IEA Future Buildings Forum

Buildings of the 21st Century
Developing Innovative Research Agendas

3rd FBF Think Tank Workshop
Workshop report

DRAFT

Holmen fjordhotel, Oslo, Norway
May 9 – 11, 2001

Contents

Preface

Jørn T. Brunsell
Trine Dyrstad Pettersen
Norwegian Building Research Institute
Norway

International Energy Agency
The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the 21 IEA participation countries to increase energy security through energy conservation development of alternative energy sources and energy research, development and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of 42 implementing Agreements, containing a total of over eighty separate energy RD&D projects.

Future Buildings Forum
The Future Buildings Forum (FBF) was officially started in June 1991 under the "Energy Conservation in Building and Community Systems Programme" of the International Energy Agency. It has the aim to contribute to a sustainable society by means of enriching international building energy research with topics which will be of importance during the next century. Today's research work focuses on existing needs. Many research proposals are just an extension of ongoing research projects.

The FBF tries to investigate the future situation which will influence the needs of the building stock. It will address energy, environment, economic, and technical issues. To do this, the FBF has established a workshop programme, dealing with selected topics which seem to be of great importance for the future. Until now it has been arranged three such Think Tank workshops. The third Think Tank was in Norway this year.

3rd Think Tank
The major aim of the 3rd Think Tank was to

- clarify the major forces and trends in the building sector the next 25 years
- discuss the resulting impacts and opportunities based on the forces and trends
- recommend research and development needs

both in new and existing buildings.

27 of the 38 participants at the Think Tank in the sunshine outside the conference room.

Workshop Summary

Executive Summary

Fred Morse
Morse Associates Inc
USA

On 8-11 May 2001, 36 representatives from 15 countries plus the IEA Secretariat met in Oslo, Norway to discuss the built environment in the year 2025 and to identify high priority R&D work that should be initiated now by the seven IEA building-related Programs. Attachment A and B present the agenda and participant list.

After a welcome reception on May 8, the Forum began on Wednesday morning, May 9, 2001, with a welcome and opening presentation. It continued with a series of invited presentations that set the stage for discussions on the second day.

The objective of the first series of presentations was to present the major forces that will shape the buildings of the future. The speakers in this session were:

- Øystein Dahle, Head of World Watch Institute, Scandinavia
- Clas-Otto Wene, IEA Secretariat, Paris
- Margrethe Aune, SINTEF, Norway
- Sverre Tiltnes, GRIP Center for Sustainable Production and Consumption, Norway
- Mark Zimmermann, EMPA ZEN, Switzerland
- Poul Eric Kristensen, Denmark

The objective of the second series of presentations was to present the implications of those forces on the built environment. The speakers in this second session were:

- Bertil Petterson, Swedish Ministry of Environment, Sweden
- Tony Rigg, UIA Architecture & Energy Work Programme, Israel
- Leigh Breslau, Design Partner, SOM, United States
- Richard Karney, Department of Energy, United States
- Asger S. Kjeldsen, Encon Electrical Utility, Denmark

On Thursday, after the day of invited presentations, the Forum participants were divided into three groups of about 10-15 people each to allow the participants to identify and rank the research and development needs for the built environment to be responsive to the market forces and trends to make the buildings of the future as sustainable and comfortable as possible. The members of each of the discussion groups were determined prior to the meeting, based on the need to have each group be relatively well balanced geographically and among the different skills represented.

There were three groups, covering one of the following areas:

- New Buildings
- Existing Buildings
- Energy Systems in Buildings

Each group discussed the five following topics:

- Additional presentations and discussions
  Clarification of the major forces and trends in the building sector
- Resulting Impacts and Opportunities
- Research and Development Needs
- Conclusions and Recommendations

The reports from these three discussion groups are shown as Attachments C, D and E respectively. On the last day of the Forum, the participants reviewed the 32 proposed R&D activities, agreed on a way to combine some and structure the remaining into four groups:

- Community Aspects
- Buildings
- Components
- Market Aspects

After omitting one activity (Using Mixed Hydrogen-Natural Gas Heating Systems in Existing Buildings), the final set of 23 proposed R&D activities were distributed among these four groups as follows:

Community Aspects

- Urban Environment Building Interactions
- Building Renovation (Decision Criteria, Impact of Clustering, Assessment Methodologies and Tools, Reference Data and Instruments for Analyzing, Promoting and Carrying out the Renovation Process)
- Comprehensive Building Sector Energy Systems Analysis
- Downsizing District H & C Systems

Buildings

- Buildings as Service Suppliers
- Buildings as Energy Suppliers
- Reference Energy Consumption and Indoor Climate Data for Existing Buildings (and Urban Energy Consumption in Comparison to Suburban Situations)
- Achievable Factor X for Building Renovation
- Concepts for Renewable Energy Use in Heritage Buildings (an expansion of Better Roof Integrated Solar Collectors for Heritage Buildings)

Components - Mechanical Systems

- Optimal Reduced Ventilation
- Lower Temperature Systems (Low Temperature Systems Analysis and Product development and Conversion of Existing High Temperature to Low Temperature Heating Systems in Retrofitted Buildings)
- Plug and Play Mechanical Systems (Integrated Comfort and Service Plug and Play Systems and Energy Efficient Plug and Play Systems for Retrofit and Integrated Mechanical Systems in Existing Buildings)
- Waste Heat Utilization
- Advanced Air Conditioning
- Room HVAC Systems with Ground-Coupled Heat Pumps (Room Sized Energy Systems and Ground Coupled Combined Heating and Cooling for Existing Buildings)
- Innovative Efficient Lighting Systems (for Existing Buildings)
- Integrated Control and Information Systems (for Existing Buildings)

Components - Building Envelope

- Advanced Envelope Insulation
- Transforming Existing Facades into Intelligent Facades

Market

- Market Entry Strategy
- Behavioral Aspects of Load Management
- Design Competition

Descriptions of these proposed R&D activities can be found in the three discussion group reports, Attachments C, D and E. If a proposed R&D activity is a combination of one or more activities described in those Attachments, the titles of those activities are shown in brackets in the above list.

The next step will be to send this set of proposed R&D needs to the seven IEA Building-related Implementing Agreements for their review. It is hoped that work on most of these proposed R&D projects will be initiated by one or more of the IEA Programs. Typically this will involve a workshop of experts to define the specific work to be done. It may be that one topic could result in several Tasks or conversely that several topics could be integrated into one Task.

Workshop presentations
Plenary Session

Global challenges

Øystein Dahle
Nordic Chairman of Head of the World Watch Institute
Vice-president World Watch Institute International
Professor II ved CICERO
Former Vice Director in Esso Norway

The following presentation was presented at a Norwegian-German energy conference in Hannover November 2000 and covers most of the issues that Dahle presented at the Think Tank 2001.

European Energy; How much is enough?

Three years ago the chairman of Gerling Akademie für Risikoforschung in Switerland, Rolf Gerling, made a speech in Norway under the title "Taking the environment into account". I am quoting from my notes covering that presentation his emphasis on the need to change the corporate mindset. To master the future, according to Gerling, we have to change things not only on the material level, but on top we have to change our attitudes, our perspective and we have to undertake a paradigm shift, that in its center is spiritual. The word "spiritual" will normally not be welcomed in a business context, but Maurice Strong, the Canadian environmental pioneer whose name most of you probably will recognize urged that word to be used even in business surroundings. As we know from corporate practice, corporations with a vision in general do much better than corporations without. By definition a vision gives direction, leads the way to a goal that is often beyond accountability. The vision these days must include sustainability as a conceptual challenge. At the society level there are in fact three challenges related to sustainability:

- Development of understanding, a framework for thinking
- Policy development with existing and new instruments and
- Technology development

It is not at all surprising that it is the insurance companies who have been most sensitive to the sustainability challenge, but even OECD has introduced ideas on this demanding arena beyond expectation from that direction. If we (the industrialized world) cannot deliver on the climate issue, the credibility on the sustainability challenge will erode according to OECD. However, we do know that government policy most often is developed in reaction to a problem and only very seldom in anticipation of a problem. Our institutions therefore need to rethink the tools we are equipped with to work the problems confronting us.

Even before the concept of environmental problems emerged in the public debate, one of our history's most admired scientists, Albert Einstein, shared with those who liked to listen to him an assessment worth reminding us on: "The world we have created through our way of thinking", said professor Einstein, "has huge problems which cannot be solved by continuing to think the same way as when we created the problems".

In all its simplicity, and all its complexity, the challenge of sustainability is to recognize and internalize the obvious fact that the world is a closed system and our economic behaviour must be adjusted accordingly. The nature of the environmental challenge can only be understood in a solidarity perspective in time and space. To limit our freedom of action today will be required to provide some freedom of action for those generations coming later.

These introductory comments go well beyond the field of energy, but the energy challenge can only be described in the context of sustainability.

A sustainable energy system is a necessary, although not sufficient, requirement for sustainable development. It is therefore of considerable interest when Gus Speth (at the time heading the United Nations Development Program (UNDP)) in his introduction to the report "Energy after Rio" (Rio + 5) said the following: The current patterns of energy production and use which shape the development process internationally, are unsustainable, - and have become more so since Rio (end quote). In other words; Not only do we have a problem, but the problem is increasing. We are moving in the wrong direction, and there is no sense of urgency.

In another, - and more recent report GEO 2000 by UNEP the magnitude of the challenge is bluntly described: the industrialized countries will have to reduce their resource consumption, including fossil energy, to one tenth of current consumption level over the next few decades in order to maintain a resource base for a responsible development of the poor countries. It is in such a context that the heated debate spreading over Europe as a brush fire on motorfuel prices is becoming ridiculous, with 1.2 billion people having to survive on a daily basis with an amount of money equivalent to the price of one liter motorfuel.

UNEP is establishing an ambition level described by a factor 10 in resource productivity. OECD has not quantified the ambition level but in its report "Guiding the transition to sustainable development" a critical role for OECD is accepted and according to OECD it is now time for the organization to concentrate on increasing resource productivity with the same effectiveness it applied to labour productivity." What is required to motivate for at commitment to improve resource productivity? The economic motivation will come provided the pricing of natural resources is reflecting the ecological realities. Again the OECD has made an attempt to assess how the ecology impacts on the economy as follows " - - the environment provides economic goods and services – not formally accounted for – at least as valuable as, and probably much more valuable than those provided by markets". What is of particular interest is OECD's willingness to accept a criticism to the dominant accounting system for progress using GNP as a key indicator. This could be an early indication that classical economic thinking is inspired by the pioneers of ecological economics.

The crucial question in the field of energy is if there is a factor 10 productivity improvement potential. In some sectors the potential is probably in the order of magnitude factor 10 with only minor further advancements to existing front technology. With emphasis on technology development prioritizing resource productivity, further improvements should be expected as is clearly demonstrated in a number of fields.

The transportation sector is of great importance in determining our energy future and a number of new technologies are moving from the laboratories through prototype demonstration to market realities. Fuel cells are of particular interest. Although large cost- and technical hurdles remain, the fuel cells development is pursued with an unprecedented combination of resources and commitment. We will hear more about these opportunities in a later presentation.

Another very exciting development with high impact potential on the energy system is the introduction of a decentralized distributed power concept. The simple version of this concept is that the small energy consumers are offered dual roles as also occasional energy suppliers. The feasibility of the concept is dependant on a reliable, accurate monitoring device for electric power, measuring power in both directions. Supplying to the grid from for instance roof based photo voltaic systems in periods where the household requirements are at a low level has been demonstrated. Wind power and photo electricity are realistic components in such a system. The large scale introduction of distributed power may still be some years away, but we should remind ourselves on how fast the transition in the field of information technology actually developed from centralized to decentralized solutions, from the mainframe to the PC, - and against high odds.

Another potential conceptual breakthrough in this small cluster of selected opportunities is the eco-efficiency concept. It offers a new way of thinking in the production/service economy and a number of corporations have developed eco-efficiency strategies for their operations. These are corporations committed to environmental improvement and stimulated by other companies and the Business Council for Sustainable Development. With support and encouragement from Governments and with a policy framework stimulating resource effectiveness, a rapid stabilization of energy needs in the industrialized countries and a subsequent accelerating reduction in energy needs is not unrealistic.

A case study could be the energy policy challenge in Norway. Due to its abundant power supplies based on hydro electricity, there has never developed a sense of energy scarcity in the country. The issue of energy quality has therefore never emerged and electric power has been used for purposes not at all requiring this energy quality (like heating). The current base case, - although wasteful or rather due to the fact that it is wasteful-, now offers the country a substantial potential for improvement by introducing a large scale heat pump program. The potential release of electric power could be in the order of magnitude 15-20 Twh or equivalent to 6-7 fossil fired power plants. Huge investments can be justified to make this happen.

Obviously large scale supplies of fossil energy will still be required for many years, and gradual substitution of higher carbon content fuels with gas will be a preferred strategy on the supply side. However, the biggest challenge in the field of energy is to manage the demand and ensure a non-growing energy system in the industrialized countries, and preferably worldwide.

The transition challenge to non-fossil alternatives offers a dynamic challenge hardly recognized in the energy debate today. In order for the renewable energy alternatives to be positioned to contribute significant quantities of energy when oil and gas resources are in worldwide decline, the alternatives need to have completed their initial growth period. This growth period is quite time consuming. Bringing any energy alternative from a contribution of 1 mill tons/year to 1 billion tons/year will require a 1000-fold increase. With 23% annual growth, 3 years will be required to double the output. Starting with 1 it will take 10 doublings to expand the output to1000. Thus if starting with 1 mill t/yr equivalent capacity it will take 30 years to reach 1 billion t/yr equivalent capacity with a 23% annual growth right, and that will cover only some 5-6% of expected worldwide energy needs at that time. The real problem, however, is that the contribution to cover the societies energy needs is the determined by net energy supply rather than gross energy supply, i.e. corrected for the amount of energy required to develop the energy system.

Since large amounts of energy are required to expand a new energy system, the net contribution is for some important energy alternatives like photo electricity significantly less than the gross contribution. With high growth rates the net contribution may not even be positive in the growth period. This is not an entirely new problem. During the 10-15 years expansion of the French nuclear capacity, there was no net contribution to the French energy system. The energy required to expand the system exceeded the output from the reactors, until the growth rate was slowed down.

This could also happen with the photo voltaic system and delay to 40 years to reach the 1 billion t/yr contribution from this source. Windpower is less energy intensive to develop and thus could be expanded faster and still maintaining a positive contribution to the energy system.

The purpose of introducing this system dynamic challenge is twofold. First it is more time consuming to introduce alternatives in meaningful quantities than even energy experts tend to think. We therefore have to start early. Second, it is therefore of even greater importance to limit the absolute magnitude of the problem of substitution. This can only be achieved by putting higher priority on the resource productivity side. It is essential that the energy system is not growing further in size.

Demand side management is very different from supply side management. It is an organizational challenge more than a technical challenge, and the experience of large scale demand side management is limited.

"There are hundreds of millions of them" according to IEA's new book on the link between energy and human activity: households and car drivers; millions of truckers; hundreds of thousands of building operators; farmers and factory managers. These are the people, the armies of discrete individuals, who make the decisions that govern energy use and CO2 emissions.

Each day they make billions of energy choices to achieve their manifold goals, few of which have much to do with energy itself. What they are interested in is producing goods, rendering services, heating houses, driving too work, and hauling freight to name just a few. Some energy applications generate output and income. Others provide convenience and comfort, or simply facilitate the business of life. Energy serves as a means to these ends. The ends themselves define the proper study of how and why people burn hydrocarbons and ultimately release carbon dioxide into the atmosphere. Energy consumption has its roots in the ways economies and societies work.

A sustainable world will require a sustainable energy system! A sustainable energy system will have to become significantly more effective than current levels. This is a priority no 1. We have hardly started, it's a long way to go and fortunately the potential to succeed is there. I will respond to the question on how much energy is enough for Europe by concluding that Europe should limit itself to the current level and strive for substantial reductions. It is technically possible but will require political will and courage.

The Energy Situation in 2025 and Beyond: Two Views on the Energy Technology Paths to the Future

Clas-Otto Wene
IEA Secretariat, Paris

Future Buildings Forum, Oslo, 9-11 May 2001

The Energy Situation in 2025 and Beyond:

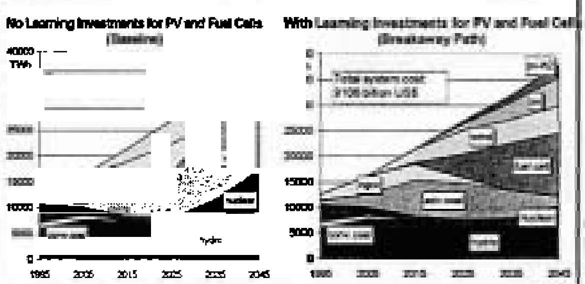
Two Views on the Energy Technology Paths to the Future

Clas-Otto Wene
IEA and Chalmers University of Technology
Niclas Mattsson
Chalmers University of Technology

Basic Message from Energy Technology Models on the Effect of Technology Learning (Experience Curves)

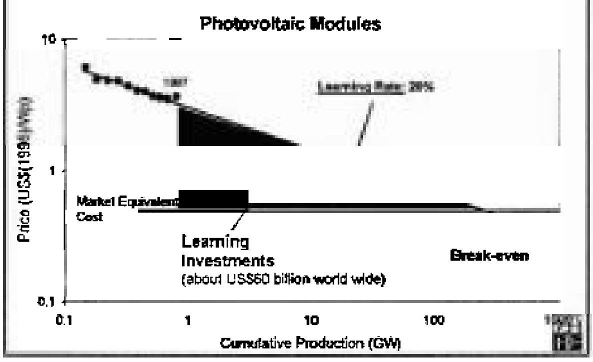
- **Technology Costs are Path Dependent**
  Future technology costs depend on market investment today = technology costs depend on the history of the energy system
- **Learning Investments create alternative low-cost technology paths**
  Providing/not providing Learning Investments creates/destroys alternative technology paths
- **Each Path represents an attractive and stable configuration of the system**
  Once started along a specific technology path, shifting to an alternative may be costly (knowledge infrastructure)

Illustrating two low-cost technology paths for the global electric system
(Results from the Genie model 1997)

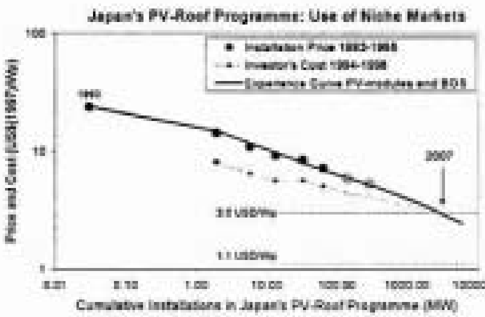


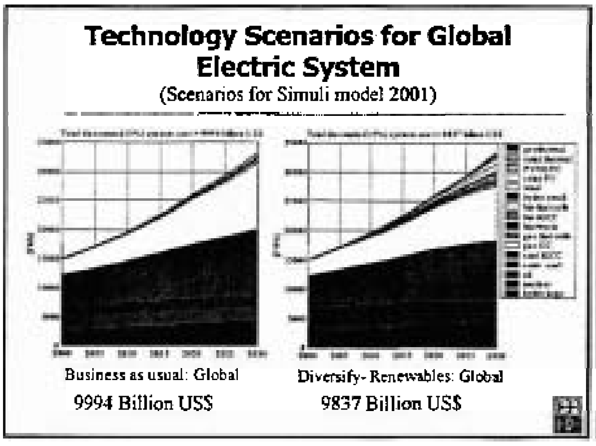
The near-term additional cost for the Breakaway Path
(Results from Genie-model 1977)

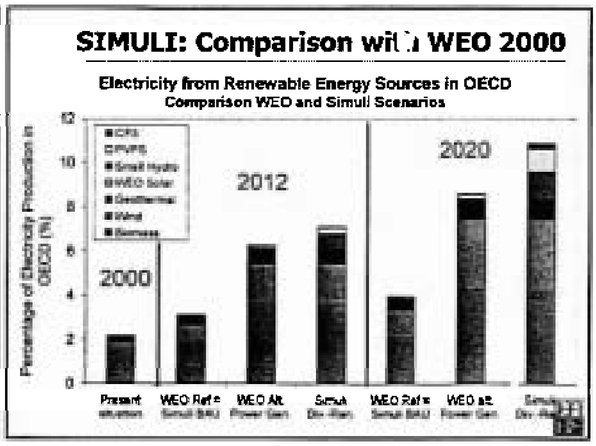
Example: Learning Investments for PV
(From IEA 2000: Experience Curves for Energy Technology Policy)

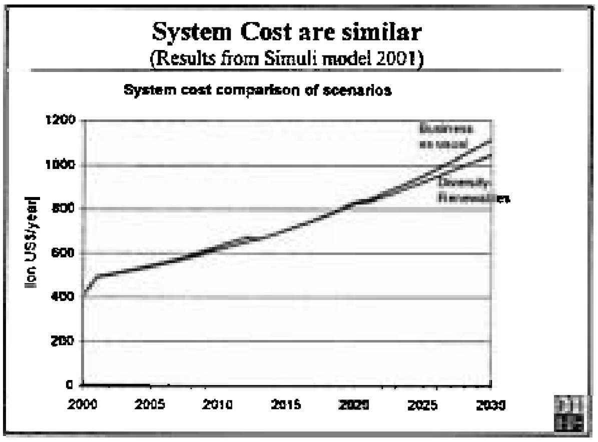


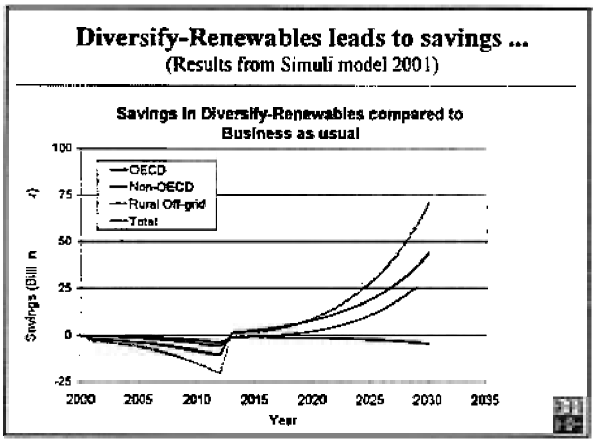
Providing Learning Investments for the Alternative Technology Path: The Japanese Example

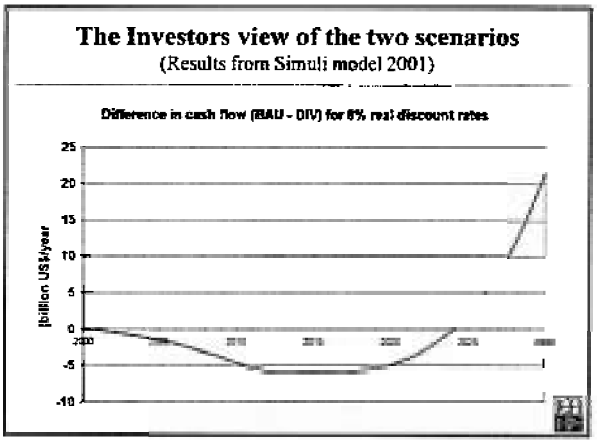


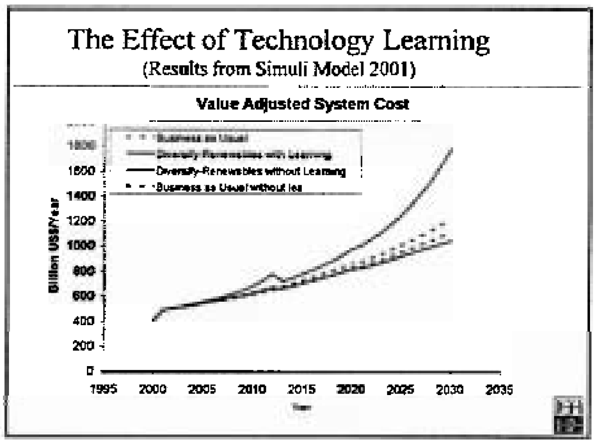

Technology Scenarios for Global Electric System
(Scenarios for Simuli model 2001)
Business as usual: Global
9994 Billion US$
Diversify- Renewables: Global
9837 Billion US$


SIMULI: Comparison with WEO 2000
Electricity from Renewable Energy Sources in OECD
Comparison WEO and Simuli Scenarios
2000
2012
2020
Percentage of Electricity Production in OECD (%)

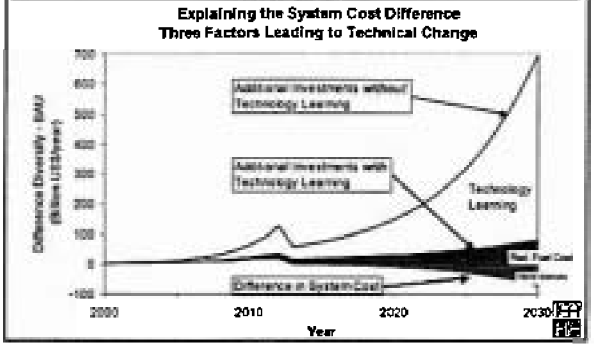

System Cost are similar
(Results from Simuli model 2001)
System cost comparison of scenarios
1200
1000
800
600
400
200
0
2000
2005
2010
2015
2020
2025
2030


Diversify-Renewables leads to savings ...
(Results from Simuli model 2001)
Savings in Diversify-Renewables compared to Business as usual
OECD
Non-OECD
Rural Off-grid
Total
100
75
50
25
0
-25
2000
2005
2010
2015
2020
2025
2030
2035
Year

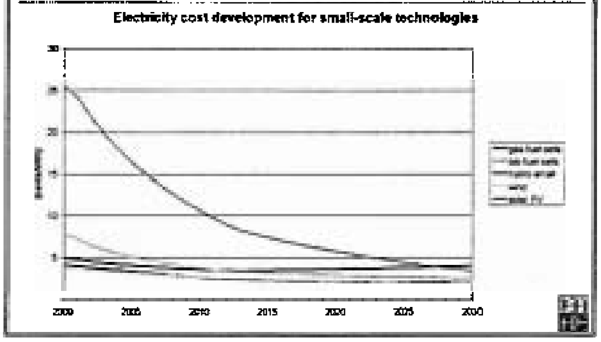

The Investors view of the two scenarios
(Results from Simuli model 2001)
[billion US$/year]
25
20
15
10
5
0
-5
-10


The Effect of Technology Learning
(Results from Simuli Model 2001)
Value Adjusted System Cost
Billion US$/Year
1600
1400
1200
1000
800
600
400
200
0
1995
2000
2005
2010
2015
2020
2025
2030
2035

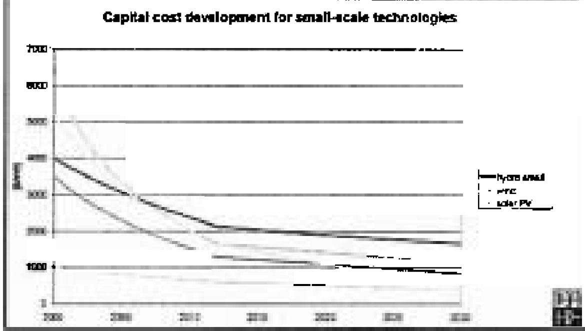
Three Factors supporting the shift to alternative technology paths
(Results from Simuli model 2001)



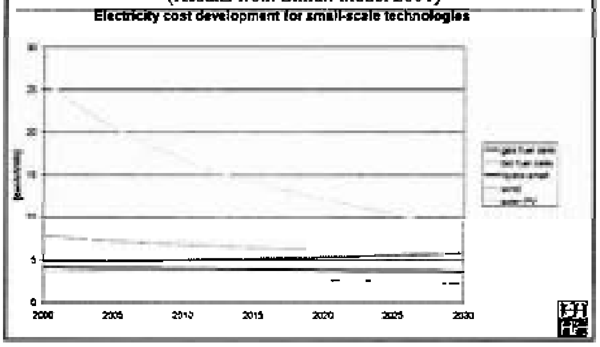
Electricity from Renewable Energy Technologies in Diversify-Renewables
(Results from Simuli model 2001)



Electricity from Renewable Energy Technologies in Diversify-Renewables
(Results from Simuli model 2001)



Electricity from Renewable Energy Technologies in Business as usual
(Results from Simuli model 2001)



Trends in Lifestyles

Margrethe Aune
Sintef, Tecnology and Management, IFIM
Norway

Trends indicating an increasing energy consumption:

- Growing number of detached houses (in Norway today, about 60% of private houses)
- Increasing living space in homes

The "comfort society"

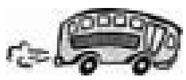
- Presentable homes
- Space and light
- Technology for work and leisure
- High quality leisure time (big cottages)

"It`s always raining here"

- The access to "unlimited" amounts of pollution free and cheap hydro power has created a special Norwegian energy culture
- The resent "power crisis" may result in increased attention on energy supply and use among people in general

What is private energy consumption?

