Sustainable Habitat and Energy Efficiency

François Creuzet

Conférence Coriolis
École Polytechnique
February 16, 2015
OUTLINE

- Saint-Gobain today
- Buildings and energy efficiency
  - What is at stake
  - Innovation in the building envelope – few examples
- Sustainable Habitat
  - Saint-Gobain Multi-Comfort program
1. Saint-Gobain today
Saint-Gobain: an ancient company

1665: Versailles: Louis XIV
SAINT-GOBAIN: A QUICK OVERVIEW

1665 - 2015

1665
Creation of the Manufacture royale des glaces

1688
Invention of glass table casting

1850
Saint-Gobain expands in Europe: Germany, Italy, Belgium and Spain

1900
Saint-Gobain diversifies into new markets and new products

1950
Merger between Pont-à-Mousson and Saint-Gobain. Ongoing internationalization

1970
Refocus on materials with a high technology content and entry into building distribution and plasterboard

1990
Saint-Gobain focuses its strategy on habitat

2007
Saint-Gobain celebrates its 350th anniversary

2015

Saint-Gobain: A QUICK OVERVIEW

1665 - 2015

1665
Creation of the Manufacture royale des glaces

1688
Invention of glass table casting

1850
Saint-Gobain expands in Europe: Germany, Italy, Belgium and Spain

1900
Saint-Gobain diversifies into new markets and new products

1950
Merger between Pont-à-Mousson and Saint-Gobain. Ongoing internationalization

1970
Refocus on materials with a high technology content and entry into building distribution and plasterboard

1990
Saint-Gobain focuses its strategy on habitat

2007
Saint-Gobain celebrates its 350th anniversary

2015

SAINT-GOBAIN RECHERCHE - Disclosure or reproduction without prior written permission of Saint-Gobain Recherche is prohibited
SAINT-GOBAIN, ONE OF THE WORLD’S TOP 100 LEADING INDUSTRIAL CORPORATIONS

2013

<table>
<thead>
<tr>
<th>Category</th>
<th>€ bn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>42.0</td>
</tr>
<tr>
<td>Recurring net income</td>
<td>1.0</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>1.4</td>
</tr>
<tr>
<td>Free cash flow</td>
<td>1.2</td>
</tr>
</tbody>
</table>

SALES
€42.025 bn

Operations in
64 COUNTRIES

Nearly
190,000 EMPLOYEES
AN INCREASINGLY INTERNATIONAL COMPANY

Operations in 64 countries with nearly 190,000 employees

Saint-Gobain in 1904
Saint-Gobain in 1980
Saint-Gobain in 2014
World leader in the habitat and construction market, Saint-Gobain designs, manufactures and distributes building and high-performance materials providing innovative solutions to today’s critical challenges of growth, energy efficiency and environmental protection.

THE reference for sustainable habitat
DEFINITION IN REFERENCE TO A MARKET: HABITAT

Four end-markets

Habitat: about 80 percent of our markets

A product logic  A market logic
SAINT-GOBAIN, ONE OF THE 100 MOST INNOVATING COMPANIES IN THE WORLD

- **7 Main R&D centers**
- **3,700 employees**
- **8 major strategic projects in:**
  - Lighting
  - Fuel cells
  - Intelligent glass
  - Lighting
  - High performance insulation systems
  - External wall insulation systems
  - Functional flexible substrate
  - Energy efficiency and environmental impact of processes
  - Energy storage

- **Nearly 400 patents filed in 2013**
- **1 in 4 Saint-Gobain products sold today was developed in the last five years**
- **12 Research centers and about 100 development units worldwide**

R&D open to the outside world:
- Partnerships with start-ups: NOVA External Venturing
- University partnerships
THE ORGANIZATION OF THE SAINT-GOBAIN GROUP

Compagnie de Saint-Gobain

Finance, R&D
Human Resources
Legal/Fiscal
Communications
Marketing

13 General Delegations

Innovative Materials
Construction Products
Building Distribution
Packaging Verallia

About 50 Activities
More than 1,000 consolidated companies
SAINT-GOBAIN SECTORS

Innovative Materials
- Flat Glass
  • No. 1 in Europe
  • No. 2 worldwide
  • Operations in 42 countries
  • Over 32,000 employees

