



Energy Efficiency at Masdar City

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10 December 2017

1- Energy Efficiency Strategy at Masdar City

2- Buildings Design – Siemens HQ, Masdar City

3- Buildings Operation at Masdar City



1- Energy Efficiency Strategy in Masdar City



To Build one of the Worlds Most Sustainable City

Masdar City seeks to create a
commercially viable and **sustainable**
city providing a **good quality of life**
with the **lowest possible**
environmental footprint







- 6 square km of land area
- 3.7m square meters
- 52% residential
- 38% commercial
- 10% community and retail
- 50,000 residents
- 40,000 workers

1



2014

2



2016

3



2018

4



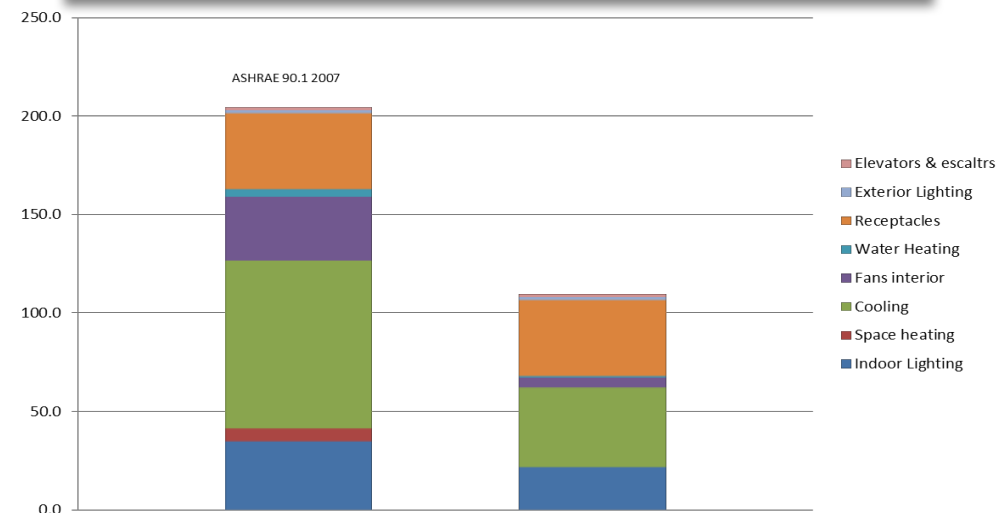
2020

- ✿ Trying to achieve low carbon at all cost without a **highly efficient demand-side** can be an expensive and wasteful undertaking
- ✿ **Pre-commissioning**: we ensure that the designers and contractors of our buildings, building systems and cooling plants implement state-of-the-art energy efficiency concepts and technologies
- ✿ **Post-commissioning**: we monitor & maintain the specified performance of buildings, building systems and cooling plants via continuous monitoring/control while inciting end-user to consume energy more efficiently
- ✿ Evaluation of technologies
- ✿ Developing energy design guidelines
- ✿ Assisting consultants & contactors
- ✿ Modeling and optimization
- ✿ Life cycle assessments
- ✿ Proper commissioning
- ✿ Hiring the right operator
- ✿ Energy management
- ✿ Enhancing operational efficiency
- ✿ Managing human behavior

| No. | Design Criteria | Mandatory Design Requirement | Reference Baseline / Remarks |
|-----|----------------------------------|--|---|
| 1 | Energy Consumption | <ul style="list-style-type: none"> 40% reduction from ASHRAE 90.1 : 2007 Compliance with Masdar Energy Design Guidelines 3.0 | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Improved Energy Performance. |
| 2 | Renewable Energy Provision | <ul style="list-style-type: none"> 75% of hot water heated by solar energy | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Renewable Energy. |
| 3 | Interior Water Use | <ul style="list-style-type: none"> 40% reduction of interior water demand | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Water Calculator. |
| 4 | Exterior Water Use - Landscaping | <ul style="list-style-type: none"> Average landscape irrigation demand to be less than 2 litres/m²/day. | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Water Calculator. |
| 5 | Construction Waste Management | <ul style="list-style-type: none"> Not less than 70% of demolition and construction waste (by weight or volume) to be recycled or salvaged. | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Improved Construction Waste Management. |
| 6 | Operation Waste Management | <ul style="list-style-type: none"> Not less than 60% of total operational waste (by weight or volume) to be diverted from landfills and incineration. This is reduced to 50% for Multi-Residential Buildings. | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Improved Operational Waste Management. |
| 7 | Embodied Carbon in Materials | <ul style="list-style-type: none"> 15% reduction in the overall construction for concrete structure buildings | <ul style="list-style-type: none"> 650 KgCO₂e/m² |
| 8 | Sustainability Rating System | <ul style="list-style-type: none"> Minimum 3 Pearl under Estidama Pearl Building Rating System. | <ul style="list-style-type: none"> Estidama Pearl Building Rating System. |
| 9 | Building Performance Monitoring | <ul style="list-style-type: none"> Design and implement monitoring strategy for major energy & water uses at building level & tenant level | <ul style="list-style-type: none"> Estidama Pearl Building Rating System Energy Monitoring & Reporting + Water Monitoring & Leak Detection |

- ✿ Designing buildings that use the minimum amount of energy without sacrificing occupant comfort and in the most cost effective way.
- ✿ MEDG provides minimum requirements for new buildings in Masdar in the following areas
 - ✿ Building Envelope
 - ✿ Heating, Ventilating, and Air Conditioning
 - ✿ Service Water Heating
 - ✿ Building Lighting Systems
 - ✿ Electric Power, Motors and Energy Management systems.
- ✿ The MEDG version 3 was developed internally in view of achieving city-wide energy efficiency KPI of 40% better than ASHRAE 90.1-2007.

- Shaded and passively cooled outdoor space
- Optimized Window-to-wall ratio
- Well insulated and airtight envelope
- High performance glazing
- External shading system
- High albedo roof coating
- High efficiency HVAC systems
- Properly sizing of MEP systems
- High effectiveness energy recovery systems
- Low lighting power density and advanced lighting controls.
- Advanced energy management system.
- Solar systems for electricity and hot water production

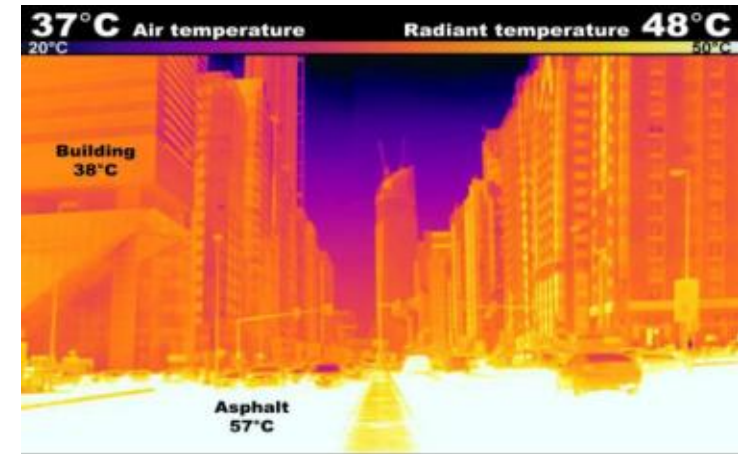




- ✿ High performance district cooling system:
 - ✿ Masdar utilizes multiple chiller plants distributed across the City that provide the highest efficiency available in district cooling anywhere the Middle East.
 - ✿ The plants are installed close to the cooling loads they serve and are connected with chilled water piping one quarter the size of conventional district cooling.
- ✿ Centralized 10 MW PV plant
- ✿ Decentralized PV systems
- ✿ Electrical cars and buses
- ✿ Solar powered LED street lighting
- ✿ Centralized energy monitoring system



- The city street grid are oriented on a northwest axis, to catch the prevailing wind and to provide some shading at the street level
- Narrow streets provide maximum shading on street level
- Creation of a walkable pedestrian environment
- Shading of public spaces using trees and artificial structures
- Using materials with high thermal mass in shaded surfaces
- Green parks separating built-up areas to capture and direct cool breezes into the heart of the city and to reduce solar gain
- Light colored paving materials to minimize the urban heat island effects
- Water features to provide evaporative cooling.
- Performing solar and wind simulations of the built form and exterior areas early in design



Compact City Based on
Traditional Design



City Design optimized to capture
passive measures



- Narrow streets enable buildings to shade other buildings
- Shading reduces cooling requirement and provides better outdoor comfort
- The orientation of the city and design of streets and buildings increase windflow

- ✿ Incorporate **goals** for energy efficient building operation
- ✿ **Train** building operators
- ✿ Perform **regular energy audits**, Collect and Analyze Data
- ✿ Obtain a clear, written set of **sequences of operation** and building control strategies
- ✿ **Adjust** energy systems operation based on demand
- ✿ **Track** actual performance against expected performance
- ✿ **Calibrate** sensors regularly
- ✿ **Share** results with occupants and operators

