NSERC Smart Net-Zero Energy
Building Strategic Research Network

Réseau De Recherche Stratégique Du sur les bâtiments a consommation
énergétique net zéro

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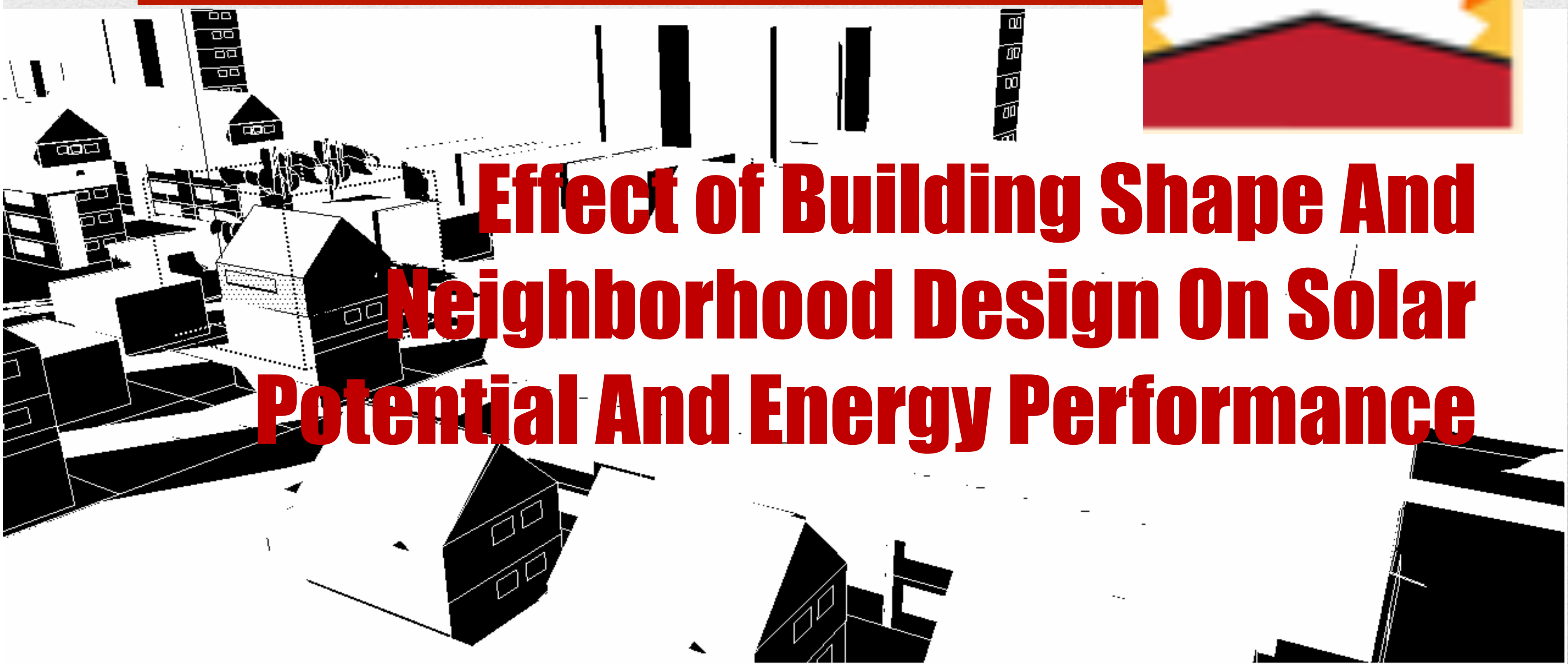
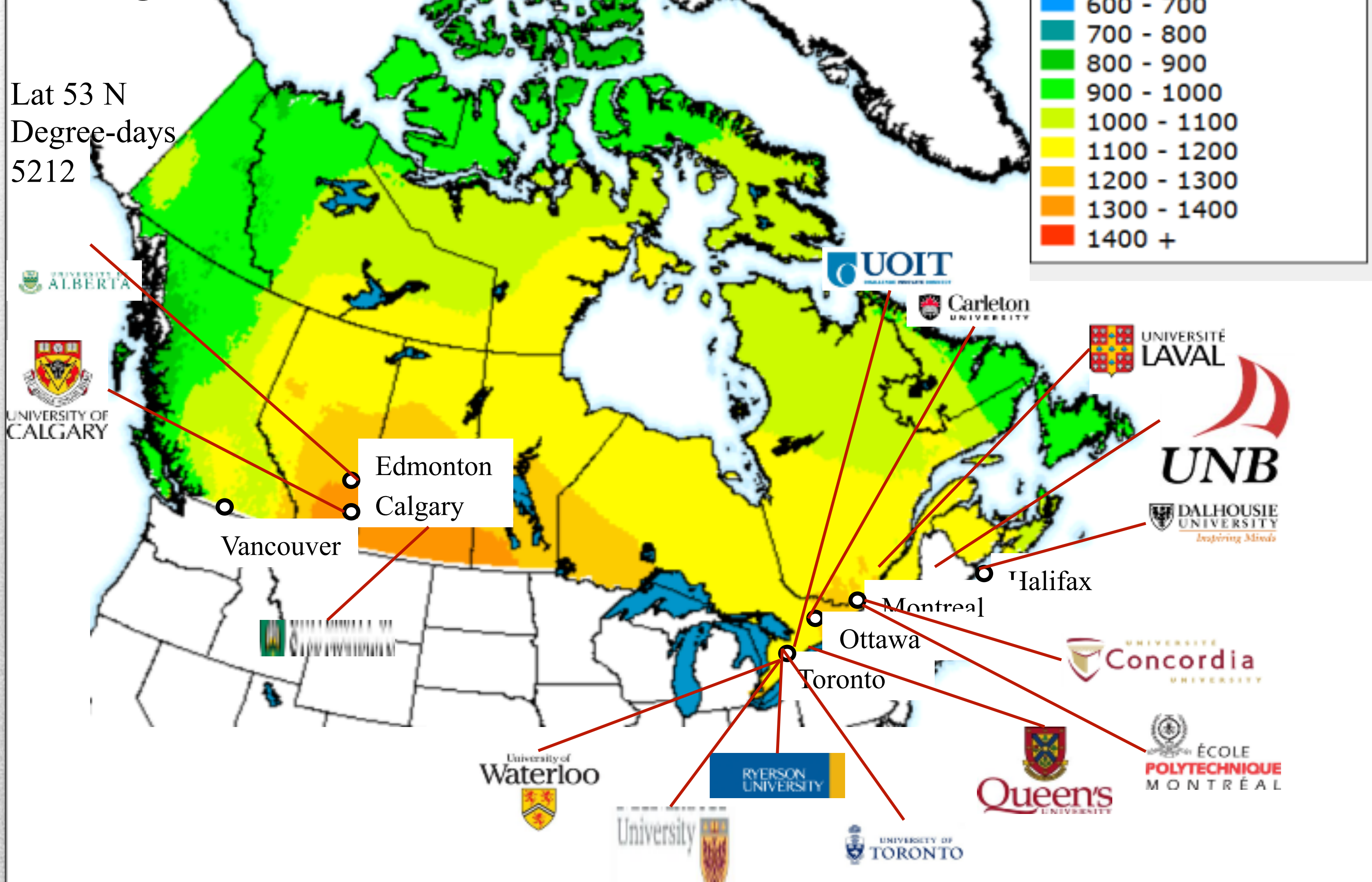
Effect of Building Shape And Neighborhood Design On Solar Potential And Energy Performance



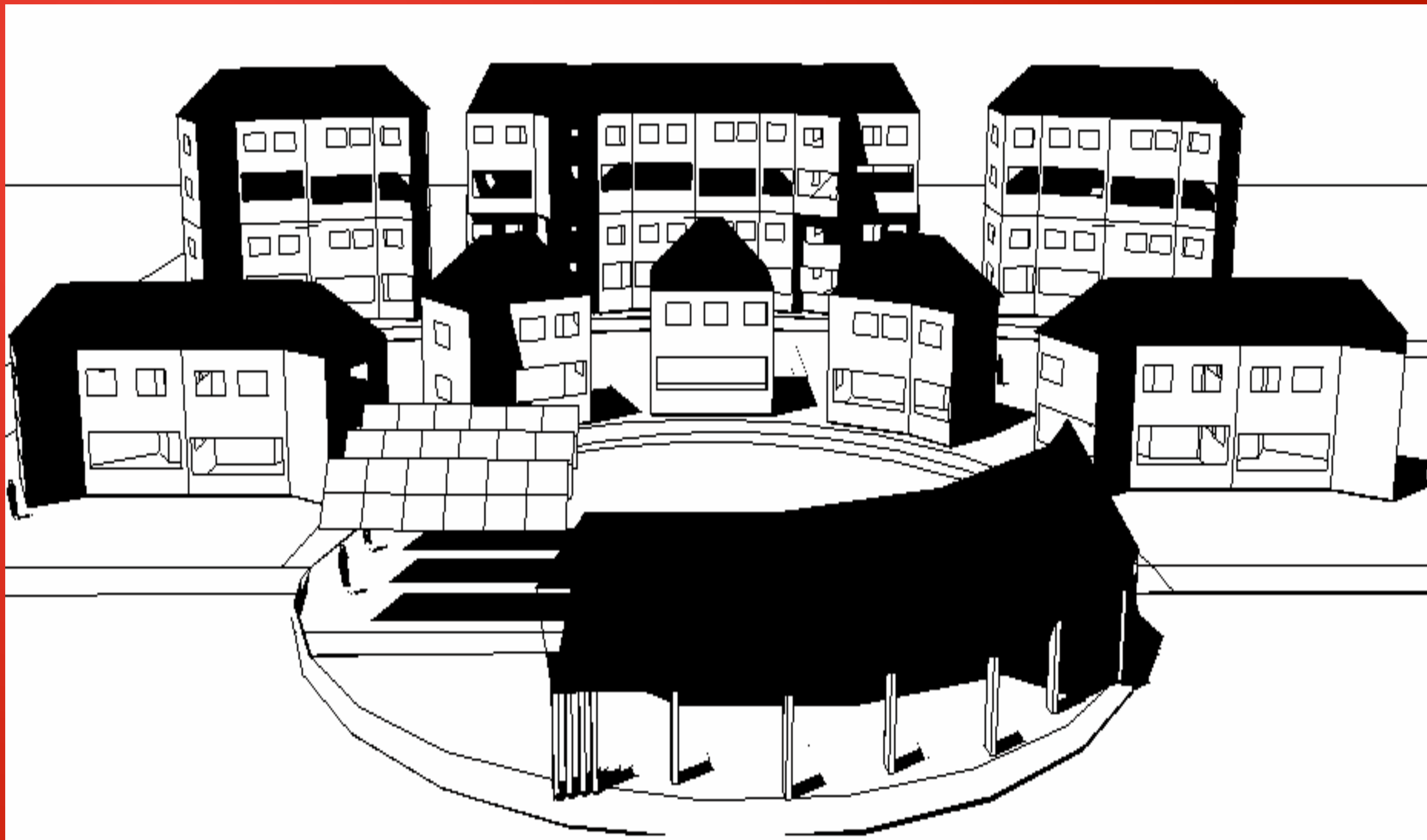
PV potential of Canada and SNEBRN

29 researchers from 15 Universities, NRCan, Hydro Quebec, Gaz-Metro, building industry leaders

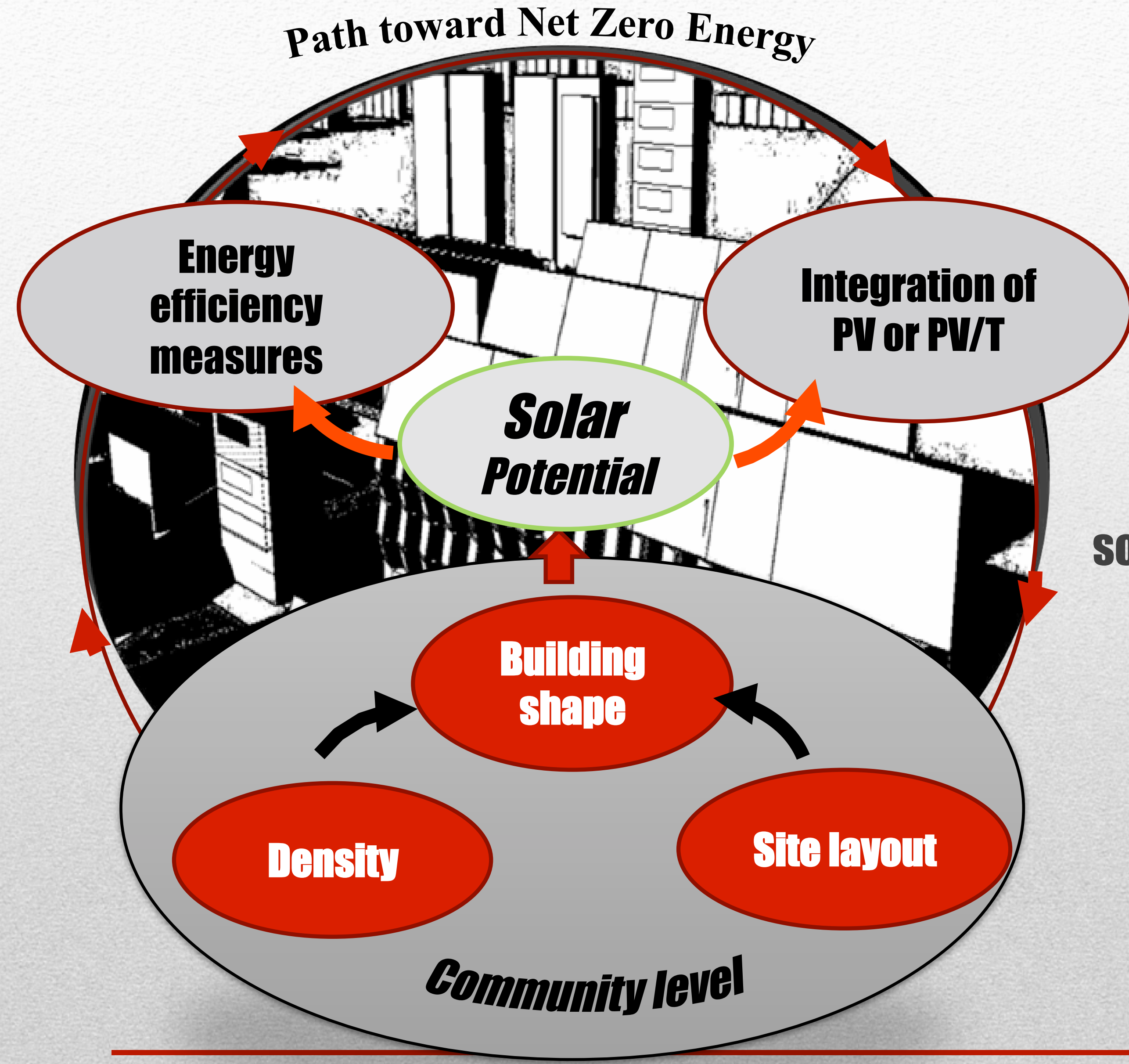


- **Building design plays a key role in influencing energy consumption of neighbourhoods.**
- **Some design parameters can significantly affect the solar potential and energy performance of houses and neighborhood**
  - **They should be implemented since the design stage.**

This presentation assumes that we have the possibility to design a whole solar neighborhood, or a cluster of buildings in a neighborhood.



