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Charting a Course to Energy Independence

Providence, RI
August 9-12, 2009

Toward NetZero Installations

Dr. Alexander Zhivov
US Army Corps of Engineers
Engineer Research and Development Center
Champaign, IL

Current Federal Building Energy Requirements

- The 2005 Energy Policy Act requires that Federal facilities be built to achieve at least a 30 percent energy savings over the 2004 International Energy Code or ASHRAE Standard 90.1-2004 as appropriate, and that energy efficient designs must be life cycle cost effective.
- All SRM Projects for major renovations of existing and new Army facilities shall comply with the requirement of EPACT 2005 to reduce energy consumption by 30% compared to a facility designed in accordance with ASHRAE 90.1-2004 (UFC-3-400-01).
- Building modifications are classified as a major renovation if the cost of renovation project exceeds 25% of the building value with the project including all or some of the following elements: alteration of overall features of the building's envelope, substantial replacement of the building's lighting, plumbing, electrical, and heating, ventilating, and air conditioning (HVAC) systems in combination with other significant alterations of the building's spaces.

EISA 2007

New buildings and buildings undergoing major renovations shall be designed so that consumption of energy generated offsite or on-site using fossil fuels is reduced, as compared with such energy consumption by a similar building in fiscal year 2003 (as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency), by the percentage specified in the following table (EISA 2007):

Fiscal Year	Percentage Reduction
2010	55
2015	65
2020	80
2025	90
2030	100

FEMP is drafting a ruling providing interpretation of EISA 2007.

Whatever interpretation will be, by 2030 newly constructed buildings and buildings after major renovations shall use Zero energy from fossil fuels.

From the 2009 ASHRAE Presidential Address

2% of Building Projects in the USA are New Construction

86% of Construction Dollars go into Existing Buildings

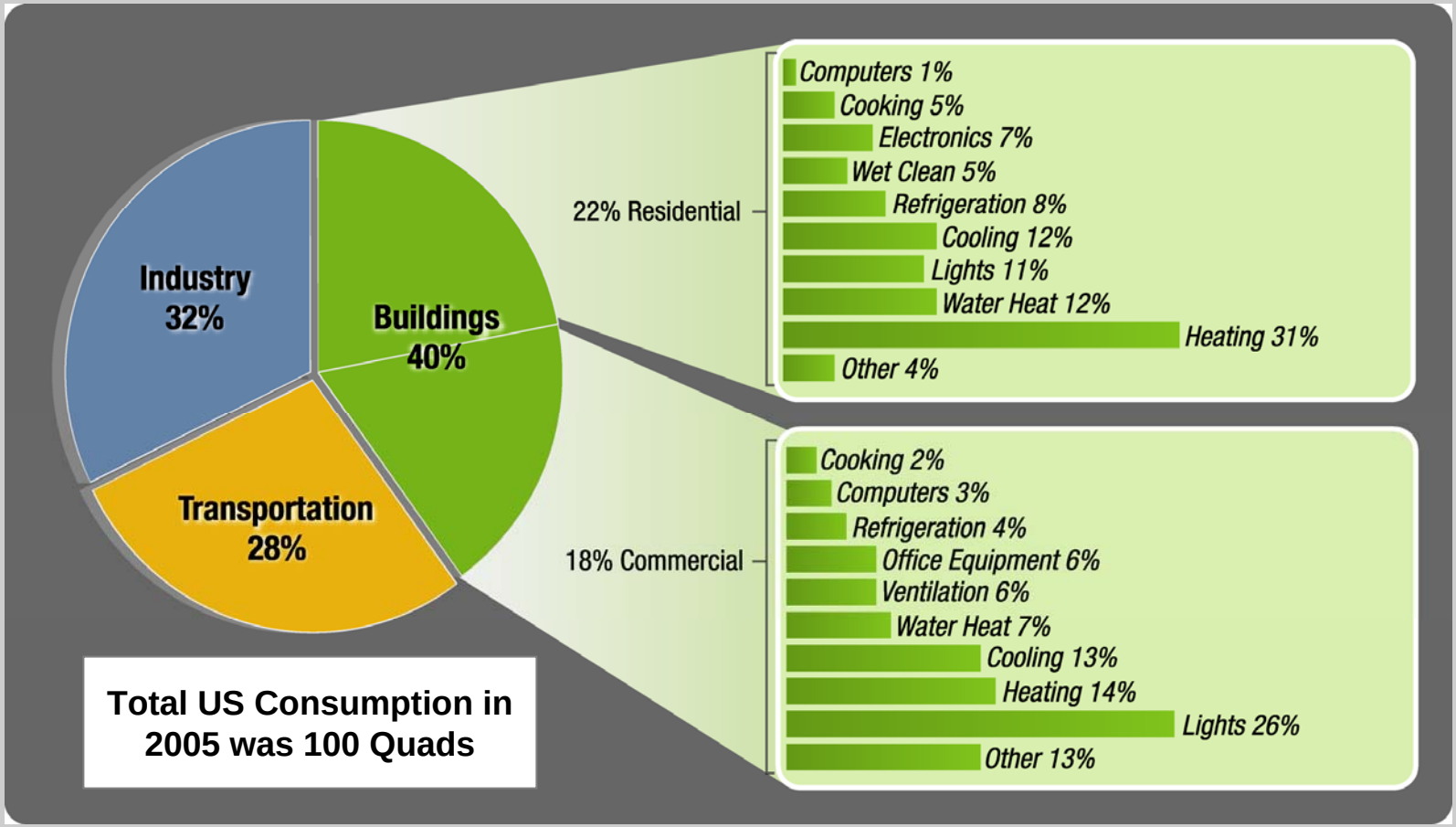
75% to 80% of All Buildings That will Exist in 2030

Exist Today!

Can we get from where we are now to NZEB in 21 years with the "business-as-usual"???

- Buildings we are constructing to-day with the requirement to be 30% more energy efficient compared to ASHRAE Std. 90.1 will be there in 21 years and probably be less efficient than they are now (with a current level of maintenance and no re-commissioning)
- ESPC projects addressing only low hanging fruit (improved efficiency of lighting, electrical, HVAC systems, controls, BEMSs..), will fail to reduce energy consumption at a current rate (not mentioning the rate required by EISA 2007) and will become less economically attractive
- SRM Projects typically don't address energy conservation

Buildings Sector Aaccounts for About 40% of US Energy, 72% of Electricity, 55% of Natural Gas.



Source: B*uildings Energy Data Book*, September 2007, Tables 1.1.3, 1.1.6, 3.1.1, 3.3.1, 4.1.5, 5.1.2, 5.3.1

Major Energy Users

- Lighting
- Heating
- Cooling
- Dehumidification
- Domestic hot water
- Building Processes (e.g., data centers, training facilities, dining facilities, hospitals, etc), and
- Appliances (refrigerators, dryers)

Energy conservation, energy generation, renewable energy sources, NZEB…. ???

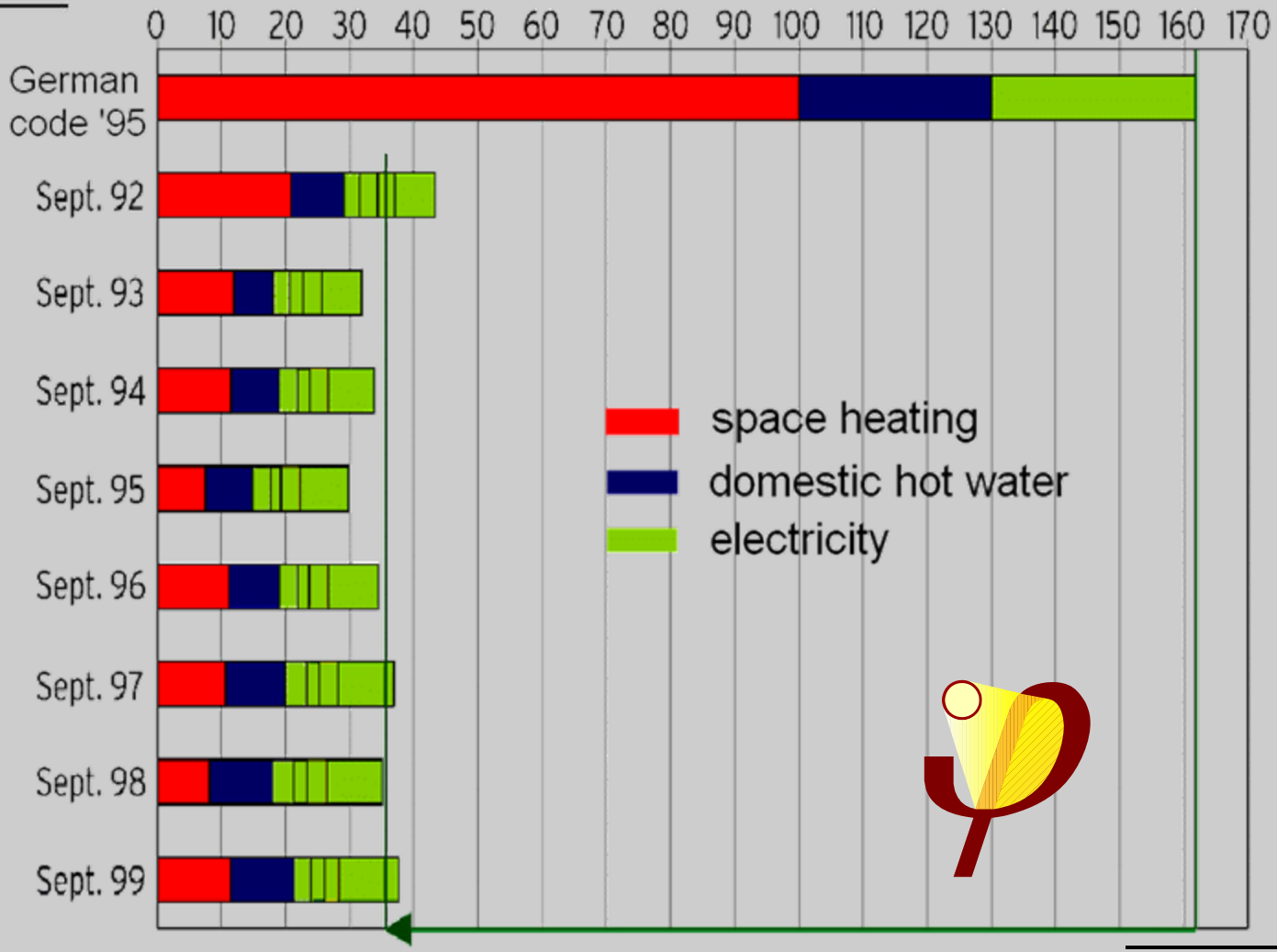
- USACE/DOE/ASHRAE Study showed that 30-35% energy reduction from the ASHRAE 90.1 2004 level can be achieved by using currently available technologies and best design and construction practices at no or minimal additional cost (< 2%);
- In Central Europe, energy reduction in residential buildings up to 90% was achieved in more than 10,000 buildings by using better insulation, airtight building envelope, triple-pane low-e energy efficient windows, energy recovery from exhaust air, advanced lighting and appliances, advanced district systems with cogeneration at a first cost increase < 10%;
- In North American climates, energy reduction beyond 35% (up to ~70%) in addition to European technologies requires **advanced cooling and dehumidification technology**. Main contributor to increased cost are advanced windows, lighting, advanced appliances.
- Between ~70% and 100% of fossil fuel reduction will require the use of central systems with integrated renewable sources of energy and thermal and electrical storages.

