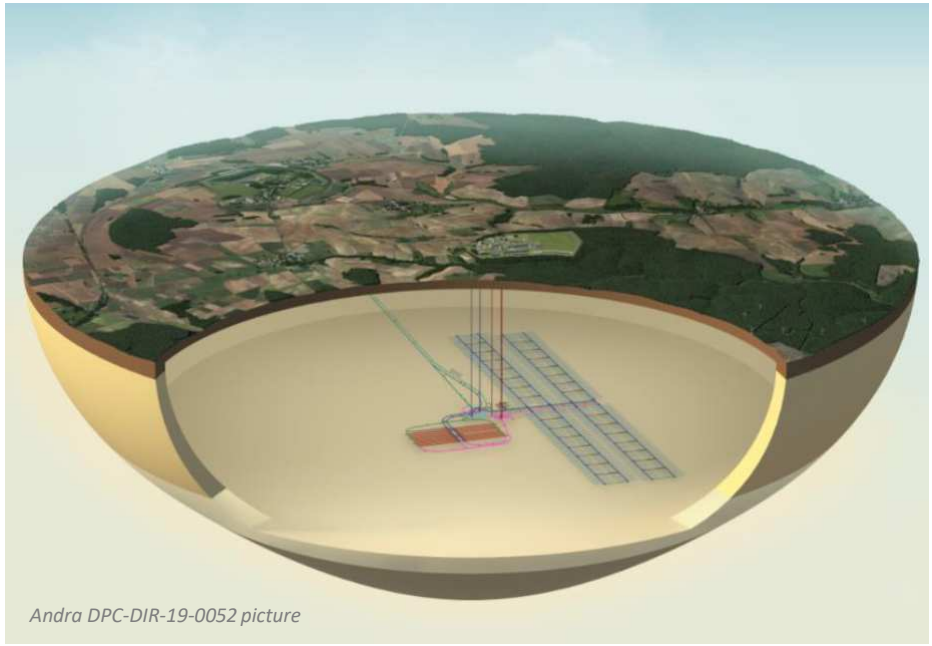
Documentary sources :

France: The Cigeo geological storage project

Industrial Geological Storage Center



Andra DPC-DIR-19-0052 picture

Project Description

Why - A project which does not meet its goals

Where - A wrong political decision with the choice of Bure and clay

How - A low cost driven design very sensible to fire risk

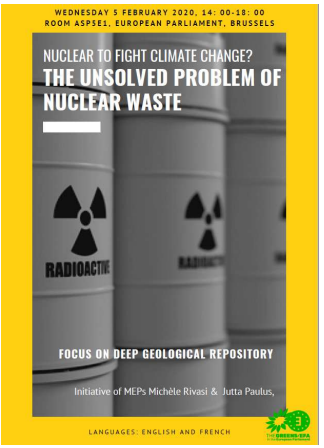
Lessons and suggestions

Parlamentum Europaeum

Dr. Bertrand Thuillier

Associate Professor - Lille University

Bruxelles, on February 5th, 2020



Documentary sources :

ANDRA
Agence nationale pour la gestion des déchets radioactifs

Description of the Cigeo project

Imagined in the **90s**
Studied in the **2000s, 2010s**
DAC/CAR (Creation Authorization Request) **# 2020**
Start of work **# 2025** - End of operations **# 2150**