- A way of achieving some important goals:
  - comfort
  - mobility
  - cosiness
  - identity



- However, energy policy seem to be addressing the rational consumer. This is a problem

Energy lifestyles

- The "self-indulgent"
- The "soberly indulgent"
- The "environmentalists"
- The "hesitant environmentalists"

The "self-indulgent"

- Do not reflect on energy consumption
- Everyday life activities direct their consumption pattern
- "My home is my project" - towards cosiness and comfort
- Ideal: detached house
- Are interested in retrofitting

The “soberly indulgent”

- Have no thoughts about energy use
- "My home is my castle" - Cosiness is important
- Represent a low consumption pattern mainly caused by small apartments.

Energ at any cost?

- In our household we are willing to pay the necessary costs in order to have a comfortable indoor temperature in all rooms. **Agree: 56%**
- We are used to an unlimited access to heat, hot water and cooking, and energy conservation should not be taken so far that any of this is taken from us:
  Agree: 68%

Ljones and Doorman 1992

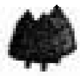
The “environmentalists

- Concerned about environment in general
- Conscious about their energy use and try to use little
- Avoid car-use
- "A home is a place for people and activity"
- Retrofitting for the case of increased comfort (visually or practically) is not important

10

The “hesitant environmentalists”

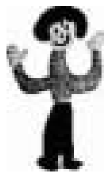
- Concerned about environmental questions
- This is not reflected in the every-day life
- Live in big houses
- One or two cars
- Not interested in modernising in general but keep the house in good condition
- "A home is a haven"



11

How do we reach the customer?

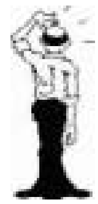
- Communicate with the “comfort society”
- Technological development in dialog with the users
- Available technology/solutions
- Competitive prices
- Visibility



12

The “problem” of attitudes:

- Attitudes does not always reflect behaviour.
- Changing attitudes does not mean changing behaviour
- A better solution: Changing behaviour before attitudes?



13

Factor 4 – 10 in the Building and Real Estate Sector

Sverre Tiltnes
GRIP Center for Sustainable Production and Consumption
Norway

FACTOR 4/10 IN THE BUILDING AND REAL ESTATE SECTOR

CASE STUDY MADE BY
GRIP SENTRE
NORWAY

Building stock

- Building and construction account for 70 per cent of all real financial assets in Norway
- Current building stock totals ca. 325 million m^2.
- Accounts for 20 per cent of Norwegian GNP

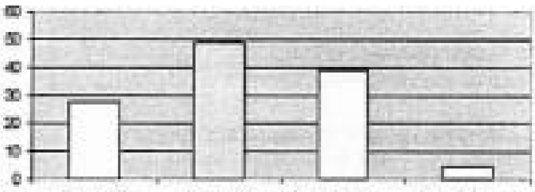
THE DESIGN AND CONSTRUCTION PROCESS

- new setting in each project
- poor co-ordination and co-operation
- tight time schedules
- planning is underestimated

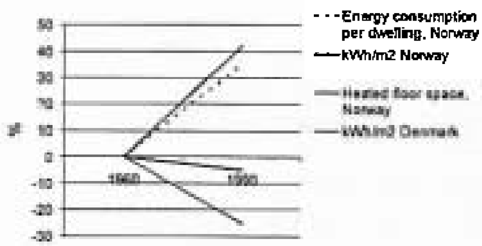
⇒

- need for more time and better co-ordination
- more responsibility on designers and contractors

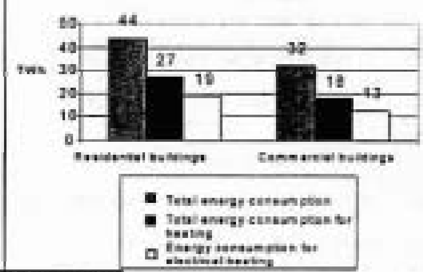
Large houses



ENERGY CONSUMTION AND USE OF FLOOR SPACE



Choice of energy source



ENERGY
(INCREASE ENERGY EFFICIENCY)

- reduce the energy consumption
  - more efficient use of space
  - energy-efficient design
  - energy-efficient management
  - new habits
- reduce environmental load per energy unit
  - using renewable energy resources
  - right energy quality for the right purpose

Raw materials

- The World Watch Institute (WWI) reckons that 40 per cent of all the raw stone, gravel and sand used every year, and 25 per cent of virgin wood, are used in building and construction.

Key measures

- re-use of existing buildings
- increased flexibility
- more efficient use of floor space
- waste minimization
- more extensive re-use and recycling of materials and products
- reduce environmental load per used material

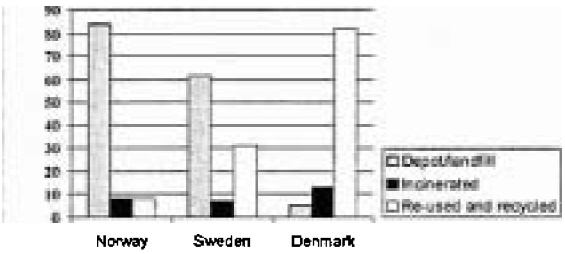
Hazardous chemicals

- About 50 000 different products are currently in use in the building and real estate sector.

HAZARDOUS SUBSTANCES
(DETOXIFICATION)

- more knowledge and control in the consumption of materials
- gradually stop using prioritised hazardous chemicals ➡ ask for documentation
- include less toxic chemicals in a closed life cycle ➡ promote re-use and recycling

Waste



Environmental potential in the sector

- reduced energy consumption: 5 TWh over ten years and 6-8 TWh in 20 years (ca. 10% of collective energy consumption in the sector.
- conversion from oil/electricity to local renewable energy: 4-6 TWh over ten years and 8-10 TWh over 20 years (ca. 12% of consumption in the sector)
- efficient use of space: residential: from 49 m2/person to 39 m2/person over 10 years
  office buildings: from 35 m2/employee to 20 m2/employee over 10 years
- wastage on site: from 55 kg/ m2 to 20 kg/ m2 built
- recycling of construction and demolition waste: from 10% to 70% in 5 years

Important measures

- changes in the official framework
- changed attitudes in the sector
- education, information and training in the sector
- cooperation within the industry and between the industry and the official sector

RECOMMENDATIONS TO THE GOVERNMENT

- taxes and regulations are necessary
- co-operation between the sector and the authorities
- focus on: defining aims and monitoring results
- the sector itself have to chose technology
- clear and predictable measures

Official framework

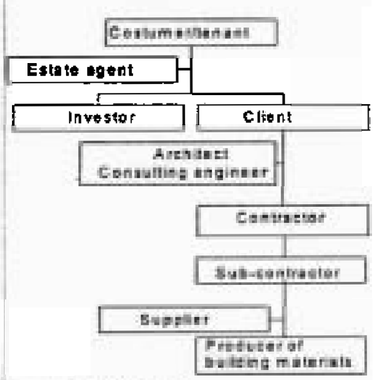
- more stringent and concrete energy specifications in the building regulations
- stricter enforcement of product labelling
- regulation of more hazardous and toxic substances and materials, particularly where safer alternatives exist
- compulsory environmental assessment and user instructions in new housing
- higher prices for electricity and fossil fuels
- economic support for use of new renewable energy
- surcharges on some hazardous substances and materials

THE INDUSTRY

- **many small and medium-size enterprises**
- **low profitability**
- **focus on construction costs**

- **little willingness to take risks**
- **need focus on life-cycle cost**

Building and real estate sector



THE INDUSTRY ITSELF

- interdisciplinary collaboration

  increased focus on the early planning-phase

- calculating life cycle costs
- increased environmental skills

Industry

- Training
- Tools
- Cooperation

"Think long and think big"

The appropriate environmental solution is often so far removed from current practice that we get bogged down in detail, focusing on relatively simple problems which are sadly also relatively unimportant.

The real challenge

- it is not technology but
- *a lack of will and an inflexible approach*

Challenges in Building Energy Efficiency in Warmer Climates

Poul E. Kristensen
MECM Energy Efficient Building
Denmark

International Energy Agency
Future Buildings Forum Think Tank 2001
Workshop Programme
9 – 11 May 2001
Holmen Fjordhotel, Oslo, Norway

Challenges in Building Energy Efficiency in Warmer Climates

Poul E. Kristensen
Chief Technical Adviser
MECM Energy Efficient Building
Putrajaya Malaysia

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

MECM demonstration project

- **Ministry of Energy Communication and Multimedia in Malaysia**
- **Design of a 20.000 m2 showcase building in Putrajaya : Supported by DANCED**
  - The Danish Agency for Cooperation in Environment and Development
- **Present the design development of the MECM building**
- **Present challenges for R&D in tropical climates**

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

MECM new building in Putrajaya OBJECTIVES

- **An Energy Efficient, Intelligent Showcase Building Without Compromising User Comfort**
- **A Study and Research Opportunity for Professionals and Academics**
- **A Demonstration of the Feasibility of the New Building Code Energy Standards**
  - 135 kWh/m²year versus 250 - 300 kWh/m²year

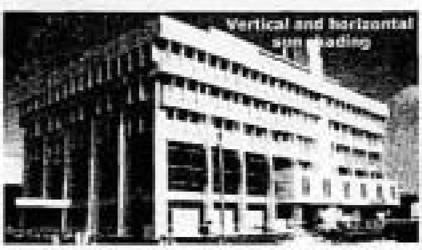
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Malaysian Architecture

Integrated sun shading

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Malaysian Architecture



Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

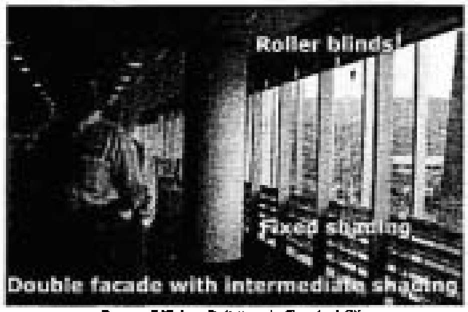
Mesiniaga Building Subang Jaya

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Securities Commission Building Kuala Lumpur

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Securities Commission Building Kuala Lumpur



Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

EGCO Tower Bangkok

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

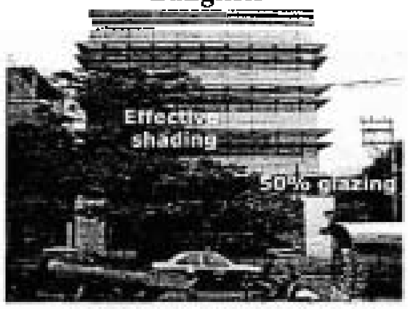
EGCO Tower Entrance

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Energy Management in EGCO Tower
Competence in Energy Management

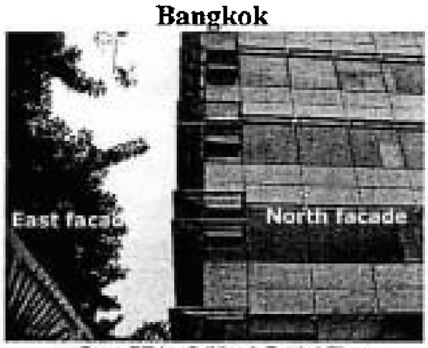
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

NEPO Office Building Bangkok



Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

NEPO Office Building Bangkok



Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

NEPO Office Building Bangkok

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

NEPO Office Building Bangkok

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

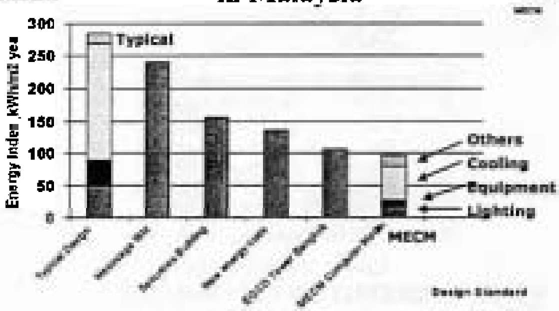
NEPO Office Building Bangkok

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

NEPO Office Building Bangkok

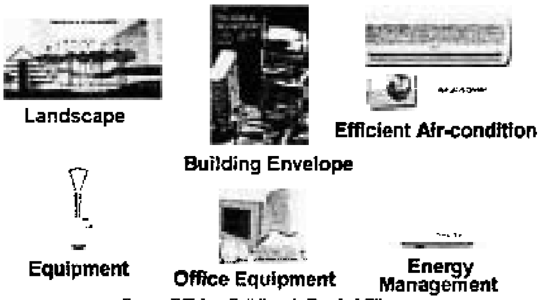
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Energy Efficient Buildings in Malaysia



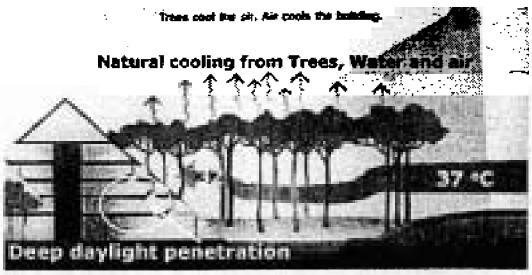
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Sustainable Building Design Requires an Integrated Approach



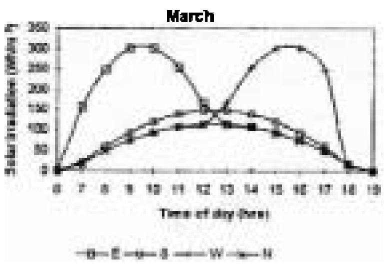
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

DEDP Energy Efficient Building Bangkok



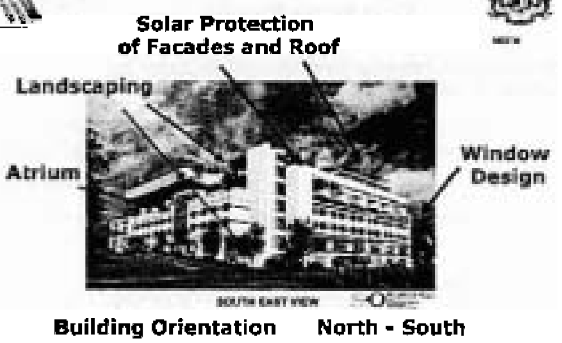
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Malaysian Architecture Solar Irradiation on Vertical Surfaces



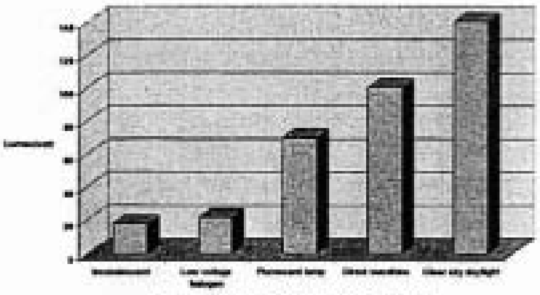
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Solar Protection of Facades and Roof



Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

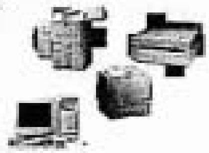
Luminous Efficacy



Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Energy Efficient Office Equipment Demonstration

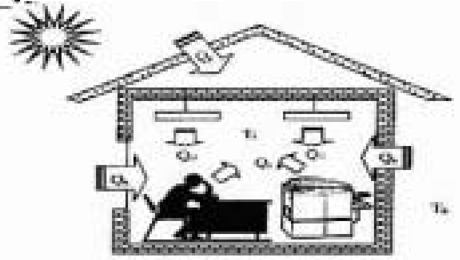
Energy Efficient Procurement
Plug Loads
•Computer
•Monitor
•Printer
•Copier
•Fax



Renewable Energy
• Rooftop Solar PV

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

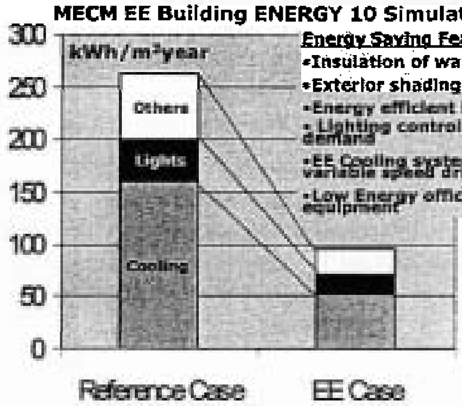
Integrated energy design



Computer Modelling
ENERGY 10 from NREL US

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

MECM EE Building ENERGY 10 Simulation



Energy Saving Features
•Insulation of walls and roof
•Exterior shading of windows
•Energy efficient lighting
• Lighting controlled to demand
•EE Cooling system with variable speed drives
•Low Energy office equipment

First Cost Estimate EE measures in new MECM building

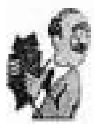
Extra Costs for EE	Extra costs RM	Percentage of building costs	Technology level
Landscaping	250,000	0.5%	Proven Technology
Daylight elements in atrium	300,000	0.6%	Innovative, Proven Technology
Insulated exterior walls	500,000	1.0%	Proven Technology
Double roof	1,000,000	2.0 %	Proven technology
Windows with selective glazing coat	400,000	0.8%	Innovative, Proven Technology
Air-conditioning	- 500,000	- 1.0%	State of the, Proven
Cooling recovery wheel	250,000	0.5%	Proven Technology, Common Practice
Lighting and sub-metering	900,000	1.8%	Proven Technology
Contingency 25%	775,000	1.6%	
Total	3,875,000	7.8%	Innovative Combination of Proven Technologies

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

MECM demonstration project First Phase Results

•Initial feasibility studies on Energy Efficiency :

- •Investments : RM 3.9 mil.
- •Net Savings : RM 0.60 mil. /year
- • Pay-back : 9 years
- •Equipment life : 15+ years
- •Building life : 50+ years



Use of proven technologies

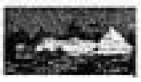
No impact on project time schedule

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

MECM demonstration project First Phase Results

•Significant Energy Savings (60%) can be achieved using cost-effective solutions

•Intelligent building design



•Intelligent energy installations

•Intelligent building management

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Challenges in Building Energy Efficiency in Tropical Climates

City growth is substantial in the Tropical part of the world :

- Mexico City
- Shanghai
- Bangkok
- Manilla
- Jakarta
- Singapore

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Challenges in Building Energy Efficiency in Tropical Climates

Factors contributing to rapidly increased consumption of fossil fuels in these cities.

- Adoption of building designs from temperate and subtropical regions
- Adoption of "Western" levels of comfort
- Increased cooling load in cities due to Heat Island Effect
- Poor quality of new building constructions
- Environment are low priority
- The growth rate

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Challenges in Building Energy Efficiency in Tropical Climates

What can be done :

Demonstrate the link between fossil fuel consumptionand environment

Good showcase buildings

Develop building design solutions specific to tropical conditions

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Challenges in Building Energy Efficiency in Tropical Climates

Implementation of already known technologies

- Efficient pumps and fans
- High efficiency lighting
- Thermal solar energy
- Advanced glazing technologies
- Energy management systems

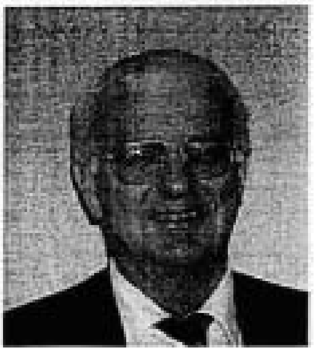
Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001

Challenges in Building Energy Efficiency in Tropical Climates

R&D on Design Solutions Specific to Tropical Conditions

- Solar driven cooling systems
- Solar driven dissicant cooling/dehumidifying
- Re-invent climatic responsive building design
- Utilisation of daylight and sunlight for lighting
- Sealed office buildings with climate control
- **Develop zero emission buildings**

Energy Efficient Buildings in Tropical Climate
IEA Futures Building Forum Oslo 09 - 11 May 2001



Building End-Use Working Party Perspective

Bertil Pettersen
Swedish Ministry of the Environment,
Sweden

A. Are there "white spots" in the RD&D programmes of the IEA Residential and Commercial Sector Implementing Agreements?

More priority driven programmes

CERT noted in its recent IA review that all programmes should be *more priority driven, i.e., more strategically responsive*. A "top down" approach should preferably be added without unsettling or downsizing the very efficient and proven "bottom up" approach that remains a major strength of the IEA collaborative programmes. New strategies mean that gaps and overlaps can change. To stimulate and facilitate discussions, this paper outlines some possible actions to identify and cover "white spots". It is based on the ongoing revision of strategies in EUWP and IAs including technology research, development, deployment and information dissemination to Member and Non-Member countries. A lot of analytical work has already been done by the IAs and by EUWP. Many adequate ideas exist. Looking at the whole Residential and Commercial Sector and not only at specific technology areas creates a better top-down strategic overview. Energy end-use technologies for buildings are integrated in renewable and infrastructure technologies such as photovoltaic, combined heat and power, energy storage, biomass pelleting or gasification, district heating and cooling and different energy carrier networks (gas, biofuels, electricity), waste and water systems, etc. The growing demand for energy, e.g., electricity, in the building sector is a crucial issue.

The importance of sustainability and system integration issues

The IAs and the EUWP have already in their strategic developments addressed the importance of taking a wider look at *sustainability and system integration issues*, including sustainable city planning and national resource management. In workshop discussions with EUWP and IA e.g., a representative of the Europan Commission has highlighted the importance of development and demonstration of technologies for safe, economic, clean, effective and sustainable preservation, recovery, renovation, construction, dismantling and demolition of the built environment, in particular for large groups of buildings.

Balancing near- and long-term objectives are important

CERT also encourages the IEA programmes to develop a new generation of technologies that are sustainable and innovative. On a long term, the needs for *"factor 10"* targets are underscored both by some IAs and "top down" reviews. Buildings and their infrastructures have long life cycles and balancing near- and long-term objectives are important. The key strategic drivers following energy security are the rapid increases of emissions and resource usage in the "business as usual" scenarios presented by the IEA and others (e.g., World strategic drivers following energy security are the rapid increases of emissions and resource usage ˙ı the "business as usual" scenarios presented by the IEA and others (e.g., World Energy Council). Non-member countries (NMCs) will more than double their energy demand and CO_2 emissions by 2020. Especially the perceived needs for reduction of greenhouse gas emissions and the likely need for a future stabilisation and even reduction of the GHG concentrations in the atmosphere are important drivers for innovative far-reaching R&D. Many other concerns exist, e.g., stratospheric ozone depletion, proliferation of certain hazardous chemicals, depletion of other on long-term scarce resources, etc.

"White spots"

Based on what have been discussed between EUWP and IA representatives some observations could be noted regarding what could be "white spots/areas" in the current programmes. A first analysis of the project portfolios has been carried out and a deeper analysis might confirm and add areas of "white spots/areas".

Short term (2008) "white spots":

Cross-cutting and new activities to facilitate the deployment of available and improved energy technologies that contribute to improved local and global environmental performance.

CERT noted that this will create increased emphasis for working together with industry to reduce barriers to deployment and facilitate deployment by pro-active initiatives. An R/C task force has started to work on these issues and will report next year.

"White spots": ***Activities to remove institutional barriers linked to standards, building codes and regulations, regarding improved technologies and new systems.*** The barriers are different in various countries and should preferably be subject to coordination.

"White spots": ***Packaging of information for specific target groups.*** If "best practice" or "new" technologies, any compilation of technology performance and data will require the involvement of outstanding expertise. Targeting also non-member countries and including system approaches will only increase the demand for such competence. A cross-cutting technology learning process and network involving the expertise in and around the IEAs should preferably be built up as a tool for linking IEA technology information to industry and to potential users.

"White spots": ***Cooperation with industry on strategic levels to reduce barriers to deployment and to increase industry involvement.*** Preferably include networking and capacity building to facilitate a deeper involvement of industry in IEA deployment activities.

Research and Development activities

"White spots": ***Community system integration and optimisation for better environment and sustainability***

Buildings are always interconnected; e.g., by energy and water supply, waste and sewage discharge/recycling, transport systems, telecommunication, etc. Community and local planning procedures and methods will considerably influence the functions and the sustainability of buildings. Novel district heating and cooling systems (using designs like combined heat and power, low temperature distribution, heat & cool storage, heat pumps, different primary fuels and heat sources, heat cascading) are examples of important system-innovations providing for better sustainability. An increasingly **integrated approach** combining many technologies, is demonstrated by work underway within various R&D frameworks, e.g., the EC City of Tomorrow.

"White spots": ***The further development of design and optimisation tools to facilitate a wide and rapid deployment of improved and new state-of-the-art technologies are important.***

Validated computer modelling software for building performance has in this sector (as in most others) presented designers with powerful new design tools. They range from modelling of specific subsystems (like room ventilation) to city planning or even regional energy and environmental planning and optimisation (IEA Energy Technology System Analysis Programme). Sophisticated tools for modelling and analysis of complex systems have been developed for the industrial sector (for instance, the analysis around which the IEA Process Integration in Industry Programme is conceived). For the building sector similar approaches have been discussed and tested but the rigidities and institutional complexity of buildings have curbed wider use. It might be noted that the overall second law thermodynamic efficiency of heating and cooling systems for buildings usually is low and limited by system rigidities. A few exceptions exist, notably some applications of heat pumps and cogen systems. First law efficiencies are not sufficient for describing the opportunities to improve complex energy systems. Considerable second law efficiencies could be reached by use of system integration design methods and the best new technologies. Numerous test and pilot plants have demonstrated and verified these opportunities.

