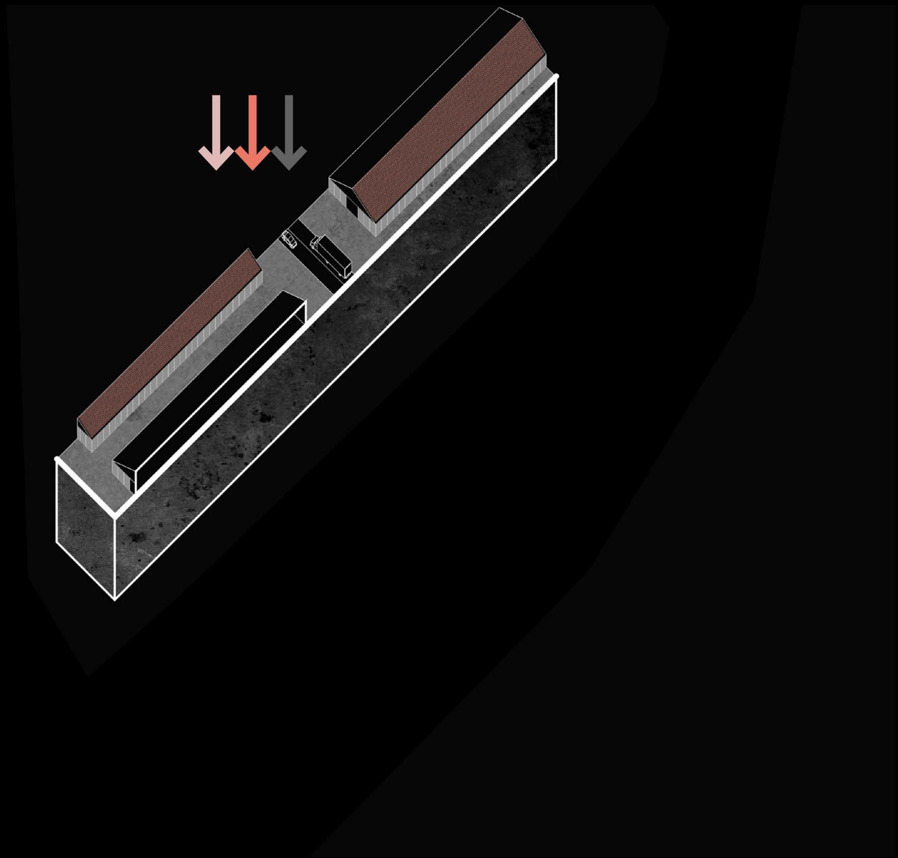
Production



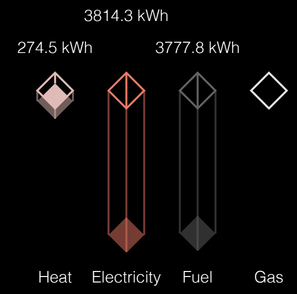
Legend

- Heat
- Electricity
- Fuel
- Gas
- Solar energy
- Wind energy
- Geothermal
- Solid biomass
- Liquid biomass

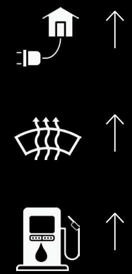
IV Scenario building: Energy flow in the built environment - Transportation sector



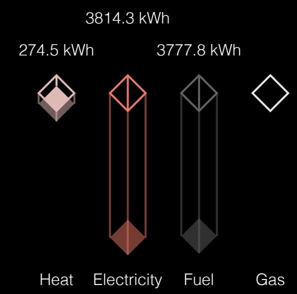
Conservative renewable energy scenario



Consumption



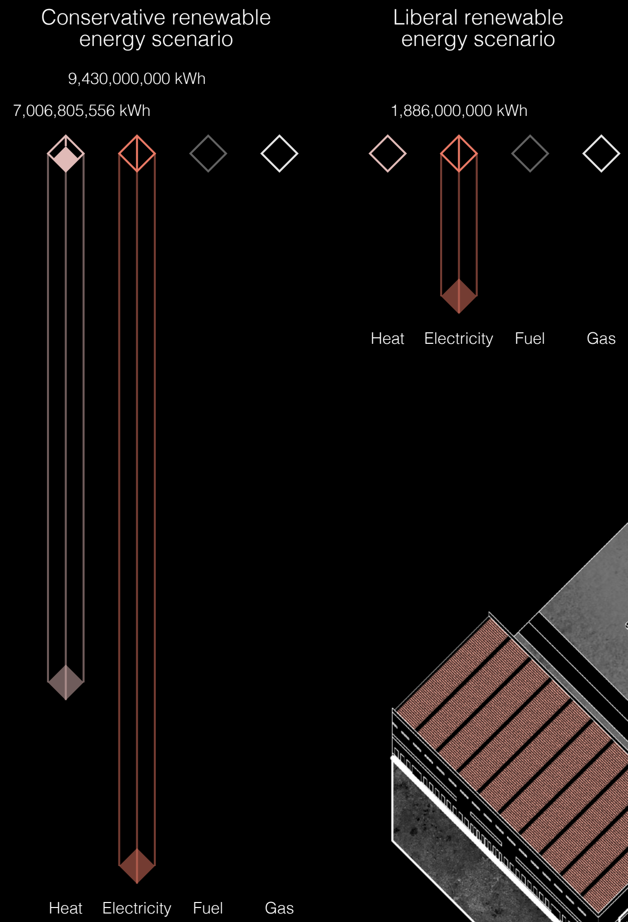
Liberal renewable energy scenario

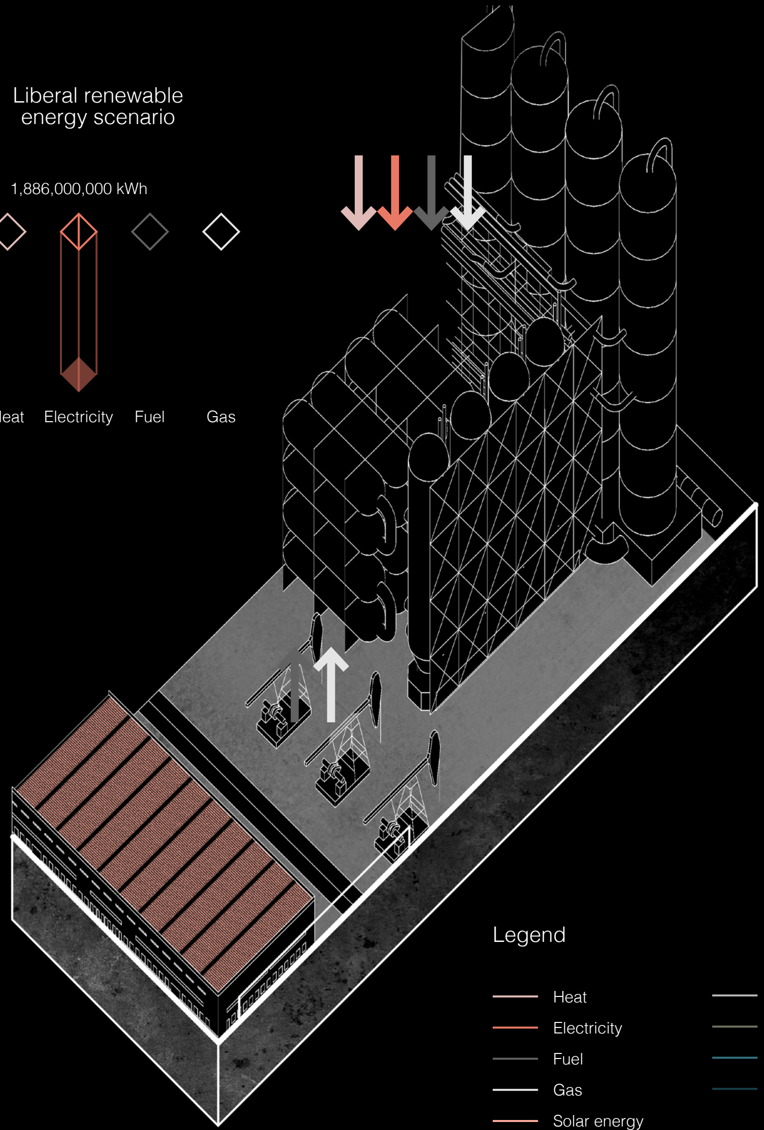


Legend

- Heat
- Electricity
- Fuel
- Gas
- Solar energy
- Wind energy
- Geothermal
- Solid biomass
- Liquid biomass

IV Scenario building: Energy flow in the built environment - Industrial sector

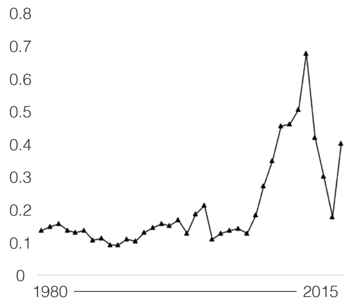


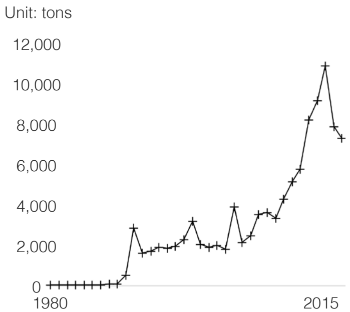


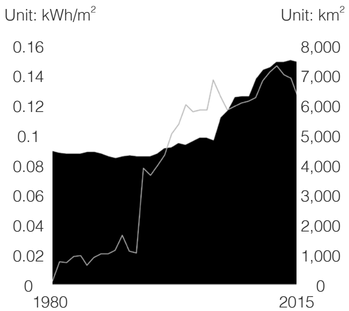
Legend

- Heat
- Electricity
- Fuel
- Gas
- Solar energy
- Wind energy
- Geothermal
- Solid biomass
- Liquid biomass

IV Scenario building: Energy flow in the built environment - Agriculture sector







① **Electricity**

40.5% (National Bureau of Statistics, 2016) > *75% of the cropped land needs irrigation,* per square meter of irrigated land consumes **0.4 kWh** of electricity to power water pumps.

② **Heat**

In 2015, greenhouses consume 271.1 kWh of heat per capita

Some greenhouses are heated by geothermal, others are equipped with combined PVT systems and ground source heat pumps, which can also work as solar power stations

③ **Gasoline**

In a post-petroleum era, it can be speculated that food will be produced much closer to consumers than it is now.

④ **Diesel**

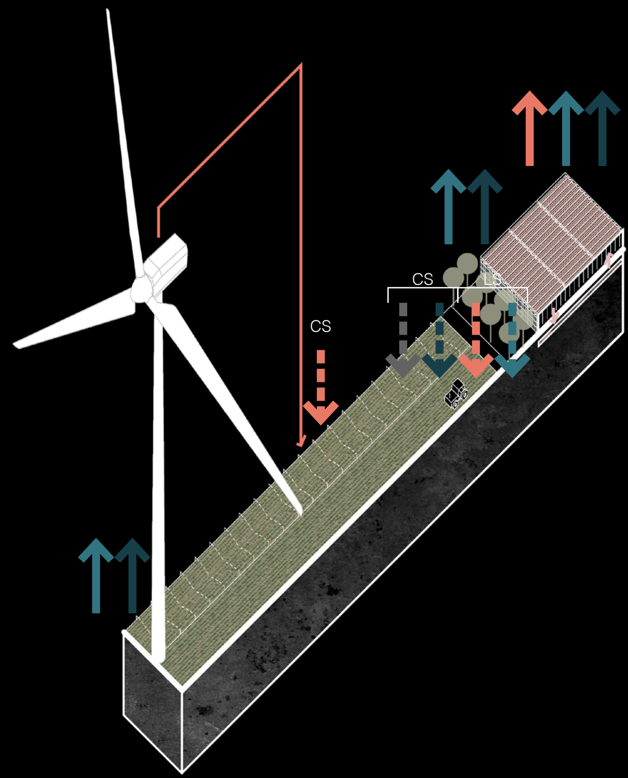
Agricultural mechanization has led to a significant increase in the diesel consumption, which then falls to 0.13 kWh/m^2 (National Bureau of Statistics, 2016; Daqing Bureau of Statistics, 2016)

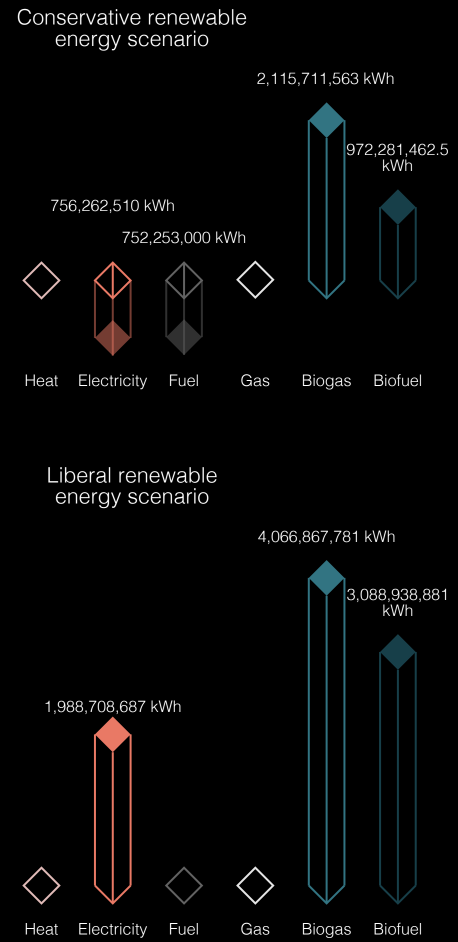
The improvement in the efficiency of agricultural machinery has led to a 20% reduction in its energy consumption.

In the conservative scenario, farm machinery runs on B20 diesel.
In the liberal scenario, 50% of the machinery is adapted to be powered by electricity, while another 50% are methane powered.
0.13 × 80% = **0.1 kWh/m^2**

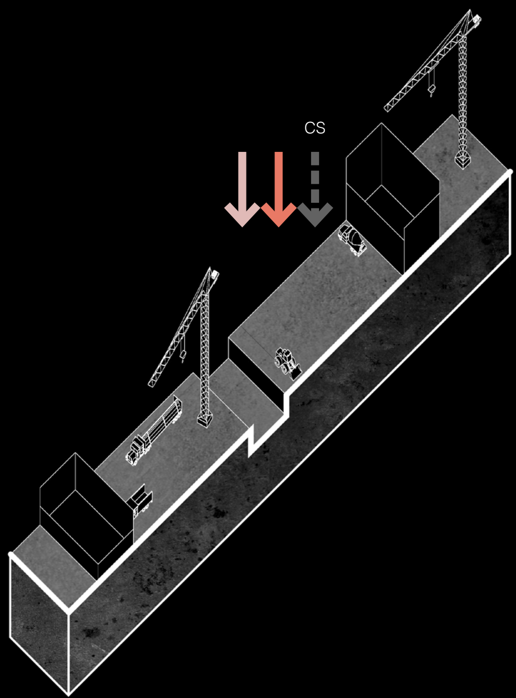
Data source: Daqing Bureau of Statistics, 2016

