Strategic Decision Making For Zero Energy Buildings in Jordan

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   2.3 Appliances Inventory
   2.4 Survey: Typical Electric Consumption

3. Energy Retrofit Strategies

4. Results
   4.1 Dynamic Simulation
   4.2 Comparing Strategies

1. Research Objective

Executive Order 13514 - "Federal Leadership in Environmental, Energy, and Economic Performance." ...Continued

"zero-net-energy building" means a building that is designed, constructed, and operated to require a greatly reduced quantity of energy to operate, meet the balance of energy needs from sources of energy that do not produce greenhouse gases, and therefore result in no net emissions of greenhouse gases and be economically viable.
Selected National Targets for New Buildings

<table>
<thead>
<tr>
<th>Country</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>75% by 2020 (c.f. base year 2006)</td>
</tr>
<tr>
<td>Finland</td>
<td>Passive house standards by 2015</td>
</tr>
<tr>
<td>France</td>
<td>By 2020 new buildings are energy-positive</td>
</tr>
<tr>
<td>Germany</td>
<td>By 2020 buildings should be operating without fossil fuel</td>
</tr>
<tr>
<td>Hungary</td>
<td>Zero emissions by 2020</td>
</tr>
<tr>
<td>Ireland</td>
<td>Net zero energy buildings by 2013</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Energy-neutral by 2013 (proposed)</td>
</tr>
<tr>
<td>Norway</td>
<td>Passive house standards by 2017</td>
</tr>
<tr>
<td>UK (England &amp; Wales)</td>
<td>Zero carbon as of 2016 (see box overleaf)</td>
</tr>
</tbody>
</table>

*Adapted from: SBI (Danish Building Research Institute), “European National Strategies to move towards very low energy buildings,” 2008*

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**EXAMPLES**

L’ILET DU CENTRE, SAINT-PIERRE, ARCHITECTES : PERRAU, REYNAUD
EXAMPLES
TOWARDS NET ZERO ENERGY BUILDINGS (NZEB)
ZERO ENERGY OR PLUS, GERMANY

Solar Siedlung Freiburg, Germany

Active House, Velux, in Copenhagen, Denmark

- Low energy buildings – 15 kWh/sqm/year
- Large solar PV systems.
- Feed in tariffs guaranteed by German government.
- These buildings produce much more than they use!
- Introduced in Parliament 2008
- Zero in 2030
- Plus Energy 2040


EXAMPLES
Efficiency House Plus with Electro-mobility
Technical Information and Details

Special features of the House:


TOWARDS NET ZERO ENERGY BUILDINGS (NZEB)
BEDZED, LONDON, UK

• Zero Carbon Buildings have been on agenda in the UK since 2005.

How to ensure CO2 neutral in future?

Examples


Key Components of Performance-Based Strategy
• Performance-Based Request for Proposals
• National Competition for Conceptual Design
• Design-Build Acquisition Strategy
• Power Purchase Agreement

Examples

NATIONAL RENEWABLE ENERGY LAB, NREL FACILITY, GOLDEN, COLORADO

Solar Decathlon Europe is an international competition among universities which promotes research in the development of efficient houses. The objective of the participating teams is to design and build houses that consume as few natural resources as possible and produce minimum waste products during their life cycle. 

www.solardecathlon.org

Between 2001 and 2012, electricity consumption has been growing over 3-7 percent in the building sector. The domestic sector in Jordan accounts for around 40% of the total electricity consumption.

### 1. Research Context: Reality of Built Environment

- **6.3 Millions**
  - Number of Jordanian population with a growing rate of urbanization 2.2%

- **83 % urban population**

- **3140**
  - (density)
  - per square kilometer

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**Meeting the Energy Challenges**

- Energy Efficiency + Renewable Energy
- Energy Efficient Behavior
- Passive Design + Clean Technology
- Building Code Compliance
- Building Energy Modeling
- Increasing Energy Prices
- Carbon Emission Increase
- Climate Change
- Population Growth

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1. Research Context  
Reality of Built Environment

1. Research Context  Reality of Built Environment

Where Does My Money Go?
Annual Energy Bill for a typical U.S. Single Family Home is approximately $2,200

- Electronics: Includes computer, monitor, TV & DVD player (4%)
- Other: Includes external power adapters, telephone, set top boxes, ceiling fans, vent fans, home audio, stoves, ovens, microwaves, coffee makers, dehumidifiers (11%)
- Heating: 29%
- Lighting: 12%
- Appliances: Includes refrigerator, dishwasher, clothes washer and dryer (15%)
- Water Heating: 14%
- Cooling: 17%

Average prices of electricity is 11.8 cents per kilowatt hour. Average price of natural gas is $11.28 per million Btu.

