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Resource Management and Waste Treatment in the Gaza Strip:

An Innovative Model for Environmental and Diplomatic Rehabilitation

Adi Mager | May 2026

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Resource Management and Waste Treatment in the Gaza Strip:
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1* **Adi Mager** is a PhD candidate at the New Environmental School at Tel Aviv University under the supervision of Prof. Vered Blass. Adi combines aerial mapping technologies, artificial intelligence, and life cycle assessment (LCA) methodologies. The research focuses on identifying illegal construction waste sites and streamlining data collection to promote a circular economy and resource management at the local level. Adi has a bachelor's degree in geography and sociology and a master's degree with honors in environment and society. She previously served as VP of Operations at a renewable energy company and gained two decades of experience in guiding complex infrastructure and environmental projects. As a policy fellow at the Mitvim Institute, she leads a regional initiative for environmental and diplomatic reconstruction in Gaza. Adi is a strategic consultant for government agencies, a teaching associate at the Faculty of Mechanical Engineering, and the author of the book *Innovation in Raw Materials for Israel's Construction & Infrastructure Sectors*.

Executive Summary

Background and nature of research

The Iron Swords War, which broke out after the October 7, 2023, massacre, led to regionally and internationally unprecedented levels of infrastructure destruction in the Gaza Strip. During the war, approximately 192,000 buildings were damaged, and approximately 3,045 kilometers of roads and streets were destroyed. This destruction translates into extremely large volumes of construction waste, estimated at between 67 and 126 million tons (depending on different scenarios). This exceeds the capabilities of conventional methods based on removal and landfilling to successfully handle the task and requires new systemic thinking.

This document presents a multidimensional model for environmental and diplomatic reconstruction, based on the principles of the circular economy. The proposed approach strives to transform construction waste from an environmental burden into a resource for reconstruction: reducing the mining of new raw materials, extending the life cycle of existing materials, and reintegrating them into construction and infrastructure processes. Because any future reconstruction process in the Gaza Strip will take place in an environment saturated with waste, addressing it is at the heart of environmental and diplomatic processes. The document recommends a shift from a “removal and landfilling” approach to a strategy that utilizes construction waste as an essential resource for the economic, environment and social rehabilitation of the area.

Innovative waste treatment – from landfilling and to a circular economy

The proposed model for transitioning from landfill to circular construction waste treatment is based on the integration of three key areas: mapping, planning, and diplomacy:

1. **Mapping:** The model's point of departure is to map as accurately as possible the amount, location and composition of the waste. The mapping was carried out using a GIS-based geospatial analysis that relies on a combination of satellite data, existing damage layers, and a spatial hexagon model as a fixed unit of analysis. For each hexagon, the extent of the damaged buildings and the composition of the debris by material were calculated, distinguishing between minimum, median, and maximum scenarios. This approach allows for consistent quantification of waste masses, identifying concentration areas and hazardous materials, creating a database and mapping using GIS, and making the maps accessible through a dynamic bilingual application.
2. **Comparative planning and learning:** another essential component of the model relies on learning from planning and reconstruction in other regions after conflicts and disasters. The study focused on the level of circular regional planning, which sees construction waste as a strategic resource for reconstruction. As part of this process, it was proposed that a multi-year, phased reconstruction be carried out in the Gaza Strip, estimated to take place over a period of about 10 years, with a recycling target of about 70 percent of the debris, amounting to tens of millions of tons. Achieving this goal is expected to enable local production of recycled building materials, reduce dependence on imported raw materials, and gradually create tens of thousands of jobs during the reconstruction phases.
3. **Implementation mechanisms and environmental diplomacy:** The model proposes viewing construction waste management as a platform for applied environmental diplomacy, based on a combination of transparent governance frameworks, regional cooperation,

and international oversight mechanisms. Within this framework, it is proposed to establish a dedicated coordination agency for reconstruction (Gaza Rehabilitation Council) that will operate in coordination with the Civilian-Military Coordination Center (CMCC) in Kiryat Gat. These agencies, with Israeli approval, will operate mechanisms for international oversight of the recycling processes and the reuse of construction materials produced in the area.

This combination of mechanisms could address security risks and enable a phased and supervised implementation of reconstruction processes. Through data management and environmental transparency, the model aims to build trust between the various actors and create a stable foundation for data-based environmental diplomacy, which serves both operational and environmental needs.

The phased reconstruction model

The plan proposes a long-term reconstruction process over the course of a decade, allowing for a gradual transition from crisis management to sustainable institutional and economic development. The process is divided into three main phases:

Phase 1: Preparation, mapping and pilot projects (first year)

This phase focuses on establishing management and coordination agencies and conducting detailed damage mapping based on GIS (geographic information systems). This system allows cross-referencing physical destruction data with infrastructure locations, soil layers, and environmental constraints on a smart digital map, thus creating an accurate data infrastructure for decision-making. At the same time, the proposal is to launch a number of targeted pilot projects to examine the technological, operational, and political feasibility of establishing sorting and recycling systems. These processes will be carried out under international oversight and in an environment of uncertainty, with the aim of establishing a reliable data infrastructure for the path ahead.

Phase 2: Expansion and capacity building (two to four years)

In this phase, it is proposed to establish and operate 3–5 central recycling facilities and to develop a regional logistics chain to handle tens of millions of tons of construction waste. The focus will be on building institutional and employment capacity, including vocational training for thousands of local workers, with the aim of gradually reducing dependence on imports of new construction materials.

Phase 3: Rehabilitation, conversion and future development (five to ten years)

Upon reaching the goal of recycling approximately 70 percent of the debris, the aim is to expand the scope of civil infrastructure reconstruction. In this phase, responsibility for managing the systems will be transferred to Palestinian entities operating within a legal and supervised framework.

Alongside the reconstruction process, it is recommended to plan in advance the conversion of waste treatment infrastructure to long-term uses upon its completion. These facilities could form the basis for advanced materials industries, logistics training centers, or permanent infrastructure for a regional circular economy. This approach aims to leverage the initial investment in reconstruction for the benefit of ongoing economic and social stability, while preventing the creation of excess temporary infrastructure.

Economic aspects and financing

The recycling process is a significant growth engine, with high revenue potential estimated at approximately $1.6 billion from the sale of green concrete and the extraction of materials such as metals. The required investment is estimated at $50 to $100 million for a central recycling facility, with financing potentially based on Multi-Partner Trust Funds (MPTF) or Public-Private Partnerships (PPP).

As a complementary or additional alternative, a framework called TRUST has been proposed, a joint initiative of the Arava Institute and the Palestinian organization Damour, to establish an artificial island off the coast of Gaza using approximately 50 million tons of recycled waste.[2] This island is planned to include a deep-water port, renewable energy systems, and a free trade zone. However, the artificial island initiative raises fundamental issues that require careful consideration: the choice of location, the implications for the Israeli coastline and the marine ecosystem, and its impact on sand currents. These questions, along with examining the composition of the materials for building the island, require in-depth environmental and engineering research as well as a proper regional discussion before practical advancement of the initiative.

Summary and key points

The study's insights show that post-disaster construction waste management is not purely an engineering challenge, but a strategic tool that encompasses geographical, planning, and diplomatic dimensions. The success of the reconstruction will be measured by the ability to lay the foundations for economic independence through a local recycling industry, transparent governance based on data-driven decision-making, and regional integration founded on trust and environmental partnerships. Cooperation around waste management provides a relatively neutral starting point, allowing for the advancement of issues that are perceived as less controversial than directly political issues. In this way, the treatment of waste resources becomes a practical basis for establishing long-term relationships and building trust between the various actors in the region.

2 Shared Environments, Shared Futures, A Perspective on Nature-Based and Decentralized Solutions for Gaza's Recovery, Arava Institute for Environmental Studies, September 2025 https://arava.org/wp-content/uploads/2025/09/Shared-Environments-Shared-Futures-September-2025-report.pdf

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1. Background chapter

1.1 General background and research context

The Iron Swords War, which broke out after the October 7, 2023, massacre, left an unprecedented environmental and social challenge, manifested in the enormous extent of destruction of infrastructure and buildings. Different international agencies have presented various estimates of the extent of the damage, ranging from approximately 137,000 to approximately 192,000 structures damaged to varying degrees. These gaps reflect differences in the definition of the types of damage, the time periods examined, and the methodologies for collecting and analyzing the data. Accordingly, the amount of debris in Gaza is also estimated to be a wide range of tens of millions of tons. Some estimates suggest approximately 100 million tons of debris; this number does not represent a single agreed-upon figure but rather serves as a general indication of the scope of the challenge. This study does not adopt a single estimate as a starting point but rather built the database (see Appendix 1) and also addresses quantitative uncertainty as an inherent characteristic of disaster and conflict situations.

The accumulation of construction waste in the Gaza Strip is not just a local problem but creates a cross-border environmental risk. Soil, water, and air pollution, exposure to hazardous materials and munition remnants, and the blocking of central urban spaces affect public health, hinder civil reconstruction, and deepen the social and housing crisis. In addition, the extent of the debris makes it difficult to rebuild transportation, water, and sewage infrastructure and limits the ability of displaced populations to return to safe residential areas.

This background highlights the understanding of the necessity of optimally addressing construction waste, as part of the overall regional and international effort to rebuild Gaza and achieve stability and security. Optimal waste treatment requires adopting a research and practical

approach that enables a transition from general assessments to data-based planning, while recognizing information gaps and limitations in access to the area. A quantification model developed for the current study is presented below, based on fixed spatial analysis units and graduated scenarios, and aims to reduce uncertainty, produce a consistent spatial picture of the debris, and support flexible and phased decision-making in the reconstruction processes.

As part of discussions about the region's future, the American initiative Project Sunrise was presented in December 2025, proposing a comprehensive plan for the rehabilitation of infrastructure and housing at a cost of approximately $112 billion.[3] While the initiative focuses on the physical and economic roadmap of the Gaza Strip, this study seeks to broaden the perspective toward a comprehensive spatial-regional vision. The proposed model addresses the need to manage construction waste as a resource within a circular economy system, with the understanding that waste treatment processes in Gaza have direct implications for infrastructure and budgetary planning in Israel. Due to interrelationships in the shared area, it is necessary to think about leveraging waste treatment for the benefit of the rehabilitation of communities in the entire area, while creating infrastructural synergy that serves the interests of both sides of the border.

1.2 Theoretical assumptions

The study is based on several key assumptions that define its theoretical and methodological framework:

1. **The Environment as a Security Issue:** The environmental challenges in the Gaza Strip pose a direct threat to public health and security in Israel due to the cross-border nature of pollution and its physical and political implications. Active Israeli involvement in environmental

3 Times of Israel, US said to pitch 'Project Sunrise' - $112B plan to rebuild Gaza as luxury destination, https://www.timesofisrael.com/us-said-to-pitch-project-sunrise-a-plan-to-rebuild-gaza-as-luxury-destination/, December 2025.

restoration could improve both the sanitary and security situation, thereby contributing to the long-term stabilization of the region.

2. **Feasibility of gradual reconstruction:** The discussion of reconstruction processes assumes relative security stability that allows for a transition from dealing with an ongoing crisis to gradual construction. In this context, there is a close connection between the immediate humanitarian response and the establishment of civilian infrastructure. Construction waste management is not merely a supplementary stage, but a central infrastructure component that directly affects the pace and quality of reconstruction.
3. **Building environmental peace:** There is a two-way interaction between professional cooperation and solving complex challenges. On one hand, managing resources such as waste and water serves as a functional platform for cooperation even in situations of political tension. On the other hand, the existence of joint operational mechanisms is sometimes the necessary condition for implementing sustainable solutions. In this view, the environment is an applied space of action in which shared interests precede and sometimes even enable broader processes of rehabilitation.
4. **Regional diplomacy:** The current environmental crisis is a potential arena for promoting environmental diplomacy, which assumes that common challenges require coordination even between parties that are in ongoing political tension. The extent of the damage in Gaza requires coordinated action that could serve as a basis for building trust mechanisms and reducing friction at the operational level.
5. **Israel's role as a supporter:** Israel has security and economic interests in the success of the treatment of construction waste, but it is essential that its contribution focus on assistance and professional guidance rather than ownership of the process. The knowledge and experience gained in Israel in the fields of the circular economy could contribute to the development of local solutions in Gaza, including creating sources of employment and promoting innovation in the fields of reconstruction. Such professional cooperation could support the response to urgent humanitarian needs in the Gaza Strip, while

strengthening the independent capabilities of the local population in managing its resources. Alongside the business potential inherent in reconstruction technologies, Israel must define its role as a support and advisory body rather than as the leader of the process, in order to ensure the initiative's legitimacy and stability.

