This project is co-funded by
the European Union and the Republic of Turkey.

Technical Assistance for Assessment of Turkey's Potential on Transition to Circular Economy

EuropeAid/140562/IH/SER/TR

Construction and Demolition Waste – Challenges and Opportunities in Turkey

Prof. Dr. Mustafa ŞAHMARAN - Hacettepe University

Activity 1.2.1. Circular Economy Training
12th May 2022 - Antalya, Türkiye

REPUBLIC OF TURKEY
MINISTRY OF ENVIRONMENT,
URBANIZATION AND CLIMATE CHANGE

Environment and Climate Action
Sector Operational Programme

deep
Circular Economy Action Plan

DAI

Construction Industry in the World

Construction Industry in Turkey

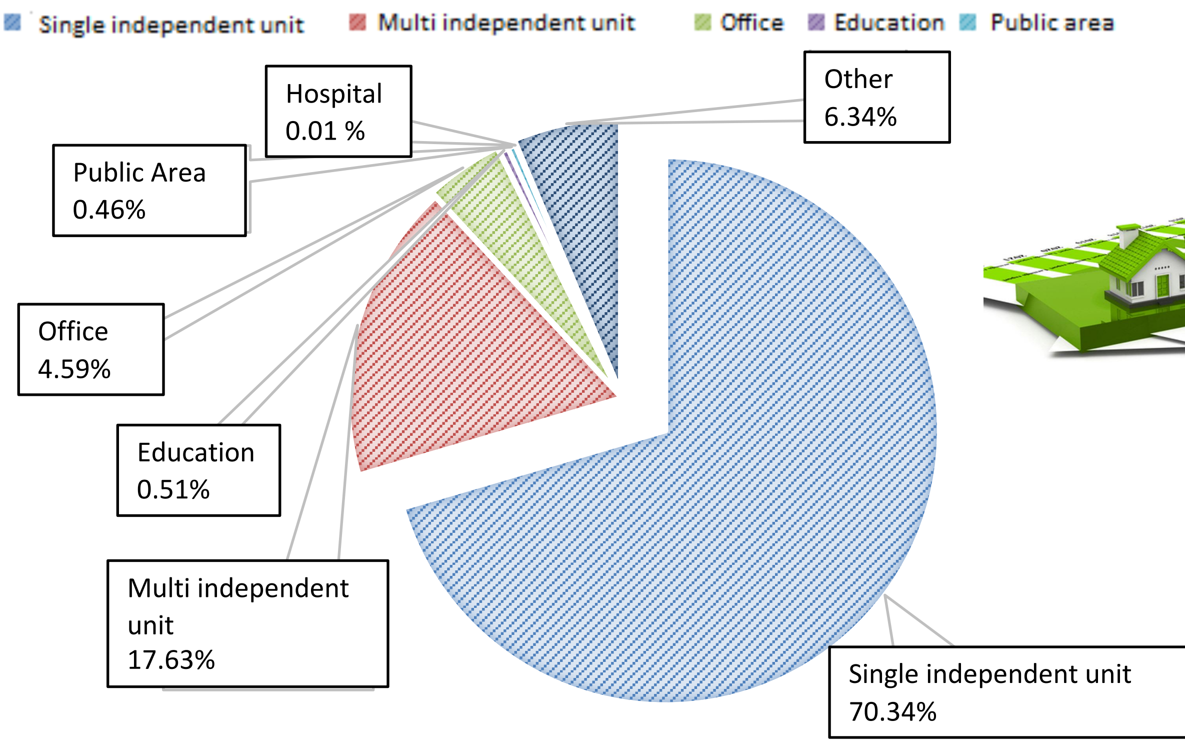
- Value-added of Construction Activities: 6.2% of Turkey's GDP [1,*]
- Exportation market of the construction materials in the World : Turkey ranks 9th with 21,158 million dollars [1]
- Total sales of construction materials: 500 billion liras, 12% of Turkey's GDP [1]
- Career opportunities created by the sector: Direct employment to 1.54 million people in Turkey [1]
- Resources consumed during the activities of the construction industry;
  - **50%** of raw materials [2]
  - **30%** of water [expecting]
  - **35%** of energy [expecting]

– Emissions and wastes as a result of construction sector activities,

- **40%** of greenhouse gas emissions [expecting]
- **40%** of the total waste produced in Turkey [expecting]

[*] Amount of value-added of construction activity in GDP
[1] İMSAD Building Sector Report, 2020
[2] Final Draft for Preparation of Turkey SCP National Action Plan and Roadmap, April 2020
[expecting] Due to the lack of available data, it was calculated taking into account only available EU metrics.

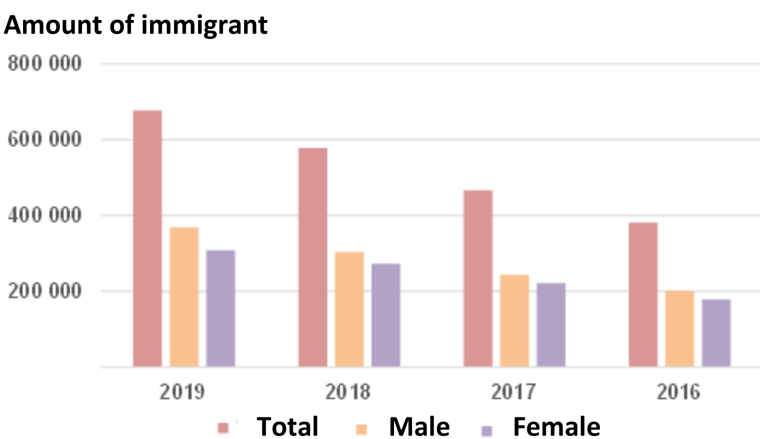
Current Situation in Turkey - Housing Stock

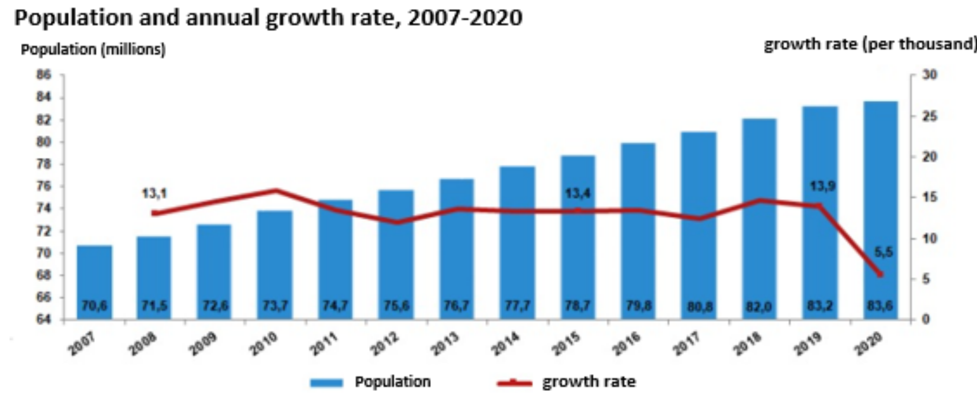


*Construction Industry Energy Efficiency Technology Atlas, 2018. Republic of Turkey Ministry of Environment, Urbanization and Climate Change (ÇŞB)

