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Life Cycle Analysis of dimensional stones production

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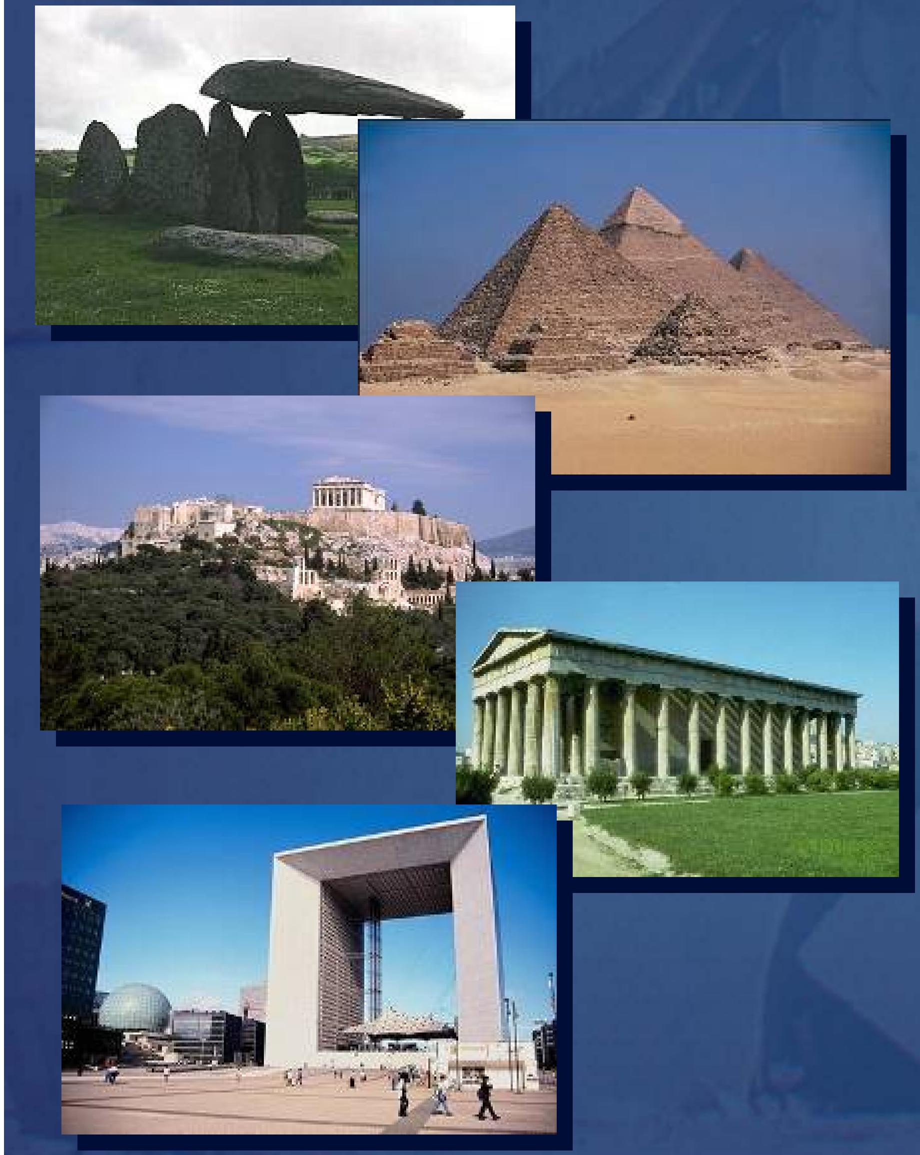
Dimensional Stones



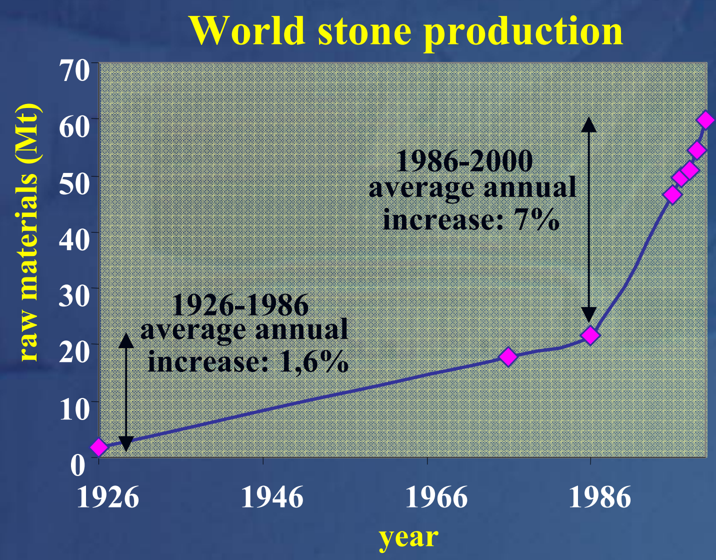
Natural stones been extracted from the earth in an orderly manner, further worked by cutting and processing and then used in various building activities either structurally or for decorative purposes

Dimensional Stones in construction

Dimensional Stones (marble, granite, limestone, etc.), due to their unique aesthetical and technical characteristics, have been extensively used for construction purposes and are still preferred by architects, engineers and consumers as a first choice material in construction applications for *facades, floors, stairs, monuments, open spaces, pavements*, etc.

No other material has managed to attain the importance of marble and granite in these applications.

Global Stone Production



Raw material

Growth rate: 260% (1986-2003)

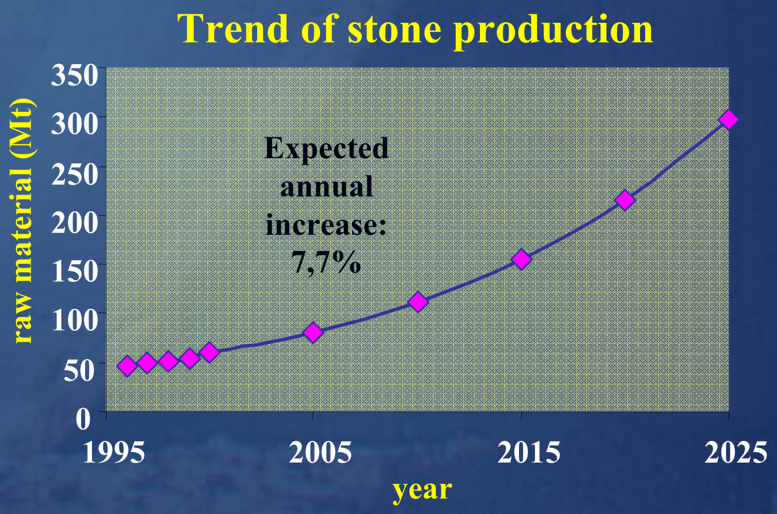
Value: 20 billion € for 2003

Finished products

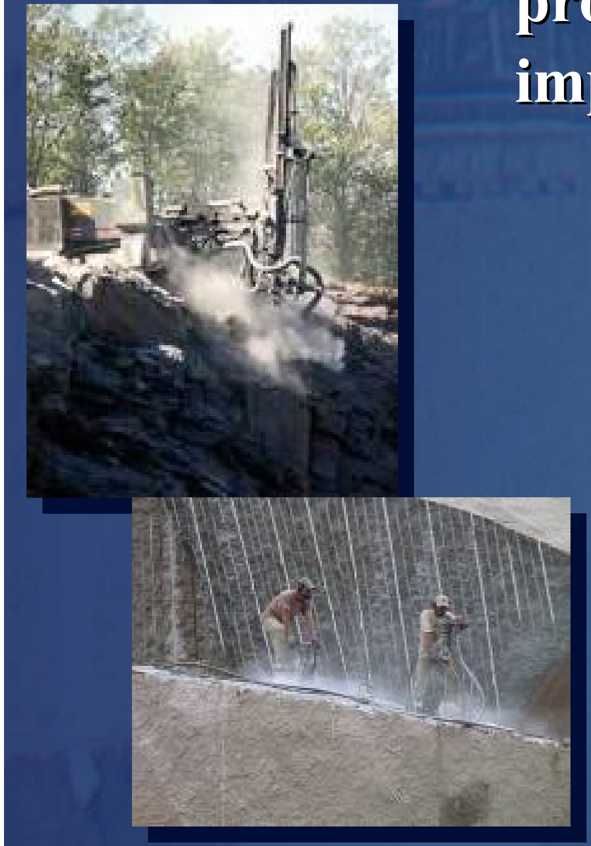
Growth rate: 61% (1996-2003)

