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Partial capture from refineries through utilization of existing site energy systems

Presenter

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Preem CCS – CLIMIT Demo project

SINTEF
preem
equinor
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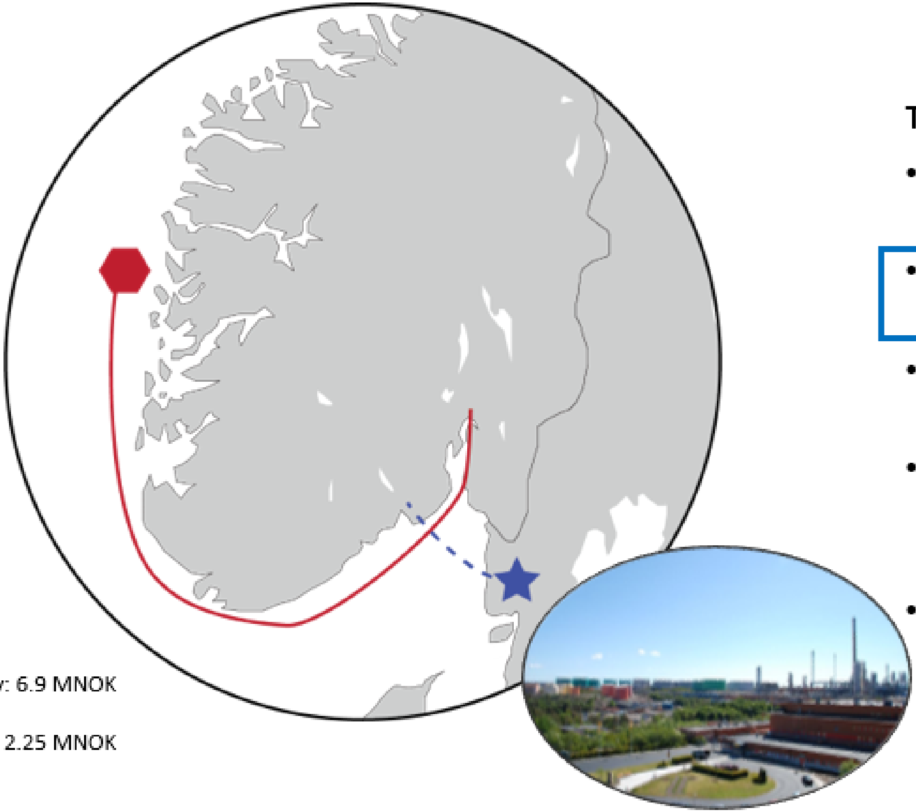
Aker Carbon Capture
CLIMIT
Swedish Energy Agency



Budget: 28 MNOK

- Gassnova: 9.5 MNOK
- Swedish Enegy Agency: 6.9 MNOK
- Preem: 8.9 MNOK
- In-kind from partners: 2.25 MNOK

Project period: 2019-2021

The project activities will focus on:

- On-site demonstration of CO_2 capture from H_2 production unit
- Excess heat utilization with compact heat exchanger design
- Value chain analysis and integration into the Norwegian full-scale CCS project
- Identifying actions to overcome regulatory barriers for transborder ship transport and storage of CO_2
- Establish a roadmap for CO_2 emission reduction pathways at Preem in the context of Swedish national targets (net zero-carbon emissions in 2045)

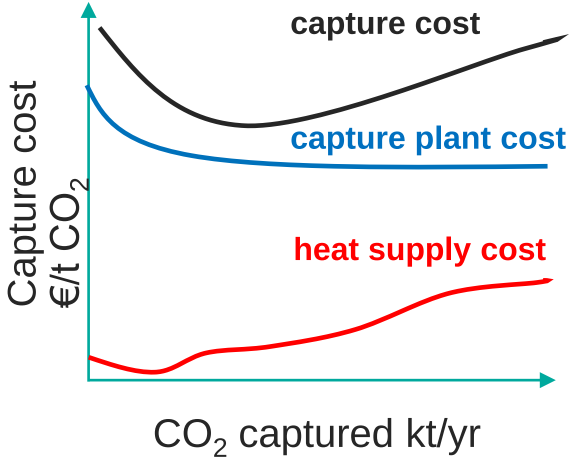
Courtesy of SINTEF

What I will talk about today

Aim:

- Identify & quantify the mix of available heat sources for CCS that give lowest total cost (incl. CAPEX) or lowest external energy consumption, considering:
  - Existing site energy system
  - Variations of available residual heat over time
  - Within context of the energy system

- Evaluate how cost and emissions of heat supply for CCS vary with the amount of CO_2 captured at the site (“partial vs full capture”) and determine their impact on capture cost



Key take aways:

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- Residual heat and unused capacity of existing site energy system are significant and can reduce capture cost by up to 50%.
- Variations in heat supply are important and need to be managed.
- Developed method: Heat supply cost curves can give input for planning a CO_2 reduction roadmap from partial capture to full capture at industrial sites

Method & assumptions

Method: Analysis of heat supply options for CCS at an industrial facility

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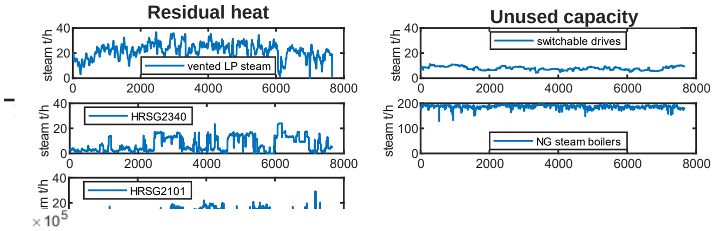
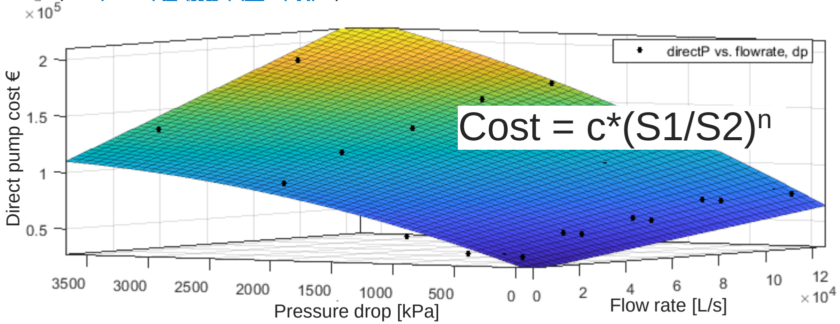
Class of heat supply	Examples of heat supplying technology	Character
I. Residual heat	Vented steam;	Intermittent





1. Identification and classification of heat sources at site level

2. Quantification of usable heat including time dependent variations (e.g. hourly scale).

3. Estimation of costs and emissions per heat source.

4. Optimization of the heat source utilization with minimum cost or emissions impact.

Steps 2-4 are automated in a model called

Heat supply cost model (HSCM)

Multi-period Mixed Integer Linear Program (MILP)
→ To include variations in availability

Objective: $\min_x TAC(x) = CAPEX_a(x) + OPEX(x)$.

$CAPEX_a(x)$, $OPEX(x)$ } Linear model: $m * x + b * y$ ← Binary variable

Method: Identification & classification of heat sources

Class of heat supply	Examples of heat supplying technology	Character
I. Residual heat	Vented steam;	Intermittent
+/- investments may be required	Heat recovery steam generators;	Intermittent
+ no/little external energy	Heat collection network (steam raising); option to include mech. vapor recompression (MVR);	~Steady
II. Unused capacity	Switching comp./pump drive from steam turbine to power;	Variable; external energy
+ no investments required		
- Import of external energy	Increase in load of existing gas-fired steam boilers	Variable; external energy
III. New capacity	Installation of new steam boilers (natural gas, electric)	Variable; external energy
- Investments required		
- Import of external energy		

Method: Preem refinery Lysekil as case study

- CO_2 sources: 1.7 Mt CO_2/yr

	%CO_2 dry	**kt CO_2/yr**
Hydrogen unit (SMR flue gas)	24	535
Combined stack 1	8	508
Combined stack 2	8	359
FCC stack	14	202
[minor stacks – neglected]	-	98