IV Scenario building: Energy flow in the built environment - Agriculture sector





IV Scenario building: Energy flow in the built environment - Construction sector



Conservative renewable energy scenario

44,082,582 kWh

7,491,677 kWh 34,145,066 kWh

Heat Electricity Fuel Gas

Liberal renewable energy scenario

78,227,648 kWh

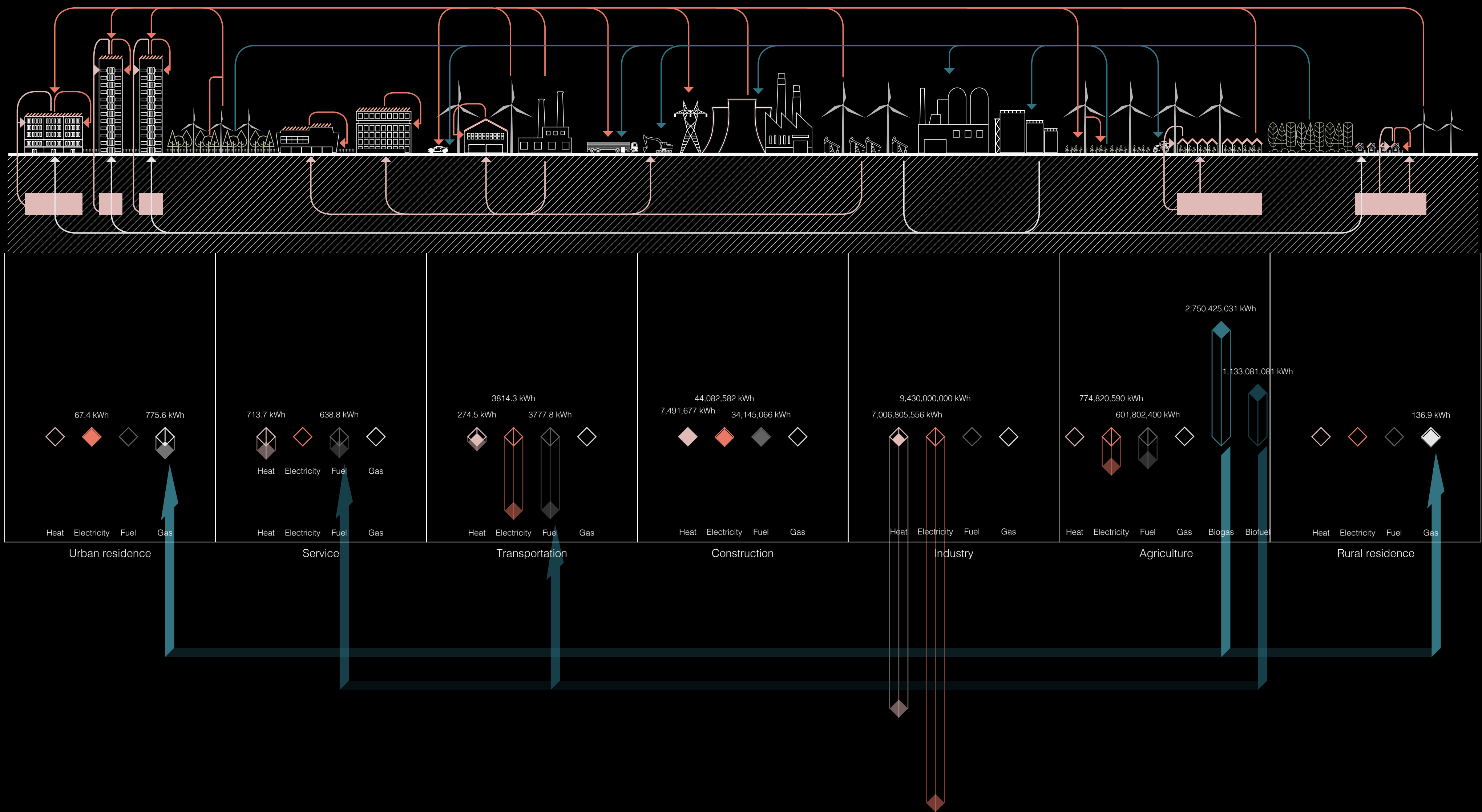
7,491,677 kWh

Heat Electricity Fuel Gas

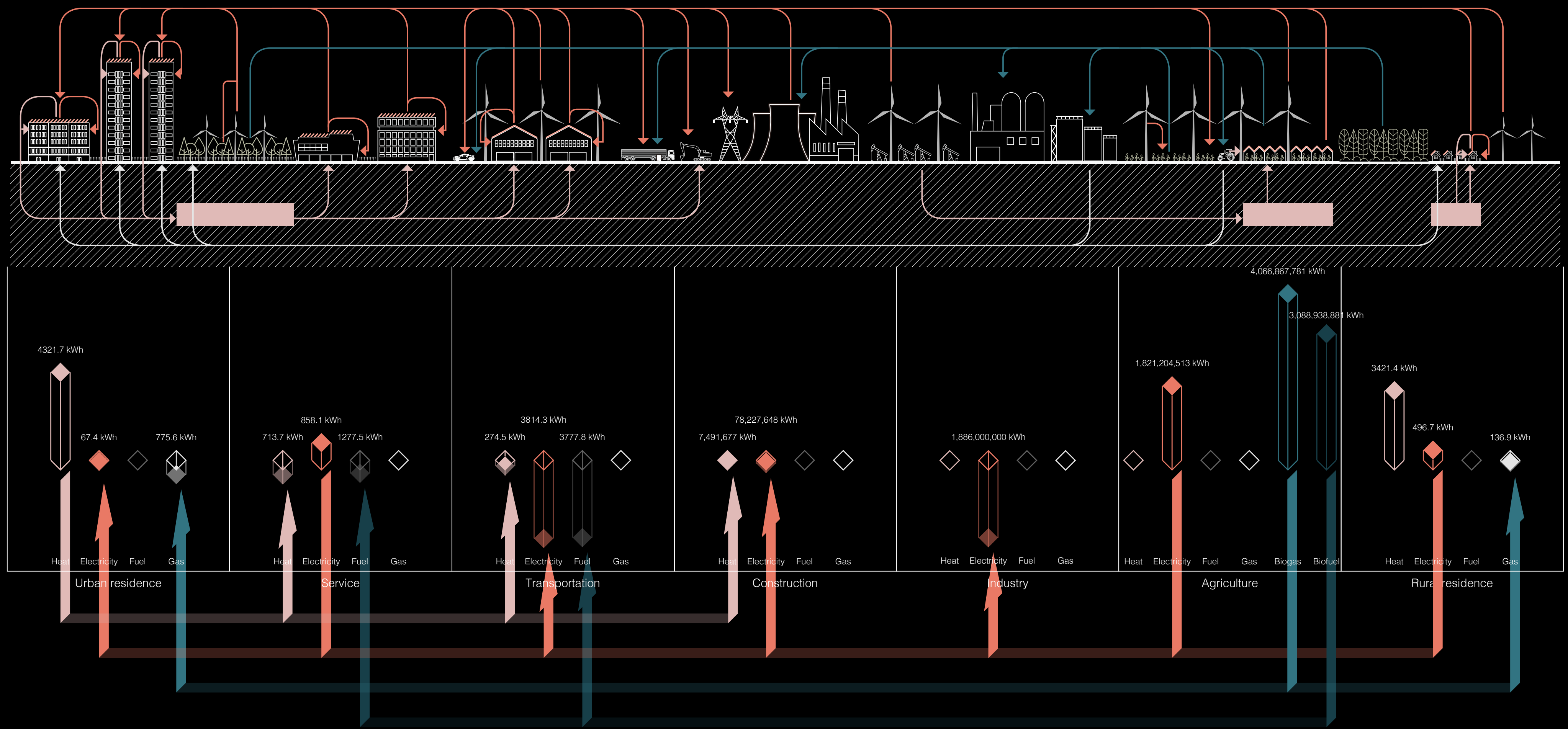
Legend

- Heat
- Electricity
- Fuel
- Gas
- Solar energy
- Wind energy
- Geothermal
- Solid biomass
- Liquid biomass

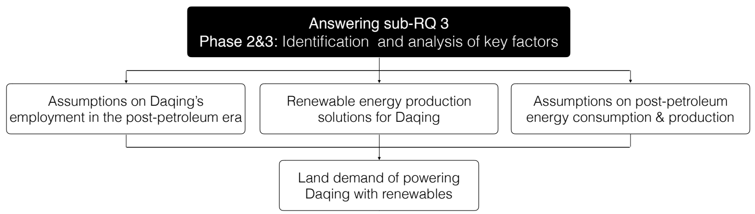
IV Scenario building: Energy flow in the built environment - Conservative scenario



IV Scenario building: Energy flow in the built environment - Liberal scenario



IV Scenario building



$$\frac{\text{Green jobs}}{\text{Employment multipliers}} = \textbf{Renewable energy production} =$$

[(Reduced) initial population + green jobs] × renewable energy production per capita
+ Renewable energy consumption + Renewable energy exports

1) identification of the scenario field; 2) & 3) identification and analysis of key factors; 4) scenario generation; 5) scenario transfer

IV Scenario building

Conservative renewable energy scenario

In the conservative renewable energy scenario, the absence of working population engaged in mining industries has led to a reduction in Daqing's urban population:

1,413,300 - (119,710 × 2.7 × 1.2) = 1,025,440

If the green jobs in renewable energy industries are taken into consideration, the total population in 2050 will be:

$$P_{cs} = [(J_{pv} + J_{wt} + J_{bp} + J_{bf}) \times 2.7 \times 1.2 + 1{,}025{,}440] / 0.85$$

PV cells, PVT, Solar greenhouses

$$J_{pv} = 20.4 \times [(748 + 1{,}174) \times P_{cs} + 500{,}000{,}000] \times 10^{-6}$$

Employment multiplier

Employment multiplier, Wind farms, On-farm wind turbines

$$J_{wt} = 1.7 \times [(329 + 3{,}882 \times 50\%) \times P_{cs} + 248{,}243{,}490 + 10{,}230{,}345{,}092 \times 50\%] \times 10^{-6}$$

Bladeless wind turbine, Wind farms

Employment multiplier

$$J_{bp} = 4.1 \times (752{,}253{,}000 + 2{,}115{,}711{,}563) \times 10^{-6}$$

Biogas, Biomass power generation

Employment multiplier

$$J_{bf} = 13.8 \times (987{,}332{,}063 / 5) \times 10^{-6}$$

Biofuel

$$P_{cs} = 1{,}706{,}779$$

Liberal renewable energy scenario

In the liberal renewable energy scenario, another 63,648 working population engaged in manufacturing industries has left the city:

1,413,300 - [(119,710 + 63,648) x 2.7 × 1.2] = 819,220

In 2015, Daqing exports 36,600,000 tons of crude oil, which equals to 425,658,000,000 kWh of energy[30]. *The liberal renewable energy scenario assumes Daqing exports 2% of equivalent electricity, 54% of which is generated by combustion of biomass, 31% is generated by wind farms, 15% by solar farms. If the green jobs in renewable energy industries are taken into account, the total population in 2050 will be:*

$$P_{ls} = [(J_{pv} + J_{wt} + J_{bp} + J_{bf}) \times 2.7 \times 1.2 + 819{,}220] / 0.85$$

PV cells, PVT, Solar farms, Solar greenhouses

$$J_{pv} = 20.4 \times [(1{,}606 + 1{,}670 + 3{,}024 \times 25\%) \times P_{cs} + 500{,}000{,}000 + 1{,}964{,}227{,}648 \times 25\% + 1{,}308{,}138{,}900] \times 10^{-6}$$

Solar farms, Solar farms for energy export

Bladeless wind turbine, Wind farms, On-farm wind turbines

$$J_{wt} = 1.7 \times [(329 + 3{,}024 \times 50\%) \times P_{cs} + 322{,}716{,}537 + 1{,}964{,}227{,}648 \times 50\% + 2{,}616{,}277{,}800] \times 10^{-6}$$

Wind farms for energy export, Wind farms

Employment multiplier

$$J_{bp} = 4.1 \times (4{,}588{,}743{,}300 + 4{,}555{,}832{,}231) \times 10^{-6}$$

Biogas, Biomass power generation

Employment multiplier

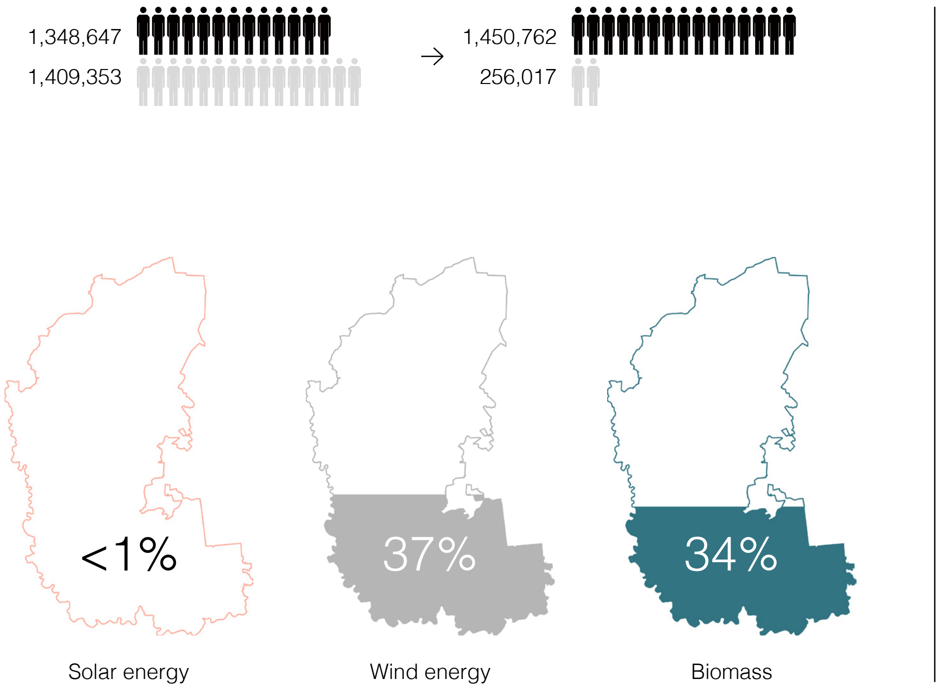
$$J_{bf} = 13.8 \times [3{,}088{,}938{,}881 / 5] \times 10^{-6}$$

Biofuel

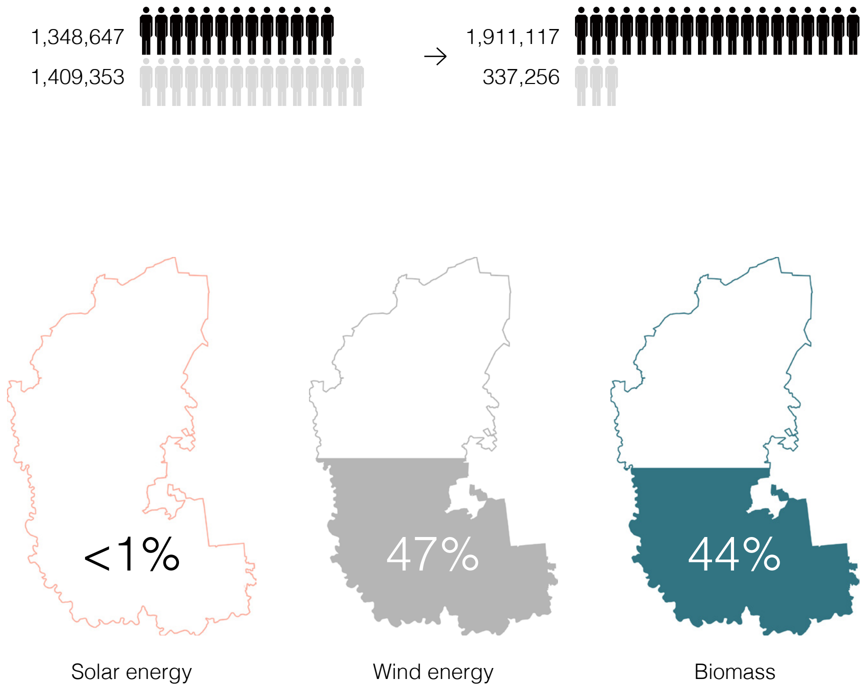
$$P_{ls} = 2{,}248{,}373$$

IV Scenario building

Conservative renewable energy scenario

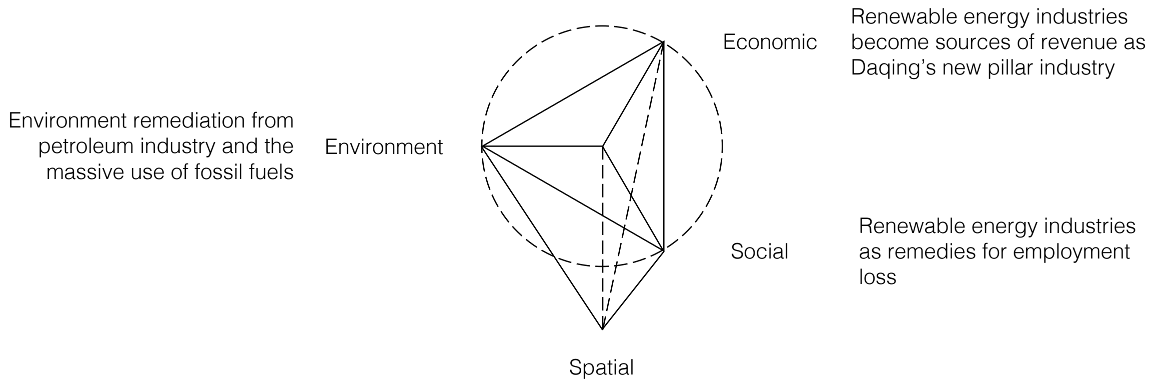


Liberal renewable energy scenario



1) identification of the scenario field; 2) & 3) identification and analysis of key factors; **4) scenario generation;** 5) scenario transfer

IV Scenario building



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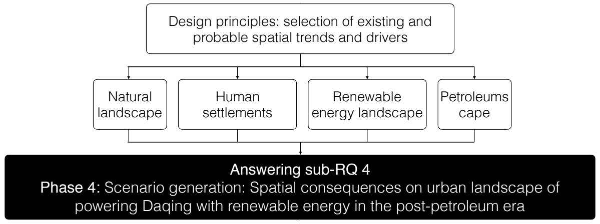
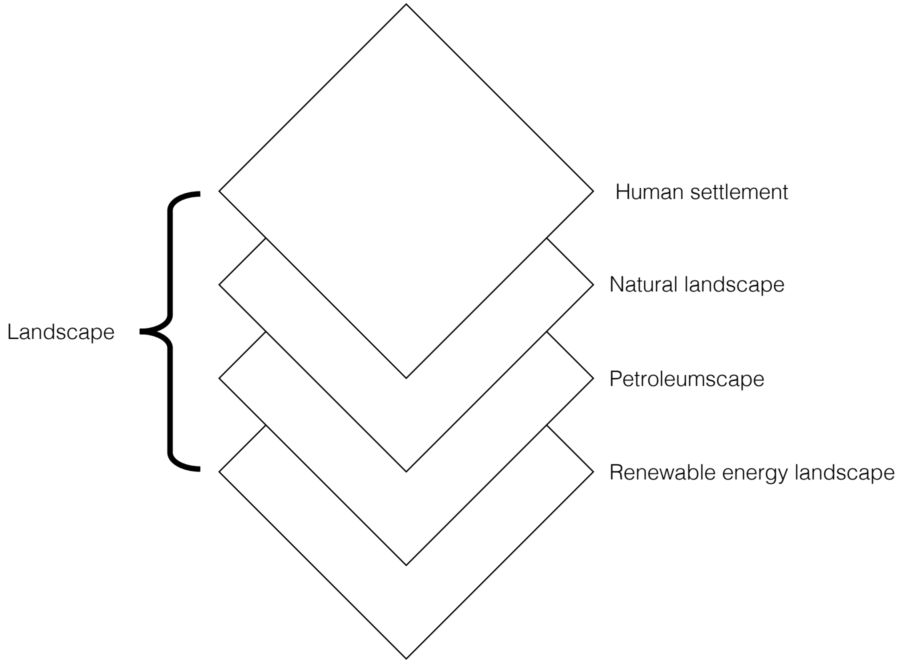
IV Scenario building





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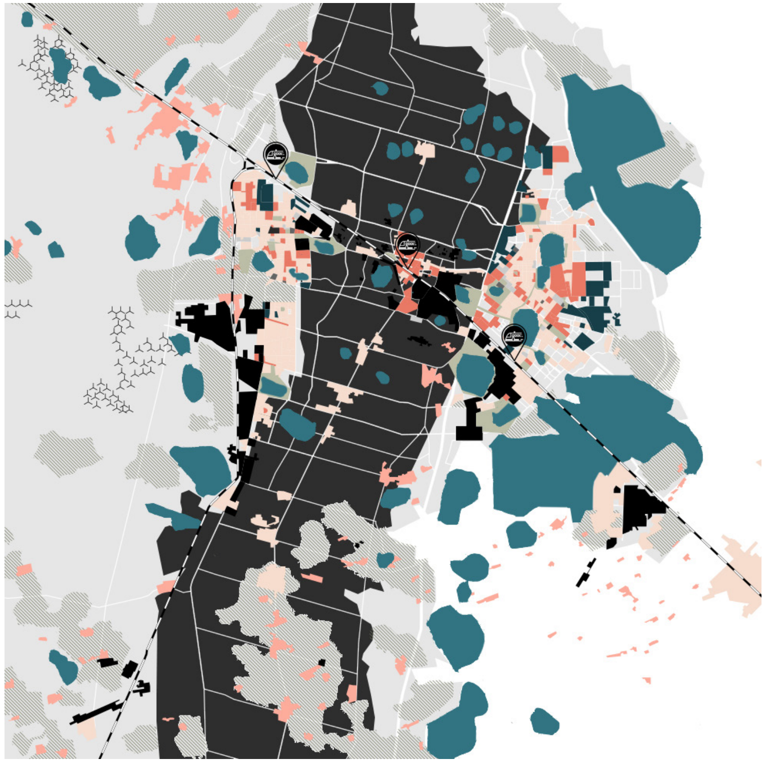
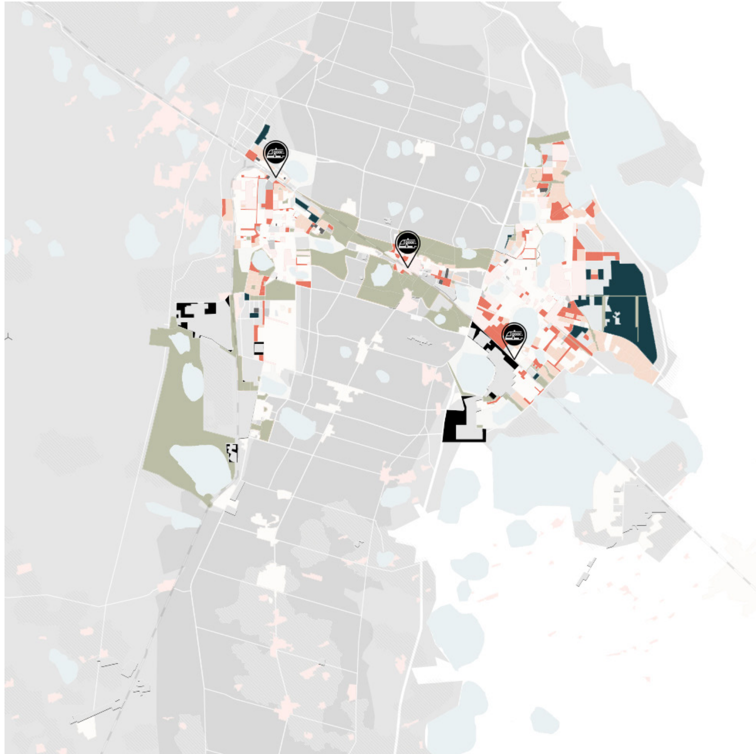
IV Scenario building

