Funded by the European Union

Theory and Practice of Forward and Reverse Synergy

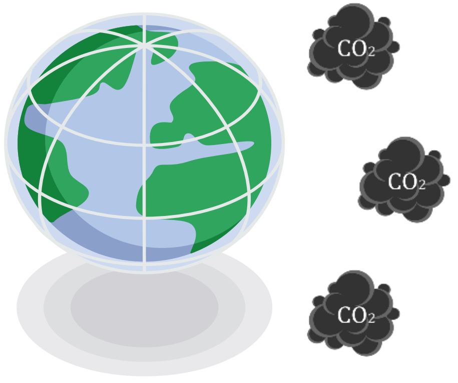
Xiao Jianzhuang
Vice President, Guangxi University

Reconmatic

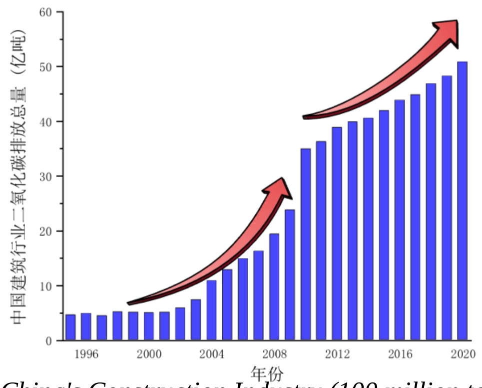
Agenda

1. Background of the current situation
2. Why forward and reverse synergy in recycling
3. How to synergise
4. Case study
5. Summary

The current situation

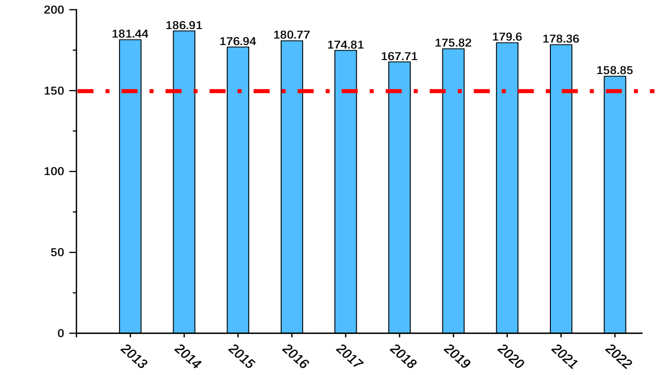


"Carbon Neutral" and "Carbon Peak"



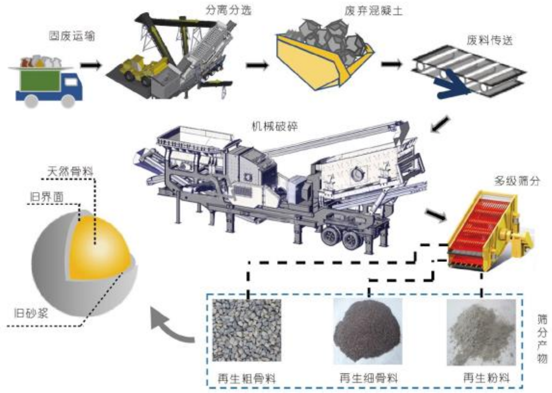
1995-2019, Total Carbon Emissions from China's Construction Industry (100 million tons)

China's construction industry emits a large amount of carbon.



2013-2022, National Demand for Sand and Gravel (100 million tons)

Huge demand for sand and gravel.



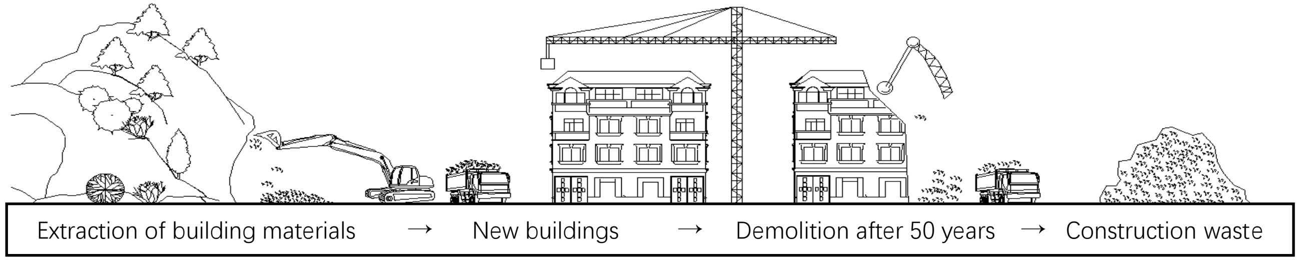
Recycling process of concrete[1]

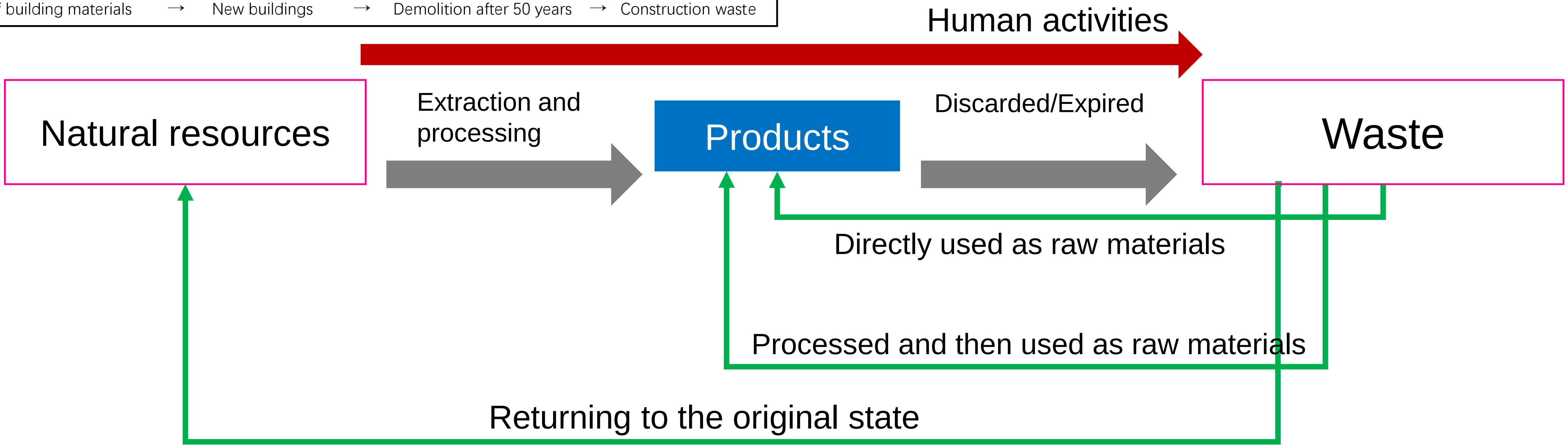
Piles of construction waste

Huge impact on the environment.

- China's construction solid waste volumes are enormous, and the issue of resource utilization has drawn significant attention.
- Reduction, reuse, and recycling of construction waste are currently the major trends in low-carbon sustainable development in the construction industry.

Background





In the traditional construction industry development model, most construction waste is directly disposed of into nature.

Background

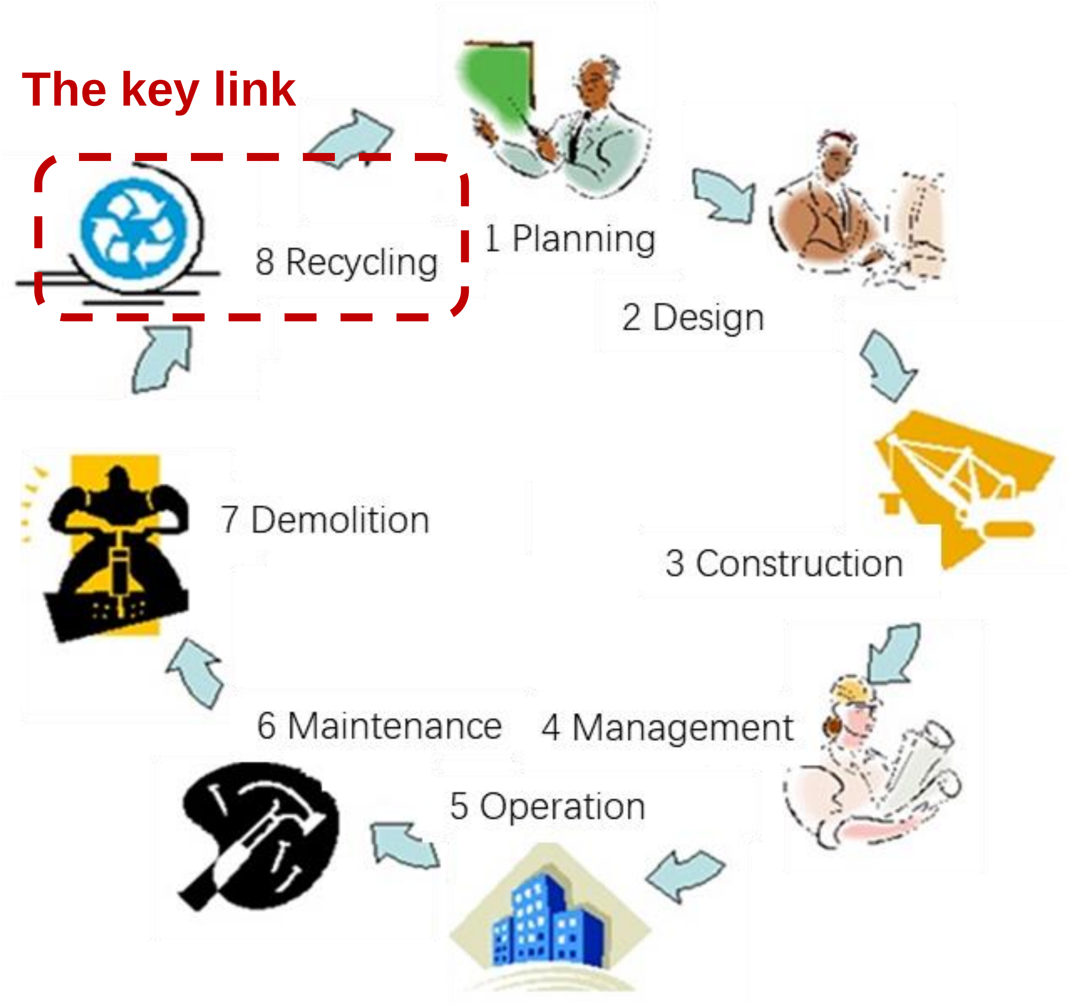
Life Cycle

Linear → Circular

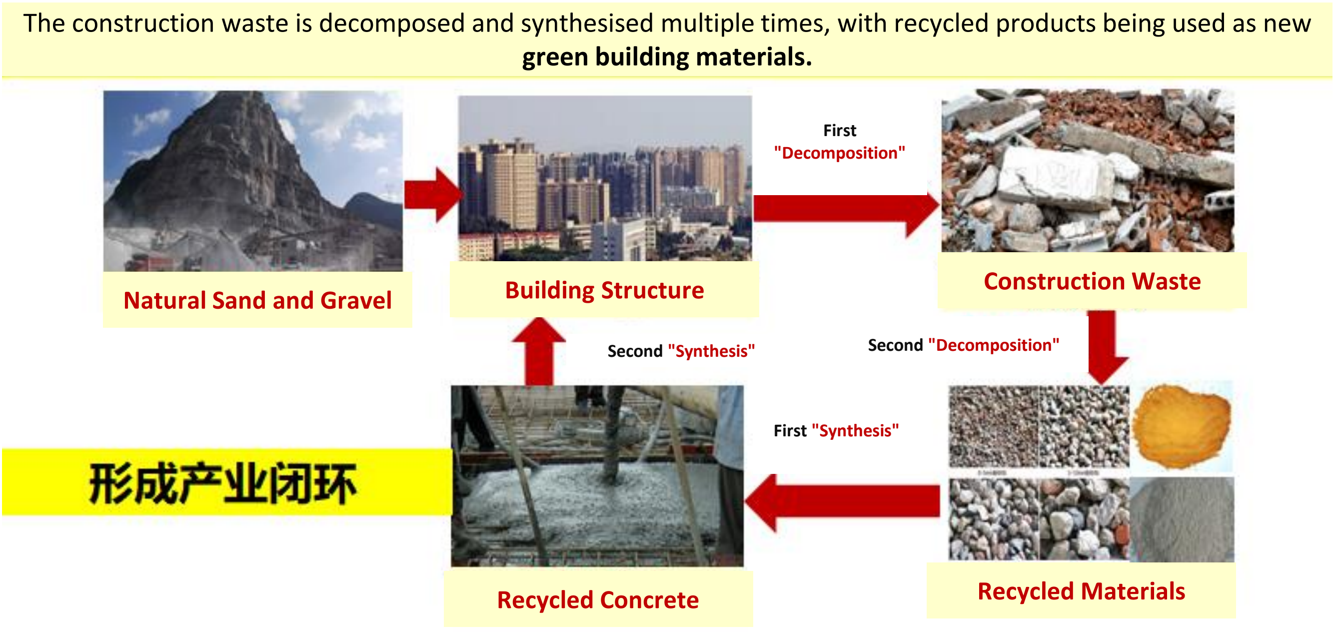
- **Forward-Reverse Synergy Planning and Application Theory for Resource Utilization**

Forward		Reverse
Waste Resource Attribute Database →	**Disposal**	← Planning for Quality Improvement
High-quality and Functional Design of Products →	**Product**	← Market Adaptation Analysis
Multi-scenario and Multi-path Application Design →	**Application**	← Systematic Large-scale Application Requirements

Background



The whole process of the construction industry



- **The recycling of construction waste contributes to the closed-loop development of the entire construction industry supply chain.**

Background

图片来源：项目组实地拍摄

Dujiangyan post-earthquake construction waste treatment plant

The State Council and the Development and Reform Commission have issued documents:

2018.12 Improve the level of resource utilisation and the quality of recycled products

2021.07 By 2030, 55% of construction solid waste should be resourced

2021.10 Promote the recycling of building materials and low-carbon building materials.

How to further increase the rate of construction solid waste resourcing

- 11th 5-Year Plan: Disposal of waste in earthquake-affected areas
- 12th 5-Year Plan: Sustainable construction in the countryside
- 13th 5-Year Plan: Solid Waste Resource Utilisation
- 14th 5-Year Plan

■ **The increasing importance of solid waste resource utilisation to achieve sustainable development in cities and towns.**

Background

- Demonstration applications landed and opened up the industry chain
- By 2020, the comprehensive utilisation rate of construction waste has reached 50% (NDRC's 14th 5-Year Plan for Circular Economy).

Background

Application Examples of Recycled Concrete

Tongji Road
2004

Fudan Road
2007

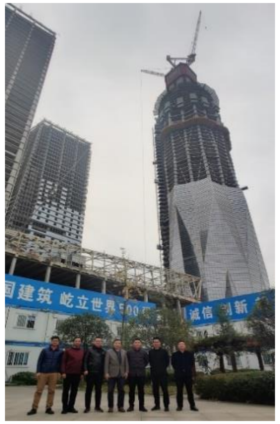
World Expo, 3 floors
2010

Yangzhou, 5 floors
2014

Sichuan post-earthquake reconstruction, 2008

Shanghai, 12 floors, 2016

Jinan, 5-floor large-span framework, 2020 (with a 100% replacement rate)



310m Pumping

Agenda

Ministry of Science and Technology projects related to ‘solid waste’

Major project

- ✓ 21 projects under the National Key Research and Development Program for "Green Buildings and Industrialized Construction" have been announced.
- ✓ 47 projects under the National Key Research and Development Program for "Solid Waste Utilization" in 2019 have been announced, mainly covering construction waste, industrial solid waste, and hazardous waste.

13th Five-Year Plan: "Green Buildings and Industrialized Construction" Key Projects

- ✓ Research and application of key technologies for green building materials through the collaborative utilization of solid waste.
- ✓ Research and application of key technologies for green building materials from industrial and urban solid waste.
- ✓ Research and application of key technologies for the efficient utilization of the entire construction waste industry chain.

13th Five-Year Plan: "Solid Waste Utilization" Special Projects

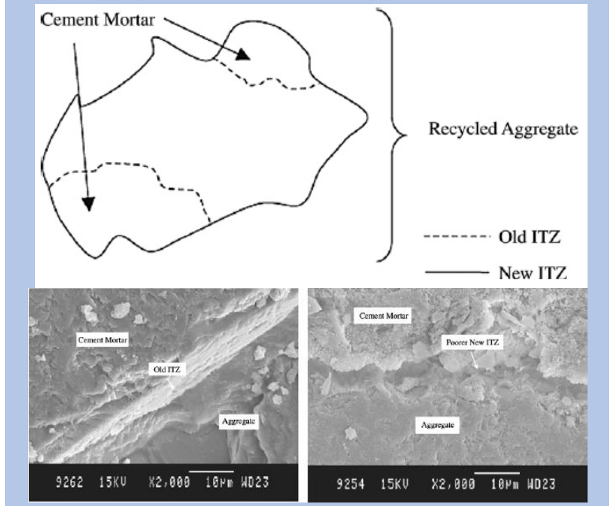
- ✓ Key technologies for large-scale, high-value mineral materials from low-grade solid waste.
- ✓ Scientific basis for the reconstruction and conversion of aluminosilicate inorganic solid waste.
- ✓ Intelligent fine sorting and upgrading technologies for urban construction waste.
- ✓ Low-cost cementitious materials from industrial solid waste and related application technologies.
- ✓ Prefabricated component technology for industrial solid waste.
- ✓ Complete set of large-scale utilization technologies and integrated demonstration for solid waste at coal power bases.
- ✓ Research on key technologies for multi-path applications of recycled concrete sand and powder.

