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CONDITION-BASED FOULING MANAGEMENT IN CRUDE-OIL PREHEAT TRAINS

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BACKGROUND AND MOTIVATION

- Fouling reduces heat recovery in crude-oil preheat trains.
- The fired heater compensates for exchanger performance losses.
- Uniform cleaning schedules may waste maintenance effort.
- Different exchangers contribute differently to furnace duty.

STUDY OBJECTIVE

- Develop a transparent, condition-based cleaning rule.
- Rank individual exchangers by predicted furnace-energy savings.
- Compare against no cleaning and 60-/90-day whole-train cleaning.
- Use the same operating conditions for all strategies.

THREE-EXCHANGER PREHEAT TRAIN

- Three shell-and-tube exchangers in series followed by a furnace.
- Model tracks temperature, flow and time-varying fouling.

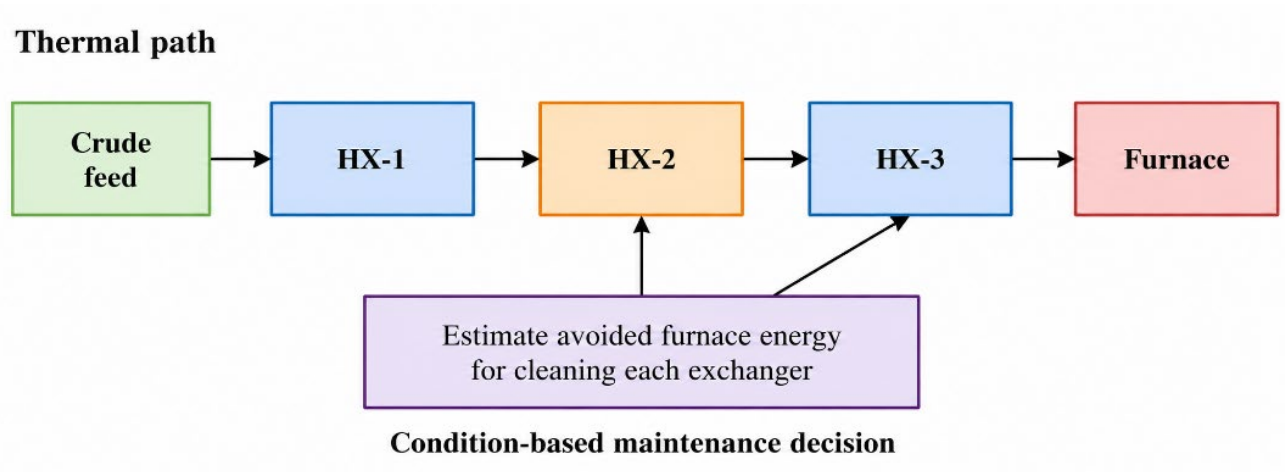


Figure 1 of the paper: thermal path and maintenance decision flow.

DYNAMIC THERMAL MODEL

- Clean heat-transfer coefficients: 320, 300 and 280 W/(m²·K).
- Exchanger areas: 350, 300 and 250 m².
- Hot-stream temperatures: 210, 260 and 310 °C.
- Furnace target outlet temperature: 350 °C.

OPERATING CONDITIONS

- 365-day deterministic simulation with daily updates.
- Crude inlet temperature varies from ~108 to 128 °C.
- Mean crude flow of 35 kg/s with less than 11% variation.
- Initial and post-cleaning fouling resistance: 5×10^{-5} m²·K/W.

TARGETED CLEANING DECISION

- For each exchanger: estimate furnace duty with current fouling.
- Virtually clean that exchanger and recalculate furnace duty.
- Project avoided energy over a 30-day horizon.
- Clean the highest-benefit eligible exchanger when $B_i \geq 1.3\ E$□and ≥45 days have elapsed.
- Cleaning penalty E□= 25 MWh per exchanger.

FOUR COMPARED POLICIES

Calendar baselines

- No cleaning
- Complete train cleaning every 60 days
- Complete train cleaning every 90 days

Proposed method

- Daily condition-based evaluation
- Only one exchanger cleaned at a time
- Priority depends on avoided furnace energy

ANNUAL ENERGY PERFORMANCE

- No cleaning: 56.785 GWh furnace energy.
- 60-day cleaning: 49.044 GWh.
- 90-day cleaning: 49.884 GWh.
- Targeted cleaning: 48.676 GWh.