What we need to focus on?

- Energy Conservation?
- Energy Generation ?
- Renewable Energy Sources?
- NZE Buildings?

Energy Conservation Beyond 30%

Between 1992 and 2008 more than 10,000 passive houses (< 10KWh/m²yr thermal energy) were constructed in Germany, Austria, Sweden, Italy, USA…



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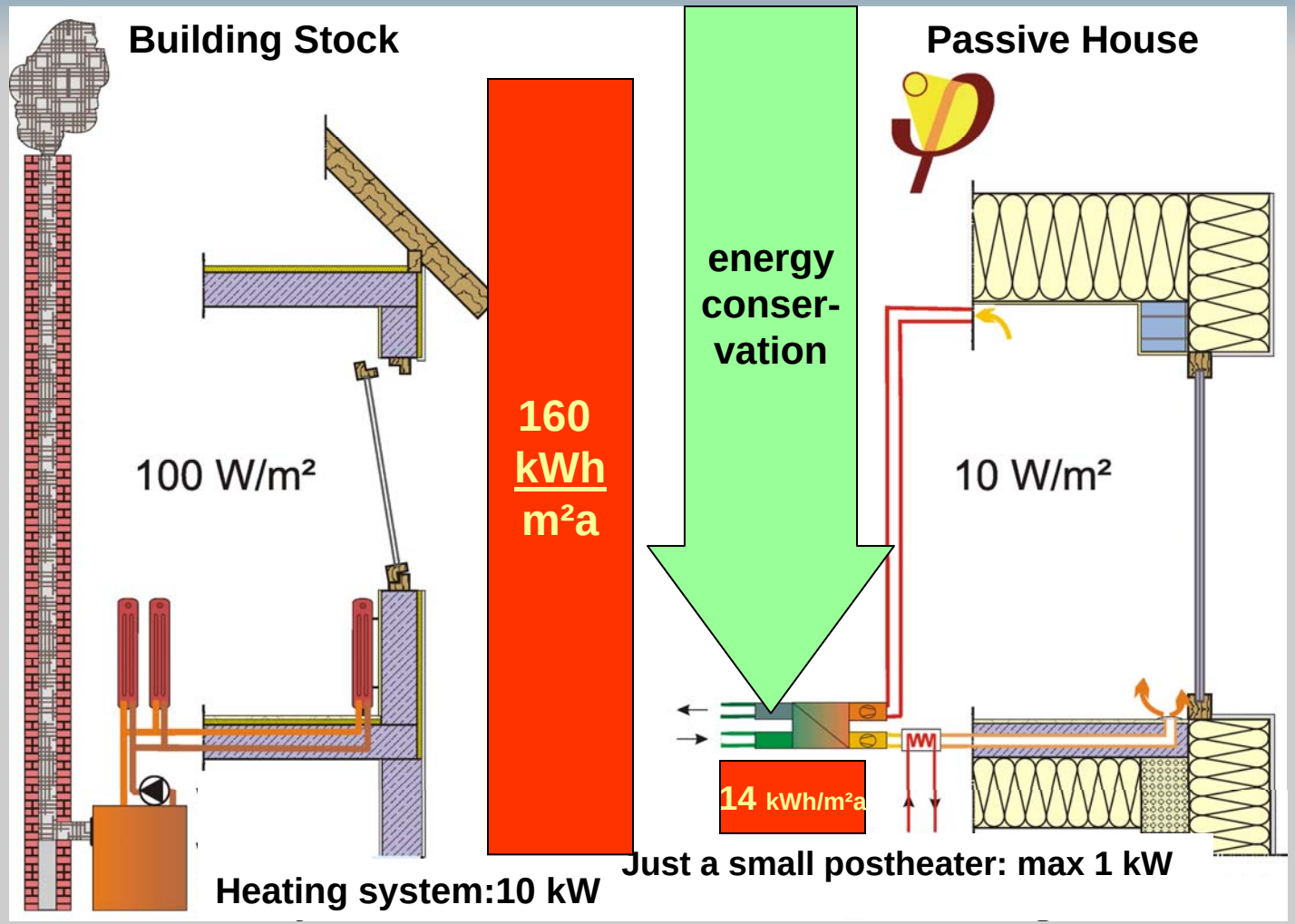
Building Stock
Passive House
energy conser-vation
160 kWh m²a
100 W/m²
10 W/m²
14 kWh/m²a
Heating system:10 kW
Just a small postheater: max 1 kW

Examples of Passive Houses

„Passivhaus“ new multifamily blocks Darmstadt, 2007 (above) and 2008 (right)

Total budget increase < 10%

Integrated building refurbishment: 38 kWh/m² (11.7 KBtu/ft²) primary energy consumption (Volkswohnung, 2002)

146 $/ft²

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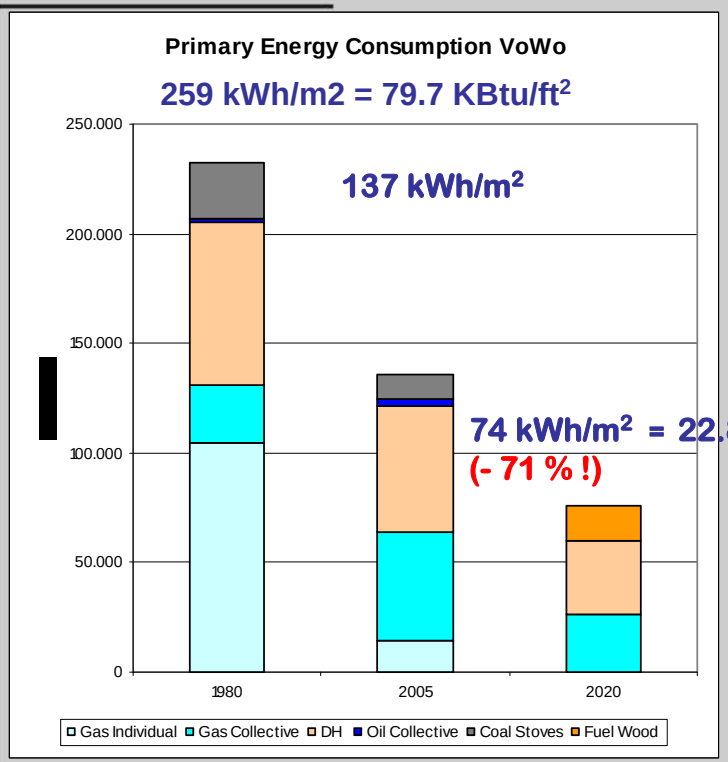
Case Study: Volkswohnung's (Karlsruhe, Germany) Retrofit Program over 35 Years:

Volkswohnung: 14.000 appartments in 460 buildings
retrofit program: 25 M €/year

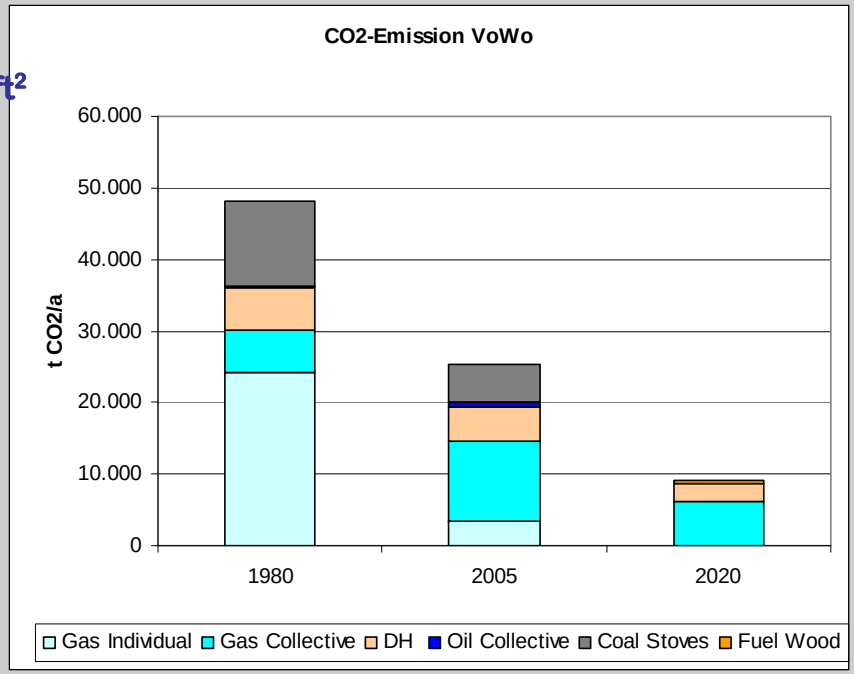
→ **City of Karlsruhe:**

- ~ **12 % of heating demand**
- ~ **3 – 4 % of PE consumption**



… big step for Volkswohnung,

small step for the city …



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Examples of Multi-Family Building Retrofits in Karlsruhe, Germany

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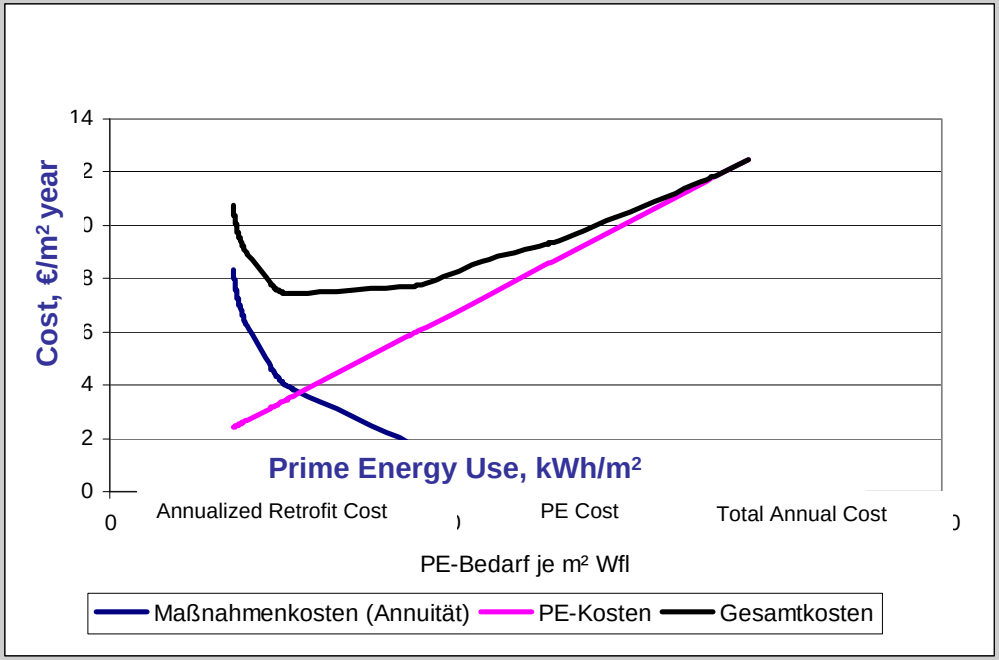
How far Energy Use Reduction is Cost Effective ?