- High-Performance Materials
  • No. 1 worldwide
  • Operations in 42 countries
  • More than 26,000 employees

Construction Products
- No. 1 worldwide
  in ductile cast iron pipe
- No. 1 worldwide
  in plasterboard and plaster
- No. 1 worldwide
  in insulation
- No. 1 in Europe
  for wall facings
- No. 1 worldwide
  for tile adhesives
- No. 2 in the United States
  in siding products
- Manufacturing operations in 55 countries
- Nearly 47,000 employees

Building Distribution
- No. 1 in Europe
  building materials distribution network
- No. 1 in Europe
  in plumbing, heating and sanitaryware products
- Operations in 27 countries
- Over 64,000 employees

Packaging Verallia
- No. 2 worldwide
  bottles and jars
- Operations in 14 countries
- Over 14,000 employees

21% of 2013 consolidated net sales

25% of 2013 consolidated net sales

45% of 2013 consolidated net sales

9% of 2013 consolidated net sales
Innovative Materials/Flat Glass

- **N°1 in Europe, N°2 worldwide**
- The Flat Glass Division manufactures, processes and sells glass products for two main markets: the building and the transportation industries.
  - **Saint-Gobain Glass**: primary glass production
  - **Saint-Gobain Sekurit**: transformation for the automotive and transportation industries
  - **Glassolutions**: transformation and distribution for the building industry and household appliances

Innovative Materials/High-Performance Materials

- **Worldwide leader in each of its businesses:**
  - Ceramic Materials
  - Performance Plastics
  - Saint-Gobain Technical Fabrics
  - Abrasives

2013 sales: 5.0 billion euros
Over 32,000 employees
Operations in 42 countries

A wide range of high-tech and high-performance products which are often co-developed

2013 sales: 4.0 billion euros
Over 26,000 employees
Operations in 42 pays
Construction Products

- **No. 1 worldwide** in ductile cast iron pipe
- **No. 1 worldwide** in plasterboard and plaster
- **No. 1 in Europe** in insulation
- **No. 1 in Europe** for facades renders
- **No. 1 worldwide** for tile adhesives
- **No. 2 in the United States** in siding products

The Construction Products Sector offers interior and exterior solutions for all types of buildings:

- Acoustic and thermal insulation
- Gypsum
- Exterior products
- Industrial mortars
- Piping

2013 sales: 11.5 billion euros
Nearly 47,000 employees
Manufacturing operations in 55 countries
Building Distribution

No. 1 in Europe in building materials distribution network

No. 1 in Europe in plumbing, heating and sanitaryware products

The Building Distribution Sector serves the newbuild, renovation and habitat markets.

- A local activity with a network of nearly 4,400 sales outlets
- A dedicated market approach: generalist and specialist brands serving professionals and private project owners with a DIY project
- 200 million face-to-face customer contacts per year

2013 sales: 18.8 billion euros
Over 64,000 employees
Operations in 27 countries
Packaging

- **World leader** in wine and spirits bottles as well as food jars
- **No. 2 worldwide** in glass packaging for the food industry
- 24 billion **bottles and jars produced in 2013**
- 10 **R&D centers worldwide**

2013 sales: 3.6 billion euros
14,000 employees
Operations in 14 countries
2. Buildings and Energy Efficiency
ENERGY SPENDINGS IN EUROPE

Millions Tonnes équivalent pétrole

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td>42%</td>
</tr>
<tr>
<td>Transport</td>
<td>28%</td>
</tr>
<tr>
<td>Industrie</td>
<td>32%</td>
</tr>
</tbody>
</table>
BUILDINGS ENERGY CONSUMPTION

kWhep/m²/an
<table>
<thead>
<tr>
<th>Year</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT 2012</td>
<td>&lt; 50 kWhep/m²/yr</td>
</tr>
<tr>
<td>2018</td>
<td>All new public buildings are nZEB’s</td>
</tr>
<tr>
<td>2020</td>
<td>All new buildings are nZEB’s</td>
</tr>
<tr>
<td>2050</td>
<td>All buildings are nZEB’s</td>
</tr>
</tbody>
</table>
RENOVATION IS THE CRITICAL CHALLENGE IN DEVELOPED COUNTRIES

