

# *Nuclear Energy and waste transmutation*

***A PASSION FOR EXTREME LIGHT***

*For the greatest benefit to human kind (Alfred Nobel)*



*Presented by*

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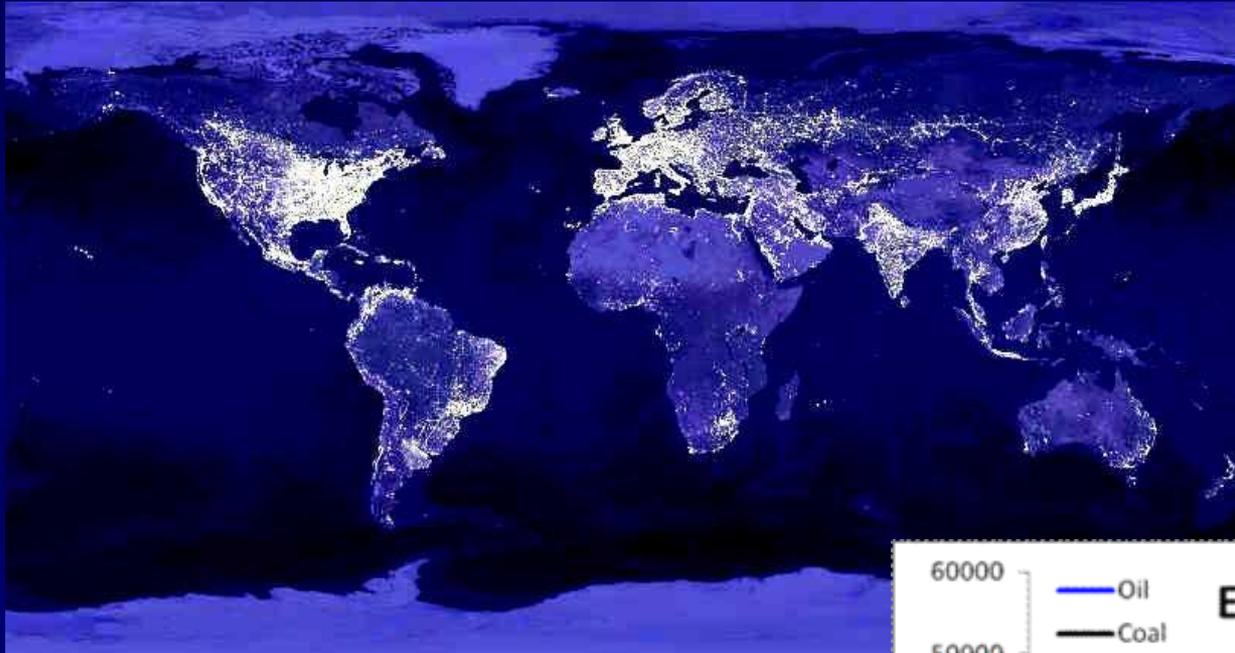
**Centesimus Annus Pro Pontifice Foundation-Convention 2019**

