

Valuing the Benefits of Insulated Battery Enclosures for Stand-Alone Photovoltaic Systems in Cold Climates

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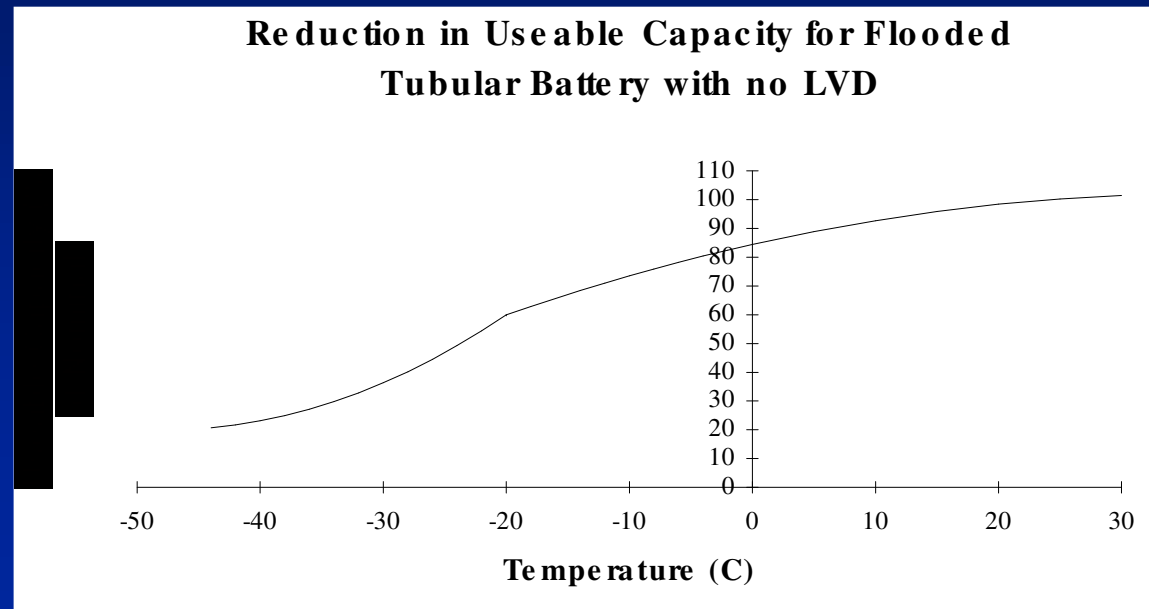
Outline

- ▼ Motivation: effects of cold on batteries
- ▼ Introduction to thermal protection
- ▼ Variables affecting cost-effectiveness of thermal protection
- ▼ Quantitative investigation
- ▼ Effect of thermal protection on battery lifetime



Effects of Cold Temperatures on Lead-Acid Batteries

- *Lower discharge capacity*
- *Decreased charge acceptance*
- *Danger of battery freezing*



Motivation

- ▼ In Canada, large battery banks are used
- ▼ Battery is significant part of system cost
- ▼ If the battery bank could be kept warm throughout winter, a smaller battery bank could be used
- ▼ If the cost of keeping the battery warm is less than the savings from a smaller battery, then system cost decreases



Thermal Protection for Batteries

- ▼ Insulation
- ▼ Heating: Surplus power from the PV array
- ▼ Phase change material (PCM)
 - ▼ Water takes a long time to freeze, and will remain at 0 °C until it is completely frozen
- ▼ But when does each of these make sense?



Variables-- Batteries

- ▼ Cost per unit capacity (high -> thermal protection)
- ▼ Volume per unit of capacity (high->PCM)
- ▼ VRLA batteries -> thermal protection
- ▼ Energy Density (low->PCM)
- ▼ Shape
- ▼ Temperature derating



Variables--Site

- ▼ Deg. sec. below freezing point of PCM
(relatively low -> PCM)
- ▼ Short, cold periods -> PCM
- ▼ Winter solar availability (high -> heating)
- ▼ Rime icing or mountain fog -> PCM