Developments in construction solid waste resourcing

2006 "11th 5-Year Plan" 2010	2011 "12th 5-Year Plan" 2015	2016 "13th 5-Year Plan" 2020	2021 "14th 5-Year Plan" present

2006 "11th 5-Year Plan" 2010

● Demonstration of earthquake-stricken area construction waste recycling and seismic energy-saving housing construction technology.



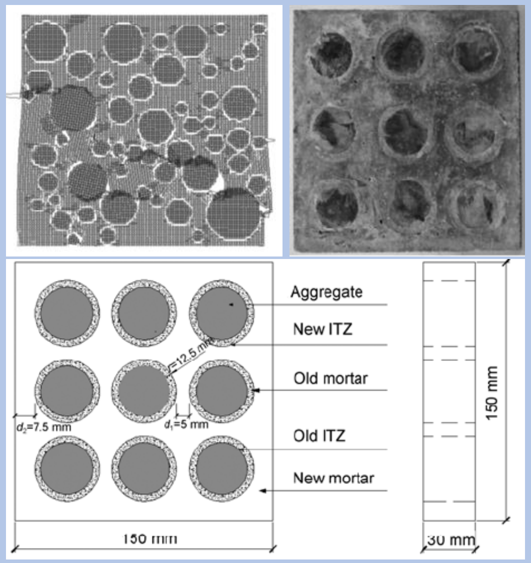
XiaoJianzhuang, An overview of study on recycled aggregate concrete in China (1996-2011)

Waste Disposal
Resourceisation

2011 "12th 5-Year Plan" 2015

● Research and demonstration of key technologies for green construction in building engineering.

● Research and demonstration of key technologies for rural housing in villages.



XiaoJianzhuang, Recent studies on mechanical properties of recycled aggregateconcrete in China—A review

Green Construction
High Performance

2016 "13th 5-Year Plan" 2020

● Research and application of key technologies for efficient utilization of the entire construction waste recycling industry chain.

● Intelligent fine sorting and upgrading technologies for urban construction waste.

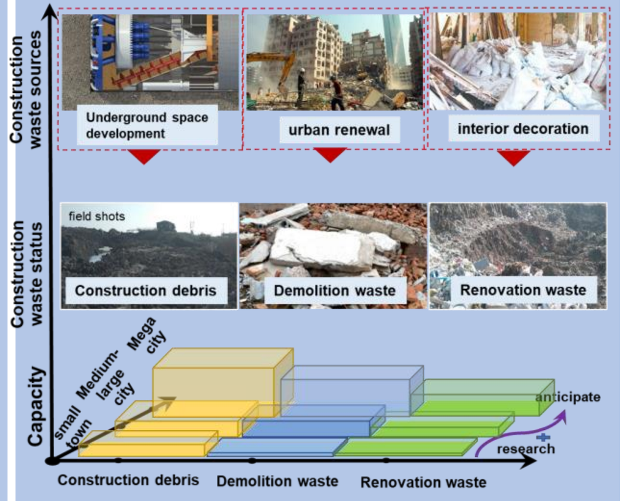
● Key technologies for multi-path applications of recycled concrete sand and powder.

0 waste city
Refinement

2021 "14th 5-Year Plan" present

● Research and demonstration of key technologies for the systematic large-scale application of urban construction waste.

● Research and Application of Key Technologies for Building Demolition and Sustainable Disposal



Sustainable Development
Systematization

About the construction solid waste project

■ Research and application of key technologies for efficient utilization of the entire construction waste recycling industry chain.

- ✓ The project follows the principles of reduction, harmlessness, and recycling, integrating key aspects of the entire construction waste recycling industry chain. It aims to address critical issues related to the generation, classification, recycling, and application of construction waste. The project will develop materials, products, processes, equipment, technologies, and standards suited for urbanization, aligned with industrialized construction, and conducive to large-scale use.
- ✓ Key areas of research and development include breakthroughs in: "lifecycle-based construction waste reduction and classification technologies," "modular processes and equipment for recycled aggregate crushing, sorting, and quality enhancement," "prefabricated recycled concrete components and structural application technologies," "preparation and application technologies for high-quality decorative, structural, and functional recycled concrete products," "preparation and application of permeable materials based on sponge city principles," and "integrated technologies for recycling soil-based construction waste.“
- ✓ The project also aims to solve challenges like establishing a unified theoretical framework for the design of "recycled block concrete" and "recycled mixed concrete."

About the construction solid waste project

■ Intelligent fine sorting and upgrading technologies for urban construction waste.

- ✓ For urban construction waste, the project aims to develop AI-based sorting technology and complete equipment sets. It will research targeted pre-treatment classification technologies, upgrade recycling techniques and products, and create an integrated solution combining research, engineering demonstration, industry promotion, and policy support for urban construction waste recycling, with a focus on demonstration projects.
- ✓ The project will develop 2-3 AI-based sorting technology systems and equipment sets for urban construction waste, with a 100% localization rate for core equipment. The system will have intelligent learning capabilities, with a waste recognition accuracy of over 95%, a brick/concrete sorting rate of over 85%, and an organic/inorganic material sorting rate of over 85%. Treatment costs will be reduced by more than 20%. Additionally, the project will create 3-5 new products for large-scale waste recycling. Two or three green demonstration projects for recycling construction waste on a scale of 100,000 tons/year will be established, meeting the requirements of the "Green Factory Evaluation Guidelines" (GB/T 36132-2018). An integrated solution for urban construction waste recycling, covering research, engineering demonstration, industry promotion, and policy support, will be proposed, with 2-3 demonstration bases established in different regions of China. The project will build a technical patent and standards system (applying for more than 10 invention patents and developing over 3 standards or specifications) and establish an innovative commercialization model.

About the construction solid waste project

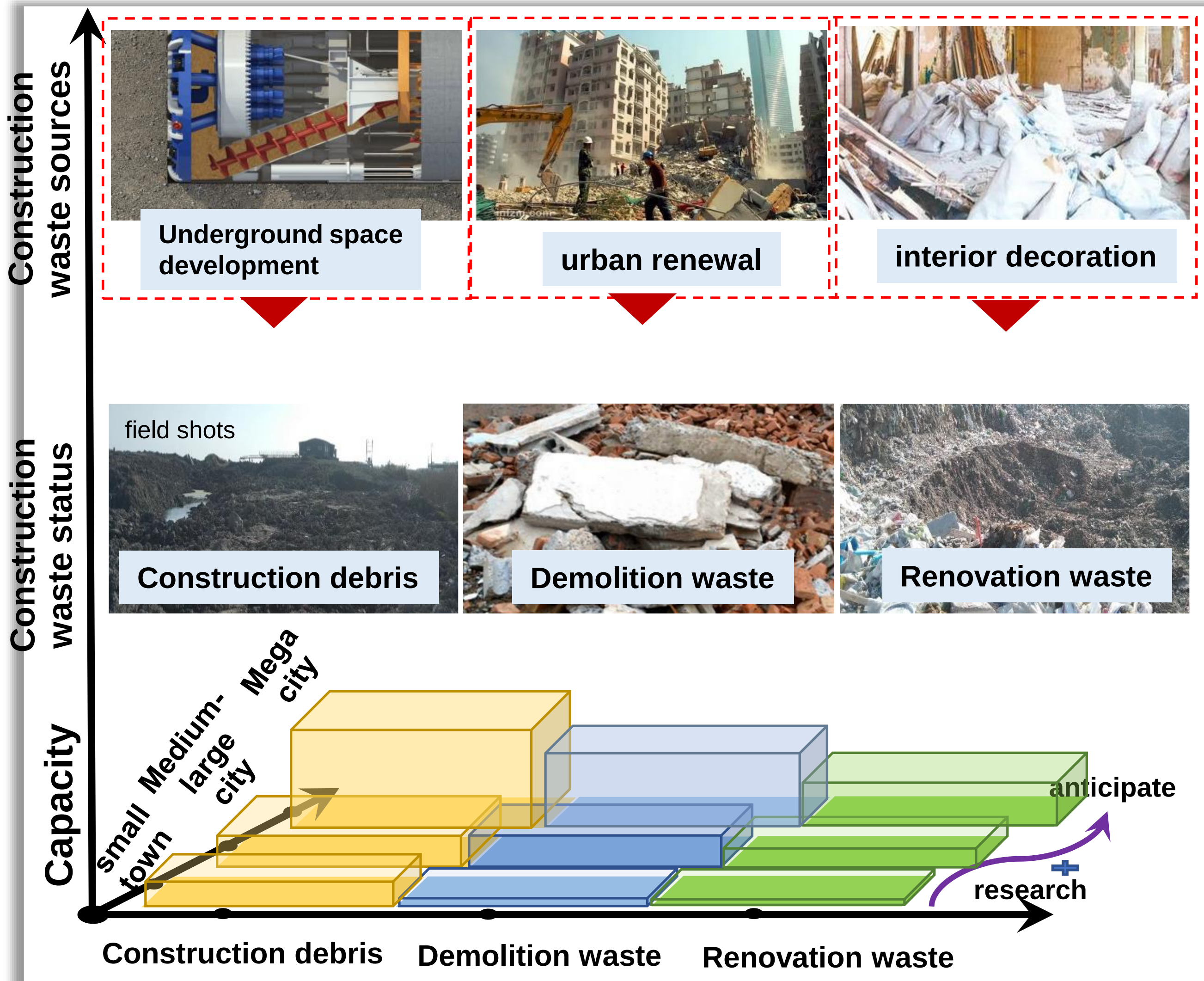
■ Key technologies for multi-path applications of recycled concrete sand and powder.

- ✓ To address the issue of low activity and difficult utilization of recycled sand powder produced during the crushing and sorting of waste concrete, research will focus on efficient crushing, grinding, and modification technologies for recycled sand powder. The project will also explore combined physical-chemical solubilization activation and targeted gradation optimization technologies. It aims to develop technologies for producing various types of recycled mortars and concrete materials from recycled sand powder, as well as technologies for high-quality utilization of recycled brick-concrete aggregate and sand powder. Furthermore, it will investigate integrated technologies for the full-cycle design, construction, and acceptance of recycled mortars and concrete, and develop comprehensive sustainability assessment methods. Engineering demonstrations will also be conducted.
- ✓ The project will establish complete sets of technologies for producing recycled mortars and concrete from waste concrete sand powder, solving technical bottlenecks such as low activity of recycled micro-powder and poor gradation of recycled sand. This will enable the cost-effective utilization of waste concrete sand powder, doubling the resource utilization rate. Specifically, the project will develop one set of equipment for processing recycled sand powder and create more than two types of specialized functional additives. The 28-day activity index of the recycled micro-powder will exceed 75%. In recycled mortar, recycled sand will account for at least 85% of fine aggregates, with a compressive strength of no less than 15 MPa and a water retention rate of over 90%. In recycled concrete, recycled sand will account for at least 30% of fine aggregates, and the combined replacement rate of recycled powder, sand, and coarse aggregate will be no less than 50%, with a compressive strength of no less than 40 MPa. The project will develop 2-3 comprehensive utilization and evaluation methods for waste concrete sand powder.

Additionally, 1-2 demonstration production lines for recycled mortar and recycled concrete using waste concrete sand powder will be established, with an annual output of at least 300,000 tons of recycled mortar and 400,000 cubic meters of recycled concrete per production line. Production costs will be reduced by over 40%. The project will also establish a system of patents and standards covering the research content (applying for more than 10 invention patents and drafting more than 3 national, industry, or group standards for review). Finally, an innovative commercialization model will be created.

China's Construction Solid Waste Status Issues

scattered distribution, mixed composition and large geographical differences



Urban Construction Waste	Engineering Spoil	Demolition Waste	Renovation Waste
Main Components	Clay, sandy soil, silt, sand and gravel	Brick, tile, steel reinforcement, lightweight materials	Brick, tile, plaster blocks, lightweight materials, ash, glass, discarded household items, etc.
Regional Variations	Composition varies greatly with depth and region, concentrated large-scale production	Mainly bricks and tiles in urban areas, concentrated large-scale production in towns	Mainly bricks and tiles in urban areas, scattered small-scale production in towns
Production Trends	Rapid increase	Gradual decrease	Steady increase
Disposal Methods	Backfilling, temporary storage and transport	On-site collaborative disposal, recycling plants, backfilling	Backfilling, transfer stations, recycling plants
Recycling Rate	Very low	Low, but improving	Extremely low

Main organizations: China Association of Environmental Protection's Construction Waste Management and Recycling Committee, Recycled Concrete Academic Committee, National Technical Committee for Standardization of Wall, Roof, and Road Building Materials (TC285).

Analysis of urban construction solid waste pain points

Urban construction solid waste

- No precise measurement;
- Large total emissions, but dispersed and exhibiting clear regional and temporal uncertainty;
- The temporal and spatial uncertainty of dynamic emissions mismatches with recycling processes and technologies;
- Stationary: Inconvenient to transport loose materials, difficult to collect good materials;Mobile: Not economical for small amounts, too much material can't be processed in time, and is difficult to apply;
- How to use it, and what can it be used for? The gap between demand (policy, cost, performance)： Disposal Technology vs. Recycling Demand.

Processing Technology and Equipment →

Recycled Materials

- How to quickly test and mix soil quality on-site?;
- High water absorption, high crushing value, poor gradation, high clay content, high water demand, unstable quality;
- Hard to meet current national standards;
- Policies, markets, and transportation affect supply and demand.

Preparation Technology →

Recycled Products

- Large performance variability;
- Low added value;
- Lack of functional design;
- Does it meet market demand?

Construction Technology and Acceptance →

Engineering Application

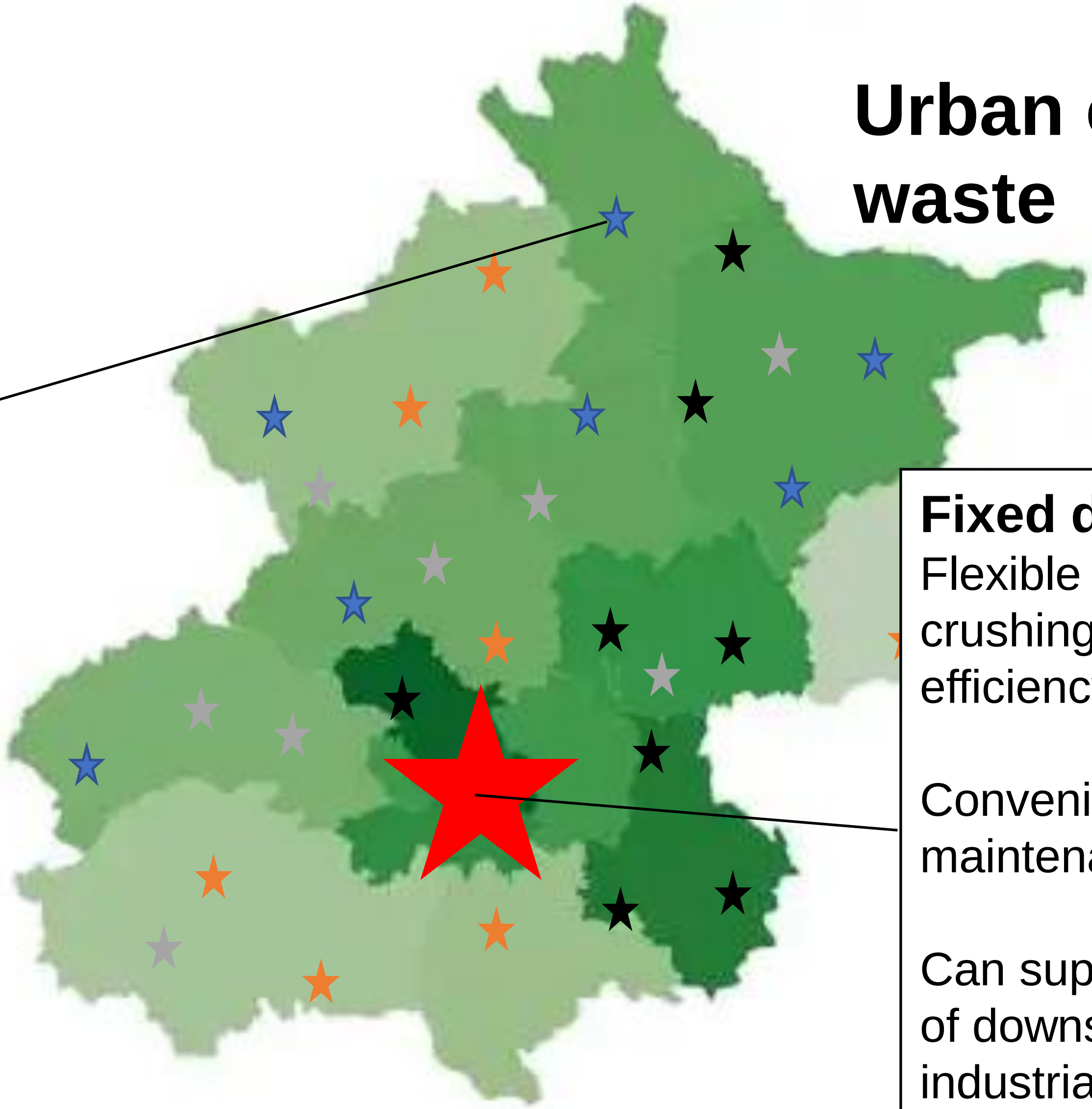
- Widely applied, but often done covertly, with safety risks;
- Lack of design and standard system support;
- Lack of coordinated application of recycled products;
- How to promote demonstrations;
- Materials are low-carbon, but is the overall project low-carbon?