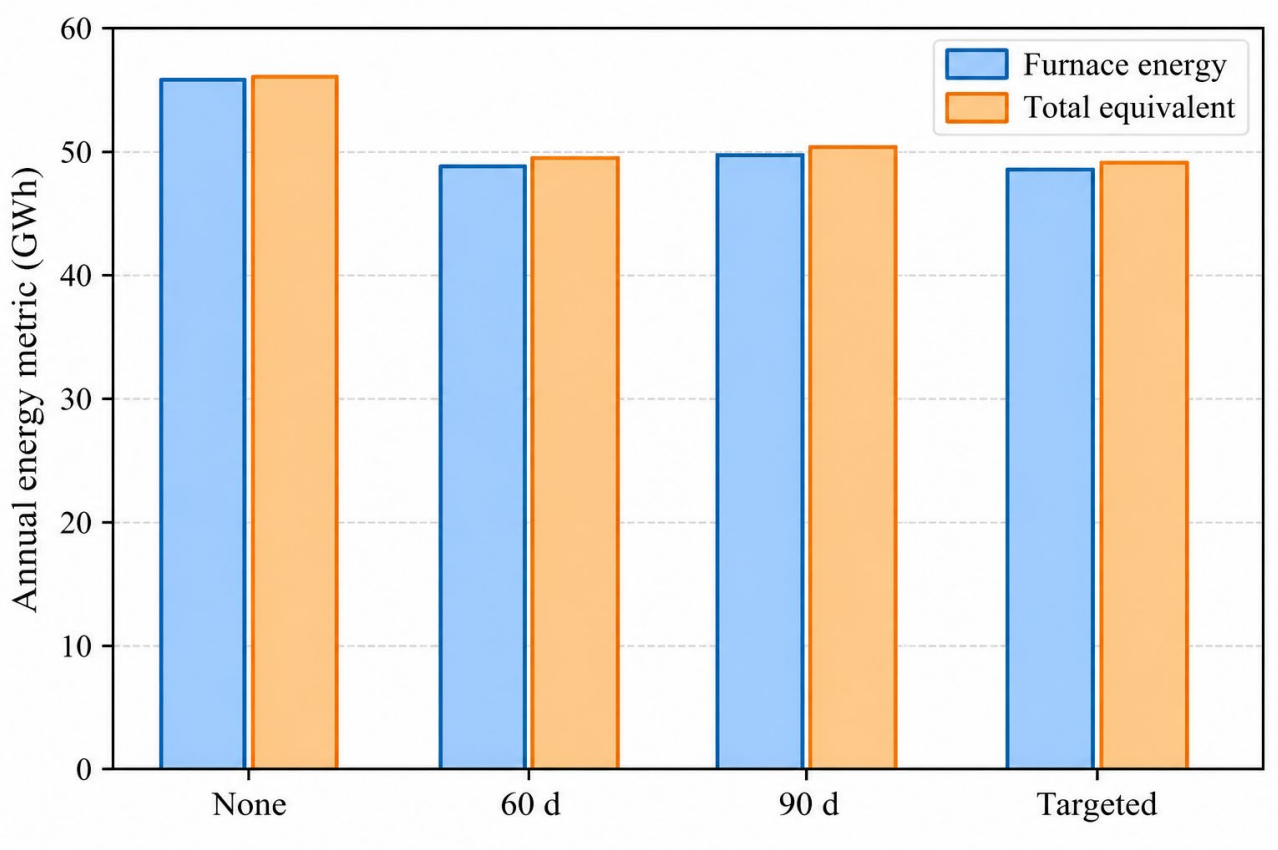


Figure 4: furnace energy and maintenance-equivalent objective.

MAIN COMPARISON: SAME CLEANING EFFORT

- 60-day schedule and targeted strategy each use 18 actions.
- Targeted cleaning saves 367.87 MWh in annual furnace energy.
- Maintenance-equivalent objective: 49.494 → 49.126 GWh.
- The improvement comes from selecting where and when to clean.