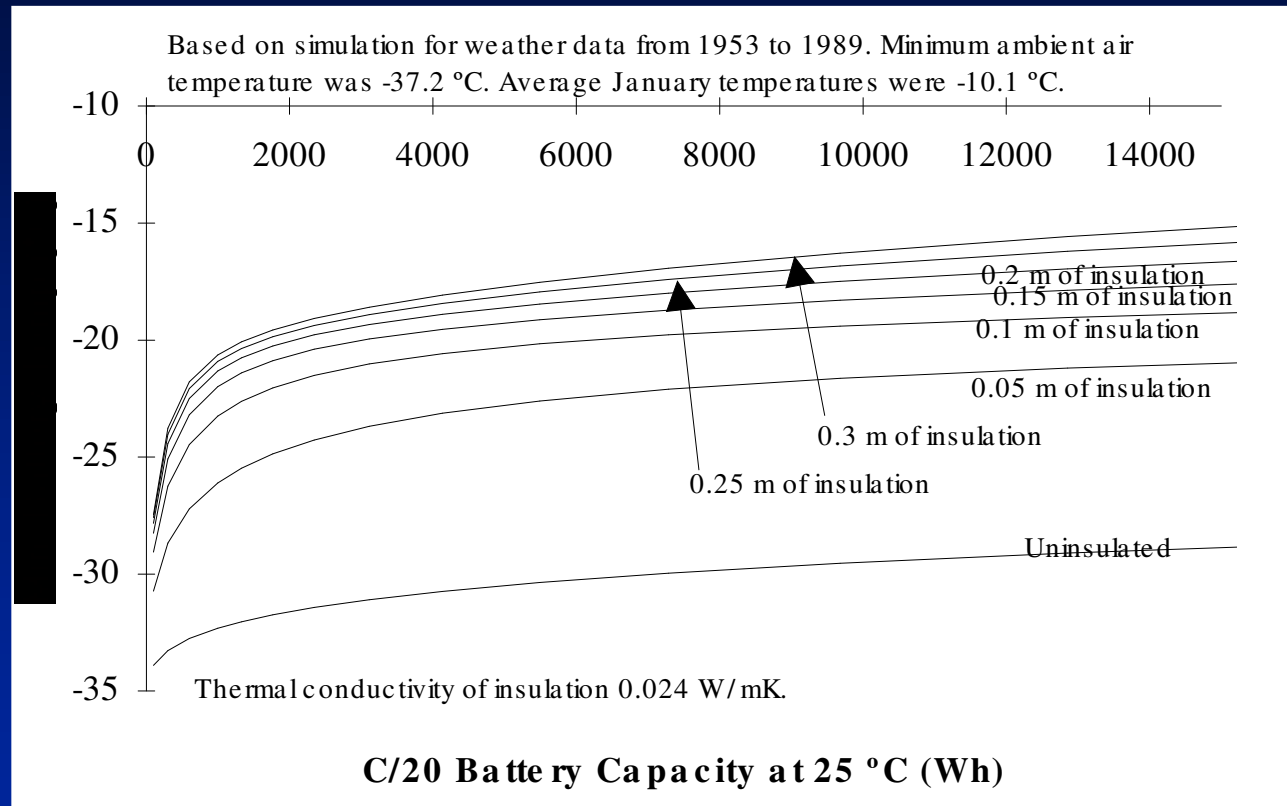
Variables--System Size and Design

- ▼ Load (large -> insulation)
- ▼ Size of the battery bank (large -> insulation)
- ▼ Array-to-load ratio (high -> heating)
- ▼ Days of autonomy (low -> insulation)