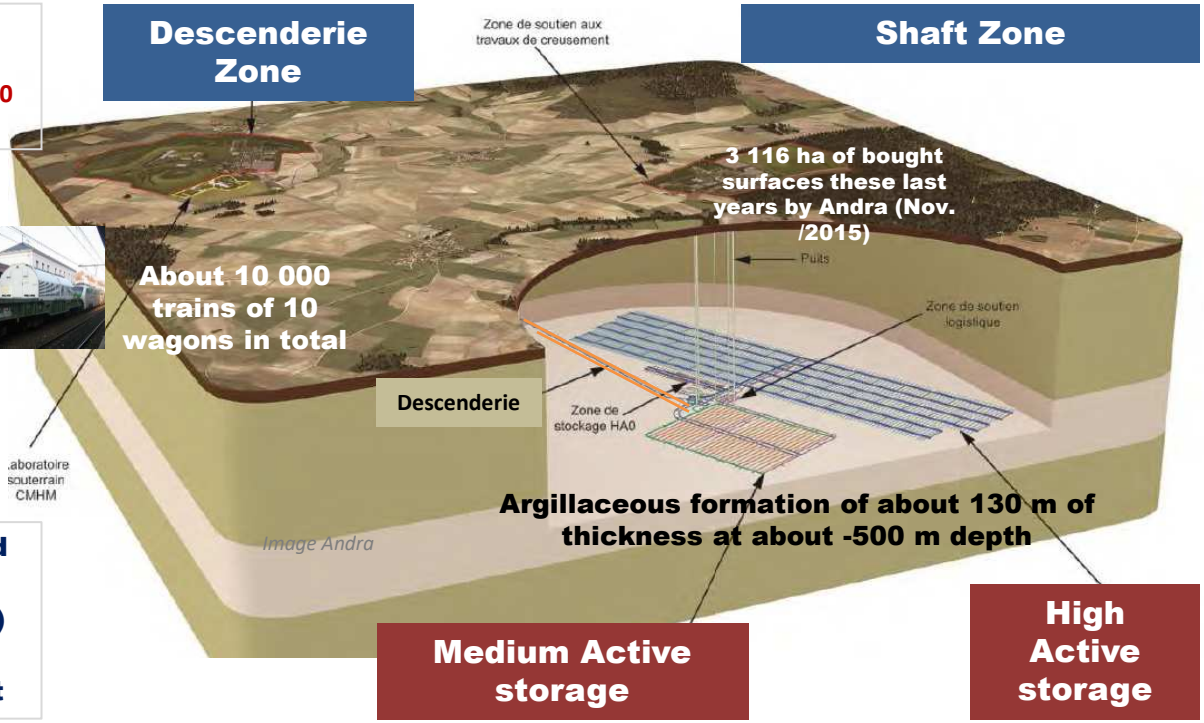
270 kms of galeries, descenderie and storage units to dig

10 to 15 kms² (possibly up to 30 km²) of underground surface

9 to 10 millions m³ of rock to extract

Descenderie Zone

Shaft Zone



About 10 000 trains of 10 wagons in total

Argillaceous formation of about 130 m of thickness at about -500 m depth

Medium Active storage

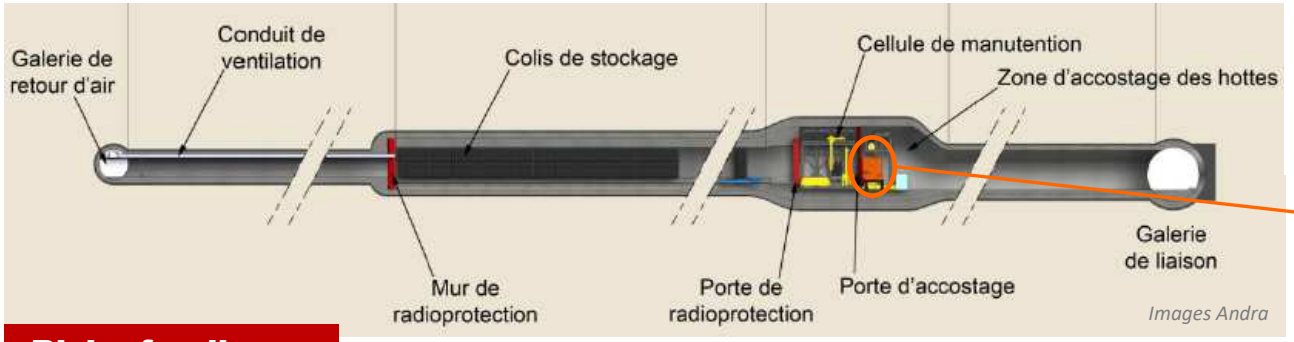
High Active storage

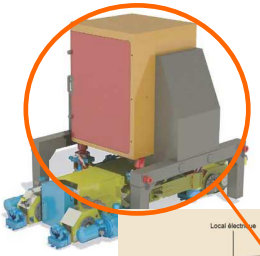
Bertrand Thuillier, February 5th, 2020

Documentary sources :