Current Situation in Turkey - Population and Immigration

- Rapidly growing population
- Refugees and immigrants

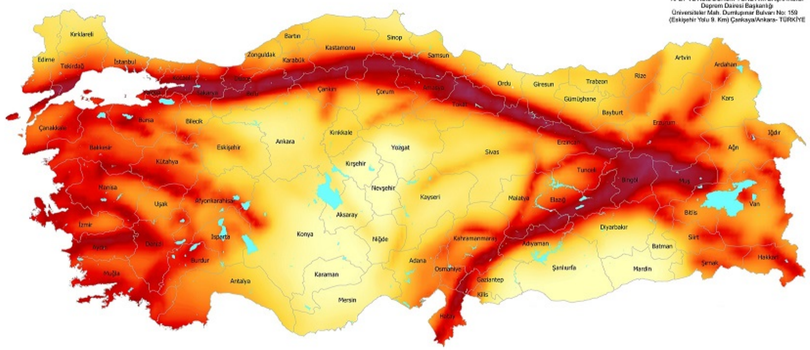


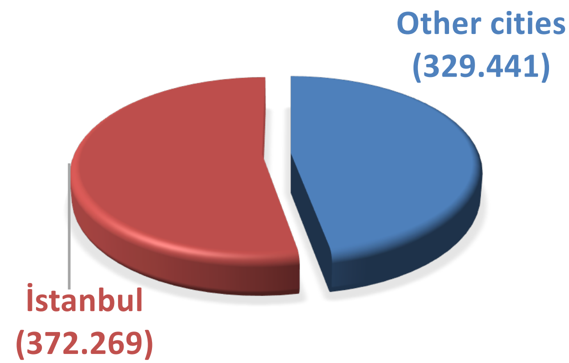


*Turkey's current population and migration data, 2019. TUIK

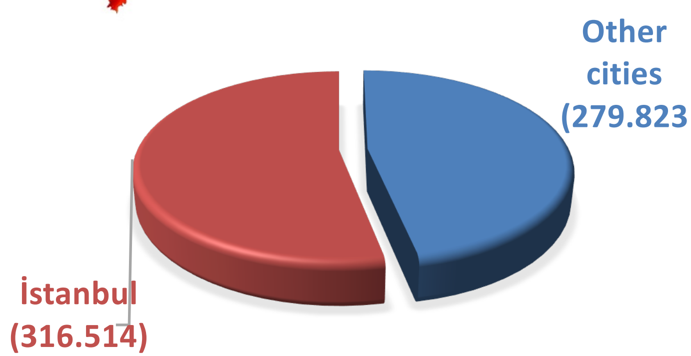
Earthquake Hazard Map and Risk Assessment