TOWARDS NET ZERO ENERGY COMMUNITIES



A holistic systematic design approach for solar neighborhoods is required

Path Towards Net Zero Energy Neighborhood

1. Housing design

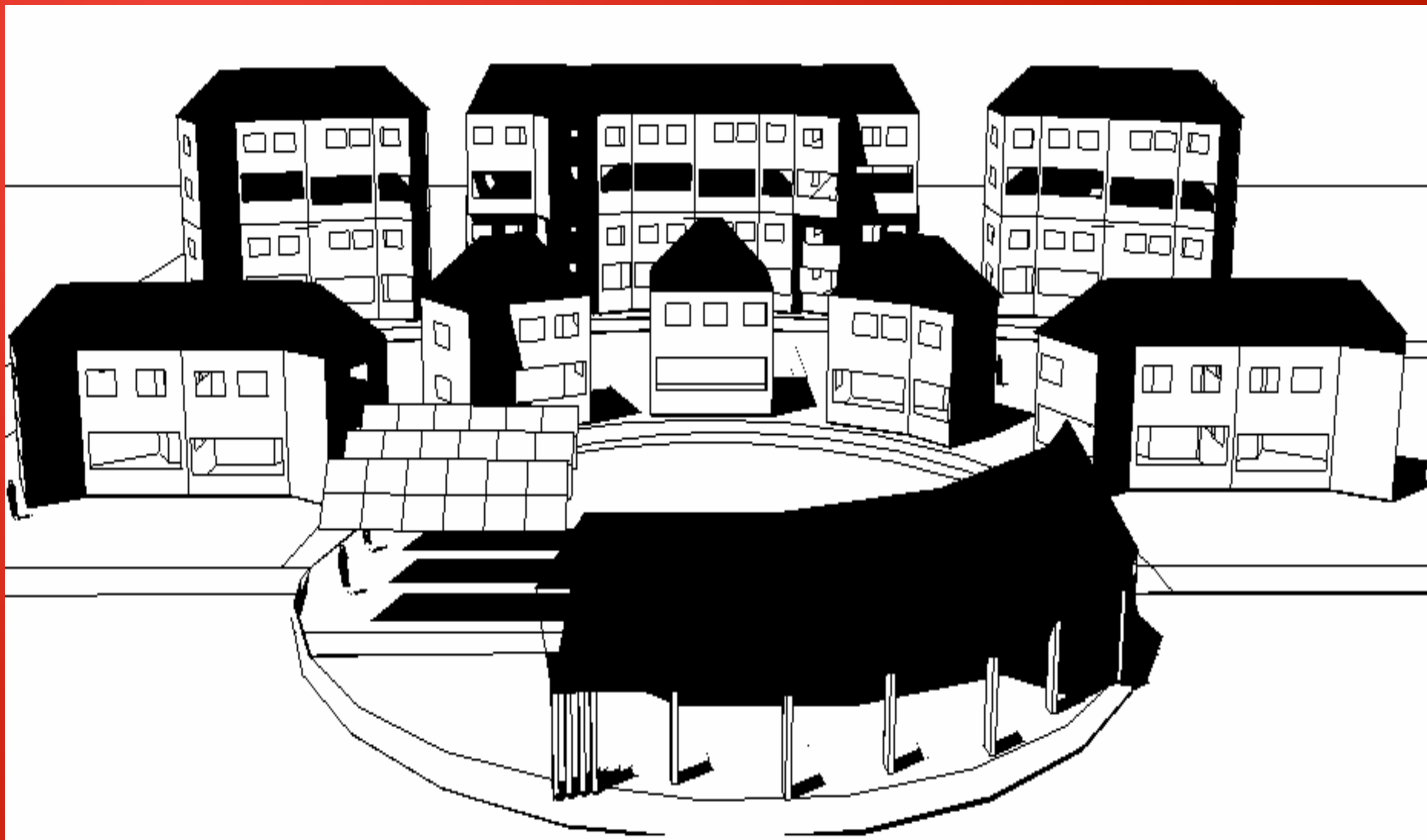
- Building envelope
- Geometrical parameters
- Roof design-ready for the integration of solar collectors

2. Neighbourhood design

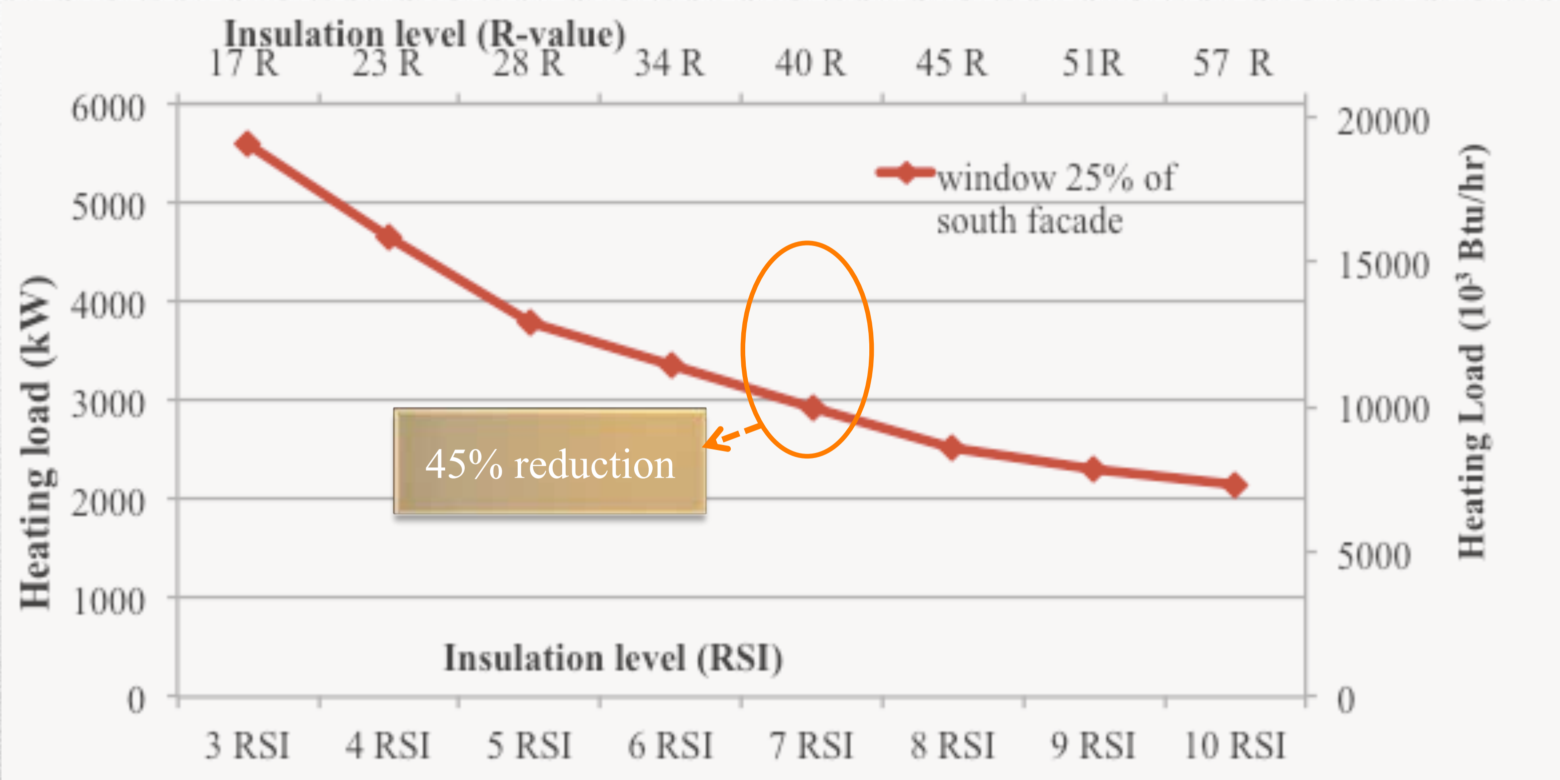
- Road layout
- Density: Row and spacing effects

3. Towards Mixed Use Neighbourhoods

Program

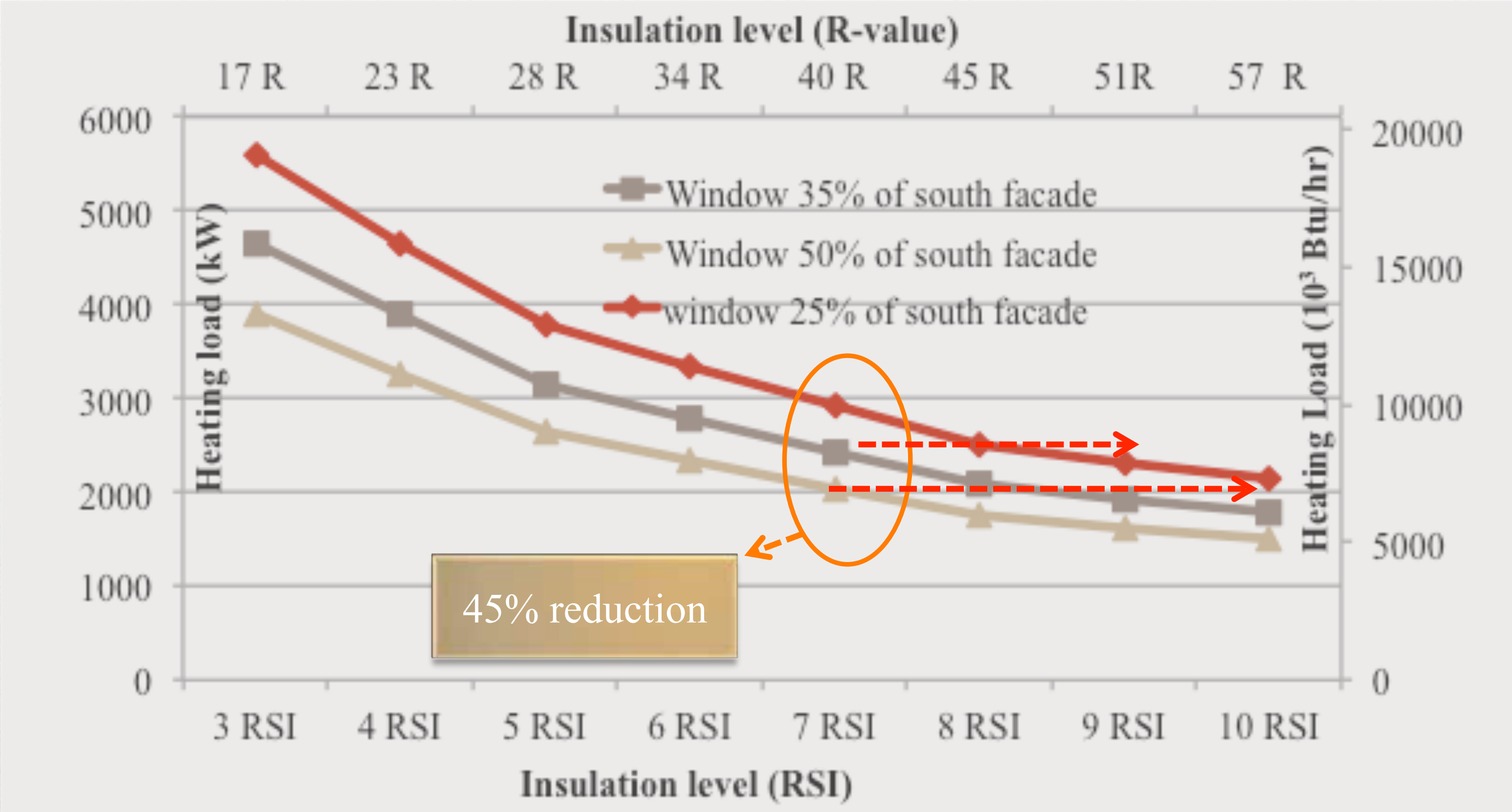


BUILDING DESIGN



Dwelling Shapes

Insulation and South Window Effect



- **Trade-off between using higher insulation and larger south facing window area.**
- **Optimal value of insulation is selected to balance between the increase in cost and energy saving.**