Underground storage – Medium Activity Unit

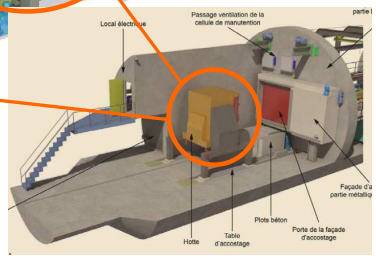
22 MA storage units # 20 kms in total





Transfer vehicle

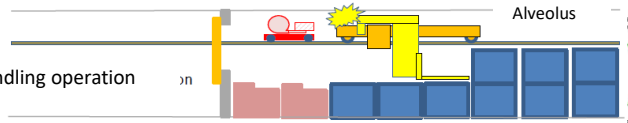
Andra pictures



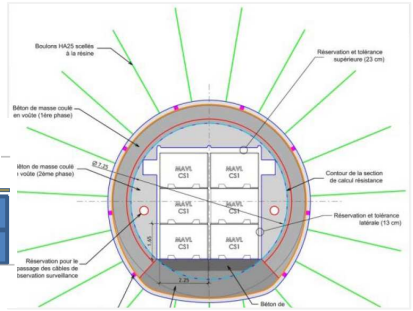
Risk of collapse

Storage units of approximately 800 to 850 m in length designed to receive packages without radiological protection

Almost impossible maintenance



Andra pictures



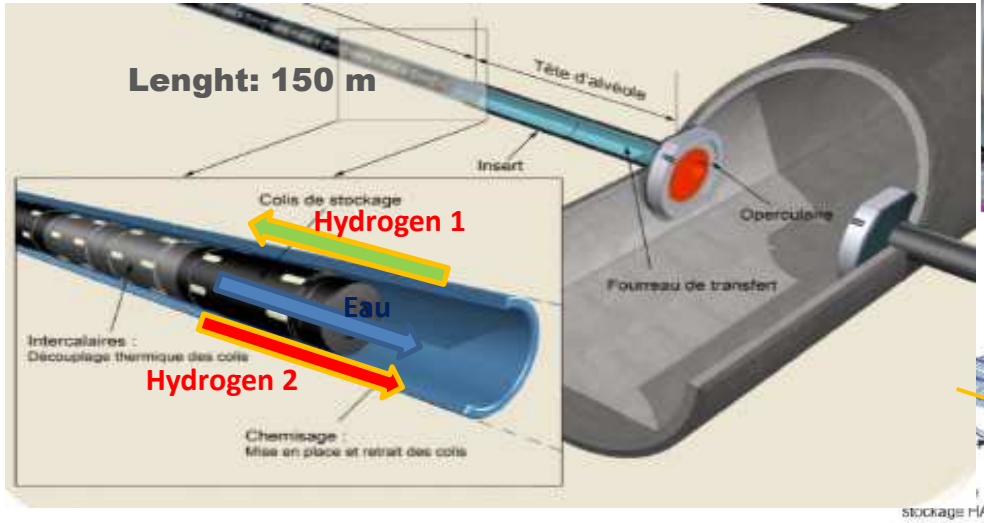
Diameter: 12 m
Digging surface> 110 m²

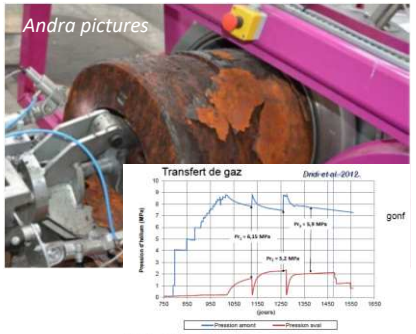
Bertrand Thuillier, February 5th, 2020

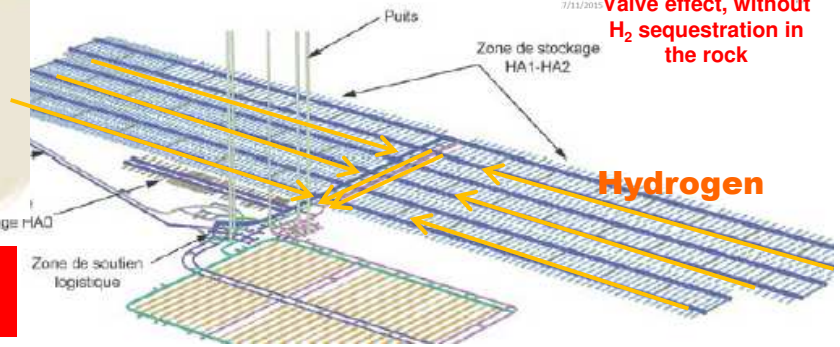
Documentary sources :

