EXPERIENCES FROM CLEAN HEATING PLAN DEVELOPMENTS IN CHINA AND MONGOLIA
清洁取暖规划的制定：中国和蒙古的经验

Gerhard Stryi-Hipp 格哈德・斯特里-希普
Head of Smart Cities Group 智慧城市组主任

Fraunhofer Institute for Solar Energy Systems
Freiburg/Germany
弗劳恩霍夫太阳能研究所，德国弗莱堡

Workshop on Air Quality Improvement in the Greater Beijing-Tianjin-Hebei Region

Beijing, 6 November 2018

Fraunhofer
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Agenda

大纲

1) **Introduction Fraunhofer**
2) Linking Air Pollution and Climate Change
3) How to design Sustainable Energy Systems
4) Examples from Mongolia and China
5) Findings and Conclusions

1）**弗劳恩霍夫研究所介绍**
2）空气污染与气候变化的联系
3）如何设计可持续能源系统
4）蒙古和中国的案例
5）结果和结论

The Fraunhofer-Gesellschaft 弗劳恩霍夫应用研究促进协会

Joseph von Fraunhofer (1787 – 1826)
约瑟夫·冯·弗劳恩霍夫（1787 - 1826）

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Researcher 科学家
- ➔ Discovery of the “Fraunhofer lines” in the solar spectrum
  发现了太阳光谱中的“弗劳恩霍夫线”

Inventor 发明家
- ➔ New methods for processing lenses
  发明了加工镜头的方法

Entrepreneur 企业家
- ➔ Director and partner in a glassworks
  皇家玻璃工厂的管理者

Fraunhofer-Society since 1949
弗劳恩霍夫协会自1949年以来

R&D commissioned from industry & governing bodies
行业与政府机构委托研发

Audio format MP3, white LED, high resolution thermocamera
音频格式MP3，白光LED，高解析度热感摄像机

Research volume:
ca- 2.1 billion euros annually
科研开发年经费：约21亿欧元

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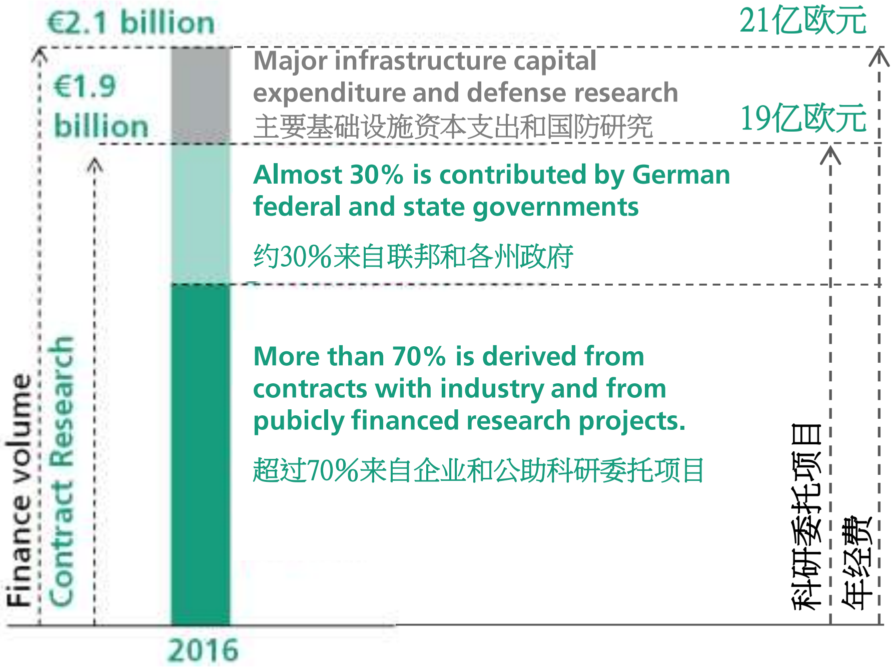
The Fraunhofer-Gesellschaft 弗劳恩霍夫应用研究促进协会

Largest Organization for Applied Research in Europe
欧洲最大的应用科学研究机构

25 327 staff
(科研人员)

72 institutes and research units
(研究所)



The Fraunhofer-Gesellschaft 弗劳恩霍夫应用研究促进协会

Connected worldwide 遍佈全球

- ▲ Subsidiary 附属公司
- ■ Research Center 研究所
- ■ Project Center 项目中心
- ■ ICON / Scientific Cooperation 科研合作
- ■ Representative / Marketing Office 代表处
- ■ Senior Advisor 高级顾问

Fraunhofer ISE 弗劳恩霍夫太阳能研究所

Performing Research for the Energy Transformation 从事能源转型研究

Location: 所在地	Freiburg im Breisgau 弗莱堡
Directors: 领导	Prof. Hans-Martin Henning Dr. Andreas Bett
Staff: 科研人员	ca 1200 约1200人
Budget 2018: 年经费 2018	€ 89 million 8900万欧元
Established: 成立	1981
Business Areas: 业务范围	5 五大领域

Largest research institute for solar energy in Europe 欧洲最大的太阳能研究所

Photovoltaics
多种光伏技术

Solar Thermal Technologies
太阳能热利用技术

Building Energy Techhnologies
建筑能源技术

Hydrogen Technologies
氢能技术

Energy System Technologies
能源系统技术

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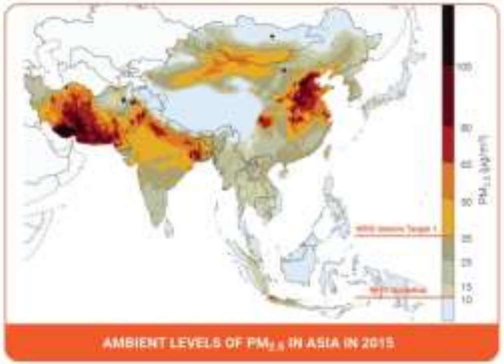
Air Pollution 空气污染



4 Billion (92%) of Asian people are living in unhealthy air conditions (UN report Oct 2018)

40亿（92%）的亚洲人口生活在不健康的空气环境中（联合国报告2018年10月）

Source: UNEP / Climate & Clean Air Coalition, Air pollution measures for Asia and the Pacific, October 2018
http://www.ccacoalition.org/en/content/air-pollution-measures-asia-and-pacific