From Dr. Reinhardt Jank, 2009



Conclusion:

- reduction of heating demand below 40 – 50 kWh/m^2 (11.4 -14.3KBtu/ft^2) results in steep increase of costs what shall be further improvements ?

→ Next steps are to look into Energy Supply System Optimization and Reneawable Sources of Energy!

Technologies for Low Energy Buildings

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Advanced Technologies for NZE Buildings

Passive

- Well-insulated envelope
- Minimized thermal bridges
- Airtight construction
- Energy efficient windows (3- or 4-panes)
- Air-to-air heat exchanger
- Heat exchange of waste water by heat pump and heat exchanger
- Passive solar gains
- Thermal mass
- Pre-heating of ventilation air by buried pipes

Active

- Exhaust air heat pump
- Ground source heat pump
- Solar water heating and PV
- Fuel cells
- Small-scale CHP using biomass

Energy Conservation Technologies

Annex 46 Database with ~400 Energy Conservation Technologies

Annex 46 ECO Search - Microsoft Internet Explorer provided by PWGSC - TPSGC

http://annex46.iea-tech-env.com/rpts/Categories.aspx

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

Annex 46
Energy Conservation Opportunities

Home Search Reports

Home : Reports : Categories

ECO Category Counts

Code	Description	#Ecos
BP	Building Processes	62
DI	Distribution	58
E	Envelope	41
ES	Electrical Systems	10
HV	HVAC Systems	63
L	Lighting	46
M	Miscellaneous	13
OP	Operation	43
R	Renewable Energy	1
W	Water	40

Annex 46 Administration - Microsoft Internet Explorer provided by PWGSC - TPSGC

http://annex46.iea-tech-env.com/editor/EcoAdmin.aspx

Home : Edit : ECOs

Search by Category: Building Processes
Search by SubCategory: All SubCategories
Search by Building Type
Search by Level
Search by Climate

All SubCategories
General Process Improvement
Process Control
Welding
Plating and metal finishing
Painting
Heat treat
Maintenance
Catering Facilities
Photo processing
Swimming pools

1 2 3 4 5 6 7

	#	Level	Cat	Title	Bldg	SubCat
Select	318		BP1	Reduc ng the process		40
Select	319		BP2	Reduce cost of product or service by eliminating waste		40
Select	320		BP3	Optimize maintenance costs to increase capacity utilization		40
Select	321		BP4	Increase process throughput by reducing cycle times		40
Select	322		BP5	Optimize yields by reducing off-specification product		40
Select	323		BP6	Reduce scrap/wastage/breakage by modifying the process causes		40
Select	324		BP7	Reduce rework by not taking short cuts that make rework		40
Select	325		BP8	Reduce downtime by optimizing planning and scheduling		40

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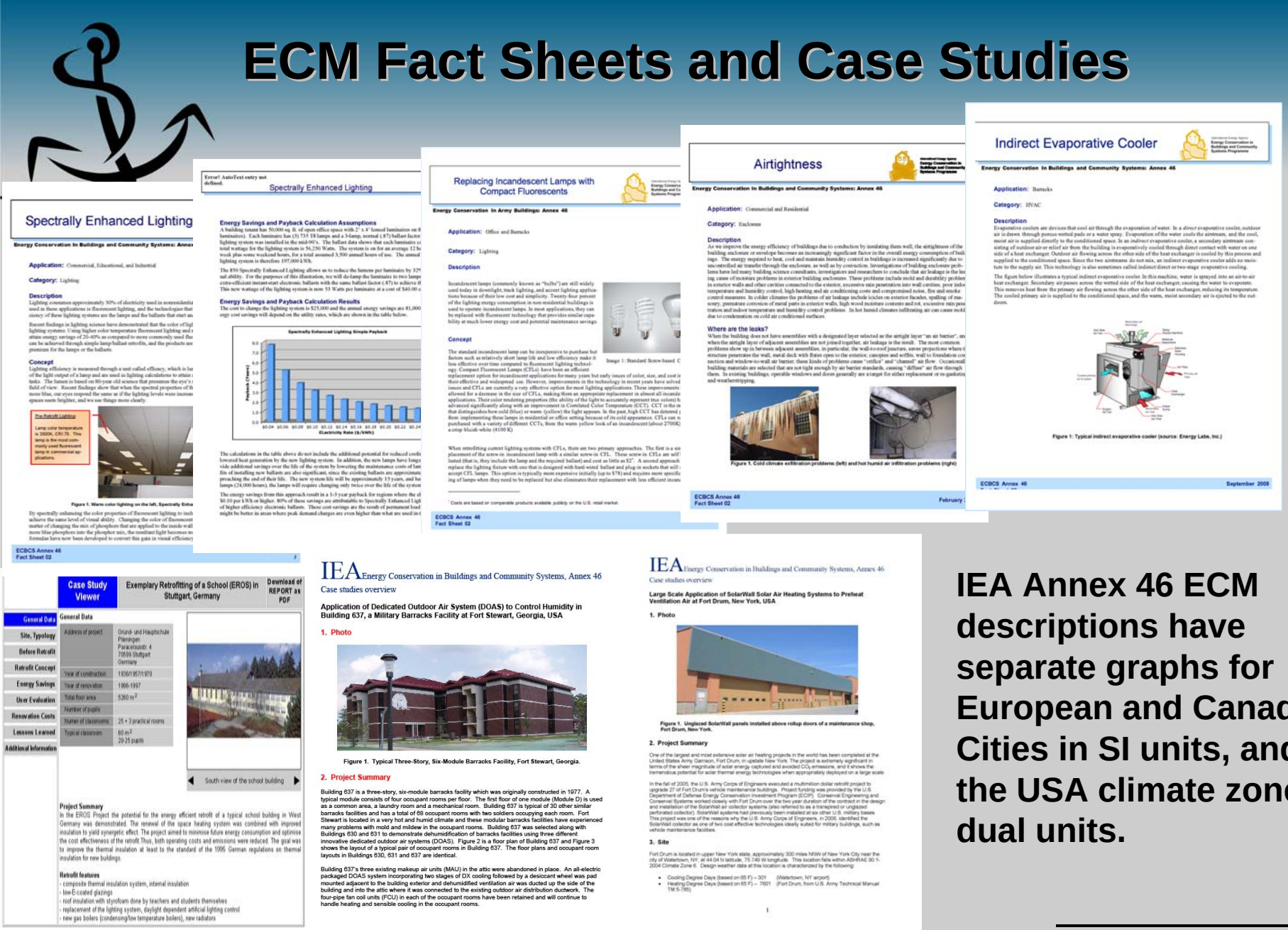
ECM Fact Sheets and Case Studies



IEA Annex 46 ECM descriptions have separate graphs for European and Canadian Cities in SI units, and for the USA climate zones in dual units.

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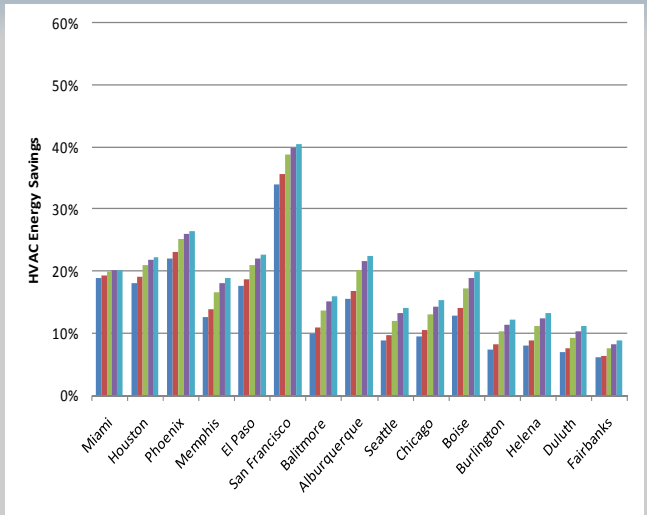
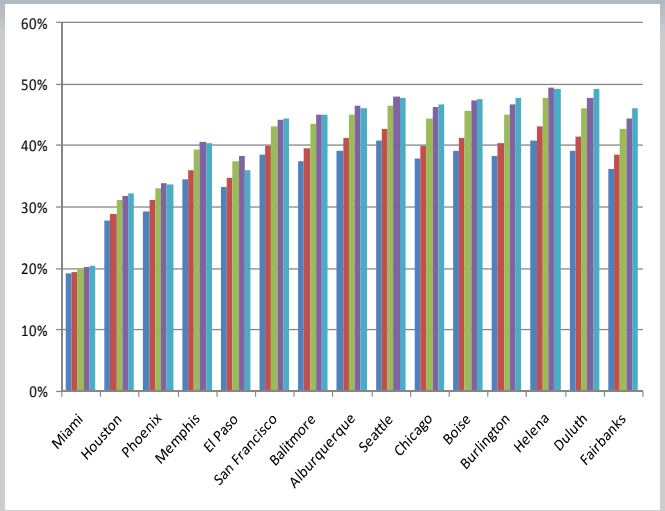
Effectiveness of Additional Insulation

