We can slow climate chan technology for new const residential buildings

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Quote for the lecture:

“Our Age of Anxiety is, in great part, the result of trying to do today’s jobs with yesterday’s tools.”
—Marshall McLuhan

Comment from the authors:

“Yesterday’s thinking!”

To accelerate an outcome, we must demonstrate a future technology is more than an improved current technology

Proposed future technology:

(1) must alleviate current problems

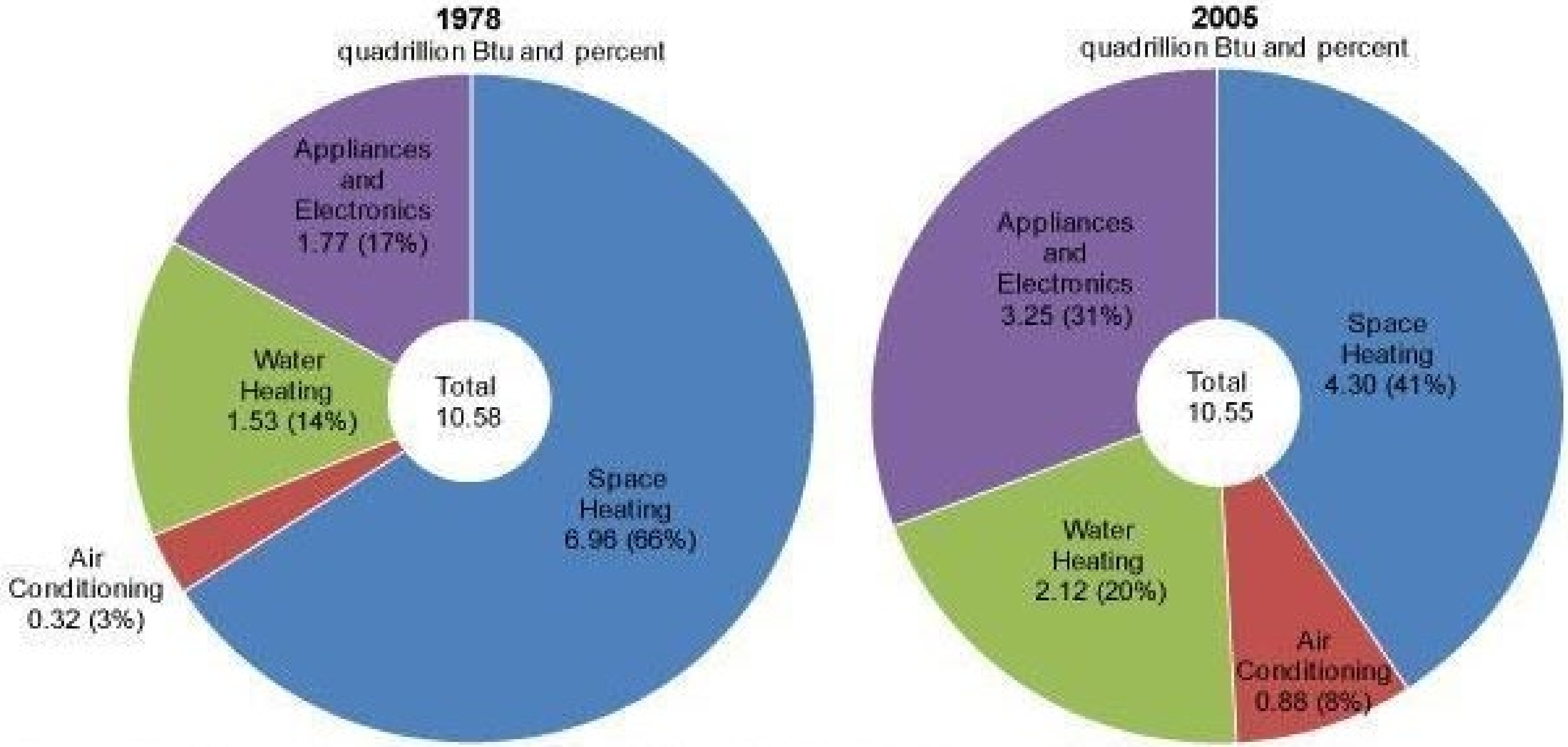
(2) must be affordable

(3) In contrast to today's technology must significantly reduce the cost of a ton of CO_2.