Turkey Earthquake Hazard Map

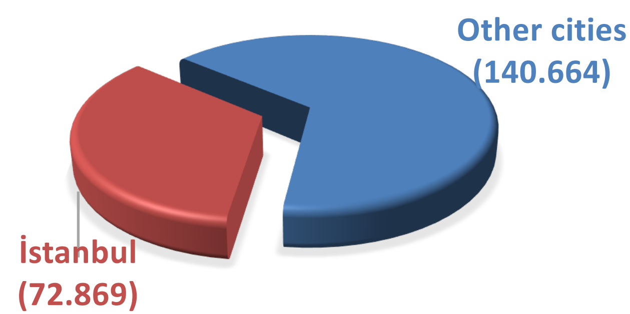




Independent building stock classified as risky



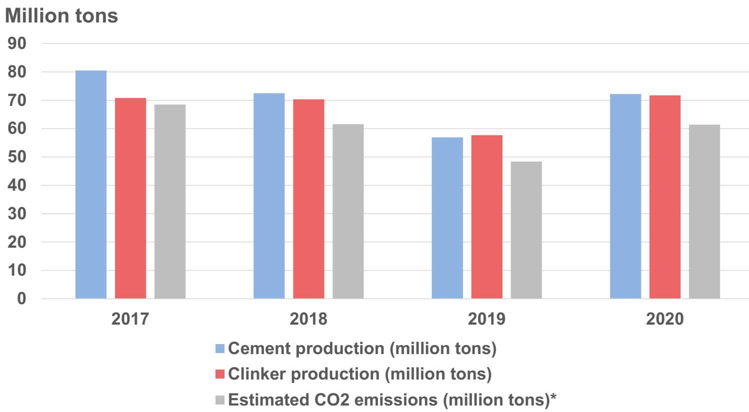
Demolished independent buildings

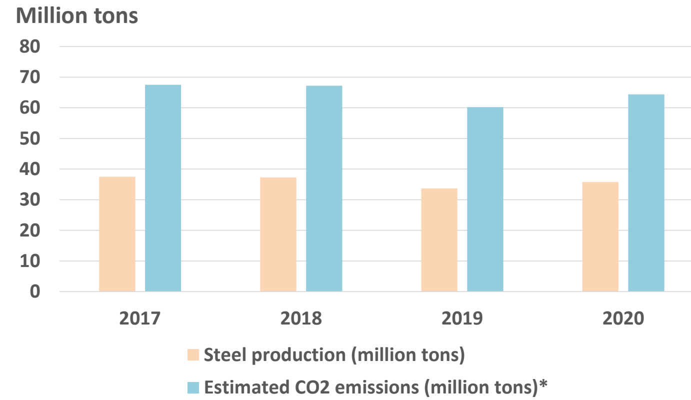


Building stock classified as risky

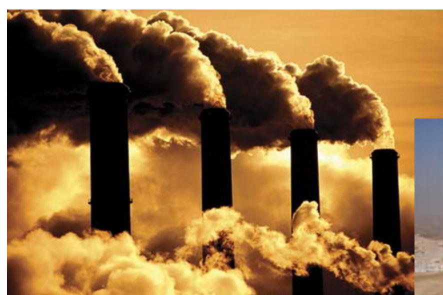
ÇŞB - 2021

Current Situation in Turkey – Cement/Iron-Steel/Aggregate Industry





Year	Aggregate production (million tons)
2017	480
2018	430
2019	220
2020	270**



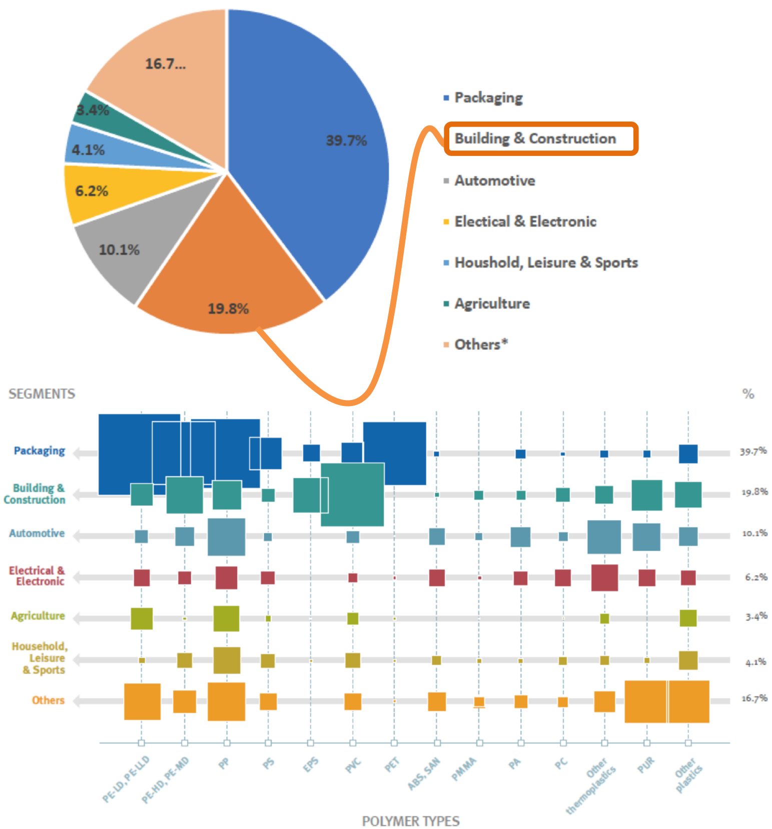
Greenhouse gas emissions

Permanent marks on the planet

Aggregate quarry

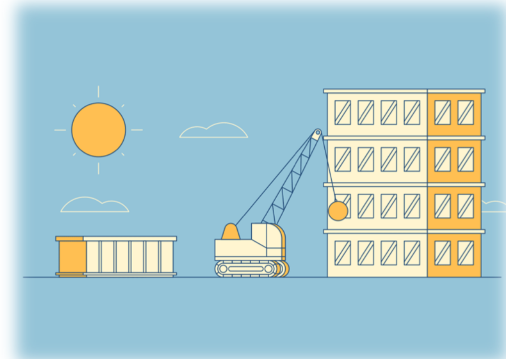
Source: TürkÇimento, Turkish Steel Industrialists Association, Aggregate Manufacturers Association

Current Situation in Turkey – Plastic Production



Source: PolynSPIRE (2019),“Map of Availability of Plastic Wastes Across Europe’’ report

Construction and Demolition Waste

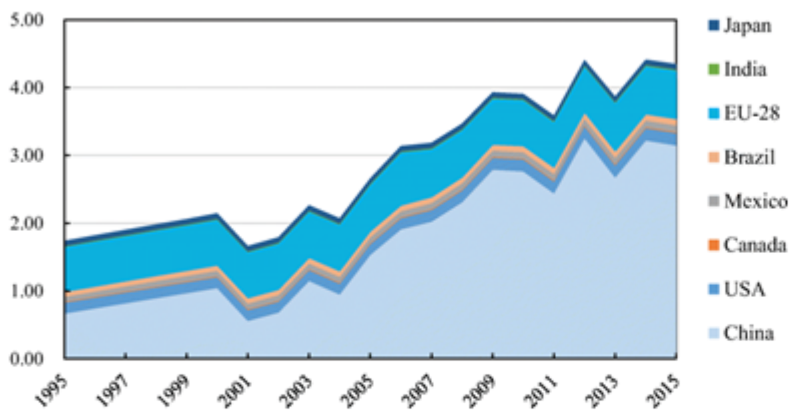


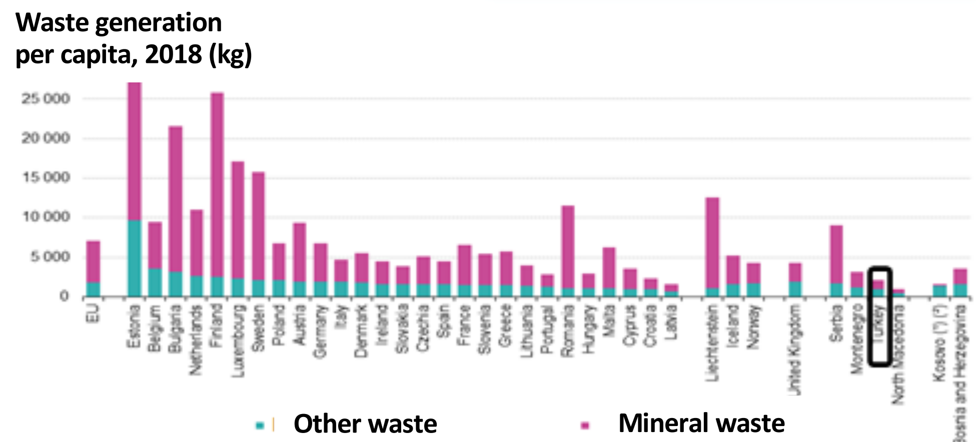
As a result of,

- Ever-increasing urban population and urban transformation,
- Continuous development of industrialization,
- Continuous development economies of countries around the world.

The production of **Construction Demolition Waste (CDW)** has increased significantly.

billion tons





Source: Waste generation, 2018 (kg per capita) - Eurostat

Construction and Demolition Waste

There are multiple adverse effects of CDW:

- waste landfilling of very large clean lands;
- causing hazardous pollution which jeopardize the surroundings;
- wasting of natural resources.






