



# Green Buildings and Recycling Technologies: A Comparison between Iraqi and International Approaches

**Maytham Kadhim Obaid, Ghassan Abukhanafer**

*Water Resources Management Engineering Department, College of Engineering, AL-Qasim Green University, Babylon 51013, Iraq.*

## ARTICLE INFO

Received: 3 Feb 2026,  
Revised: 10 Feb 2026,  
Accepted: 12 Feb 2026,  
Online: 19 Feb 2026

### Keywords:

Construction and Demolition Waste (C&DW), Green Building Practices, Recycling Technologies, Circular Economy, Sustainable Construction Policy

## ABSTRACT

Construction and demolition waste (C&DW), which are continuously generated in emerging cities, is one of the largest solid waste streams worldwide and its management has become a problem for every city government. For the purpose of environmentally sound development, recycling such waste is an essential part of green building as it provides environmental and financial benefits. The present study investigates construction waste recycling techniques, with a focus on comparative analysis between typical applications in Iraq and those adopted globally as best practices; these include sorting technology, mechanical processing, and advanced treatment processes which are used together to produce sustainable building materials. And it discusses the barriers that prevent the spread of these technologies in Iraq, ranging from the absence of legislative infrastructure, technical awareness to others that countries that have adopted circular economy policies and technological innovation have witnessed. Based on these comparisons, the study provides policy recommendations that can be implemented in Iraq to encourage adoption and penetration of recycling technologies such as environmental policy support, development of incentives for investment in clean technologies and incorporation of green building principles into local laws. This is a move toward environmentally sustainable building industry.

## 1. Introduction

Environmentally speaking, construction waste is one of the cornerstones affecting present some environmental urgencies historically conditioned by urbanization and a significant growth in construction and demolition in countries worldwide (Yi et al., 2024; Zhikang and Wusheng, 2021; Namia et al., 2022; Yu et al., 2024; Pengping et al., 2023). Global production of waste is estimated to be 2.01 billion tons by 2025 [United

Nations Environment Programmed and Global Alliance for Buildings and Construction (2025)], which could have a huge demand on natural resources, soil, water, air pollution Francesco et al., 2024; Hussein et al., 2020; Cha et al., 2014; Ding et al., 2012. Notwithstanding the 'waste' nature of construction waste, it can also become a source for green production in the event where its life cycle stages are managed well such as

Corresponding author:

E-mail addresses: [maytham@wrec.uoqasim.edu.iq](mailto:maytham@wrec.uoqasim.edu.iq) (Maytham), [ghassan@wrec.uoqasim.edu.iq](mailto:ghassan@wrec.uoqasim.edu.iq) (Ghassan)

doi: [10.5281/jgsr.2026.18682675](https://doi.org/10.5281/jgsr.2026.18682675)

2523-9376/© 2026 Global Scientific Journals - MZM Resources. All rights reserved.



This work is licensed under a Creative Commons Attribution Share Alike 4.0 International License.  
<https://creativecommons.org/licenses/by-sa/4.0/legalcode>

recycling, reusing or recovering energy (UNEP, 2022; Linda et al., 2022; Muvavagi and Whitman, 2023). System of managing construction waste effectively is essential for saving our natural resources from raping, minimize the dependency on raw materials like river sand and stone chips along with cement or clay brick, re duce green -house gas emissions f rom new building material manufacturing as well as promotes small business entrepreneurs to establish recycling business industries in locality (Dong et al., 2019; Devaki and Sh anmujabria, 2023; Chiang and Min, 2020). Besides, good management lead to attainment of UN's STG Goal 11 (Sustainable Cities and Communities) (UN News, 2022, Jinan & Fadel, 2024; Oseni et al., 2021) and goal number 12 (Responsible Consumption and Production) (UN News, 2022; Luoxiang et al., 24). On the other hand, improper management of waste has led to large carbon foot print and environmental pollution (Shamni et al., 2024; Singh et al., 2023). It is estimated that the solid waste combined with the construction and demolition wastes amounts to 30–40% of total solid waste in the world (ISPRA, 2020; Chen et al., 2022; Dong et al. The United Nations Environmental Program (in UNEP) indicates that recycling 50% to 90% of construction waste can save between 5–26% in costs and assist create employment opportunities.

International obligations: to apply standards like BREEAM or LEED, it is necessary to recycle a minimum of 70% urban waste which leads to sustainable cities (Rongrong, 2022; Figueiredo et al., 2022). Construction sector contributed to about 9% of GDP in EU, and construction waste accounted for 37.1% of total solid wastes generated (European Commission, 2023a; 2023b; Yuan et al., 2024). In the USA, construction had 4.1% of GDP in 2018; but, contributed to 67.3% of total solid waste generated by all economic sectors (Yuan et al., 2024). The situation is similar in Australia, where the proportion of GDP contributed by the construction sector was 8.1%),(2020 or 44% of all solid waste (Australian Bureau of Statistics, 2023; Wu et al., 2023). In 2020, the construction industry in Japan reached 4.1% of its GDP and construction waste contributed to about 35.5% of total solid waste across the country (Statistics Bureau, 2023; Zhao et al., 2023). China's construction sector consisted of 7% of the country's GDP and made up approximately 40% in terms of solid waste (Yuan et al., 2024). From these data, we observe that despite its high economic contribution (8% of GDP on average) the construction sector contributes to creating about 40% of total solid waste by weight (Bao et al., 2023; Al-Shurafa et al., 2024).

**Table 1.** the benefits of dealing with construction waste.

Category	Benefits	Reference
Environmental	70% waste reduction, 40-60% emission reduction	[4, 7]
Economic	15-20% material cost savings, increased property value	[2, 8]
Social	Improved indoor air quality, job creation	[1, 8]

Despite these, many countries (especially less developed) are struggling with a number of issues in the management of construction waste while weak laws, lack of public awareness and insufficient infrastructure leads to a lack of economic incentives regarding progress in various technologies, software as well as machines and techniques (Wang et al., 2024; Ding, 2022;

Caroline et al., 2022). By comparison, Sweden and Denmark, together with the Netherlands could be considered as successful models that have converted construction and demolition waste into profitable environmental resources through innovative technologies; stringent legislations as well as investments in circular economy (Yuan et al., 2024; Luoxiang et al., 2024; Seng et al., 2023).