Value: 35 billion € for 2003

The world stone production and the volume of the global stone market will experience a **five time increase** until 2025



Characteristics of the Stone Industry



Although stones are inert materials, their production has considerable environmental impacts:

- **Very low efficiency** (in quarrying only 20-25% of the original deposit is turned into marketable product)
- **Huge amounts of wastes** produced and disposed in the environment
- **Extended land use** for waste disposal
- Quarries have significant **visual impact**
- **Increased dust production** in quarrying operations
- **High water consumption**

These problems can be addressed by intelligent design of the production chain

LCA (Life Cycle Analysis)
is a promising tool for this purpose as it
provides the possibility to perform environmental improvements in combination with the rational use of raw materials and energy

What is LCA?

An objective methodology to measure and evaluate the environmental burdens associated with a product system or service by describing and assessing energy and materials used and emissions released to the environment over the life cycle.*

** BS/ISO 15686: Service Life Planning*

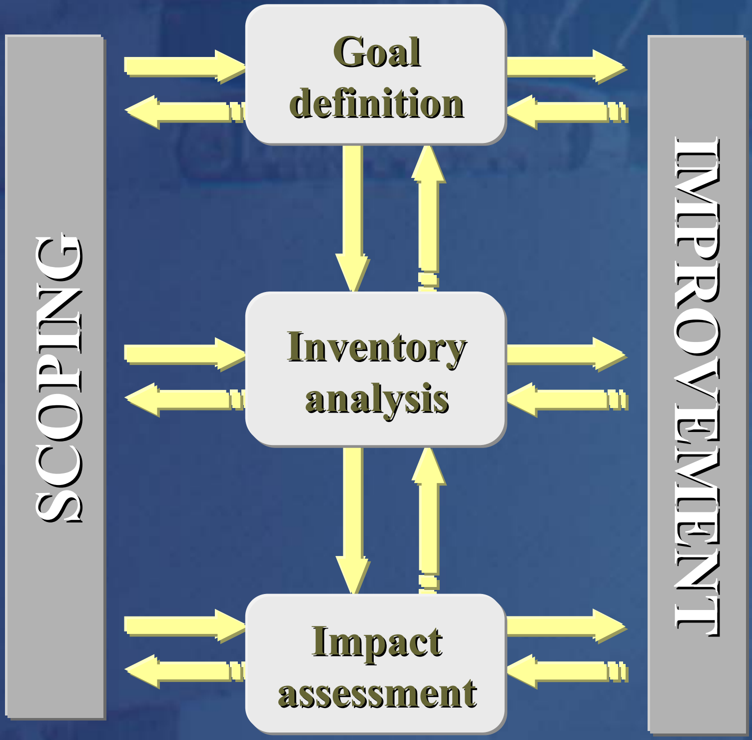
Purpose of this study

The **LCA of marble and granite production cycle**

aiming to evaluate their potential effects to the

environment and to human health

Stages of LCA methodology



SCOPING

Goal definition

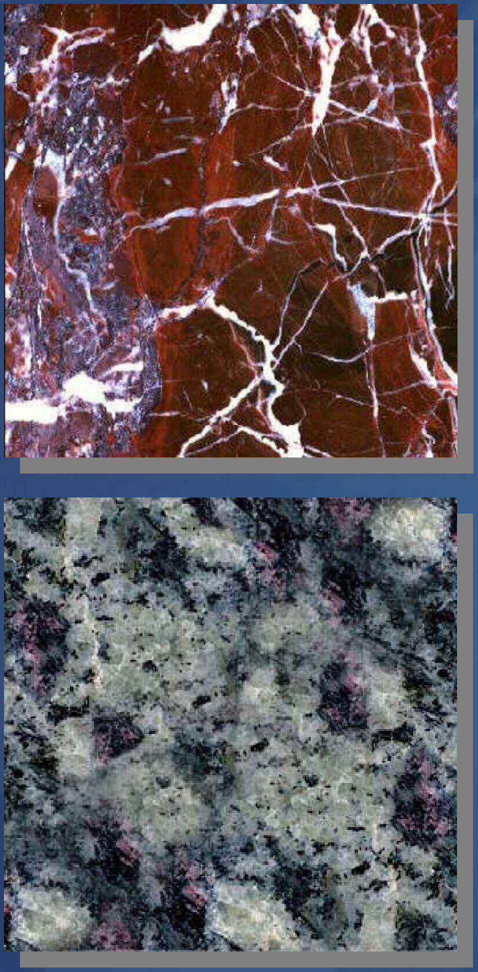
Inventory analysis

Impact assessment

IMPROVEMENT

- **Goal and Scope Definition:** define the system to be studied, its boundaries and the environmental effects to be reviewed for the assessment
- **Inventory Analysis:** identify and quantify energy and material inputs and environmental releases
- **Impact Assessment:** assess the human and ecological effects of the Inventory Analysis inputs and releases
- **Interpretation:** evaluate the results of the Inventory Analysis and the Impact Assessment to take the proper decisions for reducing the environmental effects of the system

Studied materials



The two most commercial ornamental stones in the European market have been selected:

- **Marble:** indicative example of calcareous (soft) stones
- **Granite:** indicative example of siliceous (hard) stones