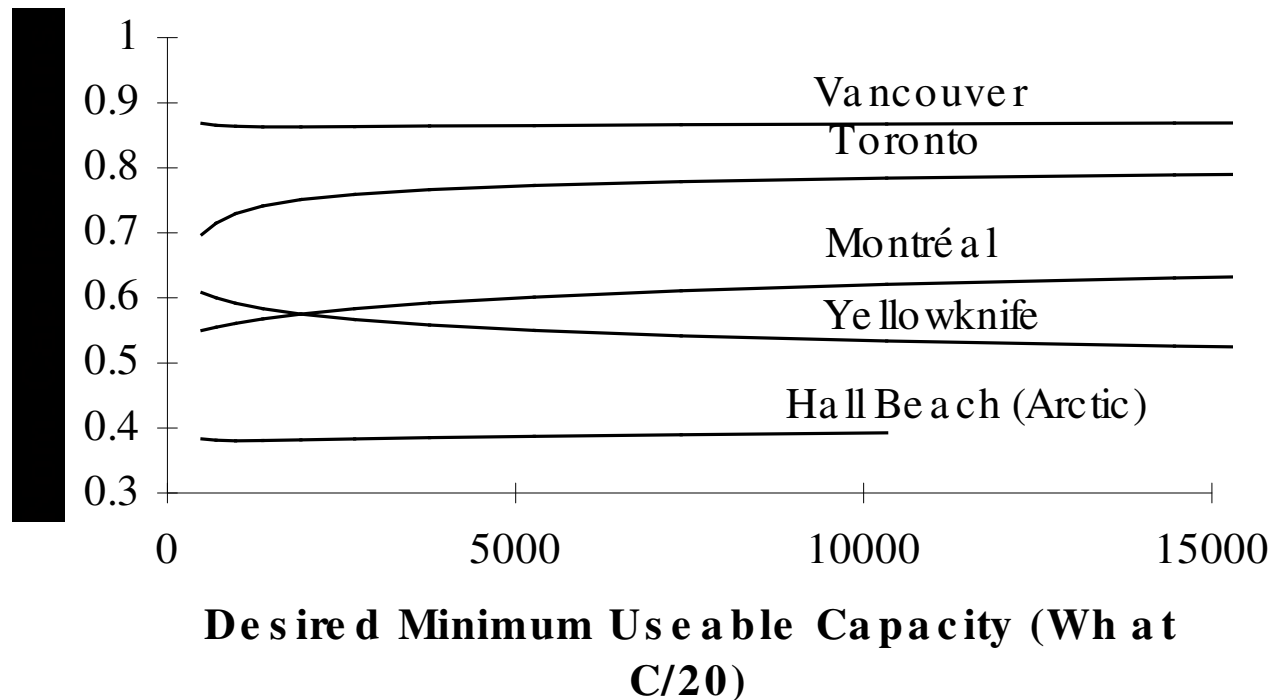


Effect of Insulation

Minimum Battery Temperatures for Various Insulated Enclosures in Montréal, Not