Effects of Housing & Construction on the Environment

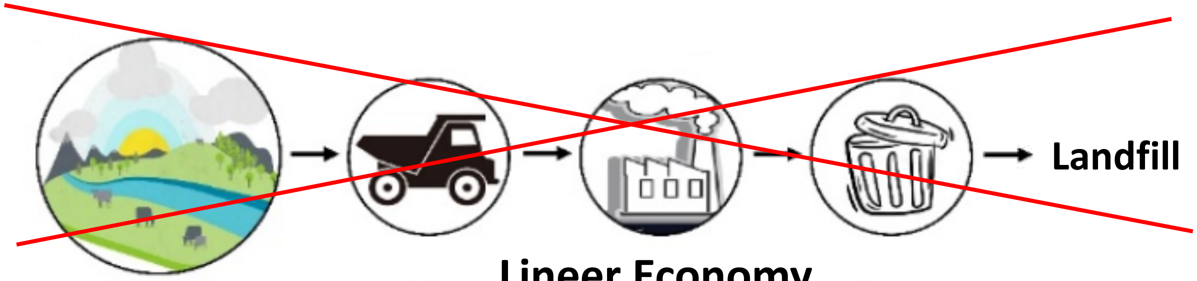
Use of sources	Value Chain	Emissions
Land, metals, minerals, wood, water, glass, energy, plastic etc.	Building materials	Land use, air, water, soil, waste
Metals, minerals, wood, water, glass, energy, plastic etc.	Design and manufacturing	Air (greenhouse gases, pollutants), water, waste
Land, metals, minerals, wood, water, glass, energy, plastic etc.	Construction	Land use, air (greenhouse gases, pollutants), water, waste
Metals, minerals, wood, water, glass, energy, plastic etc.	Use	Air (greenhouse gases, pollutants), water, waste
Energy	Recycling	Construction & Demolition Waste and Plastic Waste

Circular Economy

Circular economy throughout all life cycles means that;

- efficient use of all resources and products,
- use of renewable resources,
- evaluation of waste,
- prevention of depreciation,
- products and resources remain active and functional in the system for as long as possible.

Cradle to Cradle

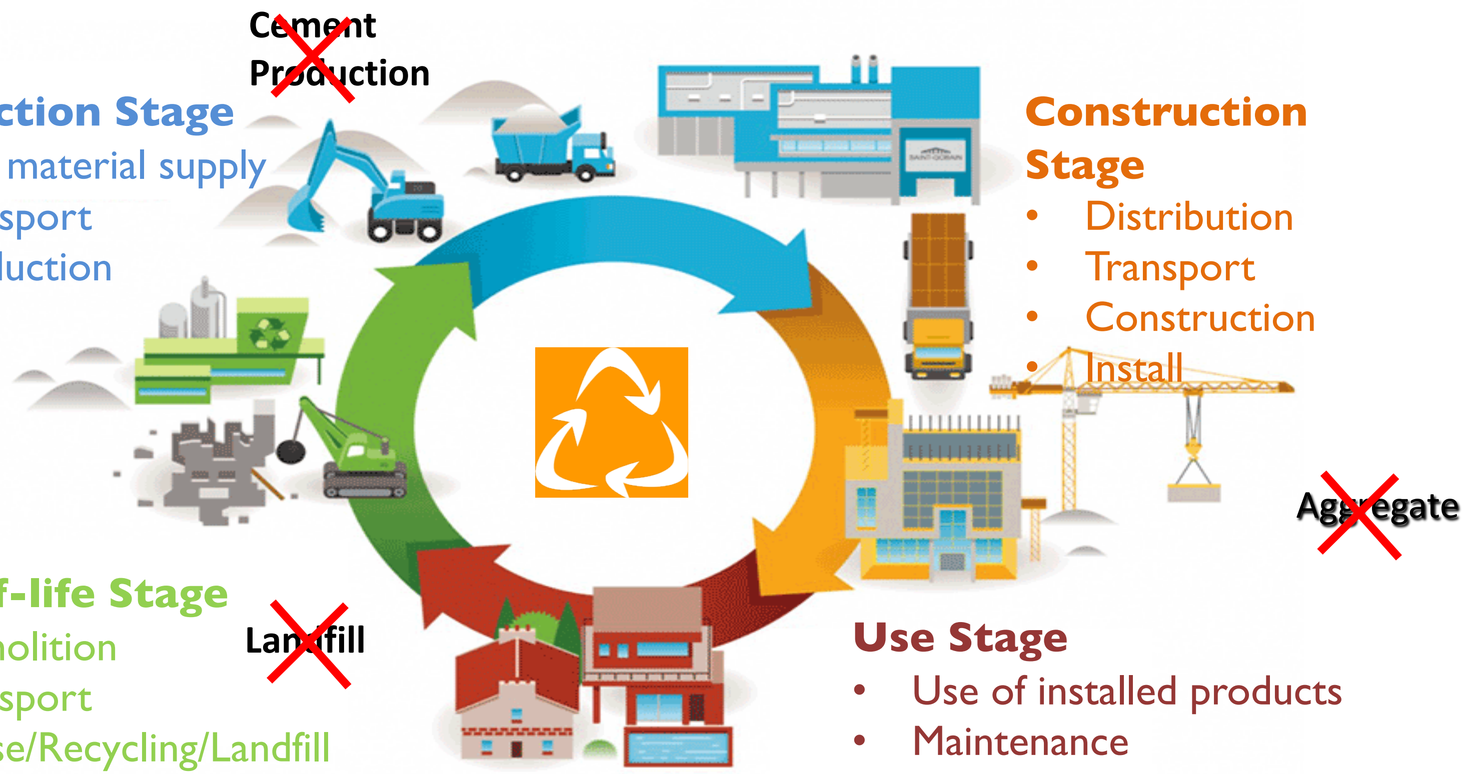


Lineer Economy

CDW Management Plan for Circular Economy

Phase	Actions	Outcomes
Pre-construction Phase	➢ Policies and strategic frameworks: economic tools ➢ Design ➢ CDW management plan	➢ CDW disposal fee to reduce waste to landfills ➢ Taxing on primary raw materials to encourage the demand for secondary building materials ➢ Encouragements for CDW management companies to reduce the high costs of recycling and recovery operations
Construction and Building	➢ Site waste management plans	➢ Designs to prevent waste ➢ Demountable designs ➢ Production of prefabricated elements
End of Service Life	➢ Pre-demolition audits ➢ Demolition processes	➢ Planning of waste management strategies ➢ Quantity, quality and risk analysis of materials ➢ Improved recycling efficiency ➢ Selective demolition
Collection and Separation	➢ Collection and separation techniques ➢ Transport processes	➢ Collection and separation of waste ➢ In situ classification ➢ Optimizing transport and distribution
Material Recovery and Production	➢ Material recycling ➢ Adaptation to circular economy ➢ Storage in field	➢ Reuse ➢ Recycle ➢ Energy recovery ➢ Sending to landfill

