FUELS FROM SOLAR THERMOCHEMICAL CYCLES

High efficiency solar fuel production via solar thermochemical cycles with sophisticated process management

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DLR

Motivation

DLR

Climate change is a big deal;
It‘s man made;
And we can do something about it.

Mike Berners-Lee, HOW BAD ARE BANANAS?, Profile Books Ltd, 2010.

‚something‘
= a million things need to be done!

Sustainable fuels for air-born, long-distance, and heavy-duty transportation

Fuels from
Solar **Thermochemical Cycles**

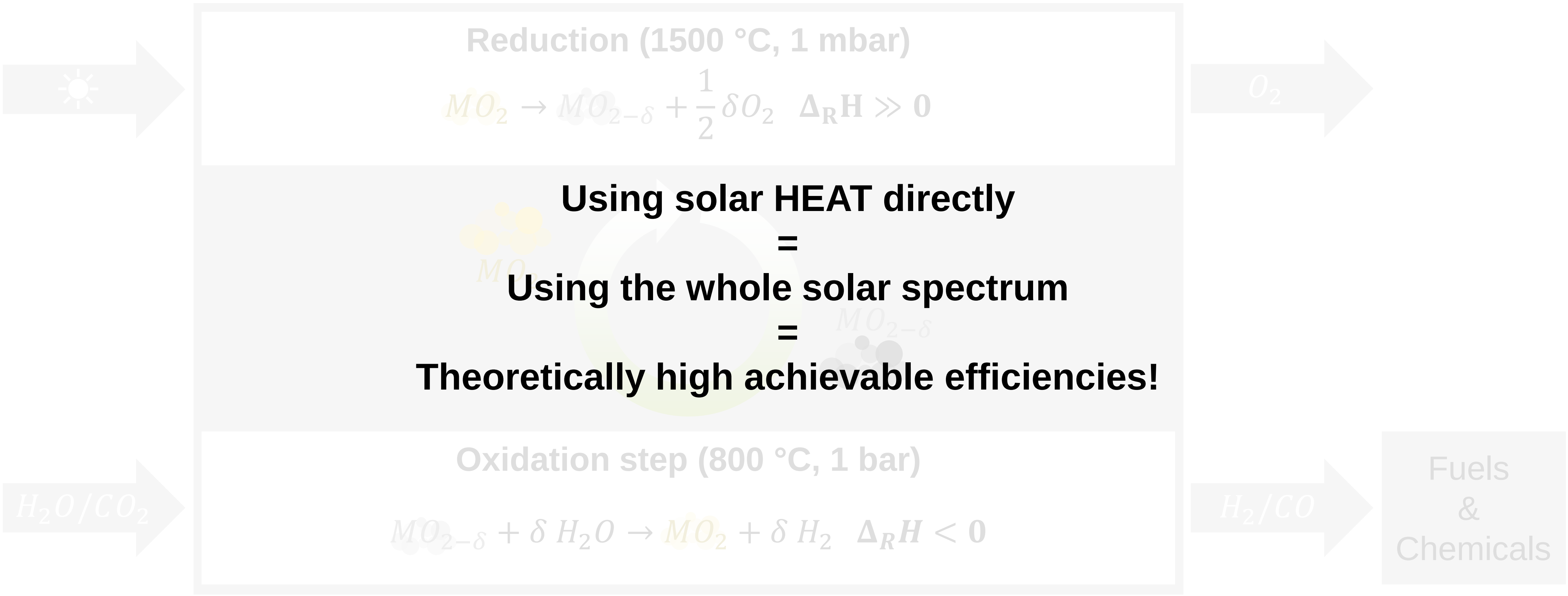
Questions I‘ll try to answer in 10,5 min

1) How can fuels be produced in **solar thermochemical cycles**?
2) What are **bottlenecks** in solar thermochemical fuel production?
3) How does our **strategy** look like?

