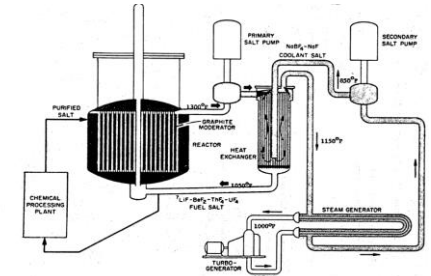
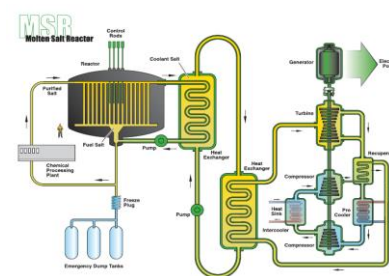
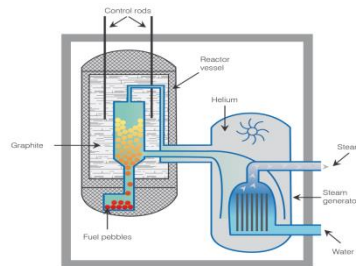
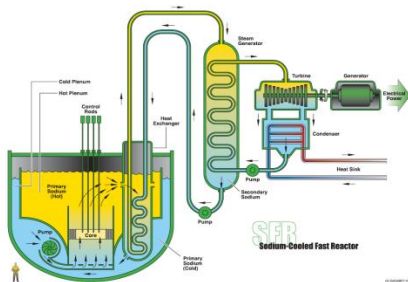


# Propaganda versus reality of „New Generation of Reactors“ (Gen IV)

An (updated) assessment

Dr. Christoph Pistner

Vienna, Oktober 7, 2019



# Agenda

**1** Introduction

**2** Systems and Evaluation Criteria

**3** Systems Details

**4** Cross Cutting Topics

**5** Conclusions

# 1

## Introduction

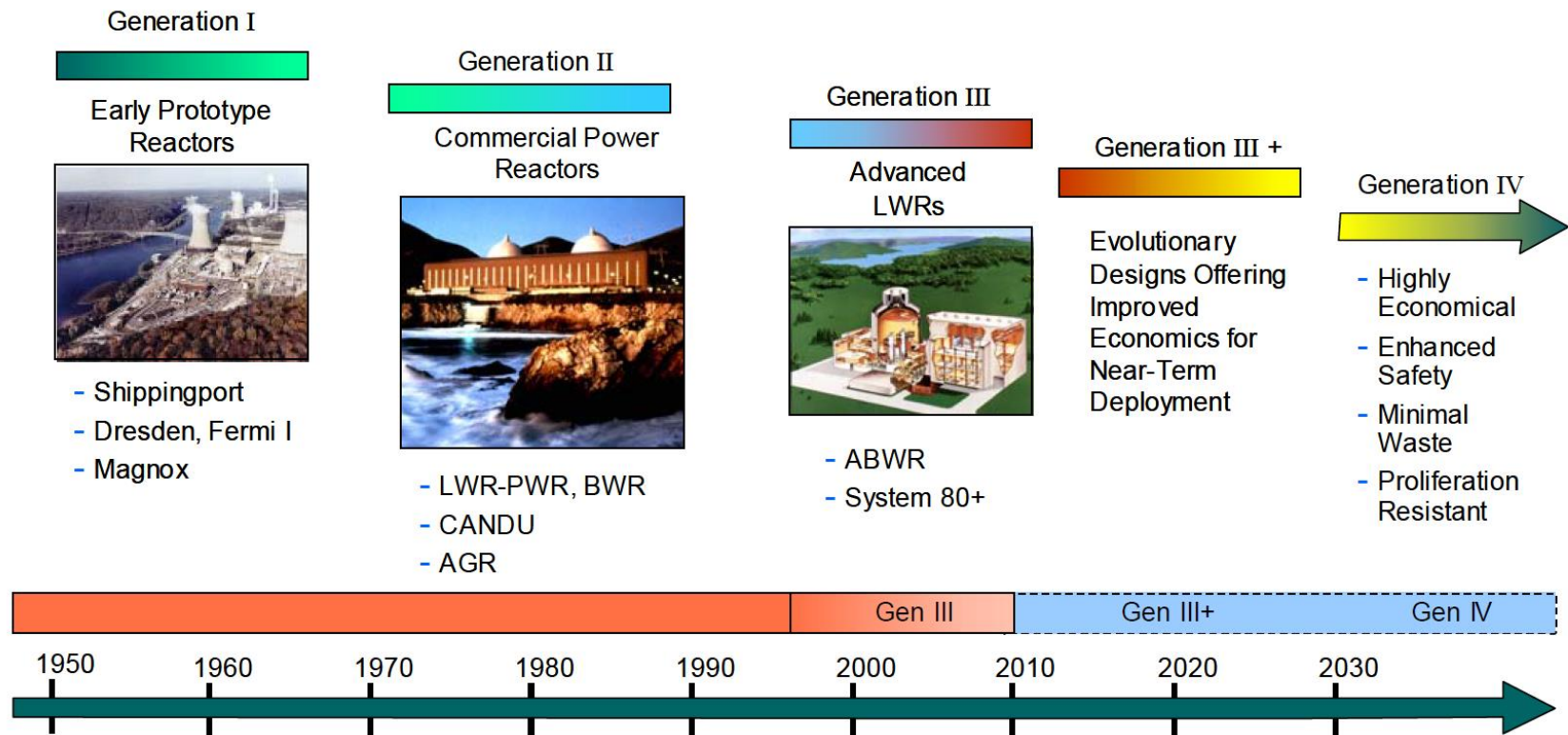
## Public Promises of „New Reactor Concepts“