Underground storage – High Activity Unit

1000 HA storage units # 150 kms in total







Valve effect, without H_2 sequestration in the rock

Hydrogen from corrosion

Corrosion HA (C) : About 3 000 m^3 H_2 per year

(1 m^3 H_2 # 2 kg of TNT)

Bertrand Thuillier, February 5th, 2020

Documentary sources :

1. Why Cigeo is not meeting its goals…

Goals:

1. To store all Medium-level Activity / Long-Lived radioactive waste (B)

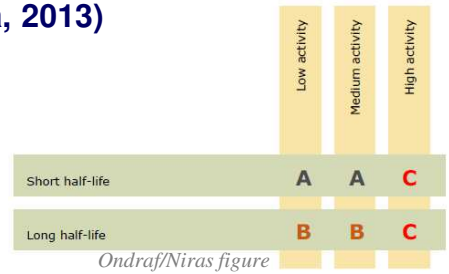
73 600 m³ waste (Andra, 2013), but:

- . 18 % in number (bitumen)
- . 20 % in number (unkown content)

2. To store all High-level Activity / Long-Lived radioactive waste (C)

10 054 m³ waste (Andra, 2013)

* L'IRSN (Radioprotection and Nuclear Safety Institute considers (2017) that the current dimensions of the Logistics Support Zone (ZSL) and access to storage unit structures are not suitable for handling irradiated fuel.

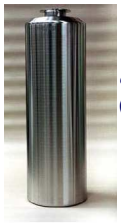


Ondraf/Niras figure

Bitumen total quantity: 9 700 t. of bitumen
Hydrogen production (radiolysis: # 1 000 m³ / year)

Contenairs in not allied steel 870 L, Andra picture

- . Volume increase (up to 70%)
- . Combustible material
- . Self-ignition



Vitrified waste ccanister (CSD-V), Andra picture

But 68 500 m³ irradiated fuel materials are not included in Cigeo !

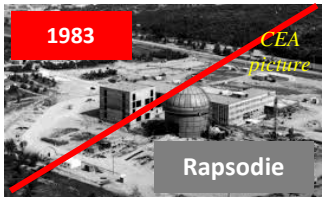
… Because Cigeo was not designed* to accept irradiated fuel !

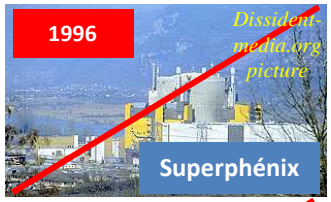
Bertrand Thuillier, February 5th, 2020

Documentary sources :

… because Cigeo is an old project imagined in the 90s

Irradiated fuel was not considered as waste in the 90s when nuclear industry was 'flamboyant'





Irradiated fuel should be able to be used in Fast Neutron Reactors (FNR/RNR)

But all the research and operating reactors are now shut down!

SYNTHÈSE DES SCÉNARIOS — **ANDRA - 2018**

Journal de l'Andra Automne / Hiver 2018	SR1	SR2[1]
Poursuite ou arrêt de la production électronucléaire	Poursuite (durée totale de fonctionnement entre 50 et 60 ans)	Poursuite (durée totale de fonctionnement de 50 ans)
Type de réacteurs déployés dans le futur parc	EPR puis RNR	EPR puis RNR
Retraitement des combustibles usés	Tous : UNE, URE, MOX et RNR	Tous : UNE, URE, MOX et RNR
Requalification des combustibles usés et de l'uranium en déchets	Aucune	Aucune

Inventory of French nuclear waste are still based on completly "unrealistic" scenarios of replacement of the nuclear power current generation by by EPR type reactors (European Pressurized Water Reactor)**, then by FNR/RNR type reactors** Fast Neutron Reactor / Réacteurs à Neutrons rapides) **to be capable to use the irradiated fuel!**

Consequently, Cigeo is really far to meet its goals

Bertrand Thuillier, February 5th, 2020

Documentary sources :

2. Why the choice of Bure, and so argillaceous formation, was a wrong decision…

Law called 'Bataille' dated 30th December, 1991

1994: 4 planned laboratories: Gard, Meuse, Haute-Marne and Vienne (granite)

1996: 3 laboratories creation requests

1998: A single Laboratory in Bure

2006: Decision of disposal in Bure

Law of June 28th, 2006: Geological disposal in Bure

Law of 1991 not respected
Public debate in 2005 not taken into account
No choice, because no other alternatives studied

3 ways and laboratories:
. Transmutation
. Long Term Storage
. Geological Disposal

Pressure from elected officials
of Meuse and Haute-Marne

… Because this choice was not based on scientific criteria, but only political, hence a very bad choice….