INTRODUCTION

Bildquelle hier angeben

Introduction: solar thermochemical cycles



Using solar HEAT directly

=

Using the whole solar spectrum

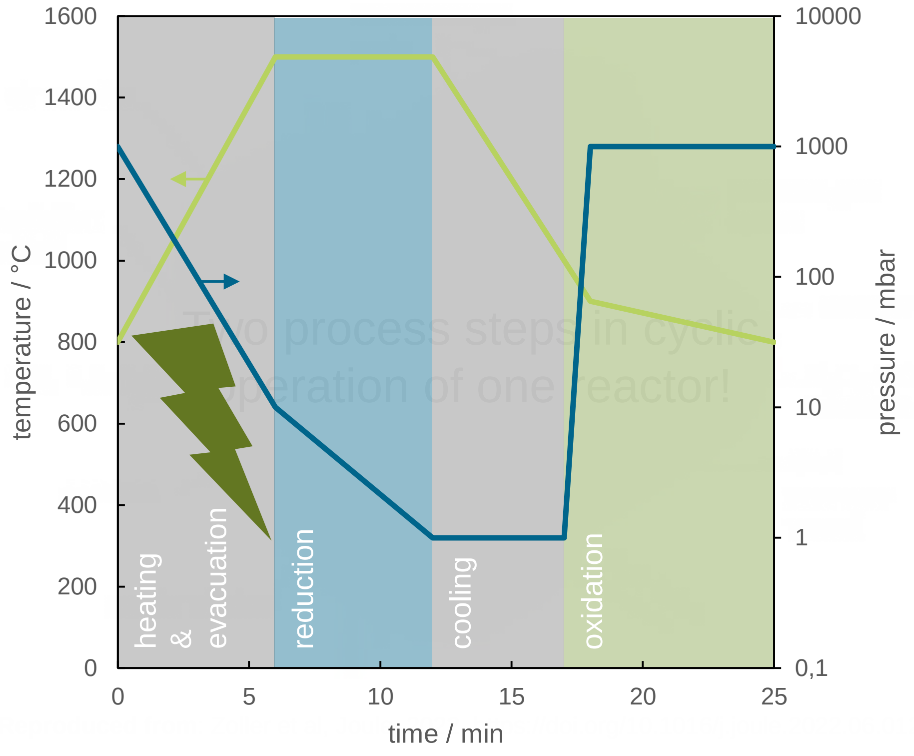
=

Theoretically high achievable efficiencies!

Introduction: state-of-the-art

SUN-to-LIQUID (EU Horizon 2020)

- Bauhaus Luftfahrt, ETHZ, DLR, IMDEA, HYGEAR, ABENGOA, and ARTTIC
- In-field demonstration at **50 kW** with 18 kg of CeO_2
- **4.1 %** solar-to-syngas energy efficiency



High sensible heat losses due to thermal cycling**:**
(1) of reactor components!
(2) of CeO_2 (low reduction extend, only 3 kg O_2 per 1000 kg CeO_2)!

Introduction: ways for optimization

Two general pathways:

1) **Material scientist‘s pathway**: redox material for low-temperature operation and with higher difference in reduction extend

2) **Engineer‘s pathway**: Sophisticated process design with main focus on heat integration and the control of radiation transport

