Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

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

An (updated) assessment

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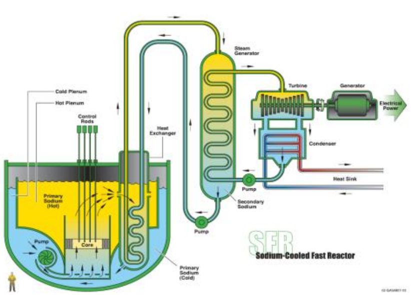
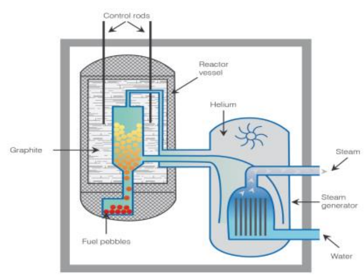
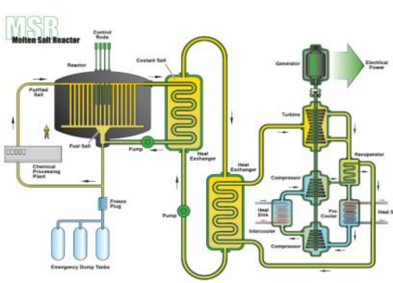
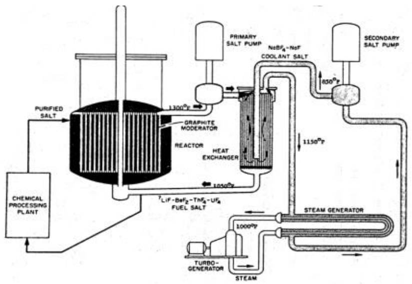
Vienna, Oktober 7, 2019









Agenda

1

Introduction

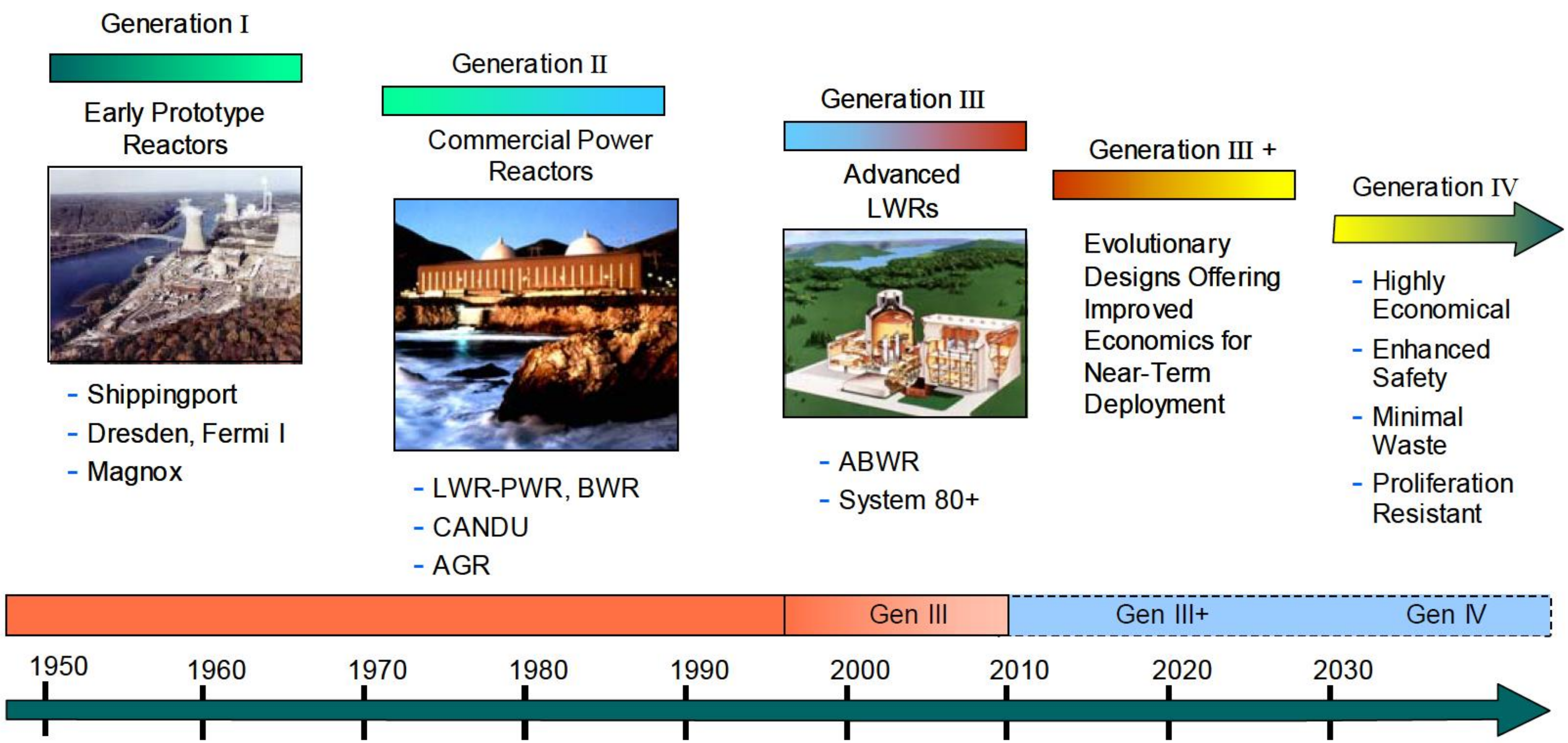
Public Promises of „New Reactor Concepts“