1.3 The theoretical framework: circular economy and environmental diplomacy

The study is based on a combination of two main paradigms: circular economy and environmental diplomacy. The circular economy approach sees waste as a valuable resource, rather than something that must be disposed of. In the case of construction waste, this principle is expressed in turning waste into raw materials for new construction processes, which allows saving natural resources and reducing pressure on the environment, the economy, and society. In the context of the Gaza Strip, implementing the principles of the circular economy is particularly essential due to the acute shortage of land for landfill and the urgent need for construction materials for reconstruction. Environmental diplomacy, for its part, focuses on using environmental challenges as leverage to promote international and regional cooperation. This theory holds that environmental problems, due to their cross-border nature, require joint solutions and can serve as a basis for dialogue and cooperation even under conditions of political conflict. In the case of Gaza, the environmental diplomatic approach may enable Israeli involvement in reconstruction while providing international legitimacy and creating incentives for all parties.

Rehabilitation planning in the Gaza Strip should be integrated within established international frameworks for strengthening resilience and within the conceptual framework of "Build Forward Better," as exemplified in the frameworks of the World Bank, the UN, and the European Union, which are developing plans for sustainable reconstruction and economic and social consolidation alongside infrastructure construction. Large-scale initiatives that follow calculations of needs and damages, along

with demands for systemic preparedness, emphasize the importance of including construction waste management in budget planning and strategies, as physical reconstruction is only complete if it includes an active local economy that is resilient to environmental and climate risks.[4]

1.4 Specific challenges and uniqueness

The Gaza Strip poses unique challenges that require a cautious multidimensional approach. Since 2007, residents of the Gaza Strip have lived under movement and trade restrictions that have created ongoing pressure on civilian infrastructure, economic systems, and local government mechanisms. Over the years, this reality has eroded the ability to develop and maintain basic environmental infrastructure, including water, sewage, and waste management systems. Meanwhile, the institutional priorities of the Hamas terrorist regime have not allowed for the consistent development of civilian management mechanisms, including environmental regulation, infrastructure oversight, and long-term investment in waste stream management.

Alongside these internal factors, the regional context and Israeli security policy have also influenced the capacity for civil action. Restrictions on the movement of goods and professionals have made it difficult to bring in dedicated equipment and create operational continuity in the infrastructure sector. The combination of internal institutional weakness and external limitations have deepened environmental vulnerability and increased the extent of the cumulative damage.

The uniqueness of the current challenge also derives from the unprecedented scale of destruction. The amount of construction waste and its spatial concentration in such a densely populated territory are exceptional even compared to other disaster and conflict zones around the world. This scale is not just a logistical challenge but an expression of an ongoing crisis of the lack of managerial and regulatory infrastructure

4 The World Bank, European Union, and United Nations. Gaza and West Bank Interim Damage, Losses, and Needs Assessment (IRDNA). February 2025

to handle material flows of exceptional proportions.

Another unique difficulty concerns the waste located underground, and in particular the system of tunnels and spaces that have been damaged or collapsed. The treatment of this waste involves exceptional engineering and security risks, and in the absence of precedents on similar scales, it suffers from a lack of professional knowledge and prior experience. Therefore, this study focuses on surface waste, leaving the subsurface issue for future dedicated research.

Understanding this complexity is essential for formulating applicable action frameworks. The study proposes mechanisms for gradual, supervised action based on environmental, planning, and diplomatic considerations, with the aim of promoting civil stability and sustainable reconstruction. Given World Bank estimates indicating a reconstruction process that will last until 2040 at least and cost tens of billions of dollars, strategic planning is necessary that combines international involvement and the development of innovative economic models to ensure financing and sustainability over time.

1.5 The study's justification and innovation

The study presents an innovative paradigm that combines advanced mapping technologies, strategic planning, and environmental diplomacy. This is a first-of-its-kind model for managing construction waste resources in the Gaza Strip – a critical issue that has not yet been comprehensively addressed in professional literature or planning practice in the Middle East. The original integration of environmental, economic, and political dimensions creates a pioneering knowledge infrastructure for understanding crisis management in complex conflict zones. The study bridges gaps between different fields of knowledge and develops an integrated model with global replication potential, which can serve as a model for environmental and economic planning in conflict zones and in areas that have experienced large-scale natural disasters.

The study's methodology is unique in its multidimensional approach that successfully combines complex academic theories with empirical research in the field. The work process included in-depth interviews with international experts, comparative analysis of global case studies, and holding multidisciplinary brainstorming sessions with a variety of professionals (see Appendix 1). This combination strengthens the feasibility of the proposed solutions, with the aim of making them economical, applicable, and highly adaptable to the changing geopolitical reality.

Beyond its scientific contribution, this study constitutes a strategic and diplomatic asset that sets a new standard for environmental innovation in the Middle East. While many reconstruction plans focus on rebuilding, this paper proposes turning the destruction itself into an engine of growth and hope, outlining a vision in which a circular economy serves as a bridge for regional cooperation. The study's ability to transform a huge environmental challenge into an economic and infrastructural opportunity makes it a cornerstone in any future effort to create stability, sustainability, and sustainable reconstruction throughout the region.

1.6 Methodology and research process

This paper is based on a multidisciplinary research process carried out by a research group initiated by Adi Mager in collaboration with the Mitvim Institute and the Frances Brody Institute for Applied Diplomacy at Tel Aviv University.[5] The methodology included a combination of quantitative data analysis and in-depth qualitative work alongside a series of roundtable meetings and consultations with experts in planning, the environment, industry, and policy in Israel. This process made it possible to formulate an innovative model that examines not only the physical aspect of optimal management of construction waste,

5 Special thanks to Bar Rapaport, Project Manager for Climate Diplomacy at the Mitvim Institute, for her guidance and professional contribution to the research, as well as to Prof. Amir Lupovici, Head of the Brody Institute for Applied Diplomacy at Tel Aviv University, for his professional support.

but also the political and economic potential inherent in it, while relying on the most recent damage and needs assessments (Appendix 1 details the team, methodology, and description of the meetings held).

2. Conceptual framework

2.1 Introduction: The geopolitical and environmental context of the Gaza Strip

The current environmental crisis in the Gaza Strip is not the product of a single event, but rather the cumulative result of ongoing geopolitical, civil, and environmental processes. Since 2007, the Gaza Strip has been subject to restrictions on movement, trade, and accessibility, which have long affected the functioning of civil systems, the local economy, and the development of basic infrastructure. This reality, along with the recurring rounds of fighting, left behind significant amounts of construction waste and damaged infrastructure, some of which was not fully dealt with over the years. This accumulation has exacerbated Gaza's structural and environmental vulnerability, increasing the complexity of the current challenge of removal, recycling, and reconstruction on an unprecedented scale. This reality has created ongoing pressure on environmental management systems, including waste treatment, water, sewage, and electricity, and has limited the ability to develop long-term planning, regulatory, and maintenance mechanisms.

At the same time, the Hamas terror regime in the Gaza Strip has shaped institutional and operational priorities that have not allowed for the consistent development of civilian governance mechanisms, including environmental management systems, infrastructure oversight, and ongoing investment in public infrastructure. The gap between growing civic needs and limited institutional capacity has contributed to the accumulation of structural failures in the management of urban and environmental space, including the optimal handling of construction waste from new construction of buildings and infrastructure, renovations, and demolitions.

Alongside these internal factors, the regional context and Israel's security policy towards the Gaza Strip also affected the ability to manage civilian

systems. Restrictions on the movement of materials, equipment, and professionals, alongside security oversight mechanisms, have reduced the scope for developing environmental infrastructure and implementing advanced technological solutions. The combination of external constraints and internal institutional weakness created a reciprocal system of influences that deepened environmental vulnerability and increased the extent of cumulative damage over the years.

The war broke out in October 2023 within this context, leading to widespread destruction on an unprecedented scale. According to various estimates, over 150,000 buildings were damaged to varying degrees, entire neighborhoods were damaged, and key civilian infrastructure collapsed or ceased to function. The scale of the destruction created exceptional amounts of debris, along with soil, water, and air pollution, exposure to hazardous materials and munition remnants, and serious damage to the functioning of waste, sewage, and water management systems. These environmental consequences are not confined within Gaza's borders. Marine pollution, damage to the coastal aquifer, the drift of contaminants, and the spread of environmental hazards are cross-border in nature, affecting the entire region. In this sense, the environmental crisis in Gaza constitutes not only a local humanitarian challenge, but also a regional and international issue with long-term implications for public health, civil stability, and environmental security.

Against this backdrop, the current project focuses on construction waste in the Gaza Strip and integrates environmental, planning, and diplomatic perspectives. The study does not just analyze the crisis; it seeks to frame it as a turning point: a shift from a perspective of destruction and damage to a perspective of infrastructure for regional cooperation, building trust mechanisms, and sustainable reconstruction based on knowledge, data, and long-term planning.

2.2 The dual challenge: Construction waste poses an ecological and logistical challenge in the absence of supporting infrastructure for optimal treatment.

The amount of debris in the Gaza Strip is unprecedented in relation to its size, building density, and the existing infrastructure capacity. These conditions pose a dual challenge with characteristics unique to this waste stream. First, the ecological and logistical challenge: the construction waste consists of exceptional volumes and masses of mixed materials that include mineral components, metals, wood and polymers, alongside hazardous materials such as asbestos and munition remnants. In some cases, bodies are also trapped in rubble, a fact that intensifies the human and sanitary complexity. Because of these characteristics, the removal, sorting, and treatment of waste pose considerable environmental and health risks and require the implementation of dedicated protocols and advanced operational capabilities.

Second, the critical lack of supporting infrastructure: the widespread destruction of water, sewage, energy, and transportation systems significantly reduces the ability to implement traditional treatment methods, such as transportation to remote sites or the establishment of centralized recycling centers. In the absence of functioning infrastructure, construction waste itself becomes a physical barrier to reconstruction in general as it blocks traffic routes, delays infrastructure work, and increases ongoing environmental risks.

Thus, it should be emphasized that the establishment and operation of recycling facilities cannot be carried out in isolation from processes of rebuilding basic infrastructure. The availability of water, energy, and access roads is a prerequisite for the proper operation of recycling systems on the required scale. Without these conditions, the operational, economic, and safety feasibility of doing so is fundamentally compromised. Hence, construction waste management is not a secondary or supplementary phase of reconstruction, but rather a fundamental component of the strategic planning itself, requiring an integrated and phased approach adapted to the limitations on the ground.

2.3 Rehabilitation of infrastructure as leverage for environmental diplomacy and economic growth

This study is based on the "Build Forward Better" (BFB) strategy, which sees construction waste as a strategic resource and not (just) an environmental burden. Through smart management and advanced recycling, it is possible to produce local raw materials, drive a green economy, and create tens of thousands of jobs. This process turns the reconstruction challenge into a lever for stability, long-term independence, and the establishment of necessary communication channels between the sides.

Beyond the industrial aspect, the joint treatment of waste streams constitutes a platform for applied environmental diplomacy. The need for cross-border logistical and operational coordination requires the building of trust mechanisms and direct communication between international partners, professionals in Israel and in the Gaza Strip. This cooperation, based on clear environmental and economic interests, may serve as a foundation for regional stability and the establishment of long-term professional relationships that would serve the security and civilian interests of the various sides in the region.