DLR APPROACH - R2MX

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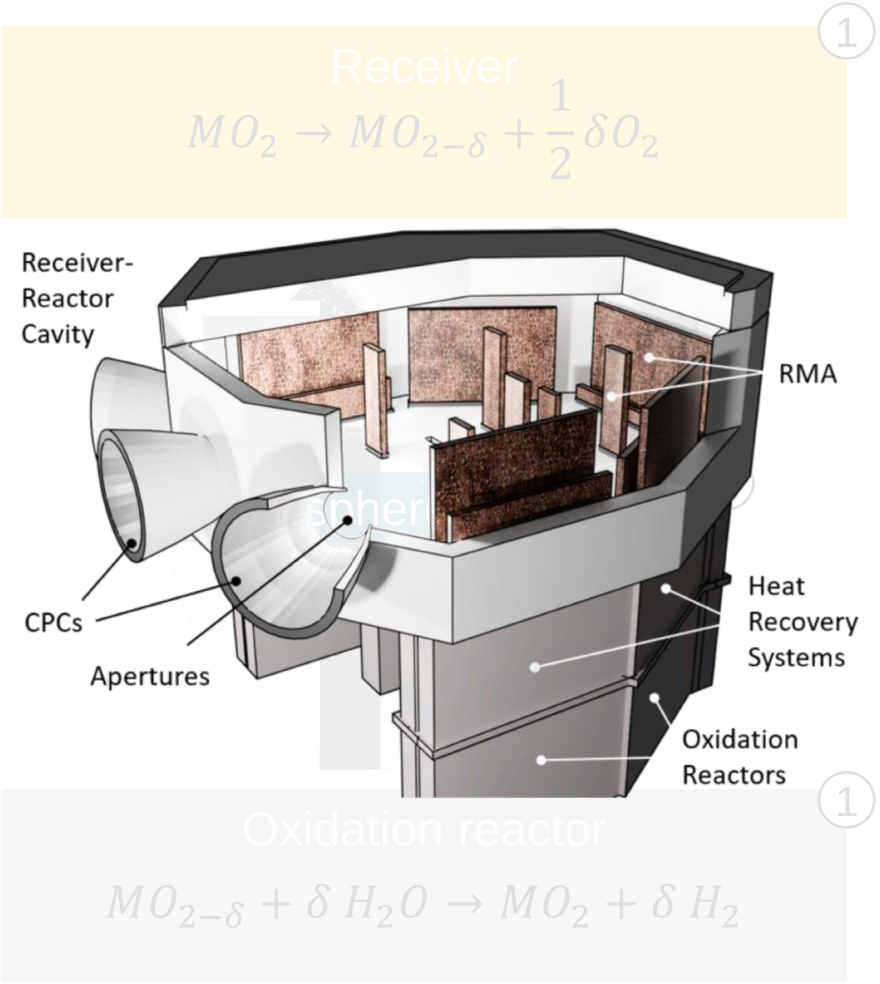
Paul Kant, FF-SVE, 2023-06-13

R2Mx: Concept

Published: Brendelberger et al, Solar Energy, 2022, https://doi.org/10.1016/j.solener.2022.02.013.

1) Separating reduction and oxidation step in two reactors
2) Separating the atmospheres
3) Employing a transport system
4) Implementing heat integration strategies