In this context, developing of sustainable construction waste management practices are not any longer a choice but a requirement in urban development of the cities to provide safe environment for future generations (Yu et al,

2024; Bao and Lu, 2021). The goal of this research is to investigate the efficiency of using technologies on recycling construction waste comparing the current situation in Iraq to leading countries in that domain.

**Table 2.** comparison between Iraq and Scandinavian countries.

Standard	Iraq	Scandinavian countries
Legislations	Weak	extreme and active
Infrastructure	Almost non existent	Ineffective
Recycle ratio	<10%	90-99%
Government support	LOW	HIGH
Community awareness	LOW	Strong(tax breaks, financing)

The present study is deduced descriptively and analytically which aims to clarify the smart waste recycling technique in relevance to sustainable development, as a second intention is through Iraqi model contrasted with world application. The objective of the current work was to evaluate the significance of some waste-to-energy technologies as a solution to the economic, social, and environmental problems in most countries, such as those with developing economies like Iraq.

**2. Results and Discussion**

**A summary of the Mosul debris recycling project**

**Goal:** 7-8 million tons of rubble, as part of the war from terrorism on 4 Mosul and to be re-used in reconstruction works. **Initiative:** The “Circular Solution” implemented project with financial support from Japan and led by United Nations Environment Programmed and International Organization for Migration in partnership with Mosul Municipality (UNEP, 2022). This initiative processed 10,000 tons of debris and transformed it into construction resources like road gravel and concrete blocks (UN Iraq, 2022). It also provided 240 temporary jobs, including 40 for women. **Obstacles:** Earlier, there was no system of rubble

dumping that caused ad-hoc disposal (UNEP, 2022).

**Global Model:** Following Japan’s post-disaster experience (Ministry of Land, Infrastructure, Transport and Tourism 2020; UN News 2022), we applied circular economy concepts such as those used in the affected regions of Iraq.

**Innovative Technologies**

**Green Concrete:** By substituting recycled materials (e.g. fly ash or waste from demolition) for ordinary cement, the researchers cut CO2 emissions by 40%.

**Prefabrication:** Minimization of construction waste (<10%) in comparison to conventional techniques (Liu et al., 2023).

**Artificial Intelligence & IOT (Internet-Of-Things):** Waste tracking methods and IoT sensors that sense material types better segregate materials for recycling. **Supporting legislation:** In the European Union, 70% of construction waste must be recycled by 2030 in accordance with the Waste Framework Directive (2008/98/EC) (Lu et al., 2021; De Lima and Seuring, 2023).

**Situation now:** Construction all across Iraq due to reconstruction, but no system for waste management. (Abdul Rasool and Mohammed, 2020). Much of the waste is dumped in unregulated landfills, leading to soil and groundwater contamination. According to the study of University of Baghdad (2022), 60% of Constructions waste in Baghdad are unsegregated, which makes it worse (Ghadhban and Mahmud, 2022; Vuthea et al., 2024; Gi-Wook et al., 2024 ).

**Regulatory and institutional mechanisms:** Providing tax breaks on green projects, seeking efforts to encourage recycling through imposition of landfill fees (Walaa et al., 2023; Destatis, 2021; Arpit et al., 2023). International Collaboration: Learning from experiences of other countries such as the UAE in adopting paving using recycled material.

**Challenges:** Technical ignorance and absence of waste-treatment infrastructures that need investment on dedicated sorting/recycling centers,56 (Baralia et al. 2023; Singh et al. 2023).

### Construction waste in Iraq

Iraqi construction and demolition waste is an emerging environmental issue with the expansion of urban cities, a country that has experienced several decades of blockages and war. The lack of proper collection and recycling systems results in accumulation of huge waste, adding to the demand for natural resources and stress on the solid waste management. As a result, the preparation of clear policies by Iraq for construction waste management and recycling is important for advancing sustainability as well as enhancing resource efficiency which support environmental sustainability (Rongrong et al., 2022; Roberta, 2025). Likewise, war rubble poses another environmental problem by being mixed with unhealthy substances that makes sorting and treating more difficult (Obaid et al., 2019). Recent data shows very large differences in construction and demolition waste generation and treatment among countries, due to the potential of implemented infrastructure facility and environmental policies.

**Table 3.** C&DW generation in different countries.

NO	Counter	C&D generation	Treatment%	Year	Reference
1	Germany	299	88	2020	DESTATIS
2	UK	68	93	2018	UK Government Statistical Service 2021
3	France	277	77	2020	ADMEME
4	Italy	59	76	2018	ISPRA
5	Russian	17	5	2019	Federal Service for State Statistics 2019
6	China	2600	N/A	2020	DENG 2022
7	Japan	N/A	97	2018	Ministry of Land Infrastructure Transport and Tourism 2020
8	India	150	1	2019	BMTPC
9	Barazil	48	20	2021	ABRELPE 2022
10	USA	601	76	2018	US EPA
11	Australia	29	77	2021	BLUE Environmental 2023

## Waste in Iraq: An environmental crisis and missed opportunities

The construction sector is a major contributing factor for the decent living in most of developing countries such as Iraq. Yet, while playing a part in development, this industry is responsible for elevated waste generation (Luangcharoenrat et al., 2019; Jingkuang et al., 2023). Iraq produces 20,000 to 30,000t of solid waste per day, of which a large fraction is construction and demolition (C&D) waste. This type of waste is frequently disposed in unauthorized dumping sites or burned

