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# A hybrid life cycle analysis method for the environmental assessment of conventional building materials


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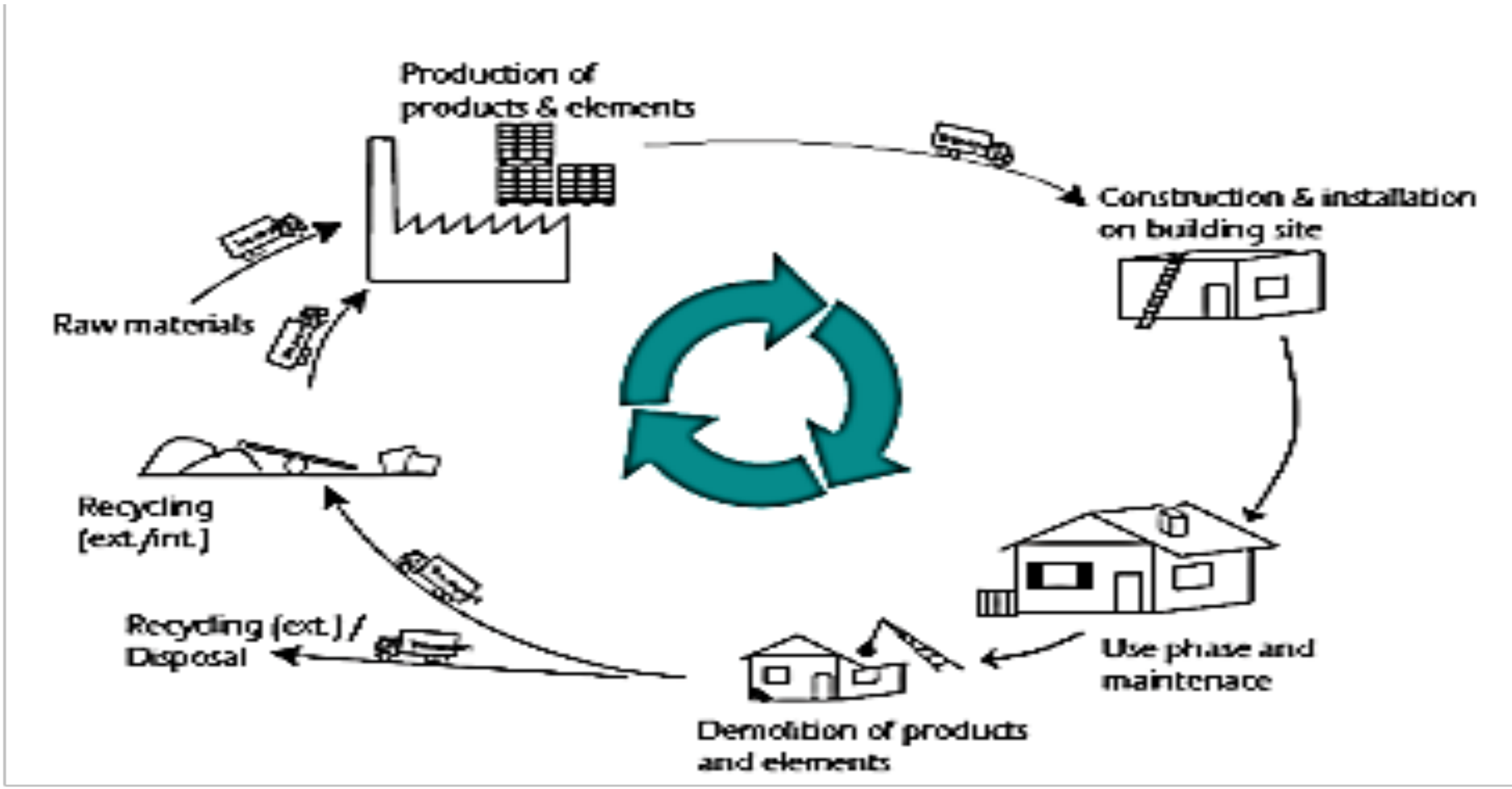
# Project objective

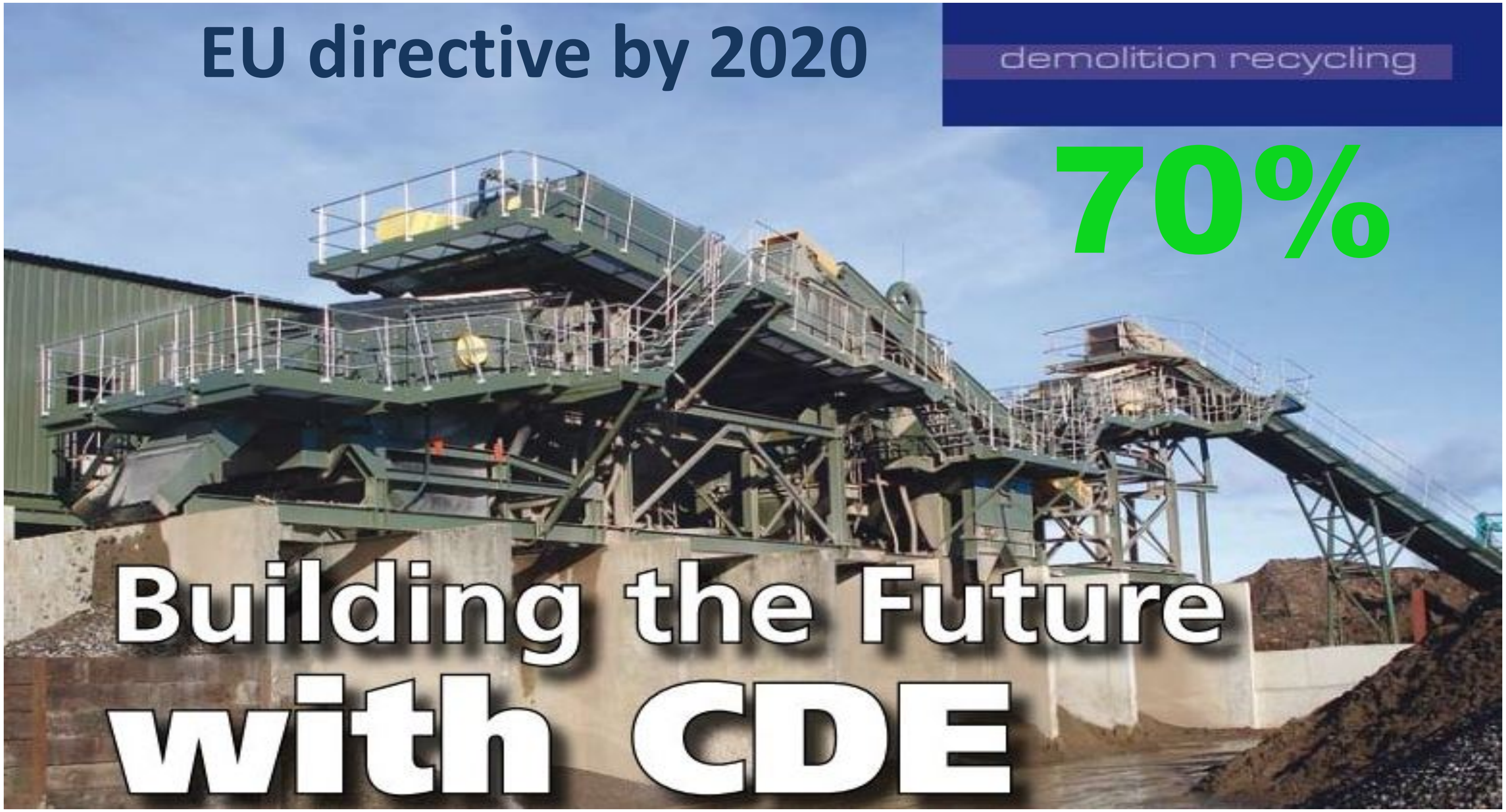
The reuse of conventional construction demolition materials (after the end of life of the materials) as materials for the production of concrete aggregates and not just the disposal in landfills.



