Premise
Design approach
Sustainable strategies
Lessons learned
KAUST Goals

- The future of energy / alternative energy
- Environmental remediation - carbon sequestering
- The future of water / desalination
- Sustainable Agriculture
- The future economy of Saudi Arabia
Research Areas

Resources, Energy, and the Environment
- Energy, Carbon capture and sequestration
- Clean Fuels (sulfur & hydrogen chemistry)
- Petrochemical process design and engineering
- Hydrogen & Fuel Cells
- Combustion
- Solar energy and photovoltaics
- Hybrid energy and cogeneration for industrial systems
- Water and sustainable development
- Desalination and water supply
- Water use and reuse management
- “Green” planning, design, and construction for desert climates (including energy efficiency)

Biosciences and Engineering
Industrial biotechnology
- Synthetic and microbial biology for bioremediation
- Biocatalysis and bioprocessing for petroleum and petrochemicals
- Agricultural Biotechnology
- Sustainable aquaculture
- “Bio-agritech” of arid regions
- Regional environment
- Coastal/terrestrial environmental science and engineering, including biology of highly saline ecosystems
- Marine environmental science and engineering Red Sea and Persian Gulf
- Environmental studies related to desalination and petroleum operations
- Health Science and Technology
- Epidemiological studies of Middle East health issues
- Human population genomics and genetics
- Region-Specific Diseases & Conditions
- Generic Pharmaceuticals

Materials Science and Engineering
- Nanomaterials
- Carbon nanomaterials
- Photovoltaic applications
- Health effects of nano materials
- Bioprocessed nanomaterials
- Membranes
- Polymers
- Materials for high stress environments
- Catalytic chemistry
- Construction materials

Mathematics and Advanced Computing
Commitment from the top and at the start

- **Typical Building Practices**: 70%
- **Market Shift**: 20%
- **Innovators & Risk Takers**: 5%

**KAUST**
Program

Master plan components
- 7.5 million square feet research and academic space

RESEARCH & ACADEMIC
- Nanotechnology
- Biotechnology
- Information Technology
- Water Desalination
- Oil, Gas, Petrochemical Technologies

RESIDENTIAL
- Male Student Housing
- Female Student Housing
- Faculty Housing
- Married Student Housing
- Single Family Units
- Multi-Family Units
- Waterfront Units
- Guest Suites

COMMUNITY
- Town Center Plaza
- Grand Mosque
- Auditorium
- Shops
- Dining
- Post Office
- Movie Theatre
- Clubs
- Community Centers
- Services
- Schools
- Clinics
- Infrastructure & Utilities

RESEARCH PARK
- Incubators
- Industry Collaboration
- Private Sector Investment
- Nanotechnology
- Biotechnology
- Pharmaceutical
- Alternative Energy

RECREATION
- Snorkeling/Diving
- Parks
- Golf
- Waterfront Promenades
- Nature Trails
- Preserves
- Athletic Fields
- Swimming Pools
Schedule

- February 2007 – Master Plan
- March 2007 – Program / Brief
- May 2007 – Design
- August 2007 – Construction Start
- May 2009 – Commissioning
- September 2009 – KAUST Opens
August 2007
April 2009
Site

- Red sea
- ‘Green’ site
- Annex to King Abdullah Economic City
- Barrier reef
- Hot, humid climate
Project Brief

690,000 SM

7,500,000 SF
Premise
Design approach
Sustainable strategies
Lessons learned
case study
research

Arabic courtyard house

Mangrove ecology

Traditional urban space

Bedouin tents

Wind towers
Climate and Human Comfort

Annual Psychrometric Chart of Rabigh, Saudi Arabia
(relative humidity lines are stepped by 10%, wetbulb lines by 10 degrees F)
2006 Data

Air Velocity:
- Up to 2.5 ft/s: Nearly Still/Unnoticeable
- 2.5-10 ft/s: Pleasant
- 10-20 ft/s: Generally Pleasant with Constant Awareness of Air Movement. Loose Paper May be Blown Around at ~160 ft/s.
- 20-30 ft/s: Slightly Draughty to Annoyingly Draughty

*Adapted from Victor Olgyay, Design with Climate: Biothermal Approach to Architectural Regionalism, Copyright 1963, Princeton University Press.

Frequency Circles
Min = 1
Max = 53
Environmental Response

- BIG STREET SCALE
- STRENGTHEN
- SOLAR ENGINES
- UNDERCROFT - cool air from below

[Related images and diagrams]
Premise
Design approach
Sustainable strategies
Implementation
Lessons learned
Sustainable Charrettes – every two weeks
Sustainable Charrettes – every two weeks

- Architectural Design
- Engineering Design
- Site Design Design
- Energy Modeling
- CFD, Daylight, Water Modeling
Sustainable Charrettes – every two weeks

- Architectural Design
- Engineering Design
- Site Design
- Energy Modeling
- CFD, Daylight, Water Modeling

OWNER
Counting / Measuring

Energy Money Carbon
Decision Making Gates

- Sustainable impact
- Capital Cost
- Upkeep Cost
- Doable technology in the region
- Schedule
Carbon Calculator
CFD Analysis – from the beginning / throughout design
Energy / Life Cycle Modeling throughout

<table>
<thead>
<tr>
<th>Summary</th>
<th>Preliminary estimates of savings and payback</th>
<th>Savings vs. Code Base</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Estimated Energy Savings $8,432 $9,878 $11,278</td>
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<td>% Savings 21% 46% 44%</td>
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<td>Incremental First Cost 3353% $53,544 $45,812</td>
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<td>Payback 7.0 5.1 4.6</td>
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<td>Peak KV savings 318 56.0 53.7</td>
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Iowa Association of Municipal Utilities