Analysis of urban construction solid waste pain points_1

Mobile disposal sites:
Convenient and flexible, with no restrictions on production sites;

Flexibility of movement and proximity of production;

High degree of automation



Urban construction waste

Fixed disposal point:
Flexible configuration, large crushing ratio, high production efficiency, large disposal capacity;

Convenient operation and maintenance, low loss and long life;

Can support the production chain of downstream products, with industrialised production advantages

Analysis of urban construction solid waste pain points_2

- **Recycled materials have large performance variability.**
- **High carbon emissions during recycled product production**

Difficult to apply recycled products with high added value.

Urgent need for tiered utilization technologies to meet multi-scenario application requirements.

Scaled components

Inconsistent size, varied performance

Original demolished materials

Difficult to use directly, hard to apply for high-quality use

Recycled materials

Large performance variability, high carbon emissions

How to safely reuse?

How to directly utilize it?

How to fully recycle?

Analysis of urban construction solid waste pain points_3

Lack of planning design before demolition, lack of construction design after demolition

Difficulty in coordinating demolition and disposal

Implement collaborative design for demolition and reuse, and coordinate the entire process

Early stage: lack of planning

Rough demolition, resource waste

Information mismatch, supply-demand imbalance

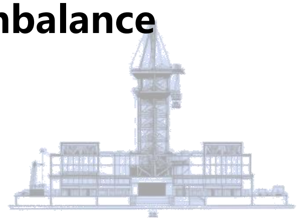
Urgent need for overall planning and design coordination

demolish

supply side

customer side

utilise



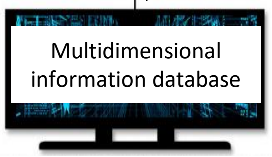
Region | Component | Composition | Product | …

Information collection, storage, and analysis

Information release, matching, and analysis

How to design for demolition?

Demolition component information



Application demand information

How to design for construction?

How to achieve digital coordination management?

The necessity of forward and reverse synergy in recycling.

Forward Design

Forward planning and design methods based on the recycling attributes of solid waste and utilization needs

Solving Problems

(1) Difficulty in matching process equipment

(2) Difficulty in applying recycled products

(3) Difficulty in promoting application technologies

Reverse Design

Reverse-guided design and control methods based on product performance feedback and engineering application requirements

Agenda

1. Background of the current situation

2. Why forward and reverse synergy in recycling

3. How to synergise

4. Case study

5. Summary

Forward and reverse synergy in recycling

- **Forward-Reverse Synergy Planning and Application Theory for Recycling**

Forward

Waste Attribute Database → **Disposal** ← Planning for Raw Material Quality Improvement

High-Quality, Functional Product Design → **Product** ← Market Adaptation Analysis

Multi-scenario, Multi-path Application Design → **Application** ← Systematic Large-Scale Application Needs

Reverse

Demolition Waste/Renovation Waste Recycled Materials

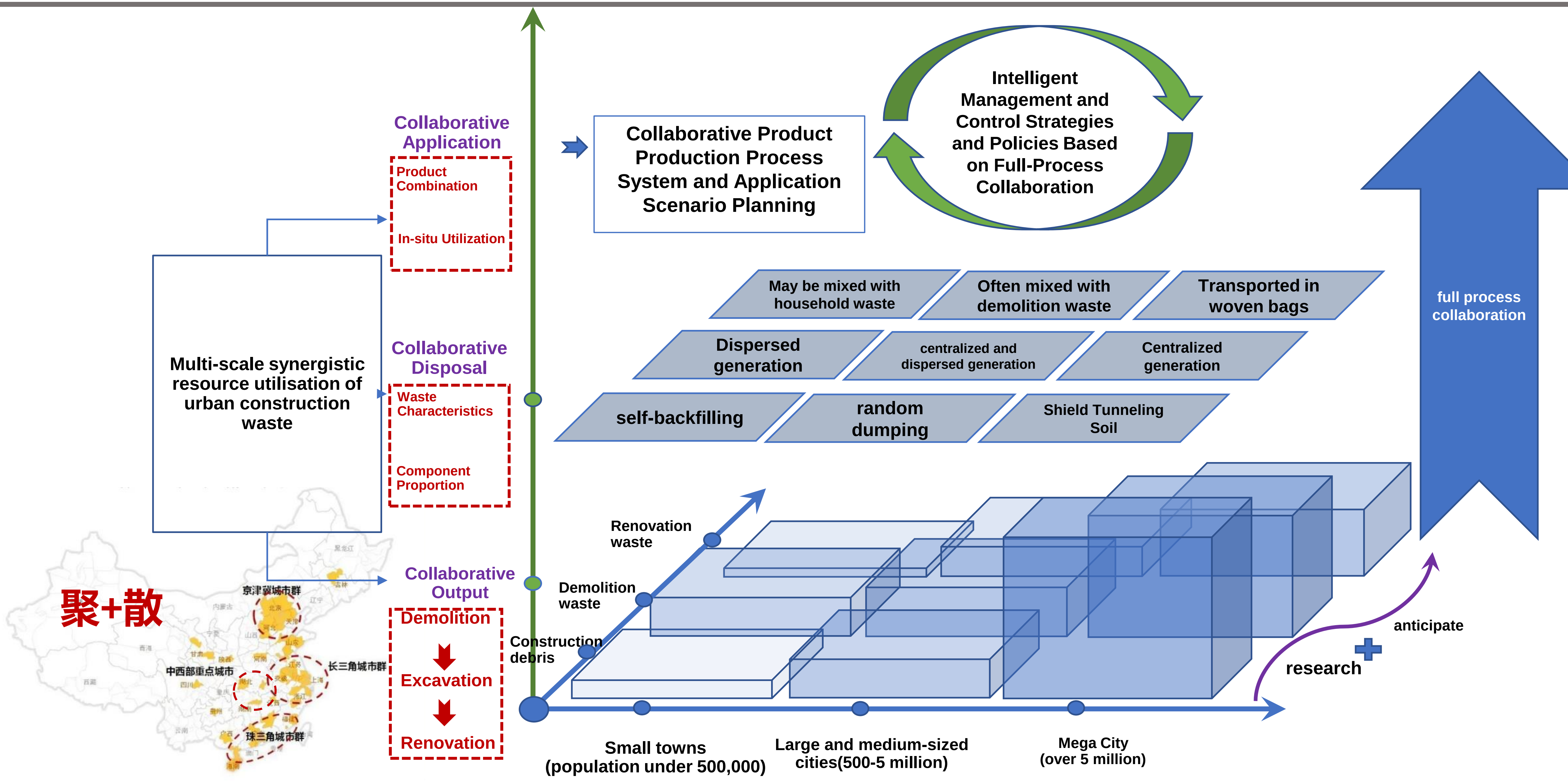
Development of Various Recycled Products

Application Scenarios

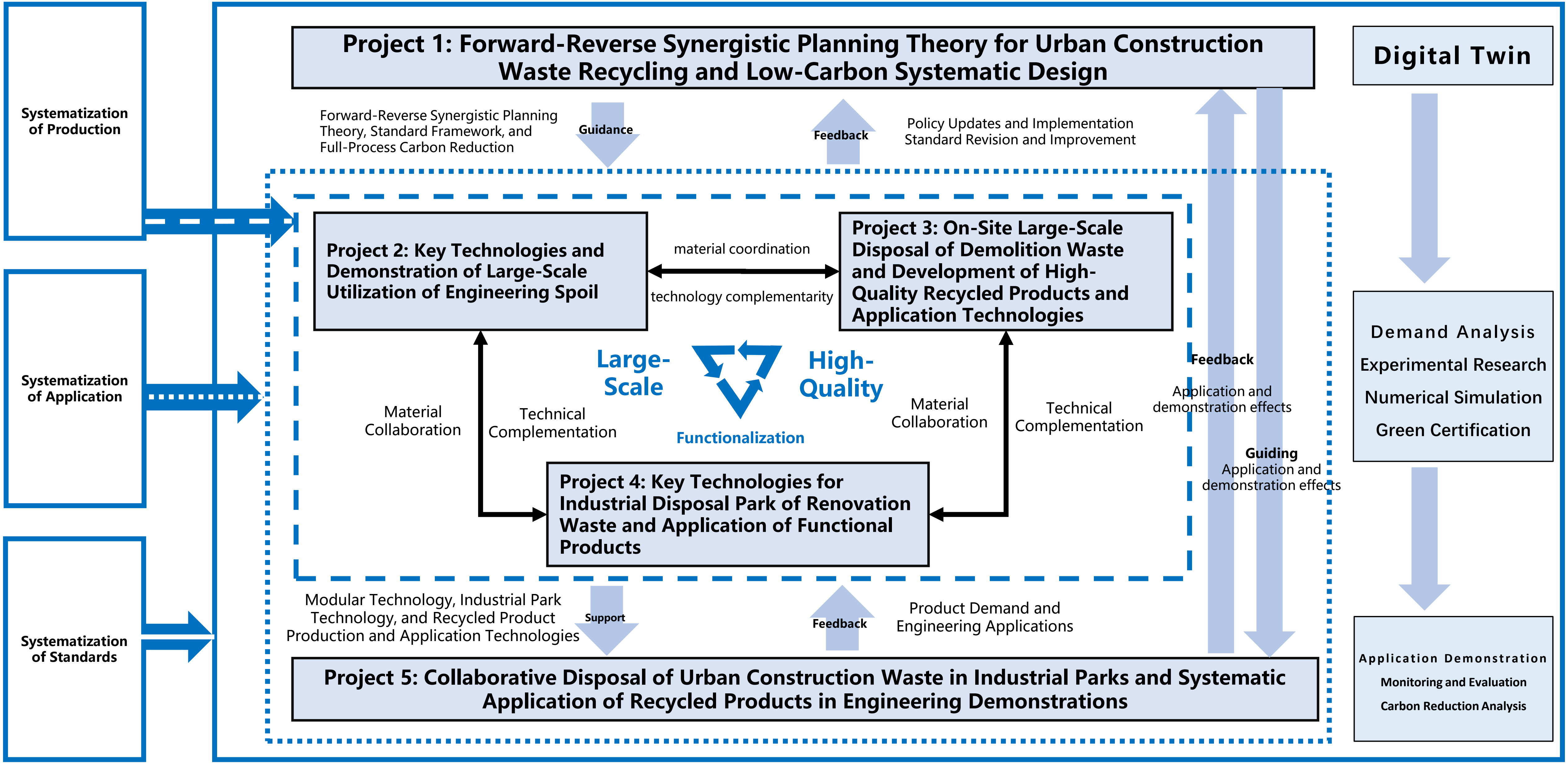
- Urban ecological restoration
- Old city renovation/new area construction
- Sponge City Construction
- Post-disaster reconstruction

Recycling Attributes → **Collaborative Development** ← **Market Compatibility**

Clarifying the true state of urban construction solid waste



Collaborative programmes



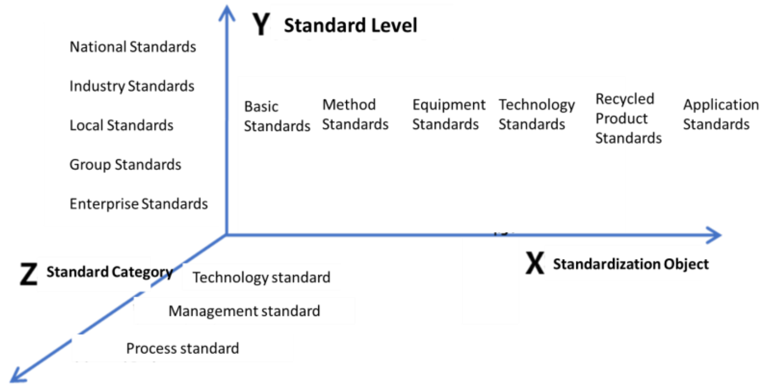
Top-level design synergy

● Standard system construction

Methods

Standard System Construction Method

- Process Method
- Classification Method
- 3D Coordinate Method
- Modular Construction Method
- Hierarchical Method
- System Integration Method

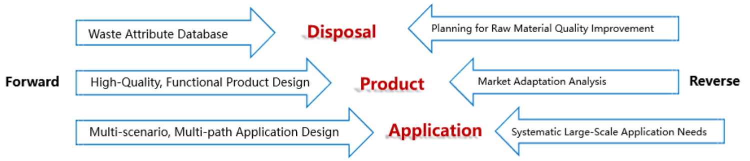


Procedure

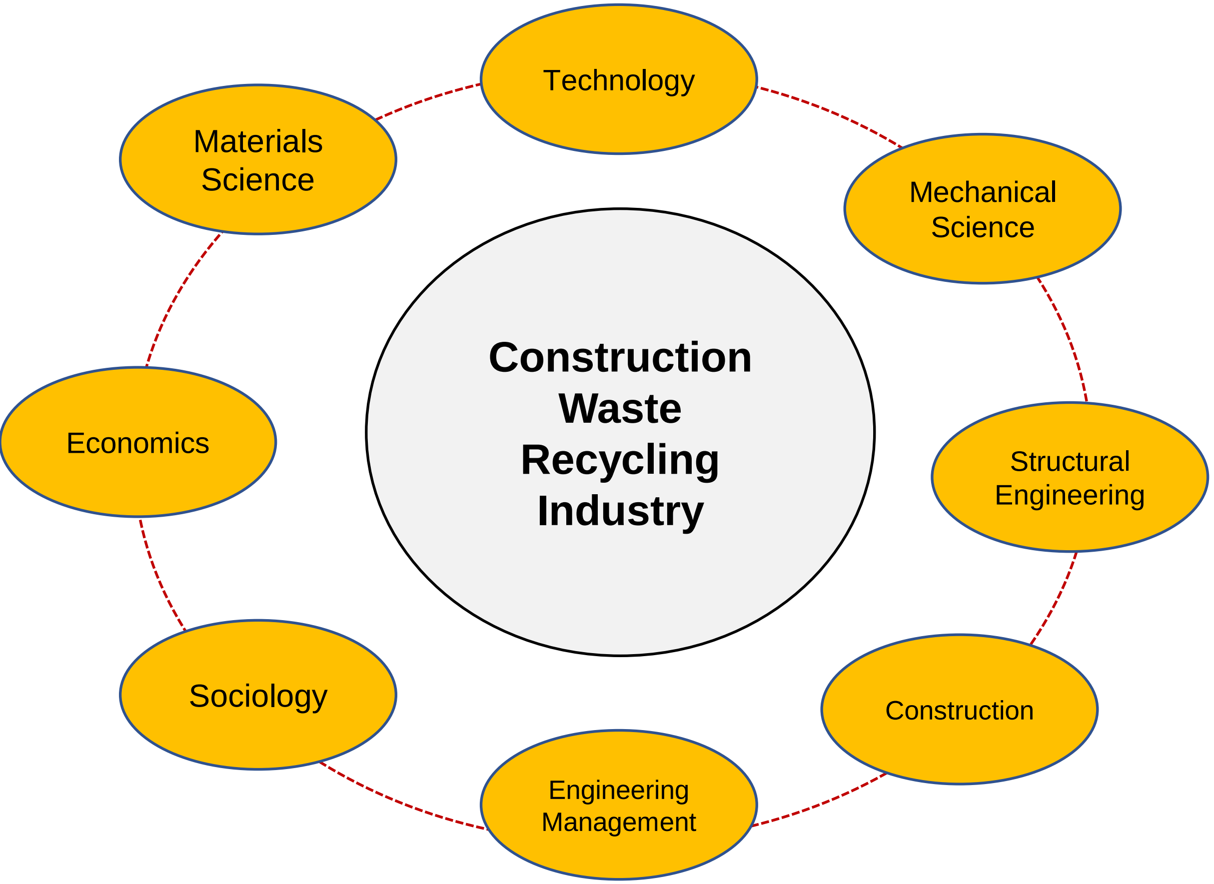
- GB/T13016-2018 《Standard system construction and principles》
- GB/T12366-2009 《Guidelines for comprehensive standardisation work》

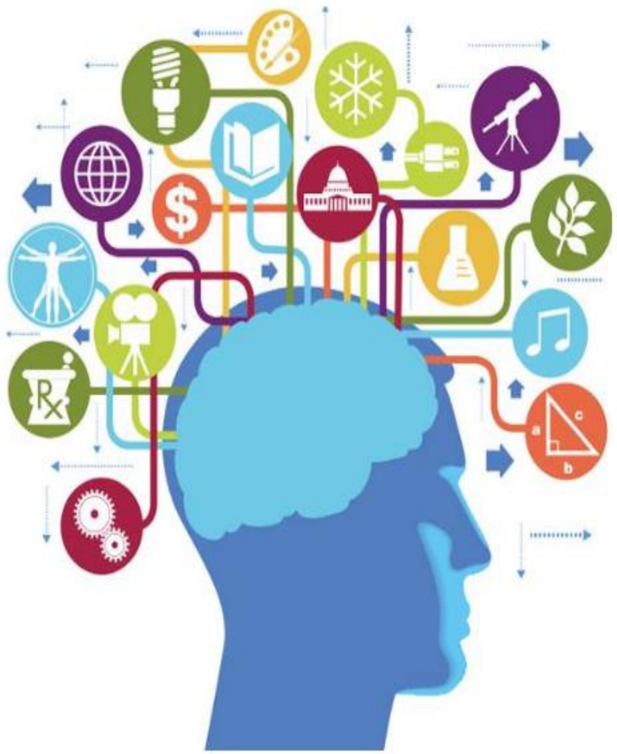
Key points

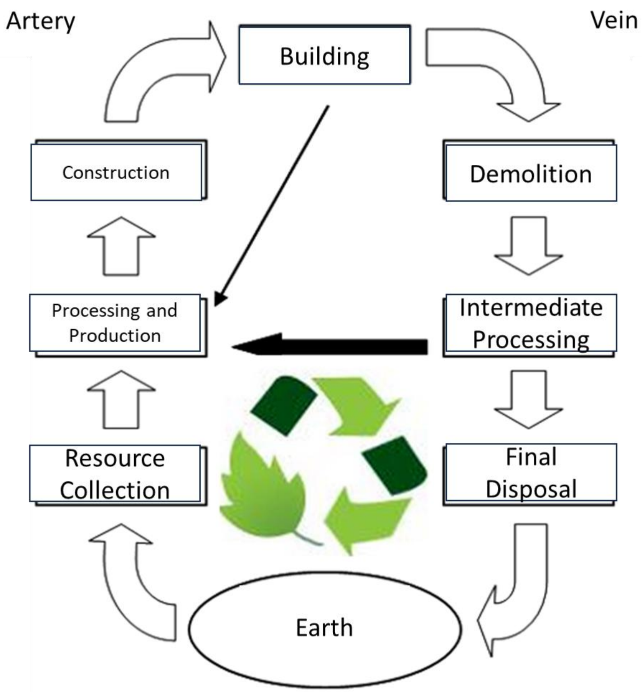
- **Forward-Reverse Synergy in Recycling**
- **Dynamic Updates**
- **Full-Process Carbon Reduction Mechanism**



