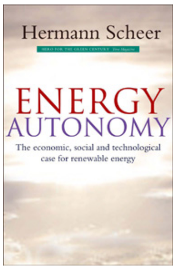
Strategic Decision Making For Zero Energy Buildings in Jordan

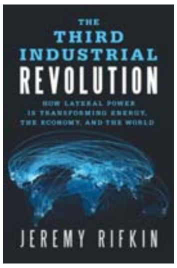
Samer Zawaydeh
Eng., CRM, REP, AEE Life Member

Shady Attia, PhD, ED®AP
shady.attia@hotmail.com
Assistant Prof. of Sustainable Building Construction
Head of Sustainable Building Design Lab (SBD)
Univeristé de Liège (Ulg)
http://www.shadyattia.net/

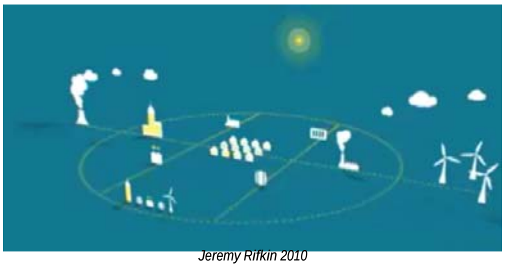
Contents

Sustainable High Performance Communities
Third Industrial Revolution: Post Fossil Fuel Era





- Decentralized Renewable Energy
- Energy Storage
- Smart Transmission Grid
- Zero Emission Transportation
- Building as Micro Plant



Jeremy Rifkin 2010

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.

التقدم نحو استهلاك منخفض للطاقة أو صفر في المنازل في اوروبا

PROGRESS TOWARDS LOW & ZERO ENERGY BUILDINGS IN EU MEMBER STATES

Selected National Targets for New Buildings

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

Adapted from: SBi (Danish Building Research Institute), "European National Strategies to move towards very low energy buildings", 2008

Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

EXAMPLES

L'ILET DU CENTRE, SAINT-PIERRE, ARCHITECTES : PERRAU, REYNAUD

Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

EXAMPLES

TOWARDS NET ZERO ENERGY BUILDINGS (NZEB)
ZERO ENERGY OR PLUS, GERMANY

Solar Siedlung Freiburg, Germany

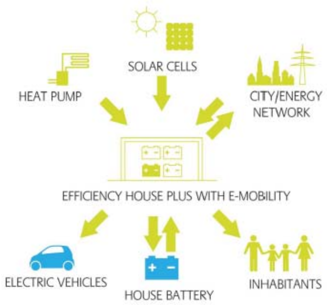
Active House, Velux, in Copenhagen, Denmark

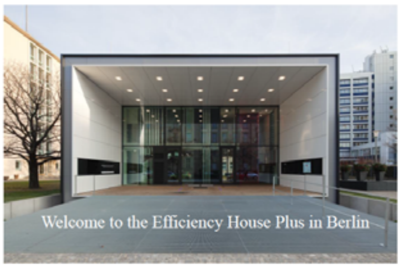
- Low energy buildings – 15 kWh/sqm/ year
- Large solar PV systems.
- Feed in tariffs guaranteed by German government.
- These building produce much more than they use!

- Introduced in Parliament 2008
- Zero in 2030
- Plus Energy 2040

EXAMPLES

Efficiency House Plus with Electro-mobility
Technical Information and Details



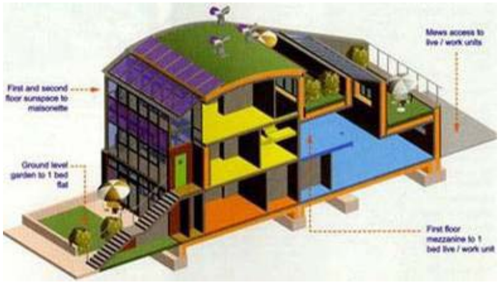


Special features of the House:

Source: Efficiency House Plus with Electro-mobility "My house is my filling station" presentation, www.bmvbs.de, www.zebau.de

EXAMPLES

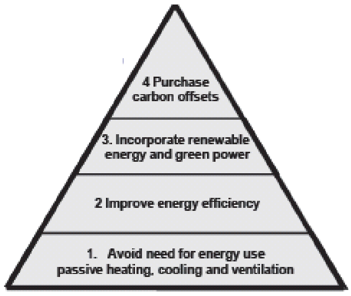
TOWARDS NET ZERO ENERGY BUILDINGS (NZEB)
BEDZED, LONDON, UK



Bill Dunster

•**Zero Carbon** Buildings have been on agenda In UK since 2005.

How to ensure CO2 neutral in future ?



EXAMPLES

NATIONAL RENEWABLE ENERGY LAB, NREL FACILITY, GOLDEN,

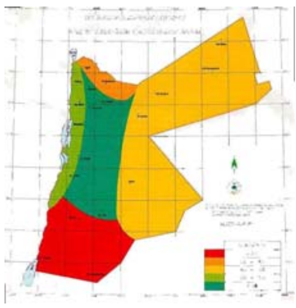
- Key Components of Performance-Based Strategy
- Performance-Based Request for Proposals
- National Competition for Conceptual Design
- Design-Build Acquisition Strategy
- Power Purchase Agreement