Work practices and mode of operation when using a pro-active "top down" cross-cutting approach to strategic coordination and development.

"White spots": ***Set up a better link mechanism to facilitate strategic coordination between National Networks and IEA Standing Committees, IEA Implementing Agreements, International Organisations and Industry and its organisations.***

This could be done in different ways. The IEA and IA home pages can serve as easy entrances (web portal functions) to links to all organisations relevant for strategic updates. If some coordination is done, it would be possible to establish mutual communication between parties involved. A

user friendly system for linking only the web pages relevant for strategic evaluations might be reasonably simple to arrange. CERT has taken steps to strengthen the links between CERT/WPs and the IAs. The dialogue between the technology experts and the strategy analysts would preferably be pro-active and not reactive. CERT has in (99)31 concluded that key messages to WPs and IAs are:
Improve linkages to Member countries' national policies and measures.
Increase the emphasis to be placed on activities aimed at deploying technologies, principally by encouraging IAs to involve industry.

This issue is related to the informal collaboration under EXCETP-International Collaboration on **Experience Curves for Energy Technology Policy**. EXCEPT is a virtual organisation initiated by IEA/CERT. It currently works with three tasks **"Case Studies-Global Learning and Local Deployment"**, **"Analysis for Policy-making"** and **"Guideline and Database for Experience Curves"**. Information on EXCETP can be found in Doc. IEA/CERT(99)46 and in IEA/GB(99)50/ANNI project 16.8. Experience curves are widespread tools for production and strategic analysis within all levels of technology-intensive industry. The fact that gathering experience through acting on competitive markets makes individuals, enterprises and industries do better is at the heart of the experience curve phenomenon. EXCETP aims, e.g., (i) to analyse global learning and local deployment of technologies with large potentials in many countries and (ii) to use analysis based on experience curves to support IEA/CERT formulation of strategies for cooperation on energy RD&D and technology policy.

Long term (2020) "white spots":

Cross-cutting and new activities to facilitate the research, development and demonstration of new energy technologies that contribute to improved local and global environmental performance.

"White spots": ***Buildings must adapt to climate change.***
Building codes and regulations, general assessments, etc., need to be adjusted to respond to climate change. Impact of heavy winds, extensive rains, snow and ice, extreme temperatures, occasional interruptions of infrastructure networks, etc., must again be assessed and taken into account.

"White spots": ***"Factor 10" targets for energy R&D.***
Long term R&D in the building sector has now an additional driver, i.e., the increasing acceptance of moving towards sustainability of resources, energy, and environment. Several studies have indicated the long-term need for "factor 10" targets for R&D as reported in the 1998 IEA/IAs Hilton Head Workshop and the 1999 IEA/EUWP Stockholm Seminar. It is

evident that a major GHG-mitigation impact must come from more innovative ways of using fossil fuels, i.e., introduction of technologies with very limited emissions of greenhouse gases and other pollutants (and not only by means of increased efficiency).

"White spots": ***R&D targeting breakthrough shares (>>20%) of renewables.***
Ambitious promotion programmes for energy efficiency in residential and commercial buildings are pursued in several countries with targets varying from 15% to 30% reduction of energy use. Pilot R&D programmes aim for 25-75% reduction in certain segments and in the longer term (more than 10 years). Most national and European Commission programmes address the importance of increasing the share of renewables in the Residential and Commercial Sector as a measure for better sustainability and energy security. The targets are challenging, i.e., increases of the shares by 50 to 100% over 10-15 years. However, this still means a target of only some 10-12% of the total energy use in the Residential and Commercial Sector.

"White spots": ***Further integration of components and technical systems for clusters of sustainable buildings.***

It is well known that there are important links between the performance of different building structure components and service systems, equipment, etc. Topics like air quality, thermal comfort, moisture and humidity balances are coupled to architectural and technical designs, construction procedures, type and function of installations, and to the way the building is used. Photovoltaic, thermal solar systems, heat pumps, etc., are dependent on integration due to the need of space and area and reduction of first cost.

"White spots": ***New technologies and concepts for building clusters and sustainable cities for the city of tomorrow.***
New advanced technologies like fuels cells, electricity and thermal storage technologies, novel district heating and cooling systems, new energy carriers, etc., might open for new concepts regarding sustainable building design, construction, management and services in building clusters, cities and mega-cities.

B. Task Force on Sustainable Building Market Development

New market development initiatives should be encouraged.

In recent years there has been much emphasis in the IEA on the development of markets for improved energy technologies. Attention to market development is particularly timely for building-related technologies because trends in the building sector are setting the stage for significant changes in the way buildings are designed, constructed and used. This movement towards more sustainable buildings will have a large impact on energy use. The Working Party on Energy End-Use Technologies (EUWP) appointed this Task Force to advise it on the implications of these trends for collaborative work in the building sector and on whether new market development initiatives should be encouraged.

There is also a serious gap in the overall programme

The Task Force has found that the building-related implementing agreements (BRIAs) are already pursuing both building sustainability and market development projects. But there is much more to be done. Moreover, in an overall perspective the IEA building-sector programme appears fragmented and incomplete. It reflects having been designed in response to earlier needs driven by the R&D agenda and it has not sufficiently adjusted to the current emphasis on a holistic, integrated, market-oriented approach. While some important cross-cutting cooperation has been achieved, for the most part each BRIA approaches market development issues independently.There is also a serious gap in the overall programme in that it does not anywhere directly address the issue of market development policy.

A more integrated IEA building programme

In this light the Task Force sees a need for action in support of change from the relevant Working Parties, CERT and Member governments. They need to support the BRIAS in their efforts to adapt to evolution in the building sector and encourage them to do it in ways that will lead to a more integrated IEA building programme. They need to take new initiatives that will help to facilitate such adaptation and fill gaps in the building programme. And they need to provide the resources necessary to carry out these activities.

Renewal of the IEA's existing programme for the building sector

Changing a complex, well-established and decentralised international programme is not an easy task – courage will be needed to do it effectively. However, in the view of the Task Force, the way to proceed is not by attempting a major structural overhaul – developing and agreeing on the design of a new approach would be difficult and subject to great risk – but rather by setting up a process that will facilitate a smooth evolution and a renewal of the IEA's existing programme for the building sector. In practical terms, some relatively small steps can be taken and built upon in the future. The initiatives we suggest will facilitate the adaptation of the BRIAs to sustainable building trends and will add some new activities in a selective and efficient way.

A gradual response to the need for change nonetheless involves a serious challenge right now for the Working Parties, CERT and Member agencies – *namely to find the resources that will be necessary to put the heightened evolutionary process into motion.*

Task Force recommendations

The EUWP Buildings Coordination Group (BCG) should play a more active role in assisting the BRIAs to adapt their programmes to sustainable building trends and become more market-oriented. Particularly useful at present would be the development of workshops with and for the BRIAs on the design of market development projects. Member countries should be encouraged to set in place a mechanism for financing the staff support that will allow the BCG to carry out its coordinating work, as well as the workshops and other activities that arise out of it.

1. *In order to enhance contacts between the BRIAs and external building-related organisations and agencies, the Working Parties should endorse the participation of IEA building activities in the International Initiative for the Sustainable Built Environment (iiSBE).* (More information on iiSBE, a new organisation that will support communication and networking in regard to sustainable building issues, is provided in Attachment A.) In this regard, the Working Parties should also: endorse the support of iiSBE by IEA Member countries; suggest to the iiSBE Board of Directors that it invite the BRIAs to participate in its technical advisory panels; and, through the BCG, designate a representative of IEA building sector activities to sit on iiSBE's Board of Directors. In the same spirit, iiSBE participants should be encouraged to become involved in BRIA activities so as to provide additional expertise on the non-energy aspects of building issues.

2. The Working Parties should endorse:
   (a) *the establishment of a process for the exchange of information on policies for sustainable building market development and their evaluation;*
   (b) *the development of that process in association with iiSBE's work on information dissemination, and*
   (c) *the participation of Member governments in the project.*

3. In order to assist in the coordination of the above initiatives and to develop others that will contribute to the growth of markets for sustainable energy technologies in buildings, *a Market Development Unit for Sustainable Buildings should be established in the IEA Secretariat and Member governments should set in place a process for financing it.*

4. *The Working Parties should encourage new cooperative projects in the area of market development policy and promotion.* These new efforts could include special projects coordinated by the Market Development Unit for Sustainable Buildings and the development of projects in a new entity specifically designed for that purpose or in existing BRIAs.

5. In order to better communicate the objectives of the EUWP for the building sector, the designation of *the Associate Chair for the Residential-Commercial sector should be changed to Associate Chair - Buildings.*

These recommendations and their rationale were discussed in more detail in the main report from the Task Force, which was presented at the IEA/EUWP meeting in Paris, 5-6 April 2001.

The EUWP recommendations

1. New sustainable building policy information exchange was approved. See points 2 and 4 above.
2. Participation in the International Initiative for the sustainable Built Environment (iiSBE) was approved. See point 2 above.
3. Provide support service for a more active Building Coordinating Group was approved, but it requires funding.
4. The proposal of a Market Development Unit for Sustainable Buildings in IEA Secretariat was discussed and referred back to BCG and to the sectretariat for development and further discussions at next meetings.

Encourage new cooperative projects on market development was strategic and was referred back to BCG for proposals.

High-Performance Commercial Building: A Technology Roadmap

Richard H. Karney
US Department of Energy
USA

What is a Technology Roadmap?

- *Industry-developed* vision and plan for the future
- Roadmaps typically contain:
  - **Trends and drivers**
  - **Performance Targets**
  - **Technology barriers**
  - **Research, development, and deployment needs**
  - **Participants' roles**

Technology Roadmap?

- DOE working with building industry to create "Tecnology Roadmaps" for a range of building technologies
  - Commersial buildings
  - Lighting
  - Windows
  - Envelope
  - HVAC
  - Residential buildings
- DOEfacilitating roadmaps – belong to "industry" not DOE

Why is DOE Doing Technology Roadmaps?

- Build relationships with industry
- Create a RD&D agenda for the industry (and DOE)
- Align DOE's activities with those important to industry
- Build support for DOE activities

Technology Roadmap Process

- Visioning: 'where should we go?'

Executive Forum

Industry leaders (CEOs, senior executives)

Develop a vision statement and strategic thrusts

Technology Roadmap Process

Roadmap: 'what needs to be done?'

- Roadmap Workshop(s)
  - Broader group
  - Develop near-, mid-, and long-term activities to meet performance targets
- Work with Industry Champions
  - Develop activities developed in workshop
  - Fill in missing details
  - Create industry partnerships

Technology Roadmap Process

Implementation: 'what should be done and who should be involved?'

- Industry buy-in
- Industry and DOE align RD&D activities

Commercial Roadmap Participa.its

150 organizations
250 people

- Architects, Engineers, Lighting and Other Designers
- Building Owners and Developers
- Building Technology Manufacturers
- Government Agencies
- Industry Organizations
- Labor
- Professional Societies
- Research Organizations
- Universities
- Utilities and Energy Service Companies

High-Performance Commercial Buildings Vision Statement

By the year 2020:

- Successful public/private partnerships will deliver highly adaptable, sustainable, cost-effective commercial buildings
- Advances in building design and operation will provide simple solutions to address the complex interactions of systems and equipment.
- America's commercial buildings will be values by occupants, owners, builders, and communities as healthy, productive, and desirable places to learn, work, and play.

Buildings Response to the Environment

- Up until 19th century
  Adapt to the environment
- From 19th until mid-20th century
  Control the environment
- Late 20th century
  Create identical interior climates regardless of environment
- 21th century
  work with the environment

Technology Workshop: 'State-of-the Art' Buildings

1949

- Vacuum-tube products (B&W TV, radio), telephone, telegraph
- Office becomes dominant building type
- Sealed Glass Box (International Style)
- Suburbs as ideal
- 'Technology can solve everything'
- 'Throwaway' society

2000

- Silicon, computers, Internet, e-mail
- Mixed use buildings
- Buildings net exporters of energy
- 'Whole' building concept, include communities
- More human, organic, environmental responsibility
- Closing the circle—waste materials become products

Buildings in 2050

- Envelope
  Organic, dynamic skin (like human skin)
- Ventilation
  Dynamic, personalized
  Decoupled from conditioning
- Materials
  Organic composites
  "plug-n-play
  Waste materials as source
- Lighting
  Solid state sources (LED)
  Dynamic levels, daylighting
- Thermal conditioning
  Micro-scale sources, individual control
- Energy Resources
  Distributed, site level
- Water
  Biological integrated with engineering
  Zero discharge
- Digital
  Micro sensors, personalized building controls, metering, wireless controls
  "smartdust"
- Transportation/Land Use
  Best building = no building
- Finance/Economics
  Service focus – not products
  Long-term, life-cycle costs

Buildings of the 21st Century

'Smart materials' that can respond to external conditions by changing their color, shape, stiffness, or permeability to air or liquids could become the stuff of future cities whose buildings are more comfortable and better able to field sudden violent challenges from earthquakes or terrorist bombs. Smart materials also could lead to cities whose infrastructure can sense--and even automatically compensate for--the wounds of corrosion, metal fatigue, age, and the other slings and arrows of urban decay.

Ivan Amato, Stuff, The Materials the World is Made of

Commercial Building Roadmap Strategies

Performance Metrics

Establish key definitions and metrics for high-performance commercial buildings.

Technology Development

Develop systems integration, monitoring, and other technologies that enable commercial buildings to optimally achieve targeted performance levels over their life cycles.

Process Change

Create models of collaborative commercial whole-buildings design and development, and establish the tools and professional education programs needed to support these processes.

Market Transformation

Stimulate market demand for high-performance commercial buildings by demonstrating and communicating compelling economic advantages.

HPCB Roadmap Implementation

Roadmap Strategies	DOE Programs
Performance Metrics	High Performance Commercial Buildings
Technology Development	Indoor Air Quality; Commercial Codes
Process Change	Rebuild America
Market Transformation	Energy Star Building Label

HPCB Roadmap Implementation

Roadmap Strategies

- Performance Metrics
- Technology Development
- Process Change
- Market Transformation

DOE Programs

- High Performance Commercial Buildings
- Indoor Air Quality
- Commercial Codes
- Rebuild America
- Energy Star Building Label

HPCB Roadmap Implementation

Roadmap Strategies

- Performance Metrics
- Technology Development
- Process Change
- Market Transformation

DOE Programs

- High Performance Commercial Buildings
- Indoor Air Quality
- Commercial Codes
- Rebuild America
- Energy Star Building Label

HPCB Roadmap Implementation

Roadmap Strategies

- Performance Metrics
- Technology Development
- Process Change
- Market Transformation

DOE Programs

- High Performance Commercial Buildings
- Indoor Air Quality
- Commercial Codes
- Rebuild America
- Energy Star Building Label

HPCB Roadmap Implementation

Roadmap Strategies

- Performance Metrics
- Technology Development
- Process Change
- Market Transformation

DOE Programs

- High Performance Commercial Buildings
- Indoor Air Quality
- Commercial Codes
- Rebuild America
- Energy Star Building Label

Summary

- Future technologies (next 20 years) are already here
- Significant improvements in efficient use of nonrenewable and renewable energy sources and environmental impact improvements possible now—savings of 50-80% over typical practice often at no increase in capital cost

Summary (continued)

- Roadmap promotes substantial change in how buildings are designed, built, operated, and maintained→team, working together throughout building life-cycle
- Requires public/private partnerships to create 21st century buildings from the shared vision
- Everyone working from same plan

High-Performance Bldgs 125 years ago

- Designed in 1881 by civil engineer and U.S. Army General Montgomery C. Meigs and completed in 1887, the building was originally built to house the Pension Bureau and was later occupied by many government agencies.
- An ingenious system of windows, vents, and open archways allows the Great Hall to function as a reservoir of light and air. The impressive Italian Renaissance design, with its central fountain and eight colossal Corinthian columns – among the tallest interior columns in the world – has also made the Great Hall a sought-after spot for gala events, including many Presidential Inaugural Balls, from 1885 to the present day.
- The building was constructed between 1882 and 1887, originally cost $886,614.04 to build and is built of 15,500,000 bricks with brick and terra cotta ornament. The building measures 400 feet by 200 feet and is 75 feet to the cornice level.

Info on all Building Technology Roadmaps

Building Technology Roadmaps:
www.eren.doe.gov/buildings/technology_roadmaps

High-Performance Commercial Buildings:
A Technology Roadmap:
www.eren.doe.gov/buildings/commercial_roadmap

DOE's buildings RD&D programs:
www.eren.doe.gov/buildings/

Building Technology Roadmaps Status

- *Vision 2020 Lighting Technology Roadmap* published March 2000
- Windows Industry Technology Roadmap published May 2000
- High-Performance Commercial Buildings: A Technology Roadmap published October 2000
- Building Envelope Technology Roadmap work started in 2000, expect to publish Spring 2001

Long-Term Trends in the Swiss Building Sector

Mark Zimmermann
EMPA ZEN
Switzerland

Since about 1960 the Swiss building sector has been consuming more resources than any other part of the Swiss economy. About 10 % of building sector energy consumption is accounted for by construction and a further 50 % by the operation of the building stock. The second largest energy consumer, with nearly 30 % of total consumption, is the transportation sector. During the last decade building energy consumption has stabilised despite the continued growth in building stock. But transportation requirements are still growing.

Setting optimism aside, we still need to ask how the building sector will develop in future. Is there further potential for improvement? What are the long term trends in the building sector?

Buildings are normally constructed for the next 30 to 100 years. Although it is difficult to forecast what will change during this time, looking ahead to the future and trying to understand future needs is never a wasted exercise. When looking ahead, we have to distinguish between desirable, feasible and likely developments. Unfortunately not every desirable development is also likely to come to fruition. A sustainable society with a sustainable construction sector is certainly a desirable scenario. Yet we cannot say to what extent a sustainable building sector will be achievable over forthcoming decades. Nevertheless, it is still important to push developments in the right direction.

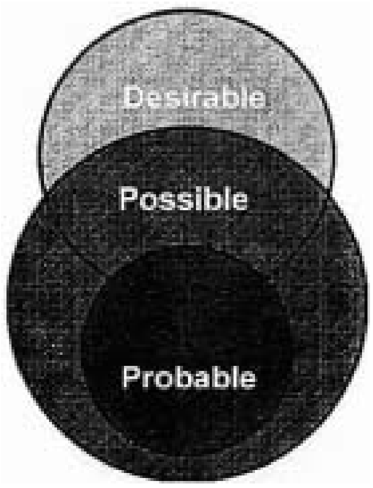


Figure 1. Unfortunately only a few scenarios are desirable, possible and also probable at the same time

Future changes will be strongly influenced by social and economic conditions.

- The economic situation will change much faster than in the past. Versatility and flexibility will become important characteristics of buildings. The final installations and finishes will be increasingly left to the tenants, especially in the commercial sector. This could often hinder integrated solutions.

- Building retrofit will of necessity gain in significance. The question of whether demolish and reconstruct rather than continuously retrofit will become increasingly important. Demands for high building standards will rise. Low quality buildings will not be able to satisfy these demands and are therefore better demolished.
- Retrofit and demolition will cause a growing number of waste problems. Reparability and building waste recycling will become an important issue that has to be thought of before construction. Increasingly, component replacement will replace repair work.
- Our economy is heavily dependent on the availability of cheap fossil fuels. Within the next 30 years, demand will outstrip supply and a large increase in energy prices is to be expected. While this will not cause any problems for energy efficient buildings, it will I ave a severe impact on the economy and especially the energy supply to third world countries.
- Traffic will continue to increase in all sectors (public and private, short- and long-distance).

Apart from these economic and social boundary conditions, some clear technological trends are emerging:

- Immense progress has been made in the field of energy efficiency. Heating energy consumption has been reduced from an average of about 25 litres per m^2 a year to about 1.5 litres of oil equivalent. The Minergie and the Passive House Standard have established the basis for broad use of this technology. It is possible to reduce heating energy consumption to 10 times lower than average not only in experimental houses but also in normal new buildings. In such buildings, the heating systems is no longer a central installation.

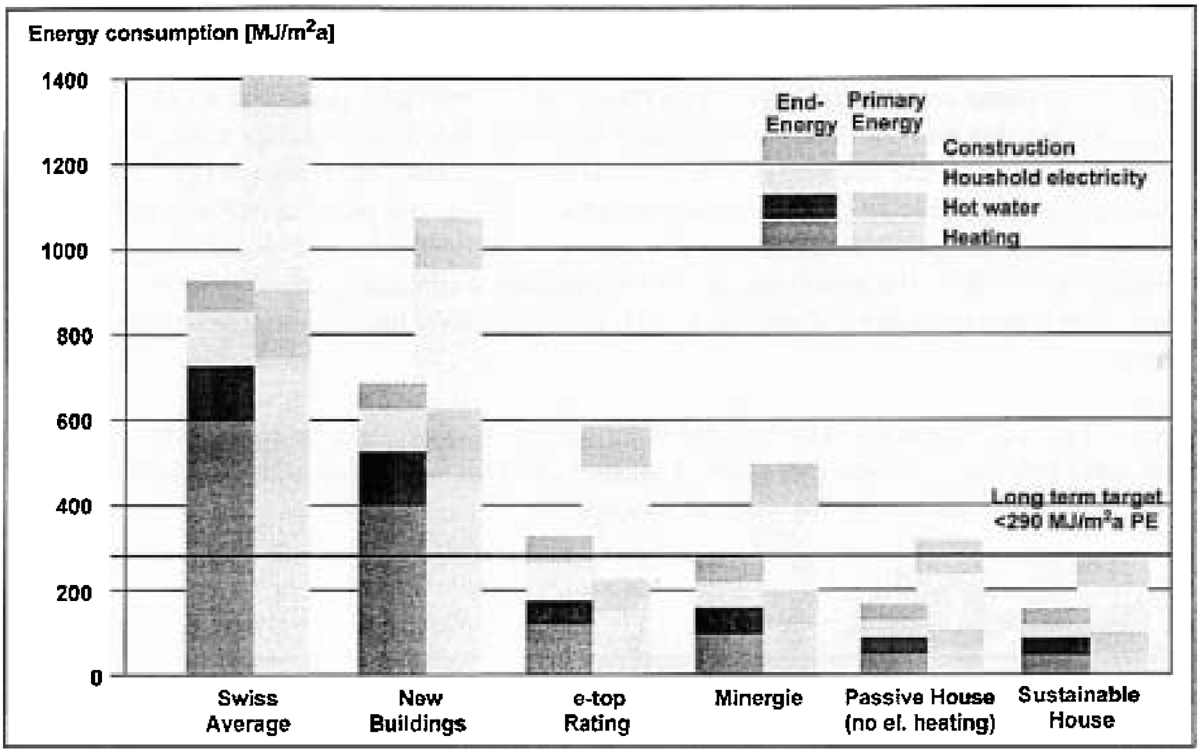


Figure 2. Energy consumption of different building energy standards. The Passive House comes already very close to sustainability, as far as primary energy consumption is concerned (Basis: 2000 Watt Society).

- The trend towards heavily glazed building envelopes that allow transparency and brightness will continue. This trend is also driven by innovative new technologies (such as electrochromic glazing, integrated photovoltaics etc.). The need for optimal sun protection will increase.
- Mechanical ventilation will become a standard technology, offering both comfort and energy efficiency thanks to efficient heat recovery. Air handling units will include intelligent energy management systems and will guarantee optimal air quality. They will replace traditional central heating systems.
- Renewable energy – such as solar energy for hot water and heating support or efficient and clean wood stoves – will be standard technologies in future homes. Other technologies like photovoltaics or transparent insulation will still need further development.
- Electricity consumption will further increase. Electronic networks, wireless communication and powerful information technologies in particular will undergo as yet unforeseeable further development. The number of installations and performance gains will outpace the savings generated by technological advances. Photovoltaics, fuel cells and electricity management systems will therefore play an important role in future new buildings and retrofits.

Overall, building technical systems will become smaller but more versatile. The low heating requirement will necessitate a reappraisal of the need for traditional central heating systems. With heavily glazed facades, comfort problems will tend to occur in summer rather than winter, and cooling will become as important as heating. Reversible systems that can both heat and cool buildings will dominate. Small electrical heating pumps will become more common. The COP will improve greatly and a COP of about 6 will be achieved for both heating and cooling. The use of ambient heat and cold will grow, especially using ground-coupled air systems and ground pipes. Electricity will be partially produced on site, using PV cells during the day and fuel cells at night and in winter. Intelligent energy management systems will optimise the use of the available electricity. These complex energy systems will increasingly be available as complete energy centres. "Plug and play" combined with minimum engineering will also become the rule in building equipment. Increasing globalisation will limit the development and maintenance of such systems to a few international companies only. Customised solutions will only be possible for very large systems.

Domestic hot water supplies will become an important energy consumer. Solar hot water systems and hot water pumps that recover waste heat, will become standard technologies. There will be little change in hot water consumption.

	Ø CH	New building	Renovation Magnusstr.
Heating	600	400	40 MJ
Hot water	130	130	9 MJ
Electricity	120	100	60 MJ
Total	850	630	109 MJ

Figure 3. Example for an advanced renovation in Zurich. Also old buildings can achieve the Passive House Standard if a complete retrofit is possible.

In 30 years time there will also be conventional buildings that are basically unchanged from today's buildings. In particular, many existing buildings will only change slightly because retrofit measures are expensive. However, such buildings will need other qualities if they are to compete against increasing comfort expectations. Unless they are well situated, architecturally outstanding or they of high historical value, they will have difficulty justifying their high energy cost and low comfort levels.

Urban Planning for a Green & Sustainable Future

Tony Rigg, Co-Director,
UIA Work Programme on Architecture & Energy
Israel

Historical Outline

In The Beginning, when fossil fuel based energy was not easily and cheaply available, all was Green.

With arrival of the era of Cheap and Available Energy, and with it Mechanised Transport, things began to change.