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
- Beause 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“



Source: GIF 2002

Who is in?

- Argentina*
- Australia *
- Brazil *
- Canada
- China
- Euratom
- France
- Japan
- Korea, Rep. of
- Russian Federation
- South Africa
- Switzerland
- United Kingdom*
- 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 14th member.

Source: Kelly 2016

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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)			●			●	●		●

Source: Kelly 2016

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 todays presentation

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Systems and Evaluation Criteria

Gen IV „New Reactor Concepts“

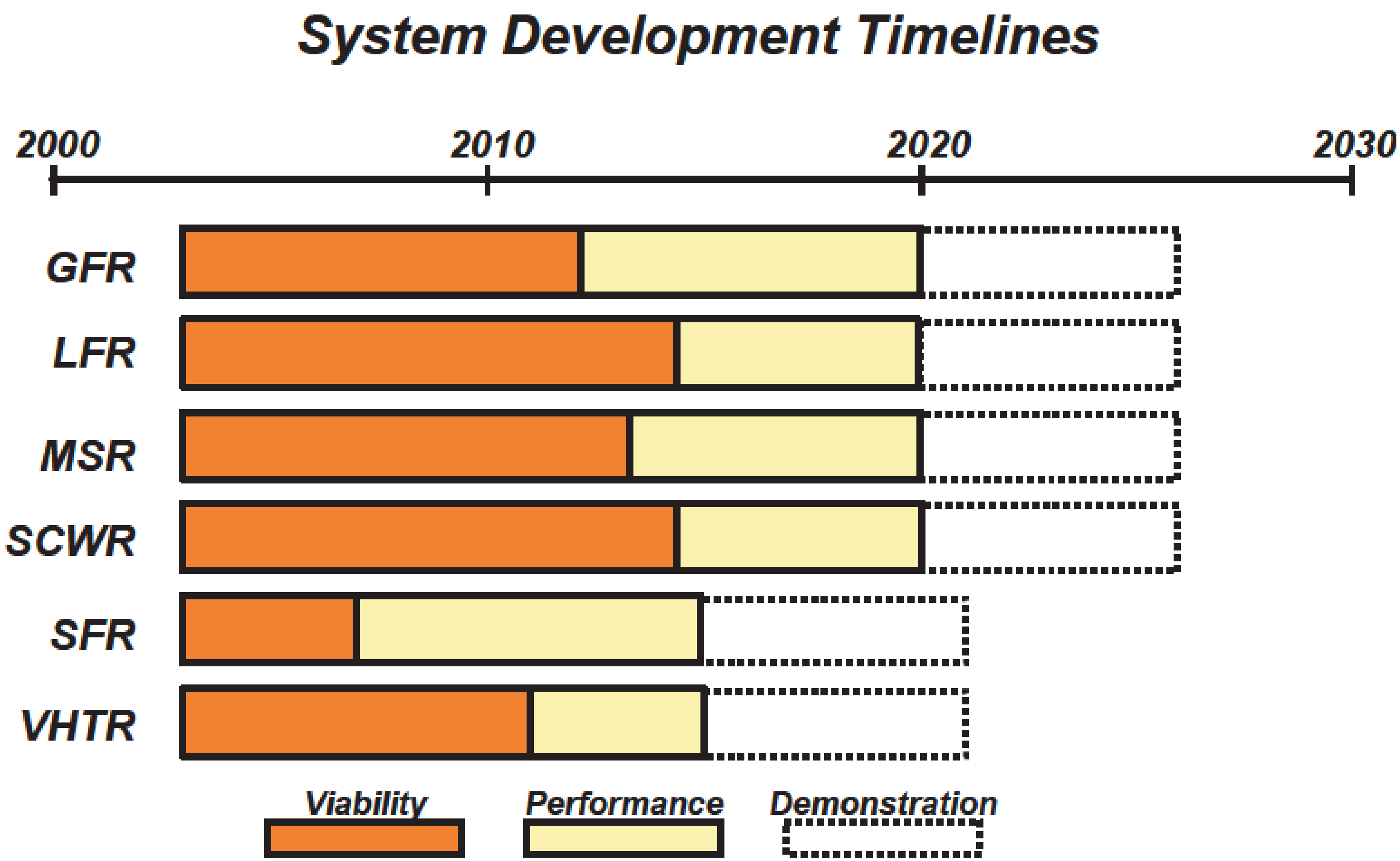
- Sodium-cooled Fast Reactor (SFR)
  - Only concept claimed to be commercially available
- (Very) High Temperature Reactor – (V)HTR
  - Currently under development espescially in China
- Gas-cooled Fast Reactor (GFR, not discussed in the following)
- Molten Salt Reactors, MSR
  - Only reactor concept 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