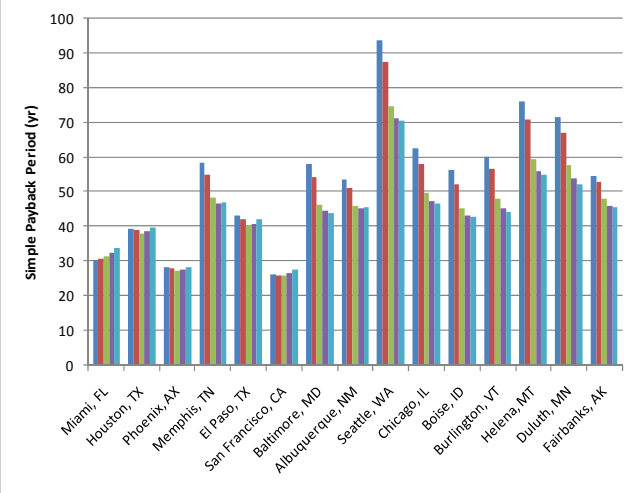
ASHRAE Standard 90.1-1989 baseline

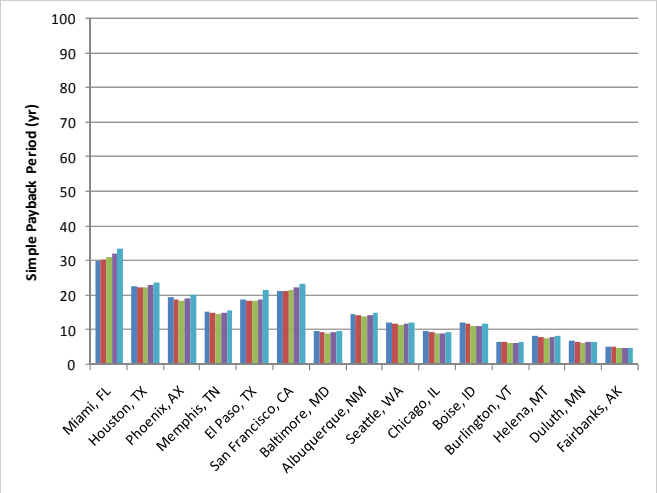


Prior to 1970 baseline



1 Inch 2 Inch 4 Inch 6 Inch 8 Inch





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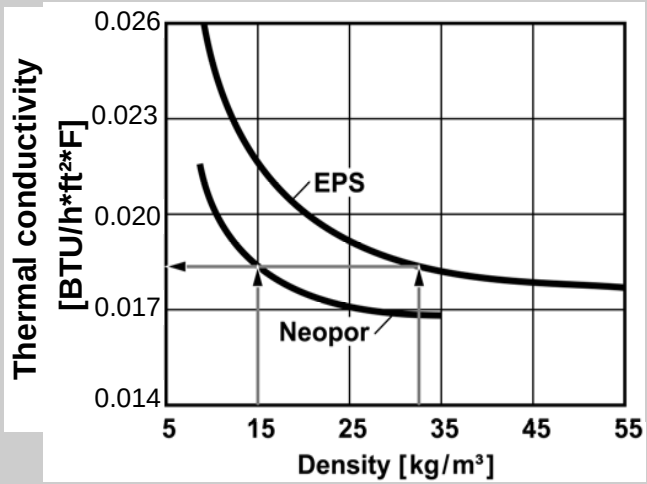
Examples of Advanced Building Envelope Insulation

Higher insulation thickness/lower thermal conductivity: mineral wool/polystyrene with with thermal conductivity of 0.030/0.035 instead instead of “regular” 0.040 W/mK

Graphite embedded EPS
- reduction of the radiant heat transfer
- reduction of the conductivity by 20 %

Vacuum insulation systems



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BE Insulation: Cost-benefit Analysis

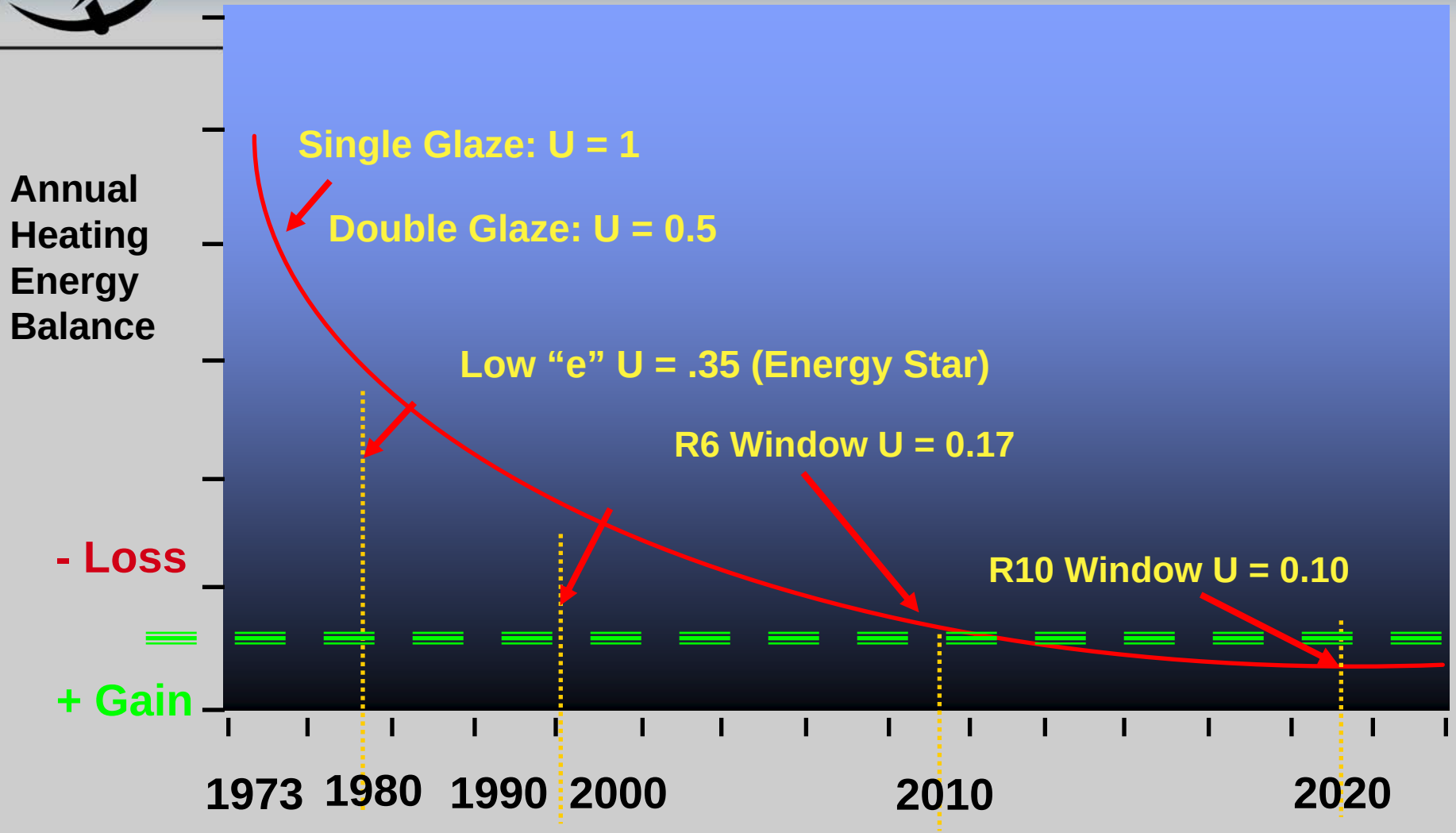
(usage period: 20 years) FI BP presentation in Chicago, 2009)

Innovative system	Average costs for the saved energy in 20 years [€/kWh]
Higher insulation thickness*	0.08
Graphite embedded EPS**	0.12
High performance plaster systems**	0.63
Vacuum insulation systems**	0.20
Light wedges***	0.12
Transparent insulation material**	0.35
Solar walls****	0.03

* compared to thickness according to requirements
** compared to conventional insulation material of same thickness
*** electrical lighting savings
**** used as preheating of a ventilation system, calculated without extra costs for mech. ventilation systems

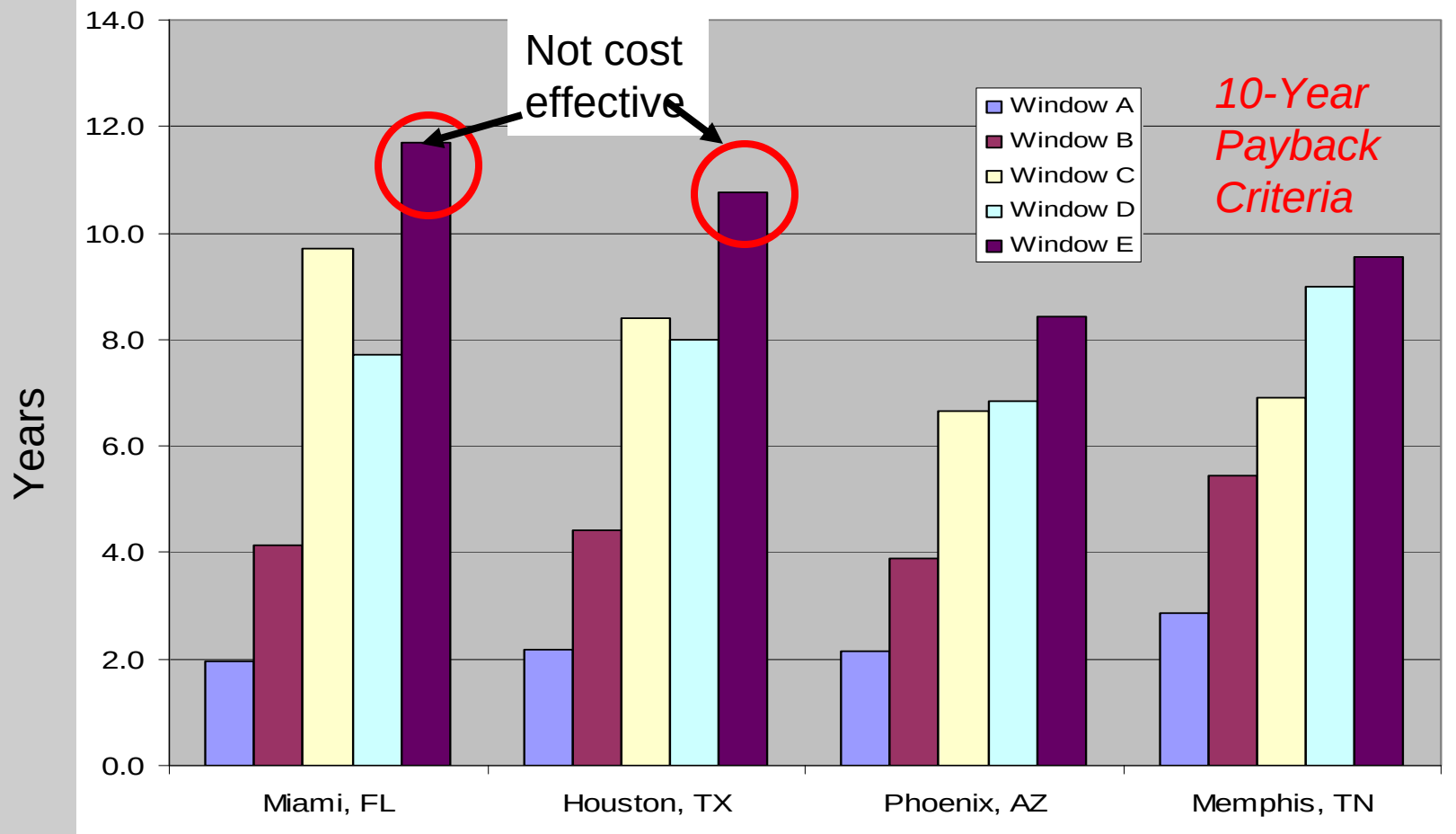
For comparison: gas: 0.08 €/kWh; district heating: 0.06/kWh; (consumption related costs only)