**The Catholic Social Teaching from inception to the digital age:**

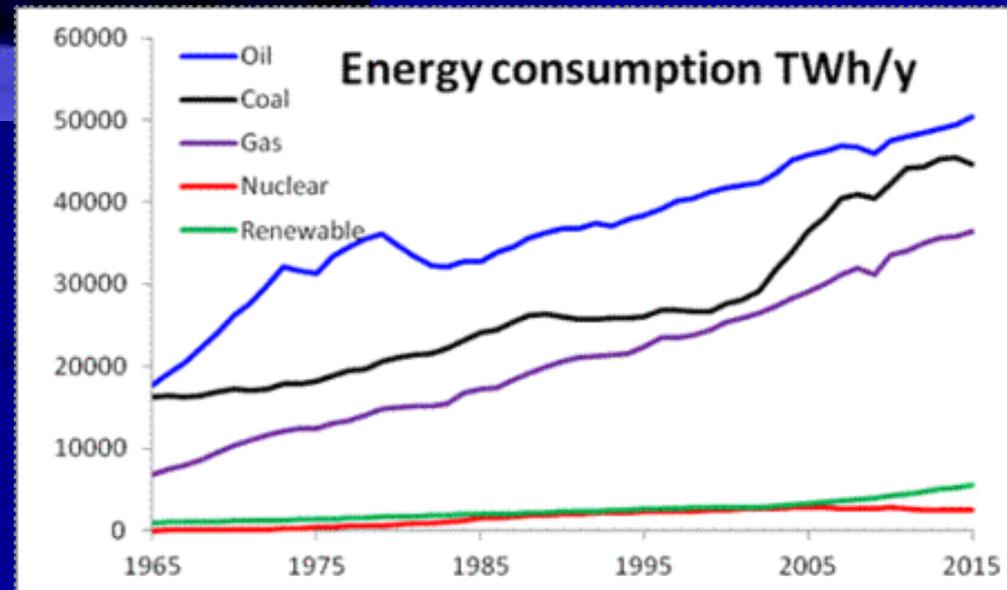
**How to live the *Laudato Si'***

# World energy consumption

## Global Facts

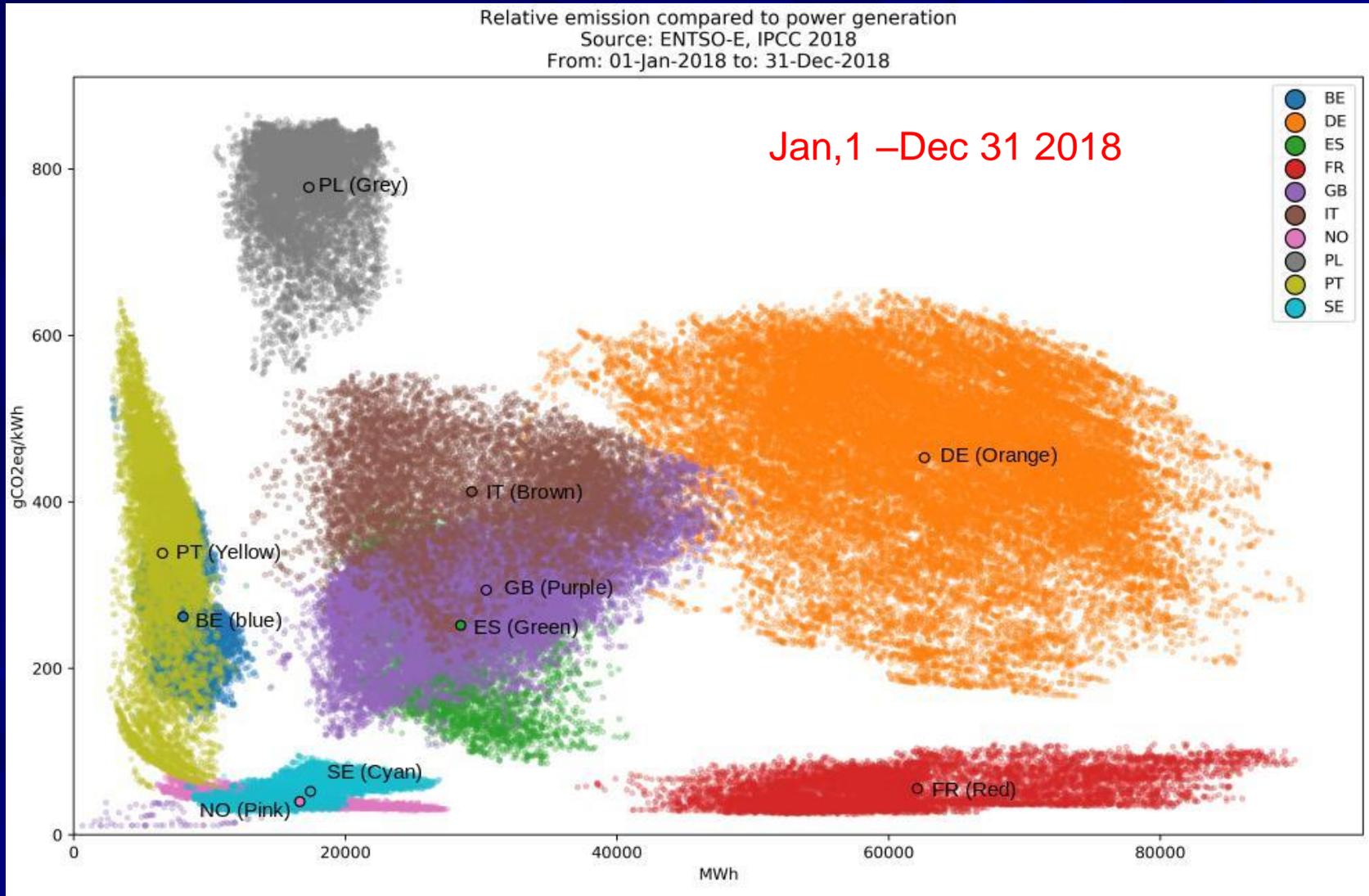


- 13,3 GTeP
- 2000 kWh/y per habitant
- (Europe 4000, USA 10000, Africa 500...)