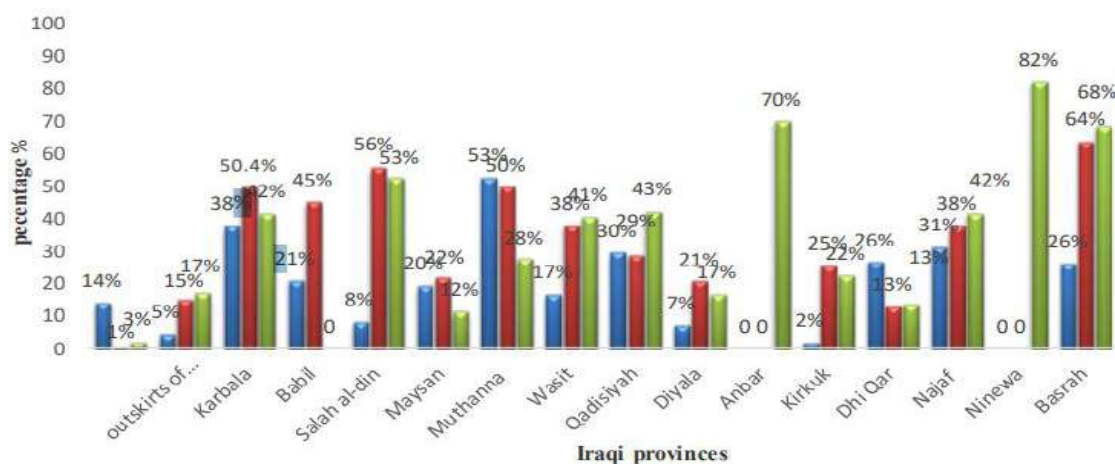
leading to environmental and health hazards (Janan and Fadhil, 2024). The capital Baghdad alone produces around 9,000 tons of garbage a day and most provinces use primitive means to dispose waste, either dumping or burning trash. Data from Jalil et al. (2020) is that about 55 to 65% of municipal waste is organic and can be composted or used for alternative energy. However, the under-investment and poor planning have so far kept the potential resource untapped (Aga et al., 2022; Devaki & Shanmujabria, 2023).

**Table 4.** C&D waste generated between 2015, 2016 and 2017, (Maytham et al., 2019).

City	No. of Municipals	C and D waste (ton / year)	Total waste (ton / year)	C and D waste (ton / year)	Total waste (ton / day)	C and D waste (ton / year)	Total waste (ton / day)
Baghdad [centre]	15	583,890.	4,118,25	3,500.8	3,838,237	59,766.4	2,522,159.9
Baghdad [outskirt]	16	15,001.5	321,273	95,201	634,245	117,424	680.777
Karbala	7	214,255	563,633	436,950	867,130.8	331,769.6	794,741.4
Babil	61	73,182.5	347,298	356,308.	785,437.2	186,884.8	575,874.8
Salahaldin	18	22,520.5	269,480	462,321	825,806	823,911.5	1,556,554
Maysan	15	126,472.	645,284	93,568	430,123	46,364	401,919
Muthana	12	184,982	348,977	179,220.	357,869.8	60,435.2	219,077.2
Wasit	17	61,320	364,015	232,194	606,506	219,078	539,544
Qadisiyah	15	134,247	452,345	167,080	579,244	236,712	554,659
Diyala	22	26,243.5	354,306	85,128	409,928	74,223.2	440,158.2
Diyala	22	26,243.5	354,306	85,128	409,928	74,223.2	440,158.2
Anbar	-NA-	-NA-	-NA-	-NA-	-NA-	2,073,483	2,954,364
Kirkuk	7	7,482.5	377,155	99,297.6	385,298.6	86,412.8	384,420.8
Dhi Qar	20	6,0663	226,997	80,924.8	620,201.8	95,707	701,822.5
Najaf	9	285,101.	902,098	341,58	895,451.2	490,947	1,168,301
Ninewa	-NA-	-NA-	-NA-	-NA-	-NA-	3,210,299	3,899,283.8
Basrah	15	433,547	1,647,64	2,120,48	3,310,214	2,249,905	3,276,539.6

**Table 5.** Comparison between Iraq and global practices.

Standard	Iraq	Global Practices
Recycling rate	Less than 10%	(50-90%)
Infrastructure	Limited	Advanced infrastructure
Lack of legislative	Absent	Tax incentives, binding regulations
Community awareness	Low	High
Efficiency and feasibility	experiments, not yet at the level of global standards.	Projects such as holcim and the environmental cluster initiatives confirm technical and economic performance. initial



**Figure 1.** Percentage of C and D waste for Iraq cities of three years (blue 2015, red 2016, green 2017), Obaid et al., (2019).

**Table 6.** shown the problems in Iraq construction industry.

No	Problems	direct impact	Proposed solutions
1	Lack of infrastructure	accumulation of 40 million tons of waste annually	establishment of sorting and recycling centers supported by the private sector
2	Informal practices	pollute air and groundwater	impose fines on indiscriminate burning, and provide alternatives
3	lack of awareness	waste of recyclable resources,	awareness campaigns & inclusion of green building concepts in engineering curricula
4	War	pollute air and land pollution	Huge, uncountable quantities
5	Administrative corruption	Lack of legislation and laws	Enforce strict laws

Effective mechanisms of waste control are non-existence in the country from source separation, treatment/handling and recycling (Elghaish et al., 2007; Gi-Wook et al., 2024). Yet, these problems also contain an opportunity for turning waste into resources. Iraq could help reduce the environmental footprint of C&D by embracing modern concepts in construction waste management include promoting reuse of recyclable materials and setting up dedicated factories for recycling concrete, steel, and other building materials besides generating new jobs, supplying cheaper building materials and boosting the drive towards a more circular economy (Kharrufa et al. 2007, Zhikang and Weisheng 2023).

### Key global recycling technologies (Comprehensive summary)

#### Mechanical recycling

**Description:** The one we're most familiar with, in which waste (plastic, paper or the like) is separated and cleaned before being melted down or crushed to make new raw materials.

**Applications:** The transformation of plastic bottles (PET) into new fibers or packaging. Converting paper to packaging materials, and metal into raw material for re-utilization in other industrial processes (Annelise and André, 2024; Junjie et al., 2022).

