Heat exchanger selection and optimization of a thermoelectric generator subsystem for HT-PEM fuel cell exhaust heat recovery

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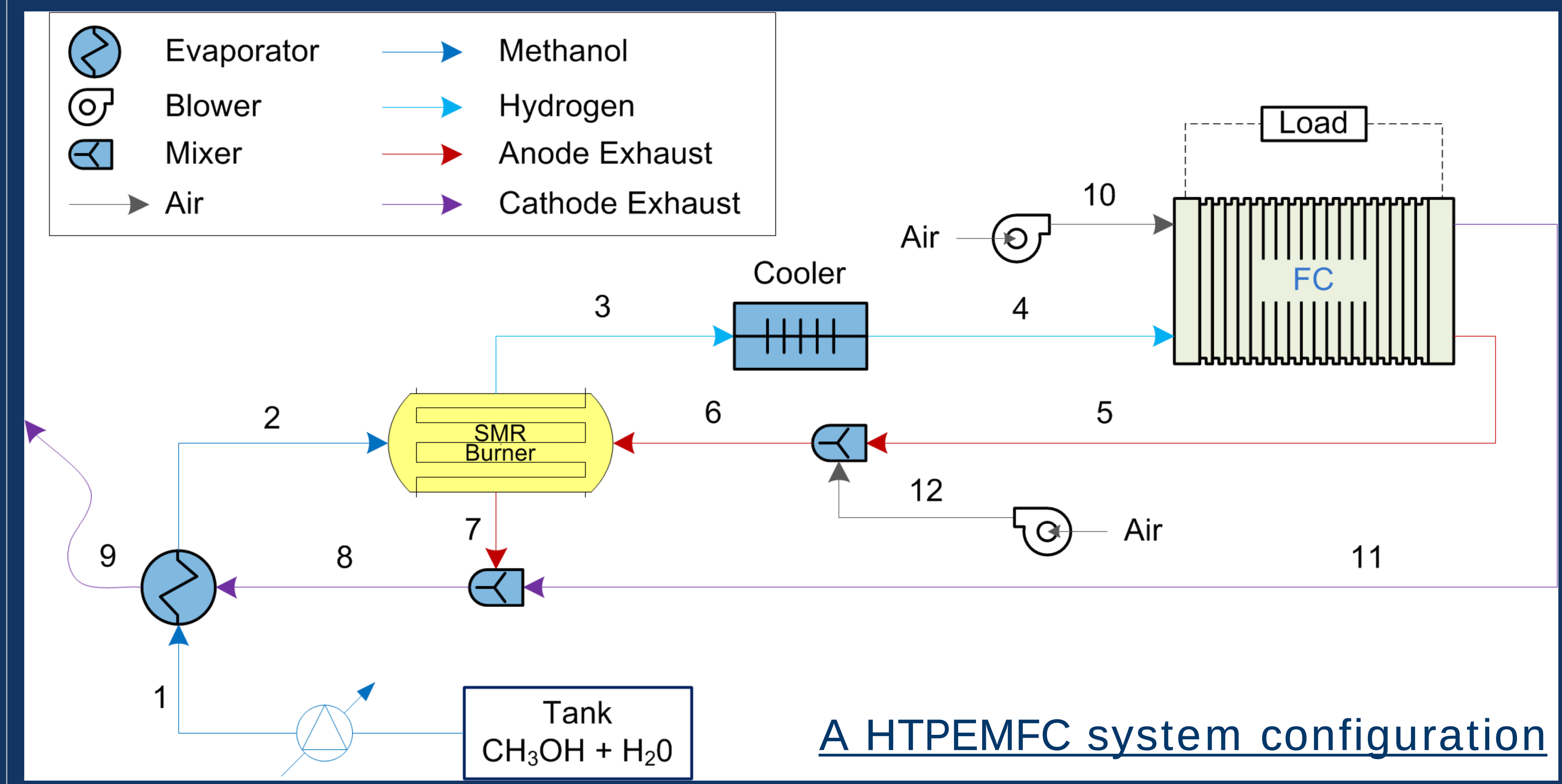
Introduction