Specific heating demand in Germany (source: DGS)
ENERGY EFFICIENCY: SAINT-GOBAIN PRODUCTS OFFER

Products and Systems for thermal performance

- Glazing (glass and frame)
- Opaque structure
- Insulation
- Air tightness
- Thermal bridges suppression

Solutions to control and take advantage of solar radiation

- Coated glass for solar control
- PhotoVoltaic integration
PRODUCTS AND SYSTEMS FOR THE BUILDING ENVELOPE: MULTI-MATERIALS AND MULTI-BRANDS
INNOVATIVE GLAZING: COATED GLASS (STACK OF ULTRA-THIN TRANSPARENT LAYERS INCL. SILVER)
LOW-E GLAZING REFLECTING HEAT BACK INTO THE ROOM
INNOVATIVE GLAZING: SOLAR GAINS

Triple Glazing is a better performer than a wall

- Solar gains compensate for the difference in thermal insulation
- Having more glazing is favorable!

<table>
<thead>
<tr>
<th>Solar Gains</th>
<th>South</th>
<th>East/West</th>
<th>North</th>
<th>Energy Balance kWh/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+115</td>
<td>+69</td>
<td>+49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 56</td>
<td>- 56</td>
<td>- 56</td>
<td></td>
</tr>
<tr>
<td>Thermal Insulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Balance kWh/m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ 59</td>
<td>+13</td>
<td>- 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Triple glazing with SGG PLANITHERM MAX Ug = 0.6 et g = 0.60 (Salzburg)

House in Vienna

Heat needs 11 kWh/m²a

Heat needs 6 kWh/m²a

Wall: U=0.12W/m²K
HIGH PERFORMANCE INSULATING SYSTEMS

Conductivity vs. Price for 1m² / R=1
NEW EXTERNAL INSULATION SYSTEMS

ETICS
- TWINNER: EPS+SW (CZ, 2011)
- Insulating mortar
- Capp8 G3 l36: Dense GW with thin render (IT, 2012)

Ventilated Façade
- F4 (FR, 2011)
- ISOVER Plus (DK, 2011)
- MULTIMAX l30 R=5 (PL, 2012)
- RKL 100mm (GW λ.31 + glass veil A2) (FI, 2011)
- Ventisol Weber

Cavity walls
- MULTIMAX l30 R=5 (NL, 2012)
- RKL (GW λ.31 associated with a bricks finish): (UK, 2011)
Window film is installed on a glazing system and adds functionality

- Solar control window film
  - Minimize solar heat gain
  - UV blocking
  - While keeping visible light

- Safety window film
  - Avoid flying glass shards in case of earthquake, accidental breakage, etc.
ARCHITECTURAL APPLICATIONS OF WINDOW FILMS

BENEFITS (ENERGY)

Energy savings

- Reduces energy consumption by
  - rejecting up to ~80% of solar energy in summer
  - reducing heat losses in winter
- Decreases energy costs up to 30%

Reduces carbon footprint

- Our architectural solar control window films reduce GHG emissions by 10 – 40% in commercial buildings
Typical solar control window film construction

- Laminate of optically clear PET films
- Functionalization through thin film – or wet coating technology
- Mounting adhesives
  - Acrylic PSA
  - Polyester CDA
  - UV absorbers
- Laminating adhesive
- UV curable acrylic hard coat

Core technologies
Roll to roll sputtering
- Wide web
- Metals, oxides
Coating and lamination
- Wide web
- High precision
- Ultra clear
The Canadian well is a geothermal solution which provides heated air in winter and cooled air in summer.