**Table 7:** Construction waste recycling techniques

Technology	Description	Use
Crushers and mills	crushing concrete and bricks	producing recycled aggregates
Magnetic separation	separating ferrous metals,	reusing iron
Manual separation	sorting wood, plastic, and glass	recycling or direct use
Washing and chemical treatment	Washing and chemical treatment: cleaning materials of contaminants	improving quality for use in construction
Energy production	burning wood and plastic	generating heat or electricity

#### Chemical recycling (Advanced)

**Description:** Cracking of materials (in particular plastics) into basic chemical components with the following procedures:

**Pyrolysis:** Turning plastic into fuel in the form of oil or gas. Depolymerization: Breaking down polymers into monomers to produce new, high-quality plastics. Gasification: Converting waste into synthetic gas (hydrogen + carbon monoxide). Advantage: Deals with mixed or contaminated

plastics, a major challenge in mechanical recycling, (Yuan, 2022, Lynda, 2022).

#### Waste-to-Energy (WTE)

**Technologies:** Incineration with Energy Recovery: Generating electricity from the burning of non-recyclable waste. Anaerobic Digestion: Converting organic waste into biogas. Challenge: Carbon emissions, but modern technologies are reducing them. (Yuan, 2021, Ding et al., 2022).

**Smart and digital technologies**

**AI Sorting:** Robots based on computer vision to sort waste with high accuracy (80 pieces/minute). Block chain: Tracking Recycled Materials Pathway to Ensure Transparency. (Samuel 2025, Gao et al., 2024, Zhenshuang et al., 2024).

**Nuclear technologies (Innovative)**

**Description:** Using radiation to improve the quality of recycled plastic or convert it into fuel and building materials. Applications: Producing concrete from recycled plastic. Degrading plastic into clean fuel. Comparison of Technologies. Technology Advantages Challenges, (Hassan et al., (2023), Jorge et al. 2025, Gavina et al., 2023).

**Mechanical:** Low cost, suitable for pure materials, does not handle contaminated waste. **Chemical:** Processes complex plastics, produces high-quality materials. High cost, high energy consumption. Energy conversion reduces waste volume, generates energy, and reduces potential carbon emissions, Howard (2023). Future Trends. Europe leads the world with 60 advanced recycling plants. Middle East: UAE and Saudi Arabia top Arab countries in recycling rates (20% and 15%, respectively), (Martin et al. 2024).

**Advanced sorting and separation technologies**

Artificial Intelligence and Robotics: Systems based on deep learning to sort concrete, metals, and

wood with up to 95% accuracy (such as Zen Robotics in Finland). Magnetic and air separation: to separate iron from aggregate and purify non-metallic materials. X-ray and spectroscopy: to detect hazardous materials (such as asbestos) in demolition waste, Devaki, et al., (2023).

**Concrete recycling and reuse**

Crushing and Screening: Converting old concrete into recycled aggregate (RCA) for use in: Road base layers (as a replacement for natural gravel) (Lima, & Seuring, 2023). New concrete to BS 8500 specifications (maximum 30% RCA in structural elements). Emerging Technologies: Enhanced Carbonation: To improve RCA quality by absorbing carbon dioxide. Green Concrete: Mixing RCA with additives such as fly ash to enhance durability. Francesco, et al., (2024),

**Recycled materials in green building certification**

**LEED (US):** Awarding points for using 20-30% recycled materials in a project. Encouraging the use of RCA in foundations and roads.

**BREEAM (UK):** Requirements to achieve 50%+ recycling of construction waste. Additional points for using 15% recycled materials.

**Successful models:** the edge project (Netherlands) – LEED Platinum certified using 90% recycled materials. Riyadh Metro Station – BREEAM compliant with 75% recycling of waste. (Alshorafa & Ergen, 202, Hector et al., 2024).

**Table 8.** Global case studies in construction waste management (Europe, USA, Asia).

NO.	Challenge	Global solution
1	RCA contamination with impurities	Aggregate washing using chemical techniques
2	High screening costs	Use of robots to reduce costs
3	Contractor resistance	Tax incentives (as in Singapore)

### Europe: The Flemish model (Belgium)

Successes: Achieving 90% recycling of construction and demolition (C&D) waste through source segregation and requiring projects to submit waste dismantling plans. Using recycled concrete (RCA) in new roads and buildings, applying BS 8500: 114 standards. Pay-as-you-drop (PAYT) policies to incentivize waste reduction. (Gellynck, & Verhelst, 2007, Nguyen et al., 2025). A considerable amount of demolition waste (DW) generated by urbanization and urban renewal has brought significant threats to the environment. However, there is a serious lack of environmental impact assessment towards city-scale demolition waste management (DWM), particularly from the systematical and dynamical perspective (Samue, 2025, Weisheng, et al., 2021). Traditionally the assessment has been conducted from a static perspective. The purpose of this paper is to comprehensively evaluate the environmental impact of city-scale DWM from a complex system perspective. A novel evaluation model was developed by innovatively integrating the geographic information system (GIS) and system hybrid simulation consisting of system dynamics (SD), agent-based modeling (ABM) and discrete event simulation (DES). The proposed model was verified (Rongrong et al., 2022, Nguyen et al., 2025). Based on an empirical analysis of Shenzhen, China, it is found that the environmental impact of city-scale DWM is mainly concentrated in the central and northeastern regions of Shenzhen, demonstrating spatial heterogeneity and regional aggregation. Furthermore, the results reveal that the model is robust and effective to assess environmental impact from four aspects, i.e., land occupation, water pollution, air pollution and energy consumption. The findings contribute to a better understanding of the status quo of city-scale DWM and accompanying environmental impacts, and coordinating various district governments to formulate effective DWM policies. Ding et al., 2022).

### Europe: ZMS Schwandor station (Germany)

This station uses the thermal energy generated from incinerating waste into electrical energy that is used to supply the region after being fed into the grid with a capacity of 220,000 m. watts/h. The grid also heats and heats water in the Schwan Dorf region with a capacity of 73,300 m. watts/h (Ghadhban and Mahmud, 2022, Shooshtarian, et al., 2024).

### United States: San Francisco

Results: Achieving 77% waste diversion (the highest rate in the United States) through: Stringent waste reduction legislation. Partnering with recycling companies to convert wood and metal into new building materials 8. Using AI to sort construction waste 14 (Fang et al., 2023, Zhiming et al. 2025).

