

ENGINEERING
HEMISPHERE

***ELECTRIC THERMAL STORAGE (ETS)
OPTION BY NOVA SCOTIA POWER: CASE
STUDY OF A STATISTICALLY
REPRESENTATIVE NOVA SCOTIA HOUSE***

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Outline

- ***Introduction***
- ***Utility Rate Structures***
- ***Electric Thermal Storage (ETS) Systems***
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- ***Current Study***
- ***Representative House***
- ***Energy Simulation***
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- ***Questions***

Introduction

- ***Canadian Energy End-use:***
 - ***One of the coldest climates in the world***
 - ***Prevalence of single family housing***
 - ***Higher residential energy end-use***
- ***Residential sector consumes 16% of total secondary energy use (1,447.2 PJ)***
 - ***63% of primary residential energy consumed for space heating***
 - ***Translates to higher heating bills***

Introduction (contd.)

- ***Primary space heating fuels:***
 - ***Electricity***
 - ***Natural Gas***
 - ***Oil***
 - ***Propane***
- ***Focus of current study:***
 - ***Electrically heated houses***
 - ***Conventional electric baseboards***

Utility Rate Structures

- **Flat Rate Electricity Rates:**
 - **Same energy rate throughout the year**
 - **Applicable to:**
 - **Heating, lighting, cooking and refrigeration**
- **Time of Day (TOD) Electricity Rates:**
 - **Day, month, year divided in to tariff slots or bands**
 - **Higher rates at peak load, low rates at off-peak load**
 - **Also called Time of Use (TOU)**

Utility Rate Structures (contd.)

- ***Time of Day (TOD) Electricity Rates (contd.):***
 - ***Benefits:***
 - ***Customers:***
 - ***Saving cost by shifting consumption to off-peak***
 - ***Utility Companies:***
 - ***Conservation of capacity***
 - ***Reduced transmission losses***
 - ***Discounted rates***

Utility Rate Structures (contd.)

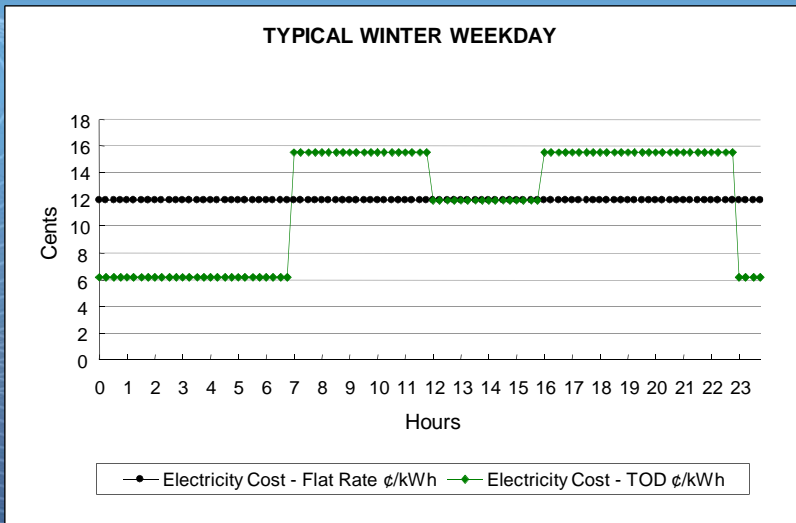
- **Electricity rates by Nova Scotia Power (NS Power)**
 - **Flat rate plan**
 - **11.796 ¢/kWh – year round**
 - **TOD plan**
 - **Winter (December – February)**
 - **7 am-12 pm: 15.320 ¢/kWh**
 - **12 pm-4 pm: 11.796 ¢/kWh**
 - **4 pm-11 pm: 15.320 ¢/kWh**
 - **11 pm-7 am: 6.028 ¢/kWh**

Utility Rate Structures (contd.)