# EU Countries

Relative CO2 emission (g CO2 equivalent/ Kwh) compared to Power generation



# ***NUCLEAR ENERGY :GLOBAL FACTS***

A rather young form of Energy, of limited importance at the world level (5%, 0.67GTep),economically viable source of electricity (2000TWh,10%), **Carbon free !!**

**Efficient —→ Fission of 14g of U = 1TeP= 42 GJ**

**⚠ Production concentrated in a few countries  
(USA +FR +Jp +Ru) = 2/3 of the world nuclear energy**

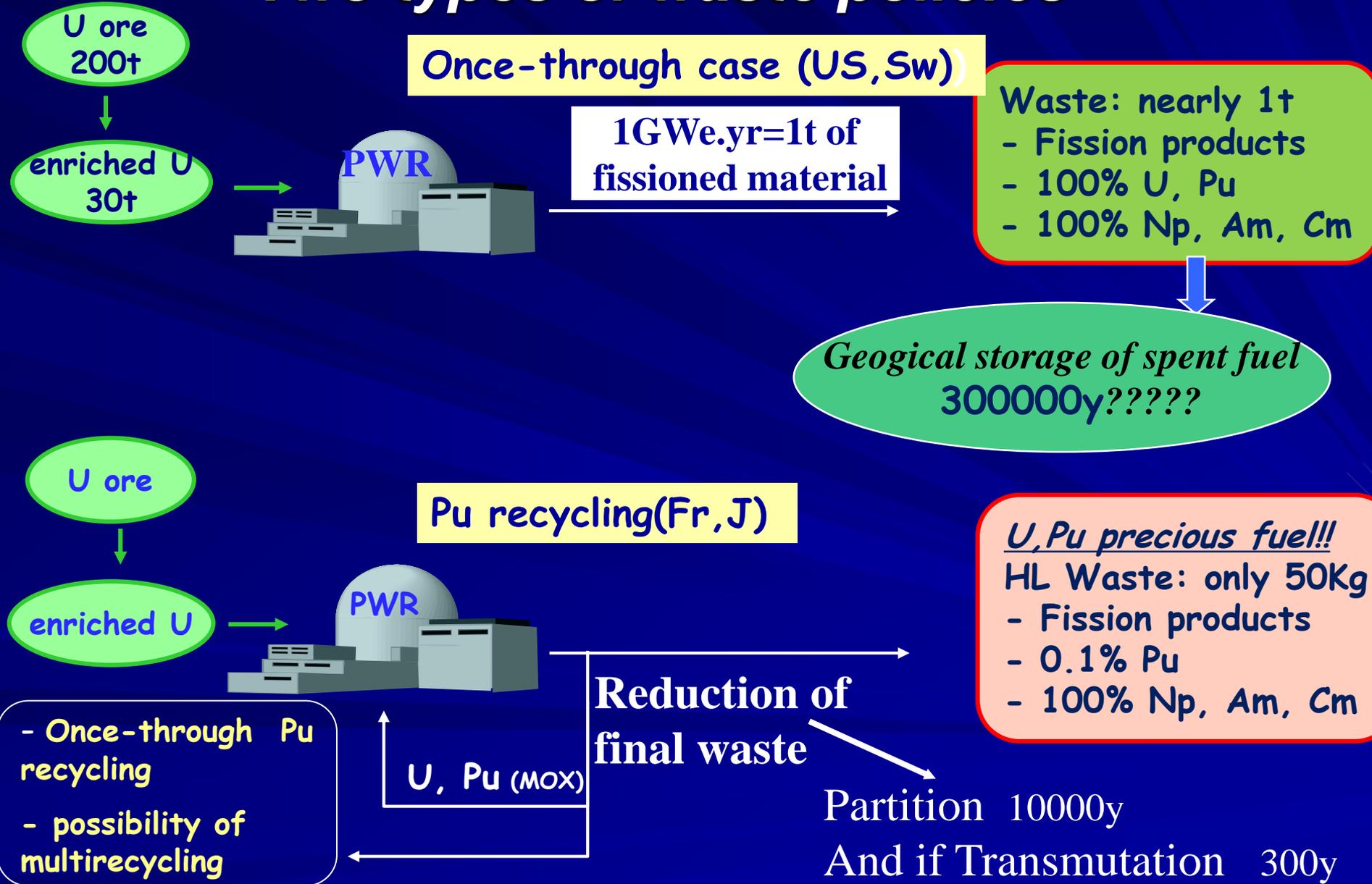
**A passionately contested energy for  
Its origin related to defense, Its cost structure (high  
investments ,delayed returns )**

**And questions insufficiently dealt with in the past  
Proliferation (Pu mostly), Safety , and Nuclear waste  
management**

