Technical Report: Waste Heat Recovery (WHR) for MXene Production Furnace

# Baseline Energy Use

From the main production report, the electricity breakdown per tonne of MXene is as follows:

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| Unit Operation | Electricity Consumption (kWh) |
| MAX Phase Furnace | ≈ 108,000 |
| Drying – Oven | ≈ 95,000 |
| Etching Reactors (CSTRs) | ≈ 60,000–80,000 |
| Washing/Neutralization | ≈ 40,000 |
| Delamination | ≈ 30,000 |
| Ancillary + Others | ≈ 100,000+ |

Total electricity consumption per tonne is approximately 430,000 kWh (430 MWh). The furnace accounts for ~25% of this total, making it a prime candidate for heat recovery.

# WHR Concept and Design

The proposed WHR system captures sensible heat from furnace exhaust gases and shell losses using a plate-fin or heat-pipe recuperator (efficiency ≈ 40–60%). The recovered heat is directed primarily to:

• Preheating drying oven make-up air (largest energy sink).

• Preheating process wash water for neutralization/delamination cycles.

Optional upgrades include furnace insulation and door-seal improvements to further cut losses.

# WHR Impact Scenarios

Three cases are considered for the impact of WHR on electricity consumption:

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| --- | --- | --- | --- |
| Scenario | Description | Electricity Saved (kWh) | New Total (kWh) |
| S1 – Basic Recuperator | 50% efficient recuperator. 20% of furnace heat recovered and used for oven air preheat. | ≈ 21,600 | ≈ 408,400 |
| S2 – Recuperator + Insulation | Scenario 1 plus 10% furnace electricity reduction via insulation upgrades. | ≈ 25,400 | ≈ 404,600 |
| S3 – Aggressive WHR | 30% furnace heat recovery + wash-water preheating (additional ≈ 1,700 kWh). | ≈ 34,100 | ≈ 395,900 |

# ;;.Recommendations

Scenario S2 (recuperator + insulation) is recommended as the most cost-effective solution. It offers a ~6% reduction in total electricity use per tonne, reducing energy from 430 MWh to ≈ 405 MWh. This provides significant operational savings with moderate capital investment.

For maximum benefit, a detailed heat balance of the furnace exhaust stream and a feasibility study for oven preheat coil integration should be conducted.