EXAMPLES

SOLAR DECATHLON, 2012 MADRID

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

1.Research Context



1.Research Context Reality of Built Environment

6.3 **Millions**

Number of Jordanian population
with a growing rate of urbanization 2.2%

83

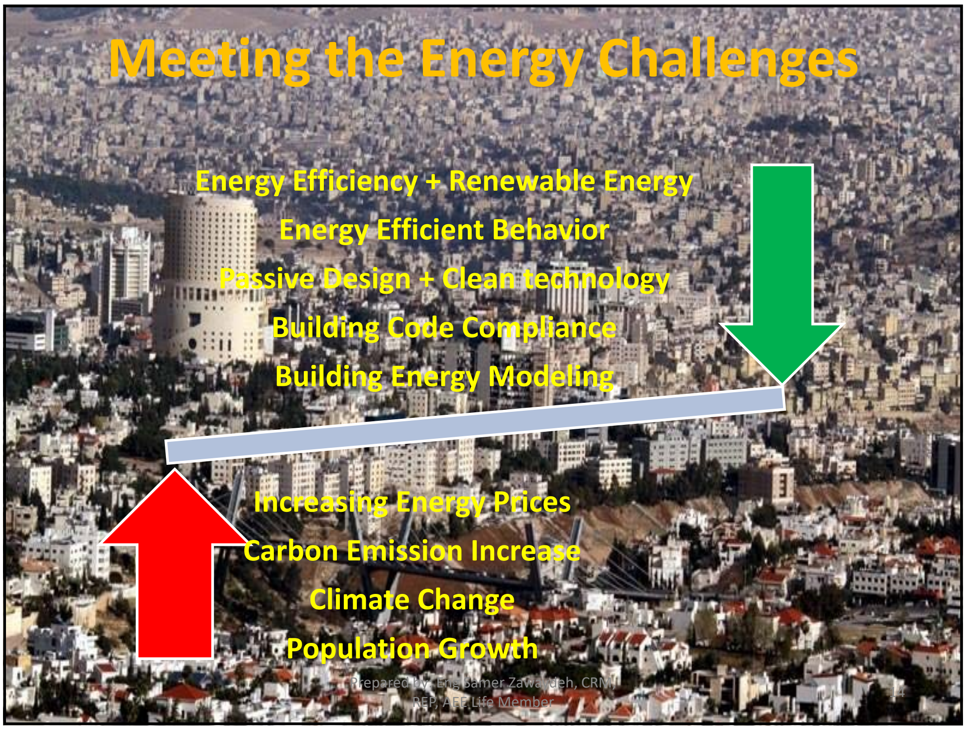
% urban population

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 .

3140

(density)
per square kilometer

13/20



1. Research Context Reality of Built Environment

التاريخ : 15-01-2013

النسور : الدولة ستفلس اقتصاديا بحال عدم رفع اسعار الكهرباء

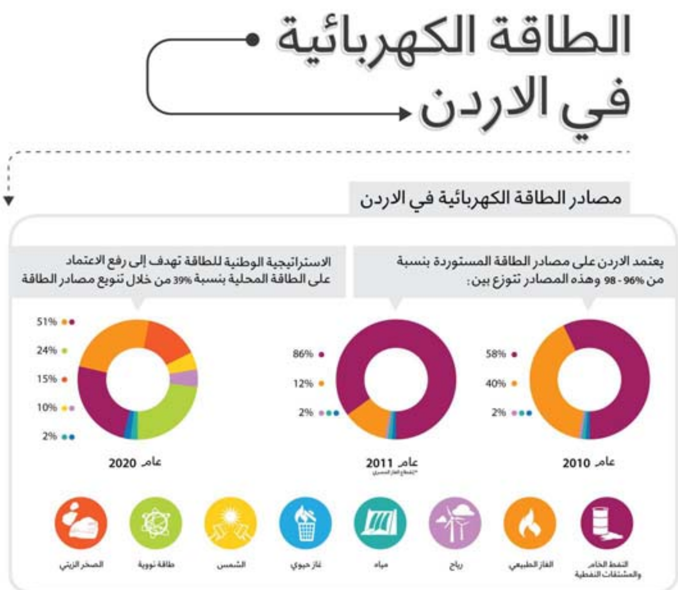
كرمالكم الإخبارية

اعلن رئيس الوزراء الدكتور عبد الله النسور في لقائه عددا من مدراء الإذاعات المحلية عزم الحكومة على ' رفع أسعار الكهرباء' عقب الانتخابات النيابية القادمة، مبررا ذلك بـأن ' الدولة ستفلس اقتصاديا في حال عدم رفع اسعار الكهرباء'.

ونوه النسور ان الحكومة ماضية في محاربة الفساد ولن تألوا جهدا في هذا المجال مستشهدا بما تقوم به الحكومة من خطوات واجراءات حولت خلالها عددا من ملفات الفساد الى القضاء ليقول كلمته فيها ، وان المطلوب اليوم هو اعادة هيبة الدولة وهذا يتأتى بالحكمة والعمل المتواصل الدؤوب واقناع المواطن ان لديه حكومة نزيهة لا تألوا جهدا في تحقيق العدالة وتطبيق سيادة القانون على الجميع .