Advanced Windows
(LBNL presentation in Chicago, 2009)



New Construction and Major Renovation or Repair Project

Modeled payback results - upgrading to <u>premium quality</u> replacement windows vs. current baseline quality replacement windows (Zones 1A, 2A, 2B, and 3A)



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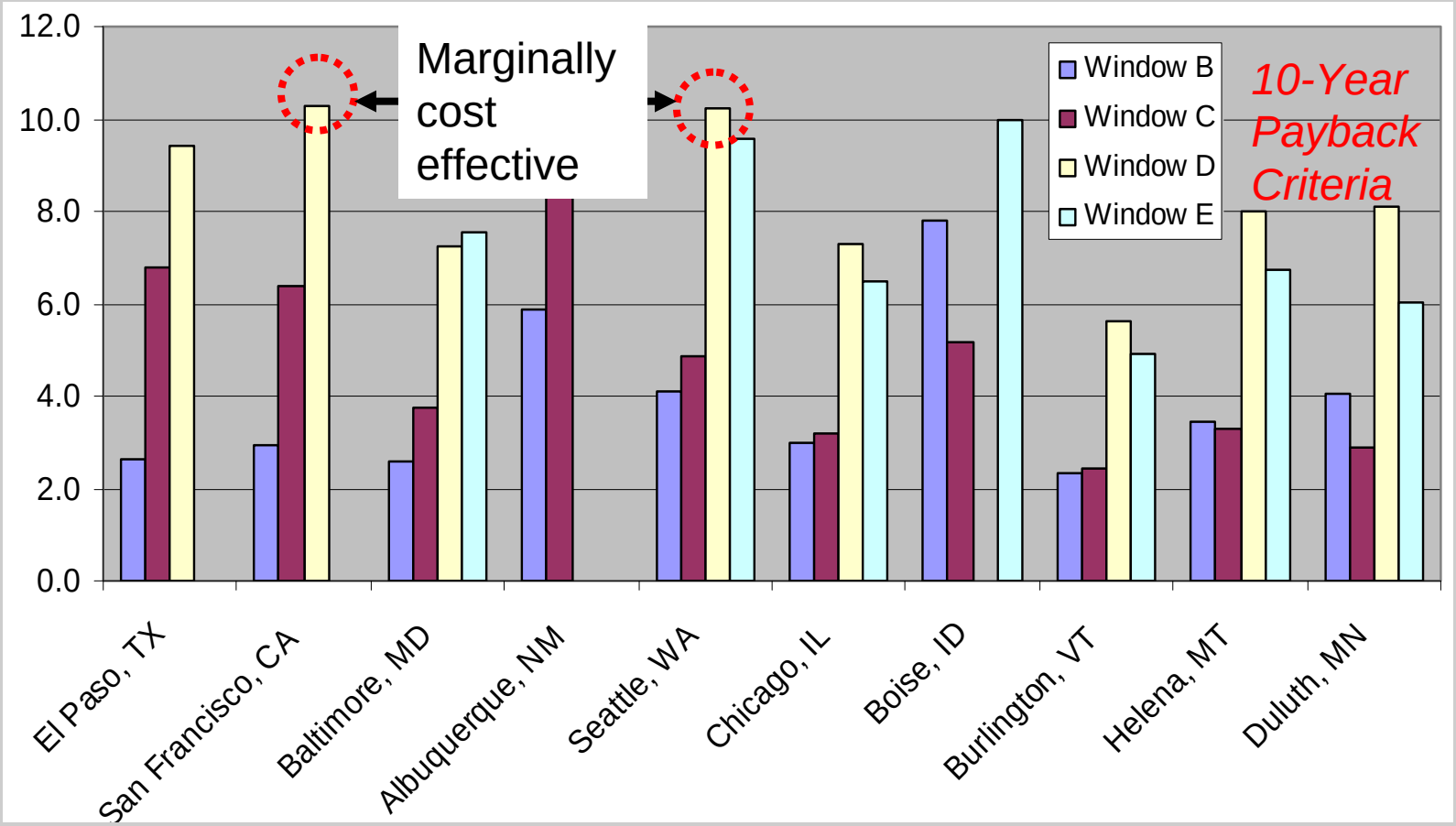
New Construction and Major Renovation or Repair Project

Modeled payback results - upgrading to <u>premium quality</u> replacement windows vs. current baseline quality replacement windows (Zones 3B, 4A, 4B, 4C, 5A, 5B, 6A, 6B and 7A)



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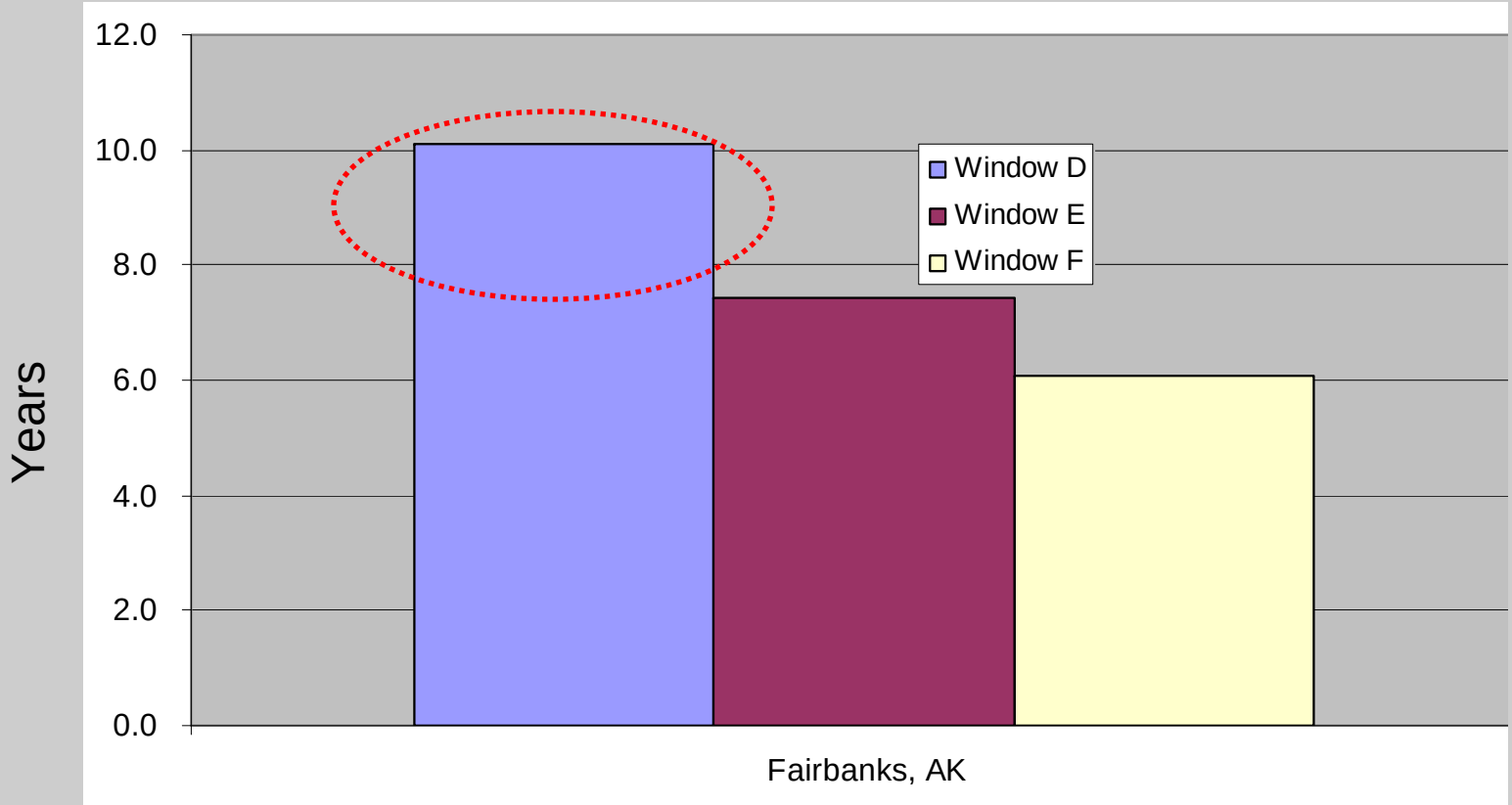
New Construction and Major Renovation or Repair Project

Modeled payback results - upgrading to <u>premium quality</u> replacement windows vs. current baseline quality replacement windows (Zone 8)



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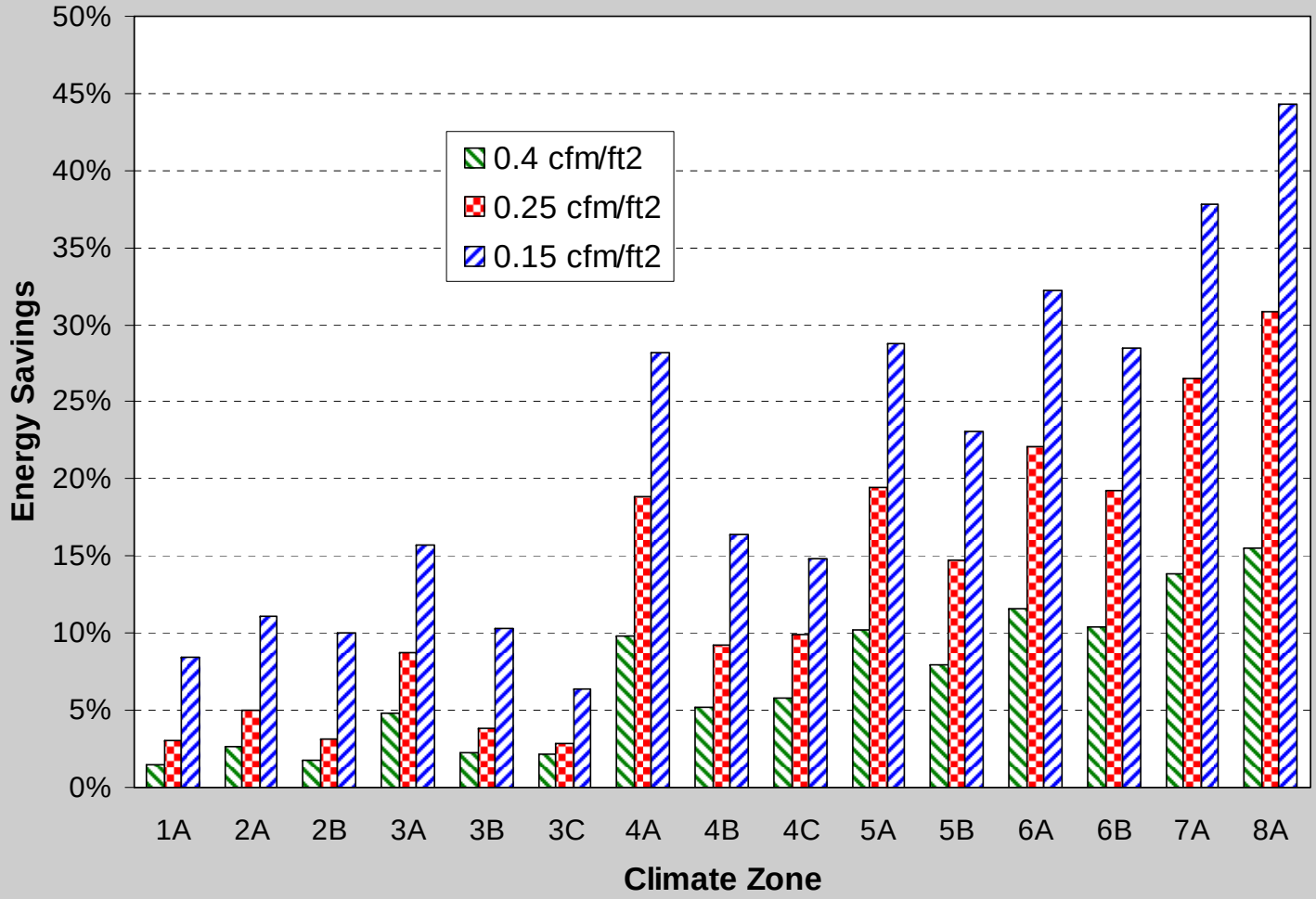
Annual Energy Savings in Barracks due to Increased Airtightness