Promises with respect to new reactors are made to general public in press media:

- 10.000 times less wastes
- Wastes remain dangerous for less than 1.000 years
- Electricity will be so cheap, even emerging countries can afford it
- Reactors are inherently safe, no severe accidents are possible
- Because of Thorium as fuel, there will be no proliferation problem
- Reactors will be available on the market within 15 to 20 years

# What are „New Reactor Concepts“?

- In 2000 establishment of „Generation IV International Forum“










































# Who is in?



- |               |           |                  |                 |
|---------------|-----------|------------------|-----------------|
| ■ Argentina*  | ■ China   | ■ Korea, Rep. of | ■ Switzerland   |
| ■ Australia * | ■ Euratom | ■ Russian        | ■ United        |
| ■ Brazil *    | ■ France  | ■ Federation     | ■ Kingdom*      |
| ■ Canada      | ■ Japan   | ■ South Africa   | ■ United States |

\*Argentina, Australia, Brazil and the United Kingdom are non-active, i.e. they have not acceded to the Framework Agreement which establishes system and project organizational levels for further co-operation. Australia signed the GIF Charter on June 22, 2016, thus becoming the GIF's newest and 14<sup>th</sup> member.

# What do they do?

Generation IV Systems	 Canada	 China	 France	 Japan	 Korea	 Russia	 Switzerland	 U.S.A.	 EU
Sodium-cooled Fast Reactor (SFR)									
Very-high Temperature Gas cooled Reactor (VHTR)									
Gas-cooled Fast Reactor (GFR)									
Supercritical-water cooled Reactor (SCWR)									
Lead-cooled Fast Reactor (LFR)									
Molten Salt Reactor (MSR)									

# Short Study on New Reactor Concepts

- On behalf of the Swiss Energy Foundation (SES)
- Performed March/April 2017
- Literature analysis on selected „new reactor concepts“
  - Systems description, historic and current experiences, assessment with respect to evaluation criteria
- Some cross-cutting issues
  - Thorium, Partitioning and Transmutation
- 124 pages study download here:  
<https://www.oeko.de/fileadmin/oekodoc/Neue-Reaktorkonzepte.pdf>
- Updated with GIF information since then for today's presentation