MARCH 7, 2013
Heating and cooling no longer majority of U.S. home energy use

Energy consumption in homes by end uses (quadrillion Btu and percent)

- Space heating: 24.0%
- Air conditioning: 18.3%
- Water heating: 4.6%
- Appliances, electronics, and lighting: 52.1%

Source: U.S. Energy Information Administration, Residential Energy Consumption Survey. Notice: Amounts represent the energy consumption in occupied primary housing units.

http://www.eia.gov/todayinenergy/detail.cfm?id=10271&src=Consumption%20Residential%20Energy%20Consumption%20Survey%202010

27/09/2016
2013 Electricity Consumption in Jordan

- Residential Consumption: 959 KWh/capita/year
- Average Family Size: 5.4 people
- Average Family Consumption: 5180 KWh/family/year

http://www.memr.gov.jo Calculations by Author


1. Research Context Reality of Built Environment

Electricity Prices increase March 2013
1. Research Context  Reality of Built Environment

Jordan, heating/cooling dominated country
Energy Prices increase March 2013

Jordan has abundant renewable energy resources to support 100% of its electricity needs well into the future. Jordan's natural wind and solar resources can provide over 60 times more electricity than the country's projected demand in 2050 (DLR, 2005).
1. Research Context

Problem & Objective:

Problem:

Objective:
Investigate the potentials of NZEBs
Theoretically and Experimentally

Building Properties:
- Insulation
- Building Codes
- Indoor air quality

Occupant Behaviour & Subsidy
Jordanian Building Energy Codes

Under Update:
1. Natural Lighting Code
2. Interior Illumination Code
3. Mechanical Ventilation and Air Conditioning Code
5. Central Heating Code

Net Zero Buildings
(Not developed yet)

Net Positive Buildings
(Not developed yet)

Energy Networking
(Not developed yet)

Green Buildings Guide
(Not issued)

Solar Energy Code
(Issued 2010)

Energy Saving
Buildings Code
(Issued 2010)

Passive House Design
(Not developed yet)

Thermal Insulation
Code
(Issued 2009)

1. Research Objective
How to design a NZEB in Jordan?
1. Research Objective
How to design a NZEB in Jordan?

How to avoid thermal bridges?

ThermoStone Brick Wall
Rockwool Thermal Insulation
Aluminum Foil (Solar Deflector)
Air Gap
Alucobond
How far should we insulate Jordanian buildings?

Thermal Insulation from **outside or Inside**

PU is applied to the exterior walls of the building then cladding is installed with mechanical support system.

Polyurethane Insulation, Dabouq, Amman Jordan

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Aqaba Residence Energy Efficiency in Jordan - Florentine Visser

Last June the first sustainable building in Jordan opened to the public. Dutch Architect Florentine Visser was responsible for the design of the Aqaba Residence Energy Efficiency (AREE) project.

The total floor area of 420m² covers three levels and comprises living room, kitchen, study, family room, six bedrooms, three bathrooms, car garage, storage, and basement.

87% Reported Energy saving
Example Aqaba Residence Energy Efficiency
= 87% Energy Savings + PV Electrical Generation =
Net Zero House

How to design roofs to allow solar panels integrating?
1. Research Objective

3. Research Methodology

a. Data Collection
b. Basecase Construction
c. Design & Construction Solutions
d. Building Performance Simulation
e. Costing Simulation
f. Recommendation

3. Location Selection

<table>
<thead>
<tr>
<th>Climate-specific characteristics</th>
<th>City</th>
<th>Al Shouma SH</th>
<th>Amman, AM</th>
<th>Al Joura, AJ</th>
<th>Al Ruweished, AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude and Longitude</td>
<td>29.5-35.0</td>
<td>31.4-35.3</td>
<td>31.9-35.9</td>
<td>32.3-35.7</td>
<td>32.5-38.1</td>
</tr>
<tr>
<td>Altitude</td>
<td>51</td>
<td>-361</td>
<td>784</td>
<td>760</td>
<td>704</td>
</tr>
<tr>
<td>ASHRAE Zone</td>
<td>3</td>
<td>2b</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

4. Case Study: Basecase Selection
4.1 Building Description
4. Case Study: Basecase Selection

4.1 Building Description

<table>
<thead>
<tr>
<th>City</th>
<th>Aqaba, AQ</th>
<th>Al Shouma, SH</th>
<th>Amman, AM</th>
<th>Al 'Ula, AJ</th>
<th>Al-Rujayla, AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude and Longitude</td>
<td>29.35.0</td>
<td>31.4.35.3</td>
<td>31.9.35.9</td>
<td>32.1.35.7</td>
<td>32.5.38.1</td>
</tr>
<tr>
<td>Altitude</td>
<td>51</td>
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<td>784</td>
<td>760</td>
<td>704</td>
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<tr>
<td>ASHRAE Zone</td>
<td>3</td>
<td>2B</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**General Characteristics**