Goal and Scope Definition

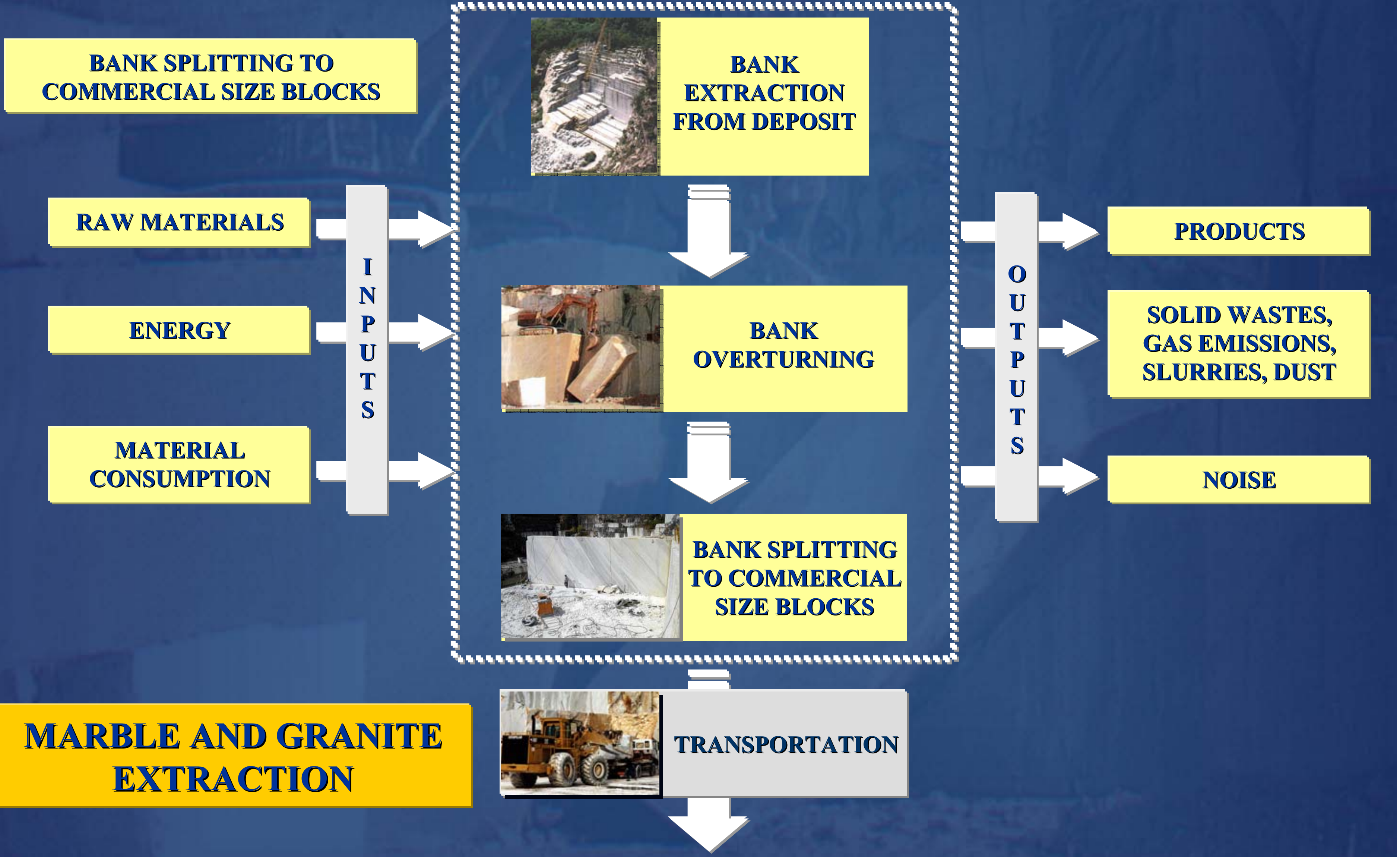
Goal of the LCA study: determine the environmental load associated with the production processes of marble and granite, to compare their environmental profiles and identify the weak points of each system.

System: the set of processes that constitute the *extraction* and *processing* of marble and granite blocks, and the *transportation* between the quarry and the processing plant.

Calculation unit: quarrying: 1 ton of marble or granite block

processing: 1 ton of final product (slab, tile)