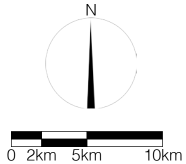


Present condition

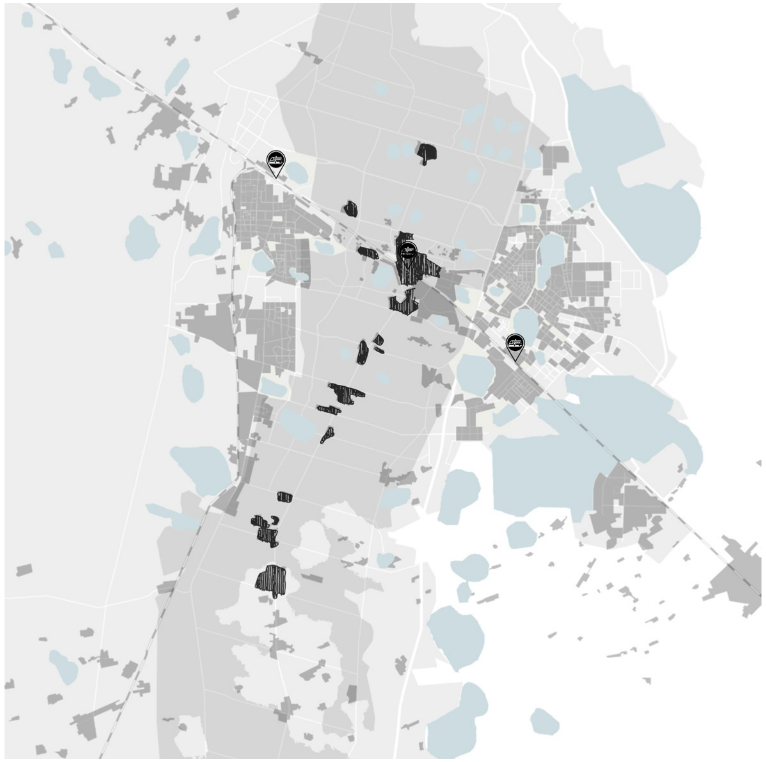


Near future (2020)

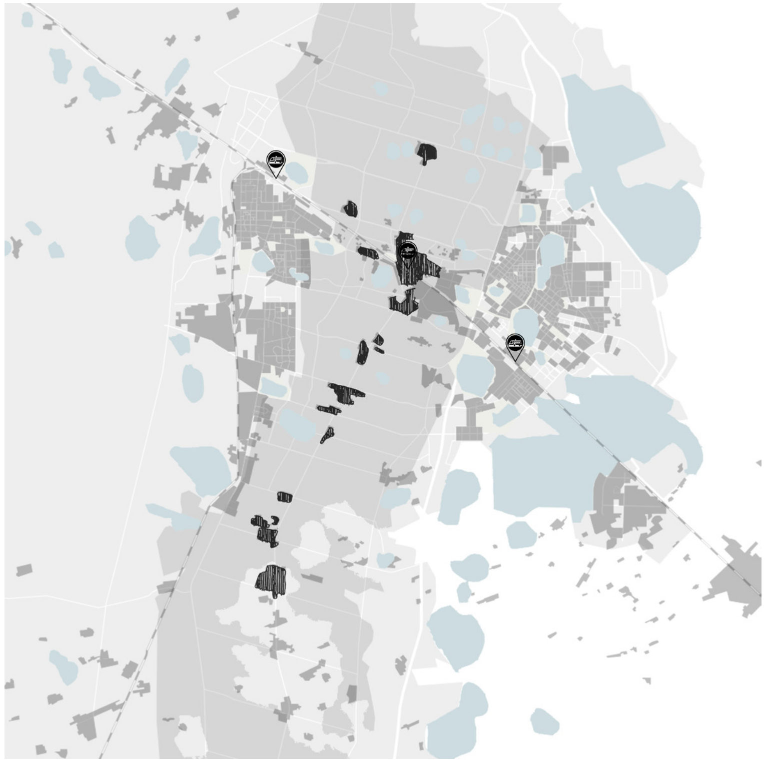
Urban residential area
Rural residential area
Water / wetland
Green space
Petroleumscape
Farmland
Urbanized area
Infrastructure



IV Scenario building

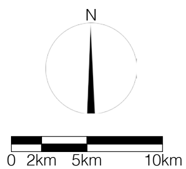


Conservative renewable energy scenario

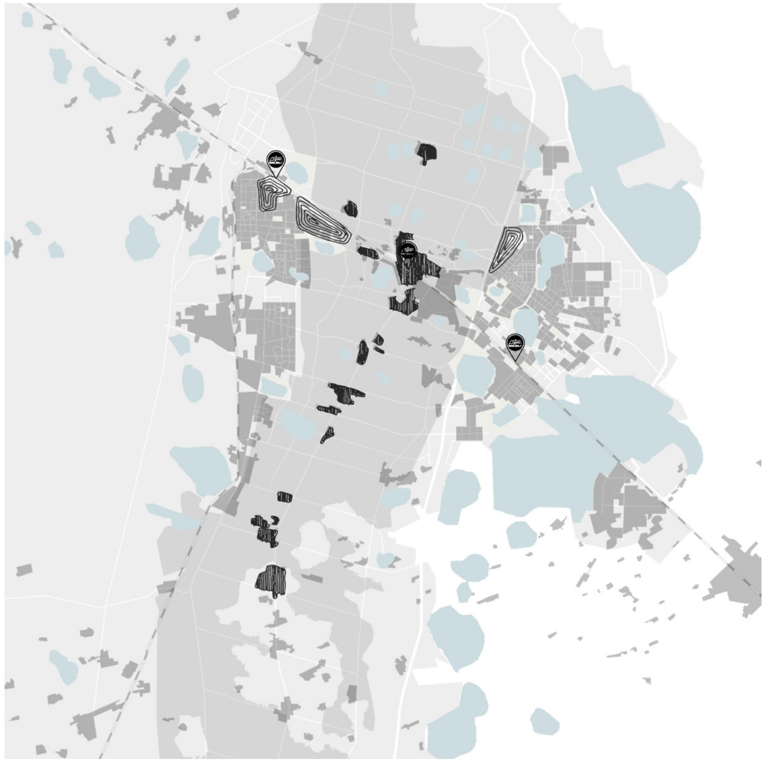


Liberal renewable energy scenario

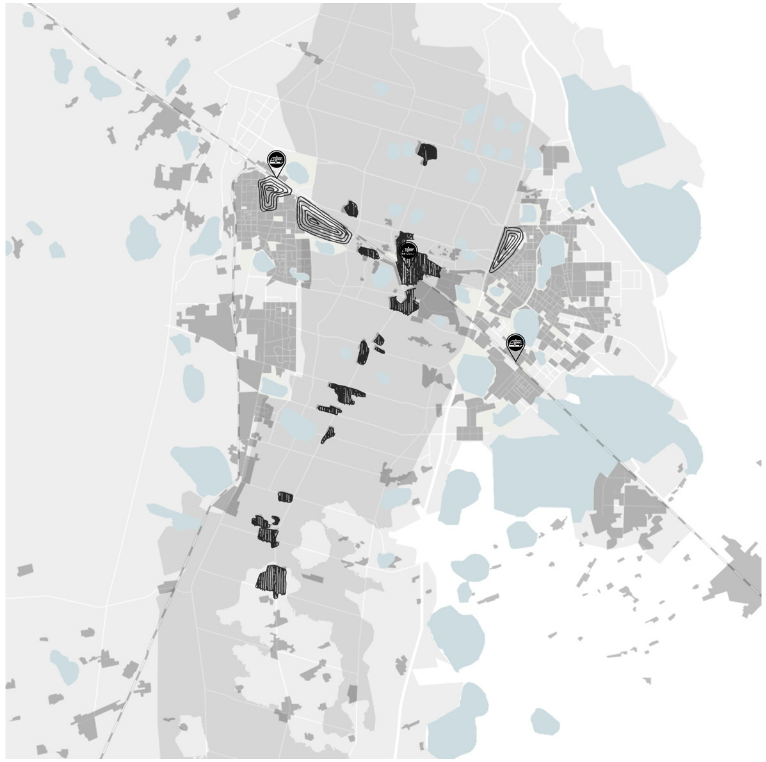
New construction Urban regeneration Demolition Green axis



