Optimization Of Net Zero Energy Houses

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Current State Of The Art In Net Zero Energy House Design

1. Minimize envelope heat loss by using a simple architectural labor, massive amounts of insulation and a high degree of airtightness.
2. Select the most efficient types of space heating, water heating and ventilation systems.
3. Use energy efficient lighting and appliances.
4. Maximize passive solar gains (while still respecting the 6% rule).
5. Use renewable energy systems to provide the balance of the energy requirements.

However, these are largely *qualitative* guidelines with little *quantitative* detail.

What are “*massive*” amounts of insulation, what is a “*high degree of airtightness*”???

Objective Of The Study

1. To develop optimization guidelines for the design of NZEH houses based on the energy performance of various conservation options, their attendant costs and the costs of renewable energy alternatives.

* *Since almost any house can theoretically achieve near-NZEH status provided the occupants are prepared to forgo the comfort, health and safety benefits of modern housing, an implicit caveat was that the occupants should not have to live "cold, dark and unwashed".*

To Illustrate…
Consider The Envelope Design For A Typical NZEH

Ceiling R-60
Walls R-54
Basement walls R-45
Basement floor R-20
Window ER: 2.8 (picture), -7.4 (operators)

Airtightness 0.75 ac/hr_{50}
(new houses 1 – 3 ac/hr_{50}, old houses 2 – 10 ac/hr_{50})

Estimated Incremental Cost
To Achieve NZEH Performance

Building envelope measures	$26,200	(16%)
Mechanical system measures	$9,700	(6%)
PV System	$130,000	(78%)
Total Incremental Cost	$165,900	

But This Raises Some Obvious Questions…

Since the PV system was so expensive (78%)…

- Should we have used more insulation?
- Could we have used a more efficient mechanical system?
- Would a larger thermal solar system have made sense?
- In other words…Was the design optimized from a cost perspective?

????

Which Leads Us To…

Observation #1 – Designing a Net Zero Energy House is easy.

Observation #2 – The challenge is designing a NZEH house to achieve its energy goal without spending excessive amounts of money.

Cost Optimization

Getting the most bang for your buck.

The process of selecting Energy Conservation Measures (ECM’s) and renewable options based on their costs and performance such that the incremental cost of upgrading the house to NZEH performance is as small as possible.

Therefore, we need performance metrics to evaluate the various options…

Performance Metric #1

ECM Value Index

$$= \frac{\text{(Incremental cost of the ECM)}}{\text{(annual energy savings)}}$$

= $ / (kWh/yr)

In other words, it is the cost of installing an ECM which will save 1.0 kWh per year.

ECM Value Index

Select values (Winnipeg, medium-sized house):

0.35 - Upgrade airtightness from 1.50 to 1.00 ac/hr$_{50}$
0.60 - Reduce base loads from 24 to 18 kWh/day
2.46 - Upgrade walls from RSI 7.57 to 8.81 (R-43 to R-50)
5.12 - Increase thermal mass
14.3 - Increase south-facing glazing area from 6% to 7%
18.3 - Upgrade basement slab from U/I to RSI 1.76 (R-10)

Performance Metric #2

PV Value Index

= (PV System Cost) / (annual energy production)
= (\$/W) / (kWh/yr•W)
= \$ / (kWh/yr)

Substitute the current (2008) PV System Cost (\$9/W) and performance (1100 Wh/yr per W) to get the cost to generate 1.0 kWh per year…

= [(9 \$/W) / (1100 Wh/yr•W)]
= \$8 per kWh/yr

In other words, the cost of installing a PV system capable of producing 1.0 kWh/yr would average about \$8.