- Passive, although coupled to a mechanical ventilation system

ELIXAIR is a complete solution

- Reduction of energy spendings
- Natural thermal regulation
  - Summer Comfort without air conditioning
  - Frost protection in winter
- Indoor air quality
PLANNING RENOVATION FOR ENERGY EFFICIENCY
SG QUICK U-VALUE OF BUILDINGS

- Thermal performance measurements are difficult
  (DPE in France; two weeks of co-heating measurement in UK)

⇒ Need of a quick and accurate method for intrinsic performance measurement: SG QUB

- QUB is a quick dynamical measurement to assess the insulation level

Evolution scheme of temperature and power

Day 1  Sunset  Day 2  Sunset
THE U. SALFORD EXPERIMENT

- QUB comparison with static measure in a full-scale climate chamber
- House retrofitted by stage
- Good agreement whatever is the insulation level
3. Sustainable Habitat
THIS IS NOT SUSTAINABLE

Source: WWF Living planet report - 2013
BUILDINGS AT THE HEART OF THE ISSUE

ENVIRONMENTAL IMPACTS

- 25-40% of all energy use
- 25-40% of solid waste generation
- 30-40% of greenhouse gas emissions
- 20% of all water consumption
BUILDINGS AT THE HEART OF THE ISSUE

SOCIAL IMPACTS

We spend up to **90%** of our time indoors—living, working, learning and playing.

Children’s learning abilities **increase 15%** if they are in a good indoor climate.
ECONOMICAL IMPACTS

Housing costs represent 15-30% of a European household’s budget.

In the USA, annual costs of building-related sickness are estimated at almost $60bn.
TOWARDS MORE SUSTAINABLE BUILDINGS

THE THREE DIMENSIONS OF SUSTAINABLE HABITAT

ENVIRONMENTAL
- Reduced environmental impact, pollution and generation of waste
- Efficient use of natural resources & energy

SOCIAL
- Human well being
- Health, comfort and safety

ECONOMIC
- Decreased operating costs, secured investments and increased property value
- Better productivity and reduced health costs
TOWARDS MORE SUSTAINABLE BUILDINGS: LIFE CYCLE ANALYSIS

- Product
  - Raw material supply
  - Transportation
  - Manufacturing

- Construction
  - Distribution
  - Transportation
  - Construction (new and renovation)
  - Installation

- Use
  - Use of products installed
  - Maintenance
  - Repair, replacement, refurbishment
  - Building’s operational use

- End of life
  - Deconstruction, demolition
  - Transportation
  - Reuse, recycling or disposal as waste
INVENTING TOMORROW’S SOLUTIONS WITH OUR ECO-INNOVATION POLICY
HABITAT TODAY: FOUR MAJOR CHALLENGES

Energy Efficiency

- Energy cost increase
- Raw material dependency
- Thermal regulation tightening
- Lighting efficiency

Environment

- Global warming
- Chemicals exposure
- Natural resources preservation
- Waste management

Comfort & Aesthetics

- Comfort, health & safety
- Home automation
- Image, fashion & customization
- Local/specific traditions

Growth

- Time constraints
- Renovation in developed countries
- Urban needs in emerging countries
- Senior care
ENVIRONMENT e.g.
ENERGY CONSUMPTION OF GLASS FURNACES

- Thermal losses: 36%
- Fumes losses: 20%
- Glass melting: 44%

![Graph showing energy consumption of glass furnaces over time](image-url)
Promouvoir l’économie circulaire
Saint-Gobain a conscience des enjeux associés aux déchets générés par le secteur de la construction et a d’ores et déjà mis en place des projets de valorisation des déchets de construction ou de démolition.
Nous estimons que l’utilisation efficace des ressources doit être une priorité et que les déchets, notamment les déchets de chantier, doivent être considérés comme des ressources stratégiques et devenir des matières premières secondaires pour nos produits.
Il est donc nécessaire de sortir du schéma linéaire classique de production pour aller vers un modèle d’économie circulaire visant à la valorisation de tous les déchets et à l’élimination de la mise en décharge.

Rapport de responsabilité sociale d’entreprise 2013, page 31
MULTI-COMFORT IMAGINES BUILDINGS FROM AN OCCUPANT’S PERSPECTIVE

- Energy efficient
- Accessible
- Safe
- Durable
- Affordable
- Easy to run and maintain
- Adaptable to all local climates
THE PROGRAM LAUNCHED TO...

... demonstrate that Saint-Gobain through its brands provides an unrivaled offer answering today, current & future multiple comfort needs in accessible, sustainable way.