# 2

## Systems and Evaluation Criteria

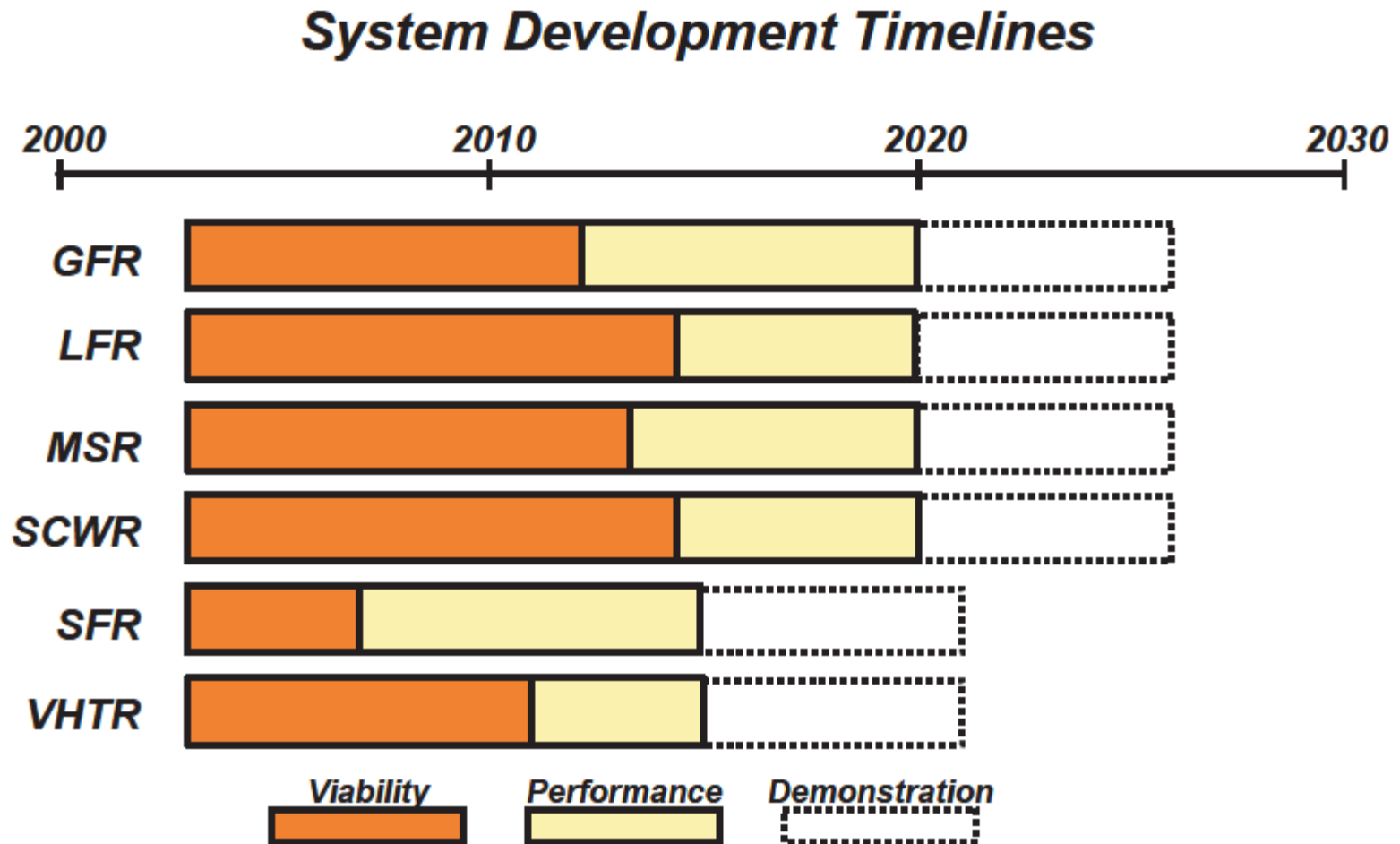
## Gen IV „New Reactor Concepts“

- Sodium-cooled Fast Reactor (SFR)
  - Only concept claimed to be commercially available
- (Very) High Temperature Reactor – (V)HTR
  - Currently under development especially in China
- Gas-cooled Fast Reactor (GFR, not discussed in the following)
- Molten Salt Reactors, MSR
  - Only reactor concept with liquide fuel
- Lead-cooled Fast Reactor (LFR, not discussed in the following)
- SuperCritical Water-cooled Reactor (SCWR, not discussed in the following)

## Gen IV Timelines (2002)

- Viability Phase:
  - resolve key feasibility and proof-of-principle issues
- Performance Phase:
  - key subsystems need to be developed and optimized
- when the system is sufficiently mature and performs well enough to attract industrial interest in large-scale demonstration of the technology →
- Demonstration phase:
  - at least six years (2014: at least 10 years), funding of several billion U.S. dollars, if successful, a system may enter a commercialization phase

# Gen IV Timelines (2002)



## Gen IV Goals (2002)

- Sustainability 1: “... meets clean air objectives and ... effective fuel utilization ...”
- Sustainability 2: “... reduce the long-term stewardship burden ...”
- Economics 1+2: “... clear life-cycle cost advantage ... level of financial risk comparable to other energy projects ...”
- Safety 1+2+3: “... very low likelihood and degree of reactor core damage. ... will eliminate the need for offsite emergency response”
- Proliferation Resistance: “... least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism”