Most efficiently designed systems are horribly inefficient after several years of operation



2- Buildings Design – Siemens HQ, Masdar City



| | |
|---|---|
| Area (GFA) | 24,142 m ² (Including 1,001 m ² retail) |
| Total Building Efficiency (NIA/GFA) | 87% |
| Population | 1349 People |
| Population Density | 17.9 m ² /person |
| Energy Consumption | 109.5 KWH/m2/year |
| Energy Savings vs Abu Dhabi BAU | 67% |
| Energy Savings vs ASHRAE 90.1 2007 Baseline | 46.50% |
| International Certification | LEED Platinum and Estidama 3 pearls |



Estidama **PBRS**

&



Masdar **SKPI's**

&

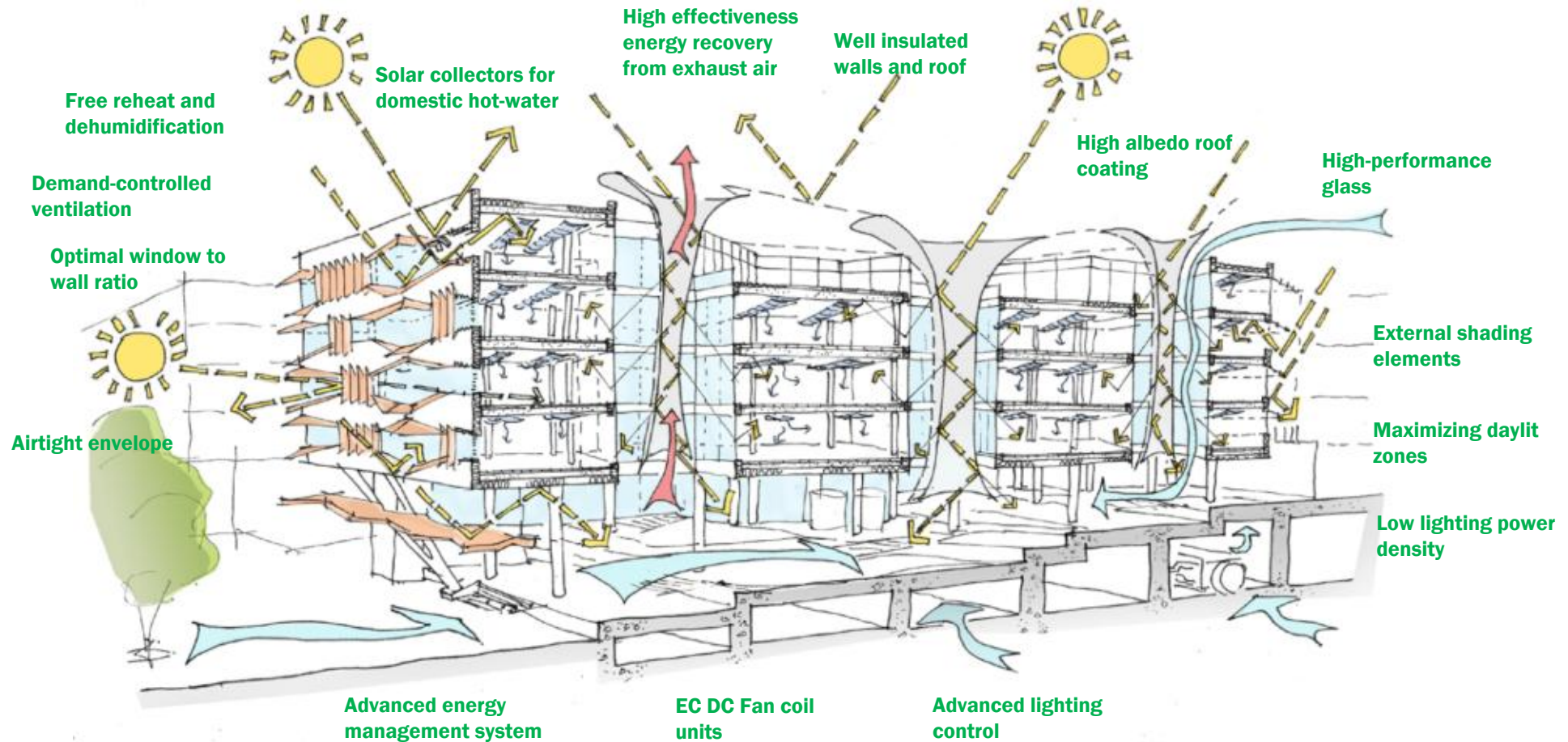


LEED **V3.0 CS**

The design process is driven by our desire for an outstanding, high performance building to maximize sustainable and commercial benefits.

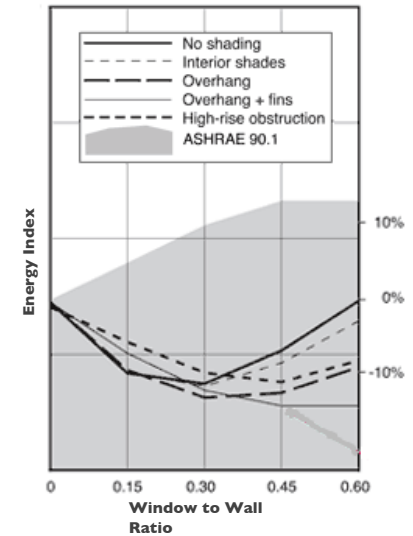
- Adopt passive design strategies where possible
- Optimize the efficiency of all systems incorporated within the design
- Use an appropriate level of technology to further enhance building performance
- Extensive energy modeling throughout all design stages
- Responding to Sustainable Design Rating Criteria to sensibly maximize results

Key Design Strategies

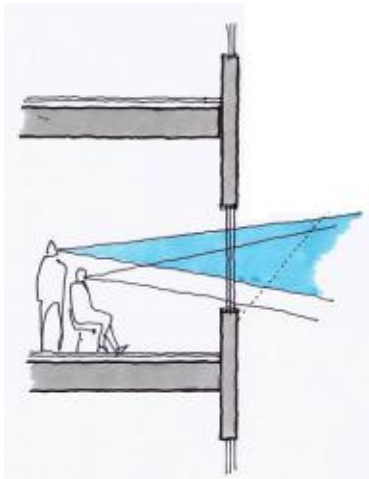


1- Window to wall ratio to minimize solar heat gain and maximize daylighting and views:

- Decrease window area and cooling energy use is decreased.
- Increase window area and lighting energy use is decreased.
- WWR between 25% and 40% is optimum.
- High, continuous windows are more effective than individual low windows to distribute light deeper into the space.



Source: Lawrence Berkeley national laboratory



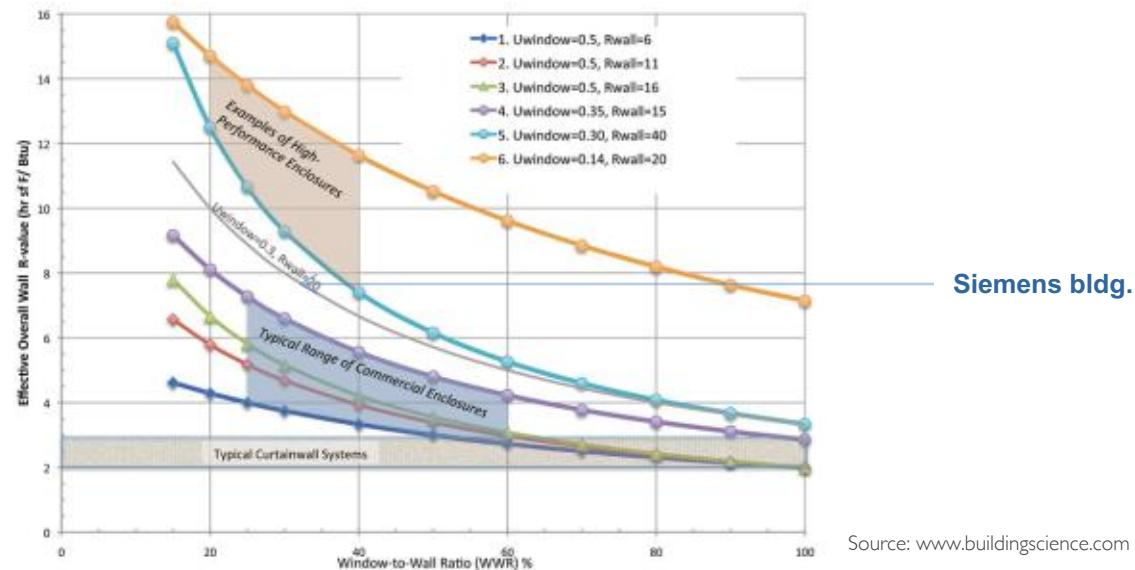
Energy performance? Cost? Views? Daylight?

