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# Potential Usage of Thermoelectric Devices in a HTPEMFC System: Two Case Studies

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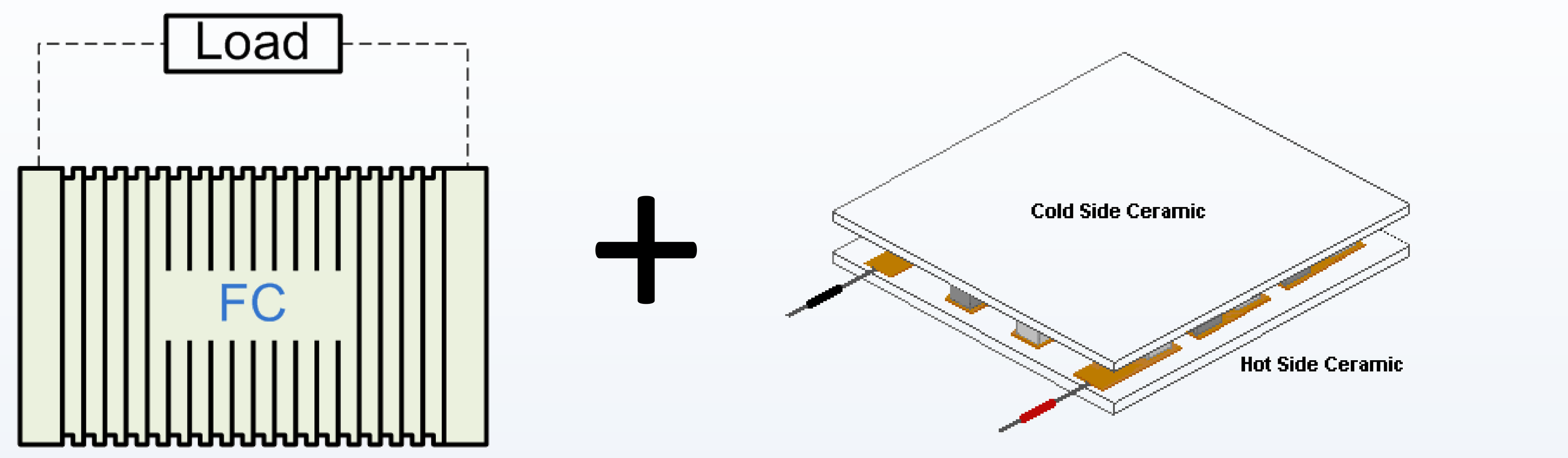
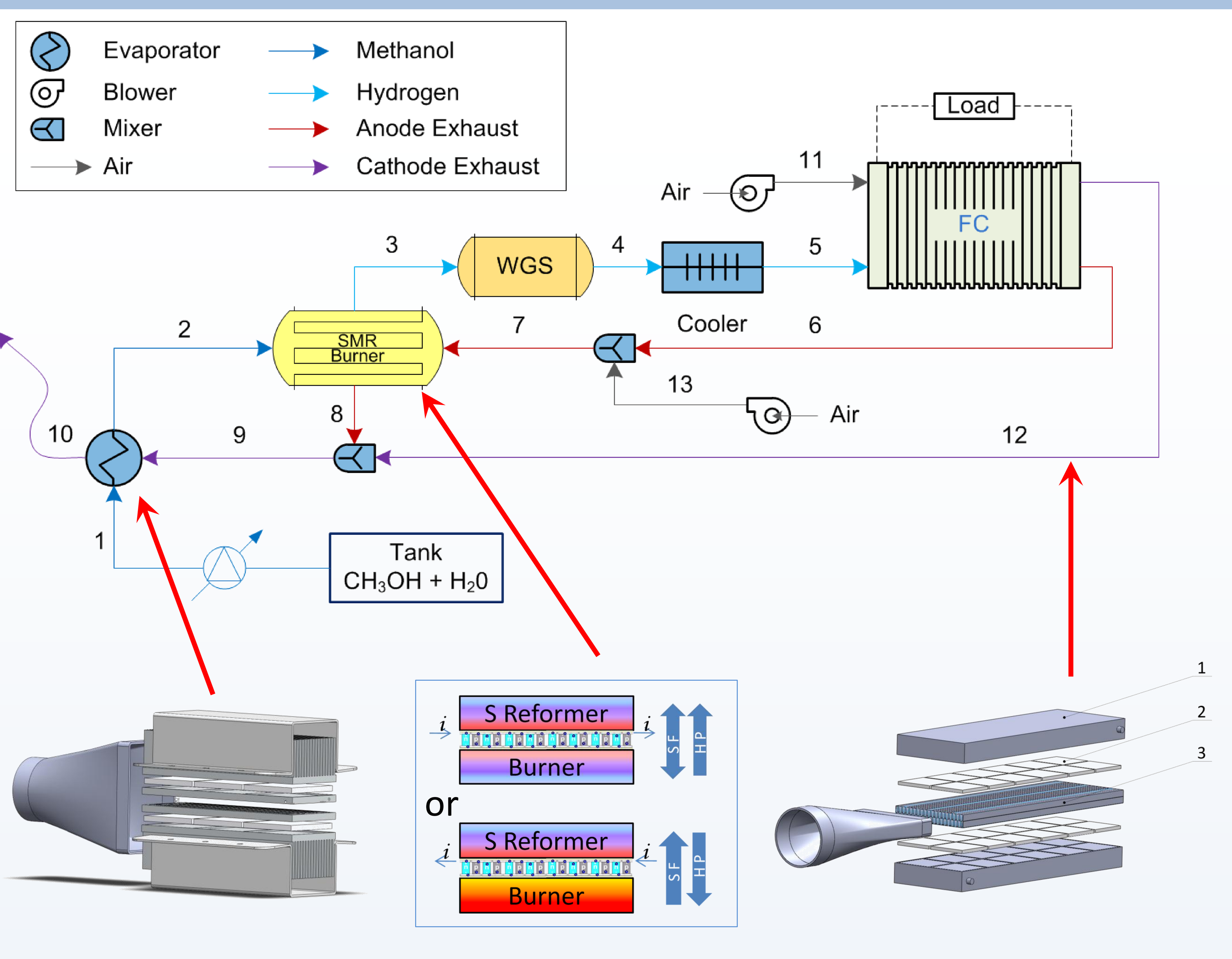
## Introduction