Bertrand Thuillier, February 5th, 2020

Documentary sources :

… because clay turns out to be the worst rock to bury

1. Water saturated rock (7 to 8 %)

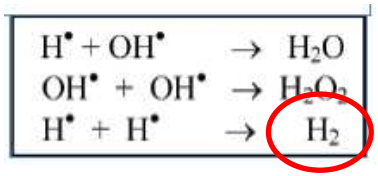
Desiccation of clay soils (desaturation of the host formation)

Cracking by desaturation

Thesis of Pierre GERARD, May 2011

Water + Radiation => Radiolysis of water

-> Very corrosive elements and Hydrogen



2. Friable rock (not self-supporting)

Destructuring by compression

Andra CLIS pictures, 2019

Fragility => Underground structures reinforced with steel (hundreds of thousands of tons) ⇨ **. Corrosion of steel . Hydrogen**

About 4 000 m³ of hydrogen per year (MA+HA corrosion) ⇨ **Mandatory Ventilation**

By these two characteristics, geological disposal in an argillaceous formation of radioactive waste = Hydrogen Plant!

Bertrand Thuillier, February 5th, 2020

Documentary sources :

3. Why the Cigeo design is very sensitive to fire risk?

Friable rock (not self-supporting) → **Very high cost of useful underground volume per unit of volume (due to supports)**

Finding the minimum cost:

Reduced package volume

The choice not to equip the packages with radiological protection for reasons of reduction in the volume of the packages (inaccessibility)

But: Impossibility of taking back defective packages and performing maintenance

Reduction in the number of storage cells

The choice to make the largest possible cells as warehouses type (economy of scale and optimizations)

But: Any divergence from a single package has an effect on the entire storage cell (systemic effect)

Bertrand Thuillier, February 5th, 2020

Documentary sources :

ANDRA
Agence nationale pour la gestion des déchets radioactifs

… because the project design is driven more by financial savings than by security concerns

Volume ++

Non-compliance of a package

Hydrogen

5 000 m^3 total / year
(1 m^3 # 2 kg TNT)

Bitumen

9 700 tons of pure bitumen

+ Non-neutralization decision in 2019

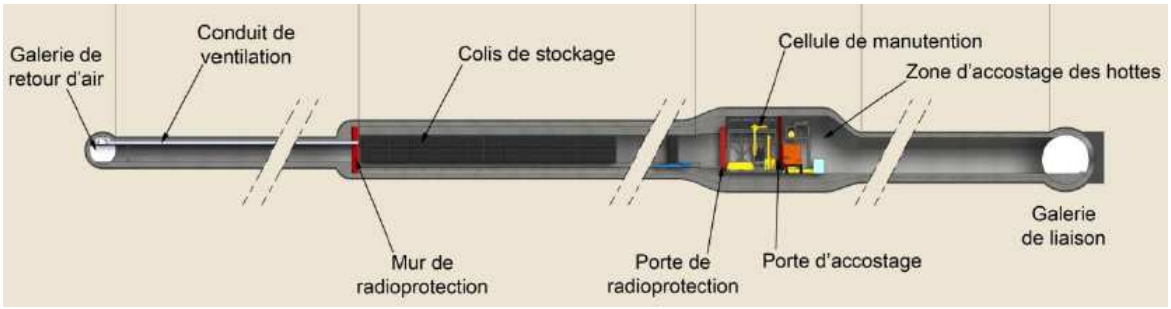
Ventilation

2 Millions of m^3 / hour

Sparks

Handling batteries

Illustrative pictures



800 m to 850 m long storage units designed to receive packages without radiological protection:
Irradiating and not accessible storage units