Minimum energy use is achieved through a balance between Daylight transmission and Solar gain.



2- Low window U value to reduce heat transfer:

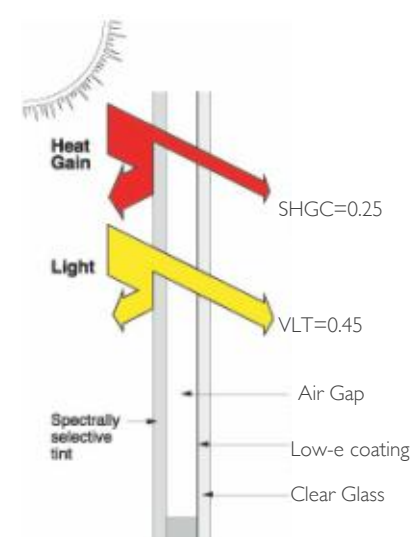
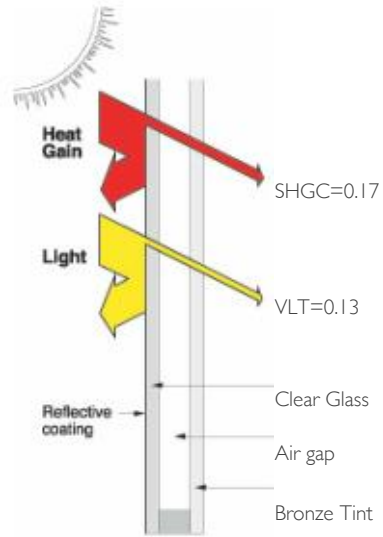
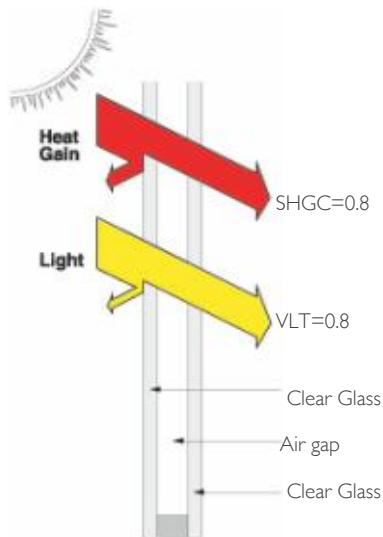
- No Curtain Wall: Aluminum framing short-circuit the insulation.
- No Triple Glazing: Triple glazing is costly.
- No Inert Gas: Inert gases between glass panes will potentially leak after few years.
- Fixed Windows: Operable windows have higher U value and infiltration rates.
- Larger windows have lower U values than smaller windows.



Source: www.buildingscience.com

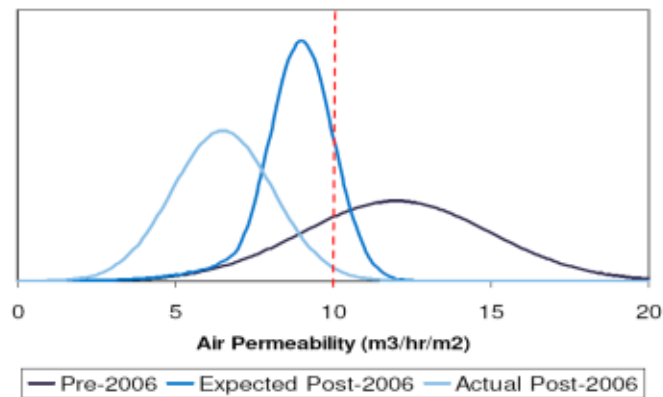
3- Balancing SHGC and VLT:

- SHGC is the fraction of solar radiation that hits the glazing that passes through the glazing and becomes heat inside the room.
- VLT is the percentage of visible light transmitted through the glazing.
- VLT/SHGC defines the performance and price of the glass.
- VLT higher than 50% increases Glare problems.
- Glass SHGC could be relaxed when external shades are used.



4- Improve Airtightness:

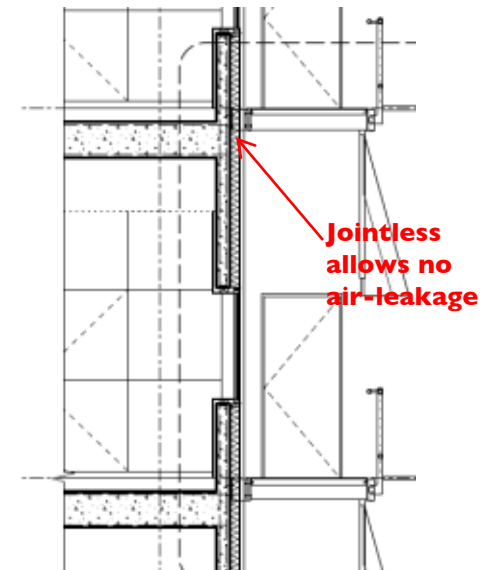
- Air-tightness target is 5.0 m³/hr.m² at 50 Pa.
- Airtight façade elements (façade, doors and windows) and continuous air barrier.
- The external wall construction to is an in-situ concrete upstand and downstand.
- Clear strategy from early design to construction.
- Well balanced air flows.
- Quality assurance (air leakage testing).



Source: <http://www.trada.co.uk/>

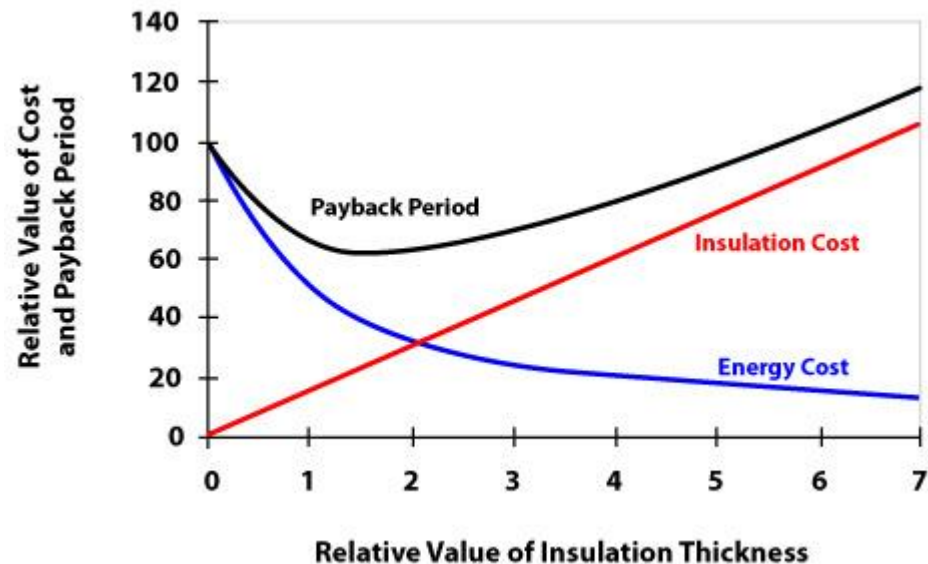
Problems due to air infiltration:

- Energy use
- Poor IAQ
- “Right-size” AC systems
- Water condensation



5- Wall and Roof Insulation:

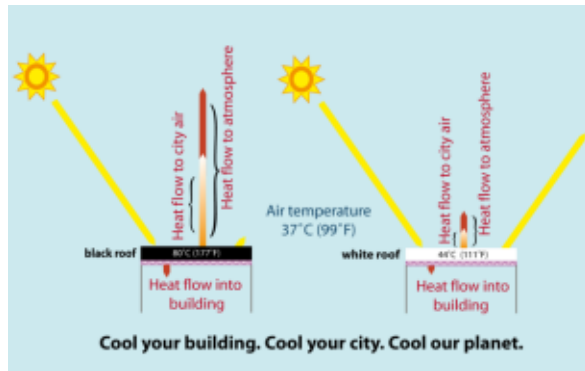
- Using EIFS (Exterior insulation finishing system) and rigid foam boards.
- Good performance with low cost.
- Simple to fix and easy to repair.
- Joint-less with no thermal weak points.
- Wall U value is $0.28 \text{ W/m}^2\cdot\text{K}$.
- Roof U value is $0.2 \text{ W/m}^2\cdot\text{K}$.