# Aim of the study

- ✓ Research Environmental indicators (in Greece) such as GWP, Ozone Depletion and their impacts to Environment. Compares the concrete production C20/25 which use common gravels with a new production of a new Concrete C20/25 (Green Concrete) which uses 70% percentage of recycled aggregates from construction waste after the ''end of their life''.
- ✓ Increase Environmental Awareness and minimize the loss of useful materials in Greece.
- ✓ Analysis of raw material separately before integrating them into concrete and then to a construction structure.

# EU directive by 2020




The recent EU directive ′′Building the future with construction, demolition and excavation waste (CDE)′′ prescribes a recycling rate of 70% of various construction and demolition waste by 2020′′. In Greece, we all need to focus on how we can meet this targets. Soon the recycling of old concrete and rubble will be mandatory.

# EU directive by 2020

The use of modern construction materials should be performed emphasizing on the energy intensity of materials, natural resources and the materials consumed, recycling and safe disposal and the effects they cause to the environment.

# LCA & Impact Assessment Methods



LCA is a powerful tool for the evaluation of life cycle of materials.
The goal of LCA is to compare the full range of environmental effects assignable to products and services by quantifying all inputs and outputs of material flows and assessing how these material flows affect the environment

## ILCD

The International Reference Life Cycle Data System (ILCD) has published ‘’Recommendations for Life Cycle Impact Assessment in the European context’’ and this methodology has been evaluated as the best within the impact category. Further, this system specifies the broader provision of the ISO 14040 and 14044 standards on environmental life cycle assessment (LCA).

## TRACI

The U.S. Environmental Protection Agency developed an Impact Assessment methodology called TRACI, short for "Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts". The aim of this method is to assist in enabling Impact Assessment for sustainability, Life Cycle Assessment, industrial ecology, process design and pollution prevention.

# Environmental Indicators Impact Assessment Methods ILCD & TRACI

## ILCD

- Global Warming Potential (GWP), [kg CO2 - Eq.]
- Ozone Depletion (ODP), [kg CFC11-Eq.]
- Acidification (AP) / [Mole of H + eq.]
- Eutrophication (EP) / [Mole of N. eq]
- Photochemical Ozone (POCP), [kg NMVOC Equiv]
- Abiotic resource depletion (ADP), [kg Sb-Equiv.]
- Resource depletion, Water [kg]
- Particulate matter [PM2.5 eq]
- Human toxicity, non-cancer effects [CTUh]

## TRACI

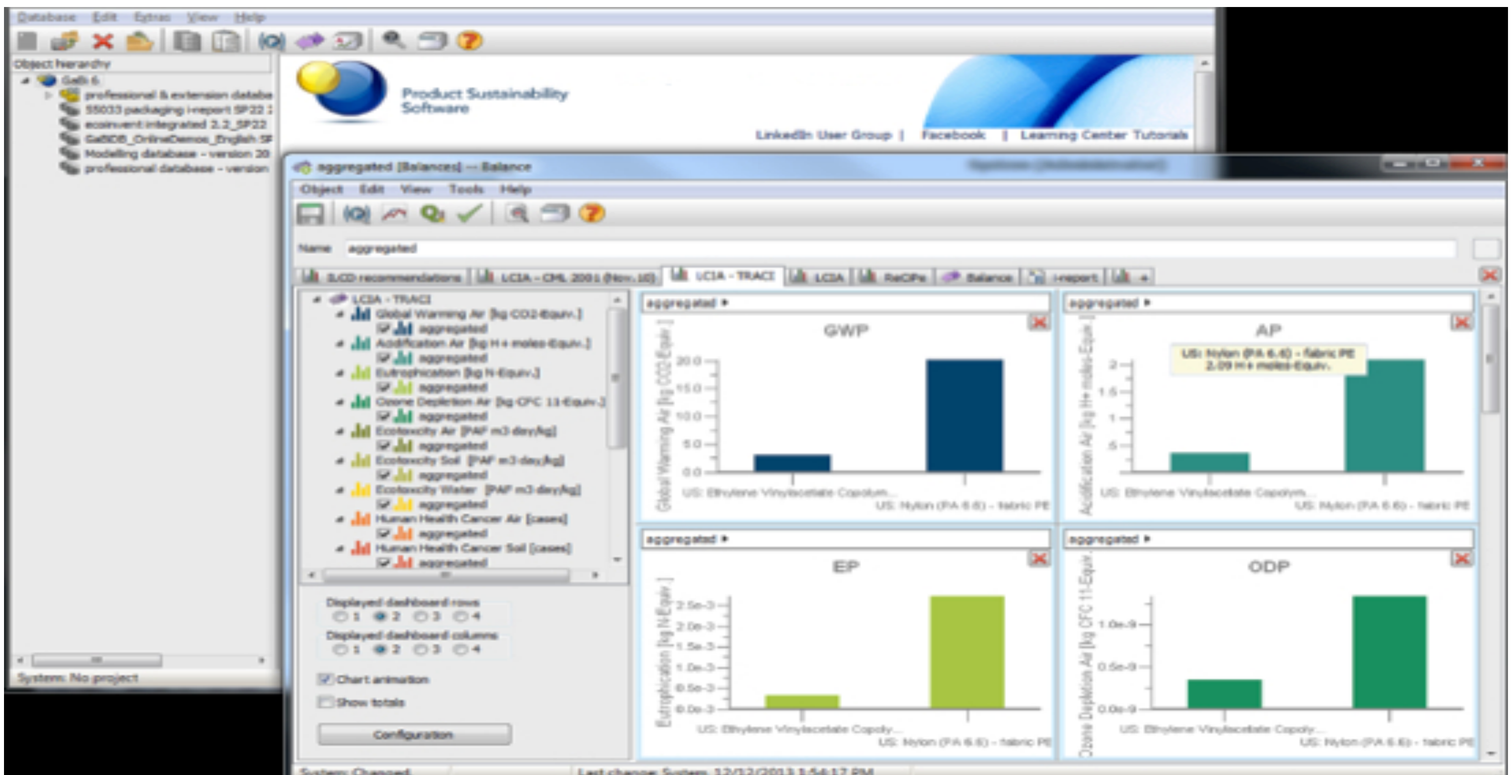
- Global warming potential (GWP)
- Ozone Depletion (OPD)
- Acidification Potential (AP)
- Eutrophication Potential (EP)