<table>
<thead>
<tr>
<th>No.</th>
<th>Strategy Description</th>
<th>Peak annual KWh energy first cost years up-payback-keep</th>
<th>Total Life Cycle Cost</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
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<tbody>
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</tbody>
</table>

Savings vs. Code Base:

- Up-payback-keep
- Total Life Cycle Cost

Costs:

- $0 0.0
- $11,108 76.1
- $4,166 76.8
- $8,331 17.7

Group 1

Group 2

Group 3
Energy Strategy

Passive
- Passive Systems, Load Minimization, Shading, Daylighting, Mass, Natural Ventilation

Active
- Active Systems, Efficient Equipment, Heat Recovery, Cogeneration, Nighttime Flushing

Green
- Renewable Systems, Geothermal, Solar Thermal, Solar Electric

Operations (Ongoing)
Baseline – ASHRAE 90.1 / Entire campus

170 kBTU / SF
Passive Strategies
1. Most Effective Strategies – Passive – Compact design / self shading

- gardens and pools
- connection devices
1. Most Effective Strategies – Passive – Compact design / self shading
2. Most Effective Strategies – Passive – Total Control of the exterior skin loads
2. Most Effective Strategies – Passive – Total Control of the exterior skin loads
3. Most Effective Strategies – Passive – Daylight as ambient light
3. Most Effective Strategies – Passive

– Daylight as ambient light
4. Most Effective Strategies – Passive – Natural ventilation of public areas

1) PASSIVE VENTILATION:
- Pedestrian spine cooled by draft created by Solar Tower.
- Openings into spine oriented so as to draw fresh air from sea, and also to allow in predominant westerly breezes.
- Air handers in mechanical penthouses draw fresh air from the courtyards along the spine, augmenting draft created by the solar tower.

2) LOCAL EVAPORATIVE COOLING:
- For use during exceptionally hot weather, misters provide areas of targeting cooling along pedestrian spine.

3) RECYCLED CONDENSATE:
- Misters along spine supplied with condensate from chiller equipment.

4) HIGH PERFORMANCE GLAZING:
- Insulated glass curtainwall.

5) INTEGRATED SHADINGS:
- All glazing that is exposed to direct sun, fully shaded by means of a custom designed terracotta baguette system.

6-8) HIGH PERFORMANCE ROOF:
- Highly reflective standing seam aluminum roofing.
- Integrated rainwater collection and storage system.
- Roof mounted PV and solar thermal panels.

9) FILTERED DAYLIGHTING:
- Custom perforated metal skylit panels allow filtered daylight into the courtyards spaces below, while high performance skylights reduce heat gain.
4. Most Effective Strategies – Passive – Natural ventilation of public areas
4. Most Effective Strategies – Passive
   – Natural ventilation of public areas
4. Most Effective Strategies – Passive
   – Natural ventilation of public areas
Lean / Passive Strategies

- ventilation criteria – meet needs
- daylighting as ambient light
- passive ventilation
- isolate high heat loads
- complete control of skin
- low friction HVAC design
- transpired collectors
- design criteria
Active Strategies
1. Most Effective Strategies – Passive – Desiccant wheel
2. Most Effective Strategies – Passive – Chilled beams
CO2 Emissions

**BASELINE**
- 170 kBTU / SF

**LEAN**
- 101 kBTU / SF

**MEAN**
- 78 kBTU / SF

**DESIGN PHASE**
- heat recovery
- variable vent stack discharge
- high efficiency equipment
- high efficiency fume hoods
- lab exhaust criteria
- tailoring hood to use
- air acuity systems
- full building commissioning
- chilled beams
- mini generators
- heat recovery chillers
- LED lighting
- lighting controls
- displacement ventilation

**OCCUPANCY**
Green / Renewable Strategies
1. Most Effective Strategies – Green – Solar Thermal
2. Most Effective Strategies – Green – Solar Electric / PVs
Mean / Active Strategies

**Baseline**
- 170 kBTU / SF

**Lean**
- 101 kBTU / SF

**Mean**
- 78 kBTU / SF

**Green**
- 4 kBTU

- solar thermal
- solar electric PV
- concentrating solar / electric
Solar Thermal / Electric for Carbon Neutral
Mean / Active Strategies

Baseline CO2 Emissions:
- Baseline: 170 kBTU / SF
- Lean: 101 kBTU / SF
- Mean: 78 kBTU / SF
- Green: 4 kBTU

Strategies:
- Solar thermal
- Solar electric PV
- Concentrating solar / electric
ALTERNATIVE TRANSPORTATION

Multiple methods of transportation are being discussed to reduce the overall carbon footprint of the project.
2. Operations – Continual Improvement Process
Premise
Design approach
Sustainable strategies
Lessons learned
What worked well?

• Fully integrated team
• Basic architectural energy response
• Internal energy strategies
• Energy modeling / CFD Model
• Parallel modeling – energy / daylight
• Having a full time staff dedicated to coordinating sustainable issues
• Weekly updates of status
What could have gone better?

• Strategies that got lost due to schedule – radiant slabs - cooling
• Controls planning should have started at the beginning
• Onsite education of construction staff
THE MOST IMPORTANT THING?

Attitude Counts
Aerial perspective
Campus quad looking to Red Sea
Library and Commons Building on Sea Court
Research Laboratories and University Center
Leading to Town Center
Courtyards, Pedestrian Spine
Wind tower, Pedestrian Spine through Labs
KAUST site, April 2009
Simplicity with depth
Transformation and Discovery
Questions