Who wants to be...

...**Bi**llionaire?

- Eiffel Tower April 2009: start of the 19th painting campaign, cost 4 millions Euros
=> In 7 years, it will have to be done again

- In U.S.A.: 300 000 bridges out of order because of corrosion

- In Europe: since 1975, 1250 bridges and civil engineering works have been put out of order, cause: corrosion

- In Europe (BRIME report): bridges and civil engineering works are designed to last 100 years, average service life re-estimated: 73 years, cause: corrosion

- etc.

Corrosion

Corrosion refers to deterioration of an object by reaction with an oxidant. That is an electrochemical phenomenon, that should not be mixed with wear or erosion.

Examples:
- Rust of iron or steel
- Green rust on copper surface

Corrosion concerns not only metals but all materials

Corrosion is a normal phenomenon: metals are going back to their original state, oxides- except noble metals that do not oxidize

Cost of corrosion

Many estimations; very credible:

⇒ National Bureau of Standards (NBS) – USA : 4,2 % of GDP
⇒ Association Corrosion Doctors –USA: 3,1 % of GDP
⇒ Paris Tech Graduate School – France- : 4% of GDP
⇒ Assoc Fournisseurs de peinture –world-: 4,5% of GDP
⇒ ESRF (Europ. Synchrotron Radiation Facilities): 3% of GDP
⇒ etc.

Range selected: between 3% and 4% of world GDP

=> How much?

World GDP basis 2007:

68 000 billion US $

3% to 4% = from 2000 to 2700 billion $!!!

Comparisons:
- Paulson banks bailout plan = 700 billion US $
- OBAMA plan = 1000 billion US $
- World Health expenses = 6000 billion US $

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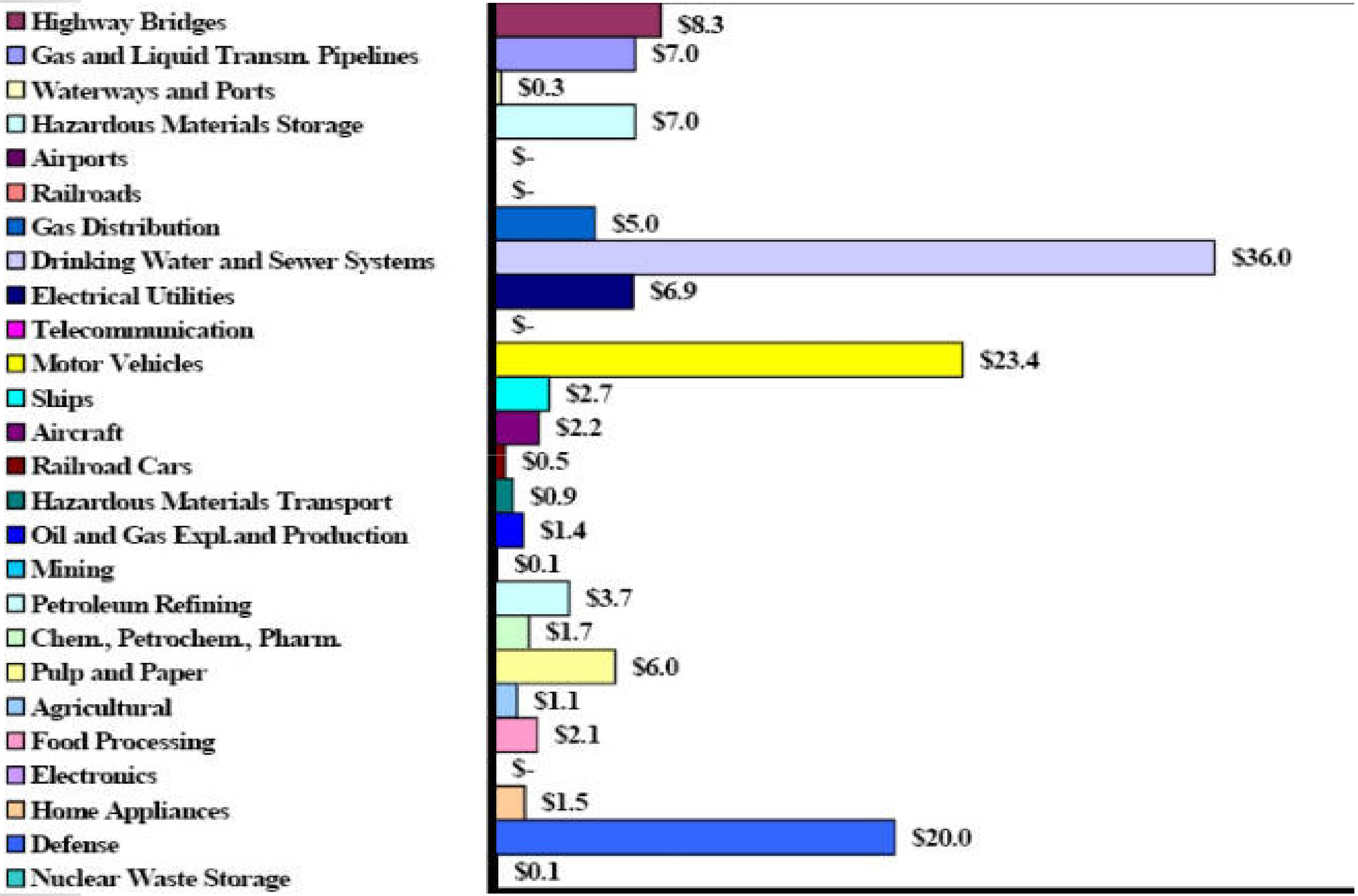
Other figures:

- Corrosion consume every year more than 200 million tons of steel!
- That represents around 6,5 tons of steel every second!

The total world production of steel is
1 250 millions tons (basis 2007)

The most affected sectors by corrosion (USA)



Water industries (USA) represent 13,3% of corrosion costs

What to do?

- Nothing: we replace
- Repairs: as one goes along, we repair
- Precautions: extra covers, protections, supervision
- Analysis of causes and effects: corrective measures
- Prevention

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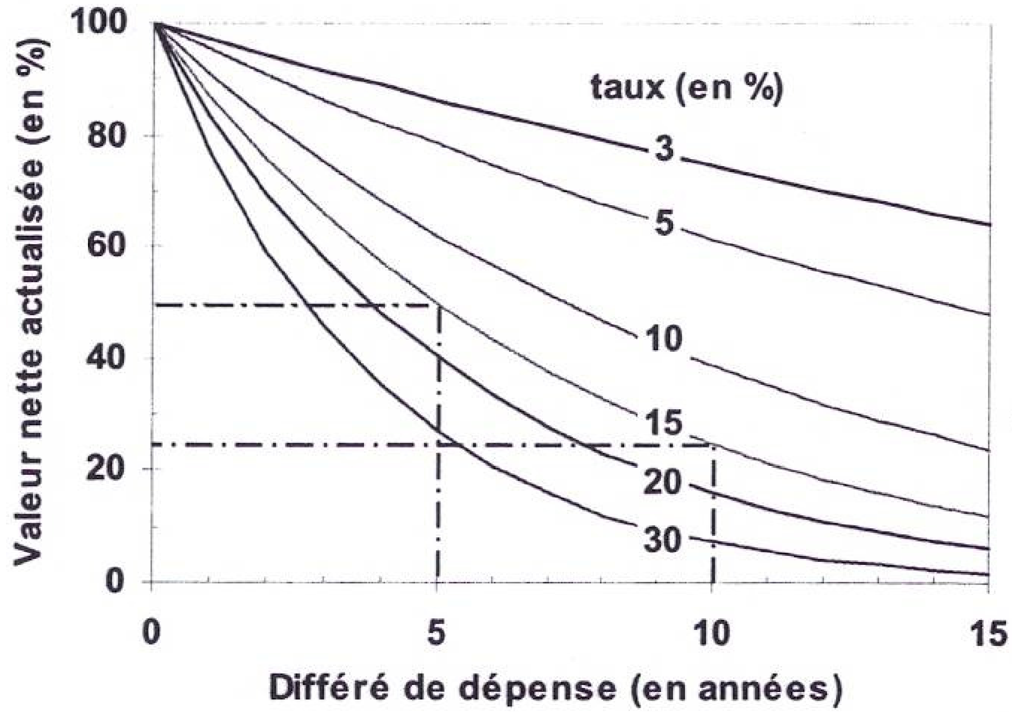
And the Shadock's method