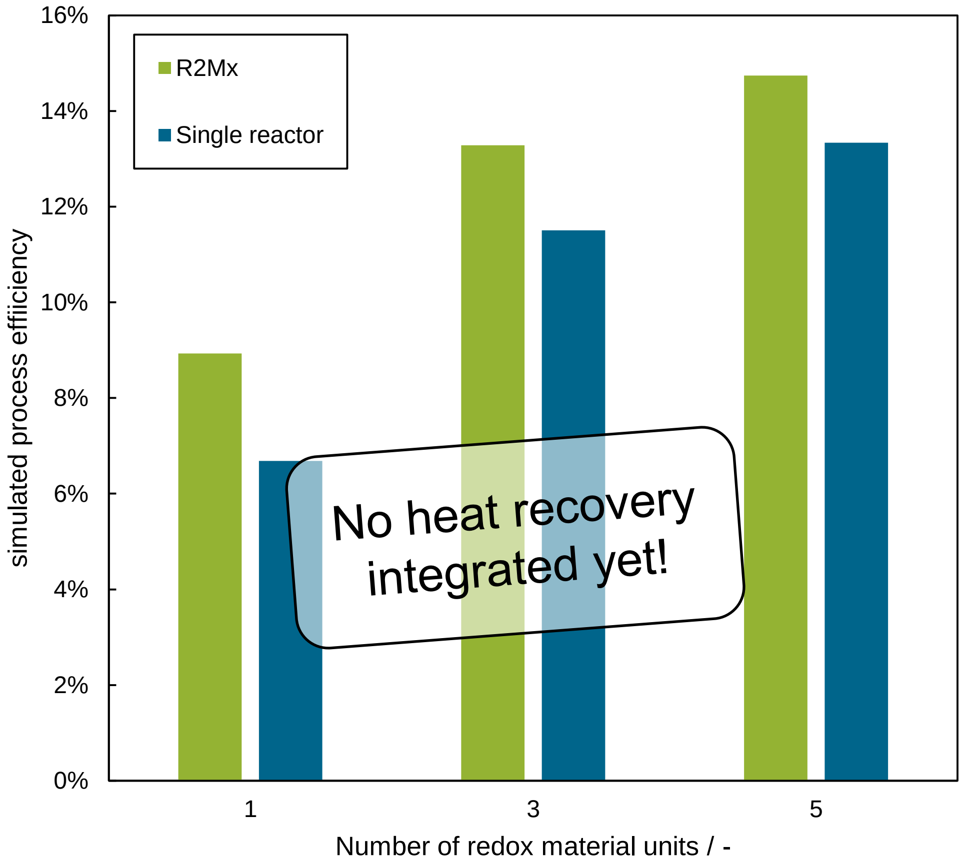


Adopted from: https://doi.org/10.1016/j.solener.2022.02.013.

R2Mx: Advantages

Reduced sensible heat losses due to:

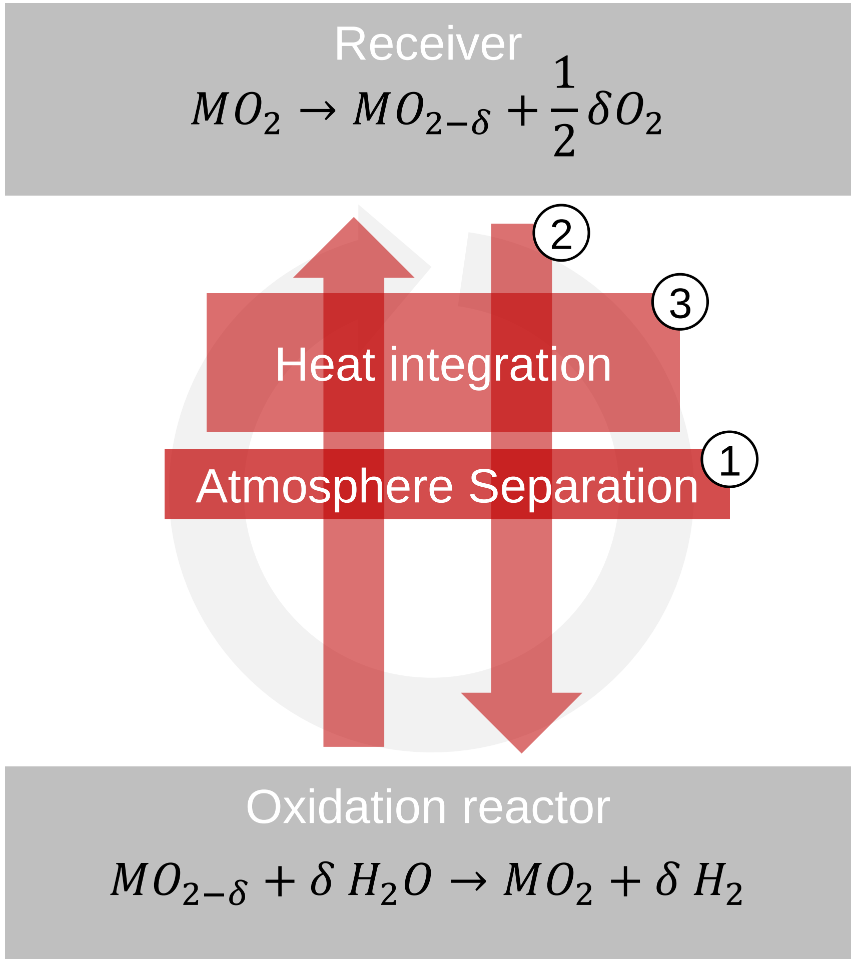
- Continuous operation (reactor components)
- Heat integration (redox material)



Adopted from: https://doi.org/10.1016/j.solener.2022.02.013.