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Low Exergy Heating and Cooling

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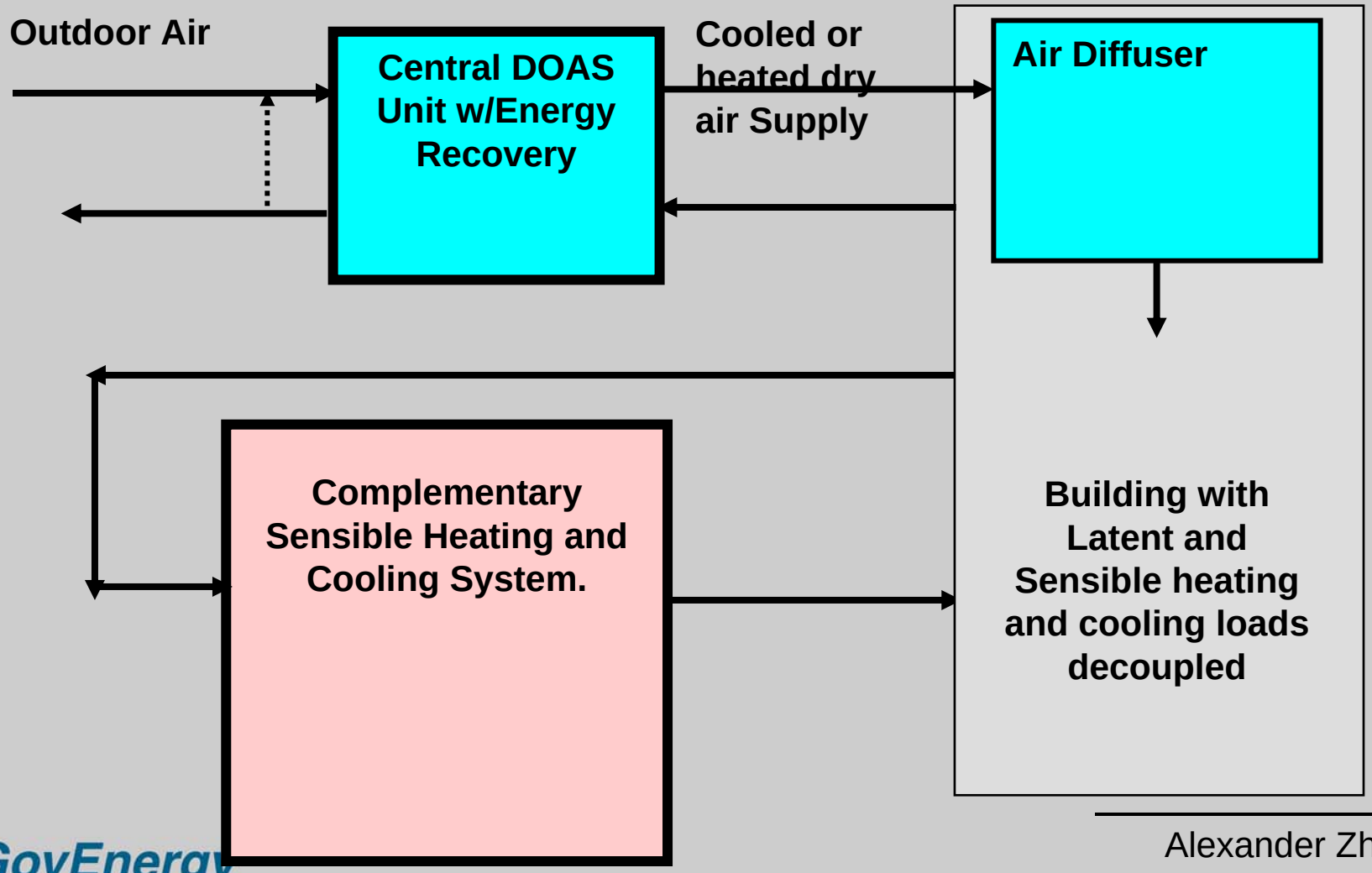
Dedicated Outdoor Air System Schematic



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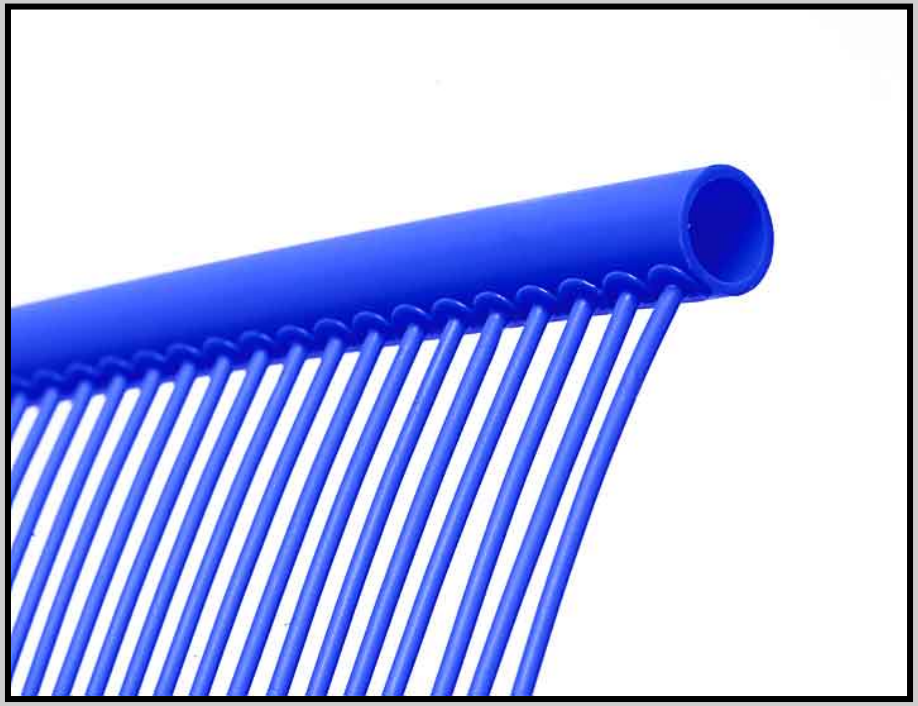
Radiant Heating/Cooling System

Installation of the capillary radiant heating/cooling system on the pre-finished surface



Two-side cooling mat detail with water feeding (or water return)

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Radiant Heating/Cooling System

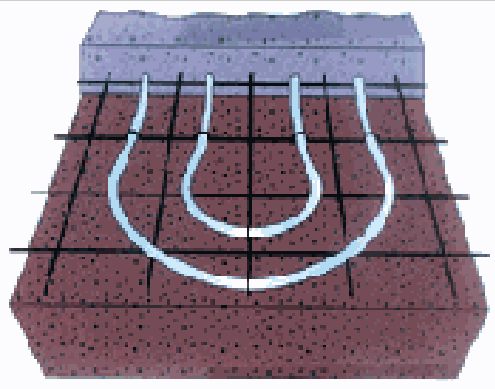
- The chilled ceiling can provide capacity up to 25 Btu/sq.ft. This capacity is generally sufficient if the building is sufficiently insulated and has a DOAS
- Pipes and fittings are made out of polypropylene (plastic). Cooling and heating by Capillary Tubes is not new to the HVAC industry. It was used for commercial and institutional projects over Europe since last fifteen years. Has at least 2 suppliers BEKA, USA and KaRo. See www.beka-klima.de for list of completed projects.
- The capillary tubes (material only) for drywall/plaster or concrete is around $6.00/sq.ft. Additional $ 8.00/sq.ft. will be for installation.