- The creation of Saint-Gobain high performance, «real-life» *reference* buildings across the world
- A *communications tool* to explain and promote our offer in the marketplace
- A way of *learning and experimenting* to drive the development of new products, solutions and services
- An opportunity to develop *3rd party partnerships*
MULTI-COMFORT RELATES THE DESIGN OF LIVING OR WORKING ENVIRONMENTS TO OUR HUMAN SENSES

**Hearing**
- Noise
- Acoustics
  - Airborne sound insulation
  - Impact sound insulation
  - Reverberation

**Vision**
- Design
- Colors
- Light
  - Day lighting
  - Glare
  - Luminance

**Touch**
- Temperature
- Texture
  - Thermal insulation
  - Airtightness
  - Summer comfort

**Thinking**
- Social
- Responsibility
- Maintenance
  - Energy consumption
  - Carbon footprint
  - Running costs

**Smell**
- Air quality
- Clean and dry
  - Fresh air supply
  - Moisture management
  - CO₂ & VOC levels
VALUE OF COMFORT?
‘PRODUCTIVITY’ GAINS IN NON-RESIDENTIAL BUILDINGS...

Offices, schools, hospitals
... are built for a purpose
WELL BEING IS OF INCREASING IMPORTANCE TO OWNERS AND TENANTS

Influence of room temperature on productivity

Source: Seppänen
WELLBEING MATTERS!
VISUAL COMFORT: A TRADE-OFF

- Daylighting
  - Aesthetic quality
  - View
  - Well-being & Health
  - Non visual effects (sleep / wake regulation, alertness, mood)

- Glare
...BUT ALSO A KEY ELEMENT TO HUMAN WELFARE

Healthcare buildings
- Shorter average length of patient stay
- Quicker post-operative recovery
- Reduction in the use of pain-relief medication
- Treatment of depressive illness

Schools
- Better learning capacities
- Higher score results
- Increased attendance rates

Offices
- Strong worker preference
- Positive impact on mood and job satisfaction
- Reduction of stress

In hospitals, daylighting quickens recovery.
In schools, natural light improves attendance rates and exams scores.
Workers feel more efficient in offices with natural lighting, windows and views.
NON-VISUAL EFFECTS OF LIGHT

- New light sensitive cells (related to the circadian cycle) have been identified in the eye about ten years ago.
- They are responsible of the Non-Visual Effects, which impact on biological functions such as:
  - Sleep/wake regulation
  - Alertness
  - Mood …
SAINT-GOBAIN SOLUTIONS FOR VISUAL COMFORT

Our solutions can influence visual comfort by several aspects

- Transparent products allow access to daylight and the view
- Translucent products allow daylight while avoiding glare and preserving privacy
- Active products can provide glare or privacy management
- Bright interior opaque products (wall, ceiling, floor) contribute to the visual impression of spaces and daylight quantity
- Lighting products can be excellent complementary light sources

Our solutions must be combined with good architectural practices
DIALIGHTING : BACK TO ENERGY EFFICIENCY

Energy efficiency is also a driver for natural lighting in buildings:

- Lighting
- Passive heating
COMFORT: INDOOR AIR QUALITY

- Scavengers in the core of plasterboard to reduce formaldehyde to inert compounds
ACOUSTIC COMFORT

Absence of unwanted sound

Ability to generate sounds without bothering other people

Right level and quality of desired sounds

Sound insulation

Reducing noise transmitted between two rooms

Room Acoustic

Enhancing acoustic Properties of rooms
ACOUSTIC COMFORT

Flexible workplaces and open space offices
Minimise disturbance and facilitate communication
Increasing flexibility and efficiency
Improves performance, health and wellbeing

*Studies show that by optimising the sound environment for both communication and concentration, the company gets more profitable*

New teaching methods creates acoustical challenges
Giving every child the best conditions for learning and for personal development
Increasing knowledge and wellbeing

*Studies show that students’ results for reading and learning correlate directly to background noise levels*

Acoustic solutions that do not compromise with hygiene requirements
A better quality of care

- Lowering blood pressure
- Improving quality of sleep
- Reducing intake of pain medication
- Lowering the amount of readmissions
- Improving wellbeing among staff and increased perceived performance