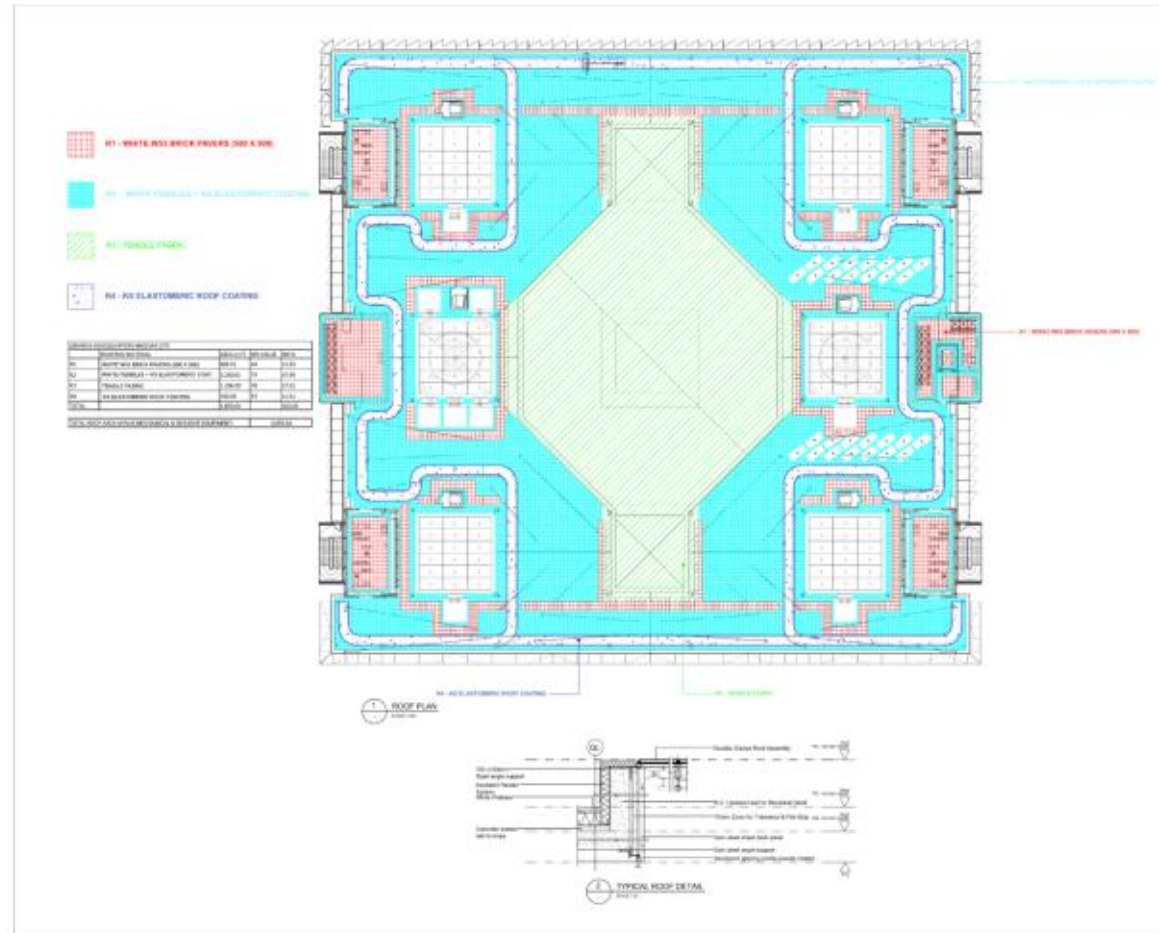
Source: US DOE, Variation in insulation cost, energy cost savings, and payback period

6- High Albedo Roof Coating:

- Roof SRI is above 78.
- Minimum maintenance compared to green roof.

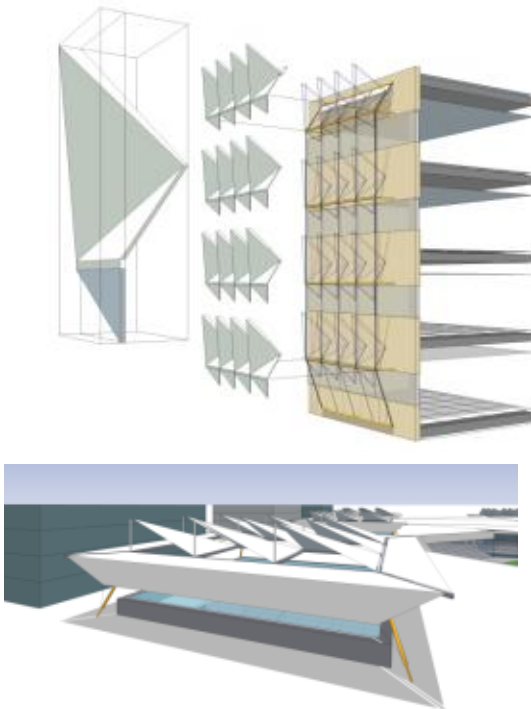


Source: Lawrence Berkeley national laboratory



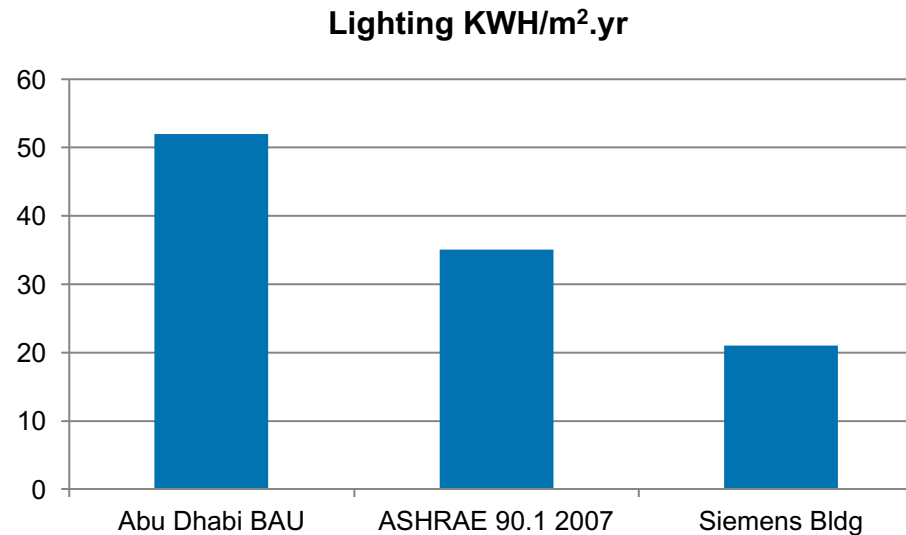
7- External Shading:

- Optimized for each orientation. It aims to provide maximum shading whilst maintain the highest levels of indirect daylighting and offer maximum views out.
- Reaching almost 100% shading of all glazed areas.



8- Advanced Lighting System:

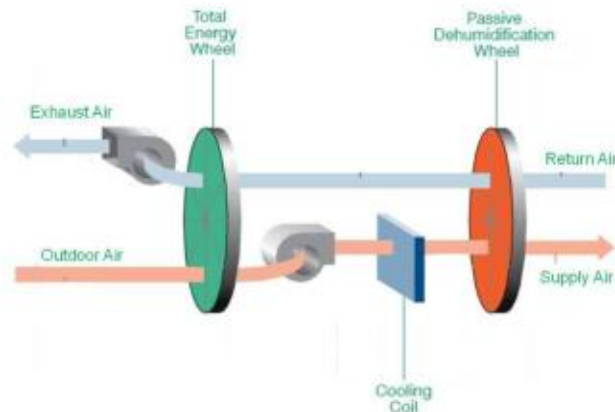
- Use high efficiency luminaires to minimize lighting power density.
- Daylighting control in perimeter zones.
- Lighting control based on occupancy.



8- Advanced Mechanical System:

- EC DC Fan coil units.
- Energy recovery wheels with high enthalpy effectiveness.
- Desiccant wheels for dehumidification and reheat.
- Low specific motor power with VFDs.
- Demand controlled ventilation.

ECDC FCUs are apx 20% more expensive than conventional FCUs, yet the number of the units installed could be reduced by up to 40% because of the lower cooling load.



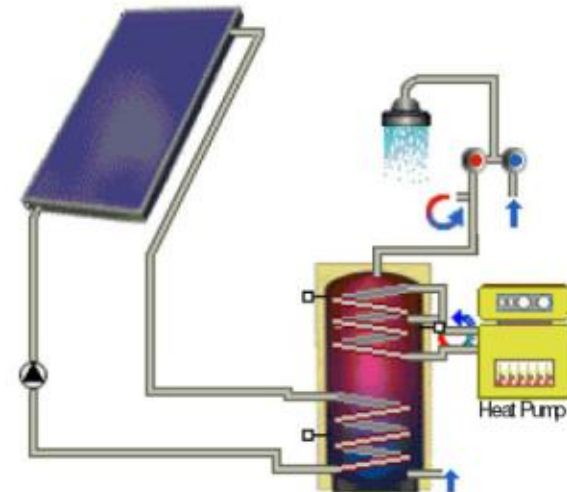
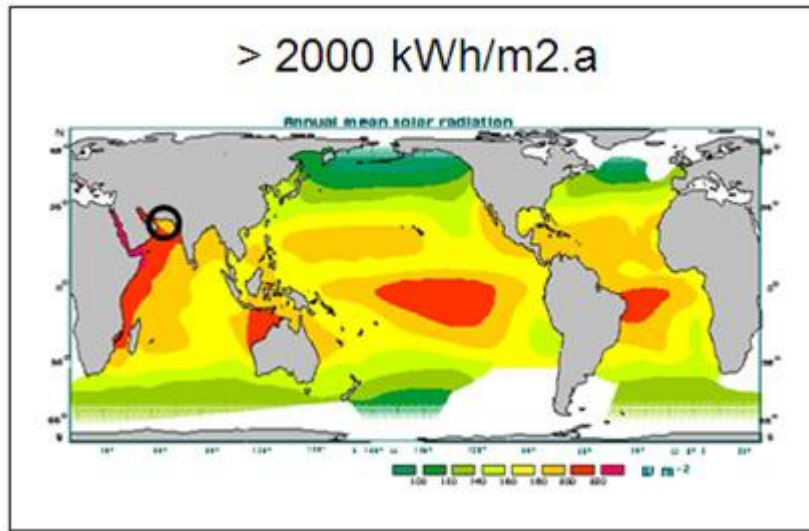
Lower RH results in better indoor air quality and lower risk of condensation.