System boundaries



BANK SPLITTING TO COMMERCIAL SIZE BLOCKS

RAW MATERIALS

ENERGY

MATERIAL CONSUMPTION

INPUTS

BANK EXTRACTION FROM DEPOSIT

BANK OVERTURNING

BANK SPLITTING TO COMMERCIAL SIZE BLOCKS

TRANSPORTATION

OUTPUTS

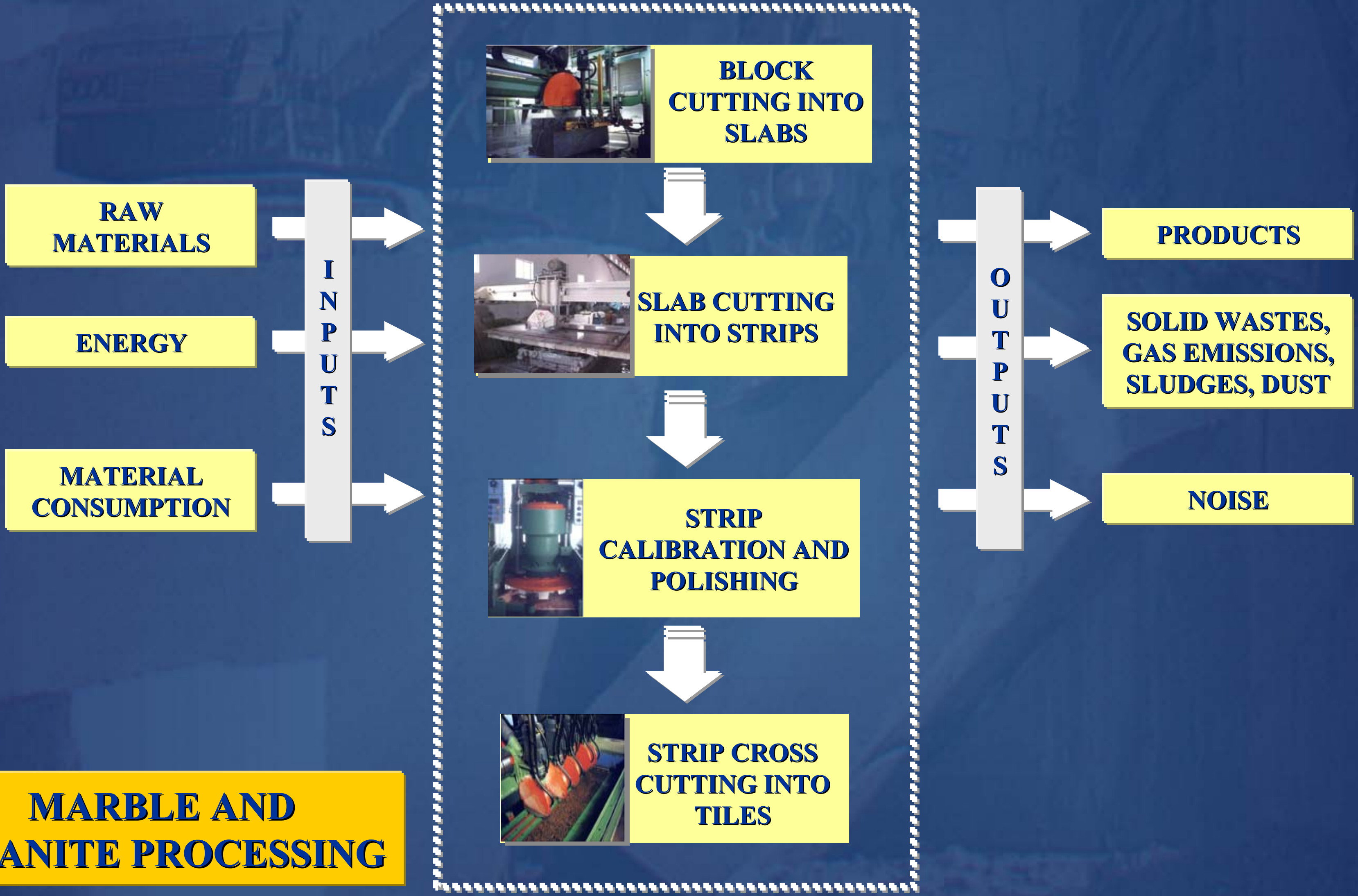
PRODUCTS

SOLID WASTES, GAS EMISSIONS, SLURRIES, DUST

NOISE

MARBLE AND GRANITE EXTRACTION

System boundaries



RAW MATERIALS

ENERGY

MATERIAL CONSUMPTION

INPUTS

BLOCK CUTTING INTO SLABS

SLAB CUTTING INTO STRIPS

STRIP CALIBRATION AND POLISHING

STRIP CROSS CUTTING INTO TILES

OUTPUTS

PRODUCTS

SOLID WASTES, GAS EMISSIONS, SLUDGES, DUST

NOISE

MARBLE AND GRANITE PROCESSING

Inventory analysis

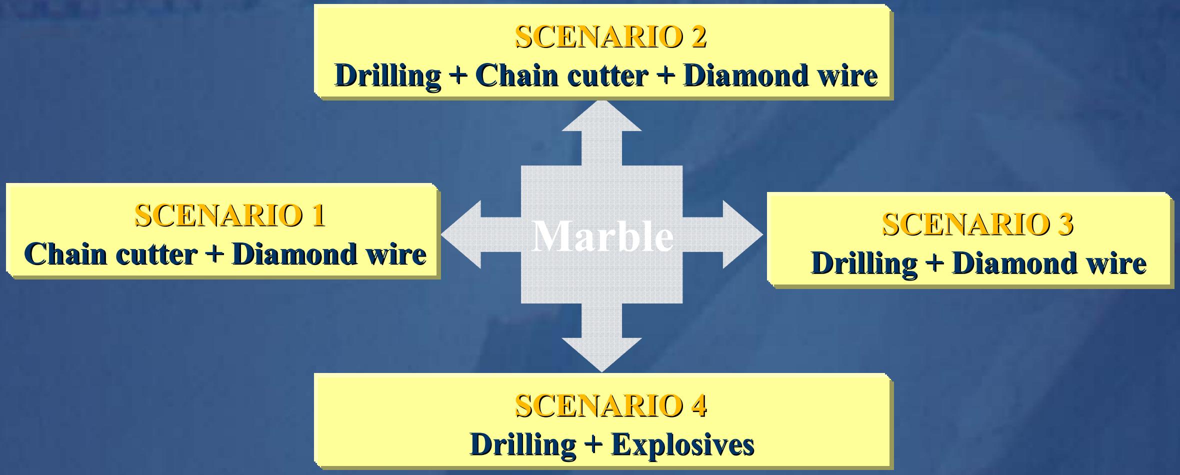
- ✓ development of the alternative marble and granite quarrying and processing scenarios
- ✓ mapping of the inputs and outputs in each scenario as a whole and in each process
- ✓ collection of the data required for the calculation of the inventory data;
- ✓ development of appropriate calculation models based on the assumptions made and the collected data
- ✓ calculation of input (energy, raw materials, water, chemicals, tools, etc.) and output (products, air emissions, liquid and solid wastes) data

Quarrying scenarios

Surface extraction of marble or granite:

a) direct production of commercial blocks

b) bank blocks production and cutting into commercial dimensions



SCENARIO 2
Drilling + Chain cutter + Diamond wire

SCENARIO 1
Chain cutter + Diamond wire

Marble

SCENARIO 3
Drilling + Diamond wire

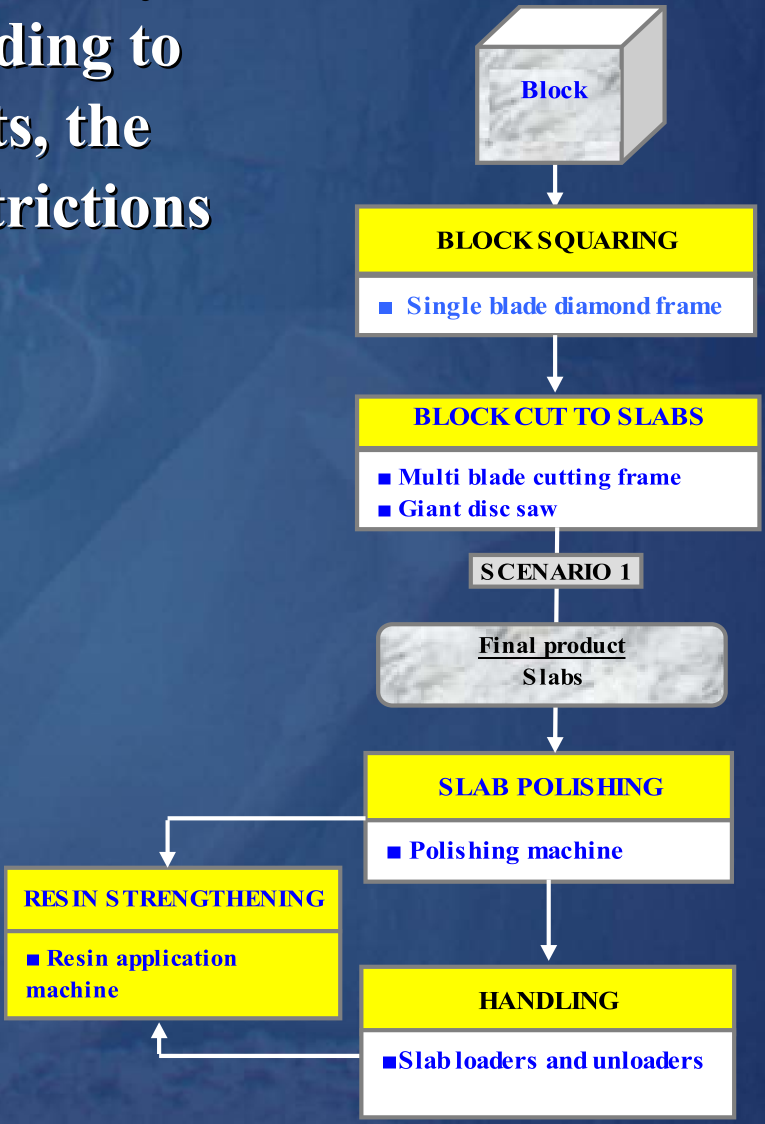
SCENARIO 4
Drilling + Explosives

Different techniques are defined by the use of different cutting machines (Chain cutters, Diamond wire and Drilling machine). The various scenarios are created through different combinations of these techniques.

Processing scenarios

Block processing scenarios are designed by combining various techniques, according to the specifications of the final products, the characteristic properties and the restrictions set by the block.

- **Scenario 1 (P1):** production of slabs (flooring and cladding applications)
- **Scenario 2 (P2):** production of tiles from slabs (not suitable for mass production).
- **Scenario 3 (P3):** mass production of tiles of standardised size.



Block

BLOCK SQUARING

■ Single blade diamond frame

BLOCK CUT TO SLABS

■ Multi blade cutting frame
■ Giant disc saw

SCENARIO 1

Final product
Slabs

SLAB POLISHING

■ Polishing machine

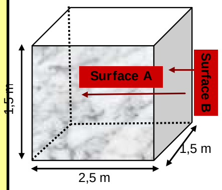
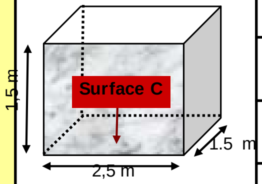
RESIN STRENGTHENING

