Dr. Bin Chen obtained his Ph.D. in Environmental Science from Peking University and did post-doctoral study in Harvard Kennedy School. He is currently Full Professor of Beijing Normal University. Dr. Chen’s research focuses on the urban metabolism and nexus issues. He has published over 250 peer-reviewed papers in prestigious international journals such as *PNAS*, *Trends in Biotechnology*, and *Nature Climate Change*. His works are widely recognized and have more than 5000 citations with H-index of 39 according to Web of Science. He is serving as Editor-in-Chief of *Energy, Ecology and Environment*, Associate Editor of *Journal of Cleaner Production, Frontiers of Earth Science*, Subject Editor of *Applied Energy*, and an editorial board member of *Ecological Modelling, Journal of Environmental Management, Journal of Hydrodynamics* and *Ecological Informatics*, etc.

**Publications**


Urban resource management from a metabolism perspective

Bin Chen
Beijing Normal University, China
chenb@bnu.edu.cn

Workshop Smart Cities 2017: Perspectives and Innovations in Quebec and China, Montreal, Quebec, Canada
Outline

- Background
- Urban challenges
- Resource and waste metabolism
- Resource efficiency
- Regulation for urban transitions
Background
Since 1950, the world has entered the process of urbanization. By 2050, more people will live in urban area.

Share of urban and rural populations, 1950–2050

(Source: Urban Europe, 2016)
Urbanization in China

Megacities in the world, 6 in China (2014)

km² of land converted to urban areas every year from agriculture, forest, and grassland

tons of standard coal consumed per day (2014)

Degree of urbanization in China from 2005 to 2015

China, as the most populous country in the world, has entered the rapid urbanization since 2005.

Urban challenges
Urban challenges

Resources requirements for urban system

Simplified scheme of resource requirements for urban socio-economic system

Resources in urban socio-economic system
Urban Water requirements

Urban water scarcity

400 billion

2079 vs 6225

of 600 cities are water scarce

China had a per capita water of 2079 m$^3$ while the world average was 6225 m$^3$

200 billion

yuan/yr economic losses caused by urban water shortage

400 billion

m$^3$ water deficit by 2050 in China
2014, energy consumption per capita in cities is over 6 tce, much higher than The national average level of 2.5 tce.

The proportion of urban energy consumption accounted for more than 80% of national energy consumption.

By 2020, the urbanization level of China will reach about 60%, while the urban energy consumption will reach 4 billion tce.

By 2030, the urban energy gap of China will reach 460 million tce/a.
China’s urban area is **85810 km² in 2016.**
National urban land area increased by **13190 km²** from 2009 to 2013, an increase of **18.2%**.

Urban land area and growth ratio in China

Urbanisation and Health in China, Gong et al., Lancet, 2012 Mar 3, 379(9818), pp. 843-52,
Urban challenges

Carbon emission

- Cities contribute to 85% of total carbon emissions of China, of which 35 largest ones contribute 40%.

Haze

Main factors:
- Unreasonable energy structure and industrial layout
- Vehicle-exhaust gas
- Lax management of air quality

Distribution:
- Temporal distribution: concentrations of particulate matter (PM) in eastern China is higher than western China and that in southern China is lower than northern China.
- Spatial distribution: heavy smog enveloping most cities in China has frequently occurred during winter, but hardly happened in summer.

Monthly average concentration of PM$_{2.5}$ in 2016
Urban challenges

Solid waste

- 161.48 million tons garbage from 261 large and medium cities produce in 2013 were disposed, with the disposal rate being 97.41%.

- The annual dumped volume of solid has reached 60 billion tons in China, which occupied 500 million m$^2$ of arable land.

For cities of China 2015, **industrial waste** reached **1.91 billion tons**, industrial hazardous waste production amounted to **28.018 million tons**, and the amount of **domestic waste was 185.64 million tons**.
Urban challenges

Wastewater

- China’s total waste water discharge has increased from **43 million tons in 2001** from **72 million tons in 2014**, increased **37%**. The total number of waste water treatment plants in cities increased from 481 in 2000 to 3,717 in 2014.
- Shanghai, Beijing, Tianjin are the top three cities of sewage discharge per capita.

Resource and waste metabolism
The development of urban settlements has a wide range of impacts on their natural environmental and other fringe ecosystems. It remains a significant challenge for scientists, industries, and government to make reasonable urban development policies to mitigate environmental impact over the next decades.

- Resources exploitation and environmental degradation
- No enough sustainable energy sources to support the future development
- High-carbon pattern of economics and infrastructures
- The challenge from urban population growth

It remains a significant challenge for scientists, industries, and government to make reasonable urban development policies to mitigate environmental impact over the next decades.
Urban metabolism is generally defined as the analysis of all the technical and economic flows of energy and materials associated with the production and consumption activities in cities.

- Including importing raw materials and products from other economies or ecosystems.
- Exchanging goods and services between economic sectors.
- Rejecting materials outside the cities' boundaries as emissions or waste to the environment.
Resource and waste metabolism

- Decomposition of urban metabolic processes into resource and waste metabolism can help to define the metabolic structural characteristics.

- **Resource metabolism**: the use of resources and the resulting outputs.

- **Waste metabolism**: the generation, reuse, and final discharge of wastes, and can be described in terms of the environmental impacts of these wastes and their cycling.