Source: GIF 2002

Gen IV Timelines (2002)



Source: GIF 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"

Source: GIF 2002

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).

Source: GIF 2018 (Highlighting by C. Pistner)

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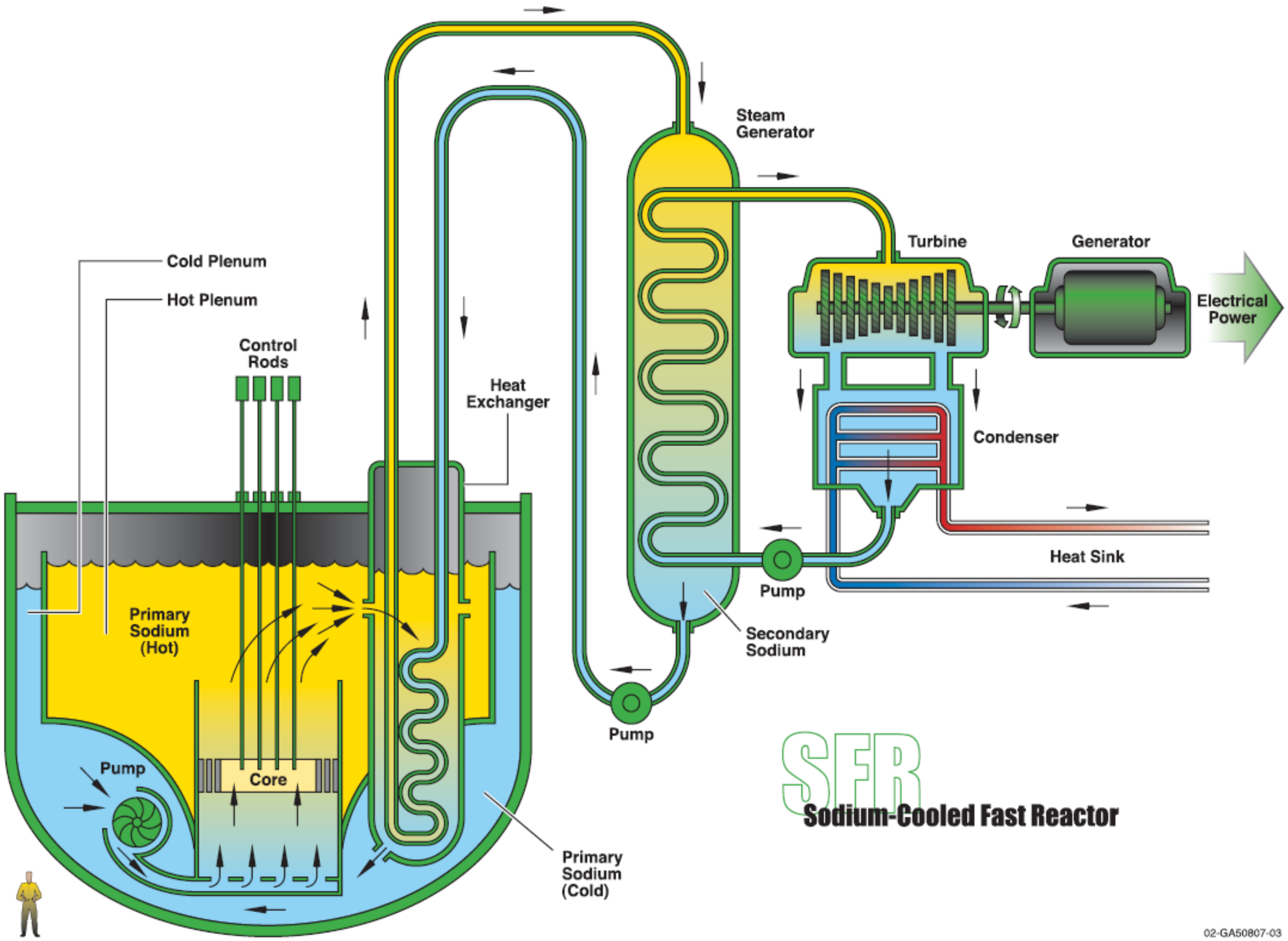
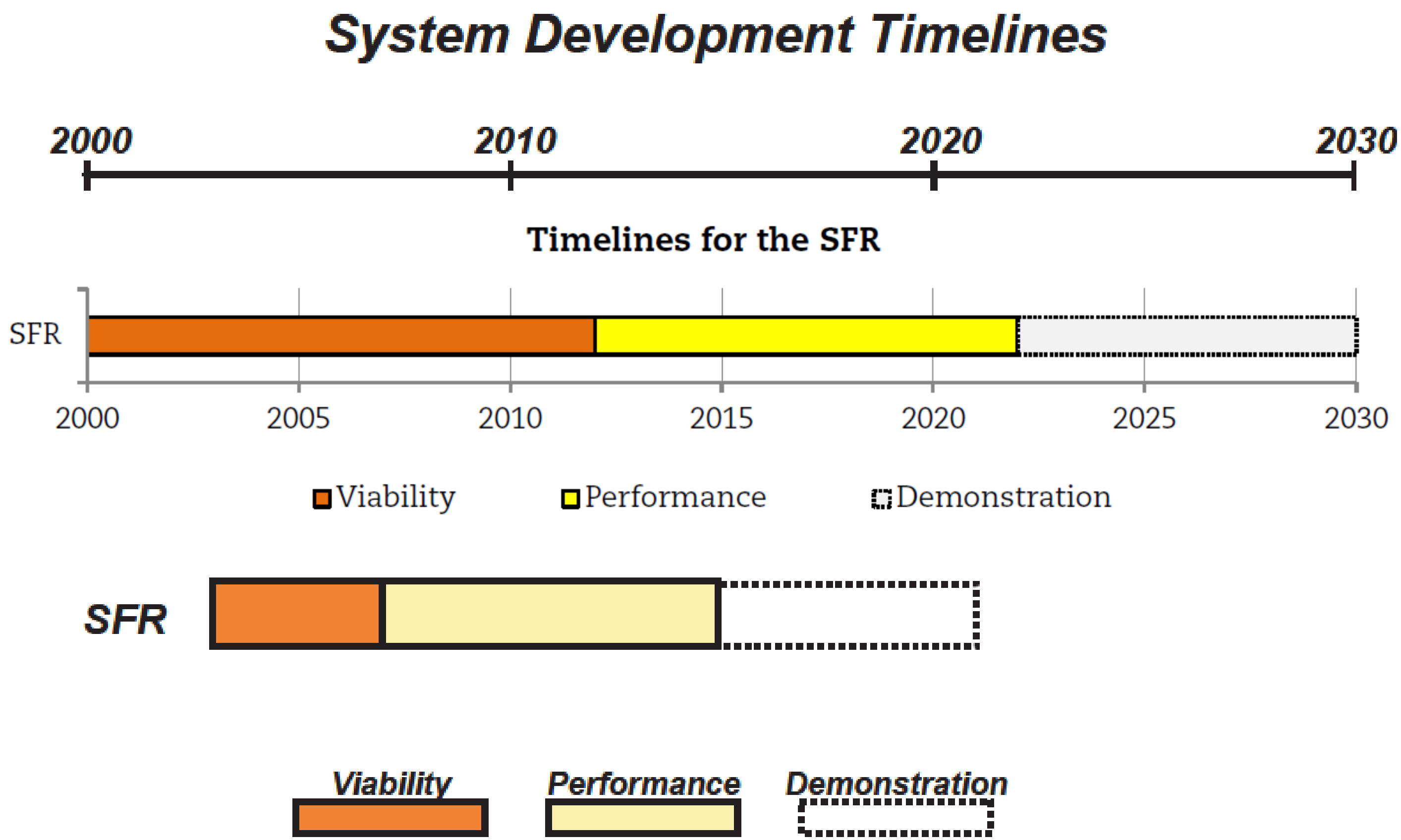
Systems Details