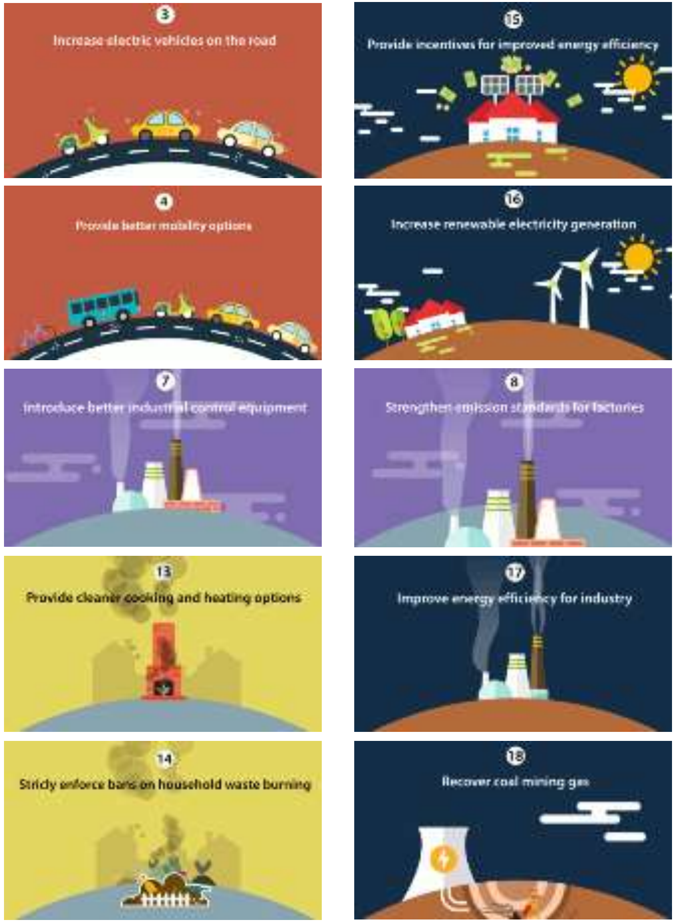
Short-term challenge - air pollution should be reduced to acceptable level **within a few years**
短期挑战 - 空气污染应在**未来几年内**降至可接受的水平

➔ Actions must start immediately
必须立即开始行动

Measures to reduce air pollution
减少空气污染的措施

- Many of the 25 measures proposed by the Climate & Clean Air Coalition are dealing with energy efficiency in generation, distribution and consumption of energy and clean energy sources
  "气候与清洁空气联盟" 提出的25项措施中，许多都涉及能源和清洁能源的生产，分配和消耗方面的能效问题
- Decarbonization of the energy system requires a comprehensive transformation of the energy system with significant increase in efficiency and replacement of fossil fuels by renewable energies
  能源系统的脱碳需要能源系统的全面转型，效率显着提高和以可再生能源替代化石燃料

➔ **Short-term measures against air pollution should be the first step of a long-term transformation of the energy system against climate change**
应对空气污染的短期措施应该是能源系统为应对气候变化的长期转变的第一步



Source: UNEP / Climate & Clean Air Coalition, Air pollution measures for Asia and the Pacific, October 2018 http://www.ccacoalition.org/en/content/air-pollution-measures-asia-and-pacific

Fraunhofer ISE: combining short-term and long-term planning approach
弗劳恩霍夫太阳能研究所：结合短期和长期规划的方法

2018 2025 2030 2035 2040 2045 2050

Short-term Action Plan
to reduce air pollution significantly and kick-start long-term transformation of the energy system

短期行动计划
显着减少空气污染并启动能源系统的长期转型

Energy Master Plan 2050
incl Transformation Roadmap
to meet climate policy goals
(based on energy system modelling)

能源总体规划 2050
包括转型路线图
以实现气候政策目标
（基于能源系统计算模型）

Analysis of the **current energy system,** development of an **energy balance**

分析**能源系统的现状**，制定**能源平衡**

Energy demand **forecast 2050**, evaluation of **renewable energy potential**

能源需求**预测2050**，评估**可再生能源的潜力**

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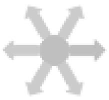
How to design an optimized sustainable energy system?
如何设计优化的可持续能源系统？

Challenges 挑战:



Decentralization: local generation must be adapted to local load profiles
分散化：本地能源生产必须适应地方层面能源需求
➔ **Individual solution for each city / district is needed**
针对每个城市/城区的個性化解决方案

Long transformation period: 20 to 40 years needed to implement a sustainable energy system
转型期长：实施可持续能源系统需时20至40年
➔ **Short-term measures must fit to long-term system solutions**
短期措施必须配合长期系统解决方案

Growing complexity: fluctuating generation, integration of storage, coupling of energy sectors, smart energy management,…
能源系统日益复杂：能源生产波动與储能技術的整合，能源原素耦合，智慧能源管理……
➔ **System optimization by computer modelling is necessary**
必要通过计算模型进行系统优化

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Transformation strategy for energy systems 能源系统转型战略

of cities and districts 城市和城区

1. **1.** Decision
   ENERGY TARGETS
   决策 设定**能源目标**
2. **2. DATA COLLECTION**
   能源数据收集
   Demand & supply需求和供应
   current & forecast现状和预测
3. **3.** Simulation
   ENERGY SYSTEM SCENARIOS
   模拟 **能源系统情景**
4. **4.** Assessment
   ENERGY SYSTEM SCENARIOS
   评估 **能源系统情景**
5. **5.** Decision
   TARGET ENERGY SYSTEM
   决策 确立**目标能源系统**
6. **6.** Development
   ROADMAP
   发展 实现确立能源目标**路径**
7. **7.** Development
   MONITORING CONCEPT
   发展 **监测方案**
8. **8.** Decision
   ENERGY MASTER PLAN
   决策 制定**能源总体规划**

IMPLEMENTATION
规划实施

Measures city governments/property owners 市政府/业主:

Measures experts/consultants 专家/顾问:

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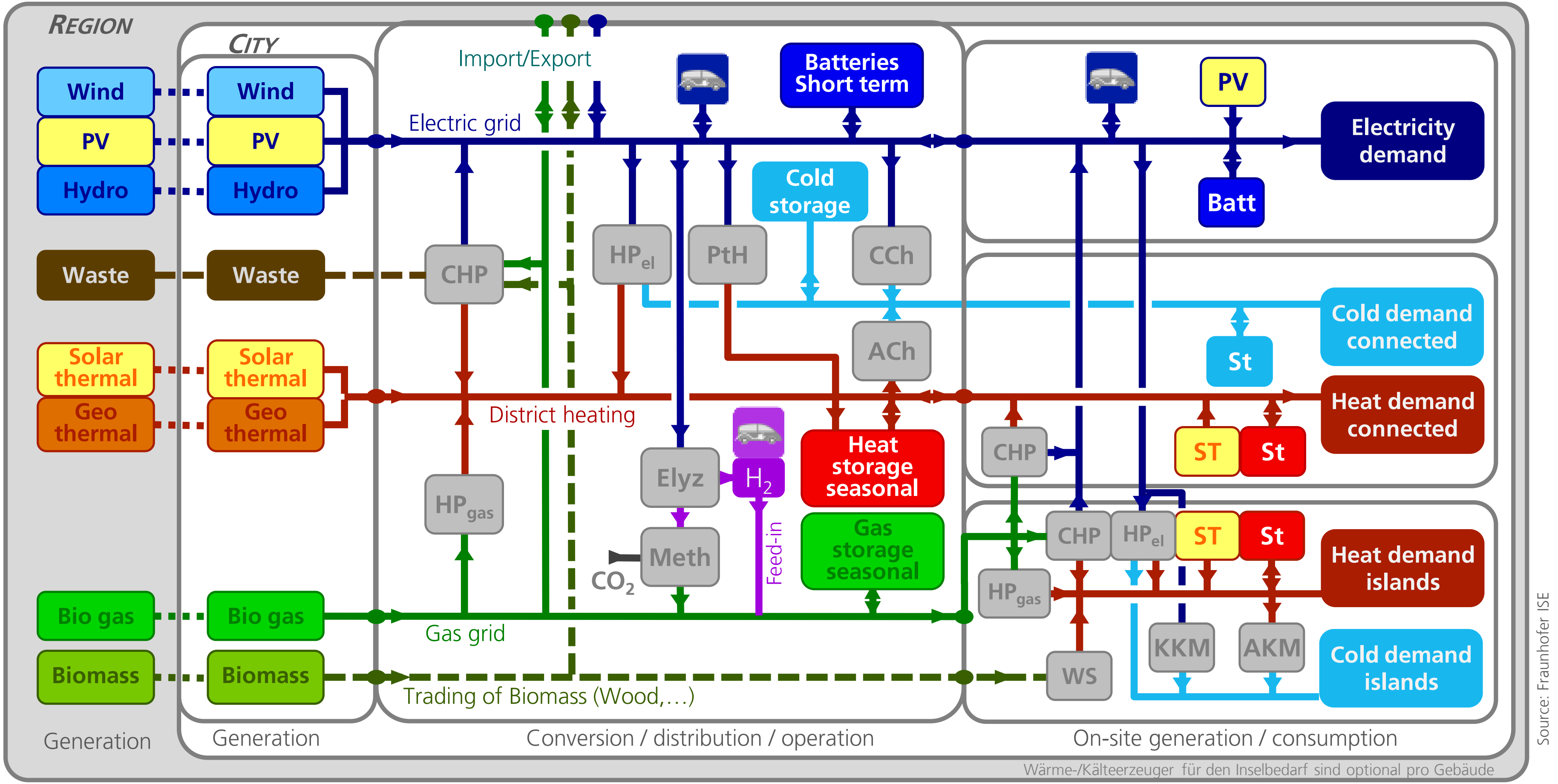
Generic energy system design for local systems with high shares on renewables
地方层面高度利用可再生能源的通用能源系统设计



HP el/gas = Heat pump electric / gas driven, CHP = Combined heat and power, WS = Wood stove, St = storage, SH = Solar heat, Elyz = Elektrolyzer, Meth = Methanation, ACh/CCh = Ab-/Adsorption / Compression Chiller

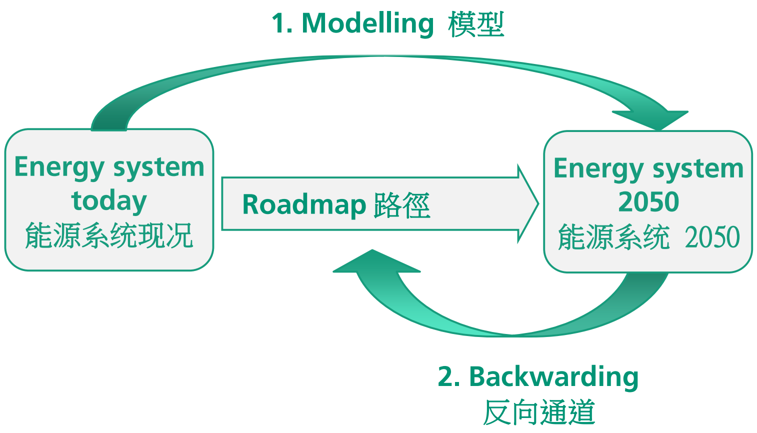
New energy system modelling tool for optimal energy system design
新能源系统模型工具用于优化能源系统设计

Fraunhofer ISE developed the modelling tool »KomMod«

- Calculation of cost-optimized energy system design
- Temporal high resolution (hourly)
- Sector-coupling (electricity, heating, cooling, transport)

弗劳恩霍夫太阳能研究所开发的模型工具 »KomMod«

- 成本优化能源系统设计的计算
- 高时间分辨率（精确到小时）
- 能源原素耦合（电力，供热，制冷，交通）



*KomMod = Urban Energy System Model 城市能源系统模型

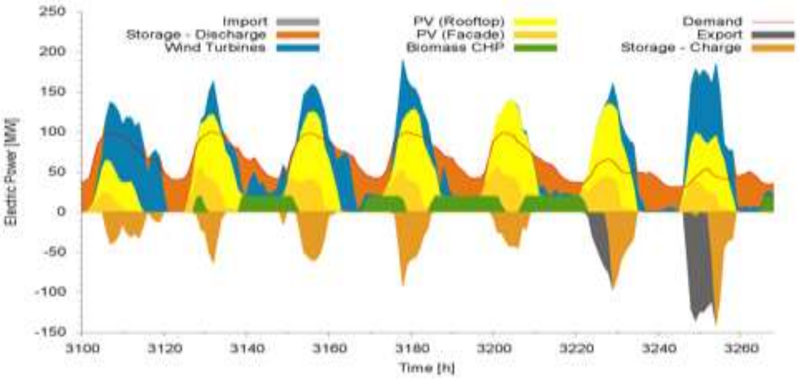
New energy system modelling tool for optimal energy system design
新能源系统模型工具用于优化能源系统设计