Cross-disciplinary synergies



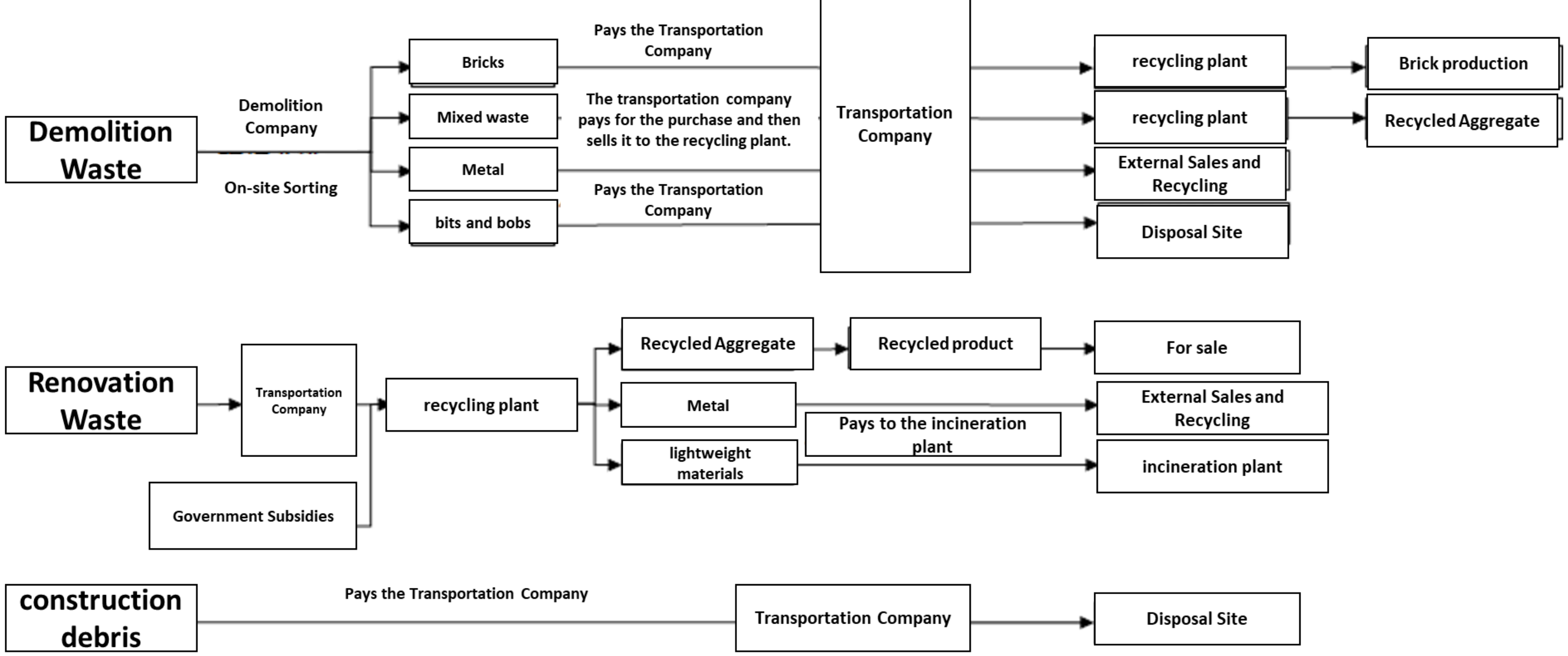


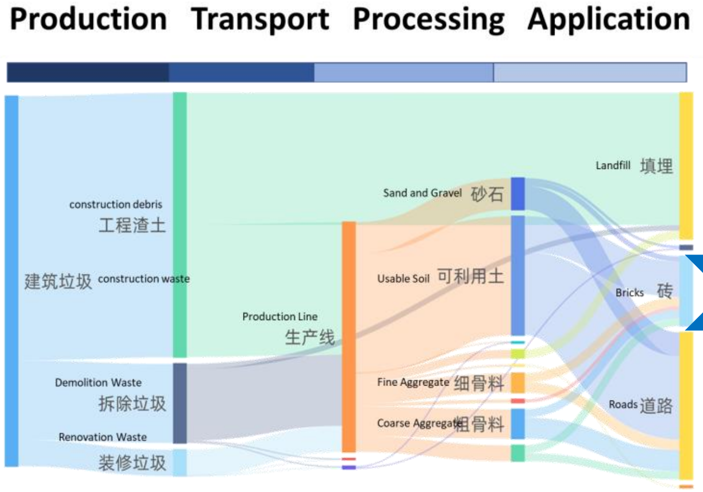


- **Based on the current understanding of recycling, it requires interdisciplinary collaboration across materials science, technology, equipment, structure, construction, management, economics, policy, and even cultural aspects.**

Multi-source solid waste output synergies

Current Situation and Market Operation Mechanism of Construction Waste Collection, Transportation, and Utilization





Transport: reasonable forecasts

Handling: material flow, process synergy

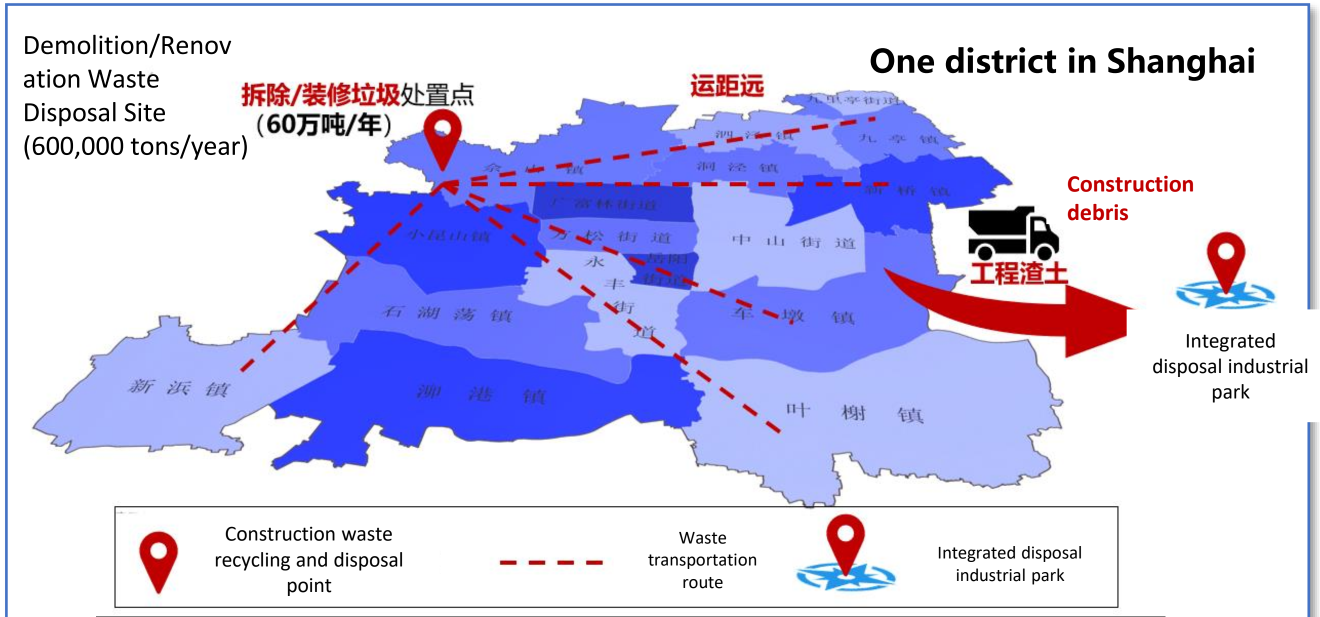
Application: Synergistic Application

Concentrated-Distributed" Disposal Coordination

Dispersed disposal: high cost, low quality

Centralized disposal: long transport distances, high carbon emissions

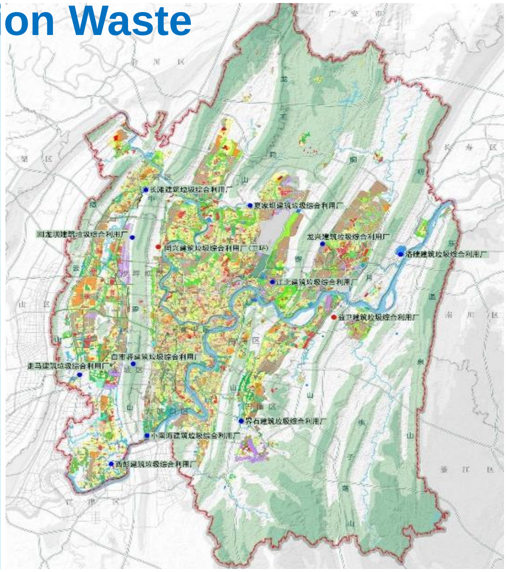
On-site modular high-efficiency disposal coordinated with centralized disposal in industrial parks



Plan disposal methods based on the characteristics of solid waste generation

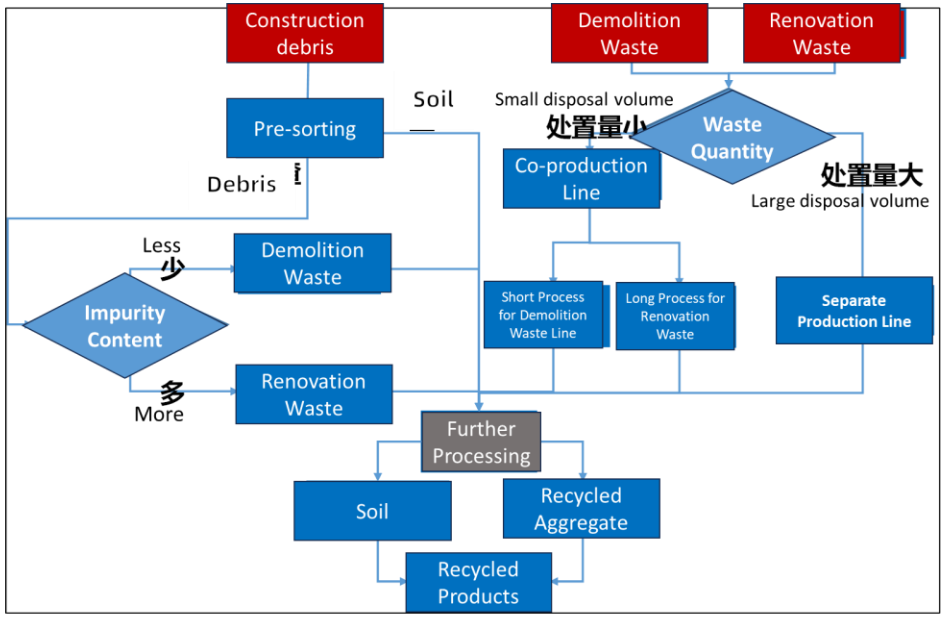
Research and Analysis on Urban-Scale Layout Planning for the Resource Utilization of Construction Waste

Shanghai Construction Waste Resource Utilisation Facilities Planning Layout Map

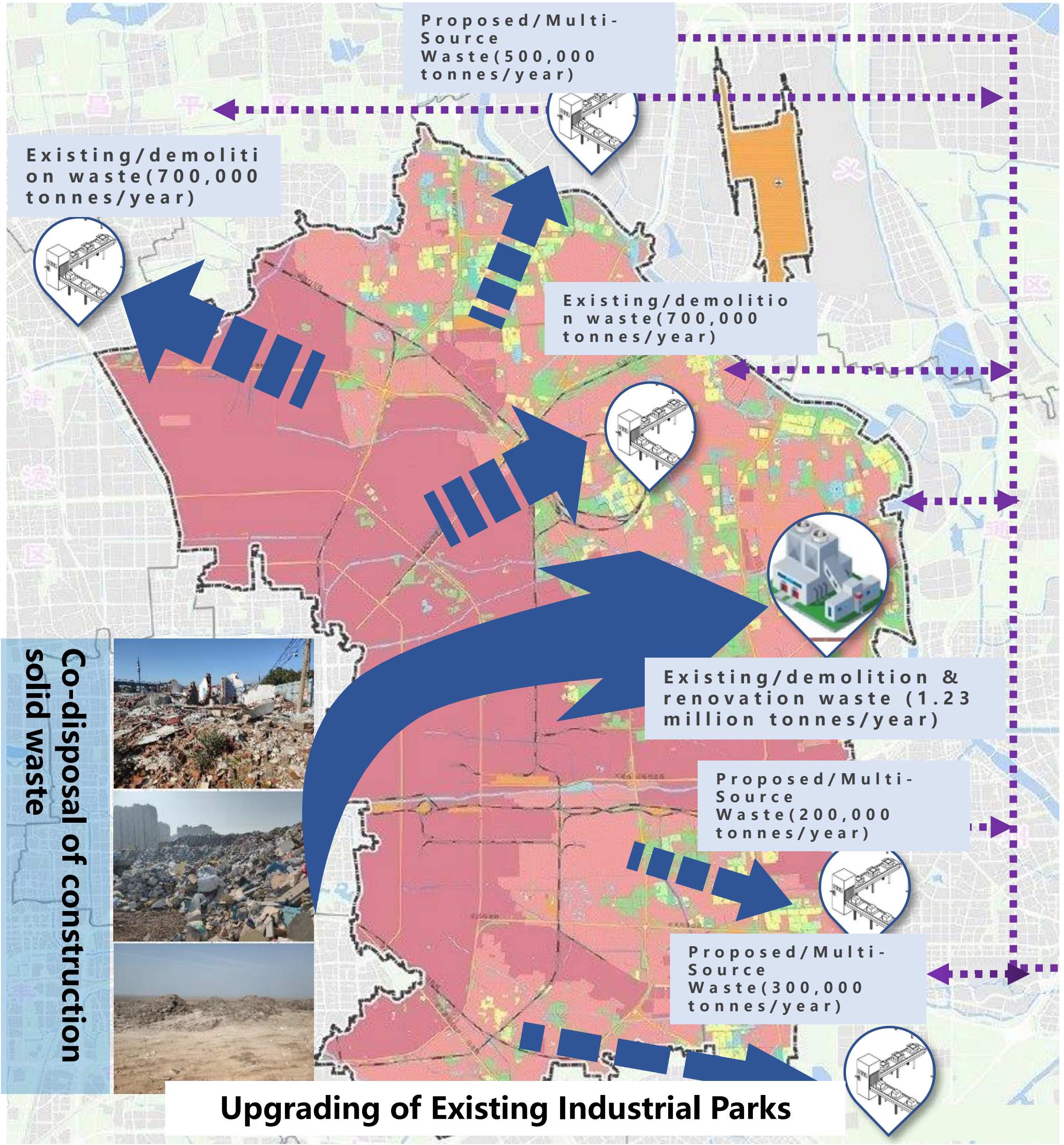


Special Plan for Construction Waste Management in Central Chongqing (2021-2035)