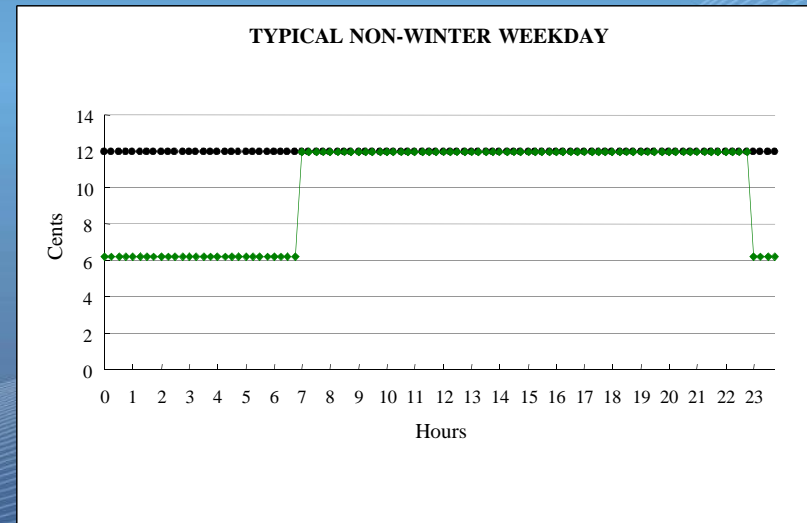
- ***Electricity rates by Nova Scotia Power (NS Power)***
 - ***TOD plan***
 - ***Non-winter (March – November)***
 - ***7 am-11 pm: 11.796 ¢/kWh***
 - ***11 pm-7 am: 6.028 ¢/kWh***
 - ***Weekends/Statutory holidays***
 - ***6.028 ¢/kWh***

Utility Rate Structures (contd.)

- **Electricity rates by Nova Scotia Power (NS Power)**



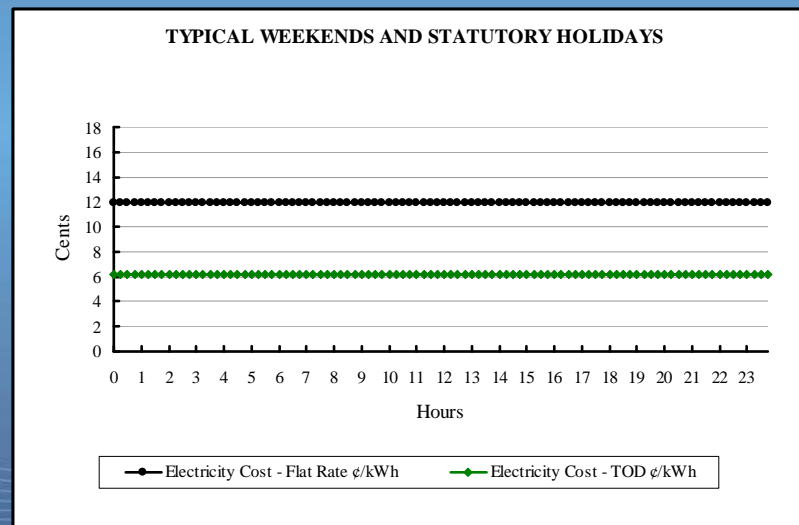
**Electricity rates for
'Winter' Weekdays**



**Electricity rates for
'Non-winter' Weekdays**

Utility Rate Structures (contd.)