Dwelling Shapes

Insulation and South Window Effect

Effect of window properties

Dwelling Shapes

Insulation and South Window Effect

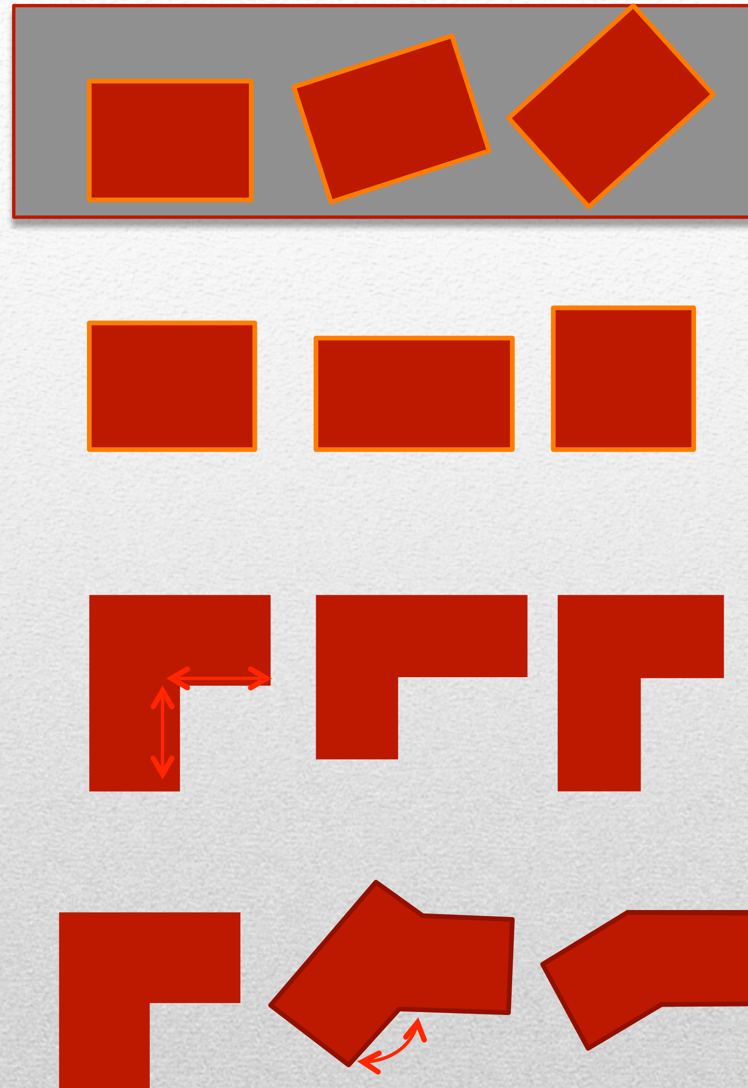
Dwelling Shapes

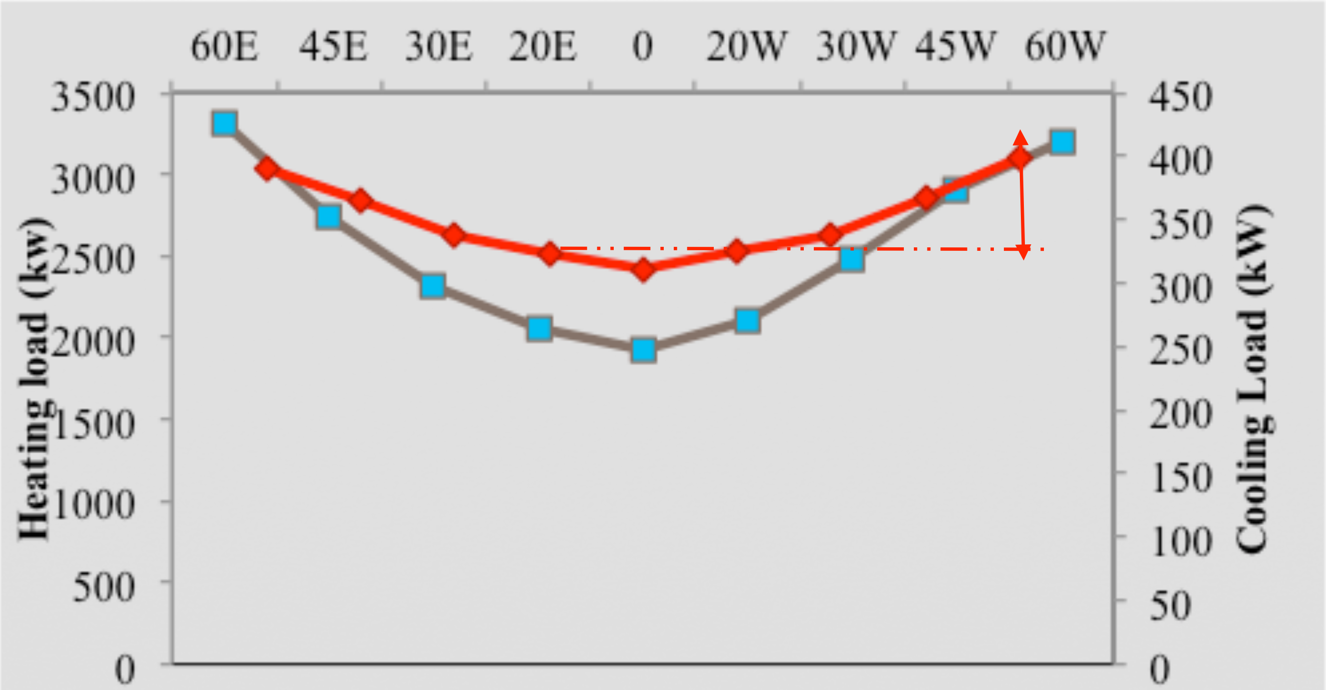
Orientation

Aspect Ratio

Depth Ratio

Angles between mutually shading facades



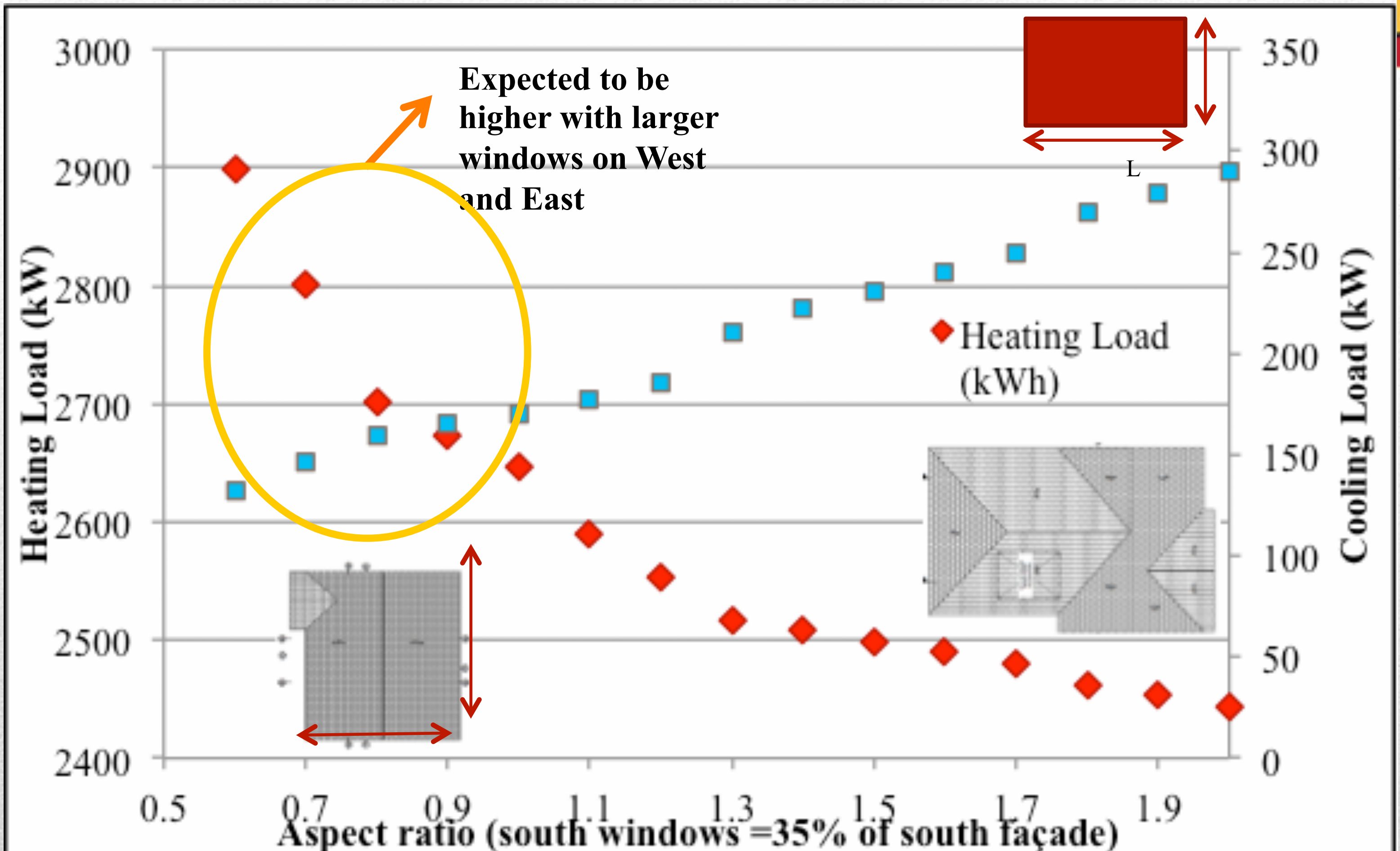


Increase of heating load by 30%

- 0°-30° - increase of heating load by 8%
- 30°-60° - increase of heating load by 30%

Dwelling Shapes

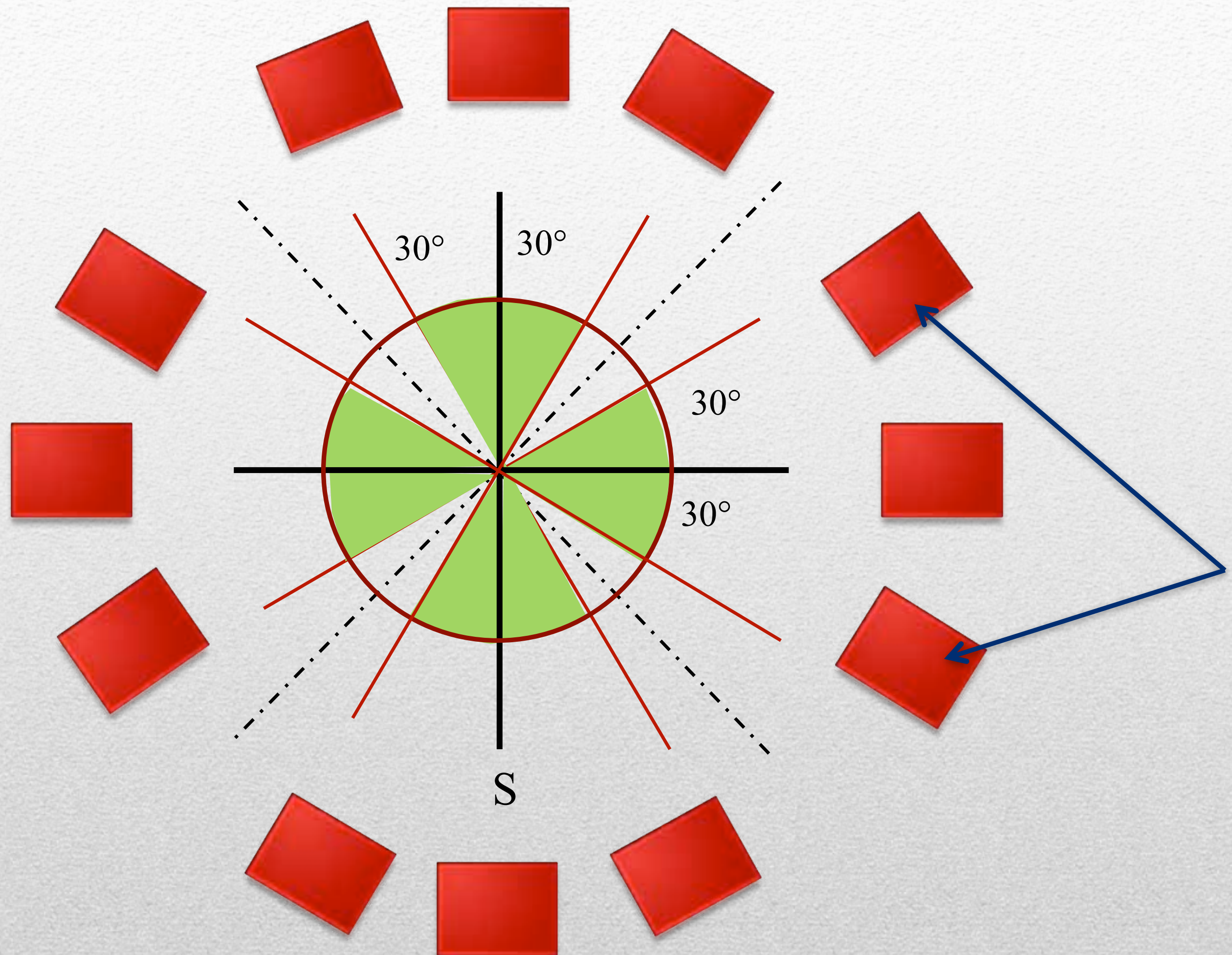
Orientation



- The aspect ratio should be selected to compromise between heating and cooling loads

