Facility-Level Optimization Framework for Korean Petrochemical Marginal Abatement Cost Curve (MACC) Analysis

PHASE 1: DATA PREPARATION AND PREPROCESSING

$\mathbf{F} = \{f_1, f_2, \ldots, f_8\}$
Facility Set
• Companies: 8
• Regions: 3 (Yeosu, Daesan, Ulsan)
• Processes: {NCC, BTX, C4}

$\mathbf{T} = \{t_1, t_2, \ldots, t_{18}\}$
Technology Set
• Categories: 9
• TRL: [3,9]
• Commercial: 2023-2035

$\mathbf{EF}_y = \{ef_{ng}, ef_{fo}, ef_{elec}\}$
Emission Factors
• Time series: 2023-2050
• Korean grid evolution
• Process emissions

$\mathbf{E}_y^{target}$ **(Korean NDC)**
Emission Targets
• 2030: 15% reduction
• 2040: 50% reduction
• 2050: 80% reduction

PHASE 2: OPTIMIZATION MODEL FORMULATION

Decision Variables
$x_{f,t,p} \in [0, 1]$
Deployment level of technology t
at facility f for process p
$\forall f \in F, t \in T, p \in P$

Objective Function
$\min \sum_{f,t,p} C_{f,t,p} \cdot x_{f,t,p}$
Minimize total annual cost
where $C_{f,t,p} = CAPEX + OPEX + \Delta FC$

Constraint Set
$\sum_{f,t,p} A_{f,t,p} \cdot x_{f,t,p} \geq E^{required}$ (1)
$\sum_{t} x_{f,t,p} \leq 1, \forall f, p$ (2)
$x_{f,t,p} \leq CAP_{f,p}, \forall f, t, p$ (3)

PHASE 3: SOLUTION ALGORITHM AND ANALYSIS

LP Solver (CBC)
Mixed Integer Programming
• Variables: $|F| \times |T| \times |P|$
• Constraints: $O(|F| \times |P|)$
• Solution: Optimal/Infeasible

Solution Analysis
$x^*_{f,t,p} \rightarrow$ Deployment Plan
• MACC curve generation
• Investment requirements
• Technology roadmap

Sensitivity Analysis
Parameter Variations
• Cost thresholds
• Technology availability
• Policy scenarios

MODEL VALIDATION AND RESULTS

Key Findings
• 2030 Target: Achievable (Heat pump technology, $2,753/tCO□)
• Technology Portfolio: Limited for deep decarbonization (>50%)
• Investment Required: $181.4B CAPEX for 2030 compliance
• Regional Distribution: Yeosu (66%), Daesan (17%), Ulsan (16%)

Model Performance
• Computational Efficiency: <1 min solution time
• Solution Quality: Optimal for feasible scenarios
• Validation: Emission intensity 2.8 tCO□/t (industry benchmark)
• Scalability: 39 viable technology-facility combinations

Mathematical Notation

F: Facility set; T: Technology set; P: Process set; $x_{f,t,p}$: Deployment variable; $C_{f,t,p}$: Technology cost; $A_{f,t,p}$: Abatement potential; $E^{required}$: Required emission reduction; $CAP_{f,p}$: Facility capacity

Fig. 1. Methodological framework for facility-level optimization in Korean petrochemical MACC analysis. The model integrates facility-specific data with alternative technologies through a linear programming approach to identify cost-optimal decarbonization pathways aligned with Korean NDC targets.