Modelling output

- Cost-effective **energy system design**
- Optimal energy system **structure**
- Generation and storage **capacities**
- Effective **operation strategy**
- Remaining **energy import/export**
- Investment and operation **costs**

模型输出

- 考虑成本效益的**能源系统设计**
- 优化能源系统**结构**
- 能源生产和存储**容量**
- 有效的**运行策略**
- 剩余**能源**的**进出口**
- 投资和运营**成本的核算**



Example result graph: Electricity generation mix for one week
结果图示例：一周的電源組成

International project experiences of Fraunhofer ISE

Design of Sustainable Energy Systems & Master Plan Development

弗劳恩霍夫太阳能研究所国际项目经验:可持续能源系统设计和总体规划的制定

Duchy of Luxembourg
卢森堡公国

Mariahoeve, Den Hague / Netherlands
Mariahoeve, 海牙/荷兰

Phuket, Nan, Rayong / Thailand
普吉岛，南，罗勇/泰国

Jiaxing-Xiuzhou / China 嘉兴秀洲 / 中国

Ulaanbaatar / Mongolia 乌兰巴托/蒙古

Naju / South Korea 罗州市/南韩

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Ulaanbaatar challenges 乌兰巴托的挑战

- Coldest capital globally (minus 40 °C in winter)
  全球最冷的首都（冬季零下40˚C）

- More than 300,000 citizens are living in more than 100,000 Gers (yurts) heated with coal stoves
  超过30万居民住在10万多个蒙古包中，使用煤炭锅炉取暖

- One of the highest levels on air pollution globally during winter, due to geographic conditions (valley)
  由于地理因素（山谷），冬季期间的空气污染是全球最严重之一

Picture: UB City in February 2018, day with heavy air pollution, day without

	2016	2050	Factor
Inhabitants [Mio] 居民［百万］	1.4	2.5	1.81
Heated area [Mio m2] 取暖面积［百万平方米］	16.3	51.6	3.18
Heat demand [GWh] 热需求[千兆瓦时]	7700	10.400	1.36
Electricity demand [GWh] 电力需求[千兆瓦时]	1970	3180	1.62

Ulaanbaatar challenges 乌兰巴托的挑战

- High dependency on coal
  高度依赖煤炭
- But: abundant renewable energy sources: wind and solar energy
  但是：拥有丰富的可再生能源：风能和太阳能
- High growth rates expected
  预计增长率高

➔ **How to reduce air pollution caused by coal-fired CHP plants (central) and stoves in yurts and detached houses (decentral), and by traffic**
如何减少由燃煤热电联产发电厂（集中），蒙古包/独立式住宅的煤炭锅炉（分布）和交通所造成的空气污染

Picture: UB City in February 2018, day with heavy air pollution, day without

	2016	2050	Factor
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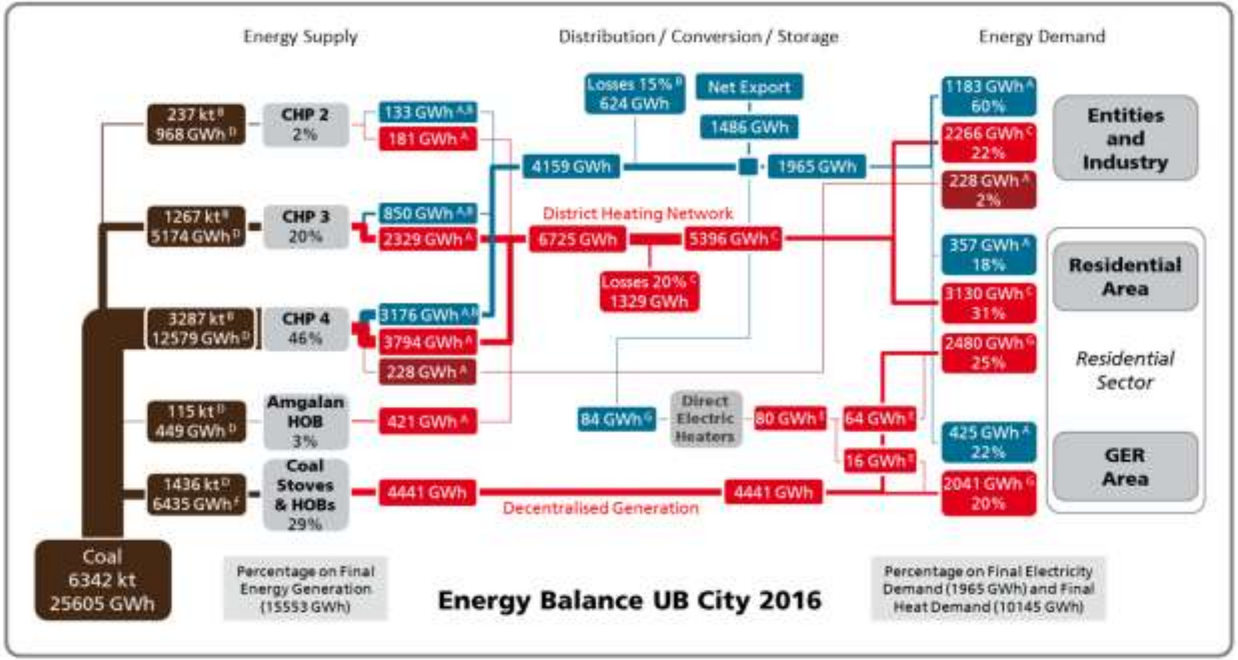
Electricity demand [GWh] 电力需求[千兆瓦时]	1970	3180	1.62