■ Resin application machine

HANDLING

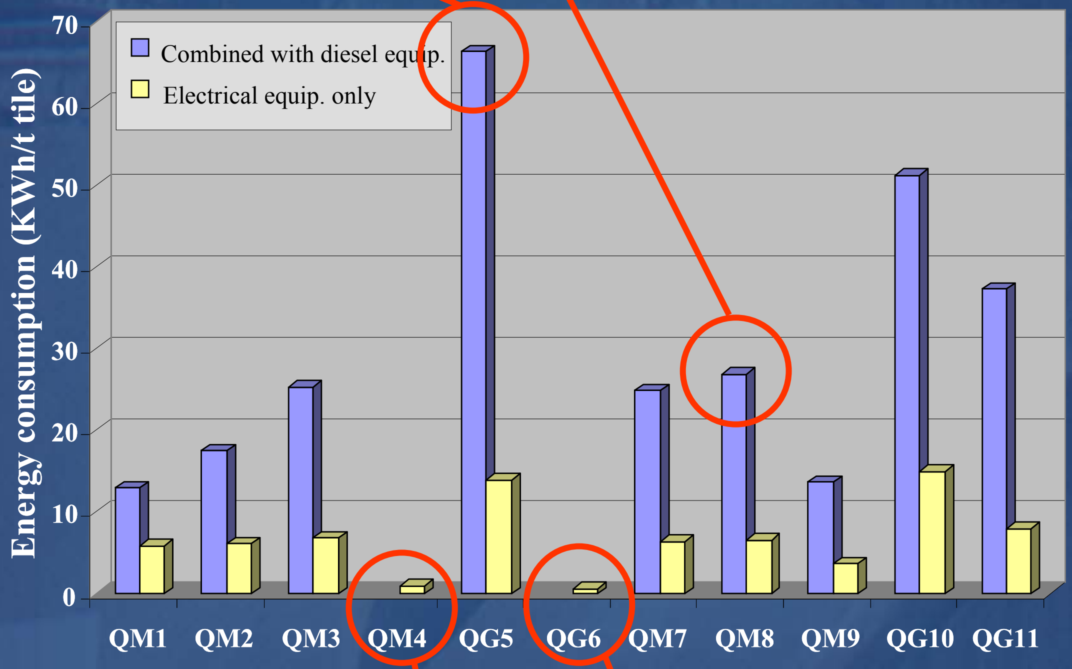
■ Slab loaders and unloaders

Data collection - calculation models

Process	Machine Type	Assumptions and technical characteristics	Inputs	Outputs
Extraction of commercial dimensions Blocks		Productivity (m^2/h): **9**	Electric energy (kWh/tn): 2.11 Lubricant consumption (kg/tn): 0..057 Chain consumption (m/tn) : 0.026 – 0.098 Diamonds consumption (no/tn): 0.0014	Type wastes: Solid Solid wastes weigth (kg/tn): 42.66
		Power engine (kW): **48**		
		Cutting surface (m^2) Surface A: **3.75,** Surface B: **2.25** Total surface: **6**		
		Cut thickness (m): **0,04**		
		Lubricant consumption (kg/h): **1.3**		
		Chain consumption (m^2/m):**15 - 40**		
		Diamonds consumption (m^2/7 diamonds):**2000**		
		Productivity (m^2/h): **6** to **14**	Electric energy (kWh/tn): 0.32 to 2.30 Lubricant consumption (kg/tn): 0..057 Wire consumption (m/tn) : 0.031 – 0.0082 Diamonds consumption (no/tn): 0.1 to 0.26 Water consumption (l/tn): 15.87 to 123..46 Diesel consumption (l/h): 18.09	Type wastes: Solid, Pulp Solid wastes weigth (kg/tn): 7.33 Ware quantity (m^3/tn): 0.01587- 0.123 Air emissions (gr/hp/h):CO:1869.3, H/C:156.78, No$_x$: 482.4, CO$_2$: 47685.24 Nose (dB):70
		Power engine (kW): **18** to **56** **90** (Diesel)		
		Cutting surface (m^2)**: 3,75**		
		Wire consumption (m^2/m): **30** to **80**		
		Water consumption (l/min): **15** to **50**		
		Cut thickness (m): **0.011**		
		Number of diamonds/wire meter: **31**		
		Diesel consumption (l/hp/h): **0.15**		
		Air emissions: **CO: 15.5, H/C:1.3, NOx:4**		

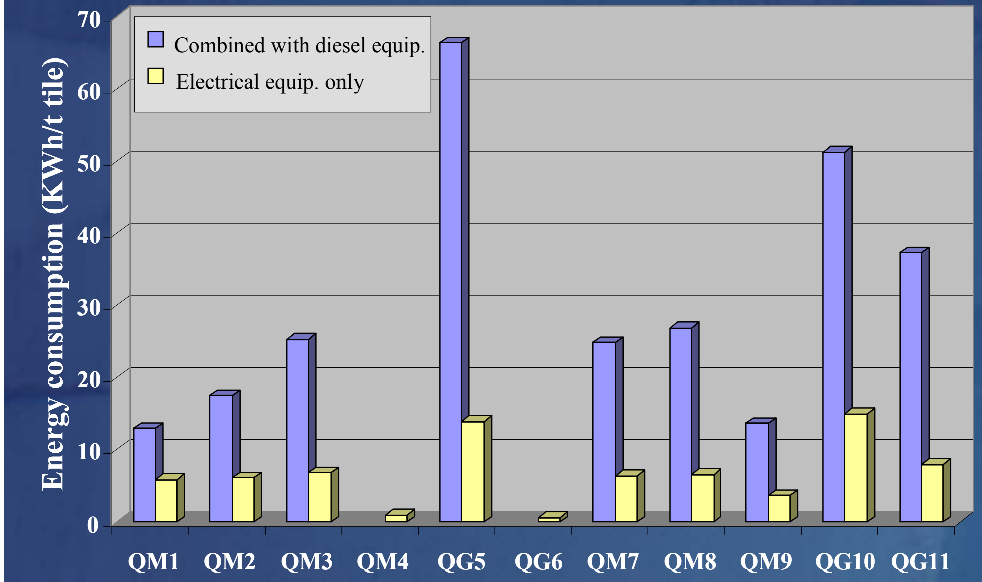
Energy consumption

Energy consumption during granite extraction is 2-2.5 times higher compared to marble extraction



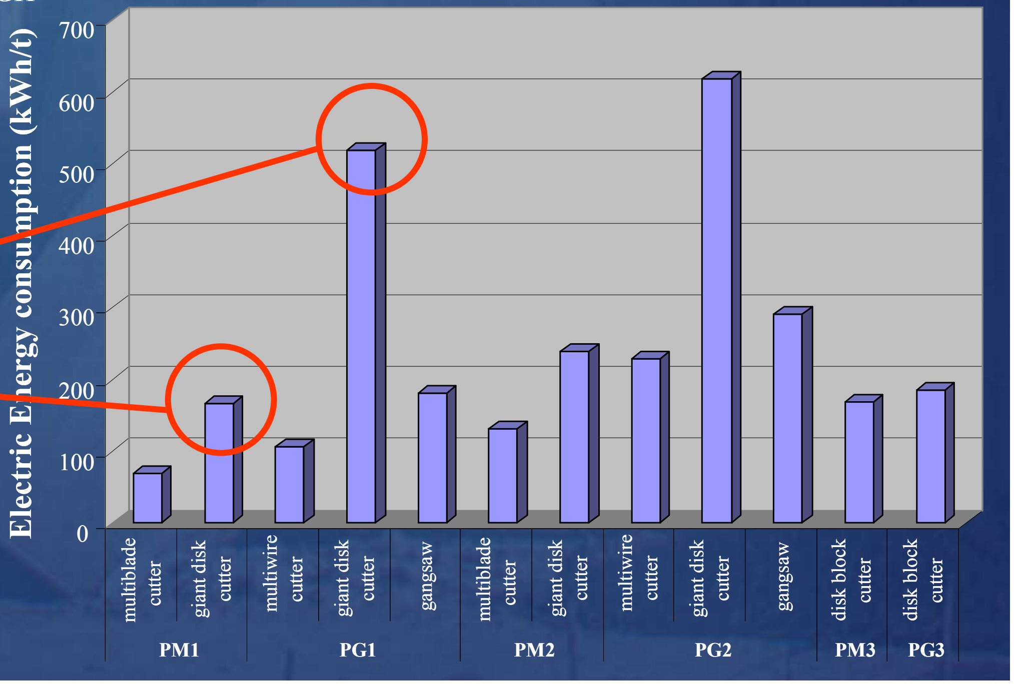
Lower energy consumption in quarrying: combined use of drilling and explosives (many disadvantages)