Low Temperature Hydronic Radiant Heating System

WAAF – Hangar 1035
High efficiency radiant panel

Low-Intensity Radiant Floor Heating/Cooling Heating/Cooling

Ft. Lewis



Ft. Drum

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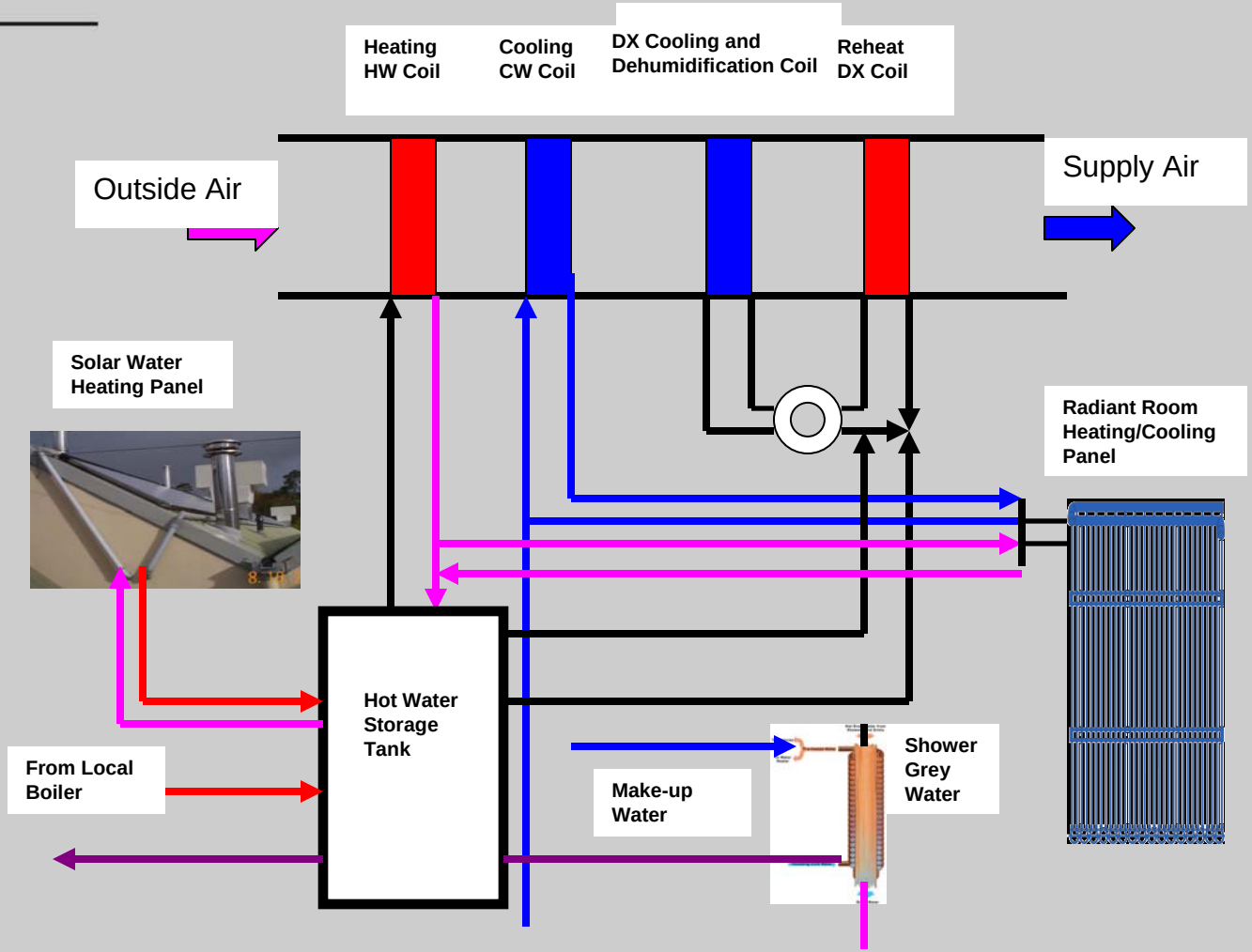
Barrack Energy Efficient Heating and Cooling Concept



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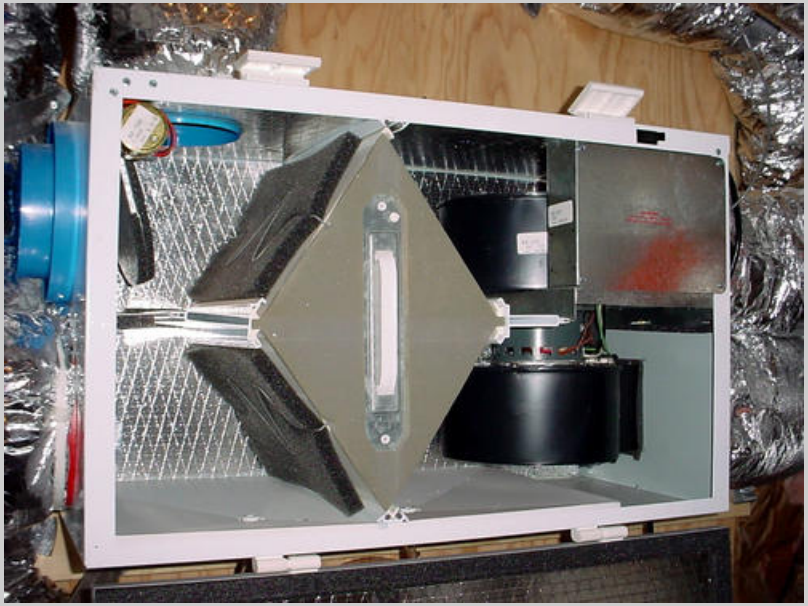
Heat Recovery from Central Exhaust

- Consolidate bathroom exhausts
- Install heat exchanger to recover heating and cooling energy (winter/summer) to pre-heat/pre-cool OA (for the DOAS)



Renewable Energy

(Freiburg, the *„Solar Capital“* of Germany)

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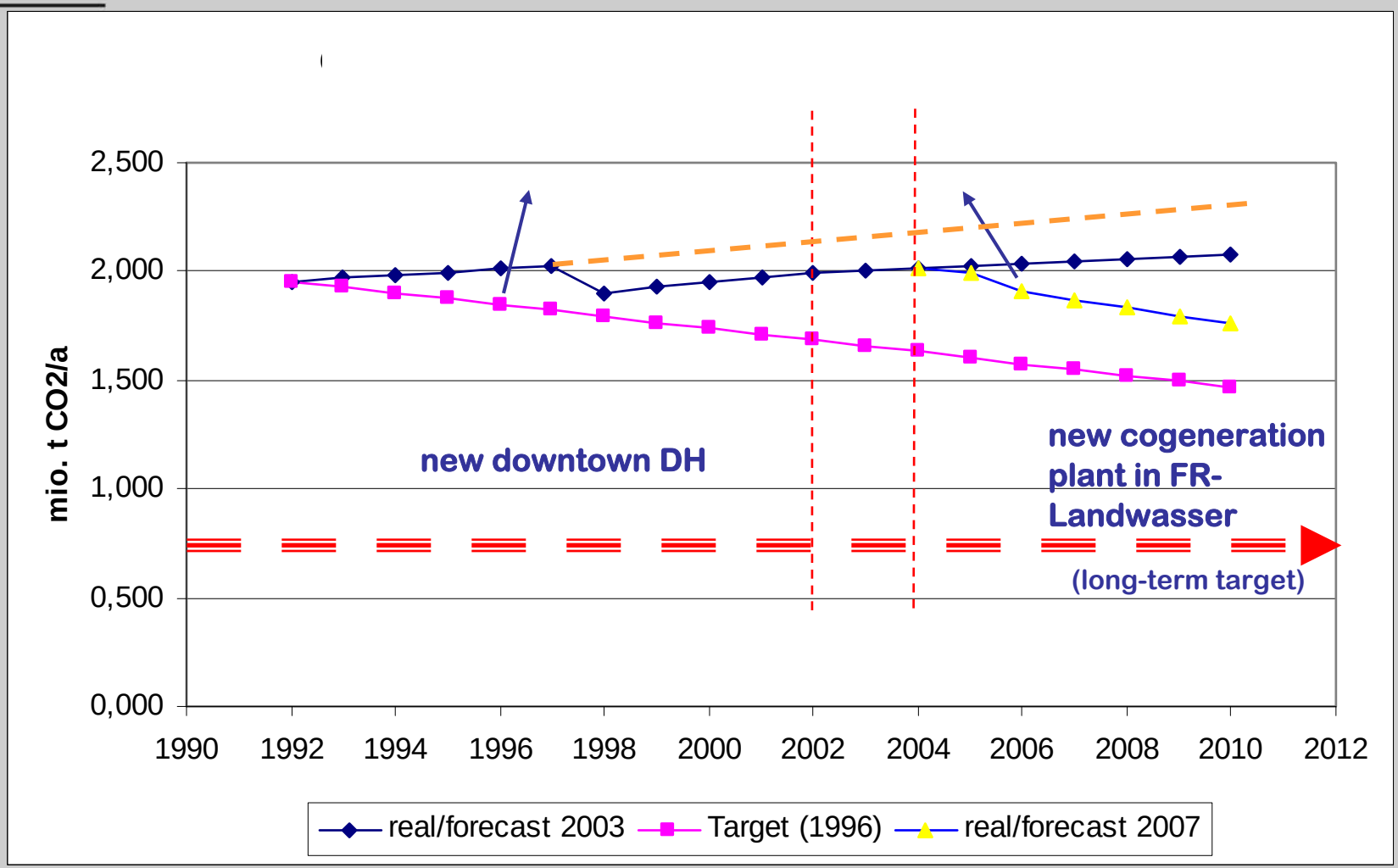
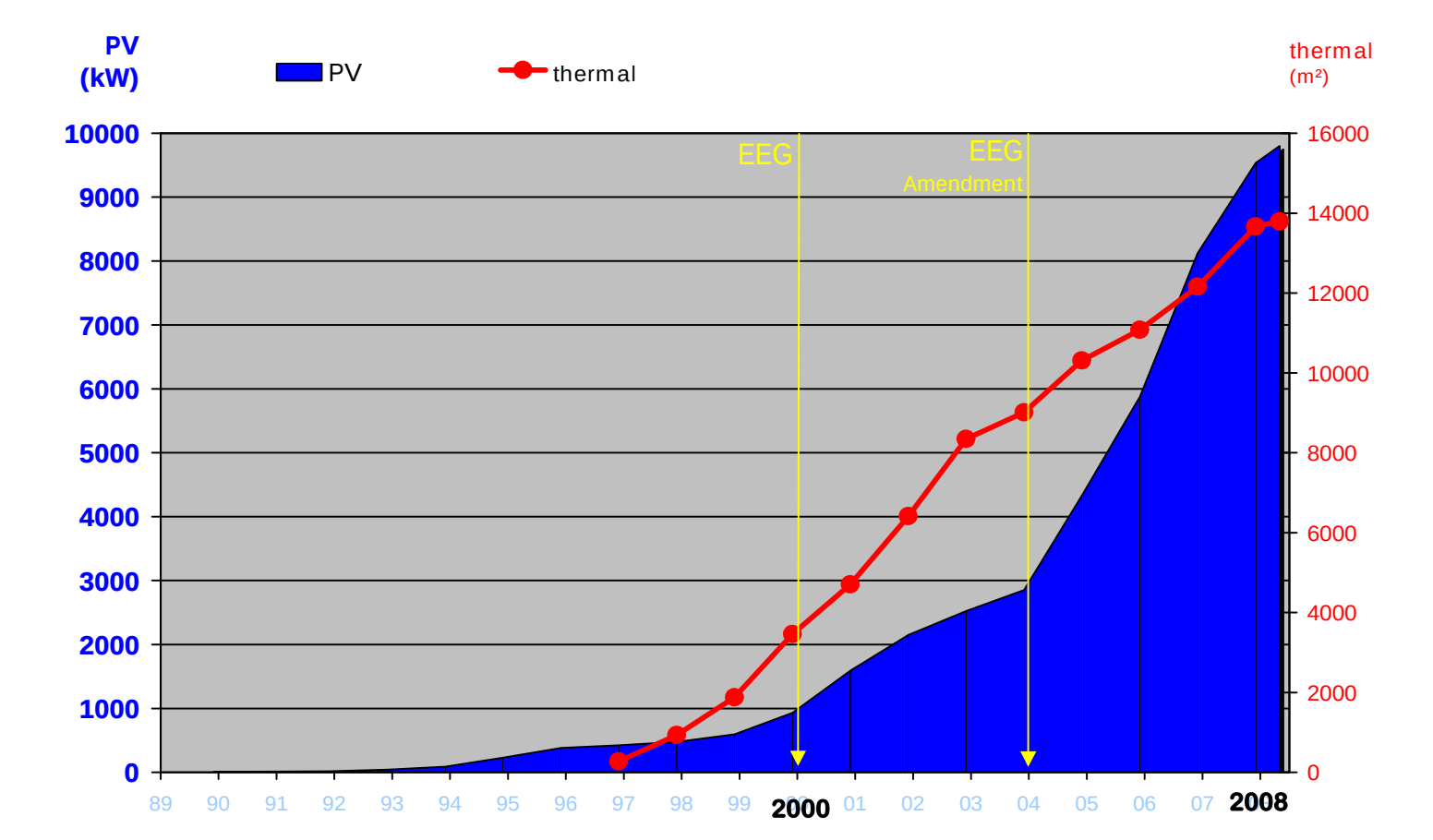
CO_2 emissions in Freiburg: plans and reality