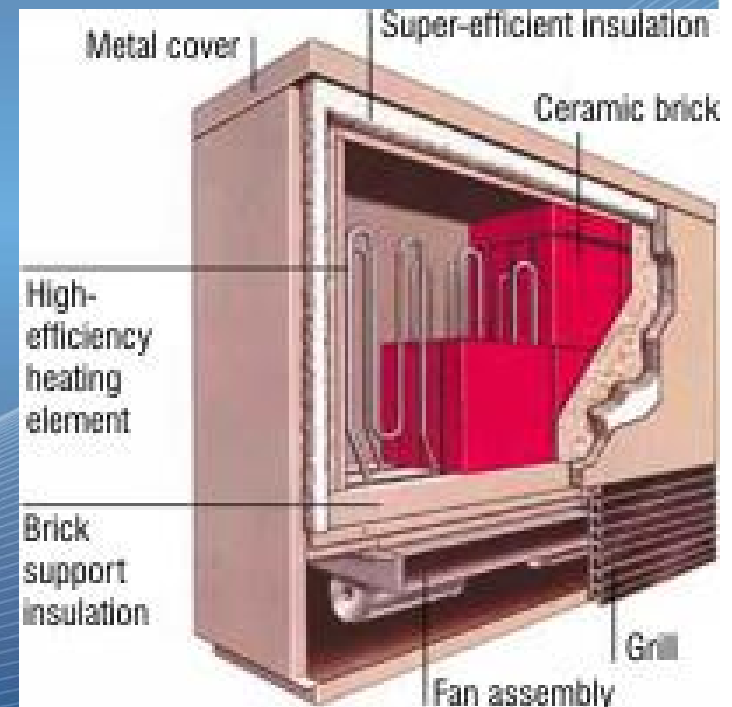
- **Electricity rates by Nova Scotia Power (NS Power)**



**Electricity rates for
Weekends/Statutory holidays**

Electric Thermal Storage (ETS) Systems

- **Stores electric thermal energy in heat storage medium**
- **Insulated metal cabinet**
 - **Refractory/ceramic core**
 - **Internal heating element**
- **Store heat during off-peak hours**
- **Controlled by thermostats**
 - **Built-in**
 - **Remote wall mounted**
- **When required, heat is discharged by a blower fan**



Picture taken from
www.steffes.com

Electric Thermal Storage (ETS) Systems

- *Heat storage control*
 - *Manual*
 - *Owners adjust brick core charge level*
 - *Automatic*
 - *Charge regulated in relation to the outdoor temperature*
- *Residential ETS unit sizes specified in terms of*
 - *Power rating of heating elements*
 - *Storage capacity in terms of charge period*

Past Studies

- ***Thermal energy storage opportunities for residential space cooling: A technology to manage demand response and reduce customer costs, C. Alvarez, A. Gabaldon, F. J. Gracia-Franco, E. Gomez, J.A. Fuenter, A. Molina, IASTES EuroPES Conference***
 - ***Thermal energy storage for residential cooling***
 - ***Not relevant to Canadian weather***

Past Studies

- **Central electric thermal storage (ETS) feasibility for residential applications: Part 1. Numerical and experimental study**, Ben Youcef Bedouani, Alain Moreau, Michel Parent, Blaise Labrecque, *International Journal of Energy Research*
 - **1-D heat transfer and validation of ETS module in TRNSYS**
 - **Forced air central ETS system**
 - **Arbitrary house**

Past Studies

- ***Thermal energy storage in forced-air electric furnaces, W. Bruce H. Cooke, R. H. Stephen Hardy, Michael T. Sulatisky, IEEE Transactions on Industry Applications, Vol 1A-16, No. 1, Jan/Feb 1980***
 - ***1-D lumped parameter model on the validation of ETS behavior***
- ***A physically based load model of residential electric thermal storage: Application to LM Programs, A Molina, A. Gabaldono, C. Alvarez, J.A. Fuentes, E. Gomez***
 - ***Physically based load model for supply management***

Past Studies

- ***Evaluation and assessment of thermal energy storage for residential heating, Hersh, H., G. Mirchandani, R. Rowe., ANL SPG-23, Argonne National Laboratory, Argonne, IL, 1982***
 - ***Referenced in ASHRAE Applications ETS design guidelines***

Current Study

- **Statistically representative existing house**
 - **Using Canada's most comprehensive databases**
- **Realistic load profiles**
 - **Using neural network and utility data (details in Reference no. 11)**
- **Energy simulations**
 - **Hourly simulations in ESP-r**
- **Unit sizing**
 - **ASHRAE guidelines**
 - **Manufacturer's data**