Dwelling Shapes

Aspect Ratio

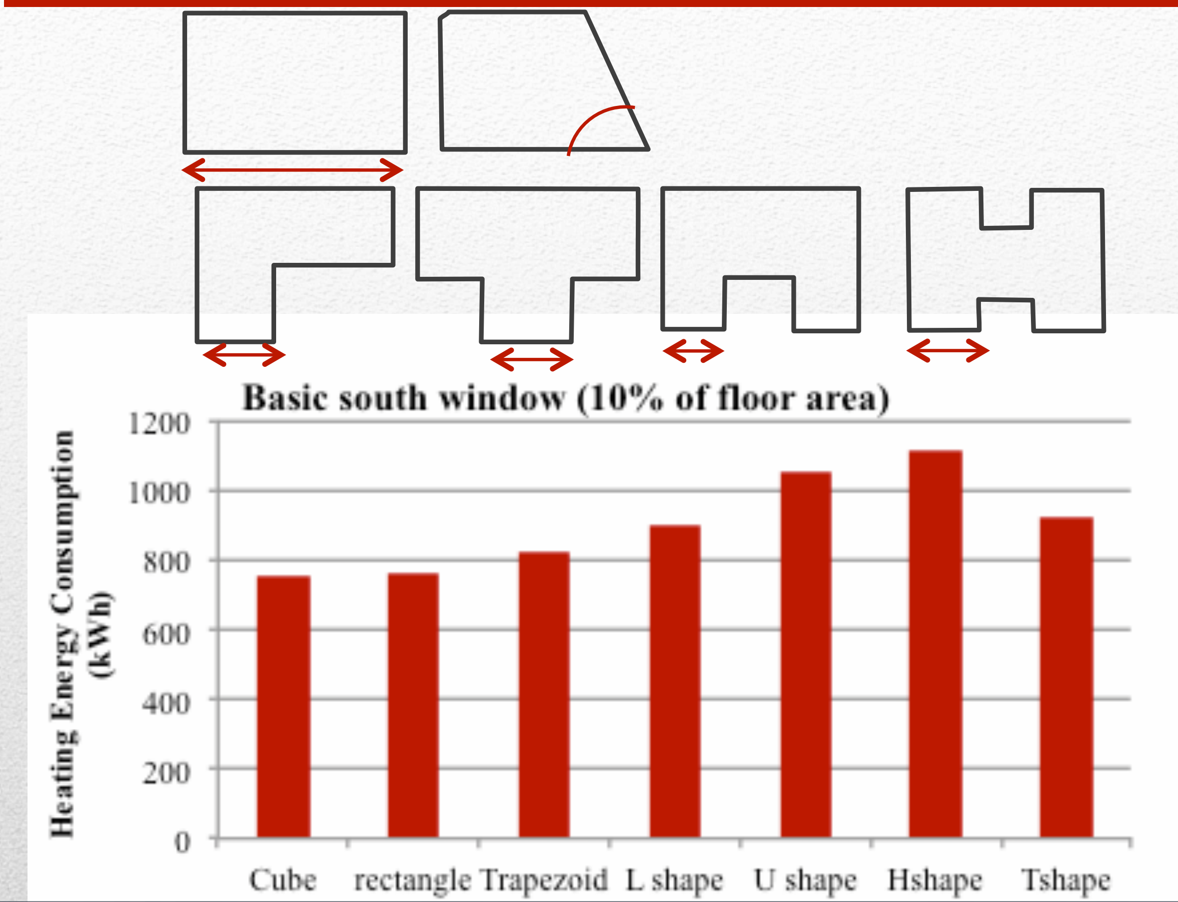


Important to design the larger facade of the building with a near south orientation

Solar neighbourhood design

Orientation

4

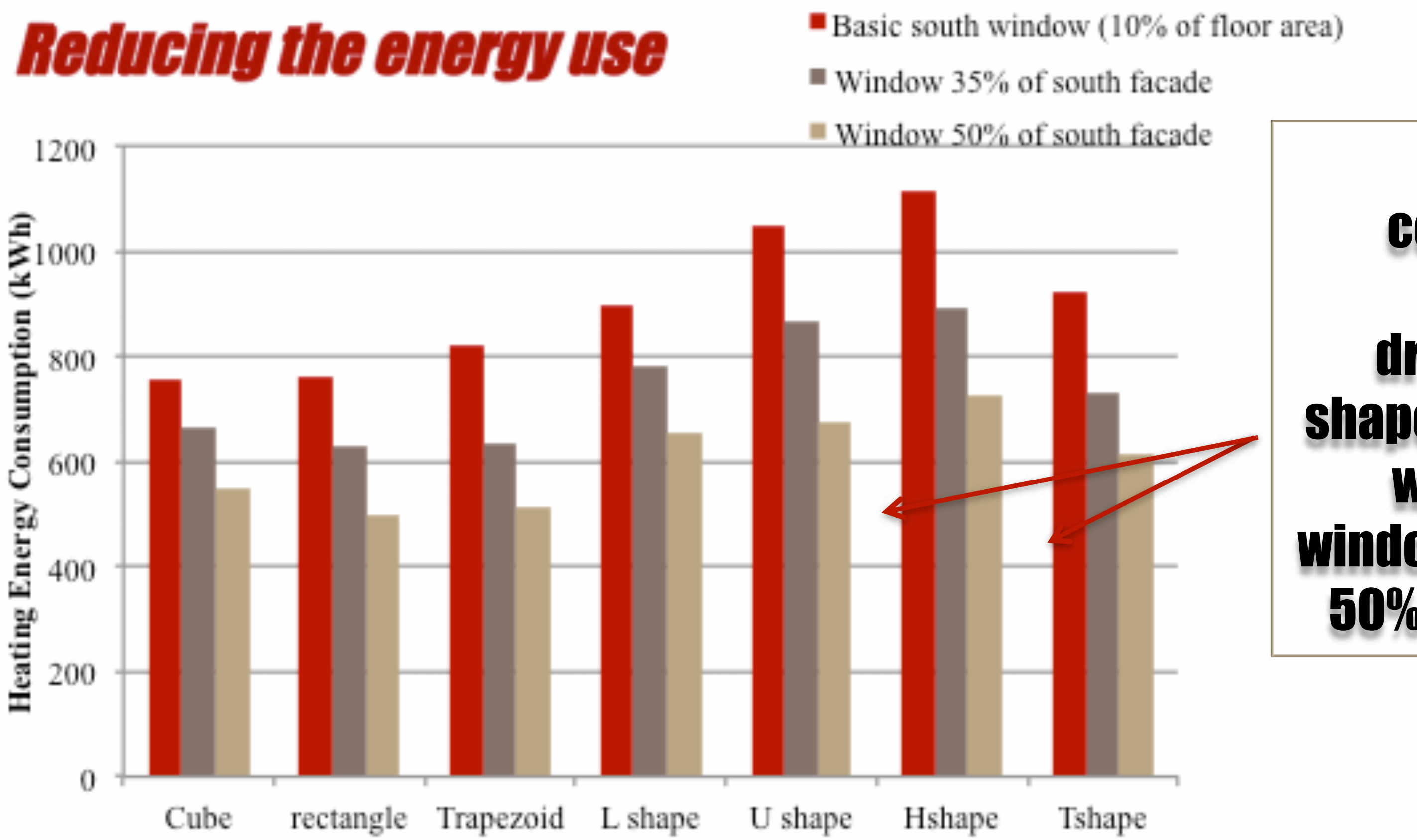


- Deviation from rectangular shape leads to increase in heating load, however
  - Proper design of facades and windows can reduce the energy use
  - Non rectangular shapes may counterbalance the increase of heating load

Dwelling Shapes

Geometry

Reducing the energy use



Heating consumption is reduced dramatically for shapes like U and H when the south window constitutes 50% of the façade.

- Deviation from rectangular shape leads to increase in heating load, however
  - Proper design of facades and windows can reduce the energy use
  - Non rectangular shapes may counterbalance the increase of heating load

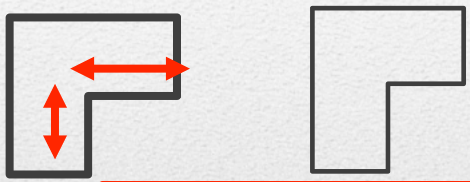
Dwelling Shapes

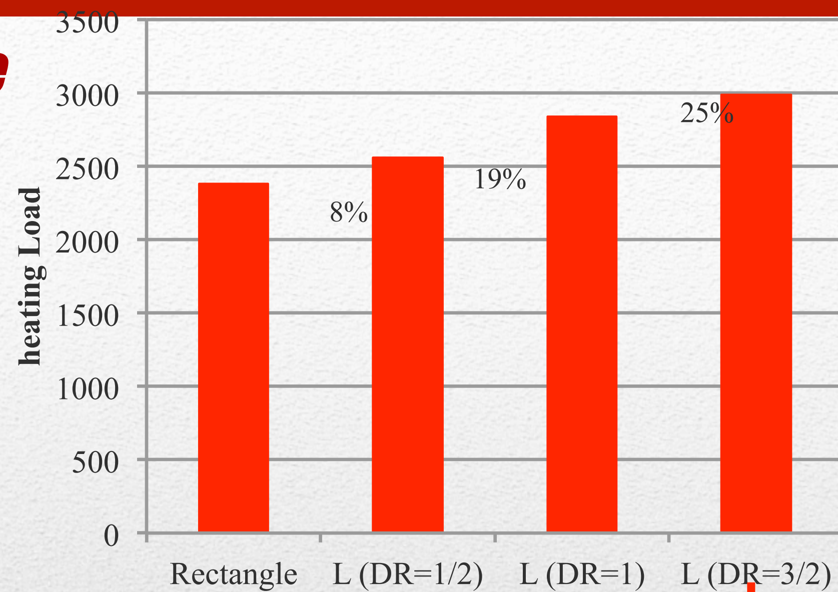
Geometry

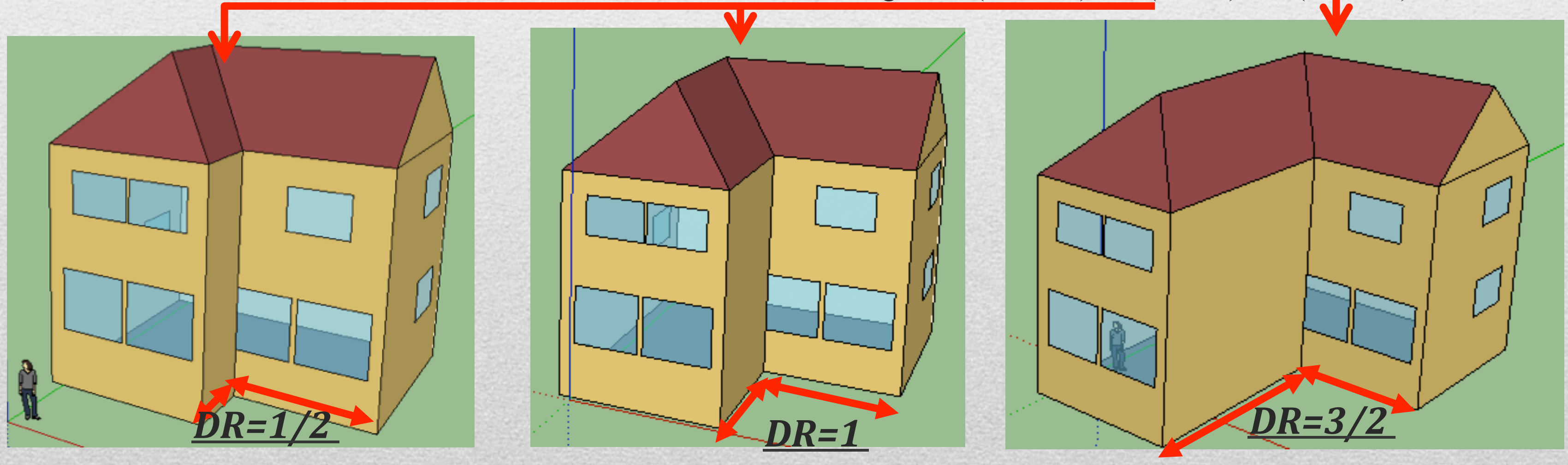
Reducing the energy use

Number of shading facades

Depth Ratio (DR)