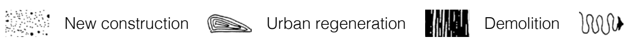
IV Scenario building

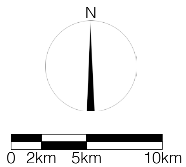


Conservative renewable energy scenario

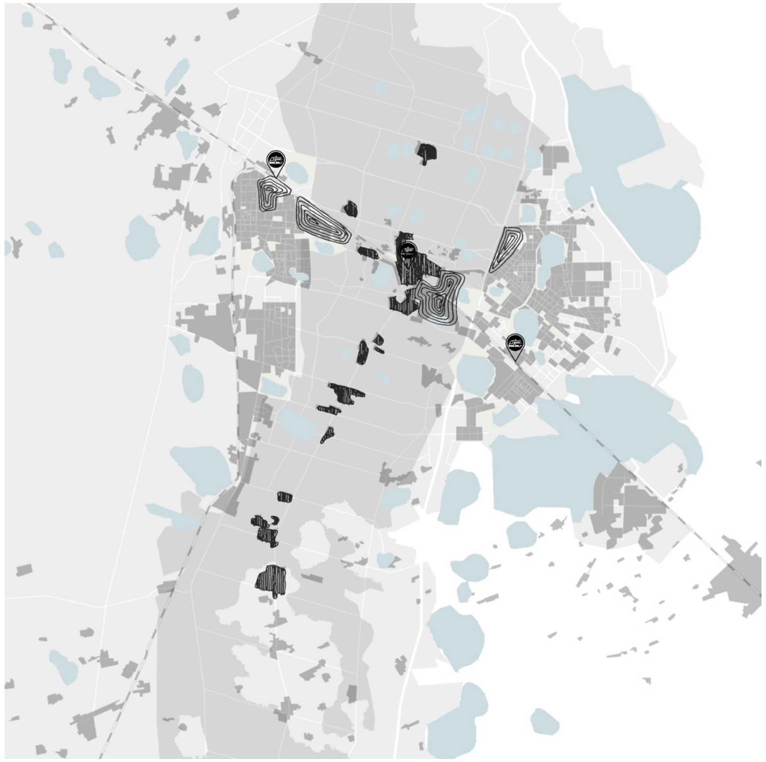


Liberal renewable energy scenario

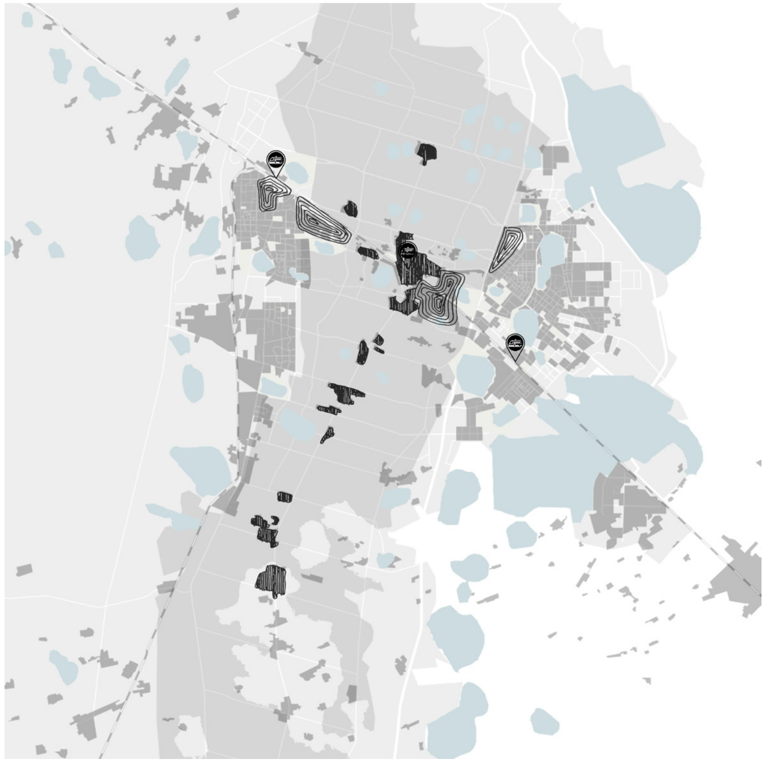




IV Scenario building

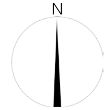


Conservative renewable energy scenario



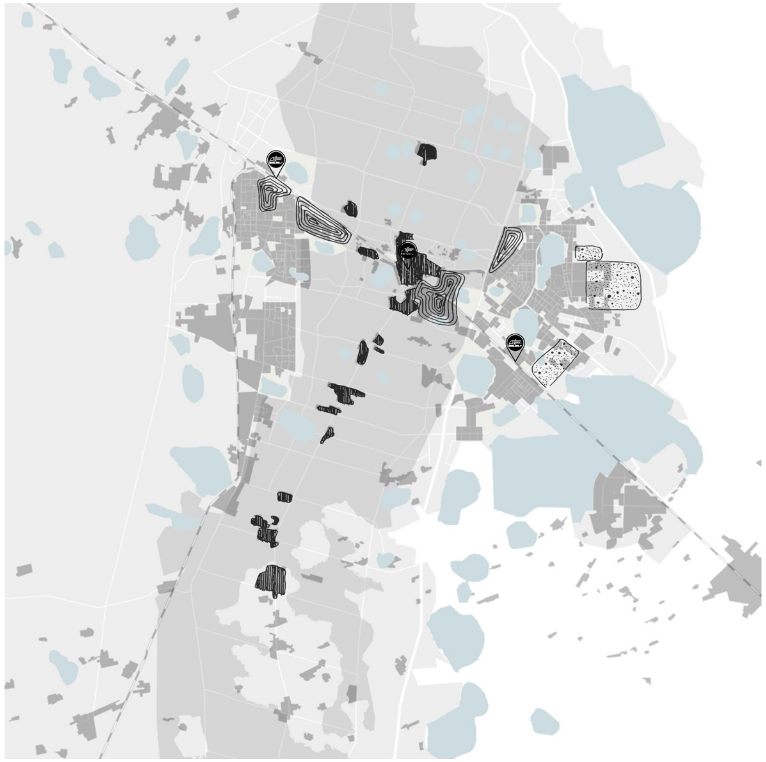
Liberal renewable energy scenario

New construction   Urban regeneration   Demolition   Green axis

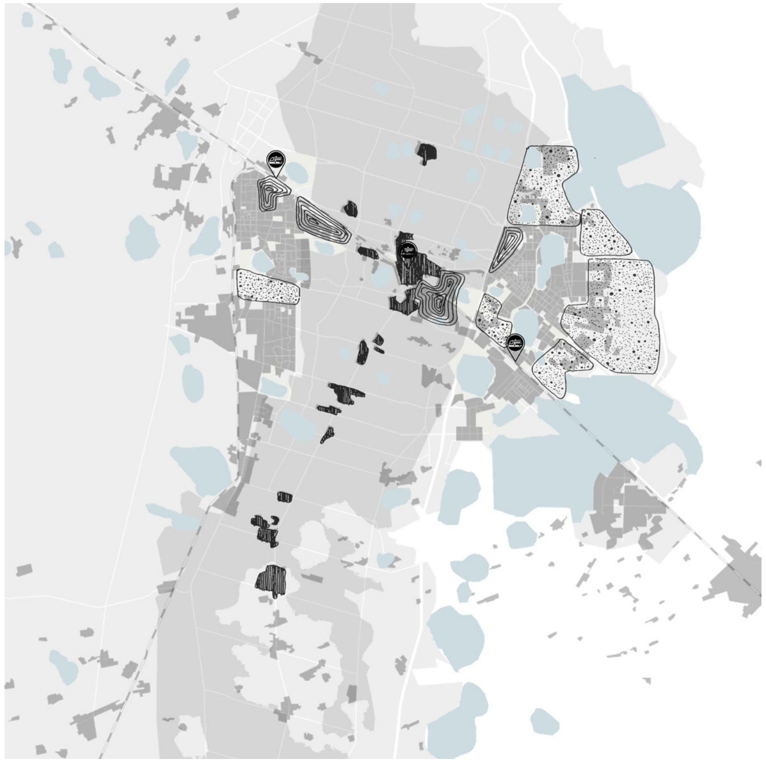


0 2km 5km 10km

IV Scenario building

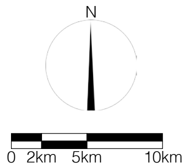


Conservative renewable energy scenario

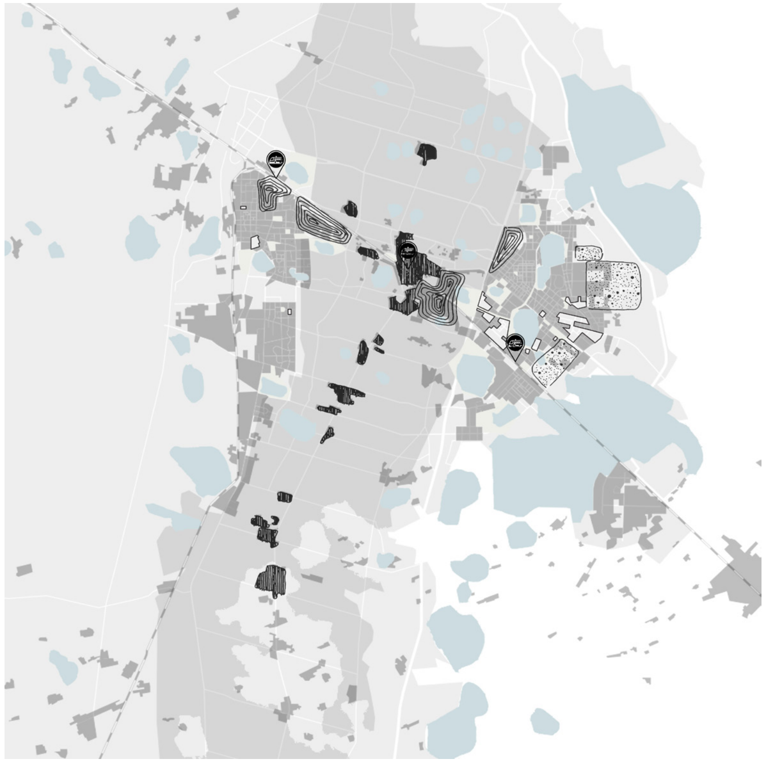


Liberal renewable energy scenario

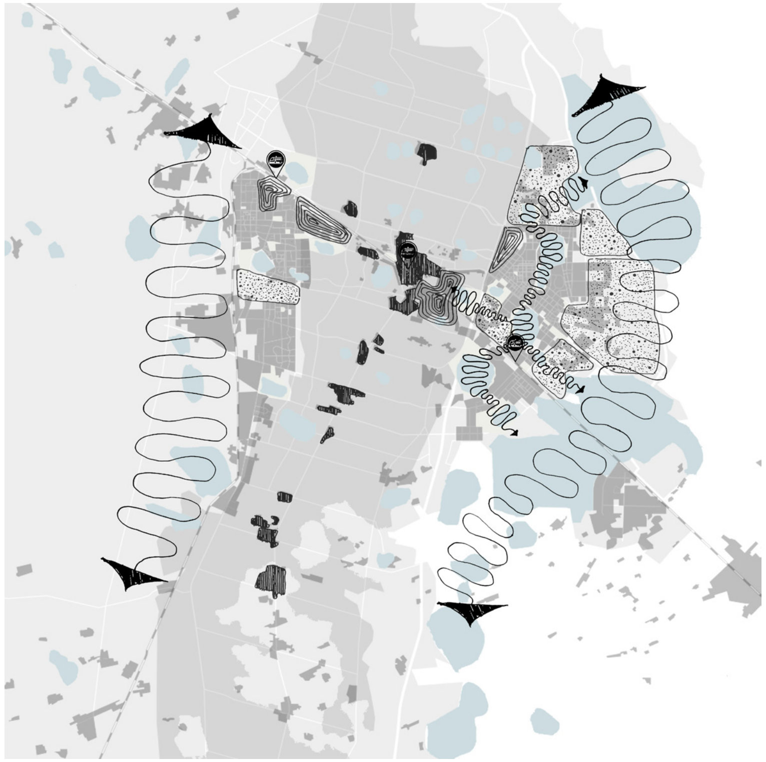
New construction Urban regeneration Demolition Green axis



IV Scenario building

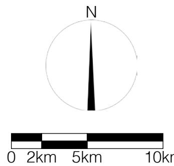


Conservative renewable energy scenario

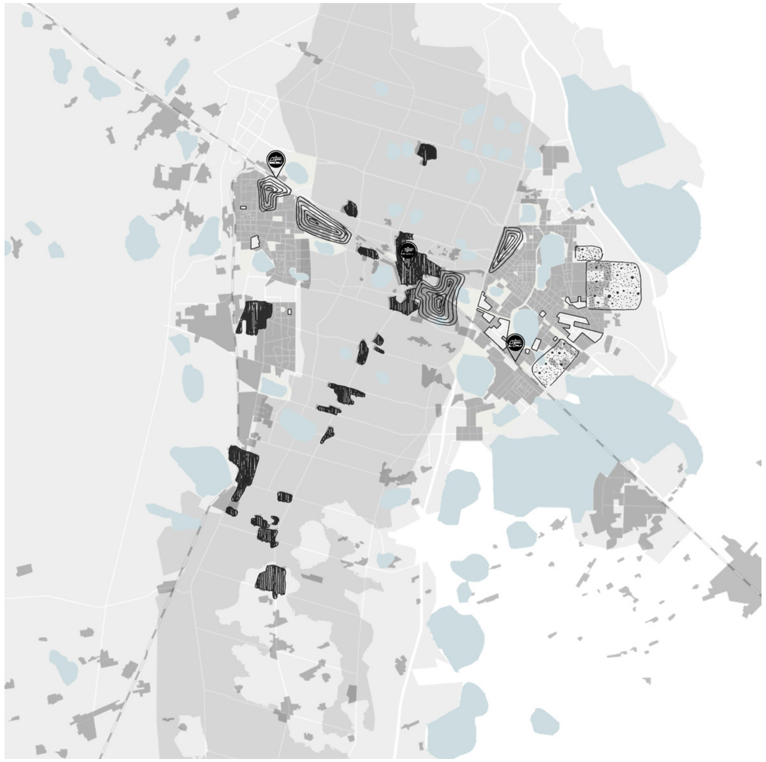


Liberal renewable energy scenario

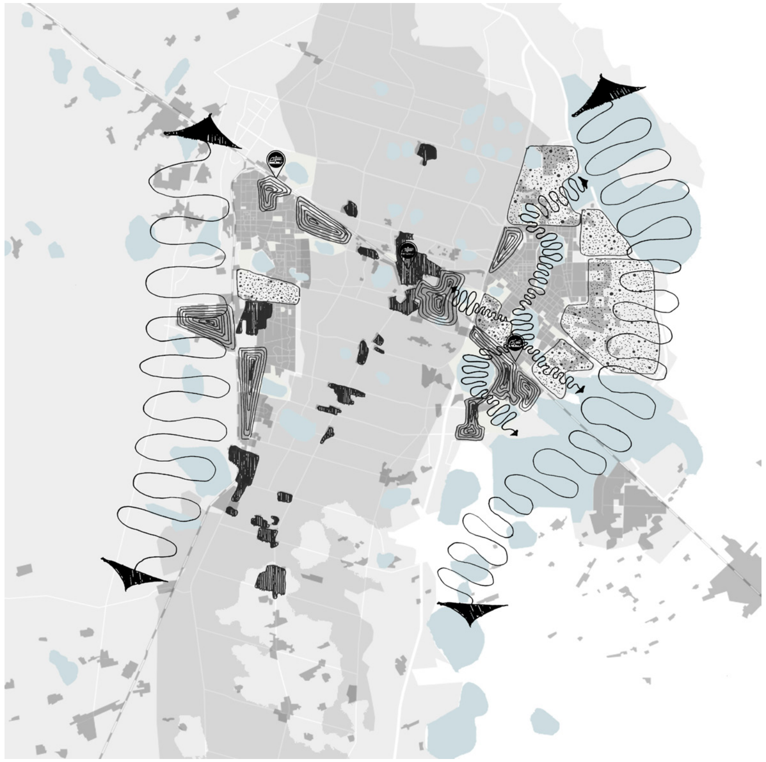
New construction Urban regeneration Demolition Green axis



IV Scenario building

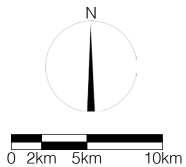


Conservative renewable energy scenario

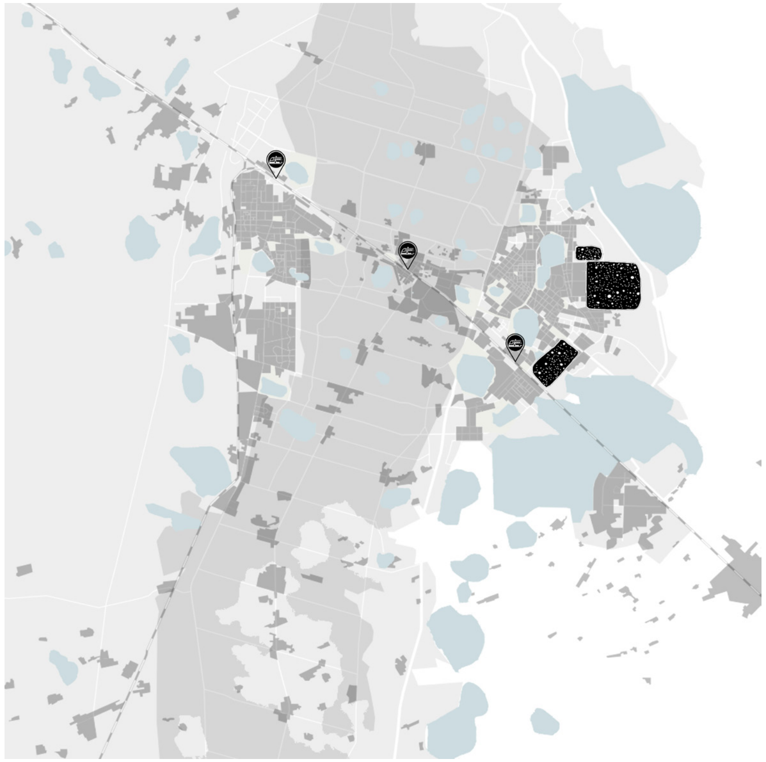


Liberal renewable energy scenario

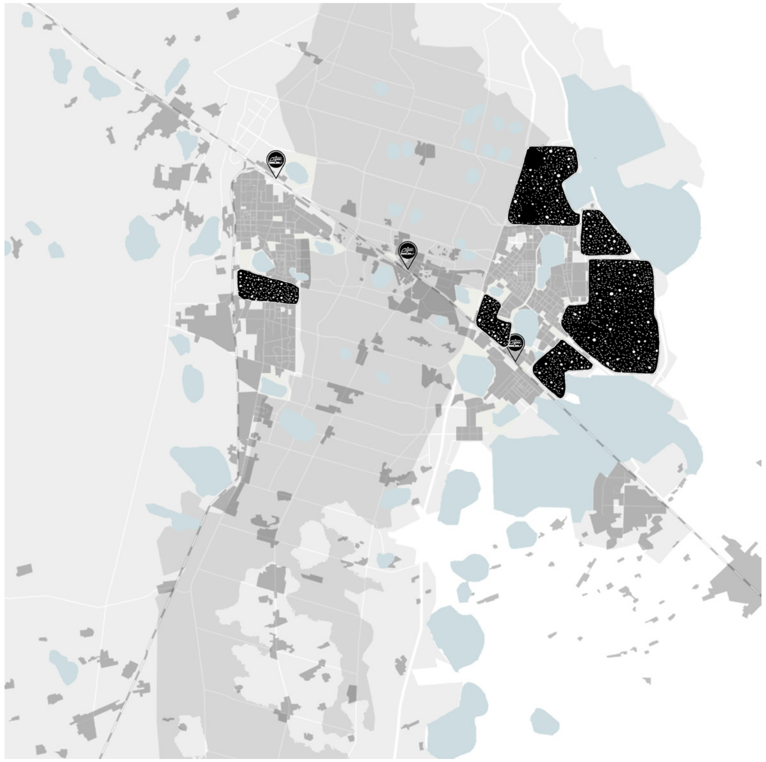
New construction Urban regeneration Demolition Green axis



IV Scenario building

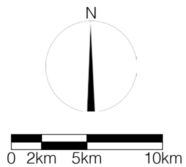


Conservative renewable energy scenario

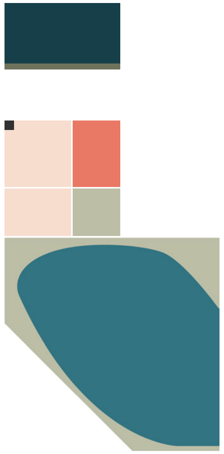


Liberal renewable energy scenario

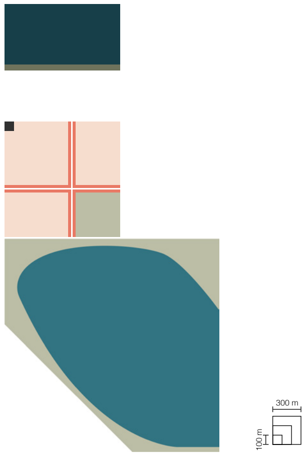
New construction   Urban regeneration   Demolition   Green axis



IV Scenario building

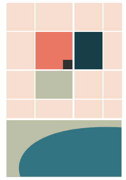


Isolated super blocks

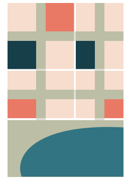


Isolated super blocks

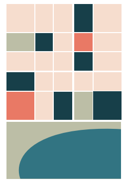
Conservative renewable energy scenario



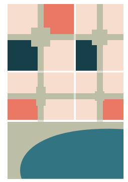
L blocks



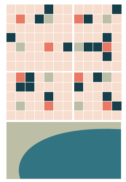
Green corridor



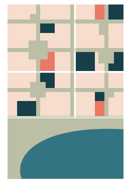
M blocks



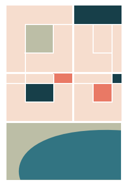
Green chain



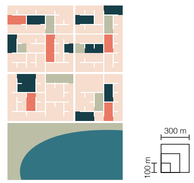
XS blocks



Green chain S



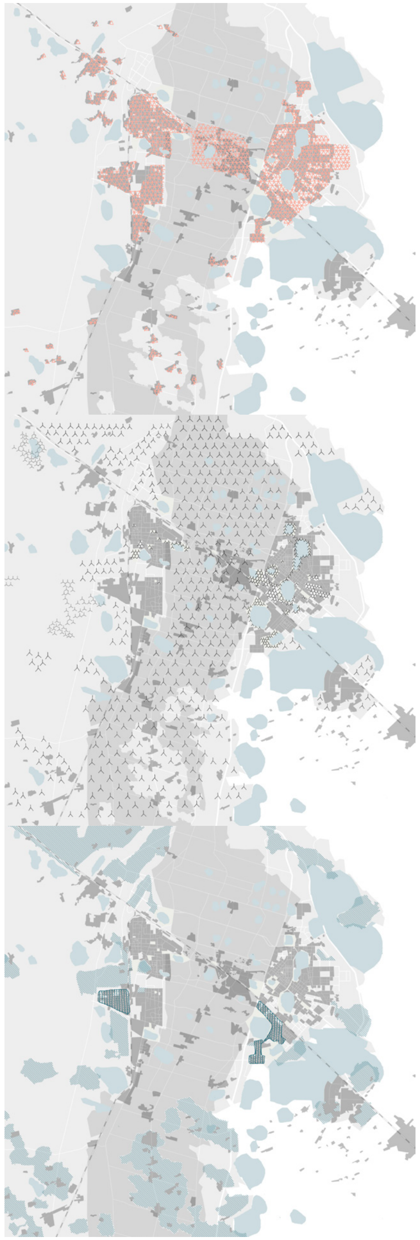
Loop



Tree

Liberal renewable energy scenario

IV Scenario building



Solar energy

Roof-mounted or wall-mounted solar panels

Solar farm

Wind energy

Urban wind turbines

Wind farm

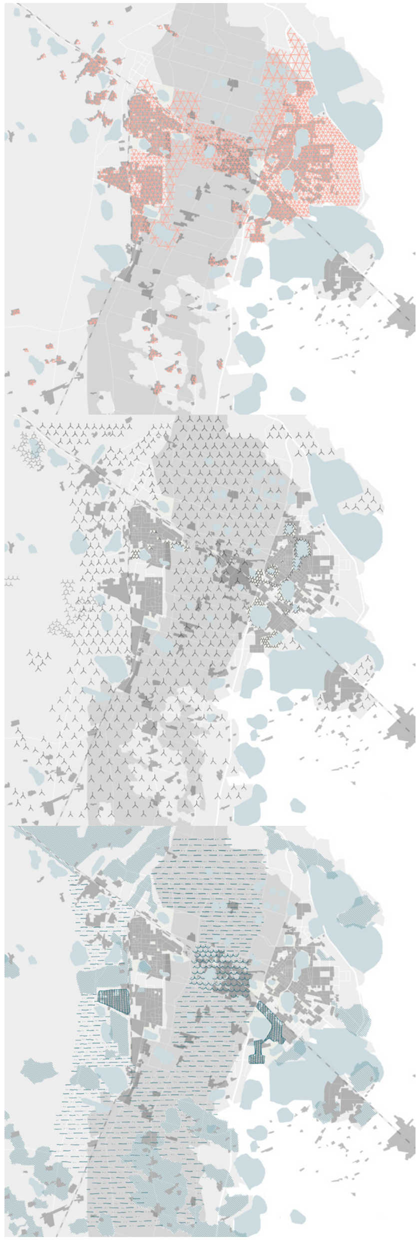
Biomass

Biorefineries

Energy crop

Geothermal green house

Waste straw



Solar energy

Roof-mounted or wall-mounted solar panels

Solar farm

Wind energy

Urban wind turbines

Wind farm

Biomass

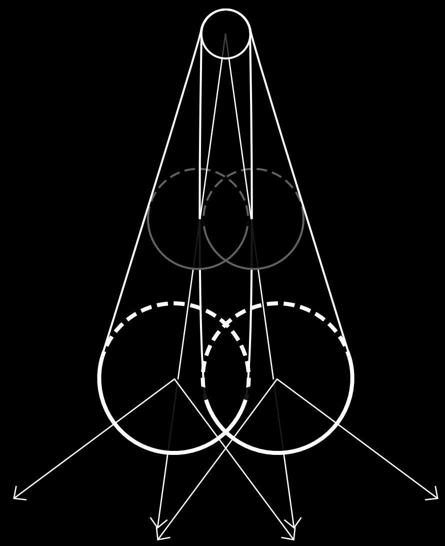
Biorefineries

Energy crop

Geothermal green house

Waste straw

V Scenario transfer: Energy = Space



1) identification of the scenario field; 2) & 3) identification and analysis of key factors; 4) scenario generation; 5) scenario transfer

V Scenario transfer: Energy = Space

Throughout the year, when the sunlight is abundant, it is essential to ensure that there are no shadows of objects such as buildings, trees or towers on the surfaces of solar collectors (GB 50794-2012).

Solar collectors installed in public space.

Solar collectors should be installed in places with the highest levels of sun exposure. In the northern hemisphere, solar panels are usually south facing (GB 50794-2012).

Solar collectors installed in business parks.

Solar collectors installed in wasteland

Solar collectors installed on the roof surfaces of industrial buildings.