***These questions generate social concerns for the future***

# Management of current waste

## Two types of waste policies



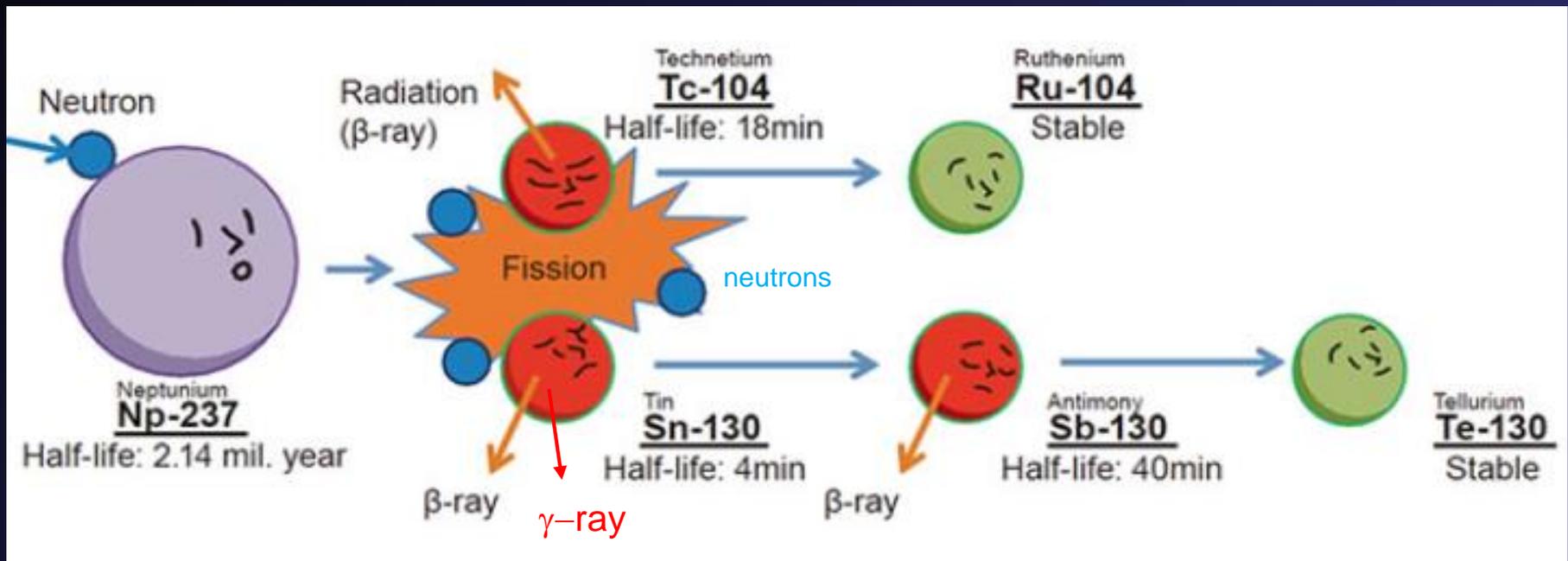
# NUCLEAR TRANSMUTATION CONCEPT

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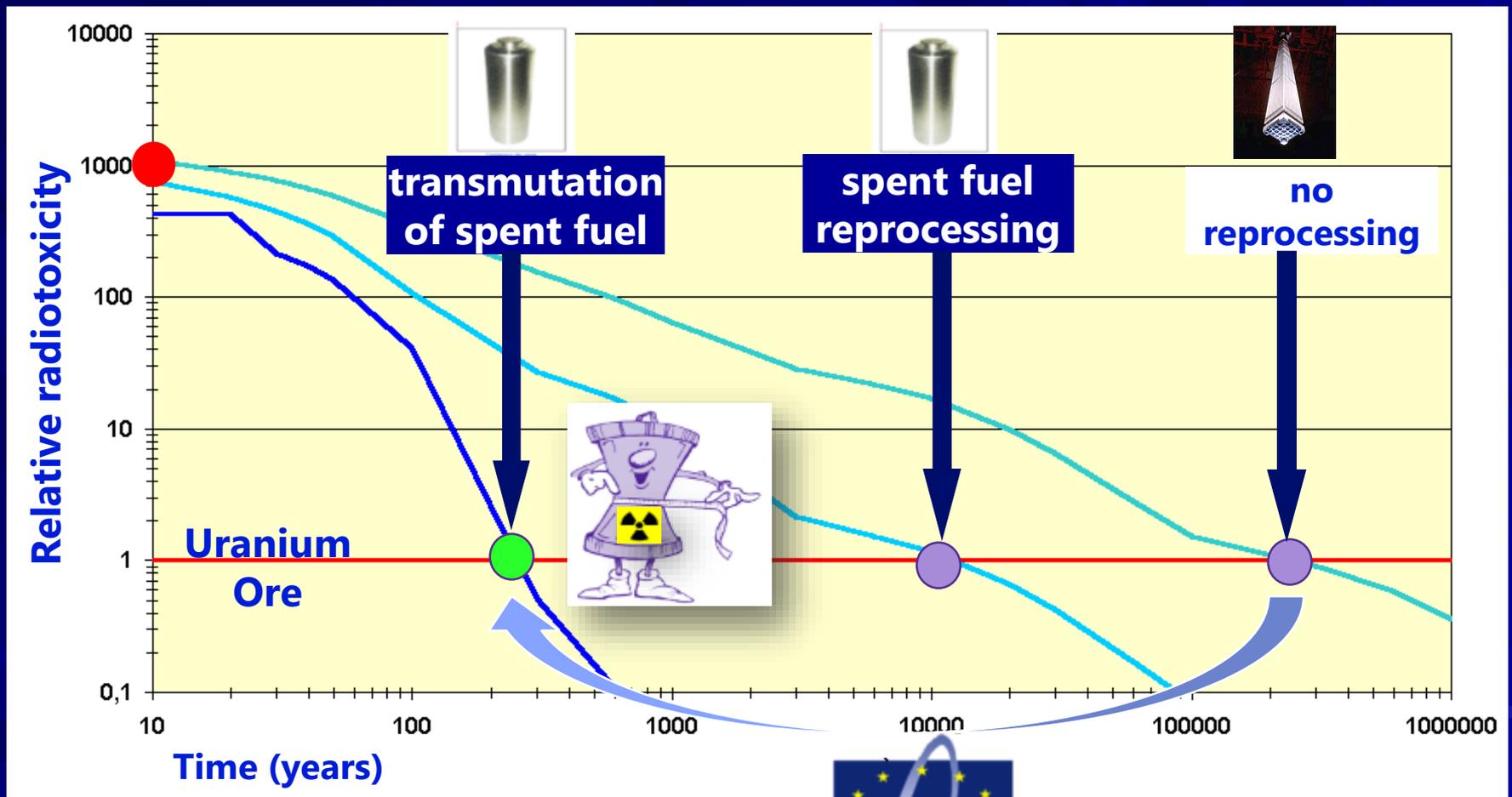
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A few kg of minor actinides MA( Pu, Am, Cu, Np,..) are responsible for most of the radiotoxicity and the long lifetime of Nuclear waste



# Motivation for transmutation



# Transmutation with an Accelerator Driven System

MYRRHA (MoI, Be)

A glance into the future...