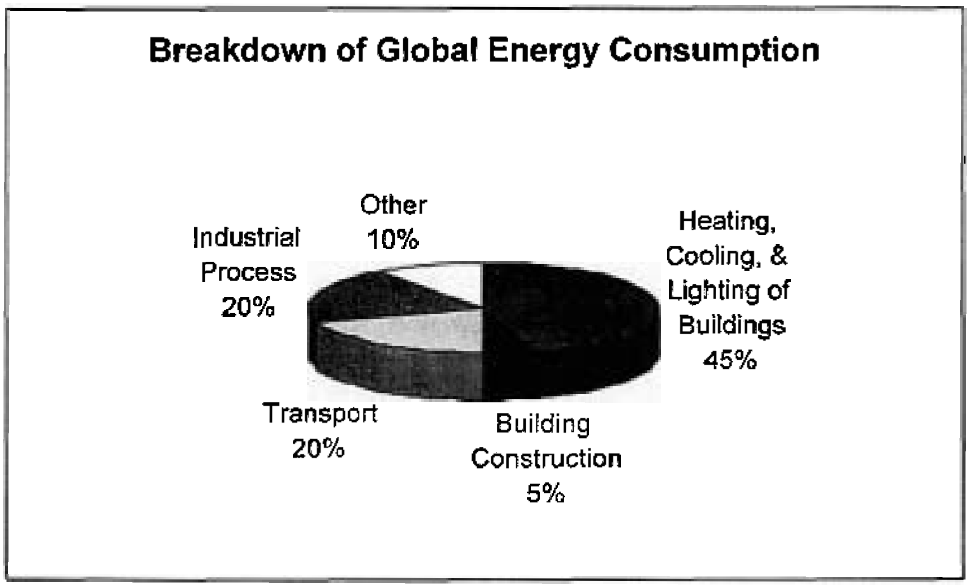
Urban planning and building design became divorced from environmental considerations and responsibility:

> Buildings ceased to be designed on the basis of form & orientation in relation to climate, and it became the norm for thermal comfort & functionality of buildings to depend entirely on mechanised, energy-dependent systems.
>
> Daylight ceased to be considered as the main source of daytime illumination.
>
> Use of locally available materials ceased to be a factor in building design.
>
> Mechanised transport, in the form of the private car, became the generating force in the planning and development of cities, and in the creation of urban sprawl.

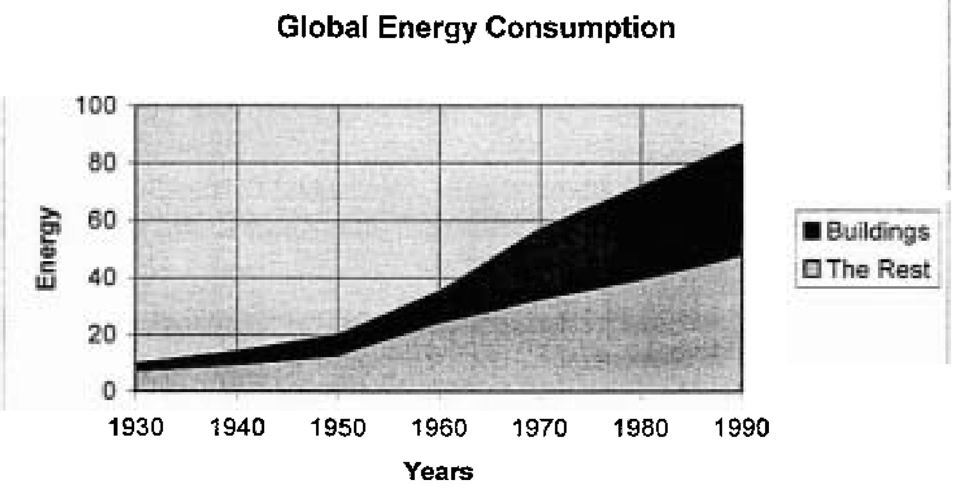
And Cities Grew…and Grew…

Current Situation

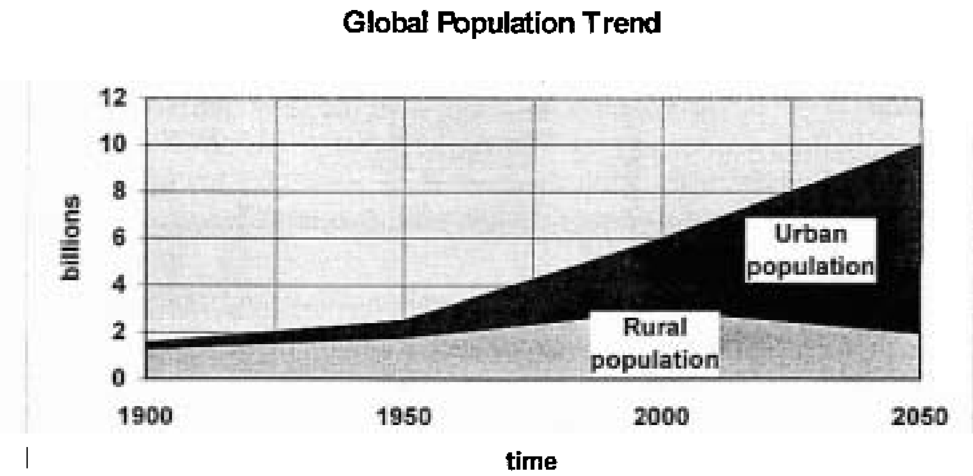
Today, we are aware that the course of development followed over the last hundred years is creating a dangerous impact on the whole global eco-system, and that steps must be taken to change this course if environmental changes and disaster are to be avoided. **This is the challenge facing the urban planning and building design establishment today.**



Today, 45% of global energy consumption is used for heating, cooling & lighting of buildings, with a further 5% in building construction. **Over 50% of this energy could have been saved through improved, climatically sensitive building design and construction, on a purely economic basis.**



Cities account for the majority of global resource consumption, produce most of the world's waste and pollution, and directly and indirectly are responsible for the majority of global environmental degradation. This is becoming increasingly important with the exponential growth of cities as a global phenomenon: in 1900, 14% of the global population of 1.8 billion lived in cities, whereas today, 50% of the present global population of 6 billion are urban dwellers – an actual increase of over 1000%.



If we look 25 years down the road, we see that globally, the population living in cities (of one million+) will almost double, and that the urban built environment will *at least* double with it, taking into account rising standards of living, dwellings, & workplaces.
We should also be acutely aware that most of this urban expansion will take place in the developing areas of the world, in Central & South America, Africa, & Asia, and *not* in North America & Europe. However, the degree to which this urban expansion impacts global environmental degradation & resource depletion will affect *everyone, everywhere.* **This scenario must be a driving force behind our visions for the future.**

There are two options that can be taken with this massive "opportunity":
Either to continue with current status quo in trends of design and construction, and continue the exponential growth of urban energy consumption, or to take the "green" road and drastically improve the energy *and* economic efficiency of the developing built environment.
The choice will be taken, one way or the other.

It is clear, however, that without directed pressure, education, regulation & incentive, the status quo will prevail, by default.

If the developing world succeeds in taking the "Green Road", it will massively reduce the potential dependence on (largely imported) fossil fuel energy, reduce CO2 emissions, and improve the overall standards of living, working and comfort conditions. Since the *real costs* involved in taking the Green Road are negligible, can we afford *not* to take it?

Furthermore, we need to take action *now* to "make a difference", and influence the course of events: in 10 years down the road the facts on the ground will be massive, and urban development, once carried out, leaves only small opportunities for future improvement in reality.

Elements of "Green" & Sustainable Design & Development

If we are to take advantage of the opportunity before us, we must plan, design, and build in ways that will bring us onto the "Green Road". This of course requires "doing things differently", compared to present practice. Whereas in northern Europe there is significant official movement in this direction (as demonstrated at the Sustainable Building 2000 Conference in Maastrich, October 2000), in most other areas of the world, official concern and action is only just beginning, if at all.

A frequently asked question is *"what are the issues that we have to deal with?"*
I have tried to put together check-list of the more energy-related concepts & issues of "Green" planning, development and building.

Planning for Sustainability

Re-Definition of "The City" is required to create an ecologically and socially sustainable, optimal "life-basis" for the majority of mankind. This is an important consideration, now that "The City" has become the normative basis for life for more than 50% of mankind: as such, we should aim to make it the *optimal* basis for life.

However, when discussing the "sustainable city", we come up against a problem of definitions: it is far easier to define what a sustainable city ***is not***, than to say what it ***should be***, as we have no existing models to look to. We have no "image" of the sustainable city to "sell". The best we can do is to analyse the issues, and then try to formulate a model as a basis for actual development and application.

Issues of Urban Sustainability

We must achieve an integration of urban planning and transport systems so that transport works as a *service* of the City, not a substitute for it.
Firstly, mixed-use high-density development, multiple centres, & public facilities should be coordinated along dedicated primary public transport routes. All major public, cultural & commercial facilities should be located within pedestrian distance of primary public transport

routes. Planning priority should be given to public transport systems, making the private car a secondary option for urban travel. (Successfully achieved in Curitiba, Brazil) This integration both reduces the *quantity* of urban travel required, and the *energy* required to facilitate it. However, economical dedicated public transport routes are a surface network, and can rarely be retrofitted into an existing urban fabric. After-the-fact construction of underground transport systems cost 50 to 80 times that of a "Curitiba type" solution, and as such can rarely be realistic solutions.

Parallel to this, the city should be planned, as far as is possible, to make pedestrian & bicycle scale access the norm of daily life. Everyday activities, involving movement between residence, place of work, schools, shops, daily recreation, and access to nature, should all have options within distances independent of mechanized transport.

The Sustainable City must develop a "cyclic metabolism" of processes of production, consumption & recycling, as opposed to the current "Linear Throughput" and mass waste generation model. This involves the integration of all city activities & processes into a cyclic regenerative system, with minimal environmental pollution and impact. Urban management and incentive are required to direct the *output* of each "process" as *resource input* to another, resulting in "absolute waste" only as an option of last resort. These processes include all material, water, and energy flows: such a system, when properly managed & integrated, can result in dramatic economic savings, aside from reduction of pollution.

The City should be developed in sympathy with its local climatic conditions, using the local climate as a generator of sustainable planning concepts.
Urban morphology determines the shading or exposure of streets, public spaces, & buildings to sun & wind. This in turn determines the comfort qualities of the urban microclimate, and to a large extent determines whether urban "heat island" effects will be created. (In Athens for example, some city-centre areas are up to 17 degree C hotter than surrounding suburban areas).

Urban planning also determines the orientation of spaces & buildings, & thus determines the solar & daylight access of buildings, and consequentially the potential building energy demand for heating, cooling, & lighting, and potential use of passive heating and photovoltaic generation. It also determines airflow through the urban matrix, and thus potential use of natural ventilation for cooling effect in buildings. Planning also determines run-off & absorption of rainwater at the urban scale, & thus "urban greenery" levels, and resulting thermal micro-climatic conditions.

The luxury of ignoring energy issues is fading fast, and energy-responsible urban systems are going to be needed to deal with increasing energy costs, pollution, and UN Climate Change Convention requirements.

Apart from reduction of energy demand and consumption in urban transport, and heating, cooling, & lighting of buildings, we must plan for *maximum urban use of renewable energy sources*, primarily solar and photovoltaic, but also wind & geothermal energy where relevant. We should use the *most efficient & least polluting energy generation systems*, including waste or surplus energy conversion & reuse, and co-generation & combined-cycle systems: where possible, we should use natural gas energy to minimise CO_2, SO_x, & NO_x pollution, and also maximise urban forest vegetation for absorption of CO_2 & SO_x.

Building for Sustainability

Within the context of the sustainable city, we must create "green" buildings. Currently, the knowledge exists to design modern, technologically advanced, economic, climatically responsive buildings that are also ecologically friendly and healthy for their inhabitants. Over the last twenty years this knowledge has been researched, developed, tested and applied in many demonstration projects worldwide, and is no longer at all experimental. However, they have not been widely applied in mainstream building construction, and "mainstreaming green" design is a major challenge in today's context.

We should design buildings in response to climate, applying strategies of climatic design, using the local climatic conditions to generate indoor comfort conditions. This is achieved through conceptual planning, using building form and orientation to reduce heating &/or cooling demands, then applying passive design concepts to provide natural heating &/or cooling effects, & only *then* considering imported energy input. We should design for maximum use of daylighting for all possible illumination requirements during daylight hours.

Buildings thus designed are inherently more comfortable for their occupants, apart from saving energy and thus reducing pollution throughout their life, and they can make a significant contribution towards expectations of increased standards of living and comfort.

However, as stated above, the potential to *achieve* this is first of all determined by the urban morphological context.

Since buildings are the major consumers of natural and manufactured resources, we should design for efficiency of building material use, avoid major use of scarce or distant-source materials, and avoid using materials whose supply causes environmental degradation. We should design to reduce the embodied energy in buildings, and restrict use of non-recyclable high-energy materials.

Buildings represent a massive investment of financial, social and material resources, and should be designed for longevity. This includes design for retaining, re-using, & recycling of building materials, & design for flexible re-use of buildings as a whole.

The Future

The above is an overall view of the major issues we should be examining in urban planning, building design and construction over the coming years, in order to address the problems of environmental pollution and degradation. Above all, time is not on our side in this quandary. The process of climatic change is generally agreed to have reached a state of non-reversibility, and the question is how far can we act to reduce the scale of unpredictable global environmental changes?

Areas for IEA to impact the Urban Development of the next 25 years

Considering the City as a whole

Studying the activities of the IEA (through its web-sites), I was struck by the wide variety of detail issues addressed, studied, and assessed. They were, though, *all details in detail*, bits-and-pieces of the puzzle: I do not see study of the organism of the City as a whole, from an energy efficiency point of view.

All these details fit together, act and interact (or not) together within the overall framework, which is the city. However, when you consider each of them *individually*, you miss the interaction, the interdependence, and ***the interactive possibilities*** that occur within the city context.

The City & Energy Efficiency
There are a number of energy-related City issues that call for investigative attention:

Energy-process flows, efficiency & wastage
The City is an energy-based organism, and without energy-flows, the city cannot exist, at least in the form that we understand today. The concept of "Minimum Energy City" is a subject that deserves serious conceptual investigation in its own right.

The dominant city energy-flow is in the form of electricity, which achieves maximum end-use delivery of only 70% of primary fossil fuel calorific value. This delivered electricity is very high grade energy, and should be used where this is necessary – not in low-grade heating applications!

Maybe district heating systems can be "morphed" into a low grade energy transfer urban infrastructure, transferring, for example, "waste" process heat from energy intensive manufacturing processes or large cooling compressors, to other urban processes requiring low-grade heating energy. An urban thermal loop, perhaps relevant in high-density urban contexts.

These are just some examples of Cyclic City Processes in the energy sector that must be part of the Sustainable City of the future: the actual solutions will be far more sophisticated, as the possibilities & potentials become understood. In the Sustainable City, energy wastage should be a phenomenon of the past.

Urban Microclimate & Heat Island Formation
The formation of Urban Heat Islands, with a microclimate significantly warmer than surrounding suburban & rural areas is a well-known phenomenon. In some cold-climate regions this can be an advantage, reducing building heating loads – as long as it does not result in creating summer cooling loads.

However, in warmer areas of the world, *including most of the areas where rapid urban development is taking place* (& will continue to do so), heat islands are a growing problem, with potentially dramatic impact of building HVAC loads & energy demand. In Athens, a recent study showed some city-centre areas to have temperatures 17 degC higher than surrounding suburban areas, resulting in a x3+ increase in peak summer cooling loads. Clearly this is a highly undesirable (besides uncomfortable) situation, to be avoided by all possible means.

While the heat island effect is known, and the causes more or less understood, as far as I know, no work has been done on conceptual planning to avoid creating heat islands. It is necessary to develop an understanding of the balance of built density, urban form, proportion and density-distribution of green open-space, type and colour of buildings & exposed hard surfaces, and their combined impact on heat island development, relative to local climatic conditions.

This is an extremely urgent area for action, in view of rapid timescale of developing world urbanisation: once the mistakes are made at the urban scale, it is virtually impossible to reverse the situation.

Urban Planning and Building Energy Demand
Heat island problems aside, urban planning has a large impact on potential building energy demand. Through site selection, land-use planning relative to topography, and building site form & orientation, urban planning determines the potential exposure of buildings to climate – for good & for bad. It determines the degree of exposure to wind & rain, sun & daylight, all the elements affecting good climatic and 'passive' building design.

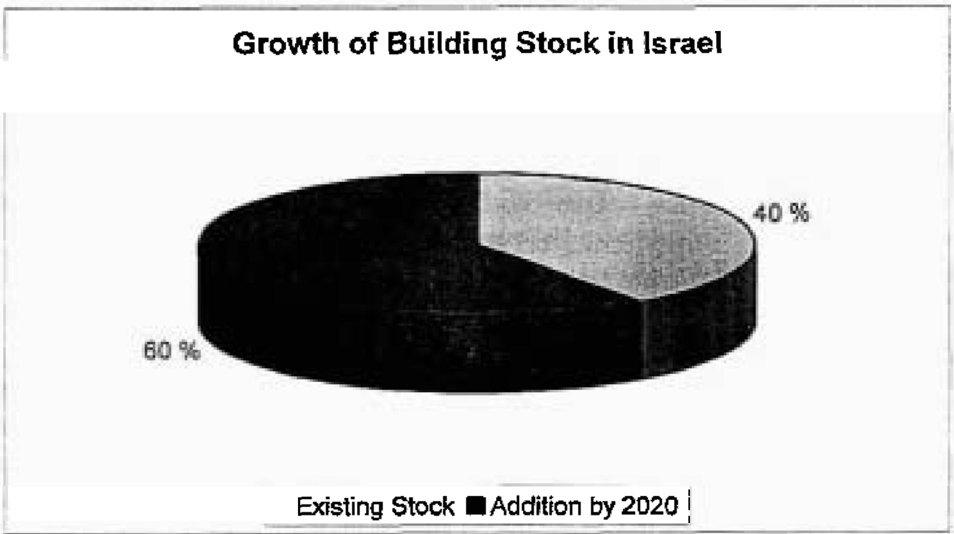
All this is known, but again as far as I know, no meaningful studies have been carried out on the impact of urban morphology on potential building energy demands at an urban scale, in different climatic scenarios. Ideally, we should develop an interactive urban thermal model planning tool.

This could be extremely meaningful, as the economic differences between good, energy-efficient planning, and energy wasteful urban development in most instances will be negligible, or non-existent.

Rates of Urban Development and Urgency of Action
We sit here in a pleasant, comfortable, developed (& developmentally static) situation, far removed from the *action of development* that is rocking our world. In spite of this idyllic Nordic setting, we must respond to, and act in relation to the ***real*** problems of urban development that are taking place at breakneck speed, "somewhere else".
Facing and addressing ***these*** problems will have an impact on the future for all of us (or our children); fine tuning the environmental imbalances of Scandinavia (whilst a worthy goal in itself) will have ***virtually no impact*** on the global future.

From the point of view of the developed world it is difficult to appreciate the rate of urban development taking place elsewhere, and the potential impact of the "mistakes" being made ***now***.

As an example, Israel is a country straddling both worlds, developed & developing. In terms of standards of living, it is close to the developed world, but in rate of development it is certainly 'developing'. While Israel is already one of the most densely populated patches of land in the world (on a par with Holland), the Israel National Master Plan for 2020 foresees that of the building stock that *will* exist in 2020, *60% does not exist today!*
This is based on predictions of natural growth, demand for higher space standards as a result of increased standards of living, and a high increase in quantity and standards of workspaces. The rate of growth of urban building stock is higher than the rate of population growth.



All these factors exist in most of the "take-off" economies of the developing world, and are impacting the rate of urban development at "roller-coaster" speed all over the globe.

Workshop Presentations
New Buildings Session

Indoor Air Quality and Energy Use in Future Buildings

Eduardo de Oliveira Fernandes
FEUP, University of Porto
Portugal

The control of the indoor air quality (IAQ) is becoming an issue of growing concern regarding the health and comfort indoors and co-related societal parameters such as public health in general, productivity of the occupants and market value of the property.

The scope of the pollution load was recently widened and seems to be now clearly defined: occupants and their activities, materials, HVAC systems and cleaning products. The issue is about the quantification of the pollution load and, maybe even more problematic, the apportionment of the sources: how do they interact and how do they contribute for the overall pollution load. For a long time only the occupants and their activities were considered as the unique pollution sources.

After the knowledge acquired for the last twenty years regarding the thermal behaviour of buildings it is now clear that ventilation rates must be defined in relation to the pollution load. Other uses of the supplied air, namely for heating and cooling, must be considered in addition to its contribution to good IAQ.

Ventilation (very often associated with filtration) was considered to be a panacea for good IAQ until it was realised that ventilation involves in general energy use that consequently may imply, besides higher running costs, worsening of the outdoor air. The experience of the energy crisis of the late 70s, early 80s and its implications on the revision of ASHRAE Ventilation Standards, is eloquent about what can be the impact of the energy restrictions. And yet, at that time the pollution sources had not been fully identified.

Among the strategies for IAQ control, also in tune with new concepts such as building sustainability, emerges the sources control strategy which implies the reduction of the pollution strength at the origin. This means reducing pollution sources by selecting cleaner materials and adopting appropriate routines for maintaining HVAC systems and components.

Sustainable buildings shall use less energy. Ventilation first purpose is IAQ. To manage those two objectives: low energy use and good IAQ, buildings shall use clean materials and use clean ventilation systems. So, the needs for air will be lower and, therefore, less energy used because there will be less air to be handled and heated or cooled before being supplied indoors.

Findings from Timber Project: Energy Performances of Different Envelope Components

M. Zinzi, G. Fasano,
ENEA-SIRE-DINT
Italy

C. Romeo
Università "LA Sapienza"
Italy

1. Introduction

This paper deals with preliminary studies carried on during the design phase on an office building to be built in Rome. The research is part of TIBER (Technologically Innovative Building with Energy Rational use), a Project financed by the THERMIE Programme.
TIBER is a project that strictly works with PTIR (Rome Industrial Technology Park), a consortium aimed to create a technology park in Rome [1]. The general aim of TIBER is to implement, promote and apply innovative energy conservation technologies, solar techniques, systems and standards for office-laboratories building, to be used as reference construction for the other buildings of PTIR.

Specific objectives of TIBER can be summarised with the following:

- To prove and promote to the architects, engineers, developers and builders that energy conservation technologies and solar systems are technically and economically viable, safe and strategic. Thus they can be applied commercially.
- To demonstrate that it is possible to significantly reduce the existing energy consumption standards for office and laboratory buildings concerning heating, cooling, ventilation and lighting.
- To apply new research results on passive solar and ventilation systems and technologies inside a real building to reduce energy consumption, with an integrated approach to the design.
- To provide a low energy use and high quality indoor visual environment through an efficient and integrated use of daylight and artificial lighting, and dedicated control strategies.
- To combine efficiently advanced HVAC systems with the proposed passive ventilation and solar systems in order to integrate load management systems.
- To improve Indoor Air Quality through the use of innovative demand control and management of ventilation systems, microclimate parameters and ecology compatible materials.
- To use low cost maintenance materials and standardised construction techniques (concrete frame, low-brick, selective double glazing units, etc.).

A building is a complex energy system and its performances can be improved operating on different components, according to various parameters as: physical and geometrical characteristic of the building, air conditioning devices and strategies, climatic conditions, users behaviour and computer integrated building systems, a new important issue in retrofitting and new buildings.
The proposed architectural and technological components are an interesting example of innovative and efficient applications that can be promoted and taken up by the market.
Moreover, the proposed combination and integration of solar technologies and other

The proposed architectural and technological components are an interesting example of innovative and efficient applications that can be promoted and taken up by the r arket. Moreover, the proposed combination and integration of solar technologies and other consumption-limiting measures are part of a whole innovative approach to the building design.

This report, in particular, deals with the energy performances advantages achievable improving the envelope characteristics. It must be noted that such operations (as adding insulating layers to the walls, mounting shading devices, etc.) often take place in building retrofitting, affecting the real efficacy of the operation. As a matter of fact, this limitation depends on operating on already existing and degraded components. More over, the extr-costs and alteration of the initial aesthetic of the building are unavoidable consequences in retrofitting operations.

Conversely, consistent economical and technical advantages can be obtained if the performances of different envelope products are predicted and evaluated during the architectural design phase. A comparative analysis of performances of the building, equipped with different envelope components and materials, was carried out and in this report some significant results are summarised for the overall energy performance of the building to be constructed.

It is important to remind that the architectural and system designs were steered according to Italian legislation and standards for building and system performances, upgraded, when needed, with ASHRAE Fundamentals.

2. Description of the Building

The building site is in a development zone on the north-east outskirts of Rome. The area of the site is 75 ha; this first building will have a volume of about 12.000 cubic metres out of the 1.5 million to be built on the same site. The schematic plan of the reference building is presented in Figure 1.

The project comprises four three-story office/laboratory blocks of different architectural design and one story block at the third level (block 4 in Figure 1). The subdivision of the whole building in five blocks was decided to permit a more flexible management of the five companies that will be hosted in the building. Table 1 describes the building and its five blocks. In next paragraphs the associated number will identify each block.

It must be reminded that the total area and volume do not coincide with the sum of the single block, because of collective spaces at ground level and stairs to upper levels.

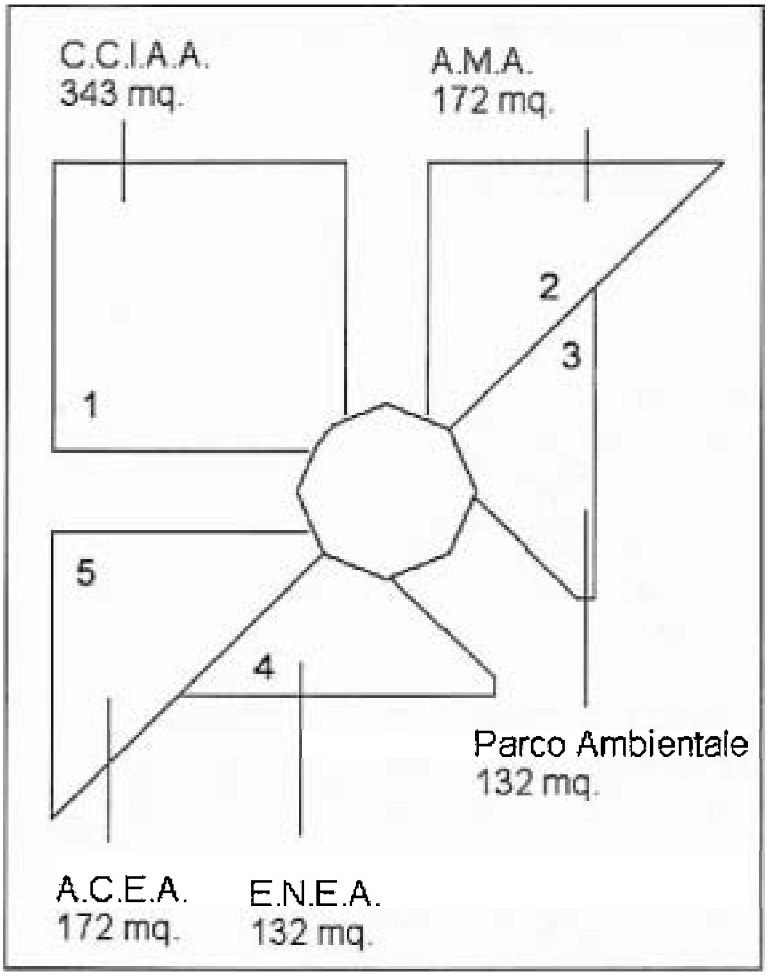


Figure 1: Schematic layout of the building

Table 1: Description of the building blocks

Block	Floor Area [m^2]	Volume [m^3]	Occupants	Orientation
1	343	3402	60	NE-NO
2	172	1468	25	NE
3	132	1101	45	SE
4	132	376	20	SO
5	172	1468	50	NO
Total	1200	12000	200	NE-NO-SE-SO

3. Description of the Climate and Weather

According to a correct way of conceiving a building, it is necessary to create a close relation in space and time between architectural objects and environmental conditions. Hence it is essential integrating the climatic component in making architecture. In order to consider climatic conditions of a particular site, a report covering the whole annual cycle is needed. Weather local data, measured by weather stations, may give information, which will allow to direct towards the most favourable design choices. However, the main object must always sets out to achieve the best level of indoor comfort and air quality.