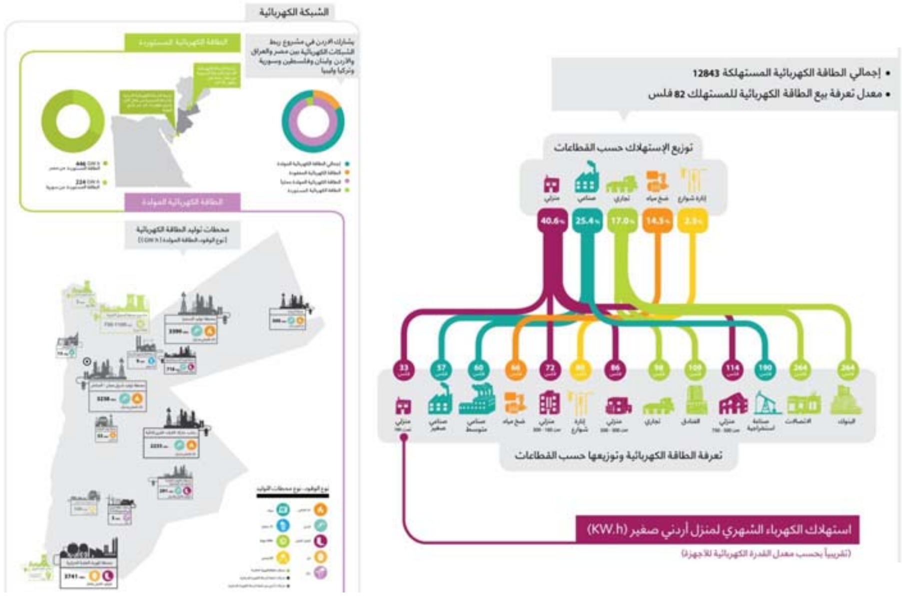
وحذر النسور قبيل رفع الدعم عن المحروقات- وبعض السلع- ان الدينار الاردني معرض للانهيار في حال عدم رفع الدعم، مطلقا اكثر من مره تحذيرات بإنهيار الاقتصاد الاردني في حال لم تقم الحكومة برفع الأسعار ، وان الحكومة مازالت تدعم اسطوانة الغاز بمبلغ 2 دينار، ليعود ويشدد على ان ' لا عودة عن قرار رفع أسعار الكهرباء ابدا'.

1. Research Context Reality of Built Environment



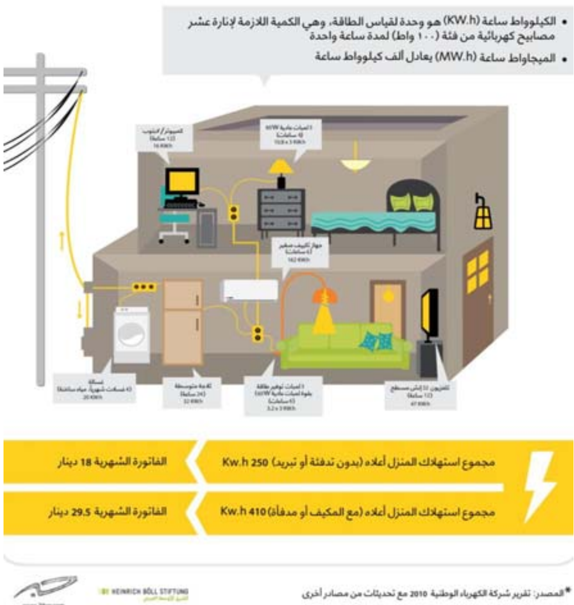
Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

1. Research Context Reality of Built Environment



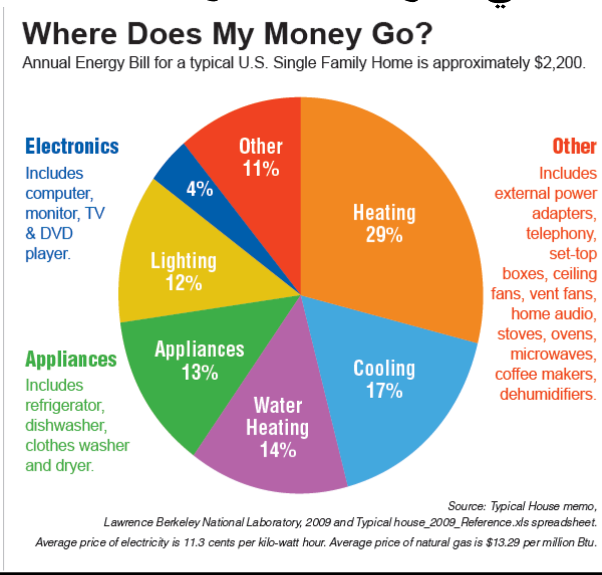
Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

1. Research Context Reality of Built Environment



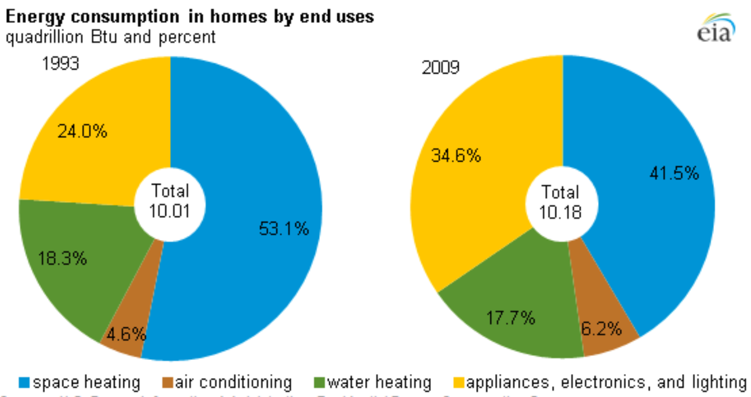
Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

اين يذهب مصروف الطاقة
في منازل العائلة الواحدة؟



MARCH 7, 2013

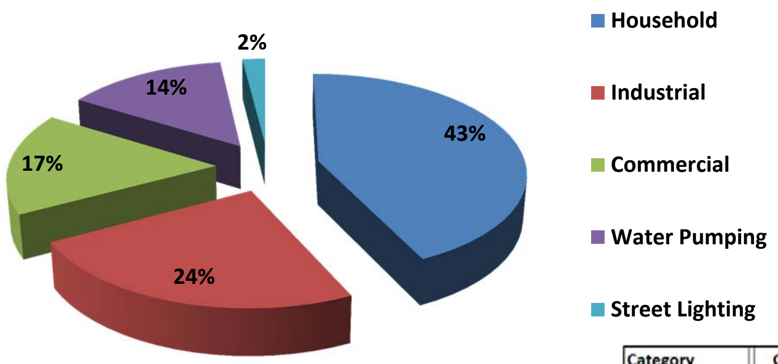
Heating and cooling no longer majority of U.S. home energy use