According to estimates based on conversations with representatives of the recycling industry in Israel, the volume of construction waste generated in Gaza by the end of 2025 is estimated at approximately 75 million tons. This quantity reflects the demolition of approximately 190,000 buildings covering approximately 50 million square meters. Given this scale, an integrated industrial model is proposed that includes demolition, sorting, and production of concrete products from the waste itself. This model is an alternative to traditional landfilling, which is accompanied by environmental damage, and reduces dependence on the external supply of aggregates. Technological feasibility also exists for full recycling of waste for the purpose of producing standard concrete. The economic potential is estimated at approximately $7.5 billion, of which approximately $2.5 billion for demolition and treatment

operations and approximately $5 billion for recycling and manufacturing products.

A pilot model for Rafah, where there are approximately 12 million tons of construction waste, presents an operational plan for establishing a recycling plant with an investment of approximately $15 million. The plant has a treatment capacity of approximately 4.5 million tons per year and a production capacity of approximately 500,000 cubic meters of green concrete. Incorporating a tender mechanism that requires the use of recycled material may position demolition management not only as a response to an environmental need, but as a central infrastructural and economic engine in the reconstruction of the area.[6]

6 Based on a series of in-depth interviews and personal correspondence with managers and senior professionals in the construction waste recycling industry in Israel, which took place in 2025. The interviewees' details are retained on file.

3. Construction waste in Gaza: data, environmental implications, existing technologies and adoption of a circular economy model

3.1 Methodology for environmental mapping of rubble and construction waste in the Gaza Strip

Optimal treatment of construction waste begins with collecting data and understanding the situation. This chapter presents the data set, the calculation method, and the final products of the estimate of demolition waste by region and various material streams as part of construction waste, i.e., concrete, metals, etc. The calculation is based on a combination of material composition definitions for each type of structure, data on the built area in each hexagon, and conversion factors from built material to volume/mass of demolition waste.

The calculations were performed at two complementary levels: on the first level, the composition of the demolition waste was calculated for each hexagon by material, and in the second level, quantification was performed by materials, so that both a local (spatial) picture and a national summary could be obtained. The calculation method was formulated to make it easy to switch between different scenarios – minimum, median, and maximum – for material composition definitions. The existing equations were defined for minimum values, but built modularly: changing the input column (e.g., moving from a minimum column to a median column) and automatically updating the demolition waste results at each level of detail. This approach allows for examining sensitivity to deviations in material composition and highlighting the natural uncertainty in the data.

Spatially, each hexagon represents a fixed analysis unit with an area of 0.25 square kilometers. For each hexagon, information was collected on the area of the buildings identified as destroyed and the average height of the destroyed buildings within it was calculated. This was translated into the number of floors, type and extent of construction, i.e. single-story and multi-story residential, industrial and agricultural buildings. The composition of demolition waste by material was then calculated for each hexagon. This results in a continuous map of potential waste, which can be displayed in three scenario modes: minimum, median, and maximum. These maps highlight major load centers and allow identification of areas where a high concentration of concrete, steel, and other materials is expected to occur.

The analysis focused on residential, agricultural, and industrial areas. Demolition waste was not calculated for greenhouses, since the available data for them does not provide reliable and consistent information on the composition of the materials. This decision maintains methodological consistency: only categories for which valid and comparable material composition data exist were included in the model. Accordingly, the waste estimate focuses on conventional construction and the types of buildings that account for the majority of the total mass.

The analysis shows that a limited number of materials, primarily concrete and metals, constitute the bulk of the calculated demolition waste mass. The gap between the minimum scenario and the median and maximum does not stem from a change in built-up area, but from differences in assumptions regarding the density and composition of materials per built-up meter. This finding emphasizes the high sensitivity of the estimate to assumptions regarding rates of concrete, steel, and other materials, and their direct impact on the volume of waste and the planning of the collection, sorting, and treatment system.

Appendix 2 details the final calculations on which the study is based, and systematically presents the data structure, mapping system, and methodology used to transition between the various reconstruction

scenarios. The appendix includes an analysis of the maps and graphs derived from the processing of the spatial data (for an extensive and visual overview of the research findings, which includes interactive spatial analysis and advanced data mapping using GIS story maps – for the Hebrew research site: click here | for the English research site: click here

3.2 Results of the analysis

This section presents the methodological framework for calculating construction waste estimates, incorporating spatial mapping, data analysis, and assumptions regarding material composition. The model begins with comprehensive GIS mapping, which uses satellites and artificial intelligence (AI) to quantify, sort, and analyze the debris, presented through a GIS story map. The mapping method is based on:

A. Hexagon model: Use of a hexagonal model to assess damage and masses at spatial resolution.

B. Database: Satellite data, UNOSAT layers and OpenStreetMap.

C. Calculating an estimate: For each hexagon, an estimate of the built-up area identified as destroyed was calculated, as well as the average height of the buildings.

3.3 Spatial estimation of demolition waste in Gaza in three scenarios

The following three maps present a systematic estimate of the rubble waste in the Gaza Strip for 2025, in three quantitative scenarios: minimum, median, and maximum. All maps use a division into spatial hexagons that represent the estimated mass of debris from collapsed structures. The division makes it possible to distinguish between areas with a low destruction load and areas with a high load, mainly around Gaza, Jabalia, Khan Yunis and Rafah. The minimum and median maps show a similar spatial pattern at different scales, while the maximum map highlights areas

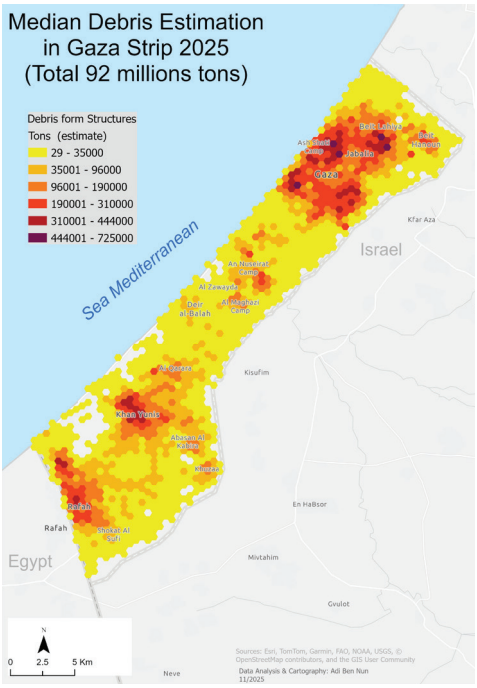
where the estimate indicates higher concentrations of destruction, up to hundreds of thousands of tons in a single hexagon.

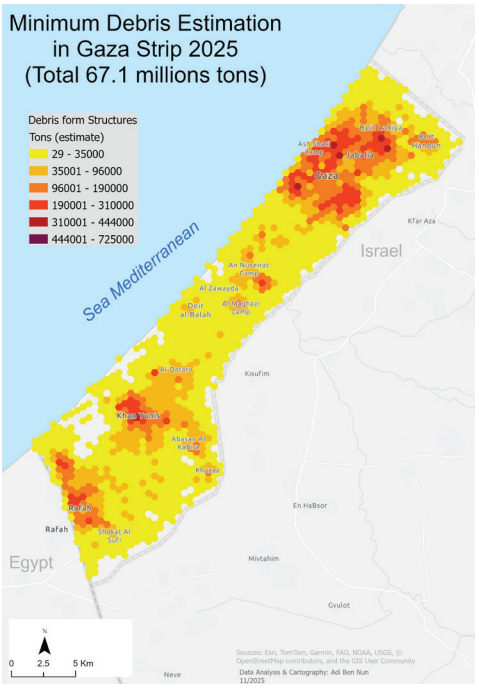
The minimum map (67.1 million tons) shows a broad distribution of destruction at relatively low loads, with clear focal points in the north of Gaza around Jabalia, Gaza, and Beit Lahia, and in the south around Khan Yunis and Rafah. In the median map (92 million tons), those areas become denser, and the volume of waste in the hexagons increases according to the color gradients, indicating an increase in the mass of material to be managed. In the maximum map (126 million tons), a pattern of concentrations of destruction in the north and south becomes more pronounced, with high density around central Gaza, Jabalia, and Khan Yunis, and particularly high values in Rafah. In addition, an orientation map is attached showing the administrative division into districts in the Gaza Strip and their relative location in the area.

The mapping presented in this paper is based on the data infrastructure of the United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA), which is the authoritative and neutral source accepted by the international community for this regional mapping. The map accurately preserves the administrative division into the five official governorates as defined by the Palestinian Central Bureau of Statistics (PCBS): North Gaza, Gaza, Deir al-Balah, Khan Yunis, and Rafah. Note that any additional internal division shown on the map is intended for the methodological needs of this study only, i.e., for the purpose of analyzing concentrations of waste and debris, and does not represent new municipal boundaries or a division that differs from the international status quo.[7] Comparing the three scenarios highlights the quantitative uncertainty between the estimates, alongside the spatial stability of the focal points of the destruction: the northern and southern regions remain the most congested in each scenario, indicating the need for a differential approach in terms of logistics, treatment, reconstruction, and infrastructure prioritization.

7 Special thanks to Dr. Adi Ben-Nun from the Hebrew University for his advice and expertise in the field of GIS, and to architect Hadasa Lev, CEO of WALK, for developing the dynamic applications and integrating the data using story maps; and to Dr. Tomer Fishman, an external consultant specializing in the circular economy, for his contribution to the data analysis.

The following table presents the baseline data that the model relies on to calculate waste estimates:





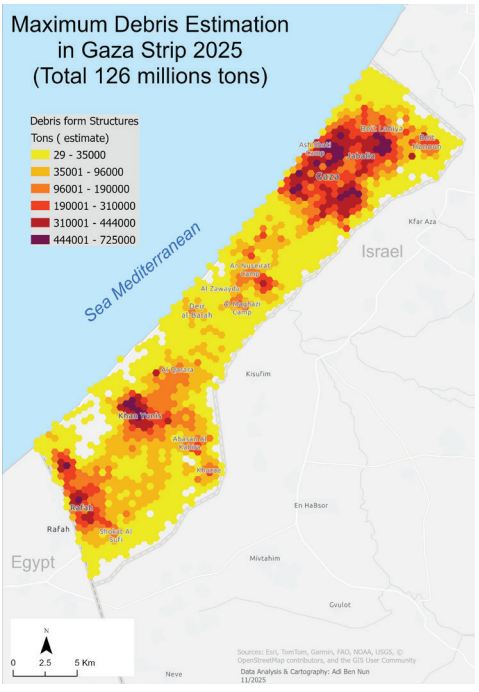


Table No. 1: Key damage data (as of August 2025)

parameter	value
Destroyed buildings	Approximately 160,000 buildings
Construction waste	snot noillim 621-76
Damaged roads	Approximately 3,045 km

*** Source:** Developed and processed by the research team as part of this report.

In terms of the geographical distribution of waste, estimates indicate approximately 53.4 million tons of waste, concentrated in the following distribution: the northern Gaza Strip - 35 percent; the central Gaza Strip - 39 percent; and the southern Gaza Strip - 26 percent. The mapping identifies the critical need for the reconstruction of primary transportation infrastructure as a prerequisite for effective waste removal.

The following table presents the estimated number of destroyed buildings and the volume of construction debris by district, in three calculated scenarios: minimum, median, and maximum:

Table No. 2: Estimate of destroyed structures and debris volumes by district and scenario (minimum, median, maximum)

District	Number of destroyed buildings	Minimum waste (million tons)	Median waste (million tons)	Maximum waste (million tons)
Deir Al-Balah	15641	5	7	10
Gaza	41424	25	35	47
Khan Younis	44828	15	20	28
North Gaza	27576	12	16	22
Rafah	29663	10	14	19
Total	**159132**	**67**	**92**	**126**

*** Source:** Developed and processed by the research team as part of this report.

The following table details the composition of construction waste by type of material and divided into the three scenarios, and highlights the contribution of each material to the total mass:

Table No. 3: Breakdown of construction waste composition by type of material and scenario (in millions of tons)

Scenario	Concrete	Steel	Glass	Polymers	Copper	Aluminum	Total (million tons)
Minimum	63.82	3.10	0.16	0.04	0.01	0.01	**67.13**
Median	86.96	4.58	0.22	0.11	0.02	0.04	**91.92**
Maximum	116.86	8.47	0.36	0.27	0.02	0.10	**126.09**

*** Source:** Developed and processed by the research team as part of this report.

To make complex findings accessible and transform them into an applied tool, an interactive GIS platform (story map) was developed for the study. This bilingual platform allows policymakers and professionals to dynamically examine layers of information, the extent of the

destruction, and potential reconstruction scenarios. The map combines 3D models and advanced spatial analyses that are a central part of the decision-making process. A full breakdown of the map features, visual methodology, and references to the interactive applications appear in Appendix 2.