Seven critical aspects of transition in construction

- Energy use is not being reduced as fast as expected
- Constant room temp. eliminates thermal mass effects
- There is no ecological definition of low energy buildings
- We need to introduce thermal storage and building automatics
- There is no reference building for the cost comparison
- There is no systematic organization of building research
- There is a misfit between occupant expectancy and the retrofits

Effect of fragmentation: Total energy used by residential buildings in the US in 1978 and 2005



With the reduced space heating, the comfort components became increased and the total energy use was not changed

One must satisfy first the occupant needs

- Until occupant needs are satisfied, all heating or cooling energy savings are used to improve occupant comfort.

- It has been established that occupants want to have control of their own environment and all critical controls must be provided. (automatics with manual override)

Ecological definition of a low energy building (LEB)

An ecological definition of a LEH includes:

1. A building with a heat pump device.
2. Solar panels, (hybrid), or other source of renewable energy
3. Thermal mass, (short-term thermal storage)
4. Long-term thermal storage (geothermal or a water tank)

Introducing thermal storage may also require building automatics

- Solar panels and water-sourced heat pump provide primary energy for heating, domestic hot water, and long-term energy storage.
- Air supply to the mechanical room comes either from geothermal preheat (climatic network) or from open air supply depending on temperature difference between these sources and the need.
- In all cases the building automatic controls make decisions in selection of the routes..

Required features of the LEB

Let us reiterate, the low-energy buildings must include heat pump (HP), (a Water Sourced HP), and solar panels, both integrated with a short and long term thermal storages.

LEB also should use adaptable indoor climate, unless air sources HP is used.

LEB also should be provided with a monitoring system and building automatic controls capable to use local weather predictions for their monitoring & modeling performance evaluation (MAPE) system.

Power of automatics to reinforce the effect of renewable sources

- In 1990, we added a building scientist with the energy modeling capability to the design team

- In 2020, we are adding a building automatics expert and the second air cavity between the old wall and new interior assembly. Environmental quality management (EQM) system that include durability, indoor environment and occupant comfort becomes the key to the next generation of construction and retrofitting technology.

A reference building must be in the same climate, socio-economic conditions and have similar building services as a proposed building

A reference building is necessary for comparing the cost because the cost of new technology may often be unpredictable.

In airtight, well-insulated High Environmental Performance (2007, Syracuse, NY), floor hydronic heating used 822 kWh/yr, while the energy predicted for the air-borne heating was 7,011 kWh/yr. Cooling was measured 2.7 MWh /yr, while only 1 MWh/yr was predicted in the traditional estimates.

Another example was the Saskatchewan Energy Conservation House, designed by the University of Illinois and built by Saskatchewan Research Council to demonstrate the new concept of passive technology

The anatomy of a failure

Why the world’s first passive house did not cause a technology change?

Case study: 1st passive house in North America 1978 U., designed and built in Regina, Canada

What happened to the passive house technology in Canada 1978

- Canadian builders accepted air tightness and more insulation but changed the heating to baseboard electrical heating to reduce the cost.
- Effects: flue-less heating caused changes in the efficiency of natural ventilation. Sick building syndrome, condensation on upper floors.
- In effect, the Canadian Building Code in 1985 required mechanical ventilation for all residential buildings

The features of the demonstration building are important

Builders are not scientists. Construction is market-driven, knowledge is used only for solving problems. The technology demonstration must allow them to repeat design without changes.

The Canadian technology demonstration was not affordable, and the applied modifications lead to its failure.

For success in the marketplace, one must understand all interactions that shape building field performance.

There is no systematic organization of building research

There are practical limits of exterior wall air-tightness. While floors and ceilings do not need any limits, too tight exterior wall requires continuous mechanical ventilation.

Some air leakage is desirable, but too much unplanned air leakage destroys system energy efficiency.

There is a need for developing practical guidance on recommended airtightness in relation to the regional climate and variable ventilation rates

Misfit between the occupant expectancy and retrofits

1. The focus on energy efficiency is not enough. The needs of homeowners such as health, resilience, affordability, maintenance, and environmental aspects must also be satisfied.

2. Retrofit must be treated as an investment and it must integrate project financing, design management and support services.

Welcome to the next generation of building and retrofitting technology

Paradigm changes and stepwise improvements

The current situation: an urgent need for public contribution to public education

National, public-private programs in Canada, US and Japan in 1980s ended some 20 years ago with realization that climate change is Priority One.

Yet, despite we are not prepared for dynamic analysis that is critical for controlling climate change, there is no public education in construction technology. The stagnation of thinking was demonstrated as the paralysis under pandemics.

Now is the time return to public education to address new construction paradigms needed for the next technology

Today's challenge to slow climate change looks like asking each American family to buy a car in 1910.

In 1910, cars were produced individually, *as we do today for most residential buildings*.