- The model with two main metabolic flows:
  - The resource metabolism flows and are represented by thick black lines;
  - The waste metabolism flows and are represented by thin black lines
  - A mixture of resource and waste metabolism is represented by dashed lines.
Resource efficiency
Urban multi-level resource efficiency management
**Resource efficiency**

**Water metabolism**

Water system efficiency
Utility Analysis
Robustness Analysis

![Diagram showing water metabolism with key pathways, sectors, and efficiency metrics.](image)

Resource efficiency

**Energy**

- Assess **urban energy metabolism** (the study of the technical and socioeconomic processes that occur in cities)
- Strong tools for **tracking urban energy flows** and indexing the energy intensity of economic sectors from the **production perspective**
Resource efficiency

Carbon

Loc: local environment; Ene: energy production sector; W&S: Water and soil stock; Con: Construction sector; Agr: Agriculture sector; ITS: Industry (product manufactory), trade and service sector; Dom: Domestic sector; Ext: External domain and market

## Energy–Carbon Nexus

### Modelling process for urban energy and carbon coupling

<table>
<thead>
<tr>
<th>Model layer</th>
<th>Modelling process for urban energy and carbon coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td><strong>Energy and carbon inventory</strong></td>
</tr>
<tr>
<td></td>
<td>• System boundary</td>
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<tr>
<td></td>
<td>• Energy supply</td>
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<tr>
<td></td>
<td>• Carbon emissions</td>
</tr>
<tr>
<td></td>
<td>• Socioeconomics</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td><strong>Construction of inter-sector flow networks</strong></td>
</tr>
<tr>
<td></td>
<td>• Sectoral structure</td>
</tr>
<tr>
<td></td>
<td>• Energy/carbon link</td>
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<tr>
<td></td>
<td>• Inter-sector relation</td>
</tr>
<tr>
<td></td>
<td>• Metabolic networks</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td><strong>Energy-carbon nexus modelling for a low-carbon economy</strong></td>
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<td>• Energy-carbon nexus</td>
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<td>• Carbon intensity</td>
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<td>• Sensitivity analysis</td>
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<td>• Low-carbon pathway</td>
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</tbody>
</table>

### Carbon flow analysis

- E1 → C1 → S1
- E2 → C2 → S2
- E3 → C3 → S3

### Secoral emissions allocation

### Energy flow analysis

### Energy metabolic network

- S1 → E12 → S2
- S1 → E13 → S3
- S2 → E23 → S3

### Carbon metabolic network

- S1 → C12 → S2
- S1 → C13 → S3
- S2 → C23 → S3

### Carbon intensity of process 1-2

### Carbon intensity of process 2-3

### Carbon intensity of process 1-3

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Supply Chain Effect On Relationship Between Sectors

The important water-energy nexus nodes for vertically integrated consumption are sectors which possess high values of vertically integrated effects for both virtual water and embodied energy, and rely on resource inputs to continue their production activities.

Regulation for urban transitions

Using systematic approach to optimize the interconnection within the whole urban system and identify the leverage point to obtain the tradeoffs and even synergies, thereby keeping city's robustness and sustainability over time.
Regulation for urban transitions

Resource Efficient Metabolism

• Design their **infrastructures and services** in such way that their **linear** metabolisms (e.g., resource–consumption–waste) can be converted into **circular metabolisms** for the goal of less impact on nature.

![Diagram](image)

Bio-inspired paradigm following the nature in its stocks and flows.

Cities and urban settlements are embedded within a hinterland of intersecting regional, national and global economic dynamics and financial flows;

Shape the urban transition to more resource efficient and inclusive urban nexus configurations.

**Resource Efficient Nexus**

- Positive feedback
- Negative feedback
- Coordination
- Utilization

**Policy scenario**

No feedback conflict

Two negative feedbacks added, $\Delta T3 \uparrow$

**Feedback conflict**

$u_{13} > u_{23}, \text{Positive feedback} >$ negative feedback, $\Delta T3 \downarrow$

$u_{13} = u_{23}, \text{Positive feedback} =$ negative feedback, $\Delta T3 = 0$

$u_{13} < u_{23}, \text{Negative feedback} >$ positive feedback, $\Delta T3 \uparrow$
Achieving “**Synergistic Effects**” based on Nexus
- higher productivity growth, greater human wellbeing

◆ **Smart or Green Urbanism**

◆ **Shift city from competition paradigm to coordination paradigm**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Air pollution reduction</th>
<th>Grid reliability and/or resilience</th>
<th>Human health and well-being</th>
<th>Land use saving</th>
<th>Urban heat island reduction</th>
<th>Water-use efficiency</th>
<th>Water quality</th>
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<tbody>
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Smart City – Nexus Paradigm

✓ Big Data + Nexus
Regulation for urban transitions

Top-Down modelling

Materials/energy models

Structure models

Integrated models

Smart Urban Management

Bottom-Up modelling

Metabolism

Ecological models of different scales

Land use models

Infrastructure models

Nexus

Ecology

Energy

Environment

Regulation for urban transitions
Call for Papers

SI: *Sustainability for Smart Cities*

Guest Editors:

Dr. Liexun Yang
Dr. Bin Chen

IF: **5.715**

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