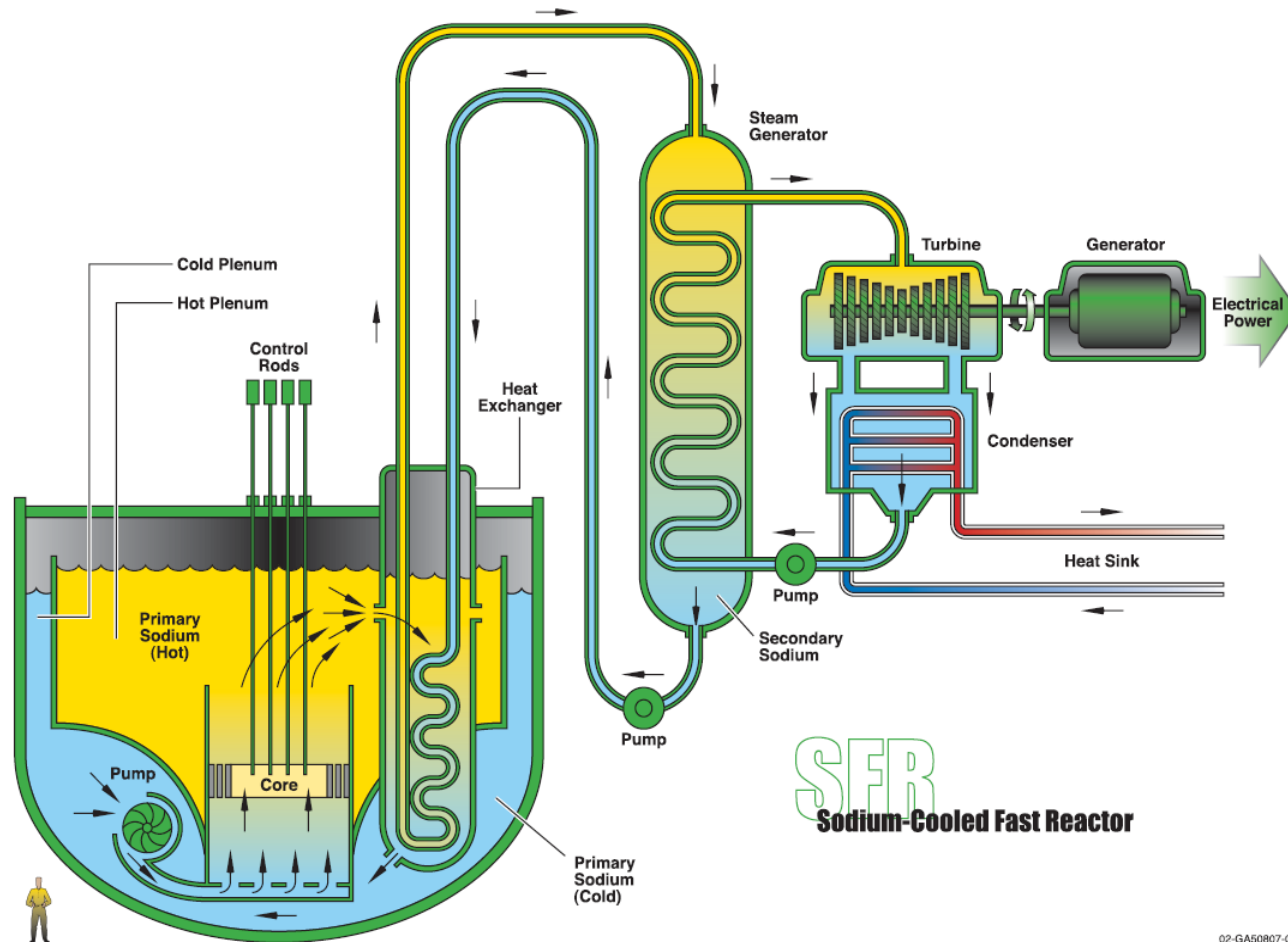
## Gen IV Goals (2018)

- “Gen IV concepts complement existing and evolutionary Gen III/III+ reactors, which will be deployed throughout the century, by providing additional options and applications, such as:
  - optimisation of resource utilisation
  - multi-recycling of fissile materials/used fuel and **reduction of the footprint of geological repositories for high-level waste**;
  - low-carbon heat supply for co-generation and high-temperature industrial applications ...
  - ... reinforcing the defence-in-depth approach ... **aimed at ... eliminating the need for emergency measures ...**”
- The time perspective is a readiness for commercial fleet deployment by **around 2045** (for the first systems).

