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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Scope

Novel "fundamentally-improved" Total Site Analysis was developed and applied for upgrade retrofit within demo site 4. New methods and software tools were developed for fundamentally improved Total Site Analysis. They are divided into fundamentally improved integration of CHP and district heating and fundamentally improved retrofit analysis of existing flexible process plants and Total Sites. Novel optimisation approach has been developed for the optimal design and operational planning of energy networks based on CHP and gas burners and considering external heat source e.g. from existing refinery. Further, software tools called TransGen and HENSYN have been developed for the retrofitting of existing Total Sites under dynamic operation conditions. They have been used besides improved Pinch Analysis methods for identification of modifications, and suggestions for retrofit upgrade.

The analysis regarding retrofitting options within demo site 4 has been performed to consider dynamic operating conditions (four representative cases to cover variations), and proposed retrofitting modifications have been valid for all the cases. Such modifications have been proposed that have the highest incremental profit by considering the trade-offs between investment cost (cost in heat exchange area and in pipes) and operating cost (savings due to reduced energy consumption and hot water production). All proposed modifications consider required amount of hot water produced for district heating. Several sets of modifications have been proposed, typically low number (when hot water production is satisfied), and higher number of modifications that enable also reduced energy consumption due to Heat and Total Site Integration besides production of hot water for district heating.

Fundamentally improved Total Site Analysis

The following steps have been considered:

- Fundamentally improved integration of CHP and district heating including
    - Identification of energy sources and demands across the boundary;
    - District heating and cooling analysis;
    - Modelling and optimisation of integrated localised and distributed energy systems.
- Fundamentally improved retrofit analysis of existing flexible process plants and Total Sites including

- Identification of retrofitting modifications at the plant and Total Site level;
- Development of software tools for automated flexible Total Site analysis;
- Calculation of the improved carbon footprint for the total site target;
- Calculation of the improved economic performance, energy savings and carbon footprint for the retrofitted designs.

The retrofit modifications have been performed for a Total Site (for all units simultaneously) under dynamic conditions. Prohibition of matches between those units and stream where there should be no integration was considered. Also, production and consumption of high-, medium- and low-pressure steam has been considered as to be fixed at current production and consumption level. Integration between processes (Total Site Integration) has been based on the distance between plants multiplied by 3 (multiplied by 6 for both directions). Only direct integration has been considered when performing integration between units. Heat loss of 10 % has been considered when integration is performed between units; energy of hot stream is 10 % higher compared to energy of cold stream in such cases.

Analysis has been performed using software tool TransGen for a certain number of the most optimal new heat exchange matches. Proposed modifications are valid for all four cases. Modifications are such that certain number of new heat exchange matches is formed (e.g., 6, 9, 15 and all profitable) by relaxing certain number of the restrictions from existing heat exchange units. The average heat exchange duties have been considered for all the streams if there have been variations between the duties at cold and hot sides.

Several options have been analysed. Those options differ in terms of reuse of existing "unused" heat exchanger area (either it could be reused or not), minimum heat transfer for all the cases (0 kW or at least 500 kW), and unfeasible or unfeasible and difficult modifications have been excluded. Two different arrangements of heat exchangers for hot water production have been analysed, in parallel and in series.

CO_2 and $CO_{2,eq}$ emission has been assessed for the analysed units and their relative reduction has been evaluated for both the demo and the entire site.

In the following tables the main results regarding reduction in energy, cost and carbon emissions are presented for: i) Total Site target, ii) Most profitable modifications but all modifications are not feasible or are difficult to be implemented, and iii) Most profitable and all feasible modifications.

Maximum potential for energy and carbon footprint savings (Total Site target)

	Case 1	Case 2	Case 3	Case 4	Average
Hot utility consumption reduction (MW)	14.5	13.9	14	9.9	13.1
Cold utility consumption reduction (MW)	19.3	19.5	19	18.1	19
Utility consumption reduction (MW)	33.7	33.4	33	27.9	32
Utility consumption reduction in 4 units (%)	49	52.7	49.2	43.8	48.7
Utility consumption reduction in demo site (%)	21.8	21.5	21.3	18	20.7
Reduction in CO_2 emissions $(1000\ t_{CO_2}\ /\ y)$	31.6 – 44.7	30.6 – 43.3	30.7 – 43.5	22.7 – 32.9	28.9 – 41.1
Reduction in $CO_{2,eq}$ emissions $(1000\ t_{CO_{2,eq}}\ /\ y)$	33.6 – 46	32.5 – 44.5	32.7 – 44.8	24.2 - 34	30.8 – 42.3