PREHEAT OUTLET TEMPERATURE

- No cleaning produces long-term thermal deterioration.
- Targeted mean outlet temperature: 278.11 °C.
- 60-day schedule mean: 277.56 °C.

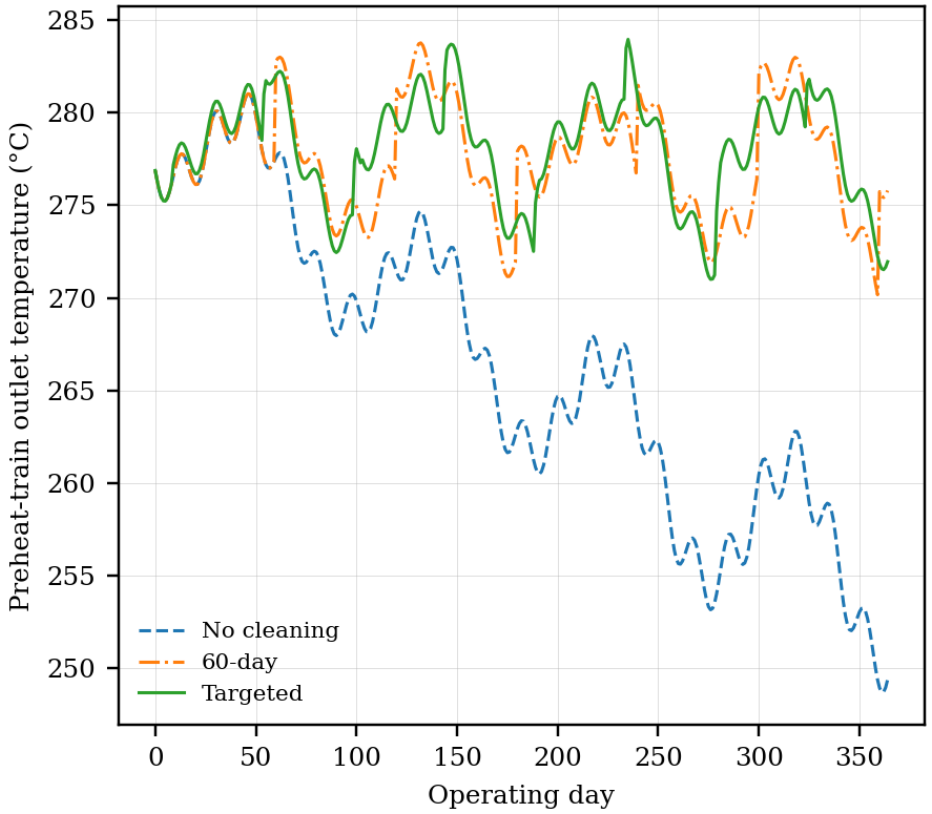


Figure 2: modeled preheat outlet temperature over 365 days.

EXCHANGER FOULING TRAJECTORIES

- Cleaning causes sharp reductions in fouling resistance.
- Exchanger-specific histories are not synchronized.