9- Solar Collectors for Domestic Hot Water:

- 28 solar thermal hot water panels of approximately 2.4m² each, connected to an 8000 liter hot water tank.
- Offset approximately 75% of the annual on site DHW.
- 2.75% of total energy demand.

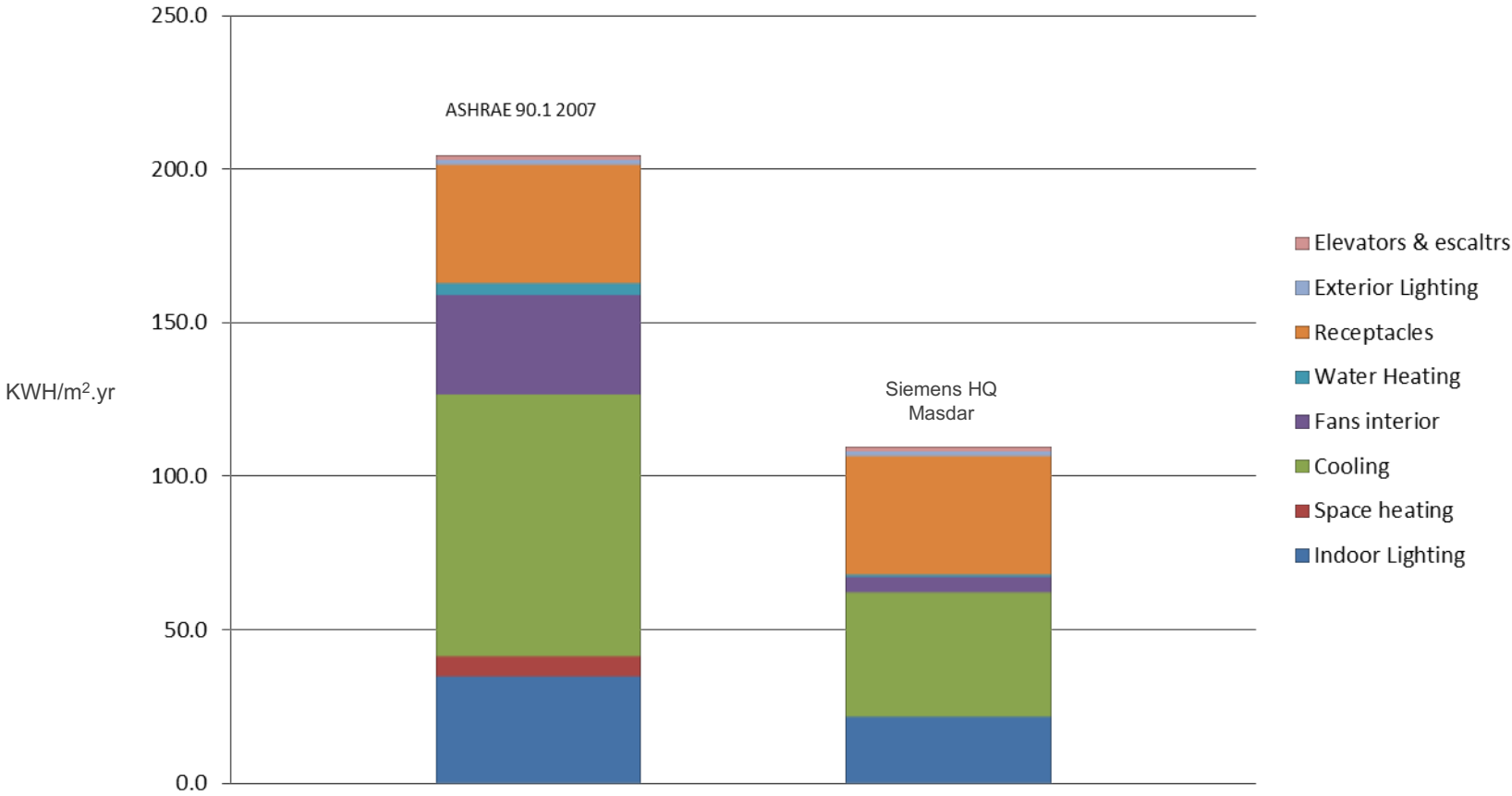
Simple, robust, easy to clean and cheaper than ETC yet offering equal energy absorption per unit area



10- Advanced energy management system:

- Measurement and Verification (M&V) Plan in fit out guidelines.
- Sub-meters for all tenant end uses as per LEED 2009 for CI EA Credit 3.





3- Buildings Operation in Masdar City



Do “green” buildings deliver the performance they promise?

Yes.....But not always!

“Green” buildings have been shown to save energy (25% according to a Post occupancy evaluation of 22 GSA buildings).

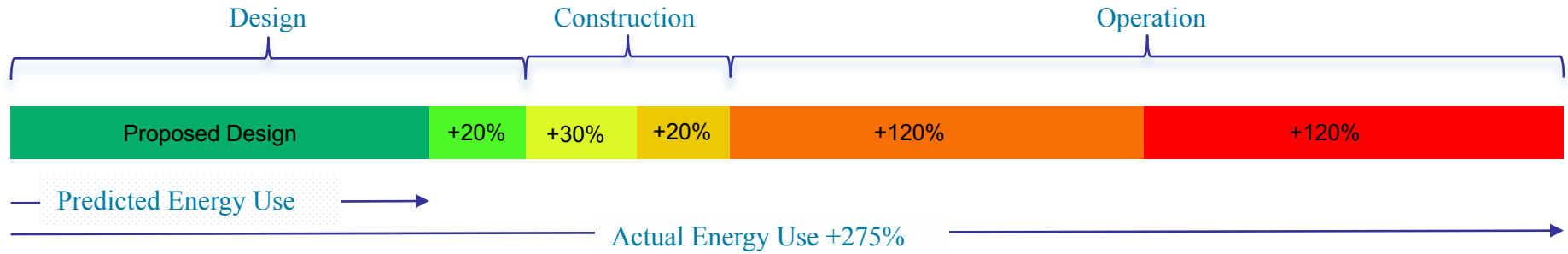
Energy savings in “green” buildings typically exceed any design and construction cost premiums within a reasonable payback period.

In order to achieve their predicted performance, “green” buildings need to be backed up by **robust commissioning, effective management, and collaboration between owners and occupiers.**



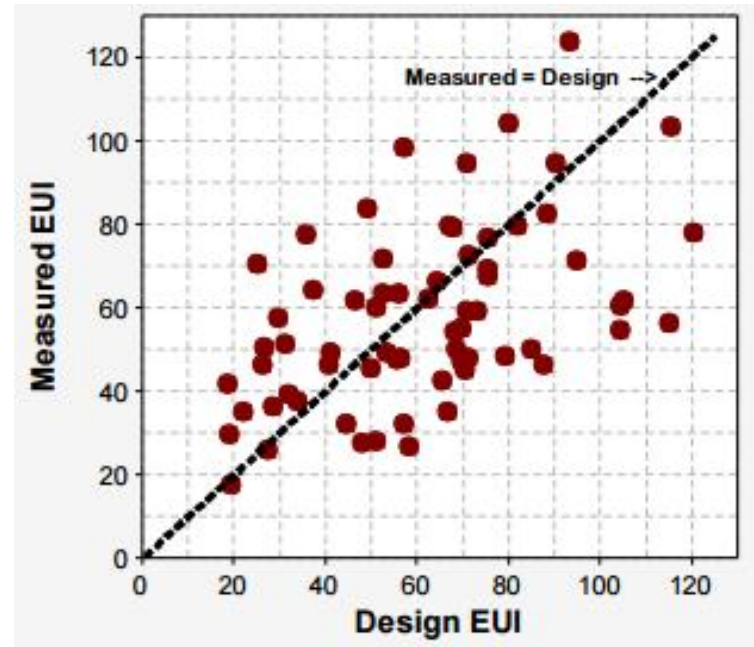
Measured versus Proposed Savings Percentages - Source: New Buildings Institute, 2008