Methanol fuelled high temperature polymer membrane fuel cell (HTPEMFC) power systems are promising as new generation vehicle engines, efficient and environmental-friendly. But a large amount of system waste heat is still exhausted unused. And by now, they still cannot get rid of large Li-ion batteries for system startup. System dynamic performance is also unsatisfactory. Because heat flux is uncontrollable during working condition fluctuating.




In this work, possibly useful waste heat from a HTPEMFC system under normal operating conditions and during system startup has been assessed separately for TEG heat recovery. To further optimize the TEG heat recovery system, a finite-difference model has been established and validated later in this paper. Finally, the use of TECs to improve system dynamics and reduce the heat loss in methanol evaporator is envisaged.

## Objectives

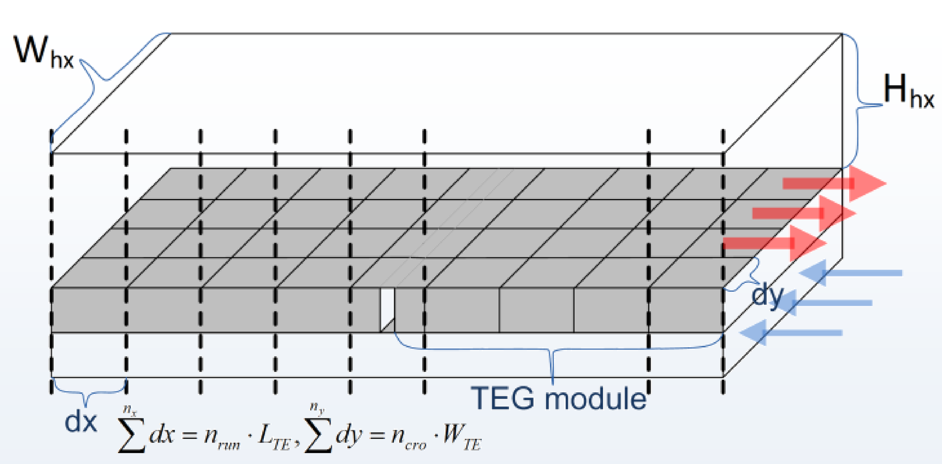



TECs + evaporator | TE-modified reformer | TEG recovery system

- To improve the transient performance of methanol evaporator and SMR reformer with TECs.
- To reduce heat loss inside methanol evaporator during system startup.
- Using TEG heat recovery for electricity to improve system efficiency under normal working conditions and to reduce the system dependence on Li-ion battery during startup.

