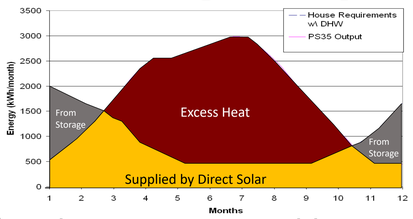
3-dimensional modelling of a thermal energy storage system

Isabelle A. Eid-Holm, Ye Hua, Handan F. Tezel

Department of Chemical and Biological Engineering, University of Ottawa

INTRODUCTION

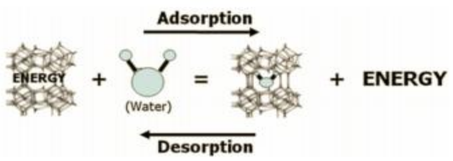
- Fossil fuels account for 87.1% of Canadians' energy supply.
- Adsorption Thermal Energy Storage (ATES) technologies present an environmentally friendly alternative energy source that will reduce our global footprint.



- This technology harnesses renewable energy and utilizes it to heat or cool homes.

THEORETICAL BACKGROUND

- Adsorption is the transfer of a gas or liquid into a porous solid material.
- There are two primary phases in adsorption thermal energy storage: adsorption and regeneration.



- Adsorption → moist air passes over the adsorbent pellets. Water is adsorbed into the pores of the adsorbent, releasing energy in the form of heat and generating hot dry air.
- Regeneration → hot dry air passes over the column removing the water from the pores of the adsorbent and regenerating the energy potential of the column.

METHODOLOGY

- Initially, a process flow diagram (PFD) describing the current thermal adsorption system was analyzed.

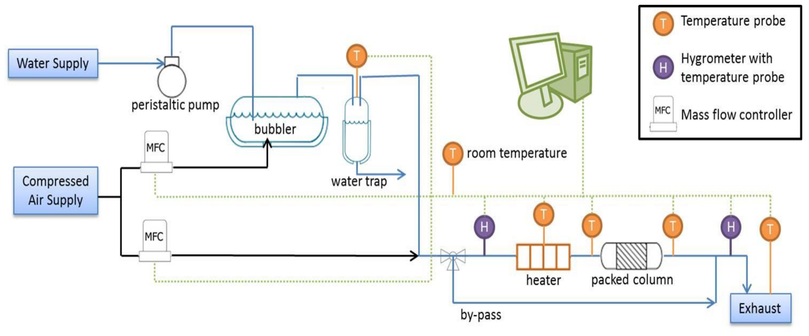


Figure 1. Process Flow Diagram (PFD) of the adsorption thermal energy storage system.

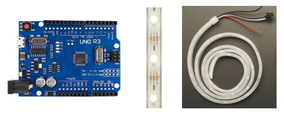
- Crucial equipment for each phase were identified:
  - *Discharging Phase*
    - Bubbler (humidification of entering air)
    - Adsorption column
    - Household ventilation system
  - *Charging Phase*
    - Solar panel, wind turbine (external energy source)
    - Heat exchanger
    - Adsorption column
    - Water collector (recycle water captured in boiler)
    - Exhaust

RESULTS

Building Material

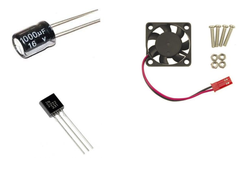
Key Building Materials:

- Plastic Cozy Cottage doll house
- 4 ft^2 of 1.125 inch medium density fiberboard (MDF)
- 10 inch polyvinyl chloride (PVC) clear plastic tubing



Essential Technological Materials:

- Arduino Uno microcontroller
- Adafruit neopixel RGB light emitting diode (LED) strip, 30 neopixels/meter
- 1000 µF capacitor
- Two 5V direct current cooling fans
- NP22* Transistor
- External power source



Circuitry

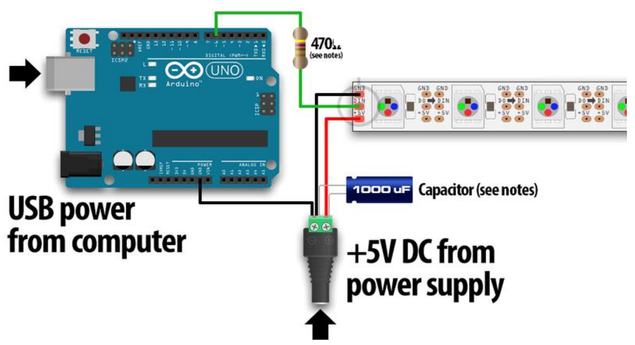


Figure 2. Electrical circuit schematic of Adafruit RGB neopixel strip

Arduino Coding

Discharging Phase

- Column is initialized to be red (dry).
- Moist (blue) air enters the column.
- Red (hot/dry) air exits the column
- Fans/ventilation turns on, heating the home.
- The column gradually changes from red to blue, as the adsorbent becomes saturated with water.
- Once saturated, adsorption column turns blue, and the charging phase is ready to commence.

Charging Phase

- Column is initialized to be blue (wet).
- Red light gradually turns on, from the solar panel to the adsorption column.
- Column gradually fades from blue to a bright red, as red (dry) air enters the column
- A red column indicates all the moisture has been removed from the column.
- Discharge phase is ready to commence.

RESULTS: ISOTHERM CURVE FITTING

The Toth Equation is an empirical modification of the Langmuir equation most commonly used to model heterogeneous adsorption systems[2].

$$C\mu = C\mu s\left(\frac{bP}{[1+(bP)^t]^{1/t}}\right)$$

Where C_μ is the maximum energy density achieved by the adsorbent-adsorbate pair.

The parameters in the Toth Equation were approximated using nonlinear curve fitting techniques in Excel.

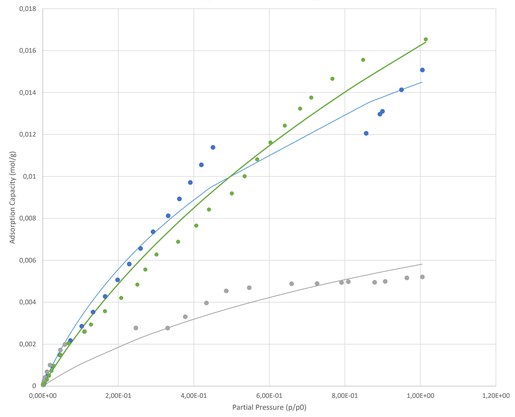


Figure 3. Isotherm curves using ***zeolite-water adsorbent-adsorbate system.

Table 1. Optimal parameter for the temperature dependent Toth equation.

$C_{\mu s,0}$	0.025 mmole/g
b_0	0.9126 (kPa)$^{-1}$
Q/RT_0	6.728
t_0	0.725
α	0.001
X	5.473

Where b_0 and t_0 are characteristic of the adsorbent-adsorbate pair, $C_{\mu s,0}$ is the saturation capacity of the adsorbent, Q/RT_0 is the heat of adsorption at the reference temperature, 293.15 K, and α and χ are positive constants.

CONCLUSIONS

1. The model will increase the public's understanding regarding how the system works, and why it would be beneficial to introduce this technology on the commercial scale.
2. Additional conclusion?

REFERENCES

[1] Source for fossil fuel information…

[2] Ayawei, N., Ebelegi, A. N., & Wankasi, D. (2017, September 5). Modelling and Interpretation of Adsorption Isotherms. Retrieved February 20, 2018, from https:///www.hindawi.com/journals/jchem/2017/3039817

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