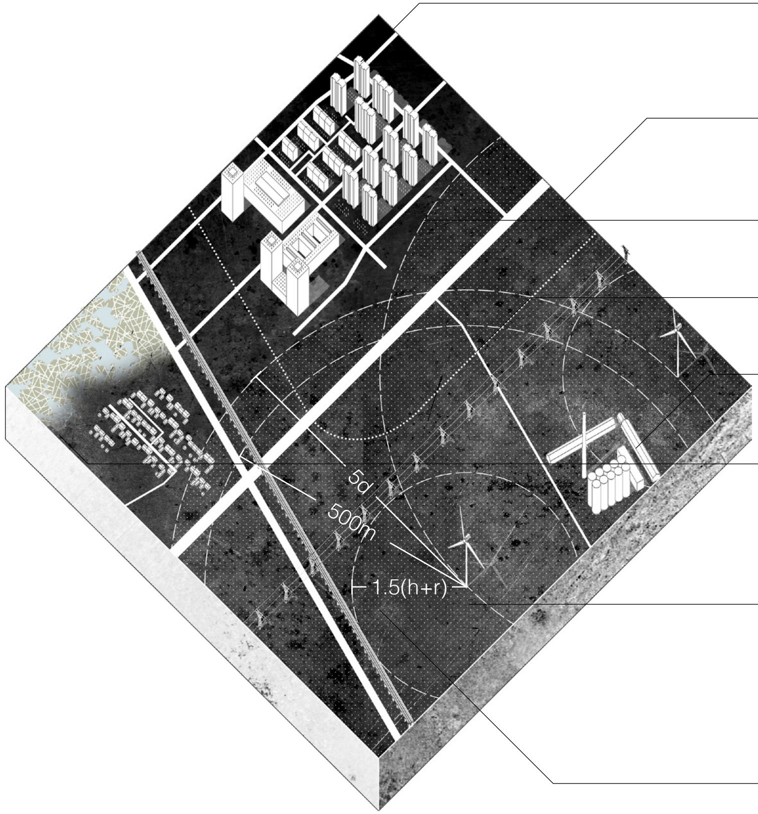
Solar collectors installed by road surface.

Solar collectors installed collectively for an entire neighbourhood.

Solar collectors installed on the roof surfaces of individual homes.

Solar greenhouses.

V Scenario transfer: Energy = Space



Bladeless turbines are adopted by end consumers in the urbanized area.

Wind turbines are preferentially placed in wasteland, inferior land, and non-cultivated land (GB 51096-2015).

Wind turbines should be spaced at five times the blade diameter.

Make use of existing roads to assemble turbines (GB 51096-2015).

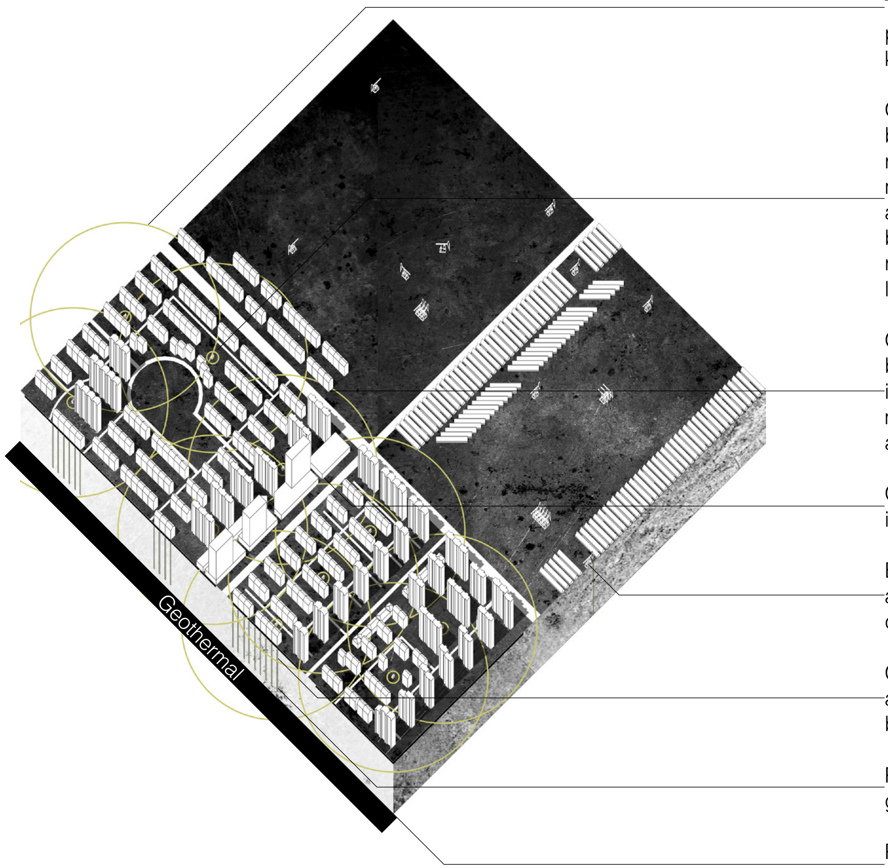
Wind turbines combined with large-scale industries.

Turbines cannot be placed within or adjacent to Nature reserves (GB 51096-2015).

The distance between turbines and dwellings has to meet the national standards for exposure to noise: 500 meters is generally considered as a safe distance (GB 51096-2015).

The distance between wind turbines and roads, railways, transmission lines, telecommunication circuits, crude oil & natural gas pipelines has to be more than 1.5 (h+r) (GB 51096-2015).

V Scenario transfer: Energy = Space



Geothermal water should not be transported over long distances. The temperature drop during transportation should not exceed 0.6 °C/km (CJJ 138-2010).

Ground source heat pumps should be installed in above ground separate pump houses that have maintenance space, adequate ventilation and good lighting. The distance between pump houses and the surrounding buildings should not be less than 10m (CJJ 138-2010).

Ground source heat pumps should be combined with PVT systems in residential buildings in order to maintain the underground heat balance.

Ground source heat pumps applied in swimming pools.

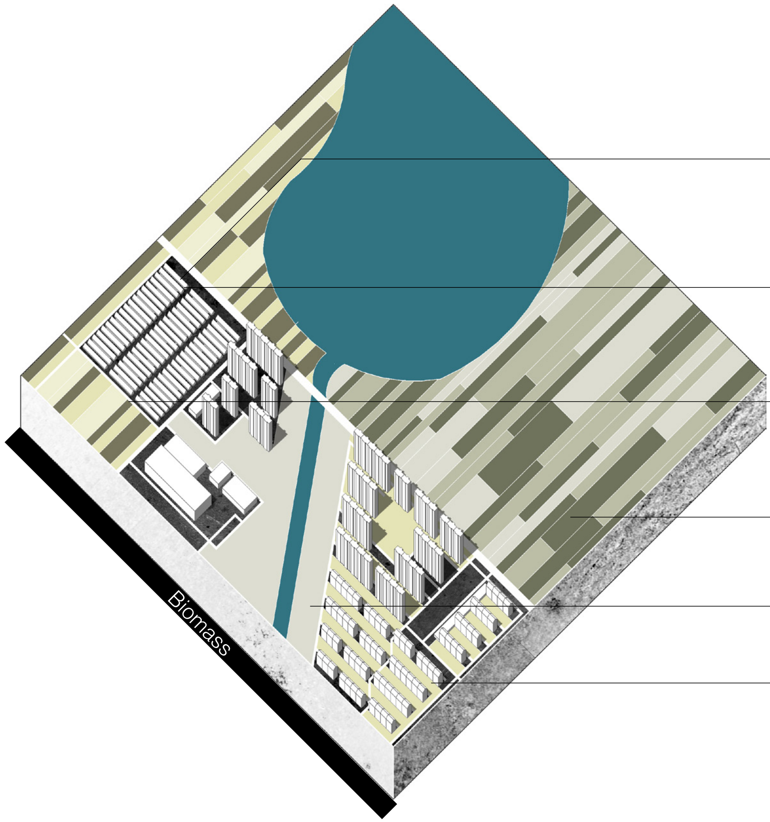
Exploit geothermal energy from abandoned oil wells for surrounding dwellings and greenhouses.

Ground source heat pumps usually adopt (single U-shaped) vertical buried tubes (GB50366-2005).

Pipes buried below underground garages (GB50366-2005).

Pipes buried in the foundation of a building (GB50366-2005).

V Scenario transfer: Energy = Space



Urban agriculture parks should be equipped with sufficient transportation infrastructure, various tour routes, and adequate parking lots (GB/Z 32711-2016).

The area of an urban agriculture park should not be less than 6.67 hm2 (GB/Z 32711-2016).

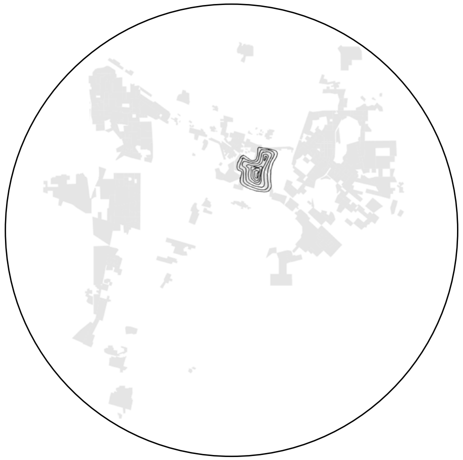
The vegetation fractional coverage (VFC) of an urban agriculture park should be more than 70% (GB/Z 32711-2016).

The cultivation of energy crops should not encroach on the land of original crops.

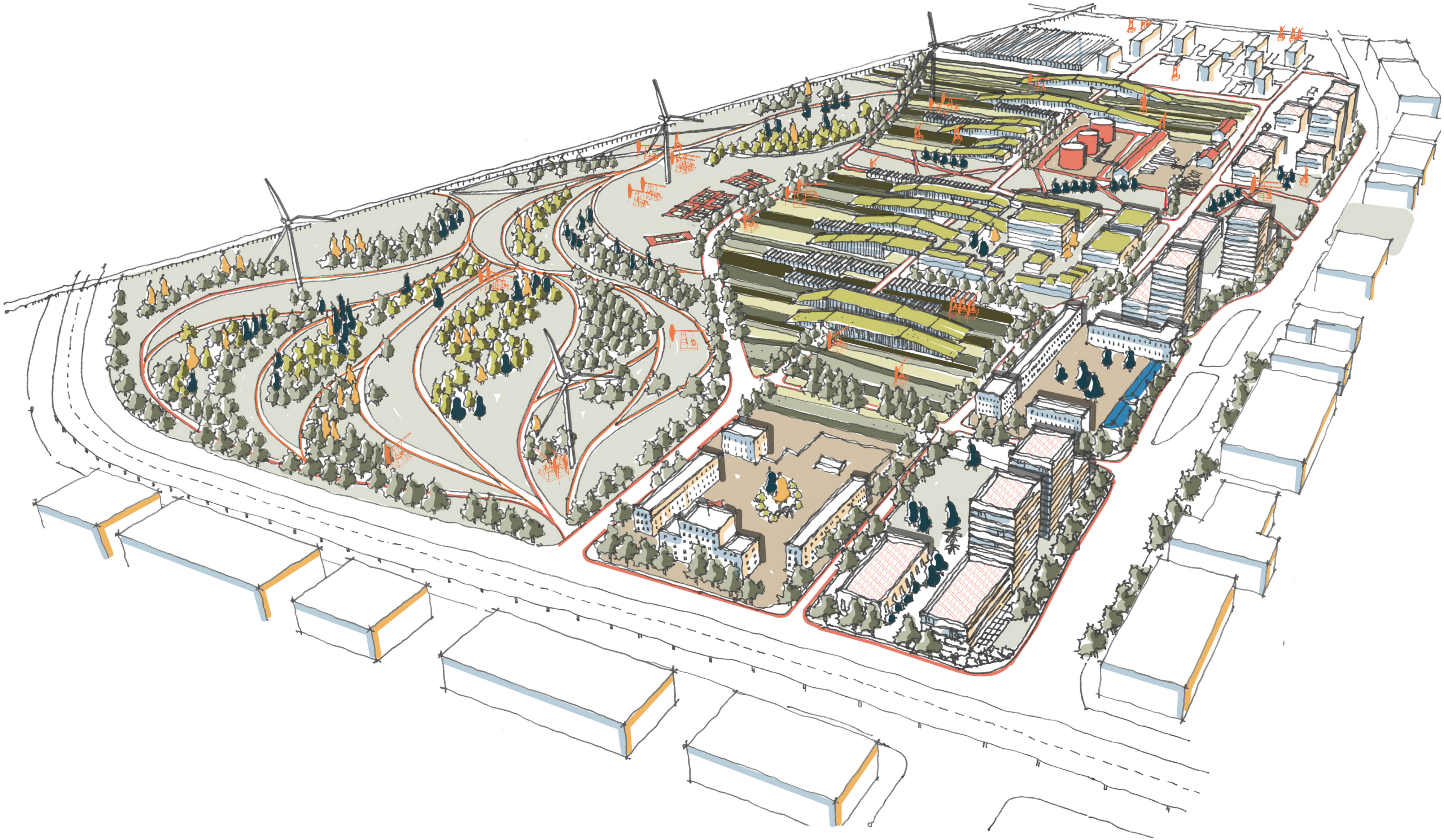
Productive landscape in public green spaces.

Productive landscape in the residential area.

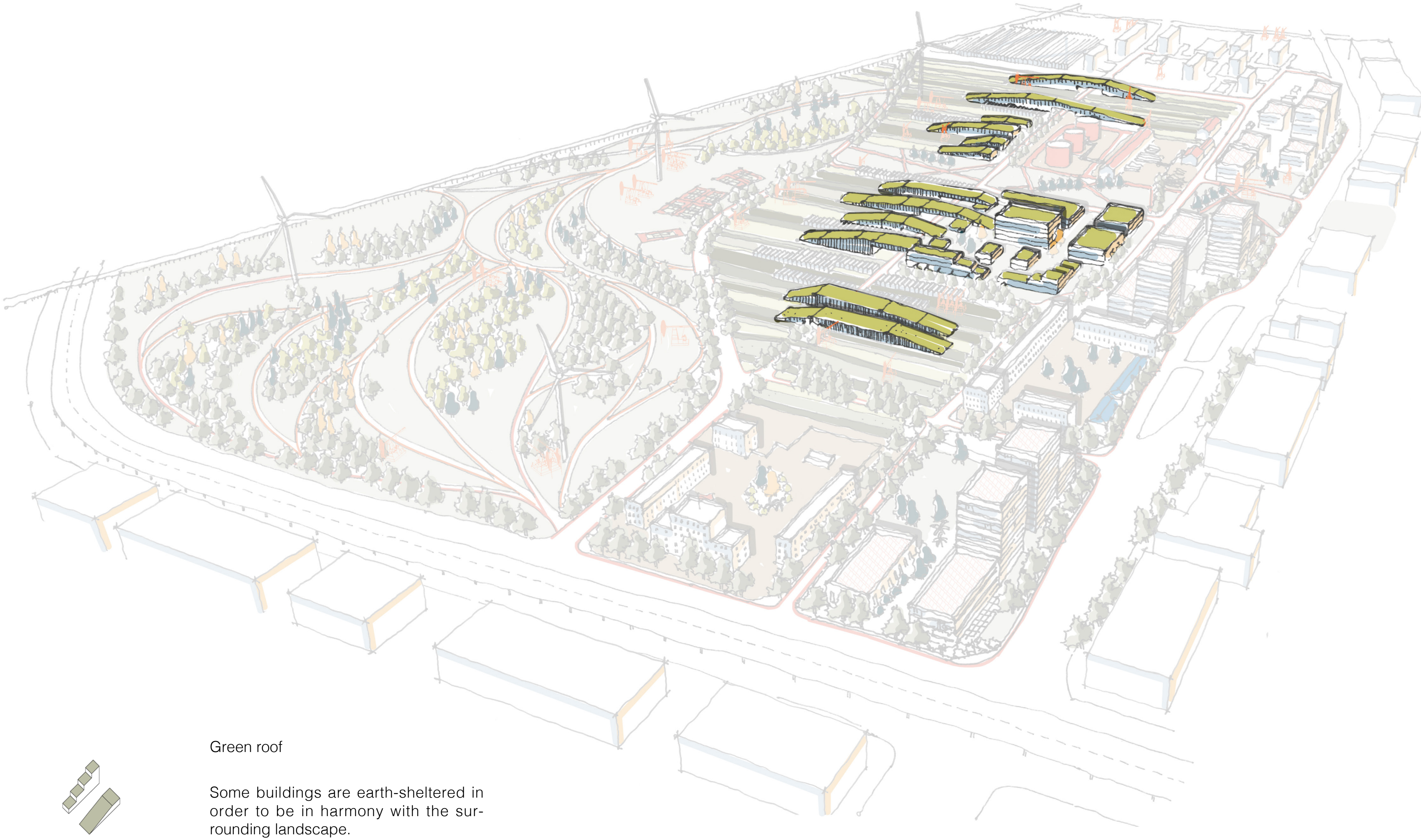
V Scenario transfer: Energy = Space



V Scenario transfer: Energy = Space



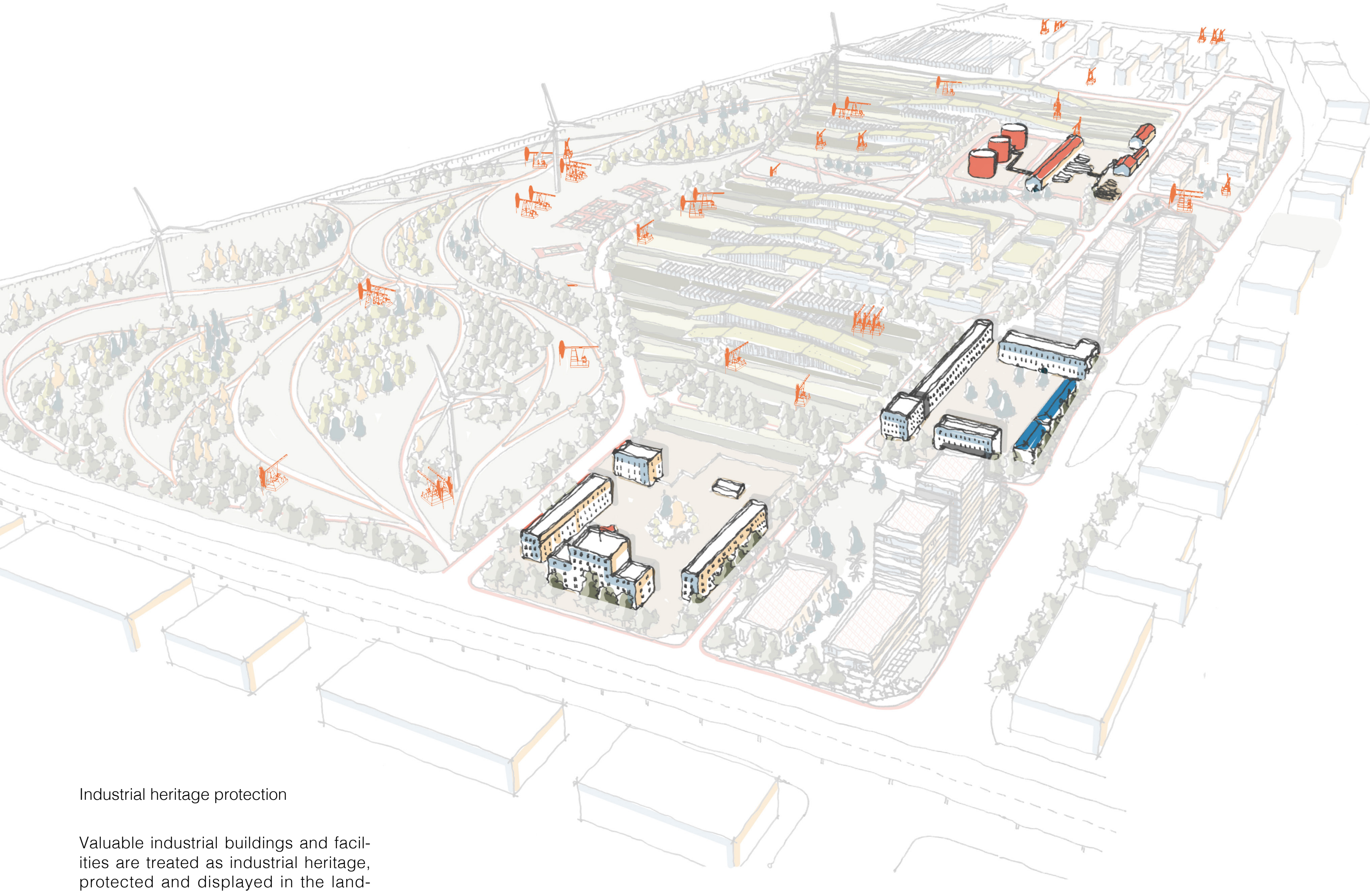
V Scenario transfer: Energy = Space

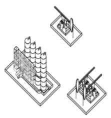


Green roof

Some buildings are earth-sheltered in order to be in harmony with the surrounding landscape.