R2Mx: Challenges

1) Need for gas-tight reactor separation
2) Transport of redox material (T~1500 °C!)
3) Reoxidation of redox material during solid-solid heat integration



SUMMARY & OUTLOOK

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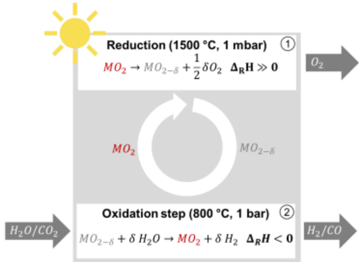
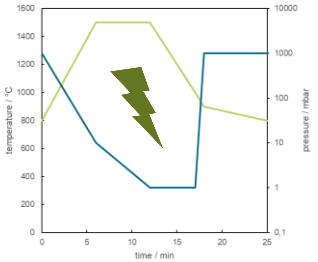
Summary: Questions I tried to answer

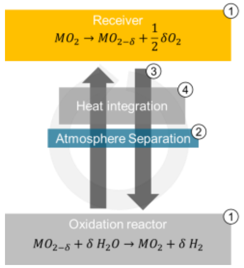
1) How can fuels be produced in solar thermochemical cycles?



2) What are bottlenecks in solar thermochemical fuel production?



3) How does our strategy look like?



Outlook: How we attack the challenge

Two projects focussing on the R2Mx technology:

1) **KISMOR**: Technology demonstration with electrical heating (6 kW)
2) **REDOX3D**: Demo with solar interface, redox material development, scale up, & operation strategies (10 kW)

Thank you for your attention!

Feel free to ask any questions!

Impressum

Topic: **High efficiency solar fuel production via solar thermochemical cycles with sophisticated process management**

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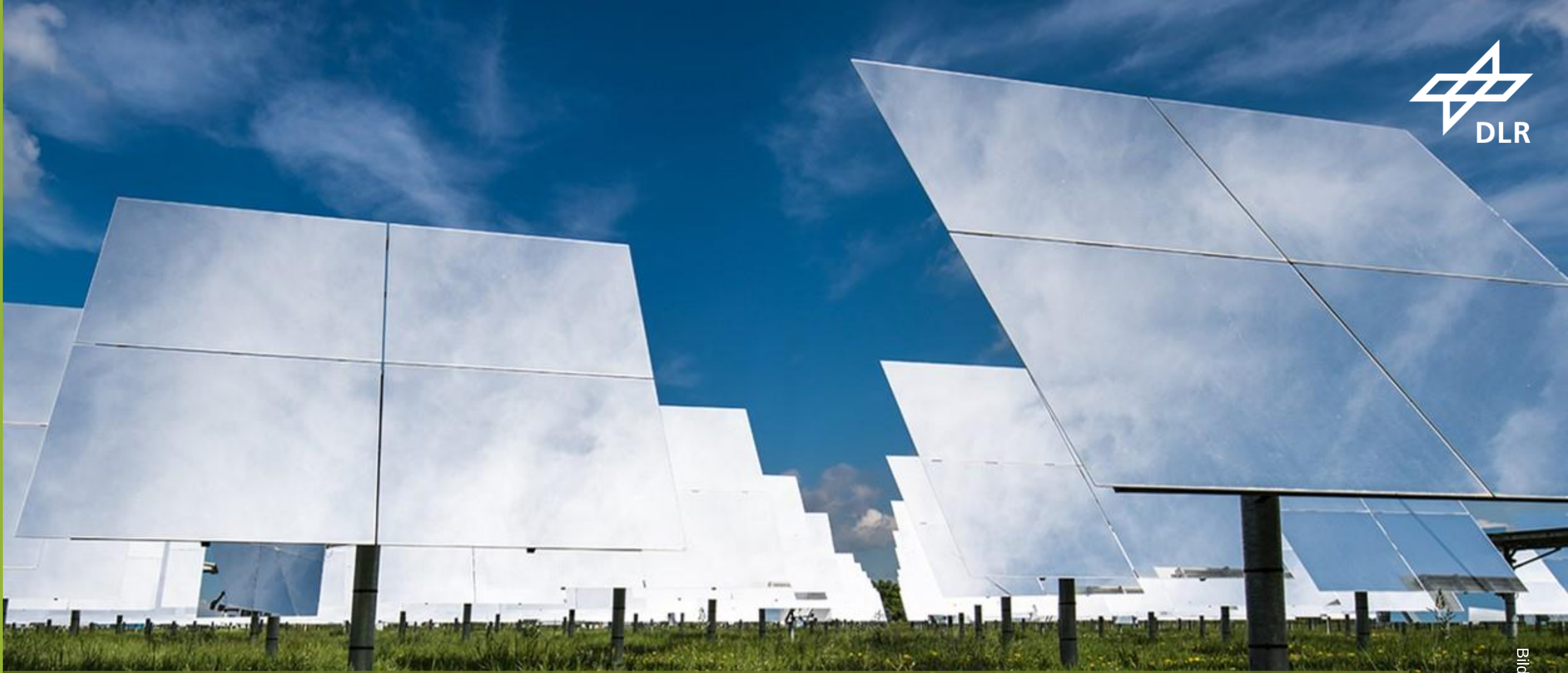
Institute: Institute for Future Fuels