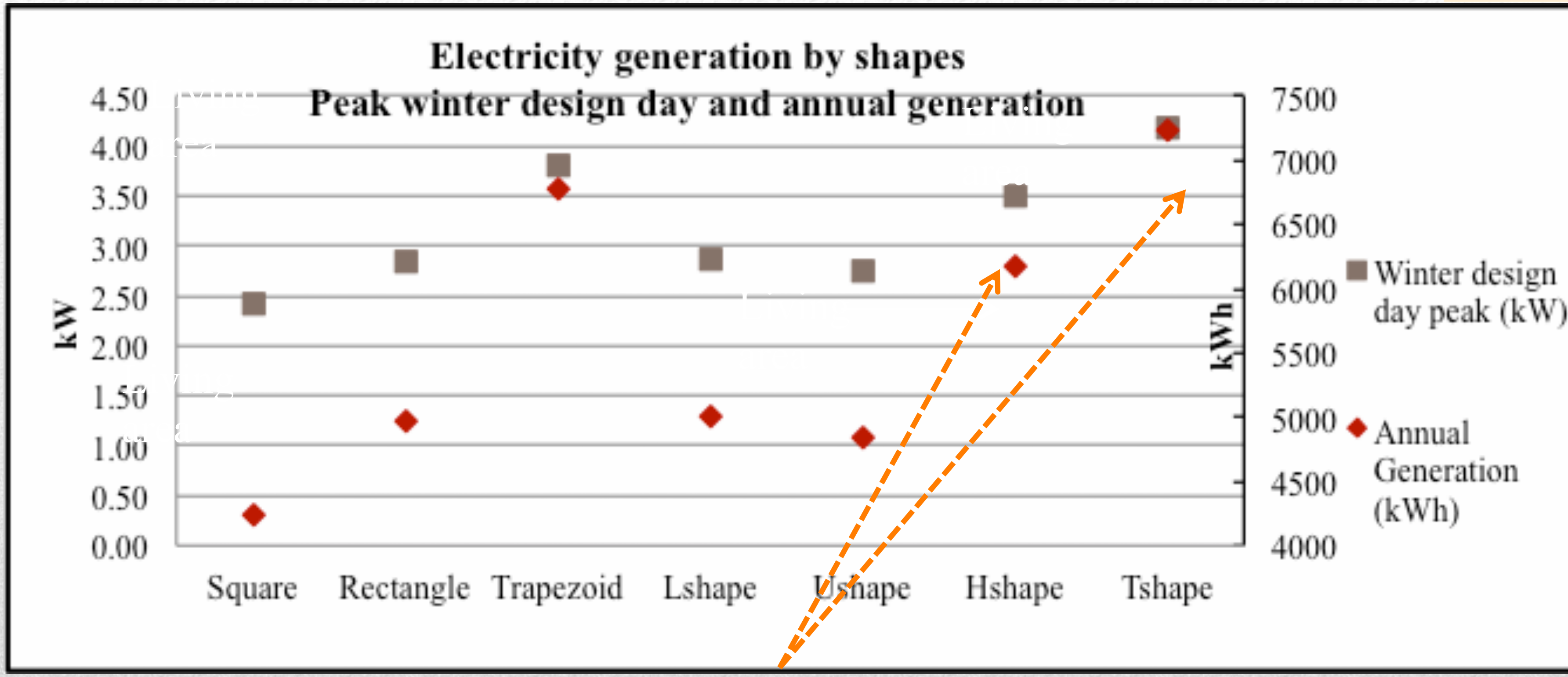




Dwelling Shapes

Geometry

Benefits of non rectangular shapes

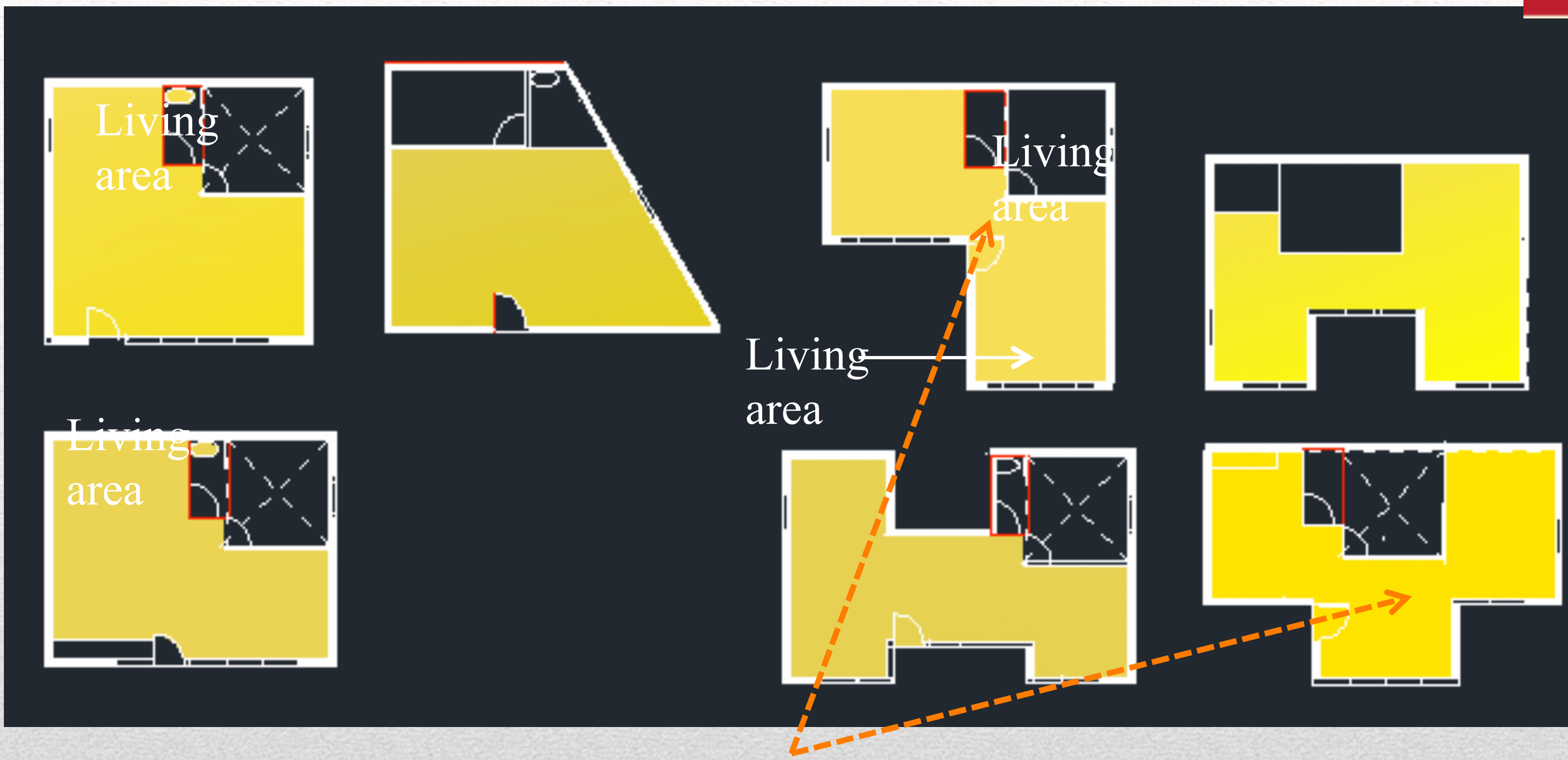


- Building shapes like in shapes, H and T shapes have larger south facing roof are for the same floor area and therefore have the potential to integrate larger PV system.

Dwelling Shapes

Geometry

Benefits of non rectangular shapes

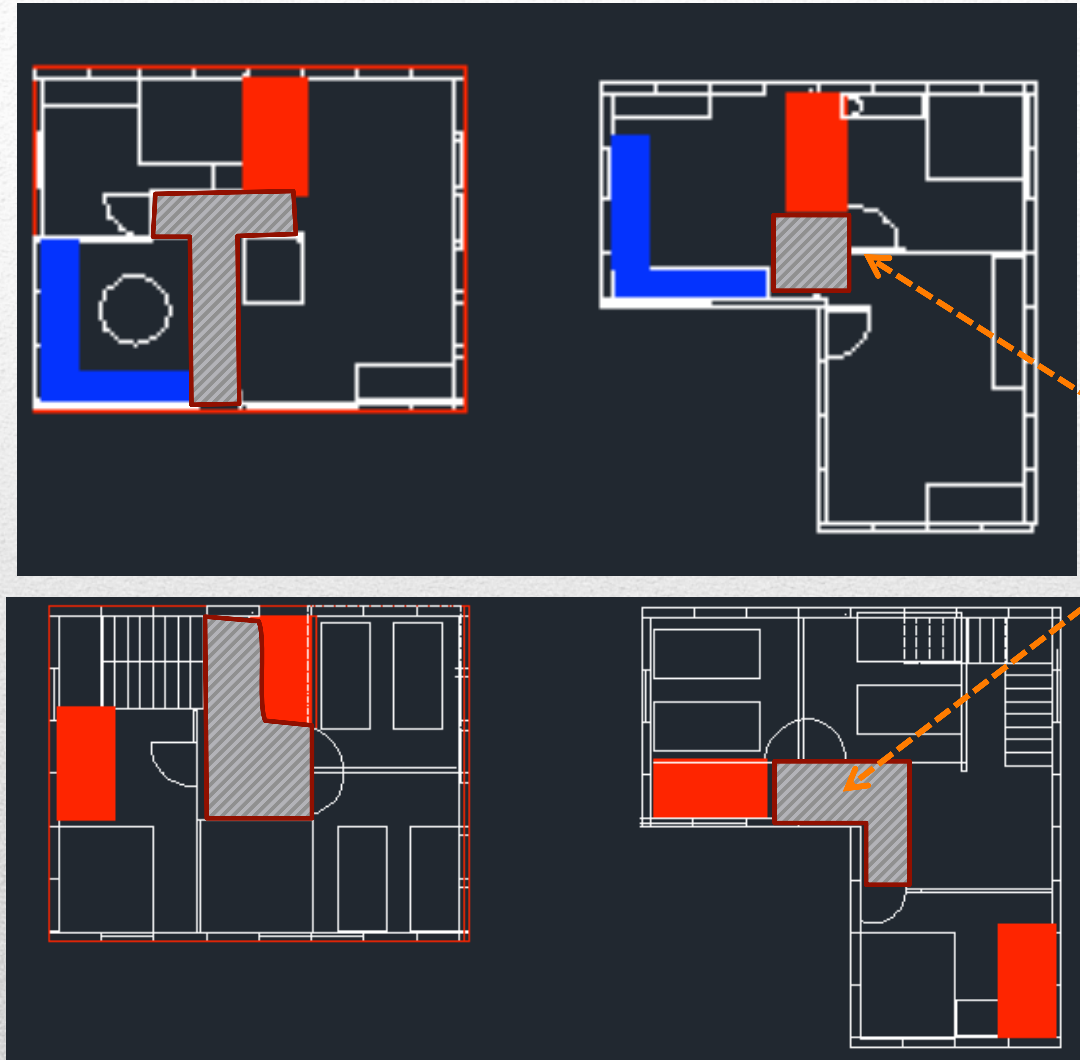


- Living areas in shapes like L , U and T shapes have less depth

→penetration of solar radiation which is beneficial for daylight and passive heat

Dwelling Shapes

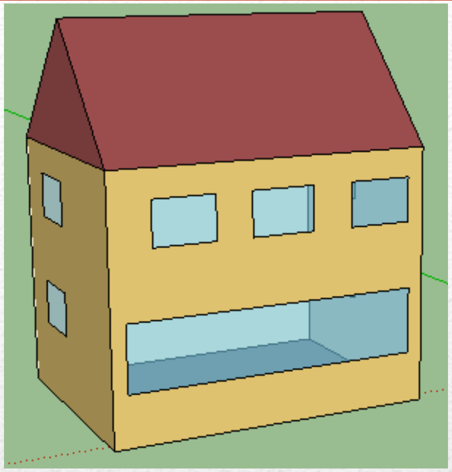
Geometry



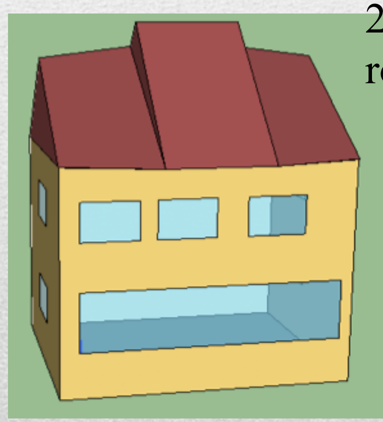
Reduction of wasted space for circulation and vestibules, which can save land area

Dwelling Shapes

Geometry

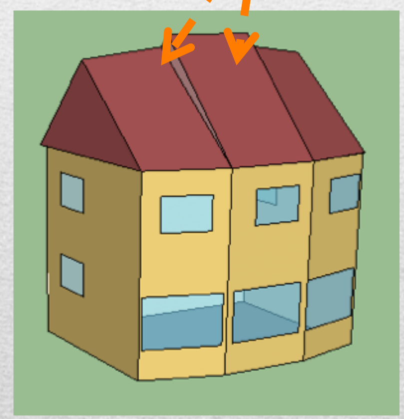


Different tilt angle
Optimal radiation
for summer and
winter



20% more
roof area

(a)