3.5 Assessment of environmental and health risks without proper treatment

The exceptional volumes of waste in the Gaza Strip pose ongoing environmental and health risks, requiring urgent intervention in two main spheres:

First, exposure to hazardous materials (hazmat) and munition remnants: The ruins of the buildings contain asbestos, heavy metals, and unexploded ordnance (UXO). The presence of these materials requires strict implementation of international protocols for removal and safe storage. The current study adopts lessons from countries that experienced similar devastation, such as the model implemented in Sri Lanka, which emphasizes the need for rigorous initial screening to prevent exposure of work teams and the population to contaminants and UXO.[8]

Second, dumping waste into the sea and water contamination: The collapse of water and sewage infrastructure leads to the massive flow of untreated wastewater into the Mediterranean Sea and the seepage of contaminants from areas with rubble into the groundwater. These processes cause irreversible damage to the marine ecology, the fishing industry, and public health in the entire region.[9] Construction waste treatment cannot be separated from water infrastructure reconstruction;

8 United Nations Secretary-General. (2011). Report of the Secretary-General's Panel of Experts on Accountability in Sri Lanka. United Nations. Available via UN Digital. (n.d).

9 EcoPeace Middle East. (2025). Pre-feasibility study: The humanitarian and trade corridor Jordan-West Bank-Israel-Gaza. Policy report, EcoPeace Middle East. Published September 30, 2025.

as long as the basic systems are not functioning, the waste removal and recycling work is carried out in a contaminated environment that poses a high risk threshold. Therefore, integrated planning is required that sees the treatment of debris and the reconstruction of infrastructure as complementary and necessary conditions for reducing environmental contamination. Within this framework, the study examines the feasibility of the Kuwait Environmental Remediation Program (KERP) model. This large-scale program, established to address the damage of the Gulf War, demonstrated that environmental restoration requires regional cooperation and complex operational mechanisms. Similarly, the current study recommends adopting a broad regional approach to enable the growth of a local recycling industry, ensure optimal treatment of hazards, and form the basis for sustainable reconstruction of the area.[10]

3.6 Turning ruins into resources: A circular economy reconstruction strategy

The changing geopolitical and environmental reality in the Gaza Strip following the protracted conflict, which began in October 2023 and lasted for over two years, poses unprecedented challenges in the history of modern reconstruction of conflict zones. The scale of the physical destruction is not only a humanitarian catastrophe – it also creates a critical opportunity for implementing innovative circular economy models. The transition from a linear model of 'take-produce-dispose' to a circular approach based on pre-planning, separation of waste streams, recycling and reuse of debris is not only an environmental goal but a strategic necessity stemming from the severe shortage of land resources and imported raw materials.

The scale of the destruction in the Gaza Strip is one of the densest

10 United Nations, "Iraq Makes Final Reparation Payment to Kuwait for 1990 Invasion," UN News, February 9, 2022; Al-Barood, A., Al-Kandari, H., & Vedhapuri, S. Kuwait Environmental Remediation Program (KERP): Criteria for Site Selection and Expected Benefits of The Revegetation Projects.

and most extensive destruction events of the 21st century. This concentration creates an unprecedented logistical and safety burden but also holds significant potential for local processing of waste and production of secondary raw materials. Rebuilding the Strip requires a combination of technological innovation, customized regulations, and international cooperation. Advanced tools such as GIS-based mapping, drone photography, and artificial intelligence allow materials to be classified and treatment sites to be optimally planned, while dedicated protocols address critical issues of ground stability, movement restrictions, and neutralizing unexploded ordnance.

The circular economy strategy proposes a transition from a linear model of production and disposal to a model based on value recovery. In the Gaza Strip, where the amount of debris is estimated at tens of millions of tons, a significant portion of the waste can be recycled and materials returned to the construction cycle. This process includes source sorting and separation of materials, crushing concrete into recycled aggregate, and recovering metals - operations that may lead to a reduction in dependence on importing new raw materials.

Recycled aggregate, for example, is a key resource that can be re-incorporated into road construction, as a base for sidewalks, and as a component in the production of new concrete. Similarly, the reinforcing steel recovered from the rubble can be melted down and reused in industry, while fill and reconstruction materials are used for land leveling and building earthen embankments. Complete components that can be restored, such as doors and windows, may be reintegrated into community construction and streamline reconstruction processes.

The transition to a circular strategy offers an economic value of hundreds of millions of dollars, alongside savings in disposal costs and reductions in greenhouse gas emissions. However, realizing this potential is contingent on a customized regulatory infrastructure, control mechanisms, and logistical coordination that takes into account the risks on the ground. A combination of technological innovation,

economic incentives, and supportive policies is the condition for establishing sustainable restoration throughout the area.

3.7 Resource management strategy and technological innovation

Turning construction waste into a strategic resource requires the implementation of advanced circular economy technologies. In order to achieve an ambitious recycling target of 70 to 90 percent, it is proposed to establish between three and five central recycling sites in the Gaza Strip equipped with modern infrastructure, including mobile shredders, magnetic separators, and optical sorting systems. Recycled products, including recycled aggregates and concrete blocks, may constitute high-quality alternatives to natural gravel, thereby contributing to reducing import costs and promoting material independence in the construction process.

Effective management of construction and demolition waste in exceptional volumes and under complex conditions requires, first and foremost, accurate mapping of the situation on the ground. To this end, the study utilizes a model developed and based on artificial intelligence (AI), which relies on decoding drone and satellite photographs using advanced image analysis algorithms. The system makes it possible to identify, classify and quantify the various waste components such as metals, wood, mineral components and polymers and translate raw visual information into a dynamic and up-to-date resource map.

For policymakers and professionals, this tool represents a paradigm shift from treating decentralized and unidentified waste to organized data management that enables informed planning, task prioritization, and data-based decision-making. The model demonstrates how artificial intelligence technologies transform academic research into an applied platform, supporting smart environmental management and promoting a circular economy even in the most challenging contexts of

regional reconstruction and development.[11]

3.8 Developing integrated models for a circular economy for construction waste

International experience in the reconstruction of destroyed areas shows that construction waste is not just a stream for industrial recycling, but a direct resource for rebuilding. After the earthquake in Haiti, concrete rubble was used to produce aggregates for infrastructure and temporary housing. In Japan, after the 2011 tsunami, construction waste was processed and incorporated into infrastructure projects, protective embankments, and shoreline reinforcement. In Europe, countries such as the Netherlands and Germany incorporate recycled aggregates in structural concrete and road paving as part of mandatory building standards. These examples indicate that, subject to appropriate regulation and quality control, recycled materials can be incorporated into permanent construction and not just temporary applications.

In this study, two complementary theoretical frameworks were used to guide the reconstruction process. First, the concept of Build Forward Better (BFB), which originates from international standards for recovery from crises and disasters of the European Union, serves as a visionary framework that strives to rebuild in a more resilient and equitable way than the pre-conflict situation.[12] Second, for the specific treatment of construction and demolition waste (CDW), the study adopts and

11 Mager, A., Gorun, A., Tsur, Y., Shahar, M., & Blass, V. (2025). Identifying materials in spatial unauthorized waste sites for local circular economy enhancement. Resources, Conservation and Recycling, 215, 108163. https://doi.org/10.1016/j.resconrec.2025.108163; Adi Mager, The Artificial Intelligence That Will Clean Up Open Space Street Language Magazine. (May 2025)

12 European Parliament, The use of Cohesion Policy Funds in natural disaster response and recovery, Policy Department for Regional Development, Agriculture and Fisheries, PE 776.002, January 2026; Food and Agriculture Organization of the United Nations (FAO) (2020), Building Forward Better: Strengthening local human capital in fragile countries, https://www.fao.org/land-water/news-archive/news-detail/en/c/1321723

emphasizes the Build Back Circular (BBC) approach.[13] This approach focuses on circular economy (CE) applications and centers around the principles of waste reduction, closing material loops, and reusing debris as a strategic resource. While BFB defines the broad goal of regional stability, BBC constitutes the operational and methodological tool that enables the realization of sustainable reconstruction in practice.

Rehabilitation after extensive destruction is taking place while facing the challenges of the climate crisis. Construction based on recycled materials reduces emissions associated with mining, cement production, and transportation. The Build Forward Better principles, developed as part of a disaster risk reduction policy by the United Nations and the World Bank, emphasize that rehabilitation is not limited to rebuilding structures, but requires adapting to the future: improving thermal insulation, managing runoff to prevent flooding, and spatial planning that reduces energy consumption. Combining a circular economy with climate-friendly planning makes it possible to turn a reconstruction process into an opportunity for upgrading systems.

The proposed economic model is based on the principles of the circular economy, which seeks to preserve the value of materials over time and reduce dependence on virgin raw materials. In contrast to the linear model of production and disposal, the circular approach sees waste as a resource with economic and environmental value. The model is guided by the expanded R6 hierarchy, which determines the order of priorities for action:

1. Reduce – Reducing waste generation from the planning and execution stage.
2. Reuse – Utilization of entire components without further substantial processing.
3. Recycle – processing waste into new raw materials.
4. Recover – Extracting energy or resources from materials that cannot be directly recycled.

13 Çetin, S., & Kirchherr, J. (2025). The Build Back Circular framework: Circular economy strategies for post-disaster reconstruction and recovery. *Circular Economy and Sustainability*, 5(3), 1689–1726.

5. Redesign – Designing buildings and products so that they allow for future disassembly, separation, and recycling.
6. Remanufacture – The production of new products using dismantled or recycled components.

Recycled aggregate, for example, is a granular material produced by crushing, screening, and sorting concrete, bricks, and asphalt. The processed products serve as a substitute for natural quarry materials, such as gravel and sand, in a wide range of applications: from the production of new concrete to road base layers, infrastructure filling and earthworks. Systematic reviews indicate that the mechanical properties of concrete based on recycled aggregate, including compressive strength and durability, meet the most stringent standards, provided that an appropriate mix design is used. Studies have shown that using high replacement rates of recycled aggregate is an achievable application from both an engineering and economic perspective.

In addition, there is strong potential for recycling additional components from the debris: metals – steel bars and scrap are collected and remelted, with significant energy savings compared to primary steel production; wood – wood waste can be shredded and processed for a variety of uses such as engineered wood panels, raw material for the paper industry, or as a renewable energy source for the production of thermal energy; glass and ceramics – these materials can be processed into decorative panels, cladding and mosaics, thereby contributing to higher-value resource recovery (upcycling).

In conclusion, effective management of construction and demolition waste after a disaster is not limited to removal and landfilling, but strives to return the materials to the production cycle and turn them into a strategic resource. The professional literature emphasizes that wise management of waste streams is intended not only to reduce environmental and health risks, but also to enable the utilization of rubble as a source of aggregates, metals, and secondary materials. This approach reduces dependence on natural resources, reduces

transportation costs, and accelerates the pace of spatial reconstruction.

In the past year, thousands of Gazans have been employed in the manual mining of iron and concrete from the rubble, a sector that has become one of the main employment engines in the Strip and is conducted under three main vectors: private demolition contractors who exploit the reserves of debris as available raw material and pay a low daily wage (about 30 NIS) for the extraction of iron intended for construction repairs; United Nations employment programs; and independent initiatives by residents who mine iron from the ruins of their homes to make a living. Alongside this activity, and despite losing control over about half of the Strip's territory, Hamas continues to be a significant economic player operating in a parasitic "shadow economy"; the organization exploits its control over the population and the lack of an IDF military presence in certain areas to collect "security fees" from aid trucks using armed men, and to seize goods in order to sell them on the black market or distribute them to its associates.[14] Alongside these challenges, models for establishing temporary residential complexes in the southern Gaza Strip, and in particular in the Rafah area, are currently being examined within the framework of the "New Gaza" model. This model includes land examination, coordination with pre-approved local contractors, and management of the system through a third party. These processes emphasize that the work of reconstruction is not limited to clearing rubble, but involves reorganizing the area, regulating infrastructure, and political-security decisions with long-term strategic implications.[15]

14 Doron Peskin, *Calcalist*, "Gaza's Economy: The Markets Are Open, the Restaurants Are 'Instant', and the Contractors Are Prospering." February 2026.