## Methods

### Finite-difference Model




To optimize the TEG heat recovery system, a finite-difference model has been built in engineering equation solver (EES) software. It is inspired by Espinosa's work and takes Smith's model for reference. Main equations are as follows.

- TEG properties

$$\sum^{n_{x,TE}}\sum^{n_{y,TE}} \alpha_i = \alpha_{TE},\ \sum^{n_{x,TE}}\sum^{n_{y,TE}} R_{e,i} = R_{e,TE},\ \sum^{n_{x,TE}}\sum^{n_{y,TE}} k_{t,i} = k_{t,TE}$$

- TEG power output

$$I_i = 0.5\alpha_i (T_{h,TE}(i) - T_{c,TE}(i)) / R_{e,i}$$

$$w_{TE,\max}(i) = \alpha_i I_i \left(T_{h,TE}(i) - T_{c,TE}(i)\right) - I_i^2 R_{e,i},\ P_{TE,\max} = \sum^{n_x}\sum^{n_y} w_{TE,\max}(i)$$

- Heat transfer

$$\dot{m}_h c_{h,i} (T_h(i) - T_h(i+1)) = UA_{h,HX}(i)(T_h(i) - T_{h,TE}(i))$$

$$\dot{m}_h c_{h,i} (T_h(i) - T_h(i+1)) = \varepsilon_{ctf}(i) \dot{m}_h c_{h,i} (T_h(i) - T_c(i))$$

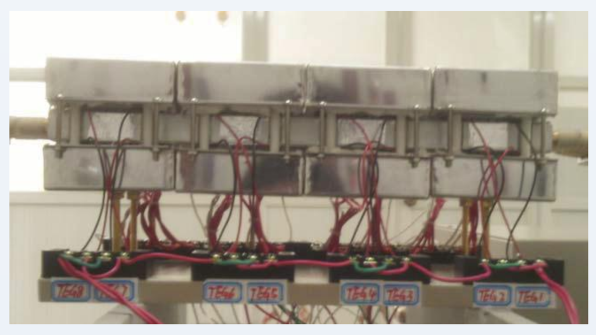
$$\varepsilon_{ctf}(i) = 1 - \exp(-NTU(i)),\ NTU(i) = UA_{tot}(i) / (\dot{m}_h c_{h,i}),$$

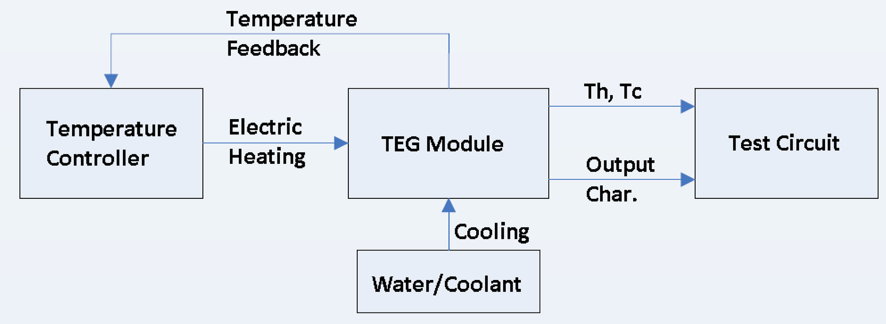
$$1/UA_{tot}(i) = 1/UA_{h,HX}(i) + 1/UA_{TE}(i)$$

- Pressure drop

$$\Delta p = (G^2 / (2\rho_{in}))[4f \cdot L_{flow}\rho_{in} / \left(D_h \overline{\rho}\right) + \left(1 + \sigma^2\right)\left((\rho_{in}/\rho_{out}) - 1\right)]$$