Actual Performance VS. Design Performance



- Calculated energy use (modeling)
- Energy modeling inaccuracy
- Construction stage changes to design
- Ineffective commissioning
- Unregulated energy use
- Management and operations

Source: "What is the Performance Gap?" by Arup, 2013



Measured VS. Designed EUI - Source: New Buildings Institute, 2008

- ✿ MEP systems oversized
- ✿ Improper commissioning
- ✿ Oversupply of outside air
- ✿ Continuous operation of systems
- ✿ Poor Fit-out works
- ✿ Low temperature set-points
- ✿ Uncalibrated sensors
- ✿ Unsuitable metering
- ✿ Uncalibrated modulating valves
- ✿ Bypass valves improperly open
- ✿ Differential pressure sensors wrongly used
- ✿ Low chilled water delta T
- ✿ Unbalanced air & water system
- ✿ Air short circuits in chiller
- ✿ Variable speed overridden
- ✿ Clogged filters
- ✿ Dirty condensers
- ✿ Unskilled operators
- ✿ Absence of O&M manuals
- ✿ Occupants lack of awareness

- ✿ Incorporate goals for energy efficiency into the O&M strategic business plan
- ✿ Implement an Energy management system based on ISO 50001
- ✿ Train building operators & Equip them with the right tools
- ✿ Perform regular energy audits, Collect and Analyze Data
- ✿ Obtain a clear, written set of sequences of operation and building control strategies and test them
- ✿ Make full use of automatic controls to guarantee efficient operation & Operate equipment only when needed
- ✿ Track actual performance against expected performance
- ✿ Calibrate energy systems regularly, Consider commissioning, re-commissioning & retro-commissioning

*Most efficiently designed
systems are horribly
inefficient after several
years of operation*



Energy Efficiency Requirements and KPIs in O&M contract

| Service Requirement | Specific Requirement | | Monitoring Details and other Relevant Information |
|---|----------------------|--|---|
| | Ref. | Detail | |
| Inventory of all energy systems | 1 | The FM Provider shall develop and maintain an inventory of all energy systems (HVAC and electrical) in Masdar city buildings and infrastructure. Inventory should include at a minimum: equipment type, reference number, location number, power rating, and operation schedule. | The inventory should be fully completed within 60days of contract starting date |
| | 2 | The FM Provider shall maintain and operate all energy equipment as per latest O&M manuals and energy efficiency best practices. | Score for each month to take account of operational efficiency of all energy equipment inspected by the Client during the reporting period. |
| Operation and Maintenance (O&M) manuals | 3 | The FM Provider shall review and maintain a technical library of all O&M documents. The FM Provider shall update O&M manuals when existing/new parameters are altered/introduced | Score for each month to take account of readiness of all O&M manuals inspected by the Client during the reporting period. |
| Calibration of sensors | 4 | The FM Provider shall submit a program of calibration of sensors as part of the maintenance plans. The FM Provider shall validate and calibrate all field sensors (both the sensor itself and the communication back to a typical controller) every 6 months. The FM Provider shall submit adequate sensors validation documents to Masdar | Score for each month to take account of readiness of all sensors validation and calibration work inspected by the Client during the reporting period. |
| Time schedules | 5 | The FM Provider shall Introduce Time schedules to operate building systems in an energy efficient manner during holidays, Ramadan and non-working hours. | Score for each month to take account of introduction of appropriate time schedules inspected by the Client during the reporting period. |
| Sustainability Management System | 6 | The FM Provider shall develop and submit to Masdar, annual energy/water/waste conservation plan and program in accordance with section 4.6.1 and agreed with Masdar | Sustainability management systems and program shall be presented to Masdar |
| | 7 | The FM Provider shall ensure proper operation of automatic meter readings through computer and web based energy monitoring systems. | Ensure proper operation of meters, communication network and servers. |
| Conservation of energy/water/waste | 8 | Implementation of the plan and agreed schedule | Monthly energy data update based on the plan and actuals |

We do energy audits to answer the following questions:

- How is the building energy and water performance? How is it compared to other similar buildings?
- Where, when and how efficient is energy consumed in the building?
- What can be done to improve the building performance and save operational cost?
- What is the impact of design decisions on operation?
- How can we achieve better buildings in the future in terms of design, construction and operation?



Case Studies – Incubator and Siemens HQ Buildings

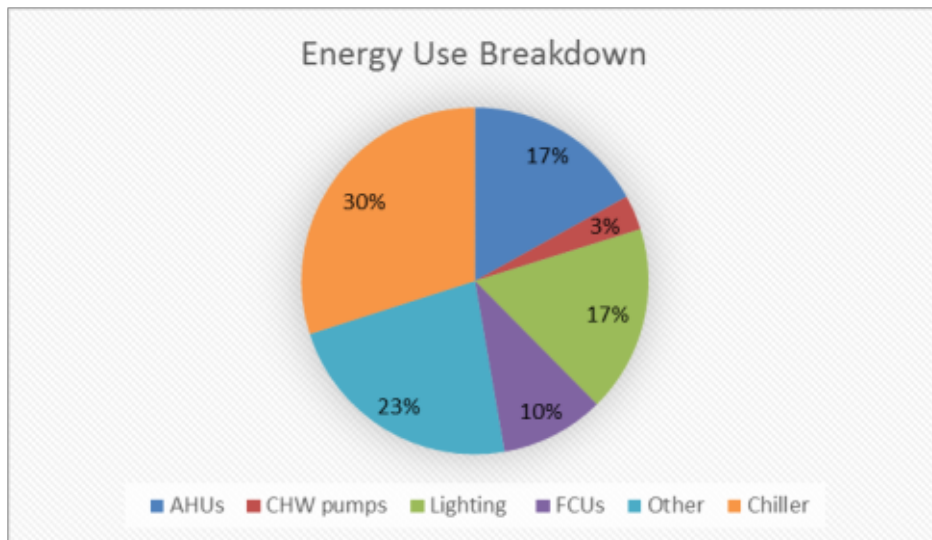


- ❑ Office Building
- ❑ Occupancy start date: Q1 2014
- ❑ Total Gross Floor Area: 12,946 m²

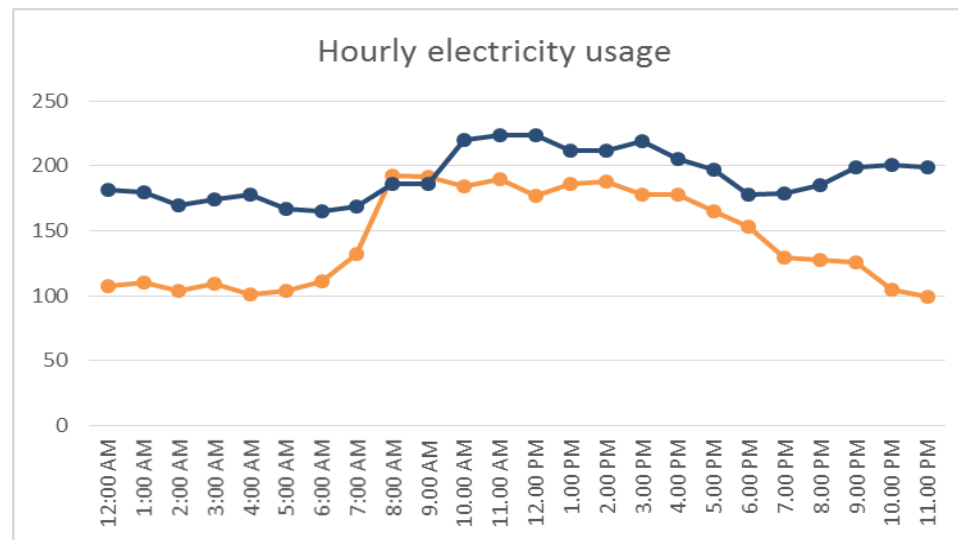


- ❑ Office Building including restaurants and grocery
- ❑ Occupancy start date: Q1 2014
- ❑ Total Gross Floor Area: 24,412 m²
- ❑ LEED Platinum CS & Estidama 3 pearls