15 Nitzan Shapira, *N12 News*, "The New Gaza": Israel Is Working in Coordination with Gazan Contractors to Prepare Land for the Next Phase of the Agreement. December 2025.

4. Social aspects

4.1 The impact of construction waste accumulation on public health and the urban environment

The accumulation of waste in the Strip causes environmental contamination, increases health risks such as respiratory diseases and infections, and deepens the humanitarian crisis. Addressing these risks requires comprehensive environmental and health planning, not just physically clearing the rubble. The following table presents the estimate of the main economic and health damage resulting from the debris crisis, according to the World Bank's assessment:[16]

Table No. 4: Economic and health damage data, according to World Bank estimates (IRDNA, February 2025):

Sector	Damage ($ billion)
WASH infrastructure	4.9
Health	1.53
GDP impact / Total GDP damage	**80% of 2023 GDP**

The cumulative damage to core infrastructure has broad social and economic implications. The accumulation of waste, amounting to approximately 330,000 tons of solid waste, creates widespread environmental contamination and significantly increases health risks, including respiratory diseases and infections, against a backdrop of poor sanitation and infrastructure conditions. The damage is particularly noticeable in two critical sectors: WASH (water, sanitation, and hygiene)

16 The World Bank, the European Union, and the United Nations. (February 2025). Assessment of Damage, Losses and Needs for Gaza and the West Bank (IRDNA) - Interim Assessment.

infrastructure, in the amount of $4.9 billion, and the health system, in the amount of $1.53 billion.

The overall economic impact of waste accumulation in Gaza is estimated to be equivalent to approximately 80 percent of the gross domestic product (GDP) in 2023. In addition to the physical damage, the rubble and debris undermine the social and economic fabric, delay a return to normality, and prolong the humanitarian crisis. A lack of basic infrastructure weakens access to essential services and requires a systemic approach that combines infrastructure rehabilitation, health services, and long-term environmental planning.

4.2 Principles of community-led rehabilitation and integrating the population

The "principles of reconstruction" in this context are not limited to the removal of rubble and the physical construction of buildings, but rather define a multi-system process that includes institutional, social, and economic rehabilitation. The overarching goal is to build long-term resilience and create conditions for lasting stability. Accordingly, the reconstruction process must be based on a community-driven model (ODHA – The Owner-Driven Housing Assistance).This model is essential to the success of the campaign as it transfers responsibility and ownership of decision-making to the local population.[17] This empowerment generates broad legitimacy, especially when it integrates the community into debris removal and recycling projects, which generate temporary employment and economic continuity. The need for a flexible, community-based model is emphasized given the unprecedented extent of the destruction. As of January 2025, the amount of direct physical damage alone is estimated at approximately $29.9 billion. The housing sector was hardest hit, with damages

17 Gunasekara, V., Philips, M., Romeshun, K., & Munas, M. (2016). Life and Debt: Assessing the Impacts of Participatory Housing Reconstruction in Post-Conflict Sri Lanka. Stability: International Journal of Security and Development, 5(1), 10.

totaling approximately $15.8 billion, accounting for about 53 percent of the total damage. Next are the economic-manufacturing sector, which suffered approximately $6.8 billion damage, and the infrastructure sector, which recorded damage totaling over $4.9 billion. Meanwhile, the city's water, sanitation, and environmental (WASH) infrastructure suffered damage estimated at $1.53 billion, accounting for about 5 percent of the total destruction. To illustrate, the value of physical damage alone is approximately 80 percent higher than the combined annual gross domestic product (GDP) of the West Bank and Gaza Strip in 2023, which was approximately $17.4 billion. Alongside the extent of the destruction, the reconstruction process itself requires a complex approach to dealing with polluting construction waste, with the cost of recycling and disposal alone estimated at approximately $1.9 billion.[18]

In addition, a well-known UN-Habitat approach to urban and community rehabilitation after conflict or disaster is the People's Process, which places the affected population at the center of the recovery and rebuilding process. This approach incorporates the voices, needs, and positions of residents into planning and implementation, through mapping needs at the community level, analyzing solutions together with residents, and developing plans that stem from participatory dialogue. In this context, it is emphasized that understanding local priorities and the community's contribution to the rehabilitation process is a condition for achieving sustainable results. Accordingly, Gaza can design reconstruction actions that do not amount to technical solutions alone, but rather reflect the social, economic, and environmental priorities of local communities, thereby creating a central component in building long-term resilience of communities and housing.[19]

18 Maghen, L. (July 2025), Sustainable Reconstruction: Lessons from the World for the Gaza Strip. The Political-Security Unit of the Berl Katznelson Foundation and the Mitvim Institute.

19 UN-HABITAT, The People's Process in Post-Disaster Reconstruction, United Nations Human Settlements Programme, 2007.

In Bosnia, a complementary aspect was demonstrated through the Property Law Implementation Programme (PLIP), a legal-administrative initiative designed to enable minorities and displaced people to return to their homes and receive restitution or compensation for their property taken during the conflict. The plan implemented a systematic mechanism for examining property rights, collecting data, and consistently pressuring local authorities to implement decisions, thereby allowing approximately 470,000 people to return to their homes. This experience teaches that post-conflict reconstruction is not limited to physical reconstruction; it also requires the restoration of legal, institutional, and social systems, as a condition for long-term stability and ongoing community integration.[20]

These lessons reinforce the need to establish dedicated financial mechanisms for environmental restoration, which combine a closed budgetary framework, multi-year planning, and long-term monitoring and measurement mechanisms. A prominent example of this is the Kuwait Environmental Restoration Program (KERP), which was established after the Gulf War to address widespread pollution damage, including oil well fires and soil contamination. The plan was based on a designated fund with international funding within the framework of the United Nations Compensation Commission, and included planning for multi-year rehabilitation phases, supervised tenders, ongoing environmental monitoring, and transparent reporting on progress. The Kuwaiti case demonstrates that large-scale environmental rehabilitation requires a stable institutional framework, guaranteed funding, and long-term oversight mechanisms, in order to ensure not only physically addressing damage but also strengthening institutional and economic resilience. In Ukraine, since 2022, government digital platforms such as Diia have been used for transparency, reporting, and public engagement in reconstruction processes and resource allocation.[21] These cases show

20 United Nations High Commissioner for Refugees (UNHCR). (2004). Returns to Bosnia and Herzegovina reach 1 million.

21 World Bank, Ukraine Third Rapid Damage and Needs Assessment. August 2022.

that decisions regarding the return of communities, the restoration of historic sites, and renewed spatial planning require broad participatory mechanisms.

Rehabilitation based on optimal management of construction waste in the Gaza Strip may serve as a lever for large-scale individual and community rehabilitation. Decisions regarding the reconstruction of residences, the restoration of communities, and the preservation of historic sites are those that renew the connection between people and places. Therefore, focusing on recycling rubble is not only an environmental act but also a basis for revitalizing living spaces, creating sources of employment, and strengthening the well-being of residents. To translate this vision into reality on the ground, it is now necessary to examine the economic feasibility of the model and the conditions for establishing stable and sustainable markets for recycled raw materials, topics that will be discussed in the next chapter.

5. Economic aspects, financing and market development

5.1 The economic model as a response to the climate crisis and local growth

Recycling construction and demolition waste (CDW) is not limited to responding to a specific environmental need, but rather constitutes an engine for local growth and strengthening economic independence. Moving to a circular economy creates employment opportunities in the sorting, processing, and manufacturing industries, and significantly reduces dependence on imported raw materials. International reports emphasize that developing local value chains around recycling contributes to strengthening the urban economy and is a key tool in the fight against the climate crisis. Using recycled materials may reduce the carbon footprint of the construction industry, reduce the amount of embodied carbon emissions associated with the production and transportation of new materials, and reduce the need for pollution-causing mining.

5.2 Construction waste-based rehabilitation as community leverage

Rehabilitation based on construction waste management in the Gaza Strip may serve as a lever for large-scale individual and community rehabilitation. Decisions regarding the reconstruction of residences, the restoration of communities, and the preservation of historic sites are those that renew the connection between people and places. Therefore, focusing on recycling rubble is not just an environmental act but a basis for revitalizing living spaces, creating sources of employment, and strengthening the well-being of residents. This labor market is driven by three factors: (a) Private demolition contractors, who exploit the rubble

reserves as available raw material and pay low daily wages for minor construction repairs. (b) UN programs, which operate in the spirit of the "People's Process" and provide proper employment frameworks.[22] (c) Independent initiatives by residents who mine iron from the ruins of their homes to make a living and for sale to merchants.

5.3 Developing markets for recycled construction products and regional incentives

Ensuring the long-term success of the Build Back Circular model requires a shift from producing only recycled materials to creating stable and regulated demand. First and foremost, strict quality assurance of the recycled raw materials, including aggregates, concrete blocks, and green concrete mixes, is required so that they meet strict international standards. Compliance with such standards is essential to removing barriers to trust among planners, architects, and contractors, and to ensure the suitability of the materials for widespread use in residential, industrial, and infrastructure construction.

At the same time, to establish the economic viability of recycling, regulatory incentives must be implemented to shape a robust local market. Public authorities and agencies must lead a legislative process that will require the integration of a specified percentage of recycled materials in national infrastructure projects, such as paving roads and constructing public buildings. In addition, incentive mechanisms for the private sector, including tax breaks and subsidies, should be developed to encourage the use of recycled materials.

Moreover, establishing regulatory requirements to ensure that recycled material flows are kept within the Strip will create steady demand for local industry and support the creation of approximately twenty thousand new jobs. Consistent implementation of mandatory standards alongside economic incentives is intended to establish recycling as an

22 UN-HABITAT, The People's Process in Post-Disaster Reconstruction, United Nations Human Settlements Programme, 2007

industry norm, turning the waste burden into a stable and ongoing economic resource.

6. Environmental diplomacy and regional cooperation

The following case studies highlight that construction waste management in disaster areas is not merely an operational issue, but a systemic challenge that requires inter-institutional and inter-state coordination. Coping with exceptional amounts of waste, environmental risks, and infrastructural limitations exceeds local capabilities, and relies on regional collaborations, knowledge transfer, and regulatory coordination. In this context, construction waste management serves as an applied arena of environmental diplomacy, in which joint action is not just a by-product of the environmental challenge, but a central condition for the ability to deal with it effectively and sustainably.

6.1 Environmental cooperation as a basis for peacebuilding and the limits of this approach

The literature on building cross-border environmental cooperation focuses on preventing or overcoming conflicts through engagement with shared environmental issues. An ecological approach to conflict analysis highlights the potential of these issues to serve as a platform for building trust and gradual solidarity, even in the absence of a comprehensive political solution.

A key advantage lies in the ability to create operational ties between local communities. These processes enable practical empowerment of disadvantaged populations through employment and influencing local solutions. In addition, they enable the application of local knowledge, spatial and operational understanding of the area that does not pass through formal bureaucratic mechanisms, which improves the quality of decision-making and strengthens the legitimacy of reconstruction processes.