Representative House

- *Developed using three databases*
 - *SHEU (Survey of Household Energy Use) by Statistics Canada*
 - *EnerGuide by Natural Resources Canada*
 - *New Housing Survey by Natural Resources Canada*
- *House located in Halifax, NS*

Representative House

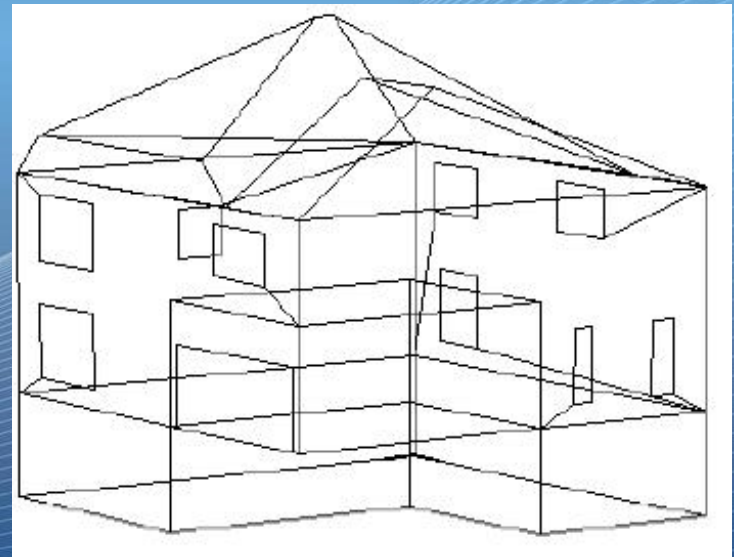
- **2 storey house with the living area of 116 m² (excluding basement)**
- **Built after 1977**
- **Construction details:**
 - **Main Wall RSI: 2.7 K·m²/W**
 - **Foundation RSI: 2.2 K·m²/W**
 - **Ceiling RSI: 5.6 K·m²/W**
- **Has a full heated basement**
- **Has an unheated attic**
- **It has 3 occupants**
- **Infiltration: 4.6 ACH @ 50Pa**
- **Glazed area of 6 m² with double glazed windows and glazed area of 2.69 m² with triple glazed windows**
- **Temperature set points:**
 - **6AM-6PM: 20 °C**
 - **6PM-10PM: 20 °C**
 - **10PM-6AM: 17 °C**
- **Has an annual 'appliance and lighting' electric consumption of 9,911 kWh**

Energy Simulations

- ***Simulated in ESP-r***
 - ***Thermal analysis, HVAC system and electrical power flow simulation environment***
 - ***Can develop new energy system models and link them to the simulation engine***
 - ***Offers computational fluid dynamics (CFD) analysis capabilities***
 - ***Well validated and used extensively by NRCan***

Energy Simulations

- **Hourly simulations for entire year (8,760 results)**
 - **Electricity consumption for space heating**
 - **Daily results**
 - **Winter/Non-winter weekdays**
 - **Weekends/Statutory holidays**
- **Daily peak load**
- **Daily heating energy consumption**



Screenshot from ESP-r

Sizing ETS units

- ***Sized using ASHRAE (HVAC Applications)***
 - ***Whole House Concept***
 - ***ETS units placed throughout the house***
 - ***Suitable if consecutive off-peak hours are more than 10***
 - ***Warm Room Concept***
 - ***Heating unit placed in the most frequently occupied zone***
 - ***Adjacent rooms heated by migrated heat***
 - ***Suitable if consecutive off-peak hours are less than 10 and/or mid-day charging block***

Sizing ETS units (contd.)