Specific site's weather data used in executing the building dynamic simulation involve various meteorological parameters. At every time step weather data appear in combination each to other and it's difficult to value their respective weight. Architectural and HVAC solutions to every single climatic problem should be taken side by side in a climatically well-balanced building.

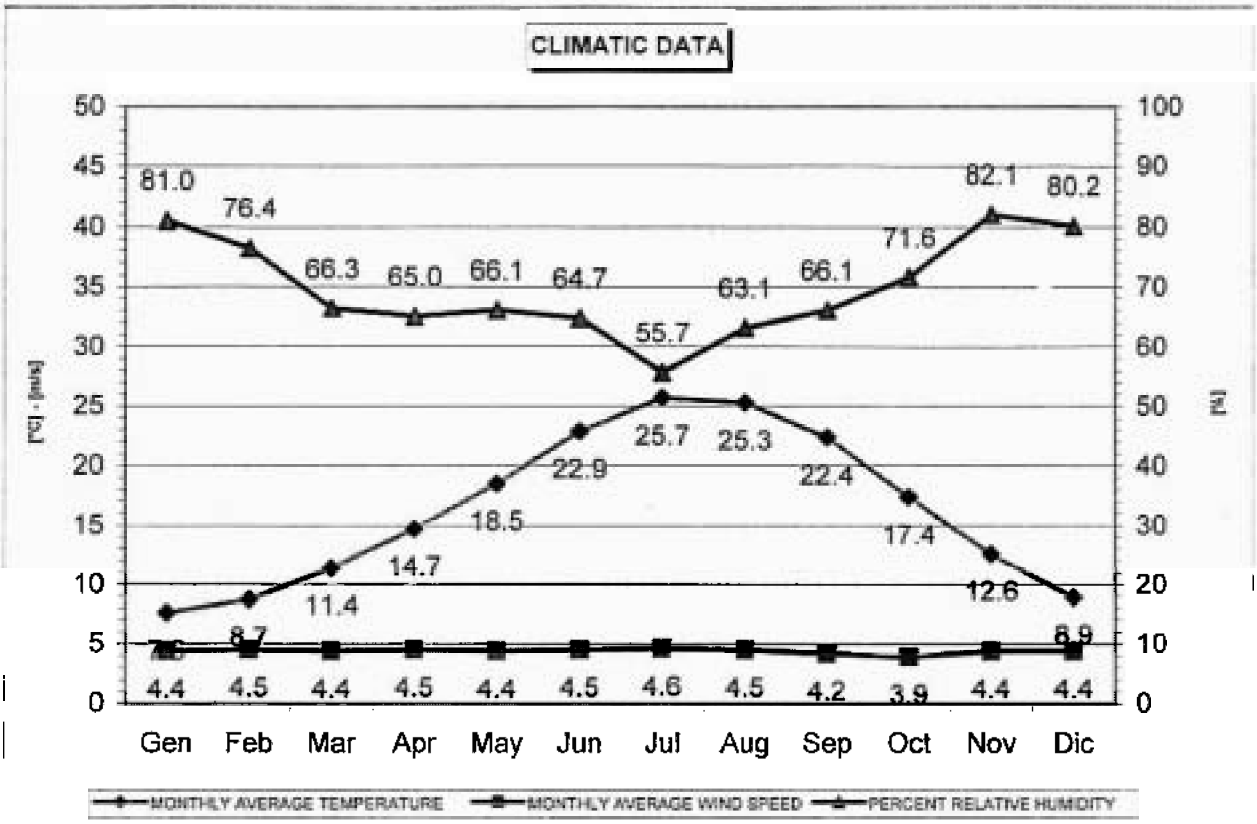


Figure 2: Monthly average daily air temperature, wind speed and relative humidity

An assigned site has a satisfactory climate characterisation when the following measured data are available:

- Monthly average *daily* global horizontal solar radiation
- Monthly average temperature
- Monthly average humidity ratio
- Monthly average wind speed and prevalent direction

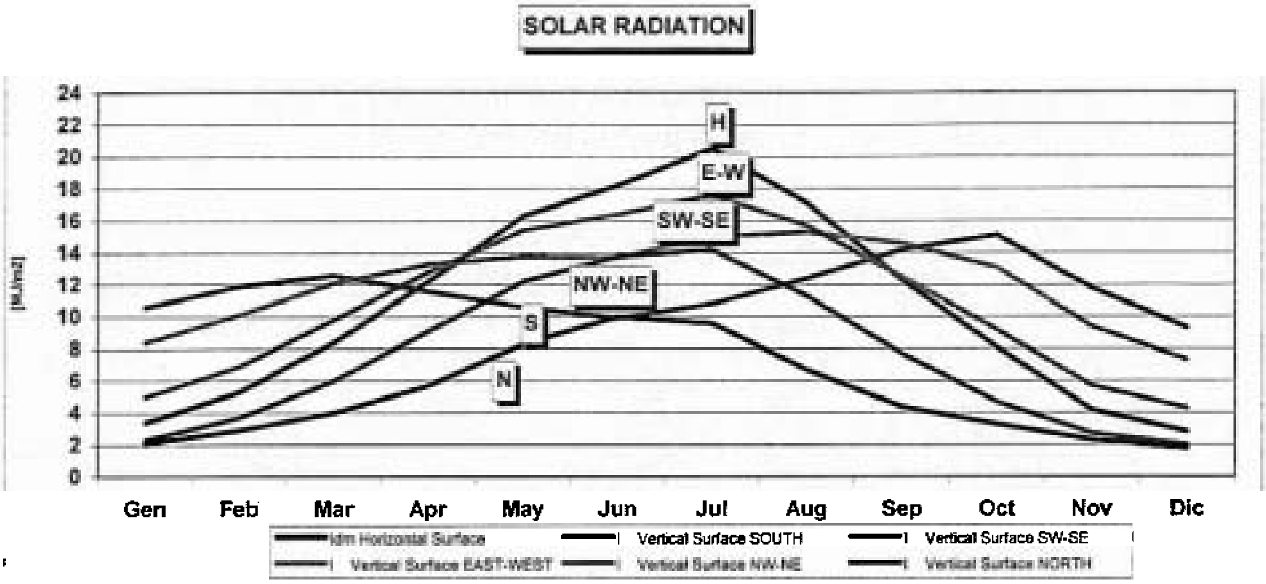


Figure 32: monthly average daily global horizontal solar radiation for different orientation

From UNI 10349 [2] standards, data concerning the outdoor air temperature, the relative humidity and the wind speed are acquired. Monthly average values are considered in this case. In Figure 2 the graphs of these weather parameters are plotted. In Figure 3 are reported the plots of the monthly average daily global horizontal solar radiation for different orientation, calculated starting from horizontal values. The above-cited standard UNI 10349 includes these values divided in beam and diffuse radiation for every month.
Monthly average values are used in this case too. All these parameters are used as input for running simulations with the building simulation tool.

4. Description of Components and Materials of the Building Envelope

In this section the criteria to select components and materials suggested for the building envelope is described. Since the aim of TIBER is the design and construction of a high-efficient energy building, the chosen materials must improve the performances obtained with traditional solutions. Such objectives can be mainly pursued by:

- Improving U-values of opaque components.
- Improving U-values and controlling g-factors of transparent components.

To check the efficiency of the selected materials it is necessary to verify the improving of building performances by the comparison of efficient versus traditional solutions. Neither this step is easily to carry out, since the thermal properties of building envelope components are widely influenced by the locality (different materials and technologies) and the age of the construction (different insulation properties). We selected four combinations of external opaque (walls and roofs) and transparent (windows) components distinguishing each to other by their average transmittance values. Their properties are summarised in Table 2. The reference components, solution A, represent average values for buildings in mid-Italy climate, without insulation in walls and clear double glazing unit without thermal break frame for windows. In the solution B, the opaque components are equipped with a thin insulation layer (2 cm.) and the windows have thermal break frames. In the solution C both the opaque (5 cm of insulation) and transparent (low emittance coated double glazing unit) components are improved. Finally high insulation levels are adopted in solution D (12 cm of insulation for opaque components and low coating and argon filled windows)

These choices have been made in order to show how improved performances of the envelope components will allow energy saving politics in building design.

Table 2: U-values of building components

Solutions	COMPONENTS								
	External wall			Roof and external floor			Window		
	Thickness [m]		Uvalue [W/m²K]	Thickness [m]		Uvalue [W/m²K]	Thickness [mm]	Uvalue [W/m²K]	gvalue [%]
	Tot	Insul		Tot	Insul				
A	0.24	-	1.06	0.25	-	1.23	4-6-4	4.50	75
B	0.26	0.02	0.75	0.26	0.02	0.97	4-12-4	3.50	75
C	0.29	0.05	0.60	0.30	0.05	0.74	4-12-4	2.50	67
D	0.36	0.12	0.41	0.37	0.12	0.47	4-16-4	1.50	59

As it can be inferred from above, the solar factor of windows was not considered as fundamental parameter because of the two following main reasons:

- On south-east and south-west facades, the solar control is achieved by means of external shading devices, meanwhile double glazing units low-emittance coatings improve thermal performances.
- On north-east and north-west facades, the influence of the solar radiation on cooling loads is not strong. For these orientations there is no need for controlling the solar radiation by means of expansive solar filter glazings or shading devices.

Table 3: Characteristics of the lamellae

PARAMETER OF LAMELLAE	
Luminous reflectance	0.85
Length [cm]	10
Pitch [cm]	10

The shading devices are realised with horizontal lamellae mounted just outside the window. The inclination of lamellae could be manually (season regulation) or mechanically (continuous regulation) operated, according to the requested level of control and the available budget. The system is designed for shading the direct radiation and redirects its visible component inside the building. To achieve satisfactory results, it is necessary to adopt high reflectance lamellae. In Table 3 are reported the main characteristics of the lamellae.

5. Description of TRNSYS Code

For accurate results in simulation analyses it is necessary to use advanced codes, able to consider all the parameters affecting the performances of the building. This necessity led to TRNSYS, a complex tool widely used for all the solar applications [3].

TRNSYS is a modular system simulation program. The modular structure of TRNSYS gives the program extreme flexibility. This code is well suited to detailed analyses of systems whose behaviour is dependent on the passage of time.

A system is defined to be a set of components, interconnected in such a manner as to accomplish a specific task. The performance of a system component (the building envelope in the case of study) will normally depend upon characteristic fixed parameters, the performance of other components, and time dependent forcing functions.

Once all of the components of a system have been identified and a mathematical description of each component is available, it is necessary to construct an information flow diagram for the system. An information flow diagram is a schematic representation of the flow of information into and out of each of the system components

One of the main features of the tool is to be a dynamic code, so transitory and capacitance phenomena, typical of energy balances in buildings, can be taken into account. Hence, even if mean monthly values are inputted, the code has internal statistical functions, which give hourly outputs of energy needs. Integrated values can be used to obtain monthly, season or annual loads.

TRNSYS is an open code, working through different routines linked together. Such routines are in the library of the code, or can be implemented *ad hoc*, this flexibility permits to cover exigencies typical of the single application.

The TRNSYS project implemented for this analysis consists of four main routines and some calculation blocks, the routines are the following:

- Weather generator
- Solar radiation processor
- Shading device routine
- Definition of characteristics of the building (Pre-Bid)

6. Results of Simulations

A first set of measurements was carried on block 1 only. The aim was to evaluate the energy savings that can be obtained using different levels of insulation. The results of this preliminary parametric analysis are summarised in Table 4. As partially expected, it was verified the decreasing of both heating and cooling loads from solution A to D. An energy approach would suggest that solution D is the best one. But it must be noted that the economy aspect of the problem should always be kept in mind.

The solution C resulted to be better than B, with limited extra-cost (3 centimetres of insulation added and adoption of low emittance glazings). Conversely the solution D even if best performing, is more expansive of C (7 centimetres of insulation added and adoption of low emittance glazings with argon in the gap). More over it must be reminded that a too *sealed* envelope can avoid the *breathing* of the building, when strong external and, often, internal cooling loads (people, lighting, appliances that in the design phase can be only partially considered) increase the indoor air temperature and pollutant emissions. Since in the design phase of TIBER, the approach was to consider all the following issues:

- energy saving,
- thermal comfort for the occupants,
- indoor air quality control,

- low construction and maintenance costs

Among the four solutions we took in account the best performing from an energetic and economical point of view resulted the solution C. So all the characteristics of the components simulated in this case of study were adopted in all the blocks of the building. In Table 4 the total heating loads for the four envelopes options and the relative percentage savings are reported.

Table 4: Block 1:Annual heating and cooling loads

	BLOCK 1 ANNUAL LOADS [kJ]				SAVINGS [%]			
	SOLUTIONS							
	A	B	C	D	A	B	C	D
HEATING	3,53E+08	3,20E+08	2,81E+08	2,66E+08	-	9,2	20,4	24,6
COOLING	1,42E+08	1,36E+08	1,30E+08	1,21E+08	-	4,5	8,2	14,7

Table 5: Percentage savings for the single blocks

BLOCK	HEATING SAVINGS [%]	COOLING SAVINGS [%]	ORIENTATION
1	20.4	8.3	NE-NO
2	20.6	5.9	NE
3	15.9	49.5	SE
4	31.4	31.2	SO
5	24.4	12.3	NO

The second set of measurements was run for the whole five blocks. The simulations are performed for each block separately, since the control strategy for heating, cooling, ventilation and lighting will be different, according to different exigencies of the five companies, which occupy the five blocks. For each block the energy loads are calculated considering first the building equipped with traditional components and materials (solution A), then with innovative solutions (solution C). In Table 5 are reported the percent energy savings achievable in the single blocks during the hot and cold season, improving the envelope materials and components. It must be noted that the annual loads do not coincide with the sum of the selected months, since, even during the winter (summer) period, a small cooling (heating) demand could exist.

Table 6: Monthly heating loads

Month	Heating loads old [kJ]	Heating loads new [kJ]	Savings [%]
OCT	2.5E+07	1.8E+07	29
NOV	1.0E+08	7.7E+07	23
DEC	1.8E+08	1.4E+08	21
JAN	1.9E+08	1.5E+08	21
FEB	1.5E+08	1.2E+08	20
MAR	1.1E+08	8.7E+07	21
APR	5.9E+07	4.6E+07	21
YEAR	7.6E+08	6.4E+08	22

Table 7: Monthly cooling loads

Month	Heating loads old [kJ]	Heating loads new [kJ]	Savings [%]
MAY	2.0E+07	1.4E+07	33
JUN	5.8E+07	4.5E+07	22
JUL	1.2E+08	9.8E+07	18
AUG	1.2E+08	9.8E+07	17

SEP	5.6E+07	4.5E+07	20
OCT	2.6E+07	2.1E+07	19
YEAR	4.0E+08	3.2E+08	20

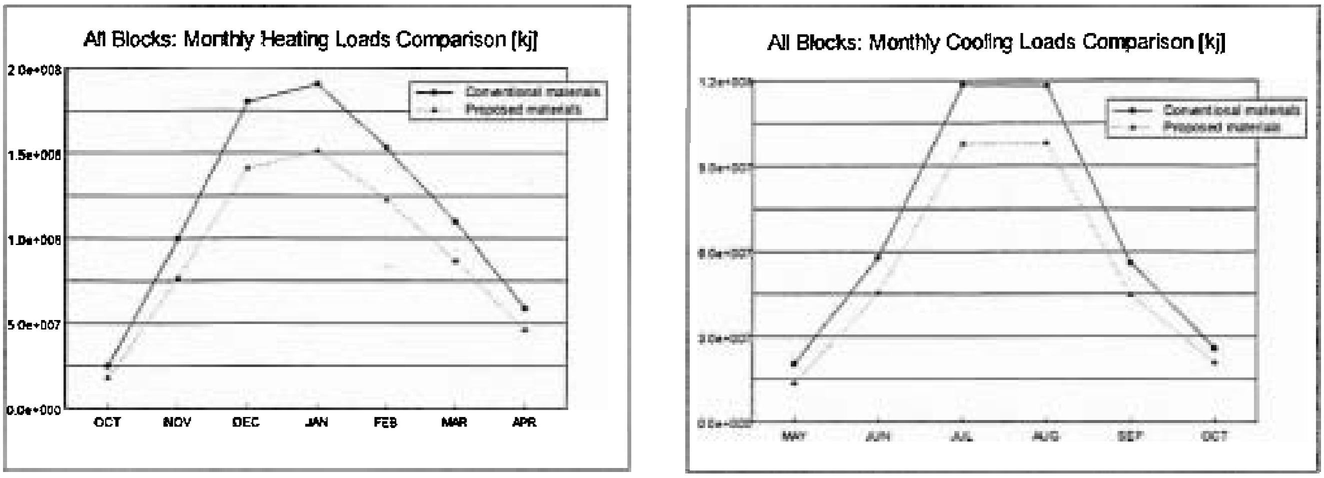


Figure 4: Monthly heating and cooling loads comparison for all blocks

More detailed analyses are presented in Tables 6 and 7, where the total heating and cooling needs are reported as a function of the month of the year. In Figure 4 the comparison plots are presented for both heating and cooling.

In Figure 5 the same kind of graph is reported for the heating season of block 1, facing north-east and north-west, where the energy savings are more significant, due to the better insulation of opaque and transparent component of the building envelope. Interesting results can be inferred from Figure 6 concerning block 3 simulations, facing south-east. In this case the shading effect of lamellae is important for reducing cooling loads, while the reduction of solar gains in winter is compensated by the better insulation properties of the windows.

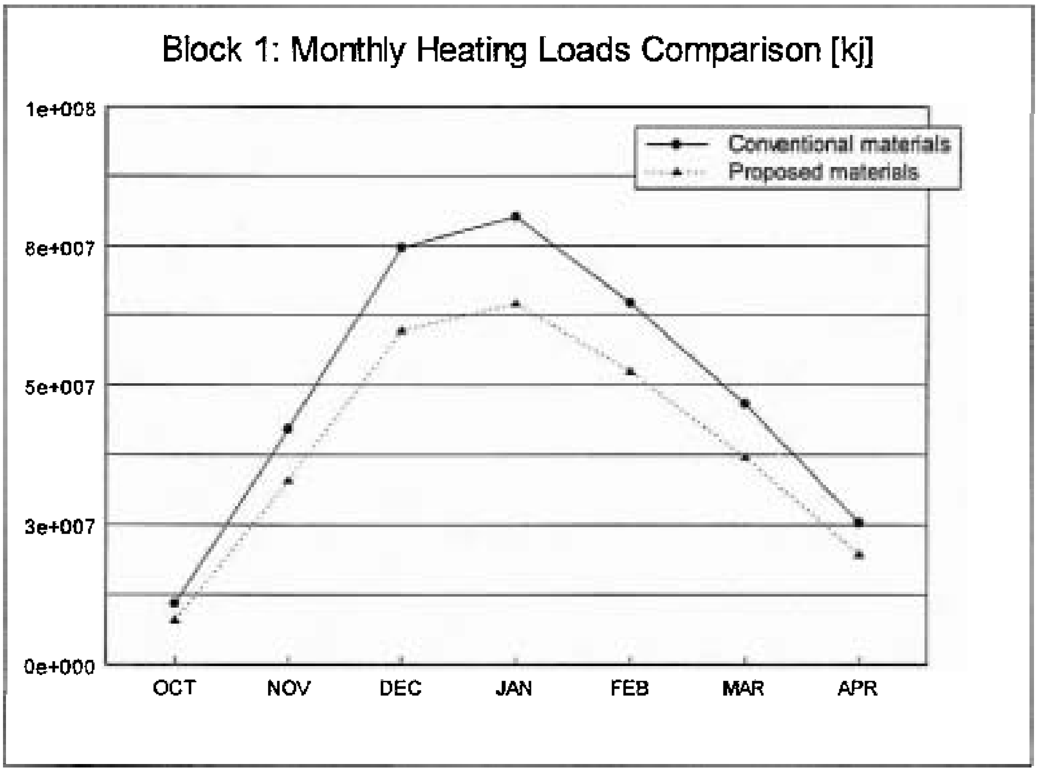


Figure 5: Monthly heating loads comparison for block1

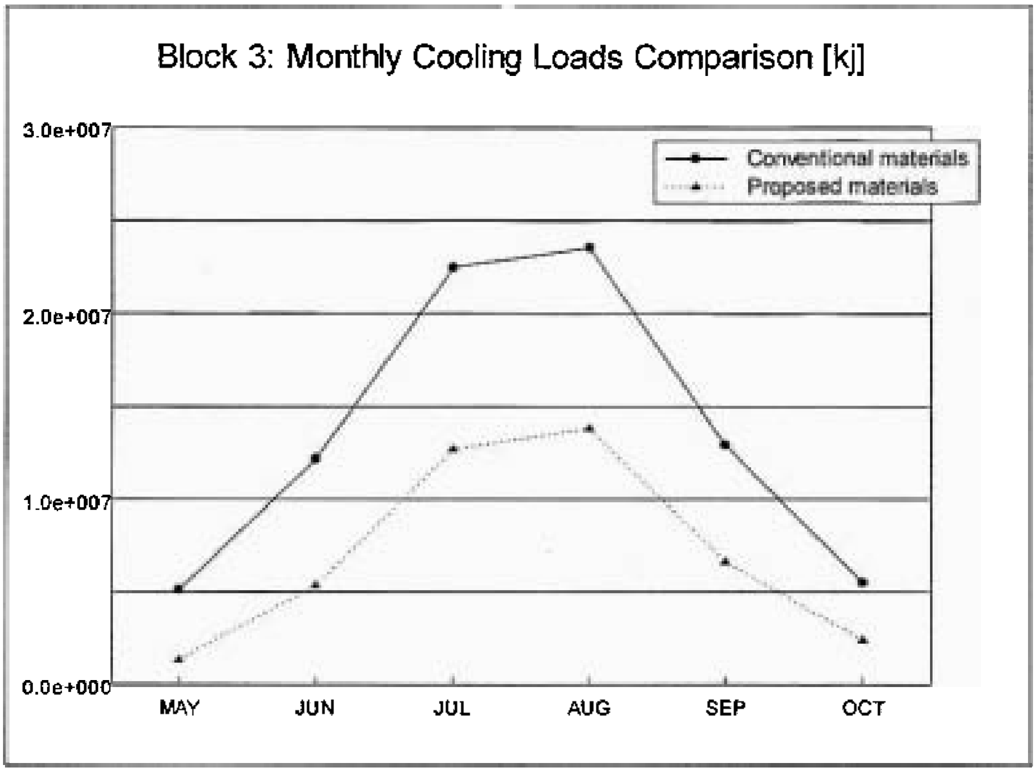


Figure 6: Monthly cooling loads comparison for block 3

7. Conclusion

The simulations, performed with two envelope options, allow verifying the efficacy of different materials and components selection. The results obtained and summarised at the precedent paragraph suggest the following conclusions:

- The parametric analysis showed that there is a limited level of insulation needed at Mediterranean latitudes. The adoption of high insulating opaque and transparent components leads to energy savings that do not justify the excessive first costs.
- During the winter season, improving the thermal loss properties of opaque and transparent components leads to energy savings of about 20%. Higher savings are obtained (about 35%) only for block three, because of the high ratio of the dispersing surfaces on the volume of the zone.
- During the cooling season only small savings (between 6 and 10%) can be obtained with the proposed components for block facing north-east and north-west. Conversely, for blocks facing south-east and south-west the savings are much higher, since the mounting of external shading devices can lead to savings of 40% or more. The average annual savings, as presented in the previous paragraph, are in the order of about 20%.
- The suggested solutions allow reducing the needs for heating, cooling and ventilation systems. Such reductions regard both the peak demand and the annual energy needs. This implies the reducing of the size of the conditioning system and the energy consumption throughout the year.
- The suggested solutions can be improved through the optimisation of user behaviour regarding, as an example, the regulation of the shading devices, according to weather conditions or the period of the year. In other cases the manual opening of the window by

occupants can reduce the ventilation and cooling loads, this is typical for intermediate months, when the natural ventilation is an efficient substitute to mechanical devices.

The study, presented in this paper, stresses the importance of adopting advanced envelope components, by the way it must be noted that the amount of energy saved with these options is only a part of a wider strategy not considered in this analysis. Optimising the whole building-system, with advanced conditioning solutions (as ice storage for the cooling season, high performance boilers for the heating season) and control strategies by means of intelligent control systems, makes more consistent the annual energy savings to be achieved.

Referanses

1. *Project T.I.B.E.R. (Technologically Innovative Building with Energy Rational Use): Activity Report n. 1 & 2.* Thermie Programme - Contract BU/163/98/IT, 2000.
2. *UNI 10249 – Riscaldamento e Raffrescamento degli edifici: Darti Climatici*, 1994.
3. *TRNSYS A Transient System Simulation Program - Release 14.2.* Beckman W. A. et al. Solar Energy Laboratory University of Wisconsin-Madison, 199

Workshop Presentations
Existing Buildings Session

Existing buildings

Hugo Hens
KU-Leuven, Department of Civil Engineering
Laboratory of Building Physics
KU-Leuven Energy Institute
Belgium

Introduction

In general, building construction and building usage causes main environmental impacts, ranging from an intense resource consumption up to gaseous, liquid and solid waste production. As part of that burden, buildings have a large share in the annual energy consumption and the related greenhouse gas emissions of a country. If both have to be reduced, energy efficient construction should be a prime objective and measure. The techniques to realize less energy consumption in buildings without jeopardizing other user related performances are well known. To mention some: a highly insulated envelope, optimal integration of passive solar accounting for winter gains and summer comfort, the use of well insulating glass, heat recovery, a very efficient HVAC system, etc.

The build environment however is a very inert system, composed of units with a very long service life and subjected to a low substitution and retrofitting rates. New construction in many cases also adds units to the existing stock, a reality that does not enhance energy efficiency of the whole, on the contrary. Consequently, if energy conservation is really taken seriously in terms of 'energy consumption should decrease', then energy performance of the existing stock, in combination with the overall performance, must receive much more attention. Legal instruments should treat thermal retrofit as of prime priority. Hence, this is not what happens actually. New construction in many countries is more and more subjected to a tough energy performance legislation, while retrofit is treated as an adventitious activity that should not be complicated by additional energy legislation. Thermal performance demands does not go beyond some modest U-value requirements.

Data are important

In Flanders, household has a share of 218 PJ in the annual end use of 800 PJ (Verbruggen 1994, Verbruggen 1996)), i.e. about 27.3%, i.e. 990 GJ or 27 500 kWh per annum and per household (Flanders counts some 2 250 000 households). To put that number into perspective, we may compare it with the annual metabolism of a human being, 880 kWh. Each household in Flanders consequently absorbs the energy produced by 31 individuals. Included the tertiary sector, where energy consumption is mainly building related, buildings use attains 306 PJ/a, i.e. 38.2% of the total. For Germany, the distribution over the different sectors in 1992 looked as given in table 1 (GRE, 1996). Table 2 contains data for the US (DOE, 1997).