Incubator Building Energy Analysis



Measured in 2015

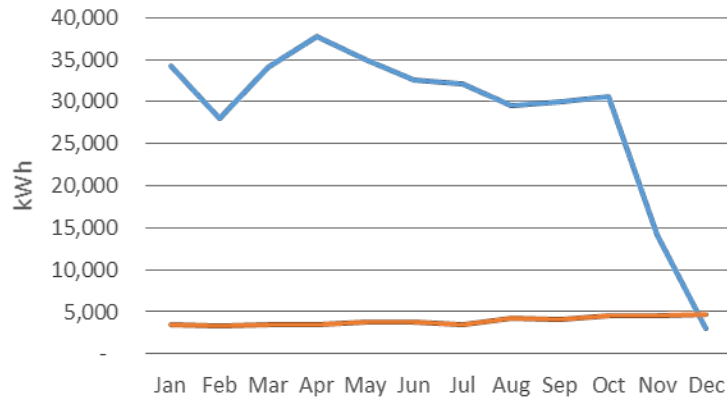


Hourly Electricity Usage (kWh) in 2015 vs. 2016

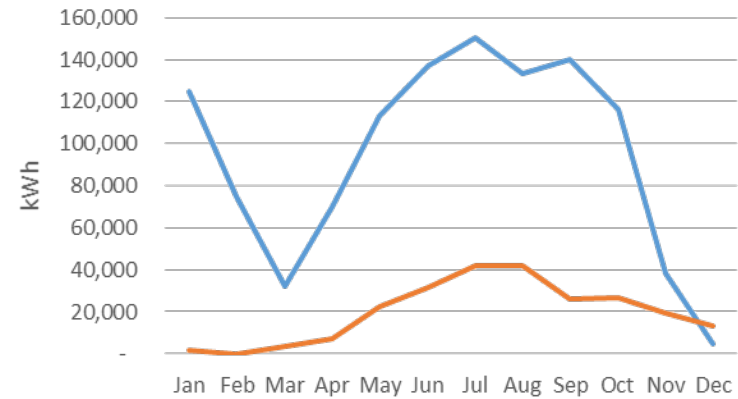
| | 2015 | | | 2016 | | |
|--------------------------------------|-------------|---------|-------|-------------|---------|-------|
| Utility | Electricity | Cooling | Total | Electricity | Cooling | Total |
| Energy Consumption (MWh) | 1,649 | 707 | 2,356 | 1,291 | 393 | 1,685 |
| Energy Utilization Index (kWh/m2/yr) | 182 | | | 130 | | |

Incubator Building After Recommissioning

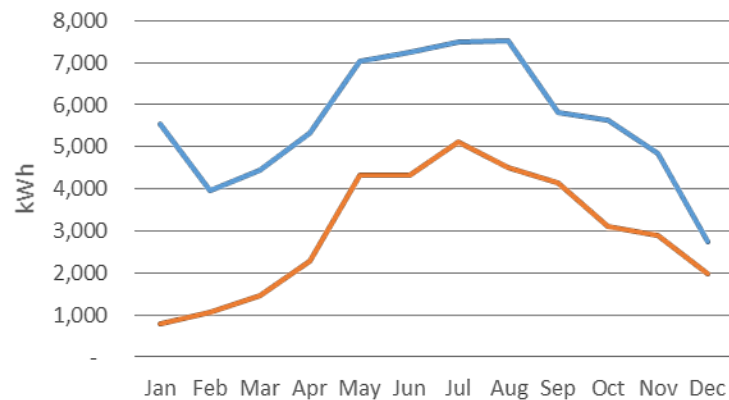
AHUs Electricity Consumption



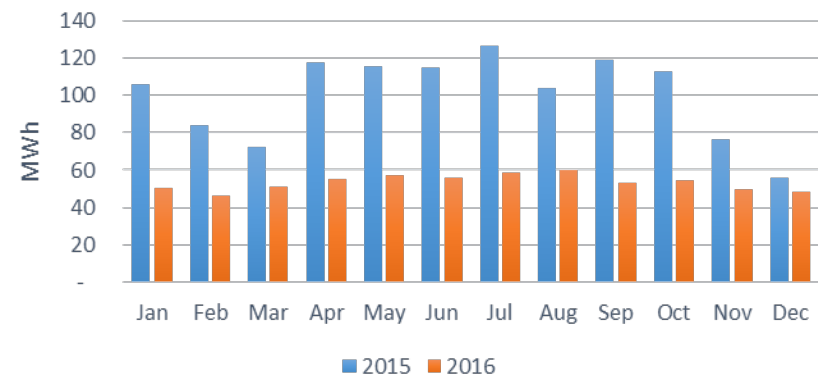
AHUs Cooling Consumption



CHW Pumps Electricity Consumption

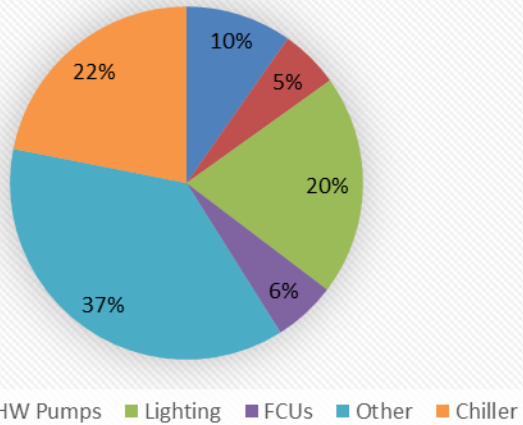


Common Area Energy Consumption

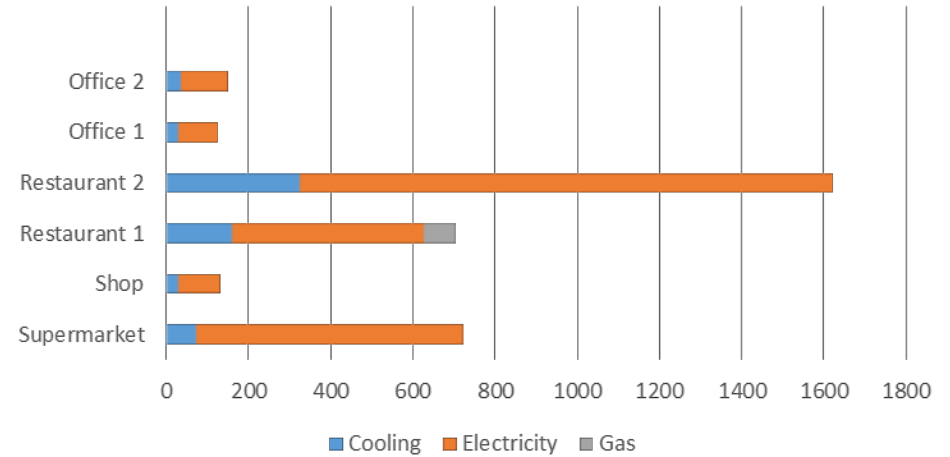


Siemens HQ Building Energy Analysis

Energy Use Breakdown

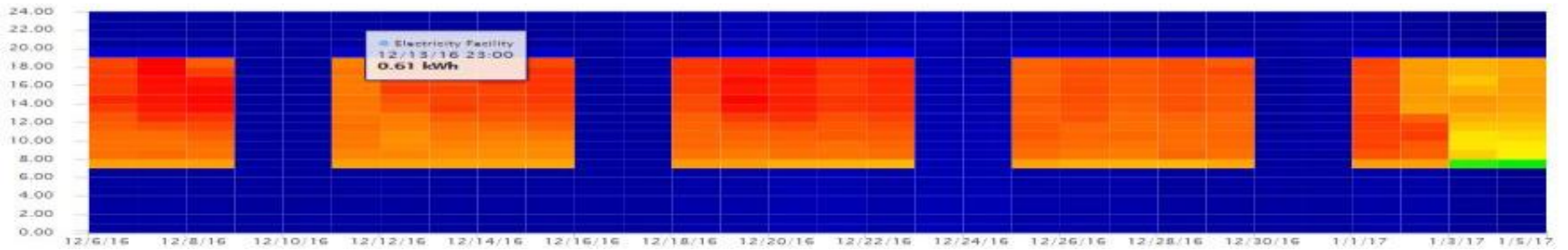


EUI per tenant per energy use (kWh/m2/yr)

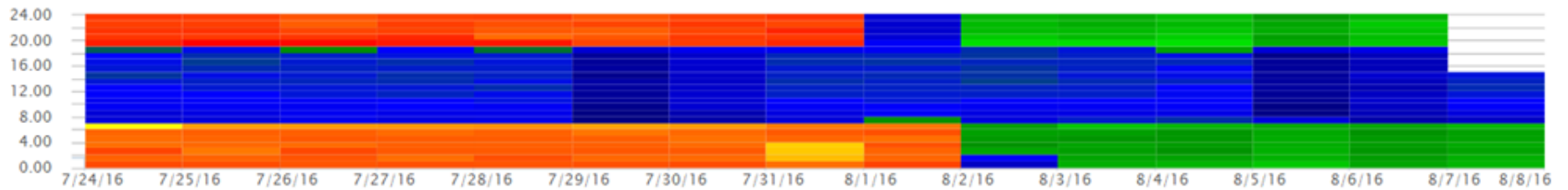


| | 2016 | | |
|--------------------------------------|-------------|---------|-------|
| Utility | Electricity | Cooling | Total |
| Energy Consumption (MWh) | 2,948 | 813 | 3,761 |
| Energy Utilization Index (kWh/m2/yr) | 154 | | |