# LCA software and Life cycle analysis



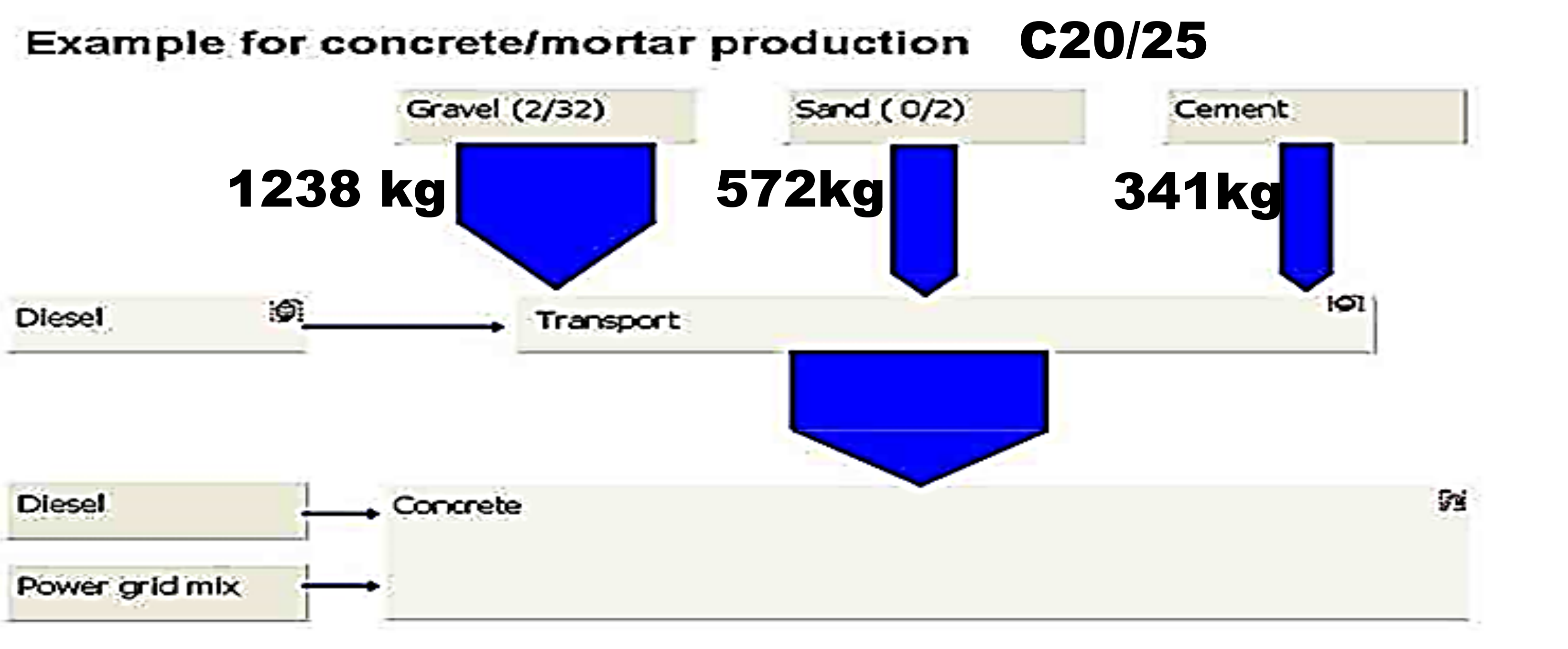
The LCA program includes:

- The user interface modeling of production system
- Impact assessment data bases with data which supporting various methodologies of the life cycle impact assessment and
- A calculator which calculate - combine data derived from the database, according to the modeling of the product system and user requirements.



# Rules of Concrete Technology in Greece

To produce 1 cubic (m3) concrete according to the mix design for class C20/25 it needs for Aggregates: 69% Gravel and 31% Sand (Rules of Concrete Technology / Ministry of Environment, Greece / YPEKA 2015).




We introduced in LCA software as data elements 572kg of sand and 1238 kg of aggregates (common Gravel). Also according to the Concrete formulation C20/25 341,00kg of Portland cement.

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# Scenario1

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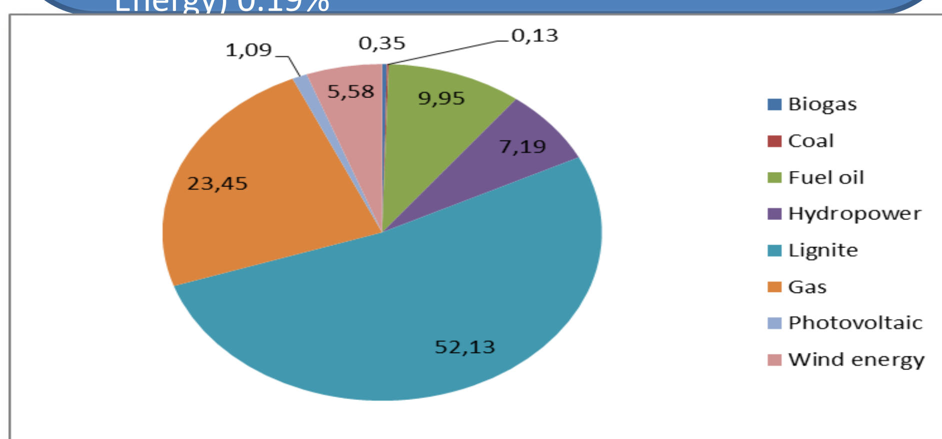
Scenario1 includes the production of Concrete C20/25 according to the Rules of Concrete Technology :

- as data elements 572kg of sand, 1238 kg of aggregates (common Gravel) and 341,00kg of Portland cement.
- distance transportation of materials 100km and mixed energy

## ILCD

Mixed Energy in Greece includes energy from various sources :