Sodium-cooled Fast Reactors (SFR)



Quelle: GIF 2002

SFR Timelines (2002/2014)



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

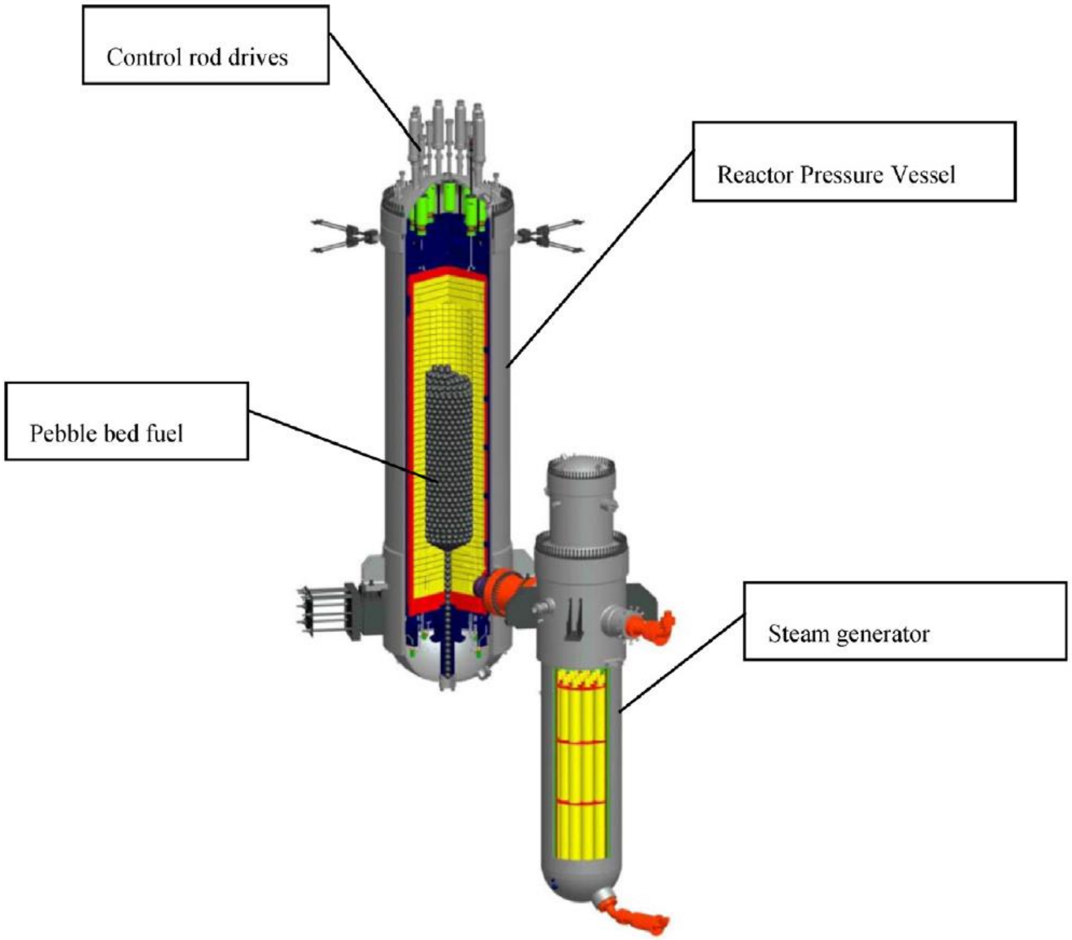
Source: GIF 2002, GIF 2014

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 forseeable 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