### Emulation Experiments





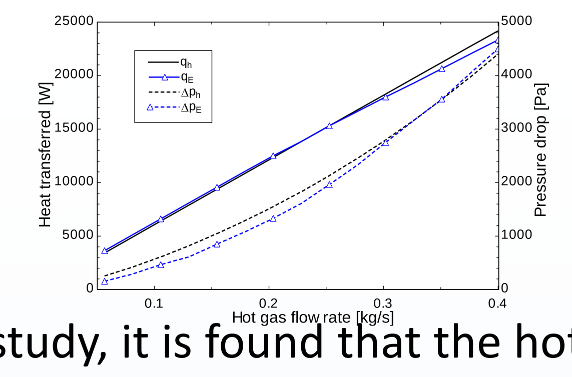

## Recent Results

- Heat recovery potentials and model validation

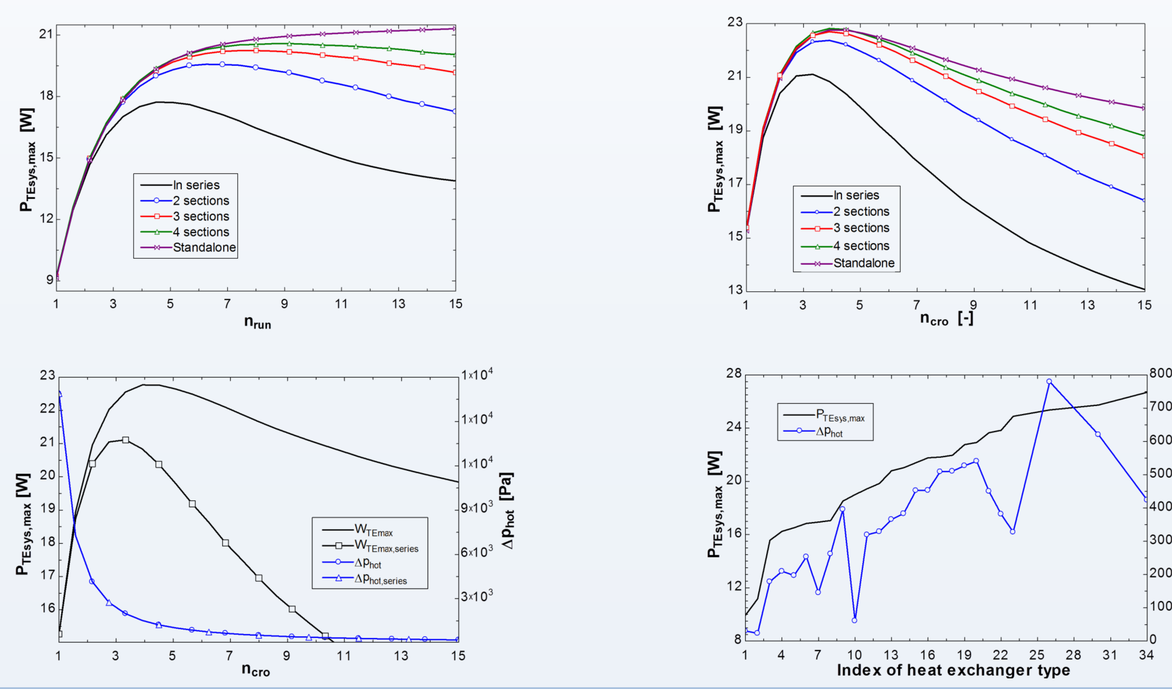
Table 2. Possible TEG installation positions

| Position | $T_H$ (℃)/$T_C$ (℃) | Heat flux (W) | TEG material | Max TEG power |
|---|---|---|---|---|
| Fuel cell - Evaporator | 145/25 | 1012 | Bi2Te3 & (Bi,Sb)2Te3 | 58W |
| Evaporator | 250/70 | 329 | Mg2SiSn & Zn4Sb3 | 24W |
| Reformer | 400*/250 | 160 | Mg2SiSn & Zn4Sb3 | 7W* |
| Cooler | 205/25 | 39 | Bi2Te3 & (Bi,Sb)2Te3 | 3.1W |
| Burner exhaust | 137.5/25 | 34.5 | Bi2Te3 & (Bi,Sb)2Te3 | 2W |

*The temperature of hydrogen catalytic combustion is in the range from 100℃ to 2210℃. Here a typical temperature is used.




- Sensitivity analysis: Through the sensitivity study, it is found that the hot fluid temperature contributes 73.98% of the system power output sensitivity. When temperature goes down, TEG power output decreases sharply and vice versa.
- Influences of TEG heat recovery system parameters




## Conclusions

- TEGs and TECs are of great potentials in improving the HTPEMFC power system.
- Various parameters of the TEG system influence its maximum power output: TEG electric connection, size, exchanger type and configuration.

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