BACKUP SLIDES

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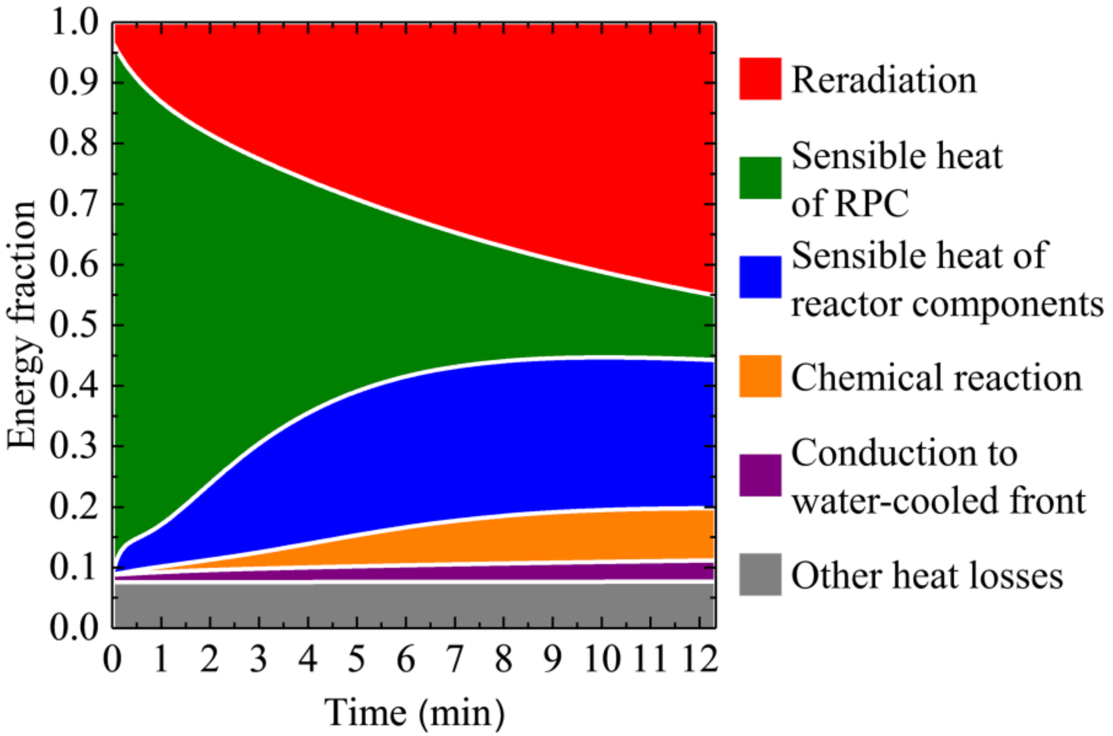
Introduction: challenges

‚Low‘ achieved overall efficiency:

1) Sensible heat losses due to heating/cooling of reactor components
2) Extreme temperatures → reradiation losses
3) Low achieveable reduction extend of CeO_2 (1 ton of CeO_2 releases only 3 kg of oxygen!) → sensible heat losses due to heating/cooling of redox material



Extracted from: https://doi.org/10.1115/1.4042059

R2Mx: What we have done so far

1) Concept developent and basic simulative work (Stefan Brendelberger)
2) PhD project on the development of sealing strategies (Estefanía Vega Puga)
3) PhD project focusing on the examination of reoxidation during solid-solid heat recovery (Philipp Holzemer-Zerhusen)
4) Project KISMOR: Technology demonstration → Construction phase completed
5) Project REDOX3D: Material development, scale up, & operation strategies → initial project phase