The history of the flow of construction materials from Egypt and Jordan to Gaza created a foundation of professional knowledge and industrial experience. On this basis, investments in separation and recycling technologies could become a lever for economic recovery. However, an analysis of the Abraham Accords shows that environmental diplomacy is a complementary tool rather than a standalone mechanism; the agreements contributed to climate resilience, but remained limited in their institutional depth and sensitive to political shocks.[23]

There is a trusteeship model (Neotrusteeship) in which powerful states or international organizations (such as the UN) temporarily assume governmental powers in a foreign territory, with the aim of restoring it after collapse or violent conflict. However, the case study of Kosovo suggests that international governance may stabilize services in the short term, but may create institutional dependency.[24]

The conclusion to be drawn is that international involvement must be time-limited and transparent. In the reality of 2026, which includes deepening territorial control in the Strip, waste management depends entirely on the control mechanisms at the crossings. Ultimately, to avoid replicating the failures of the trusteeship model, external involvement in Gaza's reconstruction should function only as a temporary "scaffolding," aimed at building capacities that allow the local community to manage its resources and environment independently, with regional cooperation, after the international mandate ends.

23 Maghen, L. (July 2025), Sustainable Reconstruction: Lessons from the World for the Gaza Strip. The Political-Security Unit of the Berl Katznelson Foundation and the Mitvim Institute.

24 Ford, J., & Oppenheim, B. (2008). Neotrusteeship in Post-Conflict States: Lessons from Kosovo and East Timor. UNU-WIDER Working Paper.

6.2 The Israeli-Emirates case: characteristics of cooperation

The relevance of Israel-United Arab Emirates relations lies in their applied economic potential. The UAE's experience in marine infrastructure and building artificial islands may be a professional asset for integrating them into the treatment of construction waste in Gaza.[25] There are four types of collaboration: commercial, academic, multilateral, and professional conferences. The presence of the private sector stands out in this context - Israeli cleantech and water companies versus Emirati government-owned companies. The success of this model is measured by the creation of continuous income streams and economic diversification. However, in Palestinian society, the Abraham Accords were perceived as a model driven by capital and trade considerations that offered no insights for building trust between Israel and the Palestinians. Rebuilding the Strip requires a combination of a "top-down" approach and the "bottom-up" needs of the residents.

6.3 The potential of multilateral and regional frameworks

Experts emphasize the importance of institutional environmental cooperation as a tool for building regional peace. Following the Abraham Accords, new platforms have developed that seek to translate diplomatic relations into practical cooperation. Among the most prominent are the Negev Forum - a regional framework that includes Israel, the United States, the United Arab Emirates, Bahrain, Egypt, and Morocco, which operates through professional working groups on food security, water, and clean energy; and the I2U2 group that includes India, Israel, the United Arab Emirates, and the United States, which focuses efforts on techno-

25 Donderer, E. & Lehrer, D. (2025). Shared Environments, Shared Futures: A perspective on nature-based and decentralized solutions for Gaza's Recovery. The Arava Institute for Environmental Studies.

economic cooperation on infrastructure and sustainability.[26]

Despite their inherent potential, these frameworks suffer from a clear structural disadvantage: the exclusion of critical stakeholders, foremost among them Jordan and the Palestinian Authority. The lessons of the past, and in particular the precedent-setting model of "electricity for water" between Israel and Jordan mediated by the UAE, show that the success of environmental initiatives depends on creating a clear common interest and the mediation of a strong third party that serves as a guarantor for the process.

To narrow the gap between the policy dictated "from above" and the reality on the ground, the establishment of a hybrid network of organizations is proposed. This network will integrate community initiatives based on local knowledge with institutional and regulatory bodies. Such integration will enable translating operational needs such as managing the construction and demolition waste system into formal policy frameworks, thereby strengthening the legitimacy of the reconstruction processes and protecting them from future political shocks.

6.4 Lessons from international and regional experience

Demolition waste management is considered one of the most complex logistical and environmental challenges in times of emergency, as it combines operational urgency with significant health risks. The experience gained in Italy after the earthquakes in L'Aquila (2009) and Emilia (2012) illustrates that the quantities and composition of waste are not constant, but vary dramatically depending on the nature of the affected area.[27] For example, dense historic centers produce huge amounts of traditional construction waste such as bricks and stone,

26 Guzansky, Y. (2025). *The Abraham Accords at Five: Resilience in the Face of Regional Turmoil*. INSS Special Publication.

27 Gabrielli, F., Amato, A., Balducci, S., Galluzzi, L. M., & Beolchini, F. (2018). Disaster waste management in Italy: Analysis of recent case studies. *Waste Management,* 71, 542-555.

while modern industrial areas are characterized by steel and reinforced concrete waste. A major health challenge that arises in these situations is the presence of asbestos in old buildings; this requires strict protection and removal protocols, as exposure to asbestos dust during demolition could create a long-term health crisis among residents and workers. Further, the case of Turkey in 2023 illustrates the unimaginable magnitude of the challenge, with the amount of waste estimated at hundreds of millions of tons. This reality has necessitated the adoption of large-scale recycling strategies that are not limited to concrete, but include systematic separation of wood, steel, and plastic.[28]

In the process of making decisions about the treatment method, decision-makers are required to choose between two main approaches: treatment at the war or disaster site, which is based on mobile shredders and saves thousands of truck trips on damaged roads, or transporting the waste to centralized treatment sites that allow the use of more advanced sorting technologies. This choice is also influenced by the fact that, unlike planned demolition, disaster waste includes the contents of the home, including stoves, air conditioners, carpets and cabinets, and hazardous pollutants such as gas tanks and chemicals, which require multi-step cleaning processes and specialized professional training.[29] Ultimately, the pace of removal and cleanup is critical to restoring community resilience. Slow removal is not only a physical barrier that prevents access to essential infrastructure and repair of water and electricity lines, it also serves as a constant reminder of the destruction and undermines the population's ability to begin the process of mental and economic rehabilitation. Therefore, a successful strategy must balance the quality of recycling with the need for rapid and efficient removal that enables free movement and the start of rebuilding.

28 World Bank. (2023, February 27). *Global Rapid Post-Disaster Damage Estimation (GRADE) Report*: February 6, 2023, Kahramanmaras¸ Earthquakes. World Bank Group.

29 United Nations Environment Program (UNEP). (2011). Disaster Waste Management Guidelines. Joint UNEP/OCHA Environment Unit.

6.5 TRUST Framework: The artificial island as a strategic solution

The TRUST initiative, developed by the Arava Institute and the Damour association, proposes the construction of an artificial island off the coast of Gaza using approximately 50 million tons of recycled construction waste. The island is intended to include a deepwater port, renewable energy facilities, and a free trade zone. The project is planned in a phased approach, from feasibility studies to the construction of marine infrastructure. The model embodies the Build Forward Better vision, but is contingent on a regional ecological assessment of the marine system in the eastern Mediterranean. Advancing the project could lay the foundation for a permanent regional institution for environmental cooperation.[30]

In conclusion, the success of the rehabilitation process is contingent on creating a diplomatic framework that will ensure long-term financial transparency and environmental risk management, turning infrastructure rehabilitation into a stable bridge to regional peace and stability.

30 Donderer, E. & Lehrer, D. (2025). Shared Environments, Shared Futures: A perspective on nature-based and decentralized solutions for Gaza's Recovery. The Arava Institute for Environmental Studies.

7. Summary and conclusions – the road to sustainable physical and diplomatic rehabilitation

The challenge of rebuilding the Gaza Strip is immense in its scope and complexity, but it embodies a pivotal opportunity to shape a more stable and sustainable reality for the entire region. The current study sought to examine the engineering, planning, and diplomatic aspects of construction waste management in disaster and conflict contexts, drawing lessons from international models and adapting them to the unique context of Gaza.

International literature and experience show that post-disaster construction waste management is not merely a technical process, but a strategic tool in which geospatial, planning, institutional, and diplomatic dimensions are inextricably integrated. The Italian analysis demonstrates how the lack of a national protocol leads to a response based on ad hoc decisions that vary between regions, and have inconsistent consequences over time. In Turkey, the aftermath of the earthquake illustrated the extraordinary quantitative challenge: waste in the hundreds of millions of tons, requiring a management chain based on planning, logistics, and quality control. In the Arab countries of the Middle East, other fundamental difficulties stand out – mainly air, soil and water pollution, a lack of dedicated infrastructure funding, the absence of institutional coordination, and gaps between government authority and the ability of the private and international sectors to integrate into the reconstruction processes.

The experience of the United Nations Compensation Commission in environmental rehabilitation following the Gulf War is one of the most prominent global examples of a dedicated, multi-year funding mechanism. Within its framework, the Kuwait Environmental Rehabilitation Plan was established, which included an initiative based on approximately three

billion dollars of international compensation, which was transferred to Kuwait to repair unprecedented environmental damage: soil and groundwater contamination following the burning of hundreds of oil wells and the creation of "oil lakes" that blackened the desert in 1991. The program focused on treating approximately twenty-six million cubic meters of contaminated soil and rehabilitating areas measuring hundreds of square kilometers, using advanced technologies including soil washing and the removal of unexploded ordnance. But beyond the technological dimension, the model is unique in the governance architecture built around it: a dedicated national agency responsible for management, control, and ongoing reporting to international agencies, with environmental restoration budgets managed separately from general humanitarian aid mechanisms. This separation enabled stability of planning over the years, close international supervision, and the ability to advance complex projects in the long term. Today, the Kuwaiti model is considered one of the largest environmental restoration projects the world has ever known, and a point of reference for countries dealing with a legacy of environmental destruction from large-scale warfare. Despite the relevance of these lessons from around the world, it is important to emphasize that Italy, Turkey, and Kuwait are functioning countries with full sovereignty over their borders, the flow of goods, and the movement of people. They are not subject to external restrictions regarding the entry and exit of supplies, technologies, or reconstruction teams.

In the context of the Gaza Strip, the situation is fundamentally different. Any reconstruction process depends on inter-state mechanisms, varying levels of security oversight, and agreements that are not under local control. This suggests that international comparison provides important insights, but they must be adapted to a much more complex political, institutional, and security reality.

The study reveals the potential inherent in recycling construction waste as an economic and material resource. Recycled aggregates can be used in new construction and infrastructure projects, and studies

show that producing recycled aggregate concrete is more economical than producing natural aggregate concrete. The vision of an artificial island, which emerged in discussions between Israeli and Palestinian experts, demonstrates how disaster can be turned into hope through the creative use of waste to build new infrastructure, including solar energy facilities, commercial and logistical areas, and tourism zones. However, caution should be exercised in presenting the idea as a fully developed plan. As of the time of writing, this is a theoretical proposal that has not yet undergone a comprehensive engineering, economic, environmental, and legal feasibility assessment, and its implementation is contingent on resolving complex questions of sovereignty, financing, and management responsibility.

The comparative examination of war waste treatment approaches shows that the combination of on-site treatment and treatment at a centralized facility is the most balanced solution in most cases. On-site treatment, meaning processing waste where it was generated, allows for efficient sorting of materials near the source and reduces costs and logistical complexity. In contrast, treatment in a centralized facility allows the use of more advanced technologies and yields high-quality materials. The choice between the two approaches or their combination should be based on a thorough analysis of the waste characteristics, local conditions, logistical capabilities available, and reconstruction schedules. It is important to note that there is another complicating factor, which is the presence of unexploded ordnance and asbestos residues, which requires adherence to strict safety procedures, poses technological challenges, and limits the ability to operate using rapid methods.

Analyzing the model of environmental cooperation between Israel and the United Arab Emirates offers essential insights into the conditions that enable successful cooperation. Cooperation based on shared interests, complementary capabilities, and relatively symmetrical power relations has a higher chance of success. However, the lessons of the past also show that environmental cooperation related to regional

conflicts can be undermined by political developments, and therefore ongoing international support and mechanisms are needed to ensure the continuity of cooperation even during times of tension. At the same time, it is clear that without suitable opening conditions that allow for the reconstruction process (especially in relation to building an alternative government and military force to Hamas in the Gaza Strip), there will be a fundamental difficulty in implementing any reconstruction plan or even advancing the basic groundwork for one in the form of beginning to effectively address the construction waste crisis in the Gaza Strip.

The success of the reconstruction will be measured not only by the pace of construction, but by the ability to lay the foundations for a different future. The first dimension is economic independence, which will be achieved through recycling and the development of local industry. As international experience shows, construction waste can be transformed from a nuisance into a resource that generates income streams, creates jobs, and contributes to economic diversification. The second dimension is transparent governance, which includes creating a transparent and inclusive governance mechanism that enables data-based decision-making and participation by diverse stakeholders. The third dimension is regional integration, which will be made possible through environmental partnerships and confidence-building. The project should be perceived as a regional project and not just an Israeli-Palestinian project, as environmental contamination will affect the entire region, including Egypt and the entire Mediterranean Sea.