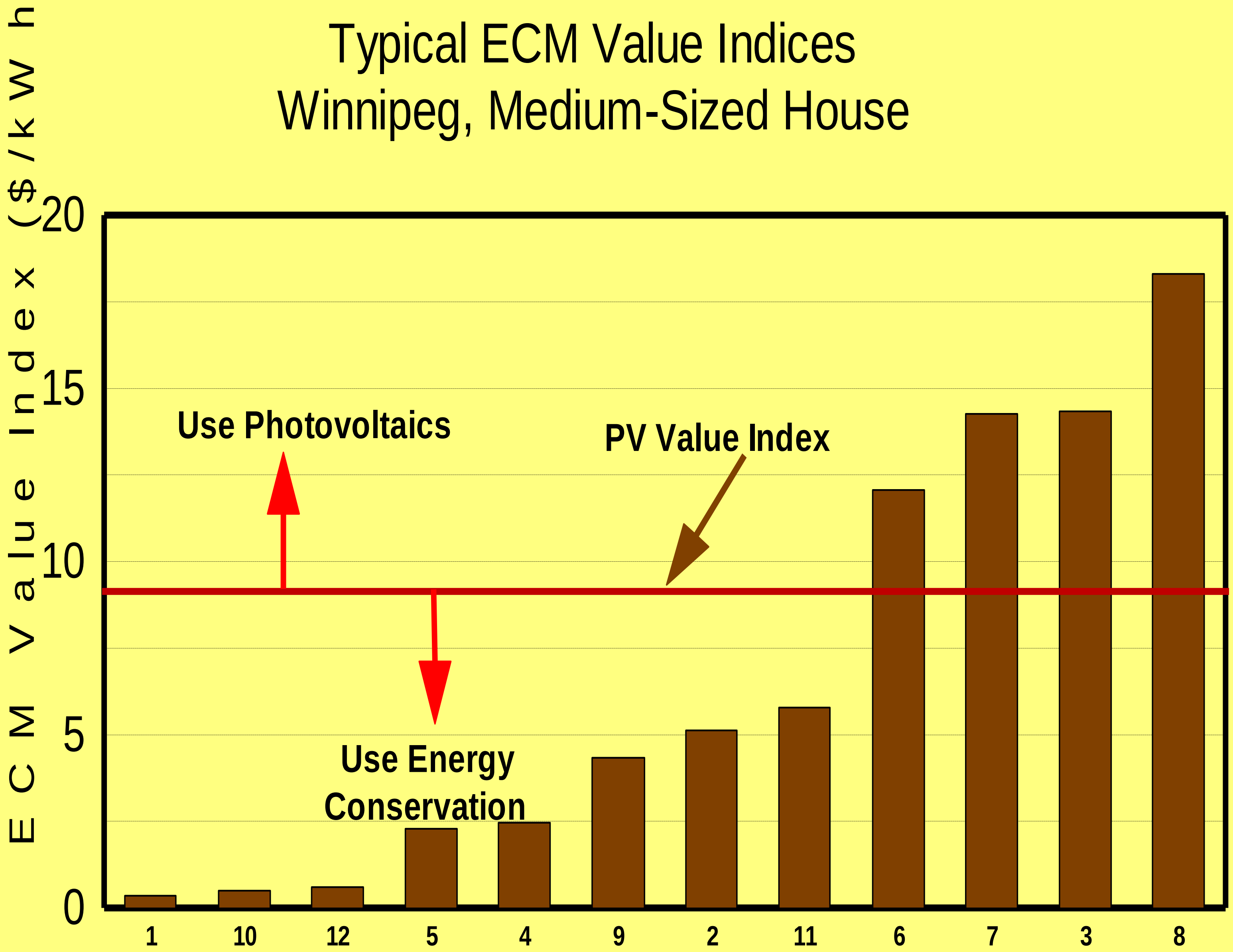
Using The ECM And PV Value Indices

Notice that the PV and ECM Value Indices have the same units ($/(kWh/yr)) and can be compared directly to each other.

Both define the investment required to save1.0 kWh/yr, whether through conservation or photovoltaics (renewables).

This gives us a tool to determine when further investments in conservation should be abandoned and re-directed to photovoltaics (or other renewables).

Typical ECM Value Indices
Winnipeg, Medium-Sized House



Advantages Of Using
The ECM And PV Value Indices Approach

- Both have equivalent environmental advantages and disadvantages.

- No knowledge is required of future conditions such as:
  - Interest rates
  - Amortization periods
  - Energy escalation rates, etc

What Was Done For The Optimization Analysis…

Three archetype houses were created ranging in size from 112 m^2 (1200 ft^2) to 279 m^2 (3000 ft^2). All were conventional, merchant-built designs, but upgraded to “typical” NZEH standards.

Insulation & airtightness levels were typical of levels found in NZEH houses in Canada.

Each was modeled in four climate zones:

- Maritime (Vancouver, 2925 Celsius Heating DD)
- Prairie (Winnipeg, 5900 DD)
- Eastern (Toronto, 3650 DD)
- Northern (Yellowknife, 8500 DD)

What Was Done (con't)…

A list of approx. 50 ECM's was assembled and their costs estimated.

Each ECM was then modeled for each house/location combination.

The Value Index was then calculated for each of the 12 house/location combination.

Finally, the ECM Value Index was compared to the PV Value Index ($8/kWh/yr) to determine the cost-effectiveness of each ECM relative to the photovoltaic option.

Design Guidelines For Net Zero Energy Houses

- Using this process, design guidelines were established for each of the 12 house/location combinations.
- The guidelines can be used by designers to create a first draft of the energy-related, design features of the house.
- Once these have been identified, the actual, proposed house design can be modeled and the design fine-tuned.
- The Value Index data can be modified to reflect local costs.

Example – Winnipeg, Medium-Sized House

Guidelines:

Thermal mass – light or medium weight framing, or heavy masonry.

Airtightness – 0.50 ac/hr_{50}, or as tight as possible.

Walls – RSI 10.57 (R-60)

Attic – RSI 14.09 (R-80)

Basement walls – RSI 4.23 (R-24)

Basement slab – RSI 1.76 (R-10), perimeter only

Heating – Electric or GSHP, COP=3.0

DHW – Conservation package, GWHR, thermal solar

Ventilation – High efficiency HRV

Base loads – 40% of R-2000 defaults (i.e. 9.6 kWh/day)

Some Other Conclusions From The Study

Cost of energy – Utility rates have no impact on the design or construction of a NZEH – provided the utility will purchase energy at the same rate as it sells it to the house.

From earlier example…

Energy Consumption: 12,214 kWh x 6.3¢/kWh

= $769

Energy Production: 12,403 kWh x 6.3¢/kWh

= $781

Some Other Conclusions (con’t)

Passive solar – The cost-effectiveness of purchasing additional south-facing glazing was very poor (Value Indices typically ranged from 10 to 50).

Some Other Conclusions (con't)

Passive solar – These poor Value Indices suggest that passive solar may not be as important to the design of NZEH as first thought.

Likewise, high performance windows had a poor cost-effectiveness.

Recommendation – use a "good" window, with a high Temperature Index to resist condensation.

$$I = [T - T_c] / [T_h - T_c] \times 100$$

Some Other Conclusions (con't)

Airtightness – Very cost-effective. A design goal of 0.50ac/hr$_{50}$ was recommended.

Walls – Optimum insulation levels ranged from RSI 5.28 (R-30) for maritime climates to about RSI 10.57 (R-60) for prairie or northern climates.

Base loads – One of the most cost-effective means of saving energy.

Any Questions??