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

http://www.eia.gov/todayinenergy/detail.cfm?id=10271&src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20%28RECS%29-b1

2013 Electricity Consumption in Jordan



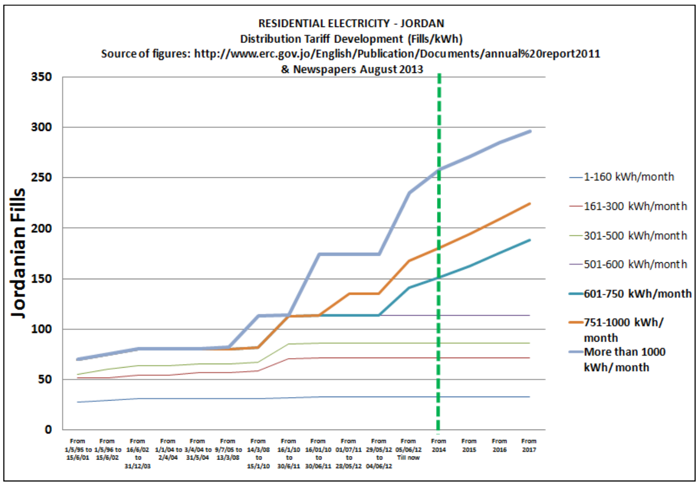
Category	GWH
Household	6265
Industrial	3541
Commercial	2415
Water Pumping	2076
Street Lighting	291
	14588

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

Source: Ministry of Energy and Mineral Resources, Facts and Figures Report 2013
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

التعرفة الكهربائية للفترة من 2013-2017

نسـب الزيـادة					التعرفة الكهربائية لعام 2017	التعرفة الكهربائية لعام 2016	التعرفة الكهربائية لعام 2015	التعرفة الكهربائية لعام 2014	التعرفة الكهربائية اعتبارا من 2013/8/15 وحتى 2013/12/31	القطـاع
2017	2016	2015	2014	2013	(فلس/ك.و.س)	(فلس/ك.و.س)	(فلس/ك.و.س)	(فلس/ك.و.س)	(فلس/ك.و.س)	
										أ. المشتركين المنزليين
0.0%	0.0%	0.0%	0.0%	0.0%	33	33	33	33	33	من 1- 160 كيلو واط ساعة شهريا
0.0%	0.0%	0.0%	0.0%	0.0%	72	72	72	72	72	من 161- 300 كيلو واط ساعة شهريا
0.0%	0.0%	0.0%	0.0%	0.0%	86	86	86	86	86	من 301- 500 كيلو واط ساعة شهريا
0.0%	0.0%	0.0%	0.0%	0.0%	114	114	114	114	114	من 501- 600 كيلو واط ساعة شهريا
7.5%	7.5%	7.5%	7.5%	0.0%	188	175	163	152	141	من 601- 750 كيلو واط ساعة شهريا
7.5%	7.5%	7.5%	7.5%	0.0%	224	209	194	181	168	من 751- 1000 كيلو واط ساعة شهريا
4.0%	5.0%	5.0%	10.0%	0.0%	296	285	271	259	235	أكثر من 1000 كيلو واط ساعة شهريا
										ب. المشتركين الاعتياديين
10.0%	10.0%	10.0%	10.0%	10.0%	53	48	44	40	36	من 1- 160 كيلو واط ساعة شهريا
10.0%	10.0%	10.0%	10.0%	10.0%	116	105	96	87	79	من 161- 300 كيلو واط ساعة شهريا
10.0%	10.0%	10.0%	10.0%	10.0%	139	126	114	104	95	من 301- 500 كيلو واط ساعة شهريا
10.0%	10.0%	10.0%	10.0%	10.0%	184	167	152	138	125	من 501- 600 كيلو واط ساعة شهريا
7.5%	7.5%	7.5%	7.5%	7.5%	202	188	175	163	152	من 601- 750 كيلو واط ساعة شهريا
5.0%	5.0%	5.0%	5.0%	5.0%	214	204	194	185	176	من 751- 1000 كيلو واط ساعة شهريا
5.0%	5.0%	5.0%	5.0%	5.0%	300	286	272	259	247	أكثر من 1000 كيلو واط ساعة شهريا

Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

1. Research Context Reality of Built Environment

Jordan, heating/cooling dominated country

Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

1. Research Context Reality of Built Environment

Energy Prices increase March 2013

الحكومة ترفع أسعار المحروقات

العرب اليوم
اعتبارا من اليوم

ارتفاع صفيحة البنزين "95 " 80 قرشا.. و"90"
70 قرشا والسولار والكاز 50 قرشا

رفعت الحكومة أسعار المشتقات النفطية اعتبارا من اليوم، بمقدار 70 قرشا لصفيحة البنزين اوكتان "90" و بمقدار 80 قرشا لصفيحة البنزين اوكتان "95"، في حين رفعت سعر صفيحة مادتي السولار والكاز نصف دينار.
وبموجب القرار ارتفع سعر صفيحة البنزين "90" من 16 دينارا الى 16.7 دينار، وصفيحة البنزين اوكتان 95 من 19.8 دينار لتصبح 20.6 دينار، وصفيحة السولار والكاز من 13.7 دينار لتصبح 14.20 دينار.
وبحسب القرار الصادر عن وزير الصناعة والتجارة، الدكتور حاتم الحلواني، بناء على تنسيب لجنة التسعير تم تثبيت سعر الغاز المنزلي عند 10 دنانير للاسطوانة.
وتأتي الاسعار الجديدة للمشتقات النفطية ، انعكاسا لأسعارها عالميا حيث يتم شهريا مراجعة الاسعار من قبل لجنة التسعير وتعديلها محليا بالنسب التي تتغير في الاسواق العالمية من حيث الانخفاض والارتفاع.
وبموجب القرار الذي سيبدأ العمل به اليوم وحتى 31 اذار الحالي تصبح أسعار المشتقات النفطية على النحو التالي:

1. Research Context Reality of Built Environment

NO to Nuclear !