Ulaanbaatar Energy Balance 2016
乌兰巴托能源平衡 2016

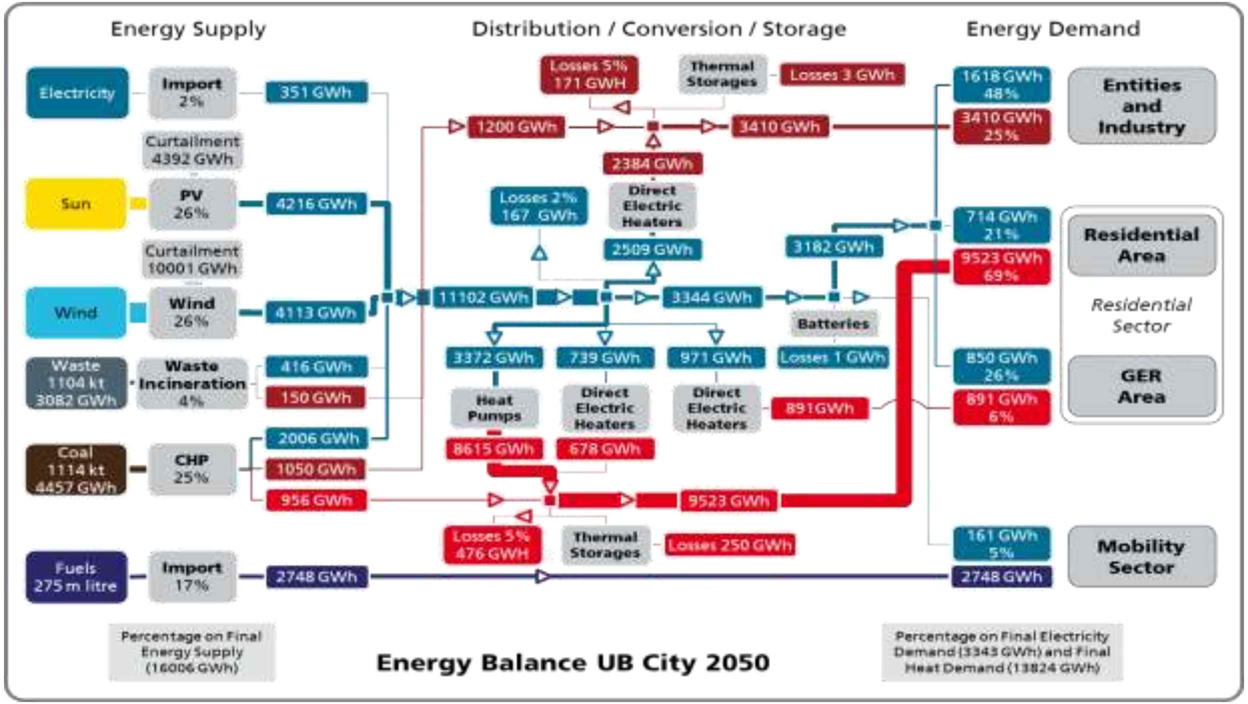
- Full dependency on coal (and fuels for transport)
  完全依赖煤炭(包括运输)
- High heat demand:
  five times of electricity demand
  热需求高:
  是电力需求的五倍
- 43% of the electricity generated in the city is exported
  43%的当地生产电力为出口
- High electricity demand by entities and industry, high heat demand by residential sector
  产业和工业的电力需求高，
  住宅的热需求高



Ulaanbaatar Energy System 2050 – Recommended scenario
乌兰巴托能源系统 2050 - 推荐情景

- 56% of final energy supply is generated by renewable energy within UB city and surrounding region (wind)
  56%的最终能源供应来自乌兰巴托城市及周边地区的可再生能源（风能）

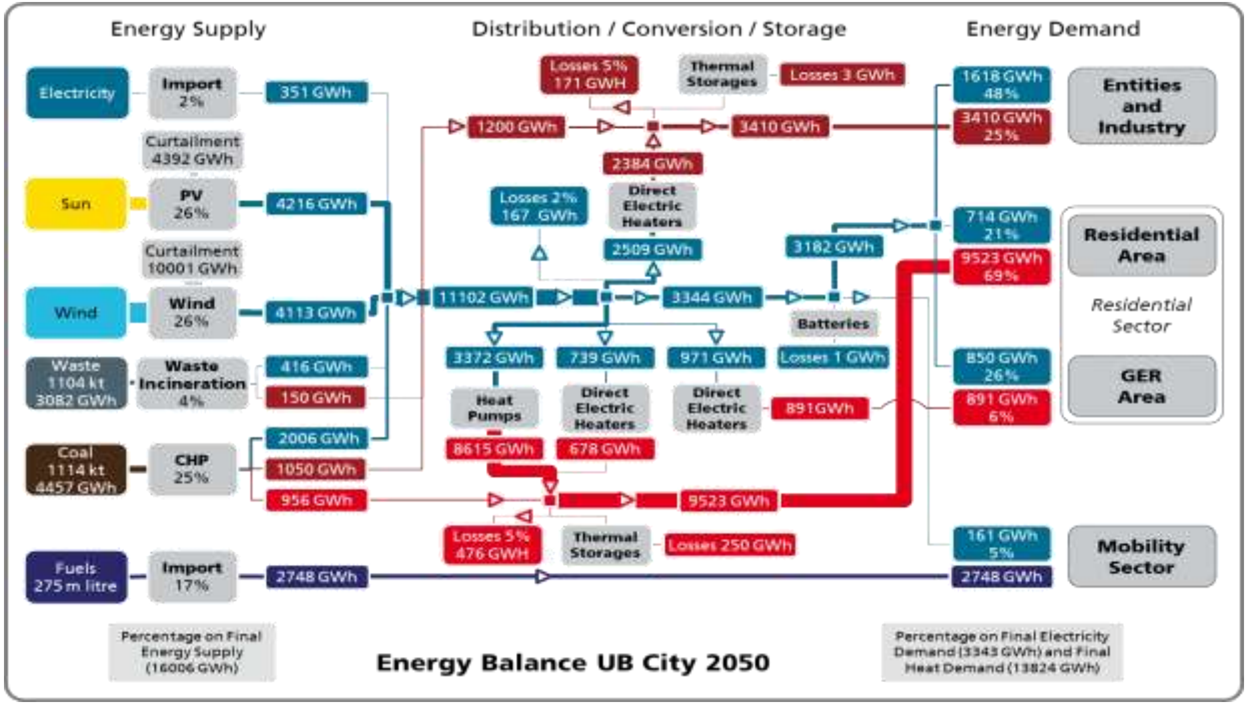
- Abundant renewable energy potential, but the mismatch of wind and solar against the demand limits its usability
  丰富的可再生能源潜力，但风能和太阳能与需求的不匹配限制了其可用性