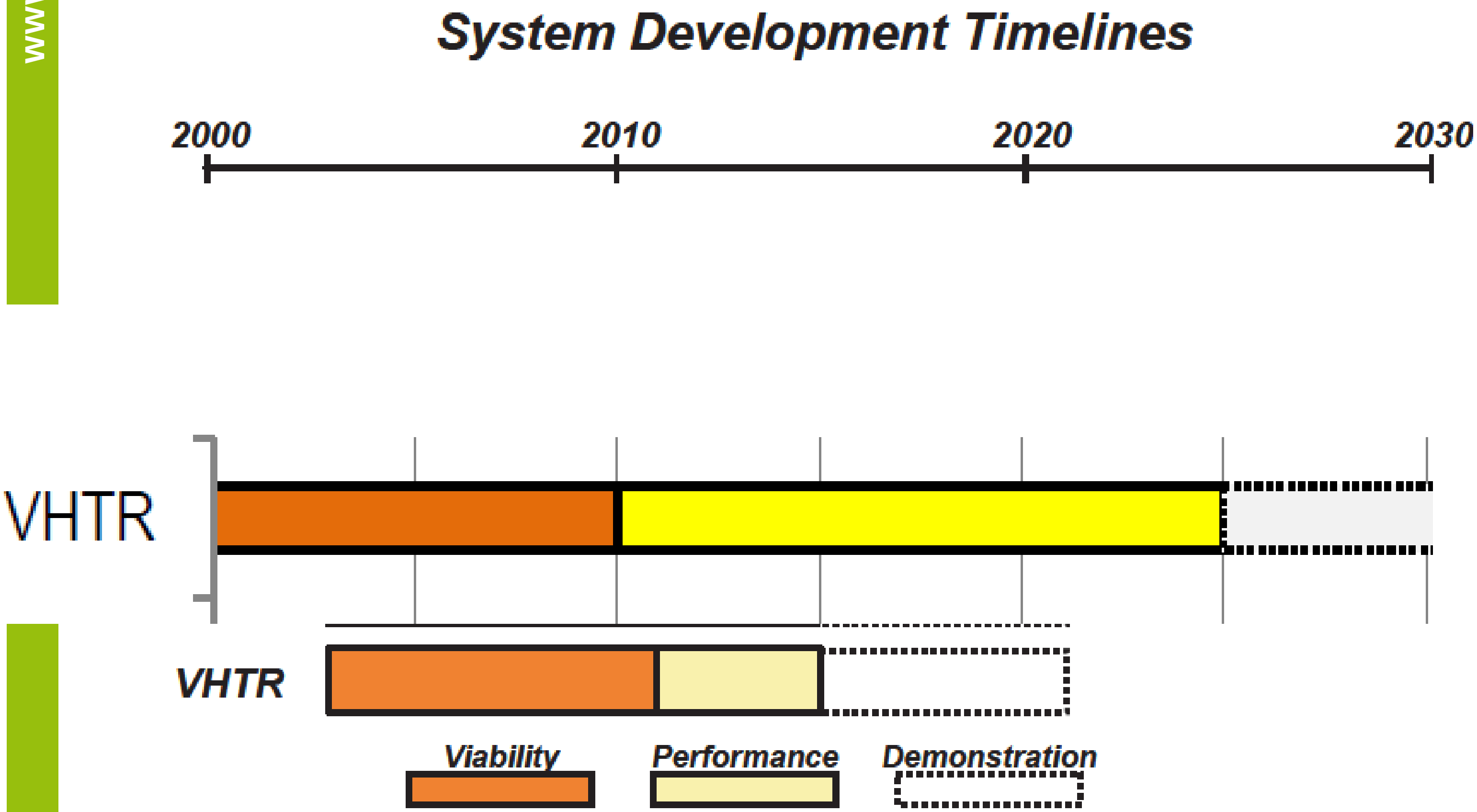
(Very) High Temperature Reactors – (V)HTR

HTR-PM



Quelle: GIF 2018

(V)HTR Timelines (2002/2014)