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:

Building Properties:
Insulation
Building Codes
Indoor air quality

Occupant Behaviour & Subsidy

1.Research Context

Problem :

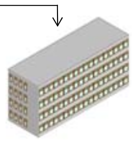
Building Properties:
Insulation
Building Codes
Indoor air quality

Occupant Behaviour & Subsidy

Objective:

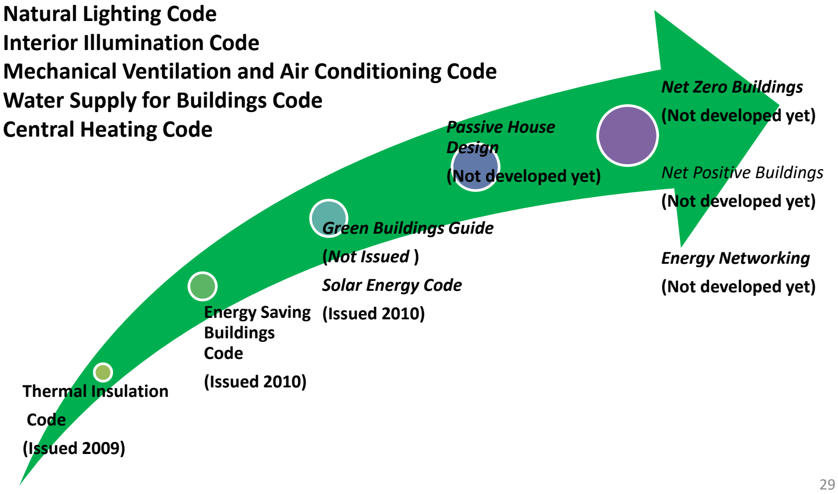
Investigate the potentials of NZEBs

Theoretically and Experimentally



Jordanian Building Energy Codes

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



29

Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

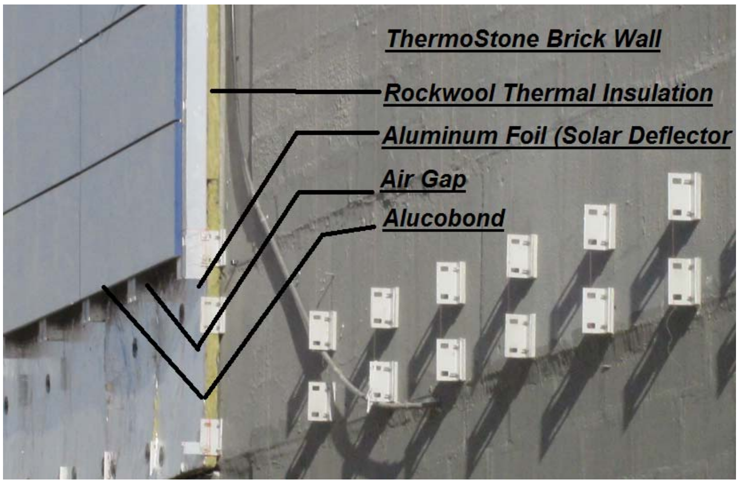
1.Research Objective
How to design a NZEB in Jordan?

Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

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

Source: Arup

How to avoid thermal bridges?



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

Aqaba Residence Energy Efficiency in Jordan - Florentine Visser

21 september 2009 / Florentine Visser
ARCHITECTURE

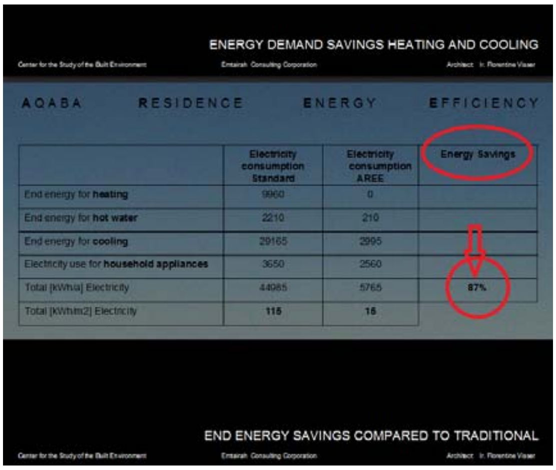
Last June the first sustainable building in Jordan opened to the public. Dutch Architect Florentine Visser was responsible for the design of the Aqaba Residence Energy Efficiency (AREE) project.

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

Slide taken from: http://www.donau-uni.ac.at/imperia/md/content/department/bauenumwelt/bs/01_aqaba_redsidence_energy_efficiency.pdf

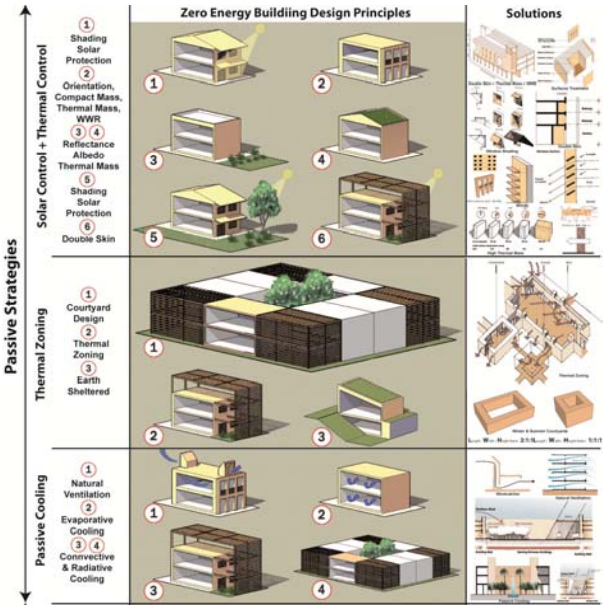


	Electricity consumption Standard	Electricity consumption AREE	Energy Savings
End energy for **heating**	9960	0	
End energy for **hot water**	2210	210	
End energy for **cooling**	29165	2995	
Electricity use for **household appliances**	3650	2560	
Total [kWh/a] Electricity	44985	5765	87%
Total [kWh/m2] Electricity	**115**	**15**	

How to design roofs to allow solar panels integrating ?