With today's dollars, the 1910 price would be US$ 25,000, and Ford has sold 19,000 cars.

In 1920, with a production line operating and manufacturing experience, the cost went down to US$ 5,000, and Ford sold 941,000 vehicles

Today, carbon emission cost about US$100 per ton of CO_2 , but if you reduce deep retrofit cost by 33% and increase the volume of retrofit 33% the cost of carbon emission may fall down to US$11.

Retrofitting: problems and solutions

Problem: A deep retrofit with the current technology is incomplete and too expensive

Solution: design an affordable building engineering solution following concepts of Ford model T

We postulate that one needs a multi-disciplinary, universal, affordable, next-generation building technology that can modify the cost-benefit relationship by at least 30 %.

Construction problem – lack of keeping with the modern thinking

- For 5000 years, being focused on improving materials, we let someone else to assembly them. Today, with zero energy and carbon emissions we must embrace new design paradigms.
- It has been started by introducing the IDP (integrated design protocol) to design building as a system.
- In new design materials are selected for a building assembly to achieve its function. Today, advanced material science makes it easy to modify materials for their service function.
- We use two names: EQM (environmental quality management) and ETA (ecological, thermo-active) technologies. The first one is a public domain and the second one a proprietary subset with critical elements protected by patents.

1. Paradigm shift – Building value depends on indoor environment and occupants' well-being

"If I had asked people what they wanted, they would have said faster horses."

Henry Ford

Cost / Sq. M. Floor -Year

- Energy Cost: $20.00
- Maintenance: $30.00
- Taxes: $30.00
- Rent: $300.00
- → "Productivity" $3000.00

Lawrence Berkeley National Laboratory

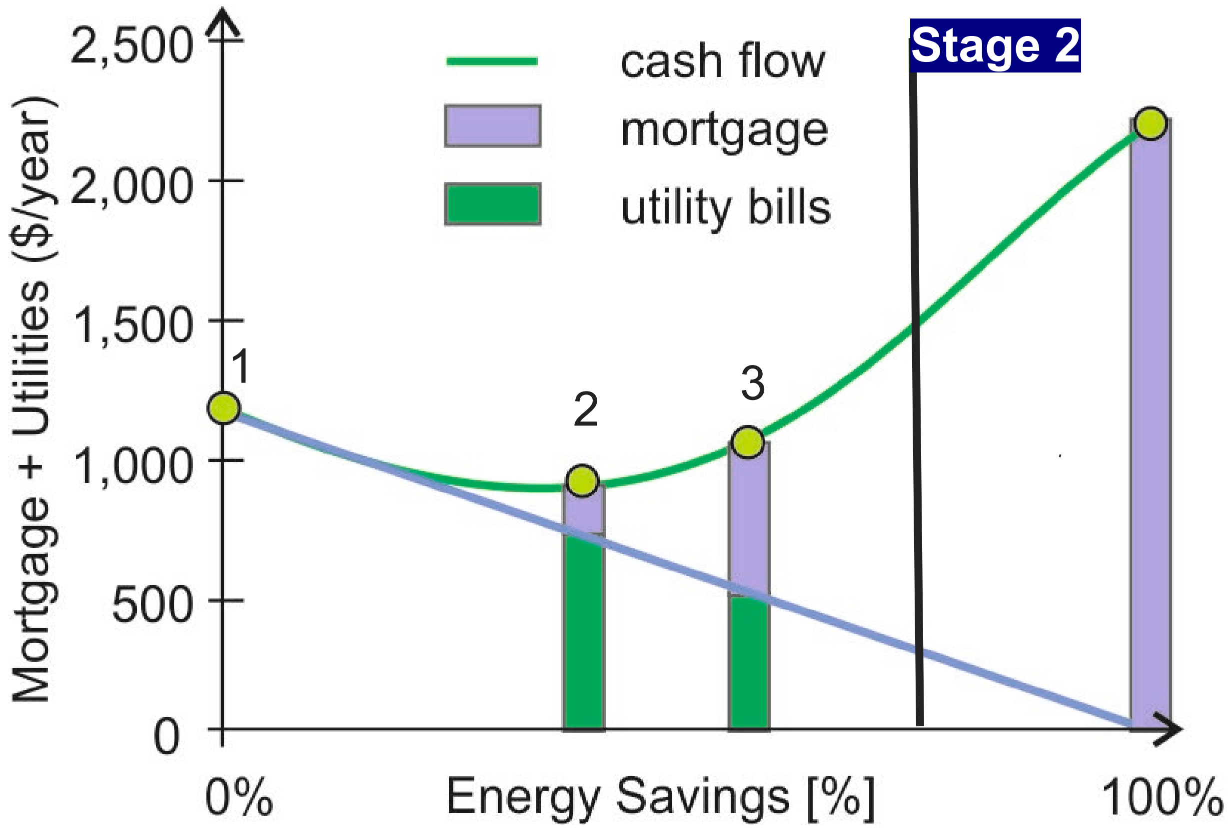
2. A two-stage construction is needed to alleviate conflict between an investor and the society