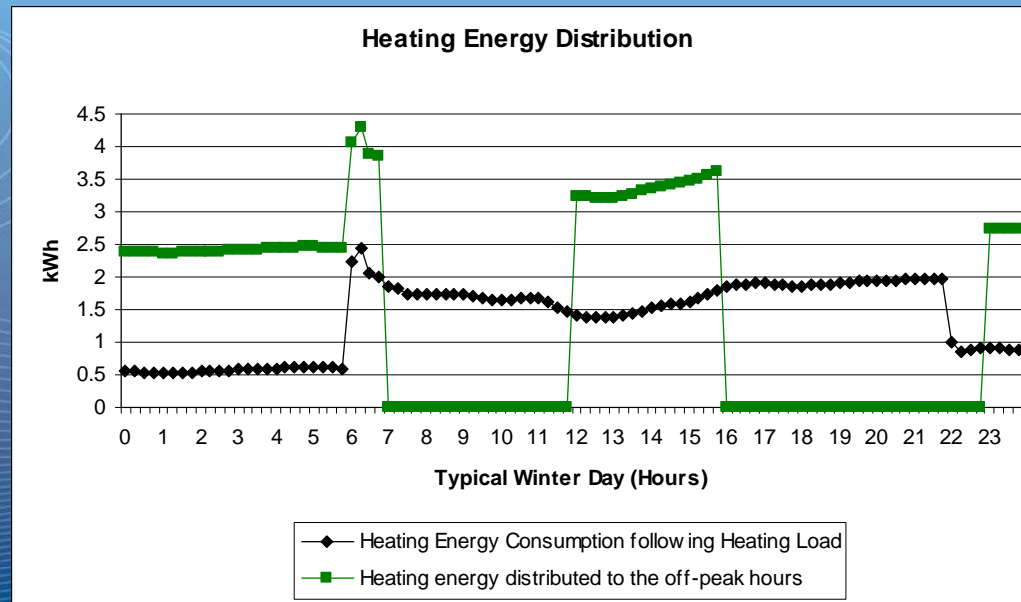
- ***NS Power's rate plan offers:***
 - ***8 consecutive hours***
 - ***4 mid-day hours during winter season***
- ***Warm room concept more suitable***

Sizing ETS units (contd.)

- ***ASHRAE Handbook HVAC Application sizing criteria:***
 - ***Heat discharge rate of the ETS units should not be less than the design heating load at any hour***
 - ***Energy stored in the unit should be equal to that of the total heating energy consumption of the design day***

Sizing ETS units (contd.)

- ***A VisualBasic routine was used to shift daily heating consumption to the off-peak hours of preceding day***



Selecting ETS units

- ***Product specs of Steffes Corporation* were used***
- ***Units sized to meet***
 - ***Seasonal maximum heating load***
 - ***Total daily heating energy consumption for each zone***
- ***Sizes discussed with Steffes technical team***

* www.steffes.com

Cost Saving Calculations

- *Monthly and seasonal heating energy cost calculated*
- *ETS blower fan energy consumption was accounted for*
- *Compared heating cost with TOD and flat rate*