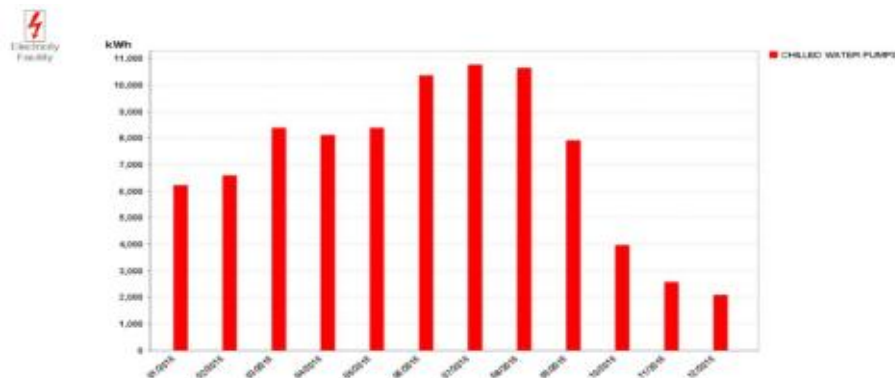
Siemens HQ Building After Recommissioning



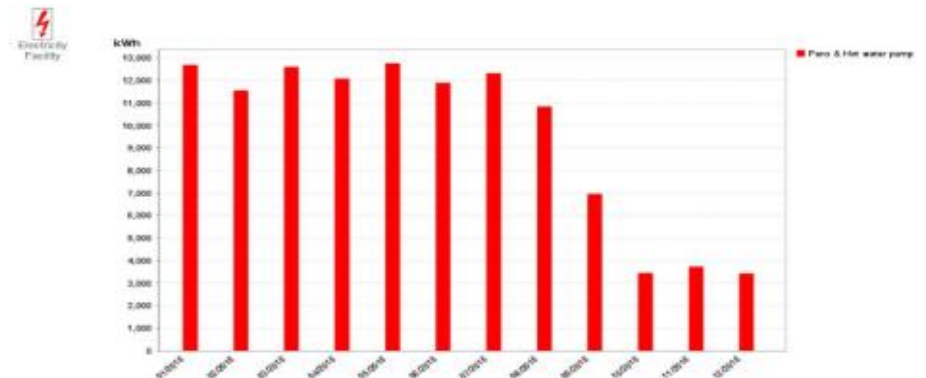
Carpet plot for FAHUs (fresh air handling units) electricity consumption



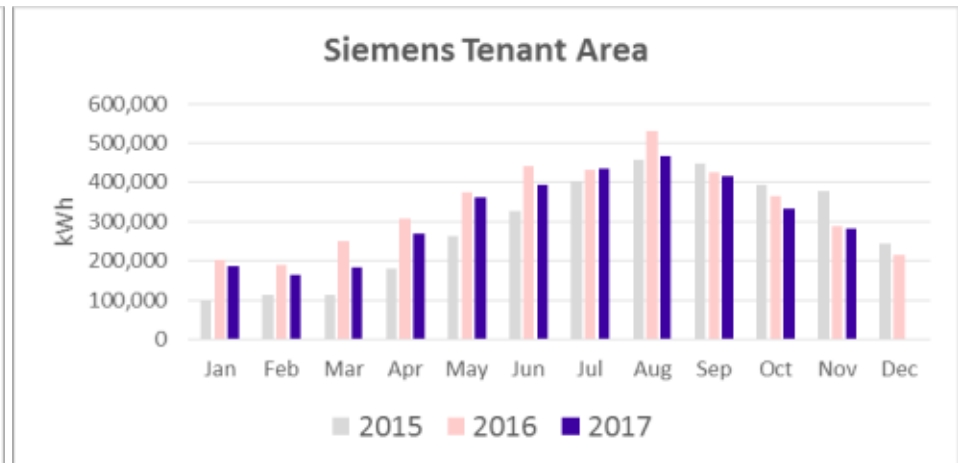
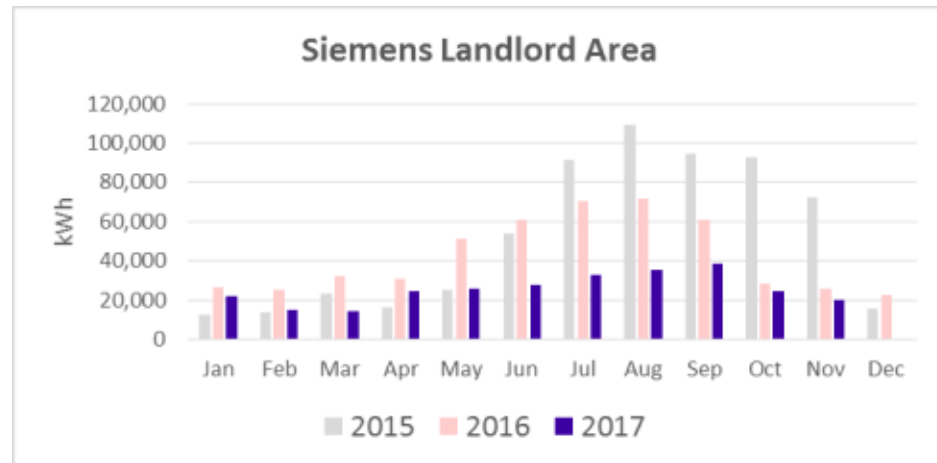
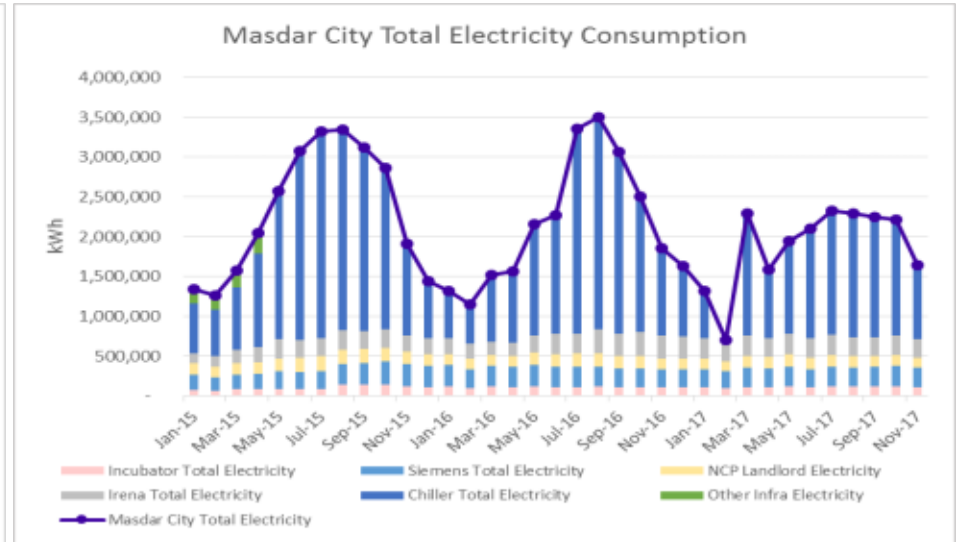
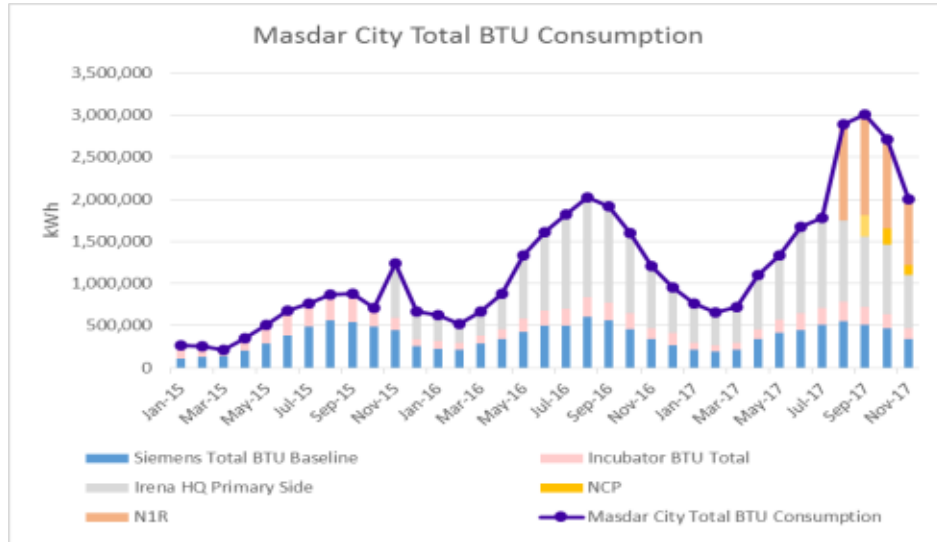
Carpet plot for exterior lights electricity consumption



CHW pumps monthly electricity consumption



FAHUs monthly electricity consumption



THANK YOU