⇨ **Fire risk**

Confirmed by IRSN in 2017, Cigeo remains very fragile, by design face to a fire

Bertrand Thuillier, February 5th, 2020

Documentary sources :

a. Fire (after a few hours)

Access impossible - Damaged ventilation - Contaminated area

Bitumen waste
(Self-ignition)

Hydrogen Production
(corrosion+MA Waste)

Bitumen

Hydrogen

Fire

Fire stop:

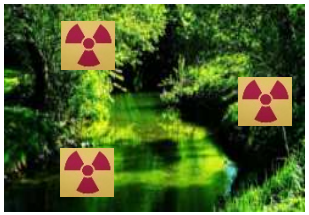
Ventilation Stop

The stopping of ventilation of a MA storage unit should not exceed 2 to 5 weeks–> H_2 level > 3%*

(*: Minimum Explosive Limit)

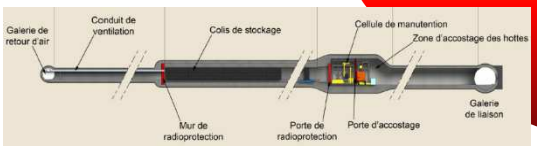
Radioactive gas emissions

Radioactive Contaminants



Illustrative picture

. Non-compliance
. Sealing defects
. Fall
. Corrosion



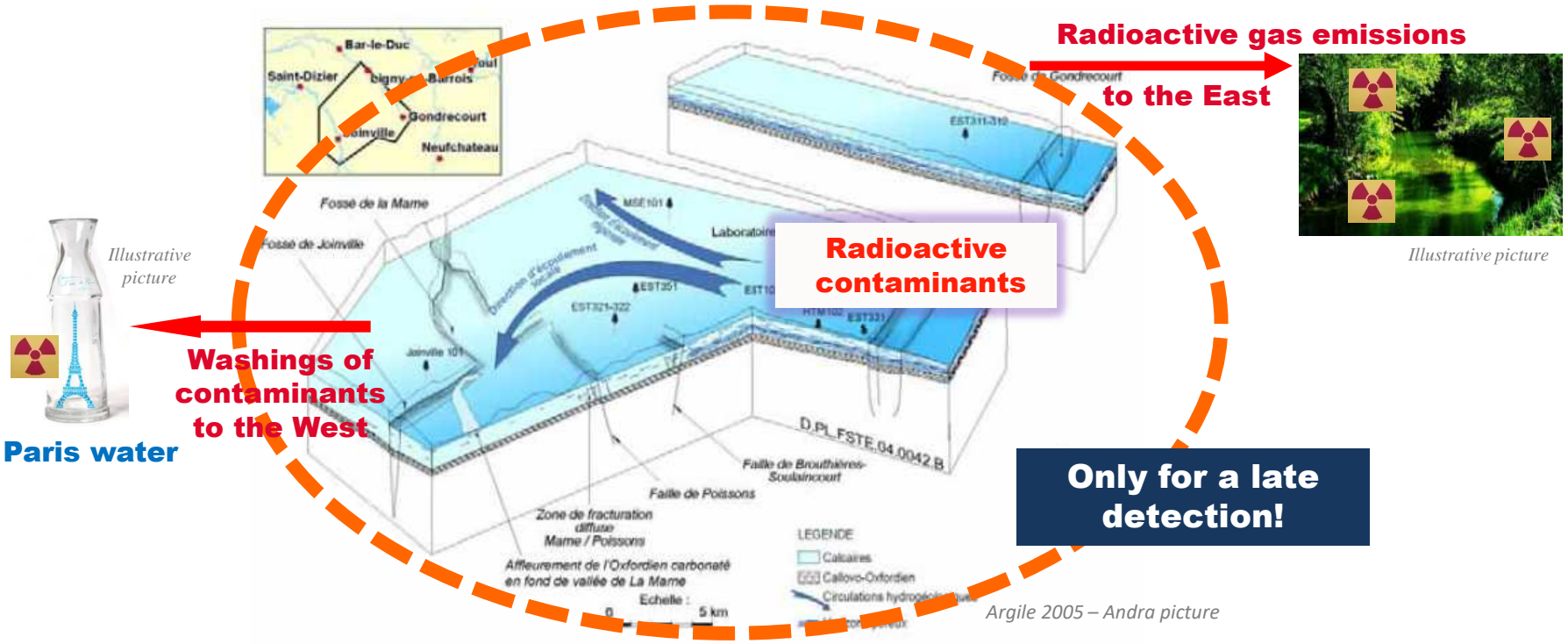
. Degradation of structures
. Contamination of galeries
. Damaged access
. Contaminated shafts ...