The conflict between society (climate change) and investors (limited funds)

Solution: A two-stage construction process

Design for both stages, Stage One to the level required by the codes, Stage Two financed on the merit of the investment value goes to ZE (zero energy) or ZER (zero energy ready)

Two-stage construction concept



Costs of utilities (green) and mortgage (blue) versus energy savings from zero to 100% savings.
1 = the reference, 2 = optimum for passive measures, 3 = PV cost equal to passive measures.

Atelier Rosemont in Montreal, Canada (social and luxury dwellings together) was built over 10 years in 5 stages

10-year of adding sustainable features, credit *L'OEUF s.e.n.c.*

1. High Performance enclosures, solar walls provided 36% reduction
2. Gray water power - the cumulative energy reduction grows to 42 %
3. Heat pump heating - all passive measures resulted in 60% reduction
4. Domestic hot water with evacuated solar panels to achieve 74%
5. Photovoltaic panels reduce energy to arrive at 92%

3. The invention of a climatic district system to replace district heating

1. Using water-sourced heat pumps and sending return water to the next building may save operational costs by providing a higher coefficient of performance than that for a separate heat pump device.

2. An investment process introducing climatic district system for preconditioning water and ventilation air increase efficiency of the investment and eliminate the difference between buildings and city districts.

Discussion on the EQM/ ETA technology with an occupant in center of the design

• The advantages of EQM/ ETA system

1. The coefficient of performance for water-sourced HP and nominal 55 °C ranges 4 to 4.4 while for air to water HP it ranges 2.5 to 3.0
2. Low exergy heated water, not suitable for heating, can be used for long-term thermal storage.
3. Efficiency of heat exchange in wall applications is higher than in floor applications.
4. Using building as a system provides much more trade-offs than for building enclosure in traditional approach.

Difference between floor and wall location, numerical simulation and measurements

Table: Energy Demand of Radiant wall Panel and Radiant Floor

Radiant Type	Heating Demand (GJ)	Cooling Demand (GJ)
Radiant Wall Panel	58.37	23.74
Radiant Floor	98.19	31.03

Table: Measured characteristics of universal wall panels

Air pressure, Pa	Amount , m^3/h	Surface output, W/m^2
4	1.45	106
8	2,95	1.07
12	**4.47**	**1.08**

In mild climates, the ground thermal capacity is almost sufficient for winter

In the Hungarian house, a simple water pump was used instead of water-sourced heat pump (note: air has insufficient thermal capacity.)

In severe cold or warm climates, two HP, periodically loaded from solar or other sources.

An operating temperature is 55 °C

EQM/ ETA technology combines theory and practice

Confusion caused by different approaches to new and old housing disappears when all buildings are considered as an economic value.

One should encourage monitoring and model performance evaluation (MAPE) to operate building automatics control systems

One should encourage integrating automatics with large data handling capability and realather input for predictability of energy under field conditions

EQM/ ETA summary

An integrated system of testing and modeling provides input of real climate and material properties

In a durability evaluation, one develops a damage function in the laboratory and uses it in the performance models. We will use this pattern of inquiry in the building performance evaluation.

EQM/ ETA system can be applied in-situ or with either heating/cooling or heating/cooling/ventilation panels

Definition of zero carbon emission

A zero-carbon emission building is a highly energy-efficient building in which carbon-free renewable energy or carbon offsets are used to compensate for the annual carbon emissions from building materials and operations. With time, they exceed the carbon emissions embodied in the original construction process.”

To achieve zero carbon emissions, we need real-time energy performance models

Solution for numeric models:

1. co- simulation of air and energy or field data verification
2. Monitoring and neural networks/Artificial Intelligence

Some examples from Cracow U of T: temperature control under steady-state, uncertainty less than 1.4%

Indoor environment: calculating PMV control under steady-state, uncertainty less than 4%

Covid 19 pandemics brought the need to modify ventilation in all countries

Traditional ventilation used a dilution of the pollution. With one air change in three hours for low energy house, there was a long period for a virus exposure. In EQM/ETA technology we use variable ventilation rate and filtration.

The need for upgrading ventilation is the reason for the authors to call for the sweeping changes in construction RIGHT NOW !