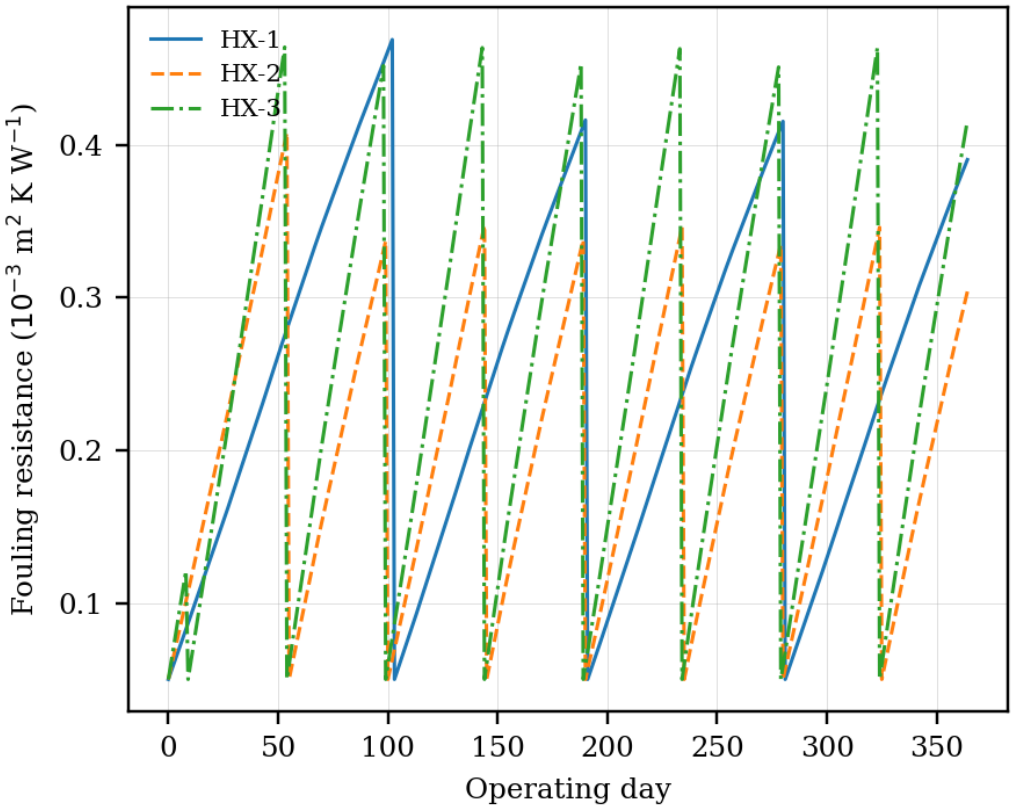


Figure 3: fouling-resistance profiles for HX-1, HX-2 and HX-3.

ALLOCATION OF 18 CLEANING ACTIONS

- HX-1: 3 actions (16.7%).
- HX-2: 7 actions (38.9%).
- HX-3: 8 actions (44.4%).
- Hot-end HX-3 has high leverage on furnace duty.