Energy consumption

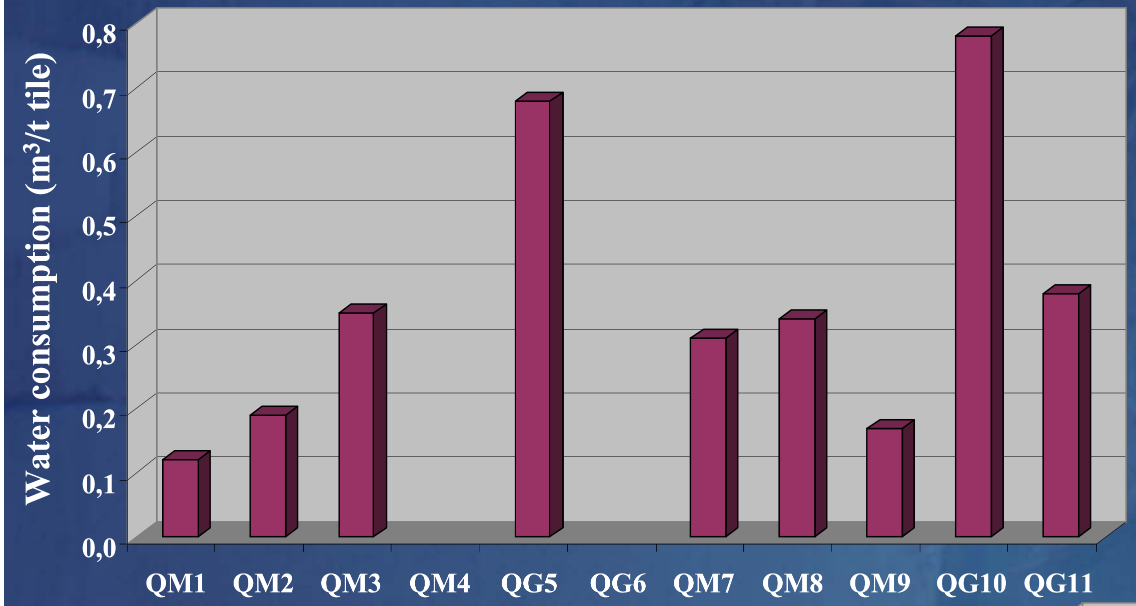


Energy consumption during processing is about 10 times higher compared to quarrying

Energy consumption during granite processing is 2.5 – 3 times higher compared to marble processing



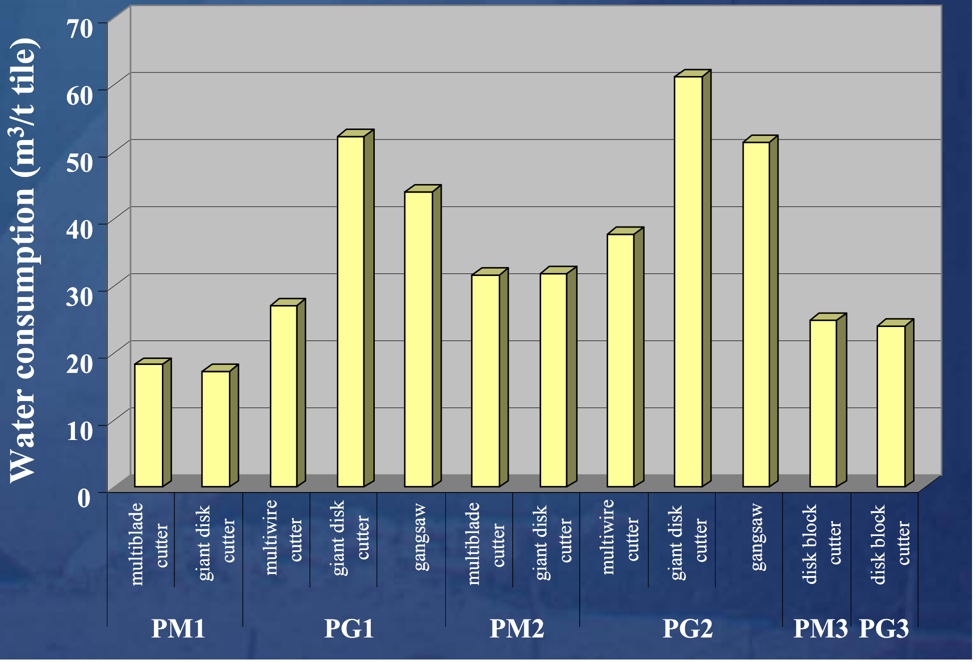
Water consumption



Water consumption is about **30 to 35 times higher in the processing** phase

water recycle ratio:

- 0.5 in quarrying
- 0.8 in processing

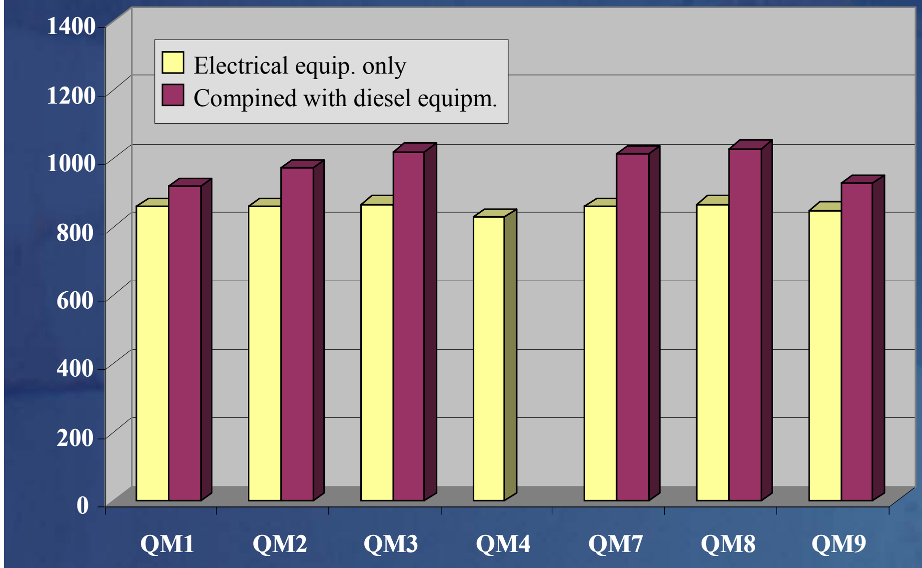


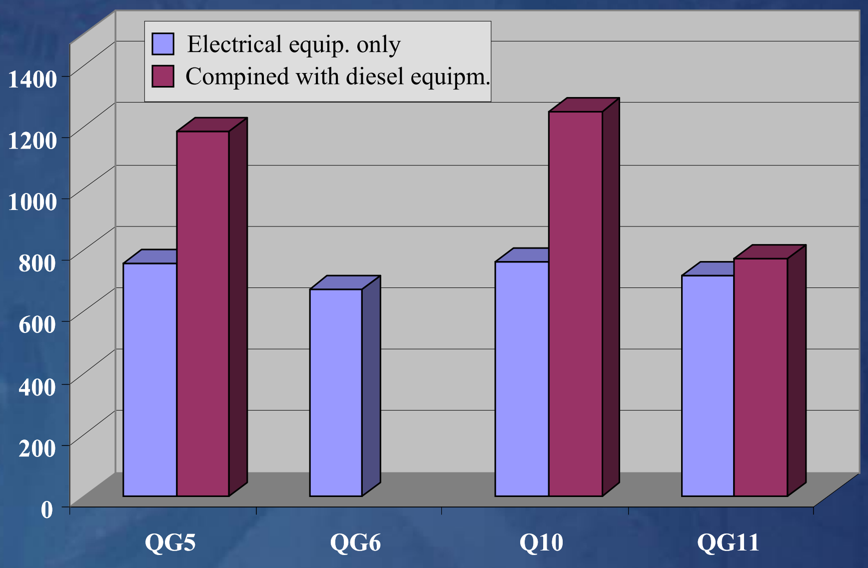
Impact assessment

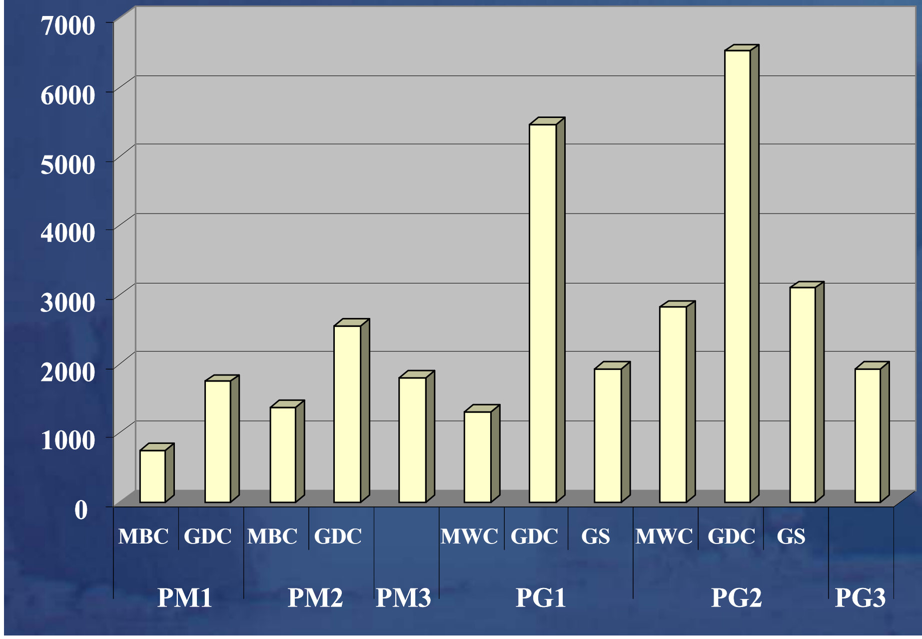
Impact Assessment methodology used in this LCA study: Eco-Indicator 99

Damage Category	Associated Impact category	Inputs/Outputs
Human Health	Respiratory effects	Dust (PM10), $NO_{x,}$ CxHy, SO_2
	Climate change	CO_2
Ecosystem	Acidification	NOx, SO_2
	Land use	Total surface occupied by the quarry/processing plant
Resources Depletion	Fossil fuels	- Electric energy from Coal - Embodied energy from diesel

Acidification

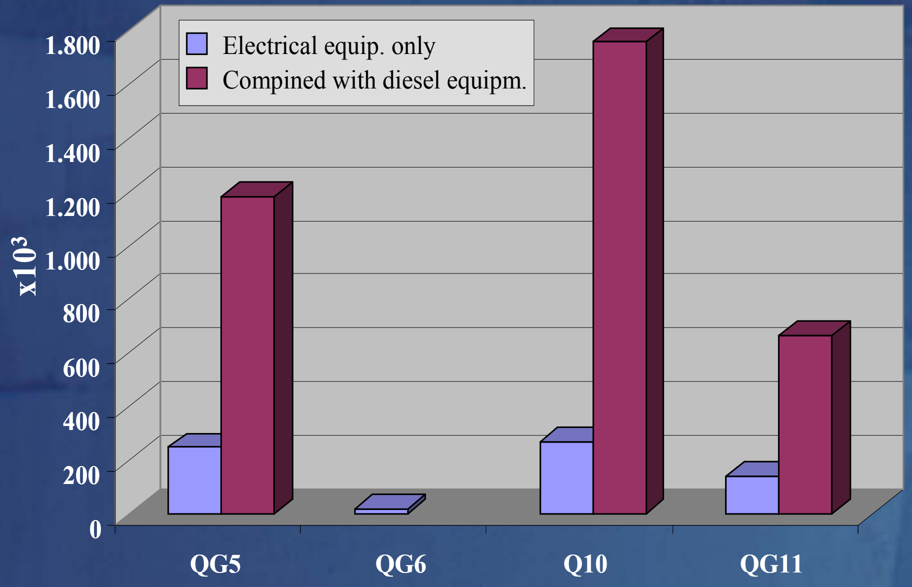


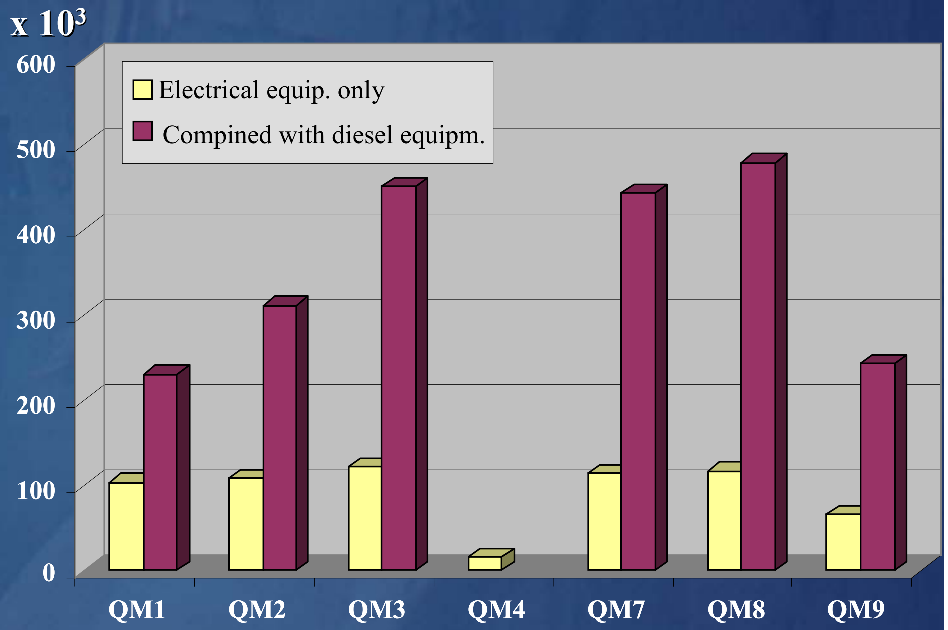


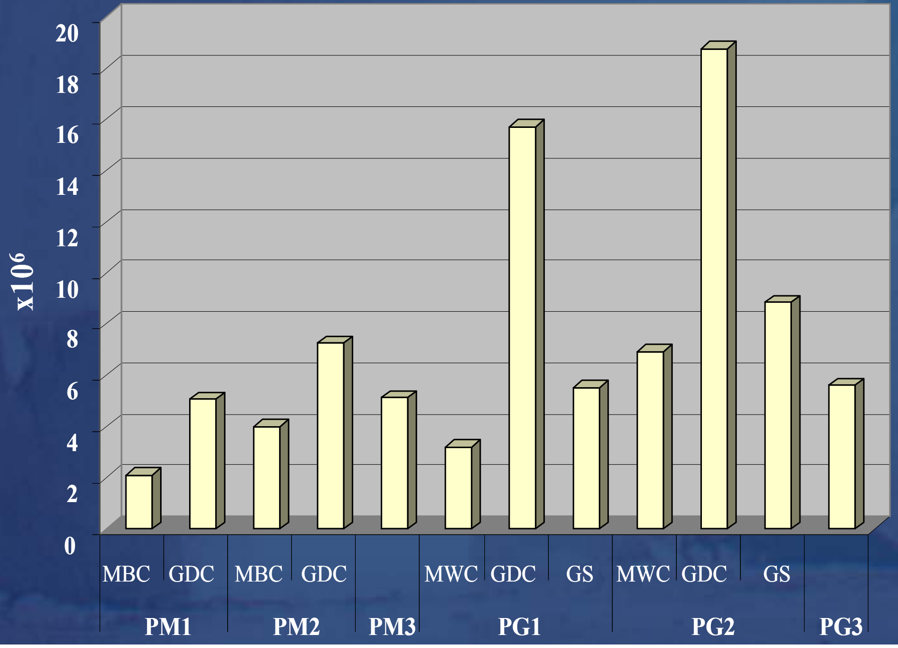


Acidification refers to the decrease in the nature resistance to acidifying depositions

