**Multi-step Automated Heat Exchanger Network Retrofit Planning**

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**Highlights**

* Heat Exchanger Network retrofitting is becoming increasingly more urgent
* The Automated Retrofit Targeting algorithm is further developed
* A petrochemical example is analysed, developing many retrofit investment plans
* The best three-step retrofit option saved 7.3 MW with a profit of 1.3 M EUR/y

**1. Introduction**

Ever-rising energy costs and environmental concern drives a cycle of continuous process energy improvement in the chemical and process industries. To remain competitive, industrial companies and sites need to retrofit and revamp their technology to keep pace with more energy-efficient new plants. Such options include disruptive projects – e.g. new reactor installation – and incremental improvement – e.g. new heat exchangers [1]. Due to the capital intensity of disruptive change, most companies favour incremental, low-risk retrofit. Recent efforts have focused on graphical retrofit techniques based on individual process stream mapping [2] and the Energy Transfer Diagram [3] as well as mathematical optimization techniques [4].

This paper presents an extension to the recently developed Automated Retrofit Targeting – ART algorithm [5]. A unique feature of the algorithm is the comprehensive search function that systematically looks at all practicable pathways for energy retrofits. This algorithm is now extended in this work to a multi-step approach, exponentially increasing the number of retrofit options while providing a long-term investment guide for energy projects. To help counteract the increase in complexity, the extended ART determines the Pareto optimal solutions, together with logical and thermodynamic constraints [6], reducing the search space to a manageable size.

**2. Methods**

The ART algorithm was previously developed and explained by Walmsley et al. [5] and further refined by Lal et al. [6]. To main brevity, please refer to these works for method details. Two changes are proposed in this work. First, the extension implements an outer iterative loop to obtain multi-step retrofit solution, detailing the retrofit action required at each step. Second, the extension finds the Pareto optimal solutions using

 (1)

by varying values of *k* and *j* at steps of 0.1. In Eq. 1, *Q* is the heat savings, *A* is the required new heat transfer area, and *n* is the number of new heat exchanger units (modifications). The approach intentionally relied on non-economic results that are key dimensions that affect economics.

**3. Results and discussion**

This work re-examines the petrochemical case study of Walmsley et al. [5]. The number of retrofit “steps” was limited to 3. Figure 1 presents the results with the various colours representing each of the sequential steps with the “best” solution (i.e. the most profitable). The algorithm selected the retrofit option with the shortest payback (1.1 y) as the first step. The 48 possible first retrofit steps are not shown due to provide better clarity. Figure 1A shows the general trend that as successive retrofit steps are taken, the ratio Q/A decreases, i.e. diminishing returns with the additional area.



**Figure 1.** Pareto front of Heat Exchanger Network retrofit options - (A) Trade-off between area and heat recovery duty. (B) Economic performance.

**4. Conclusions**

The extended multi-step Automated Retrofit Targeting algorithm, combined with the identification of the Pareto front, has enabled a new tool for retrofit investment planning. A petrochemical plant example is solved, providing multiple options for investment in Heat Exchanger Network retrofit with an estimated final profit of 1.3 M EUR/y and a payback of 1.6 y for the best solution. With a heat savings of 7.3 MW, the estimated greenhouse gas emission reduction is 11,800 t/y.

The new Automated Retrofit Targeting algorithm has many facets that will continue to be developed in future work. Some directions include heat pump integration, lifecycle analysis, detailed heat exchanger design, and network simulation.

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