Adopting a bottom-up approach is a key principle in rehabilitation planning. As emphasized, top-down peacebuilding efforts do not get far if people do not believe in them. Environmental cooperation around construction waste offers a less controversial starting point than political or security issues, while at the same time creating a foundation for lasting relationships. Quick and efficient waste removal will send a signal of hope to residents, while delays and estimates of thirty years to remove the waste convey hopelessness.

Along with the potential inherent in the models and tools presented in the study, it is important to recognize the complex political and institutional reality within which reconstruction processes will take place. Hamas' continued control of the Gaza Strip, the limited functioning of the Palestinian Authority in Gaza, and the deep and ongoing tensions with Israel create an environment full of uncertainty that limits the ability to implement solutions fully, continuously, and quickly. This reality demands caution in planning, institutional flexibility, and an understanding that environmental and infrastructural restoration processes do not take place in a vacuum, but are intertwined with systems of power, governance, and security. Explicitly addressing this complexity does not diminish the validity of the proposed model, but rather emphasizes the need for graduated, supervised, multi-actor action frameworks that can operate even under conditions of ongoing political and institutional limitations.

More broadly, it is important to emphasize that when making decisions in situations of large-scale destruction, and particularly in the context of the reconstruction of the Gaza Strip, it must be taken into account that these are processes that take long periods of time and require continuous allocation of resources. Although the initial tendency is to promote quick, low-cost solutions, this approach may miss a strategic opportunity to shape a space that is more resilient to future threats. Prudent investment in reconstruction, infrastructure, and resource management enables not only meeting immediate needs, but also strengthening the Strip's climate resilience in the face of anticipated risks, including extreme heat waves, rising sea levels, and severe storms that threaten coastal communities. In this sense, the more the reconstruction processes are planned and implemented from a long-term perspective, the greater the likelihood of building a more stable and independent Gaza, capable of dealing with future climate challenges rather than once again relying on temporary emergency solutions.

The analysis shows that dealing with construction and demolition waste is not a secondary issue within reconstruction, but a systemic

challenge that lies at the core of the Gaza Strip's recovery process. The amount of waste, its complexity, and its environmental, economic, and social implications require a dedicated, coordinated, and goal-oriented effort that cannot rely solely on general reconstruction mechanisms. Therefore, **a key recommendation is to establish a dedicated fund for construction waste management and environmental restoration, to facilitate the pooling of resources, multi-year planning, professional oversight, and the implementation of solutions on a large scale. This type of fund could serve as an institutional anchor for systematically dealing with waste, and contribute to the connection between physical reconstruction, environmental resilience, and long-term economic development.**

The international financing framework for the reconstruction of Gaza is based on two central mechanisms managed by the World Bank. The first is the Palestinian Fund for Rehabilitation and Development (PFRD), which was established at the request of the Palestinian Authority as a platform for coordinating donor funds and reconstruction efforts. The second is the Gaza Rehabilitation and Development Fund (GRAD Fund), which was established following a November 2025 UN Security Council resolution, and in which the World Bank serves as a "limited trustee." That is, it manages the flow of donor funds and transfers them to projects according to the guidelines of the governing body. The extent of the damage is estimated by the World Bank, the UN, and the European Union at approximately $70 billion, with physical damage to buildings alone estimated at approximately $30 billion. The residential sector has been hit hardest, accounting for roughly 53 percent of the total damage. Note that as of the end of 2025, full implementation of the reconstruction plans is contingent on the settlement of questions of governance, security, and access.

As part of the various reconstruction efforts, systematic treatment of construction waste should be prioritized rather than neglected. The reconstruction of the Strip, based on regional and international cooperation, can serve as a test case for utilizing resources from waste

and transforming rubble into environmental growth in conflict zones around the world.

Finally, **the establishment of a joint Israeli-Palestinian platform for the management and recycling of construction and demolition waste should be examined as part of post-war reconstruction processes.** This platform is conceived as a joint effort including cooperation between academia, industry, regulatory bodies, and civil society organizations in Israel and the Palestinian Authority, with the focus on the management, treatment, and recycling of construction and demolition waste as a central foundation for post-war physical and social rehabilitation. The large-scale destruction has produced enormous amounts of construction waste, which directly affects the Palestinian-Israeli region in terms of public health, the environment, reconstruction costs, availability of raw materials, and the pace of economic recovery. First, the proposed joint platform will be able to develop joint methodologies for mapping and quantifying construction waste, using advanced tools such as remote sensing, GIS and material flow analysis. Later, it can promote circular economy models that enable the transformation of waste into approved secondary raw materials, while formulating professional standards and regulatory coordination. The platform is intended to create and promote collaborations with recycling companies, concrete and aggregate manufacturers, and engineers and technology entrepreneurs, for the purpose of developing large-scale applied solutions. Another recommendation is to examine the incorporation of dynamic tools such as what is developed in this paper, namely the narrative GIS to serve as a diplomatic and communication research tool, making the findings available to a variety of audiences – from decision makers to aid bodies, through professionals in the fields of planning and waste, and to the general public in Israel and worldwide. Finally, the idea is to focus on examining the social and health aspects of waste management, including working conditions, exposure to hazardous materials, and the impact on disadvantaged communities, while understanding that construction waste is a professional field in which practical cooperation

can be created, based on solutions and measurable results, contributing both to sustainable physical reconstruction and to building confidence and a foundation for long-term regional cooperation.

Appendices

The appendices attached to this report are intended to present with full transparency the research, operational, and quantitative foundation on which its conclusions are based. They are organized in two complementary focuses: Appendix 1 – the personal and methodological dimension of the research, including the team, the tools, and the meetings held; and Appendix 2 – the quantitative-analytical dimension, which includes the calculations, the data set, and the transition key between the rehabilitation scenarios.

Appendix 1 – The personal and methodological dimension of the study

Research team and partners

Adi Mager serves as the study director and the initiator of the project. She is a policy fellow at the Mitvim Institute – The Israeli Institute for Regional Foreign Policies, and an international expert in construction and demolition waste management, with over twenty years of professional experience in the fields of sustainability, circular economy, and resource management. Adi is a PhD candidate at the New Environmental School at Tel Aviv University under the supervision of Prof. Vered Blass. Her research focuses on construction waste and the development of data-based tools for informed planning and management of material flows. Throughout her career, Adi has combined academic research, professional consulting, and leading policy processes and implementation in the field. Her work focuses on connecting science, regulation, planning and operational implementation, and on making current research knowledge accessible to decision-makers, authorities and entrepreneurs. Her lectures and publications deal with construction waste, selective dismantling and demolition, urban renewal, economic and regulatory aspects, and the application of circular economy principles

in projects and policy plans. In addition, she has authored a professional book on raw material innovation for infrastructure and construction, and leads collaborations between researchers, authorities, and industry in Israel and around the world.

The research team was divided into three groups:

1. **Mapping and technology group.** This group coordinated the mapping work and technologies for treating construction waste: Adi Mager led the group, which included Dana Gabay, an external consultant and environmental economics expert; Lt. Col. (res.) Tomer Barak, an expert in regional geopolitics; Dr. Tomer Fishman, an external consultant who specializes in the circular economy; Adi Ben-Nun from the Hebrew University, a GIS expert, and Hadasa Lev, CEO of WALK, an architect specializing in building dynamic and interactive applications such as story maps in GIS.
2. **Planning and reconstruction group.** This group focused on spatial planning and community rehabilitation, and was led by architect Sharon Hefez, who specializes in consulting, research, and spatial planning with an emphasis on the community; Dr. Elise Machline, Department Head at the Center for Climate Change Policy and Research, Arava Institute; Maya Jacobs, Founder and CEO of ClimateNet (in the field of climate innovation); Dr. Tal Milner-Huberman, conservation architect; Dr. Galia Limor-Sagiv, environmental researcher, landscape historian and specialist in the restoration of damaged and polluted sites, senior lecturer in the Department of Architecture, Sami Shamoon College of Engineering; and Dr. Michal Linder-Zarankin, from Tel Aviv University.
3. **Environmental policy and diplomacy group.** This group led the field of environmental policy and diplomacy, and was led by Jasmine Kalstein, the research assistant for this study and a policy and diplomacy specialist; Liel Maghen, Senior Policy Fellow at Mitvim; Bar Rapaport, Director of Political-Climate Sustainability at Mitvim; Prof. Amir Lupovici, Head of the Brody Institute for Applied Diplomacy, Tel Aviv University; Peleg Gottdiener, Advocacy officer, EcoPeace

Middle East; and Dr. David Lehrer and Dr. Shmuel Brenner from the Center for Environmental Diplomacy, Arava Institute.

4. **Academic and institutional partners.** The study was supported by a number of central academic and institutional institutions: Mitvim – the Israeli Institute for Regional Foreign Policies, which served as the lead institution and main supporter, as well as the Frances Brody Institute for Applied Diplomacy (FBIAD) at Tel Aviv University, which provided professional and financial support. As part of the study, connections were made with the construction waste recycling industry, military and security agencies, as well as startup companies involved in innovation relevant to the optimal treatment of construction waste. Among them are the companies: Arbel.ai, Eco-Brick, EVA, WAYSTA, Criaterra, Taftirium, CivicLabs, Hamitbah, and Desertech.
5. **Regional and international partners.** (1) Damour – A Palestinian non-profit organization active in the field of community development, establishing displaced persons camps, and providing water, sanitation, and temporary housing solutions for populations displaced from their homes. As part of the study, the organization contributed local knowledge and applied experience in working with displaced communities and in humanitarian contexts. (2) Arava Institute for Environmental Studies – an applied academic center specializing in cross-border environmental research. Its research contribution focuses on developing frameworks for environmental diplomacy, integrating climate and infrastructure aspects, and promoting regional discourse around shared resource management. (3) EcoPeace Middle East – A cross-border civil society organization working to promote environmental cooperation as a means of building regional trust. As part of the study, the team contributed to thinking about developing cooperation mechanisms around sensitive environmental issues, and to implementing environmental diplomacy approaches in complex political contexts.

Roundtable meetings for researchers and experts

Part I – Roundtable 1 – The meeting took place on July 17, 2025, at Tel

Aviv University and online. Key insights: Discussion of the Gaza Strip through the prism of past-present-future construction waste: The extent of the destruction and waste requires a shift from a removal-only approach to a systemic resource management approach, which includes mapping, measurement, and prioritization. Urban mining and material inventory analysis form a strategic basis for assessing waste streams and integrating circular economy principles into rehabilitation. Environmental restoration is inseparable from the political and security context; a framework for action is required that integrates civil, health, and security interests. There is also importance in Palestinian and regional partnership, data transparency, and trust-building as a condition for international funding and feasibility. It was suggested that the immediate humanitarian response be combined with long-term planning, including examining alternative materials and models of reduced-emission construction. The presenters at the roundtable were: Dr. Dotan Halevy, historian of the modern Middle East and senior lecturer in the Department of Middle Eastern and African History at Tel Aviv University; Mr. Adi Ben-Nun, Head of the GIS Center at the Hebrew University of Jerusalem; and Dr. Tomer Fishman, an international consultant specializing in the circular economy of infrastructure.

Part B - Roundtable 2 - The meeting took place on October 29, 2025, online. Key insights: An interactive narrative GIS platform was presented that enables the integration of spatial information layers, measurement tools, and the presentation of debris percentages as the foundation for an applied policy document. The management of hazardous materials data was discussed as well as underground infrastructure as a safety, engineering, and economic condition for reconstruction planning. BBC and BFB models were presented as complementary; a combination of infrastructural resilience and socio-economic transformation is required. It was agreed that political borders are not environmental borders, and therefore regional cooperation and the removal of regulatory barriers to the use of recycled materials are necessary.