Table 1. Energy consumption for Germany, 1992

Consumption	**PJ**	**%**
Industry	2562	28
Traffic	2520	28
Households	**2394**	**26**
Tertiary sector	**1527**	**17**
Army	70	1

Table 2. Energy consumption in the US per sector in (%)

Consumpti· n	**%**
Industry	32.6
Traffic	32.3
Building related	**33.7**

The three sets underline the importance of building related energy consumption. Although the size of the three countries and the climate differs substantially, the share in the annual consumption touches 40% of the total end use in all three. The share buildings have in greenhouse gas emissions is equally important. The residential sector in Flanders for example emits ±16 000 000 Ton CO_2 on an annual basis. This number includes electricity produced for lighting, appliances and heating (Hens et al., 1997). Figure 1 gives additional details on measured energy consumption in existing fuel heated buildings. The dots represent a sample of 1173 fossil fuel heated Laboratorium bouwfysica, 1997)

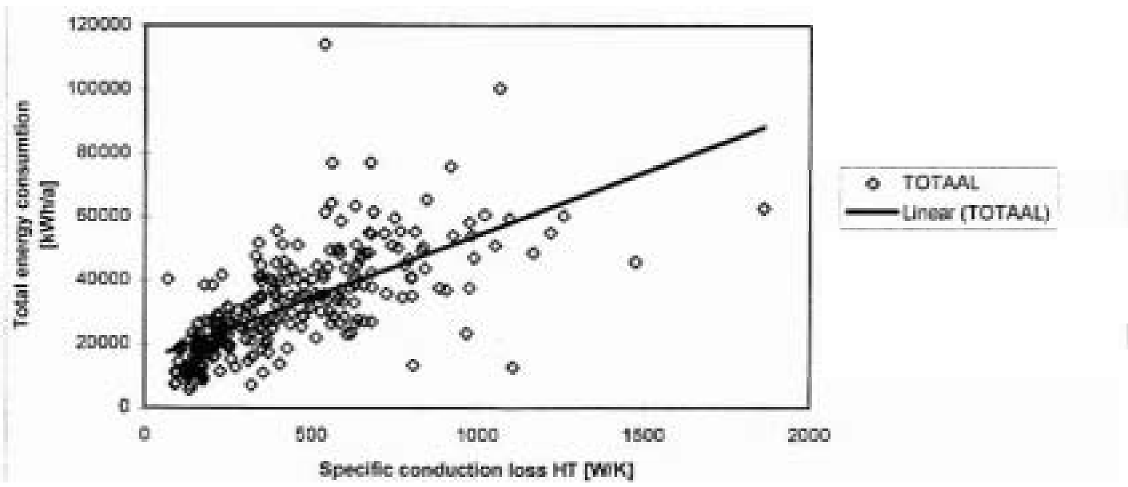


Figure 1. Total energy consumption as a function of the specific conduction loss

On the average the dwellings had a heated surface of 140 m² (range: 60-543 m²). The average level of thermal insulation was K98 for the fossil fuel cases (range: 41-180). The total annual end use for the fossil fuel dwellings decreases with the specific conduction loss (the product of the mean U-value of the enclosing surface (U_m) and that surface (A_T)). A least square approximation gave: $E_T = 19330 + 35U_mA_T$. Lower specific transmission losses may result from a smaller enclosing surface or a better thermal insulation (lower U_T).

An identical analysis on 75 electricity dwellings gave a heated surface of 240 m² (range: 56-543 m²), an average level of thermal insulation K46 (range: 30-181) and a total energy consumption: $E_T = 12508 + 22U_m A_T$ .. Electrically heated houses clearly are better insulated than their fossil fuel counterparts. Apparently, electrical heating diminishes end use, even for identical specific conduction losses. Also on the average, - fossil fuel 32 456 kWh/a, electricity 20 750 kWh/a- electrical heating gives a lower number. As well better thermal insulation as rebound effects are responsible for those savings. The higher electricity prices in fact motivate the inhabitants to economize on thermal comfort.

Table 3 lists the annual consumption per m² of heated floor for the whole sample. If we compare the average of 180 kWh/(m².a)!with the fifteen IEA-SHC-Task 13 Solar low energy houses (IEA, 1995) of table 4, then, apparently, even 28 years after the first energy crisis, the reduction-potential for energy consumption in dwellings remains impressive.

Table 3. Average energy consumption in dwellings for Belgium (measured data for 1200 houses with an age between 2 and 85 years)

	Units	Average	Stdev.	Min.	Max.
Total consumption	**kWh/(m².a)**	180	68	66	488
Consumption for H en HW	**kWh/(m².a)**	149	71	66	428
Consumption for HH	**kWh/(m².a)**	28	14	8	74

H=heating, HW=hot tap water, HH=household, lighting, apparatus

Table 4. The fifteen IEA-SHC-Task 13 Solar low energy houses (Anon, 1995)

Country, house	**Floor surface** m²	**Heating** kWh/(m².a)	**Hot water, household** kWh/(m².a)
Austria, terrace house Lustenau	85.7	21	36
Belgium, terrace house La Pleiade, LLN	180	15	26
Canada, detached house Brampton	408	12	19
Canada, detached house Waterloo	208	25	31
Denmark, terrace houses Kolding	105/98	14/12	22/23
Finland, detached house Pietarsaari	166	13	14
Germany, two-family house Rottweil	175	18	32
Germany, terrace house Berlin	170	0	15
Japan, two-family house, Iwaki	150	13	25
The Netherlands, 42 flats Amstelveen	100	12	31
Norway, terrace houses Hamar	125	9	25
Sweden, detached house Röskär	50.4	17	57
Switserland, two-family house Gelterkirchen	182	28	29
USA, detached house Grand Canyon	125	10	37
USA, detached house Yosemite	150	23	32
Averages		**15.3**	**28.8**

Predicting energy consumption and CO_2-release

Modeling the building stock

The databases of the National Institute for Statistics contain overall information on the building stock (Anon, 1996). Each dwelling in fact is characterized by five variables. Age (before 1945, 1946 to 1970, 1971 to 1980, 1981 to 1990), type (terraced, double, individual, flat), total floor area (<45 m², 45 to 64 m², 65 to 104 m², 104 to 124 m², ≥125 m²), prime energy (oil, oal, gas, butane, electricity, others) and centrally heated or not.

With these variables we constructed a set of reference dwellings that substitute the whole housing stock. For that purpose, dwellings are assumed to be simple quadratic volumes. Up to 64 m² they exist as single floor constructions only. From 65 to 104, an equal distribution between 1 and 2 floors is adopted. Above 105 m², 1, 2 and 3 floors are considered. The quadratic volumes stand alone, are coupled two by two or form rows of terraced houses. Flats are grouped in medium rise blocs with 3 (20% of the total), 4 (30% of the total) or 5 stocks (50% of the total) and two flats per stock. In the software, each interval of floor area's is replaced by its avera;e. Houses have 6% of their envelope glazed, flats 10%. Age is translated in U-factors and ventilation rates (table 5). Most houses constructed before 1945 have masonry massive walls with a thickness of 30 cm, single glass and neither roof nor floor insulation. From the second world war on, masonry cavity walls become the reference. After 1970 roof and cavity insulation and the use of double-glazing becomes common technology. In the eighties, floor insulation is added and more roof insulation applied. The U-values of table 5 are fair averages for the building technologies mentioned. The progressive decrease in average ventilation rate in the table is due to two elements: (1) the application of tighter windows and (2) the overall move to central heating after 1970. Energy vector and heating system define the heating system's efficiency.

For the period up to 1990 960 reference dwellings has been created that way. Each reference is characterized by a weighted average energy consumption, the weighting factors being the fraction of dwellings and flats per number of floors.

Table 5. Translating age into U-values and ventilation rates

	Facade U-value W/(m².K)	Roof U-value W/(m².K)	Floor U-value W/(m².K)	Glass and frames U-value W/(m².K)	Ventilation rate h^{-1}
before 1945	2.0	1.6	4	5.8/1.8	1.2
1946-1971	1.3	1.6	4	5.8/1.8	1.1
1971-1981	0.6	0.5	4	3.1/1.8	0.8
1981-1990	0.6	0.4	1.2	3.1/1.8	0.6

Energy consumption for the individual dwelling

Consumption is split in its main parts: heating, hot water and household. Cooling does not intervene. The climate in Belgium is too moderate for that, although a bad application of passive solar, resulting in glazed shrines without solar shading, and trendy behavior created some market for cooling applications. Heating is calculated using the following steady state single zone energy balance (Hens, 1997, Anon., 1999):

$$\left\{-(\Phi_{cond}+\Phi_{vent})+\eta_{rec}\left[(\Phi_{sun}-\Phi_{long})+\Phi_{free}\right]\right\}\Delta t+\eta E_{heat}=0\ (J) \qquad (1)$$

with Φ_{cond} the conduction losses through the envelope, Φ_{vent} the ventilation losses, Φ_{sun}-Φ_{long} the solar gains corrected on long wave radiation, Φ_{free} the gains coupled to building use, η_{rec} the recuperation factor for the gains, E_{heat} the energy consumption by the heating system, η the system's efficiency and Δt the time step (here 1 month). The system's efficiency consists of two partial efficiencies: production and system. In the case local heating is applied, the system's efficiency is set equal to 0.645 for oil stoves, 0.63 for coal stoves, 0.69 for gas radiators, 0.65 for butane, 0.77 for electrical accumulators and 0.61 for wood stoves. Central heating is supposed to be hydronic only, with production efficiency coupled to age. For oil boilers for example, 0.82 with a loss coefficient of 0.05 and a mean supply temperature of 80°C is adopted for dwellings constructed before 1981. After 1981, high efficiency boilers become standard, production efficiency 0.86, loss coefficient 0.02 and mean supply temperature 65°C.

The model takes 15.7°C as the average inside temperature. That value was extracted from a detailed study on energy consumption in 52 dwellings distributed equally in relation to age and total floor area (Hens, 1993). A rebound effect is not considered. The TRY-year for Ukkel, Belgium, figures as the outside climate. The calculation proceeds on monthly basis. The sum of the positive monthly heating consumption E_{heat} gives the annual total.

The hot water heat demand per reference dwelling in W is set equal to:

$$\Phi_{HW} = \max\left[82, 0.815\left(A_{fl} - 64\right)\right] \quad (2)$$

A_{fl} being the floor area in m². In the case of local heating, hot water production is a stand alone activity. With central heating, the boiler produces the hot water. The power demand for household per reference dwelling in W is calculated as:

$$\Box_{HH}=201+0.725A_{fl} \quad (3)$$

Both equations stem from a statistical analysis of measured data. Their transformation to consumption is straight forward. The equations (1), (2) and (3) together constitute the energy module within the software. The results are stored in a reference dwelling's matrix.

Simulating the reference year 1990

With the energy consumption per reference dwelling known, the calculation of the overall consumption for the residential sector in 1990 is straightforward. For each village, town and city, the number of dwellings per reference, listed in the NIS 1990 database, is multiplied with the related annual energy consumption for heating, hot water and household. In the case of individual heating, we assume electricity to be used for hot water. Household, included cooking, is electricity only. This of course is not correct as gas is a second favorite fuel for hot water and cooking. However, the NIS database does not give information on that. These simple rules, although somewhat fictitious, allow to add the totals per energy vector in an easy way. After, the results per location are totaled for each region in Belgium. Summing these totals results in the energy consumption for the country during the reference year 1990. The step to CO_2 emission demands a multiplication of the end use totals per vector with the associated CO_2 release in g/kWh, see Table 6.

Table 6. CO_2-release per kWh

Energy vector	CO2 release
Gas	
Butane	264
Electricity (end use)	375
Other	329

Future evo.utions

First, the transformations in the building stock have to be predicted. The dwelling demand primarily depends on the number of households. Two extreme cases for the evolution of that number have been implemented: (1) important increase with an annual growth of 1% in relation to the 1990 number, (2) marginal increase with an annual growth of 0.46% in relation to the 1990 number. The NIS further publishes annual data on new construction, demolition and retrofit. We used the data for 1991 to 1996 (Anon., 1996). The building industry also forecasts future needs on regular time intervals. This information, together with the housing policy of the regional governments, helped in shaping the dwelling offer in the near future.

Three different housing scenario's were considered: (1) restricted retrofit, unlimited expansion of the housing stock, i.e. business as usual, (2) explicit shift towards retrofit and reconstruction, restricted expansion of the housing stock, (3) demand guided retrofit and reconstruction, no expansion of the housing stock after 2010. The distribution of the energy vectors over the future building stock is distilled from the actual situation and a comparison with 1980. An increasing number of dwellings choose natural gas. Coal diminishes gradually, etc.

Four energy policy scenario's are included: (1) the actual legislation kept up (a level of thermal insulation K55 for new dwellings and threshold U-values in the case of retrofitting. K55 means that the average U-factor of the envelope (U_m) should equal 0.55 W/(m².K) for a compactness (V/A_T) below 1 m, 1.1 W/(m².K) for a compactness above 4 m and $U_m=0.55[(V/A_T)/3+2/3]$ for a compactness V/A_T between 1 and 4 m), (2) K40 for new buildings (K40 means that the average U-factor of the envelope (U_m) should equal 0.4 W/(m².K) for a a compactness (V/A_T) below 1 m, 0.8 W/(m².K) for a compactness above 4 m and $U_m=0.4[(V/A_T)/3+2/3]$ for a compactness V/A_T between 1 and 4 m) and tougher U-factors for roofs, walls and windows in the case of a retrofit from 2001 on (0.5 W/(m².K) for walls, 0.2 W/(m².K) for roofs, 1.2 W/(m².K) for floors and 1.3 W/(m².K) for the glazing), (3) K40 for new dwellings and tougher U-factors for roofs, walls and windows in the case of a retrofit from 2001 on, a heating energy performance of 180 MJ/(m².a) for new dwellings from 2005 on (4) a heating energy performance of 180 MJ/(m².a) for new dwellings and tougher U-factors for roofs, walls and windows in the case of a retrofit from 2001 on. Each policy creates 240 additional reference dwellings with their specific energy consumption.

Multiplication, per region, of the annual number of new, retrofitted and demolished (reference) dwellings with the appropriate energy consumption gives the yearly change in consumption per vector. Addition to the totals per energy vector of the previous year results in a prognosis over the period considered. The step to CO_2-emission does not differ from the reference year (see Table 6).

Simulation results

Reference year

Table 7 gives the energy consumption and CO_2-emission for 1990. The calculations are based on the TRY-year for Ukkel, which is colder than 1990. CO_2-emissions therefore are also given for the proper 1990 climate

Table 7. Residential energy consumption in TJ/a and associated CO_2-emissions in MTons in Belgium, 1990 (TRY for Ukkel, specific climate for 1990, Vl=Flanders, W=Wallonia, B=Brussels)

	Dwellings	Oil	Coal	Gas	But/Pro	Electric	Other	TOTAL
Energy consumption, TJ/a, TRY-year								
Vl	2 141 557	99 500	16 200	53 800	3 700	31 000	3 400	207 600
W	1 212 100	69 300	11 800	25 600	3 300	16 800	4 200	131 200
B	394 500	12 900	800	17 500	100	4 300	400	36 000
Belgium	3 748 200	181 700	28 800	96 900	7 200	52 131	8 000	374 800
CO2-emissions, MTon, TRY-year								
Vl		7.3	1.5	2.9	0.3	3.3	0.3	15.4
W		5.1	1.1	1.4	0.2	1.7	0.4	9.9
B		0.9	0.07	0.9	0.009	0.4	0.04	2.4
Belgium		13. 3	2.6	5.2	0.5	5.4	0.7	27.8
CO2-emissions, MTon, specific climate data for 1990								
Belgium		11	2.3	4.5	0.4	5.2	0.6	24.8

Even in a small country like Belgium residential energy consumption is impressive. CO_2-release in turn reaches 27 800 000 Tons per year, with oil as the major contributor, 47.5% of the total. Next stands electricity, with 21%. Gas represents a more moderate 18% for 26% of the energy consumed. The deviation on the total introduced by the climate equals 12%, which is larger than the 7.5% decrease between 1990 and 2012, inscribed for Belgium in the Kyoto protocol. In case no climate correction will be applied and an equal share of the decrease between all energy consumers is imposed on a national level, 25.98 MTons of TRY-related CO_2 release in the residential sector should be the limit in 2012.

Table 7 was validated through a comparison with a top-down analysis for the Walloon region (Flamant, 1997). The difference was only 0.4% for the total consumption. Per vector, however, the variations were larger, with a maximum of 26.1% for 'other'.

The future

Table 8 gives the energy consumption and related CO_2-emissions in the residential sector for the years 2000, 2005, 2010 and 2015. In all six combinations of housing policy and increase in number of households, the positive impact of a better energy efficiency is obvious. A positive impact yet does not mean a decrease in consumption, see a high increase of the number of household, business as usual and a K55 or K40 energy efficiency legislation beyond 2000. In case the number of households follows the line of high increase and housing policy remains business as usual, then 25.98 Mtons CO_2-release in 2012 demands for a very strict energy performance legislation for new construction beyond 2000. The annual consumption per square meter of floor area for heating should not pass 180 MJ, and very though U-factors for roofs, floors, walls and windows (U=0.5 W/(m².K) for walls, 1.2 W/(m².K) for floors, 0.2 W/(m².K) for roofs and 1.3 W/(m².K) for glass) must be imposed in the case of retrofit. Things relax in case the number of households stabilize at a low increase. Then even a K55 legislation staying unchanged until 2015, suffices to reach the 25.98 Mtons target.

Table 8. Residential energy consumption and related CO_2-emissions for Belgium, prognosis for 2000, 2005, 2010 en 2015 as a function of housing policy (HP), housing demand (HH) and energy policy (EE-policy, the four scenario's listed) (TRY-year Ukkel)

HP.	HH	Energy consumption PJ															
		2000				2005				2010				2015			
EE-policy →		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	low	364	364	364	364	355	347	347	337	349	333	327	317	348	327	314	304
	high	376	376	376	376	381	372	372	362	387	370	364	355	398	375	364	354
2	low	360	360	360	360	347	336	336	324	332	312	302	291	327	297	277	268
	high	372	372	372	372	372	360	360	350	369	349	339	329	377	347	327	317
3	low	363	363	363	363	349	338	338	328	324	303	293	282	304	273	254	244
	high	375	375	375	375	366	357	357	347	343	322	312	301	323	292	273	263
HP.	HH	CO2-emissions MTon															
		2000				2005				2010				2015			
EE-policy →		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	low	27.0	27.0	27.0	27.0	26.2	25.6	25.6	24.7	25.8	24.6	24.1	23.3	25.7	24.1	23.2	22.4
	high	27.8	27.8	27.8	27.8	28.1	27.4	27.4	26.6	28.5	27.3	26.8	26.0	29.2	27.7	26.7	25.9
2	low	26.7	26.7	26.7	26.7	25.6	24.8	24.8	23.9	24.5	23.0	22.1	21.3	24.2	21.9	20.4	19.6
	high	27.6	27.6	27.6	27.6	27.3	26.7	26.7	25.8	27.2	25.7	25.0	24.1	27.7	25.6	24.1	23.2
3	low	26.9	26.9	26.9	26.9	25.8	24.9	24.9	24.1	24.0	22.3	21.6	20.7	22.4	20.2	18.8	17.9
	high	27.7	27.7	27.7	27.7	27.2	26.3	26.3	25.5	25.4	23.4	23.0	22.1	23.9	21.6	20.2	19.3

Switching from business as usual to more retrofit and reconstruction and a restricted expansion of the housing stock diminishe energy consumption and CO_2 release independent of the increase in the number of households. For a high demand, a K40 legislation for new constructions in combination with tougher U-factors for retrofit from 2001 on, realizes the 7% decrease in 2015. Combining a demand guided retrofit and reconstruction, no expansion of the housing stock beyond 2010, with the energy policy scenario 4 could even diminish CO_2-emissions in 2015 with 31 to 36%, compared to 1990. This scenario however imposes a heavy burden on a building industry, which is client and market oriented without much concern for societal consequences of its activity. She shows no overwhelming willingness to adopt tough energy efficiency requirements as a fear for a building cost increases and associated turn over decreases is much stronger than any concern for sustainable construction.

Obstacles that complicate energy efficient retrofit

Promoting energy efficient retrofit of the existing building stock is very important for lowering the national end use bill and related greenhouse gas emissions. Table 9 therefore reviews all parameters that impact energy consumption for heating in moderate and cool climates. Exterior climate and building use does not differ between new construction and retrofit. Building design, however, is marked by freedom in new and existence in retrofit. Compactness may be low. Orientation may be wrong. Both are difficult to change. Floor plan is easier to adapt. Also the glazed surface, thermal insulation and air-tightness could be more easily upgraded. Figure 2 shows that such upgrade is very efficient. However, several obstacles may complicate the decisions. To mention a few:

Historical and heritage buildings	Restricts the possibilities for an upgrade to the utmost
Famous architect	Forget any change to the facade and the windows. Thermal bridges may stay for ever. Only roofs and glass could get a better thermal performance.
Brick facades	Building control may forbid changing that aspect. This eliminates the most effective measure, exterior insulation, as a candidate for a thermal upgrade.
Mold risk	Exchanging existing windows with single glass for tighter ones with well insulated glass panels (see table 10) may increase dust deposit and mold risk on thermal bridges, that cannot be cured, considerably.
Costs	Some measures, although very energy efficient, that are very expensive may not pass a net present value analysis covering the sum of investment, maintenance and energy cost.
No interest in energy	As the energy bill is quite low compared to other annual costs (holiday, Rome, Italy phone calling, taxation, etc.), not so many owners and tenants are motivated for an extreme energy efficiency. Some are even not willing to invest in energy efficiency measures

Table 9. Parameters of influence on the energy demand and energy consumption for heating in a cool climate

GROUP	PARAMETER	INFLUENCE (other parameters equal)
DEMAND		
Exterior climate	**Temperature**	**Demand increases with lower outside temperatures**
	Solar irradiation	Demand decreases with increasing gains
	Wind	Demand increases with higher average wind velocities
	(Rain)	(Demand increases with higher rain intensities)
Building use	**Inside temperature**	**Demand increases with higher inside temperatures**
	Temperature control	Demand decreases when the principle 'heating only one present' is better applied
	Ventilation	**Demand increases together with ventilation**
	Free gains	Demand decreases with higher free gains
Building design	Compactness	Demand decreases when the compactness increases
	Floor plan	Demand decreases when the floor plan is correctly organised
	Type, area, orientation and slope of the glazed surfaces	Demand increases with a larger glass area. She decreases in case the glass has a higher solar transmissivity, in case more glass is oriented W-S-E and in case the glass slope is close to vertical
	Thermal insulation	**Demand decreases with a lower average U-factor of the envelope**
	Thermal capacity	Demand is hardly influenced by the thermal capacity of the building construction
	Air leakage	**Demand decreases with a lower air leakage of the envelope**
CONSUMPTION		
Heating system	Type of fuel	Defines the achievable efficiency.
	Efficiency (production, distribution, control, emission)	Consumption devreases with a higher overall efficiency (see building services)

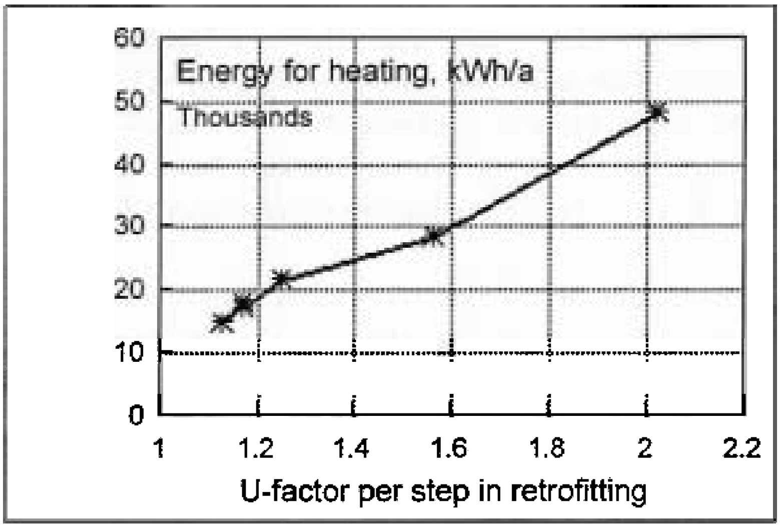


Figure 1. Energy retrofit of an existing building. Energy consumption for heating as a function of the average U-factor (Hens, 1993)

Table 10. Types of glazing

Type	U-factor W/(m².K)	g -	g_{visual} -
Single glass	5.9	0.81	0.90
Double glazing	3.0	0.72	0.80
Low e double glazing	1.8	0.63	0.70
Gas filled low-e double glazing (argon)	1.3	0.58	0.75
Gas filled low e double glazing (krypton)	1.1	0.58	0.75
Gas filled low e triple glazing (krypton)	0.7	0.50	0.65

Discussion

To be completed during the meeting.

Literature and References

Anon. (1995). IEA, Solar Heating and Cooling Programme, Solar low energy houses of IEA Task 13, James & James Publishers, London

Anon. (1996). NIS, Database T4901A14.Y91 to T4901D59.Y9, Number of dwellings in Belgium, as a function of location, type, floor area, age, heating system and primr energy vector, 8 floppy's

Anon. (1996). NIS, Statistics on new construction, retrofit, demolishment, 1 floppy

Flamant G (1997) Photographie du parc des logements résidentiels: premières conclusions, UCL, Architecture et Climat, 33 pp

Anon, (1999) Draft prEN ISO 13790 Thermal performance of buildings-Calculation of energy use for heating (supersedes prEN 832)

DOE, Office of Energy Efficiency and Renewable Energy, Scenarios of U.S. carbon reductions, 1997

Geselschaft für rationelle Energieverwendung (GRE), Heizenergieeinsparung im Gebäudebestand, BAUCOM, Böhl-Iggelheim, 1996, 99 pp

Hens H., Thermal Retrofit of a Middle Class House: a Monitored Case, Proceedings of the International Symposium on Energy Efficient Buildings, Stuttgart, 9-11 March 1993.

Hens H., Fatin A.M., Thermal Quality and Energy Use in the Existing Housing Stock, Proceedings of the International Symposium on Energy Efficient Buildings, Stuttgart, 9-11 March 1993.

Hens H., Verdonck B. (1997). Living, heating: energy, emissions, CO2-project Electrabel-SPE, 52 pp (In Dutch)

Laboratorium Bouwfysica, Databases STUD9497.xls, ANE9497.xls, ANAF9497.xls, 1997

Verbruggen A., editor, Leren om te Keren, Milieu en Natuurrapport Vlaanderen, Galant, Leuven, 1994, 823 pp

Verbruggen A., editor, Leren om te Keren, Milieu en Natuurrapport Vlaanderen, Galant, Leuven, 1996, 585 pp

Workshop Presentations
Energy systems Session

Comfort and energy in future buildings: Illustrations in Residential field

Marie Hélène Laurent, Nadège Chatagnon and Luc Tabary
ELECTRICITE DE FRANCE
Research and Development Division
FRANCE

EXECUTIVE SUMMARY

Evolution in qualitative demand for future residential and commercial buildings is expressed through very various and, sometimes, non-compatible, tendencies.