Accounting for Battery Self-Heating



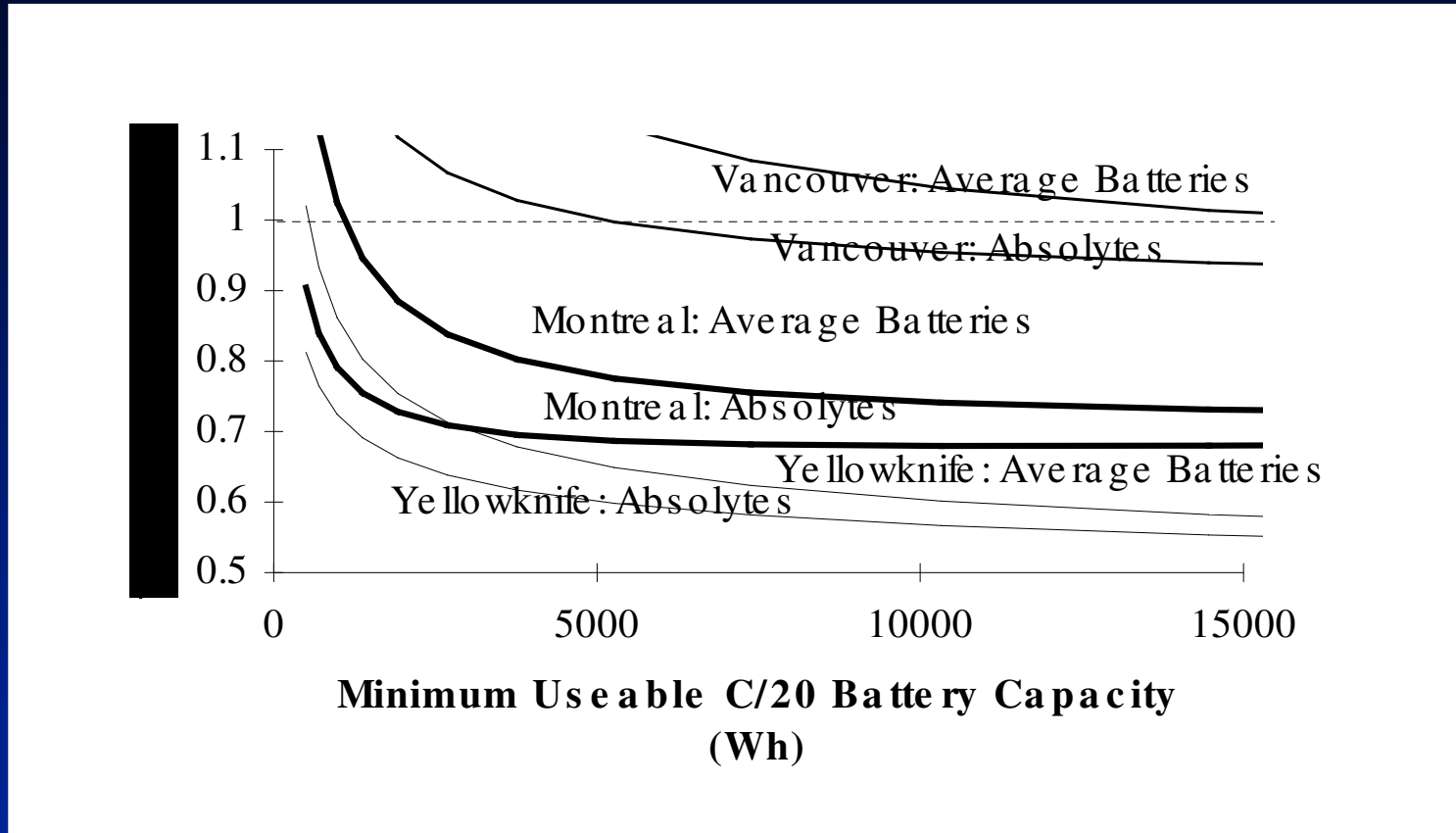
Reduction in Battery Size-- Insulated vs. Uninsulated Enclosure