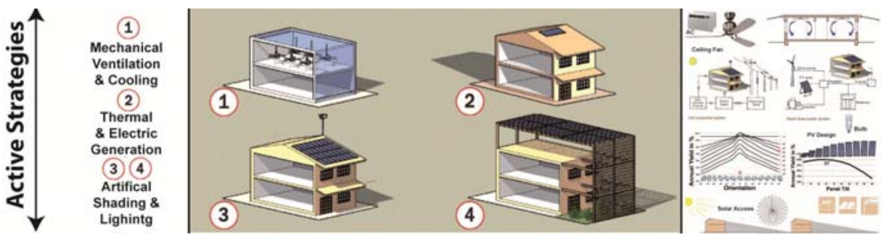
36

1.Research Objective



Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

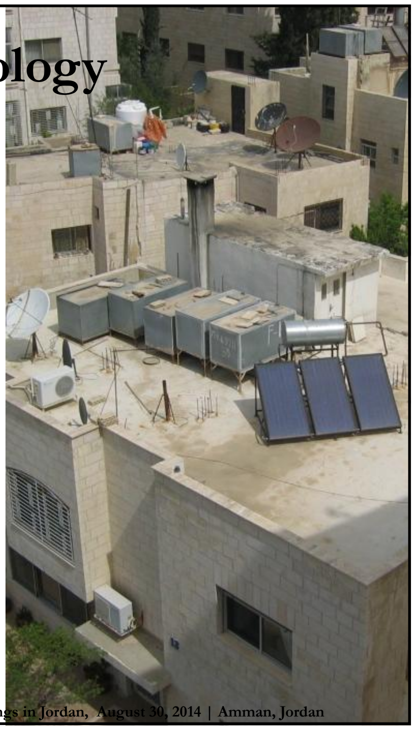
1.Research Objective



Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

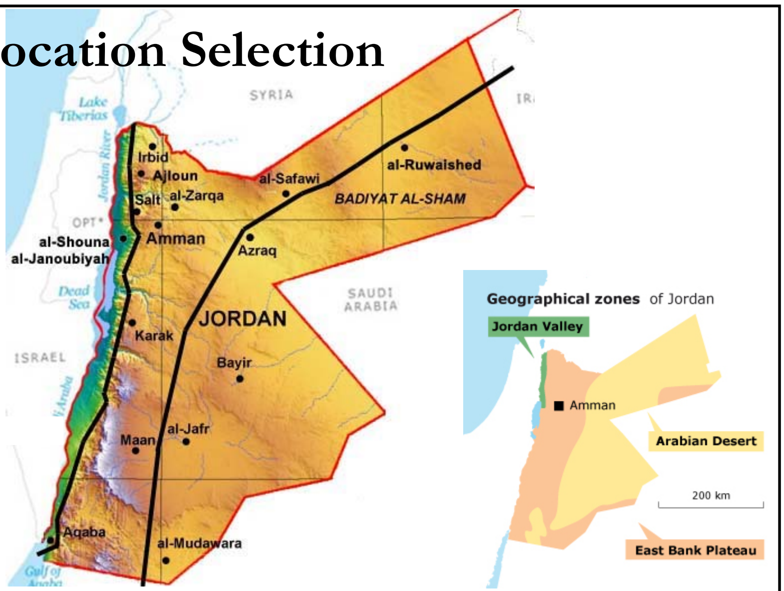
3.Research Methodology

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



Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

3. Location Selection

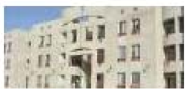


Climate-specific characteristics					
City	Aqaba, AQ	Al Shouna, SH	Amman, AM	Ajloun, AJ	Al-Ruwaished, AR
Latitude and Longitude	29.5-35.0	31.4-35.3	31.9-35.9	32.3-35.7	32.5-38.1
Altitude	51	-361	784	760	704
ASHRAE Zone	3	2b	3	3	3

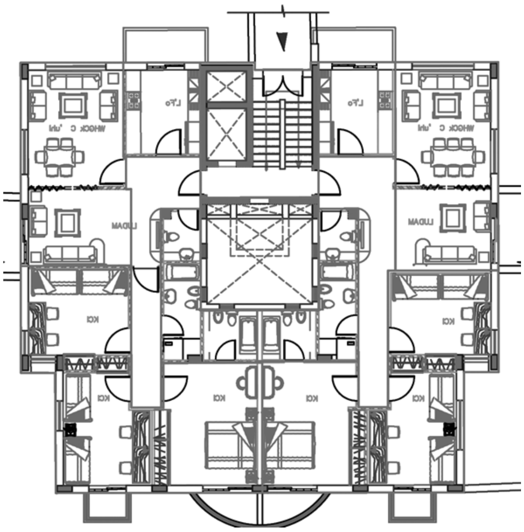
Shady Attia, Samer Zawaydeh , Strategic Decision Making Zero Energy Buildings in Jordan, August 30, 2014 | Amman, Jordan