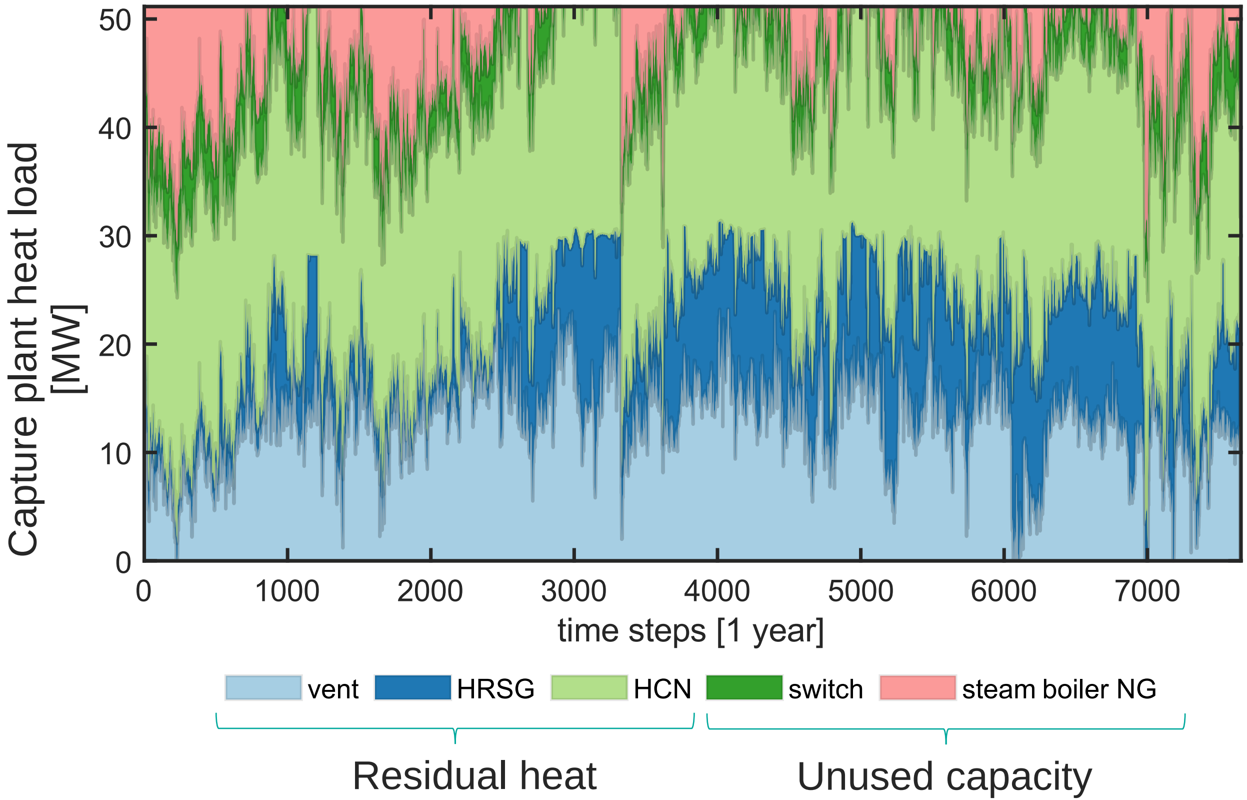
Main assumptions:

- 90% capture
- 131 C sat. steam (2.8 bara)
- Constant heat load supplied for 8500 hours/yr
- Swedish gas (41 €/MWh) & electricity prices (58 €/MWh) 2018
- Swedish electricity grid - 47 gCO_2/kWh
- European natural gas (GHG) - 65.9 gCO_2e/MJ (incl. distribution emissions)
- Lifetime 25 years, 8% discount rate, …