Life Cycle Assessment



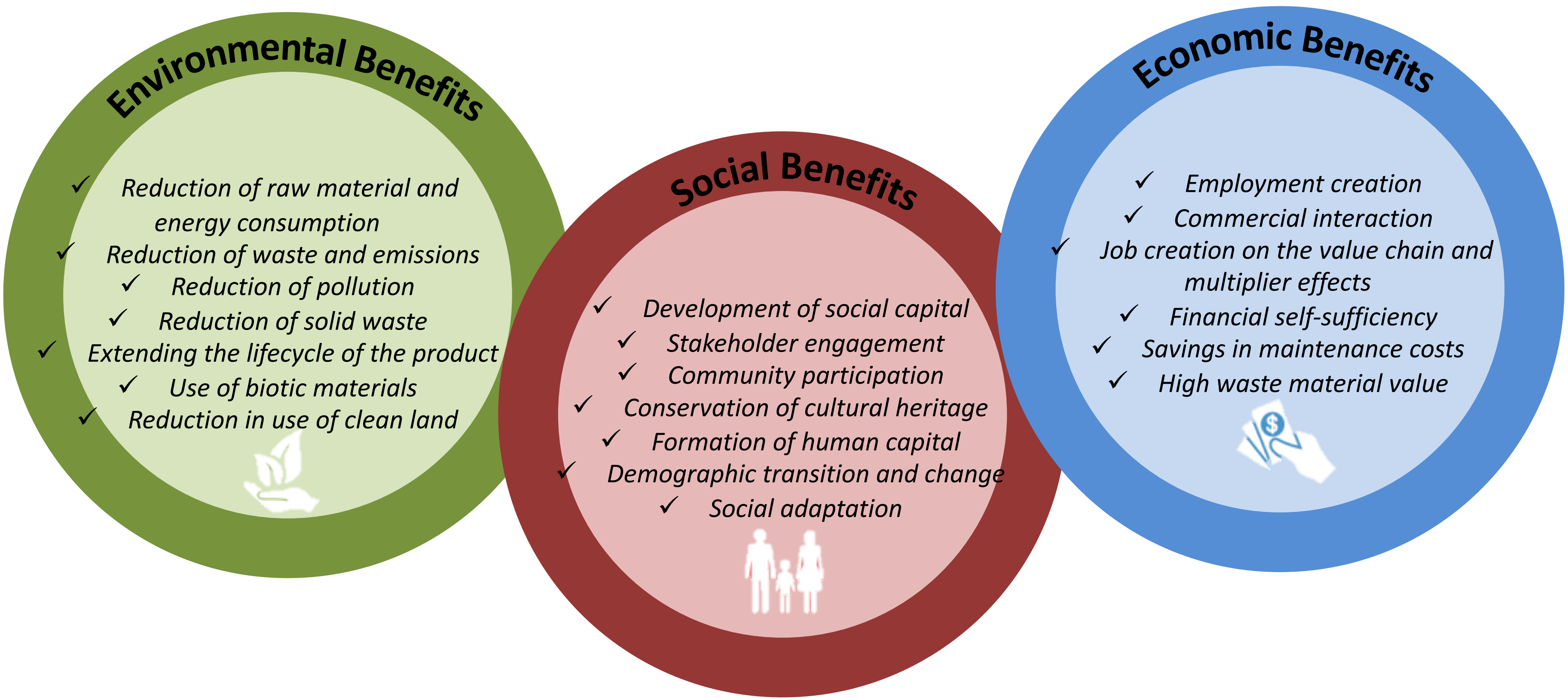
Production Stage
- Raw material supply
- Transport
- Production

Construction Stage
- Distribution
- Transport
- Construction
- Install

End-of-life Stage
- Demolition
- Transport
- Reuse/Recycling/Landfill

Use Stage
- Use of installed products
- Maintenance
- Renovation/Repair
- Functional use of the building

Benefits of Recycling of CDWs to the Circular Economy



Challenges in implementation of circular principles in the management of CDW

Challenge	Specification	CDW	Potential solutions
1- Quality of Waste	Heterogeneity (complex materials), too high content of impurities. Hazardous substances Lack of traceability. Material degradation during use.	Multicomponent products – sandwich constructions.	Less complex products. Pre-demolition audits with follow-up checks on the removal of contaminants prior to demolition. Introduction of sensors in products for securing traceability. Development of tools for detecting product degradation/ageing.
2- Technological challenge	Processing needs for new rejects. Complex products may require multiple processing steps before recycling, increasing total cost.	Prefabricated elements, fine fractions in concrete waste (cement), plastic waste, insulation waste.	New technological development/new business models. Design for disassembly (DfD).
3- Economics	Low price of virgin materials. Increase of cost due to more work intensive, higher energy needs. Lack of new business models – sharing of apparatus, facilities, etc.	Concrete waste, wood waste	Governmental measures – landfill bans, taxes, green public procurement supporting recycling. Sharing of process equipment.
4- Traceability	Lack of standards and tools. Quality systems for complex materials.	Concrete waste, reusable components/structures	Standardisation and commitments between stakeholders
5- Responsibilities	Role of different actors not clear. Extended product responsibility not applicable for construction products with long lifespan.	Products containing parts from several manufacturers	Role of building owner in construction phase.
6- Technical requirements	Potential overspecification of virgin materials, standards not suitable for recyclables.	Metal/wooden/concrete structural elements.	Development of new standards.
7- Legal issues	Difficulties for CE-marking (scope of harmonised product standards not covering waste related materials) Systems for implementation of EoW concept lacking in many EU Member States.	Metal/wooden/concrete structural elements.	Standardisation.
8- Environmental aspects	Emissions from several processes can increase impacts. Lack of assessment tools for estimation of material or landfill savings during whole lifetime – focus mainly on greenhouse gas emissions. Environmental impacts often case specific – local conditions, availability of alternative materials, transport. Risks for hazardous substances.	All waste types.	Develop further life cycle analysis indicators for the saving of natural resources – not only focus on greenhouse gases. Promotion of local solutions where materials are not transported.

Best Practices in Turkey – Selective Demolition

Challenge	Specification	CDW	Potential solutions
1- Quality of Waste	Heterogeneity (complex materials), too high content of impurities. Hazardous substances Lack of traceability. Material degradation during use.	Multicomponent products – sandwich constructions.	Less complex products. Pre-demolition audits with follow-up checks on the removal of contaminants prior to demolition. Introduction of sensors in products for securing traceability. Development of tools for detecting product degradation/ageing.

With the Selective Demolition;

- ✓ Decreased transfer of CDWs to clean landfills and consequent protection of land use,
- ✓ Evaluation of waste as secondary raw materials, consequently reducing the need for primary raw materials,
- ✓ Improved environmental protection, both locally and globally, by reducing waste storage and the use of new materials.
- ✓ Reduction in total demolition costs through storage fee savings and revenues from the sale of secondary raw materials,

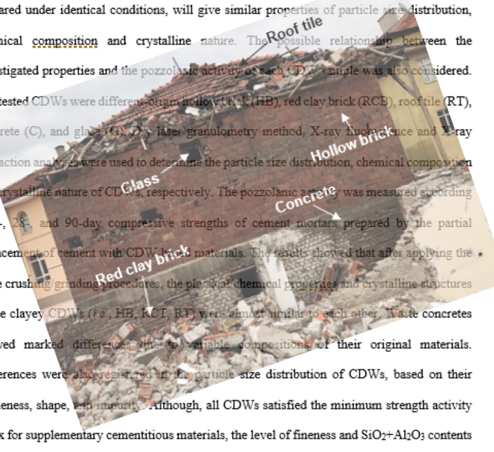
CAN BE PROVIDED.