Maximum reduction in energy and cost by certain number of most profitable modifications (Several of them are technically difficult or are technically not feasible)

	Number of new heat exchange matches			
	6	9	15	All profitable
Average hot utility consumption (MW)	44.5	42.6	40.7	35.5
Average cold utility consumption (MW)	13.7	12	10.2	5.7
Average energy consumption (MW)	58.1	54.6	50.9	41.3
Reduction of utility consumption (MW)	7.7	11.2	14.9	24.5
Utility consumption reduction in 4 units (%)	11.7	17	22.6	37.3
Utility consumption reduction in demo site (%)	5	7.2	9.6	15.8
Average incremental profit / cost savings (M€/y)	1.35	2.17	2.71	4.02

Reduction in energy, cost and carbon emissions for feasible modifications

	Number of new heat exchange matches		
	6	9	15
Average hot utility consumption (MW)	44.8	44.3	43.4
Average cold utility consumption (MW)	14.5	13.9	13.1
Average energy consumption (MW)	59.3	58.2	56.6
Reduction of utility consumption (MW)	6.5	7.6	9.2
Reduction of utility consumption in 4 units (%)	9.9	11.6	14
Reduction of utility consumption in demo site (%)	4.2	4.9	6
Average incremental profit or cost savings (M€/y)	1.2	1.3	1.5
Reduction in CO_2 emissions $(1000\ t_{CO_2}\ /\ y)$	3.71	4.81 – 5.17	6.36 – 7.22
Reduction in $CO_{2,eq}$ emissions $(1000\ t_{CO_{2,eq}}\ /\ y)$	3.95	5.12 – 5.44	6.77 – 7.53

Transferability of developed approaches to other sites

Developed new approached and software tools for fundamentally improved Total Site Analysis have been analysed in terms of their transferability to other Sites.

Approach for the optimal design and operational planning of energy networks based on energy-generating units and external heat sources available from industries could be easily applied on small and medium-sized residential areas (e.g. villages, towns and small cities). This was proved by successfully performing three-case studies or small and medium-sized villages in two different geographic locations (Italy and UK) and on an example of small city in the UK.

Approach for identification of modifications to be suggested for retrofit upgrade of a process plant and Total Site under steady-state or dynamic operating conditions could be applied within any industry and any process plant and/or Total Site. Developed software tools for Heat and Total Site Integration could be used for handling problems of any size, ranging from small processes up to complex industrial Total Sites. Developed methods and software tools are especially powerful for processes and/or Total Sites with a large number of heat exchange units.

Developed methods and approaches have large potential to contribute to energy savings within the EU-28. Total energy demand within the EU-28 (gross inland energy consumption) has been $1{,}666 \cdot 10^6$ toe in 2013 [1], and the final energy consumption excluding the losses by energy sector, distribution and transformation, has been $1{,}104 \cdot 10^6$ toe in 2013 [1]. The most significant shares of the final energy consumption besides transport have been in 2013 the industry with share of about 25.1 %, and households around 26.8 % [1].

It has been estimated by the European Commission that the energy savings potential for the European manufacturing industries is about 25 % [2]. The potential for savings potential within energy-intensive industries is: 13 – 16 % for chemicals and petrochemicals, 9 – 40 % for iron and steel, 11 – 40 % for cement and 15 – 18 % for pulp and paper [3]. Besides those potential savings there are additional savings due to Total Site Integration and district heating.

The current typical savings potential have been estimated [4] to be within petrochemical and refinery industries between 2.5 and 10 %, and at Total Site level 25 %. In terms of demo site 4 feasible energy savings potential has been around 14 % when performing 15 modifications, and when performing all profitable modifications energy saving could be up to 37.3 % (22.6 % when 15 modifications). Those savings have been obtained by considering the energy consumption in four analysed units.

References

[1] Eurostat, Consumption of energy, ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy, 2015. Last accessed: 14.06.2015.

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[4] EFENIS EC FP7 project ENER/FP7/296003/EFENIS ‘Efficient Energy Integrated Solutions for Manufacturing Industries'. Technical Annex. Brussels, Belgium2013.