# 3

## Systems Details

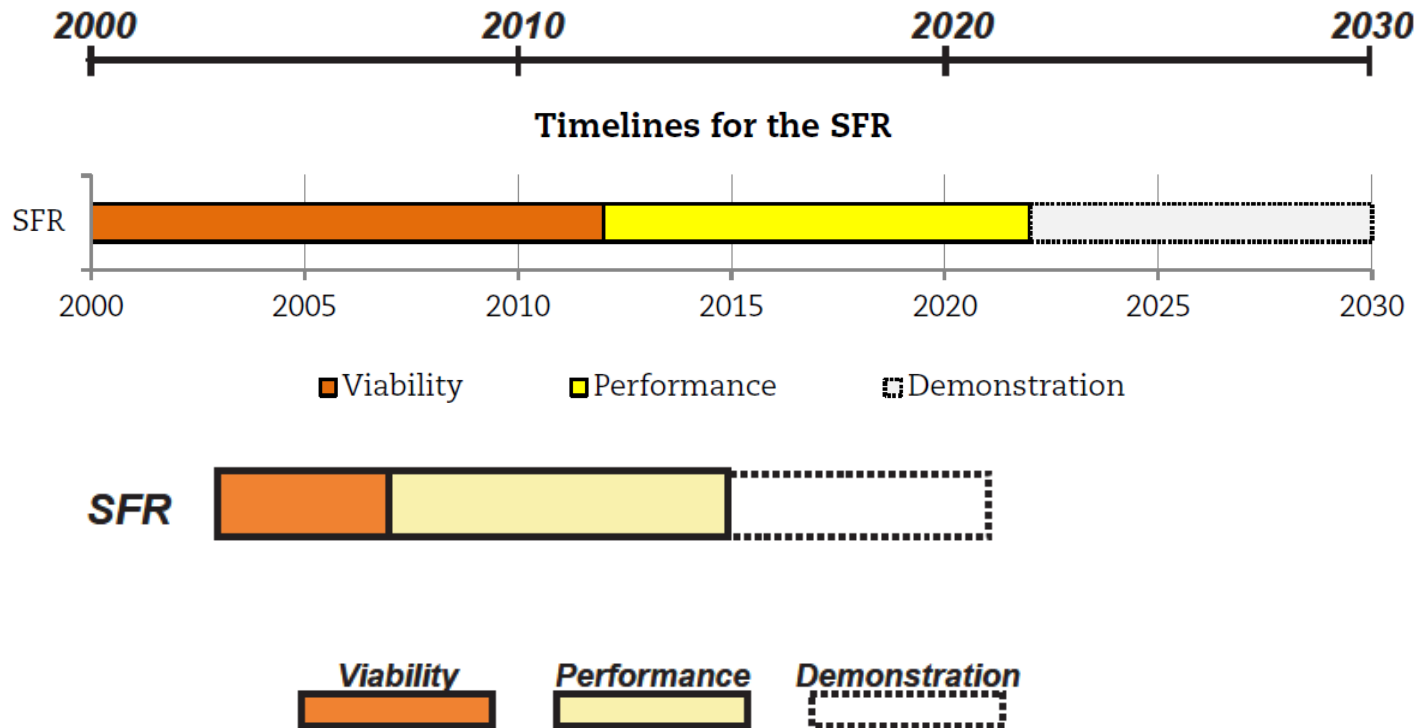
# Sodium-cooled Fast Reactors (SFR)