Industrial Park Collaborative Disposal

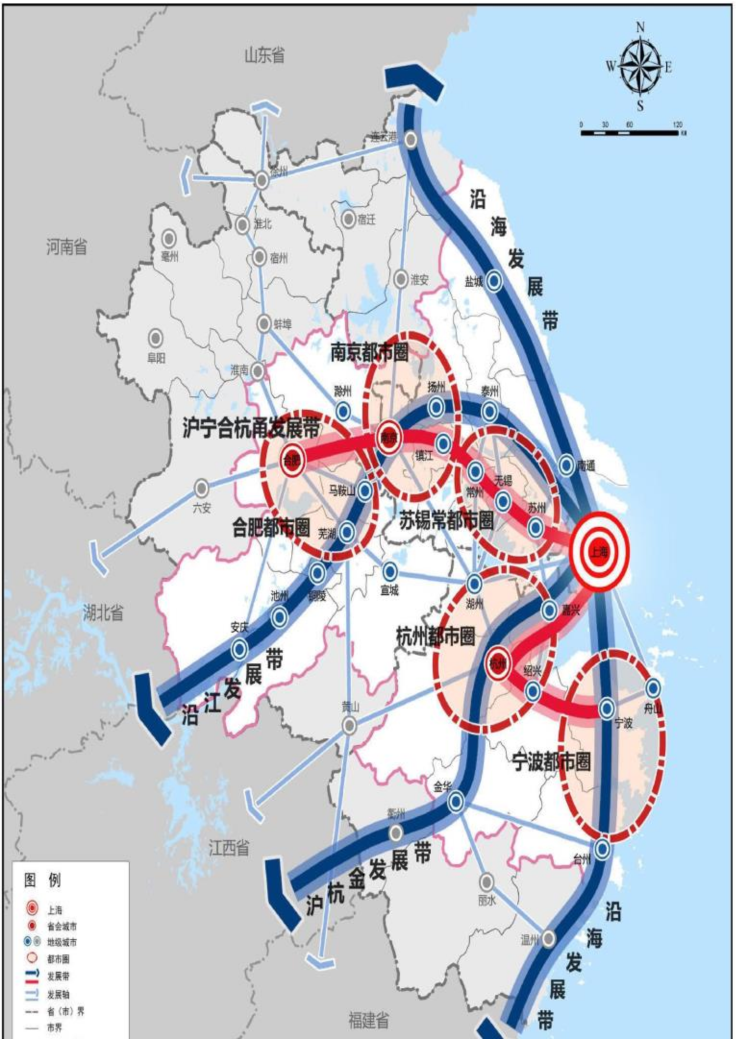


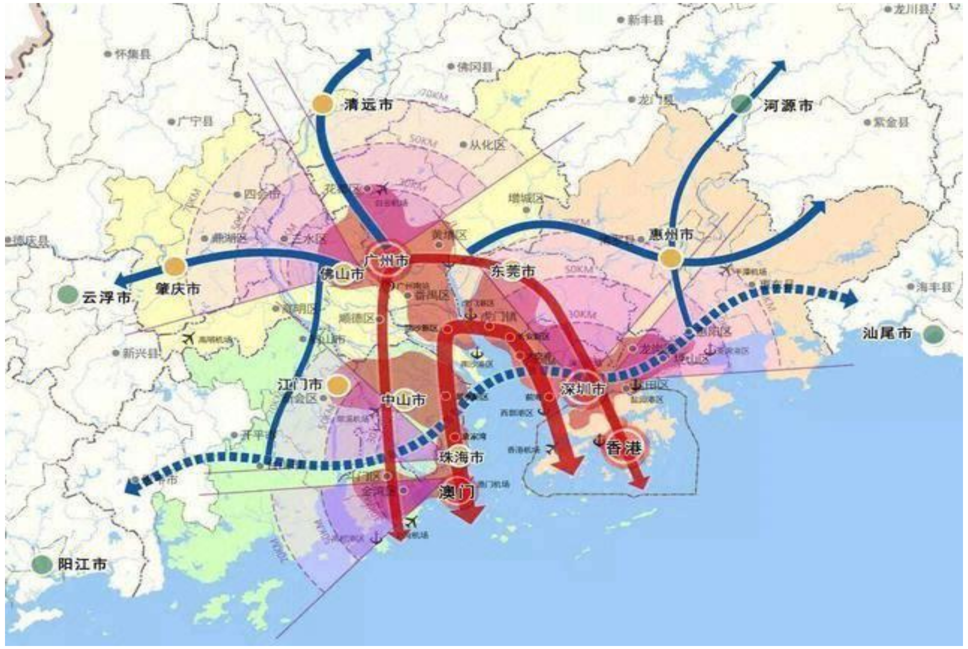
New industrial park for co-disposal

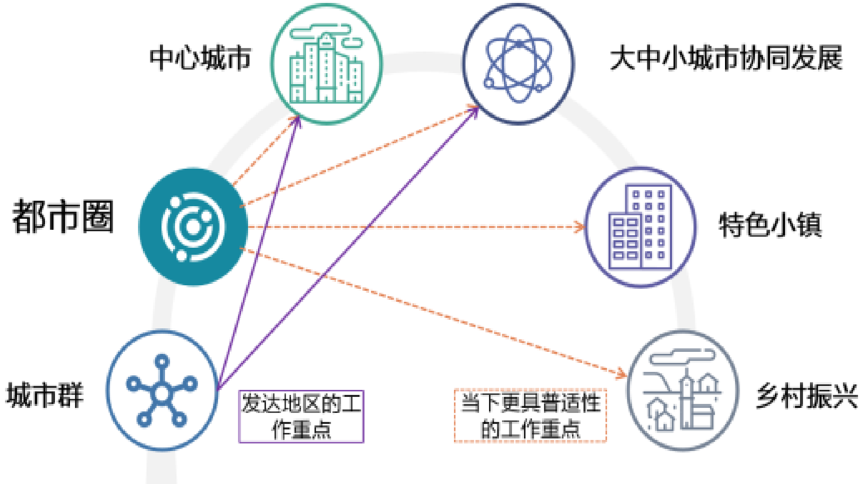


Upgrading of Existing Industrial Parks

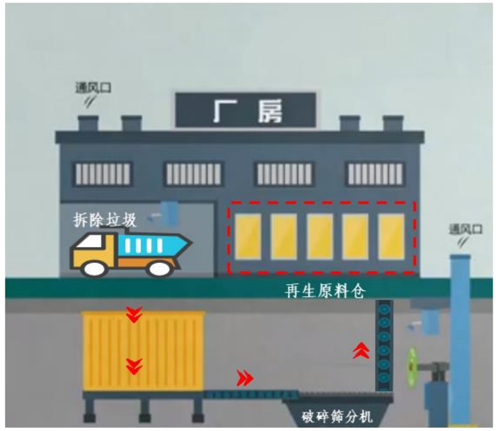
Regional (area) co-disposal



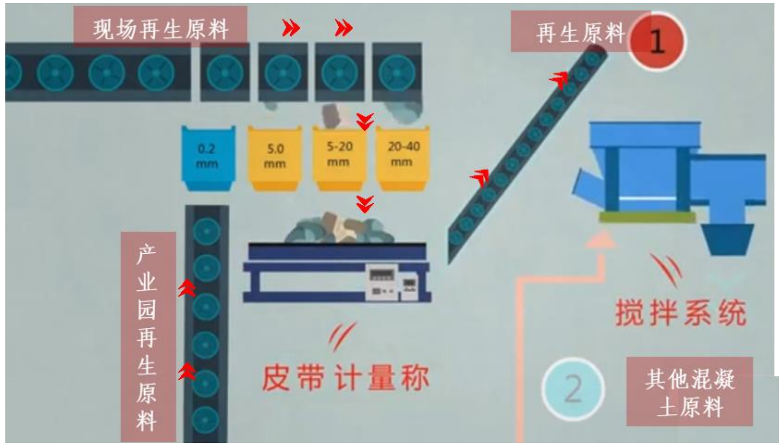




Product pivoting synergy



Multi-source Building Solid Waste Recycling System



Commercial concrete mixing

prefabricated factory

Demonstration of application engineering

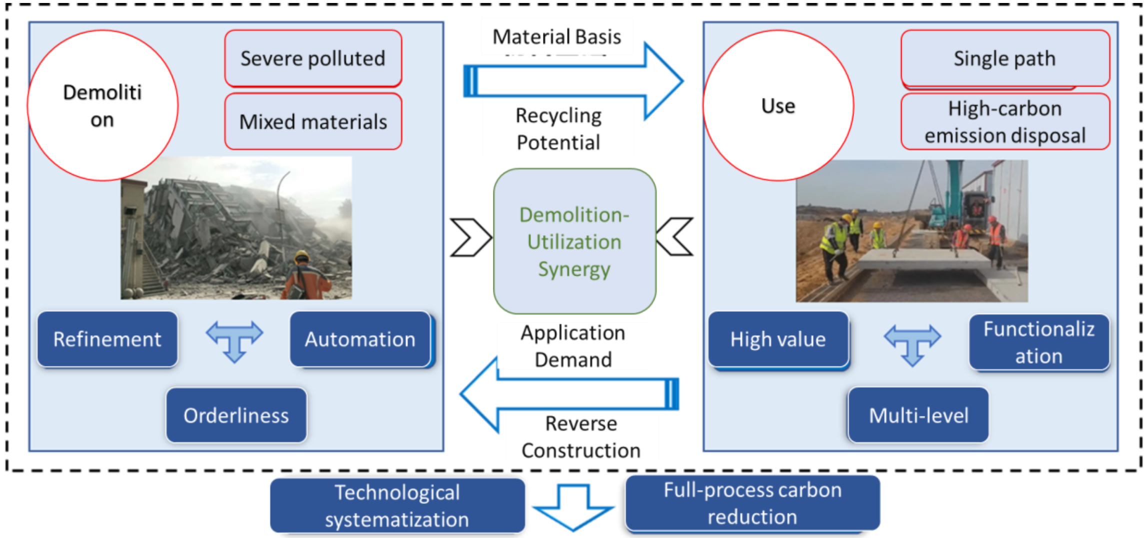
Solid Waste Disposal - Product Manufacturing synergy

Solid waste

~~Aggregate Dispatch~~

Product Dispatch

Disassembly/Use, Application Modes and Scenarios



Implementing precision demolition and green utilization system applications for integrated demolition and utilization, with large-scale engineering demonstrations.

Agenda

Research Outcomes of Forward and Reverse Synergy Theory

Research on the technological system of positive-reverse synergy for urban construction waste resource utilisation

Main Research Content	Main Research Tasks of the Project	Project Phase Objectives
Low-carbon Planning and Design Methods for Forward and Reverse Synergy	Resource utilisation database established; Accounting for carbon emission reductions from resource utilization; Research on Product Performance Improvement Methods; Accounting for the benefits of carbon emission reductions from resource utilization	
Design Principles of Process Equipment Based on Source and Application Orientation	Resource utilization production line research; Research on key parameters of existing processes	
Optimized Resource Utilization Pathways and Low-carbon Transition	Calculation of green parameters of recycled products; Market demand research for recycled products; Implementation of green certification for recycled products; Market adaptation research for recycled products	

Project Phase Objectives

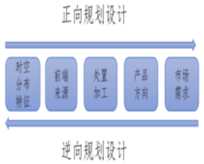
Work undertaken

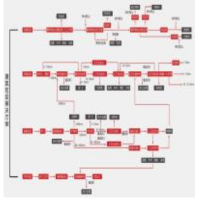
- Beijing-Tianjin-Hebei construction waste data research
- Regional fundamental database construction
- Progressive establishment of the standard
- Research on existing process equipment

Work undertaken

- Research on forward and reverse synergy planning design theory
- Standard preparation and related experimental research
- Research on key parameters of existing processes
- Calculation of green parameters of recycled products
- Research on low-carbon planning design methods
- Experimental research and standard preparation
- Research on design principles
- Market demand research for recycled products
- Standard preparation and submission for review
- Implementation of green certification for recycled products

- Submission for standard review
- Progressive engineering demonstration
- Progressive engineering demonstration





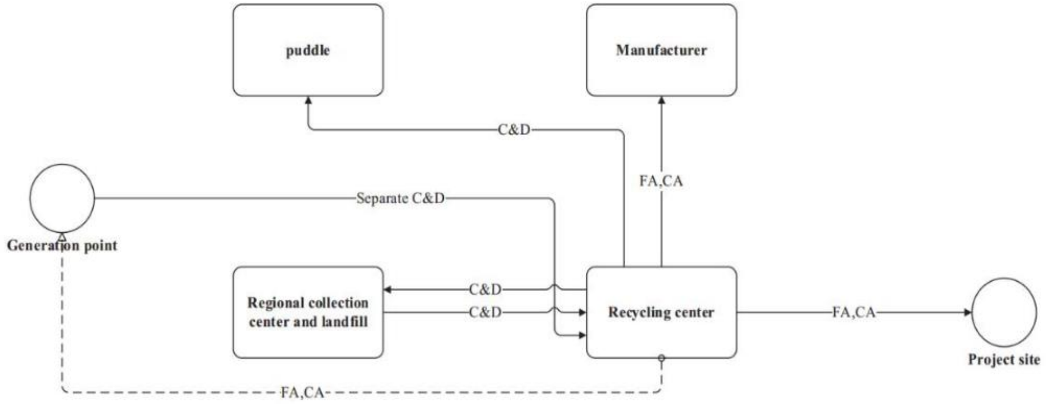
Assessment indicators

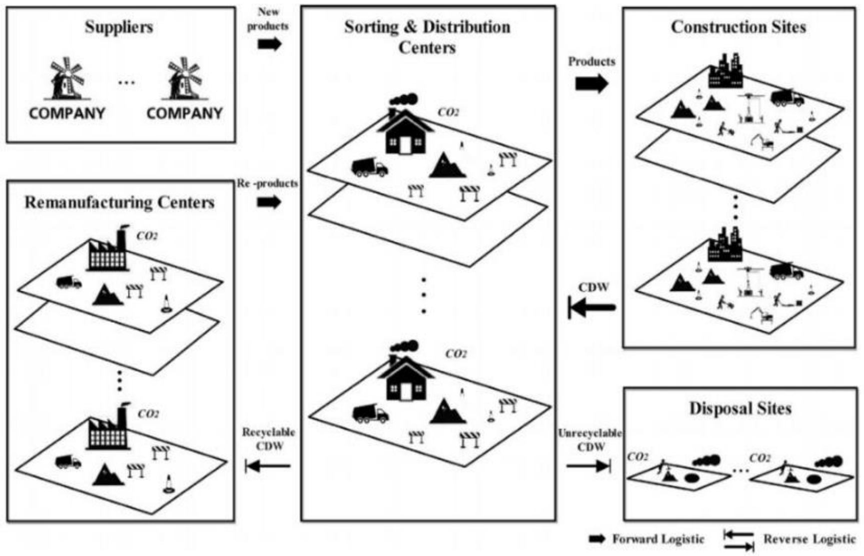
- Beijing-Tianjin-Hebei Region Construction Waste Database
- forward and reverse synergy planning design theory
- 3 standards and norms
- Design principles based on forward-reverse process equipment
- Model based on forward-reverse disposal process
- 2 green certified products
- Engineering demonstration in Tangshan and Handan areas

Theoretical Results of Forward and Reverse Synergy Research

Research on the technological system of positive-reverse synergy for urban construction waste resource utilisation

逆向
Reverse





正-逆向
Forward and Reverse

$$MinC_1 = \pi E + C$$

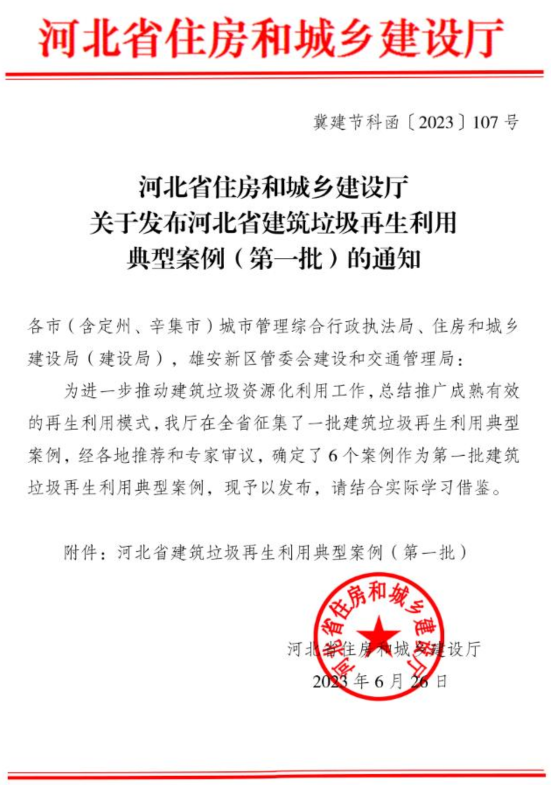
$$MinC_2 = \pi(E - A_{\max}) + C$$

$$s.t.\begin{cases} \sum_{i=1}^{I}\sum_{k=1}^{K} Q_{ij}^{k} = \sum_{m=1}^{M}\sum_{k=1}^{K} Q_{jm}^{k} + \sum_{p=1}^{P}\sum_{k=1}^{K} Q_{jp}^{k} \\ \sum_{m=1}^{M}\sum_{k=1}^{K} Q_{mj}^{'k} + \sum_{k=1}^{K} Q_{spj}^{k} = \sum_{i=1}^{I}\sum_{k=1}^{K} Q_{ji}^{'k} \\ x_j Ca_j^{\min} \le \sum_{i=1}^{I}\sum_{k=1}^{K} Q_{ij}^{k} \le x_j Ca_j^{\max} \\ x_m Da_m^{\min} \le \sum_{j=1}^{J}\sum_{k=1}^{K} Q_{jm}^{k} \le x_m Da_m^{\max} \\ x_j Ca_j^{\min} \le \sum_{m=1}^{M} Q_{mj}^{'k} + Q_{spj}^{k} \le x_j Ca_j^{\max} \\ \sum_{j=1}^{J}\sum_{m=1}^{M} Q_{jm}^{k} = \gamma \sum_{i=1}^{I}\sum_{j=1}^{J} Q_{ij}^{k} \\ \sum_{j=1}^{J} Q_{mj}^{'k} = \lambda \sum_{j=1}^{J} Q_{jm}^{k} \\ Q_{ij}^{k} \ge 0, Q_{jm}^{k} \ge 0, Q_{jp}^{k} \ge 0, Q_{mj}^{'k} \ge 0, Q_{ji}^{'k} \ge 0 \\ x_j \in \{0,1\}, x_m \in \{0,1\} \end{cases}$$

Based on operational planning analysis, a closed-loop supply chain planning and design method for urban construction waste recycling is proposed. By integrating both forward and reverse logistics, and considering the market demand for recycled products, the method addresses key stages in the disposal of urban construction waste. It incorporates economic, environmental, and social impacts to control waste disposal planning. Additionally, carbon policies such as carbon pricing are factored into the cost model, establishing an urban construction waste planning and design method based on forward-reverse synergy, aiming to maximize the resource recovery value.