We rather like to pump even if nothing happens, than taking the risk that something worst happens if we do not pump

Incidence of inflation on choices



> 10% per year: better to do nothing

Manager temptation: scheme (a) => optimum M, yes, but:

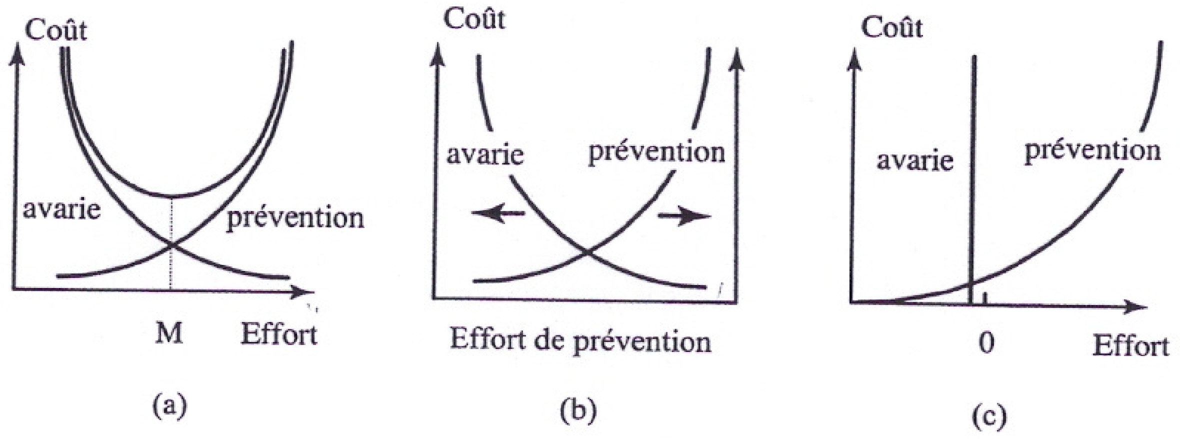


Fig. 1.2 Mauvaise et bonnes manières de comparer des coûts d'avarie et de prévention.

⇒Scheme (b) scales of costs are not the same
2nd error
⇒ Problems are random, unpredictable and can be very expensive

Do not mix defects cost and maintenance cost

Corrosion analysis, causes and effects

Existing proposals are focused on 2 models:

1st model (NACE):

=> Costs analysis and classification in direct and indirect costs, then evaluation of management and control of costs

Costs analysis

- Direct costs:
  - Design costs, construction and building
    - Materials choice
    - Precautions: increase of covers..
    - Retarding treatments (coatings, inhibitors..)
    - Application of these prevention measures
  - Management costs
    - Inspections
    - Maintenance
    - Repairs
    - Changes of corroded parts
    - rehabilitation

- Indirect costs:
  - "Collateral damages" caused to society = pollutions, exploitation break, traffic break on highways..

Model limits :

✓ Limited analysis of indirect costs

✓ Complete and exhaustive analysis of corrosion costs, then its effects

✓ No questions about corrosion causes:

- We act like if the external environment is the only and unique responsible of corrosion
- Corrosion is a natural phenomenon, so we try to reduce or at least to delay its effects
- As it will happen, we prepare ourselves

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2nd model (extract of "Prévention et lutte contre la corrosion –CNRS, CEFRACOR")

Principle:

«corrosion cost correspond to any extra expense added to what would be strictly necessary for an equipment to work in an inert environment ».