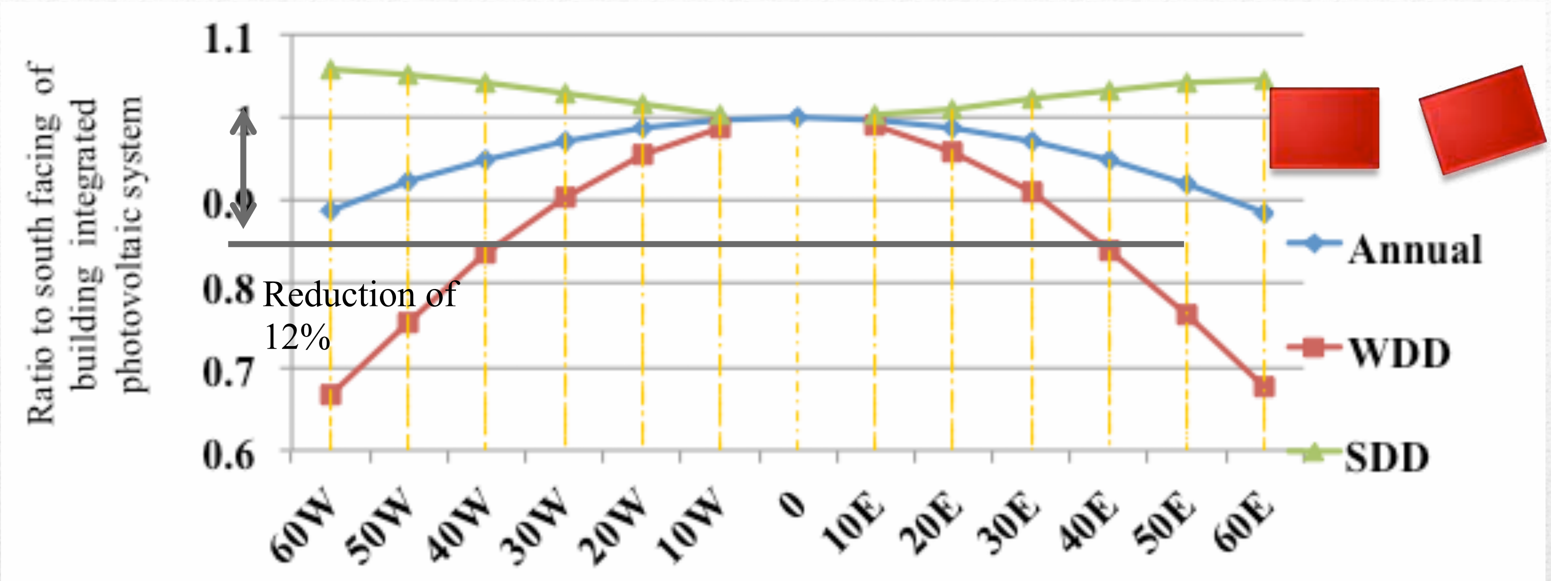


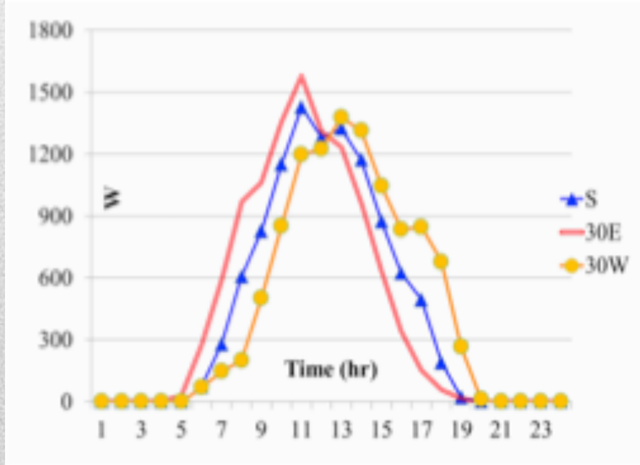
(b)

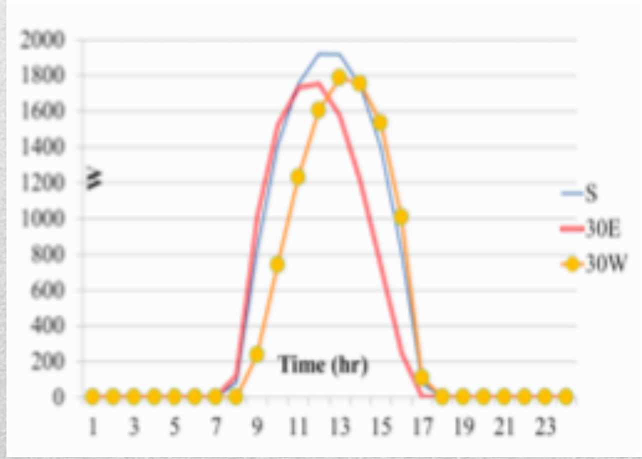
- Optimal tilt angle approximates the latitude of the location
- Optimal orientation is near south

Photovoltaic Integration

Tilt Angle

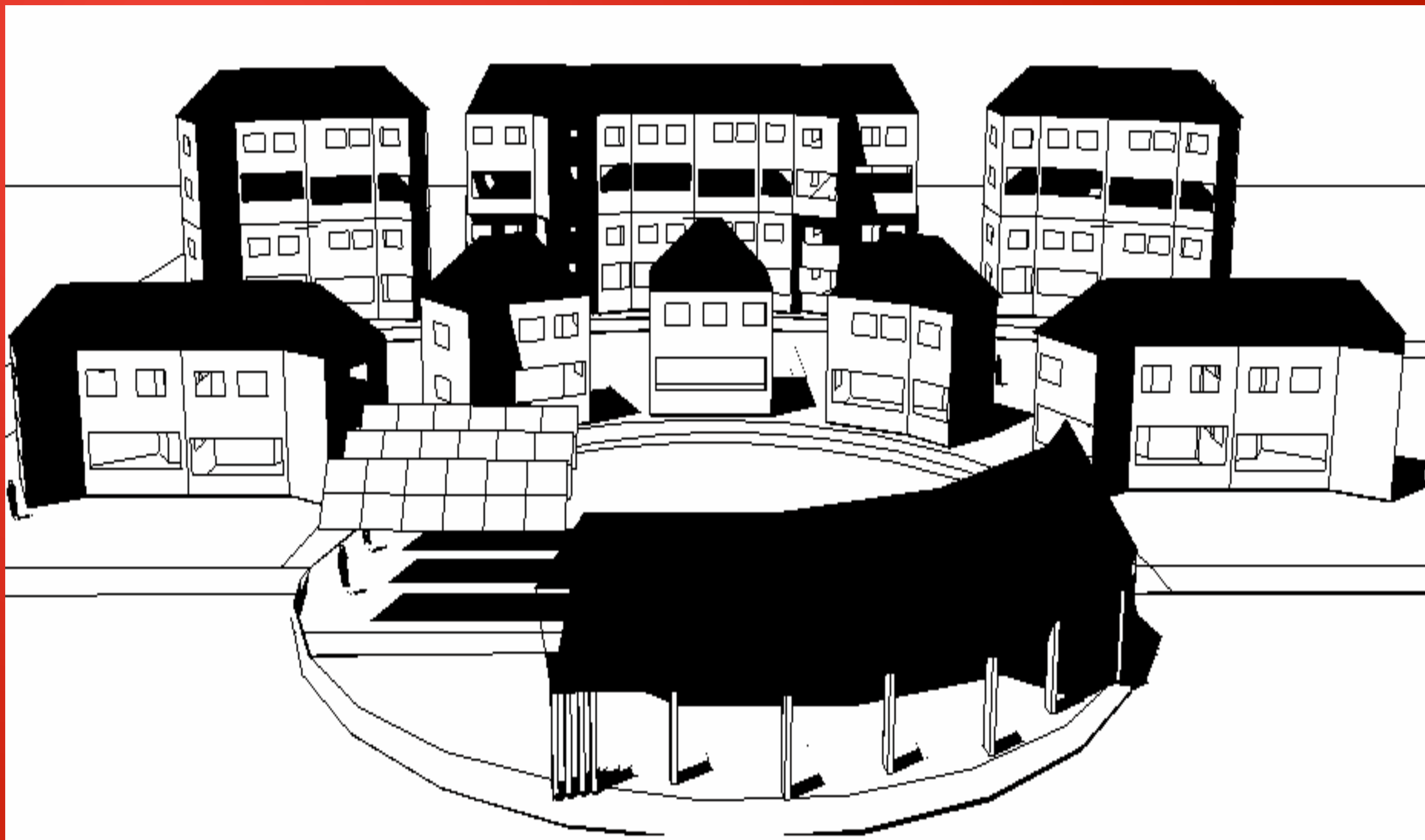






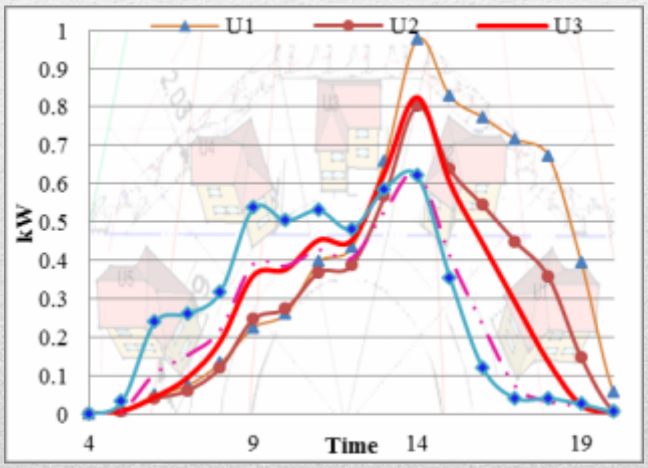
Photovoltaic Integration

Orientation



NEIGHBORHOODS

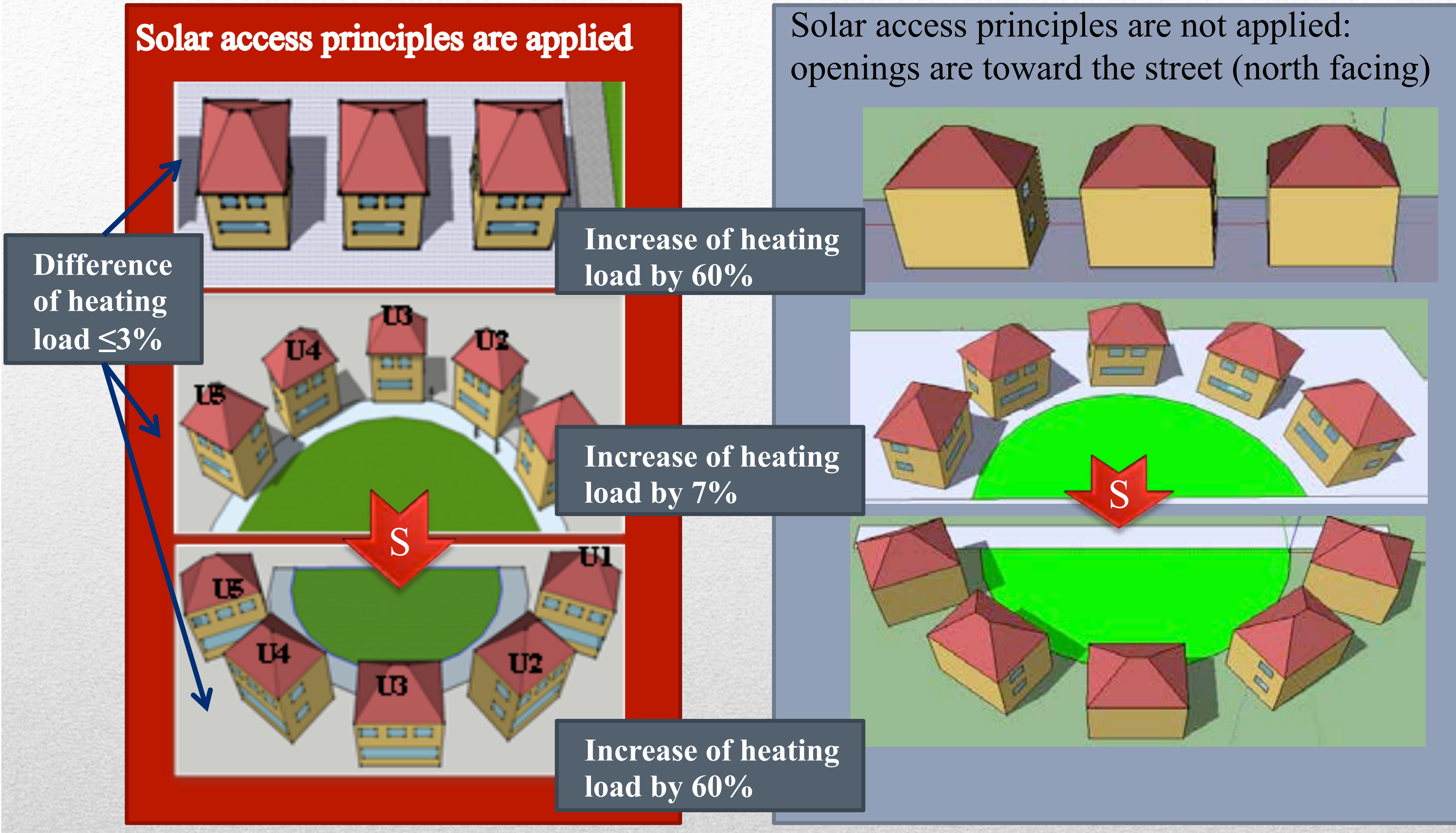
- Solar community concepts allow for:
  - **non-rectangular or rectangular house shapes and designs,**
  - appropriate BIPV roof designs,
  - optimal design passive solar gains.
- These designs affect significantly **the peak demand and the peak generation of electricity.**



Hachem C., A. Athienitis, P. Fazio, (2011), **Investigation of Solar Potential of Housing Units in Different Neighborhood Designs,** *Journal of Energy and Buildings*, Volume 43, Issue 9, Pages 2262-2273.