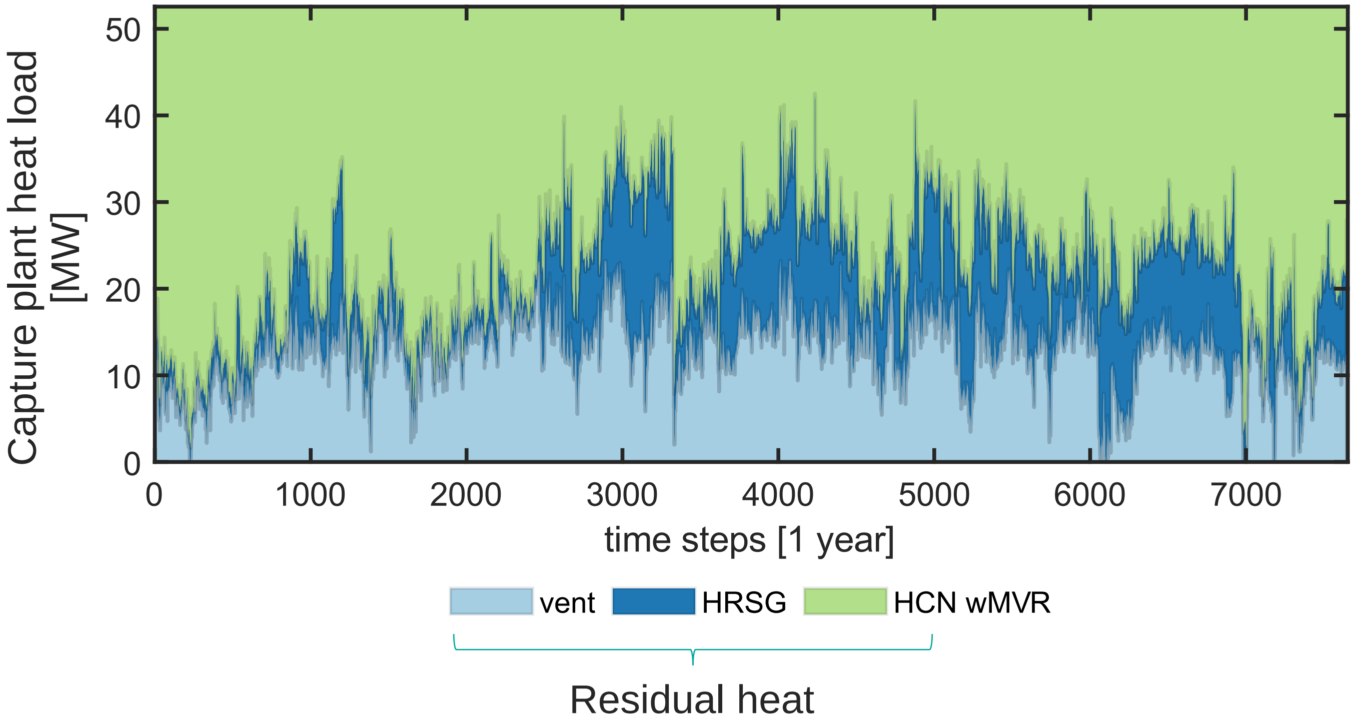
FINDINGS: Illustration of variations

Example: 90% Capture from HPU flue gas 52 MW supply; 482 kt CO_2 captured ~ 28% of site emissions