Modalities:

- ✓ Studies + acquisition and management of knowledge on corrosion
- ✓ Construction + extra-covers, choice of materials, protection…
- ✓ Operation + treatments, maintenance, preventive maintenance…
- ✓ Majors problems + reparation works and operation losses…

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1 – Question:

Is someone living permanently in a clean room immortal?

=> no, because he is carrying in himself the genes of ageing, and all kind of genes sources of diseases

2- Suggestion:

Battelle Memorial Institute and National Bureau of Standards say that "40% of corrosion costs can be saved by working on existing technologies according to the book, that means without costs overrun, or almost."

Starting from beginning:

- The ignorance of technologies, defect, let say the bad quality would be responsible for 40% of corrosion costs

- So, the non-quality would cost each year between 800 and 1000 G$!!!

- And these expenses can be avoided / saved / without any investment

Example:
effects of good practices in the use of stainless steel

Corrosion types occurring on stainless steels:

- uniform corrosion
- pitting corrosion
- crevice corrosion
- stress corrosion cracking
- intergranular corrosion
- galvanic corrosion
- ferrous pollution
- corrosion in the thermal affected zone after welding
- corrosion due to biofilm

This list can be considered exhaustive considering the water industry: all have the common causes:

Either

- ➢ Bad stainless steel grade selection
- ➢ design mistake
- ➢ construction mistake
- ➢ maintenance mistake

The cause of corrosion is not the **environment** but the **human** – designer, constructor, operator

All kind of corrosion observed on stainless steel have for origin a mistake:

- ✓ in the grade selection
- ✓ in design
- ✓ in construction
- ✓ or in maintenance

	Grade selection	Design	Construction	Maintenance
Uniform corrosion	X			
Pitting corrosion	X			X
Crevice corrosion	X	X	X	
Stress cracking corrosion	X			
Intergranular corrosion	X			
Corrosion galvanique		X	X	
Pollution corrosion			X	
Welding zones corrosion	X		X	
corrosion due to biofilm			X	

and then can be avoid without any cost overrun
That is true for other metals as well

Yes, but…

⇒ If the choice of stainless steel solution allow us to avoid corrosion, by a correct use, this solution has an cost overrun at the investment

Choices of preventive solutions have to be studied one by one taking in consideration:

➢ Costs savings realised:
- Maintenance
- Repairs
- Pickling
- Painting
- Replacements

charges are recurrent

➢ The investment price:
- Initial cost overrun of a preventive solution to reduce charges

Taking in consideration the inflation rate

Example

Exhaust system:

Before, cars exhausts system were made in carbon steel
Replacement every 18 month in average

Now, since the 90s, exhaust systems are in stainless steel
Cost of new one = 1,5 times the cost of a carbon steel one

No need to change it

Cost saving within 6 years: the price of 2.5 exhaust systems in carbon steel

Other example

Again in car industry: the cars chassis have now a 10 years guarantee against corrosion, thanks to a surface treatment

Bridges and civil engineering works

In Europe (BRIME report):

⇒ Inspection in 2007 of bridges and civil engineering works in reinforced concrete

⇒ service life expected during construction: 100 years

⇒ average service life re-estimated to 73 years

⇒ cause: corrosion of reinforcing bars

Cost of corrosion:

⇒ during 27 years, so a cost increased by 27%

⇒ cost of maintenance

⇒ costs of traffic break during repairs

⇒ and during demolition and rebuilding works

⇒ harm to operator's image

⇒ harm / cost to environment

⇒ …

Bridges and civil engineering works
Possible strategies towards corrosion phenomenon (source fib)

