



# A web-based simulator for understanding metallurgical furnaces

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APRIL 18, 2023

## Background: The project

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# SAFECI

## Electrical Conditions in SAFs—Identification and Improvement

Collaborative and knowledge-building project / EnergiX

### Research partners

NORCE

NTNU Dept. Mat. Sci.

NTNU Dept. Eng. Cyb.

### Project period

4.5 years (July 2021–December 2025)

### Budget

MNOK

### Industry partners

Elkem

Eramet

Finnfjord

Wacker

RCN 14.0

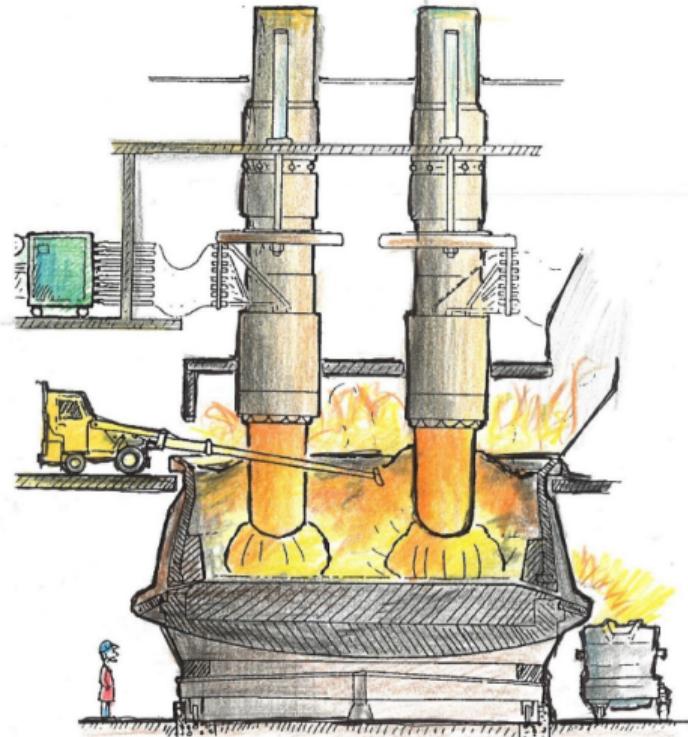
Industry 3.6

NTNU 1.5

Total 19.1



# The submerged-arc furnace



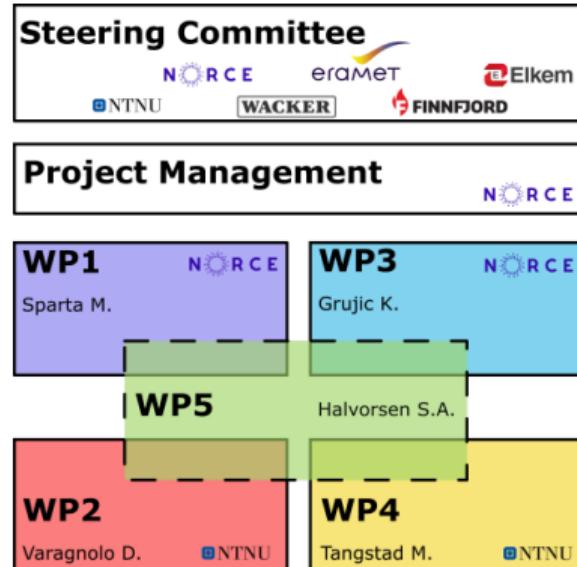
Improved electrical conditions give

- More stable operation
- Improved energy distribution
- Improved efficiency  
(reduced kWh/ton)
- Energy savings



# Project structure

- WP1** Physics-based modeling
- WP2** Data-driven modeling
- WP3** Experimental measurements
- WP4** Metallurgical interpretation
- WP5** Coordination, dissemination, and industrial exploitation