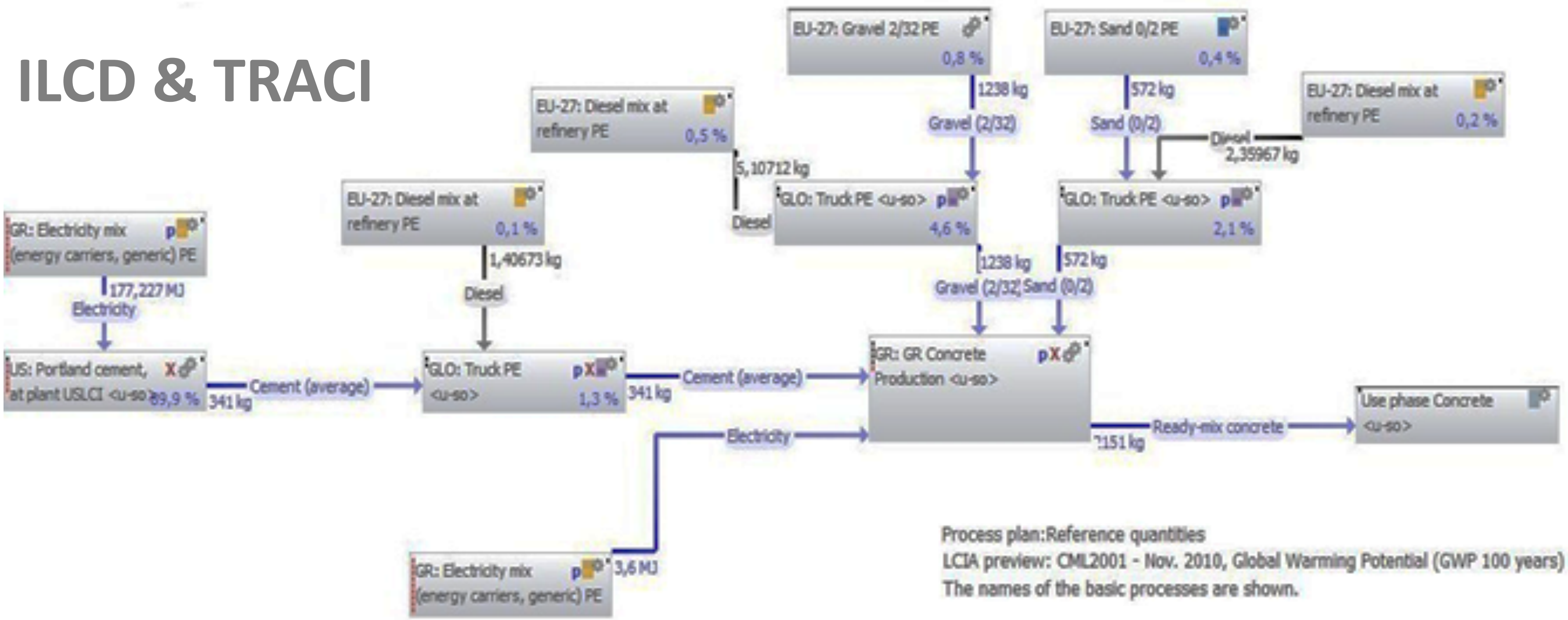
- from biogas 0,35%
- from hard coal 0,13%
- from 9.95%
- from hydropower 7,19%
- lignite 52,13%
- from natural gas 23.45%
- from photovoltaic 1,09%
- from wind energy 5.58%
- Electricity from waste incineration (Waste-to-Energy) 0.19%



# Scenario1 and Scenario 1a

## Life cycle Analysis (LCA)

## ILCD & TRACI

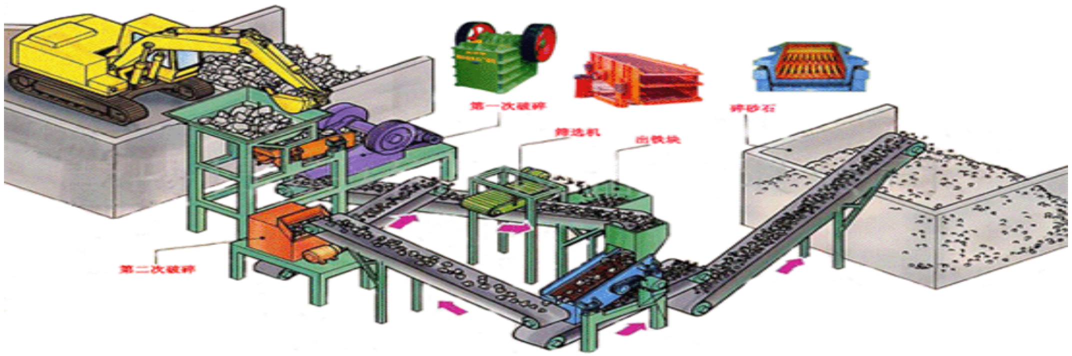



<u>Process Flow Diagram</u>

In this process plan of Scenario1 : we can see the names of the basic processes. And also we can see the quantities. The flows that enter the product system coming from the natural system (our environment, e.g. resources as diesel) or that leave the system (e.g. Carbon dioxide ($CO_2$) emissions) are called elementary flows. We create a list of all the input/output elementary flows associated with our system.

# Scenario2

# Recycling gravels /Distance transportation of materials 50km / Renewable Energy Sources



At this scenario, the production of concrete C20/25 in Greece includes three new parameters :

a) Replaced 70% of aggregates with recycled demolition materials from construction waste after their life end. According to the latest EU Directive.