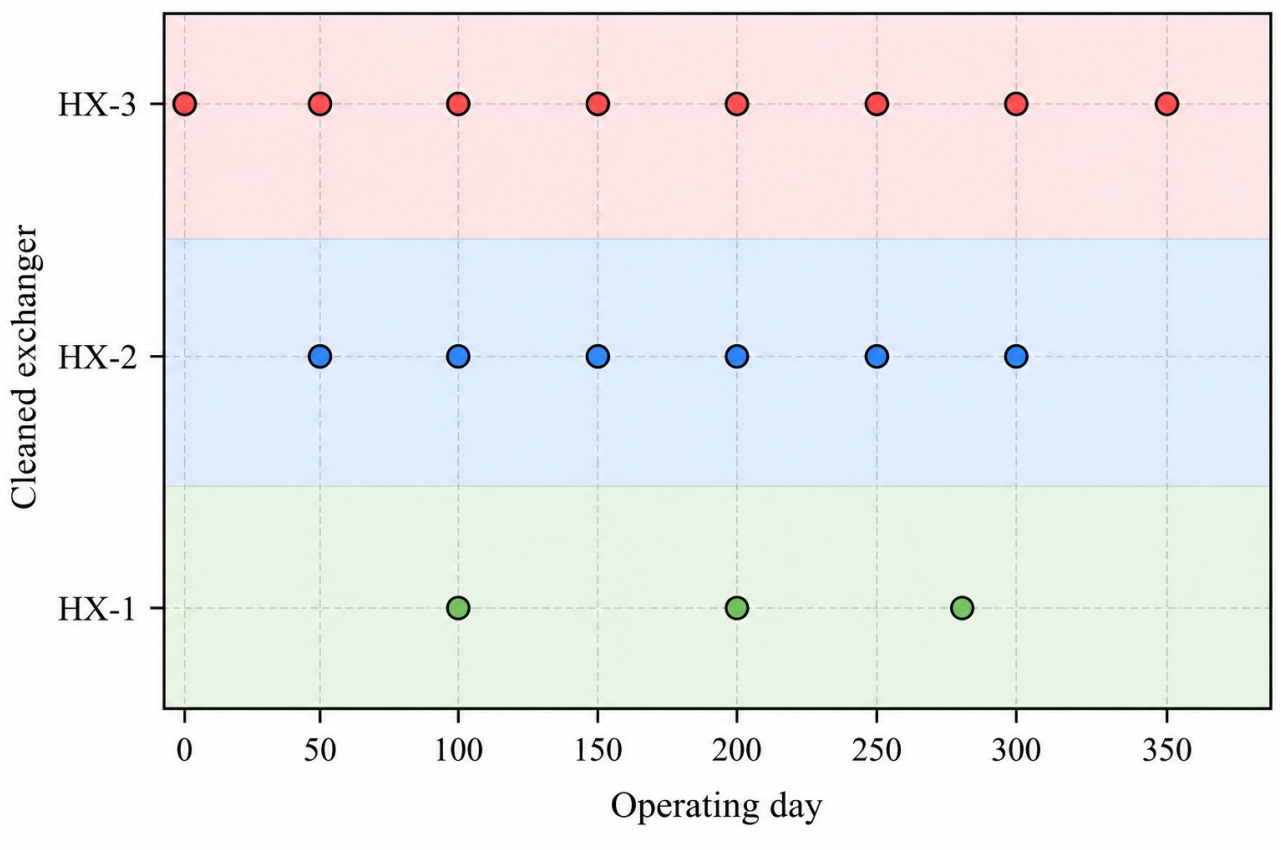


Figure 5: exchanger-specific cleaning timeline.

THRESHOLD SENSITIVITY

- Decision multiplier λ controls required benefit.
- λ from 0.7 to 1.3: 18 actions and near-flat annual objective.
- λ ≥ 1.5: 16 actions with slightly higher objective.

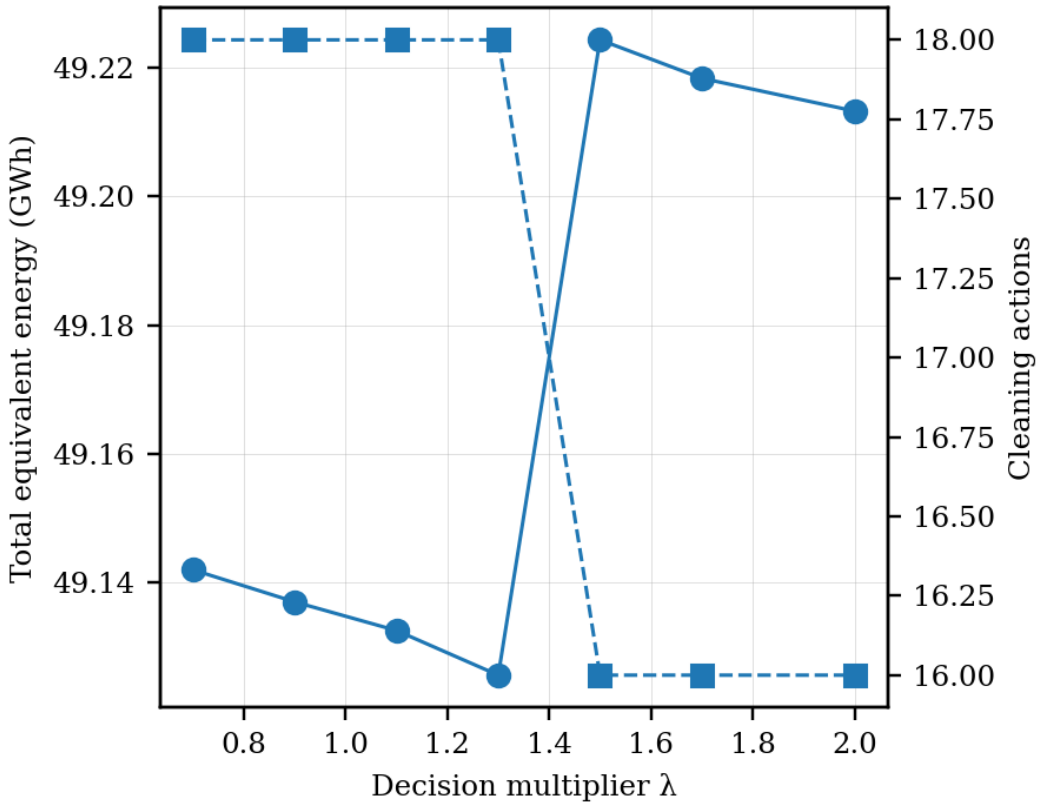


Figure 6: threshold sensitivity of objective and action count.