Ulaanbaatar Energy System 2050 – Recommended scenario
乌兰巴托能源系统 2050 - 推荐情景

- High share of solar and wind leads to high level of curtailment (or export)
  太阳能和风能的高比例导致高弃风、弃光率（或出口）

- 17% of energy demand by fuels for transport, low e-mobility share assumed
  交通燃料占能源需求的17%，假设低水平的电动交通使用率

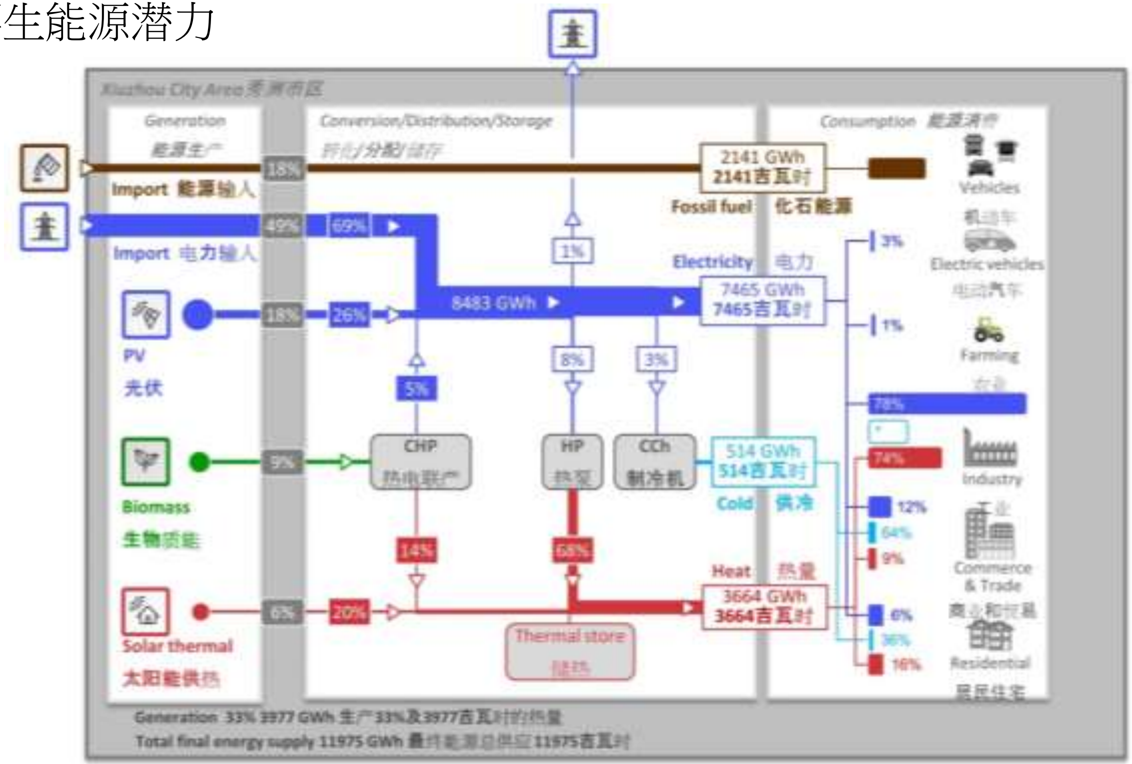


Energy System Jiaxing-Xiuzhou 2030 嘉兴-秀洲的能源系统2030

Recommended scenario: Using 80% of the local renewable energy potential
推荐情景：使用80%的当地可再生能源潜力

- Energy balance 2030 includes transport within the city
  能源平衡2030包括城市内的交通

- Due to the strong industry with high energy demand, only 33% of the overall energy demand can be generated within the city area (by using 80% of RE potential and the expected demand in 2030)
  由于高能耗的产业强大，只有 33%的总能源需求可以在城市范围内产生（通过使用80%的可再生能源潜力和2030年的预期需求）



CHP: Combined Heat & Power, HP: Heat Pump, * Cooling demand unknown, in electricity included

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Energy System Jiaxing-Xiuzhou 2030 嘉兴-秀洲的能源系统2030

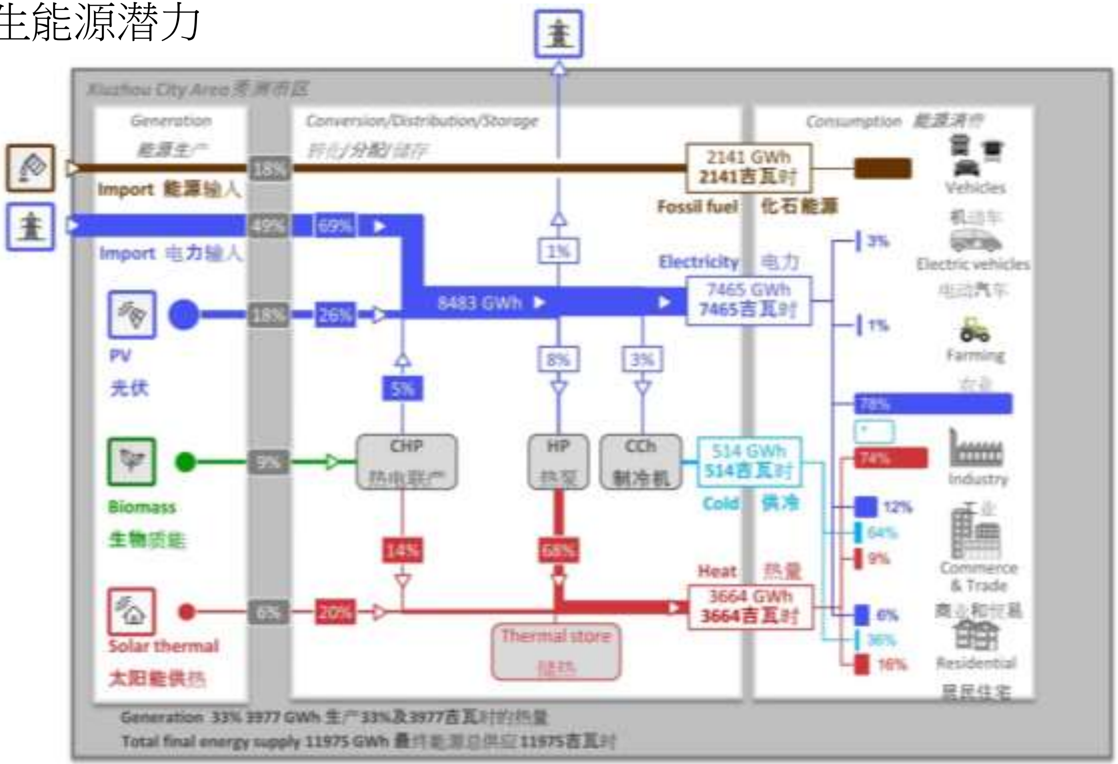
Recommended scenario: Using 80% of the local renewable energy potential