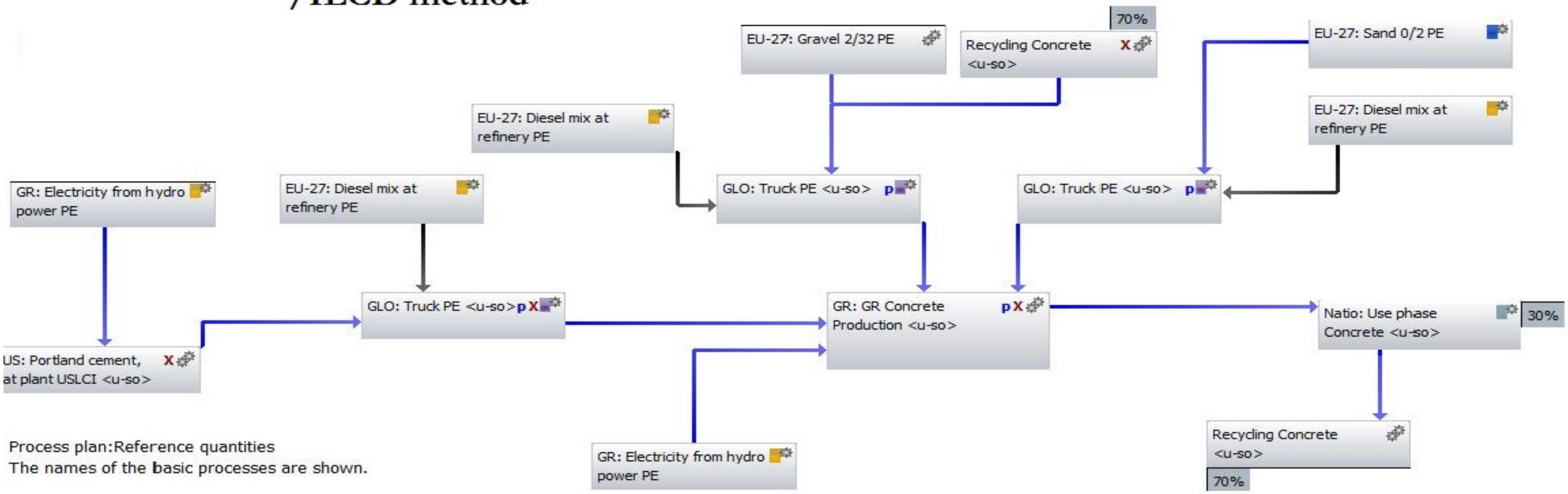
b) Reducing the distance transportation of materials from 100km to 50km. In this Scenario, ´´green areas´´ will be created in each region. Demolition products and treatment of them should be installed near the cement industry and at a distance of no more than 50km. These parameters will reduce all environmental indicators. In the future ‘‘worst-case scenario'' materials is no longer available in the country so it's a crucial parameter the distance of materials and affects all environmental indicators.

c) Energy production is considered the energy of renewable energy sources.

# Scenario2

## Life cycle analysis (LCA)

**Scenario2/Concrete C20/25/ 70% Recycling Gravel / 50km distance /ILCD method**




Process Flow Diagram :

At the second parameter, we determine the transport distance leading to a decrease in energy required during the transportation of materials and therefore a reducing the overall environmental impacts. The data for the energy carrier based on statistics of the country and LCA software database. Been used trucks for transportation of raw materials to the production plant by using diesel as energy. So 866.6 kg of aggregates is used by the recycling of construction materials after the end of their life. This contributes to a reduction of 70% in aggregate mining from the 1238 kg aggregates required for the preparation of 1m3 of concrete.

# Results

| Environmental indicators | Scenario1 ILCD | Measurement Unit ILCD method | Scenario1a TRACI | Measurement Unit TRACI method | Scenario 2 ILCD |
|---|---|---|---|---|---|
| **GWP** | 352,17 | kg CO2 – Eq. | 351,86 | kg CO2 – Eq. | 334,85 |
| **ODP** | 1,1 | e - 9kg CFC11-Eq. | 1,1 | e - 9kg CFC11-Eq. | 4,127 e – 10 kg CFC11-Eq. or 0,4127 e – 9 kg CFC11-Eq |
| **AP** | 1,674 Mole of H + eq. or 0,00167 kg of H + eq. | Mole of H + eq. | 79,37 kg H + moles-Equiv or 0,00100 kg of H + eq. | kg H + moles-Equiv | 1,527 |
| **EP** | 5,17 Mole of N. Eq or 0,07238 kg N - Equiv | Mole of N. eq | 0,063 | kg N - Equiv | 4,42 or 0,06188 kg N - Equiv |
| **POCP** | 0,99 | kg NMVOC Equiv | - | - | 0,95 |
| **ADP** | 1,467 | kg Sb-Equiv. | - | - | 2,055 |
| **Resource Depletion Water** | 87,6 | Water [kg] | - | - | 198,47 |
| **Human toxicity - Non cancer effect** | 2,793 | CTUh | - | - | 2,29 |
| **Particulate Matter** | 0,044 | PM2.5 eq | - | - | 0,039 |

In Scenario2 we observe the majority of the indicators having a significant reduction in most Environmental indicators.

# Global warming potential (GWP) & Impact at the "Resources"

## Scenario1

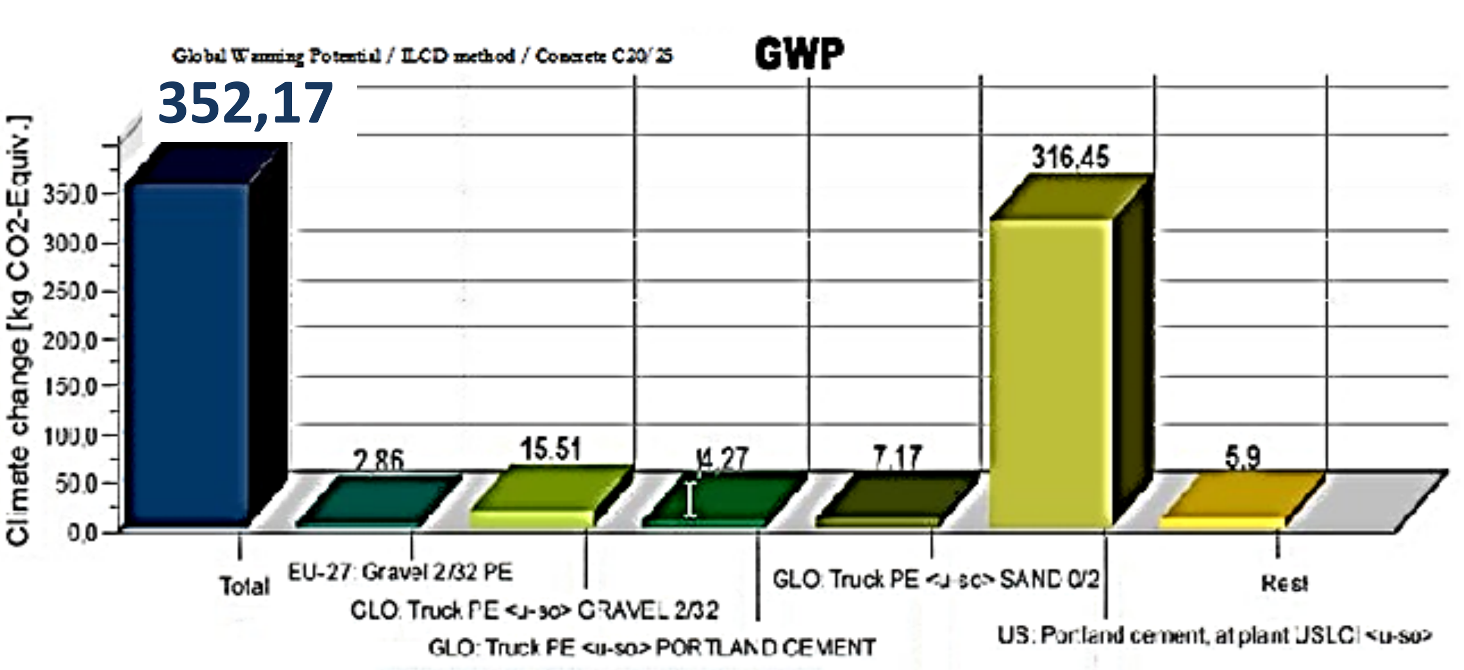
| Scenario 1 - Production of Concrete in Greece (GWP) - % | |
|---|---|
| Flows | 100 % |
| Resources | 55,8 |
| Deposited goods | 2,13 |
| Emissions to air | 6,39 |
| Emissions to fresh water | 35,53 |
| Emissions to sea water | 0,119 |
| Emissions to agricultural soil | 1,28E - 006 |
| Emissions to industrial soil | 3,32E - 007 |
| | |