Physical, Chemical and Mineralogical Characterization of Different-origin Construction and Demolition Wastes for Effective Recycling Performance

Emircan Ozcelikci[1,2*], Gurkan Yildirim[2,3], Hocine Siad[4], Mohamed Lachemi[4], Mustafa Sahmaran[2]

Abstract

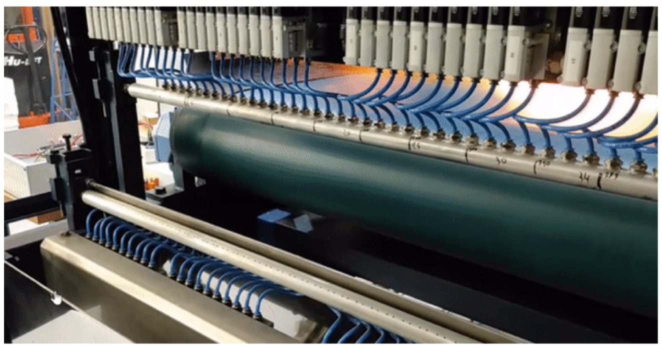
This study focuses on the detailed characterization of construction and demolition wastes (CDWs) collected from different sites to monitor whether the same type of wastes, when prepared under identical conditions, will give similar properties of particle size distribution, chemical composition and crystalline nature. The possible relationship between the investigated properties and the pozzolanic activity of each CDW sample was also considered. The tested CDWs were different-origin hollow brick (HB), red clay brick (RCB), roof tile (RT), concrete (C), and glass (G). Dry laser granulometry method, X-ray fluorescence and X-ray diffraction analyses were used to determine the particle size distribution, chemical composition and crystalline nature of CDWs, respectively. The pozzolanic activity was measured according to 7-, 28-, and 90-day compressive strengths of cement mortars prepared by the partial replacement of cement with CDW-based materials. The results showed that after applying the same crushing/grinding procedures, the physical/chemical properties and crystalline structures of the clayey CDWs (*i.e.*, HB, RCT, RT) were almost similar to each other. Waste concretes showed marked differences due to variable compositions of their original materials. Differences were also registered in the particle size distribution of CDWs, based on their brittleness, shape, and impurity. Although, all CDWs satisfied the minimum strength activity index for supplementary cementitious materials, the level of fineness and $SiO_2+Al_2O_3$ contents highly influenced their pozzolanic activity results. This highlights the importance of CDW characterization when using materials of different origins, especially for concrete waste.

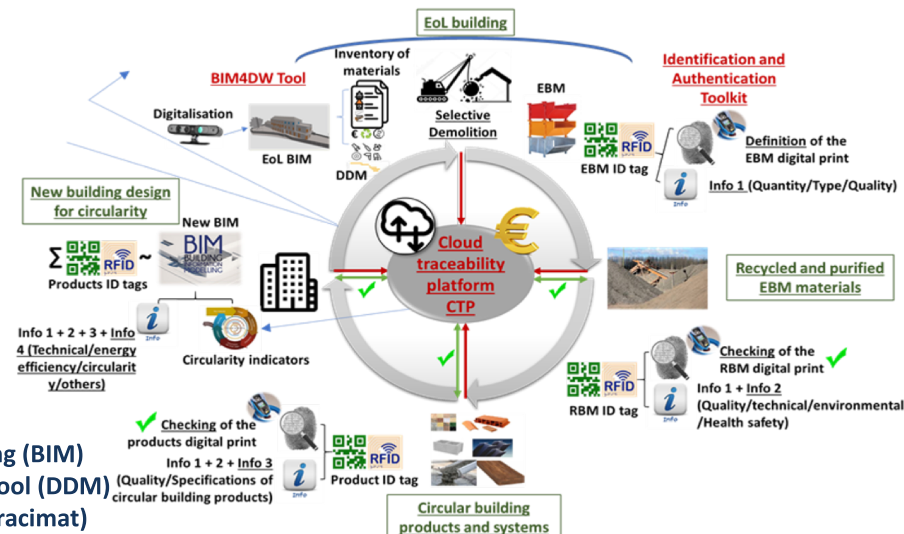


Best Practices in Turkey – Technological Advances

Challenge	Specification	CDW	Potential solutions
2- Technological challenge	Processing needs for new rejects. Complex products may require multiple processing steps before recycling, increasing total cost.	Prefabricated elements, fine fractions in concrete waste (cement), plastic waste, insulation waste.	New technological development/new business models. Design for disassembly (DfD).

Sorting Technology of mixed CDW



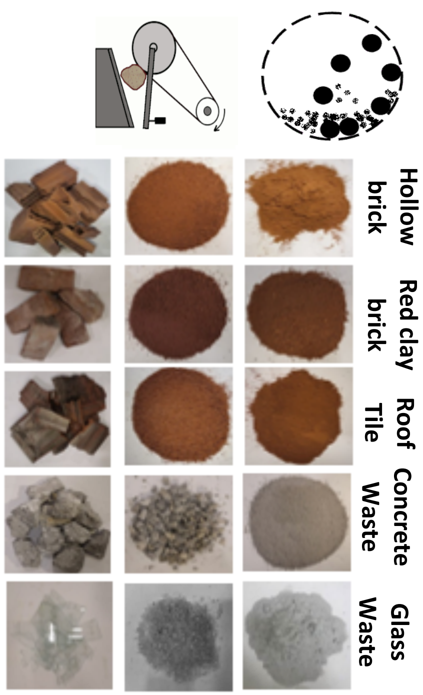


- Building information modelling (BIM)
- Demolition decision-making tool (DDM)
- İYA izleme ve takip araçları (Tracimat)
- Contactless tag identification (RFID)
- Cloud Traceability Platform (CTP)
- Hyper-Spectral Imaging (HSI)
- Thermal attrition mobile unit
- Laser-Induced Breakdown Spectroscopy
- Accelerated carbonation systems
- High purity and nano-scale micro grinding systems

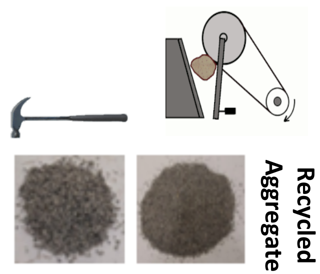
Best Practices in Turkey – Brick production and recycled asphalt applications with CDW

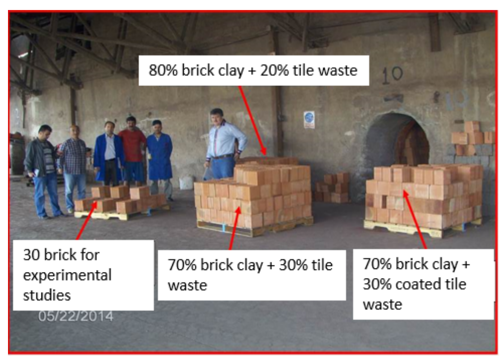
Challenge	Specification	CDW	Potential solutions
3- Economics	Heterogeneity (complex materials), too high content of impurities. Hazardous substances Lack of traceability. Material degradation during use.	Multicomponent products – sandwich constructions.	Less complex products. Pre-demolition audits with follow-up checks on the removal of contaminants prior to demolition. Introduction of sensors in products for securing traceability. Development of tools for detecting product degradation/ageing.