Solar neighbourhood design:

Optimizing solar potential

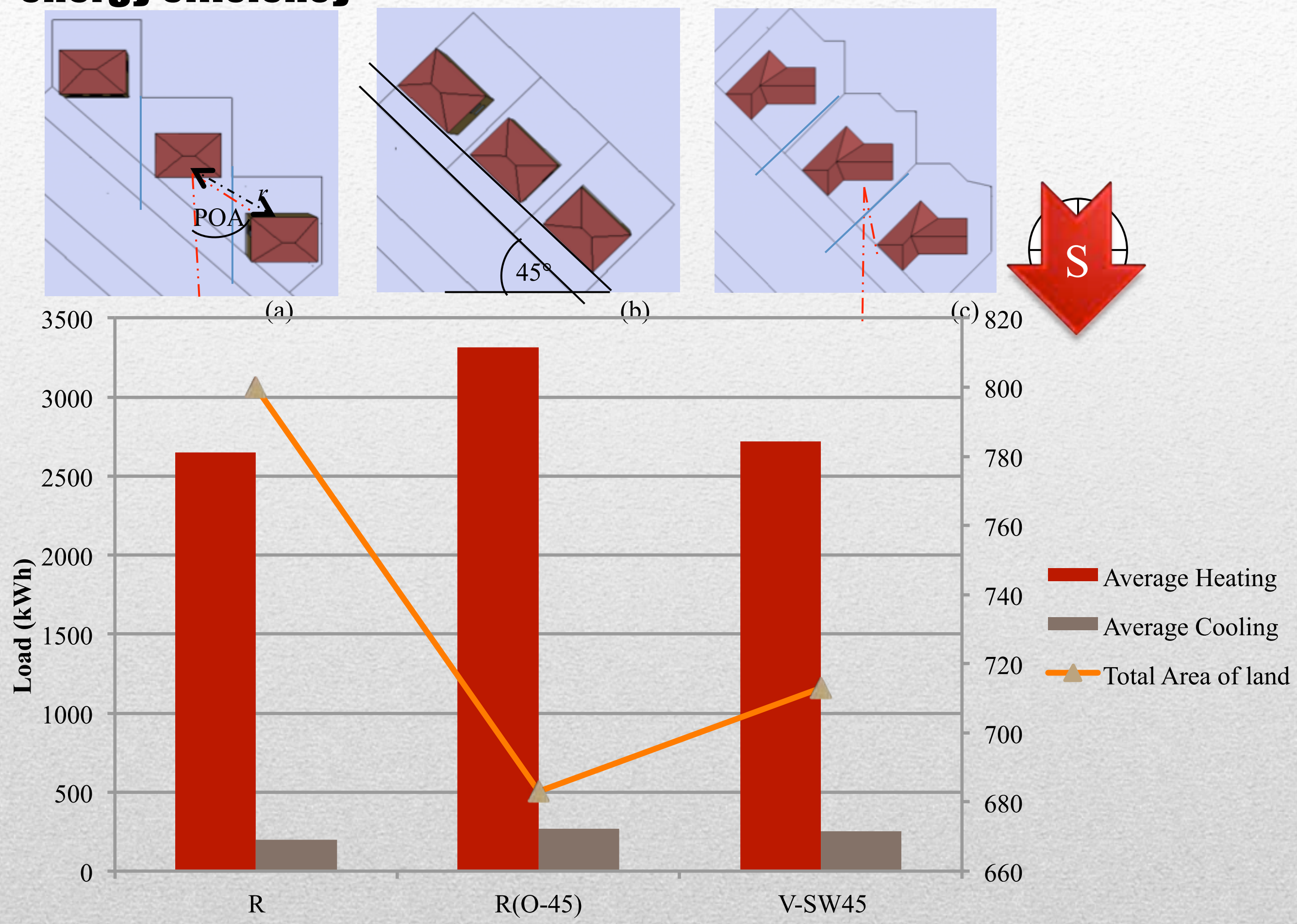


- The average heating load is not significantly affected by the layout of streets provided solar access is respected.

Solar neighbourhood design

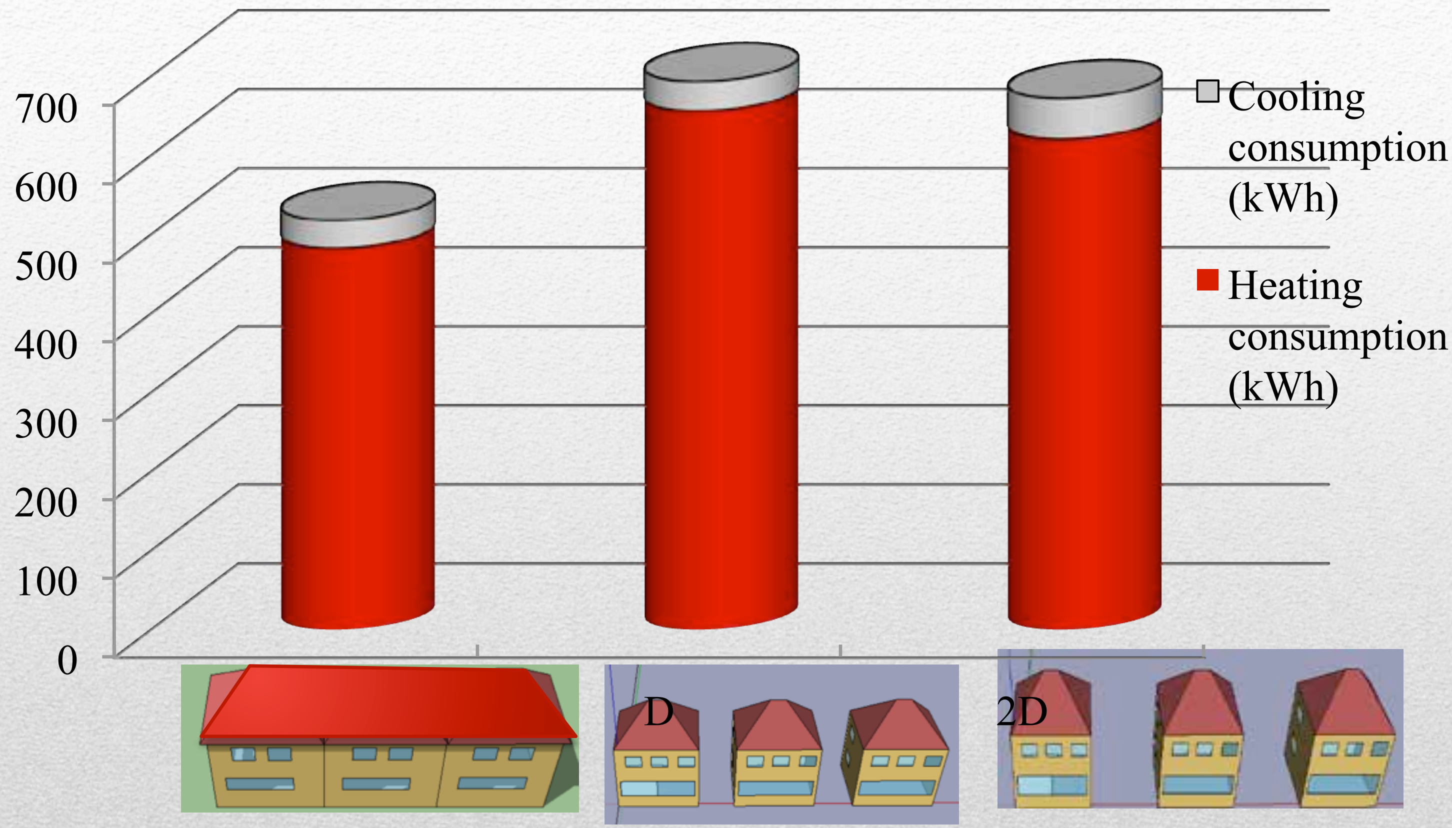
Road layout

Example of trade -off between different building shapes, land area and energy efficiency



Solar neighbourhood design

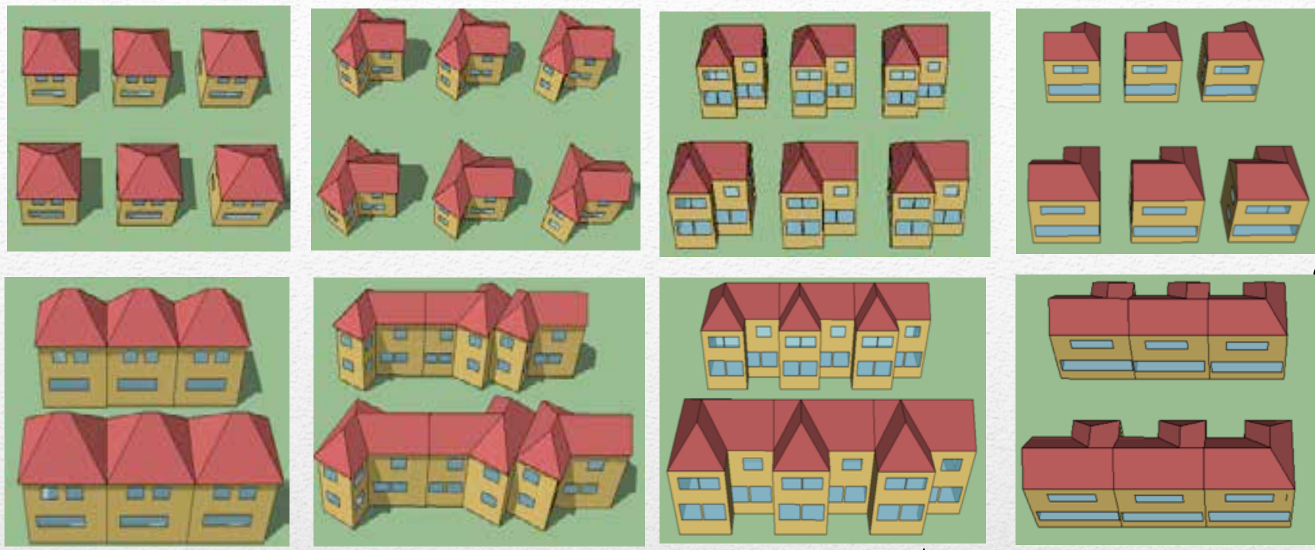
Road layout



- up to 35% reduction of heating load can be achieved in attached units

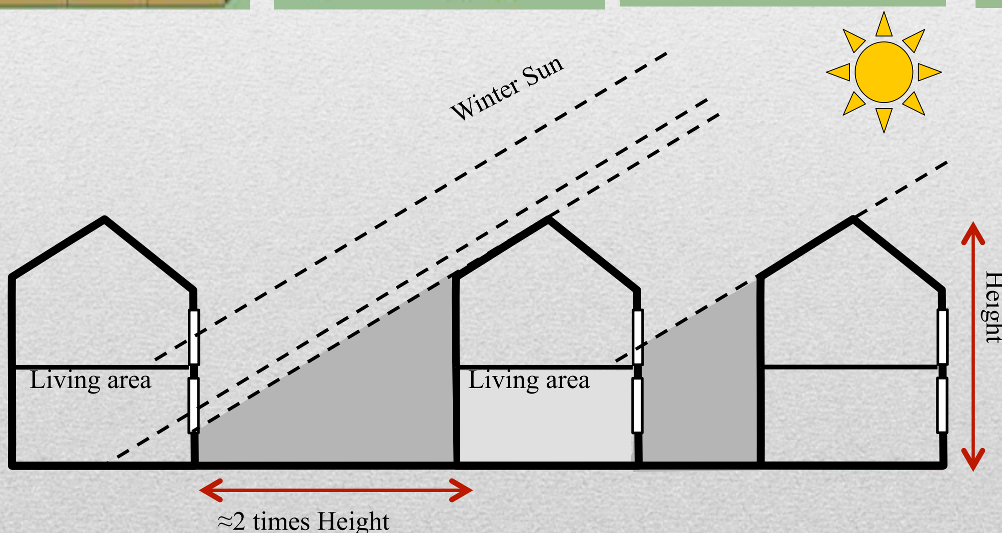
Solar neighbourhood design

Density- Effect of Spacing



(a)

(b)

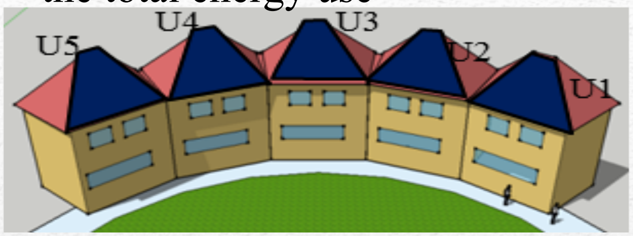


The distance between rows is dependent on the height of the shading buildings (about 2 times)