From Dr. Reinhardt Jank, 2009



Solar-Based Energy Generation in Freiburg



Electricity demand in FR: ~ 200 MW_{el}
→ PV-Capacity: ~ 2.5%

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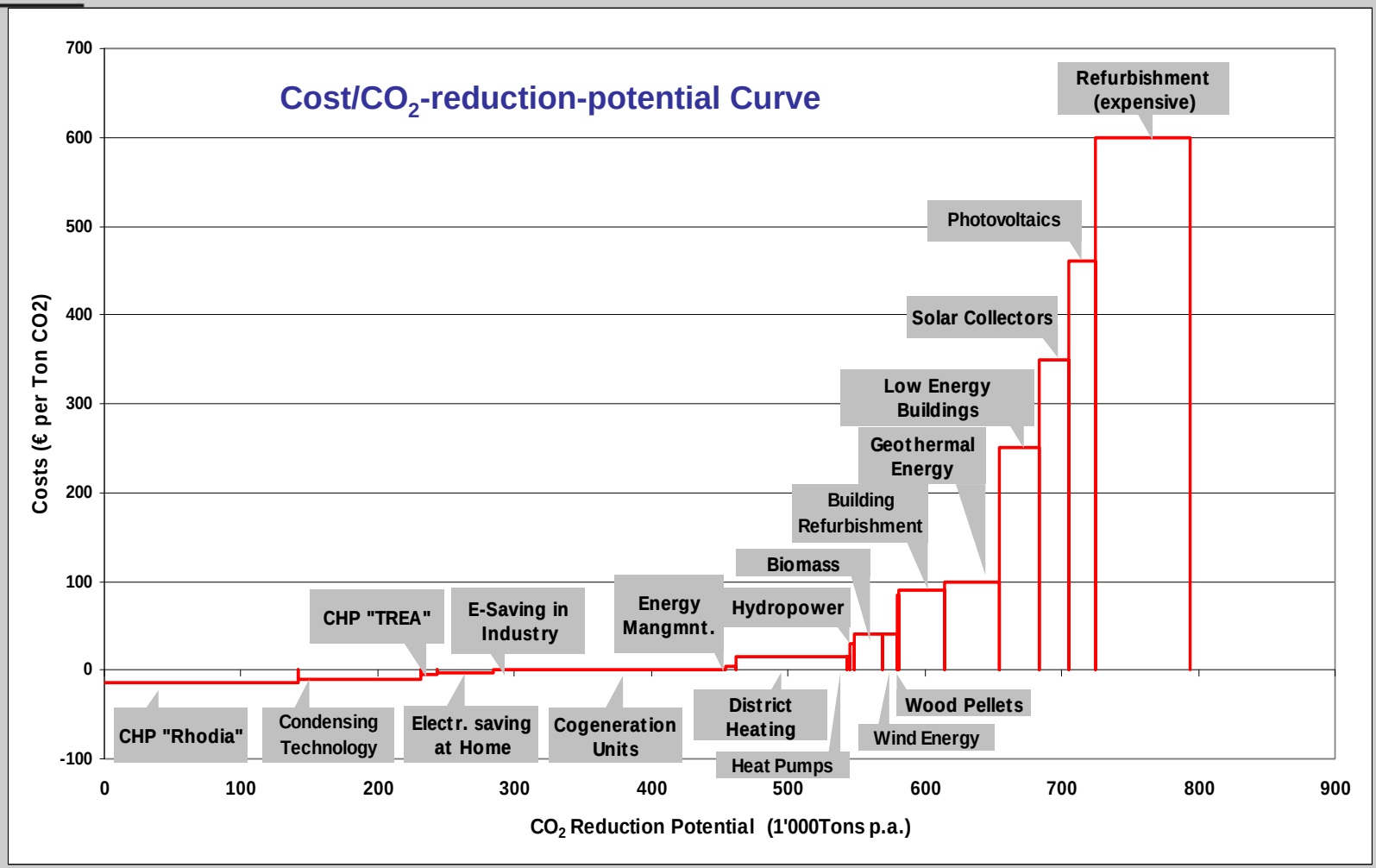
Technology Analysis (Freiburg 2004, 200.000 inhabitants)



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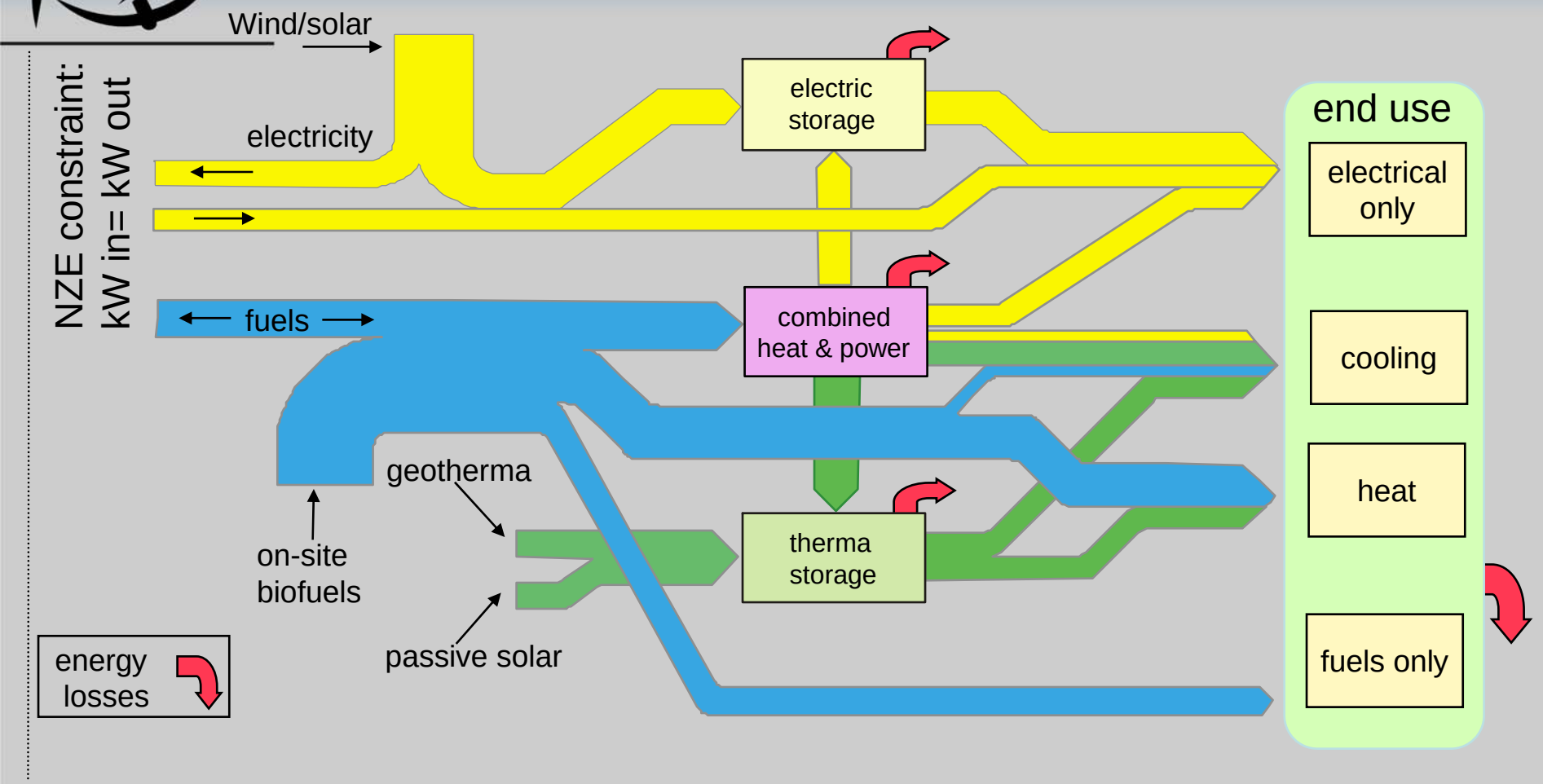
Central Energy System Architecture

From Bob Lasseter, Colorado Springs, 2009



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Thermal Energy Storage Systems

- Properly designed and applied TES systems can reduce site and source energy consumption and enable solar and wind power to become a viable part of the energy infrastructure.

- TES allow to combine thermal energy generated by CHP plants, recovered waste energy flows and those from renewable sources, i.e., solar panels, thus providing Improved Energy Efficiency, Demand Response and Demand Reduction.

NZE Building or NZE Installation/Community?

- Energy use reduction in buildings is feasible and economical. Depending upon the energy cost and climate, existing and advanced technologies and design strategies can reduce energy consumption up to 80-90% with an increased first cost < 10%
- Energy use reduction beyond this point is not cost effective. Experience shows that with the current energy costs, even residential NZE buildings are not yet economical
- However, low energy/NZE communities are feasible with a reasonable payback. They require optimization of the building envelope and systems for each building and building clusters
- While low energy or “passiv hous” technologies and design strategies for residential buildings are a common practice in European countries, holistic approach required to develop NZE building communities with a diverse sets of buildings, is still in the stage of the “art”. Optimization of building loads, building and community systems with a consideration of different low and high quality energy sources and waste streams, thermal and electrical storage systems requires further studies.

NZE Building or NZE installation/community? (Continuation)

- Meeting EISA 2007 goals will require:
  - Development of holistic energy systems concepts and applying them through advanced community-wide energy master planning
  - Setting new more stringent energy targets for new construction and major renovation projects executed today with future goals in mind
  - Executing renovation projects by building clusters with a potential to integrate these clusters into the low energy community/installation.
- This approach requires early adoption and application of advanced technologies in new construction and retrofit projects, and a holistic approach and commitment from all stakeholders (planning, financing, project management, design, construction, O&M, building users, owners and managers.)
- IEA ECBCS Annex 51 “Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision makers” is a platform for collaboration between 9 countries to collect the state-of-the art research and practical knowledge, fill-in existing gaps and develop a concept and tools for a broad range of users.

Questions or Comments ?

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