Closure: Paradigms used in EQM/ ETA technology

Paradigm shifts
in transition to
the next generation of
sustainable buildings

1. Creating functional blocks: water heating, water transmission, wall exchangers, monitoring and perf. evaluation, ventilation air

- Introducing indoor environment and occupant well-being as the basic criterion and dividing technology into functional blocks for its optimization for climatic and service conditions is a paradigm shift number one.
- Heating vs climate varies from a small HP to a large heat pump with two tanks in a closed or open circuit, connected with gray water system.
- Monitoring and Building Automatic Control (BAC) constitutes parts of MAPE (monitoring and performance evaluation) system

2.Thermal mass (short-term thermal capacity)

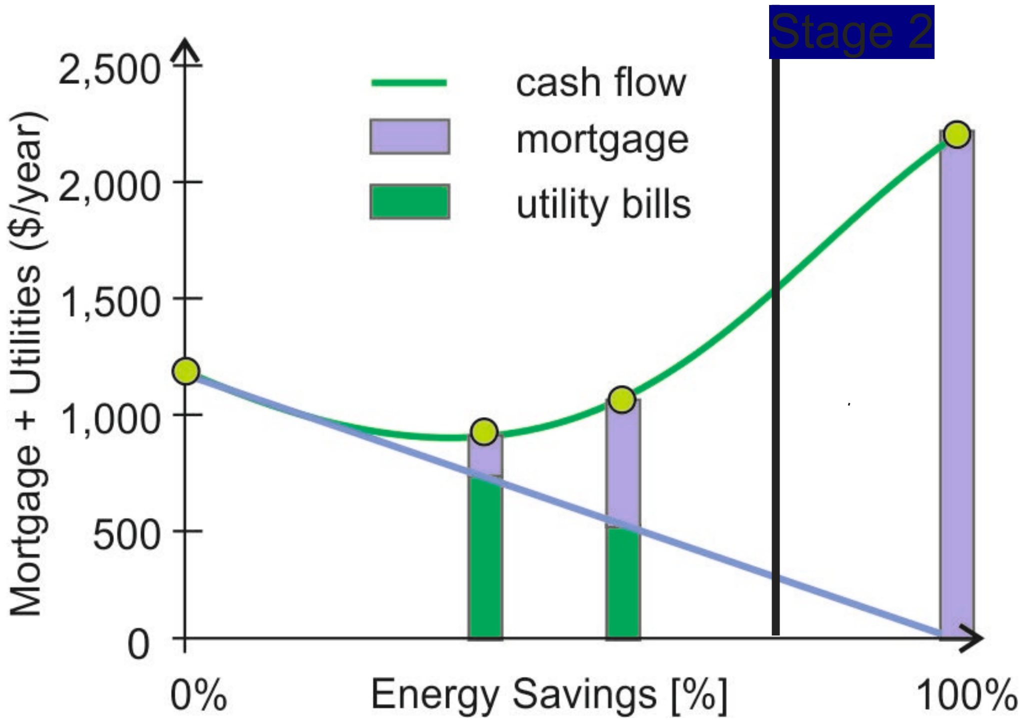
- For an effective collaboration with the smart grid, we need thermal capacity about 14 hours, making energy uptake from the grid at the end of nigh periods.
- Thermal mass is only used in the daily calculations of energy needs.
- Thermal mass relates mostly to the interior of the building.The exterior walls have lower effect and can have low thermal capacity.

3. Rechargeable, long-term thermal capacity

Technical trade-offs increase the efficiency of the construction process. Yet, to compare economic value of super-insulation with energy generation by solar panels and heat pumps we must analyze the whole system in various climates on hourly basis.

Rechargeable function is achieved with a lower quality of solar panel output or with additional energy production by the heat pump

4. Two-stage construction concept



Costs of utilities (green) and mortgage (blue) versus energy savings from zero to 100% savings.
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5. Climatic district network

1. Heating water from Building One is sent to Building Two and functions as a low terminal of the heat pump.

2. An invention of climatic district system to replace the district heating not only brings preconditioning of air and water and eliminates the difference between buildings and city districts

Final conclusions

1. While we need to change paradigm of thinking and develop retrofitting with view to slowing climate change, yet the building technology alone can't solve the problem
2. As a national priority issue, we need to create a national public-private consortium that includes public education & publicity
3. For the covid protection, in the new retrofitting technology. one must use air filtration
4. Using a gradient of air pressure in dwellings is beneficial, yet it also requires handling of humidity.
5. These are issues that could be included in the DoE Building America program.

End of the presentation: see published paper

Thank you for your attention