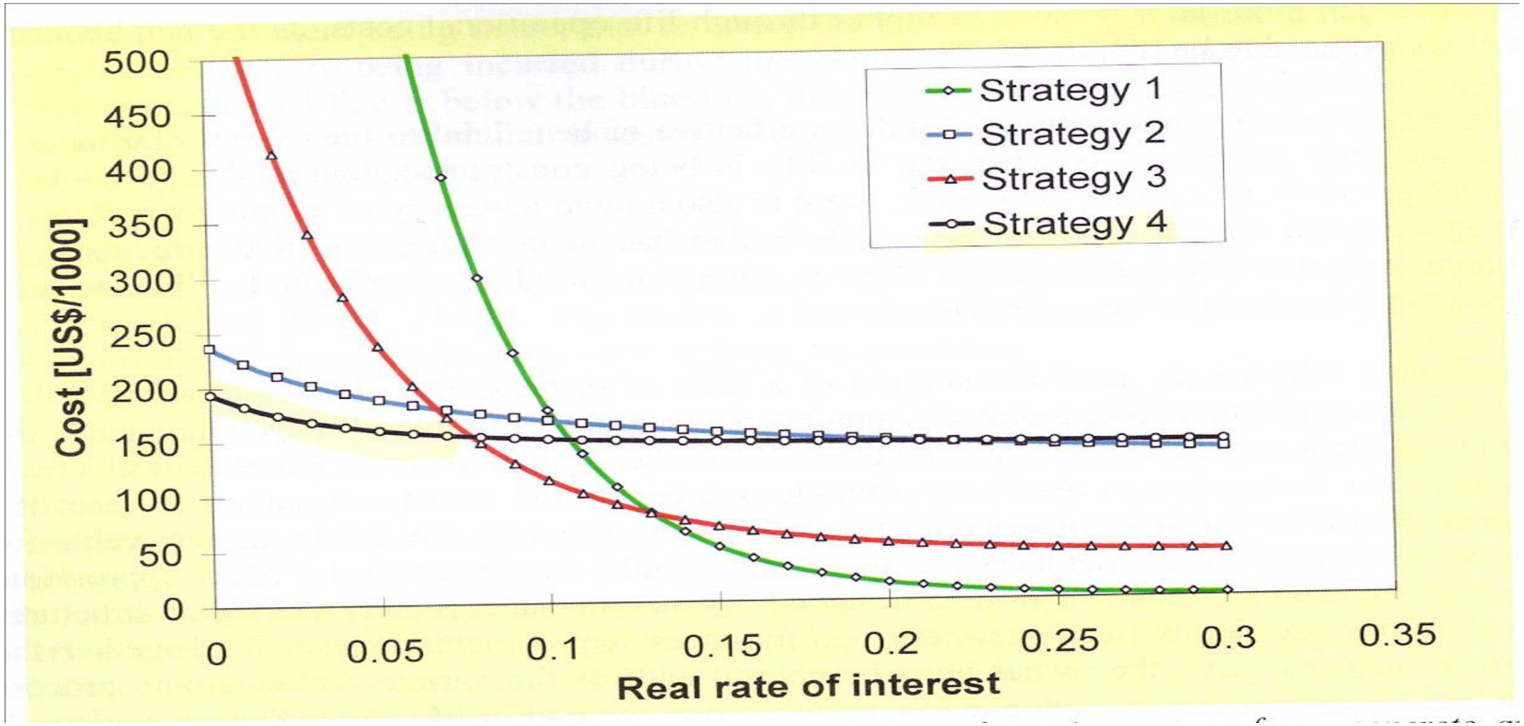
Expected service life: 50 years, corrosive environment Temp 10°C to 30°C

Strategy 1: do nothing, standard concrete composition, carbon steel rebars, repairs

Strategy 2: high performance concrete and thicker covers

Strategy 3: standard concrete, carbon steel rebars, cathodic protection

Strategy 4: standard, carbon steel rebars and partial use of stainless steel rebars



Stainless steel cost overrun in investment: 2 à 3%

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And what about the use of stainless steel in the water industries?