Illustrative pictures

Bertrand Thuillier, February 5th, 2020

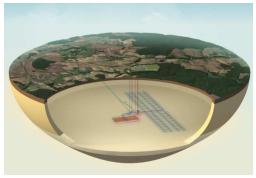
Documentary sources :

b. Surface water contamination and atmospheric radioactive releases



Description and organization of water flows in the carbonate Oxfordian

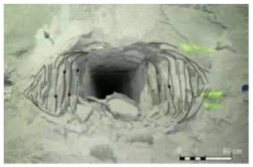
Bertrand Thuillier, February 5th, 2020



Main lessons on Cigeo

1. Cigeo is an old project already outdated and obsolete in its goals (irradiated fuel and FNR)

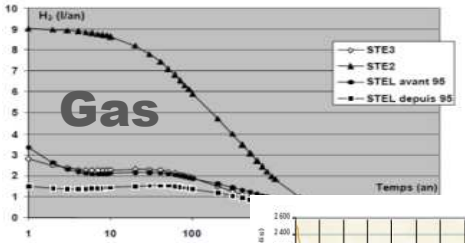
Image Super-Phoenix en voie de démantèlement

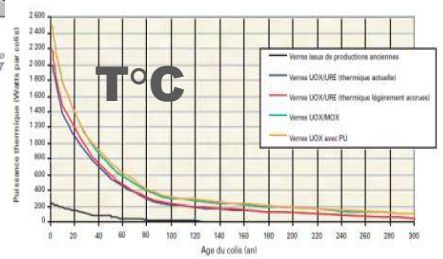


2. Located in a inappropriate rock (water saturated and friable rock) for political reasons

3. A design that is very sensitive to fire risk (hydrogen and bitumen)

4. Radioactive waste are still too hot and still too gas-generating, and therefore currently incompatible with the underground environment





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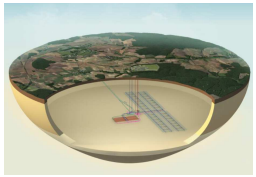


In the end, three suggestions …

1 **Set up medium term, secure dry storage solutions for at least a hundred years**

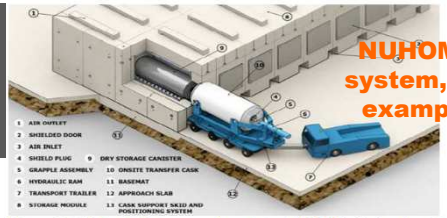


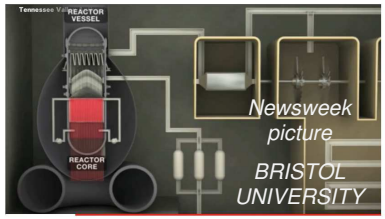
Figure n°1 : Schéma de l'entreposage à sec de type NUHOMS développé par Orano TH de San Onofre (Etats-Unis) – Source : IRSN.

2 **Allow time for science to bring up real solutions in order to neutralise and/or to really use radioactive waste:**

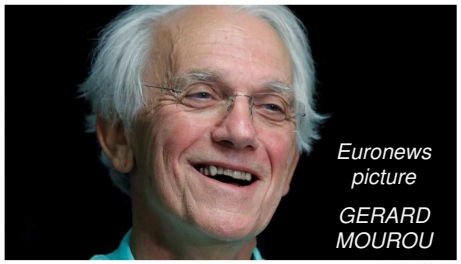
TECH & SCIENCE

DIAMOND BATTERIES CREATED WITH NUCLEAR WASTE MAY SOON PROVIDE SOURCE OF 'NEAR INFINITE' POWER

BY JASON MURDOCK ON 1/22/20 AT 9:38 AM EST



Nobel prizewinner working on making nuclear waste safe COMMENTS



3 **Pass on to future generations:**
. Reliable, credible, proven long-term scientific knowledge
. Real and sufficient funds.

Dreamstime.com picture

Bertrand Thuillier, February 5th, 2020