## Scenario2

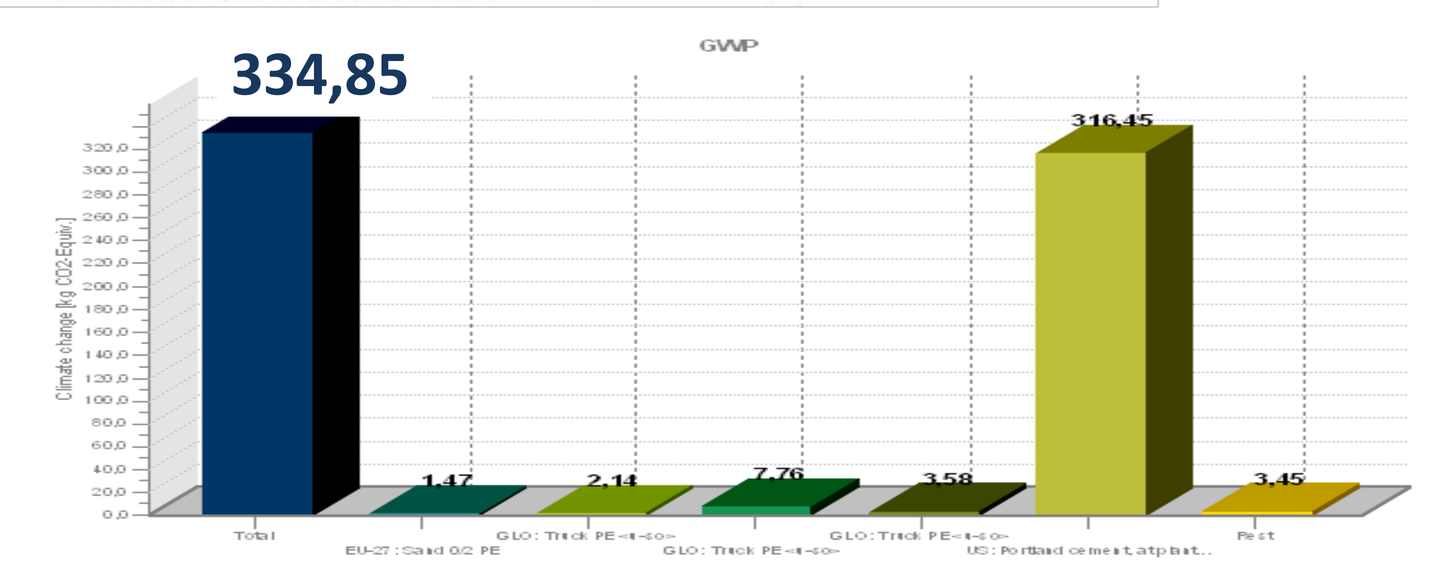
| Scenario 2 - Production of Concrete in Greece (GWP) - % | |
|---|---|
| Flows | 100 % |
| Resources | 50,58 |
| Deposited goods | 0,179 |
| Emissions to air | 1,90 |
| Emissions to fresh water | 47,32 |
| Emissions to sea water | 0,008 |
| Emissions to agricultural soil | 1,026E - 006 |
| Emissions to industrial soil | 2,692E - 007 |