V Scenario transfer: Energy = Space

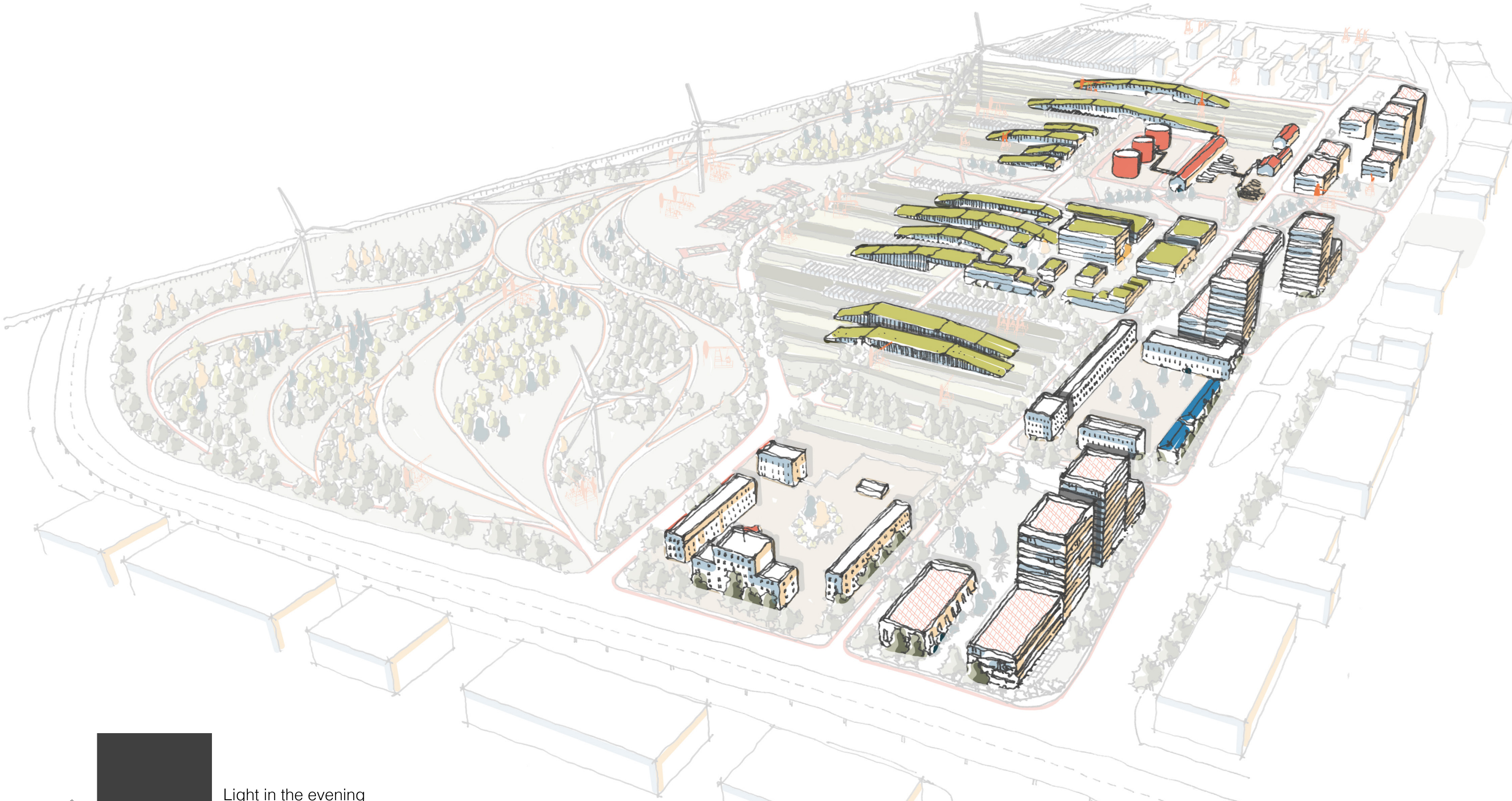


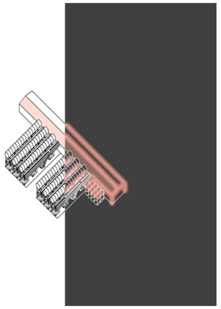


Industrial heritage protection

Valuable industrial buildings and facilities are treated as industrial heritage, protected and displayed in the landscape park.

V Scenario transfer: Energy = Space

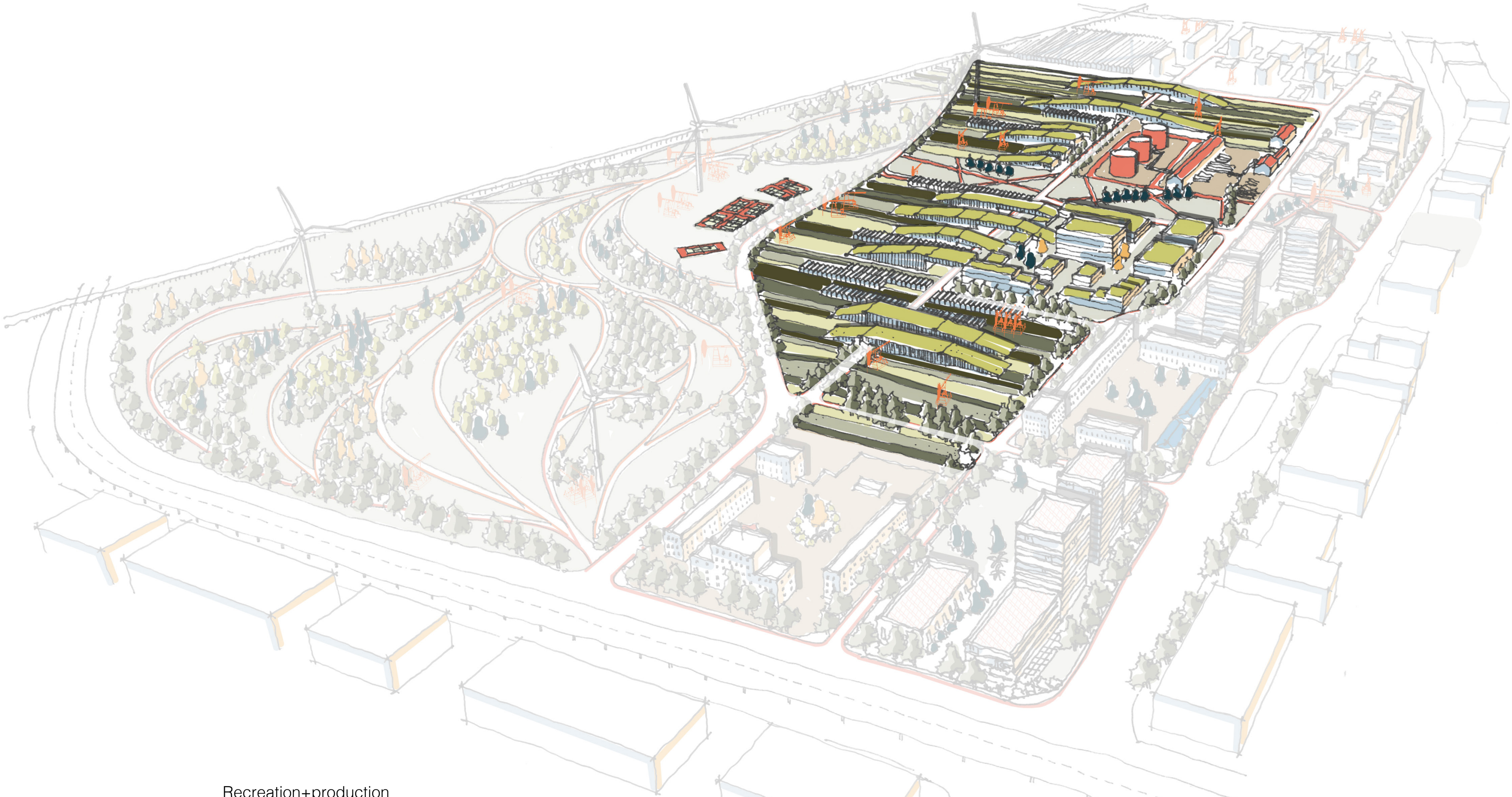


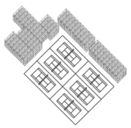


Light in the evening

Colourful lights powered by solar panels are installed on heritage buildings, giving attractive night scenes.

V Scenario transfer: Energy = Space

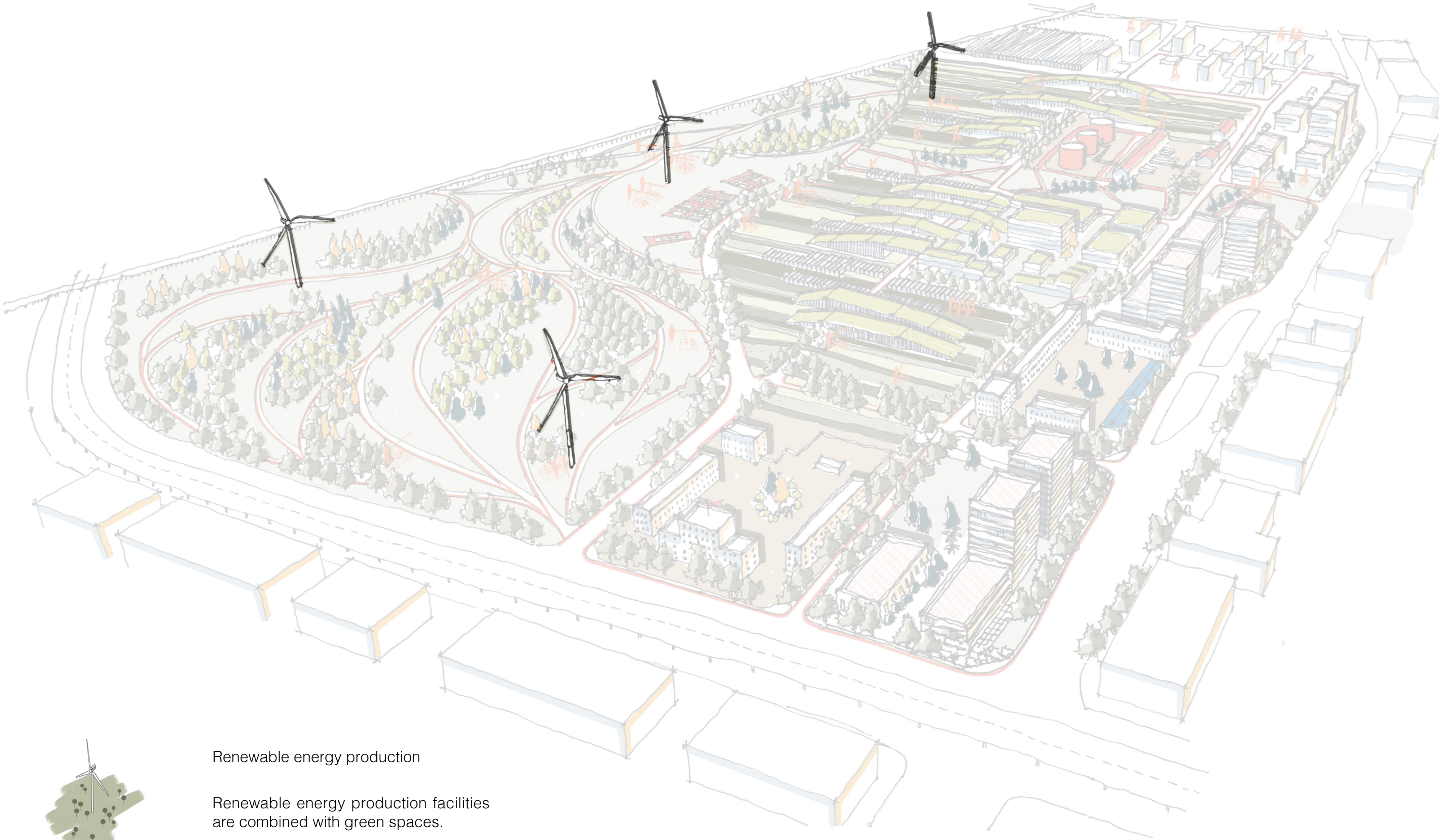




Recreation+production

The landscape heritage park serves both production and entertainment functions.

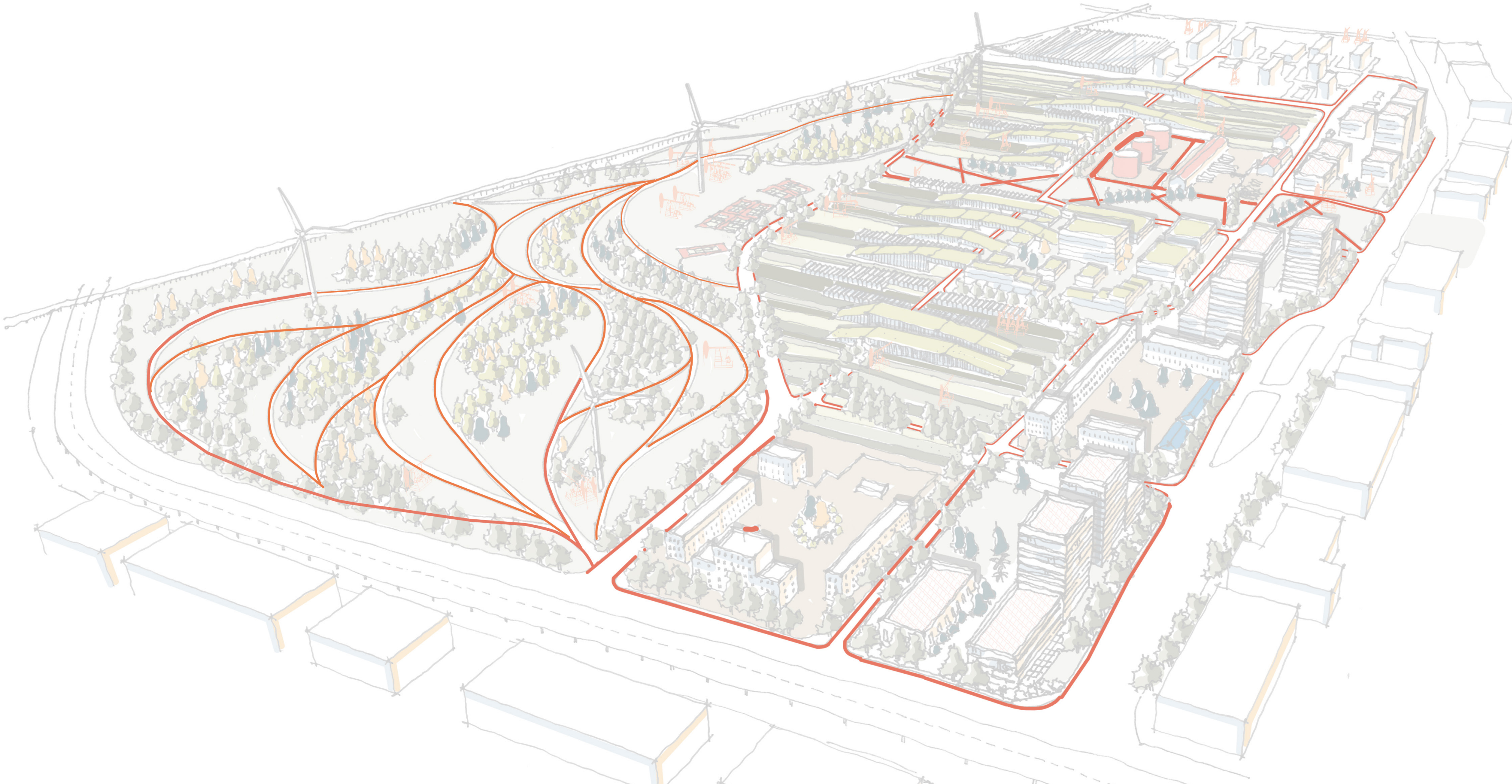
V Scenario transfer: Energy = Space

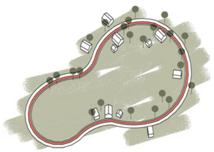


Renewable energy production

Renewable energy production facilities are combined with green spaces.