Crushing & Grinding



Crushing & Sieving





Brick production with brick and tile waste

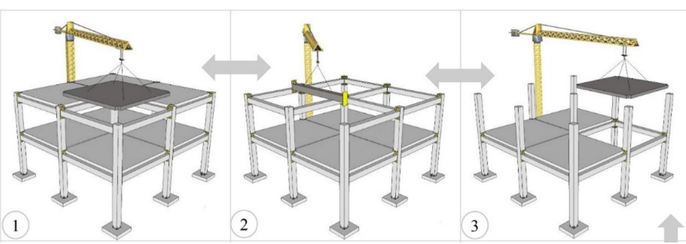
Sub-base application with CDW
İSTAÇ Bolluca Route

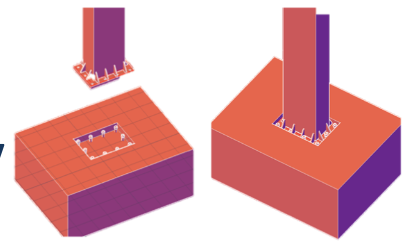
Reycled asphalt pavement
İSTAÇ Bolluca Route

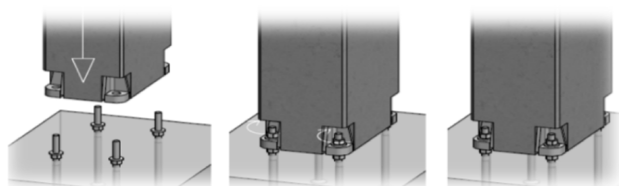
Best Practices in Turkey – Demountable System Design

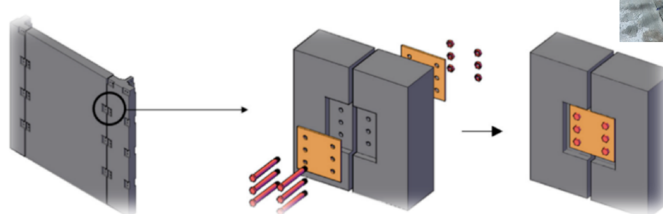
Challenge	Specification	CDW	Potential solutions
3- Economics	Processing needs for new rejects. Complex products may require multiple processing steps before recycling, increasing total cost.	Prefabricated elements, fine fractions in concrete waste (cement), plastic waste, insulation waste.	New technological development/new business models. Design for disassembly (DfD).

- ✓ **Development of a new generation binder with CDW-based materials**
- ✓ **Ability to be disassembled and rebuilt in different locations in a practical way**
- ✓ **High level of strength and durability**
- ✓ **High mobility allowing it to be built everywhere**





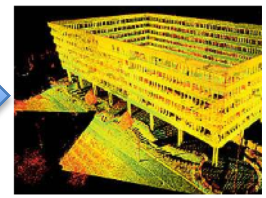


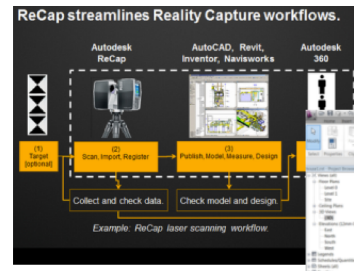


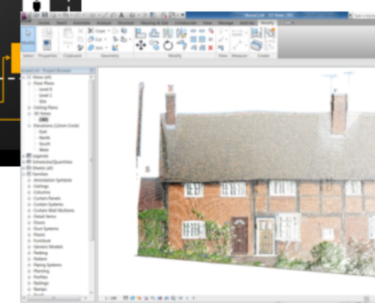
Best Practices in Turkey – Traceability

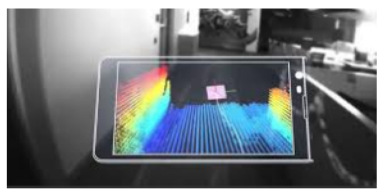
Challenge	Specification	CDW	Potential solutions
4- Traceability	Lack of standards and tools. Quality systems for complex materials.	Concrete waste, reusable components/structures	Standardisation and commitments between stakeholders

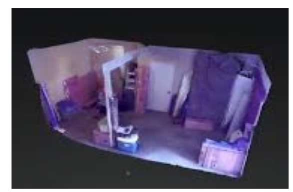
Laser Scanning

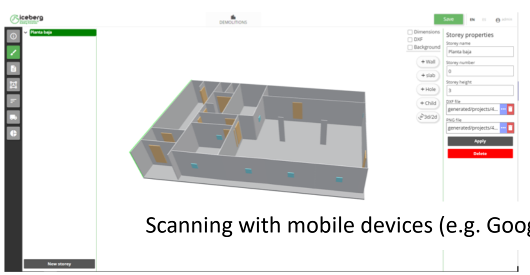












Scanning with mobile devices (e.g. Google Tango)

Existing floor plans, digitization of drawings…

Best Practices in Turkey – Extended Product Responsibility

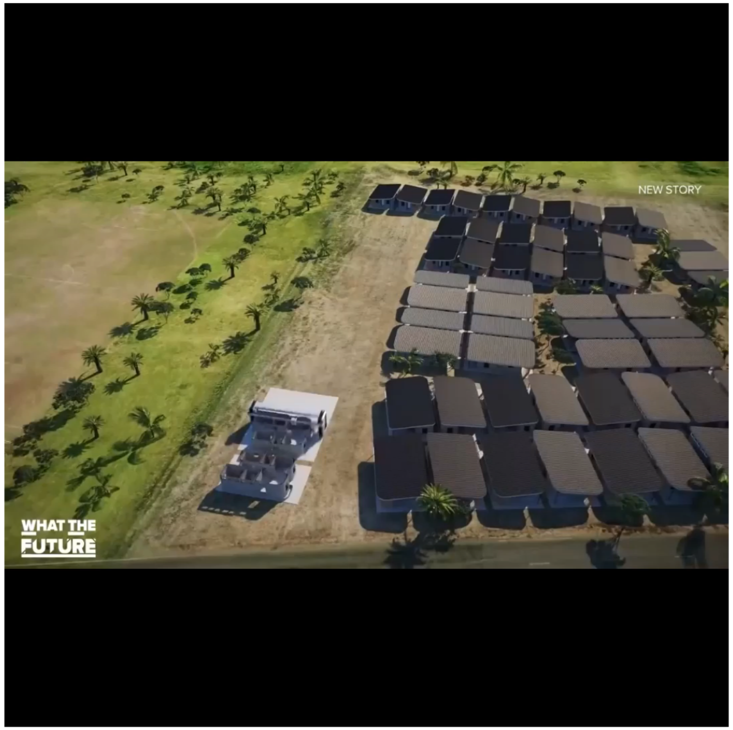
Challenge	Specification	CDW	Potential solutions
5- Responsibilities	Role of different actors not clear. Extended product responsibility not applicable for construction products with long lifespan.	Products containing parts from several manufacturers	Role of building owner in construction phase.