However, all these demands have to be satisfied in a common environment of, one more time, different constraints.

The synthesis of both demands and constraints is very specific to national contexts. For example, the concept of "sustainable building" is different from a country to another, depending on the availability of resources (space, water, energy,...).

Concerning the triangle "building - comfort - energy", our analysis for France seems to be applicable to Western Europe: demands and constraints are organized around 6 main themes:
- a wider comfort (multi-sensitive, psychological, services and life convenience),
- more flexibility (intermittent housing, adaptation to the market evolution, adaptable comfort to different rooms, activities, occupants),
- respect - and, if possible, improvement - of occupants' health.
- a limited environmental impact,
- compatibility with a refurbishment market,
- economical performance for commercial buildings with a specific theme for residential ones (to give housing and comfort to impoverished occupants).

It is not easy to give a good answer to such a variety of demands and constraints. However, the paper deals about 2 possible applications of these themes to future buildings:
- a special attention is given to "environmental respect" in a residential project.
- a house in a flat, a car connected to a house

SYMBOLS AND ABBREVIATIONS

LCA: Life Cycle Assessment
DEI: Direct Electric Heating
DHW: Domestic Hot Water
CIB: International Center for Buildings
EER: Energy Efficiency Ratio
EHQ: Environmental High Quality
LPG: Liquid Propan Gas

DSM: Demand Side Management
IAQ: Indoor Air Quality
LV: Low Voltage (25 V)
VAT: Value Added Taxes (for "inc. VAT": including VAT)
UV: Ultra Violet

NO_2: nitrogen dioxide
CO: carbon monoxide
SO_2: sulfur dioxide
CO_2: carbon dioxide
K: thermal conductivity in $W/m^2.°C$

Within the framework of our medium term program for the development of offers for the Residential and commercial fields, we needed to consider the question about changes in demand and constraints about buildings and their consequences concerning electrical comfort. This analysis was carried out mainly within the context of the Residential sector, deliberately considering the point of view of the final customer, in other words the person "using" this comfort. The analysis has to be wider than the only comfort theme.

1. Six themes to be retained

A large number of forecasts and/or society studies carried out either within EDF or across France and Europe [1, 2] are available to help define themes that will be important for the buildings of tomorrow (most of which are already important). The conclusions has to be discussed but we to summarize it by items:

Social trends:

- population ageing: → problem of resources
  → shock of dependence
  → aged workers
- professional life more chaotic and de synchronized
- more free time, but by smaller bits → more mixing between private and professional life
- more individualism (not egoism):
  → more independent workers
  → more freedom and tolerance in private worlds and more rules in public worlds
  → personalized offers
- fragile increasing of ethic values

Buildings trends:

- more refurbished buildings than new ones
- reinforcement of regulations:
  → integration of environmental effects in buildings regulations
  (especially, efforts concerning the lowering of energy consumption in buildings will increase)
  → reinforcement of "safety behaviors" about healthy and security items
- the buildings' skin and associates techniques are the main field of technical evolution
- the second one will be the indoor air quality (connected with comfort and health)
- in France, the question of the emergence of an industrial way of construction of new buildings remains

- buildings will be (partially) energy production plants

Inside equipment trends:
- part of them able to communicate with the inhabitant, other inside equipment, and repairers
- more individual
- more "immaterial equipment"

Concerning the more important items for the "building of the future", we tried to summarize these " macro-trends " in a few major themes that already exist, although their nature (constraint or demand) or importance (health) might change in coming years. These six themes are:

1.1 Personal fulfilment
- increased and expanded comfort, in a very wide sense: at the moment, the concept of comfort is centered essentially on temperature needs, but will become considerably wider in the future.
    - comfort will become multi-sensorial and will include acoustic and visual (lighting) comfort. It will also include psychological aspects (stress free environment, natural lighting, sounds).
    - consumer comfort will be better regarding the equipment's working (interfaces, realibility)
    - it will include standard conveniences (ease of use of an appliance, reliability, control) and consequently will therefore encompass the "usage → services" transition, and communication systems making these new services possible.
- recreation, pleasure
- in a safe environment.

1.2 Greater flexibility.
Families and consumers no longer belong to clearly defined categories, their needs are changing quickly (even over the time scale of a week, for example in the kitchen rudimentary microwave cooking on week days makes way for traditional family cooking at the weekend). The home and its uses must be adaptable to a variety of increasingly short life cycles (re-composition of families, late departure of teenagers, long term residence of the elderly with the return to cohabitation of several generations in the same home, work, leisure and training at home, periods of professional inactivity).

In the commercial field, flexibility of the inside spaces in a condition of success in order to follow market's trends.

1.3 Protecting (or even improving) the health of occupants.
It is today a huge and increasing market. Demand concerns:
- the realization of the need of "health capital" (deals with the current quality of air (IAQ) and water in the home
- also includes more extreme forms including looking after the elderly at home and increased medical services in the home.

But resources are limited and could lead to convergence towards medical assistance and tele-medicine (caring for elderly people and sick at home).

Health is also a factor which could either lead to the popularity of a product or its commercial ruin. Precautions will be more important concerning this theme, and it could be a raison of decreasing of creativity and innovation in future buildings (see buildings trends).

1.4 Greater sensitivity about protection of the environment.
It is a very complex and multicriteria subject. Considering the residential field:

- in the global sense, in France, this has not yet created a demand from final consumers who are not yet ready to pay (either by making personal efforts or with money). Therefore, at the moment the impetus is provided more by the policy adopted by local authorities with the result that the building regulations are regularly becoming stricter, and by the involvement of public clients in the construction of "sustainable buildings". However, it is important to be aware that the nature of this theme will change within a generation, this constraint should start to change at the demand of the final user. Increasing awareness should go outside an institutional framework to reach the consumer stage, since we are now the first generation concerned about the impact of our actions on future generations. We have also to consider as a positive point what we called the "fragile increasing of ethic values" (see social trends).
  in the local sense, there will be a backlash soon under the "neighbors look".

In the commercial field, this point is extremely important: a commercial - or industrial - activity have to prove that its behavior is ethically correct, and this includes respect of environment.

In most of cases, High Quality Environmental Buildings are made by publics policies and some private companies for residential and tertiary buildings (as high school, offices...)

Of course, first quality of Environmental High Quality (EHQ) building is its low consumption in natural resources, namely energy and water. The building of tomorrow have to consume less energy and to produce part of its consummations.

1.5 Refurbishment of buildings
Commercial buildings are not all adapted to current commercial activities (especially office buildings): they need to be refurbished. French Residential buildings are renewed at very low rate (80% of the buildings that will exist in 2030 are already built today). It is more difficult to guarantee comfort and high-energy performance if the building is not well designed. It is technically and economically difficult.

1.6 Constant economic constraint
Permanent concern of the Commercial sector, and also a strong constraint in the Residential sector that becomes acute with the increase in exclusion among a section of the population. This is the most difficult theme of all. Not only because economic constraints are drastic but because, solutions are much more dependent on non-technical factors than in other cases.

This analysis (highly concentrated on the Residential sector) is more difficult to carry out for the Commercial one. The themes are eventually the same, but they are all related (more or less strongly) to a permanent economic requirement that concerns all items:

- flexibility, if it makes it possible to adapt to markets more quickly (and therefore at lower cost),
- comfort, if it improves the "productivity" of occupants,
- and obviously the "investment - operation - maintenance (reliability)" combination.

Here again, this "demand" should accommodate to strong constraints reflected by changes in regulations (environment, health), and by the nature of the buildings (mainly a rehabilitation market).

	Residential	Commercial
Personal fulfillment		
Recreation, pleasure	demand	/
Increased comfort	demand	if increasing productivity
Safety	demand	demand
Flexibility	demand	economic necessity
Health	demand	legislation
Environment	global constraints, local changes → tomorrow's demand	legislation
Refurbishment	constraints	constraints
Economic constraints	= exclusion: constraints	underlies all demand

Tomorrow's buildings will not be a combination of these various trends since it is easy to see that they are not all compatible with each other. Nevertheless, they will be affected by all of these influences: therefore they will be even more comfortable, they must be adaptable through greater flexibility to changing needs of their occupants and managers, they must better protect the health of their users, they should be less damaging to the environment during their construction and operation, all this must be possible starting from improvements to buildings many of which already exist and under acceptable economic conditions, particularly for homes, sufficient imagination must be shown so that comfort solutions adapted to all budgets can be defined.

2. Examples of solutions provided by electrical uses in the future

2.1 Uses

We will give a few examples of electrical products currently being developed, but this is far from covering the entire possible range of future uses of electricity.

2.1.1 Windows

A great deal of progress has been made in recent years in thermal aspects of windows, but, in the future, the addition of electricity will enable them to perform new functions such as:

- control of solar flux, for example with electrically controlled "electrochrome" windows that can limit solar inputs and therefore improve comfort in the summer and/or reduce energy consumption for cooling for an air conditioned building. In winter, zone control is possible to limit glare without reducing light flux.
- variable privacy with electrically controlled liquid crystal windows. These products are available for indoor windows, and, in the future, can be used to control vision outside (materials with electrical transition) or to choose the level of intimacy (imagine a bedroom that can be seen during the day but concealed at night).
- active acoustic protection (already used for Commercial applications in ventilation) capable of "filtering" some noise (motor low frequencies) to keep only pleasant sounds (high pitch frequencies of children playing, or birds singing).
- a heating window, which can already be used to avoid the "cold wall" effect or to provide back-up heating, and in the future will be able to heat an entire room, and possibly to store and produce energy.

2.1.2 Heating
The existing range of heating products is already very wide and can satisfy many expressed needs (inertia or reactivity, integration or appearance, etc.). Therefore, the objective is not so much to create a lot of new products, as to significantly improve what has already been developed (reliability, implementation, costs) for example such as:

- inertia and storage radiators using heat storage materials based on phase change (better integration by the variety of shapes and improved compactness),
- heating floors with a fine concrete screed or faster to construct,
- easier to install and more aesthetic heating ceilings,

and make better use of the possibilities of the Joule effect to create products capable of overcoming weaknesses in the current range:

- transparent radiating or very thin panels (less than 1 cm), even more easily integrated.
- heating coatings: glue for the bathroom floor tiles, the carpet in the games room, a bath which keeps the water hot, armchair fabrics, desktop writing pad, computer mouse, etc.
- multi-function emitters: heating mirror (pleasant booster heating for the bathroom, non-misting mirror), heating doors and windows (easy to integrate products adapted to renovation), decorative elements (sculptures, cornices), etc.

2.1.3 Ventilation
Today, ventilation of homes is not always satisfactory. There are many different needs, considering the necessary improvement to Indoor Air Quality (health, energy consumption, comfort). However, the foreseeable improvement in available products is relatively poor, and this is undoubtedly one of the fields in which R&D efforts should be made. Electricity is expected to be useful for:

- health, with qualitative preliminary treatment of incoming air, for example UV or pyrolysis, and ventilation control as a function of the composition of indoors air,
- energy efficiency with the use of thermodynamic systems between incoming air and outgoing air, and ventilation as a function of the composition of indoors air,
- comfort with preliminary heat treatment of incoming air.

2.1.4 Lighting
In the same way as for windows, many technical improvements have been made to lamps over recent years. The following gives a few examples of improvements expected in the future, apart from the appearance of more energy efficient light sources:

- create complete light environments through the control and variation of light flux, color and color rendering. At the present time, the virtual window already provides "natural" lighting in rooms without any daylight.
- move light fittings on a wall at will (these systems are already available in some shops, based on Low Voltage power supplies through conducting panels).
- optical fibers will be capable of transporting light in wet rooms (showers), or places with difficult access.

2.1.5 Household appliances
Apart from the continuous widening of the "low consumption" range, the other trend in household appliances is increased communication ability to dialogue with:

- the user by means of Fuzzi logic: for example, the surface cleaning robot may suggest: "the kitchen floor is dirty, I could wash it tonight ",
- other purposes: collective control, DSM,

- outdoors: call the repair or maintenance service, shopping through the Internet.

The latter point announces the "usage → service" transition: instead of buying a clothes dryer, we rent the "washing" function and transfer a number of responsibilities from the user to the supplier: the equipment must have a long life (it belongs to the company hiring it out), it must be reliable (maintenance included in the service), and it must be recyclable (the company hiring it out recovers it at the end of its life).

This change is perceptible in household appliances but could be a useful channel towards the commercial development of new products, such as air conditioning systems or de-localized energy generation/storage systems.

2.1.6 Comfort control
Comfort is a psycho-sensorial concept which means that it is an extremely difficult subject to describe (different concepts of comfort for different individuals), and even more to quantify. Nowadays it usually includes only its sensorial aspect, and only considers heat as quantified by a temperature.

Considering heating alone, we already know that temperature gradient, air speed and heat flow parameters are all important, if only as a function of the nature of the emitters and their locations, these parameters will not all have the same "equivalent value". In the future, it will be necessary to take account of the various senses involved and the impact of psychical perception. Without actually defining an individual comfort map, we will be able to classify the preferences of 80% of the population in categories compatible with their needs for comfort: these categories will make use of the parameters mentioned above (temperature gradients, nature and location of emitters, etc). A development program is being carried out at EDF in order to define these categories.

Therefore, it is easy to understand that it is not easy to control comfort provided by a use of electricity. However, in the future, it will be necessary to control several usages harmoniously at the same time, for DSM and for comfort. The concept of "ambient comfort" or "climate" will appear and in the future we should be able to control a comfort scenario, for example such as "cinema ambiance" when we want to watch a film: less intense and warmer lighting, higher temperature, use of quieter appliances, installation of active noise absorption systems.

Therefore, control is an essential field for tomorrow. Many technical developments are still expected, but their success depends very much on their acceptance in society. Two points are essential for this acceptance:

- the control mode, for which two trends are developing:
    - self-adapting mode, as transparent as possible for the user. The controller will receive inputs from sensors unnoticed by the occupant and through a minimum of non-quantitative information supplied by the user (it's all right, it's not all right, it's too warm). EDF is currently developing a self-adapting heating manager that "learns" the habits of the home occupier in a few weeks (I don't eat at home on Mondays, I get home at about 19h00). This prototype is working well technically, but is faced with two generic difficulties:
        - it must be possible to include an unanticipated scenario by a remote controllable override mode (I'm not very well, I'm coming home).

- the controller "master" must be identified, even though there will be arguments about the controls (it's already too hot for Dad, but Grandma is always cold and wants it warmer).
- remote controls, associated with reactive uses with low inertia, for everyone who does not want to delegate or whose lifestyles are too irregular (60% of Paris executives don't know when they will get home in the evening, to the nearest hour).
- the simplicity of interfaces: although touch screens had some success a few years ago, and although the keyboard seems well accepted nowadays, no one type of interface has taken a clear lead over the others. A great deal of progress is expected in voice recognition and transfers should be expected between developments made to improve the lifestyle of the handicapped and control of uses related to indoors comfort.

3. Concepts of future buildings

3.1 An example design of an electrical and environmental home

In 1998, EDF organized an architecture and engineering competition for a detached house (the dream home of most French families) [11]. One objective was to demonstrate that electricity can serve as main energy into an environmentally friendly home. In the French definition [13], environmental quality of buildings involves both the outdoor (in terms of pollution, depletion of resources...) and the indoor environment (comfort and air quality). Moreover, the purpose was not to build an experimental house or to use technical solutions that were not yet existing. On the contrary, the objective was to design a modern house equipped with equipment available on the market and not requiring any special developments.

3.1.1 Requirements

The requirements were to design:

- a house for **"living in"** offering a pleasant lifestyle to a family of 4 persons within a living area of 150 m^2.
- a **flexible** house. The design of the house had to allow an upgradable internal area capable of matching new lifestyles (e.g. work at home) and the change in the family structure,
- a **comfortable** house in many respects:
  - ◊ indoor temperatures in summer and in winter ("four seasons" comfort),
  - ◊ acoustic, with respect to outdoor noise equipment noise, and also indoor noise,
  - ◊ visual (view outdoors, natural lighting),
  - ◊ Indoor Air Quality.
- an **environmentally** friendly house through:
  - ◊ a reduction of its impacts of the environment, from its construction to its demolition. In particular during its life - low energy and water consumption,
  - ◊ its integration into the surroundings.
- **low energy operating** costs.

3.1.2 The design project

The winning team (Pierre Lombard, Architect and Olivier Sidler, Consulting Engineer) adopted a global approach to optimise the selected solutions. They offer a very coherent and integrated project in which each technical and architectural choice is important. An overview of this project is shown on the Figure 1.

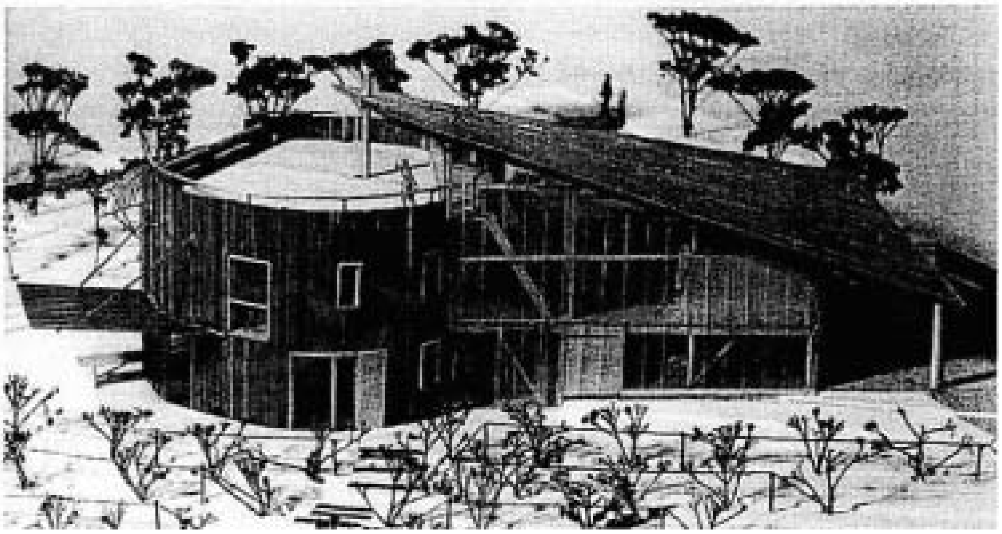


Figure 1. An overview of the prize winning house
(P. Lombart, Architect & O. Sidler, Engineer)

3.1.3 The solutions proposed

Architectural choices
The prize-winning house integrates a **bioclimatic** architecture:
- house is oriented so as to maximise solar inputs in winter.
- large well-oriented vertical windows, construction of a large integrated veranda at the south so as to benefit for solar radiation in winter while providing protection from it in summer (upper part covered and insulated, top and bottom openings enabling free cooling ventilation at night).
- plants used to improve comfort in summer: trellis with deciduous plant cover providing shade over the top of the veranda.
- house oriented to protect it from the dominant cold winds (redirected by the sloping roof),
- construction of buffer rooms at the north (garage, workshops, attic, cellar,..)
- cylindrical main volume (exchange area less than for a cube, for the same volume).

Thermal comfort
The house presents an extra insulation: outside thermal insulation and triple glazing,
The thermal inertia is high and choices (fine automatic control for heating) have been made to have a good energy management. This set of choices results in natural cooling of the house.
Heating is ensured by:
- electric radiating ceiling (good comfort and high energy efficiency),
- complementary very efficient fireplace,
- regulation.

Ventilation and Indoor Air Quality
Considering the little progress made in existing techniques (as CO_2 sensors, treatment of incoming air) and the higher cost of more efficient techniques (as dual flow), ventilation is controlled by a conventional mechanical ventilation system with regulated humidity. The materials used inside the house do not require any surface treatment (slate or linoleum floors, untreated wood for the veranda,..)

Domestic hot water

- use of economic showers and reductions in the length of the distribution network
- use of solar energy (3.3 m² sensors, double tank - solar tank + additional electrical tank, systematic preheating of water by the solar tank). Technical efforts have been integrated to limit heat losses due to the storage and the distribution (short, star, insulated network).

Household appliances

- priority has been given to the use of appliances without standby (computers, microwaves) or if not possible with simple or controlled cutoff devices,
- appliances have the Class A (low energy consumption).
- natural area for drying the washing,
- induction plates on the cooking hob (low energy consumption, no inertia) and extra insulation around the oven.

Lighting and visual comfort

Large amount of natural lighting. For further comfort, remaining lighting needs have been provided by multiple points with a variety of light fittings, but all based on a design compatible with the use of compact fluorescent lamps to reduce consumption by a factor of 3 to 5 (simply replacing conventional incandescent lamps by compact fluorescent lights without changing the light fitting degrades the degree of visual comfort).

Acoustic comfort

- Outdoors noise: fresh air through the veranda (noise buffer area), and windows with triple glazing,
- Noise related to equipment operation: appliances with excellent acoustic attenuation, heating mode chosen without noise.
- Noise inside the home: mobile partitions between rooms made from materials with high sound absorption, use of acoustic bricks with hollow compartments.

Flexibility

The house in this project is organised for use by a family of 4 persons with two children. Frequently used areas can easily be modified: the open kitchen can be concealed by a curtain, the office area can be isolated by a removable mobile partition. The different use of annexes also opens up future possibilities: independent apartment for children and teenagers, a second home with independent access.

3.1.4 Energy performance of the project

The Figure 2 gives the estimated energy consumptions concerning the laureate house. The energetic results are compared to a regulation reference which is constituted by regulatory requirements and/or common practices. Estimations have been made for the different uses concerning the individual residential sector: heating, cooking, DHW, appliances and lighting.

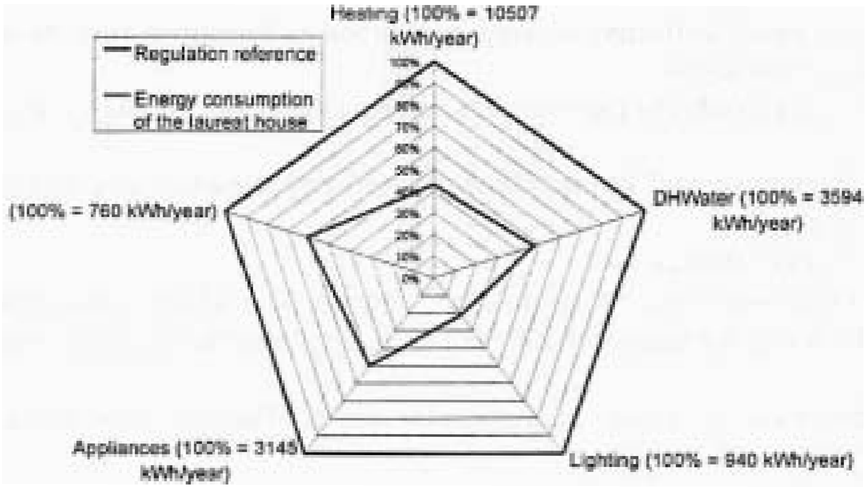


Figure 2. Energy consumptions for the winning house

Globally, energy consumption is reduced of more than 50% in comparison with the regulation reference.

The construction cost (including unheated annexes) is about 216 478 euros (inc. VAT) for an inhabitable area of 125 m^2.

3.2 A futurist concept: a house in a flat, a car connected to a house
Several ideas drove us to this concept:

- necessity to find the detached house's convenience in an urban flat,
- old dream of a flexible lodging able to follow family changing and growing,
- integration of new activities in lodging, especially manual works,
- necessity to decrease air pollution in urban areas,
- coupling of local and centralized ways of generation of electricity.

The first idea comes from future electric cars moved with fuel cells. Dr A. Lovins, from Rocky Mountain Institute [14], makes two observations:

- american cars are running only 5 % of a daytime,
- every year, US car industry produces for internal market an amount of cars giving a level of power equivalent to the existing US electric plants annual production.

He imagines that fuel cells cars could be used as small electric power plants during the other 95 % of the daytime.

During the same time, architects François Seigneur and Sylvie de la Dure [15] and EDF work on a concept of building able to receive cars inside of every flat in order to answer to the needs listed in the first part of this paper.

The possibility to run his car inside of the flat gives a lot of convenience:

- easier and safer mobility for elderly people, handicapped people and children,
- easier handling in a private (shopping) or professional context,
- safety storage of cars and its contents,

- no more underground collective parking understood as dangerous areas by inhabitants and collective house managers,
- possibility to park inside the car when it is not possible to dig underground parking.

The "inside individual garage" is a new kind of room able to partly solve problems of flexibility in lodging:
- new possibilities of storage,
- the place for the "second part of the kitchen": storage of food, apparatus, rubbish's,
- workshop, bedroom for granny visiting children, apartment for elder children, room for parties,
- use of the stored car as a room: auditorium for music, office, occasional bedroom, place of rest,

This new intermediate room facilitates the coupling of a local and mobile way of generation of electricity (electric fuel cell car) and a centralized system. Imagine a double network on a local scale: electricity and hydrogen:
- a fuel cell car is able to fill its hydrogen tank in the building or outside in the block,
- the fuel cell car is able to deliver electricity on a local network when staying at home.

Architects Seigneur and Deladure conducted the study of the concept in refurbishment of dwelling in the historic center of Marseilles for social housing. It was not possible to dig an underground parking, and the place for "car-elevators" was founded in the place of classic inside stairs. Other studies for new collective houses conclude that the "car-elevator" cost is mainly covered by the economy of the underground parking.

Figure 3. Example of a professional use

We described several advantages of this concept, but we have to discuss about its weaknesses:
- we checked that the concept is not opposed to possible evolution of urban transportation: that is true if the car is a urban one with an area of work of a few km. The larger car, the one for holiday for example, is stored a few kilometers away.
- the main criticism is coming from a medical point of view: our life is a more and more sedentary one. It is better to promoting walking than proposing ways of life avoiding it. We have to walk more, even with 20 kg of groceries.

This concept of housing will be studied for real projects of new dwelling in order to build one.