**Asia- Philippines:** San Fernando City increased its recycling rate from 12% to 80% between 2012 and 2018 through community programs and employing waste workers. Banning waste incineration and encouraging debris reuse in reconstruction ( Hassan et al., 2023)

**Asia- Malaysia:** Penang achieved 46% recycling (2019) through source separation and composting policies. Creative recycling initiatives to convert wood and plastics into economically valuable products, (Nguyen et al., 2025, Fang et al., 2023).

**Asia- Japan:** Minato station/Tokyo: One of Japan's most prominent incinerators utilizes the latest and safest technologies. It consists of three incinerators equipped with transformers to convert electrical energy. It reduces carbon emissions by 4% and generates approximately 22 megawatts of electricity, (Cha et al., (2017, Ghadhban and Mahmud, 2022, Wenbo et al., 2022)

**Table 9.** Lessons learned and strategic challenges for the world

No	Region	Strategy	Challenges
1	EU	Strict legislation circular economy	High initial costs
2	USA	Artificial Intelligence Financial Incentives	Limited Application of Technologies in Rural Areas
3	Asia	Community Participation Innovative	Solutions Lack of Infrastructure
4	Africa	Community Participation Strict legislation	Lack of Infrastructure Limited Application of Technologies in Rural Areas

**Lessons Learned and Strategic region challenges**

**Europe:** Tight economic regulation and Circular economy: High initial investment costs.

**US:** AI and Financial incentives: Scanner sounds and development dollars- Tech not used much in rural settings

**Asia:** Community Involvement and Ground breaking Solution: No infrastructure

**Contribution:** Success relies on enabler laws (Europe) Technical Innovation (US), Community Drives (Asia).

**The Current Status of CWM in Iraq**

**Lack of recycling infrastructure**

**Lack of centralized facilities:** There is no organized station for sorting and recycling construction and demolition (C&D) waste in governorates, most are subject to random disposal or open burning. (Obaid et al., 2019; Ding et al., 2022).

**War debris challenges:** In cities such as Mosul, demolition waste is contaminated by mix of

hazardous substances (explosives, chemicals), which cannot be recycled safely without technological applications (Obaid et al., 2019; Blue Environment 2023; Ding et al., 2022).

**Sparse initiatives:** The Nahrawan Waste-to-Energy Project is one of the few exceptions, but it mainly involves incineration rather than recycling as no plans to deal with concrete aggregates are mentioned.” (Devaki et al., 2023; Sahar, 2007).

**Lack of a structured market for recycled materials:** The non-availability of an organized market for recycled material, has its setbacks in the efficacy of Circular State. In the absence of well-defined regulation, the ongoing efforts are piecemeal, and it is challenging to entice investment in this crucial area (Movaffaghi and Yitmen, 2023; Wu et al., 2023).

**Informal waste disposal practices**

**Contaminated landfilling:** In Iraq, 149 such landfills out of the total 221 are not authorized (TOE, 2020) representing a risk for soil and water table pollution (Abdul Rasool and Mohammed, 2020; Maytham et al., 2019 Yuan et al., 2024).

**Indiscriminate burning:** 40% of Baghdad's waste (10,000 tons per day) is burned in the open,

releasing toxic gases (such as Dioxins that cause respiratory and cancerous diseases) (Maytham et al., 2019 27. Walaa and Nada (2023)

**Shadow economy:** Thousands of workers (such as waste collectors in Nahrawan) rely on manual waste sorting, exposing them to skin diseases and poisoning from mixed medical waste.

### Poor awareness of green building concepts

**Lack of effective legislation and policies:** There are no laws mandating the use of recycled materials in construction, unlike LEED or BREEAM global standards (Devaki et al., 2023; Nir et al., 2021).

**Waste culture:** Concrete aggregate and construction waste are considered unusable "scrap", despite their potential to be transformed into building materials (such as recycled aggregate) (Hasan et al., 2022; US EPA, 2020; Virginia et al., 2024).

**Lack of awareness and technical expertise:** Most contractors and government agencies prefer new materials due to their lower immediate costs, disregarding the long-term environmental costs (Hasan et al., 2022; Cha et al., 2017; Sadeq et al., 2022).

**Economic disincentive:** No rewards are associated with recycling and hence no profits, just expenses. Not eligible for direct financial subsidies or tax breaks, companies pay high costs to collect, sort and process recycled materials. This is bad for investors as it means a worse liability-adjusted return against traditional investment (Ayeleru et al., 2021; Movaffaghi and Yitmen, 2023).

**Recycled Product Certification (RPC):** It has been proven that Recycled Product Certification (RPC) programs can be effective in verifying a product meets the desired level of quality and in increasing product credibility to end users with a Recycled Product Certification, PwRC, as performed by compliant systems such as RecyClass or TÜV SÜD certified according to ISO 14021 and EN 15343 (Luxiang et al., 2024; Shooshtarian et al., 2024).

### 3. Conclusion

With the advocacy of build green by reusing and recycling, it is expected that more and more studies will be carried out to develop technologies for turning this waste into resources in some places of the world. Recycling technologies in Iraq are not well developed, and depend sometimes on primitive methods; breaking concrete or brick to use as packaging with no advanced sorting procedures and a lack of regulatory laws. Nowadays however, at the planetary level we are already witnessing modern technological systems (such as smart sorting, use of AI) for the recovery and re-incorporation into productive chains of its materials with a high degree of efficiency in terms of material recovery or even chemical and physical treatment. International laws also support the circular economy and projects must comply with environmental standards. The gap between Iraq and the remaining world in this aspect is due to unorganized society, Lack of economic motivation, The lack of effective laws and policy as well as poor awareness and technical heeling, Poor infrastructure for sorting and handling operations: the non-existence of organized market for recycled products. These act as barriers to recycling technologies in sustainable construction practices. To address this gulf, the report suggests creating enabling laws (that would spell out requirements and responsibilities), setting up dedicated Recycling Centers, and implementing national policies that are supportive of linkages and breakthroughs. Supporting investments in recycling plants, using principles of circular economy and amending Iraqi codes to align with international standards. Integrating forward-looking technologies with details and specificity of the Iraqi context can catalyze a transformational process into greener, sustainable urban habitats.