4. Case Study: Basecase Selection
4.1 Building Description



4. Case Study: Basecase Selection
4.1 Building Description



43/20

4. Case Study: Basecase Selection
4.1 Building Description

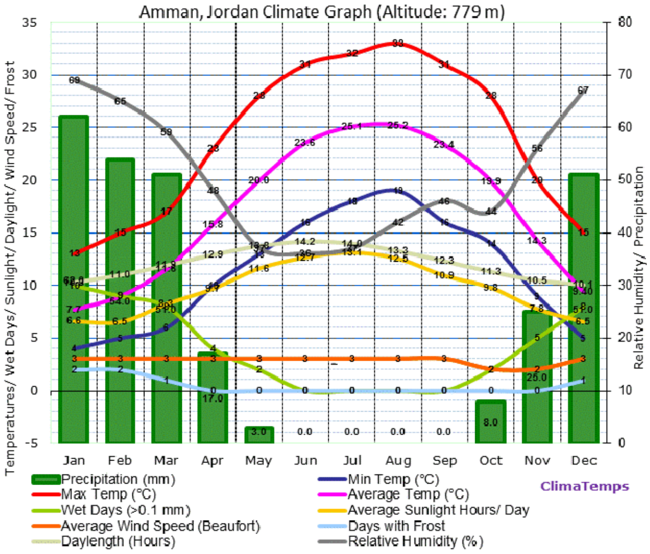
Table 1: Basecase building characteristics

Climate-specific characteristics					
City	Aqaba, AQ	Al Shouna, SH	Amman, AM	Ajloun, AJ	Al-Ruwaished, AR
Latitude and Longitude	29.5-35.0	31.4-35.3	31.9-35.9	32.3-35.7	32.5-38.1
Altitude	51	-361	784	760	704
ASHRAE Zone	3	2b	3	3	3
General Characteristics					
Building configuration:	130 m², three bedroom, rectangle-shape, one-story, single family				
Construction type:	Reinforced-concrete post and beam structure with brick infill walls				
Exterior walls:	Stone 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 aluminium 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, 0.86 energy factor				
Thermostat set point:	20°C (68°F) for heating, 25.5°C (78°F) for cooling, 5°F set back 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				

4. Case Study: Basecase Selection

4.2 Climate Analysis

Zone 1 (Aqaba and Al Shouna al-Janubiyah) are cooling dominated
Zone 2 (Amman and Ajloun) are heating dominated
Zone 3 (Al-Ruwaished) are mixed, cooling and heating dominated.



4. Case Study: Basecase Selection

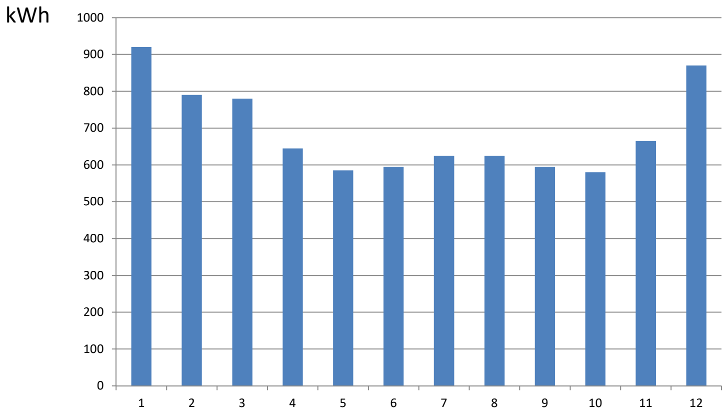
4.3 Appliances Inventory

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

4. Case Study: Basecase Selection

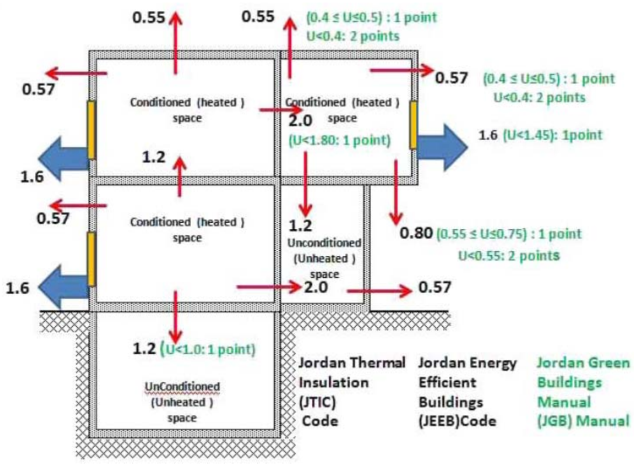
4.4 Survey: Typical Energy Consumption

Survey Results 3500- 8000 kWh/apartment/annum



5. Energy Performance

1. Envelope



Thermal Insulation
U Value for Walls

Mandatory Thermal Insulation Code Table(5-1, 5-2)	Mandatory Energy Saving Buildings Code Table(2-2, 2-3)	Mandatory Green Building Manual	Optional (1point) Green Building Manual	Optional (2 points) Green Building Manual
Solid walls = 0.57	Solid walls = 0.57	Solid walls = 0.57	Solid walls = 0.50-0.4	Solid walls = <0.4
All External walls =1.6	All External walls =1.6	All External walls =1.6	All External walls =1.45	All External walls =1.45