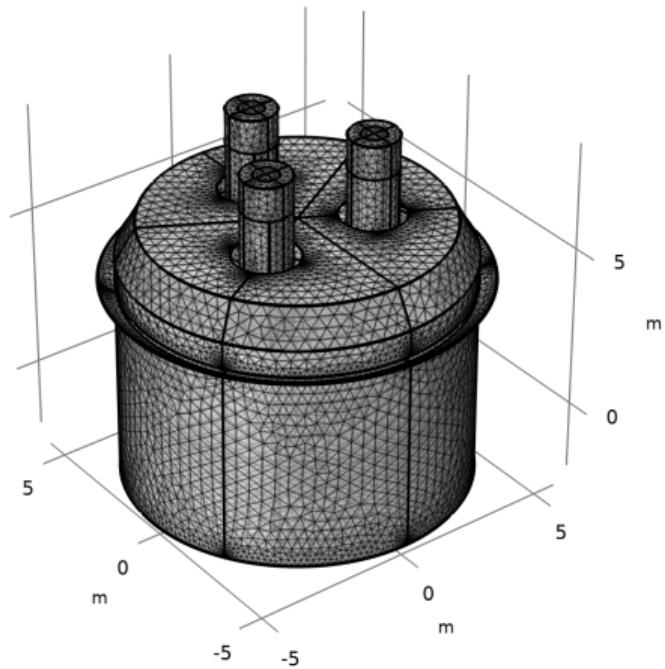
## **Finite-element models**

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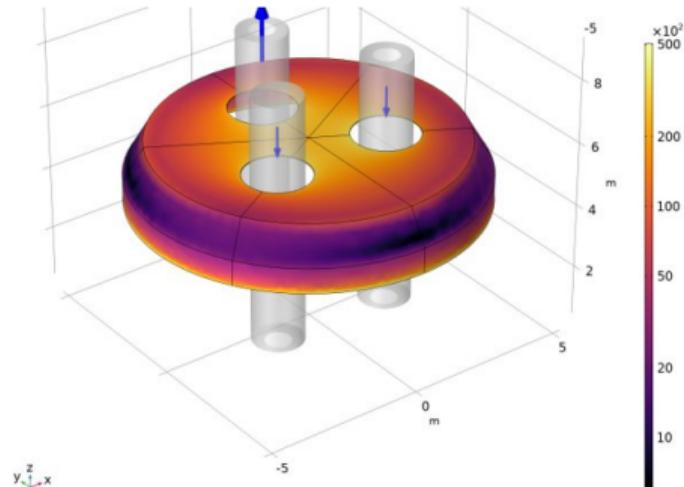
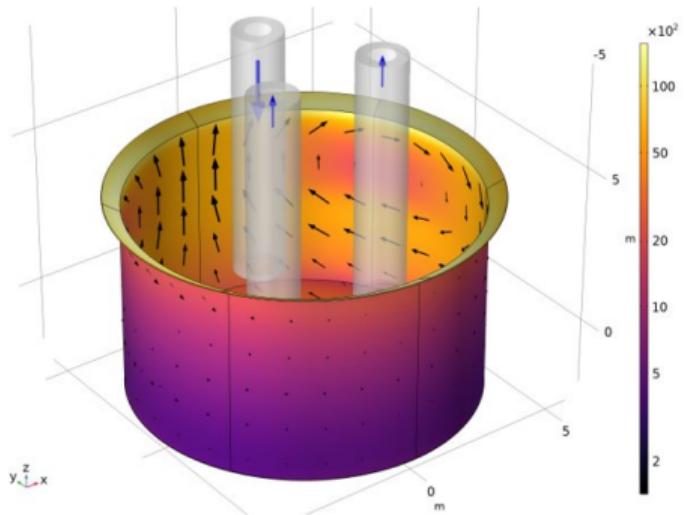
# What is a finite-element model?

- The finite-element method solves PDEs in complex geometries
- We solve Maxwell's equations for the furnace
- Computationally demanding
- Multitude of useful results