# SFR Timelines (2002/2014)

## System Development Timelines

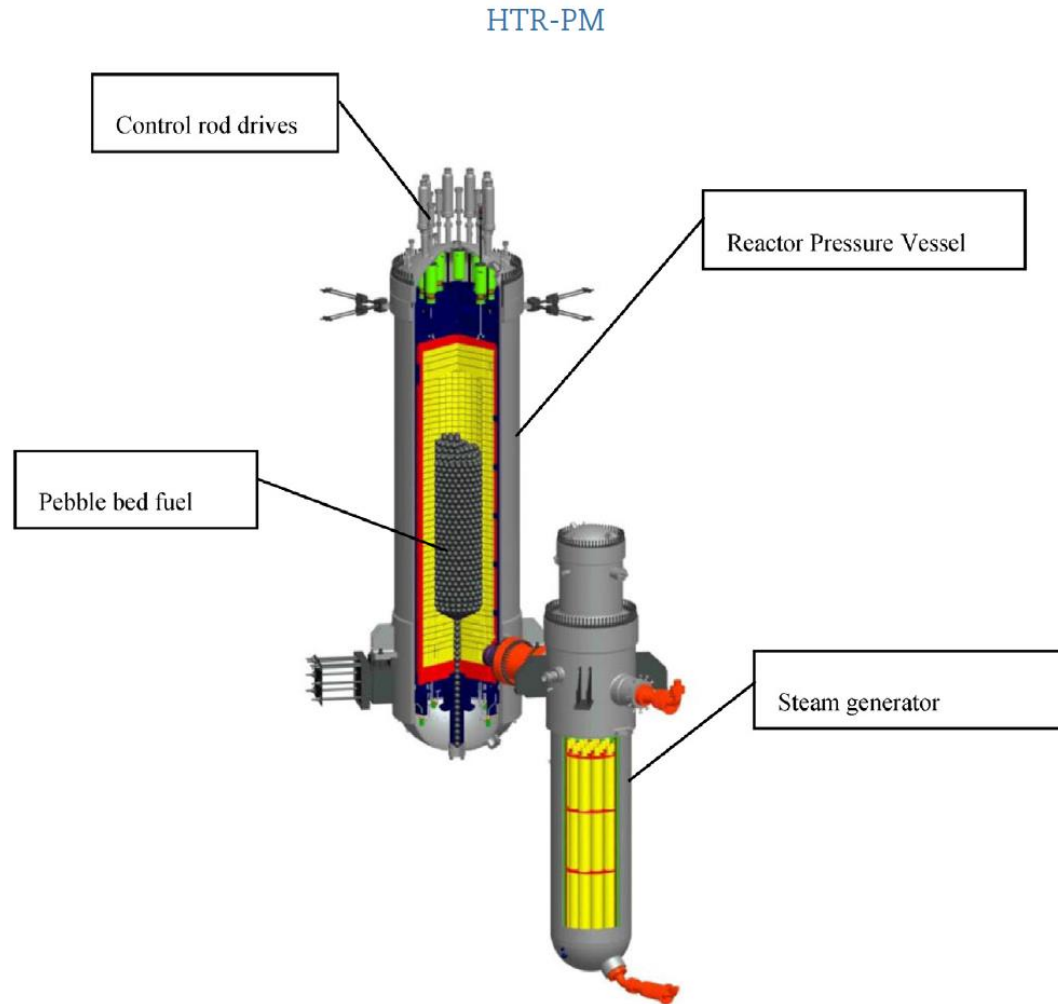


- Le Monde, 29.08.2019: la France abandonne la quatrième génération de réacteurs (ASTRID)?

## SFR - Conclusions

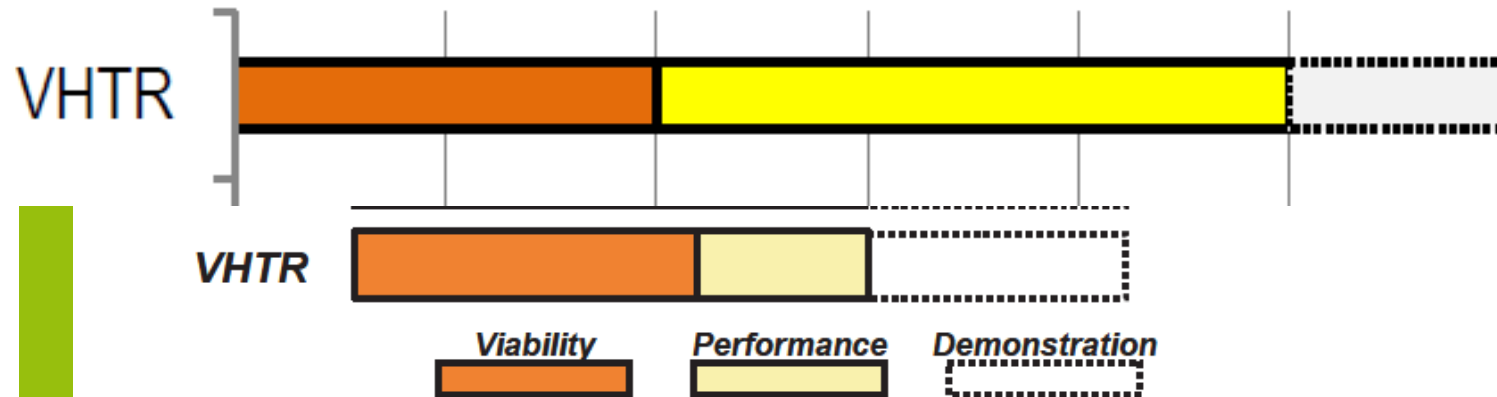
- Status: More than 20 prototype reactors and 400 years of operational experience since 70 years of R&D, still no commercially viable system
- Fuel utilization: Fundamental aspect of breeding new fissile material not needed in the foreseeable future
- Safety: Specific advantages as well as disadvantages, but safety/performance record is bad up to now
- Proliferation: Potentially significant disadvantage, as very high quality of fissile materials can be produced, but strongly depending on actual technical layout