- Building configuration: 110 m², three bedrooms, rectangle shape, one-story, single family
- Construction type: Reinforced-concrete post and beam structure with brick infill walls
- Exterior walls: Steel Cladding, Concrete wall, no insulation, Brick, Mortar
- Roof: Flat roof, tiles, cement mortar, water proofing layer, 5 cm extruded polystyrene, sand, reinforced concrete
- Windows: Window area: 25% of conditioned floor area, distributed equally on all three sides; Clear Single Pane in aluminum frame, operable window without exterior shading
- Shading: Venetian Blinds Close if indoor Temp is above comfort
- HVAC systems: LPG Heater with a 85% efficiency – Heat pumps without ducts and without ventilation system
- DHW system: 80-litre electric water heater, 0.80 energy factor
- Thermostat set point: 20°C (68°F) for heating, 25-30°C (77°F) for cooling, 5°F setback and set up in winter and summer, respectively
- Natural Ventilation: Windows and Doors are manually OPENED if cooling is needed
- Fan Forced Ventilation: No Fans for Comfort Cooling

Table 1: Basecase building characteristics

4. Case Study: Basecase Selection

4.2 Climate Analysis

Zone 1 (Aqaba and Al Shounah al-Janubiyah) are cooling dominated.
Zone 2 (Ammann and Aljouf) are heating dominated.
Zone 3 (Al-Ruwaished) are mixed, cooling and heating dominated.


4. Case Study: Basecase Selection

4.3 Appliances Inventory

kWh monthly kWh monthly kWh monthly kWh monthly kWh monthly
300 kWh 350 kWh 50 kWh 4 kWh 12 kWh
3.5 kWh 0.5 kWh 3.5 kWh 7 kWh 16 kWh
135 kWh 17 kWh 8.5 kWh 8.5 kWh 72 kWh
405 kWh 48 kWh 5.5 kWh 5.5 kWh
47.5 kWh 12 kWh 7 kWh

http://www.ttec.co.tt/consumertips/applianceconsumption/default.htm

4. Case Study: Basecase Selection

4.4 Survey: Typical Energy Consumption

Survey Results 3500-8000 kWh/apartment/annum

5. Energy Performance

1. Envelope

Thermal Insulation
U Value for Walls

<table>
<thead>
<tr>
<th>Solid walls</th>
<th>All External walls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid walls = 0.57</td>
<td>Solid walls = 0.57</td>
</tr>
<tr>
<td>All External walls = 1.6</td>
<td>All External walls = 1.6</td>
</tr>
</tbody>
</table>

Mandatory Thermal Insulation Code Table(5-1, 5-2)
Mandatory Energy Saving Buildings Code Table(2-2, 2-3)
Mandatory Green Building Manual
Optional (1 point) Green Building Manual
Optional (2 points) Green Building Manual

5. Energy Performance

1. Envelope
2. Solar Protection & Openings
3. Ventilation (Diurnal + Nocturnal)
4. Occupancy, Internal Loads & EE
5. Solar Thermal System
6. Solar Electric System
5. Energy Performance

<table>
<thead>
<tr>
<th>Properties</th>
<th>Energy Performance Characteristics</th>
<th>Measures for Maximum Energy Efficiency in ZEBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Roof/ceiling</td>
<td>U=0.05 W/m²K</td>
<td>U=0.15 W/m²K</td>
</tr>
<tr>
<td>2. Wall + floor</td>
<td>U=0.4 W/m²K (load-bearing)</td>
<td>U=0.37 W/m²K (load-bearing)</td>
</tr>
<tr>
<td>3. Water system</td>
<td>U=0.65 W/m²K (insulation)</td>
<td>U=0.65 W/m²K (insulation)</td>
</tr>
<tr>
<td>4. Operable shading</td>
<td>Operable window without external shading</td>
<td>Operable window without external shading</td>
</tr>
<tr>
<td>5. Night insulation</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>6. Infiltration</td>
<td>0.6 AIR</td>
<td>0.3 AIR</td>
</tr>
<tr>
<td>7. Internal heat gain*</td>
<td>0.14 W/m²K from heat loss, 0.1 W/m²K from appliances</td>
<td>0.14 W/m²K from heat loss, 0.1 W/m²K from appliances</td>
</tr>
<tr>
<td>8. Natural ventilation</td>
<td>Windows and doors are manually OPENED if cooling is needed</td>
<td>Windows and doors are manually OPENED if cooling is needed</td>
</tr>
<tr>
<td>9. Fan forced ventilation</td>
<td>No fan for comfort heating</td>
<td>No fan for comfort heating</td>
</tr>
<tr>
<td>10. Thermostat temperature</td>
<td>25°C (85°F) for heating, 25°C (77°F) for cooling</td>
<td>25°C (85°F) for heating, 25°C (77°F) for cooling</td>
</tr>
<tr>
<td>11. Heating system</td>
<td>Gas turbine</td>
<td>Gas turbine</td>
</tr>
</tbody>
</table>