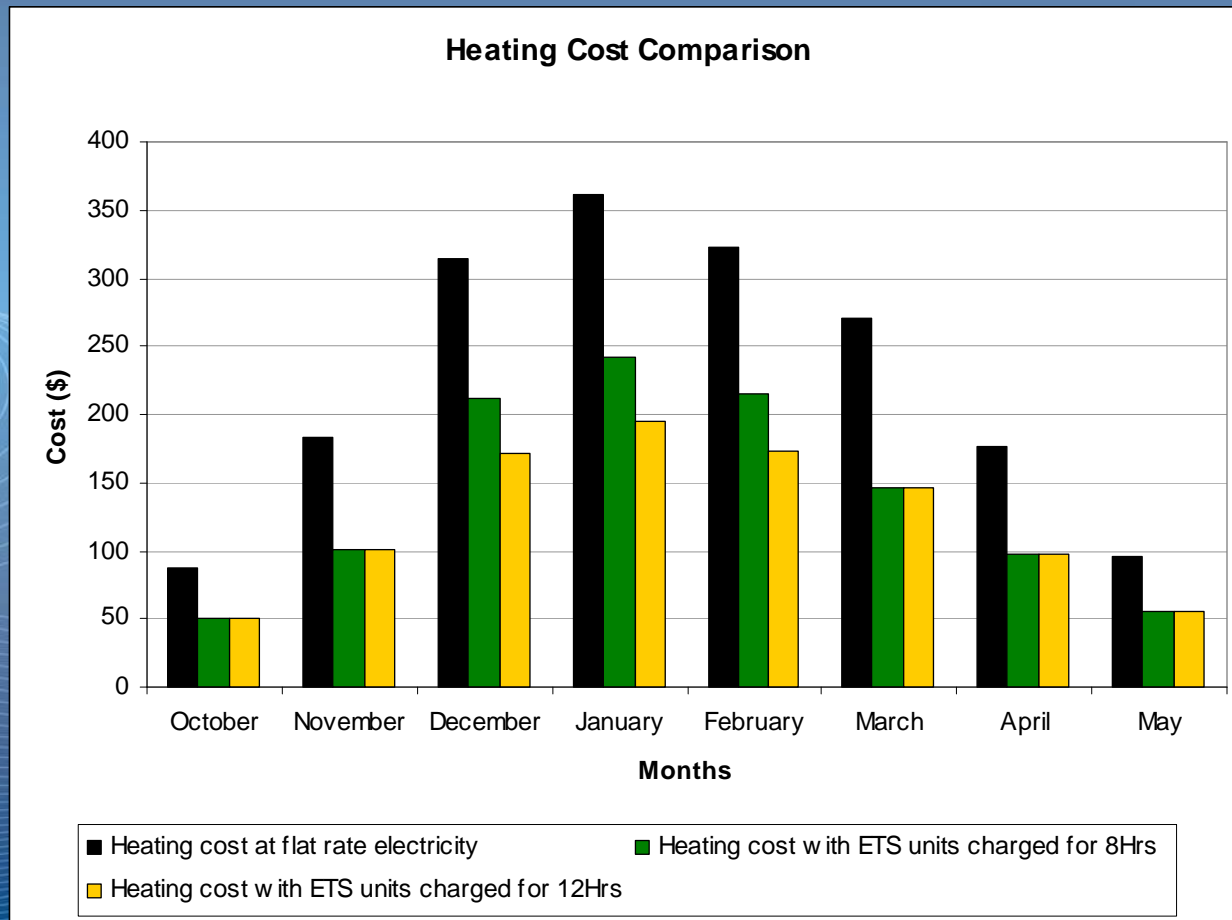
Results and Analysis

- **Heating cost using flat rate (electric baseboards):**
 - **1,900 \$/Yr**
- **Heating cost using TOD (ETS systems):**
 - **Scenario 1: 8 hrs charging (11PM-7AM)**
 - **1,120 \$/Yr**
 - **Saving: 780 \$/Yr (41%)**
 - **Scenario 2: 12 hrs charging (11PM-7AM & 12PM-4PM)**
 - **990 \$/Yr**
 - **Saving: 910 \$/Yr (48%)**

Results and Analysis

Annual Heating Cost – Flat Rate	ETS unit charging time	Annual Heating Cost – TOD	Heating Cost Saving	% Saving
\$		\$	\$	
1,900	8 Hours	1,120	780	41
	12 Hours	990	910	48

Results and Analysis



Installation cost and Payback

- ***NS Power has a list of approved contractors***
 - ***Average price quoted ~ 7000 \$***
- ***Simple Pay-back time:***
 - ***8 hrs strategy***
 - ***9 years***
 - ***12 hrs strategy***
 - ***7.6 years***

Conclusions

- ***Reasonable payback***
 - ***Existing houses still not very energy efficient***
- ***New R-2000 houses yield better payback***
- ***Compound ETS installation with other retrofits funded by government***

Future Work

- *Validation of the results using HOT3000*
- *Assessment of integration with PV and Wind-turbine energy systems*
 - *GHG reduction*
 - *Achieving net-zero housing design*
- *Computational Fluid Dynamic (CFD) analysis for thermal comfort*
- *More rigorous pay-back analysis*



Questions?