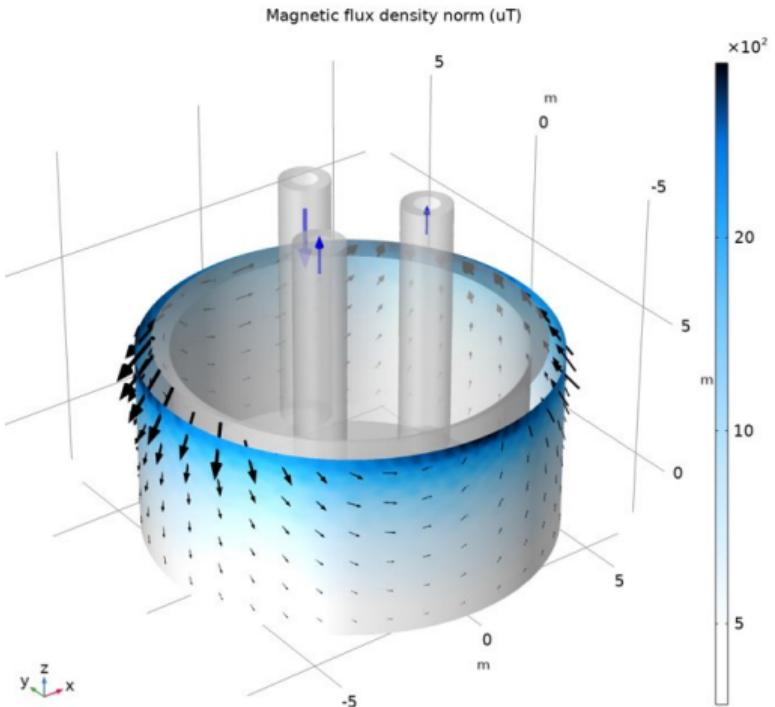


# Example results: Shell currents





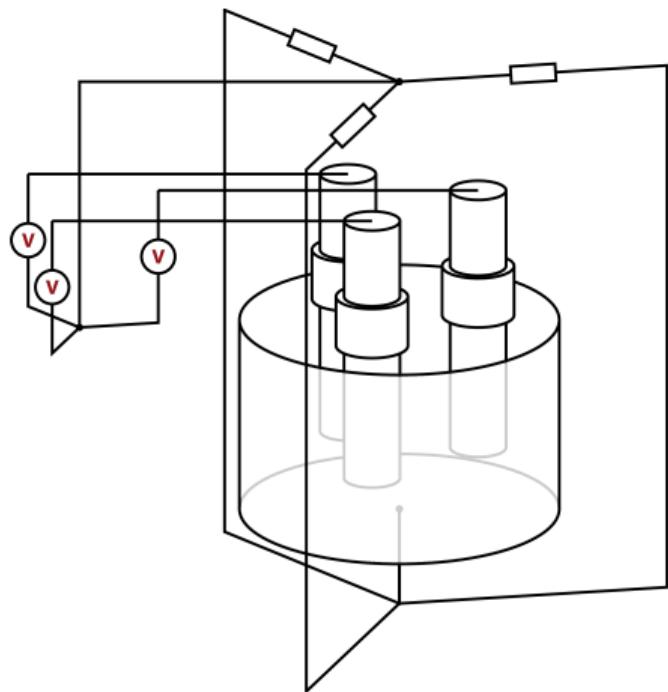
# Example results: Magnetic field





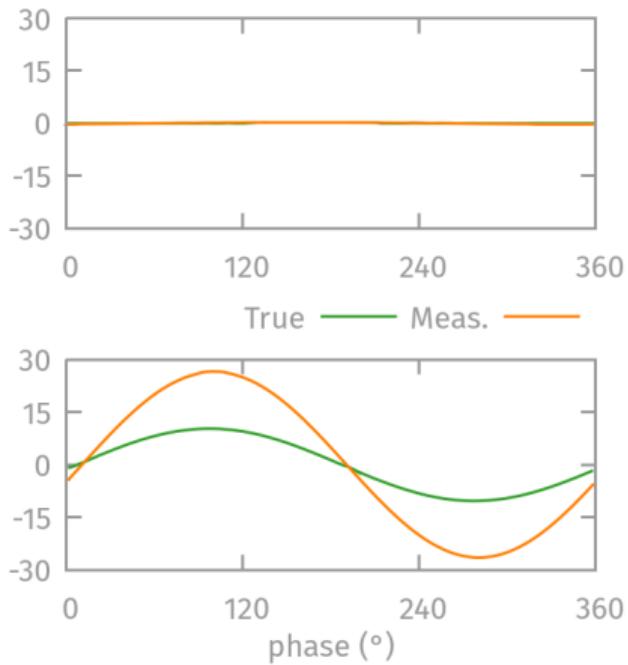
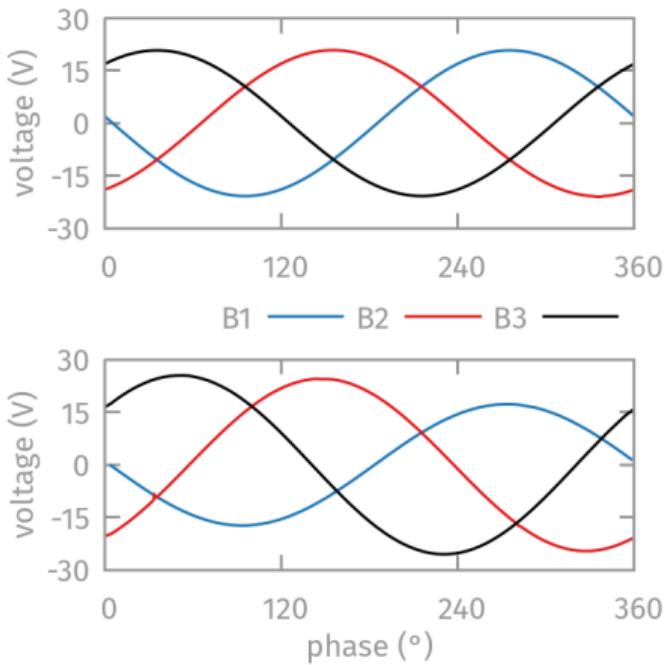
## Example results: Bøckmann I