Insulated enclosures have 15 cm of polyisocyanurate insulation.



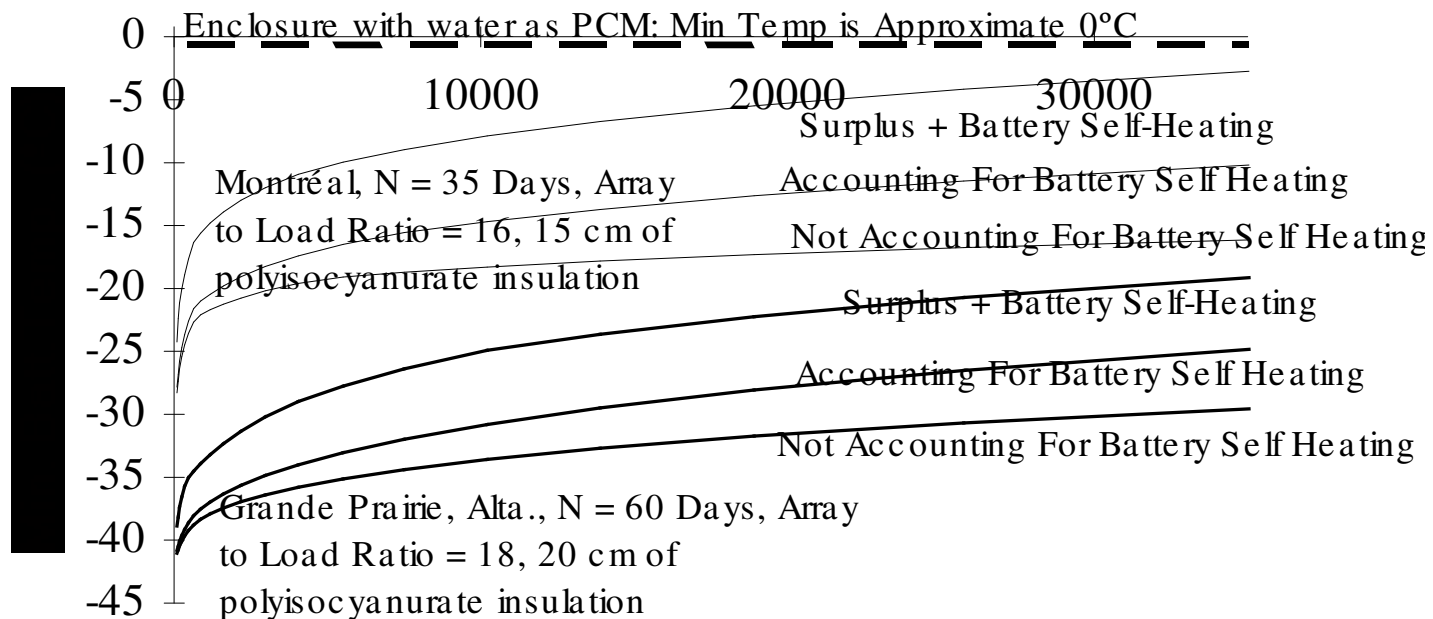
Cost: Insulated versus Uninsulated



**Total Cost of Batteries and Enclosure:
Ratio of