### 4. References

1. Yi Xu, Shujie Liu, Felix Heisel, (2024). Towards sustainable construction waste management: Study on a disassemblable brick partition wall for the architecture, construction, and engineering industry, Circular Economy Vol. 3, (1), <https://doi.org/10.1016/j.cec.2024.100078>.
2. Zhikang Bao, Weisheng Lu, (2021). A decision-support framework for planning construction waste recycling: A case study of Shenzhen, China, Journal of Cleaner

- Production, Vol. 309, <https://doi.org/10.1016/j.jclepro.2021.127449>.
3. Bingbing F., Jiacheng Yu, Zhonghao Ch., Ahmed I. O., Essam H. H., David W. R., Pow-Seng Y, Mohamed F., Ikko I., (2023). Artificial intelligence for waste management in smart cities: a review *Env.Chemistry*, Vol. (21)1959–1989. <https://doi.org/10.1007/s10311-023-01604-3>
  4. United Nations Environment Programme, & Global Alliance for Buildings and Construction (2025). Not just another brick in the wall: The solutions exist - Scaling them will build on progress and cut emissions fast. Global Status Report for Buildings and Construction 2024/2025. <https://wedocs.unep.org/20.500.11822/47214> .
  5. UNEP:(2022). Mosul's recovery moves towards a circular economy.
  6. UN Iraq: (2022). Mosul rubble recycling project.
  7. UN News: (2022), How the world helped Mosul rise from the rubble.
  8. ISPRA. (2020). Italian environment: Trend and legislation Roma, Italy: Division for environmental information, Statistics and Reporting: Italian Institute for Environmental Protection and Research.
  9. Deng, D., (2022). An insight into China's construction and demolition waste recycling industry. Invest Northern Ireland.
  10. Destatis, (2021). Brief overview waste balance. Waste Management. Wiesbaden, Germany Federal Statistical Office of Germany.
  11. Ministry of Land Infrastructure Transport and Tourism. (2020). Results from the survey on construction and demolition waste in 2018. Japan.
  12. Yu G., Jiayuan W., Xiaoxiao Xu, (2024). Machine learning in construction and demolition waste management: Progress, challenges, and future directions, *Automation in Construction*, Vol. 162, <https://doi.org/10.1016/j.autcon.2024.105380> .
  13. Australian Bureau of Statistics: Australian National Accounts
  14. UK Government Statistical Service. (2021). UK statistics on waste.
  15. US EPA. (2020). Assessing trends in materials generation and management in the United States advancing sustainable materials management:2018 fact sheet. Us Epa.
  16. Gi-Wook Cha, Choon-W. P., &Young-Ch. K., (2024). Optimal Machine Learning Model to Predict Demolition Waste Generation for a Circular Economy, *Academic-Research Digital Convergence Scale-Up Platform Center. Sustainability*, 16(16), 7064; <https://doi.org/10.3390/su16167064> .
  17. Lynda A., Santoso W., Srimannarayana G.,( 2022), Artificial intelligence applications for sustainable solid waste management practices in Australia: A systematic review, *Science of The Total Environment*, Vol. 834, <https://doi.org/10.1016/j.scitotenv.2022.155389>.
  18. Luxiang W., Zhende Z., Xinghua X., Junyu W., (2024). Research trends in the treatment and recycling of construction and demolition waste based on literature data-driven visualization, *J. of Env. Manag.t*, Vol., 371, <https://doi.org/10.1016/j.jenvman.2024.123018>
  19. Ayeleru O.O., Fajimi L.I., Oboirien B.O., Olubambi, P.A. (2021). forecasting municipal solid waste quantity using artificial neural network and supported vector machine techniques: A case study of Johannesburg, South Africa, *Journal of Cleaner Production*, Vol. 289, <https://doi.org/10.1016/j.jclepro.2020.125671>.
  20. Blue Environment. (2023). National waste report 2022. Department of climate change, energy, the environment and water.
  21. BMTPC. (2021). Annual report: 2020-2021. New Delhi, India: Ministry of Housing & Urban Affairs: Building Materials & Technology Promotion Council. <http://mohua.gov.in>
  22. Sadeq Abdul Zahra Ghadhban and Amjad Mahmuds. (2023). Design bases for waste recycling rules in cities/ Baghdad, a case, *Journal of Planning and Development*, Vol. 27(2).
  23. Nguyen T., Nguyen TR., Li Zhou, Duong Q., H., Ieromonachou P., (2025). Assessing the impact of EU policies on recycling supply chain: a system dynamic perspective on advancing packaging recycling capacity. *Annals of Operations Research* <https://doi.org/10.1007/s10479-024-06438-y>
  24. N., M., Abdul Rasool, A., J., Mohammed, (2020). Factory of sorting and recycling of waste in the district of al-mahmoudiyah between the economic and environmental impact. Vol. 12(1). <https://creativecommons.org/licenses/by/4.0>
  25. A. Singh, A. Dwivedi, D. Agrawal, D. Singh, (2023). Identifying issues in adoption of AI practices in construction supply chains: towards managing sustainability *Oper. Manag. Res* (2023), pp. 1-17. <https://doi.org/10.1007/s12063-022-00344-x>.
  26. Yuan, H., Du, W., Zuo, J., & Ma, X. (2024). Paving a traceable green pathway towards sustainable construction: A fuzzy ISM-DEMATEL analysis of blockchain technology adoption barriers in construction waste management. *Ain Shams Engineering Journal*. <https://doi.org/10.1016/j.asej.2024.102627>
  27. Walaa, S. I., and Nada. K., (2023). An environmental management plan for construction waste management, *Ain Shams Eng. J*, 14 (12). <https://doi.org/10.1016/j.asej.2023.102244>.
  28. Zhenshuang Wang, Tingyu Hu, Jingkuang Liu, (2024), Decoupling economic growth from construction waste generation: Comparative analysis between the EU and China. *Journal of Environmental Management*, Vol. 353, <https://doi.org/10.1016/j>.
  29. . Annelise Nairne Schamne , André Nagalli, (2024). BIM in construction waste management: A conceptual model based on the industry foundation classes standard, *Automation in Construction*, Vol. 159, <https://doi.org/10.1016/j.autcon.2024.105283> .
  30. Junjie Ch., Weisheng Lu, Liang Yu., Yijie Wu, Fan Xue, (2022). Estimating construction waste truck payload volume using monocular vision, *Resources, Conservation and Recycling*, Vol. 177, 106013, <https://doi.org/10.1016/j.resconrec.2021.106013>
  31. Zhikang B., Weisheng L., (2023), Applicability of the environmental Kuznets curve to construction waste management: A panel analysis of 27 European economies, *Resources, Conservation and Recycling*. Vol.188, <https://doi.org/10.1016/j.resconrec.2022.106667> .