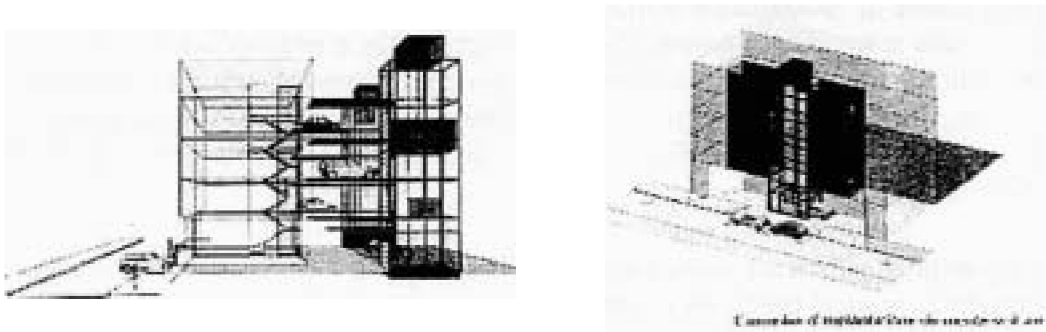


Figure 4. Example of inside and outside integration of car-lifts

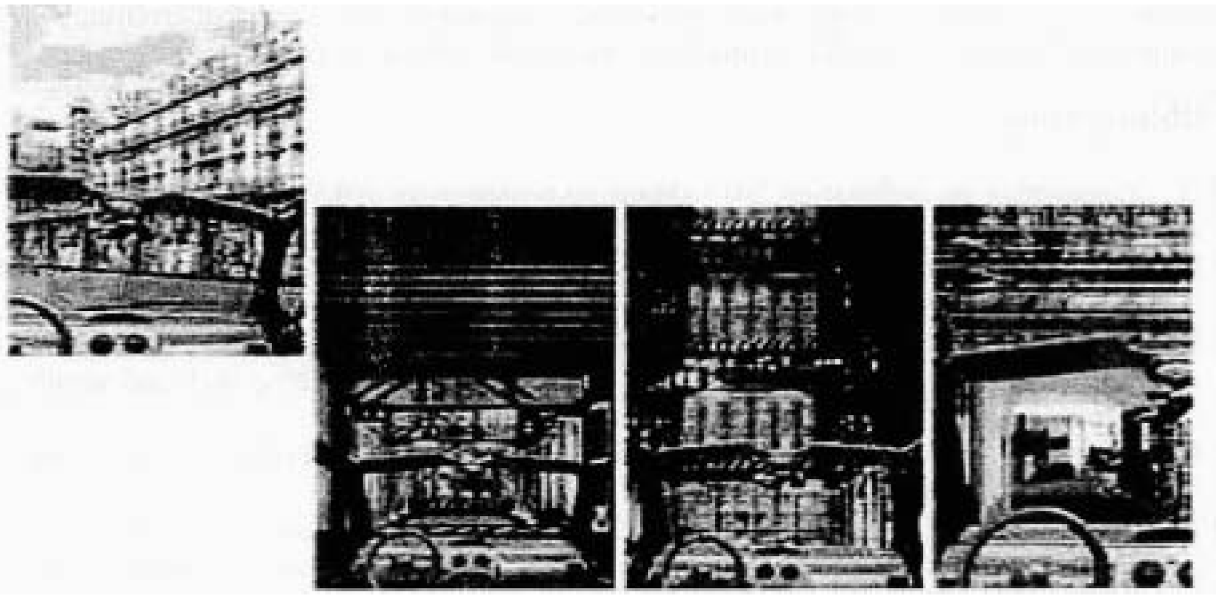


Figure 5. Coming inside of the building

4. Conclusions

Electrical applications currently being developed provide a variety of technological solutions to subjects important for comfort in tomorrow's buildings. However these innovations will only be successful if they are psychologically and socially accepted by users (delegation, amount of control, and simplicity of interfaces).

Products currently on the drawing board will undoubtedly provide solutions to demands for increased flexibility and comfort, and to the necessary requirement for increased respect of the environment. On the other hand, protection of the health of occupants and difficulties related to refurbishment of existing housing must be described in larger research programs than today. Finally, there is often still a need for means of bringing these solutions within the reach of economically deprived populations. This is undoubtedly the theme in which we have to progress and which requires the most R&D effort.

On the particular theme of "sustainable buildings" and their energy efficiency, electricity companies have made many development efforts to improve the energy efficiency of electrical uses, with the initial purpose of economic competitiveness. Electricity applications can undoubtedly contribute to the design of EHQ buildings, and some can even improve buildings either by their high energy efficiency, or by their ability to improve the Indoor Air Quality and the quality of water.

However these products, which are more energy economic, are only accepted if their use does not reduce strongly expressed needs for comfort. This compromise is possible, but the investment necessary for low energy consumption buildings and equipment is often higher than for traditional techniques (for the same service provided).

This is the strongest brake in the current context of simultaneous high energy efficiency and energy abundance. However, solutions will have to be found to lower investment costs of products and systems with a high energy efficiency if we want to continue to control global energy costs, in other words these technologies have to be made accessible to the least fortunate segments of our population, and the large amount of know how that electricity companies have built up on this theme has to be shared with developing countries.

Bibliography

[1] Prospective de l'habitat en 2015 (Housing prospects in 2015). Y. Boudjouher - 07/96 EDF-DER-SE

[2] Le bâtiment demain et après-demain (Buildings of tomorrow and after tomorrow) CSTB - 1998

[3] Logements basse consommation: Etat de l'art des technologies d'enveloppe et de ventilation. (Low consumption homes: State of the art in building shell and ventilation technologies). E. Cayre - EDF-DER-ADEB - June 96

[4] Factor Four: Twice more comfort using twice less energy. Ernst U. von Weizâcker, Amory B. Lovins, L. Hunter Lovins - 1997

[5] Etat de l'art sur les systèmes de chauffage et rafraîchissement thermodynamique en résidentiel (State on the art of thermodynamic heating and cooling systems for homes) EDF/DER/ADEB . F. Beck, C. Amartin - June 1997

[6] Futuribles - special issue - January 1999. L'an 2000, et après... (The year 2000 and after….)

[7] Sustainable development and the future of construction - A comparison of visions from various countries. CIB report - CIB Working Commision W82 "Future Studies in Construction" - May 1998

[8] CEPHEUS: Cost Efficient Passive Houses as European Standards
Communauté Européenne - 1998 (European Community)

[9] Tableaux de bord de l'économie française: 1997 – 1998 (Trend charts for the French economy). INSEE (Institut National de la Statistique et des Etudes Economiques - National Institute of Statistics and Economic Studies) - April 1997

[10] Architect ; Pierre Lombard: 48, rue Ducouëdic 75 014 PARIS - FRANCE
Consulting engineer: ENERTECH: Olivier Sidler 26 160 FELINES sur MIRANDOULE - France

[11] Un nouvel art d'habiter - Concours maison confort électrique 1998.
(A new way of housing - Concourse Electric Comfort House). EDF - 1998

[13] Définition des cibles de la qualité environnementale des bâtiments, Dossier n°1, Association HQE, Paris, Novembre 1997

[12] Energy-Efficient and Heallthy Buildings. Yan Chen – 1998. MIT, Department of Architecture, Massachussetts Institute of Technology
[13] Définition des cibles de la qualité environnementale des bâtiments, Dossier n°1, Association HQE, Paris, Novembre 1997
[14] Hypercars: materials, manufacturing and policy implications, Amory Lovins, Michael M. Brylawski – 1997. Rocky Mountains Institute
[15] Architect François Seigneur and Sylvie de la Dure: 27, rue Elie Giraud 13 200 Arles – France. Intégration de l'automobile dans le logement collectif - 2001

Energy storage

Halime Paksoy
Chairman of IEA ECES IA
Cukorava University
Turkey

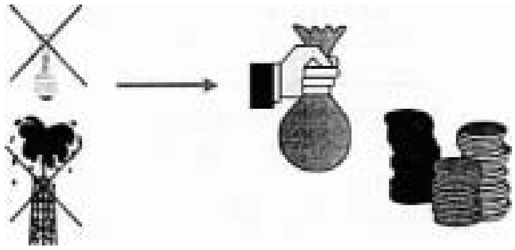
International Energy Agency

Implementing Agreement on Energy Conservation Through Energy Storage (IEA-ECES IA)

Started in 1978.

Why Energy Storage ?

Conserves energy and money

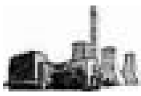


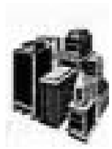
Why Energy Storage ?

- Close the gap between supply and demand of thermal energy
- Utilize diurnal and annual variations in temperature
- Increase the potential of using solar energy effectively

Why Energy Storage ?

Decouples energy supply from energy demand





Energy Storage

Why Energy Storage ?

- decrease of energy-related CO_2-emissions and hence global warming and climate change
- avoiding utilization of ozone depleting substances (ODS) in cooling
- decrease of air pollution acid rain caused by energy related SO_2 and NO_x emissions

Why Energy Storage ?

- International Commitments
  - UN meetings during last 10 years
    - Rio de Janeiro 1992 (Agenda 21)
    - Berlin 1995
    - Kyoto 1997 (Kyoto Protocol)
    - Hague 2000
  - Montreal Protocol for ODS

Operation of Energy Storage

- Seasonal (summer/winter)
- Diurnal (day/night)
- Short-term

Overview of the Technologies

- Underground Thermal Enegy Storage
- Phase Change Materials
- Adsorbtion Process
- Thermochemical Heat Storage
- Electrical Energy Storage

Underground Thermal Energy Storage (UTES)

- Thermal energy storage in the ground:
  - Aquifers (groundwater bearing strata)
  - Boreholes in soft soils and rocks
  - Rock caverns and pits
- Applications - heating and cooling
  - Communities or groups of buildings(mostly seasonal)
- Selection of suitable technology
  - geological, hydrogeological and climate conditions

Phase Change Materials

- Chemicals
  - Storing thermal energy by melting a material with desired melting point according to application
  - Recovering stored thermal energy by freezing the material
- Snow
  - Storing natural or artificially produced snow in winter to be melted in summer for cooling applications
- Ice
  - Mechanically produced with cheap off-peak electricity to be melted in peak time for cooling

Thermochemical Heat Storage

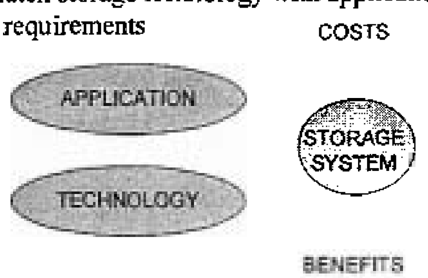
- Reactions between chemicals are driven by a heat source
  - solar energy
  - waste heat
- Chemicals produced in the reaction can be stored seperately and then mixed when heat is required
- Reaction must be reversible
- Heat or cold both consumed and delivered

Electrical Energy Storage

- Pumped Hydro
- Batteries (conventional & advanced)
- Superconducting Magnetic Energy Storage (SMES)
- Flywheels
- Fuel Cell/Electrolyser Systems
- Conventional Capacitors
- Supercapacitors/Ultracapacitors

Energy Storage The Key

Match storage technology with application requirements



Benefits of Thermal Energy Storage

- Exploiting solar energy and natural thermal energy
- Exploiting waste heat from any thermal process
- Increasing efficiency of energy use and production
- Peak-shaving (Load levelling)
- Decreasing the dependence on conventional energy resources

Benefits of Electrical Energy Storage

- spinning reserve
- load levelling
- integration with renewables
- frequency and voltage regulation
- network stability
- deferment of new capital equipment
- enhanced quality of supply/power quality
- enhanced overall energy efficiency
- emissions and environmental benefits
- asset management
- demand-side management

Applications

- Commercial Buildings Heating and Cooling
- District Heating and Cooling
- Residential Heating and Cooling
- Agriculture-Aquaculture
- Industry (process/space heating and cooling)
- Telecom Stations (cooling)
- Gas Turbine Generators (inlet air cooling to increase the efficiency)

Motivations and Challenges

- Increase the economic efficiency
- Prove the reliability of the energy system
- System integration
- Contribute to global environmental conservation

R , D & D

- Energy storage in urban planning
- Short term energy storage in combination with seasonal storage
- Combination of short term storage with absorption heat pumps
- Electrical energy storage and integration with renewables

R , D & D

- Energy storage in urban planning
- Short term energy storage in combination with seasonal storage
- Combination of short term storage with absorption heat pumps
- Electrical energy storage and integration with renewables

Adsorption Process

Heating, Cooling and Dehumidification

- Solid adsorbents (zeolites, silica)
- Liquid adsorbents(dessicants)

Heat Pumping Technologies and the Built Environment

Herman Halozan
Chairman of the IEA HPP Executive Committee
Graz University of Technology, Austria

The characteristics of advanced present and future buildings are reduced heat loads and heating demand, but due to the better insulation of the building envelope and controlled ventilation systems with exhaust air recovery cooling and dehumidifcation, respectively, may be required to guarantee thermal comfort during summer time.

For cooling there are only a few systems like compression, sorption and DEC available. For heating there is a great competition between conventional systems burning fuels and heat pumps. Heat pumping, i.e. reversing the natural heat flow from a higher to a lower temperature level, is an old technology, it is a highly efficient technology, and it is a proven and reliable technology, but it is only partly used in the built environment, especially in Europe.

The capabilities for saving energy are often neglected; the reason for this situation is a lack of knowledge on heat pumping technologies and on the energy system. The advantage of heat pumping technologies is that there is practically no limitation of the capacity, the range covers 1 kW to 45 MW.

Heat pumping technologies can be used for heating and cooling, and in some applications the excess heat of cooling can be used simultaneously for heating: on function can be carried out for free. Heat pumps save, compared with conventional systems, at least 50 % energy, and this feature can contribute to improve the environment and help to meet the Kyoto targets.

Appendix

Workshop Programme

Tuesday, May 8

19.00 Welcome Reception

Wednesday, May 9

08.30 **Welcome and Purpose of the Think Tank**
Jørn T. Brunsell, Chairman of the Future Buildings Forum, Norwegian Building Research Institute, Norway

09.15 **Global Challenges**
Øystein Dahle, Head of the World Watch Institute, Scandinavia

10.00 **The Energy Situation in 2025 and Beyond**
Claes Otto Wene, IEA Secretariat, Paris

10.45 Coffee Break

11.15 **Trends in Lifestyles**
Margrethe Aune, SINTEF, Norway

11.45 **Factor 4 - 10 in Buildings**
Sverre Tiltnes, GRIP Center for Sustainable Production and Consumption, Norway

12.15 **Long Term Trends in the Swiss Building Sector**
Mark Zimmermann, EMPA ZEN, Switzerland

13.00 Lunsj

14.00 **Challenges in Building energy efficiency in warmer climates**
Poul Kristensen, Denmark

14.30 **Buildings End-Use Working Party Perspective**
Bertil Petterson, Swedish Ministry of Environment, IEA End-Use Working Party

15.00 **Urban planning for a green and sustainable Future**
Tony Rigg, UIA Architecture & Energy Work Programme, Israel

15.30 **Existing Buildings**
Leigh Breslau, Design Partner, USA

16.00 Coffee Break

16.20 **High Performance Commercial Buildings: A Technology Roadmap**
Richard Karney, US Department of Energy, USA

15.50 **Energy systems in buildings**
Asger S. Kjeldsen, Encon Electrical Utility, Denmark

17.20 **Information about tomorrow**
Fred Morse, Morse Associates, USA

18.30 Boating Excursion on the Oslo Fjord (includes dinner)

Thursday, May 10

08.30 – 9.30 Presentations (3 Parallel Sessions)

- **New Buildings**

  Introduction by chairperson Anne Grete Hestnes

  Indoor air quality and Energy Use in Buildings
  Eduardo de Oliveira Fernandes, ASHRAE

  Application of advanced envelope components and condition strategies for optimise energy consumption in commercial buildings
  Michele Zinzi, ENEA-SIRE-DINT

- **Existing Buildings**

  Introduction by chairperson Hugo Hens

  Presentation by Hugo Hens

- **Energy Systems in Buildings**

  Introduction by chairperson Fred Morse

  Comfort and energy in future buildings.
  Marie Helene Laurent, Electricité de France – R&D

  Heat Pump technologies and the Built Environment
  Herman Halozan, Chairman of the IEA HPP Executive Committee, Graz University of Technology

  Energy storage
  Halime Paksoy, Cukurova University

09.30 Discussion on Marked Forces, Trends, Impacts and Opportunities (3 Parallel Sessions)

12.30 Rapporteurs reports (Plenary session)

13.00 Lunch

14.00 Discussion of Research and Development Needs (3 Parallel Sessions)

17.30 End of the day

18.00 Bus Sightseeing in and around Oslo (includes dinner)

19.30 Dinner

Friday, May 11

08.30 **Plenary Presentation of Conclusions and Recommendations** by Session Chairpersons
- New Buildings
- Existing Buildings Retrofit
- Energy Systems in Buildings

09.30 Coffee Break

10.00 **Synthesis of Recommendations**

12.30 **Wrap-up**

13.00 Lunch – End of Workshop

14.00 Departure for Train Connection to Airport
FBF Organising Committee Meeting

Rapporteurs report - New buildings

Session leader
Anne Grete Hestnes, Norway,

Rapporteur:
Richard Karney, USA

Introduction

Nine people participated in the New buildings group. Two presentations, one about indoor climate and one about energy performance in envelope components were first presented before the brainstorming and discussions started. The result of the discussions is shortly presented below.

Major marked forces/Trends

- Environmental consciousness
- Information technology
- Urbanisation
- Demographic change
- Media/Image
- Increased Comfort Requirements
- Environmental Directives, Codes

Impacts

- Information technology
    - New types of buildings
    - Control systems/Managements
    - Design process
- Urbanisation
    - Large buildings
    - Focus on light, ventilation, air, electricity
    - Urban planning/microclimate
    - Holistic approach
    - Combined Systems
    - Mixed use of buildings
- Environmental climate
    - Need for data, definitions
    - Desire for visible solutions
- Environmental directives/Codes

  - Building products, materials
  - Reduced energy use
  - Technologies
- Environmental consciousness
  - Change of attitude
- Demographic change
  - Different types of buildings
  - Different load approach

Opportunities

- Holistic approach
- Data, indicators, criteria, targets
- Systems, components
- Multifunctional facades
- Urban environment – building
- Building or beyond
- Building as other service suppliers
- Ventilation
- Demonstrating energy supplying buildings (communities)

R & D needs

1. **Title**
   Urban environment / building interaction

   Brief description
   Gain knowledge of how the urban environment influences the individual building's energy performance and comfort and vica versa (pollution, noise, wind, heat, light, other buildings and so on)

   Broad objectives
   Improve energy performance and comfort at an urban scale

   Expected outcome
   Planning tool to optimise more than one building for energy performance and comfort

2. **Title**
   Buildings as other service suppliers

   Brief description
   - Establish the potential of building (surfaces) for supplying other services (desalination, fuel for cars, crop drying, grey water purification, clean air ...)
   - Identify and develop the most suitable concepts

   Broad objectives
   Extend the building functionality

   Expected outcome
   New concepts

3. **Title**
   Optimal ventilation

   Brief description
   To establish optimal ventilation as a function of building use construction and materials and energy use (demand control, pollution control, efficiency….)

   Broad objectives
   To reduce energy use for ventilation
   Expected outcome
   Guidelines

4. **Title**
   Energy supplying buildings (communities?)

   Brief description
   – Develop concepts/integrated design of energy conversion systems in buildings
   – Build and show

   Broad objectives
   To demonstrate the potential of energy supplying buildings

   Expected outcome
   Demonstration buildings

Rapporteurs report - Existing buildings

Session leader
Hugo Hens, Belgium

Rapporteur
Mark Zimmermann, Switzerland

Introduction

Eight people participated in the Existing buildings group. One presentation about the importance of thermal retrofit in existing buildings were first presented before the brainstorming and discussions started. The result of the discussions is shortly presented below.

Marked forces in industrialised countries

Present

- Low energy prices
- Environmental consciousness
- Habits and status
- Traffic problems (densely populated areas)
- Increased number of households
- Governmental incentives and interventions

Within 20 – 25 years

- Increasing energy prices
- Increasing environmental costs
- Habits and status
- Safety issues
- Traffic problems (densely populated areas)
- Stabilizing number of households??

General trends and impacts

Trends

- Increasing individuality
- Increased wealth and consumption
- Aging population
- Globalization
- More frequent climate extremes
- Increased use of information technology
- Pollution?

Impacts

- Increased floor space demands

Building trends and impacts

- Availability of abandoned industrial space
- Company ownership of residential developments
- Population mobility
- Shorter service lifes of appliances

R & D Needs

The Existing group discussed the following 17 project proposals. Many of these proposals has strong connections to each other which entails that a broader program concerning existing buildings would be more appropriate than several single projects.

1. **Title**
   Decision criteria for retrofit versus new construction

   Brief description
   To establish decision criteria for retrofit versus new construction. A holistic approach (financial, life style, building condition, location and so on)

2. **Title**
   Factor x in renovation

   Brief description
   Today there is no knowledge about which factor x that is achievable in renovation and project will establish such knowledge. (concepts, performance requirements, demonstration). Factor x is explained as x times less than a reference (for example, for residential buildings, the average energy consumption / environmental load of the actual building stock).

3. **Title**
   Impact of neighborhood integration on the factor x

   Brief description
   To establish the impact of neighborhood integration (clustering) has on the factor x.

4. **Title**
   Assessment methodologies and tools applied to retrofitting

   Brief description
   Assessment methods and tools are more or less developed for existing buildings and to some extent for new buildings. No one is developed for retrofitting (life cycle, indoor climate, micro-environment, present value). This project will evaluate assessment methodologies and tools with the intention to develop the framework for a method applied for retrofitting.

5. **Title**
Innovative lighting technologies for existing buildings

Brief description
The potential for reducing electricity in the building sector is large due to use of new lighting technology in existing buildings.

6. **Title**
Roof integrated solar collectors for heritage buildings

Brief description
Solar collectors are today mostly adjusted to more modern buildings than for heritage buildings. The architectural expression are often not particular successful because of irregular roof shapes and materials, and can be a obstruction to install such solar collectors. The project will be to develop better roof integrated solar collectors for heritage buildings.

7. **Title**
Transforming existing facades into intelligent facades

Brief description
Intelligent facades, as indoor climate control, ventilation and energy production, is to some extent or at least under development. Such systems are until today directed to facades I new buildings. This project will evaluate the possibility to transform also existing facades into such intelligent facades.

8. **Title**
Ground coupled combined heating and cooling for existing buildings (heat pump technology)

Brief description

9. **Title**
Integrated information and control technology for energy efficiency in existing buildings

Brief description
More energy conscious users of buildings will reduce energy consumption both for heating, lighting and equipment significantly. Such consciousness can be obtained among other things through energy information systems integrated with control technology for energy efficiency.

10. **Title**
Energy efficient plug and play systems for retrofit

Brief description
To obtain energy efficiency in existing buildings major obstructions are often high costs and difficult logistic because several crafts are needed for small operations. If energy efficient systems were more of the "plug and play type" that reduced both costs and not at

least simplified the logistic such systems would probably be a success. The consequences wc ıld both reduced energy consumption in existing buildings and new products.

11. **Title**
Reference consumption and indoor climate data for existing buildings;

Brief description
As a basis for several other proposals on existing buildings reference consumption and indoor climate are important factors to know. The project will collect information about the reference consumption and indoor climate mainly based on statistical data from measureme ıts in different countries and climates but also to some extent on theoretical calculations.

12. **Title**
Urban energy consumption in comparison to suburban situations

Brief description
Gain knowledge of how the urban environment influences the individual building's energy performance in comparison to suburban situations.

13. **Title**
Instruments for analyzing, promoting and carrying out the renovation process

Brief description

14. **Title**
Proper usage of advanced envelope insulation for retrofit

Brief description
Adapt advanced envelope insulation to retrofitting projects.

15. **Title**
Integrated mechanical systems in existing buildings (heating-ventilation-heat recovery-hot water-electricity production);

16. **Title**
Conversion of existing high temperature to low temperature-heating systems in retrofitted buildings

Brief description
Converting of existing high temperature heating systems (radiators and floor heating) into low temperature heating systems in existing buildings is an important task to obtain more sustainable heating systems.

17. **Title**
Using mixed hydrogen-natural gas heating systems in existing buildings?

Rapporteurs report - Energy systems

Session leader
Fred Morse, USA

Rapporteur:
Malcome Orme, United Kingdom

Marked trends

- Customer choice / higher standards
- Environmental concerns
- Climate change
- Supply security
- Propaganda
- Fossil fuel resources, policies and prices

Trends

- Information technology
- More electrical equipment
- More electricity use (as preferred energy source)
- Decentralized energy technology
- Sustainable materials
- Greater use of renewable energy
- More efficient use of energy in buildings
- Facilities management
- Increased mobility

Impacts

- Buildings versus communities as energy systems
  e.g. Factor 10 reduction may lead to conflict with district heating infrastructure
- Energy storage requirements
  - centralized
  - decentralized
- Building energy management systems, optimized for:
  - profit
  - energy reduction
  - CO_2 reduction
- Load management by energy utilities (enabled by IT)
- More electrical equipment

- Increased efficiency of electrical equipment
- Possible conflict between energy and aesthetics for historic buildings

Opportunities

- Major renovations enable improvements of building and community energy systems
- Residential and work environments more integrated
- Greater availability and use of "green materials"
- Lower (higher) temperature, more cost effective, greater use of renewables and storage in district heating (cooling) systems
- Energy storage - central versus distributed
- Energy system optimization - coherence between different scales (e.g. improved power plant efficiency versus local fuel cells)
- "Plug and play" integrated comfort and service systems
- Adaptive, flexible buildings with changeable energy systems
- Larger international market for new energy technologies (speeds up technology learning)

R & D Needs High Priorities

1. **Title**
   Low Temperature Systems Analysis and Product Development

   Brief description
   To consider the use of heating / cooling at lower DT, and to take advantage of lower quality sources of energy or lower loads. (ECBCS Annex 37 possibly already covers this.)

2. **Title**
   Integrated Comfort and Service "Plug and Play" Systems

   Brief description
   To investigate optimal structural and systems integration of energy conversion technologies (e.g. integrated low-cost PV modules, solar water heating, conventional and reversible fuel cells, heat pumps, energy storage)

3. **Title**
   Comprehensive Building Sector Energy Systems Analysis

   Brief description
   On account of recent market deregulation and other factors, investigate coherence between energy systems at different scales, including methodologies to resolve conflicts and to find synergies between different levels (for buildings, communities, and national power systems)

4. **Title**
   Market Entry Strategy

Brief description
To identify niche markets by mapping high-value applications in buildings for new technologies

R & D Needs - Medium priority

- **Product Development**
  To develop low temperature heating systems for all buildings types (e.g. low temperature radiators for residential buildings) (to replace direct electric space heating, common in Norway and Sweden)
- **Load management**
  To evaluate the potential of peak load reduction by influencing behavior using information technology and feedback mechanisms.
- **Utilization of Waste Heat**
  A comprehensive review of opportunities to use waste heat for a variety of building applications, e.g. waste heat from offices used in nearby residences; waste heat from IT equipment in dedicated internet server buildings.
- **Analysis of District Heating Systems**
  To study measures to avoid oversizing in district heating and cooling system components, e.g. energy storage.

R & D Needs - Low priority

- **Advanced Air Conditioning**
  To deal with separation of latent and sensible cooling in buildings, especially in large buildings
- **Design Competition**
  A design competition covering heating, ventilation, air conditioning, and energy storage, based on optimal integration of energy systems with building design
- **Product Development for Room**
  Sized Energy Systems - to develop heating, ventilation with heat recovery, cooling units for local room conditioning in highly insulated buildings (e.g. packaged units or other local controls)