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

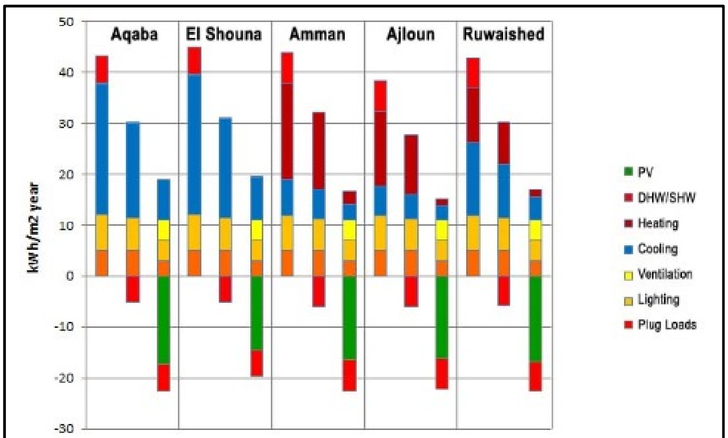
Table 2: Basecase, code compliance and maximum energy efficiency characteristics

	Properties	Basecase characteristics	Measures for Code Compliance	Measures for maximum efficiency NZEB
1	Roof U-value:	U=1 W/m².K	U=0.55 W/m².K	U=0.1 W/m².K with radiant barrier
2	Wall R-value:	U=2 W/m².K (no radiant barrier)	U=0.57 W/m².K (no radiant barrier)	U=0.2 W/m².K with radiant barrier
3	Window system:	U=5.8 W/m².K), SHGC:- Single Pane in aluminium frame	U=3.1 W/m².K), SHGC:0.75 Double Pane Low-E aluminium frame	U-value: 0.5, SHGC: 0.25, Double Pane Low-E, Argon, Fiberglass frame
4	Operable Shading:	operable window without exterior shading	operable window without exterior shading	Venetian Blinds Close if Sun on Window & Indoor Temp above comfort
5	Overhang:	none	none	1m overhang and fins (E,W, S)
6	Night insulation:	not considered	not considered	50% reduction in glass conductance, Insulated roller shutter
7	Infiltration:	0.7 ACH	0.5 ACH	0.35 ACH
8	Internal heat gain*:	0.19 kW from lighting, 0.71 kW from appliances	0.14 kW from lighting, 0.67 kW from appliances	0.05 kW from lighting, 0.50 kW from appliances
9	Natural Ventilation	Windows and Doors are manually OPENED if cooling is needed	Windows and Doors are manually OPENED if cooling is needed	Windows and Doors are manually OPENED if cooling is needed
10	Fan Forced Ventilation	no Fans for Comfort Cooling	No Fans for Comfort Cooling	Fans for Comfort Cooling
11	Thermostat set point:	20°C (68°F) for heating, 25.5°C (78°F) for cooling (RH=60%)	20°C (68°F) for heating, 25.5°C (78°F) for cooling (RH=60%)	20°C (68°F) for heating, 25.5°C (78°F) for cooling (RH=60%)
12	Heating system:	Gas Furnace: AFUE 65%	Gas Furnace: AFUE 65%	Gas Furnace AFUE: 90%
13	Cooling system:	Split System: Heat Pump EER 13/7.7	Split System: Heat Pump EER 13/7.7	Split System: Heat Pump EER 19/8.5 (Energy Star)
14	Ventilation system:	none	none	Mechanical Ventilation with heat recovery:

6. Results: Dynamic Simulation

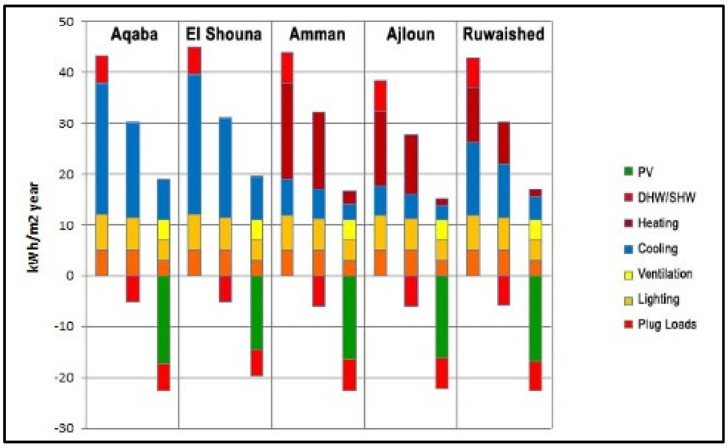
- Jordanian Thermal Insulation Code reduce the energy use up to 40% (equivalent to 32 kWh/m²/year).
- Up to 66% energy use could be reduced for the NZEB objective (equivalent to 18 kWh/m²/year)
- The reduction in fossil based DHW use resulted in an equivalent SHW energy savings (5.5 kWh/m²/year).

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.



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

Electric Rates in Tiers (2013)	T1=0.05 $, T2=0.1 $, T3=0.12 $, T4=0.15 $, T5=0.19 $			
Fuel Rates	2 Propane, 1.07043 $/therm Baseline, 1.32664 $/therm Above Baseline, Propane: 3$/Gallon, Heating Oil: 2.9$/Gallon			
	Cost (Code Compliance)	**Payback (Code Compliance)**	**Cost (Maximum Efficiency)**	**Payback (Maximum Efficiency)**
Envelope	3500 $	9 years	8.000 $	18 years
HVAC	-	-	4250 $	10 years
Flat Solar Water Heater (5m²)	900 $	3 years	900 $	3 years
PV panels (15m²) = 3000 KWh	-	-	5.000 $	12 years
Average Annual Energy Consumption/ Total Payback	32 kW/m²/year	9 years	18 kW/m²/year	44 years

- 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?**

Strategic Decision Making For Zero Energy Buildings in Jordan

Samer Zawaydeh
Eng., CRM, REP, AEE Life Member

Shady Attia, PhD, ED®AP
shady.attia@hotmail.com
Assistant Prof. of Sustainable Building Construction
Head of Sustainable Building Design Lab (SBD)
Univeristé de Liège (Ulg)
http://www.shadyattia.net/