32. Dong F, Li J, Wang Y, Zhang X, Zhang S, Zhang S. (2019). Drivers of the decoupling indicator between the economic growth and energy-related CO<sub>2</sub> in China: A revisit from the perspectives of decomposition and spatiotemporal heterogeneity. *Sci Total Environ.* 631-658. DOI: [10.1016/j.scitotenv.2019.05.269](https://doi.org/10.1016/j.scitotenv.2019.05.269).
33. Rongrong L., Lejia L., Qiang W., (2022). The impact of energy efficiency on carbon emissions: Evidence from the transportation sector in Chinese 30 provinces, *Sustainable Cities and Society*, Vol. 82, <https://doi.org/10.1016/j.scs.2022.103880>.
34. Jingkuang L., Yuxuan L., Zhenshuang W., (2023). The potential for carbon reduction in construction waste sorting: A dynamic simulation, *Energy*, Vol. 275, <https://doi.org/10.1016/j.energy.2023.127477>.
35. Weisheng L., Jinfeng L., Chris W., Fan X., Zhikang B., Bin C., (2021). Estimating construction waste generation in the Greater Bay Area, China using machine learning, *Waste Management*, Vol. 134, Pp 78-88, <https://doi.org/10.1016/j.wasman.2021.112822>.
36. Qiang W., and Min S., (2020). Drivers of decoupling economic growth from carbon emission – an empirical analysis of 192 countries using decoupling model and decomposition method, *Environmental Impact Assessment Review*, Vol. 81, <https://doi.org/10.1016/j.eiar.2019.106356>.
37. Jalil, Zahraa Ali, Naji, Hafeth I., and Mahmood, Mohammed (2020). Developing Sustainable Alternatives from Destroyed Buildings Waste for Reconstruction Projects, *Civil Engineering Journal*, Vol. 6(60-68), <https://api.semanticscholar.org/CorpusID:210951624>.
38. Arpit S., Vima. K., Pratima. V., Bharti. R., (2023). Can suppliers be sustainable in construction supply chains? Evidence from a construction company using best worst approach Management of Environmental Quality: An International J., 34 (4) pp. 1129-1157. <https://doi.org/10.1108/MEQ-03-2022-0057>.
39. Vuthea M., Kriengsak P., Koji M., (2024). Enhancing performance of construction waste management: Factor analysis from the building contractors' perspectives, *Cleaner Waste Systems*, Vol. 9, <https://doi.org/10.1016/j.cwsys.2024.100176>.
40. Gavina B., Andrea P., Roberto T. Michele, M., (2023). Waste management: A comprehensive state of the art about the rise of block chain technology. *Computers in Industry*, Vol.145, <https://doi.org/10.1016/j.compind.2022.103812>.
41. Roberta Pellegrino, Risk management of Circular Economy: a framework based on Interpretive structural model, *Procedia Computer Science*, Vol. 253, (025), Pages 683-690, <https://doi.org/10.1016/j.procs.2025.01.130>.
42. Samuel G., A., (2025). Artificial intelligence adoption dynamics and knowledge in SMEs and large firms: A systematic review and bibliometric analysis, *Journal of Innovation & Knowledge*, Vol. 10, (3), <https://doi.org/10.1016/j.jik.2025.100682>.
43. Hector Martin a, Deeksha Chebrolu a, Aaron Chadee, Tara Brooks, (2024). Too good to waste: Examining circular economy opportunities, barriers, and indicators for sustainable construction and demolition waste management, *Sustainable Production and Consumption*, Vol. 48, Pp 460-480, <https://doi.org/10.1016/j.spc.2024.05.026>.
44. Jinan H. B. & Fadhil J. D., (2024). An Economic Feasibility Study to Establish a Solid Waste Recycling Project in Wasit Governorate Vol. 20 (3) PP. 775-793. <https://doi.org/10.36325/ghjec.v20i3.17395>.
45. Yuan, L.; Lu, W.S.; Xue, F., (2021). Estimation of construction waste composition based on bulk density: A big data-probability (BD-P) model. *J. Environ. Manag.*, 292, 112822. <https://doi.org/10.1016/j.jenvman.2021.112822>.
46. M.S. Hassan, Y. Ali, A. Petrillo, F. De Felice, (2023). Risk assessment of circular economy practices in construction industry of Pakistan *Sci Total Environ*, 868, <https://doi.org/10.1016/j.scitotenv.2023.161418>.
47. Hector M., Deeksha Ch., Aaron Ch., Tara B., (2024). Too good to waste: Examining circular economy opportunities, barriers, and indicators for sustainable construction and demolition waste management, *Sustainable Production and Consumption*, Vol., 48, Pages 460-480, <https://doi.org/10.1016/j.spc.2024.05.026>.
48. Devaki, H., Shanmugapriya, S. (2023). Investigating barriers to sustainable management of construction and demolition waste: the case of India. *J. Mater Cycles Waste Manag* 25, 1594-1607. <https://doi.org/10.1007/s10163-023-01631-w>.
49. Virginia D., Barbara B., Alberto P., Bendetta P., Serena F., Leonardo T., (2024). Integrating Industry 4.0 and Circular Economy: A Conceptual Framework for Sustainable Manufacturing, *Procedia Computer Science*, vol. 232 pp. 1711-1720. <https://doi.org/10.1016/j.procs.2024.01.169>.
50. De Lima, F. A., & Seuring, S. (2023). A Delphi study examining risk and uncertainty management in circular supply chains. *International journal of production economics*, 258, 108810. <https://doi.org/10.1016/j.ijpe.2023.108810>.
51. Francesco D., Tiberio, D., Luca M., (2024), Financial sustainability of circular innovations in SMEs. A case study from the fashion industry in Italy, *Journal of Cleaner Production*, Vol. 451, <https://doi.org/10.1016/j.jclepro.2024.142042>.
52. Alshorafa, R., & Ergen, E. (2021). Determining the level of development for BIM implementation in large-scale projects: A multi-case study. *Engineering Construction and Architectural Manag.*, Vol. 28, (397-423). <https://doi.org/10.1108/ECAM-08-2018-0352>.
53. Maytham K., Ismail Abdul R., Intidhar J. I., Sasitharan N., (2019). Severity of Causative Factors to Construction Waste Generation: Iraq Construction Industry, *Journal of Science and Technology* 12(36):1-17, DOI: 10.17485/ijst/2019/v12i36/147910.
54. Maytham Kadhim Obaid, Ismail Abdul Rahman, Intidhar Jabir Idan, Sasitharan Nagapan (2019). Construction Waste and its Distribution in Iraq: An Ample Review, *Indian Journal of Science and Technology*, DOI: [10.17485/ijst/2019/v12i17/144627](https://doi.org/10.17485/ijst/2019/v12i17/144627).
55. Sahar Kharrufa, (2007). Reduction of building waste in Baghdad Iraq, *J. Building and Environment* Vol.,42 (5)2053-2061. DOI: [10.1016/j.buildenv.2006.03.011](https://doi.org/10.1016/j.buildenv.2006.03.011).
56. Yuan, H., P., Wang, Z., Shi, Y.W., Hao, J.L. (2022). A dissipative structure theory-based investigation of a

