Low-temperature heat valorization toward electricity production (LOVE)

http://love.epfl.ch/

Project context and Objectives

In the EU 27, the industry sector represents nearly one quarter of the final energy consumption and one fifth of the GHG emissions. About 75% of this energy is used in thermal processes (furnaces, reactors, boilers, dryers, etc.), but a significant part is ultimately discharged as waste heat (hot waste gases, dissipation via heated materials and surfaces, etc.).

The FP7 LOVE project focuses on the identification of low-temperature (T<120°C) waste heat sources for the European industry, and in the development and demonstration of cost efficient innovative technologies for the use of these sources for electricity production, thus encouraging optimal use of energy in process industry.

Overall, the project consists of four parallel exploration activities, shared among different work packages:

1. development of a methodology for the identification of waste heat sources in a production process and for the optimal integration of thermodynamic cycles (WP1),
2. definition of key performance indicators (economic, sustainability and technical) and the evaluation of the market potential for the proposed technologies (WP3),
3. manufacturing of two demonstration units to be installed in two cement factories (WP2 and WP4),
4. research on innovative heat exchangers and thermodynamic cycles (WP1, WP2 and WP5).

WP6 regulates management and dissemination activities.

The LOVE project started in October 2010 and will run for 3 years. This report provides an overview of the goals and progress achieved during the first year period.

Work performed since the beginning of the project and main results achieved

The status of the project is globally in line with planning and the main results achieved so far are presented in the following paragraphs.

WP1: System integration, methodology and optimization

A methodology for characterization of waste heat sources in industrial processes, based on process integration techniques and pinch analysis, has been described in Deliverable 1.1 (PP dissemination level). The methodology has been applied to a real test case from the food industry: the production of soluble coffee. The identification of the pinch point for the complete production process allowed the classification of heat that should be valorized within the process and heat that can be used for electricity production. Preliminary conclusions indicate that industries that need a lot of steam have limited potential for recovery of waste heat for power production, as hot steam can be used for more efficient applications.

Boundary conditions for comparison of different low temperature heat valorization thermodynamic cycles have been defined in accordance with WP2 and WP5. Most promising Organic Rankine Cycle (ORC) configurations to be used for the pilot demonstrators (WP2 and WP4) have been compared. Design and working fluids have been selected accordingly (see WP2). Details are summarized in an internal report (Milestone 2).

WP2: Waste heat recovery and advanced energy conversion towards implementation on demonstration power units by Rankine cycle

The exhaust gas sources to be used for demonstration in the cement plants have been confirmed (Milestone 1). The two pilots will recover the exhaust gases from the raw mill (source 1) and from the cement mill (source 2a). These sources have large potential because they are present in all cement production sites. Figure 1 shows the two concepts that are being developed for the demonstrators.

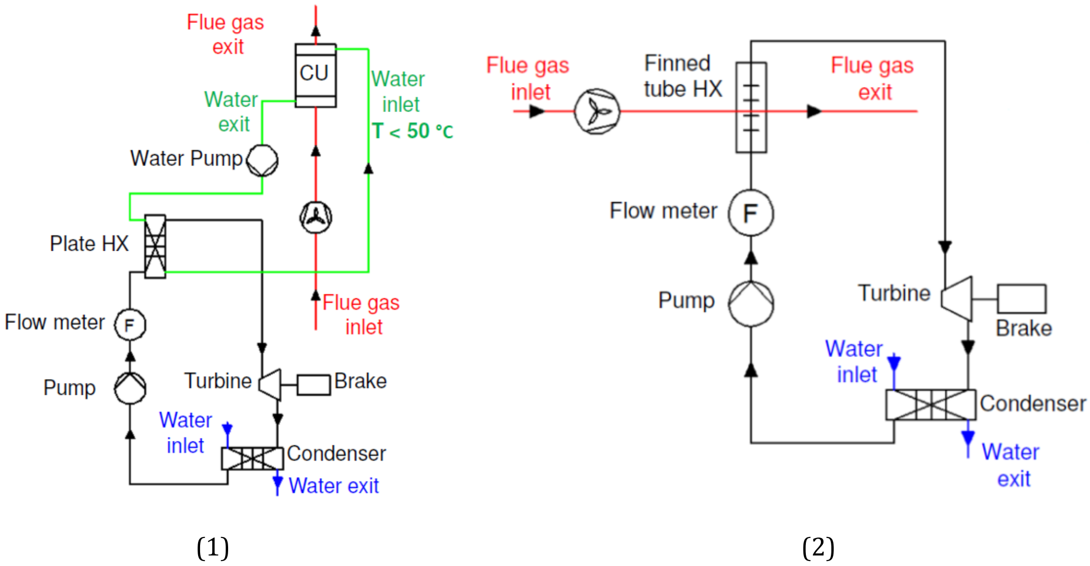

Figure 1: ORC cycles schemes for the demonstrators: (1) heat transfer from gas-to-liquid in a packed column for source 1; (2) direct boiler heat exchanger with corrosion protection for source 2a.

The two pilots will be equipped with a 100 kWe turbo generator. To optimize the ratio between efficiency and cost, the turbine is being designed with hermetic casing and ceramic ball bearings. Different working fluids have been compared based on thermo-physical, environmental, and safety criteria. Cost and availability of the fluids have also been considered. As conclusion, R-245fa has been selected for the demonstrators. The performance of other fluids, blends, and technical modifications required for the pilots scale up will be analysed theoretically and/or in the lab.