- Jordanian Thermal Insulation Code reduce the energy use up to 40% (equivalent to 32 kWh/m²/year).
- Up to 66% energy use could be reduced for the NZEB objective (equivalent to 18 kWh/m²/year).
- The reduction in fossil based DHW use resulted in an equivalent SHW energy savings (5.5 kWh/m²/year).

6. Results: Dynamic Simulation

- All ZEB strategies were integrated in the new simulation model representing the basecase apartment. The results from the EnergyPlus program were analyzed to produce the data shown in the figure.

* Jordanian Thermal Insulation Code reduce the energy use up to 40% (equivalent to 32 kWh/m²/year).
* Up to 66% energy use could be reduced for the NZEB objective (equivalent to 18 kWh/m²/year).
* The reduction in fossil based DHW use resulted in an equivalent SHW energy savings (5.5 kWh/m²/year).
6. Results: Dynamic Simulation

- The zero energy objective reduced the need for heating in the five locations and increased the cooling requirement.
- PV panels' energy will feed the HP for space cooling & heating (split system), using the electricity grid as a buffer/storage.
- This objective, a 15 square meter PV panel array.

6. Results: Economic Feasibility

Table 3: Results of cost analysis and payback time

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (Code Compliance)</th>
<th>Payback (Code Compliance)</th>
<th>Cost (Maximum Efficiency)</th>
<th>Payback (Maximum Efficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope</td>
<td>3000 $</td>
<td>9 years</td>
<td>6,000 $</td>
<td>18 years</td>
</tr>
<tr>
<td>HVAC</td>
<td>2000 $</td>
<td>10 years</td>
<td>4,000 $</td>
<td>20 years</td>
</tr>
<tr>
<td>Flat Solar Water Heater (l/m²)</td>
<td>900 $</td>
<td>3 years</td>
<td>900 $</td>
<td>3 years</td>
</tr>
<tr>
<td>PV panels (l/m²) = 3000 kWh</td>
<td>-</td>
<td>-</td>
<td>1,000 $</td>
<td>12 years</td>
</tr>
<tr>
<td>Average Annual Energy Consumption: Total Payback</td>
<td>32 kW/m²/year</td>
<td>9 years</td>
<td>18 kW/m²/year</td>
<td>44 years</td>
</tr>
</tbody>
</table>

- In Jordan, the effective tax rate is 14% and the utility inflation rate is assumed as 8%.
- From an economic point of view installing a SHW system is economically rewarding.
- The system is manufactured in Jordan and can be easily installed and maintained.
- NZEB strategy is too ambitious. Payback time (property value appreciation) is 44 years.
- The PV panels investment cost is very high.
- Upgrading the envelope and HVAC system (payback=5 years) in Jordan to meet almost the Passive House Standard requirements of 15 kW/m²/year
7. Conclusions

- **Economy:** Energy prices are still a challenge (partially subsidized)

- **Policy:** The Jordanian Code is a good start.

- **Feasibility:** Using a centralized solar thermal system for DHW for each apartments block is rewarding. A centralized system for DHW is an easy shift to renewable energy production.

- **Technology:** Solar thermal energy can be used for solar assisted cooling. Examining the potentials of thermal energy for seasonal storage and air conditioning might be a breakthrough existing barriers.

- **Next step:** Drawing on market analysis and cost feasibility in detail to maximize the life cycle benefit and cost

8. Limitations

- The study remains theoretical with certain limitations.
- Selecting an existing residential typology did not allow other passive measures such as the urban setting, orientation, form and window to wall ratio.
- The study did not explore the potential of thermal mass and two other important systems. The geothermal heat pumps for space heating and cooling and evacuated tubes option for space heating and DHW.
9. Open Discussion

• Should we go High-Tech or Low-Tech?
• Should we depend on solar renewable or geothermal?
• What comfort model should we follow ASHRAE (21-24 C) or Givoni? Or others?
• Does the payback calculation sound logic?
• What are the main barriers for NZEBs in Jordan?
• Heating vs Cooling Balance
• Regulations
• What are your concerns?

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