Beirut Solar Map

Sara Najem

National Center for Remote Sensing- CNRS

February 17, 2017

Outline

- Energy Demand/Supply in Lebanon
- Introduction
  - Solar Radiation
- Algorithm
  - City Scale Computation of Solar Irradiance
  - Model Parameters and Assumptions
- Results
- Ongoing Work

Energy Demand/Supply in Lebanon

- $\approx 95\%$ of the energy needs are imported in the form of fuel.
- National production $\approx 5\%$.
- Yearly growth in energy demand $\approx 3 - 7\%$.

---

salem2009.

salem2009.

chedid2002.

Demand/Supply

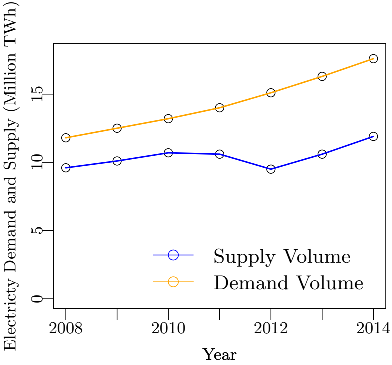


Figure : Evolution of the production and supply from 2008 to 2014

Demand/Supply

- The cost of electricity generation is around 23 cents/kWh
- Subscribers are charged 2.33 to 13.33 cents/kWh.

Energy Crisis

With 3 hours of electricity rationing in Beirut and up to 8 elsewhere in the country we're particularly interested in estimating the solar energy.

Energy Crisis

Lebanon's target for 2020: 12 percent of the energy produced from renewables (Copenhagen 2009).

Lebanon also committed to a target of 15% in its Intended Nationally Determined Contributions (INDC) submitted to the COP21 conference.

Solar Maps

- Solar maps are produced in major cities in the United States: Boston, Boulder, Cambridge, NY, San Francisco, Washington County, Wellfleet
- Internationally: Lo Barnechea (Chile), Vitacura (Chile)

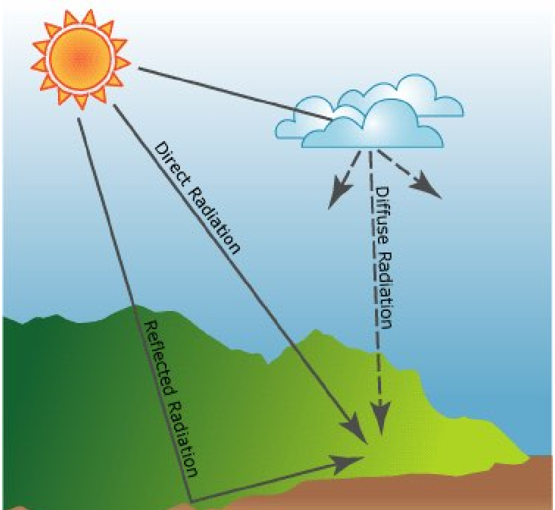
Solar Maps

- Regionally, Beirut is the first city to be mapped. It is DSS application designed for National Center ofo Remote Sensing- CNRS as part of Local-Sats.

Solar Radiation

- Direct radiation.
- Diffuse radiation.
- Reflected radiation.

Solar Radiation



Basic Definitions

- Irradiance is understood as instantaneous density of solar radiation incident on a given surface, typically expressed in W/m^2.
- Irradiation is the sum of irradiance over a time period (e.g. 1 hour, day, month, year, etc.) expressed in J/m^2.

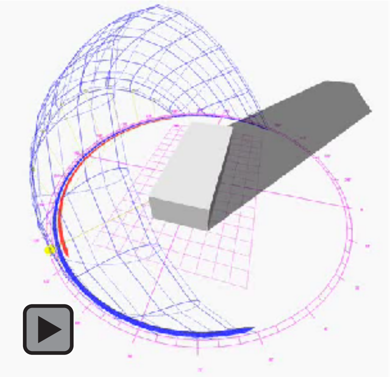
Irradiation

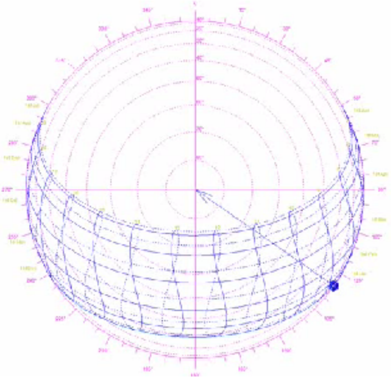
Irradiation is then affected by the sun’s position and cloud coverage and both of which are related to the location’s latitude.

Sun Path

The sun path changes on hourly and monthly scales; this has an effect on the amount of irradiation a surface gets.