Best Practices in Turkey – 3D Additive Manufacturing

Challenge	Specification	CDW	Potential solutions
6- Technical requirements	Potential overspecification of virgin materials, standards not suitable for recyclables.	Metal/wooden/concrete structural elements.	Development of new standards.

With the implementation of 3D into the construction industry

- Developing a design repertoire for post-disaster shelters
- Development of process design to automate the design-to-manufacturing workflow
- Design a tool for developing technical solutions in Additive Manufacturing (AM) where industrial robot arms can be used with binder material
- Development of eco-friendly, new generation printable building materials prepared from 100% CDW
- Production of affordable housing structures in a short time without the need for molds with additive production techniques



Best Practices in Turkey – Material Passport

Challenge	Specification	CDW	Potential solutions
7- Legal issues	Difficulties for CE-marking (scope of harmonised product standards not covering waste related materials) Systems for implementation of EoW concept lacking in many EU Member States.	Metal/wooden/concrete structural elements.	Standardisation.

ICEBERG Projesi - TUDelft

RFID reader

RFID tag in concrete cube

Evaluation of readability in concrete cube

RFID tag in aggregate

Evaluation of readability in aggregate

Best Practices in Turkey – CDW-based Green Concrete Production

LCIA Category	Units	Concerns	CML-1A Method		Impact-2002+ Method	
			100% CDW Based Concrete	Portland Cement Concrete	100% CDW Based Concrete	Portland Cement Concrete
Global warming potential (GWP100)	kg CO2 eq.	Greenhouse gas emissions to the atmosphere	-0.395	311	-4.08165	307.5908
Stratospheric ozone depletion (ODP10)	kg CFC-11 eq.	UV-B radiation that poses risks for human and animal health, ecosystems, cycles and materials	0.000118	1.2E-5	0.000118	1.24E-05
Acidification potential (AP generic)	kg SO2 eq.	Harmful impacts of acidification on soil, surface water, groundwater, ecosystem organisms and materials	-0.381	0.695	-0.40724	0.76613
Photochemical oxidation	kg C_2H_4 eq.	Formation of photo-oxidants that poses risks for human health and ecosystem.	-0.00889	0.0297	-	-
Terrestrial Ecotoxicity Potential (TETP)	1,4-dichlorobenzene equivalents	Harmful impacts on terrestrial ecosystem	0.268	1.88	7774.337 (kg TEG soil)	3544.881 (kg TEG soil)
Land Occupation	m^2 org.arable	Organic arable land damage	-	-	1.317384	2.91297
Mineral Extraction	MJ surplus	The problem of finite exhaustion of finite resources with mineral resource extraction	-	-	-8.80534	4.770854

Best Practices in Turkey – CO_2 Capture of Recycled Aggregates

Challenge	Specification	CDW	Potential solutions
8- Environmental aspects	Emissions from several processes can increase impacts. Lack of assessment tools for estimation of material or landfill savings during whole lifetime – focus mainly on greenhouse gas emissions. Environmental impacts often case specific – local conditions, availability of alternative materials, transport. Risks for hazardous substances.	All waste types.	Develop further life cycle analysis indicators for the saving of natural resources – not only focus on greenhouse gases. Promotion of local solutions where materials are not transported.


REDUCING CO2 EMISSIONS WITH NEW GREEN CONCRETE

Climate change is primarily caused by too much carbon dioxide (CO2) in the atmosphere. Human activity such as burning coal and cutting down forests is causing atmospheric CO2 to increase at an unprecedented rate, with potentially devastating global consequences. Construction and demolition waste (CDW) is one of the main offenders, responsible for 30% of total urban waste and colossal CO2 emissions. The landfilling of CDW is also extremely costly and harmful to the environment.

A new low-cost 'green concrete' made entirely from recycled CDW that not only reduces CO2 emissions, but promises safe permanent storage of CO2 through binding high levels of CO2 to itself during production. The use of recycled CDW also decreases the quarrying of new raw materials, taking away the need to strip the earth of its natural resources.

The UK-Turkey GreenLegOuse project has created a flexible, lego-like construction system that can be quickly built to provide affordable accommodation for low-income communities, including the homeless, slum-dwellers and refugees, not only in Newton Fund partner countries but countries all around the world. The system can also be disassembled and reassembled, increasing its reusability and recyclability with easy-to-implement, low-cost and energy-efficient techniques, and removing the need for heavy demolition processes and the pollution this creates.

Kadir Celep/Unsplash

The project developed research capacity in Turkey and provided opportunities to initiate completely new lines of research in this field. By working closely with the construction industry, the team aim to increase the project's impact and contribute to global economic, environmental and social development.

Lego construction system of "green" structural components for low-cost housing

Project leads:
Professor Ashraf Ashour, University of Bradford, UK and Professor Mustafa Sahmaran, Hacettepe University, Turkey

Delivery partners:
British Council, UK and the Scientific and Technological Research Council, Turkey

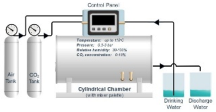
The construction industry is a huge contributor to climate change. Our circular economy approach aims to drastically reduce waste, bring down CO2 emissions and reduce environmental damage, while ensuring construction demands can be met.

Professor Mustafa Sahmaran, Hacettepe University, Turkey

28 Newton Prize 2020

- ✓ **40% reduction in water absorption capacity of recycling aggregates**
- ✓ **Carbondioksite capture at ~350 kg CO2/ Ton-paste levels as a result of carbonation.**
- ✓ **~35% increase in compressive strength of mortar mixes using recycled aggregate**

Lafarge (Fastcarb Project)



Thank You !

Prof. Dr. Mustafa ŞAHMARAN

Advanced Construction Materials Research Laboratory
Hacettepe University
Civil Engineering Department

Contact: sahmaran@hacettepe.edu.tr

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of the consortium led by DAI Global Austria GmbH & Co KG, and do not necessarily reflect the views of the European Union.