*Studies show that the sound environment affects the outcome of medical care*
MULTI-COMFORT: REFERENCE BUILDINGS, AHEAD OF LOCAL REGULATIONS

WITH PROVEN (MEASURED & DOCUMENTED) PERFORMANCE

- Thermal comfort
- Visual and day light comfort
- Indoor air comfort
- Acoustic comfort
- Mobility comfort
- Installer & maintenance comfort

→ All in an energy efficient, sustainable and affordable way

Multi-Comfort program

= “Good examples” of buildings
(not a brand, a label, or a standard)
A NET ZERO ENERGY AFFORDABLE AND COMFORTABLE HOME IS ACHIEVABLE WITH TODAY'S COMPONENTS

Beaucouzé, France
(June 2011)

BEPOS WITH ANY TYPE OF HEATING SYSTEM

509 m² field surface
162 m² living surface
260,000 €
1,500 €/m²
HOW CAN WE EVALUATE IMPACT OF OUR SOLUTIONS?
SLATINGTON ELEMENTARY SCHOOL RENOVATION EXAMPLE

Product Placement Details – 2nd Floor Area B
Blue Acoustics / Green Formaldehyde Scavenging

209
Symphony M
Mineral Bd
NRC 0.70

208
Symphony F
Fiberglass Bd
13% Scavenging
NRC 0.95

207
Symphony M
NRC 0.70
Mineral Bd

206
Symphony F
Fiberglass Bd
NRC 0.95

205
Symphony M
Mineral Bd
NRC 0.70

204
Symphony F
Fiberglass Bd
NRC 0.95
HOW CAN WE EVALUATE IMPACT OF OUR SOLUTIONS?

SLATINGTON ELEMENTARY SCHOOL RENOVATION

**Faculty Survey Results**
R. Fryer – Philadelphia University

The results show faculty observed significant improvements in every area except cooling.

**Comfort – Heating**
- Improvement: 66%
- No change or worse: 32%

**Comfort – Cooling**
- Improvement: 37%
- No change or worse: 63%

**Acoustics / Noise**
- Improvement: 69%
- No change or worse: 32%

**Indoor air quality**
- Improvement: 76%
- No change or worse: 24%

**Lighting levels**
- Improvement: 84%
- No change or worse: 16%

**Cleanliness**
- Improvement: 73%
- No change or worse: 27%

**Differences in observed student behavior:**
- Engagement up by 67%
- Trouble completing tasks down by 50%
- Noise complaints down by 88%
- Trouble seeing down by 67%
- Complaints of too hot or cold:
  - 33% say worse
  - 33% say the same
  - 33% say better
- Indoor allergies are reported as being the same, but outdoor allergies may be increasing
4.

More to come ...
SMART BUILDINGS

Dynamic, switchable windows
- Thermochromic, photochromics, …
- Under control switching
  - Clear/diffusive, electrochromic, …

New opaque envelope technologies
- e.g. Phase Change Materials

Solar Energy
- e.g. PV integration

Sensors, Connected Objects, IoT
ELECTROCHROMIC GLASS
A MORE INTEGRATED WHOLE-BUILDING APPROACH.

THE BUILDING PROCESS

- **S1**: Planning
- **S2**: Study
- **S3**: Design
- **S4**: Tender
- **S5**: Order
- **S6**: Delivery

- Authorities
- Legislation
- Standards
- Architects
- Designers
- Developers
- Engineers
- Components suppliers
- Builders
- Contractors
- Owners
- Users

From the first stages of the process:
- A shared performance target
- Building science

ESTIMATED PERFORMANCE ➔ MEASURED PERFORMANCE

SAINT-GOBAIN RECHERCHE - Disclosure or reproduction without prior written permission of Saint-Gobain Recherche is prohibited
DIGITALIZATION, PERFORMANCE EVALUATION AND COMFORT INDICATORS

- Building envelope performance evaluation
  - New constructions
  - Renovation (before & after)
- BIM, BAM, BOOM
  - Appropriate comfort modeling (interdependence of comforts)
  - Operations monitoring & maintenance (including comfort parameters)
- Responsive comfort management
  - Anticipating indoor & outdoor activity change
  - Comfort for each individually