Summary of the Gaza Strip "Day After" Technologies Webinar – Innovation and Construction Waste Management in Gaza | October 26, 2025

The event took place as an online webinar and dealt with the challenges and opportunities involved in the reconstruction of the Gaza Strip, with an emphasis on the management and recycling of construction and demolition waste. Its main goal was to connect the worlds of innovation, research, policy, and industry, and to present practical solutions that can be implemented in post-conflict arenas.

Participants included representatives from CivicLabs, DCIC DesertTech Climate and Innovation Center, the Baran Group, HamitbaH – The Technological Center for Security and Resilience in the Western Negev, as well as researchers and experts from Tel Aviv University and the Mitvim Institute. In addition, solutions from six Israeli startups operating in the fields of mapping, materials recycling, green concrete, environmental enforcement, and innovative building materials were presented.

The analysis of the situation in Gaza was presented as one of the densest and most extensive destruction events of the 21st century, with a high concentration of rubble in a limited area. This characteristic creates a significant logistical and safety challenge, but also a unique opportunity for local processing of construction waste, reducing transportation costs, and producing secondary raw materials. Key risks were presented, including the lack of infrastructure, movement restrictions for heavy equipment, the presence of hazardous materials, unexploded ordnance, and extensive underground systems.

The role of research infrastructure based on GIS, drones, and artificial intelligence was emphasized for mapping the extent of the debris, classifying materials, and supporting decision-making. This approach allows for phased planning of treatment sites, control over removal and recycling processes, and transparency with funding and regulatory agencies.

The startups presented a variety of solutions, including digital management of high-risk debris sites, full recycling of construction waste into aggregates and building materials, reducing carbon emissions in the production of cement substitutes, enforcement mechanisms to prevent illegal dumping, and the development of low-energy and recyclable building materials.

The discussion raised significant regulatory and security issues, including the handling of unexploded ordnance, soil stability, restrictions on the movement of waste outside the Strip, underground waste, and the environmental implications of infrastructure solutions on a regional scale. It was agreed that the success of reconstruction processes depends on a combination of technological innovation, customized regulation, international cooperation, and sustainable economic models.

Meeting at the Civil-Military Coordination Center (CMCC) in Kiryat Gat - November 19, 2025.

The meeting dealt with the extent of the debris in Gaza. The spatial analysis presented suggests prioritizing removal according to the areas of severe damage and the industrial and commercial areas. The operational strategy recommends the establishment of decentralized regional sorting and recycling centers, and beginning field verification in the Rafah area. The TRUST model was also briefly presented, which sees potential in using approximately 50 million tons of recycled construction waste to establish an artificial island off the coast of Gaza, designed to serve as a deep-water port and free trade zone. This model was presented to officials at the World Bank and the US government, but was not examined in depth within the framework of this study, due to the need for comprehensive environmental and ecological examinations prior to any practical assessment.

Appendix 2 - The quantitative-analytical dimension

Method for calculating the construction waste in Gaza

The calculation is based on a combination of the estimate of the built-up area identified as destroyed (an identification was made of the degree of change in the structure compared to its condition in 2023, average height calculated by the average of the heights of the buildings in the hexagon), and material intensity (MI) coefficients for the purpose of producing a spatial estimate of material and waste masses. For each hexagon, the total built-up area that was destroyed was calculated, and from this the construction volume was derived by multiplying by a representative average height. This volume was converted to a mass of materials based on the MI coefficients in the attached coefficient table, which was prepared based on data representing the types of buildings in the Middle East according to the RASMI methodology described in the journal article - see below.

These coefficients represent ranges of mass per unit area, and allow for a simple calculation by multiplying the amount of built-up areas demolished in a polygon by the number of floors and the appropriate coefficient. The coefficient table includes six main building materials: concrete, steel, glass, plastic, aluminum, and copper. For each material, coefficients were defined in kilograms per square meter of floor area for three functional building categories: multi-family residences, single-family residences, and non-residential buildings. In order to adapt to the area of the Gaza Strip, the possibility of cross-referencing building types and coefficients was examined according to characteristics such as height and number of floors. In the absence of a complete classification for all buildings, it was decided to use multi-family residential coefficients as a uniform basis and indicator for the types of buildings in the Gaza Strip, noting that the gaps between the categories are not substantially large.

For each category, three assessment values were defined – minimum, median, and maximum from the data in the aforementioned article, which serve as scenarios to reflect structural variation and uncertainty. The calculation results yielded a total range of approximately 67 to 126 million tons of waste (as of September 2025).

The table is based on the RASMI database – Regional Assessment of buildings' Material Intensities – which was developed to provide consistent global ranges of material intensity (MI) coefficients for buildings, differentiated by geographical region, frame type and structural function. MI coefficients express the mass of construction materials per unit of floor area in kilograms per square meter, and are a key tool for estimating material inventories, potential demolition waste, and future material flows. The full database includes 3,072 value ranges for eight major building materials, in four structural frame types and three use types, in 32 global regions.

The methodology relies on systematic collection of existing literature data, controlled expansion using regional and structural similarity criteria, and calculation of percentiles (0, 5, 25, 50, 75, 95, 100) without assuming a probability distribution. This approach allows for representing both true structural variability and epistemic uncertainty arising from differences between data sources, thus providing a reliable framework for estimating material masses and waste scenarios at urban and regional scales.

Information source:

Fishman, T., Mastrucci, A., Peled, Y., Saxe, S., & van Ruijven, B. (2024). RASMI: Global ranges of building material intensities differentiated by region, structure, and function. Scientific Data, 11, Article 418. https://doi.org/10.1038/s41597-024-03190-7.

Based on the article, material intensity coefficients were prepared according to type of structure and function - Based on the RASMI database. Below is the table presenting the data:

material	building_function	min kg per m2	med kg per m2	max kg per m2
concrete	nonresidential	709	1078.61	1443.14
	residential_multi	708.38	965.15	1297.09
	residential_single	470.13	787.89	1125
steel	nonresidential	34.66	54.68	92.48
	residential_multi	34.38	50.8	94.05
	residential_single	15.2	21.2	37.13
glass	nonresidential	1.01	2	3.2
	residential_multi	1.79	2.47	4
	residential_single	1.52	2	2.53
plastics	nonresidential	0.39	1.2	3
	residential_multi	0.39	1.2	3
	residential_single	0.39	1.2	3
copper	nonresidential	0.08	0.18	0.27
	residential_multi	0.08	0.18	0.27
	residential_single	0.08	0.18	0.27
aluminum	nonresidential	0.13	0.49	1.07
	residential_multi	0.13	0.49	1.07
	residential_single	0.14	0.5	1.07

The calculation was carried out in conjunction with the expertise of Dr. Tomer Fishman as an external consultant and circular economy expert, and in collaboration with Mr. Adi Ben-Nun, head of the GIS Center at the Hebrew University of Jerusalem, who guided the spatial and analytical aspects of the model.

The calculation is based on a combination of:

Estimate of the built-up area identified as destroyed in each hexagon – The extent of the structure's change compared to its condition in 2023 was identified.

Average building height – calculated by averaging the heights of the buildings in the hexagon.

Material intensity (MI) coefficients for producing a spatial estimate of material and waste masses.

For each hexagon, the total built-up area that was destroyed was calculated, and from that, the construction volume was derived by multiplying the area by the average building height (translated into the number of floors).

Details of the work stages:

Converting all data layers into one layer – Israeli Transverse Mercator

Improving building data and integrating sources – OSM & Microsoft

Creating a complete building layer with a description of the building type and height

Creating a layer of uniform hexagons

Associating each hexagon with the administrative area in which it is located

Combining the damage identification layer for buildings (point-based) with the building layer (polygonal) and its improvement.

Associate each structure with the hexagon in which it is located.

Calculating the area of buildings identified as destroyed for each hexagon

Calculating average building height in each hexagon

Summary of values for each hexagon: Calculation of the construction volume and calculation of the masses of materials and waste accumulated in each hexagon, including production of maps and summary tables.

Data sources:

Gaza Strip vector building layer – OSM

Gaza Strip vector building layer – Microsoft

Gaza Strip Vector Road Layer – OSM

Vector layer, detection of damage to buildings – UNOSAT

Administrative boundaries – Palestinian Authority

Key insights

The analysis indicates a volume of waste ranging from 67 to 126 million tons, with most of the mass consisting of concrete. Steel constitutes a relatively small portion of the total mass but is of high environmental and economic importance, so its recycling is essential. Combining the hexagonal model with MI ranges by type of use indicates clear variation between regions. Non-residential buildings, characterized by higher material density, contribute significant masses of concrete and steel when destroyed and produce localized waste concentrations. In addition, consistency was found between the various MI sources, which strengthens the credibility of the scenarios. In addition, road and infrastructure waste adds millions of tons that were not included in the initial estimates. The correlation between damage levels and the mass of materials allows for the identification of future stress points and therefore the determination of priorities for removal, treatment, and reconstruction. At this scale, the operational conclusion is that the deployment of several regional collection and recycling centers is required, rather than relying on a single central site.

In summary, the data set and calculations in question allow for:

Quantitative description of debris by materials at the hexagon level.

Creating summaries by material, for several scenarios (minimum, median, maximum).

Spatial analysis using a GIS (Geographic Information System) including maps, highlighting areas of concentration and geographic differences in material composition.

Presenting mapping and calculations in narrative geographic information systems software

The GIS story map developed as part of the study is a bilingual interactive platform (Hebrew and English), which allows the story of destruction and potential reconstruction in Gaza to be presented and made accessible through a combination of dynamic maps and modules, information layers, texts, images, and dynamic models. This is the first story map of its kind in Israel on the subject of construction waste in Gaza, and it is designed to make complex information accessible to policymakers, researchers, and the general public in a visual, interactive, and easy-to-understand language.

The story map includes maps and models with information layers based on a hexagon model, in which the Gaza Strip is divided into uniform hexagons that serve as independent units of analysis. Each hexagon combines several categories of information: population data for 2023; building data (including damage levels) based on Microsoft and UNOSAT; road and infrastructure data; and greenhouse and agricultural land data based on Sentinel2, NDVI, and OpenStreetMap. This combination allows for spatial assessment of waste volumes, identification of damage hotspots, and mapping of sensitive areas in terms of infrastructure, food security, and the economy. The story map also includes additional layers of information, such as 3D construction layers and ESRI satellite imagery, as well as layers dividing the Strip into areas: districts, municipalities, neighborhoods, security strips, and evacuation zones.

The story map shows several main maps: concentration of residential buildings in Gaza on the eve of the war; percentage of destruction of buildings in July 2025; damage to road infrastructure (approximately 3,045 km damaged, of which approximately 68 percent of the road network); damage to agricultural areas over six to seven years; and the distribution of industrial areas and greenhouses. Each map is accompanied by a brief explanation of the analysis method and creation of the information layers. Images to illustrate the application include the use of high-resolution satellite images, and a 3D model with a layer of buildings to illustrate the damage. The information in the story map details the relevant findings in

the current situation for the purpose of planning restoration and prioritizing interventions on the ground.

The story map includes independent interactive applications: a dynamic 2D map that allows zooming, turning layers on and off, displaying legends, and replacing base maps; a 3D model that allows free roaming, measurements, shading, and viewing pre-prepared views of areas such as Rafah, Khan Yunis, and the Zeitoun neighborhood in Gaza City. This component of the project is a tool for policymakers, decision-makers, and professional teams to understand the current situation in Gaza in terms of the extent of the debris, and makes it possible to examine various reconstruction scenarios and identify priority areas for waste treatment and infrastructure reconstruction.

The maps and models were prepared in close collaboration between the research team and GIS experts, including Mr. Adi Ben-Nun from the Hebrew University, architect Hadasa Lev, CEO of WALK, and conversations with government, academic and international officials. **Narrative GIS is a central product of the project: it functions as both a research tool and a diplomatic-communication tool, which makes the findings accessible to various target audiences - from decision-makers and aid agencies, through professionals in the field of waste and planning, to the general public in Israel and around the world.**

For the Hebrew story map: click here.

English story map: click here.

An explanation of the methodology and a visual demonstration also appear on the dedicated page on Adi Mager's website: www.adimager.com

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