2010-2030

1,5 Billion Euros

MYRRHA  
reactor  
building

Utilities  
buildings

ECR source &  
Injector Building

MYRRHA LINAC  
high energy tunnel

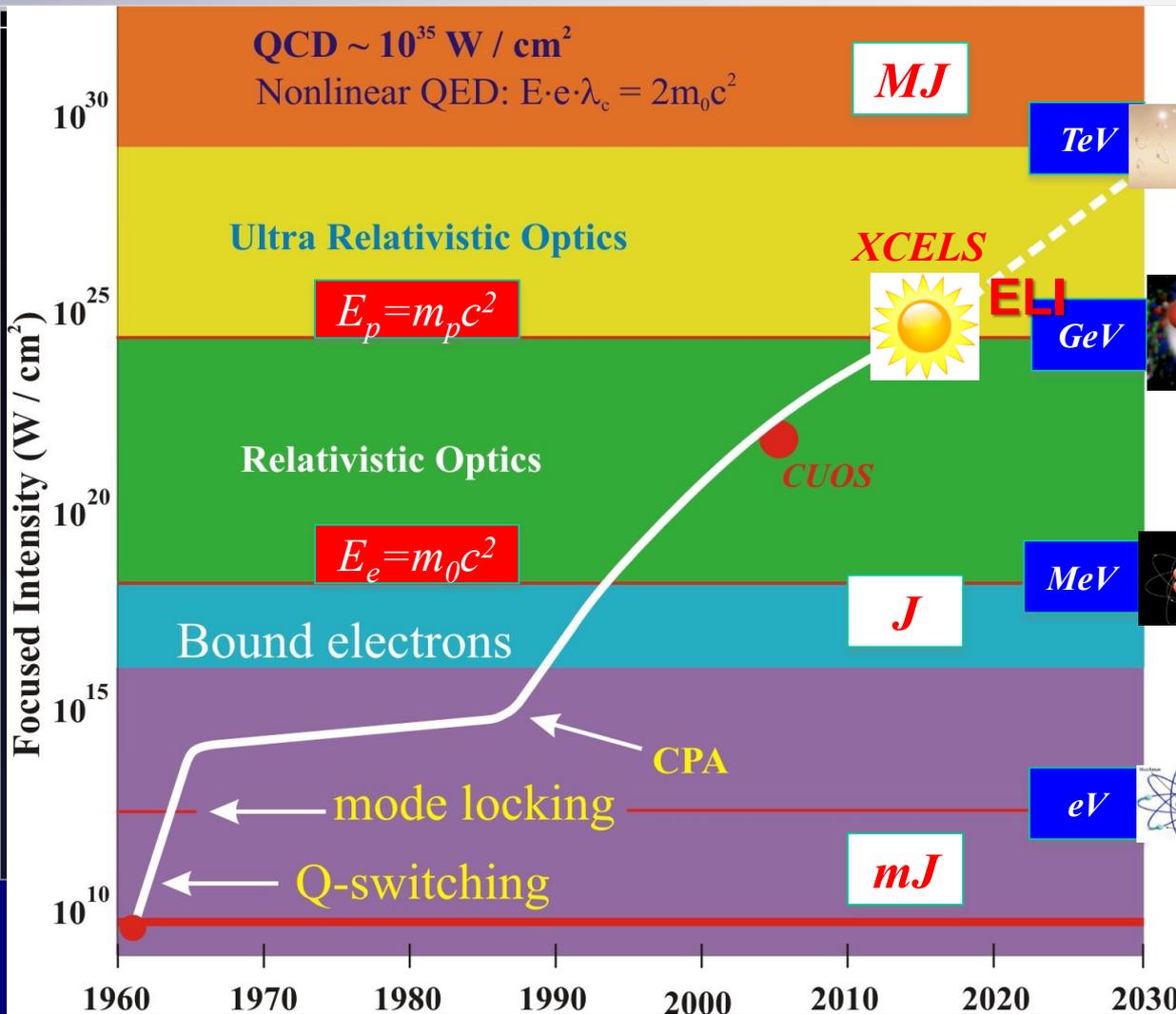
Km<sup>2</sup>

An **Accelerator-Driven-System** is: a subcritical neutron multiplication assembly driven by an external neutron source,  **$10^{17}n/s$**  obtained through the spallation mechanism with high energy ( $\sim 1\text{GeV}$ ) protons

# Ultra High Intensity Laser "A revolution"

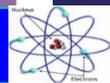
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**Donna Strickland**  
**Gérard Mourou**

**Physics NOBEL Prize**  
**2018**



# ELI: Extreme Light Infrastructure : A revolution in Laser technology

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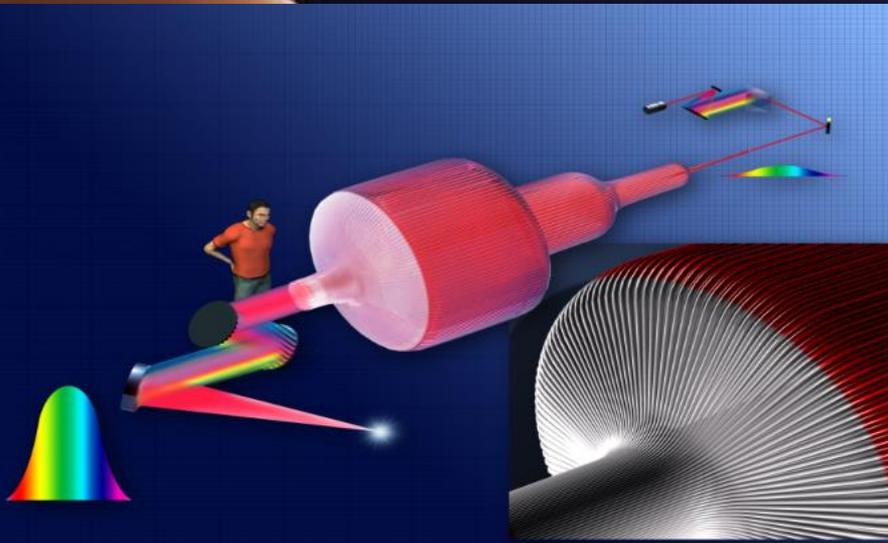
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*Giant wakefield acceleration in solid*

*Tajima et Dawson (1979)*

*Laser-particle accelerations to the GeV/mm level become possible  
Therefore new laser driven source may be the solution for transmutation*