The foot print of the main demonstrator components has been assessed and Process and Instrumentation Design (P&ID) schemes agreed. The detailed design of the components (heat exchangers and turbine) is in progress and in line with plan, as well as the preparation of a lab test bench for preliminary characterization of the heat exchangers.

WP3: Key indicators, impact study and transfer opportunities for selected industrial sectors

The methodology and the economic indicators that will be used for assessing the profitability of the LOVE technologies have been described in Deliverables 3.1 (RE dissemination level). The technologies will be evaluated based on Net Present Value (NPV), Internal Rate of Return (IRR) and Simple Payback Period (SPB) for the investment. As for renewable energies, heat recovery plants have the advantage of not incurring fuel costs. For benchmark purpose, electricity prices for renewable resources in Europe were also analysed.

The top five sectors for energy consumption in France have been reviewed, with focus on the main industrial energy usages (boilers, kilns with chemical reaction, drying and other electric usages). This facilitated the selection of key industrial sectors to study more in detail: cement, pulp & paper, steel, milk & diary, and biogas. Production volumes, manufacturing processes and waste heat carriers have been described in Deliverable 3.2 (PP dissemination level).

WP4: Application and validation: electricity production in the cement sector

Measurement campaigns have been performed in the plants of Höver (Holcim) and Beckum-Kollenbach (Cemex), in order to characterize the exhaust gases that will be used for the pilots. Reports with measurements results, ORC optimal design points and expected performance have been prepared and reviewed (Milestones 3, 4 and 5). Both sources revealed presence of humidity and dust, while source 1 also contains typical emissions representative of combustion gases. These severe environments will provide a realistic assessment on the installation's resistance and reliability.

Demonstration on source 1 will be done in the site of Höver, while demonstration on source 2a in Beckum-Kollenbach. Exact location of each piece of equipment, installation steps and site requirements are under discussion and preliminary decisions have been made regarding the equipment design. The bill of materials, cost and weight estimation of each component is in progress. Important steps in the prototype integration schedule have been agreed, and the kiln shut down in beginning 2012 will be used for preliminary works on source 1.

WP5: Exploratory research for low-temperature heat recovery and alternative conversion cycles

Makatec polymeric liquid/liquid heat exchanger has been modified in order to heat with a gas source. Two prototypes have been manufactured. Modifications have been introduced from the first to the second prototype, in order to optimize the pressure drop on gas side. The second prototype will be further improved for testing. In parallel, the setup of a lab plant for investigation of an ammonia/water resorption cycle for power generation has been started.

A one day internal workshop on alternative power cycle was organized to compare modeling approaches between WP5, WP1 and WP2 partners and discuss possible cycle layouts. Boundaries conditions for comparison of different low temperature heat valorization power cycles have been defined. Based on these boundaries, each WP will investigate specific cycles (Kalina, resorption and ORC cycles in different configurations).

An additional task of WP5 is to develop a solid/fluid heat exchanger able to recover heat from cement cooling after the grinding process (source 2b). For this purpose, a preliminary model of the Polysius cement cooler technology has been made: heat transfer coefficients, heat recovery potential and valorization options have been estimated and discussed.

WP6 - Project management and results dissemination

To facilitate efficient decision making and knowledge sharing, the LOVE consortium meets in regular cybermeetings and semi-annual physical meetings. A website has been established both to exchange internal documents and to enhance external dissemination of results. In addition, the project has been presented in public events, as the *6th Annual Conference on Industrial Energy Efficiency* at EDF R&D in France, and the *Smart Energy Strategies Conference 2011* at the ETHZ in Switzerland.

The actual implementation of the LOVE project results will be promoted by an Industrial Advisory Committee, consisting of representatives of different industrial sectors. Several companies have already expressed their agreement to join the advisory board and a first meeting is scheduled for March 2012.

Expected final results and their potential impact and use

The LOVE project aims at developing innovative solutions to generate electricity from low-temperature (< 120°C) waste heat sources identified within various industrial sectors and specifically in the cement industry. This project will result in several technological developments:

- innovative heat exchangers, able to operate in hostile environmental conditions,
- a scalable and economically viable radial inflow turbine,
- adaptation and use of the energy integration methodology, and development of multi-criteria decision-making tool for valorisation of low temperature heat sources,
- exploration of high efficiency conversion cycles and low impact working fluids.

Two transportable demonstration power units will be built and operated at two cement plants. This will increase the perspectives of exploiting the R&D results generated by the project. It has been estimated that the valorisation of the two sources selected for demonstration in 20% of the EU cement plants could yield 430 GWh p.a.

The total volume of the project is estimated to be 5 Million Euro, more than 60% funded by the European Commission.

In the second reporting year the LOVE project will face several challenges. Manufacturing and preliminary lab testing of the demonstrators' components will be a critical tasks, as well as on site work in the cement plants to prepare the setting up of the installations in 2013.

In parallel, the methodology developed in WP1 will be applied to the cement production process, while WP3 will analyse deeper the waste heat sources available in the other selected industrial sectors and the assessment of the technologies proposed in LOVE.

Finally, the lab plant under construction for WP5 will be competed, so as to be able to test the prototypes and their modifications, while the models of innovative power cycle will be further improved to allow optimized integration for the low temperature waste heat sources that will be identified in the cement process.

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