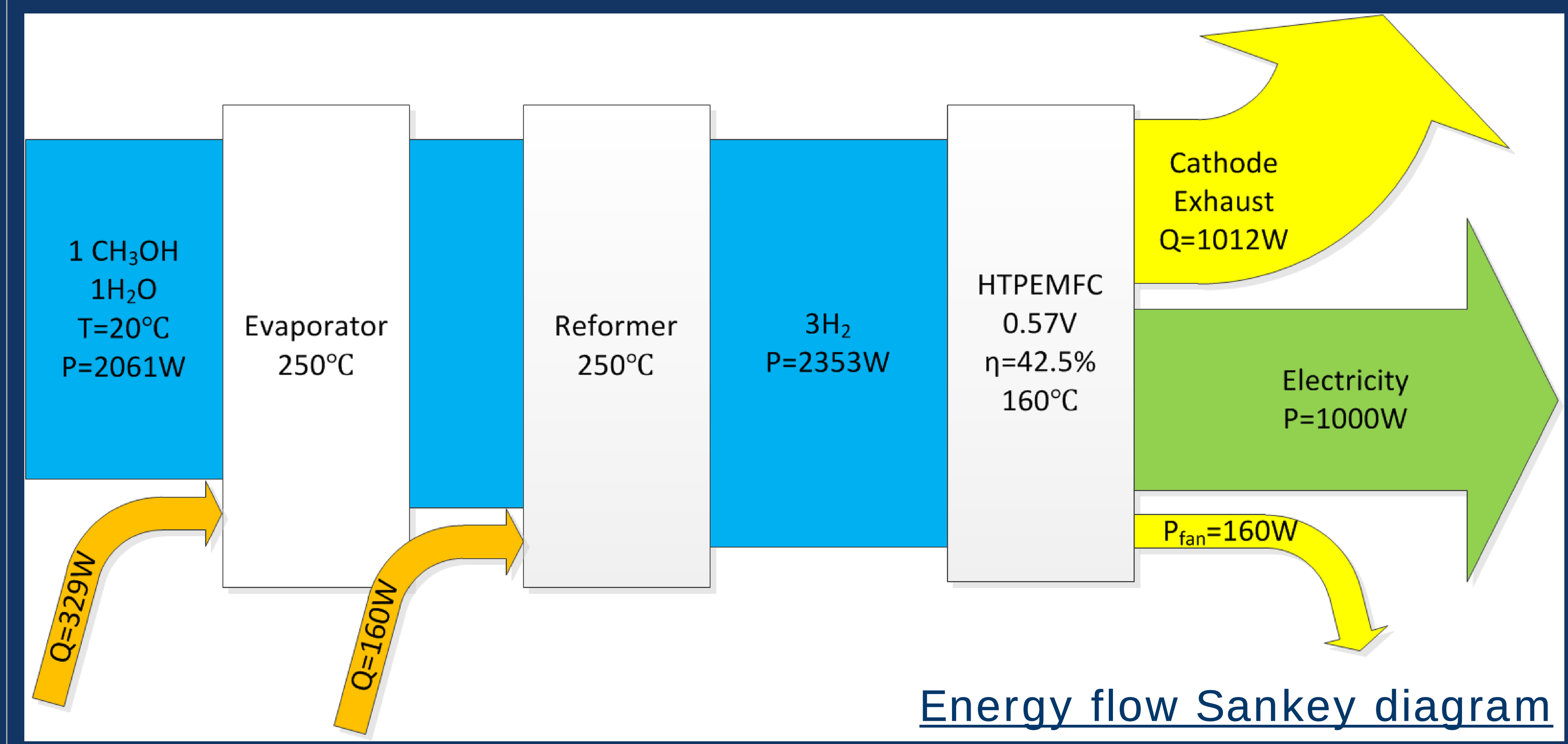
Fuel cell:

This work examines the thermoelectric exhaust heat recovery of a 1kW High Temperature Polymer Membrane Fuel Cell (HTPEMFC) power system with an on-board methanol steam reformer:



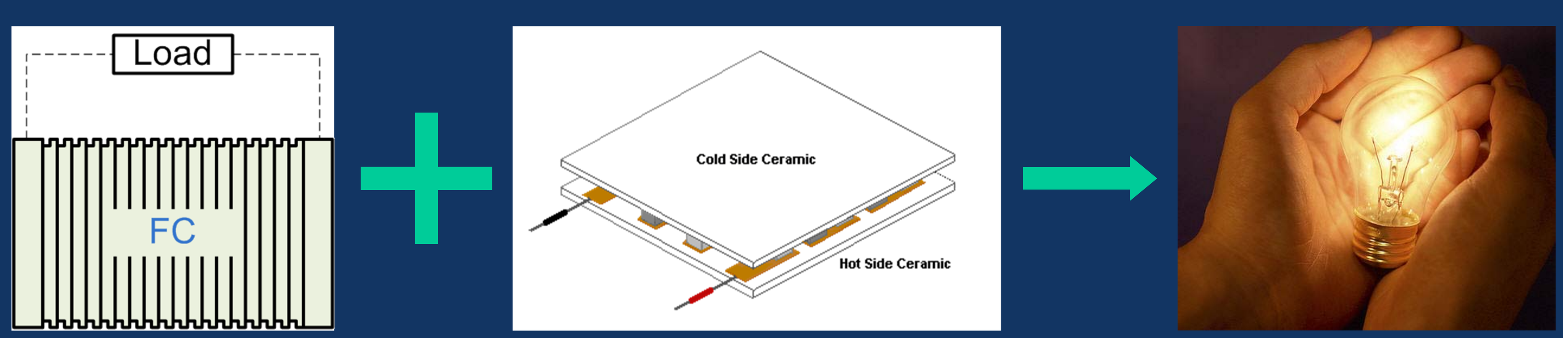
A HTPEMFC system configuration

As illustrated in the Sankey diagram, the potential exhaust heat available is 1.01 kW, at about 160℃.



Energy flow Sankey diagram

The idea here is to recover the exhaust gas heat for electricity: a TEG subsystem needs to be designed, modeled and optimized:



Previous work:

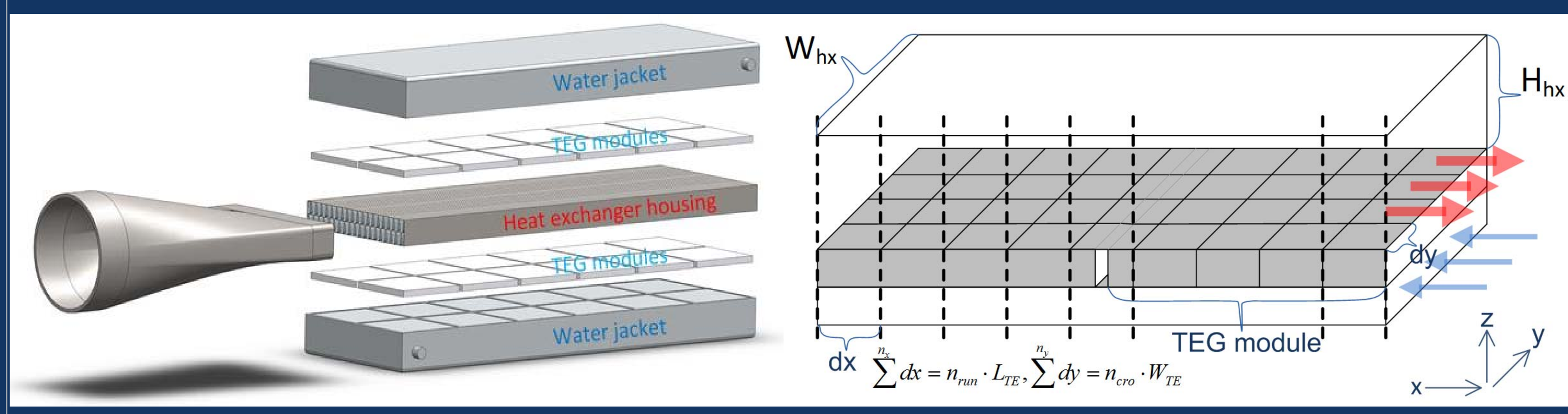
- The architecture of the TEG subsystem is decided;
- Its finite-element model is prepared, with high precision and better versatility (>90 types CHX incl.);
- Superior Compact Heat eXchanger (CHX) structure is pinpointed, pressure drop $\leq 900\text{Pa}$;
- Subsystem configuration is preliminarily optimized;
- All TEG modules are electrically in one series.