Insulated to Uninsulated**



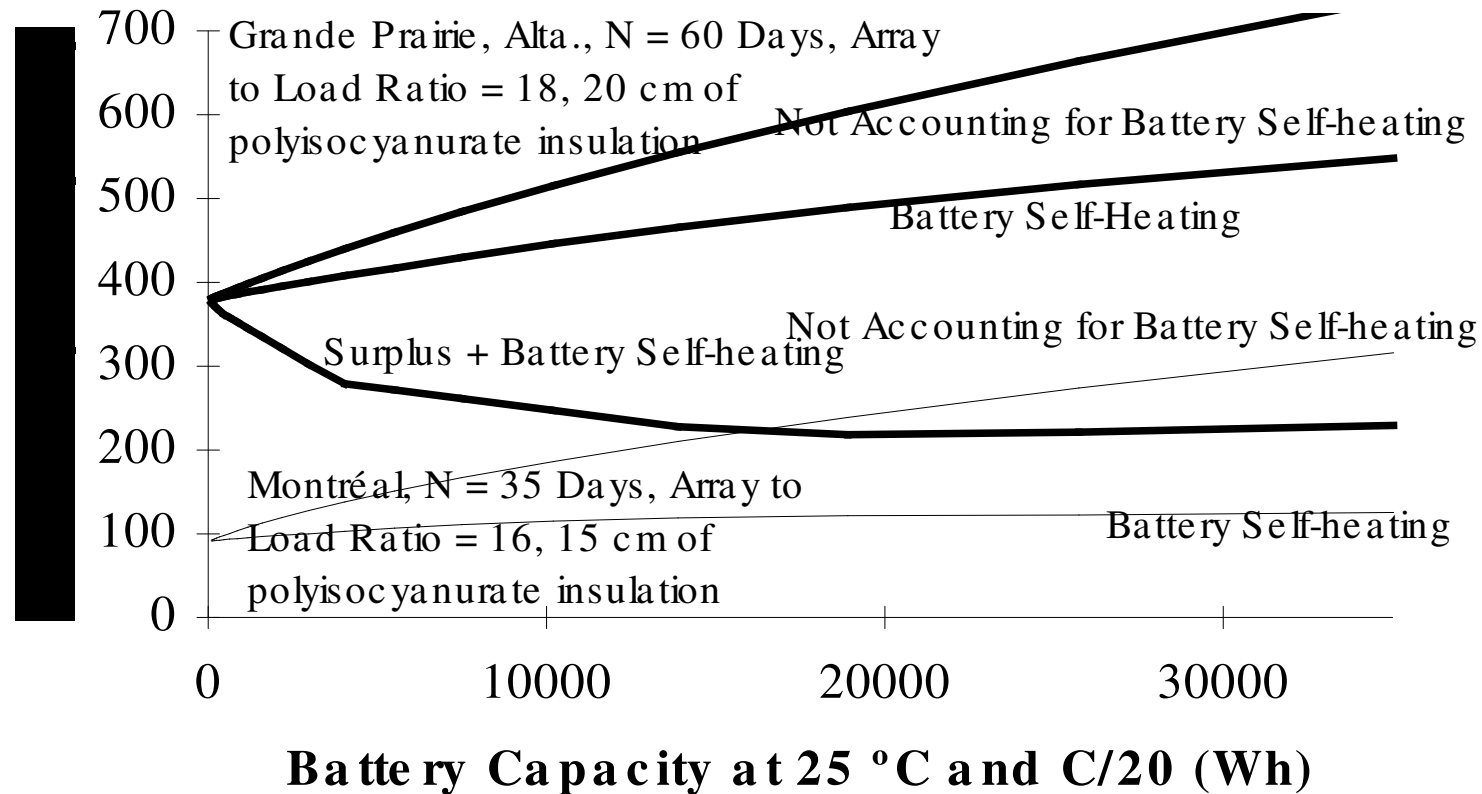
Battery Temperature: Heating and PCM



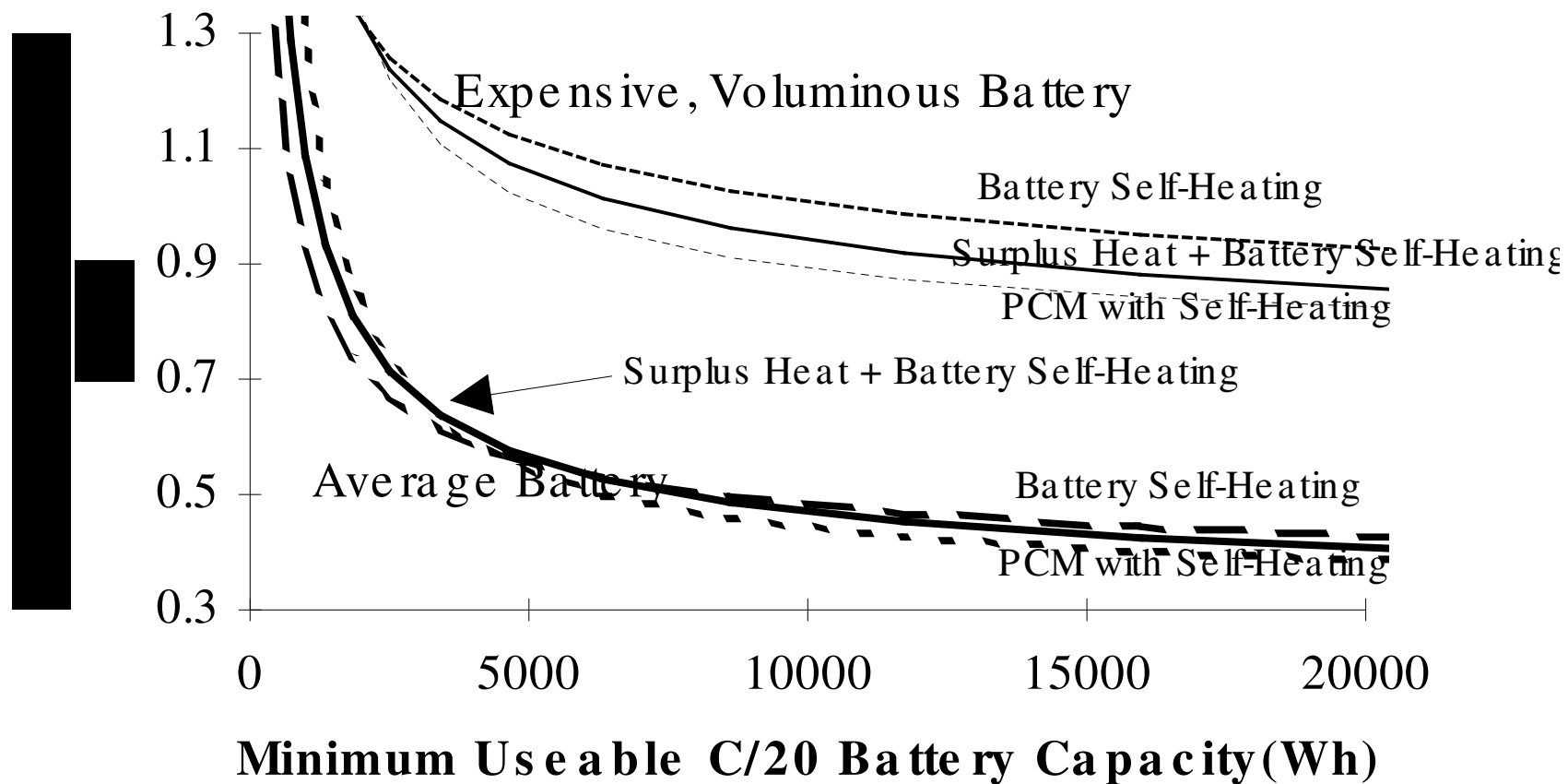
Battery Capacity at 25 °C and C/20 (Wh)