推荐情景：使用80%的当地可再生能源潜力

- Solar energy: 18% electricity and 6% heat of energy supply
  太阳能：占18%电力和6%热力供应

- Biomass: 9% of energy supply
  生物质：占能源供应的9%

- 49% of energy is imported as electricity and 18% as benzin and diesel
  49%的能源是进口电力，18%是进口汽油和柴油



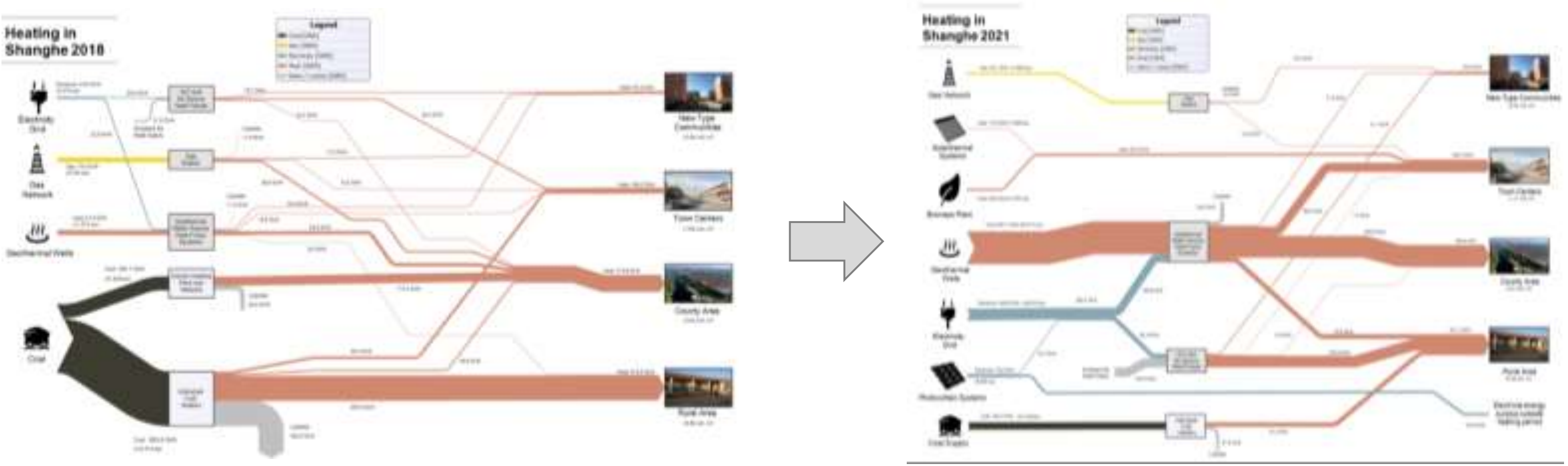
CHP: Combined Heat & Power, HP: Heat Pump, * Cooling demand unknown, in electricity included

Energy System Shanghe, Shandong Province 山东省商河市能源系统

Recommended scenario 2021　推荐情景 2021

How can the use of coal significantly be reduced on short-term?
如何在短期内大幅减少煤炭的使用量？

- Strong increase of geothermal energy for district heating is proposed to replace coal
  建议高度增加地热能在集中供暖的使用率以取代煤炭
- Electricity is replacing coal in rural areas (where district heating is not available)
  以电力供暖方式取代农村地区的煤炭锅炉（没有集中供暖的地区）



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Findings 调研结果：Resources 资源

Renewable energy sources: Solar and Wind have highest potential **可再生能源：太阳能和**风能发电潜力最大
Solar: limited installation areas within cities, if mainly highrise buildings exist **太阳能：如果主要是高**层建筑，城市内的安装区域有限
Wind: potential only outside settlement areas, wind speed not sufficient everywhere 风能：由于风速并不是在所有地方都是足够的，风能的潜力局限在聚居地之外
Biomass/waste: potential exist should be used, but can usually cover only a minor part of demand **生物能/垃圾能：如果潜能存在，**应该被使用，但通常只能满足一小部分需求
Hydro power: Perfect source, if available **水力**发电：很好的资源，如果有**潜力**
Geothermal: Perfect source, if potential is there, potential is often unknown/unsure **地**热：很好的资源，如果有潜力，但潜力通常是未知/**不确定的**
Natural gas: Low-emission bridge technology, often limited/not available and expensive **天然气：低排放**过渡技术，通常有限且价格昂贵
Clean coal: Can reduce emissions partly, if bad coal is replaced 清洁煤：如果不好的煤被替代，可以减少部分排放量

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Findings 调研结果：Technologies 技术

Efficiency: Huge potential, important pillar of transformation
提高能效：潜力巨大，是转型的重要部分

- **in generation:** CHP should be preferred (if combustion), high efficient technologies are available
  在能源生产方面：如果使用燃烧方式，热电联产应该是首选，可以使用高效技术
- **in distribution:** Losses are often not monitored, technologies exist
  在能源分配方面：损失通常不被监控，但技术存在
- **in electricity consumption:** Huge potential in equipment in households, commercial and public buildings, industrial processes **在电力消耗方面：家庭，商**业，公共建筑，工业存在巨大潜力
- **in heat consumption:** Building insulation (space heating), industrial processes, domestic hot water
  在热量消耗方面：建筑隔热（空间**供暖**），**工**业生产加工，生活热水
- **in mobility:** Low consumption vehicles, electric vehicles reduce energy demand by ca. 80%
  在交通方面：使用低能耗车辆，电动车辆，降低80%**能源需求**