Theoretical Results of Forward and Reverse Synergy Research

Research on the technological system of positive-reverse synergy for urban construction waste resource utilisation



河北省住房和城乡建设厅

冀建节科函〔2023〕107 号

河北省住房和城乡建设厅
关于发布河北省建筑垃圾再生利用
典型案例（第一批）的通知

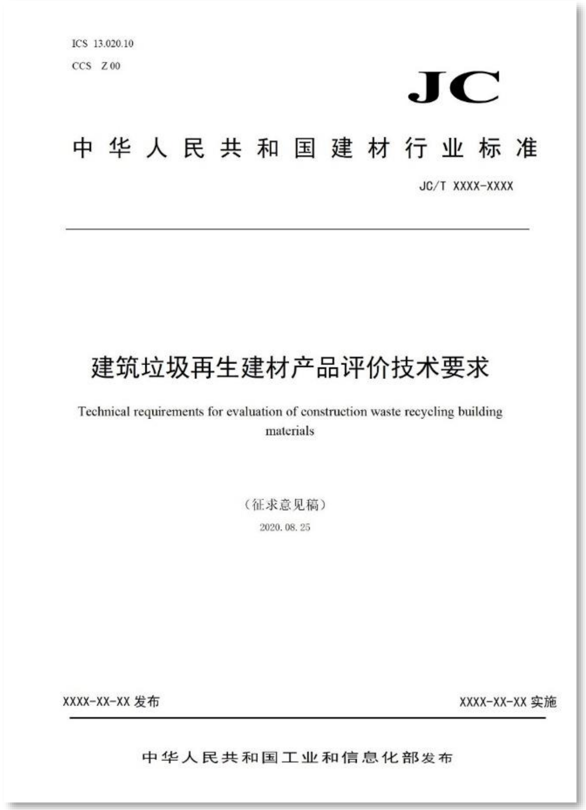
各市（含定州、辛集市）城市管理综合行政执法局、住房和城乡建设局（建设局），雄安新区管委会建设和交通管理局：

为进一步推动建筑垃圾资源化利用工作，总结推广成熟有效的再生利用模式，我厅在全省征集了一批建筑垃圾再生利用典型案例，经各地推荐和专家审议，确定了6个案例作为第一批建筑垃圾再生利用典型案例，现予以发布，请结合实际学习借鉴。

附件：河北省建筑垃圾再生利用典型案例（第一批）

河北省住房和城乡建设厅
2023 年 6 月 26 日

1. **Typical Project for Utilizing Recycled Products** — The Upgrading and Renovation Project of Yongji Road (Yingbin Avenue to Juguantun Pump Station) in Cangzhou, focusing on road drainage works.
2. **Multi-Waste Collaborative Disposal Model** — Qian'an WeiSheng Concrete for comprehensive solid waste management.
3. **Comprehensive Utilization of Construction Waste** — Qinhuangdao Hongzheng Building Materials Recycling Base Project.
4. **National Enterprise Model for Construction Waste Disposal and Recycling** — Zhangjiakou Construction Waste Disposal and Comprehensive Utilization Project.
5. **Full Life-Cycle Circular Ecosystem for the Construction Industry** — Handan Zonglou Construction Waste Comprehensive Utilization Model.
6. **Local Example of Construction Waste Recycling** — Tangshan Runteng Construction Waste Utilization Technology.



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建筑垃圾再生建材产品评价技术要求

Technical requirements for evaluation of construction waste recycling building materials

（征求意见稿）

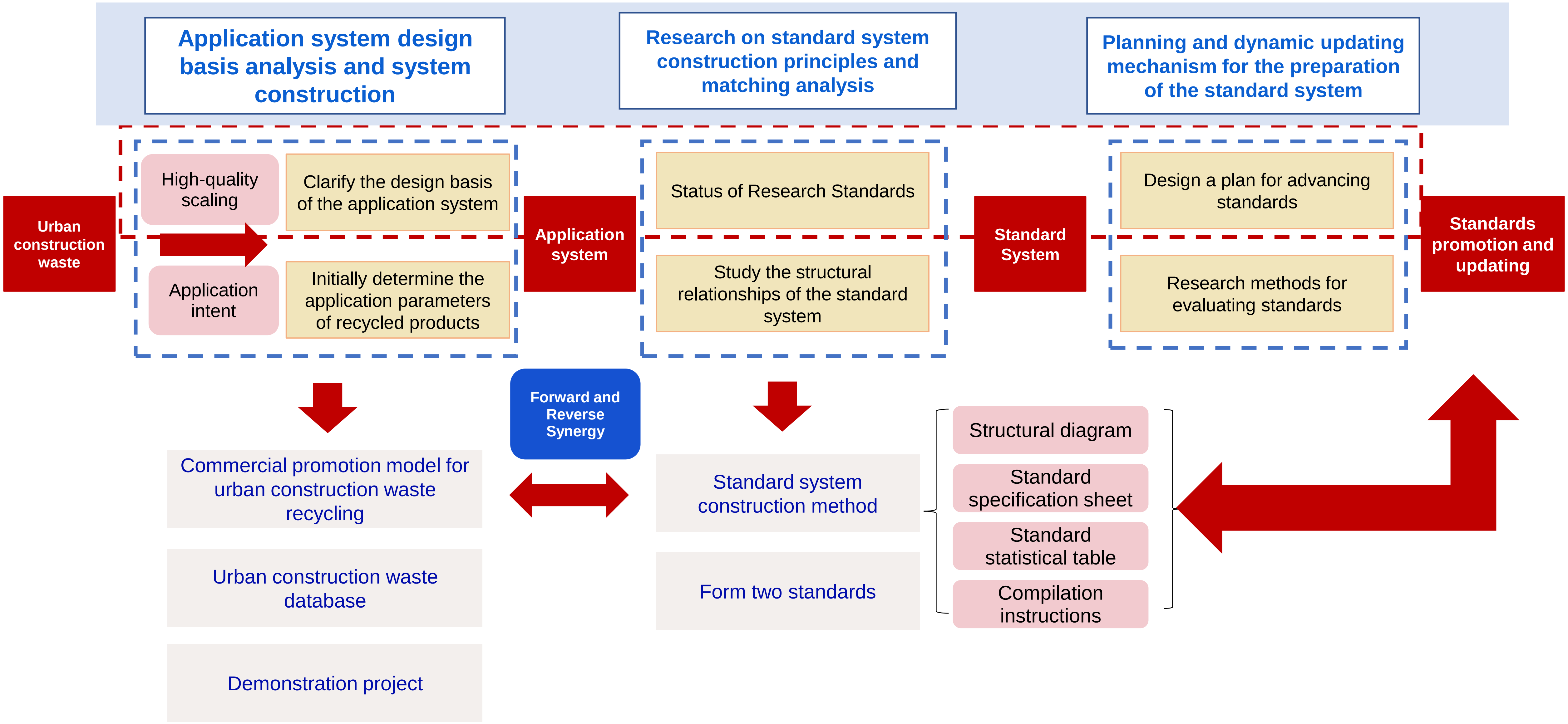
2020. 08. 25

XXXX-XX-XX 发布　　XXXX-XX-XX 实施

中华人民共和国工业和信息化部发布

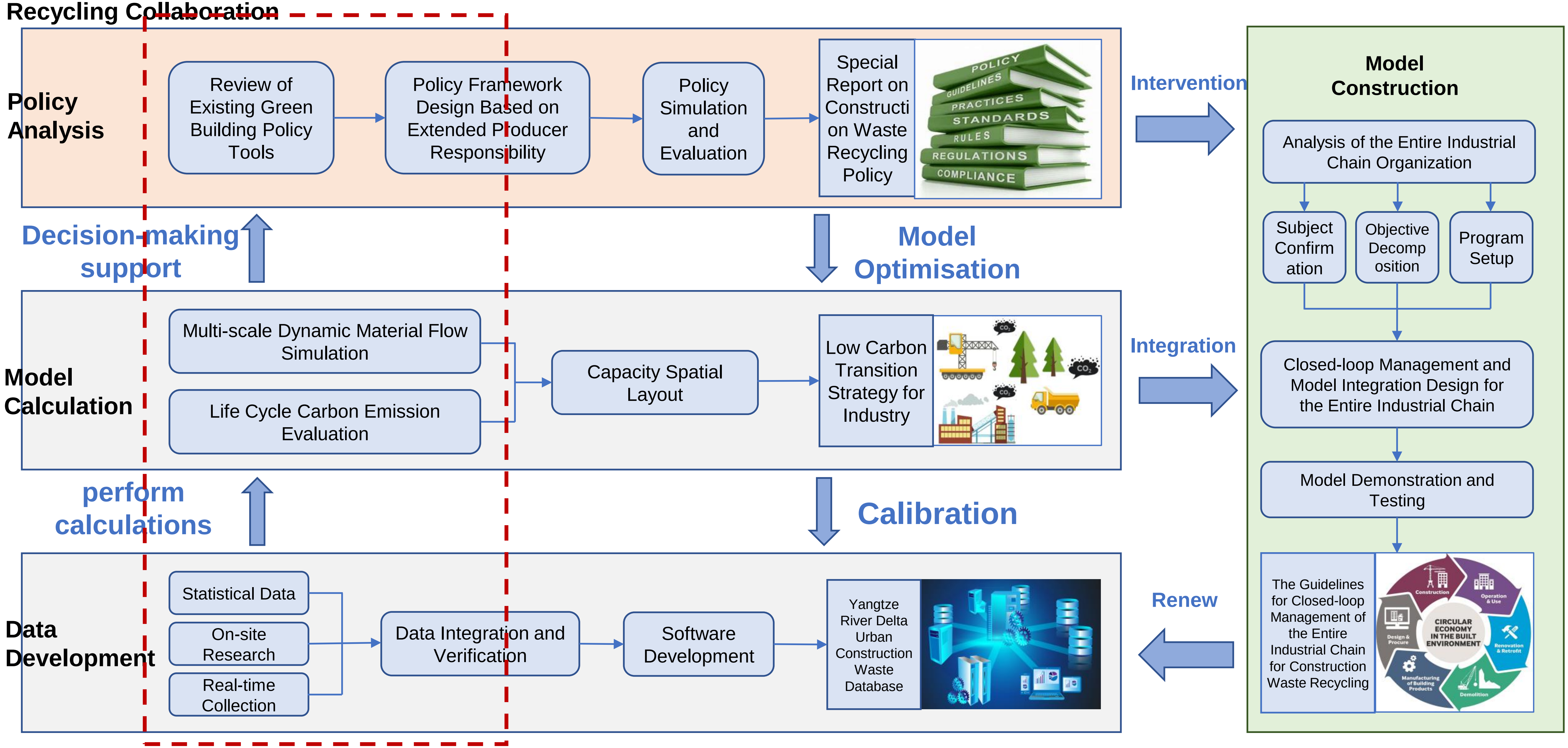
Theoretical Results of Forward and Reverse Synergy Research

Research on the Full-Process Application System and Standardization of Forward and Reverse Recycling Synergy



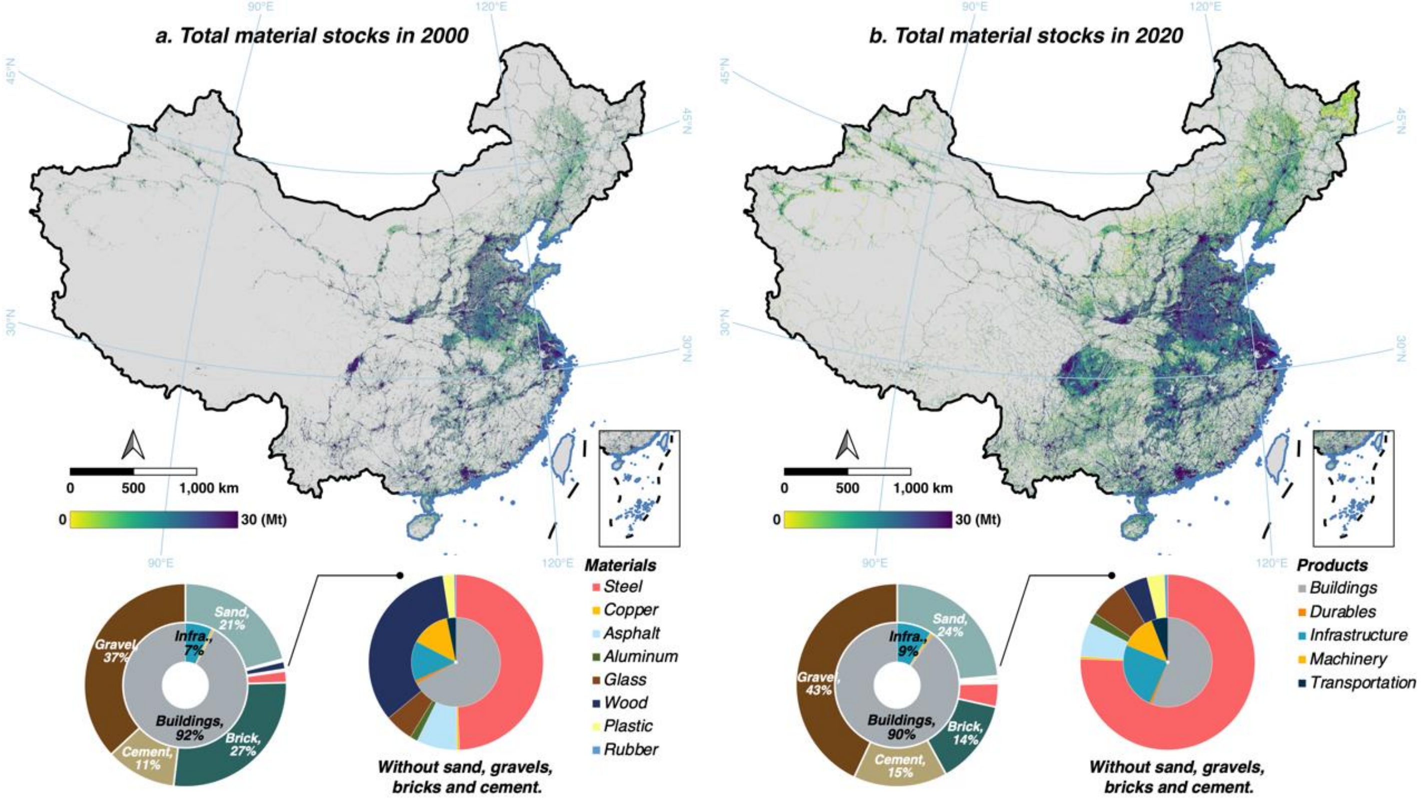
Theoretical Results of Forward and Reverse Synergy Research

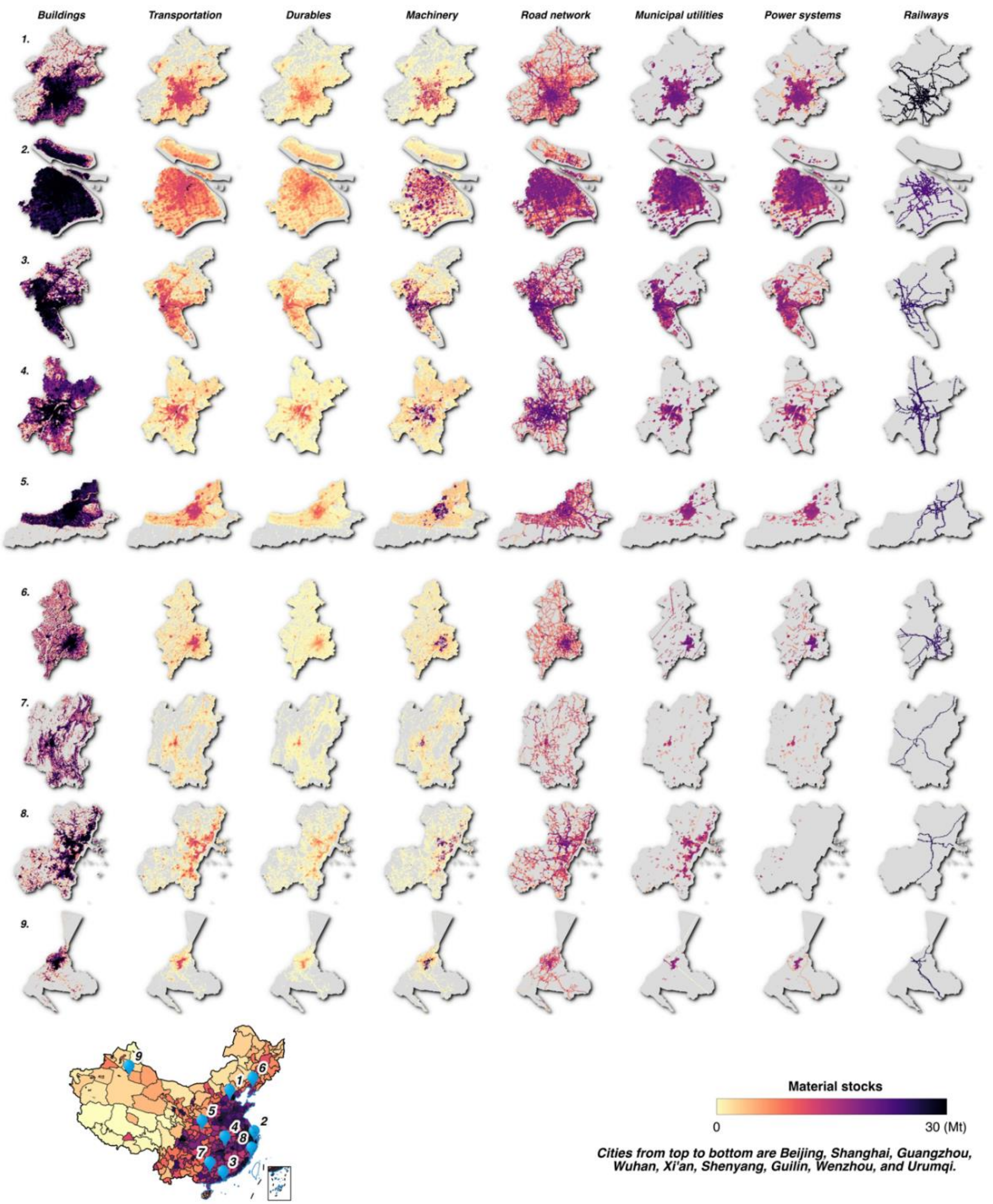
Low-Carbon Circular Strategy, Policies, and Management System for Forward and Reverse Resource Recycling Collaboration



Theoretical Results of Forward and Reverse Synergy Research

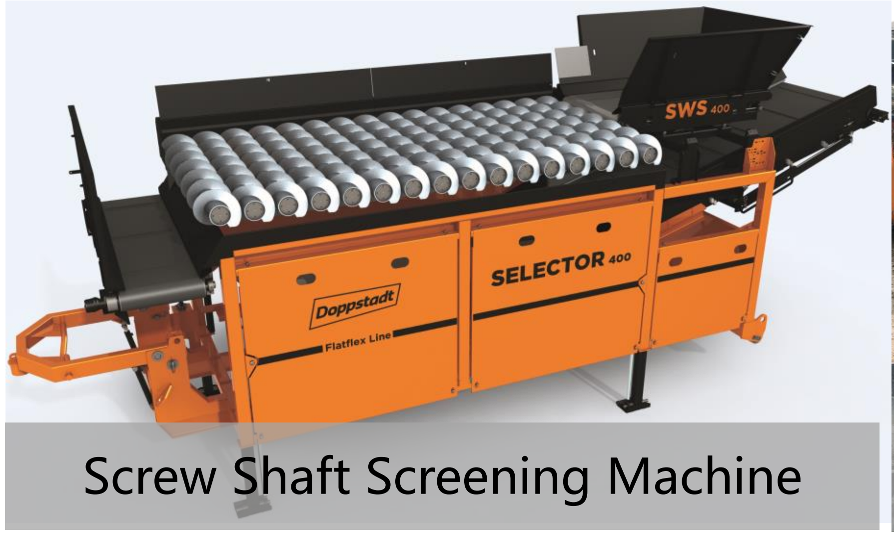
Low-Carbon Circular Strategy, Policies, and Management System for Forward and Reverse Resource Recycling Collaboration





The spatial and temporal variations in the stock distribution of building materials (sand, gravel, cement, bricks, etc.) across different regions of China over the past 20 years were analyzed. This dataset can support research on long-term dynamics, socio-economic development, and human activities, including urban expansion, carbon emissions, and resource recycling.