V Scenario transfer: Energy = Space

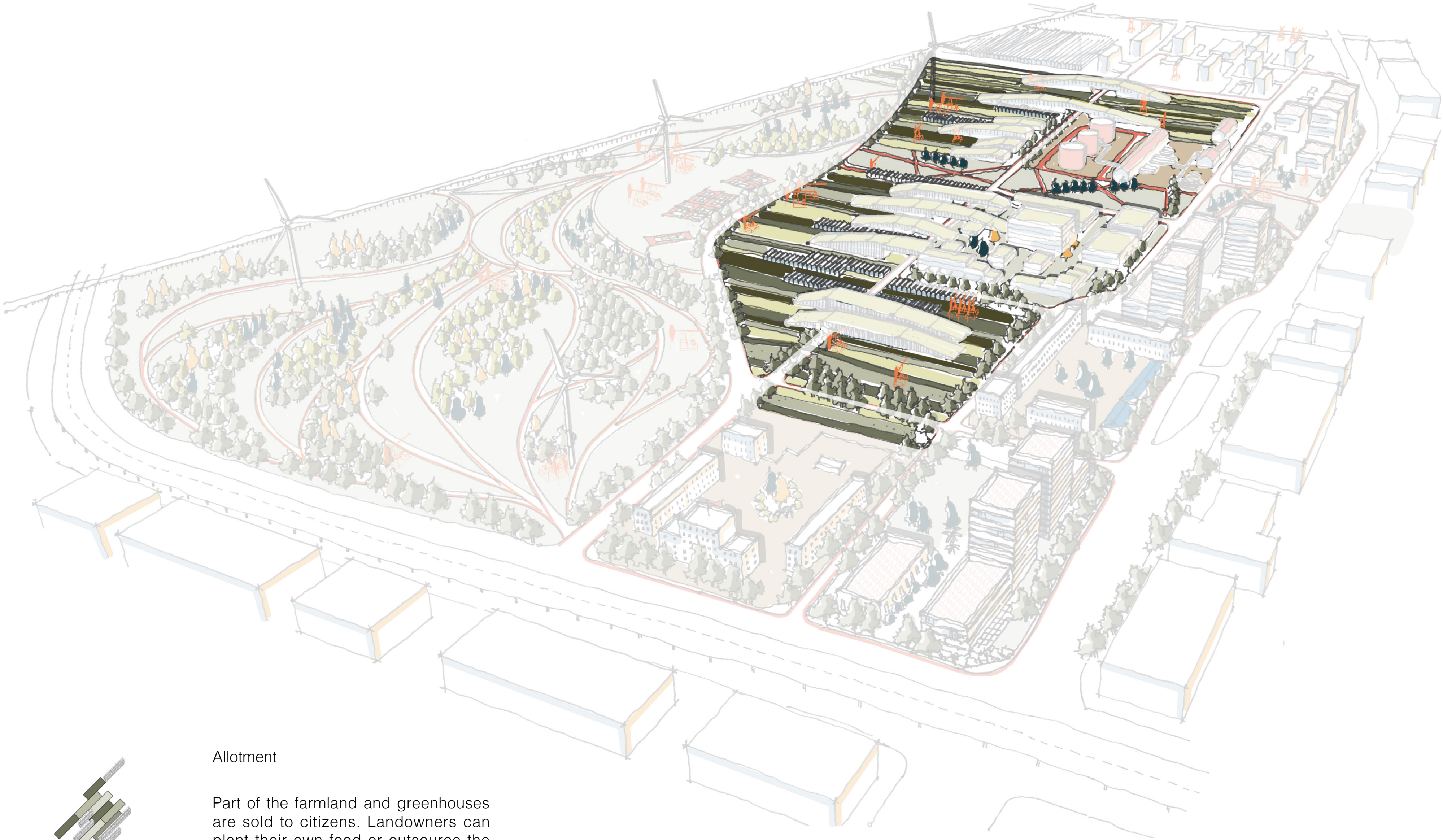




Walking and cycling routes

Every corner of the park is accessible by walking and cycling routes, visitors can travel around the park through low energy consumption ways.

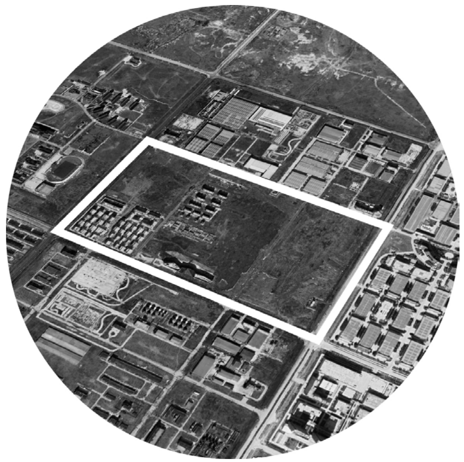
V Scenario transfer: Energy = Space



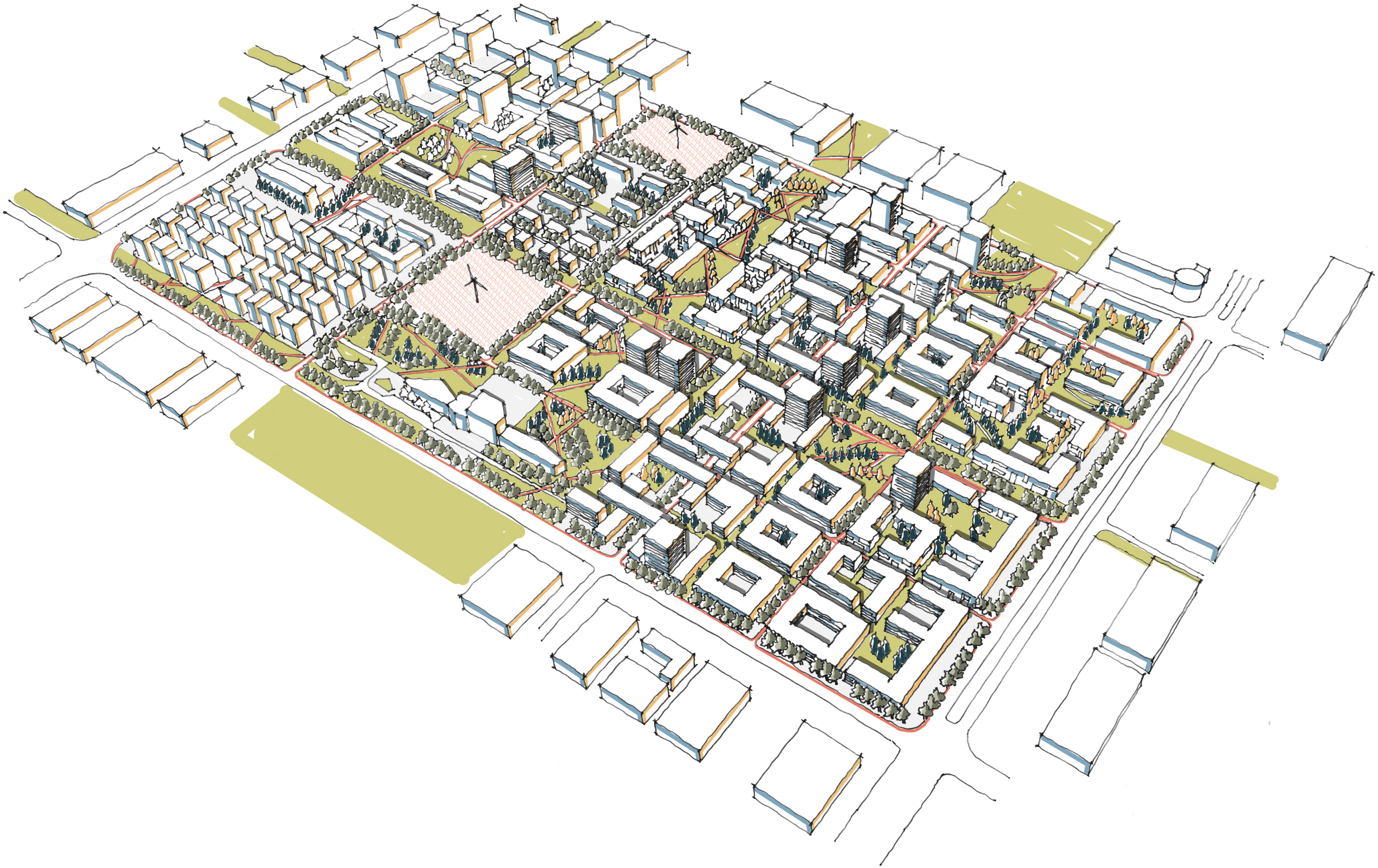
Allotment

Part of the farmland and greenhouses are sold to citizens. Landowners can plant their own food or outsource the agricultural work to professionals.

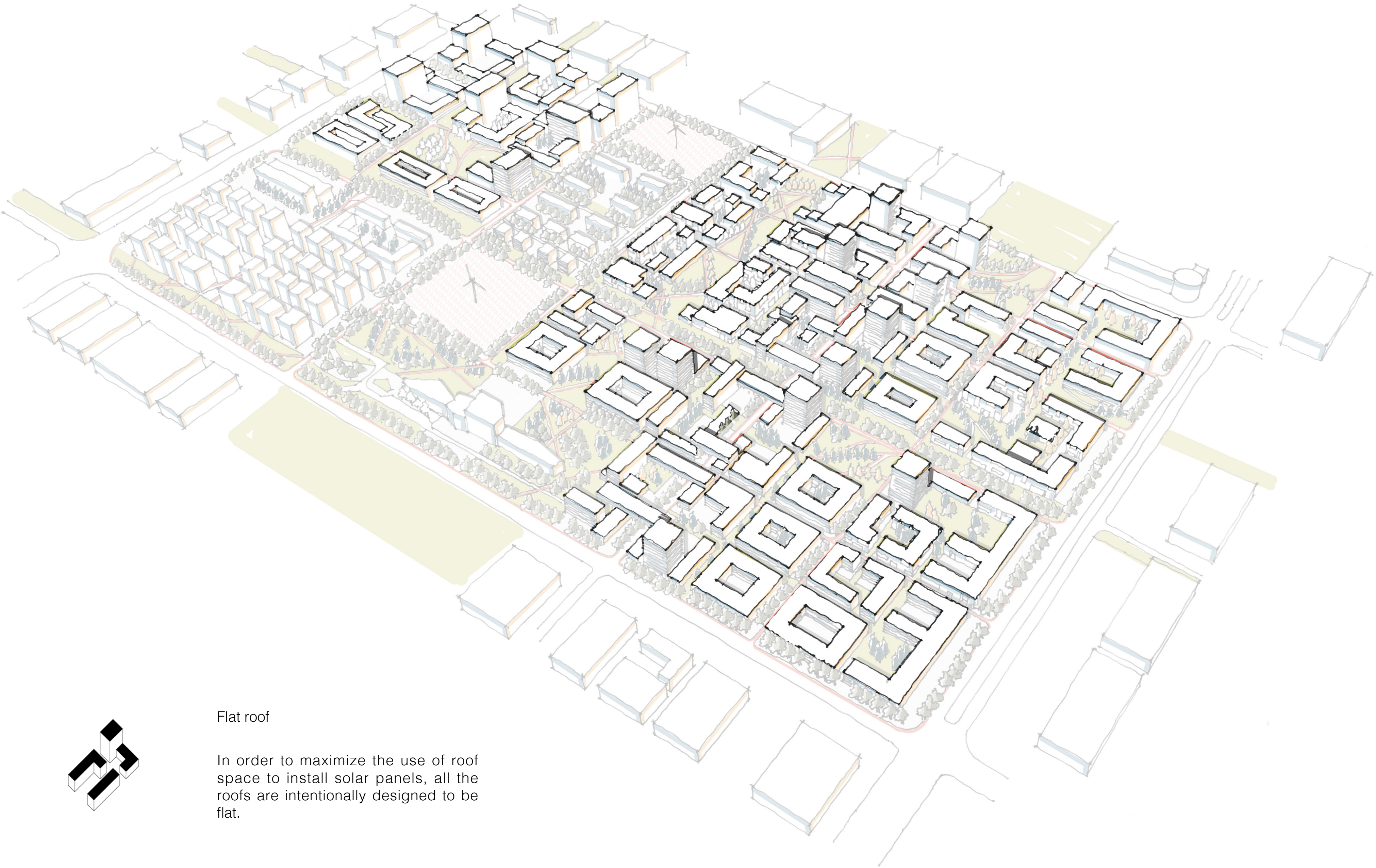
V Scenario transfer: Energy = Space



V Scenario transfer: Energy = Space



V Scenario transfer: Energy = Space



Flat roof

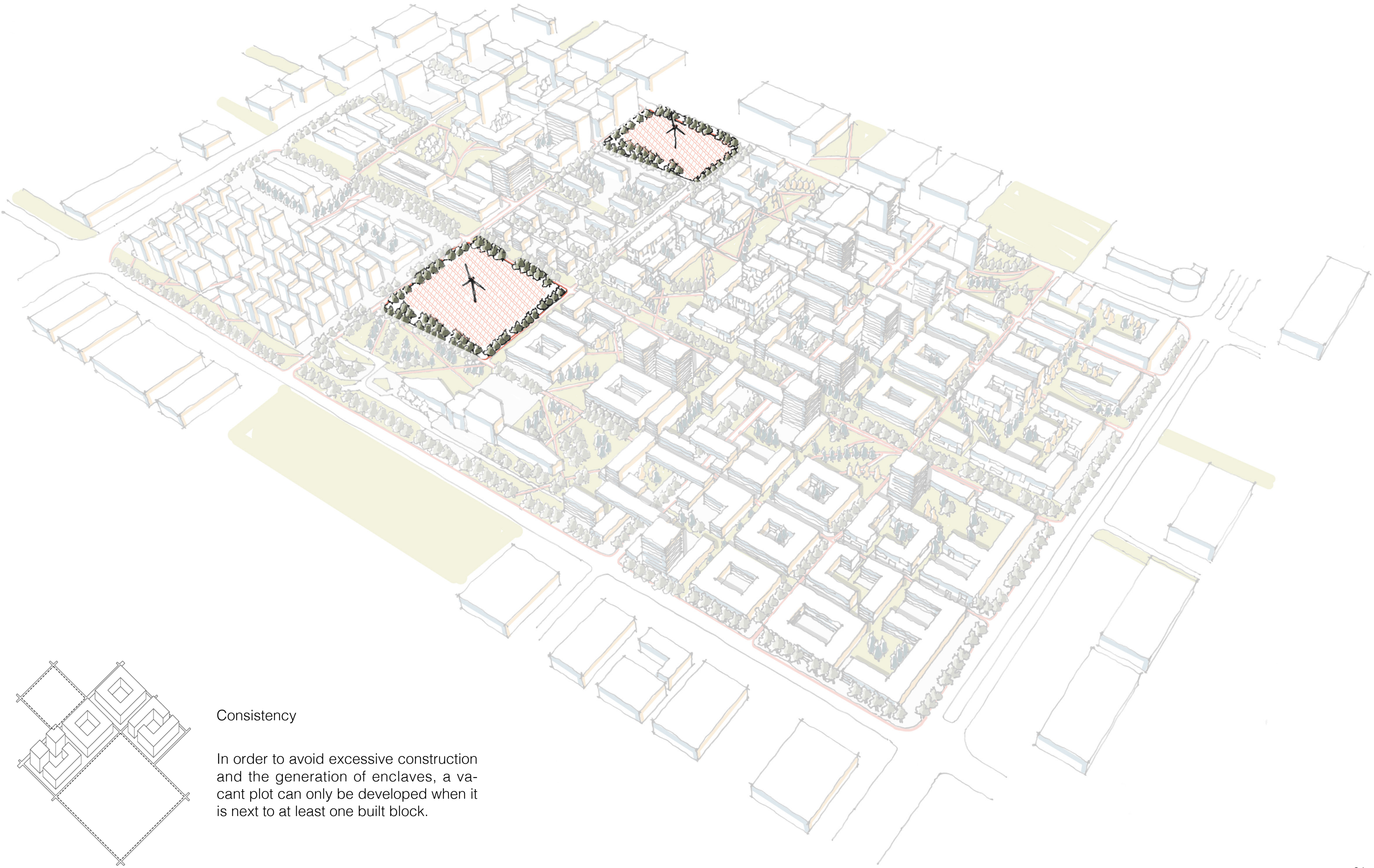
In order to maximize the use of roof space to install solar panels, all the roofs are intentionally designed to be flat.

V Scenario transfer: Energy = Space

Green necklace

All the green spaces are connected with each other, establishing an ecological corridor.

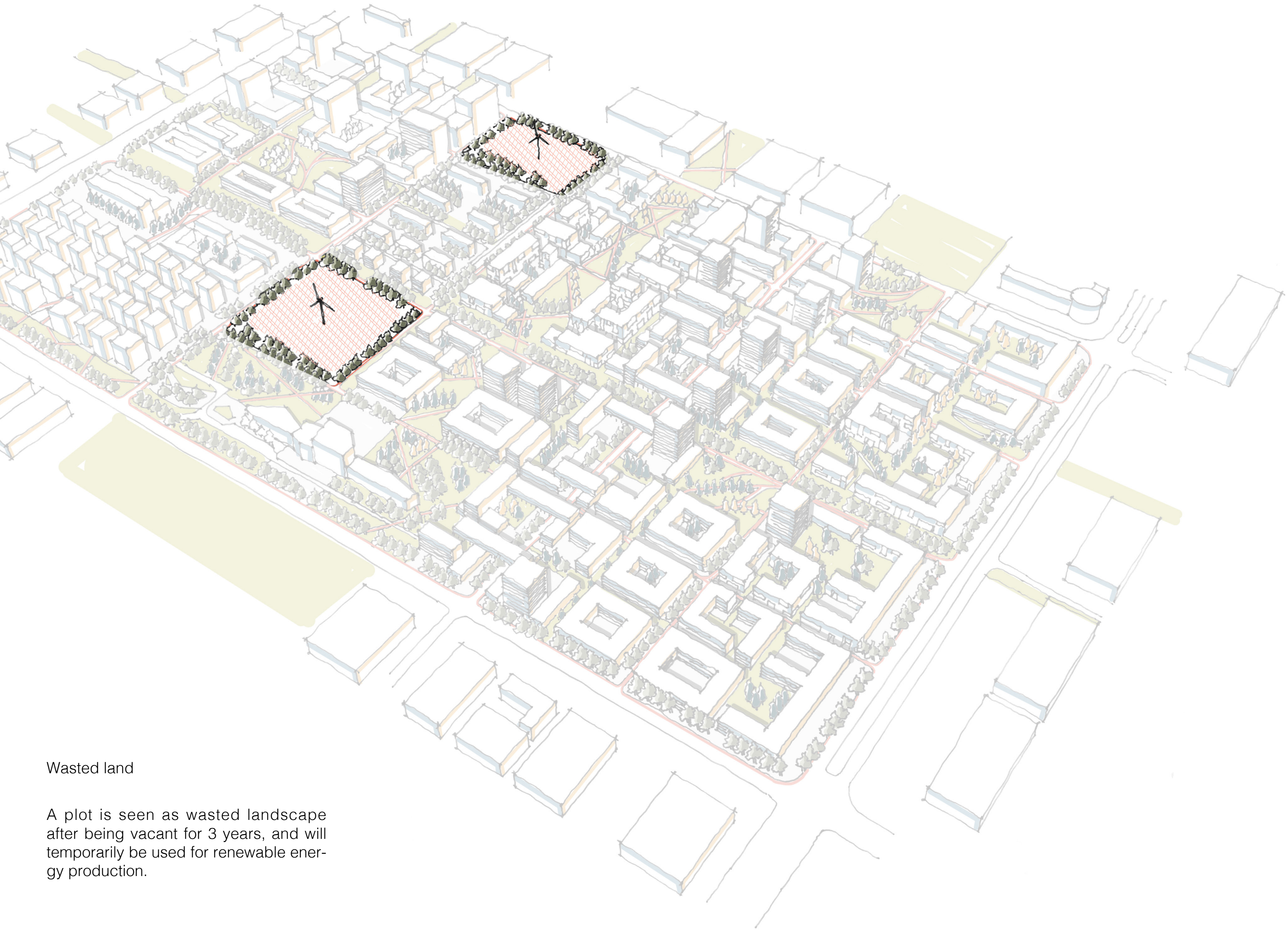
V Scenario transfer: Energy = Space



Consistency

In order to avoid excessive construction and the generation of enclaves, a vacant plot can only be developed when it is next to at least one built block.