- Large magnetic field → large induction effects
- Voltage measurement made using symmetrical leads
- Induced voltages cancel out





## Example results: Bøckmann II



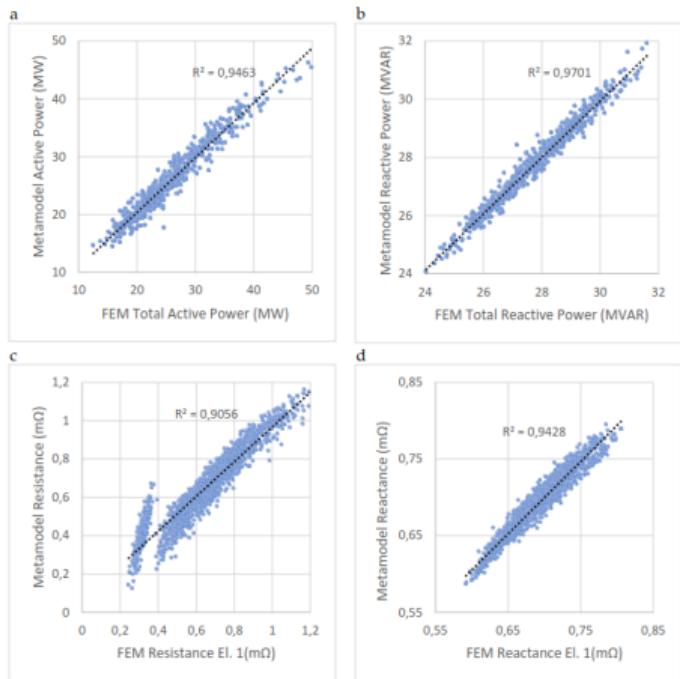
## Metamodels

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# What is a metamodel?

- Surrogate model for the FEM model
- Obtained using statistics and calculation database
- Same generalization capabilities
- Computationally lightweight
- Predicts output of FEM





# Web interface





# Where can I learn more?

<https://safeci.web.norce.cloud/>

Sparta, M., M. Fromreide, V.K. Risinggård, and S.A. Halvorsen, “Electrical conditions in submerged arc furnaces: A web-based simulator,” *SSRN Electronic Journal* (2022), <https://doi.org/hxqn>.

Sparta, M., D. Varagnolo, H. Martens, and S.A. Halvorsen, “Metamodeling of the electrical conditions in submerged arc furnaces,” *SSRN Electronic Journal* (2021), <https://doi.org/gm5kpb>.

Sparta, M., D. Varagnolo, K. Stråbø, et al., “Metamodeling of the electrical conditions in submerged-arc furnaces,” *Metallurgical and Materials Transactions B* (2021), <https://doi.org/gjssf6>.



# What's next?

- Inverse metamodel: Predict input of FEM for given output
- Identify inner state of SAF using external measurements
- Additional measurements needed:  
magnetic field, phase-resolved currents/voltages, ...
- Integrate with control system



Takk for oss. Danke. Ευχαριστώ. Dziękuje  
Merci. Gracias. Obrigado. Спасибі. Kiitos.