- construction and demolition waste minimization system in China. *J. of Env. Pla. and Ma.* 65(3):1-27, DOI: 10.1080/09640568.2021.1889484.
57. Elghaish, F., Hosseini, M. R., Kocaturk, T., Arashpour, M., & Bararzadeh Ledari, M. (2023). Digitalized circular construction supply chain: an integrated BIM-Blockchain solution. *Automation in Construction*, 148, Article 104746. <https://doi.org/10.1016/j.autcon.2023.104746>.
58. Liang Yuan, Bing Yang, Weisheng Lu, Ziyu Peng, (2024). Carbon footprint accounting across the construction waste lifecycle: A critical review of research, *Environmental Impact Assessment Review*, Vol., 107, <https://doi.org/10.1016/j.eiar.2024.107551>.
59. Wu, H.; Zuo, J.; Yuan, H.; Zillante, G.; Wang, J. (2023). Investigation of the social and economic impacts of cross-regional mobility of construction and demolition waste in Australia. *J. Resour. Conserv. Recycl.*, Vol.,190, <https://doi.org/10.1016/j.resconrec.2022.106814>.
60. Nir K., (2021). Blockchain and sustainable supply chain management in developing countries. *Int. J. of Inf. Manag.*, Vol. 60. <https://doi.org/10.1016/j.ijinfomgt.2021.102376>.
61. Wenbo. Du, Xioazhi. Ma, Hongping Y., Yue, Z., (2022). Blockchain technology-based sustainable management research: the status quo and a general framework for future application *Environ Sci Pol Res*, Vol. 29 (39) pp. 58648-58663. <https://doi.org/10.1007/s11356-022-21761-2>.
62. Karoline Figueiredo, A.W. Hammad, A. Haddad, V.W. Tam (2022). Assessing the usability of blockchain for sustainability: Extending key themes to the construction industry., *J. Clean Prod*, Vol. 343 <https://doi.org/10.1016/j.jclepro.2022.131047>.
63. Jorge Los, Santos-Ortega, Esteban Fraile-García, Javier Ferreiro-Cabello, (2025). Environmental assessment of the use of ground olive stones in mortars. Reduction of CO2 emissions and production of sustainable mortars for buildings, *j. Environmental Impact Assessment Review*, Vol. 110, <https://doi.org/10.1016/j.eiar.2024.107709>.
64. Zhiming Dong, Liang Yuan, Bing Yang, Fan Xue, Weisheng Lu, (2025) Benchmarking computer vision models for automated construction waste sorting, *Resources Conservation and Recycling* Vol. 213. <https://doi.org/10.1016/j.resconrec.2024.108026>.
65. Hasan, M.R.; Sagar, M.S.I., Ray, B.C. (2022). Barriers to improving construction and demolition waste management in Bangladesh. *Int. J. Constr. Manag.*, Vol. 23, 2333-2347. <https://doi.org/10.1080/15623599.2022.2056804>
66. Shoosharian, S. Maqsood, T. Wong, P.S. Zaman, A. Caldera, S. Ryley, T. (2024). Utilisation of certification schemes for recycled products in the Australian building and construction sector. *Bus. Strategy Environ.* Vol. 33, p.p 1759-1777. <https://doi.org/10.1002/bse.3568>.
67. Ding, Z.; Wen, X.; Cao, X.; Yuan, H. (2022). A GIS and hybrid simulation aided environmental impact assessment of city-scale demolition waste management. *Sustain. Cities Soc.*, Vol. 86, 104108. <https://doi.org/10.1016/j.scs.2022.104108>
68. H. Movaffaghi, I. Yitmen, (2023). Framework for dynamic circular economy in the building industry: Integration of Block chain Technology and Multi-Criteria Decision-Making approach Sustainability, Vol. 15 (22) <https://doi.org/10.3390/su152215914>.
69. Namya. Sh, Pradip. P., K., Muhammad. S., (2022). Global review of circular economy and life cycle thinking in building Demolition Waste Management: A way ahead for India, *j. Building and Environment*, Vol. 222. <https://doi.org/10.1016/j.buildenv.2022.109413>.