# Global Warming Potential indicator (GWP)

Scenario1

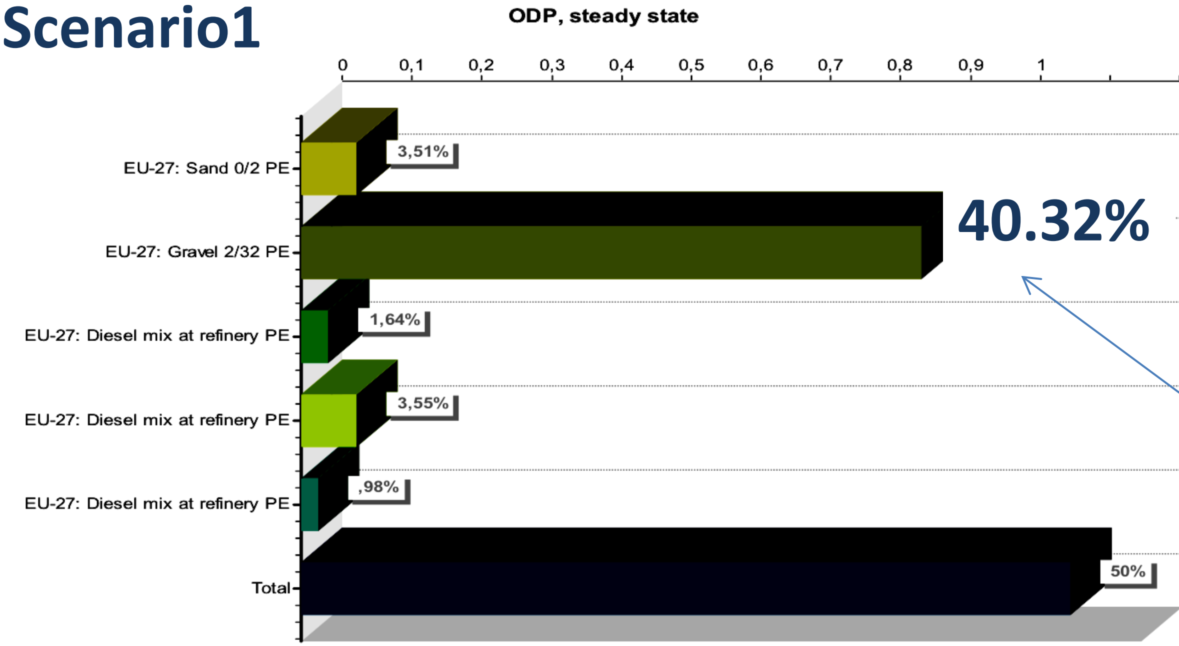



Scenario2



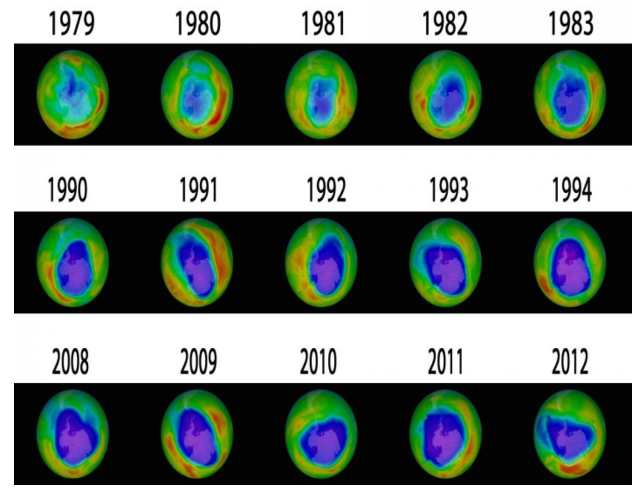
# Ozone Depletion (ODP), [kg CFC11-Eq.]

## Scenario1



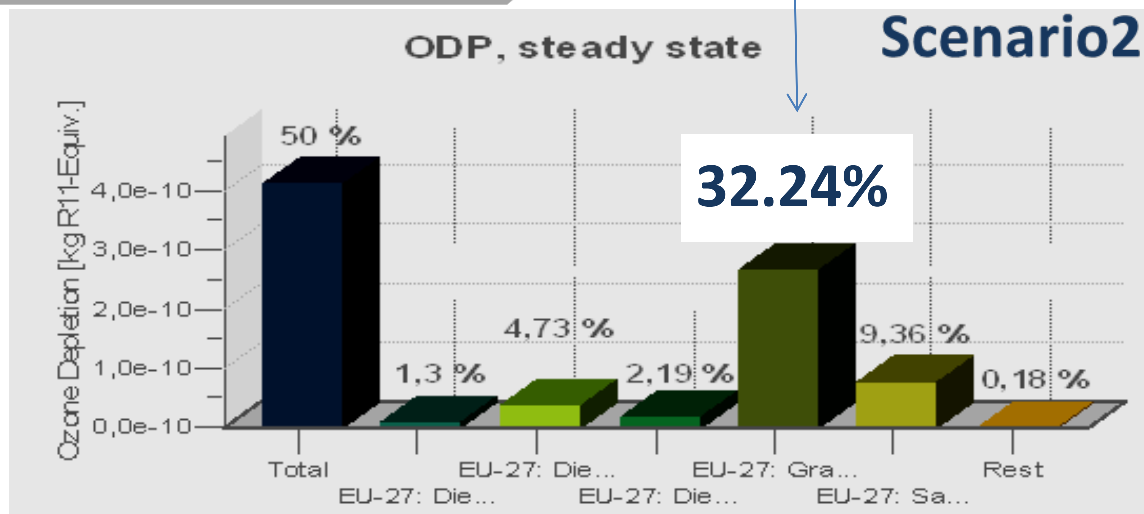

**40.32%**

## Ozone Hole




**Gravel**

## Scenario2



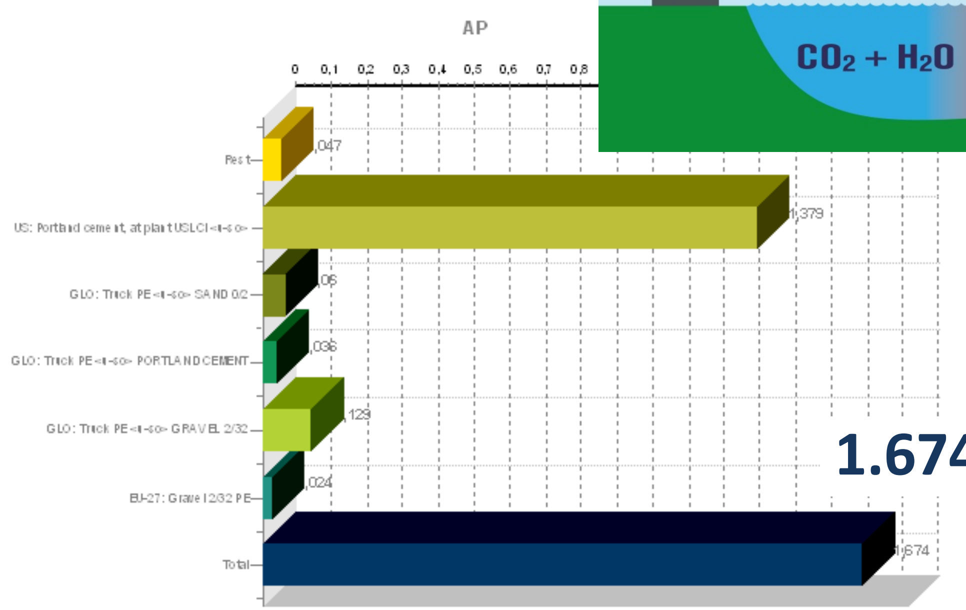

**32.24%**

Over the course of 2 to 3 months, approximately 50% of the total column amount of ozone in the atmosphere disappears.

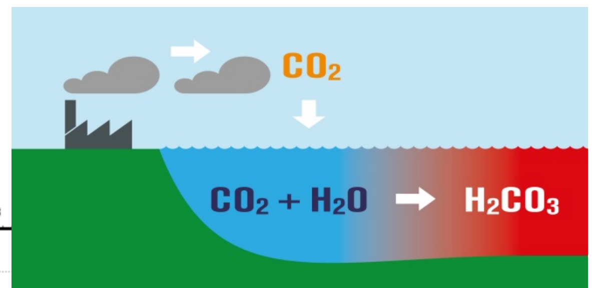
# Acidification (AP)
# [Mole of Hydrogen + equivalent ]

In addition to overheating of the atmosphere, carbon dioxide emissions have a negative effect on acidification of the oceans.
According to a report that presented at a recent South Korean conference, the acidity of the oceans has increased by 26% compared to the time before the extensive industrialization. We observe the reduction of environmental indicator Acidification (AP) in Senario2 with the value 1,527 Mole of H + eq.