Stainless steel has an excellent corrosion resistance:
- no general corrosion so no need for corrosion allowance
- no need for protective coating
- no need to control water chemistry (except biocide)
- no need for corrosion protection system
- water purity is maintained
- equipment is durable with low Life Cycle Cost

Examples of use of stainless styeel in water industries

Potable water treatment

Distribution

Plumbing

Waste water treatment

Structures

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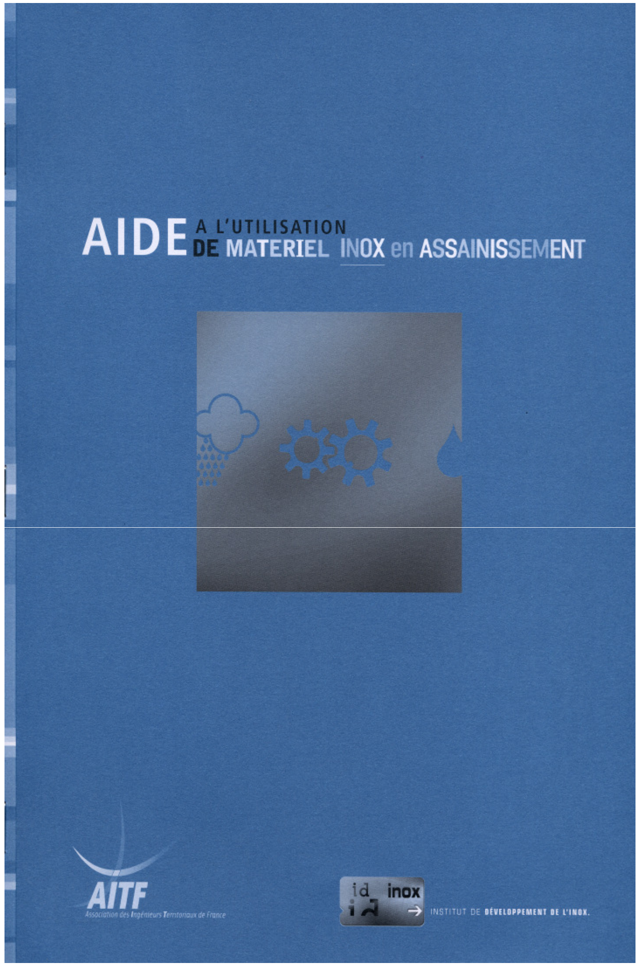

Corrosion costs reduction:

- ➢correct choice of materials
- ➢Correct use of these materials

⇒Guides for the best sue of stainless steels:

- In waste water treatment

-In potable water treatment and adduction(Nickel Institute)

-For use of stainless steel rebar (french)

Without being a proof by itself, the examples below show:

A small cost overrun at start can allow to realise huge saving on corrosion costs

To summarize:

Good practice

+

Adapted solutions chosen at the beginning

= saving on corrosion costs

Saving of 20% = 400 to 550 G$
Saving of 30% = 600 to 720 G$
Saving of 40% = 800 to 1000 G$

environmental impact of corrosion:

-Invisible

-Destructive

-Irreversible

Examples: rupture of plumbing, rupture of cable, breaking of a bolt, leaking on a tank, shipwreck.

Invisible: inspections do not always allow to identify potential major defects

Destructive: damages caused to environment by accidental pollution; dispersion corrosion products

Irreversible: back to natural state but in very diluted form and quantities; irreversible damages

Environmental impact of corrosion:

- resources consumption

Concerning steels, for example, about 200 million tons of steel should be replaced:

⇒ ore extraction + coke
⇒ transport
⇒ production energy
⇒ CO_2 emissions (200 to 400 million tons)
⇒ transformation
⇒ processing

What is the cost of these environmental impacts?

Summary - Conclusion

Corrosion is a net and irreversible loss:

- of money for humanity: more than 2000 billion $ per year
- of resources and energy for the earth and for futur generations<<

Corrosion is not a fatality:

- Human / defects are responsible of it by at least 40%
- It can and it should be fight by
  - Knowledge and processing following good practices
  - Choices of solutions adapted to investment

Prevention of corrosion should be a major goal of sustainability that has priority