Objectives

- A more thorough CHX structure selection should be carried out: pressure drop $\leq 900\text{Pa}$ will be removed;
- The electrical connection styles of TEG modules and their influences will also be discussed.

Study tools

Finite-element model of the TEG subsystem



Subsystem architecture (optimized in previous work)   Dicretization scheme

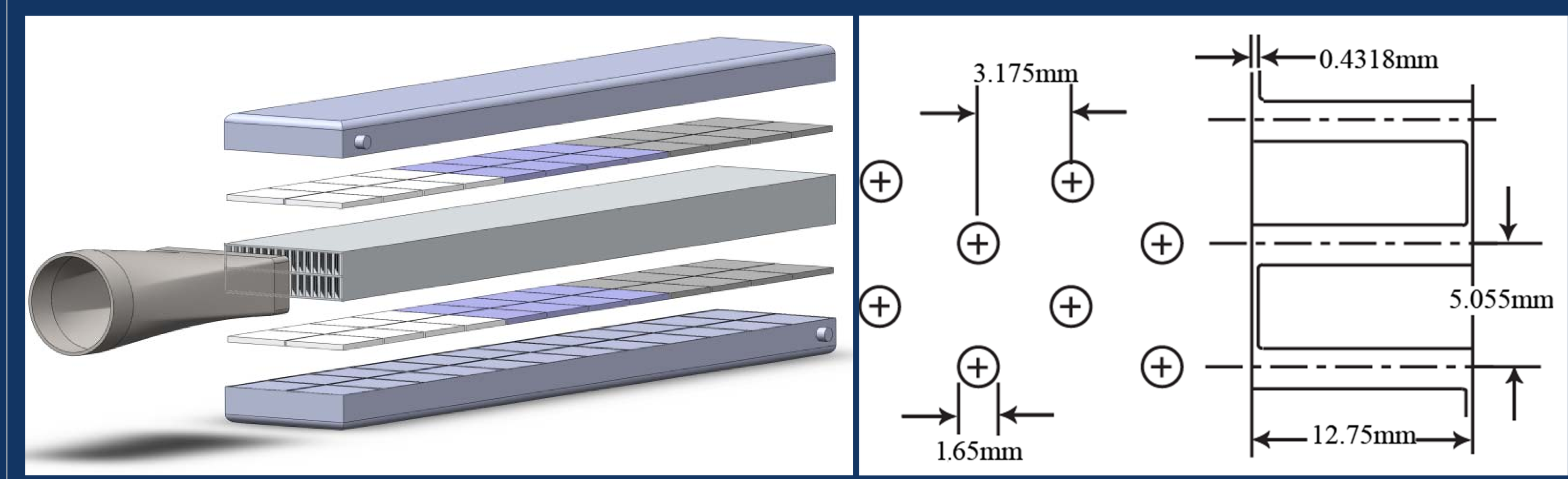
Compact heat exchanger database, more than 90 types.

Kays and London: "It should first be noted that compactness itself leads to high performance."

Sensitivity analysis on the model: input fluctuations to study the system characteristics and identify the control variables.