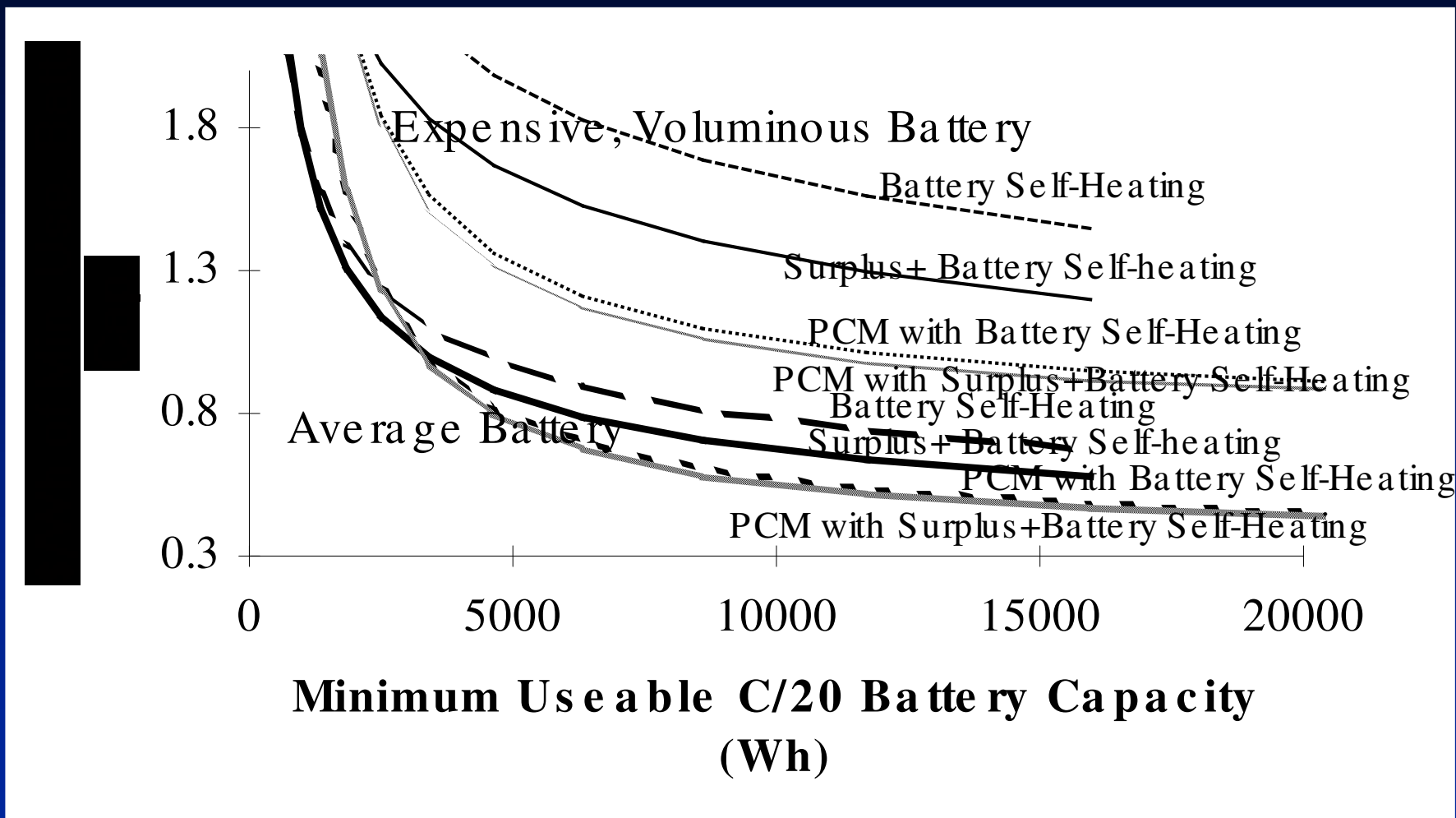
PCM Requirement



Cost per Unit Minimum Usable Battery Capacity-- Montréal



Cost per Unit Minimum Usable Battery Capacity-- Grande Prairie



Effect on Lifetime

- ▼ Will smaller battery banks cause deeper cycling and shortened battery lifetimes?
- ▼ No: in systems with greater than 6 days autonomy, cycling is not responsible for ageing
- ▼ The battery stays fully charged for all but a short period during the winter



Conclusions

- ▼ Insulation is generally cost-effective
- ▼ When battery is costly, voluminous, and site is cold, PCM makes sense
- ▼ Reducing the battery bank through the use of thermal protection will not shorten battery life