Solar neighbourhood design

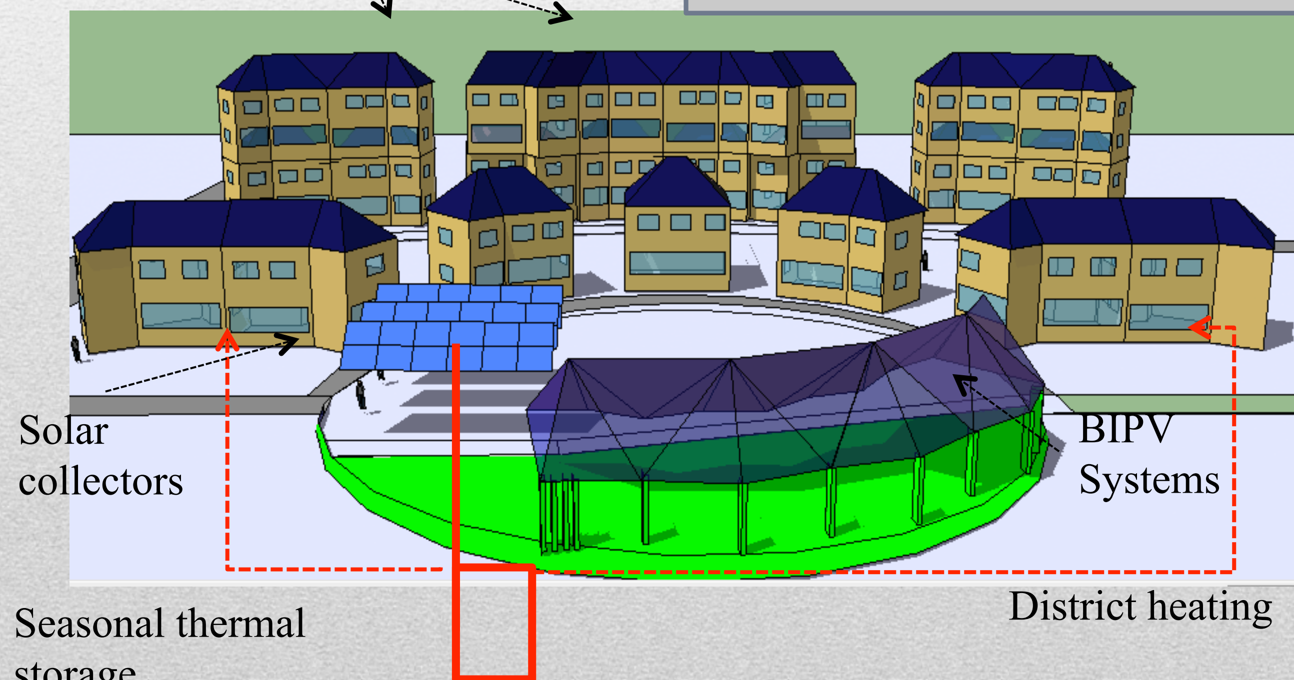
Density- Effect of Spacing

Generation of 62% of the total energy use



Generation of 80% of the total energy use

- Some house shapes (e.g L-shape) are more beneficial in a specific site layout.



Solar Neighbourhood Design

Shape of housing units

a) General site considerations
b) Minimizing total area for a given functional area .

c) Energy considerations – Passive and Active solar design.

General

- Orientation: within the optimal range. Otherwise, trade-offs in shape design should be made.
- South facing window area.

Rectangular shapes:

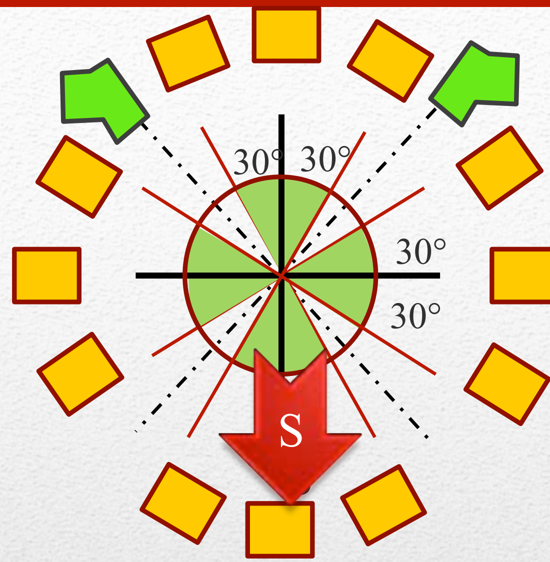
Aspect ratio – of 1.3 to 1.6 should be applied .

Self -Shading shapes (like L shape)

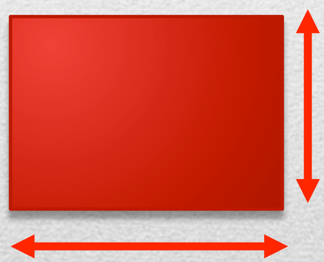
- Number of shading facades
- Ratio of shading to shaded façade widths (depth ratio), and
- Angle enclosed by the wings.

Roofs (default hip roof):

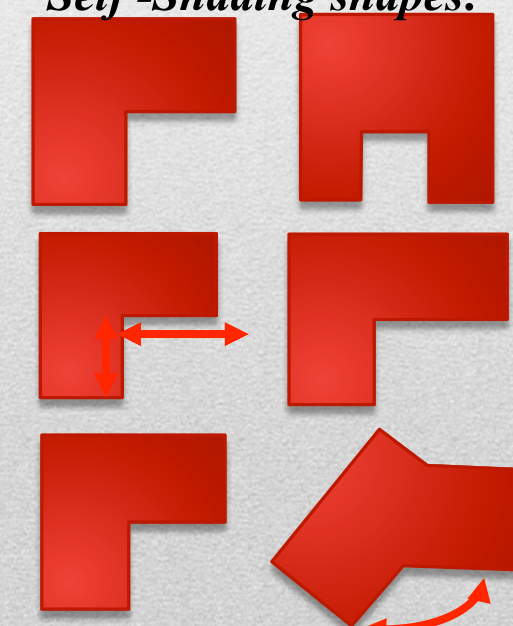
Key effects : surface area, tilt angle and orientation.



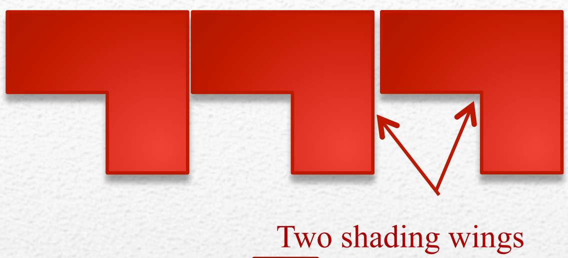
Rectangular shapes:

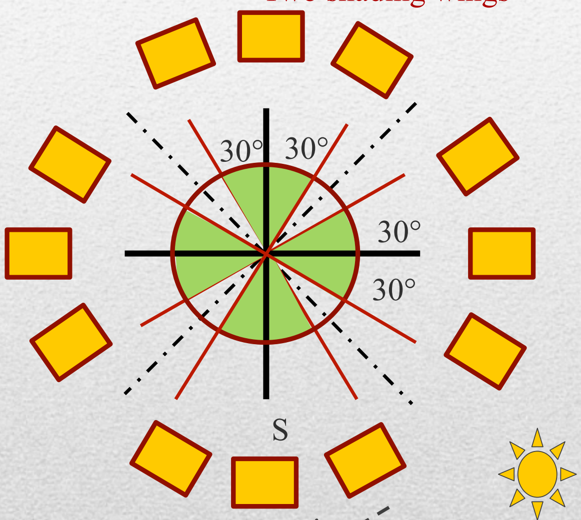


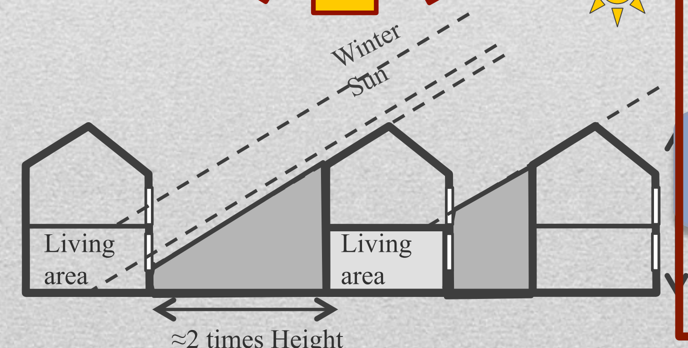
Self -Shading shapes:



Design Guidelines







Positioning of housing units on a site.

a) Straight road (east west direction)

Low density- Detached units

- Apply passive solar design for shapes. Minimum distance between adjacent units (bylaws)

High density- Attached units

- Attached units are recommended for increased density. For non-convex shapes configurations, the depth ratio and number of shading facades should be considered.

b) Curved Road

Low density- Detached units

- Planar obstruction angle (POA)
- Orientation around the curve

High Density - Attached units

- Similar observations as for straight road. Additional design issues should be addressed.

c) Row Configurations

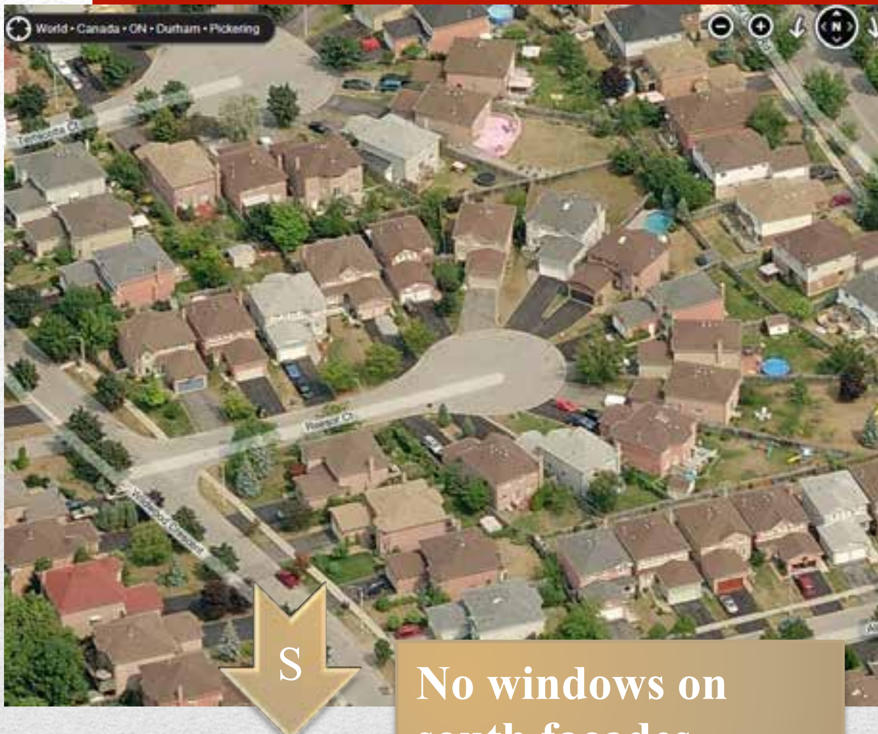
Low density – Detached units

- Distance between rows of 1.5 - 2 times the height of the shading building.

High density – Attached units

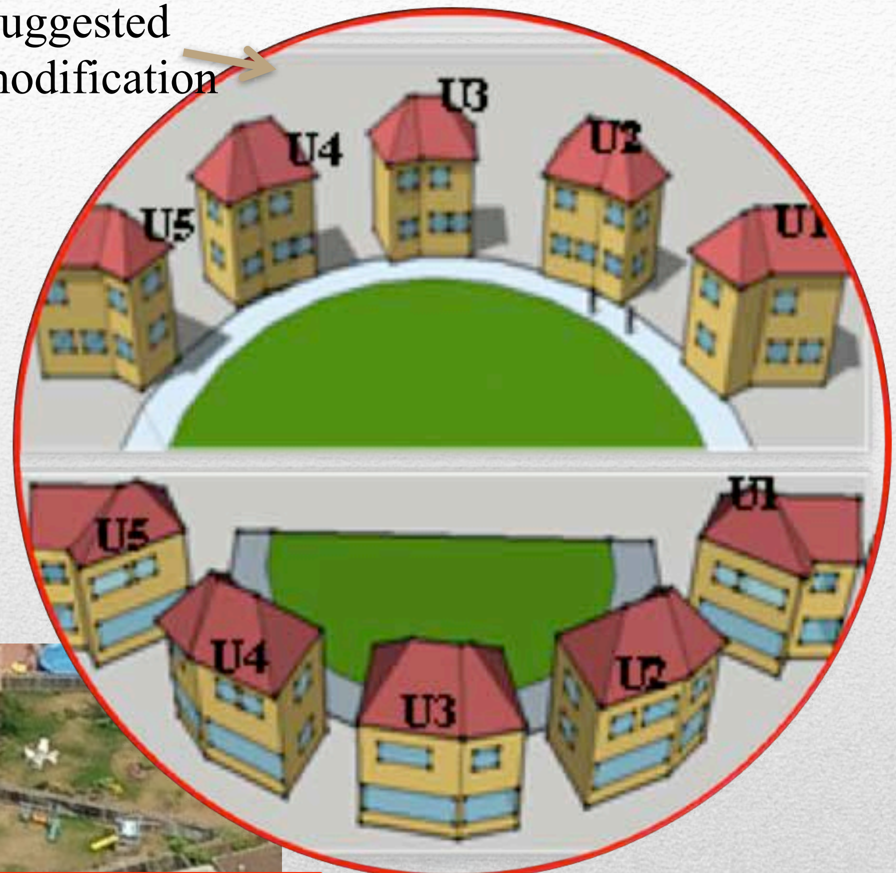
- The same design recommendations as detached units.

Design Guidelines



No windows on south facades, aspect ratio is small

Suggested modification



Garage covering the south facades

Example of Design


Thank You...