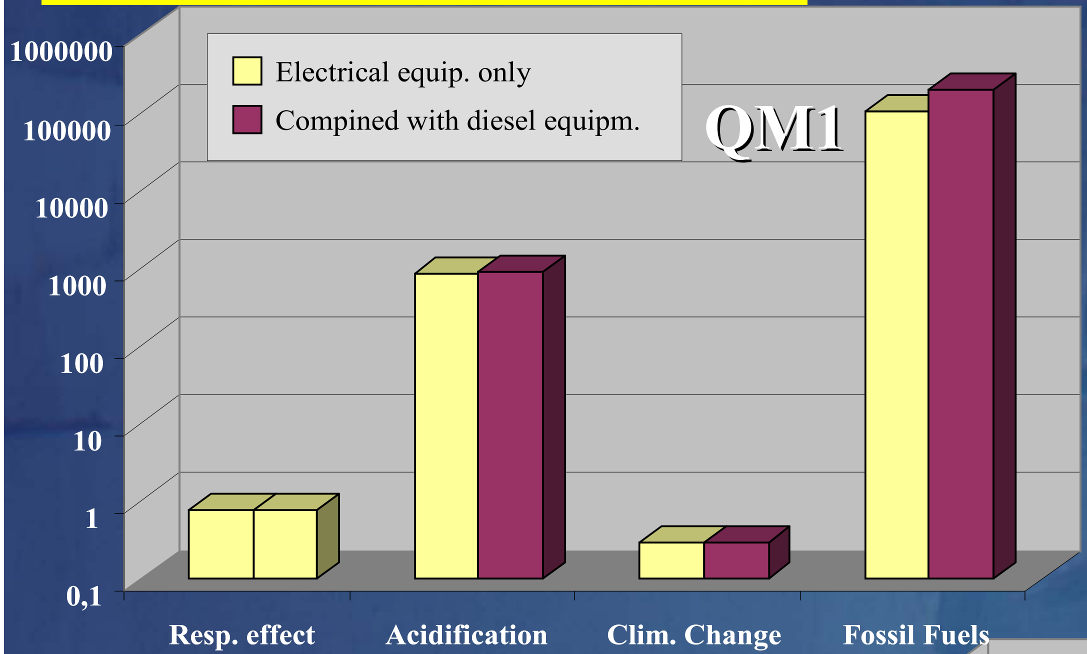
Fossil fuels

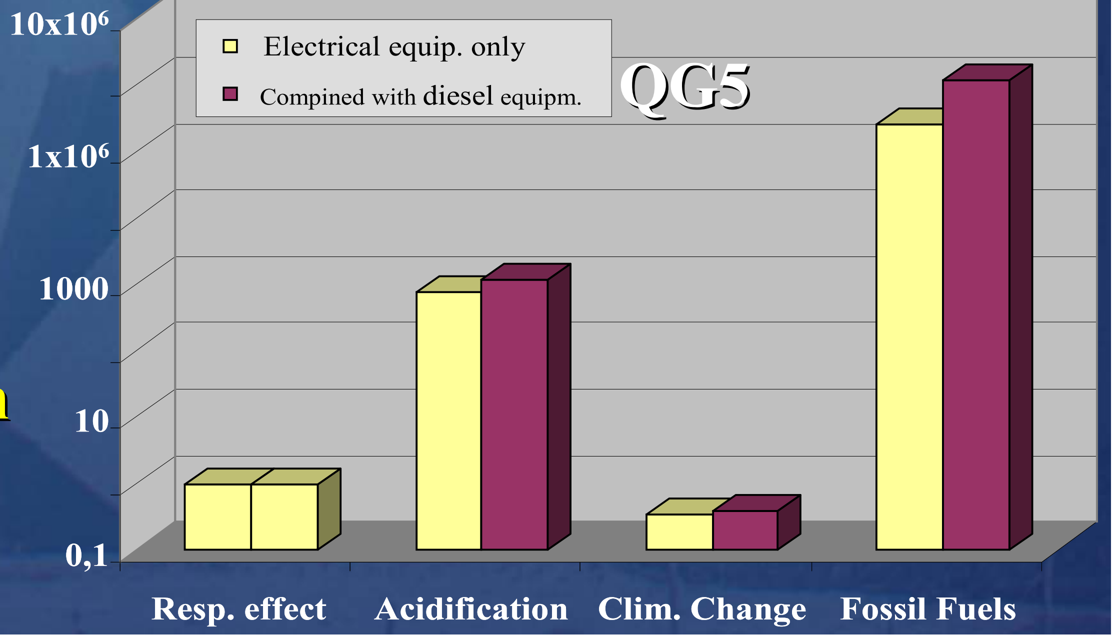






Environmental profile

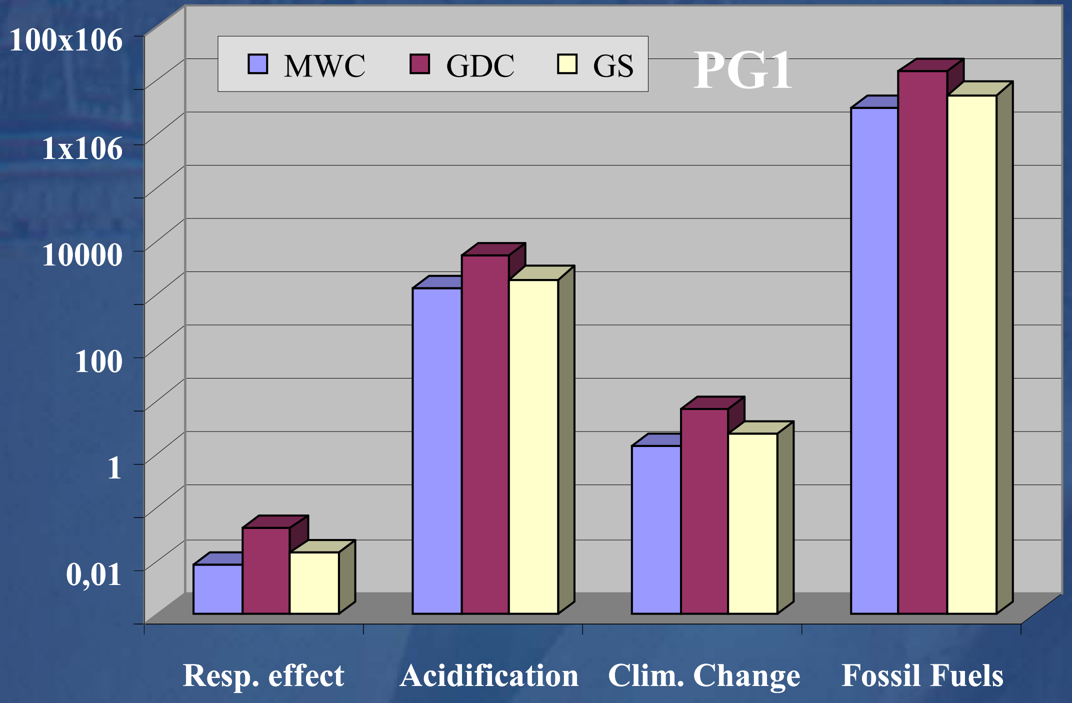




Most important Impact categories for quarrying:

Fossil fuels and Acidification

Environmental profile



Most important Impact categories for processing:

Fossil fuels and Acidification

Conclusions

✓ Impact of quarrying and processing phases:

	Quarrying	Processing
1	Fossil fuels	Fossil fuels
2	Acidification	Acidification
3	Respiratory effects	Climate change
4	Climate change	Respiratory effects

Conclusions

- ✓ Energy and water consumption is much higher in the processing phase
- ✓ Granite production is more energy intensive compared to marble production
- ✓ The environmental impact of ceramic tiles (an alternative construction product) production is significantly higher compared to stone production (e.g. embodied energy for ceramic tiles is 36 kWh/m2 tile, while for stones is 13 kWh/m2 tile)*

* G.M. Nicoletti et al. Comparative Life Cycle Assessment of flooring materials: ceramic versus marble tiles. *Journal of Cleaner Production*, 10 (2002), pp. 283-296