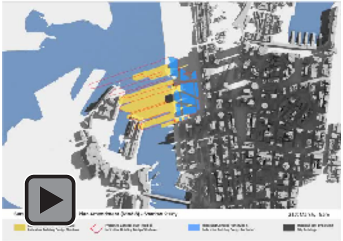
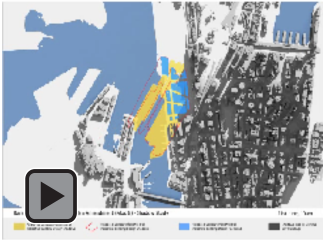
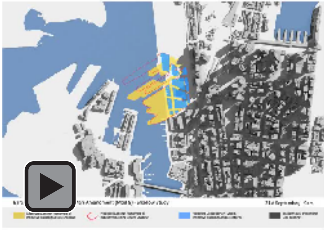
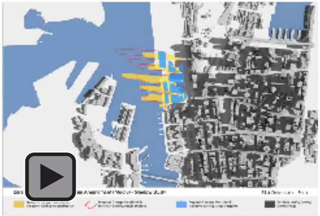
Illustrative Animation of the Solar Path





City solar irradiation

For a city things become more complex as overshadowing of rooftops from neighboring buildings comes to play.

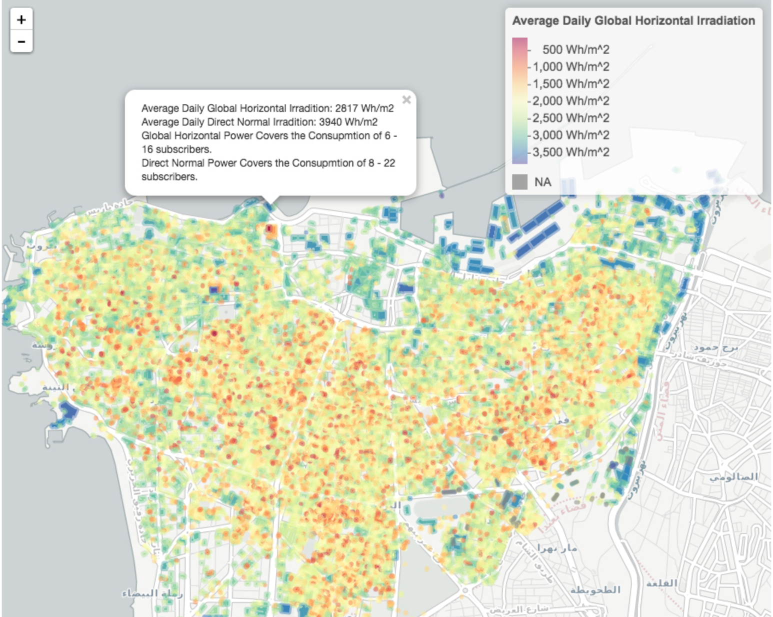





Model Parameters and Assumptions

- Flat roof-tops (LIDAR imagery or any 3D data would improve the model's predictions)
- With water tanks mounted on rooftops only a fraction of the rooftops is usable $\approx 30\%$

Model Parameters and Assumptions

- The fraction of diffuse radiation is taken to be 0.3 throughout the year.
- Panel efficiency is 10%


Average Daily Global Horizontal Irradiation
500 Wh/m^2
1,000 Wh/m^2
1,500 Wh/m^2
2,000 Wh/m^2
2,500 Wh/m^2
3,000 Wh/m^2
3,500 Wh/m^2
NA
Average Daily Global Horizontal Irradition: 2817 Wh/m2
Average Daily Direct Normal Irradition: 3940 Wh/m2
Global Horizontal Power Covers the Consupmtion of 6 - 16 subscribers.
Direct Normal Power Covers the Consupmtion of 8 - 22 subscribers.

Comparison with Climatic Zoning

- The climatic zoning Average Daily Global Horizontal Irradiation (ADGHI) $4854.6 Wh/m^2$
- (ADGHI) is $\approx 2000 Wh/m^2$
- Our computation is carried out in an urban setting taking into consideration overshadowing form neighboring buildings; this explains the discrepancy

Results

- Generation Potential 394 GW/year assuming the whole rooftop area is usable
- 30% usable rooftop yields 118 GW/year.

Results

- Subsequently the savings could range from around $9.8 M to nearly $39.3 M
- CO_2 emissions saving could range from 75,920 tCO_2 to 322,660 tCO_2

Ongoing Work

- The results are now being drafted as a policy paper in collaboration with the Director of the Energy Policy Program at Issam Fares Institute Dr. Ali Ahmad

Ongoing Work

- We are carrying out a study to model Beirut Energy hourly consumption
- Alaa Krayem is our PhD student; she is co-supervised by Dr. Haitham Zaraket of LU and Dr. Issam Lakkis of AUB.

Ongoing Work

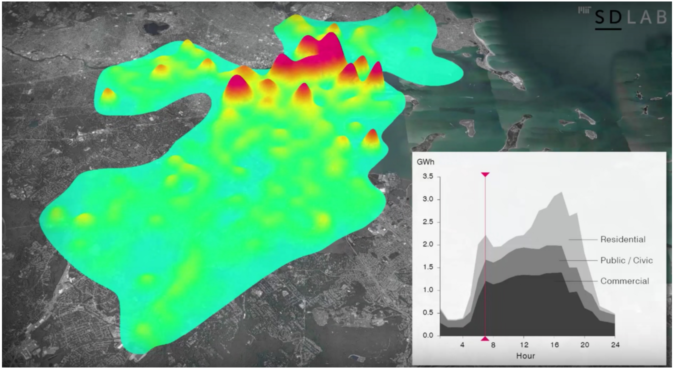


Figure : Boston's Energy Model

Thank you!