V Scenario transfer: Energy = Space



Wasted land

A plot is seen as wasted landscape after being vacant for 3 years, and will temporarily be used for renewable energy production.

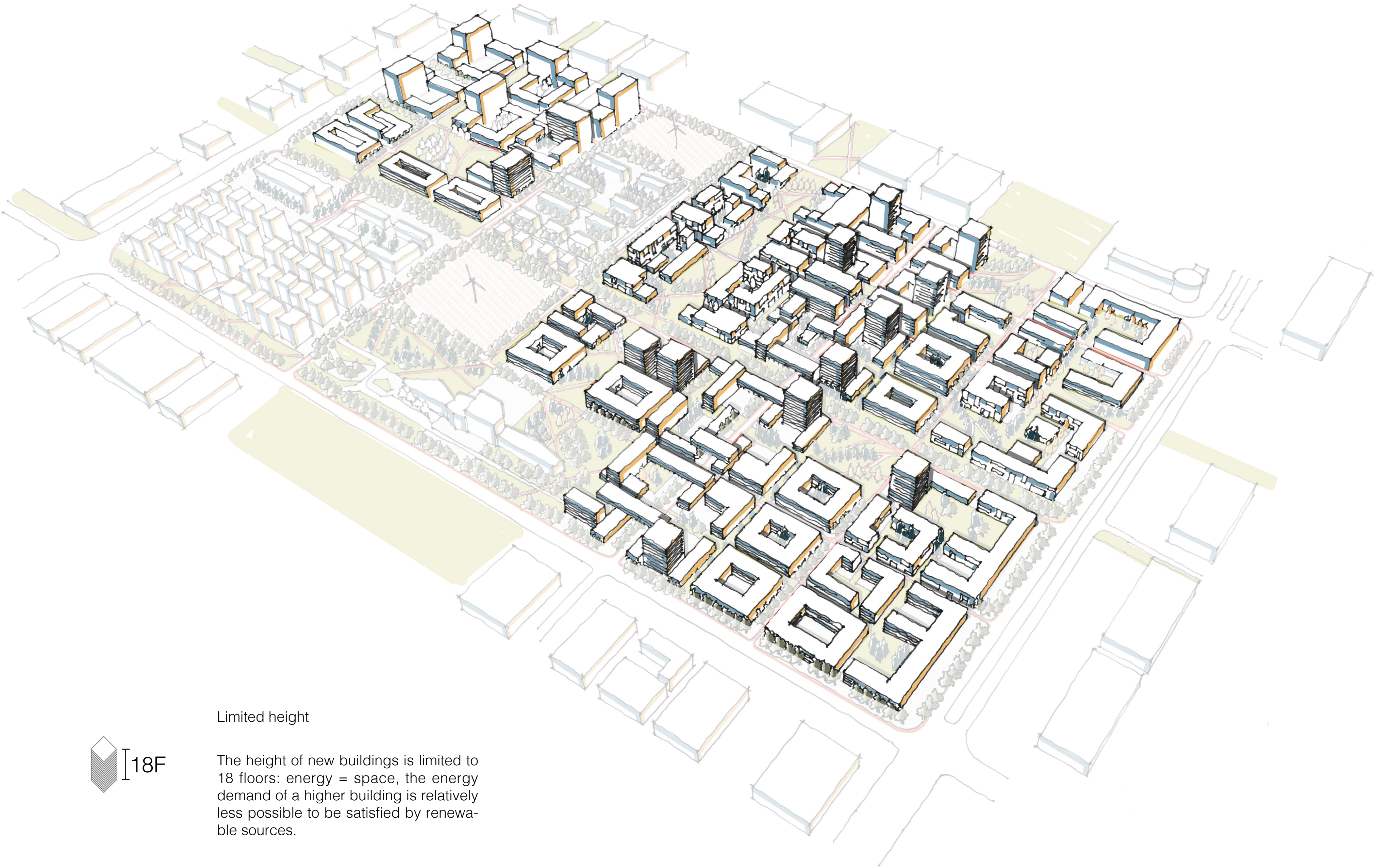
V Scenario transfer: Energy = Space

20%GFA

Open space

In one block, at least 20% of the GFA will be open space. In other words, the FAR should be less than 5.

V Scenario transfer: Energy = Space

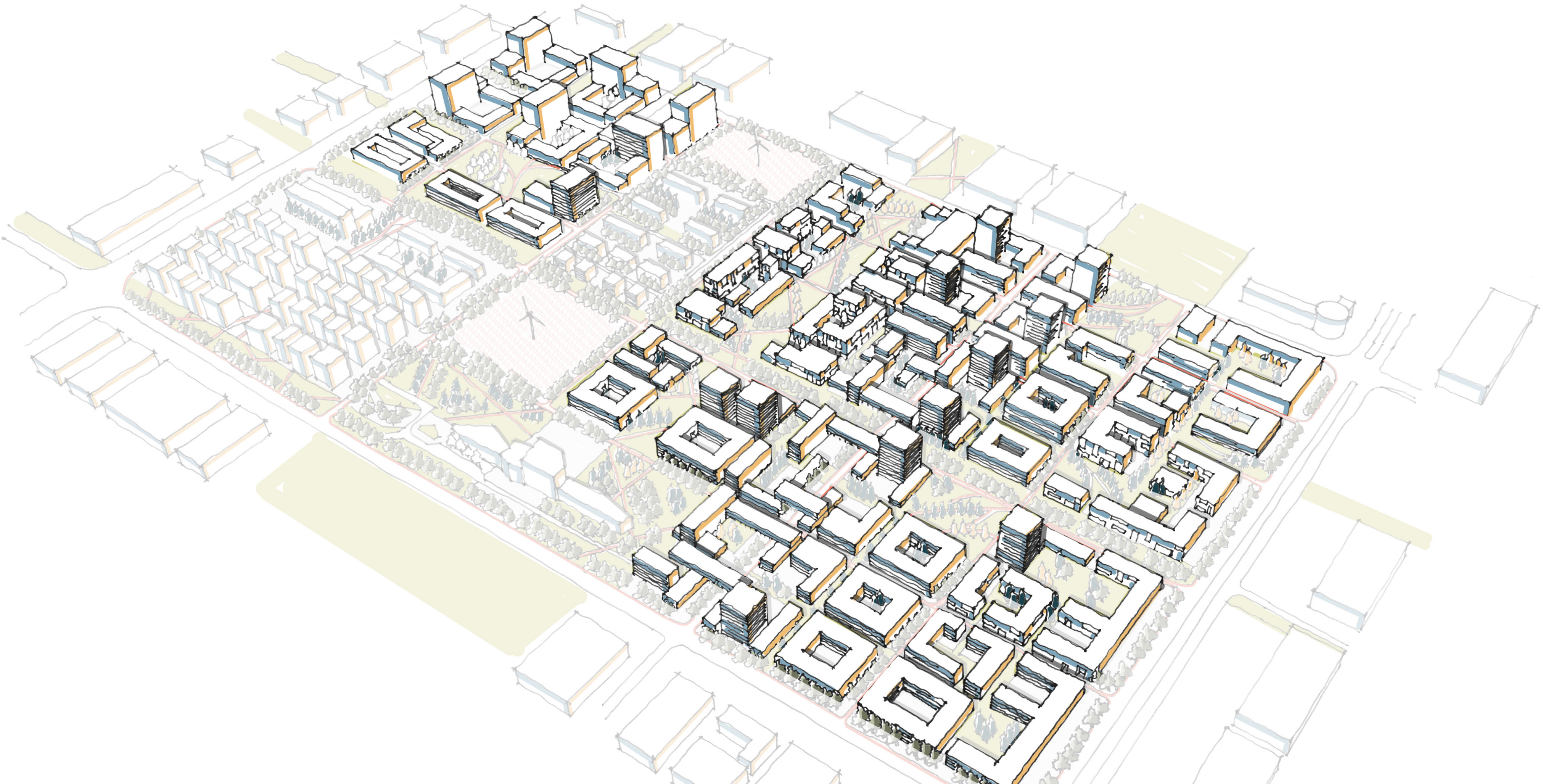


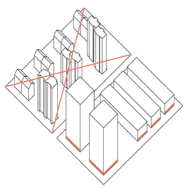
Limited height

18F

The height of new buildings is limited to 18 floors: energy = space, the energy demand of a higher building is relatively less possible to be satisfied by renewable sources.

V Scenario transfer: Energy = Space

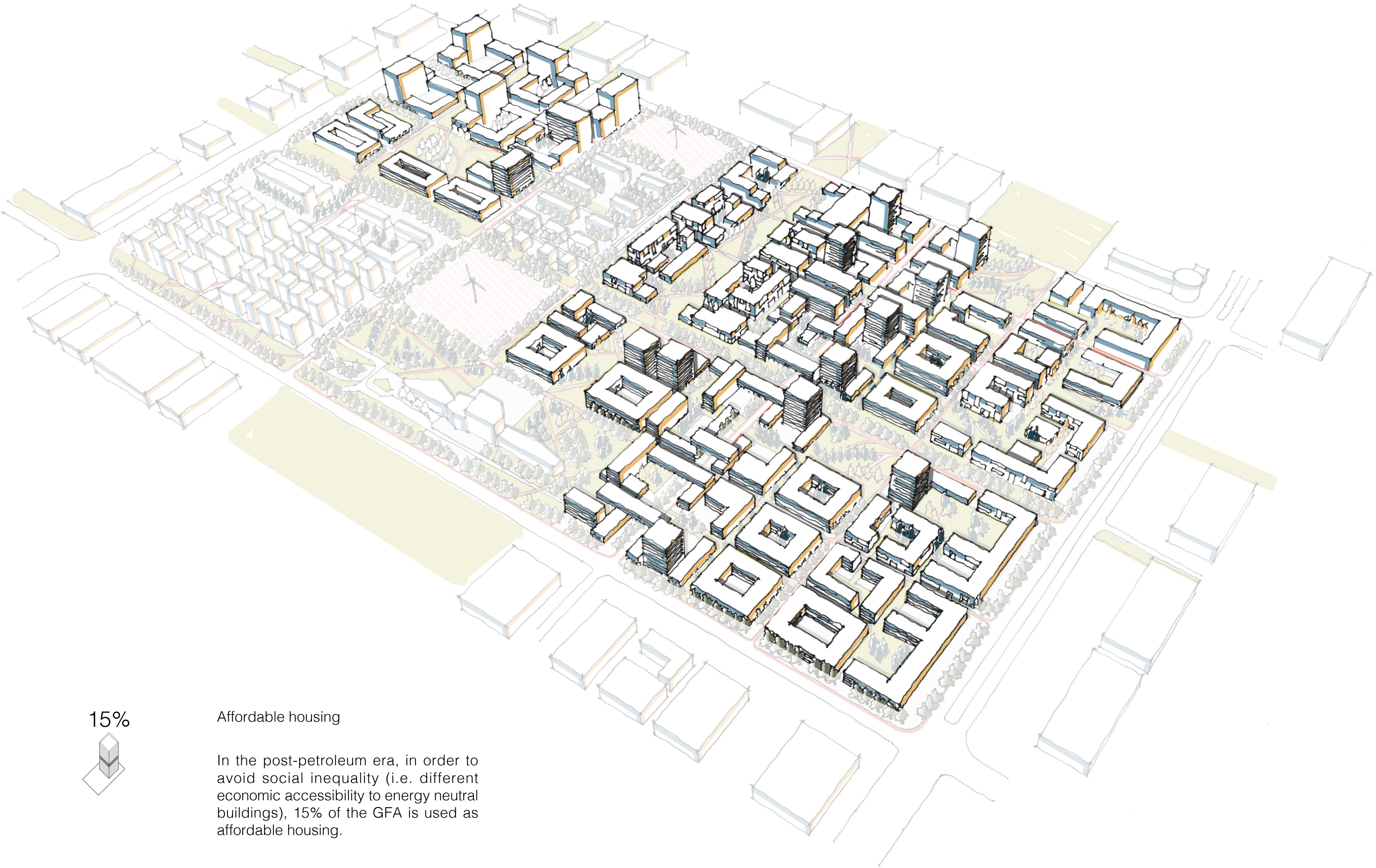




Mixed use architecture

In order to facilitate the energy exchange among different urban functions, buildings are designed to be mix-used. Ground floor spaces facing streets are for commercial use.

V Scenario transfer: Energy = Space



15%

Affordable housing

In the post-petroleum era, in order to avoid social inequality (i.e. different economic accessibility to energy neutral buildings), 15% of the GFA is used as affordable housing.

Conclusion

Sub-research questions:

1 How is the present landscape, economy, and energy demand & production of Daqing shaped by petroleum industries?

2 How will the current landscape, economy and energy demand & production of Daqing change in the near future, when the depletion becomes evident?

3 How will post-petroleum era (and the possible introduction of renewable energy) reshape the socio-economy and energy demand & production of Daqing in the far future?

4 What will be the spatial consequences on the landscape of powering Daqing with renewable energy in the post-petroleum era?

5 How will the spatial changes affect the sustainability of the landscape?

Answer:

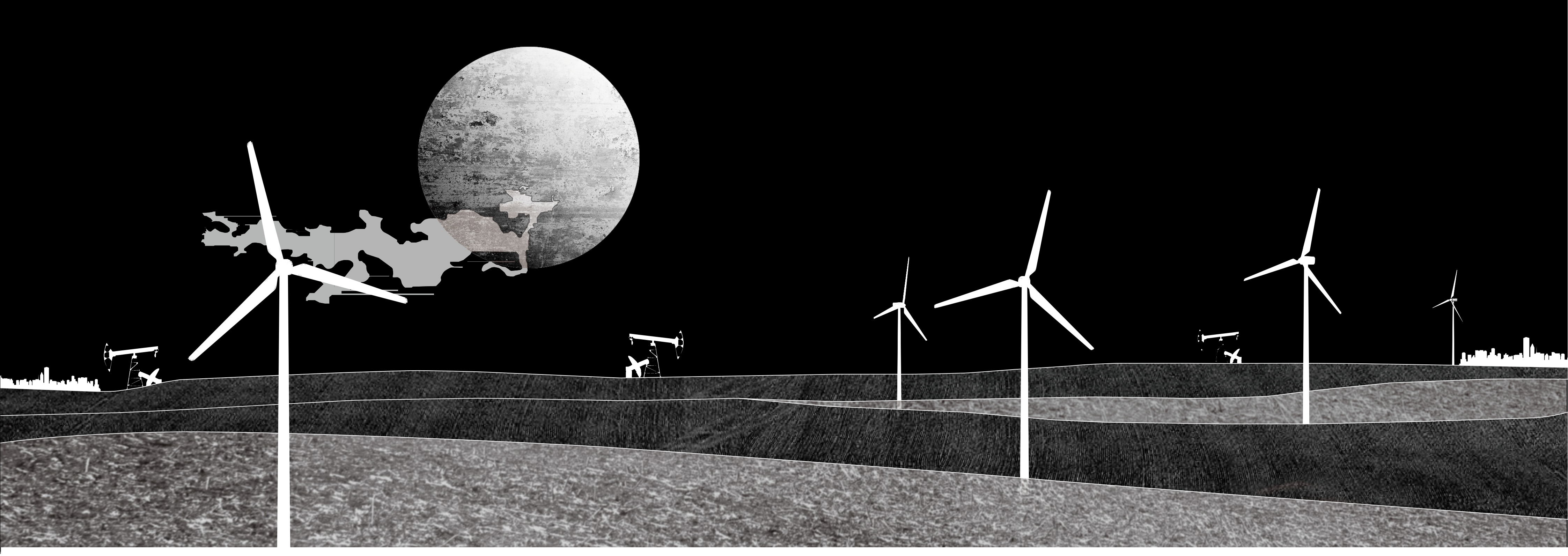
Economy: Petroleum extraction and processing industries are the main sources of revenue for the municipality; Oil industries provide 35% of the total employment;
Energy: Energy-exporter; fossil fuel-based
Landscape: The urbanized area is split into three separated parts by the oil field

Economy: Daqing's economy will continue to deteriorate
Energy: The domestic energy use patterns will not change much, while the industrial energy consumption is expected to reduce slightly
Landscape: Urban expansion will also slow down

2 scenarios
Economy: petrochemical city/petrochemical free, renewable energy industries prosper
Energy: renewable energy

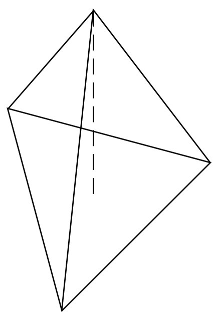
Landscape: rooftops are seen as a new layer of the urban space; wind turbines in small size and bladeless wind turbines; urban growth; solar farms and wind farms; Farmland, as the source of biomass, is combined with wind turbines

A combination of the two 2050 scenarios.
New built urban area will be mixed-use; green spaces are integrated and connected through green corridors; urban regeneration development in the old town with low spatial quality.
The urban code further defines other livability rules, including affordable housing, consistency of urban fabric, open space rate, building scale, aesthetic considerations, cultural heritage protection, recreation, and non-motorized mobility.



To be continued...

III Methodology Framework



1) identification of the scenario field; 2) & 3) identification and analysis of key factors; 4) scenario generation; 5) scenario transfer

Duijvestein, C.A.J. (2002), 'Van duurzame ontwikkeling naar duurzaam bouwen en weerterug', in Duurzaam Bouwen jaarboek 2003. Best: Aeneas.