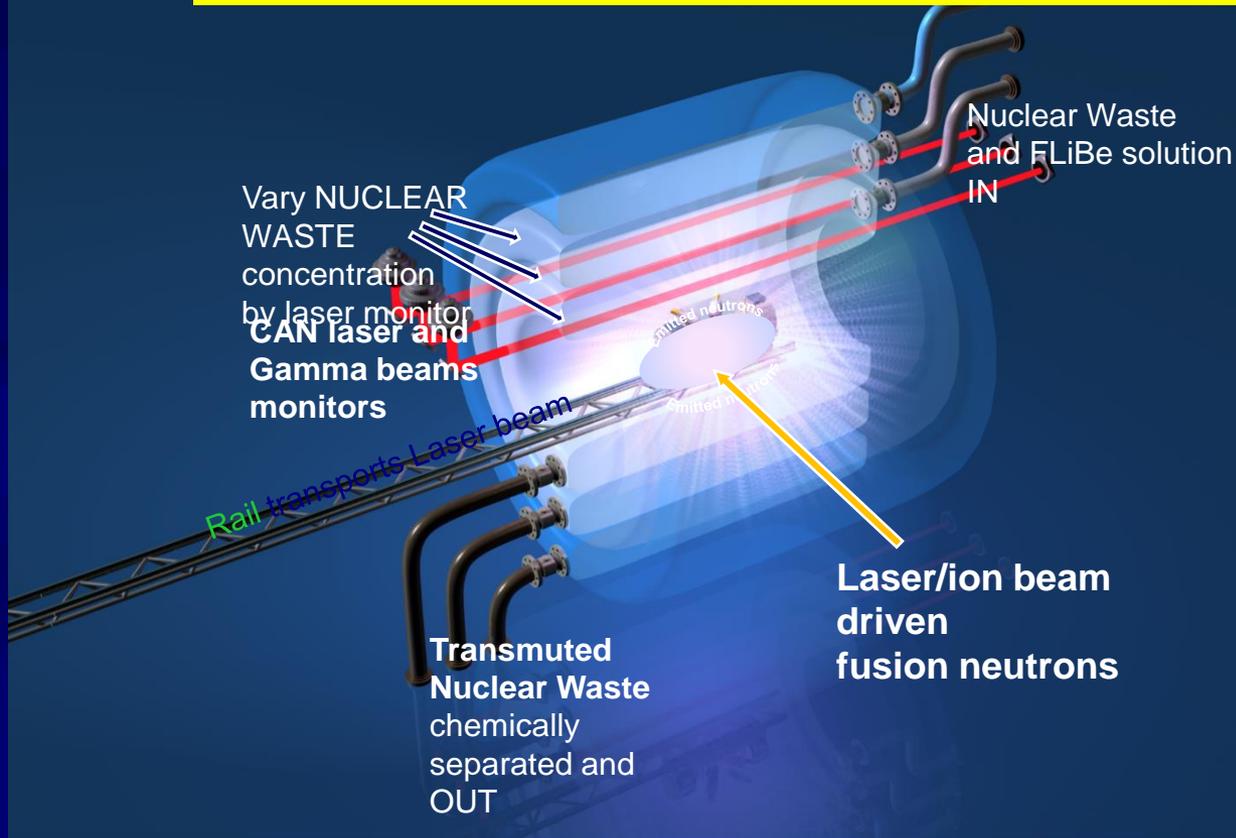
1PW Extreme Light is  
1000 times the world grid power in  
10-15s

*ICAN (European Project)*

*The Future is Fibre Accelerators (Nature Photonics  
April 2013)*

# Compact, Safe, Mobile, Liquid and Scalable TRANSMUTATOR of Spent Nuclear Waste

T.Tajima, S.Gales, G. Mourou et al



\* **Safe** by Liquid solution-FLiBe (molten salt with very high boiling point, passive safety valve)

\*\***Safe** by realtime **monitor** and **control** (by **laser** and **laser** Compton **gamma**)

\*\*\***Safe** by external **Laser- Fusion Trigger** (flexibility, **safety**, compact, **mobile**, inexpensive, compared to Acc technologies)

# MA and TRU Transmutation

■ Fast Reactor: 20 kg/Gw<sub>th</sub>yr

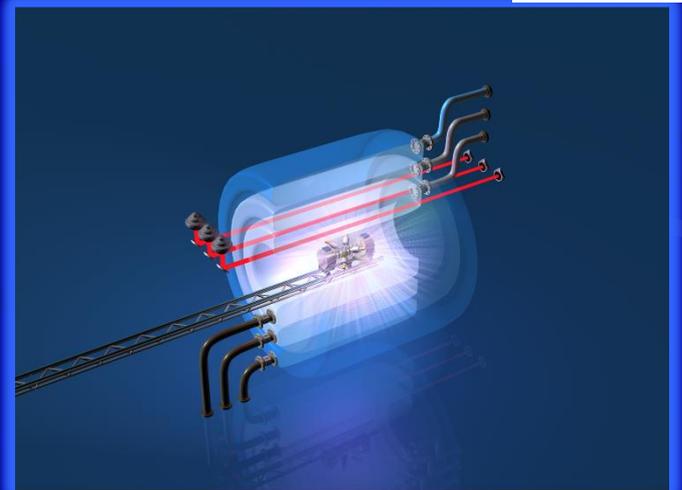
■ MYRRHA: 300 kg/Gw<sub>th</sub>yr



Our approach (without any form of optimization):