ROBUSTNESS TO FOULING-RATE UNCERTAINTY

- Test: deposition rates scaled from 80% to 120%.
- Targeted strategy remains favorable relative to 60-day cleaning.
- Advantage ranges from 285.82 to 428.51 MWh.

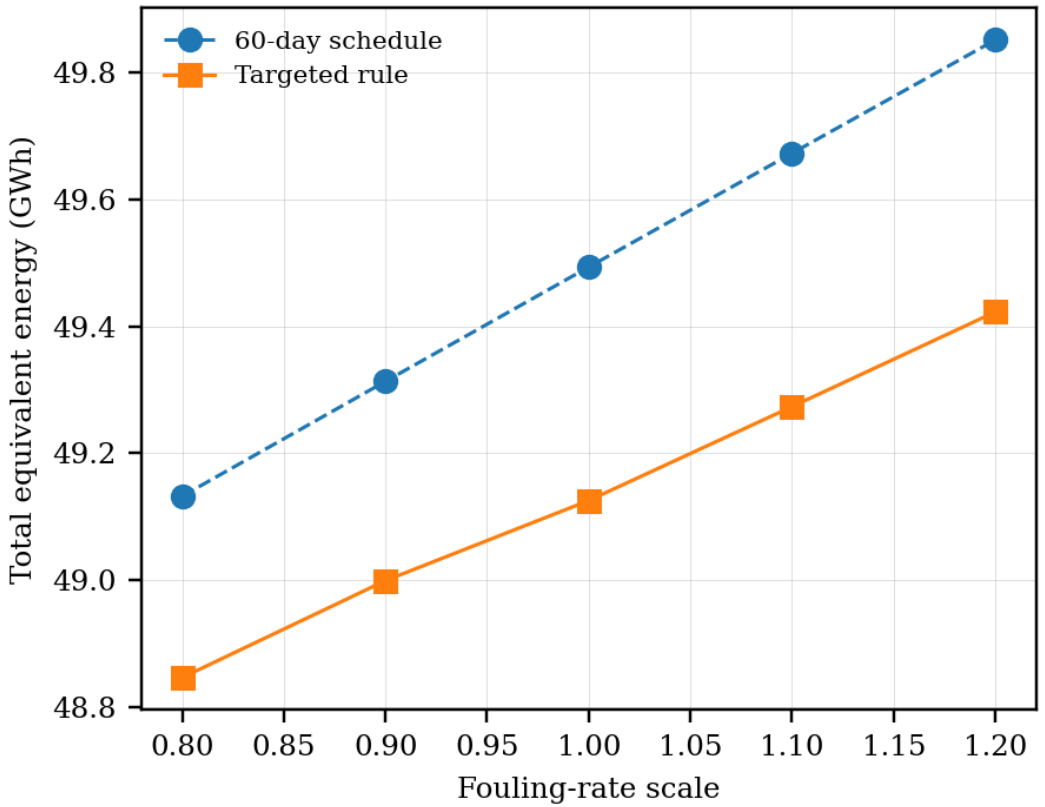


Figure 7: sensitivity to fouling-rate multipliers.

LIMITATIONS AND PRACTICAL DEPLOYMENT

- Illustrative simulation, not refinery field validation.
- Hydraulic pressure drop and cleaning downtime are excluded.
- Model requires reliable fouling estimates from plant data.
- Safety and mechanical-integrity constraints override thermal benefit.

CONCLUSIONS

- A simple energy-benefit rule improves cleaning allocation.
- 18 targeted cleanings achieve 48.676 GWh vs 49.044 GWh for 60-day scheduling.
- Decision ranking is robust across tested thresholds and fouling rates.
- Future work: validate with plant measurements and site-specific economics.