## Scenario1

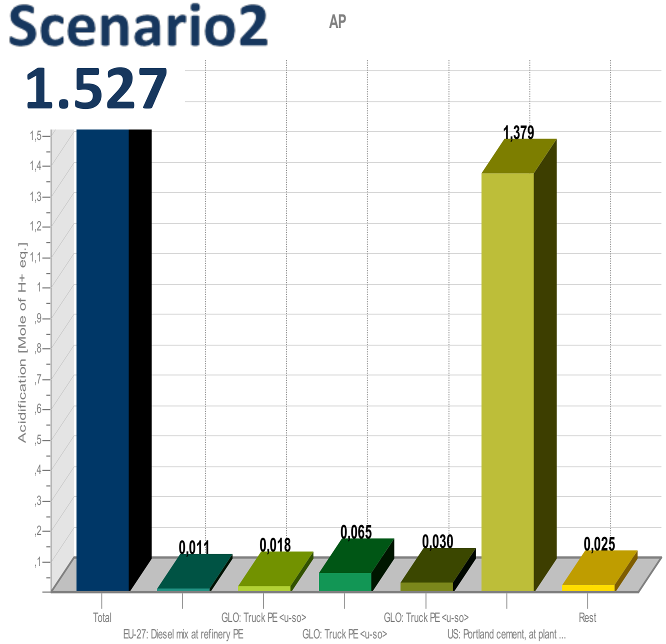



1.674




## Scenario2

1.527



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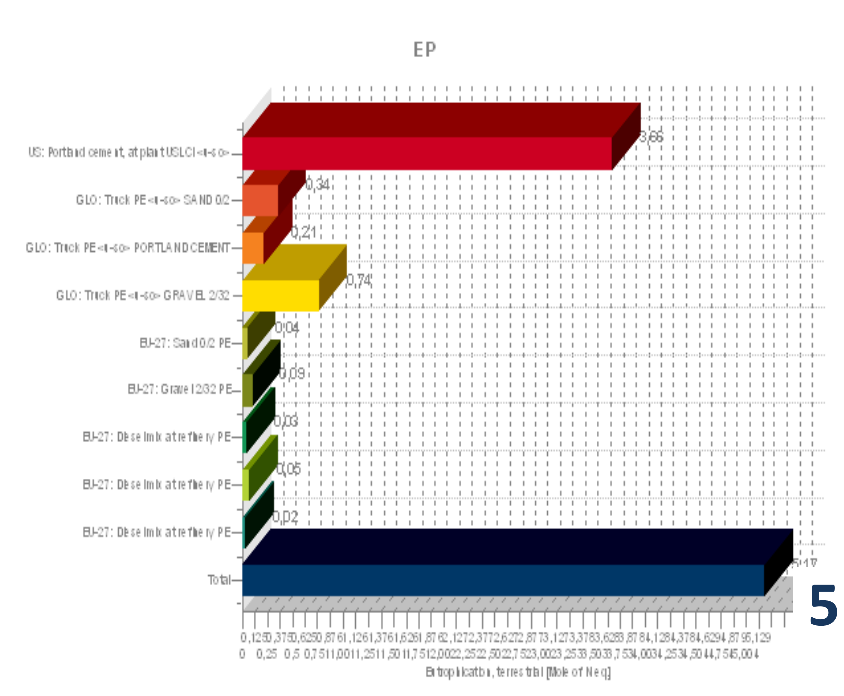
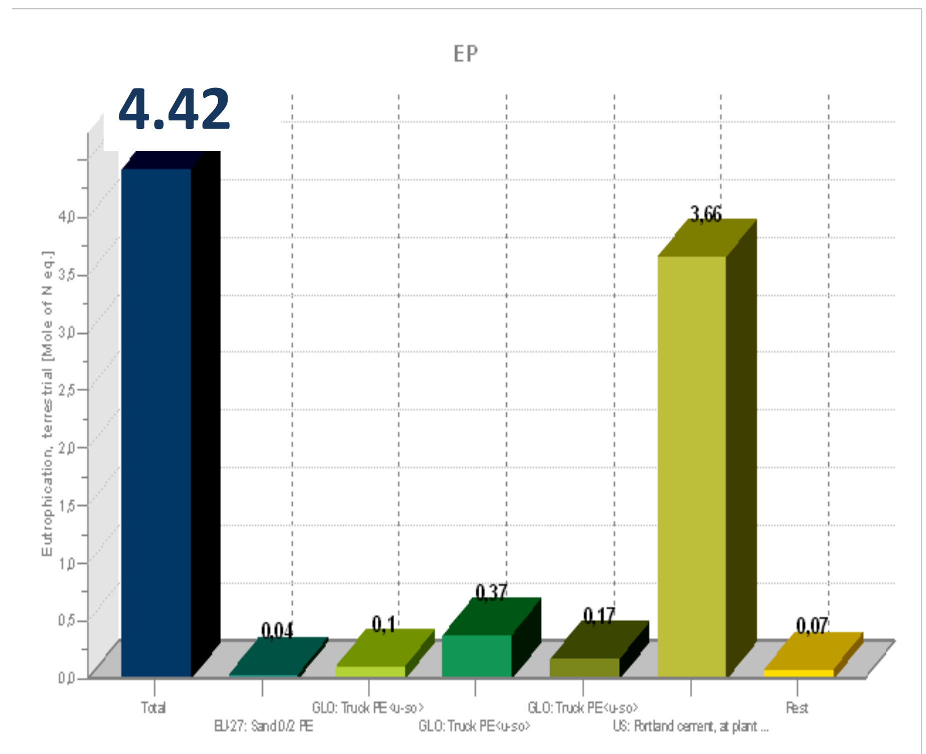
# Eutrophication (EP) - [Mole of N. eq]

Eutrophication is considered to be the most important cause of the sea environmental degradation since the 1960s. The impact of human activities on the marine environment and on resources results in pollution and eutrophication of regional seas, coastal waters and marine ecosystems.

## Scenario1




## Scenario2



# Conclusion



- ✓ This study shows that the main contributor to the Environmental Impact of concrete as a building material depends on the type of material production together with the transportation operations and the type of energy. The composition of conventional building materials plays a key role in the Environmental Assessment of a structure.

- ✓ This research at the end is trying to sensitize the use of construction demolition materials (after the end of life of the materials) as materials for the manufacture of concrete aggregates and not just the disposal in landfills. The main objective of this project is to raise awareness for minimizing loss of all the useful materials.

- ✓ The use of Renewable Energy Sources in largest percentages and the need for a quick reduction of lignite as the main contributor of Energy production in Greece is the only way for a Sustainable development of the country.

- ✓ The ILCD system and LCA method are two powerful tools in the analysis of the Life Cycle of building materials. The application of the LCA method does not guarantee the reduction of gas emissions or energy consumption but highlights the weaknesses of the production process and the likely identification of improvements in technology and management with the prospect of sustainable development.

# Conclusion



Permanent Recycling Centers of old concrete (Green points) to settle to Regions of residential areas thereby solving several problems of public bodies to manage old materials, including the problem of landfill sites. In a radius up to 50km from ''Green points'' will be installed the treatment of demolition materials including concrete producers. This will considerably reduce the transport distance of aggregates, energy consumption and consequently the environmental impact of the process.

# Thank you
# for your attention

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