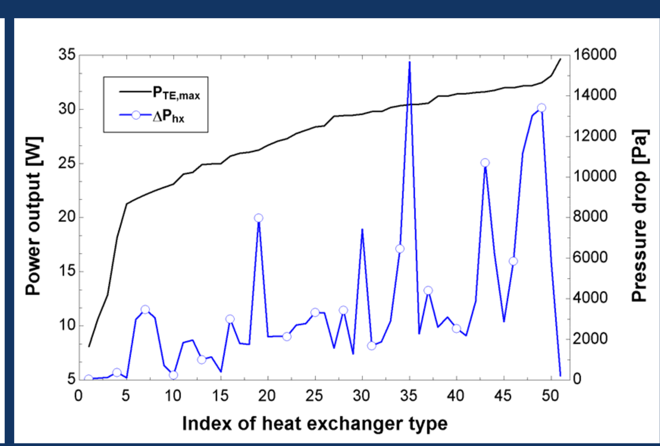
Main results

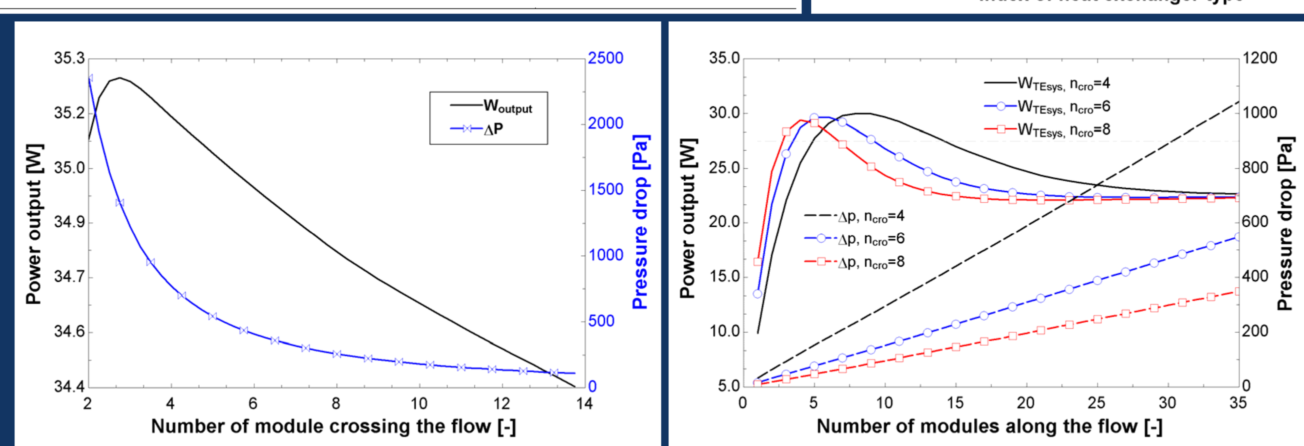
- The optimized subsystem configuration: 4x12 TEG modules (type: Melcor HT8), heat exchanger type 'Pin-fin plate-fin, surface PF-4(F)'.



- The subsystem is most sensitive to the exhaust temperature (44.51%) and TEG module performance (19.67% to the Seebeck coefficient).

Input parameters and description		Value	Uncertainty contribution (%)
α_{hx}	Heat transfer area/total volume (m^2/m^3)	915.6	1.35
α_{TE}	Seebeck coefficient of each TEG module (V/K)	0.05	19.67
$R_{TE,e}$	Electric resistance of each TEG module (Ω)	2	-4.92
$R_{TE,t}$	Heat resistance of each TEG module (K/W)	1.54	10.71
$\dot{m}_{gas}$	The exhaust gas mass flow rate (kg/s)	0.01261	7.96
Cp_{gas}	Average exhaust gas specific heat (J/kg-°C)	1047	7.96
t_{gas}	Gas temperature (°C)	148.2	44.51
t_{cw}	Coolant water temperature (°C)	20	-0.89
Output	Variable description	Value	Uncertainty (%)
$P_{TEA,max}$	Maximum power output of the system	24.10 (W)	± 4.12 (W) (±17.08%)





- More scientific approaches of CHX selection and subsystem optimization are conceived.

Publications

- X. Gao, M. Chen, S.J. Andreasen, and S.K. Kær, J. Electron. Mater. 41, 1838 (2012).
- X. Gao, S.J. Andreasen, M. Chen, and S.K. Kær, Int. J. Hydrogen Energy 37, 8490 (2012).
- X. Gao, M. Chen, G.J. Snyder, S.J. Andreasen, and S.K. Kær, J. Electron. Mater. 41, 1838 (2012). http://dx.doi.org/10.1007/s11664-013-2514-2.
- X. Gao, S.J. Andreasen, S.K. Kær, and L.A. Rosendahl, Int. J. Hydrogen Energy, to be submitted.

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