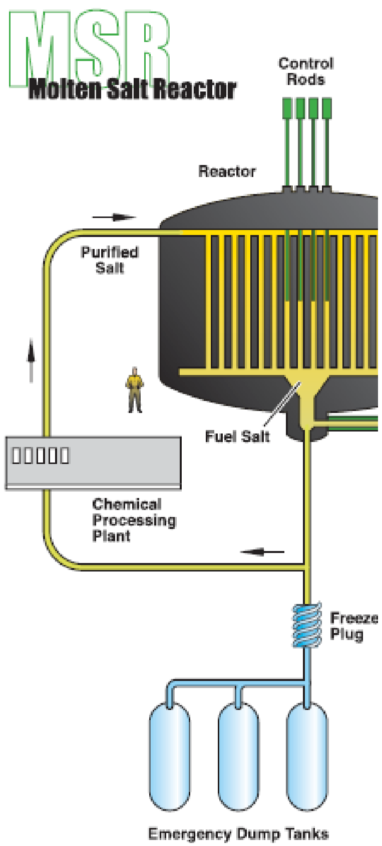


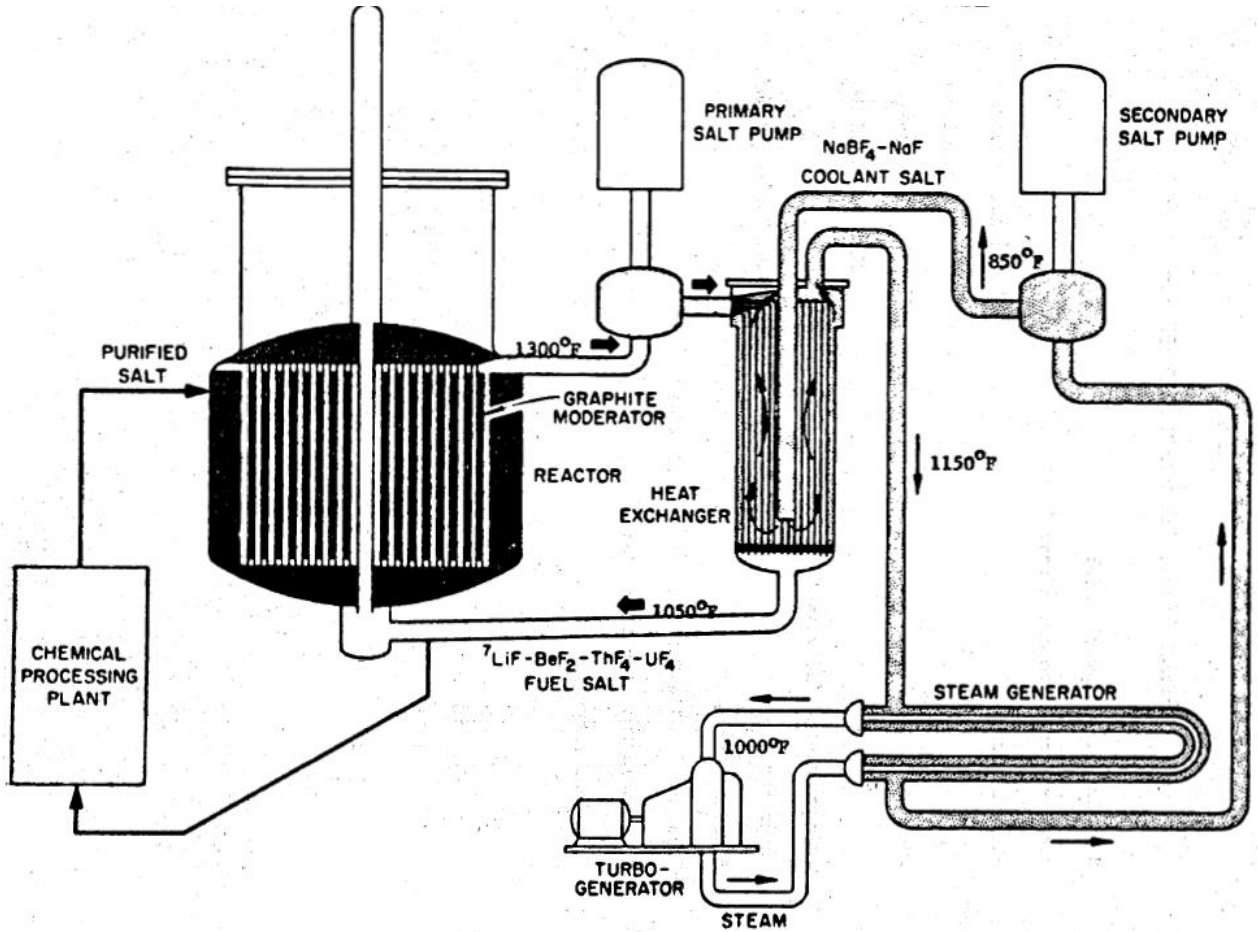
Source: GIF 2002, GIF 2014

(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

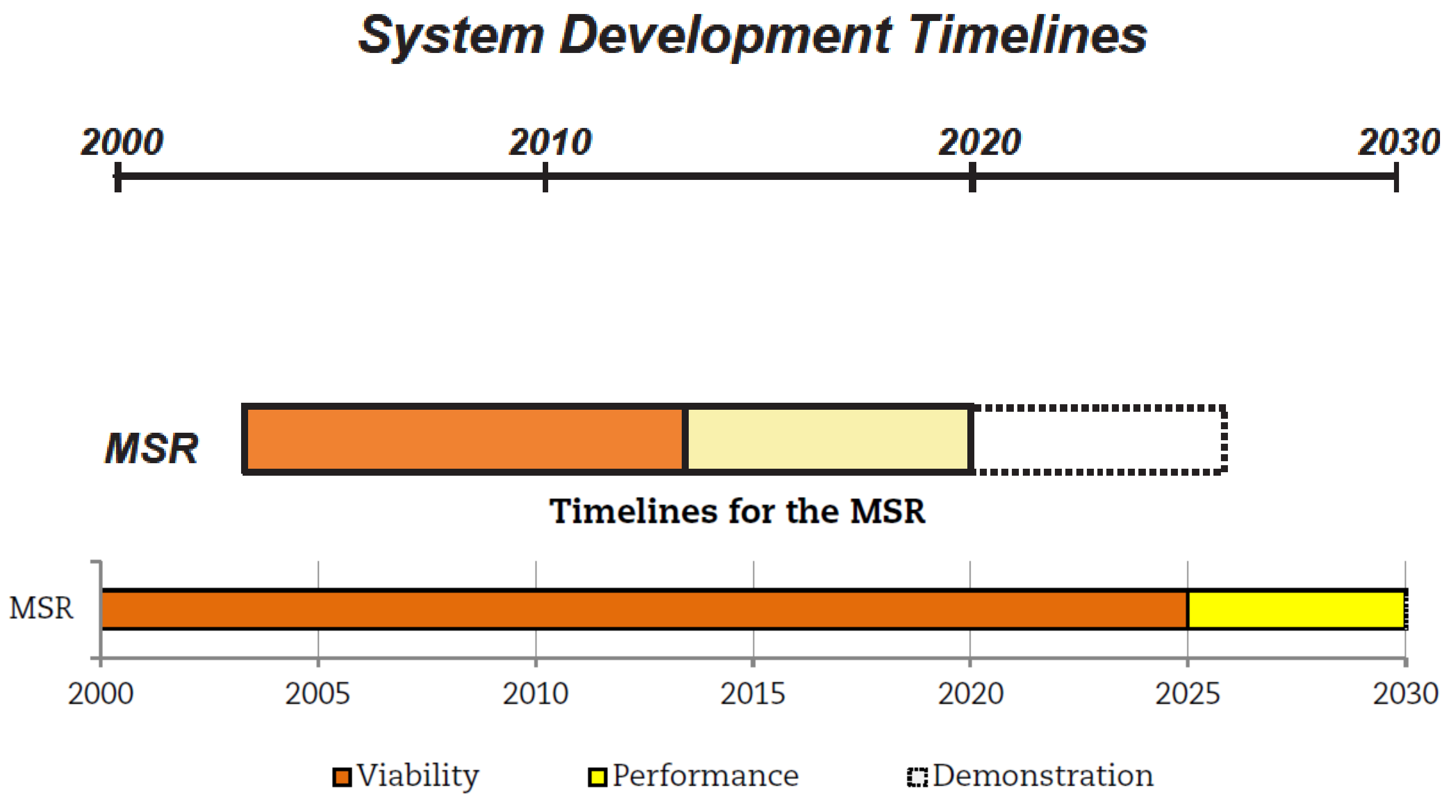
Molten Salt Reactors, MSR





Quelle: GIF 2002, AEC 1972

MSR Timelines (2002/2014)



Source: GIF 2002, GIF 2014

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 - Conlusions

- 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 - Conlusions

- 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)

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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.

Quelle: Hyman Rickover, Journal of Reactor Science and Technology Vol III, No. 3 , June 1953

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

Haben Sie noch Fragen?
Do you have any questions?