Monitoring and control: is often not existing **监控：通常不存在**

Smart technologies: Batteries and thermal storage, smart energy management, smart grid, needed for an efficient operation of the energy system
智能技术：电池和蓄热，智能能源管理，智能电网，是高效运行能源系统所必需的

Findings 调研结果：Economical 经济方面 / Social 社会方面

Economical 经济方面

Investments in clean technologies, renewable energy sources and energy efficiency are often more expensive as air polluting technologies, or at least they require higher CAPEX

在清洁技术，可再生能源和能效上的投资往往比治理空气污染技术更昂贵，需要更高的资本支出

Investor – consumer dilemma: consumers benefit from energy efficiency, but not the investors

投资者 - 消费者两难境地：消费者受益于能源效率，而不是投资者

Social 社会方面

Energy prices are often subsidized due to social reasons, this means no motivation to save energy

由于社会原因，能源价格受到补贴，导致丧失节约能源的动力

Low-income families usually use cheapest energy sources, which cause the highest air pollution – but they are also suffering the most from air pollution

低收入家庭通常使用最便宜的，污染空气最严重**的能源 - 但同**时他们也受到空气污染的影响最大

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Findings 调研结果 : Planning 策划方面 / Political 政治方面

Planning 策划方面

Multi-dimensional challenge: To develop a consistent, efficient and effective plan with significant results in short-term (on air pollution) is difficult, since **short-term and long-term planning must be harmonized**, future developments in energy demand, technologies, policies, public awareness and acceptance, etc. are often difficult to predict, different actors must contribute, international energy prices are difficult to predict, political framework conditions are unsure in future,…

多向挑战：制定一份在短期内取得重大成果的空气污染防治方案，是很难的，因为它必须是一贯的，高效的和有效的。**短期和**长期规划必须协调一致。未来能源需求，能源技术，政策，公众意识和接受度等往往难以预测。涉及多个行业领**域**，难以预测的国际能源价格和未来政治框架情形的不确定性都加剧策划上的困难性

Political 政治方面

A bundle of policies is necessary, single programs are not sufficient

一系列的政策是必要的，单个项目是不够的

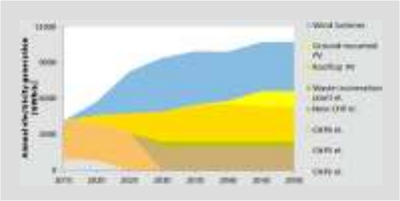
Effectiveness of political instruments differs a lot, influence is rather limited in some fields

政策的有效性差异很大，在某些领域的影响力相当有限

Effective policies are either expensive or require courage by the politicians

有效的政策要么是昂贵要么需要政治家的胆识

Steps and results of the UB City Master Plan
乌兰巴托城市能源总体规划步骤和结果



Energy system analysis of Ulaanbaatar

乌兰巴托能源系统分析

Goal:
Understand challenges and opportunities

目标：认知挑战和机遇

Optimized energy target system by 2050

优化能源目标系统到2050

Goal:
Strong CO2-reduction to mitigate climate change

目标：大力减少碳排放，以缓解气候变化

Energy transformation path until 2025

能源转型路线到2025

Goal:
Significant reduction of local air-pollution

目标：显着减少当地的空气污染

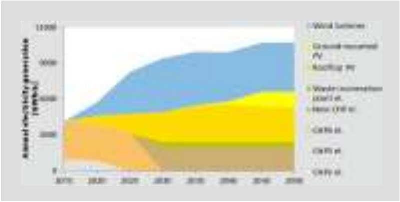
Political framework and instruments

政治框架和工具

Goal:
Enable energy system transformation

目标：实现能源系统转型

Steps and results of the UB City Master Plan 乌兰巴托城市能源总体规划步骤和结果



Energy system analysis
能源系统分析

Input data 输入数据

Goals of energy system transformation
能源系统转型的目标

Energy demand today
当今能源需求

Energy demand 2050 forecast
预测2050能源需求

Potential of renewable energy potentials in UB city and surrounding region
乌兰巴托城市及周边地区可再生能源潜力

Target system 2050
目标体系2050

Considered aspects
所考虑的层面

Fluctuating generation
能源生产波动
Coupling of electricity and heating sector
电力和供热的耦合

Modelling results 模型结果

Physical possible (supply in each hour of the year) and cost-optimal solution
提供精确到小时的计算，成本优化的解决方案
Comparison of scenarios
Recommended scenario
情景比较，方案推荐

Transformation path
转型路径

Key technical measures
关键技术措施

1. Energy efficiency: building insulation, reduction of system losses,… **能源效能**：建筑隔热，减少系统损失……

2. Electrification of the heating sector (where district heating is not available)
供热的电气化(在没有集中供暖的地区)

3. Installation of Photovoltaic and Wind power plants
安装光伏和风力发电厂

Policies of UB City and National Government
乌兰巴托城市和国家政策

1. Building efficiency law execution & improvement, consumption and cost-oriented energy tariffs 执行和改进建筑效能法，以能源消耗和成本为导向的能源价格

2. Stimulation of electric heater usage and related electric grid strengthening 刺激使用电热政策，加强电网管理

3. PV installations on public buildings, revision of renewable energy law 公共建筑配备光伏装置，修订可再生能源法

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Conclusions
总结

Electricity, heating, cooling, mobility
电力，供热，制冷，交通

Efficiency in generation, distribution, consumption
生产，分配，消费的**效能**

Air pollution 空气污染
unacceptable level
high urgency
不可接受的程度
万分紧迫性
(short-term 短期)

Electric vehicles 电动汽车
higher efficiency 提高率,
no local emissions 无本地排放

Systematic transformation of the energy system
能源系统的系统转型
long-term planning 长期计划
kick-start now
立即启动

Renewable energy
capacity building
(and clean fuels) 建设**可再生能源**（清洁燃料）

Climate change 气候变化
almost decarbonized energy system needed
需要近无碳能源系统
(long-term 长期)

Smart technologies 智能技术
metering, smart control, sector coupling,…计量，智能控制，领域耦合

Strong and **courageous policy**
有力以及有**胆识的政策**
(subsidies, regulation, energy tariffs)（补贴，监管，能源价格）

Long-term and short-term action plan
长期和短期行动计划

Thank you very much for your attention
感谢您的关注






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