■ MA only: 100 kg/GW<sub>th</sub>yr

■ Pu+MA: 250 kg/Gw<sub>th</sub>yr



# Some conclusions

- ***Nuclear energy does not appear any more to be a solved technical question***
  - ***Overall (societal, economic) boundary conditions have evolved significantly since 1980 and will still do so in future***
  - ***Innovation is and will be required .***
  - **Both Fundamental and Applied research can contribute via :  
Multi-disciplinarity approach**

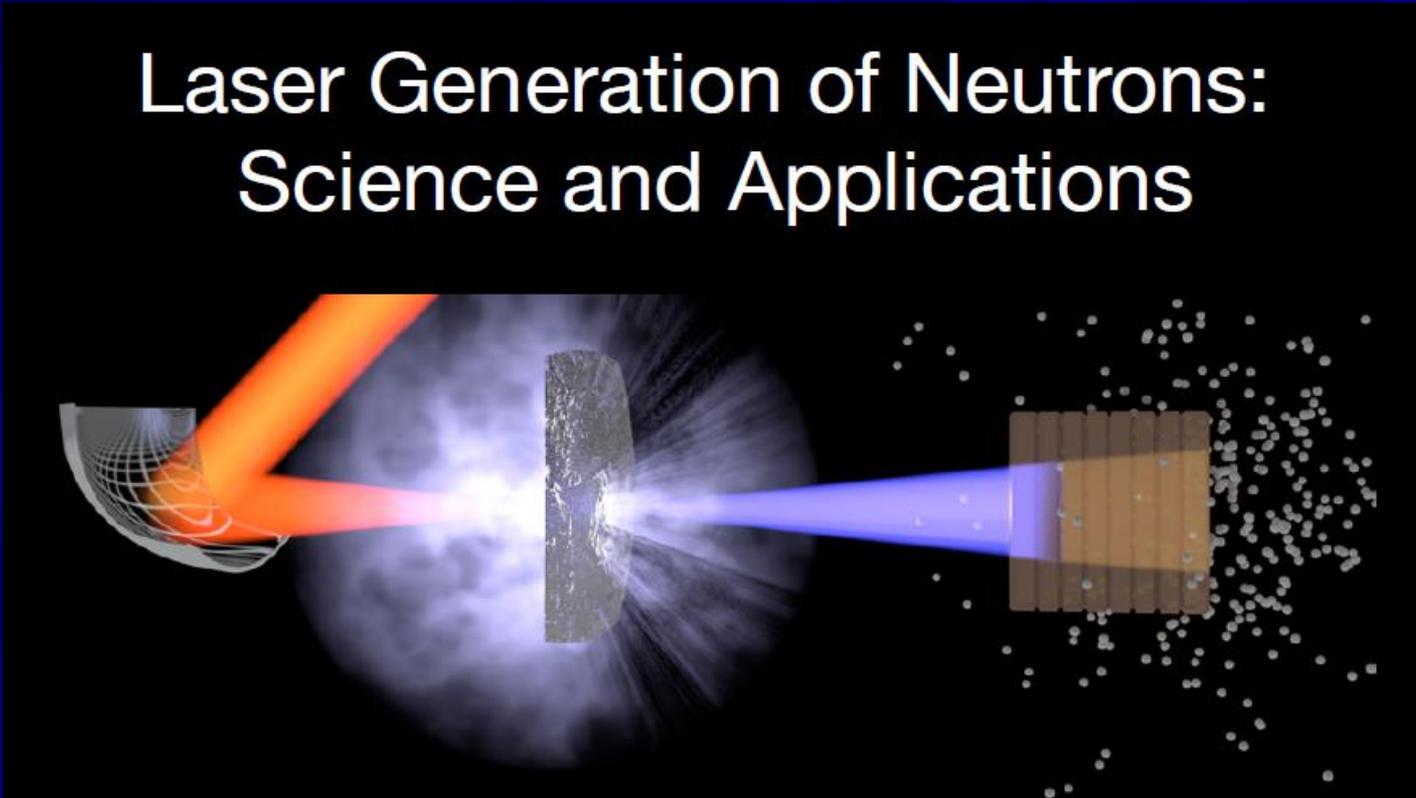
***In any nuclear energy scenario Transmutation of high level waste is a feasible solution to reduce the heat load , the volume and the time storage of remaining waste .***

***In addition on the long term it will make the transition to Carbon free energy more realistic through a safer and more acceptable nuclear energy contribution.***

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## Laser Generation of Neutrons: Science and Applications



■ Thank you for your patience