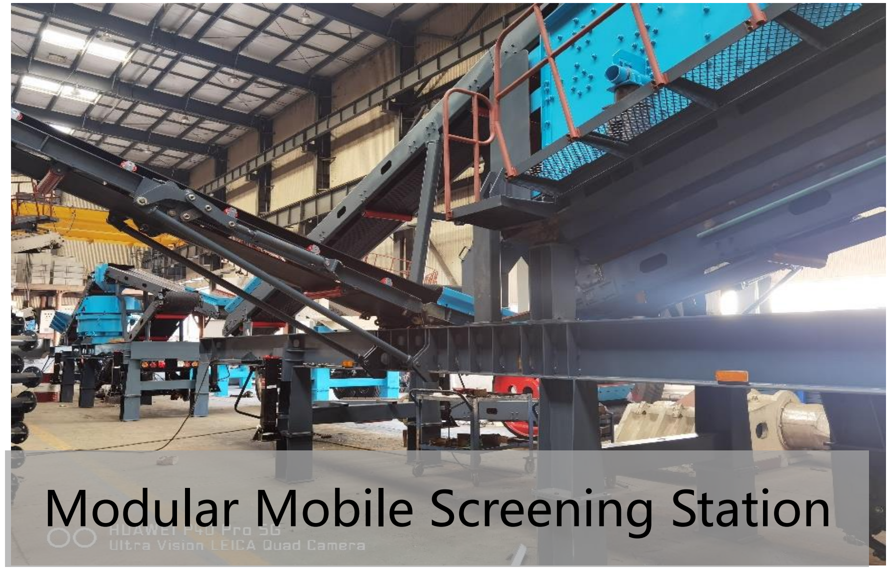
Synergy implementation case - modular equipment



Screw Shaft Screening Machine

Wind Separator

Before Shaping



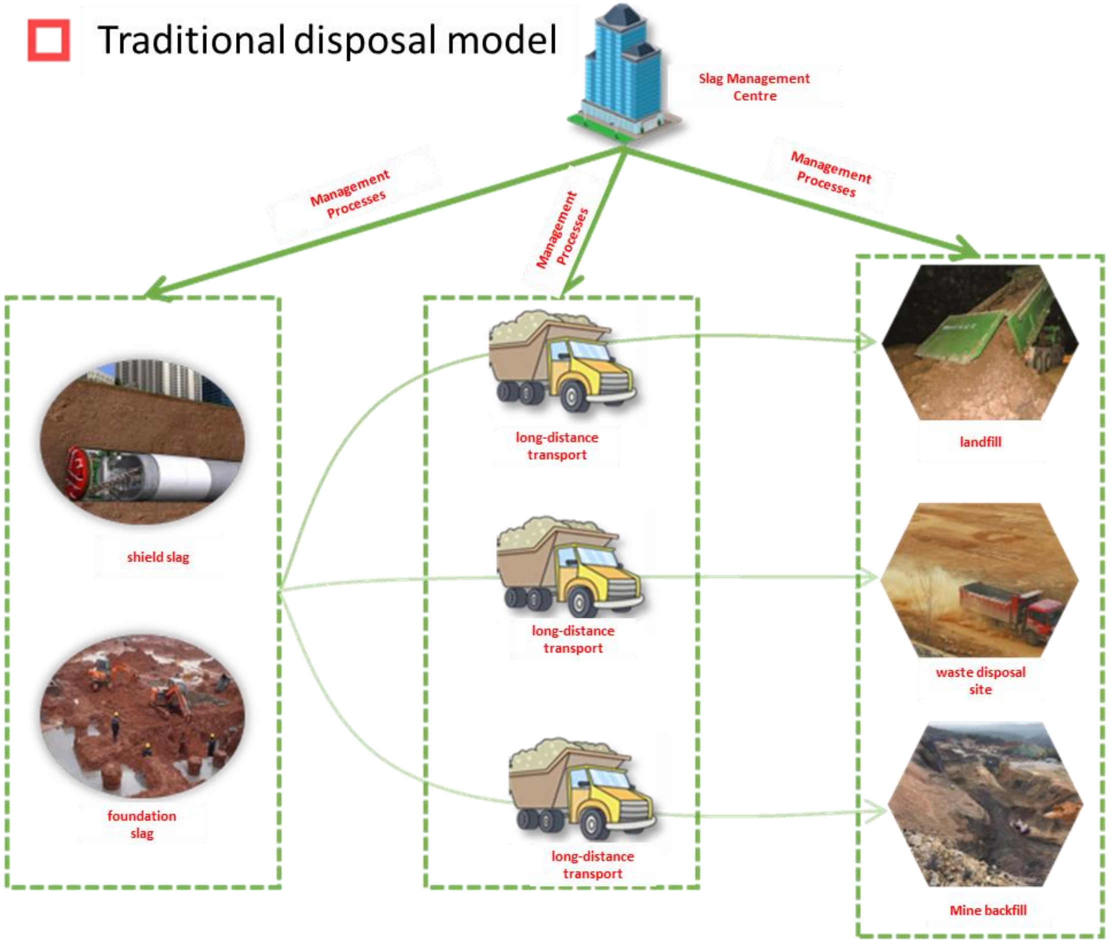
Modular Mobile Screening Station

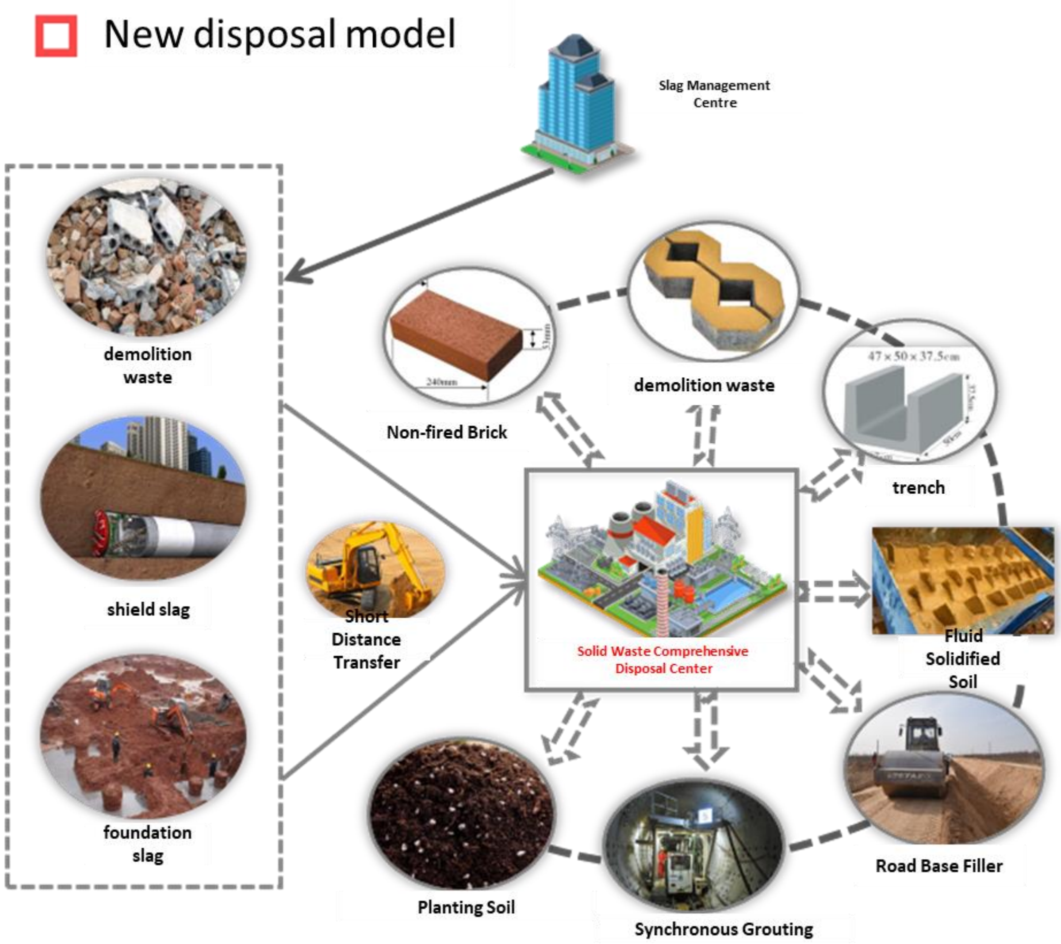
Modular Mobile Shaping and Crushing Station

After Shaping

产品枢纽化协同

Integrated Solid Waste Disposal Centre





Existing Issues

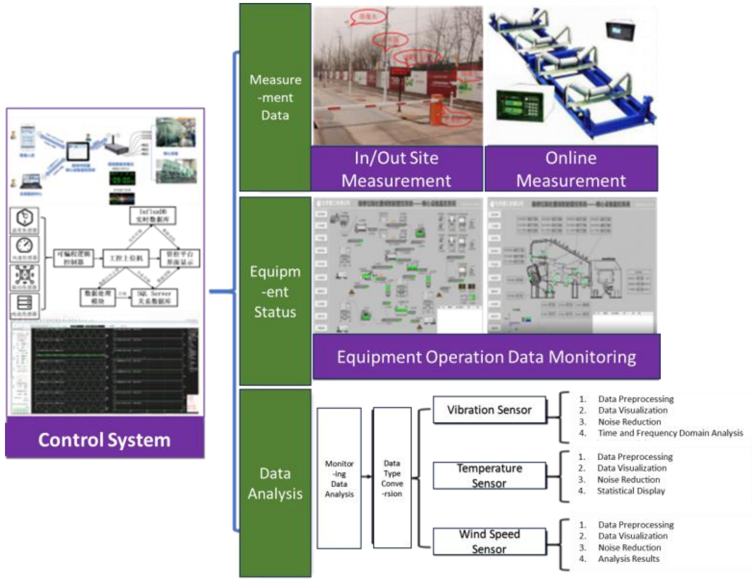
- Management process is complex, with low controllability
- Takes up a large amount of land
- Damages the environment, pollutes water sources
- High risk of landslides, significant safety hazards

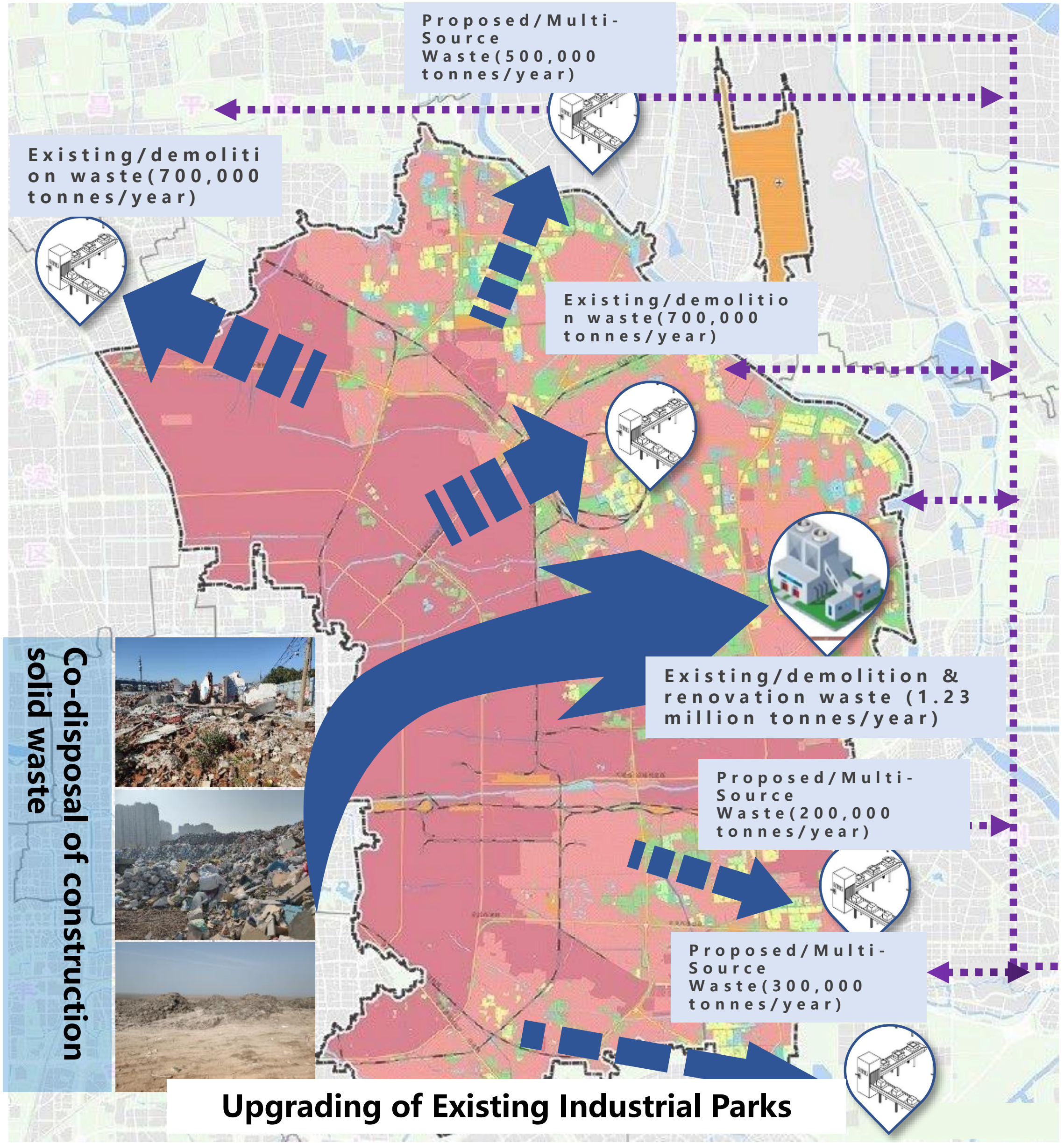
Advantages and Benefits

- Simple management
- Entire process is controllable, low carbon and environmentally friendly
- Transformation from solid waste to products, with significant economic benefits
- Releases large amounts of land, with significant ecological benefits