Objective function: minimizing annual heat supply cost



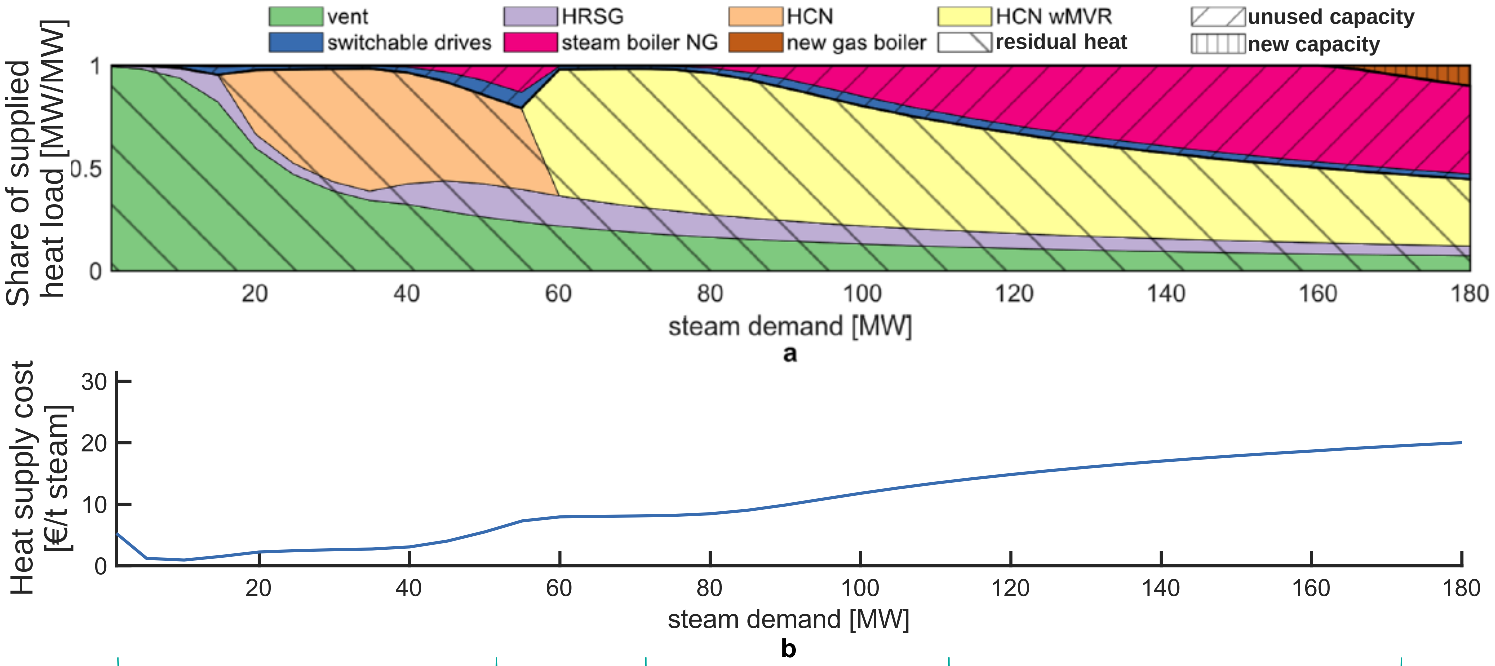
Objective function: minimizing external energy supply



FINDINGS:
Heat supply cost curves – From partial to full capture

Heat supply cost curves

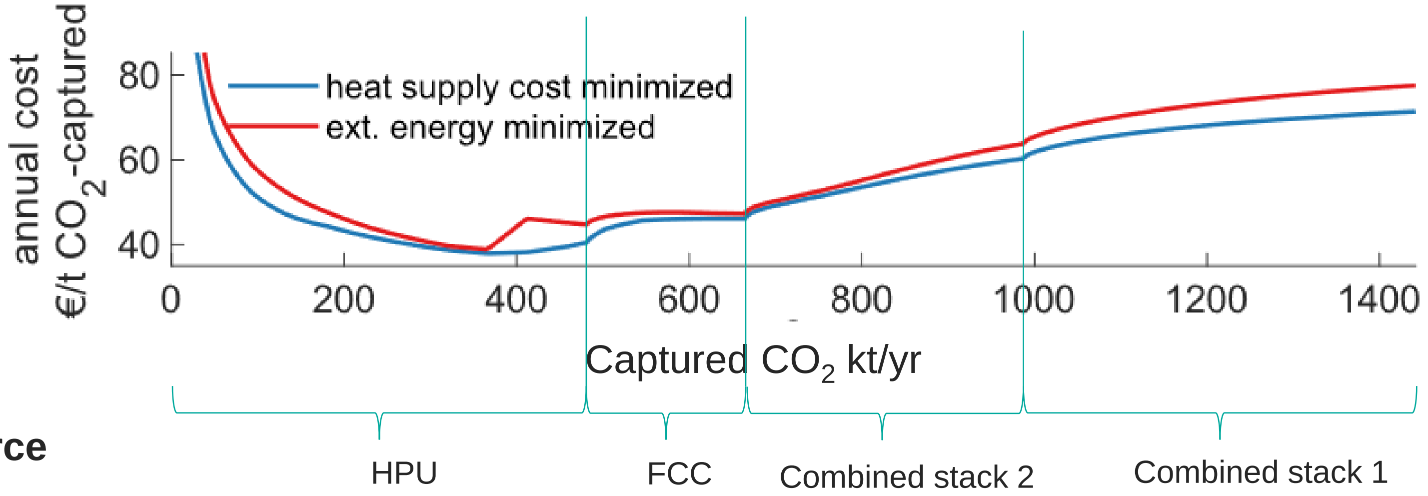
Objective function: minimized heat supply cost