# (Very) High Temperature Reactors – (V)HTR



# (V)HTR Timelines (2002/2014)

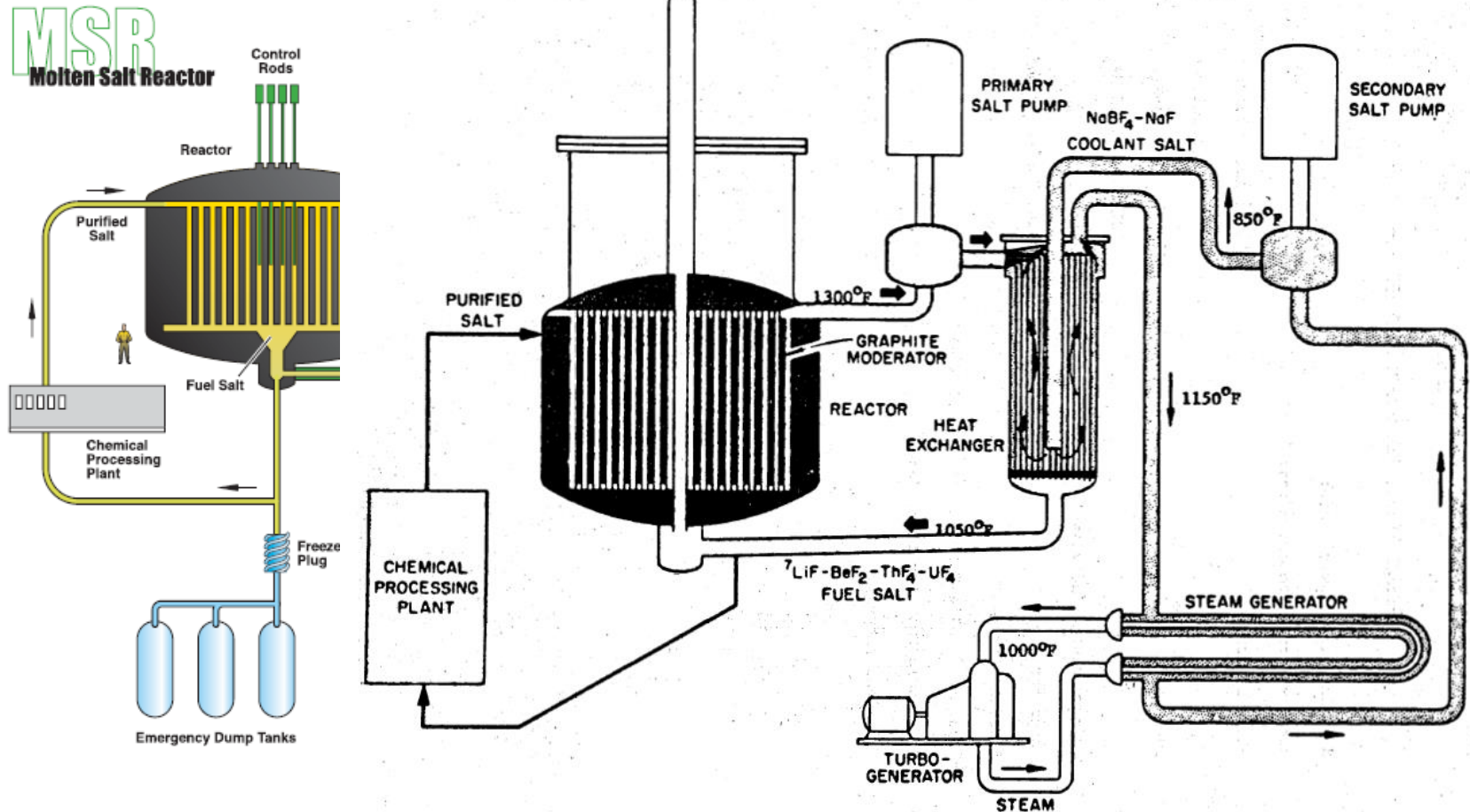
## System Development Timelines



## (V)HTR - Conclusions

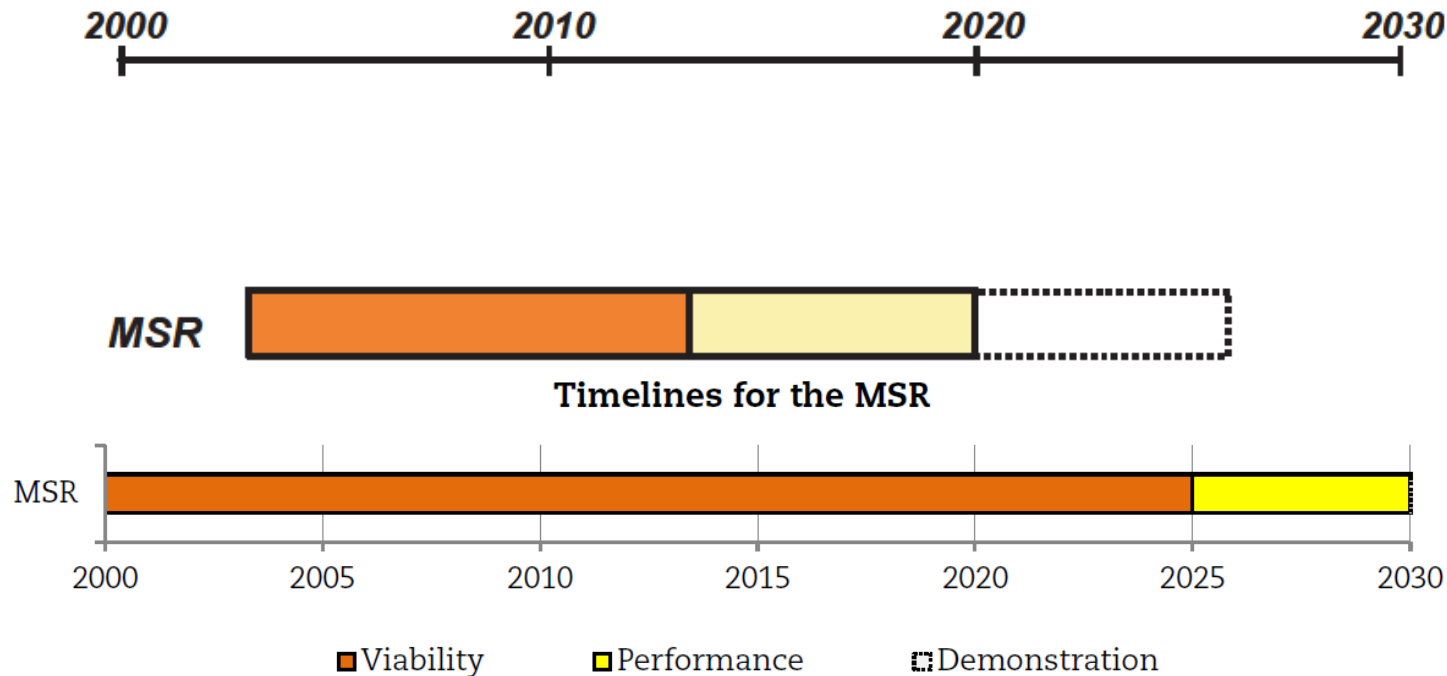
- Status: 60 years of development, several ambitious R&D programs (U.S., Germany, South Africa) have failed
- Safety:
  - Possible specific advantages with respect to loss of cooling and fuel melt, but
  - Other accident scenarios have to be considered in detail (air and water ingress, graphite fires etc.), thus no general conclusion
- Waste: Comparable waste problem, but different waste characteristics (graphite) to be considered