Smart control

Smart control of construction waste





Generate

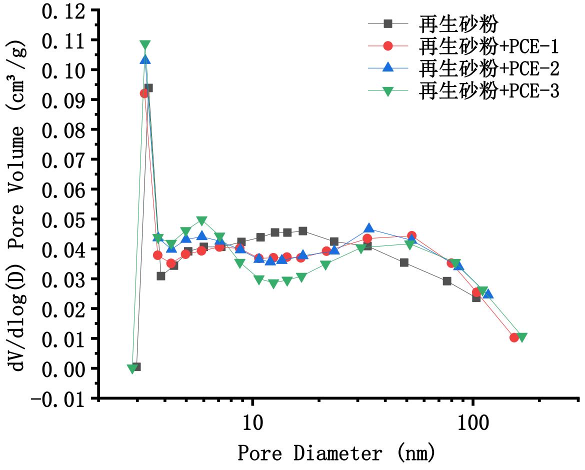
Disposal

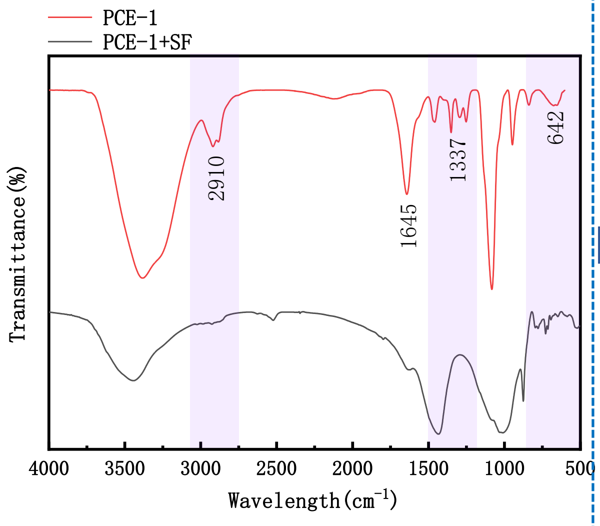
Cloud

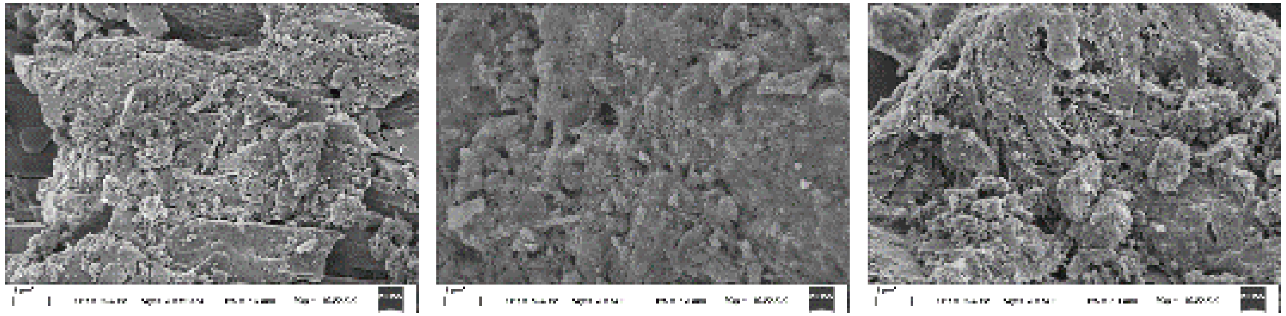
Forward and Reverse Synergy Design Method for Recycled Products

Forward and Reverse Optimization Design and Preparation of High-Performance Recycled Concrete

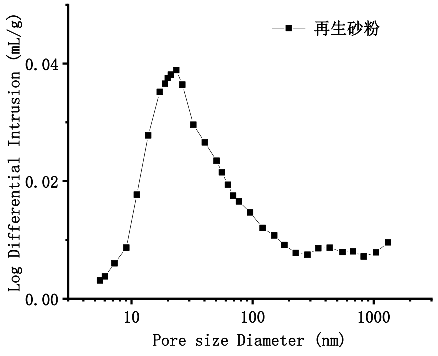
Forward Optimization of High-Performance Recycled Concrete — Additive Optimization and Blending Analysis

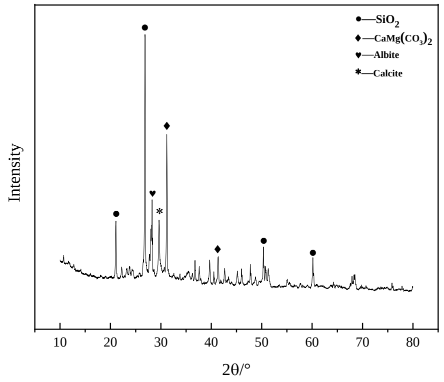




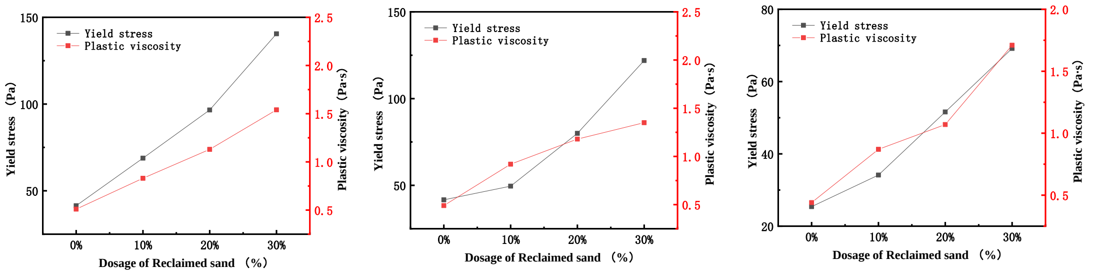


Changes in surface pore structure, micro-morphology, and functional groups of recycled sand powder before and after adsorption





Pore size distribution and phase analysis of recycled sand powder



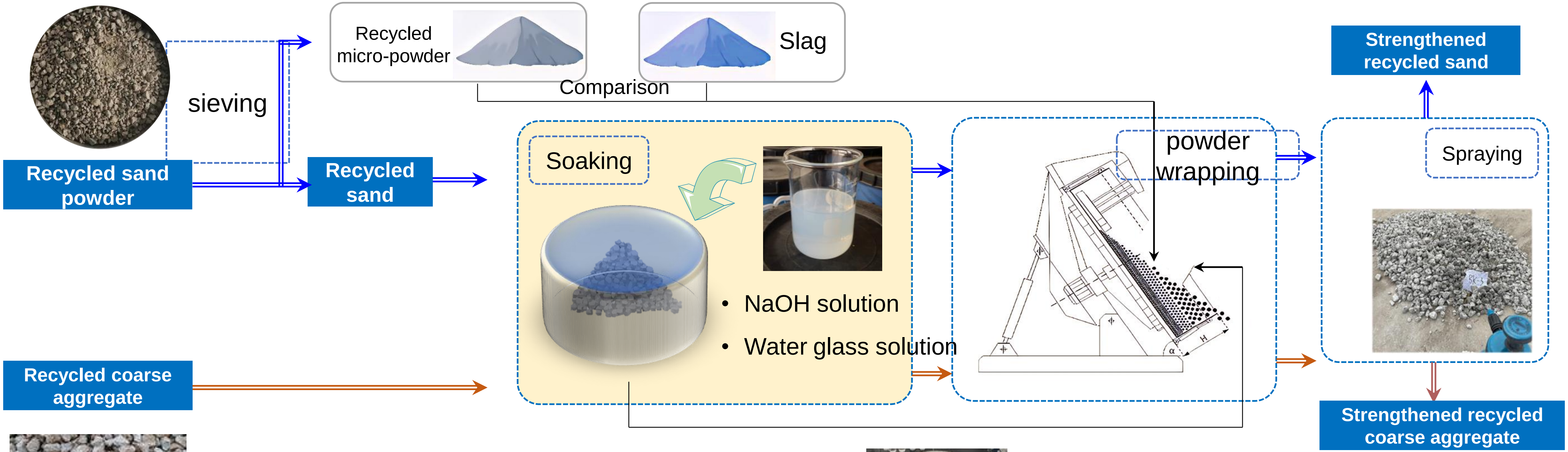
The effect of recycled sand components on mortar flowability (yield stress/plastic viscosity)

- The 10~20nm micropores in the recycled sand powder are the main cause of ineffective adsorption of polycarboxylate superplasticizer, while short main-chain and long side-chain superplasticizers have a higher resistance to ineffective adsorption.

Forward and Reverse Synergy Design Method for Recycled Products

Forward and Reverse Optimization Design and Preparation of High-Performance Recycled Concrete

- Forward Optimization of High-Performance Recycled Concrete ——Self-healing of surface defects and particle shape correction of recycled aggregates.



- ✓ The activation effect of water glass is superior to caustic soda.

- ➢ **The strengthening effect of powder wrapping can significantly reduce the negative impact of recycled coarse aggregate on concrete strength, and reasonable adjustments can increase the 7-day strength by up to 22%.**

Synergy Implementation Case - Demolition and Utilization Synergy

- Taking road and bridge expansion projects as an example, there is an urgent need for corresponding reverse design technology

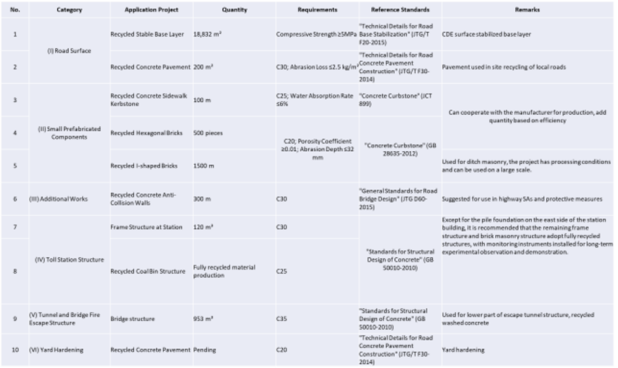
demolish

construct

Reverse

New construction

Application Scenario Planning



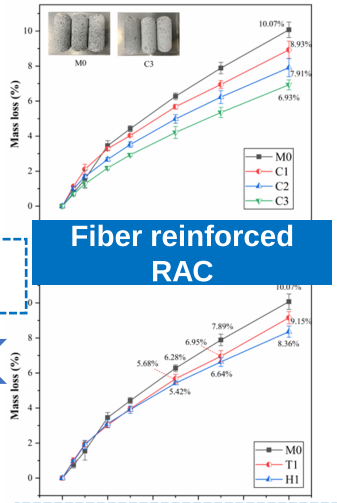
No.	Category	Application Project	Quantity	Requirements	Reference Standards	Remarks
1	(I) Road Surface	Recycled Stable Base Layer	18,832 m^3	Compressive Strength ≥5MPa	"Technical Details for Road Base Stabilization" (JTG/T F20-2015)	CDE surface stabilized base layer
2		Recycled Concrete Pavement	200 m^2	C30; Abrasion Loss ≤2.5 kg/m^2	"Technical Details for Road Concrete Pavement Construction" (JTG/T F30-2014)	Pavement used in site recycling of local roads
3	(II) Small Prefabricated Components	Recycled Concrete Sidewalk Kerbstone	100 m	C25; Water Absorption Rate ≤6%	"Concrete Curbstone" (JCT 899)	Can cooperate with the manufacturer for production, add quantity based on efficiency
4		Recycled Hexagonal Bricks	500 pieces	C20; Porosity Coefficient ≥0.01; Abrasion Depth ≤32 mm	"Concrete Curbstone" (GB 28635-2012)	
5		Recycled I-shaped Bricks	1500 m			Used for ditch masonry, the project has processing conditions and can be used on a large scale.
6	(III) Additional Works	Recycled Concrete Anti-Collision Walls	300 m	C30	"General Standards for Road Bridge Design" (JTG D60-2015)	Suggested for use in highway SAs and protective measures
7	(IV) Toll Station Structure	Frame Structure at Station	120 m^3	C30	"Standards for Structural Design of Concrete" (GB 50010-2010)	Except for the pile foundation on the east side of the station building, it is recommended that the remaining frame structure and brick masonry structure adopt fully recycled structures, with monitoring instruments installed for long-term experimental observation and demonstration.
8		Recycled Coal Bin Structure	Fully recycled material production	C25		
9	(V) Tunnel and Bridge Fire Escape Structure	Bridge structure	953 m^3	C35	"Standards for Structural Design of Concrete" (GB 50010-2010)	Used for lower part of escape tunnel structure, recycled washed concrete
10	(VI) Yard Hardening	Recycled Concrete Pavement	Pending	C20	"Technical Details for Road Concrete Pavement Construction" (JTG/T F30-2014)	Yard hardening

Product Indicators

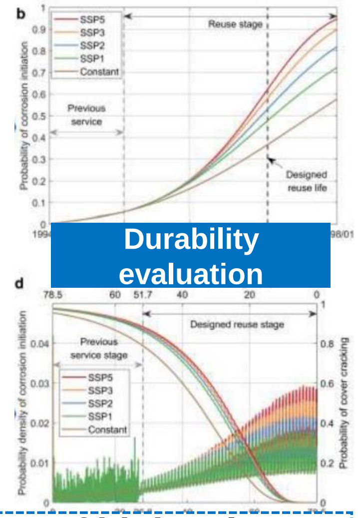
Wear resistance

Resistance to ion erosion and carbonation

➢ Bridge and road surface durability requirements



Fiber reinforced RAC



Durability evaluation

➢ Reverse design of high value-added recycled products

High-value use

Testing and reinforcement of old concrete components

➢ Reuse of old concrete components

Recycled concrete paving

➢ Waste concrete recycling

Forward

Front-end classification - Recycled materials/Reused components

Resouce Utilisation Forward and Reverse Practice

Western Land-Sea New Corridor (Pinglu) Canal Overpass Bridge Project (2024)

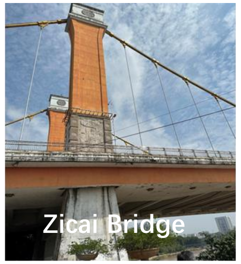
Forward Demand for Solid Waste Disposal from the Demolition of the Old Bridge

Reverse Demand for In-Situ Construction of the Replacement Bridge

沙井钦江大桥

南珠大街跨江桥

永福大桥



子材大桥

北环路跨江桥

金海湾大桥

兰海高速钦江大桥

In-situ utilisation of solid waste

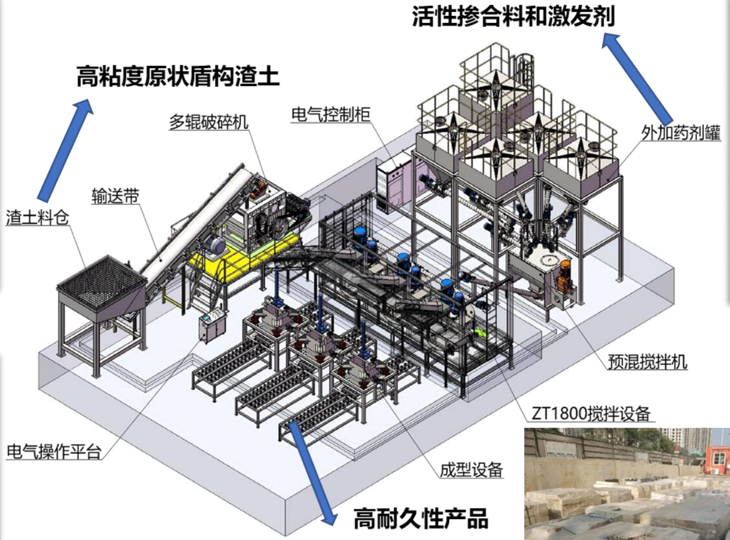
Application Scenario: Bridge Deck

Strength grade: C50

Substitution rate: 30%

Resouce Utilisation Forward and Reverse Practice

Disposal process system based on multi-source sludge resourcefulness characteristics ⟷ **Product lines based on application requirements**



Changsha Original Shield Excavation Muck Pilot Line

The nation's first mixed fill soil and demolition waste disposal project

Beijing Universal Theme Park Mixed Fill Soil Recycling and Disposal Project

Solidified Soil Mixing Equipment

Fully Automatic Palletizing Machine

Engineering Muck Disposal Equipment - Roller Kiln

Resouce Utilisation Forward and Reverse Practice

Lower level

Post-earthquake reconstruction in Wenchuan, 2008

Multi level

The first all-graded aggregate recycled concrete test building in China

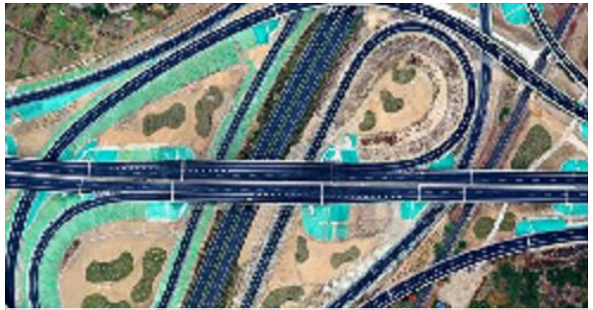
Universal Studios Beijing

Higher level

A high-rise recycled concrete building in Shanghai

Shanghai Lingang Demonstration Project - Sponge System for the Landscape Belt around the Lake

Beijing Winter Olympic Park



Hangzhou-Shaoxing-Taizhou Expressway

Village

Beijing Koutou Village Rural Construction

Town

Tianjin Outer Ring Road Upgrading Project

City

Multi-category recycled low-carbon building materials system in Zhuhai along the river boulevard

Agenda

1. Background of the current situation

2. Why forward and reverse synergy in recycling

3. How to synergise

4. Case study

5. Summary

Conclusion

- Although the national recycling rate of construction waste has increased (35-40%), there is still a severe lack of high-quality, large-scale, and systematic application technologies. There is still a significant gap to reach the 55% target by 2030, and carbon reduction research in the recycling process is lacking.
- Further deepening research on forward planning and design from the physico-chemical properties of construction waste to the development of conventional building materials, while considering product performance feedback and engineering application needs, is a key focus of the resource-based forward and reverse collaborative planning application theory.
- Promoting the top-level design of "forward-reverse synergy planning and application of construction waste recycling" will help address the key scientific and technical challenges in China's construction waste recycling process and achieve systematic applications in various scenarios and levels.
- The carbon reduction, carbon sequestration potential, and optimization methods of various recycling stages, such as source pretreatment, collection and disposal, and the production and large-scale application of recycled products, need further improvement.
- International exchanges and standards are crucial and urgently needed.

Reconmatic

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Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the HORIZON-RIA. Neither the European Union nor the granting authority can be held responsible for them.

Funded by the European Union

THANK YOU
FOR YOUR ATTENTION

Xiao Jianzhuang

Dual Carbon Science and Technology
Research Institute of Guangxi University
Green Construction Research Centre,
Tongji University

Reconmatic