CO_2 source HPU | FCC | Combined stack 2 | Combined stack 1

Capture cost curves

Capture cost = heat supply cost + capture plant cost*

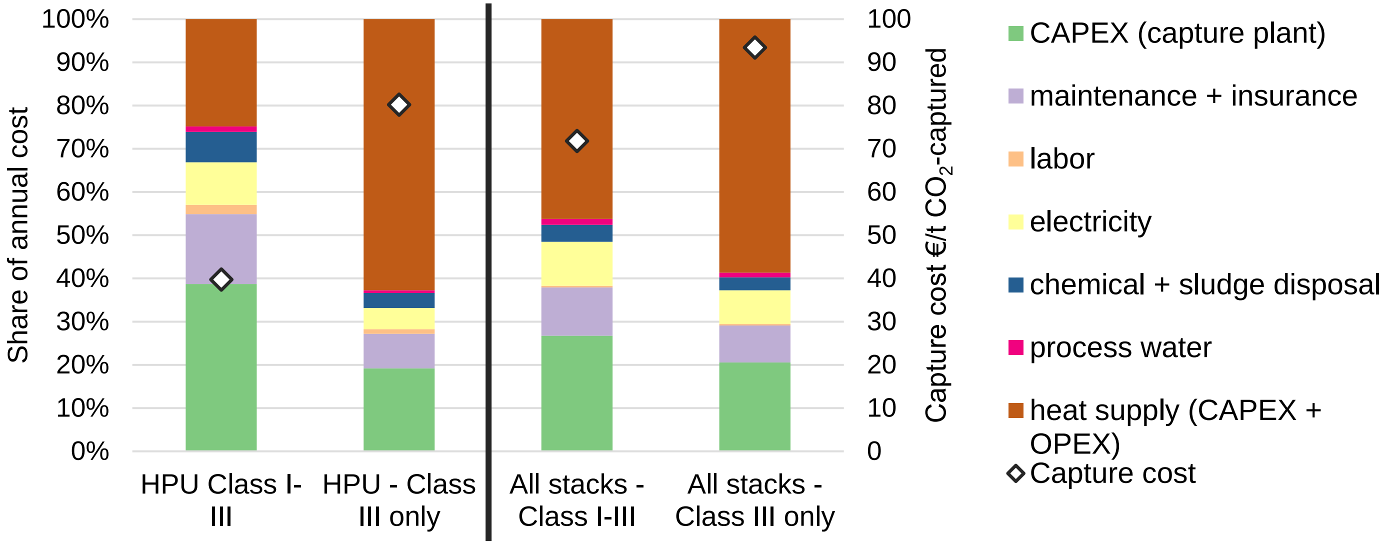


CO_2 source

*90% capture assumed
CAPEX + OPEX
30wt.% MEA

Heat supply cost and effect on capture cost*

Objective function: minimized heat supply cost



***Includes only capture cost and heat supply cost**
CO_2 liquefaction, on-site storage, transport and storage not included

Take-aways

- Developed method: Heat supply cost curves can give input for planning a CO_2 reduction roadmap from partial capture to full capture at industrial sites.
- Variations in heat supply are important and need to be managed/accounted for.
- Residual heat and unused capacity of existing site energy system can potentially supply heat to capture ~78% of site emissions w/o new steam generating capacity (no new boilers installed).
- Compared to installing new capacity alone, the use of residual heat and unused capacity can potentially lead to capture cost savings of up to 50%.

Thank you for listening!

Related publications

Reduction of CCS cost in process industry with partial capture and excess-heat:

Normann et al. 2019. CO2stCap project report, https://research.chalmers.se/en/publication/512527

Biermann 2020 *Partial carbon capture – an opportunity to decarbonize primary steelmaking* Licentiate thesis, https://research.chalmers.se/publication/509851

Other GHGT-presentations from our group:

Tue – Session 4C - Sebastian Karlsson

CCS in the pulp and paper industry – implications on regional biomass supply in Sweden

Thu – Session 10D – Johanna Beiron
A case study of the potential for CCS in Swedish combined heat and power plants

QR: Chalmers profile + publications

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