# Molten Salt Reactors, MSR



# MSR Timelines (2002/2014)

## System Development Timelines



## MSR - Conclusions

- Status: Considerable efforts between 1940s and 1970s, revival after 2000, commercially viable system not to be expected before 2060
- Safety: Some advantages possible, but
  - Significant technological development needed (materials, instrumentation)
  - Severe radiation protection problems even during normal operation to be solved
- Wastes: Different waste streams and other relevant nuclides (T, Cl-36, C-14)
- Proliferation: Specific issues due to necessary on-line fuel reprocessing, conceptual description changes depending on focus (with/without breeding of pure fissile material)



# 4

## Cross Cutting Topics

# Thorium as alternative resource - Conclusions

- No need for thorium as alternative resource due to sufficient uranium supply
- Assuming long term use of nuclear power:
  - In the very long term, possible need to breed fissile material:  
no significant difference between uranium-plutonium or thorium-uranium with respect to resources
- No existing infrastructure for thorium fuels world-wide
- No clear advantages for thorium fuels with respect to safety, wastes or economics
- With respect to proliferation, strong dependance on technical details of chosen fuel supply

# Partitioning and Transmutation - Conclusions

- Only P&T for transuranics in discussion today for Gen IV systems
- Remaining wastes will still require very long timescale for isolation from the biosphere
- Required volume in geologic repository mainly determined by heat output of wastes, without additional treatment of fission products no relevant reduction of heat output achievable
- Significant amounts of low- and medium-level wastes to be expected
- While fissile material amounts in final repository might be reduced, significant proliferation potential during P&T realisation (decades to centuries)

# 5

## Conclusions

# Conclusions I

- “New Reactor Concepts” are old
- Gradual enhancements, but no major breakthrough (game changer) identified
- No commercially available system at the horizon (< 2045)
- For some reactor concepts potential advantages with respect to single evaluation criteria are possible
- No concept provides substantial advantages in all of the evaluation criteria simultaneously
- Different evaluation criteria compete, advantages with respect to one may lead to disadvantages with respect to another
- A new reactor concept, providing advantages only with respect to one or a view criteria will not lead to a higher public acceptance

## Conclusions II

An academic reactor or reactor plant almost always has the following basic characteristics:

1. It is simple.
2. It is small.
3. It is cheap.
4. It is light.
5. It can be built very quickly.
6. It is very flexible in purpose ("omnibus reactor").
7. Very little development is required. It will use mostly "off-the-shelf" components.
8. The reactor is in the study phase. It is not being built now.

On the other hand, a practical reactor plant can be distinguished by the following characteristics:

1. It is being built now.
2. It is behind schedule.
3. It is requiring an immense amount of development on apparently trivial items. Corrosion, in particular, is a problem.
4. It is very expensive.
5. It takes a long time to build because of the engineering-development problems.
6. It is large.
7. It is heavy.
8. It is complicated.

Vielen Dank für Ihre Aufmerksamkeit!  
Thank you for your attention!

Haben Sie noch Fragen?  
Do you have any questions?

